YAKIMA/KLICKITAT FISHERIES PROJECT MONITORING AND EVALUATION
Yakima Subbasin

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THE CONFEDERATED TRIBES AND BANDS OF
THE YAKAMA NATION
Toppenish, WA 98948

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Acknowledgements

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Executive Summary

The Yakima-Klickitat Fisheries Project (YKFP) is a joint project of the Yakama Nation (lead entity) and the Washington State Department of Fish and Wildlife (WDFW) and is sponsored in large part by the Bonneville Power Administration (BPA) with oversight and guidance from the Northwest Power and Conservation Council (NPCC). It is among the largest and most complex fisheries management projects in the Columbia Basin in terms of data collection and management, physical facilities, habitat enhancement and management, and experimental design and research on fisheries resources. The YKFP is attempting to evaluate all stocks historically present in the Yakima Subbasin and apply a combination of habitat restoration and hatchery supplementation or reintroduction, to restore the Yakima Subbasin ecosystem with sustainable and harvestable populations of salmon, steelhead and other at-risk species. This project and report address regional monitoring and evaluation strategies and sub-strategies as they apply to spring Chinook, summer/fall Chinook, and coho work in the Yakima Subbasin. This project (199506325) is related to numerous other projects in the Yakima Subbasin; additional information is available in the annual reports of these related projects.

The YKFP began a spring Chinook salmon hatchery program at the Cle Elum Supplementation and Research Facility (CESRF) near Cle Elum on the upper Yakima River in 1997. This program is a supplementation effort targeting the upper Yakima River population and is designed to test whether artificial propagation can be used to increase natural production and harvest opportunities while limiting ecological and genetic impacts. It is an integrated hatchery program because only natural-origin brood-stock are used and returning hatchery-origin adults are allowed to spawn in the wild. The program employs "best practice" hatchery management principles including reduced pond densities, strict disease management protocols, random brood-stock selection, and factorial mating to maximize effective population size. Fish are reared at the central facility, but released from three acclimation sites located near the central facility at: Easton approximately 25km upstream of the central facility, Clark Flat about 25km downstream of the central facility, and Jack Creek about 12km upstream from the Teanaway River's confluence with the Yakima River. The CESRF collected its first spring Chinook brood-stock in 1997, released its first fish in 1999, and age-4 adults have been returning since 2001. The first generation of offspring of CESRF and wild fish spawning in the wild returned as adults in 2005. The program uses the adjacent, un-supplemented Naches River population as an environmental and wild control or reference system.

Adult returns of fall Chinook to the Yakima River Basin consist mostly of hatchery-origin fish returning from releases averaging 1.6 million Upriver Brights annually from

the Prosser Hatchery which have occurred since 1983. Summer-run Chinook were extirpated from the Yakima Basin by 1970. To increase the temporal and spatial distribution of summer/fall run Chinook in the Yakima River Subbasin, the program began releases of Wells Hatchery summer-run Chinook in the Yakima River Basin in 2009. Coho were extirpated from the Yakima Subbasin by the early 1980s. Pursuant to *U.S. v. Oregon* court-mandated agreements, substantial numbers (annual average > 700,000) of hatchery-reared coho salmon were released into the Yakima River since the mid-1980s. Prior to 1996 the primary purpose of releases was harvest augmentation and fish were released in sub-optimal spawning and rearing areas below Wapato Dam. With the inception of the YKFP in 1996, the objective of the coho program became "to determine the feasibility of reestablishing a naturally spawning coho population" and releases were moved upriver to more suitable habitats for natural coho.

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2016 average of approximately 10,800 fish. These increases can be attributed to returns from the Cle Elum supplementation program beginning in 2001, improved freshwater passage conditions, improved marine survival, and habitat restoration and enhancement work. Annual abundance of fall Chinook at Prosser Dam has increased from a 1983-1999 average of just over 1,000 fish to a 2000-2016 average of about 4,100 fish. While this increase coincides with improved ocean conditions, some of the increase may also be due to improved passage in the mainstem Columbia River, changes in the lower Yakima River that are making fish seek more amenable spawning areas further upriver, and improvements in spawning and rearing protocols. Over 900 summer-run Chinook passed above Prosser Dam in 2016, among the first such fish to return to the Yakima Basin in over 40 years. The coho return in 2016 was poor with only about 1,900 Coho passing above Prosser Dam. Adult Coho returns to Prosser Dam averaged about 4,500 fish from 1997-2016 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging about 900 fish since 2001.

Trends in adult productivity indices for Yakima Basin natural-origin spring Chinook appear to be very similar for both Upper Yakima and Naches populations. Trends in adult productivity indices for natural-origin coho are not as clear. Under present conditions, productivity for spring Chinook appears to peak at about 1,000 to 1,500 spawners and decline as spawner abundance approaches 2,000 fish or greater. These data indicate that density-dependent limiting factors depress natural productivity at fairly low population abundance in the Yakima River Basin. Until these factors are fully addressed, supplementation yields higher overall productivity rates and can be used to return adults to fisheries and to augment natural spawning populations.

For juvenile migration years 2000-present, annual abundance estimates of juvenile smolts migrating downstream at Prosser Dam averaged 243,600 wild/natural spring Chinook, 378,300 CESRF-origin spring Chinook, 46,700 wild/natural-origin coho, and 270,300 hatchery-origin coho. Preliminary smolt-to-adult survival indices averaged approximately 2.4% and 3.1% for natural-origin spring Chinook and coho, respectively. Because of many complexities associated with the production of smolt indices, these data are useful for analysis of trends but should not be used as direct citations of, or for comparisons of marked and unmarked, smolt-to-adult survival rates. Substantial juvenile mortality occurs as smolts migrate through the Yakima River system. Strategies have been proposed to address limiting factors and improve survival of emigrating Yakima Basin juveniles. As these strategies are implemented, we expect smolt and smolt-to-adult survival to improve.

Spatial distribution of spring Chinook spawners has increased as a result of acclimation site location, salmon homing fidelity and more fully seeding preferred spawning habitats. Spring Chinook redd counts in the Teanaway River increased from a pre-supplementation average of 3 redds per year to a post-supplementation average of 63 redds per year. Fall Chinook redd distribution in the Yakima River Basin appears to be experiencing a transition with an increasing proportion of redds observed above Prosser Dam in the most recent decade. This change is primarily attributed to substantial changes in lower Yakima River habitats in recent years. Redd counts and spatial distribution of coho have increased substantially in recent years, with about 230 redds enumerated annually on average in tributaries in the upper watersheds since 2004. In 2016, 54 coho redds were observed in tributaries in the Naches and Upper Yakima Subbasins.

Monitoring and evaluation of diversity metrics is presently focused on the CESRF spring Chinook program in the Upper Yakima River. Generally, we have detected small, but significant differences between hatchery- and natural-origin fish in some juvenile and adult traits with many results already published in the peer-reviewed literature.

In spite of slight increases observed in 2016 samples, overall average fine sediment levels in the Naches and Upper Yakima River subbasins over many years of sampling continue to trend downward.

We believe Yakima Basin spring Chinook contribute minimally to marine fisheries as their spatial and temporal ocean migration patterns do not appear to intersect with marine fisheries. However, Yakima Basin fall- and summer-run Chinook and coho do contribute substantially to marine fisheries and to mainstem Columbia River fisheries from the mouth to the Hanford Reach area. Recreational spring Chinook fisheries have returned to the Yakima River Basin after a 40-year absence. This has contributed to improved relationships between all the Basin's stakeholders and increased opportunities for collaboration.

Supplementation has increased spring Chinook redd abundance in the Upper Yakima relative to the Naches control system. We observed an average increase in redd counts in the upper Yakima about 65% greater than that in the Naches system from the pre- to post-supplementation periods. Natural-origin returns of adult spring Chinook in the post-supplementation period (2005-2016) were maintained or increased in the supplemented Upper Yakima River and appear to be declining in the Naches control system relative to the pre-supplementation period (1982-2004). After three generations of study, the results (many of which are published in the peer-reviewed literature) from the spring chinook supplementation program in the Upper Yakima River demonstrate that a well-designed and carefully managed integrated hatchery program using 100% natural-origin broodstock can produce fish for harvest and return fish to the natural spawning grounds with minimal negative impacts to the target ecosystem. Coho re-introduction research in the published literature suggests that hatchery-origin coho, with a legacy of as many as 10 to 30 generations of hatchery-influence, can reestablish a naturalized population after as few as 3 to 5 generations of outplanting in the wild.

YKFP efforts to monitor and evaluate hatchery reform focus on the CESRF spring Chinook program which was designed explicitly for this purpose from its inception. By designing the program to use only natural-origin fish for brood-stock, the program has demonstrated reduced genetic divergence for the integrated program compared to a traditional segregated hatchery program. The CESRF is also meeting or exceeding scientific recommendations for proportionate natural influence (PNI) on an annual basis with a 16-year mean annual PNI of 66%. The project is thus far meeting or exceeding most other established objectives related to hatchery reform.

Major piscivorous predators in the Yakima River Basin include: common mergansers, American white pelicans, double-crested cormorants, gulls, great blue herons, northern pike minnows, and smallmouth bass. The project has initiated efforts to control the pike minnow and smallmouth bass populations.

Project results are communicated broadly through the annual science and management conference, technical reports and peer-reviewed journal publications (see references and project-related publications), and via several related web sites described in Appendix A.

Introduction

The Yakima-Klickitat Fisheries Project (YKFP) is a joint project of the Yakama Nation (lead entity) and the Washington State Department of Fish and Wildlife (WDFW) and is sponsored in large part by the Bonneville Power Administration (BPA) with oversight and guidance from the Northwest Power and Conservation Council (NPCC). It is among the largest and most complex fisheries management projects in the Columbia Basin in terms of data collection and management, physical facilities, habitat enhancement and management, and experimental design and research on fisheries resources. Consistent with Wy-Kan-Ush-Mi Wah-Kish-Wit (CRITFC 1995) and using principles of adaptive management (Salafsky et al. 2001), the YKFP is attempting to evaluate all stocks historically present in the Yakima Subbasin and apply a combination of habitat restoration and hatchery supplementation or reintroduction, to restore the Yakima Subbasin ecosystem with sustainable and harvestable populations of salmon, steelhead and other at-risk species.

The original impetus for the YKFP resulted from the landmark fishing disputes of the 1970s, the ensuing legal decisions in *United States versus Washington* and *United States versus Oregon*, and the region's realization that lost natural production needed to be mitigated in upriver areas where these losses primarily occurred. The YKFP was first identified in the NPCC's 1982 Fish and Wildlife Program (FWP) and supported in the *U.S. v Oregon* 1988 Columbia River Fish Management Plan (CRFMP). A draft Master Plan was presented to the NPCC in 1987 and the Preliminary Design Report was presented in 1990. In both circumstances, the NPCC instructed the Yakama Nation, WDFW and BPA to carry out planning functions that addressed uncertainties in regard to the adequacy of hatchery supplementation for meeting production objectives and limiting adverse ecological and genetic impacts. At the same time, the NPCC underscored the importance of using adaptive management principles to manage the direction of the Project. The 1994 FWP reiterated the importance of proceeding with the YKFP because of the added production and learning potential the project would provide. The YKFP is unique in having been designed to rigorously test the efficacy of hatchery supplementation. Given the current depressed status of many salmon and steelhead stocks, and the heavy reliance on artificial propagation as a recovery tool, YKFP monitoring results have great region-wide significance.

Supplementation is envisioned as a means to enhance and sustain the abundance of wild and naturally-spawning populations at levels exceeding the cumulative mortality burden imposed on those populations by habitat degradation and by natural cycles in environmental conditions. A supplementation hatchery is properly operated as an adjunct to the natural production system in a watershed. By fully integrating the hatchery with a naturally-producing population, high survival rates for the component of the population in the hatchery can raise the average abundance of the total population (hatchery component plus naturally-producing component) to a level that compensates for the high mortalities imposed by human development activities and fully seeds the natural environment. However, it is important to recognize that "rebuilding natural populations will ultimately depend on improving habitat quality and quantity" (ISRP 2011, Venditti et al. 2015) of which habitat connectivity is an essential component (CRITFC 1995, Milbrink et al. 2011). Hatchery programs, even "state of the art" integrated supplementation programs designed to follow all of the best management practice recommendations (Cuenco et al. 1993, Mobrand et al. 2005), do not directly affect any of these habitat parameters which are vital to improving natural productivity. Therefore, the YKFP is working with partners in multiple forums to implement habitat restoration and water resource management projects designed to address factors limiting productivity (see Yakima Subbasin, Recovery, and Integrated plans).

The objectives of the YKFP are to: enhance existing stocks; re-introduce extirpated stocks; protect and restore habitat in the Yakima Subbasin; operate using a scientifically rigorous process that will foster application of the knowledge gained about hatchery supplementation and habitat restoration throughout the Columbia River Basin; and use Ecosystem Diagnosis and Treatment (EDT) and other modeling tools to facilitate planning for project activities. In strictly scientific terms the stated purpose of the project is, "to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining the long-term genetic fitness of the fish population being supplemented and keeping adverse genetic and ecological interactions with non-target species or stocks within acceptable limits" (RASP 1992, BPA 1996). WDFW is addressing some critical uncertainties (see Columbia River Basin Research Plan and Critical Uncertainties for the Columbia River Basin Fish and Wildlife Program) related to genetic and ecological interactions under project 1995-064-25. We are working jointly with WDFW to address fish propagation, predation, harvest, and monitoring and evaluation methodology uncertainties including:

Fish Propagation Question 1. Are current propagation efforts successfully producing fish for harvest and conservation?

> 1.1.1. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?

1.2. What is the magnitude of any demographic benefit or detriment to the production of natural-origin juveniles and adults from natural spawning of hatchery-origin supplementation adults?

1.2.1. What are the range, magnitude and rates of change of natural spawning fitness of integrated (supplemented) populations, and how are these related to management rules including the proportion of hatchery fish permitted on the spawning grounds, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock?

Predation Question 1. How effectively are undesirable impacts of predation ameliorated by management actions including hydrosystem operations, habitat modifications and predator population control?

Predation Question 2. Are there actions other than removing predators that could reduce predation on listed species?

Harvest Question 1. Do current harvest and escapement strategies provide the expected results in supporting recovery efforts and providing harvest opportunities?

Monitoring and evaluation methods Question 1. Are current methods to count fish and measure productivity accurate, reliable and cost effective?

Monitoring and evaluation methods Question 2. Are there better methods for counting fish and measuring their productivity?

YKFP-related project research in the Yakima River Basin has resulted in the publication of over 50 manuscripts in the peer-reviewed literature (see References and Project-Related Publications). The status of ongoing research relative to the above uncertainties is presented as part of this report.

This report includes sections on the following regional research, monitoring, and evaluation (RME) strategies: fish population status, harvest, hatchery, and predation. Each section addresses all relevant sub-strategies that apply to this project. The report addresses these strategies and sub-strategies as they apply to spring Chinook (*Oncorhynchus tshawytscha*), summer/fall Chinook (*O. tshawytscha*), and coho (*O. kisutch*) RM&E work in the Yakima subbasin. Steelhead (*O. mykiss*) RME work is addressed in related VSP (2010-030-00), on-reservation watersheds (1996-035-01), and Kelt Reconditioning (CRITFC 2008-458-00 and 2007-401-00) projects. WDFW is addressing hatchery uncertainties related to genetic and ecological interactions under project 1995-064-25. YKFP-related habitat activities for the Yakima Subbasin are addressed under projects 1997-051-00 and 1996-035-01 (except for sediment sampling which is addressed here). Hatchery Production Implementation (O&M) is addressed under project 1997-013-25. **Data and findings presented in this report should be considered preliminary until results are published in the peer-reviewed literature.**

Study Area

The project study area is the Yakima River Basin WRIA 37/38/39 (Figure 1).

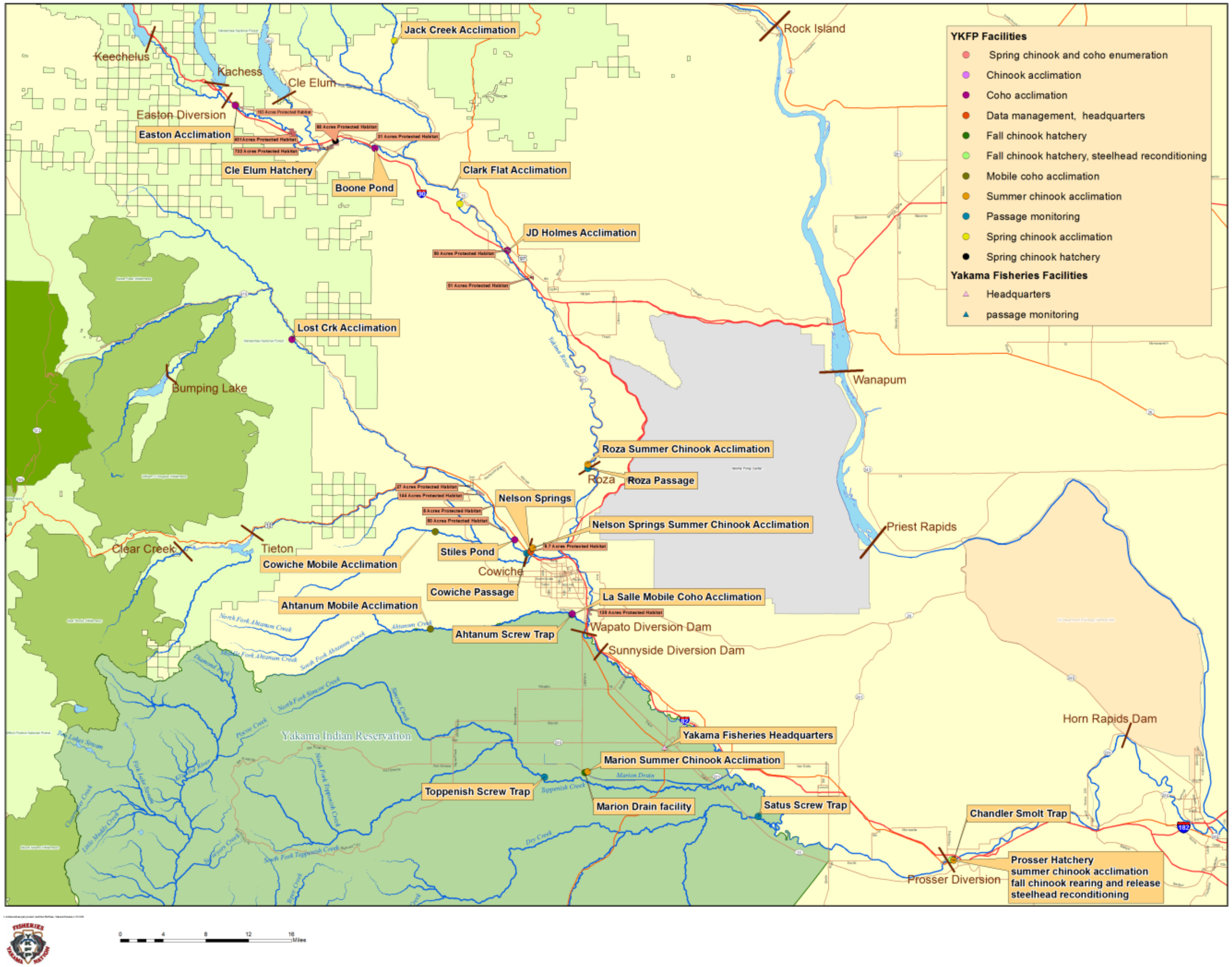

Figure 1. Yakima River Basin and Yakama Nation/YKFP-related artificial production and monitoring facilities (map provided by Paul Huffman).

Fish Population Status Monitoring

Status and Trend of Adult Fish Populations (Abundance)

Methods: Adult salmon populations in the Yakima River Basin are enumerated at Prosser Dam using video equipment installed in all three adult fish ladders (monitoringmethods.org methods 143, 144, 307, 418, 515). At both Prosser and Roza Dams, adult fish traps are also used on a seasonal basis for biological sampling and enumeration (monitoringmethods.org methods 135). When the Roza adult trap is not in operation, video equipment is also employed at the adult fish ladders there. However, camera placement and actual viewing area are limited; these combined with water clarity issues during certain river conditions all affect video enumeration at Roza Dam. Automatic Passive Integrated Transponder (PIT) tag detectors are also employed at all fish ladders at both dams (see sites RZF and PRO in ptagis.org). For the safety and protection of personnel and equipment, video and PIT-detection equipment are removed during periods of high river flow. In these instances, biologists attempt to extrapolate fish counts using data from before and after the high flow event. Although adult passage over spillways is believed to occur when flows are favorable, Prosser Dam counts are generally considered by Yakama Nation biologists to be within +/- 5% of actual fish passage. Roza Dam counts during trap operation (generally the entire spring Chinook counting period, March-September) are considered virtually 100% accurate; however during the late fall and winter counting period when video equipment is used at least part of the time, accuracy may fall to only 50-75% of actual fish passage based on preliminary evaluation of PIT tag detection data. Fish are denoted as hatchery- or natural-origin based on presence or absence respectively, of observed external or internal marks or tags (monitoringmethods.org method 342). Chinook are denoted as spring-, summer-, or fall-run based on review of PIT-detection data and visual observations of coloration and body morphometry.

At Prosser Dam, time-lapse video recorders (VHS) and a video camera were used at viewing windows at each of the three fishways. Digital video recorders (DVR) and progressive scan cameras (to replace the VHS systems) were tested at each of the three Prosser fishways in 2007 and became fully operational in February of 2008. The new system functions very similarly to the VHS system but provides digital video data readily downloadable to the viewing stations in Toppenish. This new system also allows technicians in Toppenish to scan rapidly to images of fish giving a more timely and accurate fish count. The technicians review the images and record various types of data for each fish that migrates upstream via the ladders. The data are entered into a Microsoft Access database, and daily dam count reports are regularly posted to the ykfp.org and Data Access in Real-Time (DART) web sites. Similarly at Roza Dam, adult trap data are entered into a Microsoft Access database, and daily dam count reports (with video counts integrated) are regularly posted to the ykfp.org and DART web sites. Post-season, counts are reviewed and adjusted for data gaps and knowledge about adult and jack lengths from sampling activities. Historical final counts are posted to the ykfp.org and DART web sites. In 2016, a pilot system was developed that serves Yakima Basin adult abundance and trap sampling data for the Prosser and Roza data sets. This system can be accessed at: http://dashboard.yakamafish-star.net/drupal/. Log in with user name, 'NSexternal' and password, 'SaveTheFish'.

Spring Chinook began returning from the Cle Elum Supplementation and Research Facility (CESRF) in 2000 (jacks) and 2001 (adults). All CESRF-origin spring Chinook are marked. Due to physical and logistical constraints at the Prosser Hatchery it is not possible to mark all hatchery releases of summer/fall run Chinook without jeopardizing fish health and survival but these issues are being addressed through the Master Planning process (Yakama Nation 2012). Thus, enumeration of hatchery- and natural-origin summer/fall run Chinook adult returns is not presently available but will be available in the future. New marking protocols made it possible to distinguish hatchery- and natural-origin coho beginning with return year 2001.

Results:

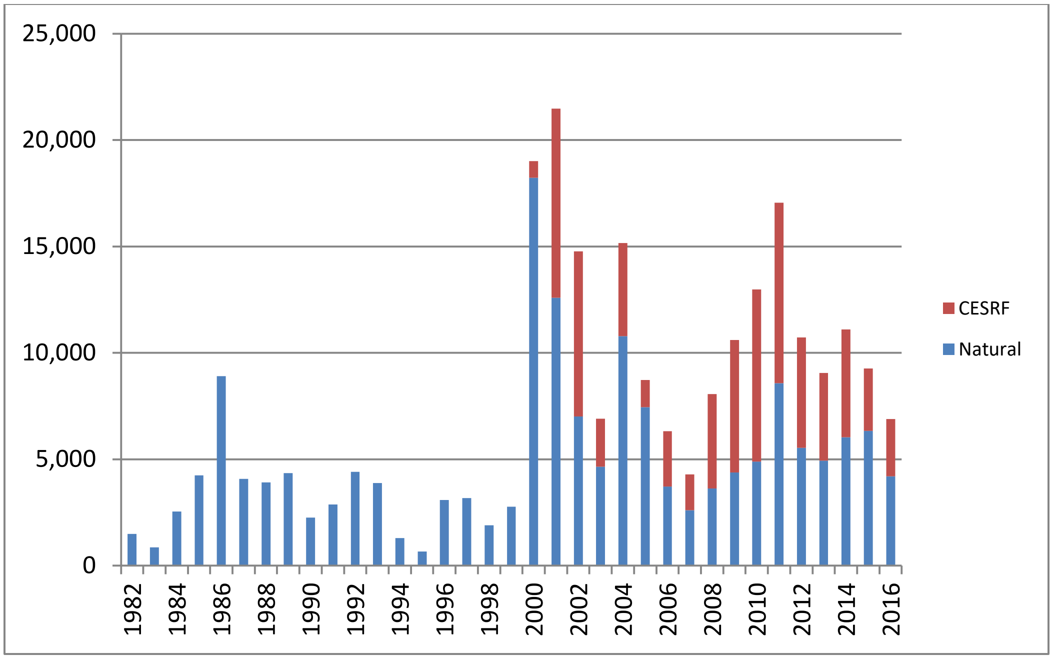

Figure 2. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Prosser Dam, 1982-present.

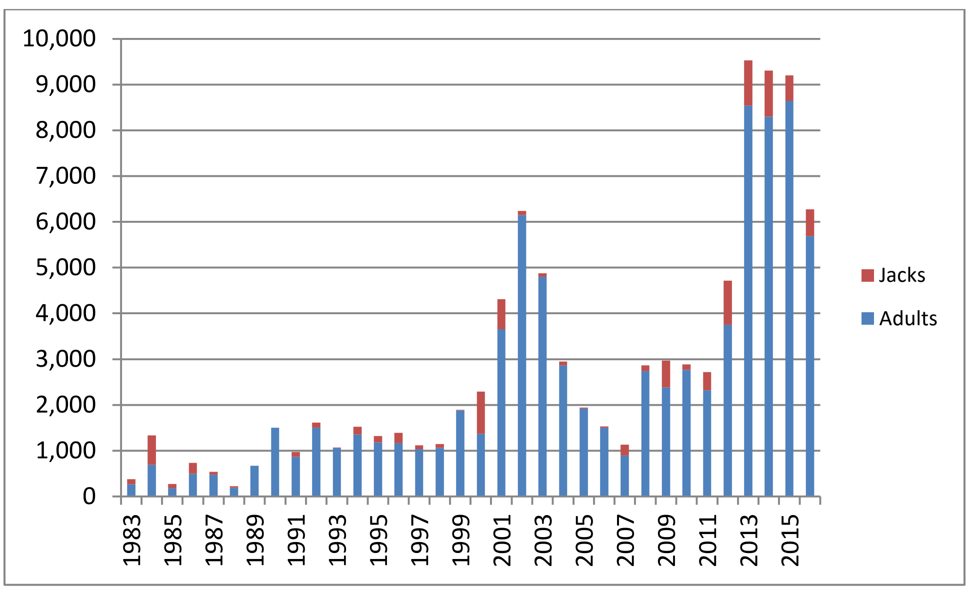

Figure 3. Estimated counts of adult and jack summer/fall run Chinook at Prosser Dam, 1983-present.

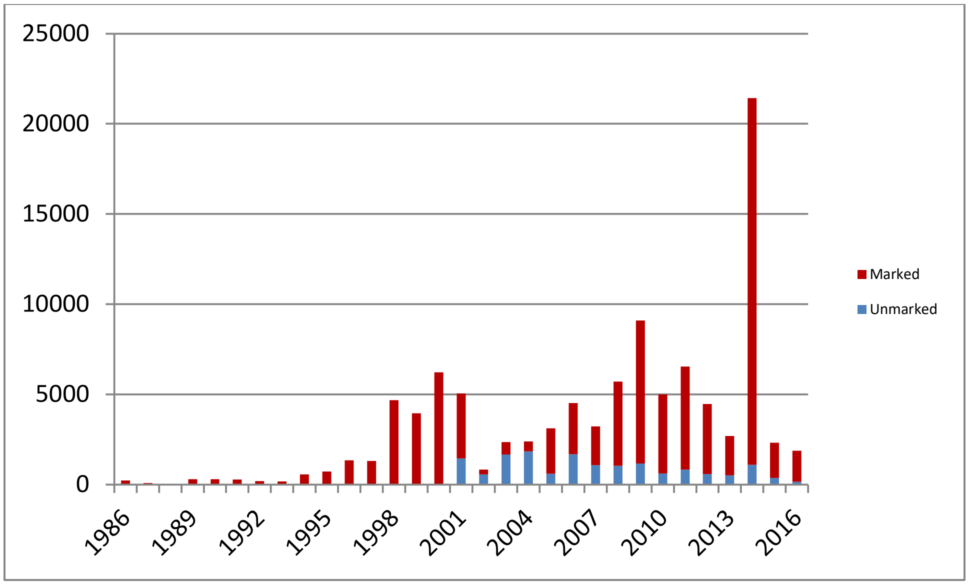

Figure 4. Estimated counts of marked (presumed hatchery-origin) and unmarked (presumed natural-origin) Coho (adults and jacks) at Prosser Dam 1986-present.

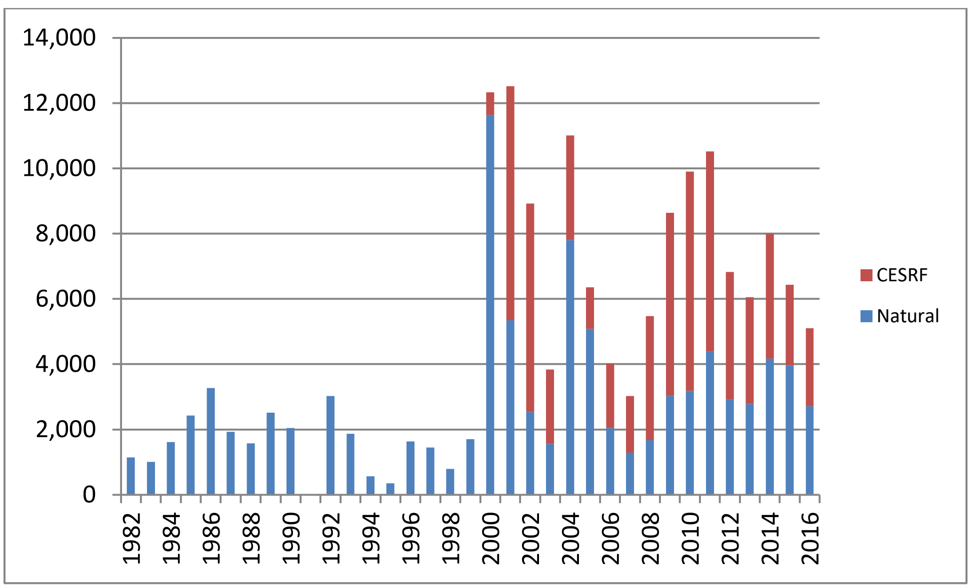

Figure 5. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Roza Dam, 1982-present.

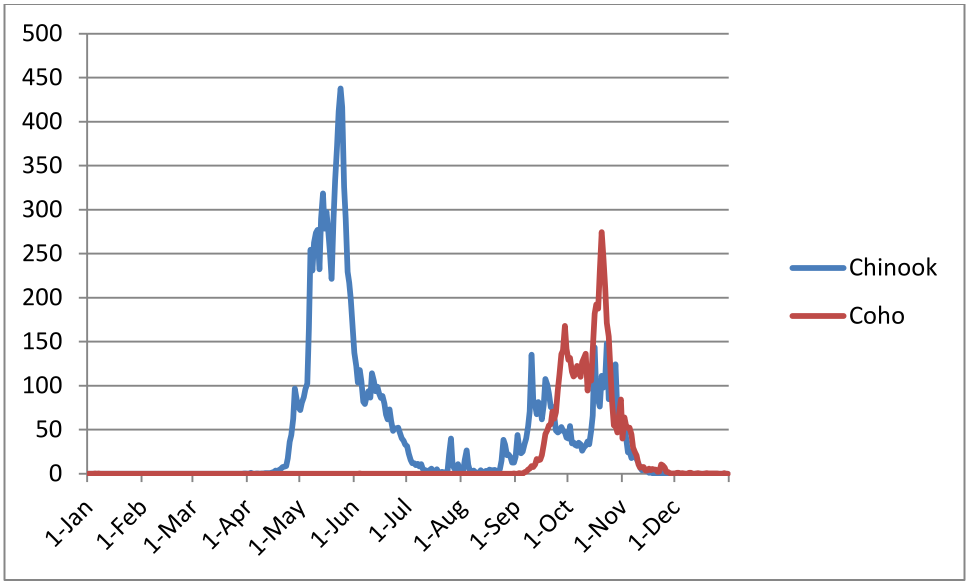

Figure 6. Average daily passage of Chinook and Coho (adults and jacks) at Prosser Dam, 2007-2016.

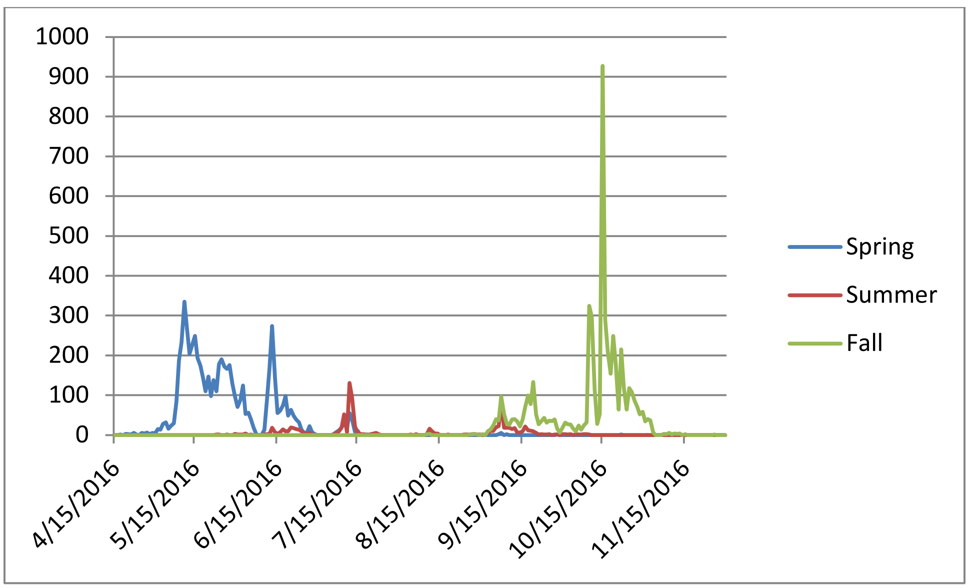

Figure 7. Passage timing of adult and jack Chinook at Prosser Dam in 2016 by run (see Methods).

Discussion:

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2016 average of approximately 10,800 fish (Figure 2). Annual abundance of spring Chinook at Roza Dam has increased from a 1982-2000 average of about 2,300 fish to a 2001-2016 average of approximately 7,300 fish (Figure 5). These increases can be attributed to returns from the Cle Elum supplementation program beginning in 2001, improved freshwater passage conditions, improved marine survival, and habitat restoration and enhancement work. The lowest adult returns since 2000 followed two years after the notable droughts which occurred during smolt outmigration years 2001 and 2005. Discussion of uncertainties relating to the Cle Elum spring Chinook supplementation program is included under Hatchery Monitoring later in this report. Additional data and detail on the Cle Elum spring Chinook supplementation program and the status of natural- and CESRF-origin spring Chinook in the Yakima River Basin are provided in Appendix B.

Although some natural production is occurring, adult returns of fall Chinook to the Yakima River Basin consist mostly of hatchery-origin fish returning from annual releases of Upriver Brights from the Prosser Hatchery which have occurred since 1983 and averaged about 1.9 million since 1999 (Yakama Nation 2012). In addition, the Yakama Nation has a goal of re-establishing Summer-run Chinook which were extirpated from the Yakima Basin by 1970. Pursuant to this goal we began releases of Wells Hatchery summer-run Chinook in the Yakima River Basin in 2009. Annual abundance of summer/fall Chinook at Prosser Dam has increased from a 1983-1999 average of just over 1,000 fish to a 2000-2016 average of over 4,400 fish (Figure 3). While this increase coincides with improved ocean conditions, some of the increase may also be due to improved passage in the mainstem Columbia River, changes (e.g., increased aquatic vegetation like stargrass *Heterantera dubia*, Wise et al. 2009) in the lower Yakima River that are making fish seek more amenable spawning areas further upriver, and improvements in spawning and rearing protocols. By re-establishing the summer-run component we seek to increase the temporal (Figures 6 and 7) and spatial distribution of summer/fall run Chinook in the Yakima River Subbasin (Yakama Nation 2012). Nearly 1,000 summer-run Chinook were estimated to pass above Prosser Dam in 2016 (Figure 7).

Coho were extirpated from the Yakima Subbasin by the early 1980s. Pursuant to *U.S. v. Oregon* court-mandated agreements, substantial numbers (annual average > 700,000) of hatchery-reared coho salmon were released into the Yakima River since the mid-1980s. Prior to 1996 the primary purpose of releases was harvest augmentation and fish were released in sub-optimal spawning and rearing areas below Wapato Dam. With the inception of the YKFP in 1996, the objective of the coho program became "to determine the feasibility of reestablishing a naturally spawning coho population" and releases were moved upriver to more suitable habitats for natural coho. Monitoring of these efforts to re-introduce a sustainable, naturally spawning coho population in the Yakima Basin have indicated that coho returns averaged about 5,200 fish from 1996-2016 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging about 900 fish annually since 2001 (Figure 4).

Status and Trend of Adult Productivity

Methods:

We used recruit-per-spawner relationships (Ricker 1975) to describe adult-to-adult productivity indices. Species-specific methods were as follows.

Spring Chinook

Estimated natural-origin spawners for the Upper Yakima River were calculated as the estimated escapement above Roza Dam plus the estimated number of spawners between the confluence with the Naches River and Roza Dam. Total natural-origin returns to the Upper Yakima River were developed using run reconstruction techniques (Appendix B). Age composition for Upper Yakima returns was estimated from spawning ground carcass scale samples (monitoring methods.org method 112) for the years 1982-1996 and from Roza Dam brood-stock collection samples (Knudsen et al. 2006; Appendix B) for the years 1997 to present. Since age-3 fish (jacks) are not collected for brood-stock in proportion to the jack run size, the proportion of age-3 fish in the upper Yakima for 1997 to present was estimated using the proportion of jacks (based on visual observation) counted at Roza Dam relative to the total run size.

Estimated spawners and total returns for Naches River Subbasin natural-origin spring Chinook were calculated using run reconstruction techniques (Appendix B). Age composition for Naches Basin age-4 and age-5 returns were estimated from spawning ground carcass scale samples (monitoring methods.org method 112). The proportion of age-3 fish was estimated after reviewing jack count (based on visual observations) data at Prosser and Roza dams.

Estimated spawners at the CESRF were the total number of wild/natural fish collected at Roza Dam and taken to the CESRF for production brood-stock (Knudsen et al. 2006; Appendix B). Total returns of CESRF-origin fish were based on run reconstruction and Roza dam sampling operations. Age composition for CESRF fish was estimated using scales and PIT tag detections from CESRF fish sampled passing upstream through the Roza Dam adult monitoring facility (Knudsen et al. 2006; Appendix B).

Coho

From central British Columbia south, the vast majority of coho salmon adults are 3-year-olds, having spent approximately 18 months in fresh water and 18 months in salt water (Loeffel and Wendler 1968, Wright 1970). Therefore we estimated a natural-origin productivity (recruits per spawner) index by dividing natural-origin returns to Prosser Dam by the estimated returns to Prosser Dam three years prior. We computed this index for both adult and combined adult and jack returns per adult and combined adult and jack spawner. Note that this method will bias productivity estimates high, as it assumes no natural production from hatchery-origin spawners.

Summer/Fall Run Chinook

Adult fall Chinook returning to the Yakima Basin consist of hatchery-origin returns from releases at and above Prosser Dam and natural-origin returns from fish spawning naturally in the Yakima River. Due to fiscal, physical, logistical, and policy considerations, only a small proportion of hatchery-origin releases have been externally marked. Therefore it is impossible at present to know the origin of unmarked adult fall Chinook counted at Prosser. Additional marking is proposed for hatchery-origin releases as part of the Master Plan (Yakama Nation 2012), which will allow development of a comprehensive brood/cohort age at return table for natural- and hatchery-origin returns. Methods and results for evaluating adult productivity of summer/fall run Chinook will be included in future reports and publications as the data become available.

Results:

Table 1. Adult-to-adult productivity indices for upper Yakima wild/natural spring Chinook.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Total	Returns/ Spawner
1984	1,715	92	1,348	139	1,578	0.92
1985	2,578	114	2,746	105	2,965	1.15
1986	3,960	171	2,574	149	2,893	0.73
1987	2,003	53	1,571	109	1,733	0.87
1988	1,400	53	3,138	132	3,323	2.37
1989	2,466	68	1,779	9	1,856	0.75
1990	2,298	79	566	0	645	0.28
1991	1,713	9	326	22	358	0.21
1992	3,048	87	1,861	95	2,043	0.67
1993	1,925	66	1,606	57	1,729	0.90
1994	573	60	737	92	890	1.55
1995	364	59	1,036	129	1,224	3.36
1996	1,657	1,059	12,882	630	14,571	8.79
1997	1,204	621	5,837	155	6,613	5.49
1998	390	434	2,803	145	3,381	8.68
1999	1,021[1]	164	722	45	930	0.91
2000	11,864	856	7,689	127	8,672	0.73
2001	12,087	775	5,074	222	6,071	0.50
2002	8,073	224	1,875	148	2,247	0.28
2003	3,341	158	1,036	63	1,257	0.38
2004	10,377	207	1,547	75	1,828	0.18
2005	5,713	293	2,630	14	2,936	0.51
2006	3,378	868	2,887	133	3,888	1.15
2007	2,322	456	3,976	65	4,498	1.94
2008	4,343	1,135	3,410	123	4,668	1.07
2009	7,056	283	2,572	109	2,964	0.42
2010	8,383	923	3,854	59	4,836	0.58
2011	8,584	832	3,908	144	4,883	0.57
2012	5,483	197	2,445		2,641	
2013	4,984	299				
2014	6,751					
2015	5,466					
2016	4,281					
Mean	4,267	356	2,912	118	3,410	1.64

1. The mean jack proportion of spawning escapement from 1999-2016 was 0.22 (geometric mean 0.16).

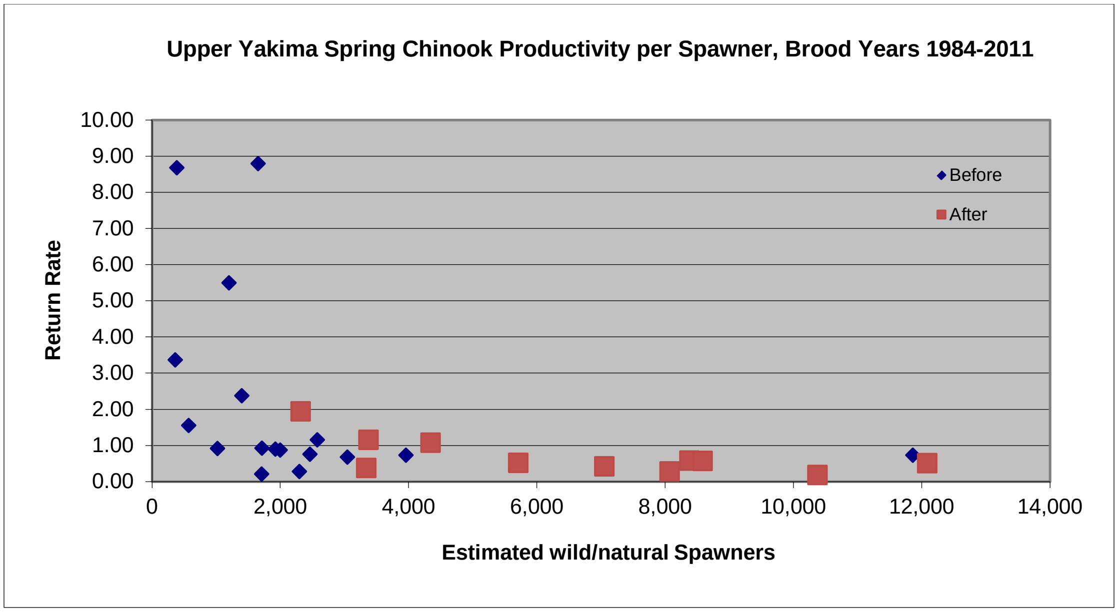

Figure 8. Upper Yakima wild/natural spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2011) commencement of supplementation.

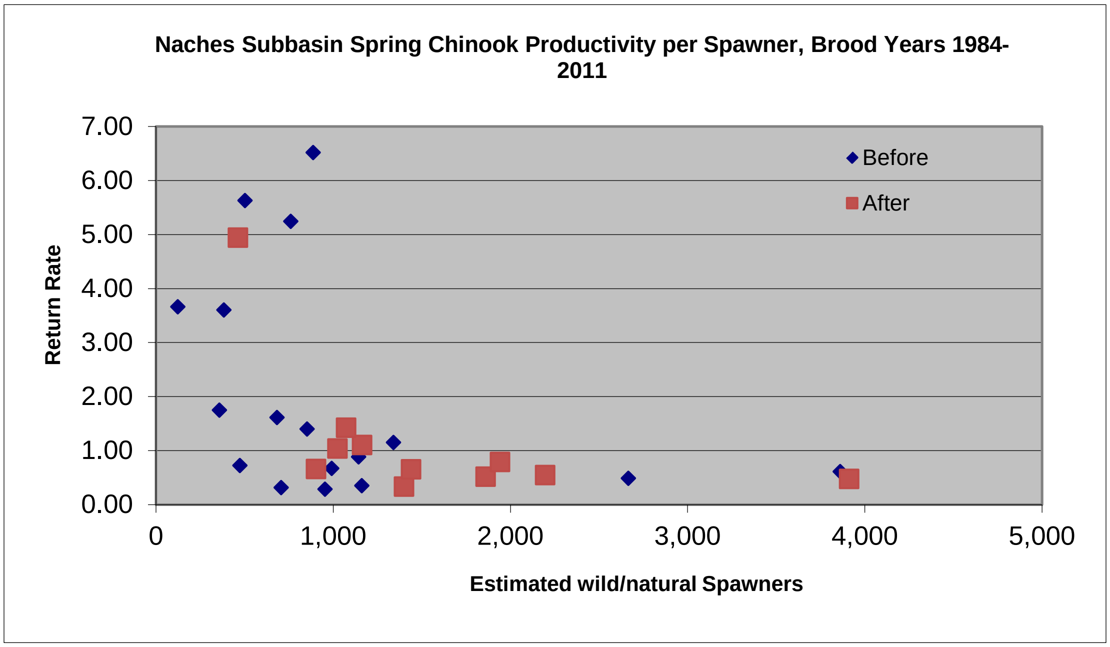

Figure 9. Naches subbasin spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2011) commencement of supplementation in the Upper Yakima River.

Table 2. Adult-to-adult productivity indices for Naches River Subbasin wild/natural spring Chinook.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Age-6	Total	Returns/ Spawner
1984	383	110	706	564	0	1,381	3.60
1985	683	132	574	396	0	1,102	1.61
1986	2,666	68	712	499	15	1,294	0.49
1987	1,162	27	183	197	0	407	0.35
1988	1,340	32	682	828	0	1,542	1.15
1989	992	28	331	306	0	665	0.67
1990	954	24	170	74	0	269	0.28
1991	706	7	37	121	57	222	0.31
1992	852	29	877	285	0	1,191	1.40
1993	1,145	45	593	372	0	1,010	0.88
1994	474	14	164	164	0	343	0.72
1995	124	40	164	251	0	455	3.66
1996	887	179	3,983	1,620	0	5,782	6.52
1997	762	207	3,081	708	0	3,996	5.24
1998	503	245	1,460	1,128	0	2,833	5.63
1999	358[1]	113	322	190	0	626	1.75
2000	3,862	71	2,060	215	0	2,346	0.61
2001	3,912	126	1,254	471	0	1,850	0.47
2002	1,861	59	753	153	0	965	0.52
2003	1,400	52	237	175	0	464	0.33
2004	2,197	107	875	218	0	1,200	0.55
2005	1,439	167	653	119	0	940	0.65
2006	1,163	192	834	254	0	1,280	1.10
2007	463	125	1,649	514	0	2,288	4.94
2008	1,074	414	827	290	0	1,531	1.42
2009	903	84	448	65	0	597	0.66
2010	1,024	209	653	198	0	1,059	1.03
2011	1,942	137	1,088	305		1,530	0.79
2012	1,110	64	419				
2013	750	110					
2014	746						
2015	1,285						
2016	790						
Mean	1,210	107	889	381	3	1,399	1.69

1. The mean jack proportion of spawning escapement from 1999-2016 was 0.09.

Table 3. Adult-to-adult productivity indices for Cle Elum SRF spring Chinook.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Total	Returns/ Spawner
1997	261	741	7,753	176	8,670	33.22
1998	408	1,242	7,939	602	9,782	23.98
1999	738[1]	134	714	16	864	1.17
2000	567	1,103	3,647	70	4,819	8.50
2001	595	396	845	9	1,251	2.10
2002	629	345	1,886	69	2,300	3.66
2003	441	121	800	12	932	2.11
2004	597	805	3,101	116	4,022	6.74
2005	510	1,305	3,052	21	4,378	8.58
2006	419	3,038	5,812	264	9,114	21.75
2007	449	1,277	5,174	108	6,558	14.61
2008	457	2,344	4,567	65	6,976	15.27
2009	486	461	2,663	58	3,181	6.55
2010	336	1,495	3,183	30	4,707	14.01
2011	377	1,233	2,340	34	3,607	9.57
2012	374	221	1,492			
2013	398	802				
2014	384					
2015	442					
2016	376					
Mean	462	1,004	3,435	110	4,744	7.94[2]

1. 357 or 48% of these fish were jacks.
2. Geometric mean.

Table 4. Estimates of adult-to-adult productivity indices for Yakima Basin natural-origin coho.

	Prosser Dam Counts		Return per Spawner Indices	
Return Year	Adults	Jacks	With Jacks	Without Jacks
2001	1,432	21		
2002	309	245		
2003	1,523	135		
2004	1,820	25	1.27	1.27
2005	472	120	1.07	1.53
2006	1,562	114	1.01	1.03
2007	1,049	32	0.59	0.58
2008	459	587	1.77	0.97
2009	982	173	0.69	0.63
2010	573	37	0.56	0.55
2011	802	24	0.79	1.75
2012	550	33	0.50	0.56
2013	424	79	0.83	0.74
2014	1,082	18	1.33	1.35
2015	362	9	0.64	0.66
2016	103	45	0.29	0.24
Mean	844	106	0.87	0.91

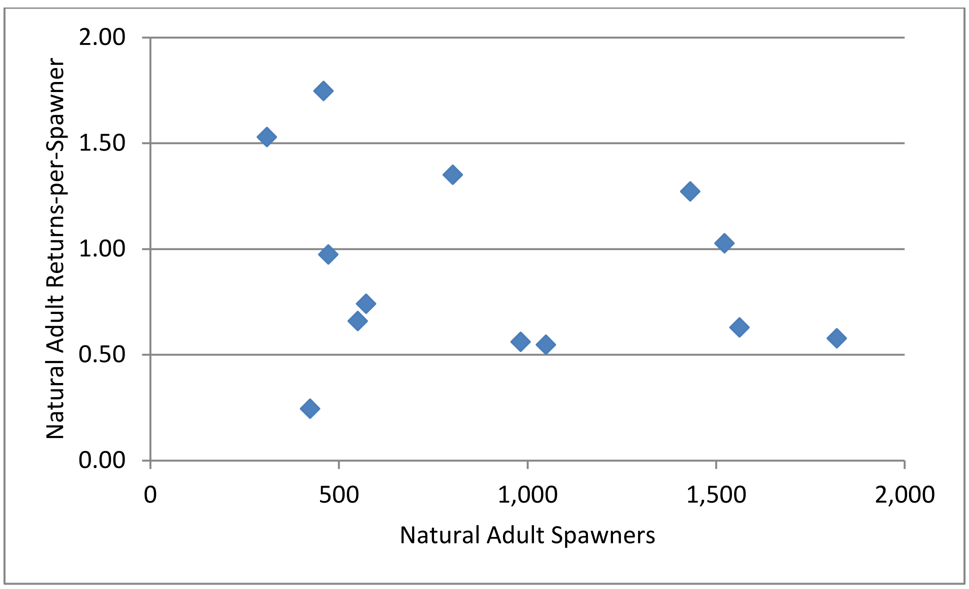

Figure 10. Productivity indices for age-3 natural-origin coho, brood years 2001-2013.

Discussion:

Trends in adult productivity indices for Yakima Basin natural-origin spring Chinook appear to be very similar for both Upper Yakima (Figure 8) and Naches (Figure 9) populations. The trend in adult productivity indices for natural-origin coho (Figure 10) is not as obvious, and 2014 marked the first year that we observed high coho spawner escapements (when hatchery-origin spawning escapement is included) similar to those we have observed with spring Chinook in some recent years. Under present conditions, productivity for spring Chinook appears to peak at about 1,000 to 1,500 spawners and declines as spawner abundance approaches 2,000 fish or greater (Figures 8-9). These data indicate that density-dependent limiting factors (see YSFWPB 2004) depress natural productivity at fairly low population abundance in the Yakima River Basin, as is the case for most salmon populations throughout the Columbia River Basin (ISAB 2015). Until these factors are fully addressed, supplementation yields higher overall productivity rates and can be used to return adults to fisheries and to augment natural spawning populations (Table 3). While higher spawner abundances under present conditions do not yield increased adult production, these fish still contribute to more fully seeding available habitats, increased spatial and temporal diversity, and nutrient enhancement that should eventually lead to increased natural food supply and higher productivity in the future (NRC 1996, see especially pp. 368-369; Kiffney et al. 2014).

Status and Trend of Juvenile Abundance

Methods: The Yakama Nation releases a number of hatchery-origin smolts annually pursuant to *U.S. v Oregon* Management Agreements. Adult returns from these releases serve to mitigate for lost harvest opportunity (due to alteration of the Columbia River ecosystem and associated losses in natural production and productivity), to augment the number of fish spawning naturally (supplementation), or a combination of the two. Juveniles are released from many locations as yearlings or subyearlings depending on the goals of the specific programs. As these juveniles migrate downstream, they are mixed with naturally produced juveniles.

Above Prosser Dam, a portion of the river flow is diverted into the Chandler canal to generate electrical power and serve irrigation districts downstream. Juvenile fish are diverted into the Canal (and subsequently the Chandler juvenile monitoring facility-CJMF, Figure 1) at different rates depending on river and canal flow. Smolt sampling efforts at the CJMF near Prosser Dam were conducted annually from early winter through early summer corresponding with salmon smolt out-migrations. A portion of entrained salmon outmigrants (regulated by a timed gate) was manually counted and sampled for biological data on a daily basis and all PIT tagged fish were interrogated. Sampling methods were described in Busack et al. (1997) and were consistent with monitoringmethods.org methods 1562, 1563, 1595, and 1614.

Paired releases of PIT-tagged smolts were made in order to estimate the fish entrainment and canal survival rates in relation to river conditions and canal operations. For outmigration years 1999 through 2014, these data were used to generate a multi-variate river flow/canal entrainment relationship (D. Neeley 2010 and 2012a). Over a range of flow diversion rates, juvenile fish entrainment rates generally fit a logistic curve: at low diversion rates, the entrainment rate is lower than the diversion rate, and at high diversion rates the entrainment rate is higher than the diversion rate. In recent years it became difficult to adapt the model to higher winter and spring flows and to river channel changes, partly because at low diversion rates it was difficult to capture enough fish to get many point estimates of entrainment rate. The releases that were made, however, still tended to support a low entrainment rate relative to diversion rate at high river flows. For some years, Prosser smolt passage estimates produced by this model were outside of what were considered reasonable bounds (e.g., entrainment-based Prosser passage estimates approached or even exceeded known releases for hatchery-origin spring Chinook far upstream). This required us to reevaluate and change our methodology. The proportions of all PIT-tagged smolts released above Prosser and detected at mid-Columbia dams that were previously detected in the Chandler Canal bypass now serve as estimates of bypass-detection efficiency. Expanded Prosser passage estimates were then derived using the juvenile sample counts and these detection efficiencies as described in Appendix C. These methods were generally consistent with monitoringmethods.org methods 435, 623 and 1743.

Results and Discussion:

At the CESRF, the number of release groups and total number of spring Chinook released diverged from the facility goal of 810,000 smolts in some years. In brood year 1997, the Jack Creek acclimation facility was not yet complete and project policy and technical teams purposely decided to under-collect brood stock to allow a methodical testing of the new facility's operations with less risk to live fish, which resulted in the stocking of only 10 of the 18 raceways. In brood year 1998, the project did not meet facility release goals due to a biological specification that no more than 50% of returning wild fish be taken for brood stock. As a result only 16 raceways were stocked with progeny of the 1998 brood. In the same year, raceway 4 at the Jack Creek acclimation site suffered mechanical failures causing loss of flow and reduced oxygen levels and resulted in the loss of approximately one-half the fish in this raceway prior to release. In the drought year of 2001, a large number of returning adults presented with high enzyme-linked immunosorbent assay (ELISA) levels of *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD). The progeny of these females were purposely destroyed. As a result, only nine raceways were stocked with fish. The project decided to use the fish from an odd raceway for a predator avoidance training sub-experiment (these fish were subsequently acclimated and released from the Easton acclimation site).

Table 5. CESRF total releases of Spring Chinook by brood year, treatment, and acclimation site.

Brood Year	Control[1]	Treatment[2]	Acclimation Site[3] CFJ	ESJ	JCJ	Total
1997	207,437	178,611	229,290	156,758		386,048
1998[4]	284,673	305,010	221,460	230,860	137,363	589,683
1999	384,563	374,226	232,563	269,502	256,724	758,789
2000	424,554	409,731	285,954	263,061	285,270	834,285
2001[5]	183,963	186,273	80,782	39,106	250,348	370,236
2002	420,764	416,140	266,563	290,552	279,789	836,904
2003	414,175	410,517	273,377	267,711	283,604	824,692
2004[6]	378,740	406,708	280,598	273,440	231,410	785,448
2005	431,536	428,466	287,127	281,150	291,725	860,002
2006	351,063	291,732	209,575	217,932	215,288	642,795
2007	387,055	384,210	265,907	254,540	250,818	771,265
2008	421,290	428,015	280,253	287,857	281,195	849,305
2009	418,314	414,627	279,123	281,395	272,423	832,941
2010	395,455	399,326	264,420	264,362	265,999	794,781
2011	382,195	386,987	255,290	248,454	265,438	769,182
2012	401,059	401,657	256,732	276,210	269,774	802,716
2013	No Experiment		215,933	214,745	216,077	646,755
2014	337,548	347,682	232,440	226,257	226,533	685,230
2015	331,316	323,631	208,239	218,225	228,483	654,947
Mean	364,206	360,753	243,454	240,111	250,459	720,842

1. Brood years 1997-2001: Optimum Conventional Treatment (OCT). Brood Years 2002-2004: Normal (High) growth. Brood Years 2005-2012: Normal feed at Cle Elum or accl. sites.
2. Brood years 1997-2001: Semi-natural Treatment (SNT). Brood Years 2002-2004: Slowed (Low) growth. Brood Year 2005, 2007-2012: saltwater transition feed at accl. Sites; 2014: BioPro vs BioVIT. Brood Year 2006: EWS diet at CESRF through May 3, 2007.
3. CFJ=Clark Flat; ESJ=Easton; JCJ=Jack Creek.
4. At the Jack Creek acclimation site only 4 of 6 raceways were stocked, and raceway 4 suffered mechanical failures resulting in the loss of about 20,000 OCT (control) fish.
5. High BKD incidence in adult broodstock reduced production to just 9 ponds (Clark Flat 1-2, Jack Creek, and Easton). Easton ponds were used for predator avoidance trained (PAT) fish and a single Cle Elum pond was spread between 6 ponds at Easton with crowders used to simulate pond densities for fish at other acclimation sites. These releases were excluded from mean pond density calculations by treatment.
6. At the Jack Creek acclimation site raceway 3 suffered mechanical failures resulting in the loss of about 45,000 high-growth (control) fish.

Table 6. Total releases of Coho by release year and acclimation site.

Release Year	Jack Creek	Cle Elum Slough	Easton Pond	Holmes Pond	Lost Creek Pond	Stiles Pond	Hundely Pond	Boone Pond	Prosser Hatchery	Total Release
1997	226,000	210,000			1,020,000	237,000				1,693,000
1998		251,136	251,019		251,106	251,133				1,004,394
1999		253,809	245,063		238,104	191,214				928,190
2000			187,659		185,773	194,131				567,563
2001			228,006	35,282	184,627	172,903				620,818
2002				264,000	139,002	268,000		139,000		810,002
2003				261,207	52,000	239,494		52,000		604,701
2004				156,237	166,232	166,223		166,180		654,872
2005				288,127	251,015	303,769		50,000	50,000	942,911
2006			101,784	195,793	231,674	285,079	39,727	89,328	81,114	1,024,499
2007			212,698	145,714	164,330	276,453			219,098	1,018,293
2008			205,926	90,188	173,009	209,524		37,806	182,719	899,172
2009			190,498	179,686	189,239	138,175		37,000	245,455	980,053
2010			263,336	179,694		131,972			190,836	765,838
2011			237,043	104,059	124,425	234,642			322,100	1,022,269
2012			213,092	92,105	94,680	200,946			221,567	822,390
2013			237,043	104,059	100,210	201,480	1,500		322,100	966,392
2014			213,092	92,105	94,680	200,946			221,567	822,390
2015			236,749	143,770	100,210	201,480			367,382	1,049,591
2016			215,045	193,067	74,220	170,399			267,830	920,561

Table 7. Total releases of fall-run Chinook by release year and release site.

Release	Prosser On-Station Release				Billy's	Stiles	Marion	Total
Year	LWH[1]	PRH[1]	Subyrl[2]	Yrlng[2]	Pond[2]	Pond[2]	Drain	Release
1997	1,694,861							1,694,861
1998	1,695,399							1,695,399
1999	1,690,000		192,000					1,882,000
2000	1,695,037		306,000				16,000	2,017,037
2001	1,699,136		427,753				12,000	2,138,889
2002	1,704,348		286,158				4,000	1,994,506
2003	1,771,129		365,409				18,000	2,154,538
2004	1,748,200		561,385				52,223	2,361,808
2005	1,700,000		466,000		75,000[3]	38,890	41,000	2,320,890
2006	1,683,664		130,002			118,835	2,000	1,934,501
2007	1,700,000[4]		50,000		5,000	75,000	15,731	1,845,731
2008	789,993		519,486[5]	1,833	11,308	72,296	5,253	1,400,169
2009	1,647,275		299,574	7,516			24,245	1,978,610
2010	1,680,045		290,282	12,167			22,945	2,005,439
2011	1,699,944	503,772	620,952	22,857				2,847,525
2012	1,200,000	405,000	269,633	19,432			72,258	1,966,323
2013	1,506,725		184,949	22,735				1,714,409
2014	1,542,702	379,970	445,347					2,368,019
2015	1,653,495	479,078	584,397					2,716,970
2016	1,593,090		562,472					2,155,562

1. Transfers from LWH=Little White Salmon NFH; PRH=Priest Rapids Hatchery.
2. Releases from local brood source adults collected at Prosser Dam or Hatchery.
3. Released from Edler Pond (approximately 2 miles downstream from Billy's Pond).
4. Of which approximately 500,000 were reared on-station at Prosser under accelerated growth conditions.
5. Of which approximately 5,400 were released from SKOV pond.

Table 8. Total releases[1] of summer-run Chinook by release year and release site.

Release Year	Prosser	Stiles Pond Subyrl	Stiles Pond Yrlng	Nelson Springs	Roza	Total Release
2009		180,911				180,911
2010		200,747				200,747
2011			176,364	39,406		215,770
2012	98,300			98,803		197,103
2013				88,208	48,355	136,563
2014				179,901	74,980	254,881
2015	55,000			99,600	122,848	277,448
2016					37,000	37,000

1. All fish released as subyearlings unless otherwise noted.

For smolt migration years 2000 to present, annual abundance estimates of juvenile smolts migrating downstream at Prosser Dam averaged 243,600 wild/natural spring Chinook, 378,300 CESRF-origin spring Chinook, 46,700 wild/natural-origin coho, and 270,300 hatchery-origin coho (Table 9). These are the years for which our data and methods are considered most reliable. Juvenile passage estimates for earlier years are provided below under "Status and Trend of Juvenile Productivity"; however, the reader should be aware that we have less confidence in these data because we have refined data collection protocols and passage estimation methods over time. As the majority of fall Chinook smolt migrants are unmarked hatchery-origin fish, we provide only the gross abundance indices below under "Status and Trend of Juvenile Productivity". The reader is cautioned to pay particular attention to the factors complicating estimates of juvenile abundance and productivity described under "Status and Trend of Juvenile Productivity".

Table 9. Estimated smolt passage at Prosser Dam for Yakima Basin wild/natural and hatchery-origin spring Chinook (see Appendix C) and coho.

Brood Year	Smolt Migr. Year	Spring Chinook Wild/ Natural	Spring Chinook Hatchery (CESRF)	Coho Wild/ Natural	Coho Hatchery
1998	2000	159,998	243,835	37,359	331,503
1999	2001	175,917	333,689	40,605	134,574
2000	2002	532,726	419,381	19,859	155,814
2001	2003	326,666	164,682	9,092	139,135
2002	2004	162,673	279,593	18,787	148,810
2003	2005	172,267	302,295	31,631	204,728
2004	2006	203,250	459,205	8,298	204,602
2005	2007	112,504	398,263	18,772	260,455
2006	2008	137,784	305,335	40,170	416,708
2007	2009	278,780	489,602	23,858	496,594
2008	2010	215,683	374,129	33,408	341,145
2009	2011	326,180	476,487	22,908	333,891
2010	2012	429,896	652,866	17,667	244,503
2011	2013	357,347	364,619	56,947	483,122
2012	2014	268,598	417,277	159,642	337,988

2013	2015	120,491	321,870	20,757	134,084
2014	2016	160,556	427,733	233,371	227,163
	Mean	243,607	378,286	46,655	270,283

Status and Trend of Juvenile Migration Survival to McNary Dam

Methods: For all species, releases of PIT tagged smolts provided a means to estimate smolt survival to McNary Dam. PIT-tag detectors were located in or near the exit(s) from the release sites (monitoringmethods.org 1558) and allowed estimation of the number of PIT-tagged fish leaving the release sites. To estimate the survival of smolts detected leaving the release sites that eventually pass McNary Dam, the proportion of PIT-tagged smolts detected leaving the release sites that were later detected at McNary Dam was divided by McNary Dam's detection efficiency. The estimated detection efficiency was the number of smolts detected passing dams downstream of McNary that were previously detected passing McNary divided by the total number of smolts passing the downstream dams, whether or not the smolts were previously detected at McNary. These methods were generally consistent with Sandford and Smith (2002) and with monitoringmethods.org methods 623 and 1536. We used weighted logistic or weighted least squares analysis of variance to analyze differences in survival metrics and indices between various release sites, years and treatments. Additional detail, results and discussion are provided in Appendices C-H.

Results and Discussion:

For spring Chinook, we compared survivals to McNary Dam of CESRF hatchery-and natural-origin PIT-tagged smolts released into the Roza Dam bypass and migrating downstream of Roza Dam contemporaneously on or after March 16. This date was selected because CESRF fish were not allowed to begin volitional emigration from the acclimation sites until March 15. Approximately 81% of natural-origin spring Chinook smolts PIT-tagged and released at Roza since 1999 migrated downstream of Roza Dam prior to March 16 (derived using queries of PTAGIS database 7/12/2013). Natural and hatchery-origin smolts contemporaneously migrating past Roza from March 16 on are referred to as "late" migrants.

Survival to McNary Dam for late-migrating natural-origin smolts exceeded that of the hatchery-origin smolts in 15 of the 17 outmigration years (Figure 11; D. Neeley, Appendix D). The pooled survival estimate was significantly higher for the natural-origin smolts. Survival analyses for additional spring Chinook treatments are presented in Appendices E and F of this report.

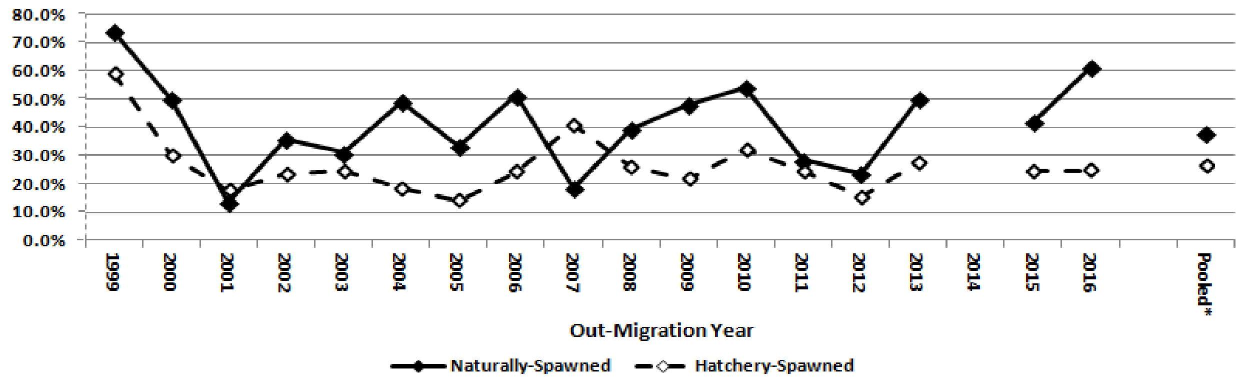

Figure 11. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for late-migrating (>March 15) Natural- (solid lines and filled diamonds) and Hatchery-origin (dashed lines and clear diamonds) Smolts. No releases occurred in 2014 because of another study conducted at Roza in that year. Pooled weighted mean was estimated using yearly release number as a weighting variable of survival percentages. Source: D. Neeley, Appendix D.

We estimated juvenile survival to McNary Dam for summer- and fall-run Chinook. Subyearling and yearling fall Chinook were released from Prosser for migration years 2008 through 2016. Summer-run Chinook subyearlings were released from Stiles pond in outmigration-years 2009 through 2011, from Nelson Springs (Buckskin Slough) in 2011 through 2015, from Prosser and Marion Drain in 2012, and from Roza Dam in 2013-14 (for locations see Figure 1). Estimates of release-to-McNary survival for these releases are presented in Appendix G.

The 2015 releases were associated with record low snow packs in the Cascade Mountains and a severe drought. For those release sites used in previous years, survival of all tagged smolt to McNary Dam (McNary) in 2015 was the lowest experienced. Because of the exceptional conditions in 2015, some fish were trucked to the mouth of the Yakima River for release. Survival for summer- and fall-run Chinook releases made from all release sites and release dates in 2015 were abysmal except for the earliest release of Fall Chinook at the mouth of the Yakima River. Survival of 2009 summer run releases was also poor due to a later release date and blockage of some irrigation diversion screen bypasses. We continued to experiment with different timing (early May through late June) and locations (Prosser Dam to the Yakima River mouth) in 2016 for both fall- and summer-run Chinook in an effort to determine ways to improve survival.

For coho, we estimated survival from acclimation site release to McNary Dam based on timing, location and brood source of the releases. Results are given in Appendix H.

The data indicate that there are substantial sources of juvenile mortality limiting survival of smolts migrating from release sites in the Yakima River basin. The YKFP is working with partners in multiple forums to implement habitat restoration and water resource management projects that address factors limiting survival and productivity (see Yakima Subbasin, Recovery, and Integrated plans).

Status and Trend of Juvenile Productivity (smolt-to-adult returns)

Methods:

Smolt abundance passage estimates at Prosser and the methods used to derive them were described above. For spring Chinook, adult return estimates to the Yakima River mouth were derived using Prosser and Roza adult abundance and harvest data (described in other sections of this report and in Appendix B) and run reconstruction techniques (Appendix B). For coho, we used Prosser adult abundance.

Adult fall Chinook returning to the Yakima Basin consist of hatchery-origin returns from releases at and above Prosser Dam and natural-origin returns from fish spawning naturally in the Yakima River. Due to fiscal, physical, logistical, and policy considerations, only a small proportion of hatchery-origin releases have been externally marked. Therefore it is impossible at present to know the origin of unmarked adult fall Chinook counted at Prosser. Additional marking is proposed for hatchery-origin releases as part of the Master Plan (Yakama Nation 2012). To derive rough smolt-to-adult return indices for fall Chinook, aggregate (marked and unmarked combined) smolt passage estimates for the age-3, -4, and -5 components for a given return year were averaged and the aggregate adult passage estimate for that return year was divided by this average smolt passage estimate. For example, the "Prosser Average Smolts" for adult return year 1988 is the average of marked and unmarked Prosser smolt estimates for juvenile migration years 1983-1985.

Results:

Table 10. Estimated smolt passage at Chandler and smolt-to-adult return indices (Chandler smolt to Yakima R. mouth adult) for Yakima Basin wild/natural and CESRF-origin spring Chinook.

			Estimated Smolt Passage at Chandler			Yakima R. Mouth Adult Returns[4]		Smolt-to-Adult Return Index[4]	
Brood Year	Smolt Migr. Year	Mean Flow[1] at Prosser Dam	Wild/ Natural[2]	CESRF Total	CESRF smolt-to-smolt survival[3]	Wild/ Natural[2]	CESRF Total	Wild/ Natural[2]	CESRF Total
1982	1984	4134	381,857			6,753		1.8%	
1983	1985	3421	146,952			5,198		3.5%	
1984	1986	3887	227,932			3,932		1.7%	
1985	1987	3050	261,819			4,776		1.8%	
1986	1988	2454	271,316			4,518		1.7%	
1987	1989	4265	76,362			2,402		3.1%	
1988	1990	4141	140,218			5,746		4.1%	
1989	1991		109,002			2,597		2.4%	
1990	1992	1960	128,457			1,178		0.9%	
1991	1993	3397	92,912			544		0.6%	
1992	1994	1926	167,477			3,790		2.3%	
1993	1995	4882	172,375			3,202		1.9%	
1994	1996	6231	218,578			1,238		0.6%	
1995	1997	12608	52,028			1,995		3.8%	
1996	1998	5466	491,584			21,151		4.3%	
1997	1999	5925	633,805	203,576	52.7%	12,855	8,670	2.0%	4.3%
1998	2000[5]	4946	159,998	243,835	41.4%	8,228	9,782	5.2%	4.0%
1999	2001	1321	175,917	333,689	44.0%	1,764	864	1.0%	0.3%
2000	2002	5015	532,726	419,381	50.3%	11,434	4,819	2.1%	1.1%
2001	2003	3504	326,666	164,682	44.5%	8,597	1,251	2.6%	0.8%
2002	2004	2439	162,673	279,593	33.4%	3,743	2,300	2.3%	0.8%
2003	2005	1285	172,267	302,295	36.7%	2,746	932	1.6%	0.3%
2004	2006	5652	203,250	459,205	58.5%	2,802	4,022	1.4%	0.9%
2005	2007	4551	112,504	398,263	46.3%	4,201	4,378	3.7%	1.1%
2006	2008	4298	137,784	305,335	47.5%	6,099	9,114	4.4%	3.0%
2007	2009	5784	278,780	489,602	63.5%	7,952	6,558	2.9%	1.3%
2008	2010	3592	215,683	374,129	44.1%	7,385	6,976	3.4%	1.9%
2009	2011	9414	326,180	476,487	57.2%	3,766	3,181	1.2%	0.7%
2010	2012	8556	429,896	652,866	82.1%	6,602	4,707	1.5%	0.7%
2011	2013	4875	357,347	364,619	47.4%	7,343	3,607	2.1%	1.0%
2012	2014	4923	268,598	417,277	52.0%	3,409[6]	1,713[6]	1.3%[6]	0.4%[6]
2013	2015	1555	120,491	321,870	49.8%				
2014	2016[6]	5765	160,556	427,733	62.4%				

1. Mean flow (cfs) approaching Prosser Dam March 29-July 4 of juvenile migration year. No data available for migration year 1991. In high flow years (flows at or > 5000 cfs) operation of the Chandler smolt sampling facility may be precluded during portions of the outmigration. Data courtesy of U.S. BOR hydromet.
2. Aggregate of Upper Yakima, Naches, and American wild/natural populations.
3. Estimated smolt-to-smolt (release from upper Yakima River acclimation sites to Chandler) survival for CESRF juveniles.
4. Includes combined age-3 through age-5 returns. CESRF adult returns and smolt-to-adult survival values are understated relative to wild/natural values since these figures are not adjusted for differential harvest rates in mark selective fisheries in marine and lower Columbia River fisheries.
5. Available data were not sufficient to estimate juvenile flow-entrainment and passage of wild/natural fish.
6. Data for most recent year are preliminary; return data do not include age-5 adult fish.

Table 11. Average combined hatchery- and natural-origin smolt counts at Prosser for fish returning at age-3, -4, and -5, combined adult returns to Prosser Dam of all age classes, and estimated Prosser smolt-to-adult return indices for Yakima River fall-run Chinook for adult return years 1988-2016.

Adult Return Year	Prosser Average Smolts[1]	Prosser Total Adults	Prosser Smolt-to-Adult Return Index (SAR)
1988	1,029,429	224	0.02%
1989	1,469,019	670	0.05%
1990	1,664,378	1,504	0.09%
1991	1,579,989	971	0.06%
1992	1,811,088	1,612	0.09%
1993	2,034,865	1,065	0.05%
1994	1,976,301	1,520	0.08%
1995	1,329,664	1,322	0.10%
1996	1,023,053	1,392	0.14%
1997	1,097,032	1,120	0.10%
1998	1,533,093	1,148	0.07%
1999	1,786,511	1,896	0.11%
2000	1,716,156	2,293	0.13%
2001	1,867,966	4,311	0.23%
2002	1,946,676	6,241	0.32%
2003	2,108,238	4,875	0.23%
2004	2,653,056	2,947	0.11%
2005	2,707,132	1,942	0.07%
2006	2,724,824	1,528	0.06%
2007	2,312,562	1,132	0.05%
2008	2,450,308	2,863	0.12%
2009	2,353,675	2,972	0.13%
2010	2,118,702	2,888	0.14%
2011	1,780,670	2,718	0.15%
2012	1,806,572	4,477	0.25%
2013	1,939,754	7,706	0.40%
2014	2,411,076	7,792	0.32%
2015	2,476,483	7,380	0.30%
2016	2,436,111	5,355	0.22%
Mean	1,936,013	2,892	0.14%

[1] Average combined hatchery- and natural-origin smolt counts for the years which would comprise the age-3, -4, and -5 adult return components for each adult return year. For example, the "Prosser Average Smolts" for adult return year 1988 is the average of hatchery- and natural-origin Prosser smolt estimates for juvenile migration years 1983-1985.

Table 12. Preliminary estimates of smolt-to-adult survival (SAR) indices for adult returns from hatchery- and natural-origin coho for the Yakima reintroduction program, juvenile migration years 2000-2015.

Juvenile Migration Year	Hatchery-origin Chandler Smolts[a]	Hatchery-origin Prosser Adults[b]	Hatchery-origin SAR Index	Natural-origin Chandler Smolts[a]	Natural-origin Prosser Adults[b]	Natural-origin SAR Index
2000	331,503	3,546	1.1%	37,359	1,432	3.8%
2001	134,574	166	0.1%	40,605	309	0.8%
2002	155,814	669	0.4%	19,859	1,523	7.7%
2003	139,135	505	0.4%	9,092	1,820	20.0%
2004	148,810	2,405	1.6%	18,787	472	2.5%
2005	204,728	2,646	1.3%	31,631	1,562	4.9%
2006	204,602	2,203	1.1%	8,298	1,049	12.6%
2007	260,455	4,132	1.6%	18,772	459	2.4%[c]
2008	416,708	8,835	2.1%	40,170	982	2.4%[c]
2009	496,594	5,153	1.0%	23,858	573	2.4%[c]
2010	341,145	7,216	2.1%	33,408	802	2.4%[c]
2011	333,891	4,948	1.5%	22,908	550	2.4%[c]
2012	244,503	1,865	0.8%	17,667	424	2.4%
2013	483,122	19,913	4.1%	56,947	1,082	1.9%
2014	337,988	2,943	0.9%	159,642	362	0.2%
2015	134,084	1,590	1.2%	20,757	103	0.5%
Mean	272,979	4,296	1.3%	34,985	844	3.3%[d]

[a] Yakama Nation estimates of coho smolt passage at Chandler.

[b] Yakama Nation estimates of age-2 and age-3 coho returns to Prosser Dam for this juvenile migration cohort.

[c] Average estimate derived from PIT-tag detections of Taneum Creek natural coho for juvenile migration years 2009-2011.

[d] Excludes migration year 2003.

Discussion:

Calculation of smolt-to-adult survival rate indices for Yakima Basin anadromous salmonids are complicated by the following factors:

1) Smolt accounting at Prosser is based on statistical expansion of Chandler smolt trap sampling data using available PIT-detection and flow data and estimated Chandler entrainment rates. Chandler smolt passage estimates are prepared primarily for the purpose of comparing relative marked versus unmarked passage estimates and not for making survival comparisons. While these Chandler smolt passage estimates represent the best available data, there may be a high degree of error associated with these estimates due to inherent complexities, assumptions, and uncertainties in the statistical expansion process. Therefore, these estimates are subject to revision.

2) Large numbers of Yakima Basin salmonid releases (all CESRF spring Chinook) are adipose-fin clipped and subjected to higher harvest rates than unmarked wild/natural fish in marine and Columbia River mark-selective fisheries. No

adjustments have yet been made in the above SAR estimates to account for differential harvest rates in these mark-selective fisheries.

3) Due to issues such as water diversion permitting, size required for tagging, and allowing sufficient time for acclimation, release time for many hatchery-origin juveniles (including all CESRF spring Chinook) may be delayed relative to their wild counterparts. For example, spring Chinook from the CESRF are not allowed to volitionally migrate until at least March 15 of their smolt outmigration year; however, juvenile sampling observations at Roza Dam indicate that a substantial number of wild/natural juveniles migrate downstream during the summer, fall, and winter months prior to their smolt outmigration year. Analysis of juvenile migrant PIT detections at Roza Dam (PTAGIS queries run 7/12/2013) indicated that approximately 81% of natural-origin spring Chinook migrated downstream of Roza in the fall or winter as juveniles (before CESRF fish would have the opportunity). Comparison of SAR data for non-contemporaneously migrating juveniles may be invalid.

Given these complicating factors, Tables 10-12 present available smolt-to-adult survival indices for Yakima River spring and summer/fall Chinook and coho. Because of the complexities noted above, these data are useful for analysis of trends but should not be used as direct citations of, or for comparisons of marked and unmarked, smolt-to-adult survival rates. The reader is encouraged to contact Yakama Nation technical staff to discuss these and other issues prior to any use of these data or any other estimation of Yakima Basin SARs that may be available through data obtained from public web sites such as RMPC, PTAGIS, DART, FPC or others.

Substantial juvenile mortality of subyearling releases of summer- and fall-run Chinook occurs in the Yakima River between their release sites and McNary Dam (Neeley 2012b). Strategies have been proposed to address limiting factors (YSFWPB 2004) and improve survival of these releases (Yakama Nation 2012). As these strategies are implemented, we expect SARs for summer- and fall-run Chinook to improve substantially from the estimates provided in Table 11 (Yakama Nation 2012). Additional discussion and results for Yakima Basin spring Chinook SARs are presented in Appendix B.

Status and Trend of Spatial Distribution (Redd Counts)

Methods: Regular foot and/or boat surveys (monitoringmethods.org methods 30, 131, 285, 1508) were conducted within the established geographic range for each species (this is increasing for coho as acclimation sites are located upriver and as the run increases in size). Redds were individually marked during each survey and carcasses were sampled to collect egg retention, scale sample, sex, and body length information and to check for possible experimental marks. River conditions vary from year to year and preclude complete accounting, especially for fall Chinook and Coho. Other agencies (WDFW, Pacific Northwest National Laboratory, and private contractors) have also conducted foot, boat, or aerial surveys for fall Chinook redds in the Yakima River Basin and we have attempted to incorporate available information from those surveys here.

Results:

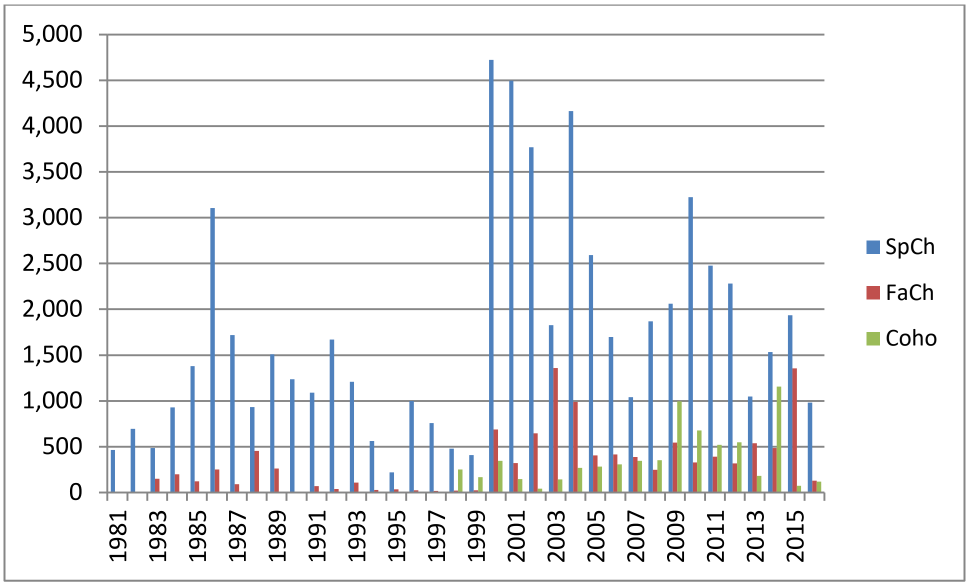

Figure 12. Redd Counts upstream of Prosser Dam in the Yakima River Basin by species, 1981-present.

Table 13. Yakima Basin spring Chinook redd counts and distribution, 1981 – present.

	Upper Yakima River System				Naches River System				
Year	Mainstem[1]	Cle Elum	Teanaway	Total	American	Naches[1]	Bumping	Little Naches	Total
1981	237	57	0	294	72	64	20	16	172
1982	610	30	0	640	11	25	6	12	54
1983	387	15	0	402	36	27	11	9	83
1984	677	31	0	708	72	81	26	41	220
1985	795	153	3	951	141	168	74	44	427
1986	1,716	77	0	1,793	464	543	196	110	1,313
1987	968	75	0	1,043	222	281	133	41	677
1988	369	74	0	443	187	145	111	47	490
1989	770	192	6	968	187	200	101	53	541
1990	727	46	0	773	143	159	111	51	464
1991	568	62	0	630	170	161	84	45	460
1992	1,082	164	0	1,246	120	155	99	51	425
1993	550	105	1	656	214	189	88	63	554
1994	226	64	0	290	89	93	70	20	272
1995	105	12	0	117	46	25	27	6	104
1996	711	100	3	814	28	102	29	25	184
1997	364	56	0	420	111	108	72	48	339
1998	123	24	1	148	149	104	54	23	330
1999	199	24	1	224	27	95	39	25	186
2000	3,349	466	21	3,836	54	483	278	73	888
2001	2,910	374	21	3,305	392	436	257	107	1,192
2002	2,441	275	110	2,826	366	226	262	89	943
2003	772	87	31	890	430	228	216	61	935
2004	2,985	330	129	3,444	91	348	205	75	719
2005	1,717	287	15	2,019	140	203	163	68	574
2006	1,092	100	58	1,250	136	163	115	33	447
2007	665	51	10	726	166	60	60	27	313
2008	1,191	137	47	1,375	158	165	102	70	495
2009	1,349	197	33	1,579	92	159	163	68	482
2010	2,199	219	253	2,671	173	171	168	40	552
2011	1,663	171	64	1,898	212	145	175	48	580
2012	1,276	125	69	1,470	337	196	189	89	811
2013	552	85	34	671	170	66	85	55	376
2014	962	138	53	1,153	129	65	158	27	379
2015	1,258	39	24	1,321	239	177	152	46	614
2016	512	83	22	617	149	106	74	37	366
Mean	1,058	126	28	1,211	165	170	116	48	499

[1] Including minor tributaries.

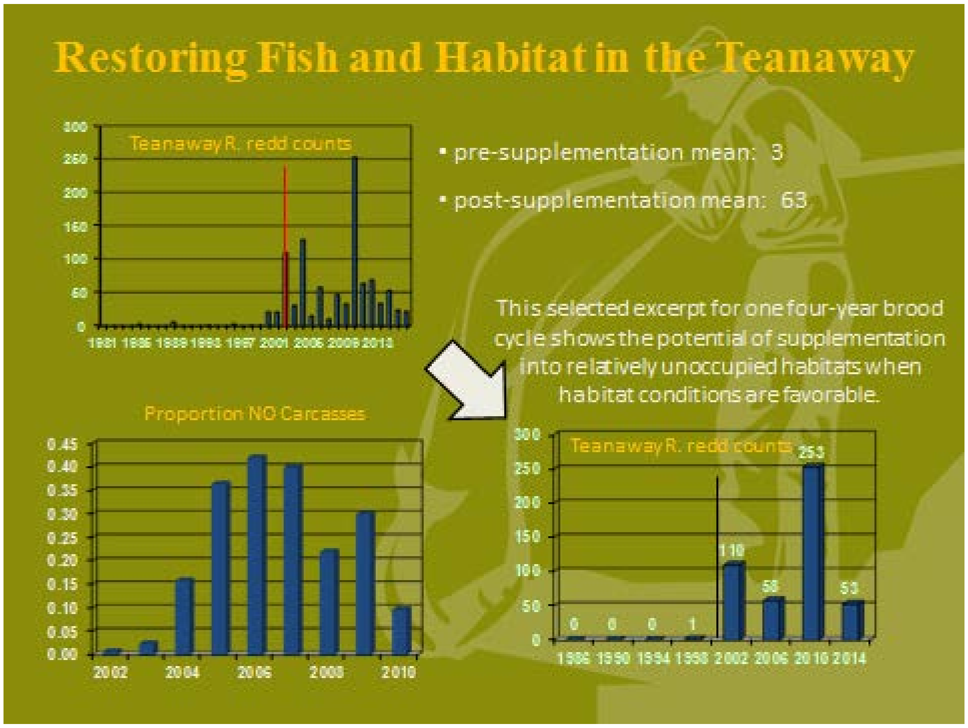

Figure 13. Teanaway River Spring Chinook redd counts, 1981-2016 (vertical lines denote pre- and post-supplementation periods) and the proportion of natural-origin (NO) carcasses observed in intensive spawning ground surveys, 2002-2010.

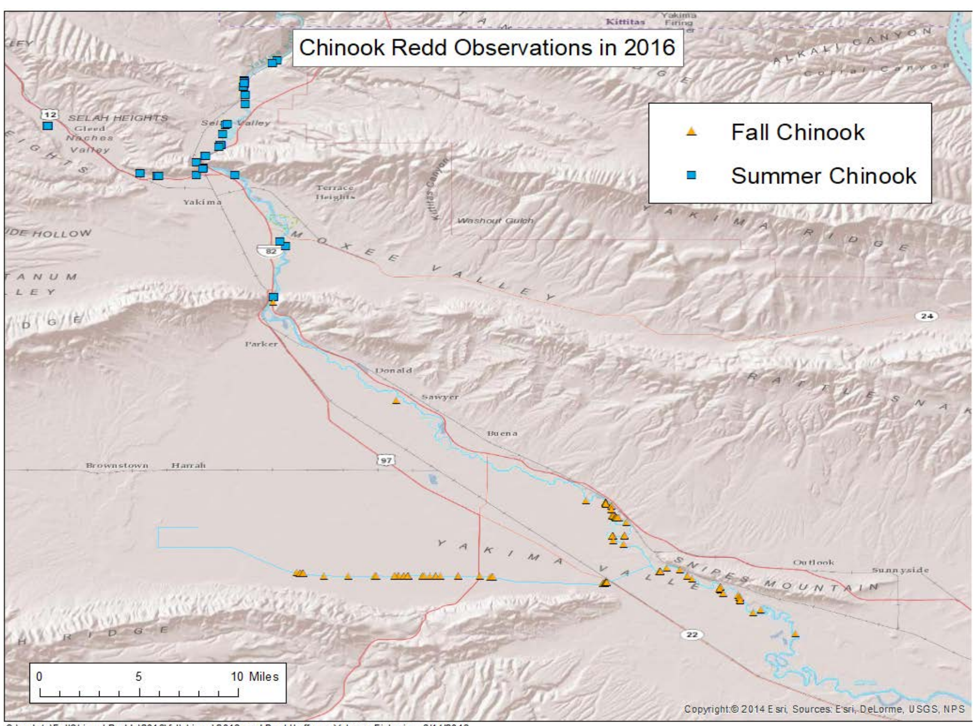

Figure 14. Distribution of summer and fall run Chinook redds in the Yakima River Basin (above Prosser Dam) in 2016.

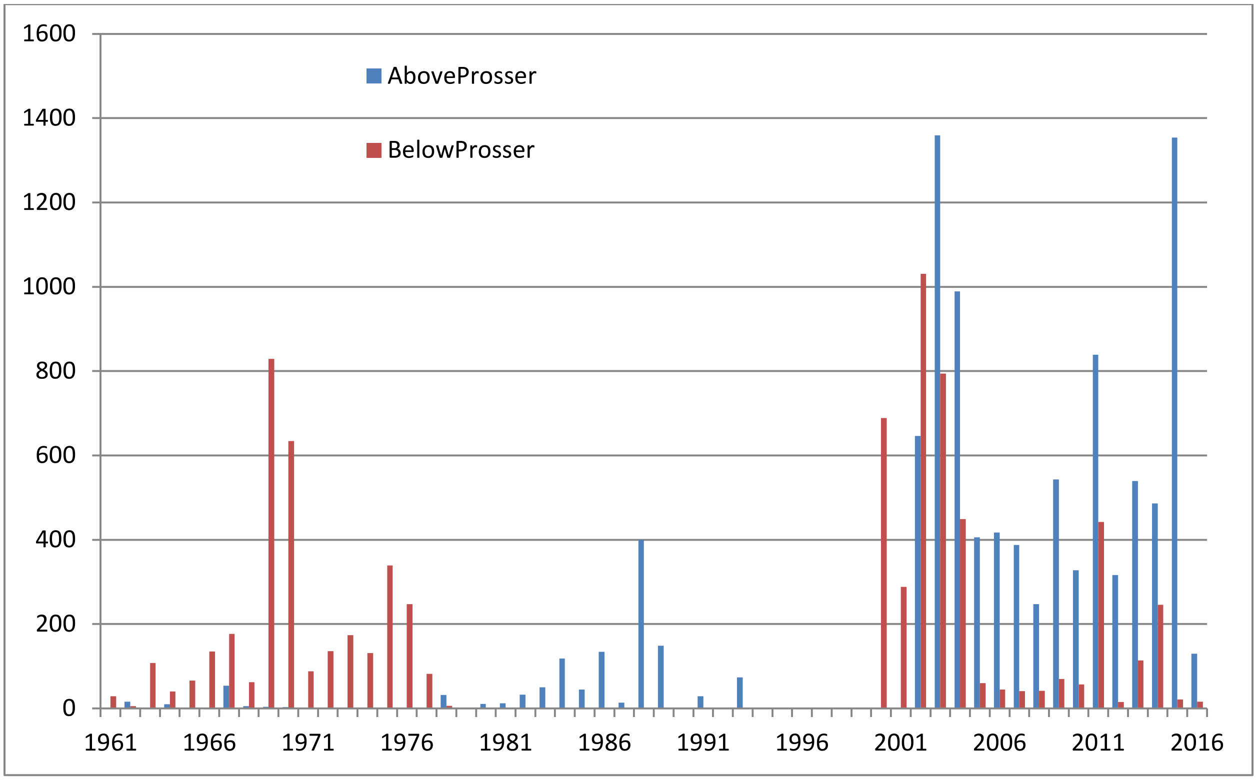

Figure 15. Fall Chinook redd counts above and below Prosser Dam, 1961-present, for years in which surveys were conducted and data are available. Data from YN, WDFW, and Pacific Northwest National Laboratory files. Note that survey completeness is highly variable due to annual flow and turbidity conditions; survey data are partial or incomplete for most years prior to 2000.

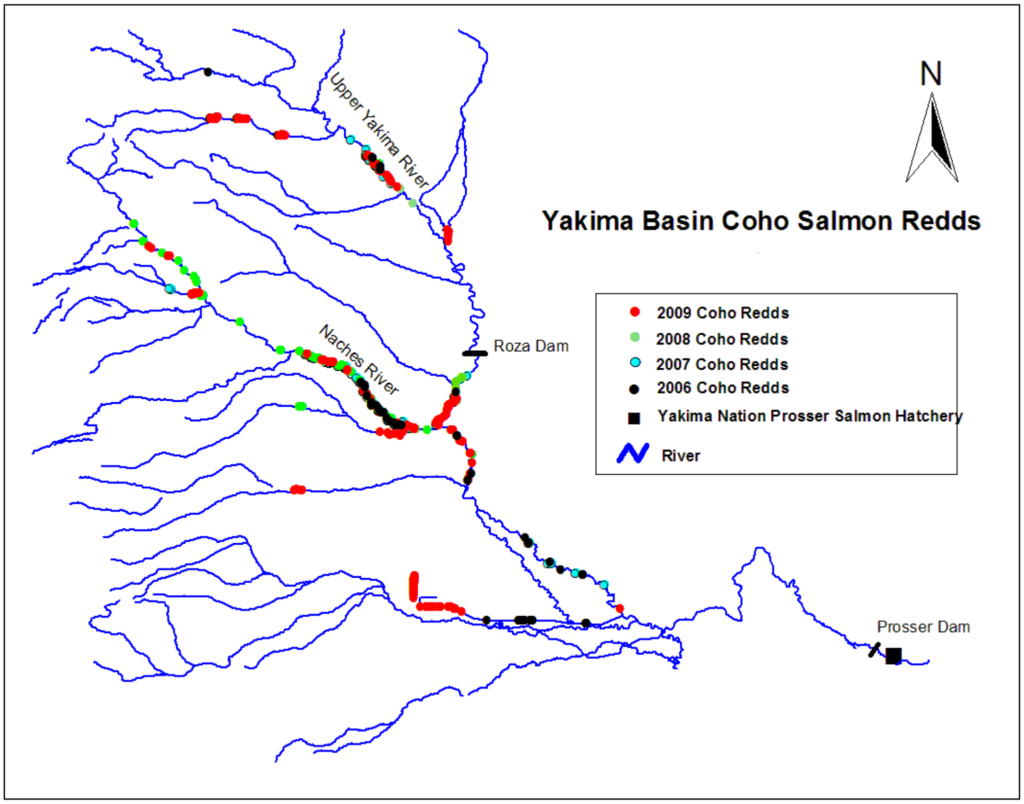

Figure 16. Distribution of coho redds in the Yakima River Basin.

Table 14. Yakima Basin coho redd counts and distribution, 1998 – present.

	Yakima River	Naches River	Tributaries	Total
1998	53	6	193	252
1999	104		62	166
2000	142	137	67	346
2001	27	95	25	147
2002	4	23	16	43
2003	32	56	55	143
2004	33	87	150	270
2005	57	72	153	282
2006	44	76	187	307
2007	63	87	195	345
2008	49	60	242	351
2009	229	281	485	995
2010	75	276	327	678
2011	82	243	196	521
2012	148	228	172	548
2013	45	69	67	181
2014	320	86	751	1157
2015	13	0	59	72
2016	27	37	54	118

Discussion:

Spatial distribution of spring Chinook spawners has increased as a result of acclimation site location, salmon homing fidelity and more fully seeding preferred spawning habitats (Dittman et al. 2010). Redd surveys in the Teanaway River conducted annually by Yakama Nation staff since 1981 demonstrate the benefits of reintroducing salmonids into underutilized habitat (Figure 13). The Jack Creek acclimation site began releasing CESRF spring chinook in 2000, with the first age-4 females returning from these releases in 2002. Redd counts in this tributary have increased from a pre-supplementation average of 3 redds per year to a post supplementation average of 63 redds per year. The proportion of natural-origin carcasses increased from less than one percent in 2002 (when CESRF fish first returned to the natural spawning grounds) to 42% in 2006 when the progeny of the 110 redds produced in 2002 (virtually 100% of which were produced by CESRF-origin fish) returned. These data clearly indicate that naturally-spawning CESRF spring Chinook were successful in returning natural-origin adults back to the Teanaway River. However, redd counts in the Teanaway River remain at or below pre-supplementation levels in some years indicating that habitat factors (primarily low late-summer and fall season flows) continue to deter returning fish and these fish are likely spawning in nearby mainstem and tributary reaches more conducive to survival of progeny (Fast et al. 2015).

Fall Chinook redd distribution in the Yakima River Basin appears to be experiencing a major transition in recent years. Historical redd survey data indicates that a substantial number of fall Chinook spawned below Prosser Dam in the lower Yakima River. However, from 2003-present, an average of approximately 80 percent (range 62 to 90 percent) of surveyed fall Chinook redds have been located above Prosser Dam (Figure 15). Biologists and habitat experts in the subbasin at least partially attribute this change in spawning distribution to the invasion of water stargrass (see Wise et al. 2009) in the lower 43 miles of the Yakima River. With the reintroduction of summer run Chinook, the Yakama Nation is expanding the distribution of summer/fall run Chinook spawners and redds into the middle reaches of the Yakima Basin between the town of Wapato upstream to the confluence with the Tieton River in the Naches subbasin and to Roza Dam in the Upper Yakima subbasin (Figures 1 and 14; Yakama Nation 2012). Figure 14 indicates a good distribution of reintroduced summer-run spawners into the intended habitats above Parker Dam in 2016, primarily age-4 fish returning from subyearling releases in 2013. This is the third year of substantial natural summer-run Chinook spawning in these habitats in over 40 years.

Coho redd counts and spawner distribution have increased substantially since reintroduction efforts began (Table 14 and Figure 16). Many redds in the mainstem were located intermixed with fall chinook redds, tucked under cut banks or were found in side channels. Tributary redd enumeration and identification continues to be accurate due to the fall low water levels, improving interagency cooperation, and relatively good weather. One of the overall goals during the present implementation phase (Phase II) of the coho program is to evaluate the transition of redds from the mainstem river into historic tributaries. With the beginning of Phase II of the Coho Program we observed large increases in tributary spawning, with an annual average exceeding 200 redds counted in tributaries since 2004 (Table 14). Although, there were large numbers of potential spawners in 2014 (~9,000 females), river conditions were very unfavorable for finding redds. Winter anchor ice in early December kept surveys to a minimum. This was followed by winter freshets that reduced visibility in the Naches River to the point where visibility was near zero. However, the stability of low water conditions in 2015 might have contributed to good survival of coho eggs from the 2014-2015 spawning season. The 2016 juvenile outmigration indicated relatively high numbers of natural origin migrating juveniles for the Yakima Basin. River conditions were again unfavorable for successful spawner surveys in 2015. Coho continue to volunteer into many tributaries, and the fidelity of adults from summer parr plants has shown good results. The tributary redd counts we observed in Cowiche Creek and Ahtanum Creek in 2014 were very encouraging. However, we have been unable to relocate adult coho in 2015 and 2016 due to the overall lack of coho adults returning to the Yakima River (Table 15). The study in Taneum Creek was set up to test reintroduction and interactions (Temple et al. 2012); it was not set up for full reintroduction. With implementation of the Coho Master Plan, we expect to double adult out plant numbers, increase escapement into Taneum Creek, and fully seed the available habitat.

Table 15. Results from Taneum Creek adult out-plant study.

Year	Number of Adult Females Outplanted	Redds	Number of Juvenile coho PIT Tagged	Juvenile Migration Year	Juvenile Survival to McNary	Natural-Origin Adults to McNary
2007	150	75	1300	2009	16%	1
2008	150	50	1867	2010	10%	16
2009	150	130	4515	2011	13%	13
2010	150	134	1054	2012	26%	7
2011	150	100	743	2013	12%	9
2012	60	54	1941	2014	12%	1
2013	9	5	231	2015	0%	0
2014	360	200	752	2016	1%	0

Status and Trend of Diversity Metrics

Methods:

Diversity metrics collected for the Cle Elum Supplementation and Research Facility spring Chinook program in the Upper Yakima River include parameters relating to: eggs (e.g., egg size, KD at emergence, emergence timing, etc.), juveniles (growth and survival, migration timing, fish health, etc.), and adults (size at age, sex composition, migration timing, etc.). Methods for monitoring the spring Chinook program were documented in: the YKFP Monitoring Plan (Busack et al. 1997), the project's "Supplementation Monitoring Plan" (Chapter 7 in 2005 annual report on project genetic studies), and numerous manuscripts in the published literature (see Results and References).

Diversity metrics for returning adult summer/fall Chinook and coho collected at the Prosser Dam denil fish trap include sex ratios, lengths, and weights (monitoringmethods.org methods 454, 1454, 1548, 1549, 1551, 4008, 4041).

Results and Discussion:

A detailed presentation of current results for the spring Chinook monitoring program (YN-collected data) are included in Appendix B of this report and are discussed in greater detail in the annual report(s) for WDFW-companion project 1995-064-25. Generally, we have detected small, but significant differences between hatchery- and natural-origin fish in some juvenile and adult traits. Results in the published literature include: Busack et al. (2007), Knudsen et al. (2006, 2008), Larsen et al. (2004, 2006, 2010, 2013), and Pearsons et al. (2009).

Sex ratios, lengths, and weight data for fall Chinook and coho salmon sampled at the Prosser denil adult sampling facility from 2001-present are presented in Tables 16-19. In addition, preliminary results of some diversity metrics relating to the effort to reestablish a natural spawning coho population in the Yakima Basin were published in Bosch et al. (2007). That study observed divergence in some diversity traits between hatchery- and natural-origin fish suggesting that some re-naturalization can be detected in just a few generations after outplanting of hatchery-origin fish in the wild.

Table 16. Sex ratio of upstream migrating fall Chinook sampled at the Prosser Dam right bank denil ladder and fish trap, 2001-present.

Return	Sample Size			Female	Female	Sample Date Range	
Year	F	J	M	Adult %	Total %	First	Last
2001	186	80	213	46.6%	38.8%	09/10/01	11/19/01
2002	389	61	512	43.2%	40.4%	09/09/02	11/25/02
2003	396	24	224	63.9%	61.5%	09/07/03	11/17/03
2004	185	40	201	47.9%	43.4%	09/06/04	11/23/04
2005	201	8	233	46.3%	45.5%	09/06/05	11/14/05
2006	107	11	84	56.0%	53.0%	09/13/06	11/06/06
2007	42	44	39	51.9%	33.6%	09/10/07	11/06/07
2008	81	23	101	44.5%	39.5%	09/08/08	11/13/08
2009	110	132	95	53.7%	32.6%	09/08/09	11/07/09
2010	239	4	162	59.6%	59.0%	09/08/10	11/03/10
2011	67	10	34	66.3%	60.4%	09/07/11	11/09/11
2012	249	109	264	48.5%	40.0%	09/04/12	11/06/12
2013	272	86	460	37.2%	33.3%	09/16/13	11/22/13
2014	681	78	725	48.4%	45.9%	09/04/14	12/10/14
2015	1047	69	1374	43.2%	42.0%	09/09/15	11/16/15
2016	158	22	128	55.2%	51.3%	09/09/16	11/12/16
			Mean	50.8%	45.0%		

Table 17. Sample size (N), mean fork and mid-eye to hypural plate (MEH) lengths (cm), and weights (pounds) of upstream migrating fall Chinook sampled at the Prosser Dam right bank denil ladder and fish trap, 2001-present.

Run	Females				Males (excluding Jacks)			
Year	N	Fork	POH	Weight	N	Fork	POH	Weight
2001	186	72.7	60.1	11.0	213	71.5	57.8	9.3
2002	389	78.4	63.9	13.5	512	76.1	60.2	12.1
2003	396	83.4	68.5	15.6	224	83.7	67.0	16.3
2004	185	82.3	67.8	15.1	201	73.9	60.0	11.2
2005	201	80.5	66.3	14.2	233	75.1	60.6	11.5
2006	107	81.5	66.3	15.6	84	81.3	64.6	15.3
2007	42	79.9	64.4	14.8	39	72.8	56.8	11.7
2008	81	70.1	56.5	9.8	101	67.8	54.0	8.9
2009	110	74.1	57.8	11.2	95	69.4	52.5	9.6
2010	239	73.3	57.8	11.3	162	70.9	54.7	9.7
2011	67	76.5	60.4	12.4	34	74.2	57.7	11.3
2012	249	70.1	53.3	9.5	264	66.4	49.6	7.9
2013	272	72.5	56.1	10.1	460	69.8	52.9	8.7
2014	681	76.1	60.8	11.9	725	69.0	53.2	8.6
2015	1047	76.2	59.5	11.4	1374	71.4	54.8	9.2
2016	158	75.3	59.5	9.7	128	71.6	55.3	8.1
Mean		76.4	61.2	12.3		72.8	57.0	10.6

Table 18. Sex ratio of upstream migrating coho sampled at the Prosser Dam right bank denil ladder and fish trap, 2001-present.

Return Year	Sample Size F	J	M	Female Adult %	Female Total %	Sample Date Range First	Last
2001	1147	44	1024	52.8%	51.8%	09/11/01	11/22/01
2002	72	201	71	50.3%	20.9%	09/11/02	11/25/02
2003	473	89	452	51.1%	46.6%	09/11/03	11/21/03
2004	586	49	509	53.5%	51.2%	09/07/04	11/16/04
2005	531	146	405	56.7%	49.1%	09/13/05	11/15/05
2006	826	97	586	58.5%	54.7%	09/17/06	11/19/06
2007	676	34	538	55.7%	54.2%	09/11/07	11/20/07
2008	666	930	514	56.4%	31.6%	09/08/08	12/04/08
2009	1644	76	1576	51.1%	49.9%	09/09/09	11/20/09
2010	999	35	673	59.7%	58.5%	09/08/10	11/19/10
2011	907	12	776	53.9%	53.5%	09/16/11	11/17/11
2012	1156	108	961	54.6%	52.0%	09/08/12	11/17/12
2013	523	146	528	49.8%	43.7%	09/20/13	11/22/13
2014	4302	135	3668	54.0%	53.1%	09/03/14	12/23/14
2015	656	67	683	49.0%	46.7%	09/13/15	12/09/15
2016	310	101	249	55.5%	47.0%	09/13/16	11/16/16
			Mean	53.9%	47.8%		

Table 19. Sample size (N), mean fork and mid-eye to hypural plate (MEH) lengths (cm), and weights (pounds) of upstream migrating coho sampled at the Prosser Dam right bank denil ladder and fish trap, 2001-present.

Run	Females				Males (excluding Jacks)			
Year	N	Fork	POH	Weight	N	Fork	POH	Weight
2001	1147	65.4	53.7	6.7	1024	65.6	52.4	6.5
2002	72	68.1	54.9	8.5	71	69.4	54.0	8.1
2003	473	65.3	52.9	7.0	452	65.7	51.4	6.8
2004	586	68.8	56.4	8.0	509	67.8	53.9	7.4
2005	531	67.5	54.9	8.0	405	67.6	53.5	7.8
2006	826	71.6	58.2	10.0	586	71.3	55.8	9.4
2007	676	66.3	52.1	7.0	538	65.5	49.9	6.6
2008	666	69.9	56.7	9.6	516	69.8	54.6	9.0
2009	1644	68.1	52.4	7.9	1576	67.2	49.7	7.2
2010	999	69.7	54.2	8.7	673	68.5	51.5	7.8
2011	907	68.6	53.7	8.2	776	68.5	51.7	7.7
2012	1156	64.3	49.5	6.8	961	62.6	46.4	6.0
2013	523	66.2	51.9	6.9	528	64.0	48.4	5.9
2014	4302	65.6	52.6	7.0	3668	63.5	49.8	6.1
2015	656	63.5	50.1	6.0	683	61.9	47.5	5.2
2016	310	66.9	52.7	6.9	249	67.4	51.6	6.4
Mean		67.2	53.6	7.7		66.7	51.4	7.1

Habitat Monitoring

While the majority of YKFP habitat activities in the Yakima Basin are addressed in a separate project (1997-051-00), we are monitoring stream sediment loads associated with the operation of dams and other anthropogenic factors (e.g. logging, agriculture and road building) under this contract as sediment loads can affect survival of salmonids (see description and references here).

Status and Trend of Fine Sediment

Methods: Representative gravel samples (McNiel core samples, monitoring methods 1504) were collected from various reaches in the Little Naches and Upper Yakima Rivers in the fall of 2016. Each sample was analyzed to estimate the percentage of fine or small particles present (<0.85 mm). The Washington State Timber, Fish, and Wildlife program established guidelines that specify the impacts that estimated sedimentation levels can have on salmonid egg-to-smolt survival. These impact guidelines will inform future analyses of "extrinsic" factors on natural production in the Yakima Basin.

Results and Discussion:

Little Naches

A total of 108 McNiel core samples were collected and processed from 9 spawning reaches in the Little Naches drainage this past year. Pyramid Creek has not been sampled since 2009 when the main road going into this reach was decommissioned. Other means to access this sampling site is needed. With this year's monitoring work, the data set for the Little Naches drainage now covers a time period of 32 years for the two historical reaches, and 25 years for the expanded sampling area that includes several tributary streams.

The average percent fine sediment less than 0.85mm for the entire Little Naches drainage in 2016 was 9.8% which was a slight increase over the past five years (Figure 17). The overall trend remains downward and similar trends can be seen when looking at individual reach conditions over the longer term monitoring period since 1992.

The overall average fine sediment found in spawning substrate remains relatively low and should lessen mortality on incubating eggs and alevins. The reduced rate of fine sediment found can be partially attributed to less anthropogenic disturbance occurring in the watershed in recent years, other than recreational activity. Timber harvest activity and road building has been minimal for several years. Landowners have also improved roads and trails to reduce sediment delivery. Further, enhanced stream protection measures have been instituted through the Northwest Forest Plan and the Central Cascades Habitat Conservation Plan for over 20 years. These factors have likely helped reduce fine sediment inputs to the stream system. However recreational activity, such as dispersed camping sites and off-road vehicle use near streams, continues to be a concern. Sediment delivery, bank erosion, and loss of riparian vegetation from recreational use have been observed in some localized areas.

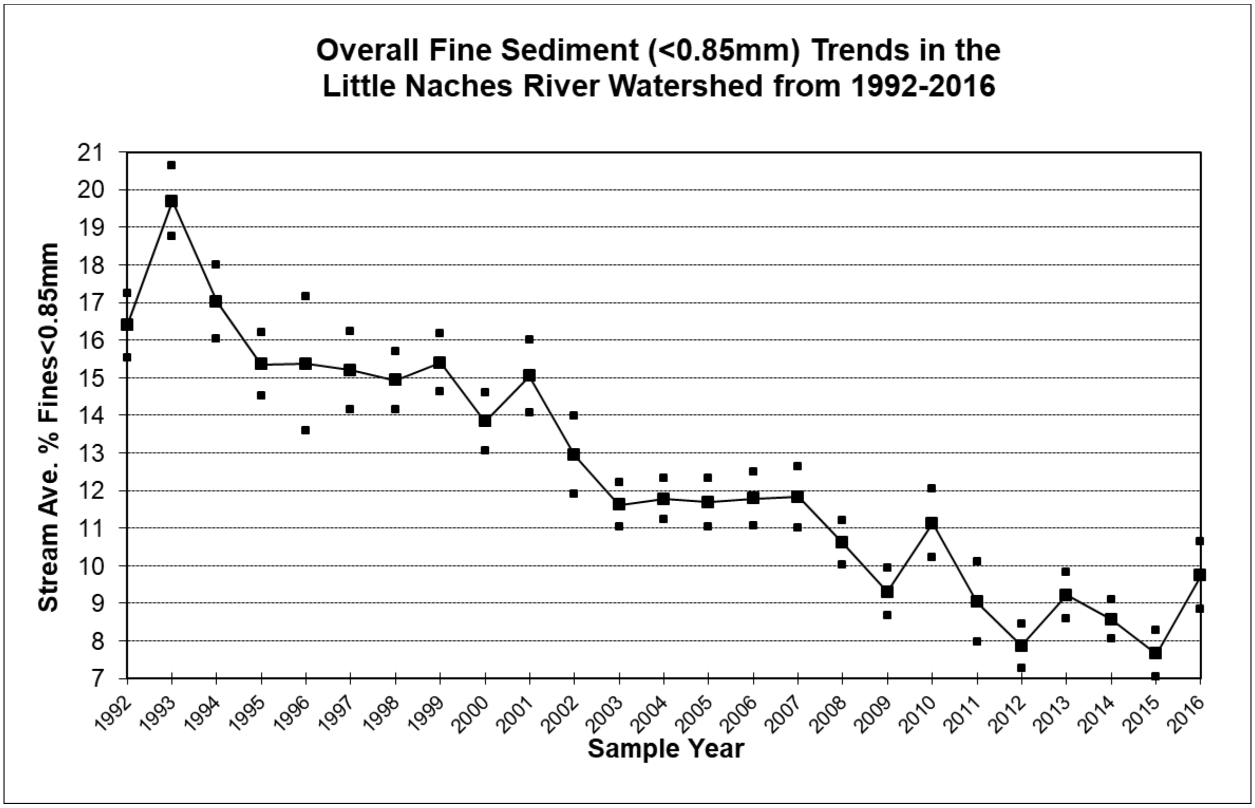

Figure 17. Overall Fine Sediment (<0.85mm) Trends with 95% confidence bounds in the Little Naches River Drainage, 1992-2016.

<u>South Fork Tieton</u>

One reach on the South Fork Tieton River (in the vicinity of Minnie Meadows) has been sampled in the past by the U.S. Forest Service. To the best of our knowledge this reach was not sampled in 2016. This stream reach typically receives significant bull trout spawning activity and the monitoring efforts provide valuable information on their spawning conditions. Average fine sediment in this reach was 8.9% in 2015, matching the previous low observed in 1999, and is well below the mean for sediment levels for the 17 years that were sampled (Figure 18).

<u>Upper Yakima</u>

A total of 60 samples were collected and processed from the Upper Yakima River drainage this past year (5 reaches, 12 samples from each reach). The same reaches (Stampede Pass, Easton, Camelot to Ensign Ranch, Elk Meadows, and Cle Elum) have been sampled annually for the past 20 years. Although the 20-year trend in average percent fine sediment less than 0.85mm for the combined Upper Yakima drainage is still downward, there was a substantial increase in observed fine sediments in 2016 compared to the past seven years (Figure 19).

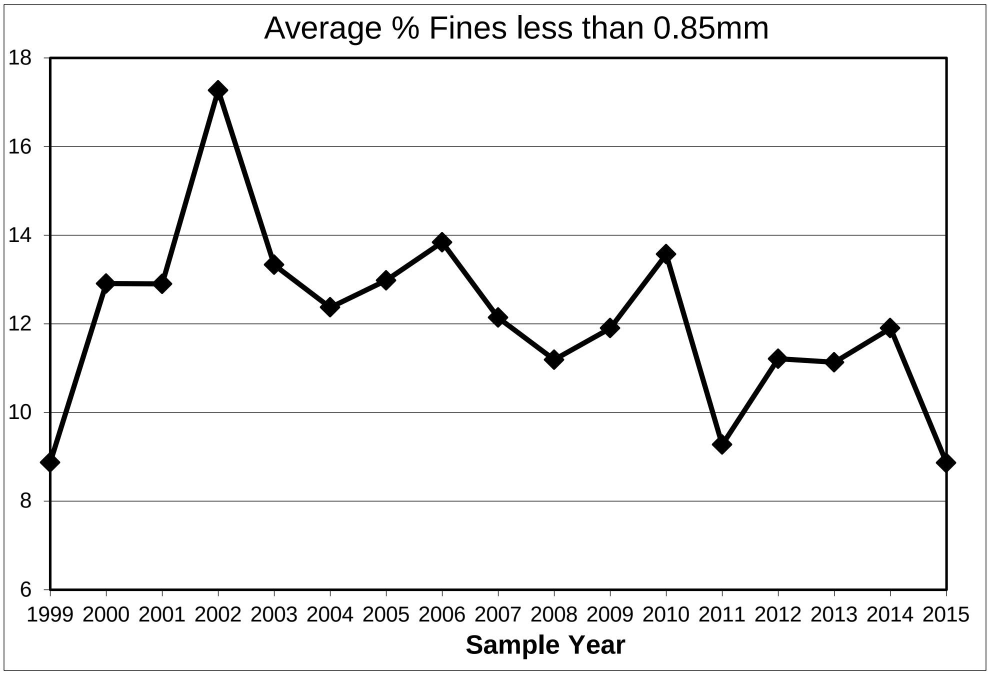

Figure 18. Fine Sediment Trends in the South Fork Tieton River, 1999-2015. Note: Data for 2007 were collected from only 1 Riffle. Data courtesy of U.S. Forest Service.

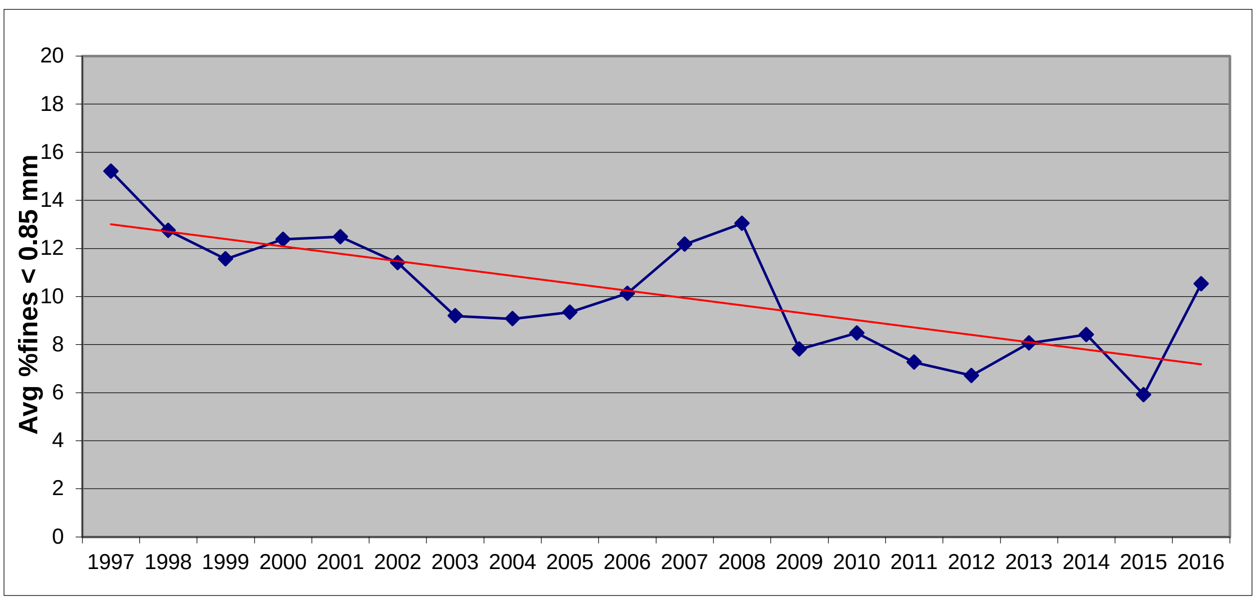

Figure 19. Overall average percent fine sediment (< 0.85 mm) in spawning gravels of the Upper Yakima River, 1997-2016.

Summary

We continue to observe a general decreasing trend in average fine sediment levels in the Little Naches and Upper Yakima drainages. These low rates of fine sediment should be conducive for egg and alevin survival and should favor salmonid spawning success.

The results of the USFS sampling in the South Fork Tieton River have also been low over a 17-year sampling period. These conditions should be favorable for early life history survival of bull trout.

Detailed field data including additional tables and graphs for samples collected in the upper Yakima and Naches basins can be obtained from Jim Mathews, fisheries biologist for the Yakama Nation (matj@yakamafish-nsn.gov).

Harvest Monitoring

Marine and Mainstem Columbia Fisheries

Methods: We evaluated recoveries of coded-wire tags (CWTs) and PIT tags in out-of-basin fisheries using queries of regional mark information system (RMIS) and PIT Tag Information System (PTAGIS) databases. We coordinated with agencies responsible for harvest management (WDFW, ODFW, USFWS, CRITFC, etc.) to estimate the harvest of target stocks. We reviewed reports produced annually by the Pacific Fisheries Management Council (marine) and the *U.S. v Oregon* Technical Advisory Committee (mainstem Columbia) to evaluate estimated harvest or exploitation rates on comparable stocks in these fisheries.

For spring Chinook, additional information was employed that is not readily available for fall Chinook and coho. Standard run reconstruction techniques (Appendix B) were employed to derive estimates of harvest from the Columbia River mouth to the Yakima River mouth for spring Chinook. Data from databases maintained by the *U.S. v Oregon* Technical Advisory Committee were used to obtain harvest rate estimates downstream of the Yakima River for the aggregate Yakima River spring Chinook population and to estimate passage losses from Bonneville through McNary reservoirs. These data, combined with the Prosser Dam counts and estimated harvest below Prosser, were used to derive a Columbia River mouth run size estimate and Columbia River mainstem harvest estimate for Yakima spring Chinook.

Results:

Table 20. Marine and freshwater recoveries of CWTs from brood year 1997-2011 releases of spring Chinook from the CESRF as reported to the Regional Mark Information System (RMIS) 21 Nov 2016.

Brood	Observed CWT Recoveries			Expanded CWT Recoveries		
Year	Marine	Fresh	Marine %	Marine	Fresh	Marine %
1997	5	56	8.2%	8	321	2.4%
1998	2	53	3.6%	2	228	0.9%
1999		2	0.0%		9	0.0%
2000		14	0.0%		34	0.0%
2001		1	0.0%		1	0.0%
2002		7	0.0%		36	0.0%
2003		4	0.0%		10	0.0%
2004	2	154	1.3%	15	526	2.8%
2005	2	96	2.0%	2	304	0.7%
2006	14	328	4.1%	16	1160	1.4%
2007	8	145	5.2%	13	1139	1.1%
2008	5	245	2.0%	7	1634	0.4%
2009	4	91	4.2%	7	588	1.2%
2010	4	164	2.4%	9	948	0.9%
2011[1]	5	162	3.0%	5	856	0.6%

1. Reporting of CWT recoveries to the RMIS database typically lags actual fisheries by one to two years. Therefore, CWT recovery data for brood year 2011 are considered preliminary or incomplete.

Table 21. Estimated run size, harvest, and harvest rates of Yakima Basin spring Chinook in Columbia River mainstem and terminal area fisheries, 1983-present.

Year	Columbia R. Mouth Run Size	Col. R. Mouth to BON Harvest	BON to McNary Harvest	Yakima R. Mouth Run Size	Yakima River Harvest	Columbia Basin Harvest Summary			Col. Basin Harvest Rate	
						Total	Wild	CESRF	Total	Wild
1983	2,452	118	99	1,441	84	300	300	0	12.3%	12.3%
1984	3,868	134	257	2,658	289	680	680	0	17.6%	17.6%
1985	5,248	191	178	4,560	865	1,234	1,234	0	23.5%	23.5%
1986	13,514	280	783	9,439	1,340	2,403	2,403	0	17.8%	17.8%
1987	6,140	96	371	4,443	517	984	984	0	16.0%	16.0%
1988	5,631	360	372	4,246	444	1,177	1,177	0	20.9%	20.9%
1989	8,869	212	663	4,914	747	1,621	1,621	0	18.3%	18.3%
1990	6,908	350	453	4,372	663	1,465	1,465	0	21.2%	21.2%
1991	4,620	183	278	2,906	32	493	493	0	10.7%	10.7%
1992	6,196	102	373	4,599	345	820	820	0	13.2%	13.2%
1993	5,117	44	311	3,919	129	484	484	0	9.5%	9.5%
1994	2,225	86	107	1,302	25	219	219	0	9.8%	9.8%
1995	1,384	1	68	666	79	149	149	0	10.7%	10.7%
1996	5,773	6	303	3,179	475	783	783	0	13.6%	13.6%
1997	5,196	3	348	3,173	575	926	926	0	17.8%	17.8%
1998	2,839	3	143	1,903	188	333	333	0	11.7%	11.7%
1999	3,918	4	180	2,781	604	789	789	0	20.1%	20.1%
2000	28,862	58	1,755	19,100	2,458	4,271	4,147	123	14.8%	14.8%
2001	31,004	948	4,050	23,265	4,630	9,629	5,528	4,101	31.1%	29.7%
2002	23,898	1,234	2,547	15,099	3,108	6,888	2,569	4,320	28.8%	24.7%
2003	9,727	274	764	6,957	440	1,478	890	588	15.2%	14.3%
2004	21,910	964	1,894	15,289	1,679	4,536	2,515	2,021	20.7%	16.1%
2005	11,903	326	741	8,758	474	1,542	1,214	328	13.0%	12.2%
2006	11,560	299	760	6,314	600	1,658	942	716	14.3%	12.8%
2007	4,981	170	343	4,303	279	791	382	410	15.9%	13.8%
2008	11,419	1,151	1,507	8,598	1,532	4,190	1,181	3,008	36.7%	26.5%
2009	12,804	1,168	934	10,701	2,353	4,455	1,237	3,218	34.8%	25.7%
2010	17,366	1,563	2,286	13,142	1,741	5,590	1,302	4,288	32.2%	21.4%
2011	22,171	1,059	1,396	17,960	4,380	6,834	2,373	4,461	30.8%	22.2%
2012	16,641	842	1,427	12,053	3,320	5,588	2,252	3,336	33.6%	27.3%
2013	14,234	847	761	10,245	2,653	4,261	1,686	2,575	29.9%	23.3%
2014	16,291	691	1,758	11,322	2,171	4,620	1,836	2,784	28.4%	21.6%
2015	11,331	460	1,263	9,351	815	2,538	1,323	1,215	22.4%	17.5%
2016[1]	10,083	462	886	6,916	444	1,792	898	893	17.8%	14.7%
Mean	10,767	432	893	7,643	1,190	2,515	1,386	1,129	20.1%	17.7%

1. Preliminary.

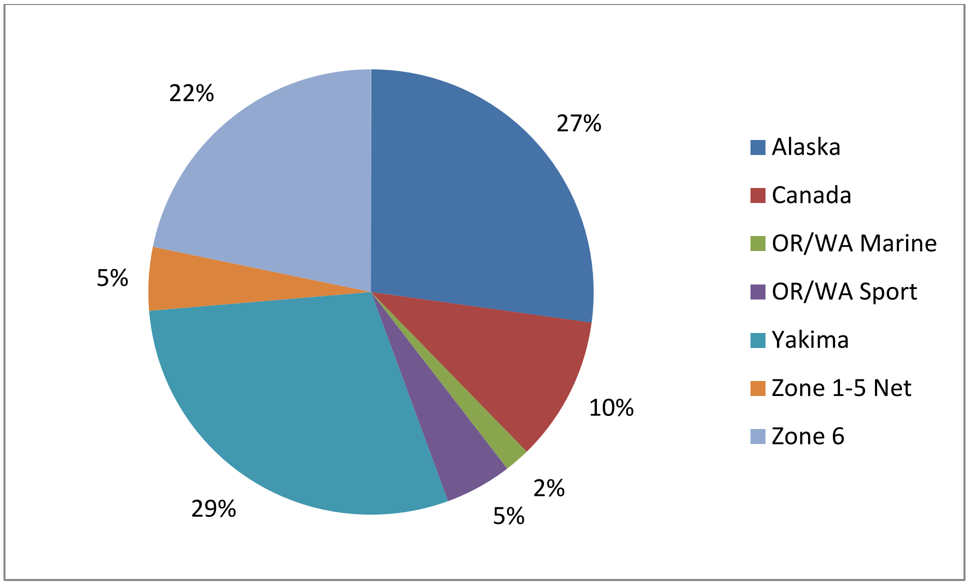

Figure 20. Distribution of coded-wire tag recoveries of Yakima Basin summer/fall run Chinook releases in marine, mainstem Columbia River, and Yakima Basin fisheries. Data retrieved from the regional mark information system (RMIS) for brood year 1997-2007 recoveries.

Recovery data for Yakima River-origin coho are presently limited because few fish have been coded wire-tagged until recent years. We will continue to collect and analyze CWT-recovery data from regional databases and will report this information in the future. 'All H Analyzer' (AHA) modeling for Master Planning purposes assumed that natural- and hatchery-origin Yakima River coho have an exploitation rate of approximately 40 and 60 percent, respectively (Yakama Nation 2012). These estimates include coho caught in marine, Columbia River and Yakima River fisheries.

Discussion:

Based on available CWT information, harvest managers have long assumed that Columbia River spring Chinook are not harvested in any abundance in marine fisheries as their ocean migration does not generally overlap either spatially or temporally with the occurrence of marine fisheries (TAC 1997). Harvest recoveries of CESRF spring Chinook as reported to RMIS to date appear to confirm this, as marine harvest apparently accounts for only about 0-3% of the total harvest of Yakima Basin spring Chinook (Table 20). Adult returns of spring Chinook from the CESRF appear to be making substantial contributions to Columbia Basin fisheries (Table 21).

Yakima Basin summer/fall Chinook are harvested in marine fisheries from Alaska to southern Oregon, and in Columbia River fisheries from the mouth to the Hanford Reach (Figure 20). Approximately 71% of harvest recoveries from Yakima Basin fall Chinook releases for brood years 1997-2007 occurred in marine (44%) and mainstem

Columbia (27%) fisheries. Out-of-basin harvest rates have not been estimated specifically for Yakima Basin summer/fall run Chinook, but the 1982-89 brood year average ocean fisheries exploitation rate for mid-Columbia River summer/fall Chinook was 39%, with a total exploitation rate of 68% estimated for the same years (PSC 1994). Chapman et al. (1994) estimated that the 1975-87 brood year mean exploitation rate for fall Chinook released from Priest Rapids Hatchery was 64%. Harvest rates of these stocks in U.S. fisheries since the mid-1990s have been reduced due to Endangered Species Act (ESA) management concerns as these stocks are intermixed with ESA-listed Snake River fall Chinook populations (NMFS 1999a-d and 2000a-c). It is assumed that Yakima River summer/fall run Chinook are harvested at the same rate in these fisheries as other mid-Columbia River summer/fall Chinook stocks.

Yakima Subbasin Fisheries

Methods: The two co-managers, Yakama Nation and WDFW, are responsible for monitoring their respective fisheries in the Yakima River. Each agency employs fish monitors dedicated to creel surveys and/or fisher interviews at the most utilized fishing locations and/or boat ramps. From these surveys, standard techniques are employed to expand fishery sample data for total effort and open areas and times to derive total harvest estimates. Fish are interrogated for various marks. Methods are consistent with monitoringmethods.org methods 404 and 960.

Results:

Table 22. Spring Chinook harvest in the Yakima River Basin, 1983-present.

	Tribal		Non-Tribal		River Totals			Harvest
Year	CESRF	Natural	CESRF	Natural	CESRF	Natural	Total	Rate[1]
1983		84		0		84	84	5.8%
1984		289		0		289	289	10.9%
1985		865		0		865	865	19.0%
1986		1,340		0		1,340	1,340	14.2%
1987		517		0		517	517	11.6%
1988		444		0		444	444	10.5%
1989		747		0		747	747	15.2%
1990		663		0		663	663	15.2%
1991		32		0		32	32	1.1%
1992		345		0		345	345	7.5%
1993		129		0		129	129	3.3%
1994		25		0		25	25	1.9%
1995		79		0		79	79	11.9%
1996		475		0		475	475	14.9%
1997		575		0		575	575	18.1%
1998		188		0		188	188	9.9%
1999		604		0		604	604	21.7%
2000	53	2,305		100	53	2,405	2,458	12.9%
2001	572	2,034	1,252	772	1,825	2,806	4,630	19.9%
2002	1,373	1,207	492	36[2]	1,865	1,243	3,108	20.6%
2003	134	306	0	0	134	306	440	6.3%
2004	289	712	569	109[2]	858	820	1,679	11.0%
2005	46	428	0	0	46	428	474	5.4%
2006	246	354	0	0	246	354	600	9.5%
2007	123	156	0	0	123	156	279	6.5%
2008	521	414	586	11[2]	1,107	426	1,532	17.8%
2009	1,089	715	541	8[2]	1,630	722	2,353	19.4%
2010	345	194	1,154	48[2]	1,499	241	1,741	13.2%
2011	1,361	1,261	1,579	179[2]	2,940	1,440	4,380	24.4%
2012	1,220	1,302	735	63[2]	1,955	1,364	3,320	27.5%
2013	846	975	786	46[2]	1,632	1,021	2,653	25.9%
2014	576	715	826	54[2]	1,402	769	2,171	19.2%
2015	121	271	385	38	506	309	815	8.7%
2016	103	185	132	24[2]	235	209	444	6.4%
Mean	560	702	565	87	1,125	653	1,169	13.5%

1. Harvest rate is the total Yakima Basin harvest as a percentage of the Yakima River mouth run size.
2. Includes estimate of post-release mortality of unmarked fish.

Table 23. Estimated fall Chinook return, escapement, and harvest in the Yakima River, 1998-2016. Data from WDFW and YN databases.

			Escapement						
	Total Return		Above Prosser		Below Prosser		WA Recreational Harvest		
Year	Adult	Jack	Adult	Jack	Adult	Jack	Adult	Jack	Rate
1998	1,743	106	1,064	84	645	22	34	0	1.8%
1999	4,056	43	1,876	20	2,046	23	134	0	3.3%
2000	4,557	1,138	1,371	922	2,931	194	255	22	4.9%
2001	5,886	869	3,651	660	1,293	151	942	58	14.8%
2002	13,369	211	6,146	95	4,923	116	2,300	0	16.9%
2003	10,092	193	4,796	79	3,874	73	1,422	41	14.2%
2004	5,825	354	2,862	85	2,231	223	732	46	12.6%
2005	3,121	45	1,920	22	491	7	710	16	22.9%
2006	2,299	67	1,499	29	363	10	437	28	19.7%
2007	1,318	460	892	240	194	26	232	194	24.0%
2008	3,403	208	2,739	124	137	17	527	67	16.4%
2009	3,315	772	2,381	591	424	106	510	75	14.3%
2010	3,474	176	2,763	125	270	12	441	39	13.2%
2011	3,325	705	2,318	400	470	81	537	224	18.9%
2012	5,436	1,348	3,634	843	1098	211	704	294	14.7%
2013	11,471	1,249	7,003	703	1936	194	2,532	352	22.7%
2014	11,549	997	7,127	665	2854	266	1,568	66	13.0%
2015	11,142	463	7,071	309	2406	100	1,665	54	14.8%
2016	6,955	537	4,946	409	1087	97	922	31	12.7%

Table 24. Estimated Coho return, escapement, and harvest in the Yakima River, 1999-2016. Data from WDFW and YN databases.

			Escapement						
	Total Return		Prosser Dam		Hatchery Denil		WA Recreational Harvest		
Year	Adult	Jack	Adult	Jack	Adult	Jack	Adult	Jack	Rate
1999	3,906	91	3,852	91			54	0	1.4%
2000	4,444	1,841	4,390	1,826			54	15	1.1%
2001	5,032	68	4,978	68			54	0	1.1%
2002	515	343	475	343			40	0	4.7%
2003	2,192	162	2,192	162			0	0	0.0%
2004	2,367	74	2,325	64			42	10	2.1%
2005	2,897	225	2,890	225			7	0	0.2%
2006	4,478	175	4,335	175	125	0	18	0	0.4%
2007	3,461	64	3,153	60	300	4	8	0	0.2%
2008	4,636	1,917	3,890	1,809	700	58	46	50	1.5%
2009	9,843	873	8,517	573	1300	300	26	0	0.2%
2010	5,776	567	4,811	183	915	384	50	0	0.8%
2011	8,073	171	6,424	121	1594	50	55	0	0.7%
2012	5,511	264	4,298	164	1200	100	13	0	0.2%
2013	3,173	848	2,290	395	837	412	46	41	2.2%
2014	25,368	584	20,997	427	4263	157	108	0	0.4%
2015	3,314	300	2,210	105	1095	195	9	0	0.2%
2016	3,383	374	1,693	188	1690	186	0	0	0.0%

Discussion:

Adult returns of spring Chinook from the CESRF have substantially increased fishing opportunity for all fishers in the Yakima Basin (Table 22) and returned recreational fisheries to the Basin after a 40-year absence. This has contributed to improved relationships between all the Basin's stakeholders and increased opportunities for collaboration.

Recreational fishers enjoy a successful annual fall Chinook fishery situated primarily near the mouth of the Yakima River (Table 23). Tribal fishers harvest a substantial, but unquantified number of Yakima Basin-destined fall Chinook (Figure 20) and coho in commercial gillnet fisheries in the Zone 6 fishing area. Because of the quantity and relatively higher quality of fall Chinook and coho available to tribal fishers in Zone 6 Columbia and Klickitat River fisheries, Yakima River tribal harvest is typically at or near zero even though regulations allowing fall season fisheries in the Yakima River are propagated annually by the Yakama Nation.

Hatchery Research

Effect of Artificial Production on the Viability of Natural Fish Populations

WDFW is addressing some critical uncertainties (see Columbia River Basin Research Plan and Critical Uncertainties for the Columbia River Basin Fish and Wildlife Program) related to genetic and ecological interactions under project 1995-064-25. We are working jointly with WDFW to address the following additional fish propagation uncertainties:

1.1.1. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?

1.2. What is the magnitude of any demographic benefit or detriment to the production of natural-origin juveniles and adults from natural spawning of hatchery-origin supplementation adults?

1.2.1. What are the range, magnitude and rates of change of natural spawning fitness of integrated (supplemented) populations, and how are these related to management rules including the proportion of hatchery fish permitted on the spawning grounds, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock?

Methods:

The YKFP began a spring Chinook salmon hatchery program at the CESRF near Cle Elum on the upper Yakima River (river kilometer 297, measuring from the confluence with the Columbia River; Figures 1 and 21) in 1997. This program is a supplementation effort targeting the upper Yakima River population and is designed to test whether artificial propagation can be used to increase natural production and harvest opportunities while limiting ecological and genetic impacts (RASP 1992). It is an integrated hatchery program (Mobrand et al. 2005) because only natural-origin brood-stock are used and returning hatchery-origin adults are allowed to spawn in the wild. The program employs "best practice" hatchery management principles (see Cuenco et al. 1993, Mobrand et al. 2005) including reduced pond densities, strict disease management protocols, random brood-stock selection, and factorial mating (Busack and Knudsen 2007) to maximize effective population size. Fish are reared at the central facility, but released from three acclimation sites located near the central facility at: Easton approximately 25km upstream of the central facility, Clark Flat about 25km downstream of the central facility, and Jack Creek about 12km upstream from the Teanaway River's confluence with the Yakima River (Figure 21). The CESRF collected its first spring Chinook brood-stock in 1997, released its first fish in 1999, and age-4 adults have been returning since 2001. The first generation of offspring of CESRF and wild fish spawning in the wild returned as adults in 2005. The program uses the adjacent, un-supplemented Naches River population as an environmental and wild control system.

To evaluate demographic benefits for spring Chinook, we compared redd count and natural-origin adult return data for the supplemented Upper Yakima and un-supplemented (control) Naches populations using a Before/After Control/Impact (BACI) analysis (Stewart-Oaten et al. 1986; Smith et al. 1993). For redd counts, the before period was defined as 1981 to 2000 and the after period as 2001 to present (hatchery-origin age-4 adults first returned to integrate with natural-origin fish on the natural spawning grounds in 2001). The first natural-origin returns of age-4 fish from these integrated population redds did not occur until 2005, so the pre- and post-supplementation (before/after) periods for natural-origin return evaluation were defined as 1982 to 2004 and 2005 to present, respectively. The spring Chinook findings described below were published in Fast et al. (2015). We are working with WDFW to incorporate additional out-of-basin control populations in this evaluation and these results will be considered for publication at a later date.

To evaluate fitness parameters for an integrated spring Chinook population, we used methods described in Knudsen et al. (2008), Schroder et al. (2008, 2010, and 2012) and Waters et al. (2015; discussed further below under Hatchery Reform). For coho, we conducted preliminary evaluation of both demographic benefits and some fitness parameters using methods described in Bosch et al. (2007).

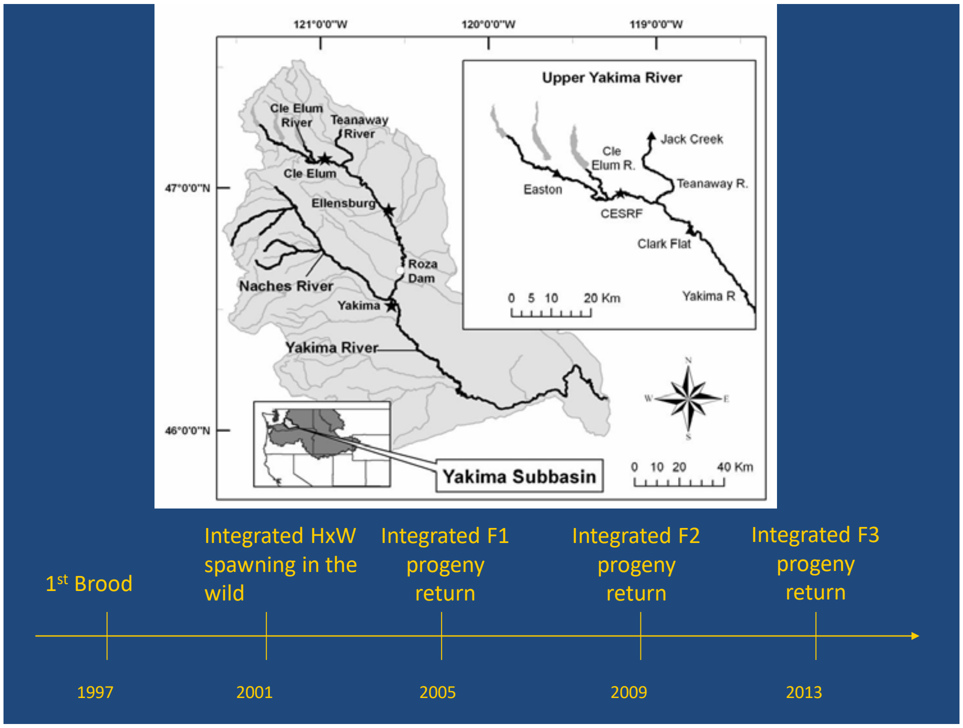

Figure 21. Map of the Yakima River Basin, Cle Elum Supplementation and Research Facility (CESRF) locations, and timeline of the spring Chinook supplementation program.

Results:

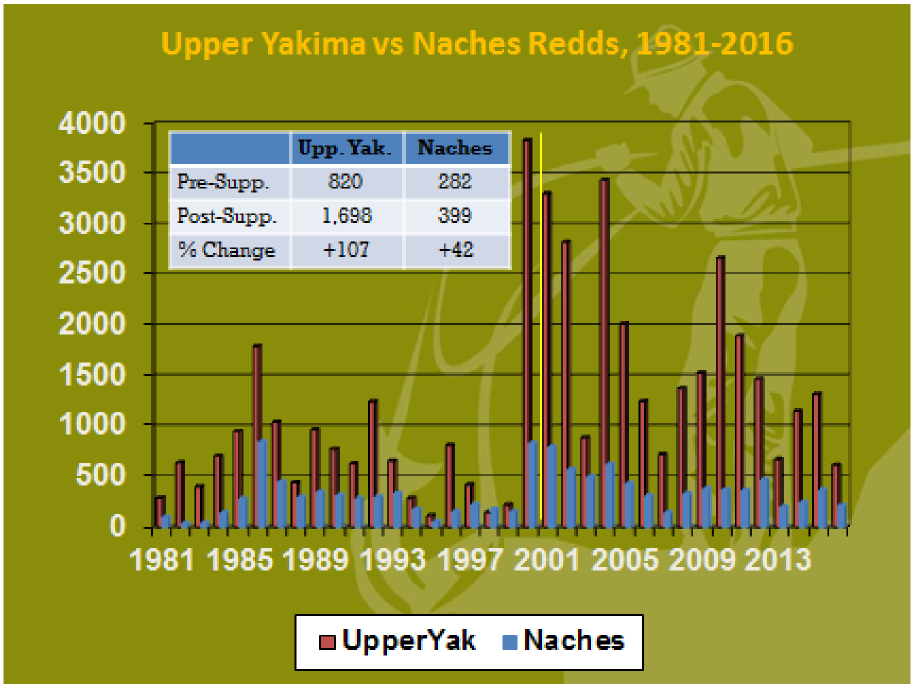

Figure 22. Spring Chinook redd counts in the supplemented Upper Yakima (red bar) relative to the un-supplemented Naches (control; blue bar) for the pre- (1981-2000) and post-supplementation (2001-2016) periods.

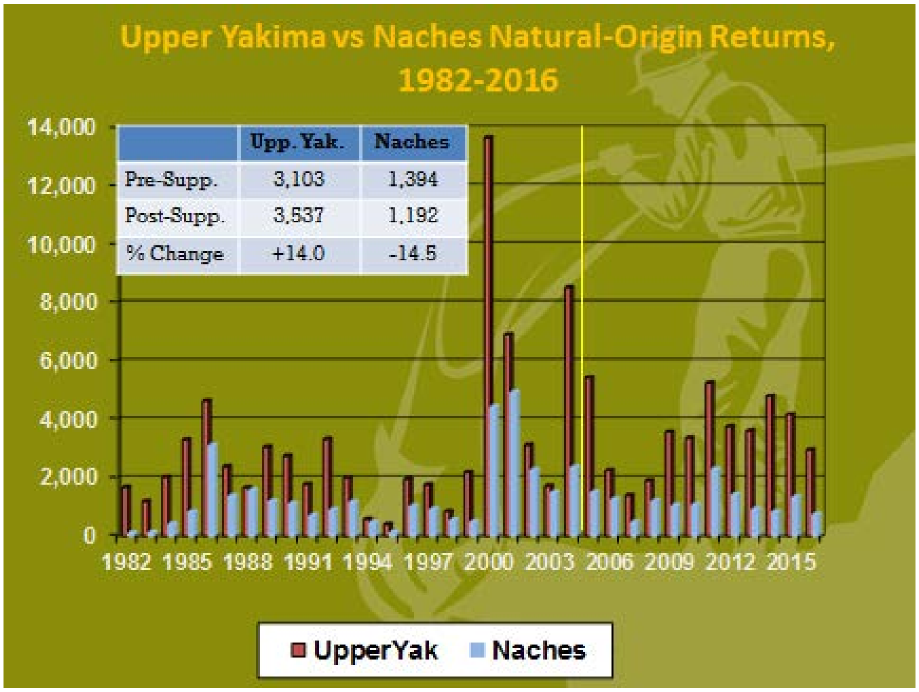

Figure 23. Natural-Origin returns of Spring Chinook in the supplemented Upper Yakima (blue bar) relative to the un-supplemented Naches (control; yellow bar) for the pre- (1982-2004) and post-supplementation (2005-2016) periods.

Discussion:

Supplementation has increased spring Chinook redd abundance in the Upper Yakima relative to the Naches control system (Figure 22). Redd counts in the post-supplementation period (2001-2016) increased in the supplemented Upper Yakima (+107%; P=0.005) but the change observed in the un-supplemented Naches control system relative to the pre-supplementation period (1981-2000) was not significant (+42%; P=0.090). As noted above, spatial distribution of spring Chinook has also increased as a result of supplementation with dramatic increases in redd abundance observed in the Teanaway River (Figure 13) in some years.

Changes in mean natural-origin return abundance in the post-supplementation period (2005-2016) relative to the pre-supplementation period (1982-2004) were not significant in either the supplemented upper Yakima River (+14.0%; P=0.633; Figure 24) or the unsupplemented Naches River system (-14.5%; P=0.604; Figure 23). We have already noted that limiting factors appear to be inhibiting natural productivity (see status and trend of adult productivity) throughout the Yakima Basin. It may also be that the post-supplementation time period is not yet long enough to detect a significant change in this natural production parameter. Given the short post-supplementation time series, these findings are preliminary. We will continue to incorporate additional years of data and out-of-basin control populations into this evaluation and publish more complete findings at a later date.

With respect to spring Chinook fitness parameters we found the following. The relationships between reproductive traits and body length were not significantly altered by a single generation of hatchery exposure. However, because hatchery females had smaller body sizes, the distributions of linked traits, such as total gamete mass and fecundity, differed by as much as 0.6 SD, probably resulting in some fitness loss. Our data support the idea that a single generation of state-of-the-art conservation hatchery propagation can produce fish with reproductive traits similar to those of wild fish, given comparable body size (Knudsen et al. 2008). No differences were detected in the egg deposition rates of wild and hatchery origin females, but pedigree assignments based on microsatellite DNA showed that the eggs deposited by wild females survived to the fry stage at a 5.6% higher rate than those spawned by hatchery-origin females (Schroder et al. 2008). Behavior and breeding success of wild and hatchery-origin males were found to be comparable (Schroder et al. 2010). Large anadromous males produced 89%, jacks 3%, yearling precocious 7%, and sub-yearling precocious 1% of the fry in our tests suggesting that large anadromous males generate most of the fry in natural settings when half or more of the males present on a spawning ground use this life history strategy (Schroder et al 2012). For additional detail on Spring Chinook findings, see Fast et al. (2015). Finally, in addition to the relative reproductive success (RRS) results reported by Schroder et al. (2008 and 2010) for artificial spawning channel studies, we are also working with our project collaborators at WDFW and CRITFC to evaluate RRS for all integrated hatchery- and natural-origin spawners above Roza Dam for brood years 2007-2011 (see https://www.cbfish.org/Document.mvc/Viewer/P154847 for the latest progress report on this project). We expect to complete genotyping for this work by 2018 and hope to publish findings by 2020. Preliminary results for just the 2007 brood year were reported by CRITFC at the 2017 Science and Management conference and are encouraging: a demographic boost from the CESRF program of 2.2X with only jacks showing statistically significant differences in RRS between hatchery-reared and natural-origin fish spawning naturally.

The YKFP is presently studying the release of over 1.0 million coho smolts annually from acclimation sites in the Naches and Upper Yakima subbasins. These fish are a combination of in-basin production from brood-stock collected in the vicinity of Prosser Dam plus out-of-basin stock generally reared at Willard or Eagle Creek National Fish Hatcheries and moved to the Yakima Subbasin for final rearing and release. Monitoring of these efforts to re-introduce a sustainable, naturally spawning coho population in the Yakima Basin have indicated that adult coho returns averaged about 4,500 fish from 1997-2016 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging about 1,000 fish annually since 2001 (Figure 4). Coho re-introduction research has demonstrated that hatchery-origin coho, with a legacy of as many as 10 to 30 generations of hatchery-influence, can reestablish a naturalized population after as few as 3 to 5 generations of outplanting in the wild (Bosch et al. 2007). The project is working to further develop a locally adapted brood-stock and to establish specific release sites and strategies that optimize natural reproduction and survival.

Effectiveness of Hatchery Reform

Hatcheries have long been a part of the fisheries landscape in the Pacific Northwest with programs originally designed to provide abundant returns for harvest in river ecosystems that were becoming increasingly exploited to serve human needs (Lichatowich 1999). Historically, hatchery programs were designed to release a specified number of juveniles from a central facility, and adult survivors, after providing many fish for harvest during their marine and freshwater migrations, would return to swim-in ladders and adult holding ponds at that same facility to spawn successive generations. Over the past two decades or more, such programs have been the subject of much scientific study regarding risks, such as domestication, they pose to natural populations if these fish spawn in the wild.

The concepts of supplementation and hatchery reform, where hatchery programs could be (re)designed to serve conservation as well as harvest purposes, first began to appear in regional discussions and the literature in the late 1980s and early 1990s (e.g, RASP 1992; Cuenco et al. 1993). In Mobrand et al. (2005) and Paquet et al. (2011), the Hatchery Scientific Review Group (HSRG) described in more scientific detail several principles that should guide integrated (conservation-oriented) hatchery programs which purposefully allow fish to spawn in the wild (note that virtually all of the HSRG recommendations were designed into the integrated CESRF program described above). The HSRG reports also recommended that traditional, harvest-oriented hatchery programs should be segregated as much as possible from natural populations to minimize risks by limiting the number of returning fish that escape to natural spawning grounds.

YKFP efforts to monitor and evaluate hatchery reform focus on the CESRF spring Chinook program which was designed explicitly for this purpose from its inception (BPA 1996). We will evaluate similar metrics for the summer/fall run Chinook and coho programs and publish those results in future reports as the Master Plan (Yakama Nation 2012) is implemented and the programs mature over time.

In addition to the integrated (supplementation-S) hatchery program described above for the CESRF, this facility also introduced a segregated "hatchery control" (HC) program in 2002 as recommended by independent scientific review. To protect the integrity of the integrated program evaluation described above, returning HC line fish were either harvested or trapped and removed at the Roza Adult Monitoring Facility (RAMF); no HC line fish were allowed to escape to the spawning grounds (determination of fish origin was based on a differential marking strategy for S and HC fish; unmarked fish were presumed wild). CESRF-project scientists hypothesized that HC-line fish, which use only returning hatchery-origin fish as brood source, would increasingly diverge in phenotypic and genetic characteristics from wild (WC or wild control) fish with increasing generations of hatchery influence, whereas S-line fish, which use only wild or natural-origin fish for brood source, would remain relatively close in characteristics to wild fish (Figure 24). These hypothetical outcomes were based on hatchery reform theory which suggests that, by using only wild or natural-origin parents to spawn successive generations of fish in the hatchery environment, mean fitness of an integrated population in the natural environment can be maintained relatively close to that of a wild population (Mobrand et al. 2005).

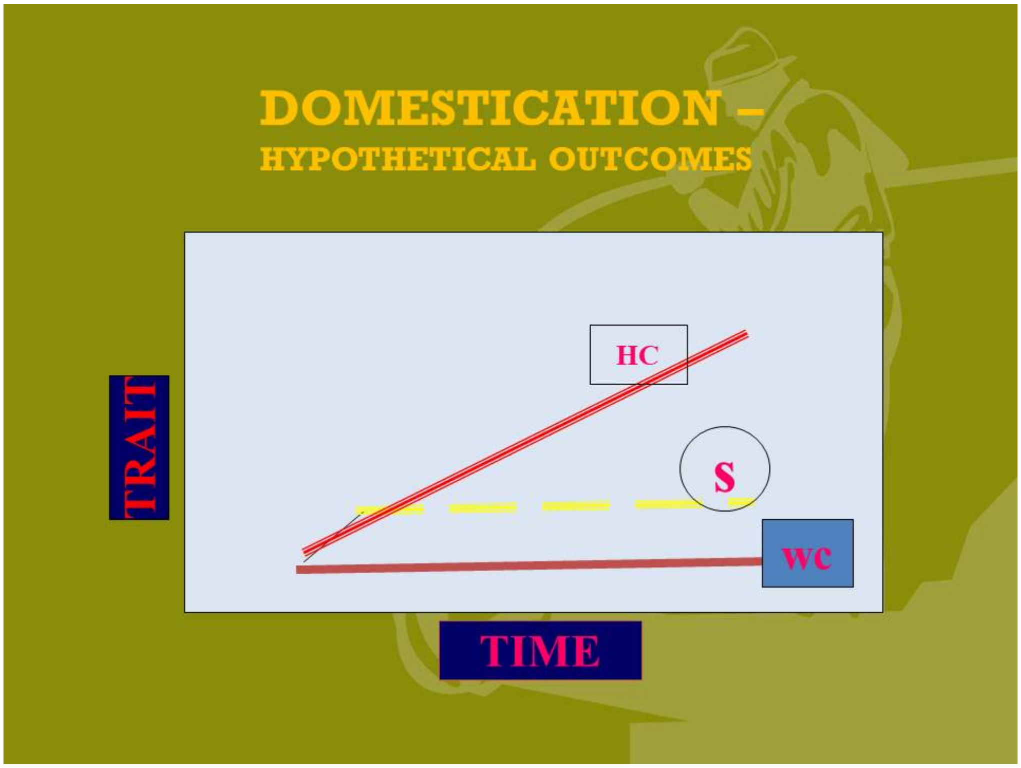

Figure 24. Hypothetical outcomes of trait divergence (domestication effects) over time for a segregated (hatchery-control or HC) line of fish, compared to an integrated (supplementation or S) line of fish and a wild (wild-control or WC) line of fish (D. Fast, Yakama Nation).

This section reports on our efforts to evaluate the effectiveness of hatchery reform measures implemented in the CESRF program.

Methods:

Methods for enumerating natural- and CESRF-origin fish at Roza Dam were described above (Status and Trend of adult abundance) and in Knudsen et al. (2006). Methods for evaluating genetic differentiation between the wild founding, integrated, and segregated populations at the CESRF were described in Waters et al. (2015).

A recently developed parameter to monitor the mean fitness of an integrated population in the natural environment is called Proportionate Natural Influence (PNI). PNI is an approximation of the rate of gene flow between the natural environment and the hatchery environment (Busack et al. 2006). The equation describing PNI is

$$PNI = \frac{pNOB}{pNOB + pHOS}$$

where pNOB is the proportion of natural-origin brood-stock and pHOS is the proportion of hatchery-origin spawners. We evaluated PNI for the CESRF program using a pNOB value of 1.0 as only natural-origin fish were used for the integrated program's broodstock.

Results and Discussion:

For CESRF integrated program return years 2001-2016, PNI averaged 66% while pHOS averaged 53% (Table 25). As stated in the introduction to this report and in the final Environmental Impact Statement for the Yakima Fisheries Project (BPA 1996), one of the explicit purposes of the project is to test the assumption that new artificial propagation or hatchery reform techniques (Cuenco et al. 1993, Mobrand et al. 2005) can be used to increase natural production without causing significant impacts to existing natural populations. Therefore it has always been the intent of this project to purposely allow integrated hatchery-origin fish to escape to the natural spawning grounds, i.e., we intentionally maintained a relatively high pHOS rate. Even with a high pHOS relative to recommendations, PNI for the CESRF integrated program remained in the "low hatchery influence for conservation of natural populations" category described by the HSRG (Paquet et al. 2011).

The project will continue to monitor PNI considering factors such as: policy input regarding controlling the number and types of fish allowed to escape to natural spawning areas, meeting overall production goals of the project, guidance from the literature relative to percentage of hatchery fish on the spawning grounds with fitness loss, considerations about what risk is acceptable in a project designed to evaluate impacts from that risk, and the numerous risk containment measures already in place in the project. The State of Washington is using mark-selective fisheries in the lower Columbia River and, when possible, in the lower Yakima River in part as a tool to manage escapement proportions. In 2011, the project implemented an effort to transfer some returning hatchery-origin CESRF adults from Roza Dam to Lake Cle Elum for the purpose of returning marine derived nutrients and salmon to the watersheds that feed the lake. These measures will also increase PNI in the major spawning areas of the Upper Yakima Basin. Additional adaptive management measures will be considered when and if monitoring and evaluation indicates a need.

Table 25. Escapement (Roza Dam counts less brood-stock collection and harvest above Roza) of natural- (NoR) and hatchery-origin (HoR) spring Chinook to the upper Yakima subbasin, 1982 – present.

	Wild/Natural (NoR)			CESRF (HoR)			Total				
Year	Adults	Jacks	Total	Adults	Jacks	Total	Adults	Jacks	Total	PHOS[1]	PNI[1]
1982			1,146								
1983			1,007								
1984			1,535								
1985			2,331								
1986			3,251								
1987			1,734								
1988			1,340								
1989			2,331								
1990			2,016								
1991			*1,583*[2]								
1992			3,009								
1993			1,869								
1994			563								
1995			355								
1996			1,631								
1997	1,141	43	1,184								
1998	369	18	387								
1999	498	468	966								
2000	10,491	481	10,972		688	688	10,491	1,169	11,660	5.9%	
2001	4,454	297	4,751	6,065	982	7,047	10,519	1,279	11,798	59.7%	62.6%
2002	1,820	89	1,909	6,064	71	6,135	7,884	160	8,044	76.3%	56.7%
2003	394	723	1,117	1,036	1,105	2,141	1,430	1,828	3,258	65.7%	60.3%
2004	6,536	671	7,207	2,876	204	3,080	9,412	875	10,287	29.9%	77.0%
2005	4,401	175	4,576	627	482	1,109	5,028	657	5,685	19.5%	83.7%
2006	1,510	121	1,631	1,622	111	1,733	3,132	232	3,364	51.5%	66.0%
2007	683	161	844	734	731	1,465	1,417	892	2,309	63.4%	61.2%
2008	988	232	1,220	2,157	957	3,114	3,145	1,189	4,334	71.9%	58.2%
2009	1,843	701	2,544	2,234	2,260	4,494	4,077	2,961	7,038	63.9%	61.0%
2010	2,436	413	2,849	4,524	1,001	5,525	6,960	1,414	8,374	66.0%	60.2%
2011	3,092	926	4,018	3,162	1,404	4,566	6,254	2,330	8,584	53.2%	65.3%
2012	2,359	191	2,550	2,661	265	2,926	5,020	456	5,476	53.4%	65.2%
2013	1,708	678	2,386	1,587	840	2,427	3,295	1,518	4,813	50.4%	66.5%
2014	3,099	685	3,784	2,150	794	2,944	5,249	1,479	6,728	43.8%	69.6%
2015	3,357	163	3,520	1,779	167	1,946	5,136	330	5,466	35.6%	73.7%
2016	2,070	266	2,336	1,198	705	1,903	3,268	971	4,239	44.9%	69.0%
Mean[3]	2,662	375	3,038	2,530	755	3,285	5,077	1,161	6,237	53.1%	66.0%

1. Proportionate Natural Influence equals Proportion Natural-Origin Brood-stock (PNOB; 1.0 as only NoR fish are used for supplementation line brood-stock) divided by PNOB plus Proportion Hatchery-Origin Spawners (PHOS).
2. This is a rough estimate since Roza counts are not available for 1991.
3. For NoR columns, mean of 1997-present values. For all other columns, mean of 2001-present values.

Both the CESRF integrated and segregated programs have now proceeded for several generations and we can evaluate actual outcomes relative to the hypothetical outcomes given in Figure 24 above. Results were presented in Waters et al. (2015) and empirically demonstrate that using managed gene flow (i.e, using only natural-origin fish for brood stock) reduced genetic divergence over time in the CESRF integrated (S-line) fish compared to the segregated (HC-line; hatchery-origin parents) fish (Figure 25). The actual results are remarkably consistent with the projected outcomes in Figure 24 demonstrating that there is considerable merit to the concepts behind hatchery reform. While some detractors of hatchery supplementation choose to highlight the differences the CESRF program has found between hatchery and natural-origin fish such as those documented in Knudsen et al. (2006 and 2008), it is important to note that integrated hatchery-origin fish were never expected to be identical to wild fish (Figure 24), but rather similar enough to increase demographic abundance of natural spawners while minimizing risk, which is exactly what the results to date for this project demonstrate (Fast et al. 2015; Koch et al. 2017). Additional evaluation is required before definitive answers to key biological cost and benefit questions relative to using this type of management over the long-term will be known with scientific certainty (Fraser 2008). The YKFP is continuing its collaboration with University of Washington and NOAA scientists to further evaluate and associate genetic divergence results from Waters et al. (2015) with the phenotypic trait analyses in Knudsen et al. (2006 and 2008).

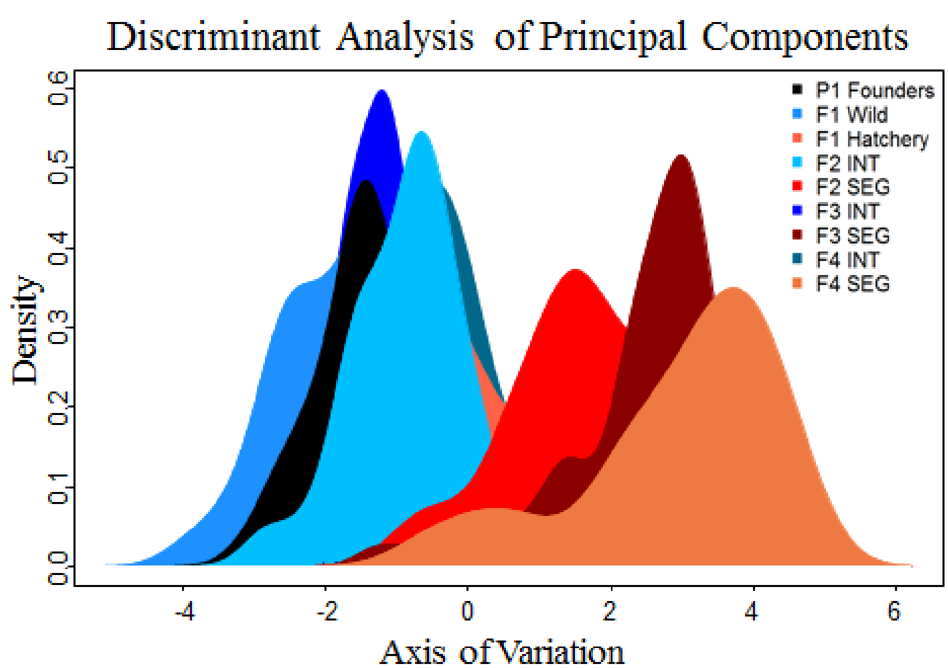

Figure 25. Estimated genetic divergence (variation) for integrated (INT blue), segregated (SEG red), and wild founder (black) spring Chinook in the CESRF program after 4 parental-generations of the hatchery program (P1=1998, F1=2002, F2=2006, F3=2010, F4=2014; updated from Figure 4 in Waters et al. 2015).

Additional information and results from the CESRF program are provided in Appendix B and in Fast et al. (2015).

Predation Management and Predator Control

Avian Predation Index

Avian predators are capable of significantly depressing smolt production. The loss of wild spring Chinook salmon juveniles to various types of avian predators has long been suspected as a significant constraint on production and could limit the success of supplementation. Therefore, a long-standing objective of the YKFP has been to monitor, evaluate, and index the impact of avian predation on annual salmon and steelhead smolt production in the Yakima Subbasin. Accurate methods of indexing avian predation across years have been developed.

Methods:

River Reach Surveys

The spring river surveys included nine river reaches (Table 26) and were generally consistent with avian point count methods described in monitoringmethods.org method 1151. The surveys account for coverage of approximately 40% of the total length of the Yakima River.

Table 26. Avian predation river reach survey start and end locations and total reach length.

Name	Start	End	Length (km)
Easton	Easton Acclimation Site	Bridge	29.3
Cle Elum	South Cle Elum Bridge	Thorp Hwy Bridge	28.3
Canyon	Ringer Road	Lmuma or Roza Recreation Site	20.8 or 29.8
Selah Section	Harrison Rd Bridge	Harlan Landing Park	6.42
Gap to gap	Harlan Landing Park	Union Gap	15.85
Parker	Below Parker Dam US Hwy 97	Hwy 8 Bridge	20.3
Zillah	US Hwy 97/ Hwy 8 Bridge	Granger Bridge Ave Hwy Bridge	16.0
Benton	Chandler Canal Power Plant	Benton City Bridge	9.6
Vangie	1.6 km above Twin Bridges	Van Giesen St Hwy Bridge	9.3

All river reach surveys were conducted by a two-person team from a 16 foot drift boat or 12 foot raft. Surveys began between 8:00 am and 9:00 am and lasted between 2 to 6 hours depending upon the length of the reach and the water level. All surveys were conducted while actively rowing the drift boat or raft downstream to decrease the interval of time required to traverse the reach. One person rowed the boat while the other person recorded piscivorous birds encountered.

All birds detected visually or aurally were recorded, including time of observation, species, and sex and age if distinguishable. Leica 10x42 binoculars were used to help observe birds. All piscivorous birds encountered on the river were recorded at the point of initial observation. Most birds observed were only mildly disturbed by the presence of the survey boat and were quickly passed. Navigation of the survey boat to the opposite side of the river away from encountered birds minimized escape behaviors. If the bird attempted to escape from the survey boat by moving down river a note was made that the bird was being pushed. Birds being pushed were usually kept in sight until passed by the survey boat. If the bird being pushed down river moved out of sight of the survey personnel, a note was made, and the next bird of the same species/age/sex to be encountered within the next 1000 meters of river was assumed to be the pushed bird. If a bird of the same species/age/sex was not encountered in the subsequent 1000 meters, the bird was assumed to have departed the river or passed the survey boat without detection, and the next identification of a bird of the same species/age/sex was recorded as a new observation.

Acclimation Site Surveys

Three Spring Chinook acclimation sites in upper Yakima River (Clark Flat, Jack Creek, and Easton) and one Coho site (JD Holmes) were surveyed for piscivorous birds from 2004 through 2016 (Figure 1). Surveys were conducted between January 23 and June 10, though dates varied for each site. Three surveys were conducted at the Spring Chinook sites each day, at 8:00 am, 12:00 noon, and 4:00 pm. The Coho site was surveyed once or twice on days hatchery personnel were feeding smolts. Surveys were conducted on foot. All piscivorous birds within the acclimation facility, along the length of the artificial acclimation stream, and 50 meters above and 150 meters below the acclimation stream outlet, into the main stem of the Yakima River or its tributaries, were recorded.

Salmon PIT Tag Surveys at Great Blue Heron Rookeries

A Passive Integrated Transponder (PIT) tag reader was used to survey for PIT tags deposited in various Yakima River Great Blue Heron Rookeries (Figure 26). Methods were generally consistent with Evans and Hostetter (2012) and with monitoringmethods.org method 255.

Areas surveyed included: Selah, Toppenish Creek, Buena, Wapato Wildlife area, Grandview, and Satus. Based on the salmon tags found at these sites consumption could be assigned to piscivorous fish: American White Pelicans, Double Crested Cormorants, and the Great Blue Herons. Predation assignment was strictly by observation. For example, the Chandler Bypass has been heavily used by pelicans since 2003 while the Selah Heronry supports herons and sometimes cormorants.

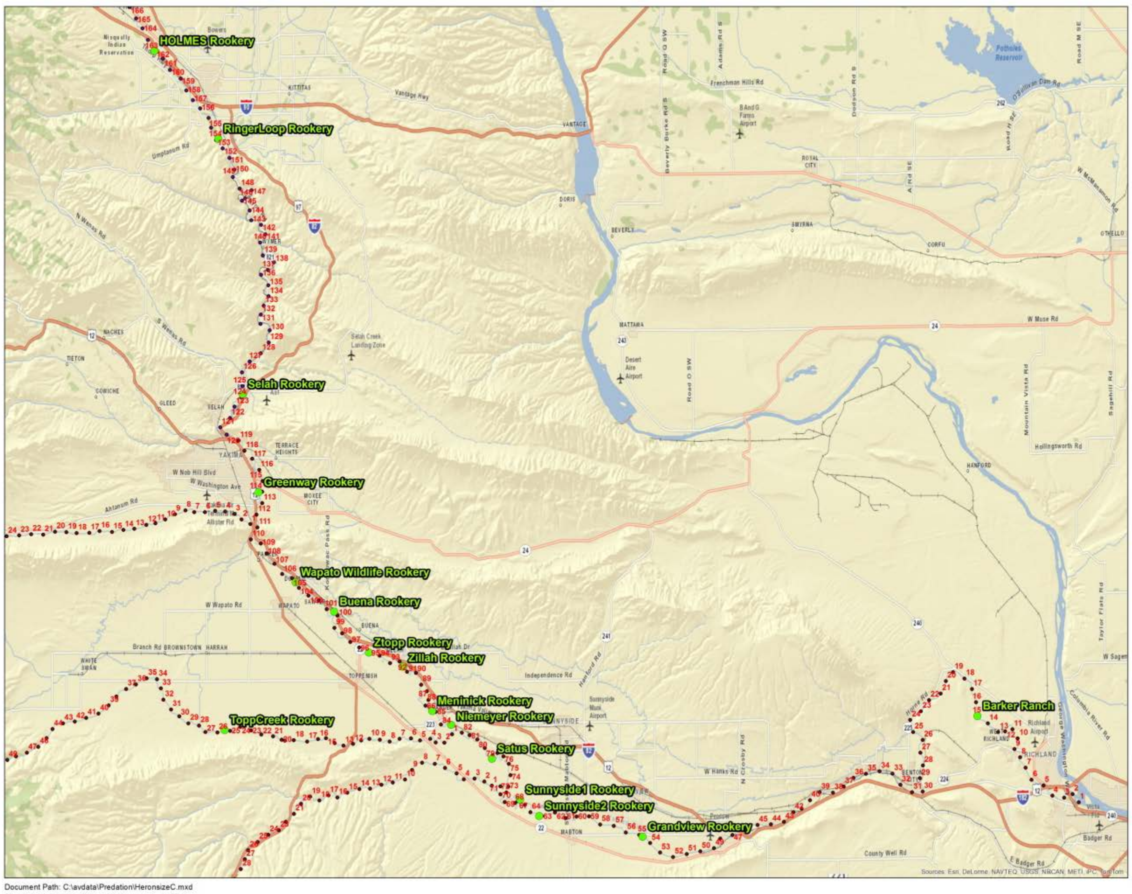

Figure 26. Map of Yakima Basin Heron Rookeries.

PIT Tag surveys were conducted using the *Portable Transceiver System: PTS Model FS2001F-ISO from Biomark*. The transceiver is designed to scan for PIT tags and identify them by their given code. A Garmin GPS unit was used to map rookeries along with survey plots or points. Additional equipment included the use of camouflage to limit disturbance for bird nest identification and counts.

Rookeries were surveyed to determine total rookery numbers and Great Blue Heron population numbers via jet boat, plane, and foot. Rookeries were surveyed in the spring and summer for population numbers using binoculars; rookeries were not entered for fear of causing bird abandonment. Once birds had fledged, rookeries were cleared of debris under nests to scan for defecated/regurgitated PIT tags.

The objectives for the study were:

- Identify all Rookeries in the Yakima Basin
- Survey populations during nesting
- Estimate detection efficiencies by seeding PIT Tags
- Clear PIT Tag deposit areas after fledging
- Survey for PIT Tags post fledge and after flooding
- Remove PIT Tags (tag collision causes interference)
- Conduct aerial flights and river surveys to monitor populations

Results and Discussion:

River Reach Surveys

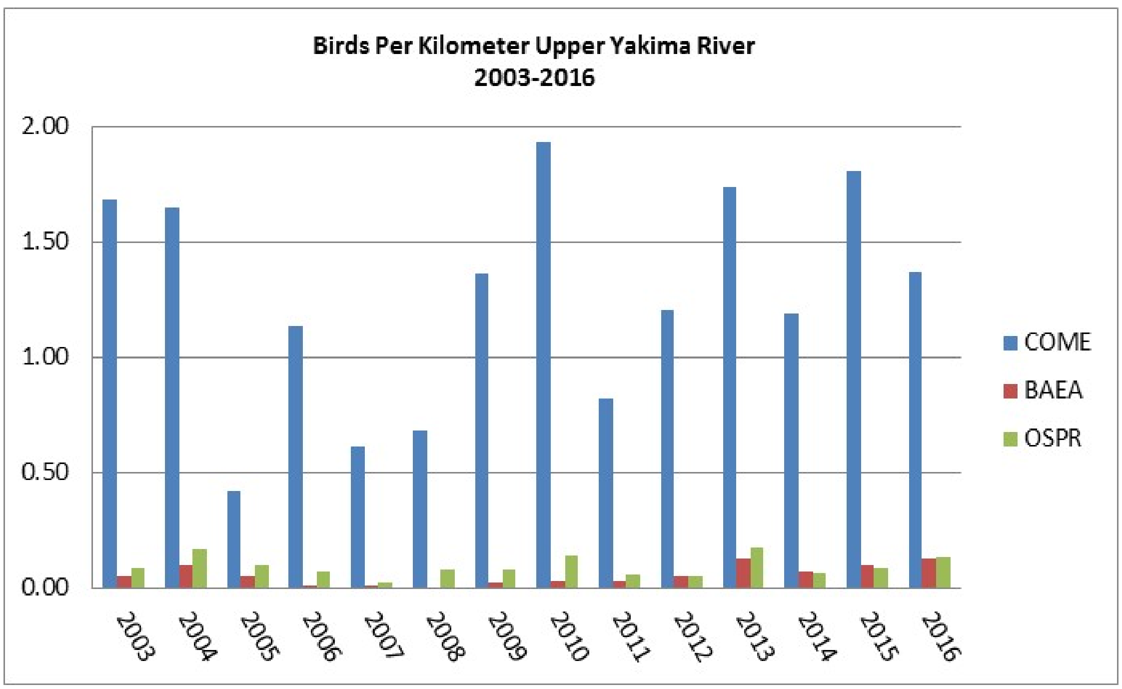

Figure 27. Upper Yakima piscivorous birds per kilometer (Common Merganser-COME, Bald Eagle-BAEA, and Osprey-OSPR).

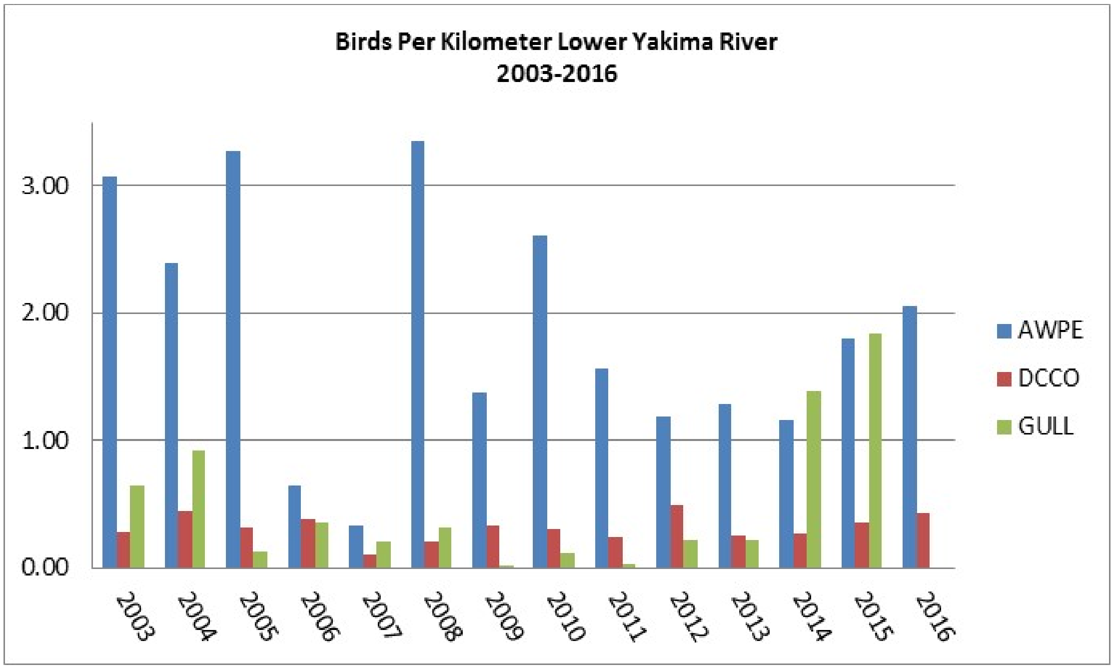

Figure 28. Lower Yakima piscivorous birds per kilometer (American White Pelican-AWPE, Double Crested Cormorant-DCCO, and Gulls-GULL).

Thirteen different piscivorous bird species were observed on the Yakima River. These included: American White Pelican, Bald Eagle, Black-crowned Night Heron, Belted Kingfisher, Caspian Tern, Common Merganser, Double-crested Cormorant, Forster's Tern, Great Egret, Great Blue Heron, Gull species, Hooded Merganser, and Osprey. These same 13 species were observed in most survey years. Graph data for river reach surveys represents a combined view of the upper Yakima River (surveys above Wapato Dam; Figure 27) and the lower Yakima River (surveys below Wapato Dam; Figure 28). The three top bird predators within these bisected areas were chosen for graph representation.

Osprey, Great Blue Heron, and Belted Kingfisher were the only species found on all six reaches in the spring, and Common Mergansers were observed on all reaches except the Vangie reach. Common Mergansers were most abundant in the upper reaches of the river (Easton and Cle Elum reaches) which was the case in all years surveyed (Figure 27).

Gull numbers in the lower Yakima River decreased in 2016, reversing the rise observed in the prior two years (Figure 28). Double Crested Cormorant numbers surveyed remained consistent with prior years. This species remains a concern due to takeover of Great Blue Heron Rookeries in various areas along the Yakima River. Monitoring of the Double Crested Cormorant on the river and in rookeries will be a priority in upcoming years as the Army Corp of Engineers culls and removes breeding habitat at the estuary of the Columbia River in efforts to reduce juvenile salmon predation (USACE 2014). These actions may result in displacement and searching out of new habitat for the Cormorants and lead to impacts on salmon in other rivers and basins. The American White Pelican numbers remain consistently high in the lower Yakima River. In the Yakima River, pelicans can be seen in groups of over 100 in the Wapato Reach of the river along the borders of the Yakama Indian Reservation.

Acclimation Sites Surveys

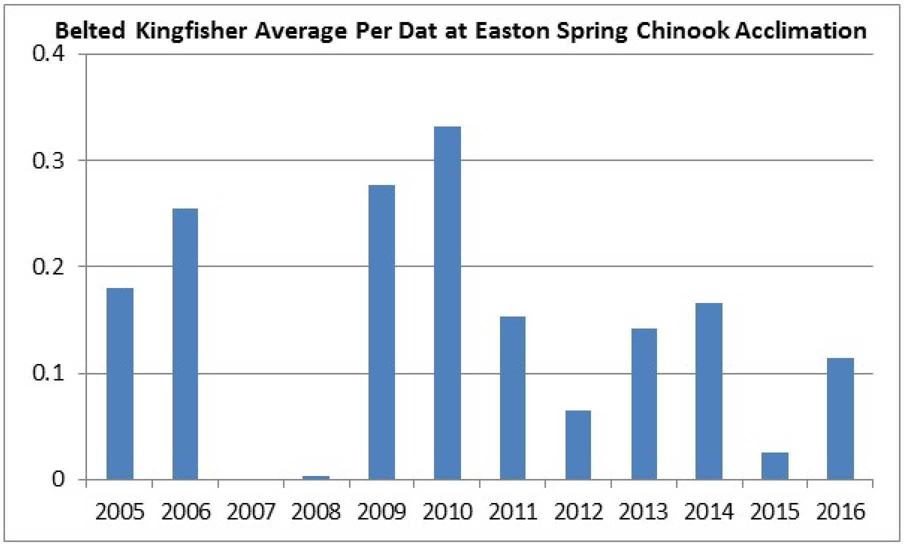

Figure 29. Average number of Belted King Fishers observed per day at the Easton spring Chinook acclimation site between 2005 and 2016 when fish were present.

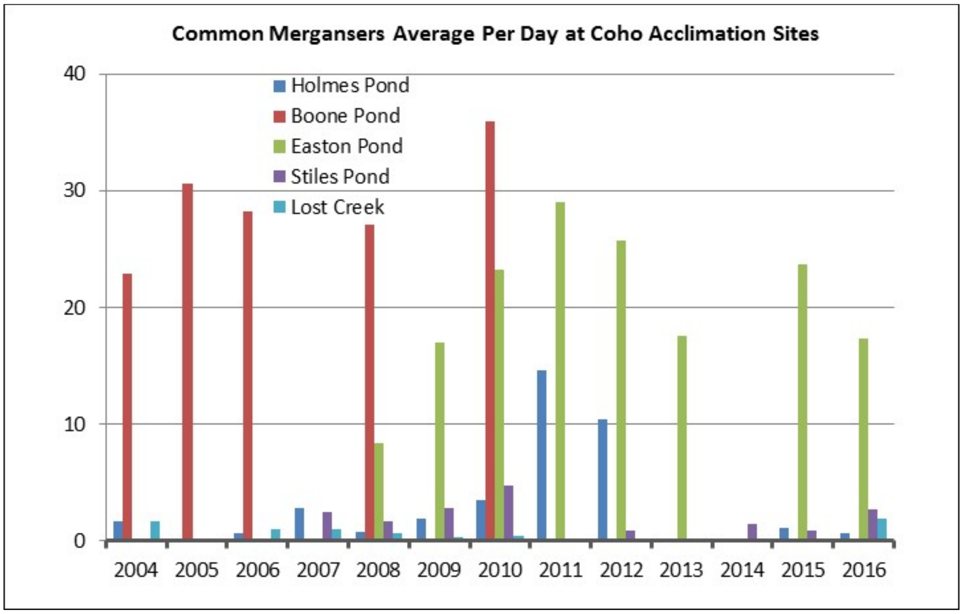

Figure 30. Average number of Common Mergansers observed per day at the JD Holmes, Boone, Easton, Stiles, and Lost Creek Pond Coho acclimation sites between 2004 and 2016 when fish were present.

Acclimation site avian abundance varied greatly between manmade concrete structures and natural or manmade ponds. Spring Chinook from the CESRF were acclimated in concrete raceways in three different locations in the Upper Yakima Basin. The raceways were covered with guide wires to control access to fish by piscivorous birds and provide a deterrent to predation. The Belted Kingfisher, due to its small size and fishing style, was the dominant predator in these acclimation sites, but numbers per day remained below any level of concern for management strategies to be implemented (Figure 29).

Coho acclimation was conducted in natural or manmade ponds which were highly accessible to piscivorous birds. The Common Merganser was the most common predator at these Coho acclimation sites (Figure 30). From 2004 to 2016 various ponds were used in alternation as Coho acclimation sites. Boone pond in the upper Yakima Basin showed a tendency to draw large numbers of Common Mergansers during coho acclimation and during recent years has been abandoned as a site of acclimation. Easton pond was used consistently as a Coho acclimation site from 2004 to 2016 (however, no data were available for this pond in 2014). Stiles pond shows relatively little bird use during Coho acclimation. Recent years have shown a steady growth in Common Mergansers utilizing Holmes pond during Coho acclimation; this may be due to the fact of lack of fish at Boone pond.

The most common birds preying on smolts in acclimations sites were the Bald Eagle, Belted Kingfishers, Common Merganser, Great Blue Heron, and Osprey. If it is assumed that birds feeding in acclimation ponds are consuming only smolts on bird days on site, an average of consumption can be calculated using the average number of birds at each site, daily energy requirements of the birds, and the average size of smolts. Calculated estimates assume that acclimation fish were the only prey for the bird species surveyed.

For the Spring Chinook sites (Clark Flat, Easton and Jack Creek), it was estimated that these bird species together consumed 553 smolts at Clark Flat, 633 smolts at Easton and 781 smolts at Jack Creek. We estimated that Great Blue Heron had the highest consumption rate at Clark Flat, with Bald Eagles and Great Blue Heron consuming the most at Easton, and Common Mergansers consuming the most at Jack Creek.

At the Coho acclimation sites (Lost Creek, Stiles, Easton Pond and Holmes), it was estimated that these bird species together consumed 24,326 juvenile Coho at Easton Pond, Common Mergansers were the most common birds observed on 31 days, consuming 23,178 juvenile Coho. Double Crested Cormorants were observed for the first time on 03/27/16 and 03/28/16, consuming 47 juvenile Coho. At Holmes, an estimated 4,342 juvenile Coho were consumed. Great Blue Herons were observed on twenty-four days, consuming an estimated 3,445 juvenile Coho. Common Mergansers were observed on six days, consuming 827 juvenile Coho. At Lost Creek, 3,460 juvenile Coho were consumed. Common Mergansers were the most common birds observed, consuming 3,307 juvenile Coho. Great Blue Herons were observed on three days, consuming 72 juvenile Coho. At Stiles, 5,000 juvenile Coho were consumed. The most common birds observed were Belted Kingfishers and Common Mergansers. Belted Kingfishers were observed on twenty-nine days, consuming 136 juvenile Coho. Common Mergansers were observed on forty days, consuming 4,618 juvenile Coho. Great Blue Herons were observed on six days, consuming 201 juvenile Coho.

Great Blue Heron Rookeries

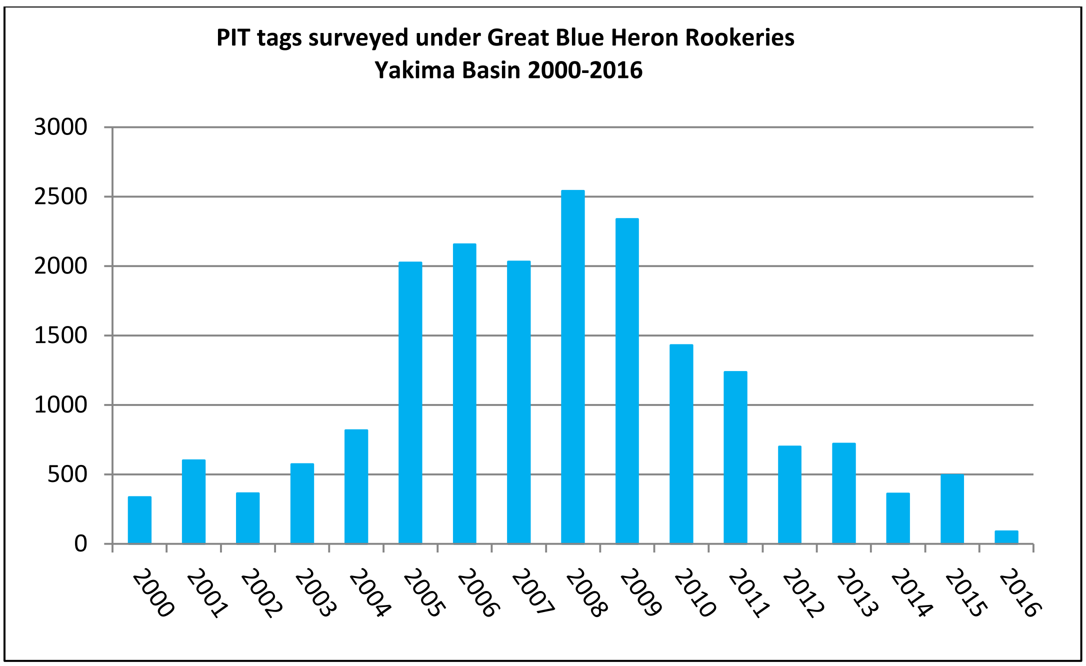

Figure 31. Number of PIT tags recovered at Yakima Basin Great Blue Heron rookery sites during surveys conducted from 2008-2016. Tags were from juvenile salmonids migrating downstream between 2000 and 2016. Total PIT tags recovered are shown by their corresponding migration year.

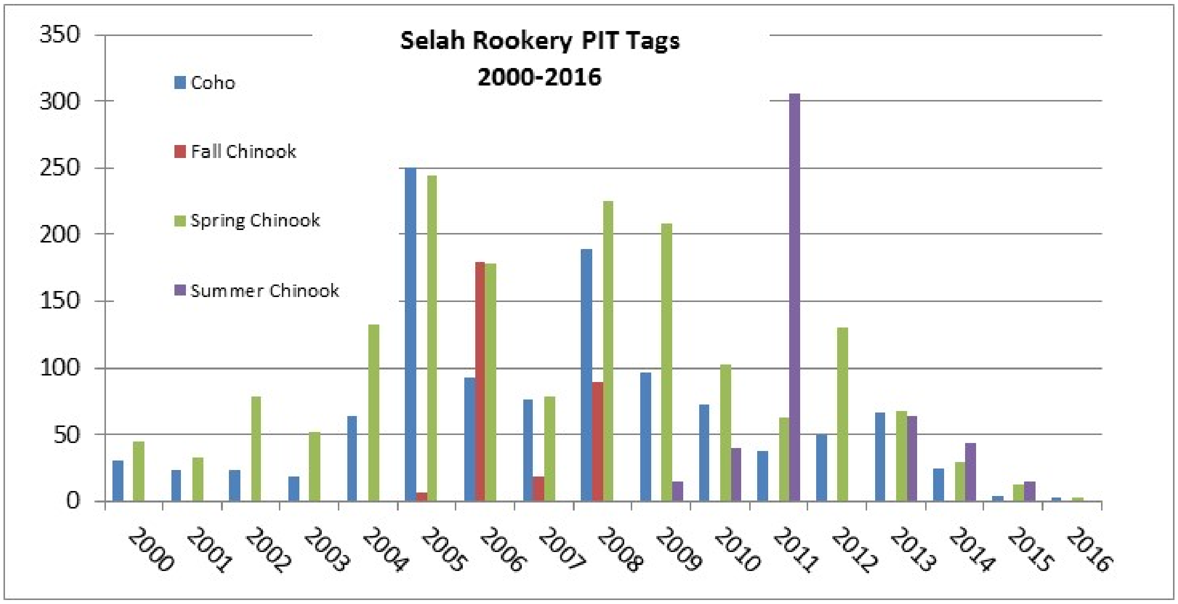

Figure 32. Number of PIT tags recovered at the Selah Great Blue Heron rookery during surveys conducted from 2008-2016. Tags were from juvenile salmonids migrating downstream between 2000 and 2016. Total PIT tags recovered are shown by species and their corresponding migration year.

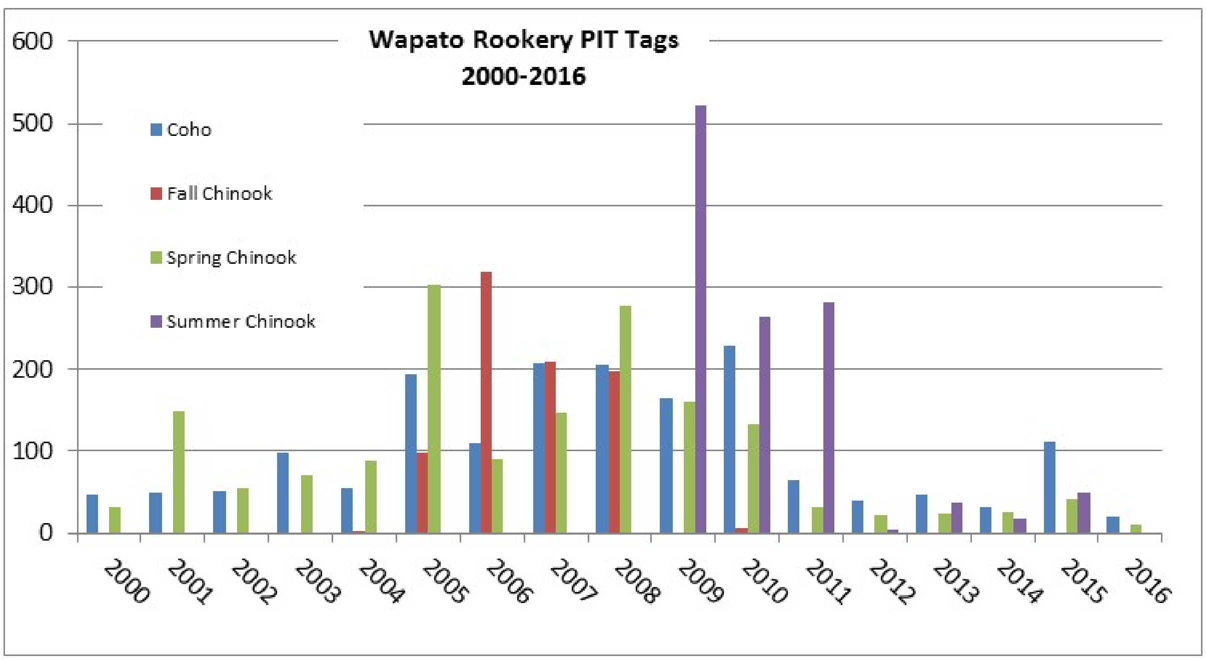

Figure 33. Number of PIT tags recovered at the Wapato Wildlife Area Great Blue Heron rookery during surveys conducted from 2008-2016. Tags were from juvenile salmonids migrating downstream between 2000 and 2016. Total PIT tags recovered are shown by species and their corresponding migration year.

Surveys of the Yakima Basin Great Blue Heron rookery sites between 2008 and 2016 recovered approximately 18,300 salmonid related PIT tags (Figure 31). Heron rookery PIT recoveries, when sorted by migration year, show higher mortality rates for juvenile migration years 2005 to 2009. This may correspond to river conditions (e.g., lower flows, low turbidity) that are likely conducive to increased smolt mortalities. For example, the migration year of 2008 was the most prevalent in PIT recoveries which could be related to drought conditions in 2007 when many 2008 migrants were released.

PIT recoveries in the Selah Heron Rookery may show the highest correlation to increases in predation opportunities due to low water flows in the Yakima River (Figure 32). Spring Chinook, released in Yakima River waters upriver of the rookery, exhibited the high numbers of PIT recoveries for migration years 2005 and 2007 which were years of relatively low flows in the Yakima River. The Selah Rookery is located near the Roza reach of the Yakima River below Roza Dam which generally produces flows lower than most Yakima River reaches during poor water years. These low flows may inhibit fish passage and increase predation opportunities.

Large numbers of summer Chinook tags have been recovered in some of the most recent years in the Selah Rookery (Figure 32). Beginning in 2013, some summer Chinook were released from a portable acclimation raceway at the Roza juvenile sampling facility (upstream of Selah; Figure 1). It is also possible that summer Chinook, acclimated at the nearby Stiles pond on the Naches River, could migrate to the Yakima River near the Selah rookery. Anecdotal evidence from the owner of the acclimation pond indicates that Herons congregate at the pond's release channel to the Naches River. These Herons are most likely from the Selah rookery.

The Wapato Wildlife area Great Blue Heron Rookery has produced the highest number of PIT recoveries when compared to all other Yakima Basin Rookeries. While Heron numbers in the rookery are high the overall difference in the Heron numbers when compared with other rookeries in the Basin is minimal. The high numbers of PIT recoveries in this rookery may be due to its location which is near to irrigation diversions and fish screening facilities. Fish diverted into these facilities are subjected to unfavorable flow conditions before being diverted back to the Yakima River via an underground pipe. Fish may become disoriented or severely injured during the diversion process making them susceptible to predation from the nearby Herons. PIT recoveries for summer Chinook migrating downstream in 2009 through 2011 were noticeably high at this rookery (Figure 33). Late release dates, low flows, and release location are the most likely factors related to the high mortality rates of these summer Chinook at the Wapato Rookery.

Fish Predation Index and Predator Control

Fish predators are also capable of significantly depressing smolt production. Thus the YKFP has a long-established objective to monitor, evaluate, and manage the impact of piscivorous fish on annual smolt production of Yakima Subbasin salmon and steelhead. By indexing the mortality rate of upper Yakima spring Chinook attributable to piscivorous fish in the lower Yakima River, the contribution of in-basin predation to variations in hatchery- and natural-origin spring Chinook smolt-to-adult survival rate can be deduced.

Based on YKFP and WDFW studies of piscivorous fish in the Yakima River Basin (Fritts and Pearsons 2004, 2006, 2008), it was determined that management of the piscivorous fish populations in the area is necessary to improve survival of juvenile salmonids. Initial steps were taken in 2009 to identify locations that would be suitable for a multi-pass removal population study. In early 2010, the YKFP began initial study checks to determine management and study goals for piscivorous fish. Presence and absence of piscivorous fish was determined through electro-fishing various sections of the Yakima River to determine temporal and spatial trends of each species of piscivorous fish. On March 1, 2013, the Washington Fish and Wildlife Commission adopted numerous changes to sport fishing rules, including the elimination of catch restrictions for non-native predators.

Methods:

Surveys for piscivorous fish were conducted year round in the Yakima River via electrofishing and were generally consistent with Tiffan et al. (2009) and with monitoringmethods.org methods 47 and 1712. Electro-fishing was conducted by jet-boat in the main stem or by backpack in side channels of the Yakima River. A Smith Root vvp-15b electro-fishing unit was used on the main stem while a smith root model 24 backpack unit was used in side channels. The preferred method of electro-fishing is pulsed direct current with varying frequencies dependent on specific conductivity and water temperature. The preferred method has been ideal for targeting piscivorous fish while not injuring salmonids. A GPS was used to locate survey transects and to calculate total distance of surveys. Electrode on time was recorded to calculate catch per unit effort, which was used as an estimate of abundance in each survey location. Piscivorous fish were collected during surveys in a bucket and sacrificed at the end of the survey.

During this project year, monthly multi-pass predator removal efforts (generally consistent with monitoringmethods.org methods 438) were conducted from March through August at Selah Gap to Union Gap (Section 1-4), Parker Dam to Toppenish (Sections 5-8), Toppenish to Granger (Sections 9-13), Benton (14-18), and Vangie (19-22) (Figure 34). Transects were approximately 1 mile sections separated by up to 1 mile and were chosen based on river flows (CFS) and ability to continue to survey these areas during low river water flows. Entire transects were sampled for presence of piscivorous fish. A comparative analysis of the multi-pass numbers for each transect was used to determine population numbers of piscivorous fish.

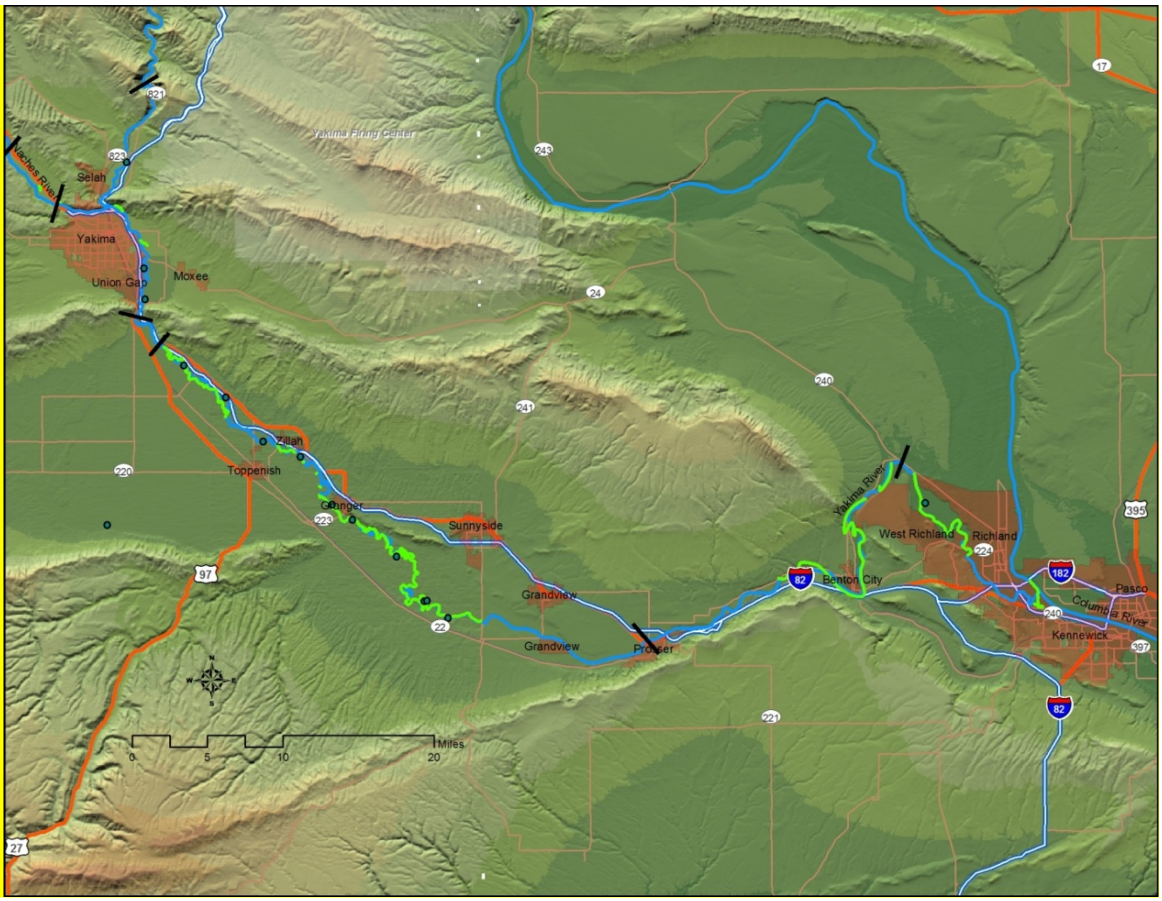

Figure 34. Map of Yakima River Piscivorous Fish Populations Study Areas (highlighted in neon green).

In addition to population estimates, stomach samples were collected from every 5th Northern Pikeminnow (NPM, *Ptychocheilusoregonensis*) greater than 200 mm in fork length and every 5th Smallmouth bass (*Micropterusdolomieu*) less than 200mm in fork length within the transects (monitoringmethods.org method 152 and 4044). NPM stomachs with fish present were further analyzed to determine the number and types of species consumed (monitoringmethods.org methods 1317 and 1445). This analysis was performed using diagnostic bones which allows determination of species (though for salmonids this is more difficult) and approximate body length.

Survey efforts for 2011 to present also included recording all fish species and their corresponding catch per unit effort for select areas of importance on the Yakima River. Included for the inclusive species monitoring is the Wapato reach, a section of the Yakima River, designated as the area (for the purpose of this report) between Union Gap at USGS River mile 107 to the boundary of the Yakama Indian Reservation at USGS River mile 60. Additional sections of the Yakima River which the species monitoring incorporates are three sections at the Yakima River Delta which include an area of the Yakima River at USGS river mile 1 to the confluence at the Columbia River, and the Delta sections to the East and West of the Bateman Island Causeway (Figure 35).

The inclusive species monitoring for the Yakima River will be used as an aid for tracking changes in fish populations and abundance as the area experiences global climate change.

Figure 35. Yakima River Delta Survey Areas.

Results and Discussion:

Wapato Reach fish species included the piscivorous Northern Pikeminnow and 10 other species of fish (Table 27). Relative catch numbers of the Northern Pikeminnow, for 2010 to present, were small compared to other fish species. Fish from the family *Catostomidae*, or suckers, were the highest relative catch for the Wapato reach (Figure 36). Salmonids were found in high abundance in the Wapato reach; catch abundance was dependent on time of year and is highest during the salmon smolt out-migration through the reach. The assemblage of fish species in the Wapato Reach were primarily native species. Fish predation in the Wapato Reach was considered to be relatively low compared to the Lower Yakima River where many non-native fish predators were found in abundance.

Table 27. Wapato Reach of the Yakima River - Fish Species identified during surveys 2010-2016.

Wapato Reach Fish Species

Family	Common Name	*Scientific Name*
Salmonidae:		
	Steelhead/Rainbow trout	*Oncorhynchus mykiss*
	Coho Salmon	*Oncorhynchus kisutch*
	Chinook Salmon	*Oncorhynchus tshawytscha*
	Mountain Whitefish	*Prosopium williamsoni*
Cyprinidae:		
	Chiselmouth	*Acrocheilus alutaceus*
	Carp	*Cyprinus carpio*
	Northern Pikeminnow	*Ptychocheilus oregonensis*
	Redside Shiner	*Richardsonius balteatus*
Catostomidae:		
	Sucker	*Catostomus columbianus, Catostomus catostomus*
Centrarchidae:		
	Smallmouth Bass	*Micropterus dolomieui*

Northern Pike Minnow were the dominant piscivorous fish in reaches of the Yakima River above Prosser Dam. Catch and CPUE of Northern Pikeminnow can vary widely over time periods in this reach (Figure 37). While numbers vary over seasons it is evident that Northern Pikeminnow populations remain in high numbers over the course of the year.

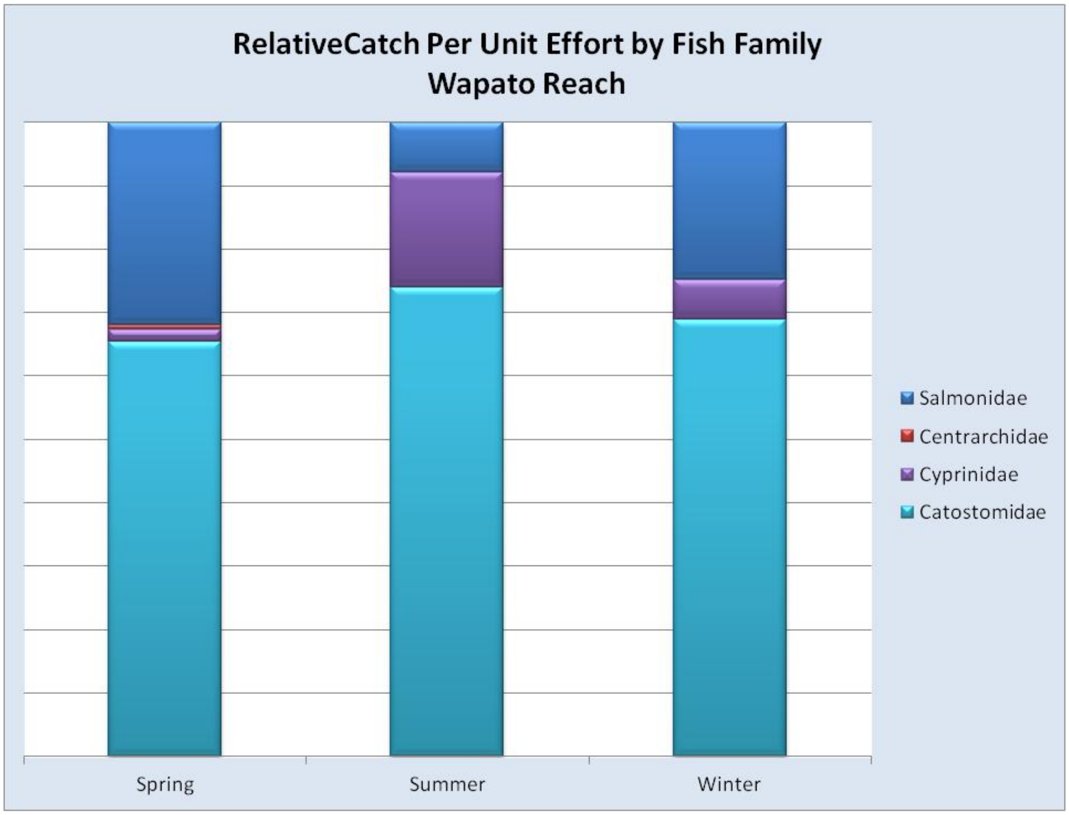

Figure 36. Wapato Reach of the Yakima River – Relative catch per unit effort by fish family.

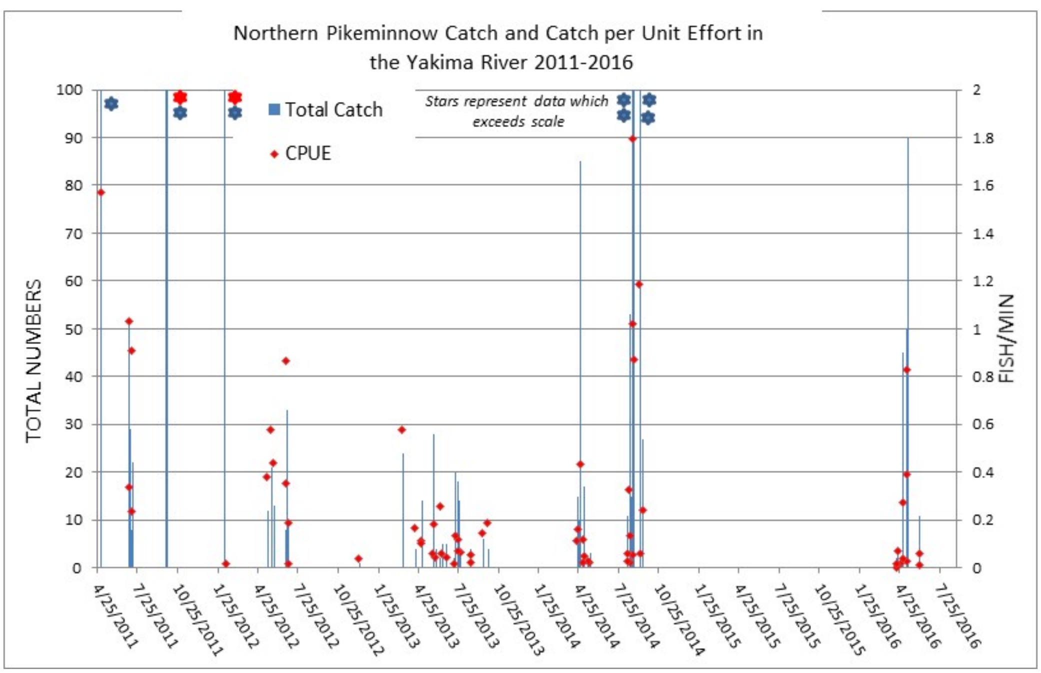

Figure 37. Number and Catch per Unit Effort (CPUE) of Northern Pike Minnow observed in surveys of the Yakima River Benton and Wapato Reaches. Data are from 2011-2016 surveys and display NPM presence over varying seasons (Data which exceeds scale is described in text and table 28).

Large amounts of piscivorous fish (many of them introduced species) were found to inhabit the Lower Yakima River, which is defined as that portion of the river between Prosser Dam and the confluence of the Yakima River with the Columbia River. During winter months high amounts of piscivorous fish, in particular NPM, were found in irrigation drains along the Yakima River. These drains remain highly productive over the winter months as their temperatures typically remain higher than the Yakima River and may range up to 10 degrees Celsius higher. Extremely low flows in 2015 prevented catch of NPM in the Yakima River. NPM management did occur in the Yakima River Delta during the fall 2015. In 2016 flows were at levels in the Yakima River and catch of NPM was highest in the early spring months. High catch rates of NPM in the Wapato Reach of the Yakima River are common in the spring and fall (Table 28). Summer surveys in the Wapato Reach are not typically conducted due to low flows and exposed rocks.

Table 28. Northern Pike Minnow Catch Total and Catch per Unit Effort (Data exceeding scale of Figure 37).

Date	Location	Total Catch NPM	Adult or Juvenile	CPUE
9/10/2014	Benton Reach	19	Adult	0.17
		92	Juvenile	0.81
8/28/2014	Benton Reach	22	Adult	0.13
		125	Juvenile	0.74
8/26/2014	Benton Reach	20	Adult	0.13
		252	Juvenile	1.66
8/25/2014	Benton Reach	60	Adult	0.43
		83	Juvenile	0.59
2/7/2012	Wapato Reach			
		134	Juvenile	5.36
9/29/2011	Wapato Reach			
		138	Juvenile	2.51
9/28/2011	Wapato Reach			
		150	Juvenile	5.17
5/3/2011	Wapato Reach			
		113	Juvenile	1.57

Overall from 2011 to 2016, Smallmouth Bass and Channel Catfish were the fish predators observed in the highest abundance in the lower reaches of the Yakima River between Prosser Dam to the confluence Columbia River. It is believed that these two species are a source of significant mortality on out-migrating juvenile salmon.

Smallmouth Bass (SMB) have been found in high numbers in the lower Yakima River and exhibit a spike in abundance during their spawning periods. Spawning for SMB is typically between April 1 and July 1, a time period that coincides with juvenile salmonid outmigration. Thus, the juvenile salmon are a readily available prey item for the adult spawning bass and their young recruits. Catch and catch per unit effort for SMB begins to rise in the May and June survey periods (Figure 38) as SMB migrate from the Columbia River into the Yakima River to spawn. A rise in catch in adults also correlates with a rise in Yakima River water temperature. As the river exceeds 20 degrees Celsius catch of adult SMB in the Lower Yakima River significantly increases during the early spring. The catch numbers for SMB in the Yakima River saw a significant increase in 2016 and Catch per unit effort rose as did catch totals (Figure 38). This rise in SMB relative abundance may correlate with the water year of 2015 which produced extremely low flows and high water temperatures. It is the increase in water temperature in the lower Yakima River which is thought to create productive habitat for SMB. Across all years there is increased catch success during the late summer and fall months and electro-fishing efforts are increased to maximize catch for managing numbers of SMB in the lower Yakima River. As part of our efforts to increase salmon populations, we are targeting SMB populations for management in hopes to increase survival of juvenile salmon outmigrants.

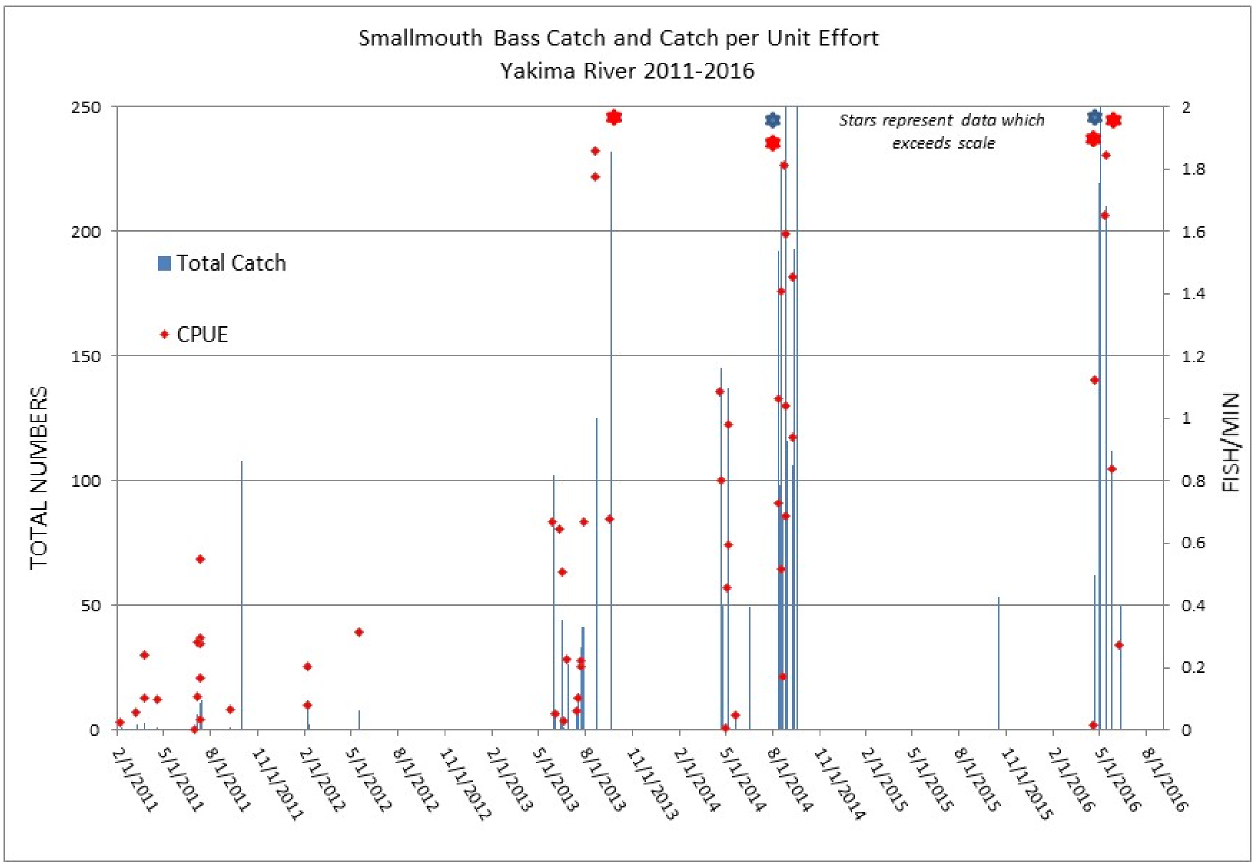

Figure 38. Number and Catch per Unit Effort (CPUE) of Smallmouth Bass observed in surveys of the Lower Yakima River (Data which exceeds scale is described in text and Table 29).

Table 29. Smallmouth Bass Catch Total and Catch per Unit Effort (Data exceeding scale of Figure 38).

Date	Location	Total Catch SMB	Adult or Juvenile	CPUE
5/2/2016	Lower Yakima Reach	74	Adult	0.45
		373	Juvenile	2.29
4/28/2016	Lower Yakima Reach	20	Adult	0.20
		199	Juvenile	1.97
9/17/2014	Benton Reach	82	Adult	0.73
		247	Juvenile	2.21
8/25/2014	Benton Reach	55	Adult	0.39
		199	Juvenile	1.42
9/19/2013	Above Prosser Dam Reach	8	Adult	0.13
		224	Juvenile	3.56

Yakima River Delta surveys from 2010 to 2016 found 23 different fish species occupied the delta at varying temporal and spatial distributions (Table 30). This is twice the number of fish species in the Delta when compared to the fish species of the Wapato Reach. Many of the fish species in the delta are introduced, non-native fish and are a warm-water species of fish. These introduced fish are adapted to the highly altered water conditions, of increased temperatures and low dissolved oxygen, which the Yakima delta displays. Water temperatures may reach highs of 80 degrees Fahrenheit in the late summer months. Relative catch abundance in the Yakima Delta for the surveys shows a high number of fish from the families of: *Centrarchidae*, *Cyprinidae*, and *Ictaluridae* (Figure 40). These families are highly represented because of large numbers of piscivorous fish present in the delta. Smallmouth Bass, Largemouth Bass, and numerous catfish are present here and use the area for spawning and rearing of juveniles.

When comparing the Wapato Reach Species/Relative Catch Abundance (Figure 36) to the Yakima Delta Species/Relative Catch Abundance (Figure 39) a glaring dissimilarity in the type of fish and their abundance between the two sections of the Yakima River is obvious. In the upper portion of the Yakima River, where natural attributes such as water temperature, riparian cover, nutrient loading, and flow that is closer to historical values the fish species consist of native species which are adapted to cold water conditions. In the lower section of the Yakima River and the Yakima River delta river attributes have been highly altered by: dams, irrigation diversions, water drawn for power, lowered flows, little riparian cover, irrigation water returned loaded with nutrients, and a blocked section of the river delta, fish species consist of a high number of introduced species many of which are piscivorous.

Table 30. Yakima River Delta - Fish Species identified during surveys 2010-2016.

Yakima River Delta Fish Species		
Family	Common Name	*Scientific Name*
Salmonidae:		
	Steelhead/Rainbow trout	*Oncorhynchus mykiss*
	Coho Salmon	*Oncorhynchus kisutch*
	Chinook Salmon	*Oncorhynchus tshawytscha*
	Mountain Whitefish	*Prosopium williamsoni*
Cyprinidae:		
	Chiselmouth	*Acrocheilus alutaceus*
	Carp	*Cyprinus carpio*
	Peamouth	*Mylocheilus caurinus*
	Speckled Dace	*Rhinichthys osculus*
	Northern Pikeminnow	*Ptychocheilus oregonensis*
	Redside Shiner	*Richardsonius balteatus*
Catostomidae:		
	Sucker	*Catostomus columbianus, Catostomus catostomus*
Ictaluridae:		
	Brown Bullhead	*Ameiurus nebulosus*
	Channel Catfish	*Ictalurus punctatus*
Centrarchidae:		
	Pumpkin Seed	*Lepomis gibbosus*
	Blue Gill	*Lepomis macrochirus*
	Smallmouth Bass	*Micropterus dolomieui*
	Large Mouth Bass	*Micropterus salmoides*
	White Crappie	*Pomoxis annularis*
Percidae:		
	Walleye	*Stizostedion vitreum vitreum*
	Yellow Perch	*Perca flavescens*
Cottidae:		
	Sculpin	*Cottus bairdi*
Clupeidae:		
	Shad	*Alosa sapidissima*

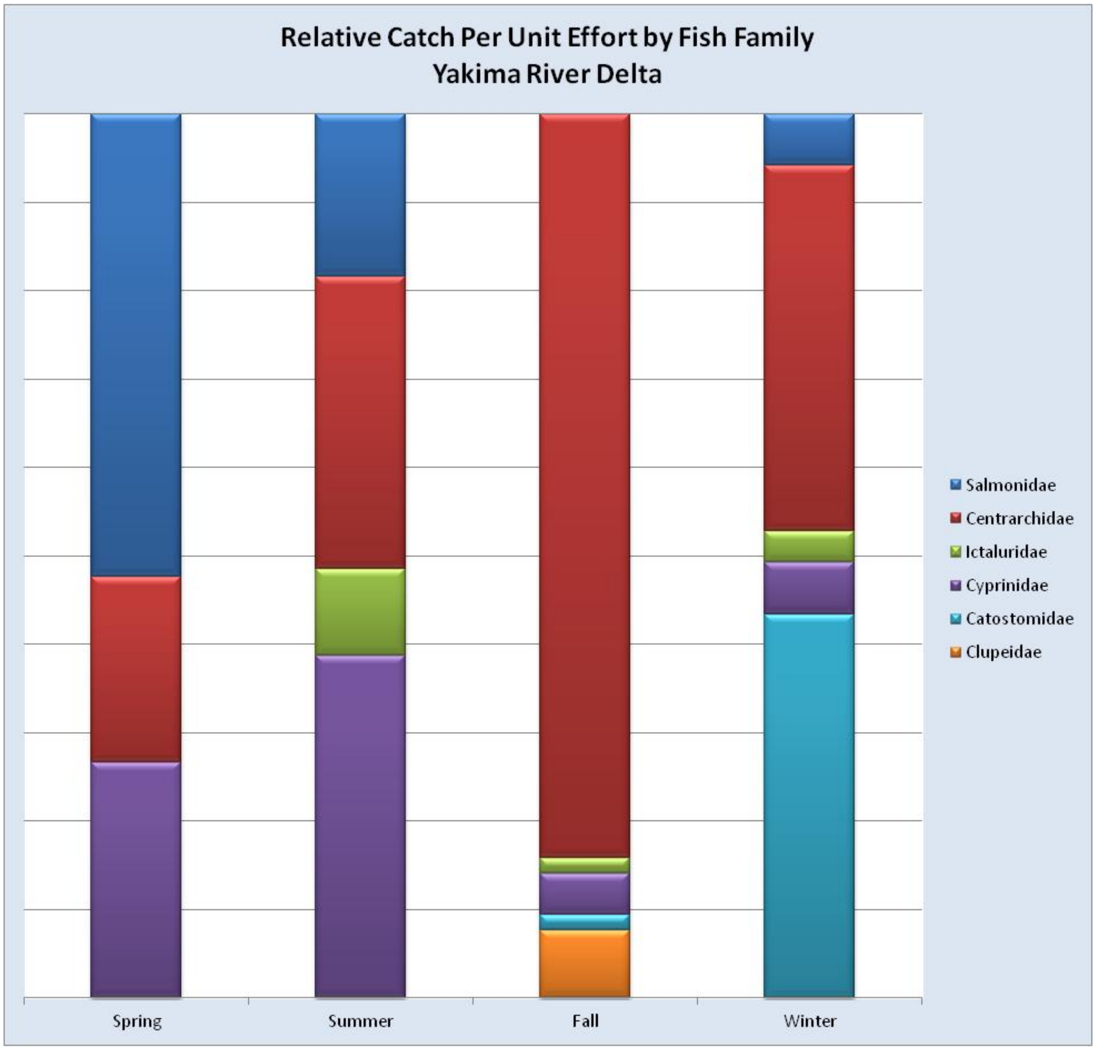

Figure 39. Yakima River Delta – Relative catch per unit effort by fish family.

SMB in the delta of the Yakima River have been found in surprisingly high numbers. The Yakima delta at all times of year contains some presence of SMB and during fall abundance of juvenile SMB reaches peak numbers. Late summer and fall temperatures in the Yakima Delta can exceed 27 degrees Celsius coupled with the blockage of the flow by the causeway this area Yakima River becomes similar to a warm water lake. While catch of SMB in the Delta remains lower than 100 fish per day at most times of year (Figure 40) the rise in the fall numbers can be astounding. The increase in SMB numbers during this time is primarily due to presence of juvenile SMB and catch total has risen to above 3000 fish in a day (Figure 40, data which exceeds scale) with catch totals of 500 fish per day very common.

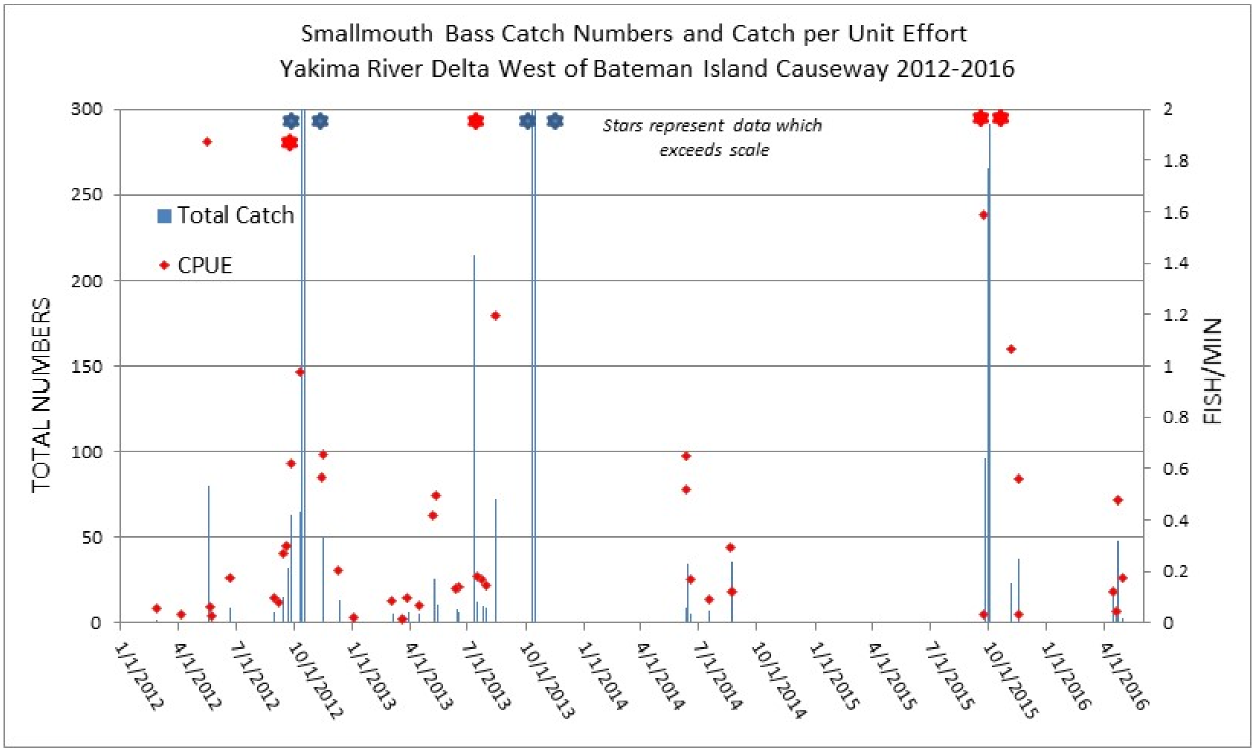

Figure 40. Number and Catch per Unit Effort (CPUE) of Smallmouth Bass observed in surveys of the Yakima River Delta area (West of the Bateman Island Causeway; data which exceeds scale is described in text).

Adaptive Management and Lessons Learned

As noted extensively throughout this report, this project is a collaborative effort involving many agencies, boards, and individuals. As such, project coordination and review of project standards and protocols occurs continually amongst tribal, state, federal, and local entities during normal day-to-day operations of the project. Project results are communicated broadly through the annual science and management conference, technical reports and peer-reviewed journal publications (see references and project-related publications), and via several related web sites described in Appendix A.

We support the principles established in Mobrand et al. (2005) and Paquet et al. (2011) that hatchery programs should be well-defined, scientifically defensible, and use informed decision making tools including adaptive management. Many of these principles were initially published in Cuenco et al. (1993) including specific recommended decision criteria, management protocols, release strategies, and risk management strategies for hatchery programs. We designed a number of these protocols and strategies into the CESRF program and they are clearly contributing to the results documented here for the Upper Yakima River Basin spring Chinook populations.

Results to date from Yakama Nation supplementation and research efforts in the Yakima River Basin indicate several lessons that may be of broader application on the regional scale.

1. We need to be realistic. Can or should we expect to see "self-sustaining natural populations" in river systems that have been highly altered from their historical state due to ever-increasing human demands on shared resources? In the highly altered systems we live and work in today, hatchery programs provide a necessary means to ameliorate some of the effects of human population growth and development.

2. We need to be honest. Hatchery programs are not the cause of poor productivity. The historical record is replete with documentation (see Dompier 2005) that the region knew exactly what it was doing to natural salmon productivity when development of the region began to intensify with implementation of the Federal Columbia River Power System as early as the 1930s.

3. We need to be patient. Hatchery reform is a relatively new concept and results for longer term 20-25 year efforts such as the Idaho Supplementation Studies (ISS; Venditti et al. 2015) and CESRF program (Fast et al. 2015) are only now becoming available. These programs empirically support the idea that hatchery reform principles can provide the expected benefits.

4. While hatchery supplementation has demonstrated increases in natural production (increased redd and juvenile abundance), supplementation by itself cannot and was never intended to increase natural productivity. To accommodate expanding human population growth and resource demand, it is imperative that we continue and even increase habitat restoration actions to ensure that sufficient spawning and rearing habitat remains available to all naturally spawning fish.

5. Every subbasin, species, and study is unique, so we should not be surprised to see differing results from the many studies of hatchery effects that are ongoing. Researchers need to continue efforts to better understand the root causes of poor natural productivity and the extent to which hatchery programs effect productivity.

6. Evaluation of hatchery programs should include evaluation of environmental and other factors so that hatchery effects are properly reported.

7. Hatchery programs should be regularly evaluated at the local level using expertise across disciplines to collaboratively and iteratively develop appropriate solutions that address the unique problems and limiting factors encountered in each subbasin or tributary that hosts a hatchery program. In the Yakima Basin, this is achieved with the annual Yakima Basin Aquatic Science and Management Conference, and we use the results to evaluate existing goals, objectives, and strategies and to adaptively manage projects in response to new information.

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APPENDICES

A. Use of Data and Products

B. Yakima River / CESRF Spring Chinook Salmon – Yakama Nation Data Summary

C. IntSTATS, Inc. 2016 Annual Chandler Certification for Yearling Outmigrating Spring Chinook Smolt

D. IntSTATS, Inc. Annual Report: Smolt Survival to McNary Dam of 1999-2013 and 2015-2016 PIT-tagged Spring Chinook released or detected at Roza Dam

E. IntSTATS, Inc. Annual Report: Comparisons between Smolt-Trait Measures of Hatchery x Hatchery- and Natural x Natural-Brood Stock for Brood-Years 2002-2016 Upper Yakima Spring Chinook

F. IntSTATS, Inc. Comparison of Pro-Feed and BioVita Feed Treatments evaluated on Natural-Origin Hatchery-Reared Upper-Yakima Spring Chinook Smolt released in 2016

G. IntSTATS, Inc. Annual Report: 2008-2016 Fall and 2009-2016 Summer Chinook Smolt-to-Smolt Survival to McNary Dam of Releases into the Yakima Basin

H. IntSTATS, Inc. Annual Report: 2016 Coho Smolt-to-Smolt Survival of Releases into the Yakima Basin

Appendix A: Use of Data & Products

All data and findings should be considered preliminary until results are published in the peer-reviewed literature.

Where will you post or publish the data your project generates?

Fish Passage Center
Yakama Nation Fisheries website
DART - Data Access in Real Time
RMIS - Regional Mark Information System
Yakima-Klickitat Fisheries Project website
BPA Pisces
StreamNet Database
cbfish.org
PTAGIS Website
Washington State SaSI

For pilot access to additional project data sets see http://dashboard.yakamafish-star.net/drupal/. Log in with user name, 'NSexternal' and password, 'SaveTheFish'.

Describe the accessibility of the data and what the requirements are to access them?

- Prosser and Roza dam daily count and trap sample data http://dashboard.yakamafish-star.net/drupal/. Log in with user name, 'NSexternal' and password, 'SaveTheFish'.
- Integration of PIT and CWT release and recovery data with PTAGIS, RMIS, and Fish Passage Center databases
- Production and support of data bases necessary to support BPA quarterly and annual reports (available via PISCES and BPA reports web site)
- Production and support of data bases necessary to support NPCC project proposals (available via CBfish.org)

Additional data is available on the ykfp.org web site and by email contact through the data managers (Yakima Basin, contact Bill Bosch, bbosch@yakama.com; Klickitat Basin, contact Michael Babcock, mbabcock@ykfp.org). Project data managers continue to participate in the Coordinated Assessments process to develop pilot exchange templates for adult and juvenile abundance and productivity parameters. However, we continue to believe that the best way to prioritize our data management work load is to develop databases to store the status and trend data we have been collecting over many years as well as the web tools necessary to access these data in downloadable format. The pilot system to share Prosser and Roza dam daily count and trap sample data is an example of the progress we are making towards this end.

Appendix B

Summary of Data Collected by the Yakama Nation relative to Yakima River Spring Chinook Salmon and the Cle Elum Spring Chinook Supplementation and Research Facility

2016 Annual Report

May 31, 2017

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Acknowledgments

Monitoring and evaluation efforts for the Cle Elum Supplementation and Research Facility (CESRF) and Yakima River spring Chinook salmon are the result of a cooperative effort by many individuals from a variety of agencies including the Yakama Nation Fisheries Program (YN), the Washington Department of Fish and Wildlife (WDFW), the United States Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration Fisheries department (NOAA Fisheries) as well as some consultants and contractors.

The core project team includes the following individuals: Dave Fast, Mark Johnston, Bill Bosch, David Lind, Paul Huffman, Joe Hoptowit, and a number of technicians from the YN; Charles Strom and a number of assistants from the CESRF; Anthony Fritts, Gabe Temple, Christopher Johnson, and a number of assistants from the WDFW; Curt Knudsen from Oncorh Consulting and Doug Neeley from IntSTATS Consulting; Sharon Lutz and assistants from the USFWS; and Don Larsen, Andy Dittman, and assistants from NOAA Fisheries. The technicians and assistants are too numerous and varied to mention each by name (and risk leaving some out). However, their hard work in the field is the source of much of the raw data needed to complete this report. We sincerely appreciate their hard work and dedication to this project.

We would especially like to thank former members of the Yakima/Klickitat Fisheries Project, Bruce Watson, Joel Hubble, Bill Hopley, Todd Pearsons, Steve Schroder, and Craig Busack. These individuals put in countless hours of hard work during the planning, design, and implementation of this project. Their contributions helped to lay a solid foundation for this project and our monitoring and evaluation efforts. Dan Barrett (retired) served as the manager of the CESRF from 1997-2002. He helped to lay a solid foundation for the critical work done day in and day out at the Cle Elum facility.

We also need to recognize and thank the Yakama Nation and WDFW for their continued support, and the Columbia River Inter-Tribal Fish Commission, the University of Idaho, the Pacific States Marine Fisheries Commission, Mobrand, Jones, and Stokes, and Central Washington University for their many contributions to this project including both recommendations and data services.

This work is funded by the Bonneville Power Administration (BPA) through the Northwest Power and Conservation Council’s (NPCC) Fish and Wildlife Program. Michelle O’Malley is BPA’s contracting officer and technical representative (COTR) for this project. David Byrnes and Patricia Smith preceded Michelle in this position and contributed substantially to the project over the years.

Abstract

Historically, the return of spring Chinook salmon (*Oncorhynchus tshawytscha)* to the Yakima River numbered about 200,000 fish annually (BPA, 1990). Spring Chinook returns to the Yakima River averaged fewer than 3,500 fish per year through most of the 1980s and 1990s (less than 2% of the historical run size).

In an attempt to reverse this trend the Northwest Power and Conservation Council (formerly the Northwest Power Planning Council, NPPC) in 1982 first encouraged Bonneville Power Administration (BPA) to "fund the design, construction, operation, and maintenance of a hatchery to enhance the fishery for the Yakima Indian Nation as well as all other harvesters" (NPPC 1982). After years of planning and design, an Environmental Impact Statement (EIS) was completed in 1996 and the CESRF was authorized under the NPCC's Fish and Wildlife Program with the stated purpose being "to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining the long-term genetic fitness of the fish population being supplemented and keeping adverse genetic and ecological interactions with non-target species or stocks within acceptable limits". The CESRF became operational in 1997. This project is co-managed by the Yakama Nation and the Washington Department of Fish and Wildlife (WDFW) with the Yakama Nation as the lead entity.

This report documents data collected from Yakama Nation tasks related to monitoring and evaluation of the CESRF and its effect on natural populations of spring Chinook in the Yakima Basin through 2016. This report is not intended to be a scientific evaluation of spring Chinook supplementation efforts in the Yakima Basin. Rather, it is a summary of methods and data (additional information about methods used to collect these data may be found in the main section of this annual report) relating to Yakima River spring Chinook collected by Yakama Nation biologists and technicians from 1982 (when the Yakama Nation fisheries program was implemented) to present. Data summarized in this report include:

- Adult-to-adult returns
- Annual run size and escapement
- Adult traits (e.g., age composition, size-at-age, sex ratios, migration timing, etc.)
- CESRF reproductive statistics (including fecundity and fish health profiles)
- CESRF juvenile survival (egg-to-fry, fry-to-smolt, smolt-to-smolt, and smolt-to-adult)
- CESRF juvenile traits (e.g., length-weight relationships, migration timing, etc.)
- Harvest impacts

The data presented here are, for the most part, "raw" data and should not be used without paying attention to caveats associated with these data and/or consultation with project biologists. No attempt is made to explain the significance of these data in this report as this is left to more comprehensive reports and publications produced by the project. Data in this report should be considered preliminary until published in the peer reviewed literature.

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Introduction

Program Objectives

The CESRF was authorized in 1996 under the NPCC's Fish and Wildlife Program with the stated purpose being "to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining the long-term genetic fitness of the fish population being supplemented and keeping adverse genetic and ecological interactions with non-target species or stocks within acceptable limits". The CESRF became operational in 1997. The experimental design calls for a total release of 810,000 smolts annually from each of three acclimation sites associated with the facility (see facility descriptions). To minimize risk of over-collecting brood stock and to maintain lower pond rearing densities, the YKFP policy group took action in 2011 to reduce the release target to 720,000 smolts for brood collection purposes. Female percentage, fecundity and survival rates are expected to result in releases between 720,000 and 810,000 smolts in most years. The first program cycle (brood years 1997 through 2001) also included testing new Semi-Natural rearing Treatments (SNT) against the Optimum Conventional Treatments (OCT) of existing successful hatcheries in the Pacific Northwest. The second program cycle (brood years 2002-2004) tested whether a slower, more natural growth regime could be used to reduce the incidence of precocialism that may occur in hatchery releases without adversely impacting overall survival to adult returns. Brood years 2005-2007 tested survival using different types of feed treatment. Subsequent broods have used a standard treatment in all raceways. With guidance and input from the NPCC and the Independent Scientific Review Panel (ISRP) in 2001, the Naches subbasin population of spring Chinook was established as a wild/natural control. A hatchery control line at the CESRF was also established with the first brood production for this line collected in 2002. Please refer to the project's "Supplementation Monitoring Plan" (Chapter 7 in 2005 annual report on project genetic studies) for additional information regarding these control lines.

Facility Descriptions

Returning adult spring Chinook are monitored at the Roza adult trapping facility located on the Yakima River (Rkm 205.8). This facility provides the means to monitor every fish returning to the upper Yakima Basin and to collect adults for the CESRF program. All returning CESRF fish (adipose-clipped fish) are sampled for biological characteristics and marks and returned to the river with the exception of fish collected for broodstock, experimental sampling, and all hatchery control line fish. Through 2006, all wild/natural fish passing through the Roza trap were returned directly to the river with the exception of fish collected for broodstock or fish with metal tag detections which were sampled for marks and biological characteristics. Beginning in 2007, all wild/natural fish were sampled (as described above) and tissue samples were collected for a "Whole Population" Pedigree Study of Upper Yakima Spring Chinook (see related project 2009-009-00).

The CESRF is located on the Yakima River just south of the town of Cle Elum (rkm 295.5). It is used for adult broodstock holding and spawning, and early life incubation and rearing. Fish are spawned in September and October of a given brood year (BY). Fish are typically ponded in March or April of BY+1. The juveniles are reared at Cle Elum, marked in October through

December of BY+1, and moved to one of three acclimation sites for final rearing in January to February of BY+2. Acclimation sites are located at Easton (ESJ, rkm 317.8), Clark Flats near the town of Thorp (CFJ, rkm 266.6), and Jack Creek (JCJ, approximately 32.5 km north of Cle Elum) on the North Fork Teanaway River (rkm 10.2). Fish are volitionally released from the acclimation sites beginning on March 15 of BY+2, with any remaining fish "flushed out" of the acclimation sites by May 15 of BY+2. The annual production goal for the CESRF program is 720,000 to 810,000 fish for release as yearlings at 30 g/fish or 15 fish per pound (fpp) although size-at-release may vary depending on experimental protocols (see Program Objectives).

Yakima River Basin Overview

The Yakima River Basin is located in south central Washington. From its headwaters near the crest of the Cascade Range, the Yakima River flows 344 km (214 miles) southeastward to its confluence with the Columbia River (Rkm 539.5; Figure 1).

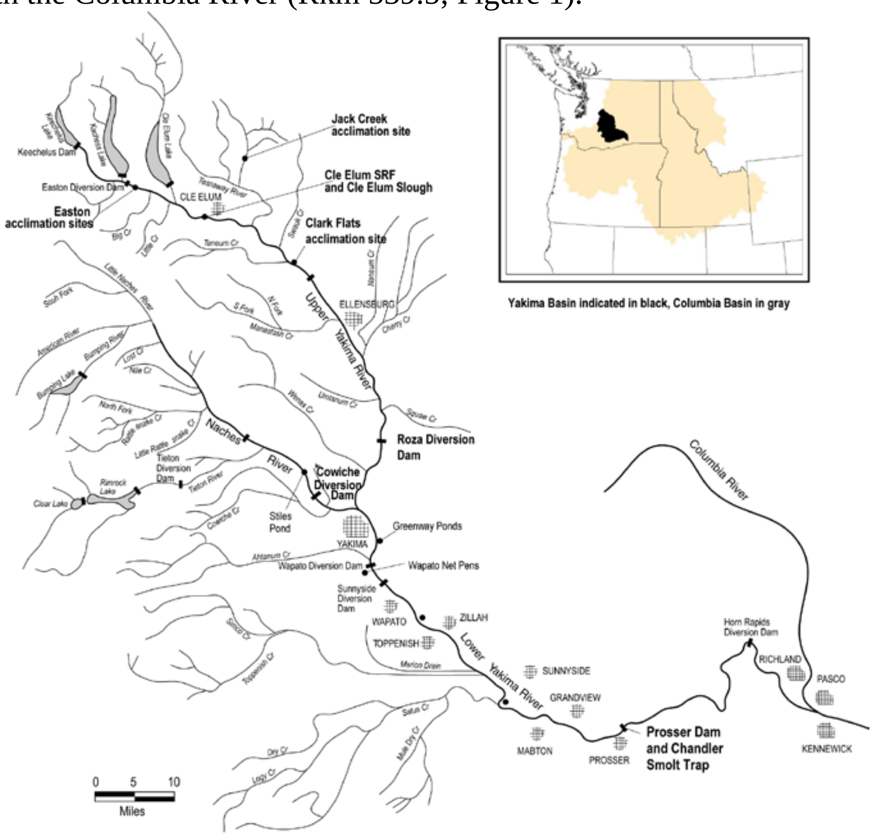

Figure 1. Yakima River Basin.

Three genetically distinguishable populations of spring Chinook salmon exist in the Yakima basin: the American River, the Naches, and the Upper Yakima Stocks (Figure 1). The upper Yakima was selected as the population best suited for supplementation and associated evaluation and research efforts.

Local habitat problems related to irrigation, logging, road building, recreation, agriculture, and livestock grazing have limited the production potential of spring Chinook in the Yakima River basin. It is hoped that recent initiatives to improve habitat within the Yakima Basin, such as those being funded through the NPCC's fish and wildlife program, the Pacific Coastal Salmon Recovery Fund, and the Washington State salmon recovery fund, will: 1) restore and maintain natural stream stability; 2) reduce water temperatures; 3) reduce upland erosion and sediment delivery rates; 4) improve and re-establish riparian vegetation; and 5) re-connect critical habitats throughout the basin. These habitat restoration efforts should permit increased utilization of habitat by spring Chinook salmon in the Yakima basin thereby increasing fish survival and productivity.

Adult Salmon Evaluation

Broodstock Collection and Representation

One of the program's goals is to collect broodstock from a representative portion of the population throughout the run. If the total run size could be known in advance, collecting brood stock on a daily basis in exact proportion to total brood need as a proportion of total run size would result in ideal run representation. Since it is not possible to know the run size in advance, the CESRF program uses a brood collection schedule that is based on average run timing once the first fish arrive at Roza Dam. We have found that, while river conditions dictate run timing (i.e., fish may arriver earlier or later depending on flow and temperature), once fish begin to move at Roza, the pattern in terms of relative run strength over time is very similar from year to year. Thus a brood collection schedule matching normal run timing patterns was developed to assure that fish are collected from all portions of the run (Figure 2).

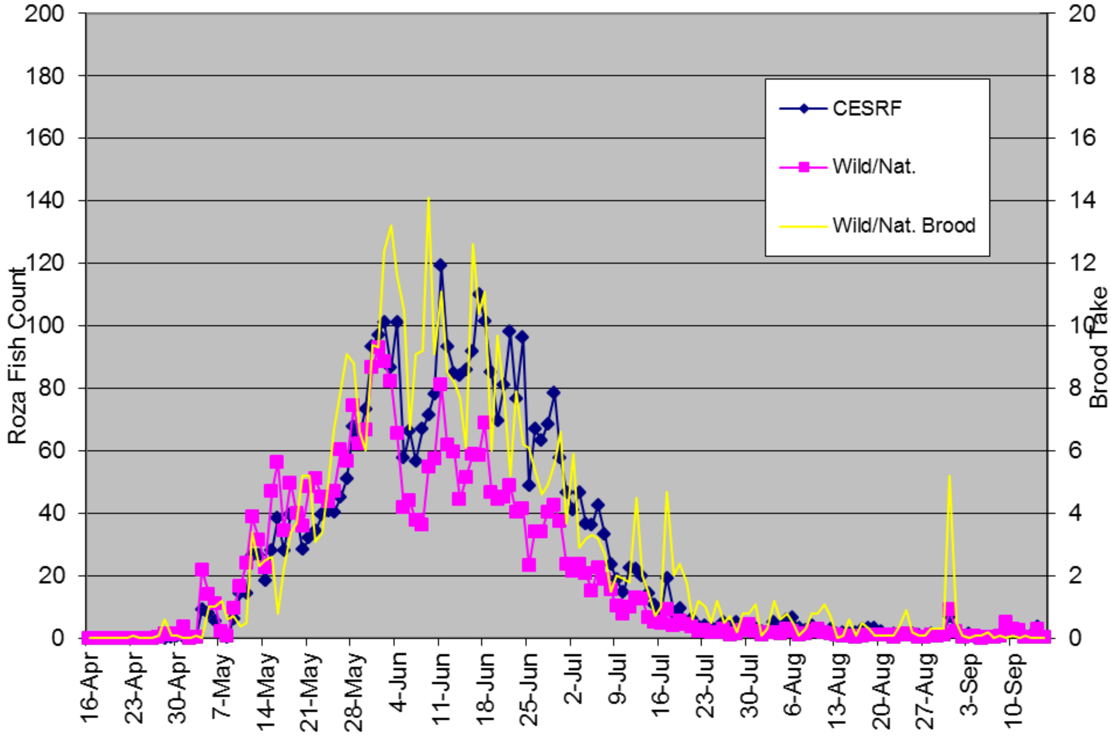

Figure 2. Mean spring Chinook run timing and broodstock collection at Roza Dam, 2007-2016.

Another program goal is to take no more than 50% of the wild/natural adult return to Roza Dam for broodstock. Given this goal and with a set brood collection schedule at Roza Dam, the project imposed a rule that no more than 50% of the fish arriving on any given day be taken for broodstock. Under-collection relative to the schedule is “carried over” to subsequent days and weeks. This allows brood collection to adjust relative to actual run timing and run strength. Performance across years with respect to these brood collection goals is given in Table 1. In 2015 the spring Chinook return was impaired by a thermal barrier in the lower Yakima River due to lack of winter snowpack and hot spring and summer air temperatures. This combined to severely reduce summer and fall flows and increase water temperatures. Mean daily water temperatures at Kiona (rkm 40 from the mouth of the Yakima R.) exceeded 70^{o} F every day from May 21 to August 29, 2015 (source U.S. BOR hydromet database). Thus, a large number of fish were delayed and passed Roza Dam in the later part of the 2015 migration period.

Table 1. Counts of wild/natural spring Chinook (including jacks), brood collection, and brood representation of wild/natural run at Roza Dam, 1997 – present.

Year	Trap Count	Brood Take	Brood %	Portion of run collected:[1] Early[3]	Middle[3]	Late[3]	Portion of collection from:[2] Early[3]	Middle[3]	Late[3]
1997	1,445	261	18.1%	26.4%	17.6%	17.7%	7.3%	83.1%	9.6%
1998	795	408	51.3%	51.1%	51.3%	51.9%	5.6%	84.3%	10.0%
1999	1,704	738	43.3%	44.6%	44.1%	35.9%	5.6%	86.3%	8.1%
2000	11,639	567	4.9%	10.7%	4.5%	4.4%	12.5%	77.8%	9.7%
2001	5,346	595	11.1%	6.9%	11.4%	10.7%	3.0%	87.7%	9.2%
2002	2,538	629	24.8%	15.7%	25.2%	26.1%	3.2%	86.3%	10.5%
2003	1,558	441	28.3%	52.5%	25.9%	36.4%	9.5%	77.8%	12.7%
2004	7,804	597	7.6%	2.6%	7.4%	12.8%	2.0%	81.6%	16.4%
2005	5,086	510	10.0%	2.2%	9.5%	21.9%	1.3%	77.0%	21.7%
2006	2,050	419	20.4%	48.5%	22.2%	41.0%	9.1%	75.1%	15.8%
2007	1,293	449	34.7%	25.0%	34.4%	60.6%	3.2%	80.0%	16.9%
2008	1,677	457	27.3%	57.7%	26.7%	32.4%	9.3%	79.0%	11.6%
2009	3,030	486	16.0%	10.0%	14.1%	35.9%	3.5%	73.9%	22.6%
2010	3,185	336	10.5%	6.4%	15.0%	22.5%	2.0%	82.6%	15.3%
2011	4,395	377	8.6%	11.3%	9.2%	21.3%	5.6%	73.2%	21.2%
2012	2,924	374	12.8%	1.9%	12.3%	27.4%	1.1%	79.9%	19.0%
2013	2,784	398	14.3%	18.5%	13.0%	22.0%	9.5%	75.1%	15.3%
2014	4,168	384	9.2%	4.8%	8.6%	16.9%	2.3%	80.5%	17.1%
2015	3,962	442	11.2%	3.1%	8.2%	40.6%	2.0%	59.9%	38.1%
2016	2,712	376	13.9%	5.3%	14.8%	18.6%	2.5%	84.7%	12.9%

1. This is the proportion of the earliest, middle, and latest running components of the entire wild/natural run which were taken for broodstock. Ideally, this collection percentage would be equal throughout the run and would match the "Brood %".
2. This is the proportion of the total broodstock collection taken from the earliest, middle, and latest components of the entire wild/natural run. Ideally, these proportions would match the definitions for early, middle, and late given in 3.
3. Early is defined as the first 5% of the run, middle is defined as the middle 85%, and late as the final 10% of the run.

Natural- and Hatchery-Origin Escapement

While the project does not actively manage for a specific spawning escapement proportion (natural- to hatchery-origin adults), we are monitoring the proportion of natural influence (PNI; Table 2). The project will adaptively manage this parameter considering factors such as: policy input regarding surplusing of fish, meeting overall production goals of the project, guidance from the literature relative to percentage of hatchery fish on the spawning grounds with fitness loss, considerations about what risk is acceptable in a project designed to evaluate impacts from that risk, and the numerous risk containment measures already in place in the project. The State of Washington is using mark-selective fisheries in the lower Columbia River and, when possible, in the lower Yakima River in part as a tool to manage escapement proportions. In 2011, the project initiated an effort to transfer some returning hatchery-origin CESRF adults from Roza Dam to Lake Cle Elum for the purpose of returning marine derived nutrients and salmon to the watersheds that feed the lake. This effort will also increase PNI in the major spawning areas of the Upper Yakima Basin. Natural- and hatchery-origin escapement to the upper Yakima Basin is given in Table 2. Wild/natural escapement to the Naches subbasin is given in Table 3.

Table 2. Escapement (Roza Dam counts less brood stock collection and harvest above Roza) of natural- (NoR) and hatchery-origin (HoR) spring Chinook to the upper Yakima subbasin, 1982 – present.

	Wild/Natural (NoR)			CESRF (HoR)			Total				
Year	Adults	Jacks	Total	Adults	Jacks	Total	Adults	Jacks	Total	pHOS[1]	PNI[1]
1982			1,146								
1983			1,007								
1984			1,535								
1985			2,331								
1986			3,251								
1987			1,734								
1988			1,340								
1989			2,331								
1990			2,016								
1991			*1,583*[2]								
1992			3,009								
1993			1,869								
1994			563								
1995			355								
1996			1,631								
1997	1,141	43	1,184								
1998	369	18	387								
1999	498	468	966								
2000	10,491	481	10,972		688	688	10,491	1,169	11,660	5.9%	
2001	4,454	297	4,751	6,065	982	7,047	10,519	1,279	11,798	59.7%	62.6%
2002	1,820	89	1,909	6,064	71	6,135	7,884	160	8,044	76.3%	56.7%
2003	394	723	1,117	1,036	1,105	2,141	1,430	1,828	3,258	65.7%	60.3%
2004	6,536	671	7,207	2,876	204	3,080	9,412	875	10,287	29.9%	77.0%
2005	4,401	175	4,576	627	482	1,109	5,028	657	5,685	19.5%	83.7%
2006	1,510	121	1,631	1,622	111	1,733	3,132	232	3,364	51.5%	66.0%
2007	683	161	844	734	731	1,465	1,417	892	2,309	63.4%	61.2%
2008	988	232	1,220	2,157	957	3,114	3,145	1,189	4,334	71.9%	58.2%
2009	1,843	701	2,544	2,234	2,260	4,494	4,077	2,961	7,038	63.9%	61.0%
2010	2,436	413	2,849	4,524	1,001	5,525	6,960	1,414	8,374	66.0%	60.2%
2011	3,092	926	4,018	3,162	1,404	4,566	6,254	2,330	8,584	53.2%	65.3%
2012	2,359	191	2,550	2,661	265	2,926	5,020	456	5,476	53.4%	65.2%
2013	1,708	678	2,386	1,587	840	2,427	3,295	1,518	4,813	50.4%	66.5%
2014	3,099	685	3,784	2,150	794	2,944	5,249	1,479	6,728	43.8%	69.6%
2015	3,357	163	3,520	1,779	167	1,946	5,136	330	5,466	35.6%	73.7%
2016	2,070	266	2,336	1,198	705	1,903	3,268	971	4,239	44.9%	69.0%
Mean[3]	2,662	375	3,038	2,530	755	3,285	5,077	1,161	6,237	53.1%	66.0%

1. Proportion Natural Influence equals Proportion Natural-Origin Broodstock (pNOB; 1.0 as only NoR fish are used for supplementation line brood stock) divided by pNOB plus Proportion Hatchery-Origin Spawners (pHOS).
2. This is a rough estimate since Roza counts are not available for 1991.
3. For NoR columns, mean of 1997-present values. For all other columns, mean of 2001-present values.

Adult-to-adult Returns

The overall status of Yakima Basin spring Chinook is summarized in Table 3. Adult-to-adult return and productivity data for the various populations are given in Tables 4-8 (Means are for 1988 to present).

Table 3. Yakima River spring Chinook run (CESRF and wild, adults and jacks combined) reconstruction, 1988-present.

	River Mouth Run Size[1]			Harvest Below Prosser	Prosser Count	Harvest Above Prosser	Spawners Below Roza[2]	Roza Count	Roza Removals[3]	Est. Escapement		Redd Counts	
Year	Adults	Jacks	Total							Upper Y.R.[4]	Naches[5]	Upper Y.R.	Naches
1988	3,919	327	4,246	333	3,913	111	60	1,575	235	1,340	2,167	424	490
1989	4,640	274	4,914	560	4,354	187	135	2,515	184	2,331	1,517	915	541
1990	4,280	92	4,372	131	*2,255*	532	282	2,047	31	2,016	*1,380*	678	464
1991	2,802	104	2,906	27	2,879	5	131		40	*1,583*	*1,121*	582	460
1992	4,492	107	4,599	184	4,415	161	39	3,027	18	3,009	1,188	1,230	425
1993	3,800	119	3,919	44	3,875	85	56	1,869	0	1,869	1,865	637	554
1994	1,282	20	1,302	0	1,302	25	10	563	0	563	704	285	272
1995	526	140	666	0	666	79	9	355	0	355	223	114	104
1996	3,060	119	3,179	100	3,079	375	26	1,631	0	1,631	1,047	801	184
1997	3,092	81	3,173	0	3,173	575	20	1,445	261	1,184	1,133	413	339
1998	1,771	132	1,903	0	1,903	188	3	795	408	387	917	147	330
1999	1,513	1,268	2,781	8	2,773	596	55	1,704	738	966	418	212	186
2000	17,519	1,582	19,101	90	19,011	2,368	204	12,327	667	11,660	4,112	3,770	888
2001	21,225	2,040	23,265	1,793	21,472	2,838	286	12,516	718	11,798	5,829	3,226	1,192
2002	14,616	483	15,099	328	14,771	2,780	29	8,922	878	8,044	3,041	2,816	943
2003	4,868	2,089	6,957	59	6,898	381	83	3,842	584	3,258	2,592	868	935
2004	13,974	1,315	15,289	135	15,154	1,544	90	11,005	718	10,287	2,515	3,414	719
2005	8,059	699	8,758	34	8,724	440	28	6,352	667	5,685	1,904	2,009	574
2006	5,951	363	6,314	0	6,314	600	14	4,028	664	3,364	1,672	1,245	447
2007	2,968	1,335	4,303	10	4,293	269	13	3,025	716	2,309	986	722	313
2008	6,615	1,983	8,598	539	8,059	993	9	5,478	1,144	4,334	1,578	1,372	495
2009	7,441	4,679	12,120	1,517	10,603	836	18	8,633	1,595	7,038	1,117	1,575	482
2010	11,027	2,114	13,142	156	12,986	1,585	9	9,900	1,526	8,374	1,491	2,668	552
2011	13,398	4,561	17,960	909	17,051	3,471	0	10,520	1,936	8,584	3,060	1,898	580
2012	11,083	970	12,053	1,331	10,722	1,989	7	6,826	1,350	5,476	1,900	1,468	811
2013	7,101	3,144	10,245	1,191	9,054	1,462	171	6,053	1,240	4,813	1,369	648	376
2014	8,850	2,472	11,322	221	11,101	1,950	23	7,997	1,269	6,728	1,130	1,149	379
2015	8,795	556	9,351	83	9,268	732	0	6,433	967	5,466	2,103	1,321	614
2016	5,517	1,399	6,916	24	6,892	420	42	5,098	859	4,239	1,332	611	366
Mean[6]	8,280	2,321	10,601	598	10,003	1,371	29	6,996	1,260	5,736	1,607	1,343	497

1. River Mouth run size is the greater of the Prosser count plus lower river harvest or estimated escapement plus all known harvest and removals.
2. Estimated as the average number of fish per redd in the upper Yakima times the number of redds between the Naches confluence and Roza Dam.
3. Roza removals include harvest above Roza, hatchery removals, and/or wild broodstock removals.
4. Estimated escapement into the upper Yakima River is the Roza count, less harvest or broodstock removals above Roza Dam except in 1991 when Upper Yakima River escapement is estimated as the (Prosser count - harvest above Prosser - Roza subtractions) times the proportion of redds counted in the upper Yakima.
5. Naches River escapement was estimated as the Prosser count, less harvest above Prosser and the Roza counts, except in 1982, 1983 and 1990 when it was estimated as the upper Yakima fish/redd times the Naches redd count.
6. Recent 10-year average (2007-2016).

Estimated spawners for the Upper Yakima River are calculated as the estimated escapement to the Upper Yakima plus the estimated number of spawners in the Upper Yakima between the confluence with the Naches River and Roza Dam (Table 3). Total returns are based on the information compiled in Table 3. Age composition for Upper Yakima returns is estimated from spawning ground carcass scale samples for the years 1982-1996 (Table 11) and from Roza Dam brood stock collection samples for the years 1997 to present (Table 13). Since age-3 fish (jacks) are not collected for brood stock in proportion to the jack run size, the proportion of age-3 fish in the upper Yakima for 1997 to present is estimated using the proportion of jacks (based on visual observation) counted at Roza Dam relative to the total run size.

Table 4. Adult-to-adult productivity indices for upper Yakima wild/natural stock.

Brood	Estimated	Estimated Yakima R. Mouth Returns				Returns/
Year	Spawners	Age-3	Age-4	Age-5	Total	Spawner
1984	1,715	92	1,348	139	1,578	0.92
1985	2,578	114	2,746	105	2,965	1.15
1986	3,960	171	2,574	149	2,893	0.73
1987	2,003	53	1,571	109	1,733	0.87
1988	1,400	53	3,138	132	3,323	2.37
1989	2,466	68	1,779	9	1,856	0.75
1990	2,298	79	566	0	645	0.28
1991	1,713	9	326	22	358	0.21
1992	3,048	87	1,861	95	2,043	0.67
1993	1,925	66	1,606	57	1,729	0.90
1994	573	60	737	92	890	1.55
1995	364	59	1,036	129	1,224	3.36
1996	1,657	1,059	12,882	630	14,571	8.79
1997	1,204	621	5,837	155	6,613	5.49
1998	390	434	2,803	145	3,381	8.68
1999	1,021[1]	164	722	45	930	0.91
2000	11,864	856	7,689	127	8,672	0.73
2001	12,087	775	5,074	222	6,071	0.50
2002	8,073	224	1,875	148	2,247	0.28
2003	3,341	158	1,036	63	1,257	0.38
2004	10,377	207	1,547	75	1,828	0.18
2005	5,713	293	2,630	14	2,936	0.51
2006	3,378	868	2,887	133	3,888	1.15
2007	2,322	456	3,976	65	4,498	1.94
2008	4,343	1,135	3,410	123	4,668	1.07
2009	7,056	283	2,572	109	2,964	0.42
2010	8,383	923	3,854	59	4,836	0.58
2011	8,584	832	3,908	144	4,883	0.57
2012	5,483	197	2,445		2,641	
2013	4,984	299				
2014	6,751					
2015	5,466					
2016	4,281					
Mean	4,267	356	2,912	118	3,410	1.64

1. The mean jack proportion of spawning escapement from 1999-2016 was 0.22 (geometric mean 0.16).

Estimated spawners for the Naches/American aggregate population (Table 7) are calculated as the estimated escapement to the Naches Basin (Table 3). Estimated spawners for the individual Naches and American populations are calculated using the proportion of redds counted in the Naches Basin (excluding the American River) and the American River, respectively (see Table 31). Total returns are based on the information compiled in Table 3. Age composition for Naches Basin age-4 and age-5 returns are estimated from spawning ground carcass scale samples (see Tables 9-12). The proportion of age-3 fish is estimated after reviewing jack count (based on visual observations) data at Prosser and Roza dams. Since sample sizes for carcass surveys in the American and Naches Rivers can be very low in some years (Tables 9 and 10), it is recommended that the data in Tables 5 and 6 be used as indices only. Table 7 likely provides the most accurate view of overall productivity rates in the Naches River Subbasin.

Table 5. Adult-to-adult productivity indices for Naches River wild/natural stock.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Age-6	Total	Returns/ Spawner
1984	383	110	706	564	0	1,381	3.60
1985	683	132	574	396	0	1,102	1.61
1986	2,666	68	712	499	15	1,294	0.49
1987	1,162	27	183	197	0	407	0.35
1988	1,340	32	682	828	0	1,542	1.15
1989	992	28	331	306	0	665	0.67
1990	954	24	170	74	0	269	0.28
1991	706	7	37	121	57	222	0.31
1992	852	29	877	285	0	1,191	1.40
1993	1,145	45	593	372	0	1,010	0.88
1994	474	14	164	164	0	343	0.72
1995	124	40	164	251	0	455	3.66
1996	887	179	3,983	1,620	0	5,782	6.52
1997	762	207	3,081	708	0	3,996	5.24
1998	503	245	1,460	1,128	0	2,833	5.63
1999	358[1]	113	322	190	0	626	1.75
2000	3,862	71	2,060	215	0	2,346	0.61
2001	3,912	126	1,254	471	0	1,850	0.47
2002	1,861	59	753	153	0	965	0.52
2003	1,400	52	237	175	0	464	0.33
2004	2,197	107	875	218	0	1,199	0.55
2005	1,439	167	653	119	0	940	0.65
2006	1,163	192	834	254	0	1,280	1.10
2007	463	125	1,649	514	0	2,288	4.94
2008	1,074	414	827	290	0	1,531	1.42
2009	903	84	448	65	0	597	0.66
2010	1,024	209	653	198	0	1,059	1.03
2011	1,942	137	1,088	305		1,530	0.79
2012	1,110	64	419				
2013	750	110					
2014	746						
2015	1,285						
2016	790						
Mean	1,210	107	889	381	3	1,399	1.69

1. The mean jack proportion of spawning escapement from 1999-2016 was 0.09.

Table 6. Adult-to-adult productivity indices for American River wild/natural stock.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Age-6	Total	Returns/ Spawner
1984	187	54	301	458	0	813	4.36
1985	337	81	149	360	0	590	1.75
1986	1,457	36	134	329	11	509	0.35
1987	567	12	71	134	0	216	0.38
1988	827	19	208	661	5	892	1.08
1989	524	11	69	113	0	193	0.37
1990	425	15	113	84	0	213	0.50
1991	414	3	5	22	0	30	0.07
1992	335	23	157	237	0	417	1.24
1993	721	8	218	405	8	639	0.89
1994	230	7	36	16	0	59	0.26
1995	98	33	32	98	0	163	1.65
1996	159	30	176	760	0	967	6.07
1997	371	13	1,543	610	0	2,166	5.84
1998	414	120	766	1,136	0	2,022	4.88
1999	61	72	99	163	0	334	5.50
2000	250	60	163	110	0	333	1.33
2001	1,917	18	364	256	0	638	0.33
2002	1,180	19	279	257	0	555	0.47
2003	1,192	23	183	440	0	646	0.54
2004	318	121	52	33	0	206	0.65
2005	464	79	173	263[1]	0	515	1.11
2006	509	45	172[1]	451	0	668	1.31
2007	523	57[1]	645	493	0	1,194	2.28
2008	504	239	461	465	0	1,165	2.31
2009	213	60	143	44	0	247	1.16
2010	467	172	326	173	0	671	1.44
2011	1,118	71	646	236		953	0.85
2012	789	41	261				
2013	619	76					
2014	385						
2015	819						
2016	542						
Mean	574	54	274	315	1	643	1.75

1. No survey samples in 2010 return year; data approximated using 2007-09, 2011 survey samples.

Table 7. Adult-to-adult productivity indices for Naches/American aggregate (wild/natural) population.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Age-6	Total	Returns/ Spawner
1984	570	164	1,109	1,080	0	2,354	4.13
1985	1,020	213	667	931	0	1,811	1.77
1986	4,123	103	670	852	31	1,657	0.40
1987	1,729	39	231	400	0	669	0.39
1988	2,167	51	815	1,557	11	2,434	1.12
1989	1,517	39	332	371	0	741	0.49
1990	1,380	40	326	168	0	533	0.39
1991	1,121	10	32	144	127	314	0.28
1992	1,188	52	1,034	661	0	1,747	1.47
1993	1,865	53	603	817	17	1,489	0.80
1994	704	21	160	167	0	348	0.49
1995	223	73	201	498	0	771	3.46
1996	1,047	209	4,010	2,359	0	6,579	6.29
1997	1,133	220	4,644	1,377	0	6,241	5.51
1998	917	364	2,167	2,316	12	4,859	5.30
1999	418[1]	185	369	279	0	833	1.99
2000	4,112	131	2,286	346	0	2,762	0.67
2001	5,829	144	1,598	785	0	2,526	0.43
2002	3,041	78	975	443	0	1,496	0.49
2003	2,592	75	387	1,028	0	1,489	0.57
2004	2,515	227	514	232	0	973	0.39
2005	1,904	246	845	174[2]	0	1,264	0.66
2006	1,672	237	1,215[2]	759	0	2,211	1.32
2007	986	182[2]	2,239	1,033	0	3,454	3.50
2008	1,578	653	1,262	803	0	2,718	1.72
2009	1,117	144	542	116	0	802	0.72
2010	1,491	381	972	412	0	1,766	1.18
2011	3,060	208	1,693	559		2,459	0.80
2012	1,900	105	662				
2013	1,369	186					
2014	1,130						
2015	2,103						
2016	1,332						
Mean	1,783	161	1,123	738	7	2,046	1.67

1. The mean jack proportion of spawning escapement from 1999-2016 was 0.09.
2. Age composition using only Naches survey samples in 2010 return year.

Estimated spawners at the CESRF are the total number of wild/natural fish collected at Roza Dam and taken to the CESRF for production brood stock. Total returns are based on the information compiled in Table 3 and at Roza dam sampling operations. Age composition for CESRF fish is estimated using scales and PIT tag detections from CESRF fish sampled passing upstream through the Roza Dam adult monitoring facility.

Table 8. Adult-to-adult productivity for Cle Elum SRF spring Chinook.

Brood	Estimated	Estimated Yakima R. Mouth Returns				Returns/
Year	Spawners	Age-3	Age-4	Age-5	Total	Spawner
1997	261	741	7,753	176	8,670	33.22
1998	408	1,242	7,939	602	9,782	23.98
1999	738[1]	134	714	16	864	1.17
2000	567	1,103	3,647	70	4,819	8.50
2001	595	396	845	9	1,251	2.10
2002	629	345	1,886	69	2,300	3.66
2003	441	121	800	12	932	2.11
2004	597	805	3,101	116	4,022	6.74
2005	510	1,305	3,052	21	4,378	8.58
2006	419	3,038	5,812	264	9,114	21.75
2007	449	1,277	5,174	108	6,558	14.61
2008	457	2,344	4,567	65	6,976	15.27
2009	486	461	2,663	58	3,181	6.55
2010	336	1,495	3,183	30	4,707	14.01
2011	377	1,233	2,340	34	3,607	9.57
2012	374	221	1,492			
2013	398	802				
2014	384					
2015	442					
2016	376					
Mean	462	1,004	3,435	110	4,744	7.94[2]

1. 357 or 48% of these fish were jacks.
2. Geometric mean.

Age Composition

Comparisons of the age composition in the Roza adult monitoring facility (RAMF) samples and spawning ground carcass recovery samples show that older, larger fish are recovered as carcasses on the spawning grounds at significantly higher rates than younger, smaller fish (Knudsen et al. 2003 and Knudsen et al. 2004). Based on historical scale-sampled carcass recoveries between 1986 and 2016, age composition of American River spring Chinook has averaged 1, 44, 54, and 1 percent age-3, -4, –5, and -6, respectively (Table 9). Naches system spring Chinook averaged 2, 61, 36 and 0.5 percent age-3, -4, –5 and -6, respectively (Table 10). The upper Yakima River natural origin fish averaged 8, 88, and 4 percent age-3, -4, and –5, respectively (Table 11). While these ages are biased toward the older age classes, we believe the bias is approximately equal across populations and is a good relative indicator of differences in age composition between populations. The data show distinct differences with the American River population having the oldest age of maturation, followed closely by the Naches system and then the upper Yakima River which has significantly more age-3's, fewer age-5's and no age-6 fish.

Table 9. Percentage by sex and age of American River wild/natural spring Chinook carcasses sampled on the spawning grounds and sample size (n), 1986-present.

Return	Males					Females					Total			
Year	3	4	5	6	n	3	4	5	6	n	3	4	5	6
1986		23.8	76.2		21		8.9	86.7	4.4	45		13.6	83.3	3.0
1987		70.8	25.0	4.2	24		42.9	57.1		21		57.8	40.0	2.2
1988			100.0		1		100.0			1		33.3	66.7	
1989		39.6	60.4		48		10.0	90.0		50		24.5	75.5	
1990	2.5	25.0	72.5		40		28.3	71.7		46	1.2	26.7	72.1	
1991		23.8	76.2		42		13.3	86.7		60		17.6	82.4	
1992		71.2	23.1	5.8	52		45.8	54.2		48		59.0	38.0	3.0
1993	4.8	14.3	81.0		21		8.0	92.0		75	1.0	9.4	89.6	
1994		44.4	55.6		18		50.0	46.7	3.3	30		49.0	49.0	2.0
1995	14.3	14.3	71.4		7			100.0		13	5.0	5.0	90.0	
1996		100.0			2		83.3	16.7		6		87.5	12.5	
1997		40.0	60.0		5		22.2	64.4	13.3	45		24.0	64.0	12.0
1998		12.1	87.9		33		6.6	93.4		76		8.3	91.7	
1999		100.0			2		40.0	40.0	20.0	5		57.1	28.6	14.3
2000		66.7	33.3		15		61.5	38.5		13		64.3	35.7	
2001		65.6	34.4		90		67.9	32.1		106		67.0	33.0	
2002	1.7	53.4	44.8		58		56.4	43.6		110	0.6	55.4	44.0	
2003		8.1	91.9		74		7.9	92.1		151		8.0	92.0	
2004		100.0			3		20.0	80.0		5		50.0	50.0	
2005		64.7	35.3		17		84.0	16.0		25		76.7	23.3	
2006		61.5	38.5		13		48.6	51.4		35		52.1	47.9	
2007	10.5	31.6	57.9		19		43.8	56.3		48	3.0	40.3	56.7	
2008		8.7	91.3		23		11.9	88.1		42		10.6	89.4	
2009	30.8	69.2			13		75.0	25.0		16	13.8	72.4	13.8	
2010	No carcasses were sampled													
2011		40.0	60.0		10		63.2	36.8		19		58.8	41.2	
2012		50.0	50.0		14		47.8	52.2		16		48.3	51.7	
2013	11.1	11.1	77.8		9		26.9	73.1		26	2.9	22.9	74.3	
2014	5.6	77.8	16.7		18		90.9	9.1		33	2.0	86.3	11.8	
2015	7.4	74.1	18.5		27		78.3	21.7		46	2.7	76.7	20.5	
2016		28.6	71.4		14		65.4	34.6		26		52.5	47.5	
Mean	3.0	46.3	50.4	0.3			43.6	55.0	1.4		1.1	43.8	53.9	1.2

Table 10. Percentage by sex and age of Naches River wild/natural spring Chinook carcasses sampled on the spawning grounds and sample size (n), 1986-present.

Return	Males					Females					Total			
Year	3	4	5	6	n	3	4	5	6	n	3	4	5	6
1986	5.0	60.0	30.0	5.0	20		33.3	64.3	2.4	42	1.6	41.9	53.2	3.2
1987	5.9	76.5	11.8	5.9	17		69.0	31.0		42	1.7	71.7	25.0	1.7
1988		50.0	50.0		8	5.6	38.9	55.6		18	3.3	46.7	50.0	
1989		70.2	29.8		47		34.9	63.5	1.6	63		50.0	49.1	0.9
1990	9.1	60.6	30.3		33	10.7	57.1	32.1		28	11.1	57.1	31.7	
1991	4.3	52.2	43.5		23		13.3	86.7		45	1.5	26.5	72.1	
1992	4.0	80.0	12.0	4.0	25		70.6	29.4		34	1.7	75.0	21.7	1.7
1993		42.3	57.7		26		18.6	81.4		43		28.6	71.4	
1994		50.0	50.0		4		30.0	70.0		10		35.7	64.3	
1995		25.0	75.0		4		28.6	71.4		7		33.3	66.7	
1996		100.0			17		75.0	25.0		16		87.9	12.1	
1997	2.9	70.6	20.6	5.9	34		57.1	36.7	6.1	49	1.2	62.7	30.1	6.0
1998		29.4	70.6		17		27.9	72.1		43		30.6	69.4	
1999	12.5	62.5	25.0		8		33.3	66.7		9	5.9	47.1	47.1	
2000	1.7	94.9	3.4		59		92.2	7.8		77	0.7	93.4	5.9	
2001	1.7	72.9	25.4		59		61.0	39.0		118	0.6	65.2	34.3	
2002	2.1	78.7	19.1		47		63.3	36.7		98	0.7	66.9	32.4	
2003	7.8	25.0	67.2		64	1.1	18.9	80.0		95	3.8	21.4	74.8	
2004	7.5	87.5	5.0		40		91.3	8.7		92	2.3	89.5	8.3	
2005		81.8	18.2		11		83.8	16.2		37		83.7	16.3	
2006		61.5	38.5		13		61.5	38.5		13		61.5	38.5	
2007		75.0	25.0		4		57.9	42.1		19		60.9	39.1	
2008	36.4	45.5	18.2		11		87.0	13.0		23	11.8	73.5	14.7	
2009	7.1	71.4	21.4		14		76.9	23.1		26	2.4	73.2	24.4	
2010		100.0			9		81.8	18.2		22	3.0	84.8	12.1	
2011	11.5	80.8	7.7		26		78.9	21.1		19	6.3	81.3	12.5	
2012	11.8	41.2	47.1		17		64.4	33.3		45	4.8	58.7	36.5	
2013	15.4	53.8	30.8		13		56.3	43.8		16	6.7	56.7	36.7	
2014		86.7	13.3		15		92.3	7.7		26		90.9	9.1	
2015		100.0			10		75.0	25.0		16		84.6	15.4	
2016		25.0	75.0		4		64.3	35.7		14		57.9	42.1	
Mean	4.7	64.9	29.7	0.7		0.6	57.9	41.2	0.3		2.3	61.2	36.0	0.4

Table 11. Percentage by sex and age of upper Yakima River wild/natural spring Chinook carcasses sampled on the spawning grounds and sample size (n), 1986-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
1986		100.0		12		94.1	5.9	51		95.2	4.8
1987	10.8	81.5	7.7	65		77.8	22.2	126	3.7	79.1	17.3
1988	22.5	70.0	7.5	40	10.4	75.0	14.6	48	15.6	73.3	11.1
1989	0.8	93.1	6.2	130	0.4	95.5	4.1	246	0.5	94.7	4.8
1990	6.3	88.4	5.3	95	2.1	94.8	3.1	194	3.4	92.8	3.8
1991	9.1	87.3	3.6	55		89.2	10.8	111	3.0	88.6	8.4
1992	2.4	91.6	6.0	167		98.1	1.9	315	0.8	95.9	3.3
1993	4.0	90.0	6.0	50	0.9	92.0	7.1	112	1.9	91.4	6.8
1994		100.0		16		98.0	2.0	50		98.5	1.5
1995	20.0	80.0		5		100.0		12	5.6	94.4	
1996	9.1	89.6	1.3	154	0.7	98.2	1.1	282	3.7	95.2	1.1
1997		96.7	3.3	61		96.3	3.7	136		96.4	3.6
1998	14.3	85.7		21	5.3	86.8	7.9	38	8.5	86.4	5.1
1999	61.8	38.2		34		94.4	5.6	36	31.0	66.2	2.8
2000	2.8	97.2		72		100.0		219	1.0	99.0	
2001	2.7	89.2	8.1	37		83.6	16.4	122	0.6	85.0	14.4
2002	2.4	58.5	39.0	41	3.6	87.5	8.9	56	5.1	73.7	21.2
2003	60.5	39.5		38	4.3	82.6	13.0	23	39.3	55.7	4.9
2004	6.5	93.5		108	0.0	99.5	0.5	198	2.3	97.4	0.3
2005	9.2	90.0		120	1.4	97.2	1.4	214	4.2	94.7	1.2
2006	23.7	74.6		59	2.3	96.5	1.2	86	11.0	87.6	1.4
2007	17.1	82.9		76	0.9	93.8	5.4	112	7.4	89.4	3.2
2008	11.8	88.2		34	0.0	95.8	4.2	24	6.9	91.4	1.7
2009	47.7	52.3		111	2.2	95.6	2.2	45	34.6	64.7	0.6
2010	27.7	72.3		47		100.0		71	11.0	89.0	
2011	37.5	62.5		16		100.0		27	13.6	86.4	
2012	25.0	75.0		8	7.7	92.3		13	14.3	85.7	
2013						100.0		8		100.0	
2014	3.3	96.7		30		100.0		59	1.1	98.9	
2015						no surveys					
2016						no surveys					
Mean	15.7	80.9	3.4		1.5	93.6	4.9		7.9	87.8	4.3

Carcasses from upper Yakima River CESRF origin fish allowed to spawn naturally have also been sampled since age-4 adults began returning in 2001. These fish averaged 13, 85, and 1 percent age-3, -4, and –5, respectively (Table 12) from 2001-2014 compared to 8, 88, and 4.3 percent respectively for their wild/natural counterparts in the upper Yakima for the same years (Table 11). The observed difference in age distribution between wild/natural and CESRF sampled on the spawning grounds may be due in part to the carcass recovery bias described above. A better comparison of age distribution between upper Yakima wild/natural and CESRF fish is from samples collected at Roza Dam which are displayed in Tables 13 and 14. However, it must be noted that jacks (age-3 males) were collected at Roza in proportion to run size from 1997 to 1999, but from 2000-present we have attempted to collect them at their mean brood representation rate (approximately 7% of the spawning population). Age-3 females do occur rarely in the Upper Yakima population, but it is likely that the data in Table 13 slightly over-represent the proportion of age-3 females due to human error associated with scale collection, handling, processing, and management and entry of these data.

Table 12. Percentage by sex and age of upper Yakima River CESRF spring Chinook carcasses sampled on the spawning grounds and sample size (n), 2001-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
2001	23.5	76.5		34	0.9	99.1		108	6.3	93.7	
2002	8.0	81.3	10.7	75		88.6	11.4	140	2.8	86.2	11.1
2003	100.0			1		100.0		1	50.0	50.0	
2004	9.5	90.5		21		98.0	2.0	51	2.8	95.8	1.4
2005	42.9	57.1		21		90.9	4.5	22	23.3	74.4	2.3
2006	26.7	73.3		15		100.0		43	6.9	93.1	
2007	66.7	33.3		6		100.0		11	23.5	76.5	
2008				0		100.0		1		100.0	
2009	60.0	40.0		5				0	60.0	40.0	
2010	28.6	71.4		7		100.0		11	11.1	88.9	
2011	37.5	62.5		16	4.5	95.5		22	18.4	81.6	
2012		100.0		4	5.3	94.7		19	4.3	95.7	
2013		100.0		1		100.0		7		100.0	
2014		100.0		20		100.0		62	1.2	98.8	
2015						no surveys					
2016						no surveys					
Mean[1]	25.3	73.8	0.9		0.5	97.2	1.8		13.4	85.4	1.2

1. Excludes years where sample size < 5.

Table 13. Percentage by sex and age of upper Yakima River wild/natural spring Chinook collected for brood stock at Roza Dam and sample size (n), 1997-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
1997	4.5	92.0	3.4	88		94.6	5.4	111	2.0	93.5	4.5
1998	22.4	73.1	4.5	134		91.6	8.4	179	9.6	83.7	6.7
1999	71.1	26.1	2.8	425		92.6	7.4	215	48.8	47.0	4.2
2000	17.8	81.7	0.4	230		98.7	1.3	313	7.5	91.5	0.9
2001	12.4	77.4	10.3	234	0.9	90.5	8.5	328	5.7	85.2	9.2
2002	16.4	78.3	5.3	226	0.6	94.8	4.7	343	6.9	88.2	4.9
2003	27.4	60.2	12.4	201		83.3	16.7	228	12.8	72.6	14.7
2004	15.1	84.5	0.4	239	0.3	99.0	0.7	305	6.8	92.6	0.6
2005	15.5	82.3	2.2	181	0.4	97.1	2.5	276	6.3	91.2	2.4
2006	11.1	77.4	11.5	226		89.4	10.6	255	5.2	83.8	11.0
2007	13.6	74.7	11.7	162		87.8	12.2	255	5.3	82.7	12.0
2008	20.0	77.4	2.6	190		95.6	4.4	252	8.6	87.8	3.6
2009	17.4	81.2	1.4	207	0.8	96.1	3.1	258	8.2	89.5	2.4
2010	20.0	79.4	0.6	155	0.4	99.3	0.4	285	7.3	92.3	0.5
2011	18.1	81.3	0.5	182	0.8	95.3	3.8	236	8.4	89.2	2.4
2012	12.5	86.5	1.0	104		97.4	2.6	189	4.4	93.5	2.0
2013	18.0	77.6	4.3	161	0.0	96.2	3.8	183	8.4	87.5	4.1
2014	20.9	76.3	2.8	177	0.0	97.8	2.2	184	10.2	87.3	2.5
2015	9.3	89.4	1.2	161	0.0	98.7	1.3	231	3.8	94.9	1.3
2016	12.5	81.6	5.9	152	0.5	95.2	4.3	210	5.5	89.5	5.0
Mean	18.8	76.9	4.3		0.2	94.6	5.2		9.1	86.2	4.7

Table 14. Percentage by sex and age of upper Yakima River CESRF spring Chinook collected for research or brood stock at Roza Dam and sample size (n), 2001-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
2001	12.5	87.5		40		100.0		75	5.1	94.9	
2002	14.7	83.8	1.5	68		98.3	1.7	115	5.5	92.9	1.6
2003	36.1	34.7	29.2	72		61.2	38.8	67	18.7	47.5	33.8
2004	19.6	80.4		46		100.0		60	8.5	91.5	
2005	17.8	75.6	6.7	45		88.1	11.9	59	7.7	82.7	9.6
2006	18.3	80.0	1.7	60		100.0		65	8.8	90.4	0.8
2007	33.3	60.8	5.9	51		87.5	12.5	56	15.9	74.8	9.3
2008	50.0	50.0		40		100.0		56	20.8	79.2	
2009	25.4	71.2	3.4	59	1.2	97.6	1.2	84	11.2	86.7	2.1
2010	27.9	72.1		61		99.0	1.0	100	10.6	88.8	0.6
2011	21.2	72.7	6.1	66	0.9	97.2	1.9	107	8.7	87.9	3.5
2012	13.0	85.2	1.9	54		97.0	3.0	101	4.5	92.9	2.6
2013	17.9	80.6	1.5	67	1.1	96.7	2.2	92	8.2	89.9	1.9
2014	31.9	66.0	2.1	47	0.0	100.0	0.0	33	18.8	80.0	1.3
2015	33.3	66.7	0.0	27	0.0	97.9	2.1	48	12.0	86.7	1.3
2016	26.5	69.4	4.1	49	0.0	100.0	0.0	47	13.5	84.4	2.1
Mean	25.0	71.0	4.0		0.2	95.0	4.8		11.2	84.4	4.4

Sex Composition

In the American River, the mean proportion of males to females in wild/natural carcasses sampled on the spawning grounds from 1986-2016 was 41:59 for age-4 and 33:67 for age-5 spring Chinook (Table 15). In the Naches River, the mean proportion of males to females was 41:59 for age-4 and 27:73 for age-5 fish (Table 16). In the upper Yakima River, the mean proportion of males to females was 33:67 for age-4 and 23:77 for age-5 fish (Table 17).

For upper Yakima fish collected at Roza Dam for brood stock or research purposes from 1997-2016, the mean proportion of males to females was 38:62 and 36:64 for age-4 fish from the wild/natural and CESRF populations, respectively (Tables 19 and 20). For these same samples, the mean proportion of males to females was 37:63 and 41:59 for age-5 fish from the wild/natural and CESRF populations (excluding years with very small age-5 sample sizes), respectively (Tables 19 and 20). For adult fish, the mean proportion of males to females in spawning ground carcass recoveries was substantially lower than the ratio found at RAMF (Tables 17 and 19), indicating that sex ratios estimated from hatchery origin carcass recoveries were biased due to female carcasses being recovered at higher rates than male carcasses (Knudsen et al, 2003 and 2004). Again, despite these biases, we believe these data are good relative indicators of differences in sex composition between populations and between years.

Sample sizes for Tables 15-20 were given in Tables 9-14. As noted earlier, few age-6 fish are found in carcass surveys and those that have been found were located in the American and Naches systems. The data indicate that age-3 females may occasionally occur in the upper Yakima and, to a lesser extent, the Naches systems.

Table 15. Percent of American River wild/natural spring Chinook carcasses sampled on the spawning grounds by age and sex, 1986-present.

Return	Age-3		Age-4		Age-5		Age-6	
Year	M	F	M	F	M	F	M	F
1986			55.6	44.4	29.1	70.9		100.0
1987			65.4	34.6	33.3	66.7	100.0	
1988			0.0	100.0	100.0	0.0		
1989			79.2	20.8	39.2	60.8		
1990	100.0		43.5	56.5	46.8	53.2		
1991			55.6	44.4	38.1	61.9		
1992			62.7	37.3	31.6	68.4	100.0	
1993	100.0		33.3	66.7	19.8	80.2		
1994			34.8	65.2	41.7	58.3		100.0
1995	100.0		100.0	0.0	27.8	72.2		
1996			28.6	71.4	0.0	100.0		
1997			16.7	83.3	9.4	90.6		100.0
1998			44.4	55.6	29.0	71.0		
1999			50.0	50.0	0.0	100.0		100.0
2000			55.6	44.4	50.0	50.0		
2001			45.0	55.0	47.7	52.3		
2002	100.0		33.3	66.7	35.1	64.9		
2003			33.3	66.7	32.9	67.1		
2004			75.0	25.0	0.0	100.0		
2005			34.4	65.6	60.0	40.0		
2006			32.0	68.0	21.7	78.3		
2007	100.0		22.2	77.8	28.9	71.1		
2008			28.6	71.4	36.2	63.8		
2009			42.9	57.1	0.0	100.0		
2010			No carcasses were sampled					
2011			25.0	75.0	46.2	53.8		
2012			24.1	75.9	22.6	77.4		
2013			12.5	87.5	26.9	73.1		
2014			31.8	68.2	50.0	50.0		
2015			35.7	64.3	33.3	66.7		
2016			19.0	81.0	52.6	47.4		
mean			40.7	59.3	33.0	67.0		

Table 16. Percent of Naches River wild/natural spring Chinook carcasses sampled on the spawning grounds by age and sex, 1986-present.

Return	Age-3		Age-4		Age-5		Age-6	
Year	M	F	M	F	M	F	M	F
1986	100.0		46.2	53.8	18.2	81.8	50.0	50.0
1987	100.0		31.0	69.0	13.3	86.7	100.0	
1988		100.0	36.4	63.6	28.6	71.4		
1989			60.0	40.0	25.9	74.1		100.0
1990	50.0	50.0	55.6	44.4	52.6	47.4		
1991	100.0		66.7	33.3	20.4	79.6		
1992	100.0		45.5	54.5	23.1	76.9	100.0	
1993			57.9	42.1	30.0	70.0		
1994			40.0	60.0	22.2	77.8		
1995			33.3	66.7	37.5	62.5		
1996			58.6	41.4		100.0		
1997	100.0		46.2	53.8	28.0	72.0	40.0	60.0
1998			29.4	70.6	27.9	72.1		
1999	100.0		62.5	37.5	25.0	75.0		
2000	100.0		44.1	55.9	25.0	75.0		
2001	100.0		37.4	62.6	24.6	75.4		
2002	100.0		37.4	62.6	20.0	80.0		
2003	83.3	16.7	47.1	52.9	36.1	63.9		
2004	100.0		29.4	70.6	20.0	80.0		
2005			22.5	77.5	25.0	75.0		
2006			50.0	50.0	50.0	50.0		
2007			21.4	78.6	11.1	88.9		
2008	100.0		20.0	80.0	40.0	60.0		
2009	100.0		33.3	66.7	33.3	66.7		
2010			33.3	66.7		100.0		
2011	100.0		58.3	41.7	33.3	66.7		
2012	66.7	33.3	19.4	80.6	34.8	65.2		
2013	100.0		43.8	56.3	36.4	63.6		
2014			35.1	64.9	50.0	50.0		
2015			45.5	54.5		100.0		
2016			10.0	90.0	37.5	62.5		
mean			40.6	59.4	26.8	73.2		

Table 17. Percent of Upper Yakima River wild/natural spring Chinook carcasses sampled on the spawning grounds by age and sex, 1986-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
1986			20.0	80.0		100.0
1987	100.0		35.1	64.9	15.2	84.8
1988	64.3	35.7	43.8	56.3	30.0	70.0
1989	50.0	50.0	34.0	66.0	44.4	55.6
1990	60.0	40.0	31.3	68.7	45.5	54.5
1991	100.0		32.7	67.3	14.3	85.7
1992	100.0		33.1	66.9	62.5	37.5
1993	66.7	33.3	30.4	69.6	27.3	72.7
1994			24.6	75.4		100.0
1995	100.0		25.0	75.0		
1996	87.5	12.5	33.3	66.7	40.0	60.0
1997			31.1	68.9	28.6	71.4
1998	60.0	40.0	35.3	64.7		100.0
1999	100.0		27.7	72.3		100.0
2000	100.0		24.2	75.8		
2001	100.0		24.4	75.6	13.0	87.0
2002	33.3	66.7	32.9	67.1	76.2	23.8
2003	95.8	4.2	44.1	55.9		100.0
2004	100.0		33.9	66.1		100.0
2005	78.6	21.4	34.2	65.8	25.0	75.0
2006	87.5	12.5	34.6	65.4	50.0	50.0
2007	92.9	7.1	37.5	62.5		100.0
2008	100.0		56.6	43.4		100.0
2009	98.1	1.9	57.4	42.6		100.0
2010	100.0		32.4	67.6		
2011	100.0		27.0	73.0		
2012	66.7	33.3	33.3	66.7		
2013				100.0		
2014	100.0	0.0	33.0	67.0		
2015			no surveys			
2016			no surveys			
mean	85.7	14.3	33.0	67.0	22.5	77.5

Table 18. Percent of upper Yakima River CESRF spring Chinook carcasses sampled on the spawning grounds by age and sex, 2001-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
2001	88.9	11.1	19.5	80.5		
2002	100.0		33.0	67.0	33.3	66.7
2003	100.0			100.0		
2004	100.0		27.5	72.5		100.0
2005	90.0	10.0	37.5	62.5		100.0
2006	100.0		20.4	79.6		
2007	100.0		15.4	84.6		
2008				100.0		
2009	100.0		100.0			
2010	100.0		31.3	68.8		
2011	85.7	14.3	32.3	67.7		
2012			18.2	81.8		
2013			12.5	87.5		
2014			24.4	75.6		
2015			no surveys			
2016			no surveys			
mean	96.5	3.5	26.6	73.4		

Table 19. Percent of upper Yakima River wild/natural spring Chinook collected for brood stock at Roza Dam by age and sex, 1997-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
1997	100.0		43.5	56.5	33.3	66.7
1998	100.0		37.4	62.6	28.6	71.4
1999	100.0		35.8	64.2	42.9	57.1
2000	100.0		37.8	62.2	20.0	80.0
2001	90.6	9.4	37.9	62.1	46.2	53.8
2002	94.9	5.1	35.3	64.7	42.9	57.1
2003	100.0		38.9	61.1	39.7	60.3
2004	97.3	2.7	40.1	59.9	33.3	66.7
2005	96.6	3.4	35.7	64.3	36.4	63.6
2006	100.0		43.4	56.6	49.1	50.9
2007	100.0		35.1	64.9	38.0	62.0
2008	100.0		37.9	62.1	31.3	68.8
2009	94.7	5.3	40.4	59.6	27.3	72.7
2010	96.9	3.1	30.3	69.7	50.0	50.0
2011	94.3	5.7	39.7	60.3	10.0	90.0
2012	100.0		32.8	67.2	16.7	83.3
2013	100.0		41.5	58.5	50.0	50.0
2014	100.0		42.9	57.1	55.6	44.4
2015	100.0		38.7	61.3	40.0	60.0
2016	95.0	5.0	38.3	61.7	50.0	50.0
mean	98.0	2.0	38.2	61.8	37.0	63.0

Table 20. Percent of Upper Yakima River CESRF spring Chinook collected for research or brood stock at Roza Dam by age and sex, 2001-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
2001	100.0	0.0	31.8	68.2		
2002	100.0	0.0	33.5	66.5	33.3	66.7
2003	100.0	0.0	37.9	62.1	44.7	55.3
2004	100.0	0.0	38.1	61.9		
2005	100.0	0.0	39.5	60.5	30.0	70.0
2006	100.0	0.0	42.5	57.5	100.0	
2007	100.0	0.0	38.8	61.3	30.0	70.0
2008	100.0	0.0	26.3	73.7		
2009	93.8	6.3	33.9	66.1	66.7	33.3
2010	100.0	0.0	30.8	69.2		100.0
2011	93.3	6.7	31.6	68.4	66.7	33.3
2012	100.0		31.9	68.1	25.0	75.0
2013	92.3	7.7	37.8	62.2	33.3	66.7
2014	100.0	0.0	48.4	51.6	100.0	0.0
2015	100.0	0.0	27.7	72.3		
2016	100.0	0.0	42.0	58.0	100.0	0.0
mean	98.7	1.3	35.8	64.2	41.2	58.8

Size at Age

Prior to 1996, samplers were instructed to collect mid-eye to hypural plate (MEHP) lengths from carcasses surveyed on the spawning grounds. From 1996 to present the method was changed and post-eye to hypural plate (POHP) lengths have been recorded. Mean POHP lengths averaged 39, 61, and 76 cm for age-3, -4, and -5 males, and averaged 63 and 72 cm for age-4 and -5 females, respectively, from carcasses sampled on the spawning grounds in the American River from 1996-2016 (Table 21). In the Naches River, mean POHP lengths averaged 42, 60, and 76 cm for age-3, -4, and -5 males, and averaged 61 and 72 cm for age-4 and -5 females, respectively (Table 22). For wild/natural spring Chinook sampled on the spawning grounds in the upper Yakima River, mean POHP lengths averaged 44, 60, and 72 cm for age-3, -4, and -5 males, and averaged 59 and 69 cm for age-4 and -5 females, respectively (Table 23). Beginning in 2012, carcass sampling in the Upper Yakima was scaled back considerably as large numbers of escaping fish are sampled at Roza Dam (Tables 27-28). From 2001-2016, CESRF fish returning to the upper Yakima have been generally smaller in size-at-age than their wild/natural counterparts (Tables 23-28).

Table 21. Counts and mean mid-eye (MEHP) or post-orbital (POHP) to hypural plate lengths (cm) of American River wild/natural spring Chinook from carcasses sampled on the spawning grounds by sex and age, 1986-present.

	Males								Females					
Return	Age 3		Age 4		Age 5		Age 6		Age 4		Age 5		Age 6	
Year	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP
1986			5	57.1	16	80.9			4	65.8	39	75.2	2	74.0
1987			17	58.0	6	80.8	1.0	86.0	9	64.5	12	76.9		
1988					1	79.0			1	63.0				
1989			19	61.1	29	77.4			5	63.0	45	73.5		
1990	1	41.0	10	63.6	29	77.3			13	62.5	33	73.6		
1991			10	59.5	32	77.1			8	65.1	52	73.4		
1992			37	60.6	12	76.2	3.0	86.7	22	64.1	26	76.4		
1993	1	47.0	3	64.0	17	80.2			6	63.7	69	75.5		
1994			8	67.3	10	83.0			15	70.8	14	76.4	1	85.0
1995	1	44.4	1	70.0	4	83.5					12	76.4		
		POHP		POHP		POHP		POHP		POHP		POHP		POHP
1996			2	56.3					5	59.0	1	67.0		
1997[1]			2	62.0	1	63.0			4	62.8	14	64.4	5	71.0
1998			4	58.3	29	79.1			5	64.0	71	73.4		
1999			2	50.5					2	61.0	2	73.0	1	77.0
2000			10	57.9	5	83.2			8	63.9	5	76.2		
2001			59	65.9	31	77.6			72	63.6	34	73.0		
2002	1	40.0	31	63.0	26	77.3			62	64.4	48	74.7		
2003			6	63.0	68	79.4			12	64.3	139	76.7		
2004			3	56.0					1	58.0	4	77.5		
2005			11	60.6	6	80.2			21	62.6	4	74.8		
2006			8	60.8	5	75.4			17	61.8	18	71.7		
2007	2	37.0	6	62.8	11	76.5			21	60.0	27	73.3		
2008			2	67.5	21	83.1			5	67.4	37	78.9		
2009	4	44.0	9	68.3					12	62.6	4	69.8		
2010				No samples						No samples				
2011			4	65.5	6	82.8			12	65.8	7	75.9		
2012			7	64.1	7	77.3			22	63.7	24	74.3		
2013	1	34.0	1	56.0	7	70.1			7	65.7	18	70.3		
2014	1	36.0	14	61.1	3	66.7			30	61.2	3	63.3		
2015	2	42.0	20	63.4	5	77.4			36	61.3	10	71.2		
2016			4	65.0	10	71.5			17	59.7	9	67.6		
Mean[2]		38.8		61.4		76.3				62.6		72.3		74.0

[1] Carcasses sampled in 1997 had a mix of MEHP and POHP lengths taken. Only POHP samples are given here.
[2] Mean of mean values for 1996-2016 post-eye to hypural plate lengths.

Table 22. Counts and mean mid-eye (MEHP) or post-orbital (POHP) to hypural plate lengths (cm) of Naches River wild/natural spring Chinook from carcasses sampled on the spawning grounds by sex and age, 1986-present.

	Males								Females							
Return	Age 3		Age 4		Age 5		Age 6		Age 3		Age 4		Age 5		Age 6	
Year	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP
1986	1	45.0	12	62.7	6	74.3	1.0	80.0			14	64.5	27	73.6	1	83.5
1987	1	37.0	12	64.2	2	80.5	1.0	94.0			29	67.9	13	75.7		
1988			4	62.0	4	74.6			1	45.0	7	69.1	10	73.6		
1989			33	58.4	14	77.5					22	61.7	40	73.2	1	75.0
1990	3	53.0	20	59.4	10	75.9			3	51.7	16	60.9	9	73.7		
1991	1	31.0	12	56.3	10	72.8					6	62.5	39	71.1		
1992	1	42.0	20	58.8	3	72.3	1.0	83.0			24	62.4	10	71.7		
1993			11	60.0	15	77.7					8	63.3	35	72.5		
1994			2	62.5	2	77.0					3	63.7	7	73.1		
1995			1	59.0	3	73.0					2	64.0	5	73.8		
		POHP		POHP		POHP		POHP		POHP		POHP		POHP		POHP
1996			17	58.1							12	60.3	4	69.6		
1997[1]	1	39.0	24	59.8	4	71.5	2.0	78.0			28	60.0	15	68.6	1	75.0
1998			5	57.8	12	75.0					12	61.1	31	71.6		
1999	1	40.0	5	61.2	2	73.0					3	58.7	6	75.0		
2000	1	35.0	56	58.2	2	84.0					71	59.5	6	72.8		
2001	1	45.0	43	61.4	15	73.4					72	62.2	46	74.5		
2002	1	40.0	37	63.6	9	77.3					62	62.4	36	71.8		
2003	5	41.4	16	62.2	43	79.4			1	41.0	18	62.8	76	75.6		
2004	3	46.0	35	59.8	2	74.5					84	61.5	8	75.8		
2005			9	60.1	2	78.0					31	61.7	6	71.7		
2006			8	56.9	5	76.0					8	63.8	5	71.2		
2007			3	61.3	1	67.0					11	56.9	8	72.1		
2008	4	42.0	5	59.6	2	81.5					20	62.0	3	78.7		
2009	1	43.0	10	67.9	3	76.3					20	63.9	6	73.2		
2010			9	60.3							18	62.6	4	72.0		
2011	3	44.3	21	61.9	2	78.0					15	60.4	4	76.8		
2012	2	51.5	7	67.3	8	75.8			1	41.0	29	61.6	15	71.1		
2013	2	37.0	7	56.1	4	75.0					9	58.7	7	71.3		
2014			13	61.8	2	71.0					24	56.7	2	67.5		
2015			10	59.3							12	60.4	4	65.8		
2016			1	47.0	3	77.0					9	53.9	5	68.8		
Mean[2]		42.0		60.1		75.8		78.0		41.0		60.5		72.2		75.0

[1] Carcasses sampled in 1997 had a mix of MEHP and POHP lengths taken. Only POHP samples are given here.
[2] Mean of mean values for 1996-2016 post-eye to hypural plate lengths.

Table 23. Counts and mean mid-eye (MEHP) or post-orbital (POHP) to hypural plate lengths (cm) of upper Yakima River wild / natural spring Chinook from carcasses sampled on the spawning grounds by sex and age, 1986-present.

	Males						Females					
Return	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP
1986			12	60.8					48	58.7	3	70.3
1987	7	45.3	53	58.5	5	73.0			96	59.3	28	70.6
1988	9	40.0	28	59.0	3	79.0	5	52.6	36	59.2	7	70.3
1989	1	50.0	121	59.7	8	70.6	1	40.0	235	58.6	10	67.2
1990	6	47.0	84	58.0	5	77.0	4	51.5	184	59.3	6	72.5
1991	5	39.6	48	56.2	2	67.5			99	57.6	12	68.8
1992	4	43.0	153	58.4	10	71.2			309	58.2	6	69.5
1993	2	44.0	45	60.7	3	75.0	1	56.0	101	59.5	8	70.3
1994			15	62.9					49	61.3	1	72.0
1995	1	43.0	4	62.0					12	61.4	0	
		POHP		POHP		POHP		POHP		POHP		POHP
1996	14	40.9	138	59.1	2	66.5	2	41.0	277	58.6	3	68.0
1997			59	59.3	2	74.0			131	58.6	5	69.4
1998	3	38.7	18	56.4			2	47.0	33	57.5	3	66.7
1999	21	38.8	13	57.4					34	58.9	2	69.8
2000	2	41.0	70	60.3					219	58.3	0	
2001	1	43.0	33	60.7	3	74.7			102	60.6	20	69.8
2002	1	44.0	24	64.9	16	69.3	2	46.0	49	62.5	5	70.2
2003	23	44.4	15	59.8					19	62.4	3	67.8
2004	7	47.3	101	59.9					197	58.7	1	67.0
2005	11	49.2	108	60.6	1	75.0	3	48.7	207	59.5	3	67.3
2006	14	41.8	44	59.4	1	72.0	2	39.5	82	58.3	1	71.0
2007	13	44.2	61	61.7					101	60.6	6	66.0
2008	3	48.3	29	60.5					22	59.7	1	77.0
2009	53	46.8	58	57.6			1	51.0	43	60.2	1	68.0
2010	13	47.7	34	60.5					70	59.5		
2011	6	47.0	10	58.9					27	59.3		
2012	2	44.5	6	58.0			1	47.0	12	57.5		
2013			No samples						8	56.6		
2014	1	45.0	29	61.2					59	61.3		
2015			No samples						No samples			
2016			No samples						No samples			
Mean[1]		44.3		59.8		71.9		45.7		59.4		69.1

[1] Mean of mean values for 1996-2014 post-eye to hypural plate lengths.

Table 24. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River CESRF spring Chinook from carcasses sampled on the spawning grounds by sex and age, 2001-present.

Return	Males						Females					
	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
2001	8	40.5	25	59.0	1	69.5	1	41.0	107	59.0		
2002	6	47.7	61	61.2	8	68.9			124	60.6	16	71.2
2003	1	42.0							1	69.0		
2004	2	52.0	19	60.8					50	57.9	1	68.0
2005	8	41.8	12	59.9			1	46.0	20	59.6	1	72.0
2006	4	42.3	11	54.0					43	57.0		
2007	4	44.3	2	58.5					11	60.1		
2008	0		0						1	58.0		
2009	3	47.7	2	---								
2010	2	44.0	5	61.8					11	55.5		
2011	6	40.7	10	59.1			1	46.0	21	59.0		
2012			4	63.0			1	50.0	18	57.3		
2013			1	---					7	53.6		
2014			20	60.8					62	59.0		
2015			No samples						No samples			
2016			No samples						No samples			
Mean		44.3		59.8		69.2				58.9		70.4

Table 25. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River wild/natural spring Chinook from carcasses sampled at the CESRF prior to spawning by sex and age, 1997-present.

	Males						Females					
Return	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
1997	4	39.7	81	59.7	3	73.3			105	60.5	6	68.9
1998	28	43.0	95	57.3	6	67.0			161	59.2	15	65.6
1999	124	41.4	75	59.5	10	64.6			199	60.4	16	67.4
2000	19	42.0	145	59.0	1	77.0			263	59.4	3	69.4
2001	17	42.9	115	59.6	14	74.1			196	60.5	19	69.8
2002	23	42.1	113	60.6	5	72.9	1	36.6	233	61.2	9	70.9
2003	37	42.7	92	60.4	19	73.7			164	61.4	31	69.4
2004	18	42.4	108	58.9	1	67.8			225	58.3	2	66.5
2005	19	42.1	113	60.0	2	67.3	1	42.6	223	59.8	5	67.8
2006	17	41.0	82	56.7	20	70.4			197	57.8	24	68.1
2007	20	44.6	108	58.8	17	67.6			181	59.4	24	67.2
2008	17	45.5	121	59.6	4	71.1			209	59.7	11	68.4
2009	16	44.4	122	61.5	3	69.3	1	50.4	206	60.3	6	68.0
2010	9	45.0	88	61.5	1	71.2			192	60.9		
2011	11	47.5	91	60.3	1	75.3	1	52.5	182	60.2	4	72.9
2012	13	43.7	83	59.8	1	62.4			178	59.3	5	66.6
2013	18	45.8	112	59.6	7	70.0			161	58.9	6	69.7
2014	27	43.3	112	61.3	5	70.0			173	59.9	4	63.1
2015	8	41.2	110	59.6	2	71.7			167	59.9	2	70.5
2016	16	45.9	110	61.4	8	68.9			159	60.4	7	68.0
Mean		43.3		59.8		70.3				59.9		68.3

Table 26. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River CESRF spring Chinook from carcasses sampled at the CESRF prior to spawning by sex and age, 2001-present.

	Males						Females					
Return	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
2001			4	61.3					33	60.4		
2002	2	40.2	25	59.6					63	59.4	2	66.1
2003	17	42.6	16	57.8	15	74.0			31	59.7	19	70.4
2004	6	39.4	9	57.1					42	59.3		
2005	6	37.9	21	58.4	2	68.7			38	58.6	5	68.0
2006[1]			3	57.2					3	56.3		
2007	8	40.4	18	59.3	1	71.4			35	58.2	5	67.6
2008	17	43.8	9	59.1					28	59.4		
2009	5	43.8	11	61.1					32	60.1	1	67.5
2010	11	41.8	18	59.2					40	61.0		
2011	4	43.4	10	62.7	1	79.2			32	60.4	2	71.7
2012	3	39.0	23	59.3	1	73.7			43	59.4	1	67.2
2013	2	45.7	24	60.3					32	57.3		
2014	7	39.2	21	61.8	1	70.2			32	60.5		
2015	7	38.9	17	58.5					42	59.2	1	66.7
2016	2	42.8	22	61.4	2	75.0			34	60.8		
Mean		41.4		59.6		73.2				59.4		68.2

[1] Few length samples were collected since these fish were not spawned in 2006.

Table 27. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River wild/natural spring Chinook from fish sampled at Roza Dam by sex[1] and age, 1997-present.

Return	Males						Females					
	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
1997	4	39.6	81	60.6	2	73.3			121	60.5	10	70.6
1998	36	42.4	108	58.3	11	67.7	1	58.5	201	59.4	13	67.0
1999	350	40.7	80	59.4	11	67.5	2	46.8	256	60.3	19	68.3
2000	40	41.3	145	60.5	1	77.0	1	46.0	354	60.2	4	72.1
2001	32	42.9	111	61.9	28	73.8			371	61.2	24	70.7
2002	43	41.6	146	61.2	21	71.4	2	52.5	379	60.7	8	70.3
2003	54	43.3	52	64.6	18	75.3	1	51.0	262	61.9	45	71.2
2004	41	43.4	121	61.1	1	69.0			394	59.4	2	69.5
2005	35	43.2	134	61.1	5	74.2			307	60.8	6	68.3
2006	27	41.3	77	59.1	22	72.6	1	47.0	336	58.8	27	69.5
2007	31	42.9	83	60.8	18	69.8	1	50.0	280	60.5	34	69.7
2008	38	45.8	101	61.7	8	72.4			293	60.7	8	69.1
2009	36	45.3	125	63.4	4	71.5	3	52.7	297	61.9	8	69.9
2010	39	43.7	129	62.6	1	74.0	1	51.0	298	62.8	1	70.0
2011	42	46.7	154	61.2	3	77.3	2	53.0	235	61.9	10	75.3
2012	27	43.6	113	60.5	1	63.0			202	60.3	5	68.0
2013	31	45.4	132	59.9	8	70.6			181	59.8	7	70.6
2014	38	44.7	138	62.2	5	72.2			181	61.2	4	65.5
2015	16	44.0	150	61.2	3	72.0			245	61.2	3	71.7
2016	21	46.0	130	62.3	10	71.4			210	61.6	10	69.8
Mean		43.4		61.2		71.8		50.8		60.8		69.9

Table 28. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River CESRF spring Chinook from fish sampled at Roza Dam by sex[1] and age, 2001-present.

Return	Males						Females					
	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
2001	473	39.9	548	59.5			1	58.0	1795	59.2		
2002	26	38.7	383	59.5	19	67.7			1152	59.1	15	66.1
2003	392	41.8	48	61.8	61	73.0	2	47.0	207	60.3	154	70.8
2004	48	40.3	100	60.5			1	44.0	351	59.2	2	71.0
2005	98	40.4	58	60.1	6	73.0			160	59.1	12	68.7
2006	26	40.4	89	58.0					318	57.4	2	70.5
2007	174	41.4	46	60.7	6	71.7	1	47.0	185	59.0	13	69.8
2008	93	44.8	60	60.7			2	54.5	191	60.1	1	67.0
2009	254	43.6	78	62.8	5	65.0	1	50.0	212	61.8	6	69.5
2010	106	42.5	196	61.0	1	67.0	1	60.0	361	61.8	1	72.0
2011	155	42.9	146	60.9	8	73.5	2	57.5	265	61.5	13	73.4
2012	45	40.6	131	59.3	3	65.7	1	45.0	250	59.9	6	69.2
2013	92	44.4	122	59.0	3	70.0			163	58.8	4	69.3
2014	78	42.8	111	61.0	2	71.0			163	60.5	3	71.7
2015	19	41.2	90	59.5					146	60.3	3	72.0
2016	86	44.5	73	61.1	3	77.3	2	48.0	102	61.2	1	65.0
Mean		41.7		60.3		70.4		51.1		59.9		69.7

[1] Sex determined by visual observation prior to 2010 and by ultrasound from 2010 to present.

Migration Timing

Wild/natural spring Chinook adults returning to the upper Yakima River have generally shown earlier passage timing at Roza Dam than CESRF spring Chinook (Figures 2 and 3).

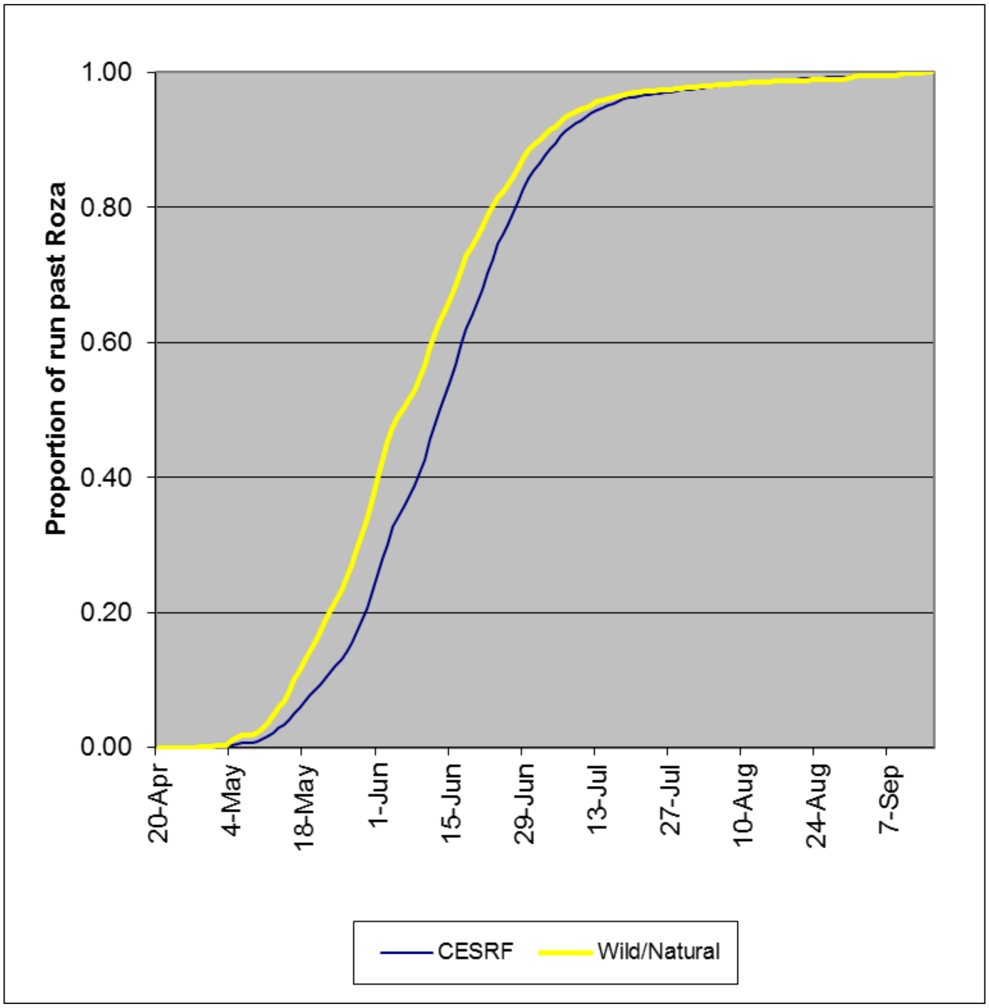

Figure 3. Proportionate passage timing at Roza Dam of wild/natural and CESRF adult spring Chinook (including jacks), 2007-2016.

Table 29. Comparison of 5%, median (50%), and 95% passage dates of wild/natural and CESRF adult spring Chinook (including jacks) at Roza Dam, 1997-Present.

	Wild/Natural Passage			CESRF Passage		
Year	5%	Median	95%	5%	Median	95%
1997	10-Jun	17-Jun	21-Jul			
1998	22-May	10-Jun	10-Jul			
1999	31-May	24-Jun	4-Aug			
2000	12-May	24-May	12-Jul	21-May[1]	15-Jun[1]	27-Jul[1]
2001	4-May	23-May	11-Jul	8-May	28-May	15-Jul
2002	16-May	10-Jun	6-Aug	20-May	13-Jun	12-Aug
2003	13-May	11-Jun	19-Aug	13-May	10-Jun	24-Aug
2004	4-May	20-May	24-Jun	5-May	22-May	26-Jun
2005	9-May	22-May	23-Jun	15-May	31-May	2-Jul
2006	1-Jun	14-Jun	18-Jul	3-Jun	18-Jun	19-Jul
2007	16-May	5-Jun	9-Jul	24-May	14-Jun	19-Jul
2008	27-May	9-Jun	9-Jul	31-May	17-Jun	14-Jul
2009	31-May	14-Jun	17-Jul	2-Jun	19-Jun	17-Jul
2010	11-May	30-May	5-Jul	12-May	2-Jun	9-Jul
2011	6-Jun	23-Jun	16-Jul	9-Jun	24-Jun	15-Jul
2012	30-May	14-Jun	9-Jul	30-May	13-Jun	8-Jul
2013	22-May	4-Jun	3-Jul	24-May	8-Jun	8-Jul
2014	15-May	1-Jun	2-Jul	18-May	5-Jun	8-Jul
2015[2]	4-May	16-May	31-Aug	5-May	18-May	31-Aug
2016	17-May	29-May	28-Jun	21-May	4-Jun	20-Jul

1. In 2000 all returning CESRF fish were age-3 (jacks).
2. Mean daily water temperatures at Kiona (rkm 40 from the mouth of the Yakima R.) exceeded 70^{o} F every day from May 21 to August 29, 2015 (source U.S. BOR hydromet database) causing delayed passage for late migrating fish.

Spawning Timing

Median spawn timing for CESRF spring Chinook is earlier than that observed for wild/natural fish in the Upper Yakima River. These differences are due in part to environmental conditions and spawning procedures at the hatchery. It must also be noted that spawning dates in the wild are only a coarse approximation, derived from weekly redd counts not actual dates of redd deposition. A clear delineation of wild/natural spawn timing between subbasins is apparent, with American River fish spawning about 1 month earlier than Naches Basin fish which spawn about 2 weeks earlier than Upper Yakima fish.

Table 30. Median spawn[1] dates for spring Chinook in the Yakima Basin.

Year	American	Naches	Upper Yakima	CESRF
1988	14-Aug	7-Sep	3-Oct	
1989	14-Aug	7-Sep	19-Sep	
1990	14-Aug	12-Sep	25-Sep	
1991	12-Aug	12-Sep	24-Sep	
1992	11-Aug	10-Sep	22-Sep	
1993	9-Aug	8-Sep	27-Sep	
1994	16-Aug	14-Sep	26-Sep	
1995	14-Aug	7-Sep	1-Oct	
1996	20-Aug	18-Sep	23-Sep	
1997	12-Aug	11-Sep	23-Sep	23-Sep
1998	11-Aug	15-Sep	30-Sep	22-Sep
1999	24-Aug	8-Sep	27-Sep	21-Sep
2000	7-Aug	20-Sep	19-Sep	19-Sep
2001	14-Aug	13-Sep	25-Sep	18-Sep
2002	12-Aug	11-Sep	23-Sep	24-Sep
2003	11-Aug	14-Sep	28-Sep	23-Sep
2004	17-Aug	12-Sep	27-Sep	21-Sep
2005	15-Aug	15-Sep	27-Sep	20-Sep
2006	15-Aug	14-Sep	26-Sep	19-Sep
2007	14-Aug	12-Sep	25-Sep	25-Sep
2008	11-Aug	12-Sep	23-Sep	23-Sep
2009	17-Aug	10-Sep	23-Sep	28-Sep
2010	17-Aug	12-Sep	21-Sep	21-Sep
2011	23-Aug	8-Sep	21-Sep	20-Sep
2012	21-Aug	11-Sep	24-Sep	25-Sep
2013	19-Aug	11-Sep	25-Sep	23-Sep
2014	19-Aug	18-Sep	29-Sep	24-Sep
2015	20-Aug	17-Sep	28-Sep	23-Sep
2016	16-Aug	16-Sep	27-Sep	20-Sep
Mean	15-Aug	12-Sep	25-Sep	22-Sep

1. Approximately one-half of the redds in the system were counted by this date and one-half were counted after this date. For the CESRF, approximately one-half of the total broodstock were spawned by this date and one-half were spawned after this date.

Redd Counts and Distribution

Table 31. Yakima Basin spring Chinook redd count summary, 1981 – present.

	Upper Yakima River System				Naches River System				
Year	Mainstem[1]	Cle Elum	Teanaway	Total	American	Naches[1]	Bumping	Little Naches	Total
1981	237	57	0	294	72	64	20	16	172
1982	610	30	0	640	11	25	6	12	54
1983	387	15	0	402	36	27	11	9	83
1984	677	31	0	708	72	81	26	41	220
1985	795	153	3	951	141	168	74	44	427
1986	1,716	77	0	1,793	464	543	196	110	1,313
1987	968	75	0	1,043	222	281	133	41	677
1988	369	74	0	443	187	145	111	47	490
1989	770	192	6	968	187	200	101	53	541
1990	727	46	0	773	143	159	111	51	464
1991	568	62	0	630	170	161	84	45	460
1992	1,082	164	0	1,246	120	155	99	51	425
1993	550	105	1	656	214	189	88	63	554
1994	226	64	0	290	89	93	70	20	272
1995	105	12	0	117	46	25	27	6	104
1996	711	100	3	814	28	102	29	25	184
1997	364	56	0	420	111	108	72	48	339
1998	123	24	1	148	149	104	54	23	330
1999	199	24	1	224	27	95	39	25	186
2000	3,349	466	21	3,836	54	483	278	73	888
2001	2,910	374	21	3,305	392	436	257	107	1,192
2002	2,441	275	110	2,826	366	226	262	89	943
2003	772	87	31	890	430	228	216	61	935
2004	2,985	330	129	3,444	91	348	205	75	719
2005	1,717	287	15	2,019	140	203	163	68	574
2006	1,092	100	58	1,250	136	163	115	33	447
2007	665	51	10	726	166	60	60	27	313
2008	1,191	137	47	1,375	158	165	102	70	495
2009	1,349	197	33	1,579	92	159	163	68	482
2010	2,199	219	253	2,671	173	171	168	40	552
2011	1,663	171	64	1,898	212	145	175	48	580
2012	1,276	125	69	1,470	337	196	189	89	811
2013	552	85	34	671	170	66	85	55	376
2014	962	138	53	1,153	129	65	158	27	379
2015	1,258	39	24	1,321	239	177	152	46	614
2016	512	83	22	617	149	106	74	37	366
Mean	1,058	126	28	1,211	165	170	116	48	499

[1] Including minor tributaries.

Homing

A team from NOAA fisheries conducted studies to determine the spatial and temporal patterns of homing and spawning by wild and hatchery-reared salmon released from CESRF facilities from 2001 to 2010. These studies collected GPS information on each redd and carcass recovered within a survey reach. Carcass surveys were conducted annually in late-September to early October by NOAA personnel in cooperation with Yakama Nation survey crews over five different reaches of the upper Yakima River and recorded the location of each redd flagged and carcass recovered. For each carcass sex, hatchery/wild, male status (full adult, jack, mini-jack), and CWT location was recorded. Data collected on the body location of CWTs allowed the identification of the release site of some fish. While these studies were not designed to comprehensively map carcasses and redds in all spawning reaches in the upper watershed, preliminary data indicate that fish from the Easton, Jack Creek, and Clark Flat acclimation facilities had distinct spawner distributions. A more complete description of this project is available from NOAA fisheries and in this publication:

Dittman, A. H., D. May, D. A. Larsen, M. L. Moser, M. Johnston, and D. Fast. 2010. Homing and spawning site selection by supplemented hatchery- and natural-origin Yakima River spring Chinook salmon. Transactions of the American Fisheries Society 139:1014-1028.

Straying

The regional PTAGIS (PIT tag) and RMIS (CWT) databases were queried in late November 2016 to determine the number of CESRF releases not returning to the Yakima River Basin. For adult (age-3, -4, or -5) PIT tagged fish, a stray is defined as detection at an out-of-basin facility in the Snake (Ice Harbor or Lower Granite) or Upper Columbia (Priest Rapids, Rock Island, or Wells) without a subsequent detection at Prosser or Roza Dam. For coded-wire tagged fish, a stray is generally defined as a tag recovery in tributaries of the Columbia River upstream (and including the Snake River Basin) of its' confluence with the Yakima River. Marked (adipose fin clipped) fish are occasionally found during carcass surveys in the Naches River system. All marked fish observed in spawning ground carcass surveys in the Naches Basin are assumed to be CESRF fish and are used to estimate in-basin stray rates.

Table 32. Estimated number of PIT- and CWT-tagged CESRF fish not returning to the Yakima River Basin (strays), and marked fish sampled during spawner surveys in the Naches Basin, per number of returning fish, brood years 1997-present.

	CESRF PIT-Tagged Fish			All CESRF Fish			CESRF Age-4 Fish		
Brood Year	Roza Adult Returns	Adult Strays	Stray Rate	Yakima River Mth Return	CWT Strays	Stray Rate	Yak R. MthRtn	In-Basin Strays[1]	Stray Rate
1997	598	2	0.33%	8,670	1	0.01%	7,753		
1998	398	0	0.00%	9,782			7,939	1	0.01%
1999	23	0	0.00%	864			714		
2000	150	4	2.67%	4,819	2	0.04%	3,647	4	0.11%
2001	80	3	3.75%	1,251			845	2	0.24%
2002	97	5	5.15%	2,300			1,886	1	0.05%
2003	31	0	0.00%	932			800		
2004	125	1	0.80%	4,022	4	0.10%	3,101		
2005	142	0	0.00%	4,378			3,052		
2006	462	3	0.65%	9,114			5,812		
2007	240	1	0.42%	6,558	5	0.08%	5,174	1	0.02%
2008	215	0	0.00%	6,976			4,567	1	0.02%
2009	110	0	0.00%	3,181			2,663	1	0.04%
2010	207	5	2.42%	4,707	2	0.04%	3,183		
2011[2]	181	28	15.47%	3,665	12	0.33%	2,340		
2012[2]	69	13	18.84%						

[1] All marked fish observed in spawning ground carcass surveys in the Naches Basin are assumed to be CESRF fish.

[2] For brood year 2011, age 5 data are preliminary and for BY2012 data are through age 4 only and are preliminary. Water temperature in the lower Yakima River was greater than 70^o F on average from May 29 to Aug. 29, 2015 which likely caused many fish returning that year (BY2011 age-4 and BY2012 age-3) to seek cooler water in other parts of the Columbia Basin.

CESRF Spawning and Survival

As described earlier, a portion of natural- and hatchery-origin (NoR and HoR, respectively) returning adults are captured at Roza Dam during the adult migration and taken to the CESRF for broodstock and/or research purposes. Fish are held in adult holding ponds at the CESRF from capture in the spring and summer until spawning in September through early October. All mortalities during the holding period are documented by sex and origin. During the spawning period data are kept on the number of males and females of each origin used for spawning or other purposes. All females have samples taken that are later evaluated for presence of BKD-causative agents. Eggs from females with high BKD-presence indicators are generally excluded (see Female BKD Profiles). Once fertilized, eggs are placed in holding troughs until shock time. Dead eggs are then sorted and hand-counted. All live eggs are machine counted, sorted into two lots per female (treatment and control) and placed into incubation (heath) trays. Using hand counts of egg samples from a subsample of female egg lots, WDFW staff determined that machine counts are biased and that the best approximation of live egg counts is given by the following equation:

$$\left(\left(\frac{\text{no. eggs in subsample}}{\text{wt. of subsample}} * \text{total egg mass wt}\right) * 0.945\right) - \text{dead eggs}$$

where

the first 3 parameters are from egg samples taken from females at spawn time,
dead eggs are the number of dead or unfertilized eggs counted at shock time, and
the 0.945 value is a correction factor from 1997 and 2000 WDFW studies.

Total egg take is calculated as the total number of live eggs, dead eggs, and all documented egg loss (e.g. spilled at spawn time, etc.). Heath trays are periodically sampled during incubation and dead fry are culled and counted. The number of live eggs less documented fry loss is the estimate of the number of fry ponded. Once fry are ponded, mortalities are counted and recorded daily during the rearing period. Fish are hand counted in the fall prior to their release as they are 100-percent marked. This hand-count less documented mortalities from marking through release is the estimate of smolts released. Survival statistics by origin and life-stage are given in Tables 33 and 34.

Table 33. Cle Elum Supplementation and Research Facility spawning and survival statistics (NoR brood only), 1997 - present.

Brood Year	Total Collected	Total Morts.	PreSpawn Survival	No. Fish Spawned[1] Males[2]	Females	% BKD Loss	Total Egg Take	Live Eggs	% Egg Loss[3]	Fry Ponded[4]	Live-Egg-Fry Survival	Smolts Released	Fry-Smolt Survival	Live-Egg-Smolt Survival
1997	261	23	91.2%	106	132	2.6%	500,750	463,948	7.3%	413,211	98.5%	386,048	93.4%	91.9%
1998	408	70	82.8%	140	198	1.4%	739,802	664,125	10.2%	627,481	98.7%	589,648	94.0%	92.7%
1999	738[5]	24	96.7%	213	222	2.7%	818,816	777,984	5.0%	781,872	97.3%	758,789	97.0%	94.5%
2000	567	61	89.2%	170	278	9.2%	916,292	851,128	7.1%	870,328	97.3%	834,285	95.9%	93.4%
2001	595	171	71.3%	145	223	53.2%	341,648	316,254	7.4%	380,880	98.6%	370,236	97.2%	96.1%
2002	629	89	85.9%	125	261	10.0%	919,776	817,841	11.1%	783,343	98.0%	749,067	95.6%	93.6%
2003	441	54	87.8%	115	200	0.0%	856,574	787,933	8.0%	761,990	98.4%	735,959	96.6%	95.0%
2004	597	70	88.3%	125	245	0.4%	873,815	806,375	7.7%	776,941	97.8%	691,109	89.0%	87.0%
2005	526	57	89.2%	136	241	0.0%	907,199	835,890	7.9%	796,559	98.1%	769,484	96.6%	94.7%
2006	519	45	91.3%	122	239	1.7%	772,357	703,657	8.9%	631,691	97.3%	574,361	90.9%	88.3%
2007	473	49	89.6%	149	216	0.9%	798,729	760,189	4.8%	713,814	98.9%	676,602	94.8%	93.7%
2008	480	38	92.1%	151	253	2.0%	915,563	832,938	9.0%	809,862	99.0%	752,109	97.3%	96.3%
2009	486	57	88.3%	142	219	1.4%	850,404	848,339	0.2%	770,706	98.2%	744,170	96.6%	94.6%
2010	483	20	95.9%	102	193	0.5%	787,953	753,464	4.4%	726,325	98.9%	702,751	96.8%	95.6%
2011	455	28	93.8%	103	197	0.0%	798,229	765,221	4.1%	721,197	98.1%	684,481	94.9%	93.0%
2012	363	14	96.1%	111	209	0.0%	819,775	788,605	3.8%	737,705	98.2%	712,036	96.5%	94.7%
2013	385	15	96.1%	153	179	0.6%	683,484	658,796	3.6%	613,493	98.9%	575,156	93.8%	92.6%
2014	384	39	89.8%	133	188	0.0%	679,374	639,989	5.8%	636,092	96.5%	599,908	94.3%	91.1%
2015	436	116	73.4%	128	182	0.5%	654,361	615,189	6.0%	613,796	97.0%	594,736	96.9%	94.1%
2016	394	57	85.5%	142	173	0.0%	687,218	652,110	5.1%	593,514	96.2%			
Mean	481	55	88.7%	136	212	4.4%	766,106	716,999	6.4%	688,040	98.0%	657,944	95.2%	93.3%

1. Total collected minus total mortalities does not equal total spawned. This is because some fish are used in the spawning channel, some have been released back to the river, and some have not been used.
2. Includes jacks.
3. All documented egg loss at spawn time plus dead eggs counted at shock divided by the estimated total egg take.
4. Based on physical counts at mark time and all documented rearing mortality from ponding to release, except for BY2013 it is live eggs (est.) minus fry loss.
5. Approximately one-half of these were jacks, many of which were not used in spawning.
6. Approximately 45,000 smolts lost at Jack Creek due to frozen equipment in February, 2006.
7. EWOS feed treatment had high mortality and was discontinued in May 2007; resulted in lower survival to release.
8. Approximately 36,000 NoR (Table 33) and 12,000 HoR (Table 34) fish were culled in July 2009 to reduce pond densities; these fish were added back in to fry-smolt and live-egg-smolt survival calculations.
9. Table 34 -- From 2002 to present this is the estimated total egg take from all HxH crosses. Due to the large surplus of eggs over the approximately 100K needed for the HxH line, many surplus fry were planted in nearby land-locked lakes and some surplus eggs were destroyed.
10. Table 34 -- For only those HxH fish which were actually ponded.

Table 34. Cle Elum Supplementation and Research Facility spawning and survival statistics (HoR brood only), 2002 - present.

Brood Year	Total Collected	Total Morts.	PreSpawn Survival	No. Fish Spawned[1] Males[2]	Females	% BKD Loss	Total Egg Take[9]	Live Eggs[10]	% Egg Loss[3]	Fry Ponded[4]	Live-Egg-Fry Survival	Smolts Released	Fry-Smolt Survival	Live-Egg-Smolt Survival
2002	201	22	89.1%	26	72	4.2%	258,226	100,011	7.8%	91,300	98.2%	87,837	96.2%	94.4%
2003	143	12	91.6%	30	51	0.0%	219,901	83,128	7.3%	91,204	98.8%	88,733	97.3%	96.1%
2004	126	19	84.9%	22	49	0.0%	187,406	94,659	5.9%	100,567	98.3%	94,339	93.8%	92.2%
2005	109	6	94.5%	26	45	0.0%	168,160	89,066	12.2%	92,903	98.1%	90,518	97.4%	95.6%
2006	136	21	84.6%	28	41	2.4%	112,576	80,121	8.6%	74,735	97.6%	68,434	91.6%	89.4%
2007	110	15	86.4%	26	35	0.0%	125,755	90,162	3.2%	96,912	99.2%	94,663	97.7%	96.9%
2008	194	10	94.8%	51	67	1.5%	247,503	106,122	5.1%	111,797	98.9%	97,196	97.4%	96.4%
2009	164	24	85.4%	30	38	0.0%	148,593	91,994	0.8%	91,221	98.3%	88,771	97.3%	95.6%
2010	162	9	94.4%	29	55	1.8%	215,814	94,925	8.4%	96,144	97.9%	92,030	95.7%	93.7%
2011	166	7	95.8%	28	49	0.0%	188,075	89,107	4.5%	88,852	98.4%	84,701	95.3%	93.8%
2012	140	8	94.3%	29	42	0.0%	148,932	95,438	2.0%	94,031	98.8%	90,680	96.4%	95.3%
2013	186	5	97.3%	38	43	0.0%	155,383	80,534	2.9%	75,842	98.2%	71,599	94.4%	92.7%
2014	86	11	87.2%	21	29	0.0%	104,121	74,843	1.6%	91,702	97.2%	85,322	93.0%	90.4%
2015	61	23	62.3%	15	22	13.6%	66,238	64,646	2.4%	62,625	96.9%	60,211	96.1%	93.1%
2016	114	25	78.1%	33	35	0.0%	129,355	121,466	6.1%	74,947	95.2%			
Mean	140	14	88.0%	29	45	1.6%	165,069	155,690	5.3%	88,985	98.0%	85,360	95.7%	94.0%

See footnotes for Table 33 above.

Female BKD Profiles

Adults used for spawning and their progeny are tested for a variety of pathogens accepted as important in salmonid culture (USFWS Inspection Manual, 2003), on a population or "lot" basis. At the CESRF, and in the Columbia Basin it has been accepted that the most significant fish pathogen for spring Chinook is *Renibacterium salmoninarum*, the causative agent of Bacterial Kidney Disease (BKD). All adult females and 30-60 juveniles from each acclimation pond are individually tested for levels of *Renibacterium salmoninarum* using ELISA (Enzyme linked Immuno-sorbant Assay). ELISA data are reported annually to CESRF and YKFP staff for management purposes, eventual data entry and comparisons of ponds and rearing parameters. To date, no significant occurrences of other pathogens have been observed. Periodic field exams for external parasites and any signs of disease are performed on an "as needed" basis. Facility staff have been trained to recognize early signs of behavior changes or diseases and would report any abnormalities to the USFWS, Olympia Fish Health Center for further diagnostic work.

Adult females are ranked from 0 to 13 based on the relative amounts of BKD in the tissue samples of the tested fish. All BKD ranks below 5 are considered low risk for transferring significant BKD organisms through the egg to cause significant disease in progeny receiving proper care. The progeny of adults with BKD rank 6 are considered to be moderate risk and those with BKD rank 7 or greater are considered to be high risk. Given these data, the CESRF chose to rear only the progeny of females with a BKD rank of 6 or less through brood year 2001. Beginning with brood year 2002, the progeny of fish with BKD rank 6 (moderate risk) or greater (high risk) have not been used for production purposes at the CESRF. For additional information, see Appendix B.

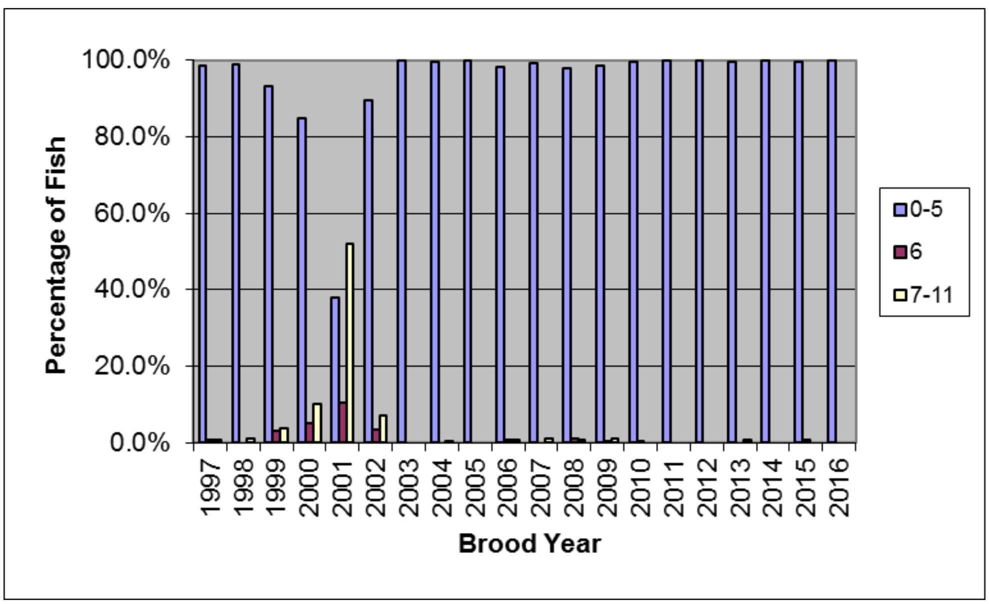

Figure 4. Proportion of wild/natural females spawned at CESRF by BKD rank, 1997 – present.

Fecundity

Fish collected at Roza Dam are taken to the CESRF for spawning and/or research purposes. Egg loss due to spill or other reasons at spawn time is documented. When eggs are shocked, unfertilized (dead) eggs are hand-counted and remaining eggs are machine counted. Due to error associated with machine counts, average fecundity is calculated using spawn-time egg sample data (see discussion above under CESRF Spawning and Survival) and adding in documented egg loss for all females divided by the number of females (N) in the sample.

Table 35. Mean fecundity by age of adult females (BKD rank < 6) spawned at CESRF, 1997-present.

	Wild/Natural (SN)						CESRF (HC)					
Brood	Age-3		Age-4		Age-5		Age-3		Age-4		Age-5	
Year	N	Fecundity	N	Fecundity	N	Fecundity	N	Fecundity	N	Fecundity	N	Fecundity
1997			105	3,842.0	4	4,069.9						
1998	2[1]	3,908.9	161	3,730.3	15	4,322.5						
1999	3[1]	4,470.4	183	3,968.1	14	4,448.6						
2000			224	3,876.5	2	5,737.9						
2001			72	3,966.9	9	4,991.2			18	4,178.9		
2002	1	1,038.0	205	3,934.7	7	4,329.4			60	3,820.0	1	4,449.0
2003			163	4,160.2	31	5,092.8			30	3,584.1	19	5,459.9
2004			224	3,555.4	2	4,508.3			42	3,827.2		
2005	1	1,769.0	218	3,815.5	5	4,675.1			38	3,723.9	5	4,014.7
2006			196	3,396.4	24	4,338.9			36	3,087.3		
2007			178	3,658.3	24	4,403.3			33	3,545.2	2	4,381.9
2008			207	3,814.0	10	4,139.9			58	3,898.0		
2009	1	2,498.2	195	4,018.9	6	4,897.1			34	3,920.3		
2010			185	4,103.0					54	3,996.6		
2011	1[1]	3,853.1	179	4,000.1	4	5,692.1			41	3,843.3	2	4,098.2
2012			186	3,901.0	5	4,982.8			41	3,537.4	1	3,900.5
2013			159	3,760.3	6	5,068.0			36	3,498.7	2	4,955.3
2014			171	3,889.4	4	4,599.5			25	3,627.1	1	5,335.8
2015			166	3,963.0	2	5,249.3			14	3,975.1	1	3,793.3
2016			159	3,969.1	7	4,959.4			34	3,675.9	1	4,375.5
Mean				3,866.2		4,763.5				3,732.9		4,476.4

1. Given their length and fecundity, these fish may have been incorrectly aged.

Juvenile Salmon Evaluation

Food Conversion Efficiency

At the end of each month that fish are in the rearing ponds at the CESRF or the acclimation sites, a sample of fish are weighed and measured to estimate growth. These data, in addition to monthly mortality and pond feed data are entered into the juvenile growth and survival tracking database. Hatchery managers monitor food conversion (total pounds fed during a month divided by the total pounds gained by the fish) to track how well fish are converting feed into body mass and to evaluate the amount of feed that needs to be provided on a monthly basis. Average monthly food conversion and growth statistics for the CESRF facilities by brood year are provided in the following tables and figures.

Table 36. Mean food conversion (lbs fed/lbs gained) of CESRF juveniles by brood year and growth month, 1997 – present.

Brood Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1997	2.2		1.1	0.8	1.2	0.8	1.5	1.5		1.9		5.3
1998		1.0	0.9	1.0	0.9	0.8	2.4	1.4	2.1	-0.3	1.0	1.2
1999		1.0	1.1	1.1	1.2	1.5	1.8	1.0		-0.5	0.3	1.7
2000	0.8	0.8	1.0	1.5	1.2	1.4	2.2	2.0	1.6	2.1	2.5	2.4
2001	1.1	1.1	2.6	1.1	1.3	1.2	1.6	2.0	2.3	2.5	2.8	0.9
2002	0.9	1.0	1.4	1.2	1.4	1.1	1.5	2.2	4.0	-1.4	2.9	1.0
2003	0.6	1.0	0.9	1.4	1.2	1.2	4.6	0.7	0.9	-0.2	1.8	1.0
2004	0.9	1.0	1.2	1.6	2.4	1.2	1.7	2.0	2.8	0.9	-2.6	1.1
2005	0.8	0.7	1.3	1.0	1.3	1.2	1.5	-0.8	0.4	-0.4	2.2	
2006	0.8	0.7	0.6	0.9	0.8	1.0	1.6	-1.0		-2.6	0.6	0.6
2007	0.7	0.7	0.9	0.9	1.0	0.8	2.2	-1.6	1.9	2.0	0.7	0.9
2008	0.5	0.6	0.9	0.9	1.0		0.8	1.7	-1.1	0.9	0.9	0.6
2009	0.5	1.2	1.0	0.7	1.1	1.0	1.5	4.1	0.6	-2.8	0.8	0.9
2010	0.6	0.8	1.3	0.8	0.8	1.8	2.8	1.3		0.8	0.8	0.7
2011	0.9	0.6	0.8	0.7	1.1	0.9		0.7		0.6	0.9	1.0
2012	0.8	1.4	1.1	0.8	1.3	1.4	1.0	1.1		1.0	3.1	1.2
2013	0.6	0.9	0.7	0.9	1.0	1.1	2.7	1.4		0.4	0.8	2.5
2014	0.5	2.2	0.7	1.0	2.4	0.7	4.3	0.5		1.7	0.9	0.8
2015	0.8	0.9	0.8	1.0	1.3	0.9	-1.8	0.7	-0.8	1.0	0.5	0.9
Mean	0.8	0.9	1.1	1.0	1.3	1.1	1.9	1.1	1.6	0.4	1.2	1.1

Length and Weight Growth Profiles

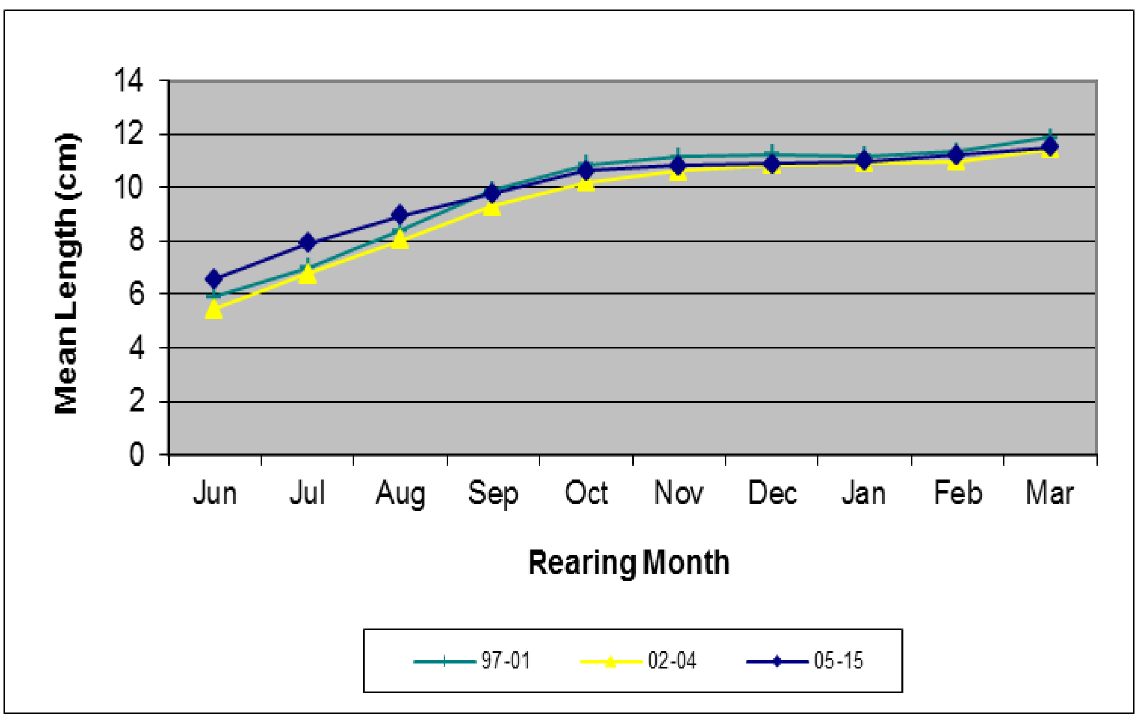

Figure 5. Mean length (cm) of "standard growth treatment (Hi)" CESRF juveniles by brood year and growth month, 1997 - present.

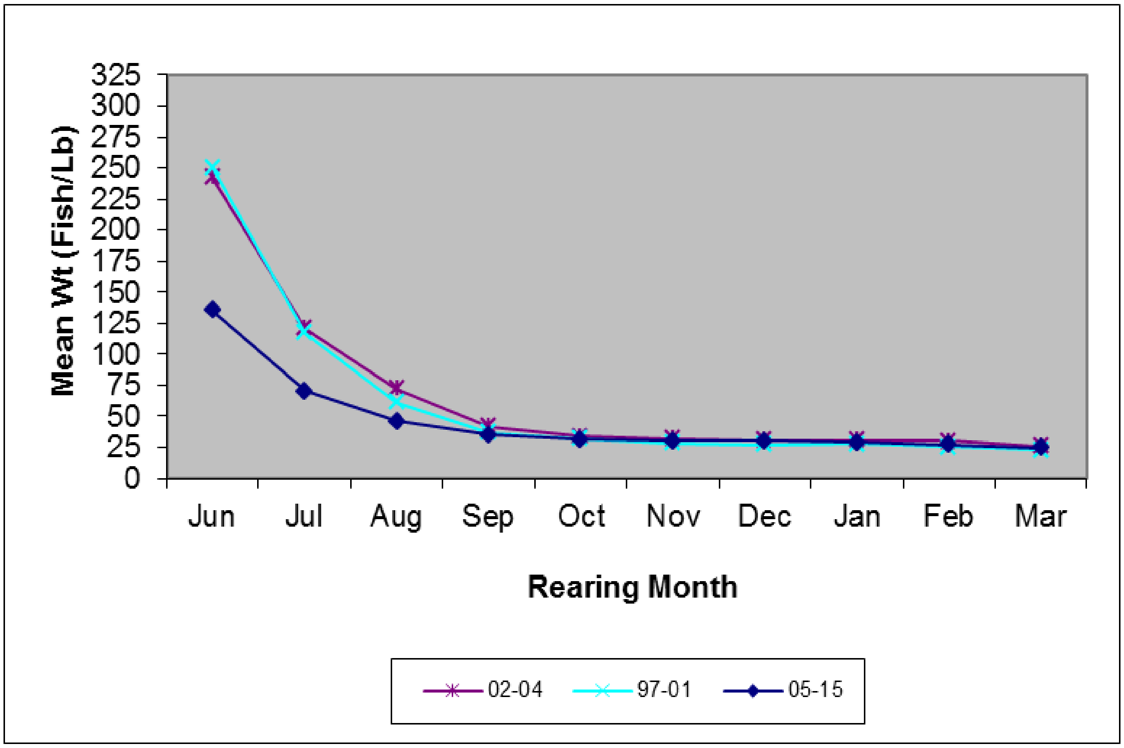

Figure 6. Mean Weight (fish/lb) of "standard growth treatment (Hi)" CESRF juveniles by brood year and growth month, 1997 - present.

Juvenile Fish Health Profile

Approximately 5-60 fish from each acclimation site pond were sacrificed for juvenile fish health samples in the spring (usually in March) of their release year. Tissue samples from these fish were processed at USFWS laboratories in Olympia, Washington for presence of bacterial kidney disease (BKD) using enzyme-linked immunosorbent assay (ELISA) tests (see Female BKD Profiles and Appendix B for additional discussion). Fish were ranked from 0 to 13 based on the relative amounts of BKD in the tissue samples of the tested fish. Based on empirical evidence, fish with BKD ranks of 0-5 were considered to be low risk for incidence of BKD in the presence of a good fish culture and rearing environment (i.e., water temperature and flows, nutrition, densities, etc. all must be conducive to good fish health). Mean BKD ranks for all juvenile fish sampled ranged from 0.11 to 3.32 for the 16 brood years when adequate samples were available (Table 37), indicating that juvenile fish released from the CESRF appear to be well within the low risk category for all release years to date.

Table 37. Mean BKD rank of juvenile fish sampled at CESRF acclimation sites by brood year, 1997-present.

Brood	Acclimation Site			Pooled
Year	Clark Flat	Easton	Jack Cr.	Mean
1997	1.22	1.81		1.46
1998	0.88	0.80	0.53	0.76
1999		No Samples		
2000	1.40	1.89	1.50	1.60
2001	1.50	0.98	1.55	1.30
2002	0.18	0.08	0.06	0.11
2003	0.29	0.47	0.33	0.36
2004		No Samples		
2005		No Samples		
2006	1.96	1.81	1.61	1.79
2007	1.64	1.29	1.84	1.59
2008	2.04	1.51	2.08	1.88
2009	2.34	2.49	2.71	2.51
2010	1.21	1.81	1.97	1.66
2011	1.44	0.73	0.82	1.00
2012	2.33	2.52	2.61	2.49
2013	2.76	4.10	3.07	3.32
2014	2.89	2.89	3.11	2.96
2015	1.67	2.50	1.83	2.00

1. For the 1999, 2004 and 2005 broods, antibody problems were encountered and the USFWS was unable to process the samples.
2. High BKD incidence in adult broodstock reduced production to just 9 ponds (Clark Flat 1-2, Jack Creek, and Easton). Easton samples were for predator avoidance trained (PAT) fish and were the cumulative equivalent of one Cle Elum pond (i.e., ~6,500 fish per pond).

Incidence of Precocialism

For brood years 2002-2004, the YKFP tested two different feeding regimes to determine whether a slowed-growth regime reduces the incidence of precocialism without a reduction in post-release survival. The two growth regimes tested were a normal (High) growth regime resulting in fish which were about 30/pound at release and a slowed growth regime (Low) resulting in fish which were about 45/pound at release. As a critical part of this study, a team from NOAA Fisheries conducted research to characterize the physiology and development of wild and hatchery-reared spring Chinook salmon in the Yakima River Basin. While precocious male maturation is a normal life-history strategy, the hatchery environment may be potentiating this developmental pathway beyond natural levels resulting in potential loss of anadromous adults, skewing of sex ratios, and negative genetic and ecological impacts on wild populations. Previous studies have indicated that age of maturation is significantly influenced by endogenous energy stores and growth rate at specific times of the year. These studies will help direct rearing strategies at the CESRF to allow production of hatchery fish with physiological and life-history attributes that are more similar to their wild cohorts.

Relevant Publications:

Larsen, D. A., B. R. Beckman, K. A. Cooper, D. Barrett, M. Johnston, P. Swanson, and W. W. Dickhoff. 2004. Assessment of High Rates of Precocious Male Maturation in a Spring

Chinook Salmon Supplementation Hatchery Program. Transactions of the American Fisheries Society 133:98-120.

Beckman, B.R. and Larsen D.A. 2005. Upstream Migration of Minijack (Age-2) Chinook Salmon in the Columbia River: Behavior, Abundance, Distribution, and Origin. Transactions of the American Fisheries Society 134:1520–1541.

Larsen, D.A., B.R. Beckman, C.R. Strom, P.J. Parkins, K.A. Cooper, D.E. Fast, W.W. Dickhoff. 2006. Growth Modulation Alters the Incidence of Early Male Maturation and Physiological Development of Hatchery-reared Spring Chinook Salmon: a Comparison with Wild Fish. Transactions of the American Fisheries Society 135:1017-1032.

Larsen, D.A., B.R. Beckman, and K.A. Cooper. 2010. Examining the Conflict between Smolting and Precocious Male Maturation in Spring (Stream-Type) Chinook Salmon. Transactions of the American Fisheries Society 139: 564-578.

Larsen, D.A., D.L. Harstad, C.R. Strom, M.V. Johnston, C.M. Knudsen, D.E. Fast, T.N. Pearsons, and B.R. Beckman. 2013. Early Life History Variation in Hatchery- and Natural-Origin Spring Chinook Salmon in the Yakima River, Washington. Transactions of the American Fisheries Society 142:2, 540-555.

Pearsons, T.N., C.L. Johnson, B.B. James, and G.M. Temple. 2009. Abundance and Distribution of Precociously Mature Male Spring Chinook Salmon of Hatchery and Natural Origin in the Yakima River. North American Journal of Fisheries Management 29:778-790.

CESRF Smolt Releases

The number of release groups and total number of fish released diverged from facility goals in some years. In brood year 1997, the Jack Creek acclimation facility was not yet complete and project policy and technical teams purposely decided to under-collect brood stock to allow a methodical testing of the new facility's operations with less risk to live fish, which resulted in the stocking of only 10 of the 18 raceways. In brood year 1998, the project did not meet facility release goals due to a biological specification that no more than 50% of returning wild fish be taken for brood stock. As a result only 16 raceways were stocked with progeny of the 1998 brood. In the same year, raceway 4 at the Jack Creek acclimation site suffered mechanical failures causing loss of flow and reduced oxygen levels and resulted in the loss of approximately one-half the fish in this raceway prior to release. In the drought year of 2001, a large number of returning adults presented with high enzyme-linked immunosorbent assay (ELISA) levels of *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD). The progeny of these females were purposely destroyed. As a result, only nine raceways were stocked with fish. The project decided to use the fish from an odd raceway for a predator avoidance training sub-experiment (these fish were subsequently acclimated and released from the Easton acclimation site).

Table 38. CESRF total releases by brood year, treatment, and acclimation site.

Brood Year	Control[1]	Treatment[2]	Acclimation Site CFJ	ESJ	JCJ	Total
1997	207,437	178,611	229,290	156,758		386,048
1998[3]	284,673	305,010	221,460	230,860	137,363	589,683
1999	384,563	374,226	232,563	269,502	256,724	758,789
2000	424,554	409,731	285,954	263,061	285,270	834,285
2001[4]	183,963	186,273	80,782	39,106	250,348	370,236
2002	420,764	416,140	266,563	290,552	279,789	836,904
2003	414,175	410,517	273,377	267,711	283,604	824,692
2004[5]	378,740	406,708	280,598	273,440	231,410	785,448
2005	431,536	428,466	287,127	281,150	291,725	860,002
2006	351,063	291,732	209,575	217,932	215,288	642,795
2007	387,055	384,210	265,907	254,540	250,818	771,265
2008	421,290	428,015	280,253	287,857	281,195	849,305
2009	418,314	414,627	279,123	281,395	272,423	832,941
2010	395,455	399,326	264,420	264,362	265,999	794,781
2011	382,195	386,987	255,290	248,454	265,438	769,182
2012	401,059	401,657	256,732	276,210	269,774	802,716
2013	No Experiment		215,933	214,745	216,077	646,755
2014	337,548	347,682	232,440	226,257	226,533	685,230
2015	331,316	323,631	208,239	218,225	228,483	654,947
Mean	364,206	360,753	243,454	240,111	250,459	720,842

Table 39. CESRF average pond densities at release by brood year, treatment, and acclimation site.

Brood	Treatment		Acclimation Site		
Year	Control[1]	Treatment[2]	CFJ	ESJ	JCJ
1997	41,487	35,722	38,215	39,190	
1998[3]	35,584	38,126	36,910	38,477	34,341
1999	42,729	41,581	38,761	44,917	42,787
2000	47,173	45,526	47,659	43,844	47,545
2001[4]	41,116	41,667	40,391	6,518	41,725
2002	46,752	46,238	44,427	48,425	46,632
2003	46,019	45,613	45,563	44,619	47,267
2004[5]	42,082	45,190	46,766	45,573	38,568
2005	47,948	47,607	47,855	46,858	48,621
2006	39,007	32,415	34,929	36,322	35,881
2007	43,006	42,690	44,318	42,423	41,803
2008	46,810	47,557	46,709	47,976	46,866
2009	46,479	46,070	46,521	46,899	45,404
2010	43,939	44,370	44,070	44,060	44,333
2011	42,466	42,999	42,548	41,409	44,240
2012	44,562	44,629	42,789	46,035	44,962
2013	No Experiment		35,989	35,791	36,013
2014	37,505	38,631	38,740	37,710	37,756
2015	36,813	35,959	34,707	36,371	38,081
Mean	42,860	42,366	41,993	40,706	42,379

1. Brood years 1997-2001: Optimum Conventional Treatment (OCT). Brood Years 2002-2004: Normal (High) growth. Brood Years 2005-2012: Normal feed at Cle Elum or accl. sites.
2. Brood years 1997-2001: Semi-natural Treatment (SNT). Brood Years 2002-2004: Slowed (Low) growth. Brood Year 2005, 2007-2012: saltwater transition feed at accl. Sites; BY2014-present: BioPRO vs BioVIT diet. Brood Year 2006: EWS diet at CESRF through May 3, 2007.
3. At the Jack Creek acclimation site only 4 of 6 raceways were stocked, and raceway 4 suffered mechanical failures resulting in the loss of about 20,000 OCT (control) fish.
4. High BKD incidence in adult broodstock reduced production to just 9 ponds (Clark Flat 1-2, Jack Creek, and Easton). Easton ponds were used for predator avoidance trained (PAT) fish and a single Cle Elum pond was spread between 6 ponds at Easton with crowders used to simulate pond densities for fish at other acclimation sites. These releases were excluded from mean pond density calculations by treatment.
5. At the Jack Creek acclimation site raceway 3 suffered mechanical failures resulting in the loss of about 45,000 high-growth (control) fish.

Mean length and weight at release by brood year are shown in Figures 5 and 6 under Juvenile Salmon Evaluation, length and weight growth profiles. Mark information and volitional release dates are given in Appendix A.

Smolt Outmigration Timing

The Chandler Juvenile Monitoring Facility (CJMF) located on the fish bypass facility of Chandler Canal at Prosser Dam (Rkm 75.6; Figure 1) serves as the cornerstone facility for estimating smolt production in the Yakima Basin for several species and stocks of salmonids. Daily species counts in the livebox at the CJMF are expanded by the canal entrainment, canal survival, and sub-sampling rates in order to estimate daily passage at Prosser Dam (Neeley 2000). Expansion techniques for deriving Chandler smolt passage estimates are continually being reviewed and revised to incorporate new information. A subset of fish passing through the

CJMF is sampled for presence of internal (CWT or PIT) or external (fin-clip) marks. All fish with marks are assumed to be of hatchery origin; otherwise, fish are presumed to be of natural origin.

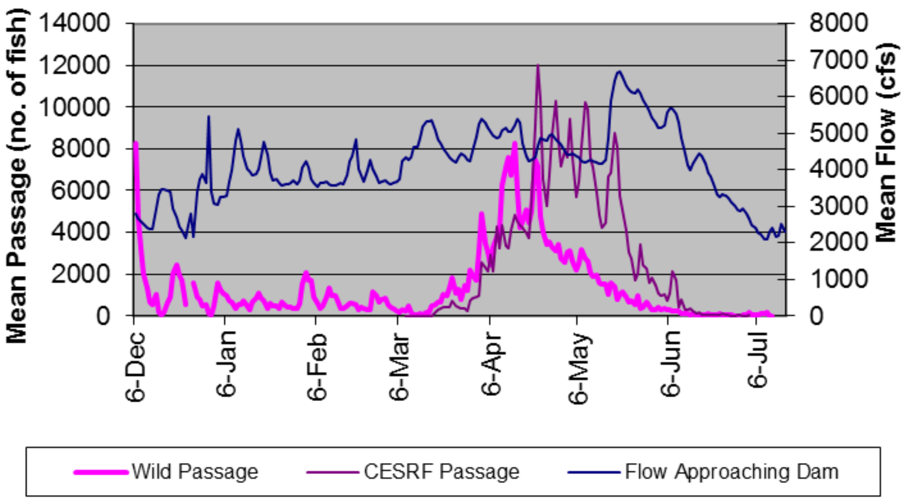

Figure 7. Mean flow approaching Prosser Dam versus mean estimated smolt passage at Prosser of aggregate wild/natural and CESRF spring Chinook for outmigration years 1999-2016.

Smolt-to-Smolt Survival

OCT-SNT Treatment (Brood Years 1997-2001, Migration Years 1999-2003)

Results of this experiment have been published:

Fast, D. E., D. Neeley, D.T. Lind, M. V. Johnston, C.R. Strom, W. J. Bosch, C. M. Knudsen, S. L. Schroder, and B.D. Watson. 2008. Survival Comparison of Spring Chinook Salmon Reared in a Production Hatchery under Optimum Conventional and Seminatural Conditions. Transactions of the American Fisheries Society 137:1507–1518.

Abstract — We found insufficient evidence to conclude that seminatural treatment (SNT; i.e., rearing in camouflage-painted raceways with surface and underwater structures and underwater feeders) of juvenile Chinook salmon *Oncorhynchus tshawytscha* resulted in higher survival indices than did optimum conventional treatment (OCT; i.e., rearing in concrete raceways with surface feeding) for the specific treatments and environmental conditions tested. We reared spring Chinook salmon from fry to smolt in paired raceways under the SNT and OCT rearing treatments for five consecutive years. For four to nine SNT and OCT raceway pairs annually, we used passive integrated transponder, coded wire, and visual implant elastomer tags to compare survival indices for juvenile fish from release at three different acclimation sites 340–400 km downstream to passage at McNary Dam on the Columbia River, and for adults from release to adult return to Roza Dam in the upper Yakima basin. The observed differences in juvenile and adult survival between the SNT and OCT fish were either statistically insignificant, conflicting in their statistical significance, or explained by significant differences in the presence of the causative agents of bacterial kidney disease in juvenile fish at release.

High-Low Growth Treatment (Brood Years 2002-04, Migration Years 2004-2006)

Two early-rearing nutritional regimes were tested using hatchery-reared Yakima Upper spring Chinook for brood years 2002 through 2004. A low nutrition-feeding rate (low treatment or low) was administered at the Cle Elum Hatchery through early rearing to determine whether that treatment would reduce the proportion of precocials produced compared to a conventional feeding rate during early rearing. The conventional feeding rate, which served as a control treatment, is referred to here as a high nutrition-feeding rate (high treatment or high). Feed was administered at a rate of 10 grams/fish for the low treatment and 15 grams/fish for the high treatment through mid-October, after which sufficient feed was administered to both sets of treated fish to meet their feeding demands. The treatments were allocated within pairs of raceways (blocks), there being a total of nine pairs. The Low nutritional feed (Low) had a significantly lower release-to-McNary survival than did the High nutritional feed (High), respective survivals being 18.1% and 21.2% ($P < 0.0001$; D. Neeley, Appendix B of 2008 annual report). The Low survival to McNary was consistently lower than the High at all sites in all years. Low-treated fish were smaller fish at the time of release and had somewhat later McNary passage times than high-treated fish.

Control versus Saltwater Transfer Treatment (Brood Years 2005, 2007- 2010; Migration Years 2007, 2009- 2013)

Prior to releases in 2007, 2009- 2013, two feed treatments were allocated to raceways within adjacent raceway pairs. Fish from each raceway within the pairs were fed BioVita prior to smoltification, then the BioVita feed for one of the raceway pairs was supplemented with a BioTransfer diet and the other was not. The intent of the experiment was to determine whether the Transfer-supplemented-feed treatment increased the rate of smoltification, the non-supplemented treatment serving as the control. Analyses indicated no significant or substantial differences between the supplemented and non-supplemented feed when averaged over years. See Appendix D of this annual report for additional detail.

Control (Bio-Oregon) versus EWOS Feed Comparison (Brood Year 2006, Migration Year 2008)

This experimental design was similar to that described above for the Control versus saltwater transfer treatment study, with the standard Bio-Oregon pellets fed to half of the rearing ponds and an EWOS (www.ewos.com) diet fed to the other ponds. The different feed treatments only lasted about 6 weeks from the time of initial ponding as we found substantially higher mortalities for fish receiving the EWOS feed. From May 7, 2007 until these fish were released in 2008 all fish in this study received the Bio-Oregon diet. For the parameters of interest, we found no significant or substantial differences between the two feeding treatments (Appendix B of 2008 annual report).

Smolt-to-Adult Survival

Calculation of smolt-to-adult survival rates for Yakima River spring Chinook is complicated by the following factors:

1) Downstream of the confluence of the Yakima and Naches rivers the three populations of spring Chinook (Upper Yakima, Naches, and American) are aggregated. A subsample of the aggregate wild/natural populations is PIT-tagged as part of the Chandler juvenile sampling operation but their origin is not known at the time of tagging. Through 2003, the primary purpose of this subsampling effort was to derive entrainment and canal survival estimates (see 2 below). Due to issues such as tag retention and population representation, adult detections of smolts PIT-tagged at Chandler cannot be used in any valid smolt-to-adult survival analyses.

2) Smolt accounting at Prosser is based on statistical expansion of Chandler smolt trap sampling data using available flow data and estimated Chandler entrainment rates. Chandler smolt passage estimates are prepared primarily for the purpose of comparing relative wild versus CESRF passage estimates and not for making survival comparisons. While these Chandler smolt passage estimates represent the best available data, there may be a relatively high degree of error associated with these estimates due to inherent complexities, assumptions, and uncertainties in the statistical expansion process. Therefore, these estimates are subject to revision. We are in the process of developing methods to subdivide the wild/natural outmigration into Upper Yakima, Naches, and American components based on DNA samples of juveniles taken at Chandler since 1998.

3) Installation of adult PIT detection equipment at all three ladders at Prosser Dam was not completed until the fall of 2005. Therefore, detection of upstream-migrating PIT-tagged adult spring Chinook at Prosser Dam was not possible for all returning fish until the spring of 2006. Periods of high flow may preclude use of automated detection gear so 100% detection of upstream migrants is not possible in all years.

4) Through 2006, detection of upstream-migrating PIT-tagged adult spring Chinook at Roza Dam occurred at an approximate 100% rate only for marked CESRF fish and wild/natural fish taken for broodstock. The majority of wild/natural fish were passed directly back to the river without PIT interrogation.

5) For the 1997 brood (1999 out-migration), 400 Khz PIT-tags were used. Mainstem detection facilities were not configured to detect these tags at nearly the efficiency that they can detect the newer 134.2 kHz ISO tags. Although all marked adult fish are trapped and hand-wanded for PIT detections of adults at Roza Dam, the reliability of the 400kHz detection gear and problems with hand-sampling in general likely precluded a complete accounting of all 1997 brood PIT returns.

6) All CESRF fish are adipose-fin clipped and subjected to higher harvest rates than unmarked wild/natural fish in marine and Columbia River mark-selective fisheries. No adjustments have yet been made in the following tables to account for differential harvest rates in these mark-selective fisheries.

7) PIT tag retention is a factor in estimating survival rates (Knudsen et al. 2009). No attempt has been made to correct the data in the following tables for estimates of tag retention.

8) The ISAB has indicated that “more attention should be given to the apparent documentation that PIT-tagged fish do not survive as well as untagged fish. This point has major implications for all uses of PIT-tagged fish as surrogates for untagged fish.” Our data appear to corroborate this point (Tables 45-46). However, these data are not corrected for tag loss. If a fish loses its PIT tag after detection upon leaving the acclimation site, but before it returns as an adult to Roza Dam, it would be included only as a release in Table 45 and only as an adult return in Table 46. Knudsen et al. (2009) found that smolt-to-adult return rates (SARS) based on observed PIT tag recoveries were significantly underestimated by an average of 25% and that after correcting for tag loss, SARS of PIT-tagged fish were still 10% lower than SARS of non-PIT-tagged fish. Thus, the data in Table 45 under-represent “true” SARS for PIT-tagged fish and SARS for PIT-tagged and non-PIT-tagged fish are likely closer than those reported in Tables 45 and 46.

9) Due to issues relating to water permitting, size required for tagging, and allowing sufficient time for acclimation, CESRF juveniles are not allowed to migrate until at least March 15 of their smolt year. However, juvenile sampling observations at Roza Dam indicate that a substantial number of wild/natural juveniles migrate downstream during the summer, fall, and winter months prior to their smolt outmigration year (Figure 7). Comparison of SAR data for non-contemporaneously migrating juveniles may be invalid (see Copeland et al. 2015).

Given these complicating factors, Tables 40-46 present available smolt-to-adult survival data for Yakima River CESRF and wild/natural spring Chinook. Unfortunately, true “apples-to-apples” comparisons of CESRF and wild/natural smolt-to-adult survival rates are not possible from these tables due to complexities noted above. The reader is cautioned to correct these data for, or acknowledge the factors noted above prior to any use of these data.

Table 40. Estimated smolt passage at Chandler and smolt-to-adult return indices (Chandler smolt to Yakima R. mouth adult) for Yakima Basin wild/natural and CESRF-origin spring Chinook.

			Estimated Smolt Passage at Chandler			Yakima R. Mouth Adult Returns[4]		Smolt-to-Adult Return Index[4]	
Brood Year	Smolt Migr. Year	Mean Flow[1] at Prosser Dam	Wild/ Natural[2]	CESRF Total	CESRF smolt-to-smolt survival[3]	Wild/ Natural[2]	CESRF Total	Wild/ Natural[2]	CESRF Total
1982	1984	4134	381,857			6,753		1.8%	
1983	1985	3421	146,952			5,198		3.5%	
1984	1986	3887	227,932			3,932		1.7%	
1985	1987	3050	261,819			4,776		1.8%	
1986	1988	2454	271,316			4,518		1.7%	
1987	1989	4265	76,362			2,402		3.1%	
1988	1990	4141	140,218			5,746		4.1%	
1989	1991		109,002			2,597		2.4%	
1990	1992	1960	128,457			1,178		0.9%	
1991	1993	3397	92,912			544		0.6%	
1992	1994	1926	167,477			3,790		2.3%	
1993	1995	4882	172,375			3,202		1.9%	
1994	1996	6231	218,578			1,238		0.6%	
1995	1997	12608	52,028			1,995		3.8%	
1996	1998	5466	491,584			21,151		4.3%	
1997	1999	5925	633,805	203,576	52.7%	12,855	8,670	2.0%	4.3%
1998	2000[5]	4946	159,998	243,835	41.4%	8,228	9,782	5.2%	4.0%
1999	2001	1321	175,917	333,689	44.0%	1,764	864	1.0%	0.3%
2000	2002	5015	532,726	419,381	50.3%	11,434	4,819	2.1%	1.1%
2001	2003	3504	326,666	164,682	44.5%	8,597	1,251	2.6%	0.8%
2002	2004	2439	162,673	279,593	33.4%	3,743	2,300	2.3%	0.8%
2003	2005	1285	172,267	302,295	36.7%	2,746	932	1.6%	0.3%
2004	2006	5652	203,250	459,205	58.5%	2,802	4,022	1.4%	0.9%
2005	2007	4551	112,504	398,263	46.3%	4,201	4,378	3.7%	1.1%
2006	2008	4298	137,784	305,335	47.5%	6,099	9,114	4.4%	3.0%
2007	2009	5784	278,780	489,602	63.5%	7,952	6,558	2.9%	1.3%
2008	2010	3592	215,683	374,129	44.1%	7,385	6,976	3.4%	1.9%
2009	2011	9414	326,180	476,487	57.2%	3,766	3,181	1.2%	0.7%
2010	2012	8556	429,896	652,866	82.1%	6,602	4,707	1.5%	0.7%
2011	2013	4875	357,347	364,619	47.4%	7,343	3,607	2.1%	1.0%
2012	2014	4923	268,598	417,277	52.0%	3,409[6]	1,713[6]	1.3%[6]	0.4%[6]
2013	2015	1555	120,491	321,870	49.8%				
2014	2016[6]	5765	160,556	427,733	62.4%				

1. Mean flow (cfs) approaching Prosser Dam March 29-July 4 of juvenile migration year. No data available for migration year 1991. In high flow years (flows at or > 5000 cfs) operation of the Chandler smolt sampling facility may be precluded during portions of the outmigration. Data courtesy of U.S. BOR hydromet.
2. Aggregate of Upper Yakima, Naches, and American wild/natural populations.
3. Estimated smolt-to-smolt (release from upper Yakima River acclimation sites to Chandler) survival for CESRF juveniles.
4. Includes combined age-3 through age-5 returns. CESRF adult returns and smolt-to-adult survival values are understated relative to wild/natural values since these figures are not adjusted for differential harvest rates in mark selective fisheries in marine and lower Columbia River fisheries.
5. Available data were not sufficient to estimate juvenile flow-entrainment and passage of wild/natural fish.
6. Data for most recent year are preliminary; return data do not include age-5 adult fish.

Table 41. Estimated wild/natural smolt-to-adult return rates (SAR) based on adult detections of PIT tagged fish. Roza tagged smolts to Bonneville Dam adult returns.

		Wild/Natural smolts tagged at Roza				
Brood	Number	Adult Returns at Age[1]				
Year	Tagged	Age 3	Age 4	Age 5	Total	SAR[1]
1997	310	0	1	0	1	0.32%[2]
1998	6,209	15	171	14	200	3.22%
1999	2,179	2	8	0	10	0.46%
2000	8,718	1	51	1	53	0.61%
2001	7,804	9	52	3	64	0.82%
2002	3,931	2	46	4	52	1.32%
2003	1,733	0	6	1	7	0.40%
2004	2,333	1	8	1	10	0.43%
2005	1,200	0	8	0	8	0.67%
2006	1,675	12	33	2	47	2.81%
2007	3,795[a]	6	47	2	55	1.45%
2008	105	0	1	0	1	0.95%
2009	2,087	0	3	1	4	0.19%
2010	2,647	4	22	1	27	1.02%
2011	2,473	1	9	1	11	0.44%
2012			No Releases			
2013	524	1				

a. Includes 1752 fish tagged and released in late August and early Sept.

Table 42. Estimated CESRF smolt-to-adult return rates (SAR) based on adult detections of PIT tagged fish. Roza tagged smolts to Bonneville Dam adult returns.

		CESRF smolts tagged at Roza				
Brood	Number	Adult Returns at Age[1]				
Year	Tagged	Age 3	Age 4	Age 5	Total	SAR[1]
1997	407	0	2	0	2	0.49%[2]
1998	2,999	5	42	2	49	1.63%
1999	1,744	1	0	0	1	0.06%
2000	1,503	0	1	0	1	0.07%
2001	2,146	0	4	0	4	0.19%
2002	2,201	4	5	0	9	0.41%
2003	1,418	0	3	1	4	0.28%
2004	4,194	3	13	0	16	0.38%
2005	2,358	0	3	0	3	0.13%
2006	4,130	32	31	2	65	1.57%
2007	3,736	10	21	0	31	0.83%
2008	1,071	4	3	0	7	0.65%
2009	3,641	2	4	0	6	0.16%
2010	4,064	4	13	1	18	0.44%
2011	513	0	0	0	0	0.00%
2012	201	0	0			
2013	1,432	0				

1. CESRF adult returns and smolt-to-adult survival values are understated relative to wild/natural values since these figures are not adjusted for differential harvest rates in mark selective fisheries in marine and lower Columbia River fisheries.
2. The reliability of the 400kHz detection gear precluded an accurate accounting of all 1997 brood PIT returns. Therefore, this is not a true SAR. It is presented for relative within-year comparison only and should NOT be compared to SARs for other years.

Table 43. Overall wild/natural smolt-to-adult return rates (SAR) based on juvenile and adult detections of fish PIT-tagged and released at Roza Dam (Table B.49 in McCann et al. 2016). McNary smolts to Bonneville Dam adult returns. For 2010 and 2014 migration years, few if any wild smolts were PIT-tagged at Roza.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	MCN-to-BOA with Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	2,581	6.90	6.10	7.73	7.48	6.67	8.38
2001	521	1.54	0.73	2.52	1.92	0.98	3.04
2002	2,130	2.25	1.73	2.82	2.30	1.77	2.86
2003	2,143	2.47	1.91	3.04	2.89	2.27	3.55
2004	1,297	3.70	2.87	4.62	3.78	2.95	4.70
2005	519	1.35	0.57	2.20	1.35	0.57	2.20
2006	565	1.59	0.76	2.65	1.77	0.85	2.78
2007	362	1.93	0.86	3.26	1.93	0.86	3.26
2008	512	6.84	4.93	8.96	9.19	6.85	11.73
2009	990	4.95	3.78	6.21	5.56	4.33	6.88
2010	0	--	--	--	--	--	--
2011	411	0.97	0.24	1.79	0.97	0.24	1.79
2012	826	2.79	1.85	3.85	3.27	2.19	4.45
2013	704	1.42	0.75	2.25	1.56	0.83	2.44
2014[B]	0	--	--	--	--	--	--
Geometric mean		2.46			2.71		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete with 2-salt returns through June 17, 2016.
[C] No PIT-tagged smolts released in 2010 or 2014.

Table 44. Overall CESRF smolt-to-adult return rates (SAR) based on juvenile and adult detections of PIT tagged fish (Table B.53 in McCann et al. 2016). McNary smolts to Bonneville Dam adult returns.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	MCN-to-BOA with Jacks %SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	14,416	3.65	3.35	3.96	3.99	3.67	4.31
2001	9,269	0.28	0.19	0.38	0.29	0.20	0.39
2002	11,753	1.37	1.20	1.55	1.73	1.54	1.93
2003	11,978	0.59	0.48	0.71	0.86	0.72	1.01
2004	7,982	1.54	1.30	1.78	1.85	1.59	2.10
2005	5,792	0.66	0.49	0.83	0.78	0.59	0.98
2006	10,283	1.24	1.06	1.41	1.59	1.40	1.80
2007	12,661	1.01	0.86	1.16	1.51	1.33	1.68
2008	11,686	3.17	2.86	3.46	5.06	4.64	5.47
2009	15,382	1.82	1.65	1.99	2.29	2.10	2.49
2010	12,473	1.52	1.33	1.71	2.53	2.30	2.79
2011	11,866	0.94	0.79	1.09	1.21	1.04	1.38
2012	15,719	1.22	1.07	1.37	1.76	1.57	1.96
2013	13,269	1.38	1.20	1.56	1.95	1.74	2.16
2014[B]	12,895	0.58	0.47	0.70	0.84	0.70	0.97
Geometric mean		1.15			1.53		

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete with 2-salt returns through June 17, 2016.

Table 45. Estimated release-to-adult survival of PIT-tagged CESRF fish (CESRF tagged smolts to Bonneville and Roza Dam adult returns).

Brood	Number	Adult Detections at Bonn. Dam					Adult Detections at Roza Dam				
Year	Tagged[1]	Age3	Age4	Age5	Total	SAR	Age3	Age4	Age5	Total	SAR
1997[2]	39,892	18	182	4	204	0.51%	65	517	16	598	1.50%
1998	37,388	49	478	48	575	1.54%	54	310	34	398	1.06%
1999	38,793	1	25	1	27	0.07%	1	22	0	23	0.06%
2000	37,582	42	159	2	203	0.54%	37	112	1	150	0.40%
2001	36,523	32	71	0	103	0.28%	22	58	0	80	0.22%
2002[3]	39,003	25	119	4	148	0.38%	15	80	2	97	0.25%
2003	38,916	7	37	1	45	0.12%	3	27	1	31	0.08%
2004	36,426	37	123	4	164	0.45%	24	98	3	125	0.34%
2005	39,119	63	126	2	191	0.49%	44	96	2	142	0.36%
2006	38,595	221	354	15	590	1.53%	187	264	11	462	1.20%
2007	38,618	73	279	3	355	0.92%	55	182	3	240	0.62%
2008	39,013	135	192	3	330	0.85%	81	132	2	215	0.55%
2009	36,239	32	110	3	145	0.40%	23	85	2	110	0.30%
2010	38,737	85	187	6	278	0.72%	62	142	3	207	0.53%
2011	38,165	77	191	2	270	0.71%	57	122	2	181	0.47%
2012	38,343	33	75				10	59		69	0.18%
2013	38,278	90					68				

1. When tag detection data are available, this is the number of unique PIT tags physically detected leaving the acclimation sites. Otherwise, this is the number of fish PIT tagged less documented mortalities of PIT-tagged fish from tagging to release.
2. BY1997 used 400 kHz tags and Bonneville Dam was not fully configured for adult detection of this type of tag; therefore we saw more detections at Roza Dam where fish were manually wanded for adult PIT detections.
3. Includes HxH fish beginning with this brood year.

Table 46. Estimated release-to-adult survival of non-PIT-tagged CESRF fish (CESRF tagged smolts to Roza Dam adult returns).

Brood	Number	Adult Returns to Roza Dam				
Year	Tagged[1]	Age3	Age4	Age5	Total	SAR
1997[2]	346,156	623	5,663	120	6,406	1.85%
1998	552,295	936	5,834	534	7,304	1.32%
1999	719,996	103	652	13	768	0.11%
2000	796,703	1,005	2,764	69	3,837	0.48%
2001	333,713	290	791	9	1,091	0.33%
2002[3]	797,901	332	1,771	135	2,238	0.28%
2003	785,776	115	1,568	14	1,696	0.22%
2004	749,022	683	3,688	202	4,574	0.61%
2005	820,883	1,012	5,302	22	6,336	0.77%
2006	604,200	2,383	6,427	287	9,096	1.51%
2007	732,647	1,024	5,645	87	6,756	0.92%
2008	810,292	1,552	3,680	76	5,308	0.66%
2009	796,702	389	3,106	67	3,562	0.45%
2010	756,044	721	3,618	28	4,368	0.58%
2011	731,017	780	2,318	138	3,236	0.44%
2012	764,373	172	2,187		2,359	0.31%
2013	608,477	1,251				

1. These fish were adipose fin-clipped, coded-wire tagged, and (beginning with 4 of 16 ponds in 1998) elastomer eye tagged. This is the number of fish physically counted at tagging.
2. BY1997 used 400 kHz tags and Bonneville Dam was not fully configured for adult detection of this type of tag; therefore we saw more detections at Roza Dam where fish were manually wanded for adult PIT detections.
3. Includes HxH fish beginning with this brood year.

Harvest Monitoring

Yakima Basin Fisheries

For spring fisheries in the Yakima River Basin, both the WDFW and the Yakama Nation employ two technicians and one biologist to monitor and evaluate in-basin harvest in the respective sport and tribal fisheries. Harvest monitoring consists of on-the-water surveys to collect catch data and to record tag information (e.g., elastomer, CWT, etc.) where possible for adipose-clipped fish. Survey data are expanded for time, area, and effort using standard methods to derive estimates of total in-basin harvest by fishery type (sport and tribal) and catch type (CESRF or wild denoted by adipose presence/absence).

Table 47. Spring Chinook harvest in the Yakima River Basin, 1983-present.

	Tribal		Non-Tribal		River Totals			Harvest
Year	CESRF	Wild	CESRF	Wild	CESRF	Wild	Total	Rate[1]
1983		84		0		84	84	5.8%
1984		289		0		289	289	10.9%
1985		865		0		865	865	19.0%
1986		1,340		0		1,340	1,340	14.2%
1987		517		0		517	517	11.6%
1988		444		0		444	444	10.5%
1989		747		0		747	747	15.2%
1990		663		0		663	663	15.2%
1991		32		0		32	32	1.1%
1992		345		0		345	345	7.5%
1993		129		0		129	129	3.3%
1994		25		0		25	25	1.9%
1995		79		0		79	79	11.9%
1996		475		0		475	475	14.9%
1997		575		0		575	575	18.1%
1998		188		0		188	188	9.9%
1999		604		0		604	604	21.7%
2000	53	2,305		100	53	2,405	2,458	12.9%
2001	572	2,034	1,252	772	1,825	2,806	4,630	19.9%
2002	1,373	1,207	492	36[2]	1,865	1,243	3,108	20.6%
2003	134	306	0	0	134	306	440	6.3%
2004	289	712	569	109[2]	858	820	1,679	11.0%
2005	46	428	0	0	46	428	474	5.4%
2006	246	354	0	0	246	354	600	9.5%
2007	123	156	0	0	123	156	279	6.5%
2008	521	414	586	11[2]	1,107	426	1,532	17.8%
2009	1,089	715	541	8[2]	1,630	722	2,353	19.4%
2010	345	194	1,154	48[2]	1,499	241	1,741	13.2%
2011	1,361	1,261	1,579	179[2]	2,940	1,440	4,380	24.4%
2012	1,220	1,302	735	63[2]	1,955	1,364	3,320	27.5%
2013	846	975	786	46[2]	1,632	1,021	2,653	25.9%
2014	576	715	826	54[2]	1,402	769	2,171	19.2%
2015	121	271	385	38[2]	506	309	815	8.7%
2016	103	185	132	24[2]	235	209	444	6.4%
Mean	560	702	565	87	1,125	653	1,169	13.5%

1. Harvest rate is the total Yakima Basin harvest as a percentage of the Yakima River mouth run size.
2. Includes estimate of post-release mortality of unmarked fish.

Columbia Basin Fisheries

Standard run reconstruction techniques are employed to derive estimates of harvest from the Columbia River mouth to the Yakima River mouth for spring Chinook. Data from databases maintained by the *United States versus Oregon* Technical Advisory Committee (TAC) are used to obtain harvest rate estimates downstream of the Yakima River for the aggregate Yakima River spring Chinook population and to estimate passage losses from Bonneville through McNary reservoirs. These data, combined with the Prosser Dam counts and estimated harvest below Prosser, are used to derive a Columbia River mouth run size estimate and Columbia River mainstem harvest estimate for Yakima spring Chinook.

Table 48. Estimated run size, harvest, and harvest rates of Yakima Basin spring Chinook in Columbia River mainstem and terminal area fisheries, 1983-present.

						Columbia Basin Harvest Summary			Col. Basin Harvest Rate	
Year	Columbia R. Mouth Run Size	Col. R. Mouth to BON Harvest	BON to McNary Harvest	Yakima R. Mouth Run Size	Yakima River Harvest	Total	Wild	CESRF	Total	Wild
1983	2,452	118	99	1,441	84	300	300	0	12.3%	12.3%
1984	3,868	134	257	2,658	289	680	680	0	17.6%	17.6%
1985	5,248	191	178	4,560	865	1,234	1,234	0	23.5%	23.5%
1986	13,514	280	783	9,439	1,340	2,403	2,403	0	17.8%	17.8%
1987	6,140	96	371	4,443	517	984	984	0	16.0%	16.0%
1988	5,631	360	372	4,246	444	1,177	1,177	0	20.9%	20.9%
1989	8,869	212	663	4,914	747	1,621	1,621	0	18.3%	18.3%
1990	6,908	350	453	4,372	663	1,465	1,465	0	21.2%	21.2%
1991	4,620	183	278	2,906	32	493	493	0	10.7%	10.7%
1992	6,196	102	373	4,599	345	820	820	0	13.2%	13.2%
1993	5,117	44	311	3,919	129	484	484	0	9.5%	9.5%
1994	2,225	86	107	1,302	25	219	219	0	9.8%	9.8%
1995	1,384	1	68	666	79	149	149	0	10.7%	10.7%
1996	5,773	6	303	3,179	475	783	783	0	13.6%	13.6%
1997	5,196	3	348	3,173	575	926	926	0	17.8%	17.8%
1998	2,839	3	143	1,903	188	333	333	0	11.7%	11.7%
1999	3,918	4	180	2,781	604	789	789	0	20.1%	20.1%
2000	28,862	58	1,755	19,100	2,458	4,271	4,147	123	14.8%	14.8%
2001	31,004	948	4,050	23,265	4,630	9,629	5,528	4,101	31.1%	29.7%
2002	23,898	1,234	2,547	15,099	3,108	6,888	2,569	4,320	28.8%	24.7%
2003	9,727	274	764	6,957	440	1,478	890	588	15.2%	14.3%
2004	21,910	964	1,894	15,289	1,679	4,536	2,515	2,021	20.7%	16.1%
2005	11,903	326	741	8,758	474	1,542	1,214	328	13.0%	12.2%
2006	11,560	299	760	6,314	600	1,658	942	716	14.3%	12.8%
2007	4,981	170	343	4,303	279	791	382	410	15.9%	13.8%
2008	11,419	1,151	1,507	8,598	1,532	4,190	1,181	3,008	36.7%	26.5%
2009	12,804	1,168	934	10,701	2,353	4,455	1,237	3,218	34.8%	25.7%
2010	17,366	1,563	2,286	13,142	1,741	5,590	1,302	4,288	32.2%	21.4%
2011	22,171	1,059	1,396	17,960	4,380	6,834	2,373	4,461	30.8%	22.2%
2012	16,641	842	1,426	12,053	3,320	5,588	2,252	3,336	33.6%	27.3%
2013	14,234	847	761	10,245	2,653	4,261	1,686	2,575	29.9%	23.3%
2014	16,291	691	1,758	11,322	2,171	4,620	1,836	2,784	28.4%	21.6%
2015	11,331	460	1,263	9,351	815	2,538	1,323	1,215	22.4%	17.5%
2016[1]	10,083	462	886	6,916	444	1,792	898	893	17.8%	14.7%
Mean	10,767	432	893	7,643	1,190	2,515	1,386	1,129	20.1%	17.7%

1. Preliminary.

Marine Fisheries

Based on available CWT information, harvest managers have long assumed that Columbia River spring Chinook are not harvested in any abundance in marine fisheries as the timing of their ocean migration does not generally overlap either spatially or temporally with the occurrence of marine fisheries (TAC 1997). The Regional Mark Information System (RMIS) will be queried regularly for any CWT recoveries of CESRF releases in ocean or Columbia River mainstem fisheries. Table 49 gives the results of a query of the RMIS database run on Nov. 21, 2016 for CESRF spring Chinook CWTs released in brood years 1997-2011. Based on the information reported to RMIS to date, it is believed that marine harvest accounts for about 0-3% of the total harvest of Yakima Basin spring Chinook. CWT recovery data for brood year 2012 were considered too incomplete to report at this time.

Table 49. Marine and freshwater recoveries of CWTs from brood year 1997-2011 releases of spring Chinook from the CESRF as reported to the Regional Mark Information System (RMIS) 21 Nov, 2016.

Brood	Observed CWT Recoveries			Expanded CWT Recoveries		
Year	Marine	Fresh	Marine %	Marine	Fresh	Marine %
1997	5	56	8.2%	8	321	2.4%
1998	2	53	3.6%	2	228	0.9%
1999		2	0.0%		9	0.0%
2000		14	0.0%		34	0.0%
2001		1	0.0%		1	0.0%
2002		7	0.0%		36	0.0%
2003		4	0.0%		10	0.0%
2004	2	154	1.3%	15	526	2.8%
2005	2	96	2.0%	2	304	0.7%
2006	14	328	4.1%	16	1160	1.4%
2007	8	145	5.2%	13	1139	1.1%
2008	5	245	2.0%	7	1634	0.4%
2009	4	91	4.2%	7	588	1.2%
2010	4	164	2.4%	9	948	0.9%
2011[1]	5	162	3.0%	5	856	0.6%

1. Reporting of CWT recoveries to the RMIS database typically lags actual fisheries by one to two years. Therefore, CWT recovery data for brood year 2011 are considered preliminary or incomplete.

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Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2015.

Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2006	CLE01	CFJ04	BIO	WW	3.5	Right	Red	Snout	3/15/2008	5/14/2008	190101	2,000	36,945	38,607
2006	CLE02	CFJ03	EWS	WW	3.5	Left	Red	Snout	3/15/2008	5/14/2008	190102	2,000	31,027	32,790
2006	CLE03	ESJ02	BIO	WW	3.2	Right	Green	Snout	3/15/2008	5/14/2008	190103	2,000	36,931	38,762
2006	CLE04	ESJ01	EWS	WW	3.2	Left	Green	Snout	3/15/2008	5/14/2008	190104	2,000	29,635	31,400
2006	CLE05	JCJ02	BIO	WW	3.3	Right	Orange	Snout	3/15/2008	5/14/2008	190105	2,000	36,735	38,383
2006	CLE06	JCJ01	EWS	WW	3.3	Left	Orange	Snout	3/15/2008	5/14/2008	190106	2,000	28,984	30,680
2006	CLE07	ESJ04	BIO	WW	3.4	Right	Green	Snout	3/15/2008	5/14/2008	190107	2,000	38,212	40,006
2006	CLE08	ESJ03	EWS	WW	3.4	Left	Green	Snout	3/15/2008	5/14/2008	190108	2,000	32,726	34,519
2006	CLE09	CFJ02	BIO	WW	3.4	Right	Red	Snout	3/15/2008	5/14/2008	190109	2,000	36,485	38,097
2006	CLE10	CFJ01	EWS	WW	3.4	Left	Red	Snout	3/15/2008	5/14/2008	190110	2,000	29,907	31,647
2006	CLE11	JCJ04	BIO	WW	3.3	Right	Orange	Snout	3/15/2008	5/14/2008	190111	2,000	39,491	40,703
2006	CLE12	JCJ03	EWS	WW	3.3	Left	Orange	Snout	3/15/2008	5/14/2008	190112	2,000	33,418	35,273
2006	CLE13	ESJ06	BIO	WW	3.4	Right	Green	Snout	3/15/2008	5/14/2008	190113	2,000	38,609	39,841
2006	CLE14	ESJ05	EWS	WW	3.4	Left	Green	Snout	3/15/2008	5/14/2008	190114	2,000	31,573	33,404
2006	CLE15	JCJ06	BIO	WW	3.4	Right	Orange	Snout	3/15/2008	5/14/2008	190115	2,000	36,844	38,619
2006	CLE16	JCJ05	EWS	WW	3.4	Left	Orange	Snout	3/15/2008	5/14/2008	190116	2,000	29,857	31,630
2006	CLE17	CFJ06	BIO	HH	3.2	Right	Red	Posterior Dorsal	3/15/2008	5/14/2008	190117	4,000	34,299	38,045
2006	CLE18	CFJ05	EWS	HH	3.2	Left	Red	Posterior Dorsal	3/15/2008	5/14/2008	190118	4,000	26,643	30,389

[1] BIO = BioVita (BioOregon Protein Inc.) or control diet; EWS = EWOS (EWOS Canada Ltd.). All fish were switched to BioVita diet beginning May 3, 2007. All fish are progeny of wild/natural parents unless denoted as HH which designates the hatchery control line. “Avg BKD” denotes the average BKD ELISA ranking of the female parents whose progeny were in these ponds.

[2] The number of fish released is estimated as the total number of fish counted at marking less mortalities documented from mark to release.

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Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2007	CLE01	JCJ06	BIO	WW	2.8	Right	Orange	Snout	3/15/2009	5/15/2009	190151	2,000	38,044	39,840
2007	CLE02	JCJ05	STF	WW	2.8	Left	Orange	Snout	3/15/2009	5/15/2009	190152	2,000	40,066	41,843
2007	CLE03	JCJ04	BIO	WW	2.7	Right	Orange	Snout	3/15/2009	5/15/2009	190153	2,000	40,843	42,647
2007	CLE04	JCJ03	STF	WW	2.7	Left	Orange	Snout	3/15/2009	5/15/2009	190154	2,000	40,196	41,979
2007	CLE05	CFJ06	BIO	WW	2.8	Right	Red	Snout	3/15/2009	5/15/2009	190155	2,000	40,855	42,717
2007	CLE06	CFJ05	STF	WW	2.8	Left	Red	Snout	3/15/2009	5/15/2009	190156	2,000	40,475	42,345
2007	CLE07	ESJ06	BIO	WW	2.6	Right	Green	Snout	3/15/2009	5/15/2009	190157	2,000	42,549	44,387
2007	CLE08	ESJ05	STF	WW	2.6	Left	Green	Snout	3/15/2009	5/15/2009	190158	2,000	43,243	45,080
2007	CLE09	CFJ02	BIO	HH	2.7	Right	Red	Posterior Dorsal	3/15/2009	5/15/2009	190159	4,000	43,803	47,625
2007	CLE10	CFJ01	STF	HH	2.7	Left	Red	Posterior Dorsal	3/15/2009	5/15/2009	190160	4,000	43,256	47,038
2007	CLE11	ESJ02	BIO	WW	2.8	Right	Green	Snout	3/15/2009	5/15/2009	190161	2,000	41,098	42,945
2007	CLE12	ESJ01	STF	WW	2.8	Left	Green	Snout	3/15/2009	5/15/2009	190162	2,001	40,535	42,405
2007	CLE13	ESJ04	BIO	WW	2.7	Right	Green	Snout	3/15/2009	5/15/2009	190163	2,009	39,308	41,190
2007	CLE14	ESJ03	STF	WW	2.7	Left	Green	Snout	3/15/2009	5/15/2009	190164	2,000	36,663	38,533
2007	CLE15	JCJ02	BIO	WW	2.9	Right	Orange	Snout	3/15/2009	5/15/2009	190165	2,000	40,312	42,083
2007	CLE16	JCJ01	STF	WW	2.9	Left	Orange	Snout	3/15/2009	5/15/2009	190166	2,000	40,594	42,426
2007	CLE17	CFJ03	STF	WW	2.8	Right	Red	Snout	3/15/2009	5/15/2009	190167	2,000	40,687	42,561
2007	CLE18	CFJ04	BIO	WW	2.8	Left	Red	Snout	3/15/2009	5/15/2009	190168	2,000	41,704	43,621

[1] BIO = BioVita (BioOregon Protein Inc.) or control diet; STF = salt-water transition diet at acclimation sites. All fish are progeny of wild/natural parents unless denoted as HH which designates the hatchery control line beginning with brood year 2002. "Avg BKD" denotes the average BKD ELISA ranking of the female parents whose progeny were in these ponds.

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2008	CLE01	ESJ01	STF	WW	3.3	Right	Orange	Snout	3/15/2010	5/11/2010	190191	2,000	44,917	46,704
2008	CLE02	ESJ02	BIO	WW	3.3	Left	Orange	Snout	3/15/2010	5/11/2010	190192	2,000	45,576	47,414
2008	CLE03	CFJ03	STF	WW	3.2	Right	Red	Snout	3/15/2010	5/11/2010	190193	2,000	44,099	45,931
2008	CLE04	CFJ04	BIO	WW	3.2	Left	Red	Snout	3/15/2010	5/11/2010	190194	2,000	42,464	44,271
2008	CLE05	JCJ05	STF	WW	3.0	Right	Green	Snout	3/15/2010	5/11/2010	190195	2,000	46,118	47,936
2008	CLE06	JCJ06	BIO	WW	3.0	Left	Green	Snout	3/15/2010	5/11/2010	190196	2,000	43,708	45,466
2008	CLE07	ESJ05	STF	WW	3.2	Right	Orange	Snout	3/15/2010	5/11/2010	190197	2,000	48,468	50,299
2008	CLE08	ESJ06	BIO	WW	3.2	Left	Orange	Snout	3/15/2010	5/11/2010	190198	2,000	47,611	49,419
2008	CLE09	CFJ05	STF	HH	2.9	Right	Red	Posterior Dorsal	3/15/2010	5/11/2010	190199	4,000	45,169	48,942
2008	CLE10	CFJ06	BIO	HH	2.9	Left	Red	Posterior Dorsal	3/15/2010	5/11/2010	190201	4,000	44,493	48,254
2008	CLE11	JCJ01	STF	WW	3.3	Right	Green	Snout	3/15/2010	5/11/2010	190202	2,000	44,583	46,413
2008	CLE12	JCJ02	BIO	WW	3.3	Left	Green	Snout	3/15/2010	5/11/2010	190203	2,000	45,086	46,856
2008	CLE13	ESJ03	STF	WW	3.1	Right	Orange	Snout	3/15/2010	5/11/2010	190204	2,000	45,518	47,317
2008	CLE14	ESJ04	BIO	WW	3.1	Left	Orange	Snout	3/15/2010	5/11/2010	190205	2,000	44,879	46,704
2008	CLE15	CFJ01	STF	WW	3.2	Right	Red	Snout	3/15/2010	5/11/2010	190206	2,000	45,169	46,893
2008	CLE16	CFJ02	BIO	WW	3.2	Left	Red	Snout	3/15/2010	5/11/2010	190207	2,000	44,149	45,962
2008	CLE17	JCJ03	STF	WW	3.2	Right	Green	Snout	3/15/2010	5/11/2010	190208	2,000	45,807	47,580
2008	CLE18	JCJ04	BIO	WW	3.2	Left	Green	Snout	3/15/2010	5/11/2010	190209	2,000	45,157	46,944

[1] BIO = BioVita (BioOregon Protein Inc.) or control diet; STF = salt-water transition diet at acclimation sites. All fish are progeny of wild/natural parents unless denoted as HH which designates the hatchery control line beginning with brood year 2002. “Avg BKD” denotes the average BKD ELISA ranking of the female parents whose progeny were in these ponds.

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2009	CLE01	CFJ05	STF	HH	3.0	Right	Red	Posterior Dorsal	3/15/2011	5/16/2011	190215	4,000	40,109	43,965
2009	CLE02	CFJ06	BIO	HH	3.0	Left	Red	Posterior Dorsal	3/15/2011	5/16/2011	190216	4,000	41,012	44,806
2009	CLE03	JCJ01	STF	WW	3.0	Right	Orange	Snout	3/15/2011	3/31/2011	190217	2,000	37,245	39,048
2009	CLE04	JCJ02	BIO	WW	3.0	Left	Orange	Snout	3/15/2011	3/31/2011	190218	2,000	42,212	44,053
2009	CLE05	CFJ01	STF	WW	3.2	Right	Red	Snout	3/15/2011	5/16/2011	190219	2,000	47,016	48,761
2009	CLE06	CFJ02	BIO	WW	3.2	Left	Red	Snout	3/15/2011	5/16/2011	190220	2,000	46,733	48,569
2009	CLE07	ESJ05	STF	WW	3.1	Right	Green	Snout	3/15/2011	5/16/2011	190221	2,000	46,302	48,089
2009	CLE08	ESJ06	BIO	WW	3.1	Left	Green	Snout	3/15/2011	5/16/2011	190222	2,000	46,969	48,721
2009	CLE09	ESJ01	STF	WW	3.0	Right	Green	Snout	3/15/2011	5/16/2011	190223	2,000	43,612	45,379
2009	CLE10	ESJ02	BIO	WW	3.0	Left	Green	Snout	3/15/2011	5/16/2011	190224	2,000	43,173	44,962
2009	CLE11	JCJ05	STF	WW	3.1	Right	Orange	Snout	3/15/2011	3/31/2011	190225	2,000	47,585	49,306
2009	CLE12	JCJ06	BIO	WW	3.1	Left	Orange	Snout	3/15/2011	3/31/2011	190226	2,000	47,644	49,434
2009	CLE13	ESJ03	STF	WW	3.2	Right	Green	Snout	3/15/2011	5/16/2011	190227	2,000	45,277	47,036
2009	CLE14	ESJ04	BIO	WW	3.2	Left	Green	Snout	3/15/2011	5/16/2011	190228	2,000	45,529	47,208
2009	CLE15	JCJ03	STF	WW	3.1	Right	Orange	Snout	3/15/2011	3/31/2011	190229	2,000	43,825	45,592
2009	CLE16	JCJ04	BIO	WW	3.1	Left	Orange	Snout	3/15/2011	3/31/2011	190230	2,000	43,209	44,990
2009	CLE17	CFJ03	STF	WW	3.2	Right	Red	Snout	3/15/2011	5/16/2011	190231	2,000	45,587	47,451
2009	CLE18	CFJ04	BIO	WW	3.2	Left	Red	Snout	3/15/2011	5/16/2011	190232	2,000	43,952	45,571

[1] BIO = BioVita (BioOregon Protein Inc.) or control diet; STF = salt-water transition diet at acclimation sites. All fish are progeny of wild/natural parents unless denoted as HH which designates the hatchery control line beginning with brood year 2002. "Avg BKD" denotes the average BKD ELISA ranking of the female parents whose progeny were in these ponds.

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Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2015.

Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2010	CLE01	CFJ05	STF	WW	4.2	Right	Red	Snout	3/15/2012	5/14/2012	190256	2,000	40,221	41,972
2010	CLE02	CFJ06	BIO	WW	4.2	Left	Red	Snout	3/15/2012	5/14/2012	190257	2,000	40,845	42,664
2010	CLE03	CFJ03	STF	HH	4.0	Right	Red	Posterior Dorsal	3/15/2012	5/14/2012	190258	4,000	43,725	47,415
2010	CLE04	CFJ04	BIO	HH	4.0	Left	Red	Posterior Dorsal	3/15/2012	5/14/2012	190259	4,000	40,976	44,615
2010	CLE05	ESJ01	STF	WW	4.2	Right	Green	Snout	3/15/2012	5/14/2012	190260	2,000	40,710	42,374
2010	CLE06	ESJ02	BIO	WW	4.2	Left	Green	Snout	3/15/2012	5/14/2012	190261	2,000	40,419	42,157
2010	CLE07	JCJ01	STF	WW	4.0	Right	Orange	Snout	3/15/2012	5/14/2012	190262	2,000	43,833	45,471
2010	CLE08	JCJ02	BIO	WW	4.0	Left	Orange	Snout	3/15/2012	5/14/2012	190263	2,000	43,815	45,573
2010	CLE09	ESJ03	STF	WW	4.1	Right	Green	Snout	3/15/2012	5/14/2012	190264	2,000	42,528	44,257
2010	CLE10	ESJ04	BIO	WW	4.1	Left	Green	Snout	3/15/2012	5/14/2012	190265	2,000	42,649	44,443
2010	CLE11	ESJ05	STF	WW	4.2	Right	Green	Snout	3/15/2012	5/14/2012	190266	2,000	43,878	45,633
2010	CLE12	ESJ06	BIO	WW	4.2	Left	Green	Snout	3/15/2012	5/14/2012	190267	2,000	43,750	45,498
2010	CLE13	JCJ03	STF	WW	4.2	Right	Orange	Snout	3/15/2012	5/14/2012	190268	2,000	41,816	43,473
2010	CLE14	JCJ04	BIO	WW	4.2	Left	Orange	Snout	3/15/2012	5/14/2012	190269	2,000	41,052	42,772
2010	CLE15	JCJ05	STF	WW	4.1	Right	Orange	Snout	3/15/2012	5/14/2012	190270	2,000	42,894	44,603
2010	CLE16	JCJ06	BIO	WW	4.1	Left	Orange	Snout	3/15/2012	5/14/2012	190271	2,000	42,371	44,107
2010	CLE17	CFJ01	STF	WW	4.2	Right	Red	Snout	3/15/2012	5/14/2012	190272	2,000	42,329	44,128
2010	CLE18	CFJ02	BIO	WW	4.2	Left	Red	Snout	3/15/2012	5/14/2012	190273	2,000	41,829	43,626

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2011	CLE01	JCJ05	STF	WN	4.1	Right	Orange	Snout	3/15/2013	5/15/2013	190320	2,000	42,452	44,225
2011	CLE02	JCJ06	BIO	WN	4.1	Left	Orange	Snout	3/15/2013	5/15/2013	190321	2,000	42,217	44,056
2011	CLE03	CFJ05	STF	HC	4.0	Right	Red	Posterior Dorsal	3/15/2013	5/15/2013	190322	4,000	38,432	42,092
2011	CLE04	CFJ06	BIO	HC	4.0	Left	Red	Posterior Dorsal	3/15/2013	5/15/2013	190323	4,000	38,743	42,609
2011	CLE05	ESJ01	STF	WN	4.1	Right	Green	Snout	3/15/2013	5/15/2013	190324	2,000	38,404	40,250
2011	CLE06	ESJ02	BIO	WN	4.1	Left	Green	Snout	3/15/2013	5/15/2013	190325	2,000	37,931	39,731
2011	CLE07	CFJ01	STF	WN	4.1	Right	Red	Snout	3/15/2013	5/15/2013	190326	2,000	40,449	42,308
2011	CLE08	CFJ02	BIO	WN	4.1	Left	Red	Snout	3/15/2013	5/15/2013	190327	2,000	39,281	41,088
2011	CLE09	JCJ03	STF	WN	4.0	Right	Orange	Snout	3/15/2013	5/15/2013	190328	2,000	43,588	45,243
2011	CLE10	JCJ04	BIO	WN	4.0	Left	Orange	Snout	3/15/2013	5/15/2013	190329	2,000	41,715	43,288
2011	CLE11	ESJ05	STF	WN	4.0	Right	Green	Snout	3/15/2013	5/15/2013	190330	2,000	40,964	42,610
2011	CLE12	ESJ06	BIO	WN	4.0	Left	Green	Snout	3/15/2013	5/15/2013	190331	2,000	40,905	42,759
2011	CLE13	CFJ03	STF	WN	4.0	Right	Red	Snout	3/15/2013	5/15/2013	190332	2,000	42,298	44,190
2011	CLE14	CFJ04	BIO	WN	4.0	Left	Red	Snout	3/15/2013	5/15/2013	190333	2,000	41,111	43,003
2011	CLE15	JCJ01	STF	WN	3.9	Right	Orange	Snout	3/15/2013	5/15/2013	190334	2,000	42,769	44,590
2011	CLE16	JCJ02	BIO	WN	3.9	Left	Orange	Snout	3/15/2013	5/15/2013	190335	2,000	42,230	44,036
2011	CLE17	ESJ03	STF	WN	4.0	Right	Green	Snout	3/15/2013	5/15/2013	190336	2,000	39,770	41,479
2011	CLE18	ESJ04	BIO	WN	4.0	Left	Green	Snout	3/15/2013	5/15/2013	190337	2,000	39,823	41,625

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2012	CLE01	ESJ03	STF	WN	3.7	Right	Green	Snout	3/15/2014	5/15/2014	190367	2,000	44,358	45,902
2012	CLE02	ESJ04	BIO	WN	3.7	Left	Green	Snout	3/15/2014	5/15/2014	190368	2,000	44,999	46,758
2012	CLE03	CFJ03	STF	HC	3.8	Right	Red	Posterior Dorsal	3/15/2014	5/15/2014	190369	4,000	42,147	45,670
2012	CLE04	CFJ04	BIO	HC	3.8	Left	Red	Posterior Dorsal	3/15/2014	5/15/2014	190370	4,000	41,497	45,010
2012	CLE05	ESJ05	STF	WN	3.8	Right	Green	Snout	3/15/2014	5/15/2014	190371	2,000	43,627	45,512
2012	CLE06	ESJ06	BIO	WN	3.8	Left	Green	Snout	3/15/2014	5/15/2014	190372	2,000	44,507	46,420
2012	CLE07	CFJ05	STF	WN	3.7	Right	Red	Snout	3/15/2014	5/15/2014	190373	2,000	41,067	42,932
2012	CLE08	CFJ06	BIO	WN	3.7	Left	Red	Snout	3/15/2014	5/15/2014	190374	2,000	37,499	39,367
2012	CLE09	CFJ01	STF	WN	3.7	Right	Red	Snout	3/15/2014	5/15/2014	190375	2,000	42,001	43,629
2012	CLE10	CFJ02	BIO	WN	3.7	Left	Red	Snout	3/15/2014	5/15/2014	190376	2,000	38,364	40,124
2012	CLE11	JCJ01	STF	WN	3.8	Right	Orange	Snout	3/15/2014	5/15/2014	190377	2,000	41,425	43,279
2012	CLE12	JCJ02	BIO	WN	3.8	Left	Orange	Snout	3/15/2014	5/15/2014	190378	2,000	44,713	46,491
2012	CLE13	ESJ01	STF	WN	3.7	Right	Green	Snout	3/15/2014	5/15/2014	190379	2,000	42,619	44,499
2012	CLE14	ESJ02	BIO	WN	3.7	Left	Green	Snout	3/15/2014	5/15/2014	190380	2,000	45,217	47,119
2012	CLE15	JCJ03	STF	WN	3.7	Right	Orange	Snout	3/15/2014	5/15/2014	190381	2,000	43,330	45,200
2012	CLE16	JCJ04	BIO	WN	3.7	Left	Orange	Snout	3/15/2014	5/15/2014	190382	2,000	42,900	44,729
2012	CLE17	JCJ05	STF	WN	3.7	Right	Orange	Snout	3/15/2014	5/15/2014	190383	2,000	43,240	45,034
2012	CLE18	JCJ06	BIO	WN	3.7	Left	Orange	Snout	3/15/2014	5/15/2014	190384	2,000	43,257	45,041

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2013	CLE01	CFJ05	WN	3.8	Right	Red	Snout	3/15/2015	5/6/2015	190401	2,000	36,097	37,928
2013	CLE02	CFJ06	WN	3.8	Left	Red	Snout	3/15/2015	5/6/2015	190402	2,000	34,541	36,343
2013	CLE03	ESJ05	WN	3.7	Right	Green	Snout	3/15/2015	5/6/2015	190403	2,000	33,761	35,473
2013	CLE04	ESJ06	WN	3.7	Left	Green	Snout	3/15/2015	5/6/2015	190404	2,000	34,682	36,295
2013	CLE05	CFJ03	WN	3.9	Right	Red	Snout	3/15/2015	5/6/2015	190405	2,000	34,495	36,240
2013	CLE06	CFJ04	WN	3.9	Left	Red	Snout	3/15/2015	5/6/2015	190406	2,000	32,054	33,823
2013	CLE07	ESJ03	WN	3.8	Right	Green	Snout	3/15/2015	5/6/2015	190407	2,000	32,866	34,672
2013	CLE08	ESJ04	WN	3.8	Left	Green	Snout	3/15/2015	5/6/2015	190408	2,000	34,418	36,130
2013	CLE09	CFJ01	HC	3.8	Right	Red	Posterior Dorsal	3/15/2015	5/6/2015	190409	4,000	32,264	36,029
2013	CLE10	CFJ02	HC	3.7	Left	Red	Posterior Dorsal	3/15/2015	5/6/2015	190410	4,000	31,648	35,570
2013	CLE11	JCJ03	WN	3.7	Right	Orange	Snout	3/15/2015	5/6/2015	190411	2,000	34,948	36,725
2013	CLE12	JCJ04	WN	3.7	Left	Orange	Snout	3/15/2015	5/6/2015	190412	2,000	35,508	37,236
2013	CLE13	ESJ01	WN	3.6	Right	Green	Snout	3/15/2015	5/6/2015	190413	2,000	34,013	35,805
2013	CLE14	ESJ02	WN	3.6	Left	Green	Snout	3/15/2015	5/6/2015	190414	2,000	34,580	36,370
2013	CLE15	JCJ01	WN	3.7	Right	Orange	Snout	3/15/2015	5/6/2015	190415	2,000	32,151	33,810
2013	CLE16	JCJ02	WN	3.7	Left	Orange	Snout	3/15/2015	5/6/2015	190416	2,000	33,703	35,249
2013	CLE17	JCJ05	WN	3.8	Right	Orange	Snout	3/15/2015	5/6/2015	190417	2,000	35,987	37,604
2013	CLE18	JCJ06	WN	3.8	Left	Orange	Snout	3/15/2015	5/6/2015	190418	2,000	33,807	35,453

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Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2014	CLE01	JCJ01	VIT	WN	1.7	Right	Orange	Snout	3/15/2016	5/12/2016	190427	2,000	35,198	37,071
2014	CLE02	JCJ02	PRO	WN	1.7	Left	Orange	Snout	3/15/2016	5/12/2016	190428	2,000	33,966	35,853
2014	CLE03	ESJ05	VIT	WN	1.6	Right	Green	Snout	3/15/2016	5/12/2016	190429	2,000	33,202	35,121
2014	CLE04	ESJ06	PRO	WN	1.6	Left	Green	Snout	3/15/2016	5/12/2016	190430	2,000	32,271	34,191
2014	CLE05	CFJ01	VIT	WN	1.5	Right	Red	Snout	3/15/2016	5/12/2016	190431	2,000	34,849	36,728
2014	CLE06	CFJ02	PRO	WN	1.4	Left	Red	Snout	3/15/2016	5/12/2016	190432	2,000	33,272	35,097
2014	CLE07	JCJ05	VIT	WN	1.5	Right	Orange	Snout	3/15/2016	5/12/2016	190433	2,000	37,322	38,943
2014	CLE08	JCJ06	PRO	WN	1.5	Left	Orange	Snout	3/15/2016	5/12/2016	190434	2,000	36,493	38,274
2014	CLE09	CFJ03	VIT	WN	1.9	Right	Red	Snout	3/15/2016	5/12/2016	190435	2,000	36,883	38,786
2014	CLE10	CFJ04	PRO	WN	1.9	Left	Red	Snout	3/15/2016	5/12/2016	190436	2,000	34,619	36,507
2014	CLE11	JCJ03	VIT	WN	1.5	Right	Orange	Snout	3/15/2016	5/12/2016	190437	2,000	37,505	39,376
2014	CLE12	JCJ04	PRO	WN	1.5	Left	Orange	Snout	3/15/2016	5/12/2016	190438	2,000	35,212	37,016
2014	CLE13	ESJ01	VIT	WN	1.4	Right	Green	Snout	3/15/2016	5/12/2016	190439	2,000	37,387	39,279
2014	CLE14	ESJ02	PRO	WN	1.4	Left	Green	Snout	3/15/2016	5/12/2016	190440	2,000	38,002	39,894
2014	CLE15	ESJ03	VIT	WN	1.4	Right	Green	Snout	3/15/2016	5/12/2016	190441	2,000	37,749	39,146
2014	CLE16	ESJ04	PRO	WN	1.4	Left	Green	Snout	3/15/2016	5/12/2016	190442	2,000	36,736	38,626
2014	CLE17	CFJ05	VIT	HC	1.2	Right	Red	Posterior Dorsal	3/15/2016	5/12/2016	190443	4,000	40,014	43,232
2014	CLE18	CFJ06	PRO	HC	1.3	Left	Red	Posterior Dorsal	3/15/2016	5/12/2016	190444	4,000	38,272	42,090

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2015	CLE01	ESJ01	PRO	WN	2.9	Right	Green	Snout	3/15/2017	5/15/2017	190457	2,000	32,798	34,620
2015	CLE02	ESJ02	VIT	WN	2.9	Left	Green	Snout	3/15/2017	5/15/2017	190458	2,000	32,700	34,552
2015	CLE03	JCJ03	PRO	WN	2.9	Right	Orange	Snout	3/15/2017	5/15/2017	190459	2,000	38,469	40,305
2015	CLE04	JCJ04	VIT	WN	2.9	Left	Orange	Snout	3/15/2017	5/15/2017	190460	2,000	34,615	36,415
2015	CLE05	CFJ05	PRO	WN	2.9	Right	Red	Snout	3/15/2017	5/15/2017	190461	2,000	33,149	35,007
2015	CLE06	CFJ06	VIT	WN	2.9	Left	Red	Snout	3/15/2017	5/15/2017	190462	2,000	32,516	34,357
2015	CLE07	CFJ01	PRO	HC	2.6	Right	Red	Posterior Dorsal	3/15/2017	5/15/2017	190463	4,000	28,055	31,894
2015	CLE08	CFJ02	VIT	HC	2.6	Left	Red	Posterior Dorsal	3/15/2017	5/15/2017	190464	4,000	24,464	28,317
2015	CLE09	JCJ01	PRO	WN	3.0	Right	Orange	Snout	3/15/2017	5/15/2017	190465	2,000	38,098	39,927
2015	CLE10	JCJ02	VIT	WN	3.0	Left	Orange	Snout	3/15/2017	5/15/2017	190466	2,000	35,807	37,611
2015	CLE11	ESJ03	PRO	WN	2.8	Right	Green	Snout	3/15/2017	5/15/2017	190467	2,000	33,136	34,968
2015	CLE12	ESJ04	VIT	WN	2.8	Left	Green	Snout	3/15/2017	5/15/2017	190468	2,000	34,248	36,014
2015	CLE13	ESJ05	PRO	WN	2.8	Right	Green	Snout	3/15/2017	5/15/2017	190469	2,000	37,837	39,669
2015	CLE14	ESJ06	VIT	WN	2.8	Left	Green	Snout	3/15/2017	5/15/2017	190470	2,000	36,564	38,402
2015	CLE15	JCJ05	PRO	WN	2.9	Right	Orange	Snout	3/15/2017	5/15/2017	190471	2,000	34,354	36,206
2015	CLE16	JCJ06	VIT	WN	2.9	Left	Orange	Snout	3/15/2017	5/15/2017	190472	2,000	36,156	38,019
2015	CLE17	CFJ03	PRO	WN	2.8	Right	Red	Snout	3/15/2017	5/15/2017	190473	2,000	36,915	38,720
2015	CLE18	CFJ04	VIT	WN	2.8	Left	Red	Snout	3/15/2017	5/15/2017	190474	2,000	38,105	39,944

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Appendix C
2016 Annual Chandler Certification for Yearling Outmigrating Spring Chinook Smolt

Doug Neeley, Consultant to the Yakama Nation

Summary

Spring Chinook juvenile Prosser Passage was estimated using the following steps.

1) Estimating individual sampling rates from the Chandler Canal bypass;

2) Estimating detection efficiencies of the Chandler bypass detector;

3) Expanding daily tallies of sampled smolt by daily Step 1 sample-rate estimates and then dividing that expansion by Step 2 bypass-detection efficiencies to estimate the daily Prosser passage;

4) Multiplying naturally-spawned tally-based passage estimates by estimated proportions[1] of naturally-spawned smolt that are of American, Naches, and Upper Yakima River stock origin to the their respective passage estimates.

The resulting juvenile Prosser-passage estimates[2] are given in Table 1. Figure 1.a. presents the total naturally-spawned and total hatchery Prosser juvenile passages; Figure 1.b. presents separate estimates of naturally-spawned Prosser passages for each stock; and Figure 1.c. presents the proportional contributions of those stock to the naturally-spawned passage. In this report naturally-spawned and wild smolt are used interchangeably. The naturally-spawned Upper-Yakima juveniles are all from a naturally-spawned brood source, but a portion of the brood's parents are from naturally-spawned parents taken into hatchery for spawning, their progeny (brood source) being reared in the hatchery. There are no American and Naches stock hatchery components.

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[1] As of this writing, the 2016 stock-proportion estimates were not available.

[2] These estimates differ from any previously provided for reasons discussed in section <u>Hatchery Estimates and Evidence of Bias of Estimates</u> at the end of the text.

Table 1. Brood-Year 1997-2014 Estimated Spring Chinook Juvenile Passage by Stock

		Wild				Hatchery	
Brood Year	Outmigration Year	Total	American	Naches	Upper Yakima	Upper Yakima	Wild % of Upper Yakima
1997	1999	633,805	68,371	101,392	464,042	203,576	69.5%
1998	2000	159,998	40,862	44,707	74,430	243,835	23.4%
1999	2001	175,917	0	0	0	333,689	
2000	2002	532,726	20,329	105,236	407,161	419,381	49.3%
2001	2003	326,666	45,324	78,768	202,575	164,682	55.2%
2002	2004	162,673	34,379	57,597	70,696	279,593	20.2%
2003	2005	172,267	45,429	57,892	68,946	302,295	18.6%
2004	2006	203,250	12,023	76,192	115,035	459,205	20.0%
2005	2007	112,504	12,575	30,220	69,709	398,263	14.9%
2006	2008	137,784	7,820	37,415	92,550	305,335	23.3%
2007	2009	278,780	32,315	94,901	151,564	489,602	23.6%
2008	2010	215,683	29,631	75,552	110,500	374,129	22.8%
2009	2011	326,180	19,166	63,135	243,879	476,487	33.9%
2010	2012	429,896	39,323	135,716	254,857	652,866	28.1%
2011	2013	357,347	25,109	83,671	248,567	364,619	40.5%
2012	2014	268,598	29,201	81,059	158,337	417,277	27.5%
2013	2015	120,491	13,248	28,794	78,449	321,870	19.6%
2014*	2016*	160,556				427,733	

* Estimates For BY 2014 based on calibration ratio

Figure 1.a. Total Yakima Naturally-Spawned and Upper-Yakima Hatchery-Spawned Spring Chinook Juvenile Passage at Prosser

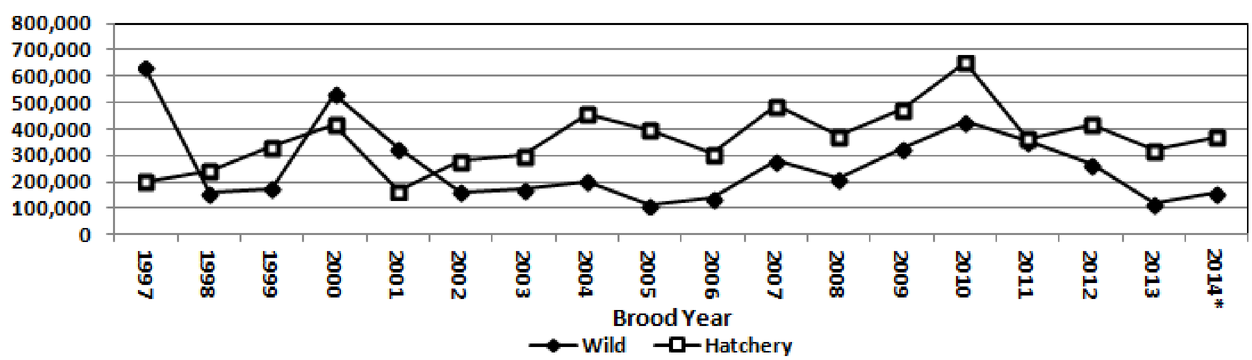


Figure 1.b. Total Yakama Naturally-Spawned Juvenile Prosser-Passage by Origin (Stock)

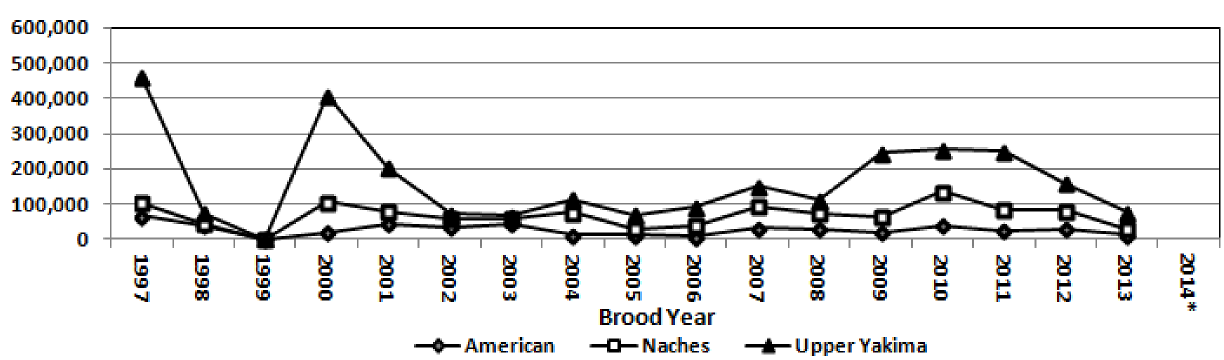
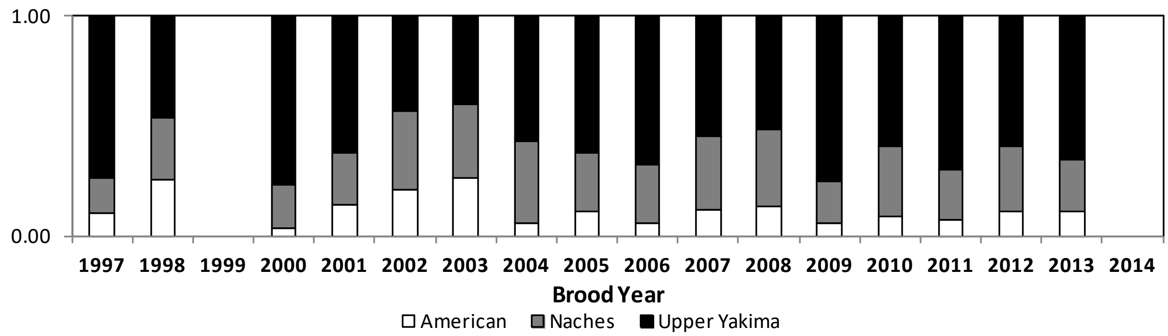


Figure 1.c. Proportional Composition of Naturally-Spawned Juvenile Prosser-Passage by Origin (Stock)



Methodology

The four steps listed in the introduction are detailed below.

Step 1: A timer gate, when opened, directs the bypass flow into the counting station carrying smolt with it. Timer-gate rate (TR) settings vary over days based on the number of the sampled smolt entering counting facility so as to not to overwhelm the capacity of the facility or the ability of the staff to tally those smolt by species and stock. For each timer-rate setting, the sample rate (SR) is computed by dividing the number of PIT-tagged Spring Chinook smolt detected in the sampling facility by total number detected by a bypass detector located upstream of the timer gate. The sample-rate estimates for each timer-gate rate setting are presented for each year in Appendix A.1.

Step 2: From outmigration year 1999[3] through 2014 estimates were derived by developing flow-based predictors of the smolt-entrainment rate into Chandler Canal and predictors of the survival of bypassed smolt from below the canal's headgates to the bypass detector. In some years, estimates of passage using these predictors were found to over-estimate passage, providing estimates of hatchery-smolt passage that exceeded the total number of hatchery smolt released. The methodology has been changed: The proportions of all PIT- tagged smolt released above Prosser and detected at mid-Columbia dams[4] that were previously detected in the Chandler Canal bypass serve as estimates of bypass-detection efficiency. There are actually four methods of estimating detection efficiency. These detection efficiency estimates were then applied to five sampled smolt passage periods at Prosser used for genetic sampling purposes: Pre-March, March, April, May, post-May. One of the methods has been selected based on findings contained in this report and is now being used for smolt-smolt survival estimates for Coho and Spring, Fall, and Summer Chinook as well as for the juvenile Prosser passage

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[3] **The first year that Spring Chinook hatchery smolt were released into the Upper Yakima and the first year that wild/naturally spawned smolt were sampled and genetically assigned to stock: Upper Yakima, Naches and American River broods.**

[4] **In order of downstream detection: McNary. John Day, and Bonneville Dams.**

estimates presented in this report. The four methods of estimating detection efficiencies are presented in Appendix A.2 along with their estimate assignment to the five periods.

Step 3. On a daily basis the sampled Spring Chinook smolt are tallied as to source (hatchery-spawned or naturally-spawned). These tallies are divided by the sample rates from Step 1. The sample-rate adjusted tallies for each source are added over days within each of five time periods and are then divided by the respective period's pooled detections efficiencies from Step 2.

Step 4: Within the time periods, the naturally-spawned smolt from Step 3. are subsampled and genetically assessed by the Washington Department of Fish and Wildlife (WDFW) as to brood origin (American, Naches, and Upper Yakima). Within each period, the brood proportions of those sampled smolt are computed by WDFW (Appendix A.3). The naturally-spawned passage estimates within each period from Step 3 are multiplied by each of the period's brood-source proportions. Each brood's time-period naturally-spawned passage estimates are then added over periods to estimate brood's total passages as are the hatchery passage estimates.

Different Passage Estimates

The results of four methods of juvenile-passage estimation are presented in Table 2.A.1) for naturally spawned smolt and in Table 2.A.2) for hatchery smolt. Also presented in those tables are passage estimates based on flow-based detection efficiency predictors used for outmigration years 2004[5]-2014. The problem with the flow-predictor-based estimates is illustrated in Table 2.A.2) wherein the hatchery juvenile-passage estimates exceed the numbers of hatchery smolt released in some outmigration years (note shaded cells in Table 2.A.2). For this reason the flow-predictor-based estimates have been rejected. Note that the shaded Brood Year (BY) 2014 estimates in both tables are impossibly large and a calibrated estimate is given. (Calibrated estimates are discussed in Section Hatchery Estimates and Evidence of Bias of Estimates , and all methods' estimates, both un-calibrated and calibrated are given in Appendix B.).

[5] **Separate flow-based passage estimates prior to 2004 were not separated into naturally-spawned and hatchery-spawned sources.**

Table 2.A.1) Naturally-Spawned Prosser Smolt Passage based on different Detections-Efficiencies

		Expanded Total Naturally-Spawned Juvenile Passage at Prosser based on four methods of estimating Prosser bypass detection efficiency estimated from detections in bypass and at mid-				
Brood Year	Outmigration Year	1.a) McNary* Stratified***	1.b) McNary* Unstratified****	1.c) Pooled over Mid-Columbia Dams** Stratified***	1.d) Pooled over Mid-Columbia Dams** Unstratified****	Flow-based Predictors of Daily Detection Efficiencies used in the past
1997	1999	619,099	541,799	633,805	613,350	
1998	2000	178,387	107,274	159,998	108,568	
1999	2001	177,893	165,654	175,917	166,004	
2000	2002	533,244	393,510	532,726	406,565	
2001	2003	326,245	306,029	326,666	313,743	
2002	2004	*165,079*	159,296	162,673	153,933	601,563
2003	2005	170,146	162,952	172,267	166,813	416,670
2004	2006	192,734	202,426	203,250	200,641	269,841
2005	2007	112,224	112,441	112,504	112,967	237,713
2006	2008	121,350	146,490	137,784	163,016	643,950
2007	2009	267,142	353,229	278,780	369,392	225,963
2008	2010	215,600	197,149	215,683	200,716	322,561
2009	2011	323,281	270,507	326,180	276,077	482,608
2010	2012	520,794	635,616	429,896	590,173	376,890
2011	2013	350,393	326,935	357,347	349,607	294,585
2012	2014	252,195	243,897	268,598	259,122	170,299
2013	2015	117,939	118,585	120,491	122,717	
2014	2016	1,946,118	1,362,051	2,055,187	1,562,109	
2014*****	2016*****	157,621	128,134	160,556	146,954	

* Detection (DE) efficiency based on only McNary Dam

** DE based on pooled Estimates from McNary, John Day, and Bonneville Dams

*** Stratified by similar daily detection efficiency rates from Columbia River dams periods at Prosser

**** No stratification: DE = (Total joint Prosser and lower dam detections)/(Total lower dam detections)

***** BY 2014 estimate based on calibrated estimate discussed in Appendix A.4.

Table 2.A.2) Hatchery-Spawned Prosser Smolt Passage based on different Detections-Efficiencies

		Expanded Upper-Yakima Hatchery Juvenile Passage at Prosser based on four methods of estimating Prosser bypass detection efficiency estimated from detections in bypass and at mid-Columbia dam detections			
Brood Year	Out-Migration Year	1.a) McNary* Stratified***	1.b) McNary* Unstratified****	1.c) Pooled over Mid-Columbia Dams** Stratified***	1.d) Pooled over Mid-Columbia Dams** Unstratified****
1997	1999	179,134	168,334	203,576	190,564
1998	2000	235,749	238,829	243,835	241,709
1999	2001	333,797	329,434	333,689	330,130
2000	2002	405,907	406,629	419,381	420,120
2001	2003	161,493	163,771	164,682	167,898
2002	2004	*282,357*	300,717	279,593	290,593
2003	2005	291,597	295,696	302,295	302,701
2004	2006	432,303	468,884	459,205	464,749
2005	2007	397,110	398,240	398,263	400,104
2006	2008	269,448	253,743	305,335	282,369
2007	2009	459,012	443,790	489,602	464,097
2008	2010	367,906	379,282	374,129	386,144
2009	2011	463,350	484,840	476,487	494,822
2010	2012	682,404	670,120	652,866	622,211
2011	2013	344,280	335,437	364,619	358,699
2012	2014	392,491	382,606	417,277	406,490
2013	2015	314,538	315,912	321,870	326,920
2014	2016	4,908,275	4,349,960	5,475,179	4,988,882
2014*****	2016*****	397,534	409,219	427,733	469,325

* Detection (DE) efficiency based on only McNary Dam

** DE based on pooled Estimates from McNary, John Day, and Bonneville Dams

*** Stratified by similar daily detection efficiency rates from Columbia River dams periods at Prosser

**** No stratification: DE = (Total joint Prosser and lower dam detections)/(Total lower dam detectior

***** BY 2014 estimate based on calibrated estimate discussed in Appendix A.4.

Naturally-Spawned Passage Estimators' Correlations with Returns

To ascertain which of the non-flow based estimated passage estimates is the "best", the decision was made to correlate the Naturally-spawned juvenile Prosser passage with estimates of return from the report 2016 Run Size Forecast for Yakima River Adult Spring Chinook.

Two sets of Pearson's Correlation Coefficients were estimated:

1) Estimated Upper Yakima naturally-spawned juvenile Prosser passage correlated with estimated upper Yakima naturally-spawned returns to Roza Dam (derived from Forecast Table 4) produced by that brood's outmigration; and

2) Estimated total naturally-spawned Prosser juvenile passage correlated with estimated total Yakima Basin naturally-spawned returns to Prosser Dam (derived from Forecast Table 3) produced by that brood's outmigration.

For reference purposes, relative values of estimated values of Pearson's Correlation Coefficients are classified based on Table 3.

Table 3. Correlation Coefficient (r) range

Very High	0.90	≤ r ≤	1.00
Moderately High	0.75	≤ r <	0.90
Moderate	0.25	≤ r <	0.75
Moderately Low	0.10	≤ r <	0.25
Very Low	0.00	≤ r <	0.10

The respective data sets used for the correlations are presented in Table 4.A. and Table 4.B. along with Pearson's Correlation Coefficient estimates and associated 1-sided Type 1 error probabilities for a positive correlation. Note that there were no separate listings for Age 4 and 5 returns in the Forecast Tables; therefore Age 5 Roza returns are assigned to the incorrect brood year. The resulting bias associated with Table 4.A. will be small because the Roza returns' proportions of Age 5 returns are small. In Table 4.B., in addition to Upper Yakima Prosser returns, the Prosser return numbers include Naches and American stock returns which, in addition to Age-3 and Age-4 returns, have Age-5 and possibly some age-6 returns that are individually tallied; therefore there should be even less bias associated with these estimates.

The Prosser detection-efficiency estimator selected is the one with the highest juvenile -passage correlation with adult-return, which for both tables is column c), the juvenile-passage estimate based on stratified detection efficiencies that are pooled from three mid-Columbia dams[6].

From Tables 4.A. and 4.B., respective Figures 2.A.and 2.B. present the return estimates and column c) Juvenile-passage estimates[7]. Also presented are juvenile Prosser passage correlations with return estimates. The reason that the calibrated estimates are not presented here is that the comparable correlations based on stratified detection rate estimates are higher for the non-calibrated than the calibrated estimates. However, calibrated estimates are discussed later.

[6] Bonneville, John Day, and McNary dams

[7] The column a) estimates have the highest correlations with return estimates for both the Table 3.A. Upper Yakima and the Table 3.B. Prosser naturally-spawned juvenile passage estimates.

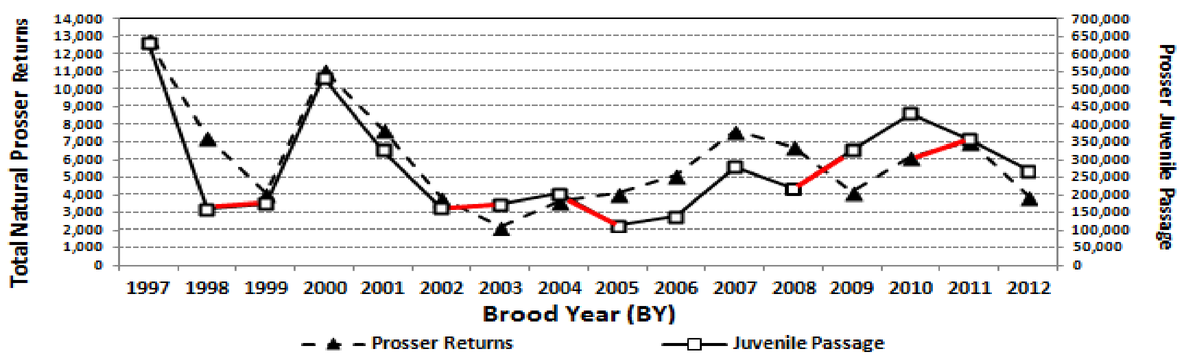
Table 4.A. Upper-Yakima Naturally-Spawned Juvenile-Passage Estimates and Roza-Return Assignments and Brood Year 1997-2011 Correlations

(yellow highlighted columns used in analysis)

		Expanded Upper Yakima Naturally-Spawned Juvenile Passage at Roza				
Brood Year	Out-Migration Year	1.a) McNary* Stratified***	1.b) McNary* Unstratified ****	1.c) Pooled over Mid-Columbia Dams** Stratified***	1.d) Pooled over Mid-Columbia Dams** Unstratified ****	Naturally-Spawned Roza Returns (Forecast Table 4)
1997	1999	462,195	401,314	464,042	454,312	5,540
1998	2000	86,605	39,764	74,430	40,244	2,741
1999	2001	Stock-based Genetic Data not Available				917
2000	2002	407,565	300,615	407,161	310,588	7,867
2001	2003	202,248	189,971	202,575	194,760	5,587
2002	2004	*71,799*	68,104	70,696	65,811	2,116
2003	2005	67,930	64,422	68,946	65,949	1,245
2004	2006	109,094	114,528	115,035	113,518	1,611
2005	2007	68,947	70,371	69,709	70,701	2,552
2006	2008	81,499	101,377	92,550	112,814	3,488
2007	2009	145,727	195,845	151,564	204,806	3,877
2008	2010	110,497	101,421	110,500	103,255	3,655
2009	2011	241,589	202,769	243,879	206,944	2,294
2010	2012	310,128	379,309	254,857	352,191	4,155
2011	2013	244,835	227,650	248,567	243,437	4,498
2012	2014	148,099	140,748	158,337	149,534	2,618
2013	2015	77,298	77,664	78,449	80,370	281
2014	2016	Stock-based Genetic Data not yet Provided				

Figure 2.A. Upper-Yakima Naturally-Spawned Juvenile Prosser-Passage Estimates and Naturally-Spawned Roza-Returns* Assignments

Figure 1.B. Total Yakama Naturally-Spawned Juvenile Prosser-Passage Estimates and Prosser-Return Assignments*



*Inclusive of Wild/Natural of Upper Yakima, Wild Naches, and American Stock from Forecast Table 3 where Jacks are assigned to Brood Year + 3 and Adults to Brood Year + 4

NOTE: Red line indicates Roza Return change from one year the next is opposite in direction of that of Escapement

	All Years	Omit BY 2000	Sign test of trends	
			Same Trend	10
Pearson's Correlation Coefficient	0.8052	0.7526	Total Trends	15
t Ratio	5.08	4.12	Percentage	66.7%
1-sided p for positive true Correlation > 1	0.000084	0.00060	1-sided P	0.1509

Table 4.B. Total Yakima Naturally-Spawned Juvenile Prosser-Passage Estimates and Prosser-Return Assignment and Brood Year 1997-20112 Correlations

(yellow highlighted columns used in analysis)

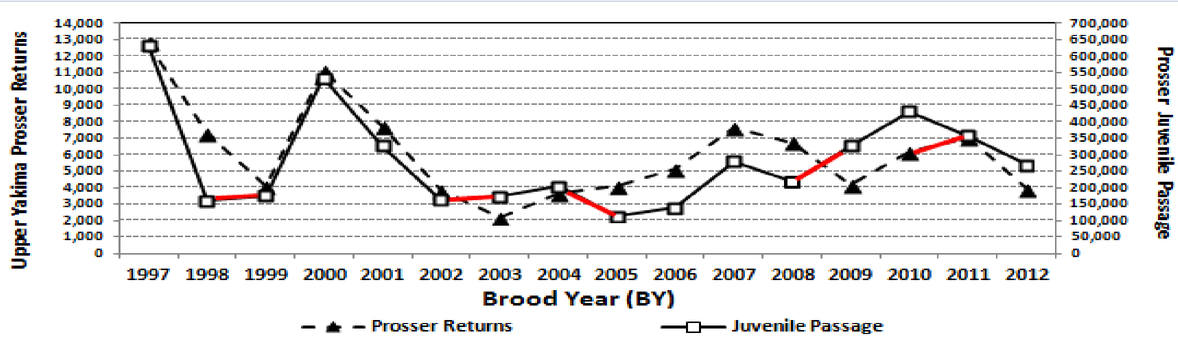
		Expanded Total Naturally-Spawned Juvenile Passage at Prosser				
Brood Year	Out-Migration Year	1.a) McNary* Stratified ***	1.b) McNary* Unstratified****	Pooled over Mid-Columbia Dams** Stratified ***	1.d) Pooled over Mid-Columbia Dams** Unstratified** **	Naturally-Spawned Prosser Returns (Forecast Table 3)
1997	1999	619,099	541,799	633,805	613,350	12,808
1998	2000	178,387	107,274	159,998	108,568	7,283
1999	2001	177,893	165,654	175,917	166,004	4,090
2000	2002	533,244	393,510	532,726	406,565	11,128
2001	2003	326,245	306,029	326,666	313,743	7,731
2002	2004	*165,079*	159,296	162,673	153,933	3,850
2003	2005	170,146	162,952	172,267	166,813	2,195
2004	2006	192,734	202,426	203,250	200,641	3,687
2005	2007	112,224	112,441	112,504	112,967	4,089
2006	2008	121,350	146,490	137,784	163,016	5,118
2007	2009	267,142	353,229	278,780	369,392	7,610
2008	2010	215,600	197,149	215,683	200,716	6,739
2009	2011	323,281	270,507	326,180	276,077	4,167
2010	2012	520,794	635,616	429,896	590,173	6,148
2011	2013	350,393	326,935	357,347	349,607	7,002
2012	2014	252,195	243,897	268,598	259,122	3,941
2013	2015	117,939	118,585	120,491	122,717	555
2014	2016	157,621	128,134	160,556	146,954	

Pearson's Juvenile Passage Correlation Coefficient with Return

	1.a)	1.b)	Pooled Stratified	1.d)
Correlation	0.7721	0.6159	0.8052	0.6833
t-ratio	4.55	2.93	5.08	3.50
Type 1 Error p *****	0.00023	0.00554	0.00008	0.00176

* Prosser Detection efficiency (DE) based on only McNary Dam
** Prosser DE based on pooled DE estimates from McNary, John Day, and Bonneville Dams
*** A mid-Columbia Dam stratum having similar adjacent-day Prosser detection efficiencies
**** No stratification
***** 1-sided test for positive correlation
NOTE: Dark grey-shaded cells reflect incomplete returns
NOTE: Year's with any grey shading not included in correlations.

Figure 2.B. Total Yakima Basin Naturally-Spawned Juvenile Prosser-Passage Estimates and Naturally-Spawned Prosser-Returns* Assignments



*Inclusive of Wild/Natural of Upper Yakima, Wild Naches, and American Stock from Forecast Table 3 where Jacks are assigned to Brood Year + 3 and Adults to Brood Year + 4

NOTE: Red line indicates Roza Return change from one year the next is opposite in direction of that of Escapement

	All Years	Omit BY 2000	Sign test of trends	
Pearson's Correlation Coefficient	0.8052	0.7526	Same Trend	10
t Ratio	5.08	4.12	Total Trends	15
1-sided p for positive true Correlation > 1	0.000084	0.00060	Percentage	66.7%
			1-sided P	0.1509

In both Table 4.A. and 4.B. the highest correlation estimates are associated with estimate c), **r = 0.78** and **r = 0.81,** respectively. Both estimates are moderately high and highly significantly larger than 0 (Type 1 Error p = 0.0003 and p =0.0001, respectively). When the one brood year that appeared to contribute most to those correlation coefficients (brood year 2000) was omitted, the correlation estimate of the Upper Yakima Prosser smolt passage (Figure2 .a.) increased slightly (from 0.78 to 0.79), but the correlation between total Prosser juvenile passage and total Prosser return (Figure 2.B.) decreased (from = 0.81 to r = 0.75). It is noted here that the year-to-year trends are similar in direction for the juvenile passage and the return estimates, the trends are the same in 79% of the 15 yearly differences in Figure 2.a. and in 67% of the 16 yearly differences in Figure 2.b., the former being significant at the 5% level based on a 1-sided test (those juvenile trends that differ in direction from return trends are given in red in Figures 2.A and 2.B.).

Adjusting Effect of Naturally-spawned Juvenile Passage Estimate's Correlation with Return for the effect of Spawner Number

The effect of the spawner number on naturally-spawned juvenile Prosser passage and return is assessed. In addition to the earlier presented estimates of juvenile Prosser passage and Upper Yakima (Roza) return assignments (Table 4.a.), Table 5.A. presents the brood-year Upper Yakima (Roza) escapement from Table 6. of the 2016 Run Size Forecast for Yakima River Adult Spring Chinook report. Table 5.B. presents the correlations among these three variables; Table 5.C. presents the partial correlation between the juvenile passage and associated return adjusted for the number of spawners. The Upper Yakima escapement is used as an indicator of spawner number.

From Table 5.B. it can be seen that Upper Yakima returns are positively correlated to both the number of spawners (escapement) and the juvenile passage. The question is to what degree, if any, is the contribution of Juvenile passage to return affected by the brood's spawner number. Table 5.C. is an attempt to answer that question. The table adjusts the correlation between juvenile passage and return for the spawner number. The adjusted rounded correlation of juvenile passage with return number is hardly affected by spawner number, the rounded correlations being 0.78 (Table 5.B.) and 0.77 (Table 5.C.) for the respective unadjusted and adjusted estimates. This indicates that the moderately high Upper Yakima juvenile Prosser passage correlation with return is not indirectly tied to the number of naturally spawning brood fish that produced those juvenile. Had there been a notable reduction in the correlations from Table 5.B. to Table 5.C., it might be inferred that spawner number had an measureable impact on the juvenile passage and return correlation, but such was not the case.

Table 5.A. Upper-Yakima in-stream Spawners and Naturally-Spawned Juvenile Prosser Passage and Return to Prosser

Brood Year	Out-migration Year	Upper Yakima Escapement (Forecast Table 6)	Juvenile Passage	Roza Returns (Forecast Table 4)
1997	1999	1,184	464,042	5,540
1998	2000	387	74,430	2,741
1999	2001	966	not available	917
2000	2002	11,660	407,161	7,867
2001	2003	11,798	202,575	5,587
2002	2004	8,044	70,696	2,116
2003	2005	3,258	68,946	1,245
2004	2006	10,287	115,035	1,611
2005	2007	5,685	69,709	2,552
2006	2008	3,364	92,550	3,488
2007	2009	2,309	151,564	3,877
2008	2010	4,334	110,500	3,655
2009	2011	7,038	243,879	2,294
2010	2012	8,374	254,857	4,155
2011	2013	8,584	248,567	4,498
2012	2014	5,476	158,337	2,618
2013	2015	4,813	78,449	281
2014	2016	6,728	not provided	0

NOTE: Dark shaded cells reflect incomplete returns

Table 5.B. Upper Yakima Escapement, Prosser Juvenile Passage, and Upper Yakima Return Correlations

	Upper-Yakima Escapement	Juvenile Prosser Passage	Upper-Yakima Returns
Escapement	1.0000		
Passage	0.2152	1.0000	
Returns	**0.3149**	**0.7787**	1.0000
t -Ratio	1.20	4.47	
Type 1 Error *	0.3789	0.0003	

NOTE: Year's with any shading in Table 5.A. not included in correlations.
* 1-sided test for positive correlation

Table 5.C. Upper Yakima Juvenile Passage and Return Correlations adjusted for Escapement

	Juvenile Prosser Passage	Upper-Yakima Returns
Passage	1.0000	
Returns	**0.7670**	1.0000
t -Ratio	4.31	
Type 1 Error*	0.0004	

NOTE: Year's with any shading in Table 5.A. not included in correlations.
* 1-sided test for positive correlation

Hatchery Estimates and Evidence of Bias of Estimates

There is evidence of bias in juvenile passage in some years. Table 6.a. presents estimates of Hatchery Prosser-to-McNary survival computed by taking estimates of Release-to-McNary Survival from other reports and dividing them by estimates of release-to-Prosser survival from this report's analysis.

The selected 1999-outmigrant estimator (Tables 6.a. Column 5) gave a 102% Prosser-to-McNary survival estimate (Brood Year 1997). The other three 1999 estimators gave even higher estimates of Prosser-to-McNary survival. The 1999 Release-to-McNary survival estimate is the highest of all of the years. However, this high release-to-McNary survival may not be the cause of the impossibly high Prosser-to-McNary estimate. The proportion of hatchery PIT-tagged hatchery smolt detected in the bypass that were previously detected leaving acclimation sites should be comparable to the proportion of PIT-tagged smolt detected leaving the acclimation sites. This is true for all years except for 1999 outmigrants (Table 6.a. Column 7 value = 0.243 versus Column 8 value = 0.998). This may indicate that the bias in the Prosser-to-McNary survival estimates are associated with Prosser passage information and not due to variables used to estimate release-to-McNary survival.

There were serious problems with the 2016 estimates. The selected 1999-outmigrant estimator gave a wildly high and impossible estimate of 2016 Release-to-Prosser survival (799%) and a resulting near 0% estimate of Prosser-to-McNary survival. The other three 2016 estimators gave Release-to-Prosser survival estimates of over 700% as well. In this case the problem may again be a Prosser issue. Column 10 of Table 6.a. gives the total detections when the Timer-Gate (TR) settings were at 33% and 50%. The number of sample room detections in 2016 was the lowest by far, and those TR settings were the only ones for which fish were run through the sample room detector in 2016. In several previous years there were other TR settings, so the detection numbers for than those years were even higher than those given in the table.

None of other years' passage and survival estimates stand out, and the shaded values of associated variables for outmigration year 2000 through 2015 were likely not problematic.

The Release-to-McNary survivals that were given in the 2015 Annual Report were found to have been in error, and have been re-estimated. The 2015 report indicated biases associated with 2010 releases which this report does not; however the 2015 report indicated no bias associated with the 2009 releases which this report does. As yet, there has been no resolution to the as to how to correct the 1999 biases.

Estimates based on calibration of Estimator c) are given in Table 6.b., and the 2016 calibrated estimate of Prosser Passage is being used in place of the un-calibrated estimate[8]. The formulas for calculating the calibrator is discussed preceding Table 6.b.

[8] The calibrated 2009 release had a less than a 100% calibrated Prosser-to McNary estimate (99%): however, it barely differed from the 102% un-calibrated estimate; therefore the 99% estimate was not substituted for the 102% estimate.

Table 6.a. Expanded Hatchery Survival Estimates based on Stratified Pooled* Dam estimator and associated variables

Brood Year	Out-migration Year	1. Estimated Juvenile Prosser Passage	2. Release Number	3. Release-to-Prosser Survival (1./2.)	4. Release-to-McNary Survival*	5. Prosser-to-McNary Survival (4./3.)	6. Sampling Rate for Timer Rate Setting = 33%	7. Chandler Bypass Proportion Previously Detected at Release	8. Proportion of PIT-tagged smolt detected leaving Acclimation Sites	9. Pooled McNary Detection Efficiency	10. McNary sample room detections for TR = 33% and 50%
1997	1999	203,576	386,048	52.73%	53.8%	102.09%	27.50%	0.243	0.998	0.266	4,413
1998	2000	243,835	589,648	41.35%	36.15%	87.42%	26.20%	0.995	0.972	0.298	8,482
1999	2001	333,689	758,789	43.98%	23.33%	53.05%	9.18%	0.998	0.975	0.768	9,103
2000	2002	419,381	834,285	50.27%	30.81%	61.30%	27.65%	0.997	0.938	0.462	950
2001	2003	164,682	370,236	44.48%	30.63%	68.85%	22.06%	0.943	0.912	0.452	17,360
2002	2004	279,593	836,904	33.41%	18.71%	56.01%	22.86%	0.997	0.975	0.491	12,079
2003	2005	302,295	824,692	36.66%	14.72%	40.17%	25.61%	0.992	0.973	0.411	3,476
2004	2006	459,205	785,448	58.46%	28.17%	48.18%	33.00%**	0.997	0.910	0.336	5,960
2005	2007	398,263	860,002	46.31%	31.50%	68.03%	26.41%	0.991	0.978	0.355	7,723
2006	2008	305,335	642,795	47.50%	29.35%	61.80%	21.49%	0.998	0.965	0.277	6,125
2007	2009	489,602	771,265	63.48%	40.66%	64.04%	25.40%	0.994	0.965	0.370	4,809
2008	2010	374,129	849,305	44.05%	31.32%	71.09%	19.28%	0.994	0.975	0.259	13,227
2009	2011	476,487	832,941	57.21%	32.38%	56.60%	33.00%**	0.936	0.906	0.279	7,722
2010	2012	652,866	794,781	82.14%	39.82%	48.47%	32.29%	0.994	0.968	0.265	3,175
2011	2013	364,619	769,182	47.40%	35.18%	74.21%	32.10%	0.992	0.954	0.237	8,471
2012	2014	417,277	802,716	51.98%	33.49%	64.42%	29.81%	0.996	0.959	0.237	2,643
2013	2015	321,870	646,755	49.77%	29.16%	58.59%	27.39%	0.993	0.957	0.198	11,256
2014	2016	5,475,179	685,230	799.03%	34.93%	4.37%	28.81%	0.993	0.953	0.273	620

The calibration was intended to adjust for possible unknown biases associated Prosser sampling. The hatchery counts that are expanded are those of the total of tallied body-tagged (coded-wire and elastomer tagged) sampled smolt. These expansions are then divided by the proportion of released fish that are body tagged. This is done in order to include released PIT-tagged smolt because the PIT-tagged smolt were not tagged with body tags. This expansion would be biased to the degree that PIT-tagged smolt and body-tagged smolt differed in their survival or tag shedding rates.

To deal with possible issues with the sampling rates of PIT tagged smolt, the expanded estimates were multiplied by a calibration factor computed as follows.

$$\text{Calibrator} = \frac{\Sigma[(\text{All Body Hatchery Smolt detected in Bypass})/(\text{Detection Efficiency})]}{(\text{Proportion of Released Smolt that were PIT-tagged}) * (\text{Expanded Passage of all Hatchery Smolt})}$$

The summation is over the genetic sampling strata (pre-March, March, April, May, post-May). The calibration values differed for the four estimation methods within each year. These hatchery-smolt base calibrations were applied to expanded naturally-spawned passage estimates as well as to hatchery passage estimates. The calibrated passage estimates are given Table 6.b.

Table 6.b. Calibration of expanded Hatchery Survival Estimates based on Stratified Pooled* Dam estimators and associated variables

Brood Year	Out-migration Year	1. Estimated Juvenile Prosser Passage	2. Release Number	3. Release-to-Prosser Survival (1./2.)	4. Release-to-McNary Survival*	5. Prosser-to-McNary Survival (4./3.)
1997	1999	210,026	386,048	54.40%	53.83%	98.95%
1998	2000	319,738	589,648	54.23%	36.15%	66.67%
1999	2001	290,690	758,789	38.31%	23.33%	60.90%
2000	2002	364,837	834,285	43.73%	30.81%	70.46%
2001	2003	159,457	370,236	43.07%	30.63%	71.11%
2002	2004	301,129	836,904	35.98%	18.71%	52.00%
2003	2005	244,018	824,692	29.59%	14.72%	49.76%
2004	2006	304,868	785,448	38.81%	28.17%	72.58%
2005	2007	361,729	860,002	42.06%	31.50%	74.90%
2006	2008	275,351	642,795	42.84%	29.35%	68.53%
2007	2009	424,951	771,265	55.10%	40.66%	73.79%
2008	2010	393,496	849,305	46.33%	31.32%	67.59%
2009	2011	423,088	832,941	50.79%	32.38%	63.74%
2010	2012	401,466	794,781	50.51%	39.82%	78.83%
2011	2013	780,410	769,182	101.46%	35.18%	34.67%
2012	2014	413,954	802,716	51.57%	33.49%	64.94%
2013	2015	371,970	646,755	57.51%	29.16%	50.70%
2014	2016	427,733	685,230	62.42%	34.93%	55.95%

NOTE: Dark shaded areas indicate passage survival bias, low detection -

The reason that the Calibrated estimates were rejected in general is that the correlation between Upper Yakima Juvenile Prosser passage and Upper-Yakima return was lower for the calibrated than the un-calibrated estimate within each of the estimation methods (Table 6.c).

Table 6.c. Upper Yakima Juvenile Passage and Return Correlations for eight methods of estimation

	Expanded Upper-Yakima Estimates				Calibrated Expanded Estimates			
	McNary-based Expansion		Pooled-Dam-based Expansion		McNary-based Expansion		Pooled-Dam-based Expansion	
Measure	**Stratified**	**Not Stratified**	**Stratified**	**Not Stratified**	**Stratified**	**Not Stratified**	**Stratified**	**Not Stratified**
r	**0.7723**	0.6910	**0.7787**	0.7054	**0.6695**	0.5997	**0.6657**	0.5920
r^2	**0.5964**	0.4775	**0.6063**	0.4976	**0.4482**	0.3596	**0.4431**	0.3505
SE(r)	**0.1762**	0.2005	**0.1740**	0.1966	**0.2060**	0.2219	**0.2070**	0.2235
df	**13**	13	**13**	13	**13**	13	**13**	13
t	**4.3832**	3.4468	**4.4744**	3.5885	**3.2496**	2.7019	**3.2161**	2.6485
p	**0.0004**	0.0022	**0.0003**	0.0017	**0.0032**	0.0091	**0.0034**	0.0100

Even though the calibrated correlations had lower correlations than the un-calibrated, the decision was made to use the 2014 brood-year calibrated estimate of 2016 Juvenile passage. The BY 1997 calibrated brood-year estimate of Prosser-to-McNary survival barely differed from that of the un-calibrated estimate so the un-calibrated estimate of passage was retained.

Appendix A.1 Timer-Gate Rate (TR) and Sample-Rates Estimates (SR)

The sample rates used are the calibrated estimates given below. With exception of timer-gate rate = 100%, the calibration is based on the most common timer-gate rates[9] used (TR = 33% and TR = 50%). This is because, with the exception of TR = 100%, the non-33%/50% timer-gate rates are rarely used and are , therefore, based on too few detections to give reliable estimates of the sample rates. The calibration rate is calculated as follows:

The calibration rate = (total of TR-33% and TR-50% sample-facility detections)/(total of TR-33% and TR-50% bypass detections)

The TR = 100% sample rate is based on all days over all years when the smolt were actually run through the counting-facility detector. When the river temperatures are high late in the outmigration, the fish are usually transported without running them through the sample-facility detector.

In cases where SR values exceeded the TR = 33% the SR values were equated to the TR values. This was because SR values for other TR settings were near or less than their TR values. Over years, SR values strongly tend to be lower than their TR values.

In the case of outmigration year 2001, the actual values are extremely low for both TR = 33% and TR = 50%. In the case of outmigration year 2010 which had next to the lowest sample rates, the TR = 33% actual SR value was very low but the actual value of SR for TR = 50% was comparable to several of the values in other years but was based on only 8 days of detections. The fact that the hatchery Prosser-to-McNary survival rates for those two years are well within the range of those over all of the years indicate that the low sample rates (which strongly impact the release-to-McNary estimates) were not problematic.

[9] **Timer Gate Rate is proportion of time that the bypass gate is opened to Sample Room**

Table A.1. Sample Room Sample Rates for given Timer-Gate settings.

Out-Migration Year	Calibration Value	Estimated Sample Rates* (SR) for different Timer-Gate Rates									
		Timer-Gate Rate (TR)									
		0.05	0.1	0.2	0.25	0.33	0.4	0.45	0.5	0.75	1
1999	0.833	4.2%	8.3%	16.7%	20.8%	27.5%	33.3%	37.5%	41.7%	62.5%	97.8%
2000	0.794	4.0%	7.9%	15.9%	19.8%	26.2%	31.8%	35.7%	39.7%	59.5%	97.8%
2001	0.278	1.4%	2.8%	5.6%	7.0%	9.2%	11.1%	12.5%	13.9%	20.9%	97.8%
2002	0.838	4.2%	8.4%	16.8%	20.9%	27.7%	33.5%	37.7%	41.9%	62.8%	97.8%
2003	0.669	3.3%	6.7%	13.4%	16.7%	22.1%	26.7%	30.1%	33.4%	50.1%	97.8%
2004	0.693	3.5%	6.9%	13.9%	17.3%	22.9%	27.7%	31.2%	34.6%	52.0%	97.8%
2005	0.776	3.9%	7.8%	15.5%	19.4%	25.6%	31.0%	34.9%	38.8%	58.2%	97.8%
2006	1.000	5.0%	10.0%	20.0%	25.0%	33.0%	40.0%	45.0%	50.0%	75.0%	97.8%
2007	0.800	4.0%	8.0%	16.0%	20.0%	26.4%	32.0%	36.0%	40.0%	60.0%	97.8%
2008	0.651	3.3%	6.5%	13.0%	16.3%	21.5%	26.0%	29.3%	32.6%	48.8%	97.8%
2009	0.770	3.8%	7.7%	15.4%	19.2%	25.4%	30.8%	34.6%	38.5%	57.7%	97.8%
2010	0.584	2.9%	5.8%	11.7%	14.6%	19.3%	23.4%	26.3%	29.2%	43.8%	97.8%
2011	1.000	5.0%	10.0%	20.0%	25.0%	33.0%	40.0%	45.0%	50.0%	75.0%	97.8%
2012	0.979	4.9%	9.8%	19.6%	24.5%	32.3%	39.1%	44.0%	48.9%	73.4%	97.8%
2013	0.973	4.9%	9.7%	19.5%	24.3%	32.1%	38.9%	43.8%	48.6%	72.9%	97.8%
2014	0.903	4.5%	9.0%	18.1%	22.6%	29.8%	36.1%	40.7%	45.2%	67.8%	97.8%
2015	0.830	4.1%	8.3%	16.6%	20.7%	27.4%	33.2%	37.3%	41.5%	62.2%	97.8%
2016	0.873	4.4%	8.7%	17.5%	21.8%	28.8%	34.9%	39.3%	43.7%	65.5%	97.8%

*** Except for TR = 1 estimates rates = TR x Calibration Value, the calibrated value being that used the expand daily sample counts, for TR = 1, estimate is total sample room detection divided by total bypass detections over all years**

Appendix A.2 Stratified Prosser Dam Detection-Efficiency Estimates

Daily Prosser detection efficiencies are estimated separately at the three mid-Columbia Dams using all Spring Chinook smolt PIT-tagged above Prosser Dam. The daily detection efficiency is estimated by dividing the individual joint Prosser and downstream dam's daily detections by the total downstream dam's daily detection. There are four different estimation procedures used and presented in this report:

a. McNary stratified: The detection rate efficiencies are stratified at McNary Dam into adjacent days having relatively homogeneous daily estimates of McNary detection efficiencies. These joint daily McNary and Prosser detection numbers of PIT-tagged Spring Chinook smolt released above Prosser are added over the days included in each stratum and divided by the associated within-strata total downstream dam detections.

b. The joint daily McNary and Prosser detection numbers of PIT-tagged Spring Chinook smolt released above Prosser are added over all days and divided by total detections over all days (no stratification).

c. Pooled stratified: The same procedures given in a. above are followed independently at Bonneville and John Day Dams and the results when assigned to the five sampling periods and pooled over the three downstream dams within those periods. This method is the selected method, and the detection efficiencies from this method are presented in Table A.2. The conceptual details of this method follow the table.

d. The joint daily detections over all days and over the three downstream dams are added together and divided by the daily total detections over all days and over the three downstream dams (no stratification).

For each downstream dam, daily downstream estimates are assigned to the five genetic sampling periods (Pre-March, March, April, May, and Post-May) at Prosser. The total tallied smolt within the periods adjusted for sampling rate are then divided by the detection efficiencies pooled over the three downstream dams to estimate period passages, then the period passages are added to get total passage.

Table A.2.a. Estimated Prosser Detection Efficiencies based on Downstream-Dam Estimates assigned to Genetic Sampling Prosser Periods and pooled over the Downstream Dams

Brood Year	Outmigration Year	Pre-March	March	April	May	Post-May	Unstratified (Pooled)
1997	1999	19.39%	19.39%	19.39%	23.02%	3.78%	20.31%
1998	2000	15.86%	15.86%	30.01%	51.11%	30.02%	41.16%
1999	2001	77.31%	77.31%	77.31%	85.93%	90.87%	83.72%
2000	2002	32.78%	32.78%	53.93%	65.24%	7.92%	57.61%
2001	2003	47.35%	47.35%	61.28%	51.76%	11.36%	57.07%
2002	2004	59.43%	59.43%	59.43%	86.82%	86.82%	66.77%
2003	2005	60.09%	60.09%	71.86%	57.07%	57.07%	68.40%
2004	2006	20.06%	20.06%	20.06%	22.00%	22.00%	20.73%
2005	2007	28.26%	28.26%	28.26%	23.65%	23.65%	26.19%
2006	2008	48.80%	48.80%	66.68%	31.19%	7.85%	41.45%
2007	2009	26.18%	26.18%	21.29%	11.43%	11.43%	14.59%
2008	2010	45.40%	45.40%	45.40%	57.39%	35.45%	51.28%
2009	2011	17.61%	17.61%	28.31%	29.53%	29.53%	27.31%
2010	2012	17.16%	12.00%	7.97%	6.17%	6.17%	7.36%
2011	2013	27.48%	27.48%	35.06%	21.14%	21.14%	30.51%
2012	2014	13.15%	13.15%	13.15%	13.15%	5.04%	13.03%
2013	2015	37.07%	37.07%	62.12%	57.56%	57.56%	51.38%

*** Pooled over McNary, John Day, and Bonneville Dams**

The following is a general presentation for the selected method. In that presentation, the assessed dam is Prosser; the downstream dams are Bonneville, John Day, and McNary; and the periods are the genetic sampling periods: Pre-March, March, April, May, and Post-May.

For each dam down-stream of the dam for which detection efficiencies are being estimated, the assessed and downstream dams' joint detections at a downstream dam are obtain for each assessed dam's date and down-stream dam's date. Within each downstream-dam date, the detections are pooled over the assessed dam's dates to give the total assessed dam's detections on that downstream date. These joint totals are then divided by total downstream dam detections to get the estimated assessed dam's detection efficiency rate for that down-stream dam date. These detection rates are used as a dependent variable in a stepwise logistic regression. The dependent variables are indicator variables for the down-stream dam Julian detection dates. For a given downstream dam detection date, the indicator variable (IV) is assigned the value 0 if the actual down-stream dam date is less than the given IV Julian date and assigned the value 1 if that date is equal to or greater that IV date as illustrated below.

Table A.2.b. Variables used in getting stratified detection efficiencies

Lower Dam Julian Date	Assessed and Downstream Dam's Detections	Total Lower Downstream Detections	Upstream Dams Detection Rate	…	Indicator Variables IV-40	IV-4s	IV-4s	IV-43	IV-44	IV-45	IV-46	IV-47	IV-48	IV-49	IV-50	IV-5s	IV-5s	IV-53	IV-54	IV-55	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
40	25	205	0.1219512	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
41	25	154	0.1623377	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
42	35	244	0.1434426	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
43	50	208	0.2403846	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
44	75	280	0.2678571	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
45	220	420	0.5238095	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
46	90	380	0.2368421	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
47	220	490	0.4489796	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
48	220	424	0.5188679	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
49	250	624	0.400641	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
50	275	670	0.4104478	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
51	220	460	0.4782609	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
52	225	520	0.4326923	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
53	95	372	0.2553763	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
54	70	289	0.2422145	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
55	80	330	0.2424242	…	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Using the total lower dam's total detections at the downstream dam as the weight, a weighted stepwise logistic regression of the assessed dam's detection rate is run on the indicator variables. The regression output will be the list of out down-stream dam Julian dates which will establish strata boundaries. The detection rates for the sorted listed date and all the dates up to but not including the next listed sorted date are pooled together as a stratum of reasonably homogeneous detection rates. The dates preceding the first sorted listed date are also pooled into a separate stratum.

A smolt passing the assessed dam during one of the periods could pass the down-stream dam during any of the down-stream dam strata[10]. It is necessary to proportionately assign down-stream strata detection efficiencies to the assessed dam's passage periods for the purpose of expanding the assessed dam counts within those periods.

Referring to Table A.2.c., the number of the joint detections (x in Table A.2.c.) within a lower dam stratum that came from the assessed dam time period was computed for each lower dam stratum. For each stratum, the period's number of joint detections was divided by the period's joint detections over all periods, giving the period's relative frequency within the stratum (P in Table A.2.c.). The stratum's total downstream-dam detections (n in Table A.2.d) were multiplied by the relative frequency proportions to assign those stratum totals to the periods. Within the period, the stratums' detection efficiencies were weighted by the stratum downstream totals assigned to the period to obtain the mean detection efficiency for the period (example highlighted in yellow at the bottom of Table A.2.d).

[10] For hatchery Spring Chinook, McNary passage periods the following passage periods were established were established: Pre-April , Early April through April 15, Late April, Early May through May 15, Late April, Early June through Jun 15, Late June, Post-June.

Table A.2.c. Allocation of proportions of Joint Assessed and Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata

Stratum	Measure	Joint Number (x) of Downstream Dam and Assessed Dam Detections Period a	Period b	Period c	...	Period p	Total
1	Joint Detections	x(a,1)	x(b,1)	x(c,1)	...	x(p,1)	x(1)
	Proportional Distribution	P(a,1)=x(a,1)/x(1)	P(b,1)=x(b,1)/x(1)	P(a,1)=x(a3)/x(1)	...	P(p,1)=x(p,1)/x(1)	
2	Joint Detections	x(a,2)	x(b,2)	x(c,2)		x(p,2)	x(2)
	Proportional Distribution	P(a,2)=x(a,2)/x(2)	P(b,2)=x(b,2)/x(2)	P(a,2)=x(a3)/x(2)	...	P(p,2)=x(p,2)/x(2)	
3	Joint Detections	x(a,3)	x(b,3)	x(c,3)		x(p,3)	x(3)
	Proportional Distribution	P(a,3)=x(a,3)/x(3)	P(b,3)=x(b,3)/x(3)	P(a,3)=x(a3)/x(3)	...	P(p,3)=x(p,3)/x(3)	
...	...	...	...	...	...	...	...
s	Joint Detections	x(a,s)	x(b,s)	x(c,s)		x(p,s)	x(s)
	Proportional Distribution	P(a,s)=x(a,s)/x(s)	P(b,s)=x(b,s)/x(s)	P(a,s)=x(as)/x(s)	...	P(p,s)=x(p,s)/x(s)	

Table A.2.d. Allocation of Total Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata and Estimation of Assessed Dam's Period Detection Efficiencies

Stratum	Downstream Detections	Detection Efficiencies*	Number (n) of Downstream Detections* Period a	Period b	Period c	...	Period p
1	n(1)	de(1)=x(1)/n(1)	n(a,1) = n(1)*P(a,1)	n(b,1) = n(1)*P(b,1)	n(c,1) = n(1)*P(c,1)	...	n(p,1) = n(1)*P(p,1)
2	n(2)	de(2)=x(2)/n(2)	n(a,2) = n(2)*P(a,s)	n(b,2) = n(2)*P(b,s)	n(c,2) = n(2)*P(c,s)	...	n(p,2) = n(2)*P(p,s)
3	n(3)	de(3)=x(3)/n(3)	n(a,3) = n(3)*P(a,3)	n(b,3) = n(3)*P(b,3)	n(c,3) = n(3)*P(c,3)	...	n(p,3) = n(3)*P(p,3)
	...	...	...	...	...	...	...
s	n(s)	de(s)=x(4)/n(4)	n(a,s) = n(s)*P(a,s)	n(b,s) = n(s)*P(b,s)	n(c,s) = n(s)*P(c,s)	...	n(p,s) = n(s)*P(p,s)
Total			n(a)	n(b)	n (c)	...	n(p)

Example of detection efficiency for Period b: [n(b,1)*de(1) +n(b,2)*de(2) +n(b,3)*de(3)+...+n(b,s)*de(s)]/n(b)

This estimation procedure is separately performed for each of the down-stream dams, and then the within period detection rate estimates are weighted by the total allocated to the period (the row labeled "Total" in Table A.2.d. taken from each of the downstream dam's tables)   While subject to bias, there is evidence presented in this report's text that this procedure gives a less-biased detection-efficiency estimator application than just using the assessed dam and down-stream dam detections divided by the total down-stream dam detections ignoring strata and periods.

Appendix A.3. Estimated Stock Distributions within Genetic Sampling Periods [11]

Out-migration Year	Brood	Sampling Strata				
		Pre-March	March	April	May	Post-May
1999	American	8.08%	8.08%	8.08%	12.00%	28.00%
	Naches	6.06%	6.06%	6.06%	29.00%	33.00%
	U. Yakima*	85.86%	85.86%	85.86%	59.00%	39.00%
2000	American	16.18%	16.18%	22.14%	46.94%	46.94%
	Naches	22.06%	22.06%	30.99%	36.73%	36.73%
	U. Yakima*	61.76%	61.76%	46.88%	16.33%	16.33%
2001	American	genetic assignment to Upper Yakima Stock not possible				
	Naches					
	U. Yakima*					
2002	American	3.81%	3.81%	3.81%	3.86%	3.86%
	Naches	19.68%	19.68%	19.68%	20.29%	20.29%
	U. Yakima*	76.51%	76.51%	76.51%	75.85%	75.85%
2003	American	13.43%	13.43%	13.43%	16.03%	16.03%
	Naches	21.64%	21.64%	21.64%	34.24%	34.24%
	U. Yakima*	64.93%	64.93%	64.93%	49.73%	49.73%
2004	American	6.46%	4.27%	21.50%	34.72%	31.25%
	Naches	33.84%	29.27%	36.47%	34.03%	18.75%
	U. Yakima*	59.70%	66.46%	42.03%	31.25%	50.00%
2005	American	21.39%	18.87%	29.57%	32.14%	0.00%
	Naches	35.32%	7.55%	35.36%	23.21%	17.86%
	U. Yakima*	43.28%	73.58%	35.07%	44.64%	82.14%
2006	American	7.36%	0.00%	5.52%	5.45%	2.27%
	Naches	39.88%	25.96%	35.95%	39.11%	15.91%
	U. Yakima*	52.76%	74.04%	58.53%	55.45%	81.82%
2007	American	9.10%	14.50%	6.81%	16.75%	11.54%
	Naches	18.20%	32.30%	24.72%	29.78%	26.07%
	U. Yakima*	72.70%	53.20%	68.47%	53.47%	62.39%

[11] Provided by the Washington Department of Fish and Wildlife'

Appendix A.3. (continued) Estimate Stock Distributions within Genetic Sampling Strata [8]

Out-migration Year	Brood	Sampling Strata				
		Pre-March	March	April	May	Post-May
2008	American	8.33%	0.00%	5.22%	5.00%	14.81%
	Naches	8.33%	14.29%	25.22%	31.11%	51.85%
	U. Yakima*	83.33%	85.71%	69.57%	63.89%	33.33%
2009	American	9.80%	10.93%	12.06%	10.95%	36.29%
	Naches	35.60%	32.43%	29.25%	40.78%	28.23%
	U. Yakima*	54.60%	56.64%	58.69%	48.27%	35.48%
2010	American	30.31%	0.00%	14.16%	11.88%	0.00%
	Naches	7.35%	19.50%	37.13%	33.63%	75.49%
	U. Yakima*	62.34%	80.50%	48.71%	54.49%	24.51%
2011	American	8.64%	0.00%	3.49%	5.92%	16.65%
	Naches	18.19%	19.75%	23.96%	13.10%	0.00%
	U. Yakima*	73.17%	80.25%	72.55%	80.98%	83.35%
2012	American	10.99%	5.31%	6.17%	13.65%	23.46%
	Naches	31.62%	29.60%	29.32%	38.48%	29.45%
	U. Yakima*	57.39%	65.09%	64.51%	47.87%	47.09%
2013	American	8.23%	2.30%	5.72%	16.96%	6.39%
	Naches	17.43%	20.59%	27.50%	29.53%	7.85%
	U. Yakima*	74.34%	77.11%	66.78%	53.51%	85.76%
2014	American	11.65%	12.03%	9.09%	11.95%	13.86%
	Naches	41.19%	21.74%	30.16%	38.12%	0.00%
	U. Yakima*	47.16%	66.23%	60.74%	49.93%	86.14%
2015	American	13.86%	11.62%	8.92%	14.74%	14.74%
	Naches	16.80%	26.32%	23.13%	24.09%	24.09%
	U. Yakima*	69.34%	62.06%	67.96%	61.17%	61.17%
2016	American	not yet available				
	Naches					
	U. Yakima*					

Appendix B. Detail Passage-Estimation Table

1999			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	41,233	407	29,431	51,920	1,577	124,569	124,569		
	American	WDFW Percent	8.1%	8.1%	8.1%	12.0%	28.0%				
		Estimated Prosser Tally	3,332	33	2,378	6,230	442	12,415	12,415		
	Naches	WDFW Percent	6.1%	6.1%	6.1%	29.0%	33.0%				
		Estimated Prosser Tally	2,499	25	1,784	15,057	520	19,885	19,885		
	Upper Yakima	WDFW Percent	85.9%	85.9%	85.9%	59.0%	39.0%				
		Estimated Prosser Tally	35,402	350	25,269	30,633	615	92,269	92,269		
		Yakima Passage Wild Tally	41,233	407	29,431	51,920	1,577	124,569	Total	Total	
McN-Expanded '	Estimate a.	Detection Efficiency	18.50%	18.50%	18.50%	25.49%	5.04%				
		Total Passage	222,873	2,201	159,082	203,681	31,262	619,099	619,099	639,757	
		American Passage	18,010	178	12,855	24,442	8,753	64,238	64,238	66,381	
		Naches Passage	13,507	133	9,641	59,067	10,316	92,666	92,666	95,758	
		American & Naches Passage	31,517	311	22,496	83,509	19,070	156,904	156,904	162,140	
		Upper Yakima Passage	191,355	1,890	136,586	120,172	12,192	462,195	462,195	477,618	
Mcn-Unstratifie	Estimate b.	Detection Efficiency	22.99%	22.99%	22.99%	22.99%	22.99%				
		Total Passage	179,338	1,771	128,008	225,822	6,860	541,799	541,799	563,084	
		American Passage	14,492	143	10,344	27,099	1,921	53,998	53,998	56,120	
		Naches Passage	10,869	107	7,758	65,488	2,264	86,486	86,486	89,884	
		American & Naches Passage	25,361	251	18,102	92,587	4,184	140,485	140,485	146,004	
		Upper Yakima Passage	153,977	1,521	109,906	133,235	2,675	401,314	401,314	417,080	
Pooled Str Entra	Estimate c.	Detection Efficiency	19.39%	19.39%	19.39%	23.02%	3.78%				
		Total Passage	212,650	2,101	151,786	225,518	41,751	633,805	633,805	653,886	
		American Passage	17,184	170	12,266	27,062	11,690	68,371	68,371	70,538	
		Naches Passage	12,888	127	9,199	65,400	13,778	101,392	101,392	104,605	
		American & Naches Passage	30,072	297	21,465	92,462	25,468	169,764	169,764	175,142	
		Upper Yakima Passage	182,579	1,803	130,321	133,056	16,283	464,042	464,042	478,743	
Pooled UnStr En	Estimate e.	Detection Efficiency	20.31%	20.31%	20.31%	20.31%	20.31%				
		Total Passage	203,022	2,005	144,913	255,644	7,766	613,350	613,350	637,446	
		American Passage	16,406	162	11,710	30,677	2,174	61,130	61,130	63,531	
		Naches Passage	12,304	122	8,783	74,137	2,563	97,908	97,908	101,754	
		American & Naches Passage	28,710	284	20,493	104,814	4,737	159,038	159,038	165,286	
		Upper Yakima Passage	174,312	1,722	124,420	150,830	3,029	454,312	454,312	472,161	
Hatchery		Prosser Hatchery Tally	0	7	1,812	31,529	1,371	34,719	Expanded Total	Calibrated Total	Calibration Value
	Estimate a.	Total Passage	0	39	9,796	123,685	27,175	160,696	179,134	185,111	1.0334
	Estimate b.	Total Passage	0	32	7,883	137,130	5,963	151,007	168,334	174,947	1.0393
	Estimate c.	Total Passage	0	38	9,347	136,946	36,292	182,622	203,576	210,026	1.0317
	Estimate e.	Total Passage	0	36	8,924	155,240	6,750	170,950	190,564	198,051	1.0393

Appendix B. Detailed Passage-Estimation Table (Continued)

2000			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	12,637	252	11,172	19,815	814	44,690	44,690		
	American	WDFW Percent	16.2%	16.2%	22.1%	46.9%	46.9%				
		Estimated Prosser Tally	2,044	41	2,473	9,301	382	14,241	14,241		
	Naches	WDFW Percent	22.1%	22.1%	31.0%	36.7%	36.7%				
		Estimated Prosser Tally	2,788	56	3,462	7,279	299	13,883	13,883		
	Upper Yakima	WDFW Percent	61.8%	61.8%	46.9%	16.3%	16.3%				
		Estimated Prosser Tally	7,805	156	5,237	3,235	133	16,566	16,566		
		Yakima Passage Wild Tally	12,637	252	11,172	19,815	814	44,690	Total	Total	
	Estimate a.	Detection Efficiency	12.54%	12.54%	31.64%	52.58%	31.00%				
		Total Passage	100,754	2,008	35,311	37,686	2,627	178,387	178,387	234,171	
		American Passage	16,298	325	7,816	17,689	1,233	43,362	43,362	56,922	
		Naches Passage	22,225	443	10,943	13,844	965	48,420	48,420	63,562	
		American & Naches Passage	38,524	768	18,759	31,533	2,199	91,782	91,782	120,484	
		Upper Yakima Passage	62,231	1,240	16,552	6,153	429	86,605	86,605	113,688	
	Estimate b.	Detection Efficiency	41.66%	41.66%	41.66%	41.66%	41.66%				
		Total Passage	30,333	605	26,818	47,564	1,955	107,274	107,274	139,009	
		American Passage	4,907	98	5,936	22,326	918	34,184	34,184	44,297	
		Naches Passage	6,691	133	8,311	17,472	718	33,326	33,326	43,184	
		American & Naches Passage	11,598	231	14,247	39,798	1,636	67,510	67,510	87,481	
		Upper Yakima Passage	18,735	373	12,571	7,765	319	39,764	39,764	51,527	
	Estimate c.	Detection Efficiency	15.86%	15.86%	30.01%	51.11%	30.02%				
		Total Passage	79,697	1,589	37,229	38,770	2,713	159,998	159,998	209,803	
		American Passage	12,892	257	8,241	18,198	1,273	40,862	40,862	53,581	
		Naches Passage	17,580	350	11,537	14,242	997	44,707	44,707	58,623	
		American & Naches Passage	30,472	607	19,778	32,440	2,270	85,568	85,568	112,204	
		Upper Yakima Passage	49,224	981	17,451	6,330	443	74,430	74,430	97,599	
	Estimate e.	Total Passage	41.16%	41.16%	41.16%	41.16%	41.16%				
		Total Passage	30,699	612	27,141	48,137	1,979	108,568	108,568	140,685	
		American Passage	4,966	99	6,008	22,595	929	34,596	34,596	44,831	
		Naches Passage	6,772	135	8,411	17,683	727	33,728	33,728	43,705	
		American & Naches Passage	11,738	234	14,419	40,278	1,656	68,324	68,324	88,536	
		Upper Yakima Passage	18,961	378	12,722	7,859	323	40,244	40,244	52,149	
Hatchery		Prosser Hatchery Tally	0	11	12,187	59,659	21,234	93,091	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	91	38,517	113,466	68,501	220,575	235,749	309,471	1.3127
	Estimate b.	Total Passage	0	27	29,253	143,206	50,971	223,458	238,829	309,481	1.2958
	Estimate c.	Total Passage	0	72	40,610	116,731	70,728	228,141	243,835	319,738	1.3113
	Estimate e.	Total Passage	0	28	29,606	144,933	51,586	226,152	241,709	313,213	1.2958

Appendix B. Detailed Passage-Estimation Table (Continued)

2001			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	4,679	3,236	101,993	27,763	1,307	138,977	138,977		
	American	WDFW Percent									
		Estimated Prosser Tally							0		
	Naches	WDFW Percent									
		Estimated Prosser Tally			genetic assignment to Upper Yakima Stock not possible				0		
	Upper Yakima	WDFW Percent									
		Estimated Prosser Tally							0		
		Yakima Passage Wild Tally						138,977	Total	Total	
	Estimate a.	Detection Efficiency	76.07%	76.07%	76.07%	86.78%	91.94%				
		Total Passage	6,150	4,253	134,076	31,992	1,421	177,893	177,893	153,933	
		American Passage							0	0	
		Naches Passage							0	0	
		American & Naches Passage							0	0	
		Upper Yakima Passage							0	0	
	Estimate b.	Detection Efficiency	83.90%	83.90%	83.90%	83.90%	83.90%				
		Total Passage	5,577	3,857	121,571	33,092	1,558	165,654	165,654	148,247	
		American Passage							0	0	
		Naches Passage							0	0	
		American & Naches Passage							0	0	
		Upper Yakima Passage							0	0	
	Estimate c.	Detection Efficiency	77.31%	77.31%	77.31%	85.93%	90.87%				
		Total Passage	6,052	4,185	131,931	32,310	1,438	175,917	175,917	153,248	
		American Passage							0	0	
		Naches Passage							0	0	
		American & Naches Passage							0	0	
		Upper Yakima Passage							0	0	
	Estimate e.	Detection Efficiency	83.72%	83.72%	83.72%	83.72%	83.72%				
		Total Passage	5,589	3,865	121,828	33,162	1,561	166,004	166,004	148,560	
		American Passage							0	0	
		Naches Passage							0	0	
		American & Naches Passage							0	0	
		Upper Yakima Passage							0	0	
Hatchery		Prosser Hatchery Tally	0	4	96,207	148,783	16,931	261,925	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	5	126,468	171,448	18,415	316,337	333,797	288,840	0.8653
	Estimate b.	Total Passage	0	5	114,674	177,343	20,181	312,202	329,434	294,816	0.8949
	Estimate c.	Total Passage	0	5	124,446	173,151	18,633	316,235	333,689	290,690	0.8711
	Estimate e.	Total Passage	0	5	114,916	177,717	20,223	312,862	330,130	295,438	0.8949

Appendix B. Detailed Passage-Estimation Table (Continued)

2002			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	66,506	26,080	101,052	40,512	62	234,213	234,213		
	American	WDFW Percent	3.8%	3.8%	3.8%	3.9%	3.9%				
		Estimated Prosser Tally	2,534	994	3,850	1,566	2	8,945	8,945		
	Naches	WDFW Percent	19.7%	19.7%	19.7%	20.3%	20.3%				
		Estimated Prosser Tally	13,090	5,133	19,890	8,220	13	46,345	46,345		
	Upper Yakima	WDFW Percent	76.5%	76.5%	76.5%	75.8%	75.8%				
		Estimated Prosser Tally	50,883	19,954	77,313	30,726	47	178,922	178,922		
		Yakima Passage Wild Tally	66,506	26,080	101,052	40,512	62	234,213	Total	Total	
	Estimate a.	Detection Efficiency	31.69%	31.69%	56.34%	65.90%	25.20%				
		Total Passage	209,858	82,295	179,367	61,477	247	533,244	533,244	462,989	
		American Passage	7,995	3,135	6,833	2,376	10	20,348	20,348	17,667	
		Naches Passage	41,305	16,198	35,304	12,474	50	105,331	105,331	91,453	
		American & Naches Passage	49,300	19,333	42,137	14,850	60	125,679	125,679	109,121	
		Upper Yakima Passage	160,558	62,963	137,230	46,628	187	407,565	407,565	353,868	
	Estimate b.	Detection Efficiency	59.52%	59.52%	59.52%	59.52%	59.52%				
		Total Passage	111,740	43,819	169,781	68,066	104	393,510	393,510	346,392	
		American Passage	4,257	1,669	6,468	2,631	4	15,028	15,028	13,229	
		Naches Passage	21,993	8,625	33,417	13,810	21	77,867	77,867	68,543	
		American & Naches Passage	26,250	10,294	39,885	16,441	25	92,895	92,895	81,772	
		Upper Yakima Passage	85,490	33,525	129,896	51,625	79	300,615	300,615	264,620	
	Estimate c.	Detection Efficiency	32.78%	32.78%	53.93%	65.24%	7.92%				
		Total Passage	202,911	79,571	187,367	62,093	784	532,726	532,726	463,440	
		American Passage	7,730	3,031	7,138	2,400	30	20,329	20,329	17,685	
		Naches Passage	39,938	15,662	36,879	12,599	159	105,236	105,236	91,549	
		American & Naches Passage	47,668	18,693	44,016	14,998	189	125,565	125,565	109,234	
		Upper Yakima Passage	155,243	60,878	143,350	47,095	595	407,161	407,161	354,206	
	Estimate e.	Total Passage	57.61%	57.61%	57.61%	57.61%	57.61%				
		Total Passage	115,447	45,272	175,414	70,324	108	406,565	406,565	357,885	
		American Passage	4,398	1,725	6,682	2,718	4	15,527	15,527	13,668	
		Naches Passage	22,723	8,911	34,526	14,269	22	80,450	80,450	70,817	
		American & Naches Passage	27,121	10,635	41,208	16,986	26	95,977	95,977	84,485	
		Upper Yakima Passage	88,326	34,637	134,206	53,337	82	310,588	310,588	273,400	
Hatchery		Prosser Hatchery Tally	5	2,254	126,919	101,160	171	230,509	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	16	7,111	225,281	153,510	680	386,599	405,907	352,428	0.8682
	Estimate b.	Total Passage	9	3,786	213,241	169,962	288	387,287	406,629	357,941	0.8803
	Estimate c.	Total Passage	16	6,876	235,328	155,049	2,164	399,432	419,381	364,837	0.8699
	Estimate e.	Total Passage	9	3,912	220,316	175,601	298	400,136	420,120	369,817	0.8803

Appendix B. Detailed Passage-Estimation Table (Continued)

2003			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	30,359	16,582	98,537	33,294	272	179,045	179,045		
	American	WDFW Percent	13.4%	13.4%	13.4%	16.0%	16.0%				
		Estimated Prosser Tally	4,078	2,227	13,236	5,338	44	24,923	24,923		
	Naches	WDFW Percent	21.6%	21.6%	21.6%	34.2%	34.2%				
		Estimated Prosser Tally	6,570	3,589	21,325	11,400	93	42,977	42,977		
	Upper Yakima	WDFW Percent	64.9%	64.9%	64.9%	49.7%	49.7%				
		Estimated Prosser Tally	19,711	10,766	63,975	16,557	135	111,144	111,144		
		Yakima Passage Wild Tally	30,359	16,582	98,537	33,294	272	179,045	Total	Total	
	Estimate a.	Detection Efficiency	45.1%	45.1%	61.9%	54.7%	13.4%				
		Total Passage	67,353	36,787	159,149	60,921	2,035	326,245	326,245	315,636	
		American Passage	9,047	4,941	21,378	9,767	326	45,461	45,461	43,982	
		Naches Passage	14,576	7,961	34,443	20,859	697	78,536	78,536	75,982	
		American & Naches Passage	23,624	12,903	55,821	30,626	1,023	123,997	123,997	119,965	
		Upper Yakima Passage	43,729	23,884	103,328	30,295	1,012	202,248	202,248	195,671	
	Estimate b.	Detection Efficiency	58.5%	58.5%	58.5%	58.5%	58.5%				
		Total Passage	51,891	28,342	168,422	56,908	466	306,029	306,029	295,976	
		American Passage	6,970	3,807	22,624	9,124	75	42,600	42,600	41,201	
		Naches Passage	11,230	6,134	36,450	19,485	159	73,458	73,458	71,045	
		American & Naches Passage	18,201	9,941	59,073	28,609	234	116,058	116,058	112,245	
		Upper Yakima Passage	33,691	18,401	109,349	28,299	232	189,971	189,971	183,731	
	Estimate c.	Detection Efficiency	47.3%	47.3%	61.3%	51.8%	11.4%				
		Total Passage	64,119	35,020	160,800	64,329	2,398	326,666	326,666	316,301	
		American Passage	8,613	4,704	21,600	10,314	93	45,324	45,324	43,885	
		Naches Passage	13,877	7,579	34,800	22,026	487	78,768	78,768	76,268	
		American & Naches Passage	22,490	12,283	56,400	32,339	579	124,091	124,091	120,154	
		Upper Yakima Passage	41,630	22,737	104,400	31,990	1,819	202,575	202,575	196,147	
	Estimate e.	Detection Efficiency	57.1%	57.1%	57.1%	57.1%	57.1%				
		Total Passage	53,199	29,056	172,667	58,342	477	313,743	313,743	303,436	
		American Passage	7,146	3,903	23,194	9,354	77	43,674	43,674	42,239	
		Naches Passage	11,513	6,288	37,368	19,976	163	75,309	75,309	72,835	
		American & Naches Passage	18,659	10,191	60,562	29,330	240	118,983	118,983	115,074	
		Upper Yakima Passage	34,540	18,865	112,105	29,013	237	194,760	194,760	188,362	
Hatchery		Prosser Hatchery Tally	0	2,058	67,386	15,896	233	85,573	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	4,565	108,836	29,087	1,743	144,230	161,493	156,242	0.9675
	Estimate b.	Total Passage	0	3,517	115,178	27,170	399	146,264	163,771	158,391	0.9671
	Estimate c.	Total Passage	0	4,346	109,965	30,714	2,054	147,078	164,682	159,457	0.9683
	Estimate e.	Total Passage	0	3,605	118,081	27,855	409	149,950	167,898	162,383	0.9671

Appendix B. Detailed Passage-Estimation Table (Continued)

2004			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	5,652	7,240	70,520	19,028	346	102,786	102,786		
	American	WDFW Percent	6.5%	4.3%	21.5%	34.7%	31.3%				
		Estimated Prosser Tally	365	309	15,160	6,607	108	22,549	22,549		
	Naches	WDFW Percent	33.8%	29.3%	36.5%	34.0%	18.8%				
		Estimated Prosser Tally	1,913	2,119	25,721	6,475	65	36,292	36,292		
	Upper Yakima	WDFW Percent	59.7%	66.5%	42.0%	31.3%	50.0%				
		Estimated Prosser Tally	3,374	4,812	29,639	5,946	173	43,944	43,944		
		Yakima Passage Wild Tally	5,652	7,240	70,520	19,028	346	102,786	Total	Total	
	Estimate a.	Detection Efficiency	58.4%	58.4%	58.4%	87.2%	87.2%				
		Total Passage	9,680	12,400	120,771	21,832	397	165,079	165,079	177,523	
		American Passage	626	529	25,963	7,580	124	34,822	34,822	37,447	
		Naches Passage	3,276	3,629	44,049	7,429	74	58,457	58,457	62,864	
		American & Naches Passage	3,901	4,158	70,012	15,009	198	93,280	93,280	100,311	
		Upper Yakima Passage	5,778	8,241	50,759	6,822	198	71,799	71,799	77,212	
	Estimate b.	Detection Efficiency	64.5%	64.5%	64.5%	64.5%	64.5%				
		Total Passage	8,760	11,221	109,291	29,489	536	159,296	159,296	176,383	
		American Passage	566	479	23,495	10,239	167	34,947	34,947	38,695	
		Naches Passage	2,964	3,284	39,862	10,034	100	56,245	56,245	62,279	
		American & Naches Passage	3,531	3,763	63,357	20,274	268	91,192	91,192	100,974	
		Upper Yakima Passage	5,229	7,458	45,934	9,215	268	68,104	68,104	75,409	
	Estimate c.	Detection Efficiency	0.5943	0.5943	0.5943	0.8682	0.8682				
		Total Passage	9,511	12,183	118,664	21,916	398	162,673	162,673	175,202	
		American Passage	615	520	25,510	7,610	124	34,379	34,379	37,027	
		Naches Passage	3,219	3,566	43,281	7,458	75	57,597	57,597	62,034	
		American & Naches Passage	3,833	4,086	68,791	15,068	199	91,976	91,976	99,061	
		Upper Yakima Passage	5,678	8,097	49,873	6,849	199	70,696	70,696	76,141	
	Estimate e.	Detection Efficiency	0.66773204	0.66773204	0.66773204	0.66773204	0.66773204				
		Total Passage	8,465	10,843	105,611	28,496	518	153,933	153,933	170,445	
		American Passage	547	463	22,704	9,894	162	33,770	33,770	37,392	
		Naches Passage	2,865	3,174	38,520	9,697	97	54,352	54,352	60,182	
		American & Naches Passage	3,412	3,636	61,224	19,591	259	88,122	88,122	97,574	
		Upper Yakima Passage	5,053	7,207	44,387	8,905	259	65,811	65,811	72,870	
Hatchery		Prosser Hatchery Tally	0	1,662	99,011	83,912	283	184,868	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	2,847	169,565	96,276	324	269,013	282,357	303,642	1.0754
	Estimate b.	Total Passage	0	2,576	153,446	130,045	438	286,505	300,717	332,974	1.1073
	Estimate c.	Total Passage	0	2,797	166,606	96,651	326	266,380	279,593	301,129	1.0770
	Estimate e.	Total Passage	0	2,490	148,280	125,667	423	276,860	290,593	321,764	1.1073

Appendix B. Detailed Passage-Estimation Table (Continued)

2005			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	37,617	3,569	66,596	6,246	63	114,092	114,092		
	American	WDFW Percent	21.4%	18.9%	29.6%	32.1%	0.0%				
		Estimated Prosser Tally	8,047	673	19,689	2,008	0	30,418	30,418		
	Naches	WDFW Percent	35.3%	7.5%	35.4%	23.2%	17.9%				
		Estimated Prosser Tally	13,288	269	23,550	1,450	11	38,568	38,568		
	Upper Yakima	WDFW Percent	43.3%	73.6%	35.1%	44.6%	82.1%				
		Estimated Prosser Tally	16,282	2,626	23,357	2,789	52	45,106	45,106		
		Yakima Passage Wild Tally	37,617	3,569	66,596	6,246	63	114,092	Total	Total	
	Estimate a.	Detection Efficiency	60.7%	60.7%	71.4%	69.2%	69.2%				
		Total Passage	61,931	5,876	93,219	9,028	92	170,146	170,146	135,748	
		American Passage	13,249	1,109	27,561	2,902	0	44,820	44,820	35,759	
		Naches Passage	21,876	443	32,965	2,096	16	57,396	57,396	45,793	
		American & Naches Passage	35,125	1,552	60,525	4,998	16	102,216	102,216	81,552	
		Upper Yakima Passage	26,806	4,324	32,694	4,030	75	67,930	67,930	54,197	
	Estimate b.	Detection Efficiency	70.0%	70.0%	70.0%	70.0%	70.0%				
		Total Passage	53,727	5,097	95,116	8,921	91	162,952	162,952	129,782	
		American Passage	11,494	962	28,121	2,868	0	43,444	43,444	34,601	
		Naches Passage	18,978	385	33,635	2,071	16	55,085	55,085	43,872	
		American & Naches Passage	30,472	1,346	61,757	4,939	16	98,530	98,530	78,473	
		Upper Yakima Passage	23,255	3,751	33,360	3,983	74	64,422	64,422	51,309	
	Estimate c.	Detection Efficiency	60.1%	60.1%	71.9%	57.1%	57.1%				
		Total Passage	62,602	5,939	92,669	10,945	111	172,267	172,267	139,057	
		American Passage	13,392	1,121	27,398	3,518	0	45,429	45,429	36,671	
		Naches Passage	22,113	448	32,770	2,541	20	57,892	57,892	46,732	
		American & Naches Passage	35,506	1,569	60,168	6,059	20	103,321	103,321	83,403	
		Upper Yakima Passage	27,096	4,370	32,501	4,886	91	68,946	68,946	55,654	
	Estimate e.	Detection Efficiency	68.4%	68.4%	68.4%	68.4%	68.4%				
		Total Passage	54,999	5,218	97,370	9,133	93	166,813	166,813	132,857	
		American Passage	11,766	985	28,788	2,936	0	44,474	44,474	35,421	
		Naches Passage	19,428	394	34,432	2,120	17	56,390	56,390	44,912	
		American & Naches Passage	31,194	1,378	63,220	5,056	17	100,864	100,864	80,333	
		Upper Yakima Passage	23,806	3,840	34,150	4,077	76	65,949	65,949	52,524	
Hatchery		Prosser Hatchery Tally	21	8	159,590	37,455	16	197,090	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	35	13	223,388	54,132	24	277,593	291,597	232,647	0.7978
	Estimate b.	Total Passage	31	11	227,934	53,495	23	281,494	295,696	235,505	0.7964
	Estimate c.	Total Passage	36	13	222,070	65,629	29	287,777	302,295	244,018	0.8072
	Estimate e.	Total Passage	31	11	233,334	54,762	24	288,163	302,701	241,084	0.7964

Appendix B. Detailed Passage-Estimation Table (Continued)

2006			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	10,385	400	21,517	9,248	45	41,594	41,594		
	American	WDFW Percent	7.4%	0.0%	5.5%	5.4%	2.3%				
		Estimated Prosser Tally	765	0	1,187	504	1	2,457	2,457		
	Naches	WDFW Percent	39.9%	26.0%	36.0%	39.1%	15.9%				
		Estimated Prosser Tally	4,141	104	7,736	3,617	7	15,605	15,605		
	Upper Yakima	WDFW Percent	52.8%	74.0%	58.5%	55.4%	81.8%				
		Estimated Prosser Tally	5,479	296	12,593	5,127	37	23,533	23,533		
		Yakima Passage Wild Tally	10,385	400	21,517	9,248	45	41,594	Total	Total	
	Estimate a.	Detection Efficiency	21.0%	21.0%	21.0%	23.7%	23.7%				
		Total Passage	49,364	1,901	102,278	38,999	191	192,734	192,734	128,158	
		American Passage	3,634	0	5,644	2,124	4	11,406	11,406	7,585	
		Naches Passage	19,685	494	36,772	15,252	30	72,234	72,234	48,031	
		American & Naches Passage	23,319	494	42,416	17,376	35	83,640	83,640	55,616	
		Upper Yakima Passage	26,045	1,408	59,862	21,623	156	109,094	109,094	72,542	
	Estimate b.	Detection Efficiency	20.5%	20.5%	20.5%	20.5%	20.5%				
		Total Passage	50,540	1,947	104,715	45,005	220	202,426	202,426	133,676	
		American Passage	3,721	0	5,779	2,451	5	11,955	11,955	7,895	
		Naches Passage	20,154	505	37,648	17,601	35	75,943	75,943	50,151	
		American & Naches Passage	23,875	505	43,427	20,052	40	87,899	87,899	58,046	
		Upper Yakima Passage	26,665	1,441	61,288	24,953	180	114,528	114,528	75,631	
	Estimate c.	Detection Efficiency	20.1%	20.1%	20.1%	22.0%	22.0%				
		Total Passage	51,765	1,994	107,254	42,031	206	203,250	203,250	134,938	
		American Passage	3,811	0	5,919	2,289	5	12,023	12,023	7,982	
		Naches Passage	20,643	518	38,561	16,438	33	76,192	76,192	50,584	
		American & Naches Passage	24,454	518	44,480	18,727	37	88,215	88,215	58,566	
		Upper Yakima Passage	27,312	1,476	62,774	23,304	168	115,035	115,035	76,372	
	Estimate e.	Detection Efficiency	20.7%	20.7%	20.7%	20.7%	20.7%				
		Total Passage	50,094	1,930	103,791	44,608	218	200,641	200,641	132,498	
		American Passage	3,688	0	5,728	2,429	5	11,850	11,850	7,825	
		Naches Passage	19,976	501	37,316	17,446	35	75,274	75,274	49,709	
		American & Naches Passage	23,664	501	43,044	19,875	40	87,123	87,123	57,534	
		Upper Yakima Passage	26,430	1,429	60,747	24,733	179	113,518	113,518	74,964	
Hatchery		Prosser Hatchery Tally	3	9	46,130	45,561	19	91,722	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	14	43	219,277	192,140	81	411,555	432,303	287,459	0.6649
	Estimate b.	Total Passage	15	44	224,500	221,728	93	446,380	468,884	309,637	0.6604
	Estimate c.	Total Passage	15	45	229,944	207,074	87	437,166	459,205	304,868	0.6639
	Estimate e.	Total Passage	15	44	222,520	219,773	92	442,444	464,749	306,907	0.6604

Appendix B. Detailed Passage-Estimation Table (Continued)

2007			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	566	523	17,147	11,159	189	29,583	29,583		
	American	WDFW Percent	9.1%	14.5%	6.8%	16.7%	11.5%				
		Estimated Prosser Tally	51	76	1,167	1,869	22	3,185	3,185		
	Naches	WDFW Percent	18.2%	32.3%	24.7%	29.8%	26.1%				
		Estimated Prosser Tally	103	169	4,239	3,323	49	7,883	7,883		
	Upper Yakima	WDFW Percent	72.7%	53.2%	68.5%	53.5%	62.4%				
		Estimated Prosser Tally	411	278	11,740	5,967	118	18,514	18,514		
		Yakima Passage Wild Tally	566	523	17,147	11,159	189	29,583	Total	Total	
	Estimate a.	Detection Efficiency	30.2%	30.2%	30.2%	21.9%	21.9%				
		Total Passage	1,872	1,728	56,711	51,048	866	112,224	112,224	102,697	
		American Passage	170	251	3,860	8,550	100	12,931	12,931	11,833	
		Naches Passage	341	558	14,022	15,200	226	30,347	30,347	27,770	
		American & Naches Passage	511	809	17,882	23,750	326	43,278	43,278	39,604	
		Upper Yakima Passage	1,361	920	38,829	27,297	540	68,947	68,947	63,093	
	Estimate b.	Detection Efficiency	26.3%	26.3%	26.3%	26.3%	26.3%				
		Total Passage	2,151	1,986	65,172	42,413	719	112,441	112,441	101,215	
		American Passage	196	288	4,436	7,104	83	12,107	12,107	10,898	
		Naches Passage	391	642	16,114	12,629	188	29,963	29,963	26,972	
		American & Naches Passage	587	930	20,550	19,733	271	42,070	42,070	37,870	
		Upper Yakima Passage	1,564	1,057	44,622	22,680	449	70,371	70,371	63,345	
	Estimate c.	Detection Efficiency	28.26%	28.26%	28.26%	23.65%	23.65%				
		Total Passage	2,002	1,849	60,674	47,178	800	112,504	112,504	102,183	
		American Passage	182	268	4,130	7,902	92	12,575	12,575	11,421	
		Naches Passage	364	597	15,001	14,048	209	30,220	30,220	27,448	
		American & Naches Passage	547	865	19,131	21,950	301	42,794	42,794	38,869	
		Upper Yakima Passage	1,456	984	41,543	25,228	499	69,709	69,709	63,314	
	Estimate e.	Detection Efficiency	26.19%	26.19%	26.19%	26.19%	26.19%				
		Total Passage	2,161	1,996	65,477	42,611	723	112,967	112,967	101,688	
		American Passage	197	289	4,457	7,137	83	12,163	12,163	10,949	
		Naches Passage	393	645	16,189	12,688	188	30,103	30,103	27,098	
		American & Naches Passage	590	934	20,646	19,825	272	42,267	42,267	38,047	
		Upper Yakima Passage	1,571	1,062	44,831	22,786	451	70,701	70,701	63,642	
Hatchery		Prosser Hatchery Tally	0	629	61,236	37,776	281	99,922	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	2,079	202,534	172,814	1,285	378,712	397,110	363,397	0.9151
	Estimate b.	Total Passage	0	2,389	232,752	143,581	1,068	379,790	398,240	358,479	0.9002
	Estimate c.	Total Passage	0	2,224	216,687	159,714	1,188	379,813	398,263	361,729	0.9083
	Estimate e.	Total Passage	0	2,400	233,841	144,253	1,073	381,568	400,104	360,156	0.9002

Appendix B. Detailed Passage-Estimation Table (Continued)

2008			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	4,964	1,052	44,603	16,505	443	67,567	67,567		
	American	WDFW Percent	8.3%	0.0%	5.2%	5.0%	14.8%				
		Estimated Prosser Tally	414	0	2,327	825	66	3,632	3,632		
	Naches	WDFW Percent	8.3%	14.3%	25.2%	31.1%	51.9%				
		Estimated Prosser Tally	414	150	11,248	5,135	230	17,176	17,176		
	Upper Yakima	WDFW Percent	83.3%	85.7%	69.6%	63.9%	33.3%				
		Estimated Prosser Tally	4,137	902	31,028	10,545	148	46,759	46,759		
		Yakima Passage Wild Tally	4,964	1,052	44,603	16,505	443	67,567	Total	Total	
	Estimate a.	Detection Efficiency	71.4%	71.4%	71.4%	35.6%	10.8%				
		Total Passage	6,952	1,473	62,485	46,346	4,094	121,350	121,350	109,088	
		American Passage	579	0	3,260	2,317	606	6,763	6,763	6,080	
		Naches Passage	579	210	15,757	14,419	2,123	33,088	33,088	29,745	
		American & Naches Passage	1,159	210	19,017	16,736	2,729	39,851	39,851	35,825	
		Upper Yakima Passage	5,794	1,263	43,468	29,610	1,365	81,499	81,499	73,264	
	Estimate b.	Detection Efficiency	46.1%	46.1%	46.1%	46.1%	46.1%				
		Total Passage	10,762	2,281	96,703	35,784	961	146,490	146,490	131,304	
		American Passage	897	0	5,045	1,789	142	7,874	7,874	7,057	
		Naches Passage	897	326	24,386	11,133	498	37,240	37,240	33,379	
		American & Naches Passage	1,794	326	29,431	12,922	641	45,113	45,113	40,437	
		Upper Yakima Passage	8,968	1,955	67,272	22,862	320	101,377	101,377	90,867	
	Estimate c.	Detection Efficiency	48.8%	48.8%	66.7%	31.2%	7.9%				
		Total Passage	10,172	2,156	66,892	52,920	5,644	137,784	137,784	124,254	
		American Passage	848	0	3,490	2,646	836	7,820	7,820	7,052	
		Naches Passage	848	308	16,868	16,464	2,927	37,415	37,415	33,741	
		American & Naches Passage	1,695	308	20,358	19,110	3,763	45,235	45,235	40,793	
		Upper Yakima Passage	8,477	1,848	46,534	33,810	1,881	92,550	92,550	83,461	
	Estimate e.	Detection Efficiency	41.4%	41.4%	41.4%	41.4%	41.4%				
		Total Passage	11,976	2,538	107,612	39,821	1,069	163,016	163,016	146,117	
		American Passage	998	0	5,615	1,991	158	8,762	8,762	7,854	
		Naches Passage	998	363	27,137	12,389	554	41,441	41,441	37,145	
		American & Naches Passage	1,996	363	32,752	14,380	713	50,203	50,203	44,998	
		Upper Yakima Passage	9,980	2,175	74,861	25,441	356	112,814	112,814	101,118	
Hatchery		Prosser Hatchery Tally	23	233	43,465	65,164	930	109,816	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	33	326	60,890	182,980	8,595	252,823	269,448	242,222	0.8990
	Estimate b.	Total Passage	50	505	94,235	141,281	2,017	238,088	253,743	227,438	0.8963
	Estimate c.	Total Passage	48	477	65,185	208,936	11,851	286,496	305,335	275,351	0.9018
	Estimate e.	Total Passage	56	561	104,866	157,219	2,245	264,947	282,369	253,096	0.8963

Appendix B. Detailed Passage-Estimation Table (Continued)

2009			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	15,913	543	27,585	9,394	473	53,907	53,907		
	American	WDFW Percent	9.80%	10.93%	12.06%	10.95%	36.29%				
		Estimated Prosser Tally	1,559	59	3,327	1,029	172	6,146	6,146		
	Naches	WDFW Percent	35.6%	32.4%	29.2%	40.8%	28.2%				
		Estimated Prosser Tally	5,665	176	8,068	3,831	134	17,873	17,873		
	Upper Yakima	WDFW Percent	54.6%	56.6%	58.7%	48.3%	35.5%				
		Estimated Prosser Tally	8,689	307	16,191	4,534	168	29,888	29,888		
		Yakima Passage Wild Tally	15,913	543	27,585	9,394	473	53,907	Total	Total	
	Estimate a.	Detection Efficiency	28.4%	28.4%	21.2%	12.5%	12.5%				
		Total Passage	56,040	1,911	130,062	75,334	3,795	267,142	267,142	232,832	
		American Passage	5,492	209	15,686	8,249	1,377	31,013	31,013	27,030	
		Naches Passage	19,950	620	38,038	30,723	1,071	90,402	90,402	78,791	
		American & Naches Passage	25,442	828	53,724	38,972	2,448	121,415	121,415	105,821	
		Upper Yakima Passage	30,598	1,082	76,338	36,362	1,347	145,727	145,727	127,011	
	Estimate b.	Detection Efficiency	15.3%	15.3%	15.3%	15.3%	15.3%				
		Total Passage	104,271	3,555	180,751	61,551	3,101	353,229	353,229	315,865	
		American Passage	10,219	388	21,799	6,740	1,125	40,271	40,271	36,011	
		Naches Passage	37,120	1,153	52,863	25,102	875	117,113	117,113	104,725	
		American & Naches Passage	47,339	1,541	74,662	31,842	2,000	157,384	157,384	140,737	
		Upper Yakima Passage	56,932	2,014	106,089	29,710	1,100	195,845	195,845	175,128	
	Estimate c.	Detection Efficiency	26.2%	26.2%	21.3%	11.4%	11.4%				
		Total Passage	60,791	2,073	129,580	82,196	4,141	278,780	278,780	241,967	
		American Passage	5,958	226	15,628	9,000	1,503	32,315	32,315	28,047	
		Naches Passage	21,642	672	37,897	33,521	1,169	94,901	94,901	82,369	
		American & Naches Passage	27,599	899	53,525	42,521	2,671	127,215	127,215	110,417	
		Upper Yakima Passage	33,192	1,174	76,055	39,674	1,469	151,564	151,564	131,550	
	Estimate e.	Detection Efficiency	14.6%	14.6%	14.6%	14.6%	14.6%				
		Total Passage	109,042	3,718	189,022	64,368	3,242	369,392	369,392	330,318	
		American Passage	10,686	406	22,797	7,048	1,177	42,114	42,114	37,659	
		Naches Passage	38,819	1,206	55,282	26,251	915	122,472	122,472	109,517	
		American & Naches Passage	49,505	1,612	78,078	33,299	2,092	164,586	164,586	147,176	
		Upper Yakima Passage	59,537	2,106	110,943	31,069	1,151	204,806	204,806	183,142	
Hatchery		Prosser Hatchery Tally	31	233	23,789	39,531	645	64,228	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	111	819	112,163	317,029	5,170	435,292	459,012	400,060	0.8716
	Estimate b.	Total Passage	206	1,524	155,876	259,027	4,224	420,857	443,790	396,847	0.8942
	Estimate c.	Total Passage	120	888	111,747	345,905	5,641	464,301	489,602	424,951	0.8680
	Estimate e.	Total Passage	216	1,593	163,009	270,879	4,418	440,115	464,097	415,006	0.8942

Appendix B. Detailed Passage-Estimation Table (Continued)

2010			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	3,738	3,204	70,483	24,871	637	102,933	102,933		
	American	WDFW Percent	30.31%	0.00%	14.16%	11.88%	0.00%				
		Estimated Prosser Tally	1,133	0	9,981	2,955	0	14,069	14,069		
	Naches	WDFW Percent	7.4%	19.5%	37.1%	33.6%	75.5%				
		Estimated Prosser Tally	275	625	26,167	8,364	481	35,911	35,911		
	Upper Yakima	WDFW Percent	62.3%	80.5%	48.7%	54.5%	24.5%				
		Estimated Prosser Tally	2,330	2,579	34,334	13,552	156	52,952	52,952		
		Yakima Passage Wild Tally	3,738	3,204	70,483	24,871	637	102,933	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	45.0%	45.0%	45.0%	59.2%	43.6%				
		Total Passage	8,309	7,122	156,665	42,045	1,459	215,600	215,600	226,805	
		American Passage	2,519	0	22,186	4,995	0	29,699	29,699	31,243	
		Naches Passage	611	1,389	58,163	14,140	1,101	75,404	75,404	79,322	
		American & Naches Passage	3,129	1,389	80,349	19,135	1,101	105,103	105,103	110,565	
		Upper Yakima Passage	5,180	5,733	76,316	22,910	358	110,497	110,497	116,240	
	Estimate b.	Detection Efficiency	52.2%	52.2%	52.2%	52.2%	52.2%				
		Total Passage	7,160	6,137	134,998	47,635	1,219	197,149	197,149	206,873	
		American Passage	2,170	0	19,117	5,659	0	26,947	26,947	28,276	
		Naches Passage	526	1,197	50,119	16,020	921	68,782	68,782	72,175	
		American & Naches Passage	2,696	1,197	69,236	21,679	921	95,729	95,729	100,450	
		Upper Yakima Passage	4,464	4,940	65,761	25,956	299	101,421	101,421	106,423	
	Estimate c.	Detection Efficiency	45.4%	45.4%	45.4%	57.4%	35.4%				
		Total Passage	8,235	7,058	155,261	43,333	1,796	215,683	215,683	226,848	
		American Passage	2,496	0	21,987	5,148	0	29,631	29,631	31,165	
		Naches Passage	605	1,377	57,642	14,573	1,356	75,552	75,552	79,463	
		American & Naches Passage	3,101	1,377	79,629	19,721	1,356	105,183	105,183	110,628	
		Upper Yakima Passage	5,134	5,682	75,632	23,612	440	110,500	110,500	116,220	
	Estimate e.	Detection Efficiency	51.3%	51.3%	51.3%	51.3%	51.3%				
		Total Passage	7,290	6,248	137,440	48,497	1,241	200,716	200,716	210,616	
		American Passage	2,209	0	19,463	5,761	0	27,434	27,434	28,787	
		Naches Passage	536	1,219	51,026	16,310	937	70,027	70,027	73,480	
		American & Naches Passage	2,745	1,219	70,489	22,071	937	97,461	97,461	102,268	
		Upper Yakima Passage	4,544	5,030	66,951	26,426	304	103,255	103,255	108,348	
Hatchery		Prosser Hatchery Tally	0	204	58,305	129,493	737	188,739	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	453	129,598	218,915	1,688	350,653	367,906	387,026	1.0520
	Estimate b.	Total Passage	0	390	111,674	248,021	1,411	361,496	379,282	397,989	1.0493
	Estimate c.	Total Passage	0	449	128,436	225,621	2,078	356,584	374,129	393,496	1.0518
	Estimate e.	Total Passage	0	397	113,694	252,508	1,436	368,036	386,144	405,189	1.0493

Appendix B. Detailed Passage-Estimation Table (Continued)

2011			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	24,805	4,142	30,530	15,829	99	75,405	75,405		
	American	WDFW Percent	8.6%	0.0%	3.5%	5.9%	16.6%				
		Estimated Prosser Tally	2,143	0	1,066	937	16	4,162	4,162		
	Naches	WDFW Percent	18.2%	19.8%	24.0%	13.1%	0.0%				
		Estimated Prosser Tally	4,512	818	7,316	2,074	0	14,720	14,720		
	Upper Yakima	WDFW Percent	73.2%	80.3%	72.5%	81.0%	83.4%				
		Estimated Prosser Tally	18,149	3,324	22,149	12,818	82	56,523	56,523		
		Yakima Passage Wild Tally	24,805	4,142	30,530	15,829	99	75,405	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	17.5%	17.5%	28.7%	30.9%	30.9%				
		Total Passage	141,624	23,652	106,452	51,234	320	323,281	323,281	286,030	
		American Passage	12,236	0	3,716	3,034	53	19,039	19,039	16,845	
		Naches Passage	25,761	4,671	25,508	6,713	0	62,654	62,654	55,434	
		American & Naches Passage	37,998	4,671	29,224	9,747	53	81,693	81,693	72,279	
		Upper Yakima Passage	103,626	18,980	77,228	41,488	267	241,589	241,589	213,751	
	Estimate b.	Detection Efficiency	27.9%	27.9%	27.9%	27.9%	27.9%				
		Total Passage	88,984	14,861	109,524	56,784	355	270,507	270,507	242,348	
		American Passage	7,688	0	3,823	3,362	59	14,933	14,933	13,378	
		Naches Passage	16,186	2,935	26,245	7,440	0	52,806	52,806	47,309	
		American & Naches Passage	23,874	2,935	30,067	10,803	59	67,738	67,738	60,687	
		Upper Yakima Passage	65,109	11,926	79,457	45,982	296	202,769	202,769	181,661	
	Estimate c.	Detection Efficiency	17.6%	17.6%	28.3%	29.5%	29.5%				
		Total Passage	140,886	23,528	107,826	53,604	335	326,180	326,180	289,626	
		American Passage	12,173	0	3,764	3,174	56	19,166	19,166	17,018	
		Naches Passage	25,627	4,647	25,838	7,023	0	63,135	63,135	56,060	
		American & Naches Passage	37,800	4,647	29,601	10,198	56	82,301	82,301	73,078	
		Upper Yakima Passage	103,086	18,882	78,225	43,406	279	243,879	243,879	216,548	
	Estimate e.	Detection Efficiency	27.3%	27.3%	27.3%	27.3%	27.3%				
		Total Passage	90,816	15,166	111,779	57,953	362	276,077	276,077	247,338	
		American Passage	7,846	0	3,901	3,432	60	15,240	15,240	13,654	
		Naches Passage	16,519	2,995	26,785	7,593	0	53,893	53,893	48,283	
		American & Naches Passage	24,366	2,995	30,686	11,025	60	69,133	69,133	61,936	
		Upper Yakima Passage	66,450	12,171	81,093	46,928	302	206,944	206,944	185,401	
Hatchery		Prosser Hatchery Tally	70	4,100	57,391	66,500	631	128,692	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	398	23,409	200,108	215,247	2,043	441,206	463,350	409,959	0.8848
	Estimate b.	Total Passage	250	14,708	205,884	238,562	2,265	461,669	484,840	434,369	0.8959
	Estimate c.	Total Passage	396	23,287	202,692	225,202	2,138	453,716	476,487	423,088	0.8879
	Estimate e.	Total Passage	255	15,011	210,123	243,474	2,311	471,174	494,822	443,312	0.8959

Appendix B. Detailed Passage-Estimation Table (Continued)

2012			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	16,064	6,786	14,634	4,939	993	43,415	43,415		
	American	WDFW Percent	11.0%	5.3%	6.2%	13.6%	23.5%				
		Estimated Prosser Tally	1,765	360	903	674	233	3,935	3,935		
	Naches	WDFW Percent	31.6%	29.6%	29.3%	38.5%	29.4%				
		Estimated Prosser Tally	5,079	2,009	4,291	1,901	292	13,571	13,571		
	Upper Yakima	WDFW Percent	57.4%	65.1%	64.5%	47.9%	47.1%				
		Estimated Prosser Tally	9,220	4,416	9,440	2,365	468	25,909	25,909		
		Yakima Passage Wild Tally	16,064	6,786	14,634	4,939	993	43,415	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	10.6%	10.6%	6.8%	6.4%	6.4%				
		Total Passage	150,937	63,757	213,889	76,777	15,434	520,794	520,794	316,506	
		American Passage	16,586	3,386	13,197	10,477	3,621	47,267	47,267	28,726	
		Naches Passage	47,722	18,874	62,712	29,545	4,545	163,398	163,398	99,304	
		American & Naches Passage	64,308	22,260	75,909	40,022	8,166	210,666	210,666	128,030	
		Upper Yakima Passage	86,629	41,497	137,980	36,754	7,267	310,128	310,128	188,477	
	Estimate b.	Detection Efficiency	6.8%	6.8%	6.8%	6.8%	6.8%				
		Total Passage	235,182	99,343	214,240	72,314	14,537	635,616	635,616	388,656	
		American Passage	25,844	5,276	13,219	9,868	3,411	57,617	57,617	35,231	
		Naches Passage	74,357	29,408	62,815	27,828	4,281	198,690	198,690	121,492	
		American & Naches Passage	100,201	34,684	76,034	37,696	7,692	256,307	256,307	156,722	
		Upper Yakima Passage	134,981	64,659	138,206	34,618	6,845	379,309	379,309	231,934	
	Estimate c.	Detection Efficiency	17.2%	12.0%	8.0%	6.2%	6.2%				
		Total Passage	93,620	56,530	183,542	80,101	16,102	429,896	429,896	264,355	
		American Passage	10,288	3,002	11,325	10,931	3,778	39,323	39,323	24,181	
		Naches Passage	29,600	16,735	53,814	30,825	4,742	135,716	135,716	83,456	
		American & Naches Passage	39,888	19,737	65,139	41,755	8,520	175,039	175,039	107,636	
		Upper Yakima Passage	53,733	36,794	118,403	38,346	7,582	254,857	254,857	156,719	
	Estimate e.	Detection Efficiency	7.4%	7.4%	7.4%	7.4%	7.4%				
		Total Passage	218,368	92,241	198,923	67,144	13,497	590,173	590,173	360,870	
		American Passage	23,996	4,898	12,274	9,162	3,167	53,498	53,498	32,712	
		Naches Passage	69,041	27,306	58,324	25,839	3,975	184,485	184,485	112,806	
		American & Naches Passage	93,037	32,204	70,598	35,001	7,142	237,983	237,983	145,518	
		Upper Yakima Passage	125,331	60,036	128,325	32,143	6,356	352,191	352,191	215,352	
Hatchery		Prosser Hatchery Tally	0	1,485	19,931	21,162	905	43,483	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	13,952	291,316	328,930	14,071	648,269	682,404	414,724	0.6077
	Estimate b.	Total Passage	0	21,739	291,795	309,813	13,253	636,599	670,120	409,754	0.6115
	Estimate c.	Total Passage	0	12,370	249,984	343,174	14,680	620,208	652,866	401,466	0.6149
	Estimate e.	Total Passage	0	20,185	270,933	287,663	12,306	591,087	622,211	380,460	0.6115

Appendix B. Detailed Passage-Estimation Table (Continued)

2013			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	28,451	18,683	50,994	8,258	290	106,676	106,676		
	American	WDFW Percent	8.2%	2.3%	5.7%	17.0%	6.4%				
		Estimated Prosser Tally	2,341	429	2,916	1,401	19	7,106	7,106		
	Naches	WDFW Percent	17.4%	20.6%	27.5%	29.5%	7.9%				
		Estimated Prosser Tally	4,959	3,847	14,023	2,439	23	25,290	25,290		
	Upper Yakima	WDFW Percent	74.3%	77.1%	66.8%	53.5%	85.8%				
		Estimated Prosser Tally	21,150	14,407	34,055	4,419	248	74,280	74,280		
		Yakima Passage Wild Tally	28,451	18,683	50,994	8,258	290	106,676	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	26.7%	26.7%	37.1%	23.4%	23.4%				
		Total Passage	106,549	69,970	137,366	35,270	1,238	350,393	350,393	767,934	
		American Passage	8,769	1,608	7,855	5,982	79	24,293	24,293	53,241	
		Naches Passage	18,571	14,408	37,774	10,415	97	81,265	81,265	178,103	
		American & Naches Passage	27,340	16,016	45,628	16,397	176	105,558	105,558	231,344	
		Upper Yakima Passage	79,208	53,955	91,738	18,873	1,061	244,835	244,835	536,589	
	Estimate b.	Detection Efficiency	32.6%	32.6%	32.6%	32.6%	32.6%				
		Total Passage	87,195	57,260	156,284	25,309	888	326,935	326,935	803,449	
		American Passage	7,176	1,316	8,936	4,293	57	21,778	21,778	53,519	
		Naches Passage	15,198	11,791	42,976	7,474	70	77,507	77,507	190,476	
		American & Naches Passage	22,374	13,106	51,912	11,766	126	99,285	99,285	243,995	
		Upper Yakima Passage	64,820	44,154	104,372	13,543	762	227,650	227,650	559,454	
	Estimate c.	Detection Efficiency	0.2748	0.2748	0.3506	0.2114	0.2114				
		Total Passage	103,515	67,978	145,428	39,056	1,370	357,347	357,347	764,845	
		American Passage	8,519	1,562	8,316	6,624	88	25,109	25,109	53,742	
		Naches Passage	18,043	13,997	39,991	11,533	108	83,671	83,671	179,085	
		American & Naches Passage	26,562	15,560	48,306	18,157	195	108,780	108,780	232,827	
		Upper Yakima Passage	76,953	52,418	97,122	20,898	1,175	248,567	248,567	532,019	
	Estimate e.	Detection Efficiency	0.3051	0.3051	0.3051	0.3051	0.3051				
		Total Passage	93,241	61,231	167,121	27,064	950	349,607	349,607	859,166	
		American Passage	7,674	1,407	9,556	4,590	61	23,288	23,288	57,231	
		Naches Passage	16,252	12,608	45,956	7,992	75	82,882	82,882	203,685	
		American & Naches Passage	23,926	14,015	55,512	12,582	135	106,170	106,170	260,916	
		Upper Yakima Passage	69,315	47,216	111,609	14,482	814	243,437	243,437	598,250	
Hatchery		Prosser Hatchery Tally	0	13,014	69,719	20,263	791	103,787	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	48,738	187,807	86,542	3,380	326,467	344,280	754,537	2.1916
	Estimate b.	Total Passage	0	39,885	213,671	62,100	2,425	318,081	335,437	824,343	2.4575
	Estimate c.	Total Passage	0	47,350	198,830	95,831	3,743	345,754	364,619	780,410	2.1403
	Estimate e.	Total Passage	0	42,651	228,489	66,406	2,594	340,139	358,699	881,509	2.4575

Appendix B. Detailed Passage-Estimation Table (Continued)

2014			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	1,621	4,340	14,949	11,897	959	33,767	33,767		
	American	WDFW Percent	11.7%	12.0%	9.1%	11.9%	13.9%				
		Estimated Prosser Tally	189	522	1,360	1,421	133	3,625	3,625		
	Naches	WDFW Percent	41.2%	21.7%	30.2%	38.1%	0.0%				
		Estimated Prosser Tally	668	944	4,509	4,535	0	10,656	10,656		
	Upper Yakima	WDFW Percent	47.2%	66.2%	60.7%	49.9%	86.1%				
		Estimated Prosser Tally	765	2,874	9,080	5,940	826	19,486	19,486		
		Yakima Passage Wild Tally	1,621	4,340	14,949	11,897	959	33,767	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	13.9%	13.9%	13.9%	13.9%	6.0%				
		Total Passage	11,677	31,257	107,660	85,679	15,923	252,195	252,195	249,942	
		American Passage	1,360	3,760	9,791	10,236	2,208	27,355	27,355	27,111	
		Naches Passage	4,810	6,795	32,474	32,662	0	76,741	76,741	76,055	
		American & Naches Passage	6,170	10,555	42,266	42,898	2,208	104,096	104,096	103,166	
		Upper Yakima Passage	5,507	20,701	65,395	42,781	13,715	148,099	148,099	146,776	
	Estimate b.	Detection Efficiency	13.8%	13.8%	13.8%	13.8%	13.8%				
		Total Passage	11,711	31,349	107,976	85,931	6,930	243,897	243,897	240,662	
		American Passage	1,364	3,771	9,820	10,266	961	26,183	26,183	25,835	
		Naches Passage	4,824	6,815	32,570	32,758	0	76,966	76,966	75,946	
		American & Naches Passage	6,188	10,586	42,390	43,024	961	103,149	103,149	101,781	
		Upper Yakima Passage	5,523	20,762	65,587	42,907	5,969	140,748	140,748	138,881	
	Estimate c.	Detection Efficiency	13.1%	13.1%	13.1%	13.1%	5.0%				
		Total Passage	12,334	33,016	113,718	90,500	19,031	268,598	268,598	266,459	
		American Passage	1,437	3,972	10,342	10,812	2,638	29,201	29,201	28,969	
		Naches Passage	5,080	7,178	34,302	34,500	0	81,059	81,059	80,414	
		American & Naches Passage	6,517	11,149	44,644	45,312	2,638	110,260	110,260	109,382	
		Upper Yakima Passage	5,817	21,866	69,074	45,188	16,392	158,337	158,337	157,077	
	Estimate e.	Total Passage	13.0%	13.0%	13.0%	13.0%	13.0%				
		Total Passage	12,442	33,306	114,717	91,295	7,363	259,122	259,122	255,685	
		American Passage	1,449	4,007	10,433	10,907	1,021	27,817	27,817	27,448	
		Naches Passage	5,125	7,241	34,603	34,803	0	81,771	81,771	80,686	
		American & Naches Passage	6,574	11,247	45,036	45,710	1,021	109,588	109,588	108,135	
		Upper Yakima Passage	5,868	22,058	69,681	45,585	6,342	149,534	149,534	147,551	
Hatchery		Prosser Hatchery Tally	0	1,493	16,126	31,612	1,114	50,344	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	10,749	116,139	227,664	18,480	373,031	392,491	388,984	0.9911
	Estimate b.	Total Passage	0	10,781	116,480	228,332	8,043	363,636	382,606	377,532	0.9867
	Estimate c.	Total Passage	0	11,354	122,673	240,474	22,087	396,588	417,277	413,954	0.9920
	Estimate e.	Total Passage	0	11,454	123,751	242,586	8,545	386,336	406,490	401,099	0.9867

Appendix B. Detailed Passage-Estimation Table (Continued)

2015			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	2,548	13,541	35,320	11,639	4	63,052	63,052		
	American	WDFW Percent	13.9%	11.6%	8.9%	14.7%	14.7%				
		Estimated Prosser Tally	353	1,573	3,149	1,716	1	6792	6,792		
	Naches	WDFW Percent	16.8%	26.3%	23.1%	24.1%	24.1%				
		Estimated Prosser Tally	428	3,564	8,169	2,804	1	14966	14,966		
	Upper Yakima	WDFW Percent	69.3%	62.1%	68.0%	61.2%	61.2%				
		Estimated Prosser Tally	1,767	8,404	24,002	7,119	2	41295	41,295		
		Yakima Passage Wild Tally	2,548	13,541	35,320	11,639	4	63052	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	52.9%	52.9%	52.9%	56.3%	56.3%				
		Total Passage	4,820	25,614	66,809	20,689	6	117,939	117,939	136,009	
		American Passage	668	2,976	5,956	3,050	1	12,651	12,651	14,589	
		Naches Passage	810	6,742	15,451	4,985	2	27,990	27,990	32,278	
		American & Naches Passage	1,478	9,718	21,408	8,035	3	40,641	40,641	46,867	
		Upper Yakima Passage	3,342	15,897	45,401	12,655	4	77,298	77,298	89,142	
	Estimate b.	Detection Efficiency	53.2%	53.2%	53.2%	53.2%	53.2%				
		Total Passage	4,793	25,468	66,427	21,890	7	118,585	118,585	136,544	
		American Passage	664	2,959	5,922	3,227	1	12,773	12,773	14,708	
		Naches Passage	805	6,703	15,363	5,274	2	28,148	28,148	32,411	
		American & Naches Passage	1,469	9,662	21,285	8,501	3	40,921	40,921	47,118	
		Upper Yakima Passage	3,323	15,806	45,141	13,389	4	77,664	77,664	89,426	
	Estimate c.	Detection Efficiency	37.1%	37.1%	62.1%	57.6%	57.6%				
		Total Passage	6,875	36,531	56,858	20,221	6	120,491	120,491	139,246	
		American Passage	953	4,244	5,069	2,981	1	13,248	13,248	15,310	
		Naches Passage	1,155	9,615	13,150	4,872	2	28,794	28,794	33,275	
		American & Naches Passage	2,108	13,859	18,219	7,853	2	42,042	42,042	48,585	
		Upper Yakima Passage	4,767	22,671	38,639	12,368	4	78,449	78,449	90,660	
	Estimate e.	Detection Efficiency	51.4%	51.4%	51.4%	51.4%	51.4%				
		Total Passage	4,960	26,355	68,741	22,653	7	122,717	122,717	141,302	
		American Passage	687	3,062	6,129	3,339	1	13,218	13,218	15,220	
		Naches Passage	833	6,937	15,898	5,458	2	29,128	29,128	33,540	
		American & Naches Passage	1,521	9,999	22,027	8,797	3	42,347	42,347	48,760	
		Upper Yakima Passage	3,439	16,356	46,714	13,856	4	80,370	80,370	92,542	
Hatchery		Prosser Hatchery Tally	0	41,325	90,070	26,254	11	157,660	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	78,169	170,371	46,668	19	295,227	314,538	362,731	1.1532
	Estimate b.	Total Passage	0	77,722	169,397	49,377	21	296,517	315,912	363,757	1.1514
	Estimate c.	Total Passage	0	111,483	144,995	45,612	19	302,109	321,870	371,970	1.1557
	Estimate e.	Total Passage	0	80,430	175,300	51,098	21	306,849	326,920	376,431	1.1514

Appendix B. Detailed Passage-Estimation Table (Continued)

2016			Pre-March	March	April	May	Post-May	Total	Expanded Total	Calibrated Total	
Wild		Prosser Wild Tally	26,060	34,810	38,196	31,423	659	131,148	131,148		
	American	WDFW Percent			Not yet available						
		Estimated Prosser Tally									
	Naches	WDFW Percent			Not yet available						
		Estimated Prosser Tally									
	Upper Yakima	WDFW Percent			Not yet available						
		Estimated Prosser Tally									
		Yakima Passage Wild Tally	0	0	0	0	0	0	Expanded Total	Calibrated Total	
	Estimate a.	Detection Efficiency	5.5%	5.5%	5.5%	22.8%	22.8%				
		Total Passage	474,915	634,364	696,085	137,864	2,889	1,946,118	1,946,118	157,621	
		American Passage									
		Naches Passage									
		American & Naches Passage									
		Upper Yakima Passage									
	Estimate b.	Detection Efficiency	9.6%	9.6%	9.6%	9.6%	9.6%				
		Total Passage	270,651	361,520	396,695	326,345	6,840	1,362,051	1,362,051	128,134	
		American Passage									
		Naches Passage									
		American & Naches Passage									
		Upper Yakima Passage									
	Estimate c.	Detection Efficiency	5.9%	5.9%	4.4%	21.5%	21.5%				
		Total Passage	441,717	590,019	874,210	146,178	3,064	2,055,187	2,055,187	160,556	
		American Passage									
		Naches Passage									
		American & Naches Passage									
		Upper Yakima Passage									
	Estimate e.	Detection Efficiency	8.4%	8.4%	8.4%	8.4%	8.4%				
		Total Passage	310,405	414,620	454,961	374,279	7,844	1,562,109	1,562,109	146,954	
		American Passage									
		Naches Passage									
		American & Naches Passage									
		Upper Yakima Passage									
Hatchery		Prosser Hatchery Tally	0	82,728	126,851	185,369	596	395,544	Expanded Total	Calibrated	Value
	Estimate a.	Total Passage	0	1,507,614	2,311,712	813,290	2,614	4,635,230	4,908,275	397,534	0.0810
	Estimate b.	Total Passage	0	859,180	1,317,431	1,925,175	6,188	4,107,974	4,349,960	409,219	0.0941
	Estimate c.	Total Passage	0	1,402,225	2,903,267	862,333	2,772	5,170,597	5,475,179	427,733	0.0781
	Estimate e.	Total Passage	0	985,376	1,510,935	2,207,945	7,097	4,711,353	4,988,882	469,325	0.0941

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Appendix D
Annual Report: Smolt Survival to McNary Dam of 1999-2013 and 2015-2016 PIT-tagged Spring Chinook released or detected at Roza Dam

Doug Neeley, Consultant to the Yakama Nation

Introduction and Summary

From 1999[1] through 2013 and 2015-2016, survival estimates to McNary Dam (McNary) of PIT-tagged hatchery-spawned Spring Chinook (hatchery) and naturally spawned (natural) smolt released into the Roza Dam (Roza) juvenile bypass system were made and compared. These releases were not made in 2014 because of radio-tagged studies conducted at Roza in that year. Radio-tag studies were also conducted in 2016 as well, but there were a limited number of days when PIT-tagged releases were made, enabling estimation of Roza-to-McNary survivals based on relatively small releases numbers.

Roza-to-McNary survival estimates are compared between PIT-tagged hatchery smolt and PIT-tagged natural smolt contemporaneously released with hatchery smolt at Roza, the contemporaneously released natural smolt being referred to as "late" natural smolt. Survival-estimate comparisons are also made between late and "early" natural smolt, the early natural smolt being those released before observed hatchery-smolt passage at Roza. All smolt releases in this study were originally collected from the Roza bypass system, PIT-tagged if not previously PIT-tagged, and then all PIT-tagged fish were released back into the bypass.

The mean McNary survival of late natural smolt over years is significantly and substantially greater than that of hatchery smolt but is not significantly different than that of early natural smolt; however, survival of early natural smolt may be underestimated in some years.

The detection efficiencies used to estimate Release-to-McNary given in the 2015 Annual Report were found to have been in error, and have been re-estimated. The current estimation procedures are presented in Appendix A[2].

Methodology

[1] **The first outmigration year of Upper Yakima River hatchery-origin Spring Chinook**

[2] **In Appendix A. "Assessed Dam' is McNary, "Downstream Dams" are Bonneville and John Day, and "Periods" are Pre-April, Early April (through April 15), Late April, Early May (through May 15), Late May, Early June (through June 15), Late June, and after June**

All smolt releases included in the analyses were grouped into seven-day intervals; i.e., smolt released between Julian dates 1 and 7 were treated as one release group, those released between Julian dates 8 and 14 were treated as another group, etc. These groups are referred to as Julian weeks. This was primarily done to have consistency over years, but if there were not a sufficient number of smolt within a Julian week, then adjacent seven-day groups were sometimes combined into a common group. Weighted logistic analyses of variation both within and over years were used to analyze the proportion surviving to McNary, there weights being the release numbers of fish used to estimate the proportions. Comparisons of late-natural and hatchery smolt were treated as paired comparisons with the Julian-date intervals treated as blocks. Comparisons between early and late natural smolt proportions were treated as independent comparisons since they involved different Julian-date intervals.

Comparison of Natural- and Hatchery-Origin Smolt Survival to McNary from Contemporaneous Roza Releases

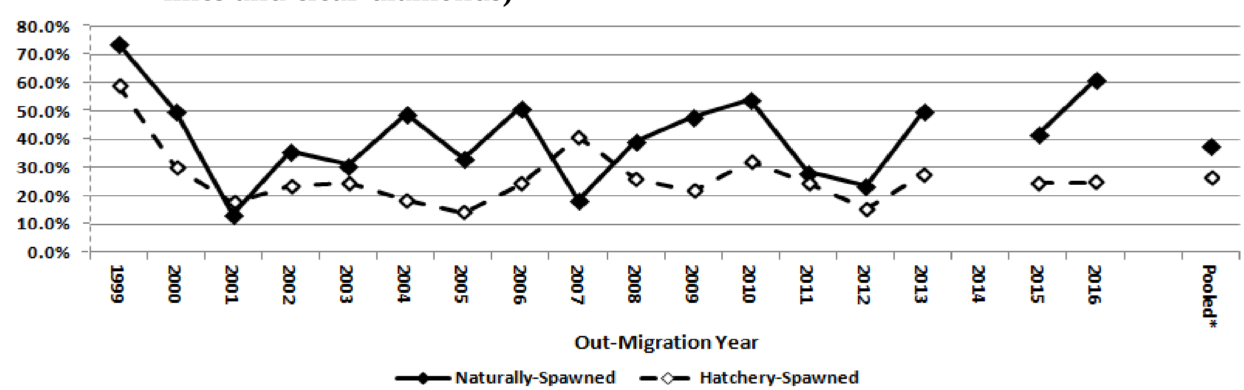
As was the case in all but two of the previous years, late naturally spawned smolt released at Roza in 2016 had a higher mean Roza-to-McNary survival rate than did hatchery smolt. Table 1.a. and Figure 1. present the contemporaneously released late-natural- and hatchery-smolt survivals.

Table 1.a. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Late Natural Smolt and Hatchery Smolt

	Brood Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Pooled
	Outmigration Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Naturally-Spawned	Survival	73.9%	49.8%	13.3%	35.8%	30.9%	49.1%	33.5%	51.3%	18.3%	39.4%	47.8%	54.0%	28.4%	23.8%	50.0%		42.0%	61.4%	37.8%
	Number Released	1,082	2,048	1,744	716	2,146	2,099	1,420	3,689	2,477	4,406	3,188	1,130	4,035	4,424	230	0	1,503	433	36,770
Hatchery-Spawned	Survival	59.1%	29.9%	17.5%	23.3%	24.6%	18.4%	14.0%	24.3%	40.6%	25.9%	21.7%	32.0%	24.3%	15.3%	27.6%		24.3%	24.7%	26.3%
	Number Released	312	3,196	1,424	1,221	1,190	74	80	500	336	421	239	105	962	191	38	0	358	36	10,683
Natural - Hatchery Difference		14.7%	19.9%	-4.2%	12.4%	6.4%	30.6%	19.4%	27.0%	-22.3%	13.5%	26.1%	22.0%	4.1%	8.5%	22.3%	n.a.	17.6%	36.7%	11.5%

Note: Positive Hatchery-Spawned - Naturally-Spawned Differences shaded in Yellow

Figure 1. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Late Natural Smolt (solid lines and filled diamonds) and Hatchery Smolt (dashed lines and clear diamonds)



*** Weighted mean using yearly release number as a weighting variable of survival percentages**

As can be seen from Table 1.a. and Figure 1, the late natural smolt survival exceeded that of the hatchery smolt in 15 or 88%[3] of the 17 outmigration years.

Because naturally-spawned smolt will have survived the in-stream environment longer than hatchery-spawned smolt by the time that they pass Roza Dam, it has always been hypothesized that, for smolt contemporaneously released at Roza, the survival to McNary of naturally-spawned-smolt would be greater than that of hatchery-spawned smolt even though the hatchery smolt tend to be larger. Therefore, a one-sided test for the hypothesis

$$\text{natural survival} - \text{hatchery survival} > 0$$

was performed based on the null hypotheses of no survival difference. The natural survival pooled over years was highly significantly greater than the pooled hatchery survival (P=0.0002 from Table 1.b.).

Table 1.b. Logistic Analysis of Variance of Natural versus Hatchery 1999-2016 Smolt Survival from Roza Release to McNary Dam

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error (P)	1-sided Type 1-Error*	Denominator Source
Year	2299.91	16	143.74	6.98	0.0000		Among Julian Weeks
Among Julian Week Groupings within Year	1853.222	90	20.59	3.93	0.0000		Error
Natural vs Hatchery (Stock)	276.42	1	276.42	19.67	0.0004	0.0002	Year x Stock
Year x Stock	224.84	16	14.05	2.68	0.0024		Error
Error	361.524	69	5.24				

* Test for Natural Survival > Hatchery Survival

Comparison of Early and Late Natural-Origin Smolt Survival to McNary

In 1999 and 2010 there were no early naturally-spawned smolt releases at Roza prior to Roza passage of hatchery smolt, and, as stated before, there were no PIT-tagged releases in 2014. Table 2.a. and Figure 2. present the naturally-spawned early- and late-smolt survivals from Roza to McNary for those outmigration years within those years for which early arriving natural-origin smolt were available.

Table 2.a. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Early and Late[4] Natural Smolt

	Brood Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Pooled
Passage Period**	Outmigration Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Late	Survival		33.1%	47.5%	22.6%	31.4%	34.0%	26.1%	19.7%	31.9%	31.0%	43.0%		23.1%	30.0%	27.1%		36.3%	22.8%	29.6%
	Realeased		3,013	755	6,747	6,614	3,857	1,653	1,833	1,072	1,254	1,804		1,040	2,482	2,435		167	97	34,823
Early	Survival	73.9%	49.8%	13.3%	35.8%	30.9%	49.1%	33.5%	51.3%	18.3%	39.4%	47.8%	54.0%	28.4%	23.8%	50.0%		42.0%	61.4%	37.9%
	Released	312	3,196	1,424	1,221	1,190	74	80	500	336	421	239	105	962	191	38		358	36	10,683
Late - Early Difference		n.a.	-16.8%	34.2%	-13.2%	0.4%	-15.1%	-7.4%	-31.6%	13.5%	-8.4%	-4.8%	n.a.	-5.2%	6.3%	-22.8%	n.a.	-5.7%	-38.6%	-8.3%

n.a. (not applicable) omitted because outmigration years 1999 and 2010 with all wild-release passage prior hatchery-release passage at Roza and 2014 because of no PIT-Tagged Releases

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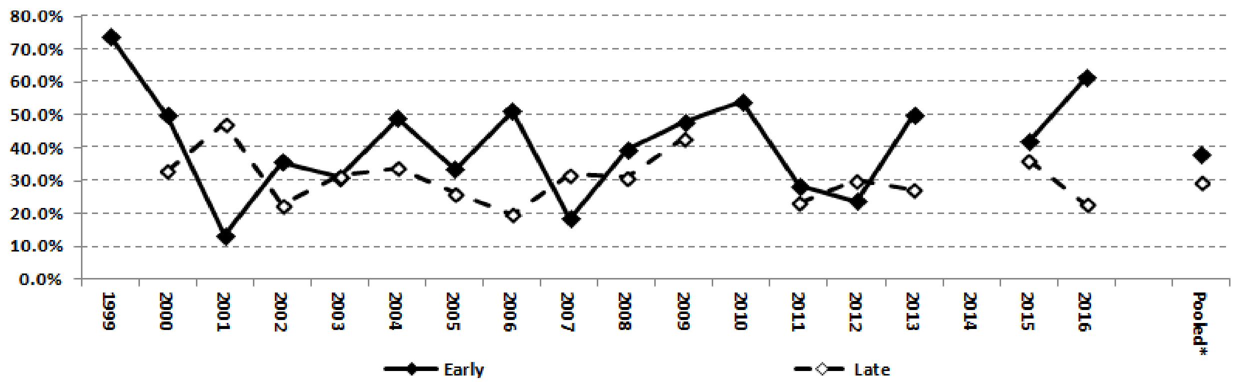
[3] **The 88% is significantly greater than what would be expected by chance (P = 0.0012) based on a 1-sided binomial distribution sign test).**

[4] **Passing Roza contemporaneously with hatchery smolt**

Of the fifteen years with early releases, late releases had higher Roza-to-McNary survival in 11 (73%[5]) of those years. The pooled mean survival estimate over years was also not significant (P = 0.1437, Table 2.b.).

Figure 2. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Early Natural Smolt (solid lines and filled diamonds) and for Late Natural Smolt (dashed lines and clear diamonds)



*** Weighted mean using yearly release number as a weighting variable of survival percentages**

Table 2.b. Logistic Analysis of Variance of 1999-2016 Early versus Late Natural Smolt Survival from Roza Release to McNary Dam

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error (P)	Denominator Source
Year	**1043.17**	**16**	**65.20**	**6.72**	**0.0000**	**Error**
Early verses Late	122.07	1	122.07	2.40	0.1437	Interaction
Year x Early vs Late Interaction	**712.35**	**14**	**50.88**	**5.24**	**0.0000**	**Error**
Error	1378.1	142	9.70			

Figure 3. presents the individual year Prosser-to-McNary Dam Plots within Julian-week groupings for natural and hatchery releases at Prosser. As can be seen in those individual year plots, in some years the first early releases are made before the first Julian week of the stated out-migration year, and in most years the first early natural release date is before the Julian week beginning on Julian date 47. McNary Dam's bypass is generally watered up after Julian date 90. It may well be that many of the early releases pass McNary before they could be detected, in which case early-release survival estimates may be underestimated.

[5] **The 73% is not significantly different than what would be expected by chance (P = 0.1286) based on a 2-sided binomial distribution sign test).**

Figure 3. Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week grouping (Natural Smolt – Solid diamonds and sold lines, Hatchery Smolt – clear squares and dashed lines)

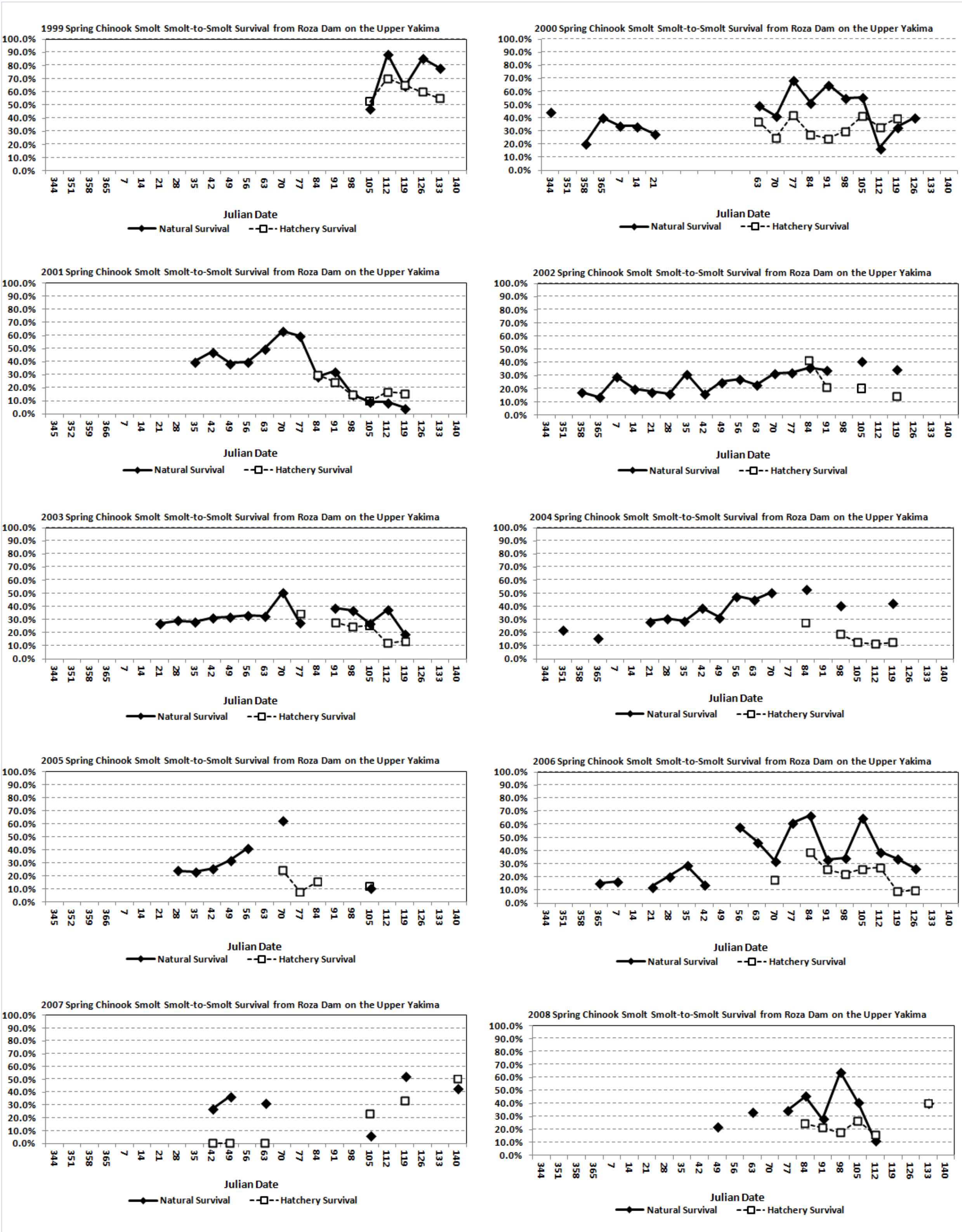
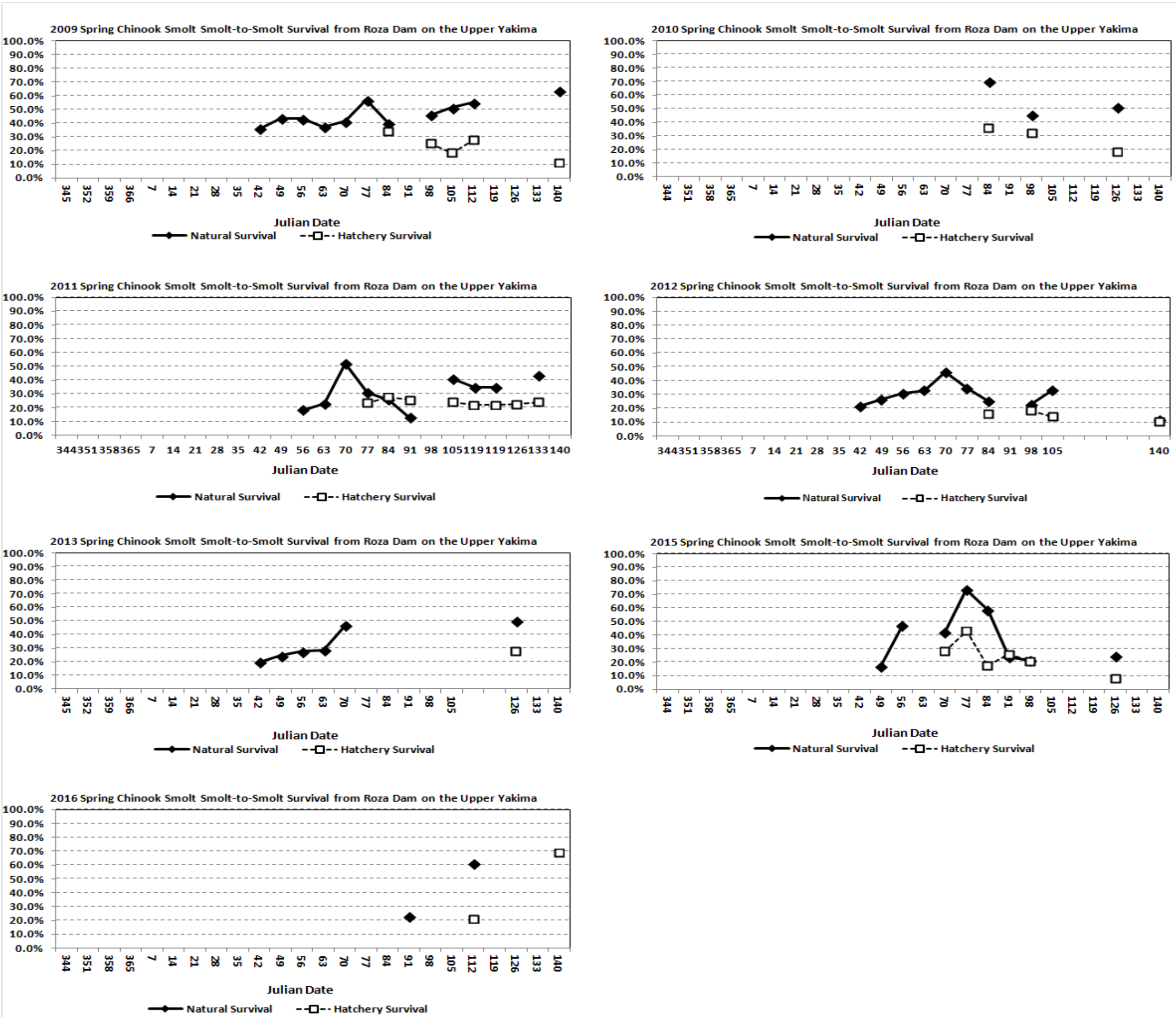


Figure 3. (continued) Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week grouping (Natural Smolt – Solid diamonds and sold lines, Hatchery Smolt – clear squares and dashed lines)



Appendix A. Estimating Detection Rate Efficiencies and Expanding the Assessed dam Detections by those Efficiencies

For each dam down-stream of the dam for which detection efficiencies are being estimated, the joint assessed and downstream dams' joint detections at a downstream dam are obtain for each assessed dam's date and down-stream dam's date. Within each downstream-dam date, the detections are pooled over the assessed dam's dates to give the total assessed dam's detections on that downstream date. These joint totals are then divided by total downstream dam detections to get the estimated assessed dam's detection efficiency rate for that down-stream dam date. These detection rates are used as a dependent variable in a stepwise logistic regression. The dependent variables are indicator variables for the down-stream dam Julian detection dates. For a given downstream dam detection date, the indicator variable (IV) is assigned the value 0 if the actual down-stream dam date is less than the given IV Julian date and is 1 if that date is equal to or greater that IV date as illustrated below.

Table A.1. Variables used in getting stratified detection efficiencies

Lower Dam Julian Date	Assessed and Downstream Dam's Detections	Total Lower Downstream Detections	Upstream Dams Detection Rate	…	Indicator Variables																…
					IV-40	IV-4s	IV-4s	IV-43	IV-44	IV-45	IV-46	IV-47	IV-48	IV-49	IV-50	IV-5s	IV-5s	IV-53	IV-54	IV-55	
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
40	25	205	0.1219512	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
41	25	154	0.1623377	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
42	35	244	0.1434426	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
43	50	208	0.2403846	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
44	75	280	0.2678571	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
45	220	420	0.5238095	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
46	90	380	0.2368421	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
47	220	490	0.4489796	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
48	220	424	0.5188679	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
49	250	624	0.400641	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
50	275	670	0.4104478	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
51	220	460	0.4782609	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
52	225	520	0.4326923	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
53	95	372	0.2553763	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
54	70	289	0.2422145	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
55	80	330	0.2424242	…	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Using the total lower dam's total detections at the downstream dam as the weight, a weighted stepwise logistic regression of the assessed dam's detection rate is run on the indicator variables. The regression output will be the list of out down-stream dam Julian dates which will establish strata boundaries. The detection rates for the sorted listed date and all the dates up to but not including the next listed sorted date are pooled together as a stratum of reasonably homogeneous detection rates. The dates preceding the first sorted listed date are also pooled into a separate stratum.

A smolt passing the assessed dam during that period could pass the down-stream dam during any of the down-stream dam strata[6]. It is necessary to proportionately assign down-stream strata

---

[6] For hatchery Spring Chinook, McNary passage periods the following passage periods were established were established: Pre-April , Early April through April 15, Late April, Early May through May 15, Late April, Early June through Jun 15, Late June, Post-June.

detection efficiencies to the assessed dam's passage periods for the purpose of expanding the assessed dam counts within those periods.

Referring to Table A.2., the number of the joint detections (x in Table A.2.) within a lower dam stratum that came from the assessed dam time period was computed for each lower dam stratum. For each stratum, the period's number of joint detections was divided by the period's joint detections over all periods, giving the period's relative frequency within the stratum (P in Table A.2.). The stratum's total downstream-dam detections (n in Table A.3) were multiplied by the relative frequency proportions to assign those stratum totals to the periods. Within the period, the stratums' detection efficiencies were weighted by the stratum downstream totals assigned to the period to obtain the mean detection efficiency for the period (example highlighted in yellow at the bottom of Table A.3).

Table A.2. Allocation of proportions of Joint Assessed and Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata

		Joint Number (x) of Downstream Dam and Assessed Dam Detections					
Stratum	Measure	Period a	Period b	Period c	...	Period p	Total
1	Joint Detections	x(a,1)	x(b,1)	x(c,1)	...	x(p,1)	x(1)
	Proportional Distribution	P(a,1)=x(a,1)/x(1)	P(b,1)=x(b,1)/x(1)	P(a,1)=x(a3)/x(1)	...	P(p,1)=x(p,1)/x(1)	
2	Joint Detections	x(a,2)	x(b,2)	x(c,2)		x(p,2)	x(2)
	Proportional Distribution	P(a,2)=x(a,2)/x(2)	P(b,2)=x(b,2)/x(2)	P(a,2)=x(a3)/x(2)	...	P(p,2)=x(p,2)/x(2)	
3	Joint Detections	x(a,3)	x(b,3)	x(c,3)		x(p,3)	x(3)
	Proportional Distribution	P(a,3)=x(a,3)/x(3)	P(b,3)=x(b,3)/x(3)	P(a,3)=x(a3)/x(3)	...	P(p,3)=x(p,3)/x(3)	
...	...	...	...	...	...	...	...
s	Joint Detections	x(a,s)	x(b,s)	x(c,s)		x(p,s)	x(s)
	Proportional Distribution	P(a,s)=x(a,s)/x(s)	P(b,s)=x(b,s)/x(s)	P(a,s)=x(as)/x(s)	...	P(p,s)=x(p,s)/x(s)	

Table A.3. Allocation of Total Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata and Estimation of Assessed Dam's Period Detection Efficiencies

			Number (n) of Downstream Detections*				
Stratum	Downstream Detections	Detection Efficiencies*	Period a	Period b	Period c	...	Period p
1	n(1)	de(1)=x(1)/n(1)	n(a,1) = n(1)*P(a,1)	n(b,1) = n(1)*P(b,1)	n(c,1) = n(1)*P(c,1)	...	n(p,1) = n(1)*P(p,1)
2	n(2)	de(2)=x(2)/n(2)	n(a,2) = n(2)*P(a,s)	n(b,2) = n(2)*P(b,s)	n(c,2) = n(2)*P(c,s)	...	n(p,2) = n(2)*P(p,s)
3	n(3)	de(3)=x(3)/n(3)	n(a,3) = n(3)*P(a,3)	n(b,3) = n(3)*P(b,3)	n(c,3) = n(3)*P(c,3)	...	n(p,3) = n(3)*P(p,3)
	...	...	...	...	...	...	...
s	n(s)	de(s)=x(4)/n(4)	n(a,s) = n(s)*P(a,s)	n(b,s) = n(s)*P(b,s)	n(c,s) = n(s)*P(c,s)	...	n(p,s) = n(s)*P(p,s)
Total			n(a)	n(b)	n (c)	...	n(p)

Example of detection efficiency for Period b: [n(b,1)*de(1) +n(b,2)*de(2) +n(b,3)*de(3)+...+n(b,s)*de(s)]/n(b)

This estimation procedure is separately performed for each of the down-stream dams, and then the within period detection rate estimates are weighted by the total allocated to the period (the row labeled "Total" in Table A.3. taken from each of the downstream dam's tables) While subject to bias, there is evidence that this procedure gives a less-biased detection-efficiency estimator application than just using the assessed dam and down-stream dam detections divided by the total down-stream dam detections ignoring strata and periods.

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Appendix E
Annual Report: Comparisons between Smolt-Trait Measures of Hatchery x Hatchery- and Natural x Natural-Brood Stock for Brood-Years 2002-2016 Upper Yakima Spring Chinook

Doug Neeley, Consultant to the Yakama Nation

Summary

Hatchery x Hatchery (HxH or Hatchery Control - HC) and Natural x Natural (NxN or Supplemental Hatchery -SH) stock[1] reared at the Cle Elum Facility were allocated to Clark Flat acclimation-site raceway pairs from brood year 2002 through the present. With the exception of the 2013 brood (released as smolt in 2015), the raceways within each pair were assigned different feed treatments. To avoid potential interaction with treatments that differed over years, the treatment that was common over all years was used in this analysis[2].

The following juvenile traits are analyzed:

1) Pre-release weight
2) Volitional-release-to-McNary survival[3]
3) Percent of fish detected leaving pond (volitional release)
4) Mean and median acclimation-pond volitional-release date
5) Mean and median McNary Dam (McNary) passage date

Of these above enumerated traits, the HxH - NxN main effect differences that were significant at the 5% significance level were:

3) Percent of fish detected leaving the pond, the HxH cross having the lower percentage over years (and presumably having the lower pre-release survival);
5) McNary Mean Passage Date, HxH cross having later mean and median passage dates over years.

[1] **HxH and NxN Stock are part of domestication selection study. The original progenitors of both stocks were wild Upper-Yakima Stock. Both Stocks are reared in the hatchery, but HxH are progeny of hatchery-spawned parents, and NxN are progeny of naturally spawned parents. Protocol dictates that HxH progeny never spawn outside of the hatchery, and NxN progeny are never spawned in the Hatchery.**

[2] **In previous reports, all treatments were included which led to a complicated and somewhat confusing analysis.**

[3] **The detection efficiencies used to estimate Release-to-McNary survival given in the 2015 Annual Report were found to have been in error, and have been re-estimated. The current estimation procedures are presented below in Appendix A .**

Design of Experiment and Analysis Procedures

The HxH stock assignment was superimposed at only the Clark Flat Acclimation Site at which there were three pairs of raceways[4] with two feed treatments[5] allocated to the different raceways within each pair, the treatments not common to all years being excluded from the analysis in this report. The HxH Stock was allocated to one of the three pairs of raceways, and the NxN Stock to the other two pairs[6]. Thus there were twice as many raceways at Clark Flat assigned to the NxN Stock than to the HxH Stock. The "error" in the analyses of variation presented in this report is primarily[7] based on the variation among the NxN raceways within years.

A proportion of fish in each raceway was PIT-tagged for the primary purpose of estimating smolt-to-smolt survival from volitional release to McNary Dam on the Columbia River, located 70 km below the Yakima River confluence with the Columbia River. Beginning with the 2006 brood, there were twice as many HxH fish PIT-tagged per raceway than there were NxN fish to give approximately an equal total number of PIT-tagged fish for both the HxH and NxN stocks at Clark Flat.

Both main effect the HxH–NxN difference and the yearly HxH–NxN differences interaction within years were tested at the 5% significance level using either a weighted-least-squares analysis of variance or a weighted-logistic-analysis of variation[8]. The analyses of variation are presented in Appendix B. Year was taken to be a random effect; therefore, the weighted mean HxH - NxN main-effect difference over years was tested against the Stock x Year interaction, and that interaction was tested against the "error" variation.

---

[4] Raceways within each pair were similar in that they were physically adjacent to each other and in that they both received progeny from the same sets of diallele crosses, there being different male and female parental sets assigned to the different raceway pairs. This could result in smolt within raceway pairs being more similar than smolt from different raceway pairs due to genetic and/or parental-effect similarities within pairs.

[5] In every year, two treatments were evaluated. For 2004 through 2006 releases, they were Low and High Nutrition BioVita Feed levels Feeds, the High BioVita Feed level being the standard or Control over all years that the HxH-NxN trials have been conducted.

[6] NxN stock was the only stock used at the other two acclimation sites; i.e., allocated to all three pairs of raceways at both the Easton and Jack Creek sites, the data from which are not included in the analysis.

[7] The 2015 releases had only the Control treatment assigned giving three additional raceways within pairs available to the analysis.

[8] In the case of percentages (proportions), the analysis was a weighted logistic analysis of variation, and for the other measures, the analysis was a weighted least squares of variance, the weights being the number of observations used to compute the raceway estimates.

Mean Pre-Release Smolt Weight

Table and Figure 1 present the pre-release fish-weight means estimated from total weight and fish count from a bulk sample taken from each raceway. The main-effect-mean difference between stock was not significant at the 5% level (Type 1 Error P = 0.50 Appendix Table B.1.). The Stock x Year interaction was significant at the 5% significance level (Type 1 Error P = 0.011, Appendix Table B.1.). The nature of the interaction is evident from Figure 1 wherein the absolute magnitude of the weight differences are the largest in 2015 and 2016; however the NxN mean weight was greatest in 2015, but the HxH mean weight was greatest in 2016.

Figure 1. Release-Year 2004-2016 HxH and NxN Mean pre-release Juvenile Weight of Spring Chinook Smolt released from the Clark Flat Acclimation Site

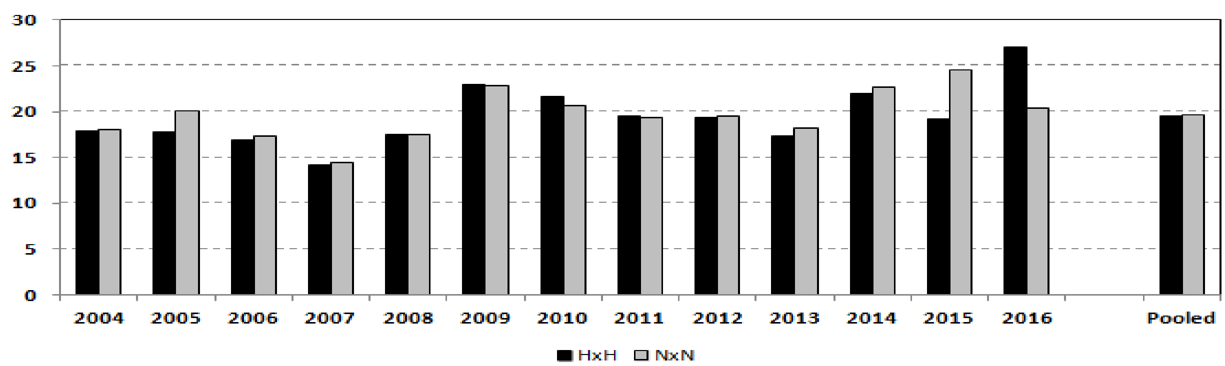

Table 1. Release-Year 2004-2016 HxH and NxN Mean pre-release Juvenile Weight of Spring Chinook Smolt released from the Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	Detection Date	17.94	17.75	16.84	14.22	17.49	22.90	21.69	19.54	19.38	17.27	21.99	19.20	27.00	19.48
NxN	Detection Date	18.12	20.04	17.33	14.45	17.52	22.84	20.71	19.39	19.52	18.19	22.65	24.59	20.32	19.66
	Difference	-0.18	-2.29	-0.49	-0.23	-0.03	0.06	0.99	0.15	-0.14	-0.91	-0.66	-5.39	6.68	-0.19

Release-to-McNary Smolt-to-Smolt Survival

The mean Release-to-McNary survival is the estimated percent of all PIT-Tagged fish detected leaving the acclimation site that pass McNary. Estimates are given in Table and Figure 2. The main-effect-mean difference between stock was not significant at the 5% level (Type 1 Error P = 0.21, Appendix Table B.2.). The HxH mean is lower than the NxN mean in 58% of the 13 years thus far analyzed. The Stock x Year interaction was significant at the 5% significance level (Type 1 Error P = 0.016, Appendix Table B.2) with a high range of differences observable over years from Table 2.

Figure 2. Release-Year 2004-2016 HxH and NxN Mean Release-to-McNary Smolt-to-Smolt Survival for Spring Chinook Smolt released from the Clark Flat Acclimation Site

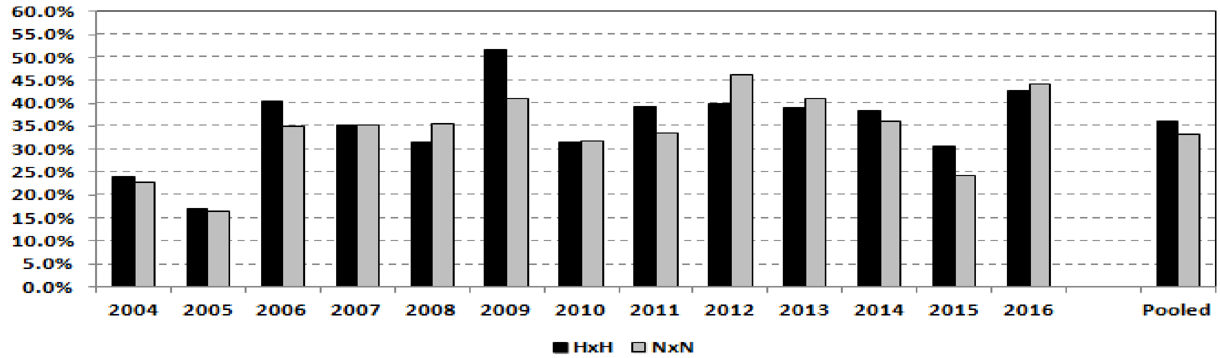

Table 2. Release-Year 2004-2016 HxH and NxN Mean Release-to-McNary Smolt-to-Smolt Survival for Spring Chinook Smolt released from the Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled	Adjusted**
HxH	Survial	24.1%	17.1%	40.4%	35.24%	31.6%	51.7%	31.5%	39.4%	39.8%	38.9%	38.4%	30.7%	42.7%	36.0%	35.6%
	Number Released*	2,162	2,135	2,147	2,172	3,805	3,757	3,949	3,905	3,889	3,782	3,797	7,379	3,765	46,644	
NxN	Survial	23.0%	16.3%	35.0%	35.23%	35.4%	41.0%	31.9%	33.5%	46.4%	41.0%	36.2%	24.4%	44.1%	33.2%	32.6%
	Number Released*	4,352	4,343	4,344	4,364	3,846	3,939	3,894	3,929	3,879	3,840	3,850	7,733	3,838	56,151	
	Difference	1.1%	0.7%	5.4%	0.01%	-3.8%	10.7%	-0.5%	5.8%	-6.5%	-2.1%	2.2%	6.4%	-1.4%	2.8%	

*** Number detected at release**

Mean Percent of PIT-Tagged Smolt Detected leaving the Acclimation Site

Table and Figure 3 present the individual release-year HxH and NxN stock percentages of fish detected leaving the acclimation site. The estimate is simply the ratio as a percentage[9] of the number of fish detected leaving the acclimation-site raceway to the total number of fish originally tagged; this percentage could be used as a measure of pre-release survival[10]. The HxH - NxN main-effect mean difference is negative and significant at the 0.5% level (Type 1 Error P = 0.0034, Appendix Table B.3.), indicating a lower pre-release HxH survival compared to that for the NxN stock The stock comparisons' interactions with years was not quite significant at the 5% level (Type 1 Error P = 0.065, Appendix Table B.3. The HxH mean is lower than the NxN mean in 85% of the 13 years thus far analyzed.

[9] Besides pre-release mortality, failure to be read by the acclimation detector could be due to a failure in the detector itself or pre-release PIT-tag shedding. In the past adjustments for the latter were made by dividing the proportion of PIT-tagged smolt detected at the acclimation site by the proportion of PIT-tagged smolt detected at McNary that were previously detected at the acclimation site. These adjustments frequently gave survival estimates greater than 100%. For this reason the estimates given are no longer adjusted. Conclusions regarding comparisons among estimates given in this report assume that PIT-tag detector failure rates and PIT-tag shedding rates did not differ between the stock nor between the treatments within years. The assumptions also applies to the estimated comparisons of percent survival to McNary, of percent fish detected leaving the acclimation site, and of mean and median dates of volitional release and of McNary passage presented later in this report.

[10] It would be a measure of pre-release survival if the detection efficiency were 100%. Attempts in the past to adjust for failure of the detection efficiency to be 100% resulted in adjusted percent of PIT-tagged fish detected leaving the site often exceeding 100%.

Figure 3. Release-Year 2004-2016 HxH and NxN Mean Percent of PIT-Tagged Smolt detected at Release from Clark Flat Acclimation Site

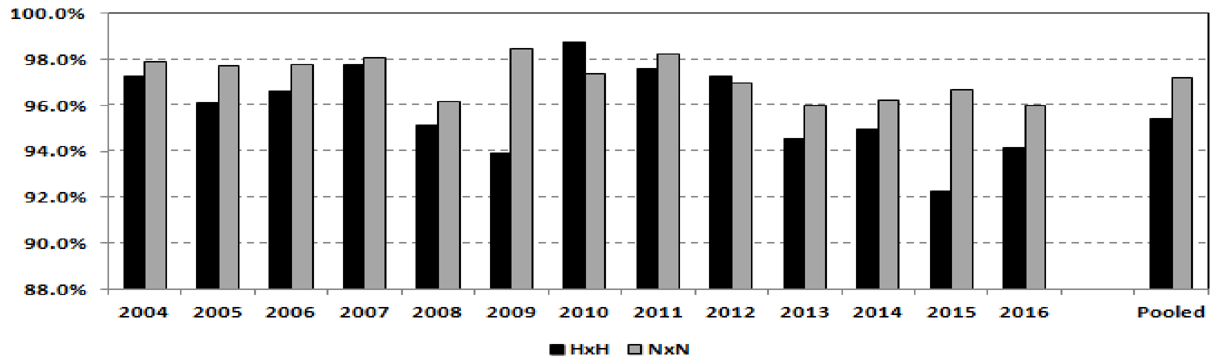

Table 3. Release-Year 2004-2016 HxH and NxN Mean Percent of PIT-Tagged Smolt detected at Release from Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	**Survial**	**97.3%**	**96.1%**	**96.6%**	**97.75%**	**95.1%**	**93.9%**	**98.7%**	**97.6%**	**97.2%**	**94.6%**	**94.9%**	**92.2%**	**94.1%**	**95.4%**
	Number Tagged	2,223	2,222	2,222	2,222	4,000	4,000	4,000	4,000	4,000	3,999	4,000	7,999	4,000	48,887
NxN	**Survial**	**97.9%**	**97.7%**	**97.7%**	**98.07%**	**96.2%**	**98.5%**	**97.3%**	**98.2%**	**97.0%**	**96.0%**	**96.2%**	**96.7%**	**96.0%**	**97.2%**
	Number Tagged	4,446	4,444	4,444	4,450	4,000	4,000	4,000	4,000	4,000	4,000	4,000	8,000	3,999	57,783
Difference (HxH - NxN)		**-0.6%**	**-1.6%**	**-1.1%**	**-0.32%**	**-1.0%**	**-4.5%**	**1.4%**	**-0.6%**	**0.3%**	**-1.4%**	**-1.3%**	**-4.4%**	**-1.8%**	**-1.8%**

Volitional Release Dates

The mean and median dates of detections of smolt leaving acclimation ponds are given in Tables 4.a. and 4.b. The negative mean HxH – NxN main-effect difference in means was not significant at the 5% level (Type 1 Error P = 0.22, Appendix Table B.4) but the HxH – NxN interaction with years was significant (Type 1 Error P = 0.002). The less powerful non-parametric Wilcoxon Rank Sign Test for differences in medians was also not significant at the 5% level. Note from Table 4.b., that the two largest magnitudes by far among the median differences was associated with 2012 and 2016 releases, and in both cases it was the HxH stock that was leaving the acclimation site much later than the NxN stock. With respect to the means, Table 4.a., the four years (2007, 2011, 2012, 2016) with the largest absolute magnitude HxH-NxN differences are years that the HxH stock was leaving later than the NxN stock.

Based on the mean – median difference in Table 4.c., there is some evidence of a right-skewed distribution over years for both the HxH ((mean of the mean - median HxH differences = 3.4) and NxN stock ((mean of the mean - median NxN differences = 2.2); however, based on the ranked values used in the Wilcoxon Rank Sign Test, the HxH – NN differences are not significantly different, even at the 20% significance level.

Figure 4.a. Release-Year 2004-2016 HxH and NxN Mean Date of PIT-Tagged Smolt Detected leaving Clark Flat Acclimation Site

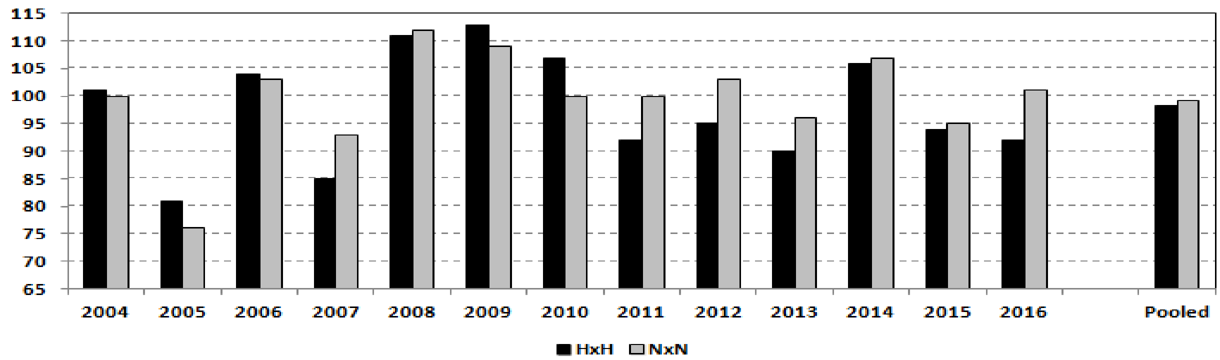

Figure 4.b. Release-Year 2004-2016 HxH and NxN Median Date of PIT-Tagged Smolt Detected leaving Clark Flat Acclimation Site

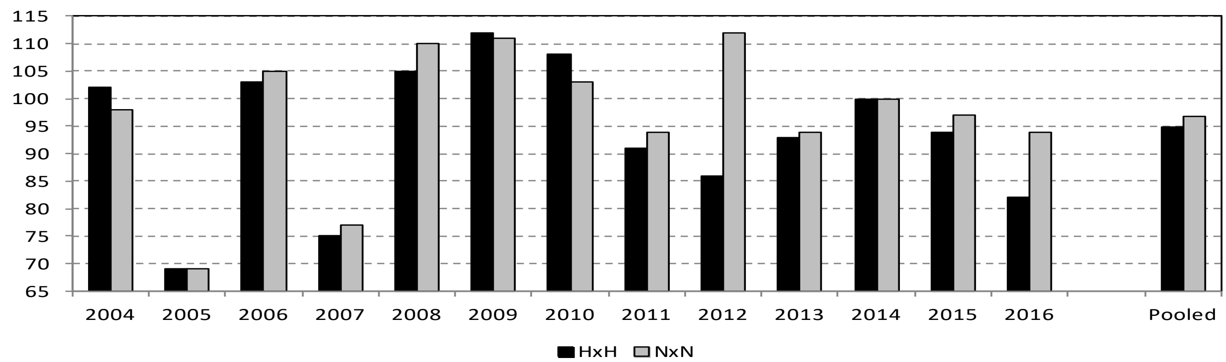

Table 4.a. Release-Year 2004-2016 HxH and NxN Mean Date of PIT-Tagged Smolt Detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	**Detection Date**	**101**	**81**	**104**	**85**	**111**	**113**	**107**	**92**	**95**	**90**	**106**	**94**	**92**	**98.2**
	Number Released*	2,162	2,135	2,147	2,172	3,805	3,757	3,949	3,905	3,889	3,782	3,797	7,379	3,765	46,644
NxN	**Detection Date**	**100**	**76**	**103**	**93**	**112**	**109**	**100**	**100**	**103**	**96**	**107**	**95**	**101**	**99.1**
	Number Released*	4,352	4,343	4,344	4,364	3,846	3,939	3,894	3,929	3,879	3,840	3,850	7,733	3,838	56,151
Difference (HxH - NxN)		**1**	**5**	**1**	**-8**	**-1**	**4**	**7**	**-8**	**-8**	**-6**	**-1**	**-1**	**-9**	**-0.9**

*** Number detected at release**

Table 4.b. Release-Year 2004-2016 HxH and NxN Median Date of PIT-Tagged Smolt Detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	**Detection Date**	**102**	**69**	**103**	**75**	**105**	**112**	**108**	**91**	**86**	**93**	**100**	**94**	**82**	**94.8**
	Number Released*	2,162	2,135	2,147	2,172	3,805	3,757	3,949	3,905	3,889	3,782	3,797	7,379	3,765	46,644
NxN	**Detection Date**	**98**	**69**	**105**	**77**	**110**	**111**	**103**	**94**	**112**	**94**	**100**	**97**	**94**	**96.9**
	Number Released*	4,352	4,343	4,344	4,364	3,846	3,939	3,894	3,929	3,879	3,840	3,850	7,733	3,838	56,151
Difference (HxH - NxN)		**4**	**0**	**-2**	**-2**	**-5**	**1**	**5**	**-3**	**-26**	**-1**	**0**	**-3**	**-12**	**-2.1**

Table 4.c. **Difference in Table 4.a. Mean and Table 4,b, Median Cle Elum detection Dates**

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	Detection Date	-1	12	1	10	6	1	-1	1	9	-3	6	0	10	3.4
NxN	Detection Date	2	7	-2	16	2	-2	-3	6	-9	2	7	-2	7	2.2

Mean McNary-Dam Juvenile-Passage Dates

The mean and median Dates of McNary Passage are respectively given in Table 5.a. and 5.b. and in Figure 5.a. and 5.b. Based on means, both the HxH – NxN main-effect difference and the HxH – NxN comparisons' interaction with year were significant (Type 1 Error P = 0.019 and P = 0.004, respectively; Appendix Table B.5). The Wilcoxon Ranked Sum test for median differences was also significant at the 5% level. Based on differences between the mean and median (Table 5.c.), there is little evidence of skewness in passage McNary passage date (mean of the mean - median HxH differences = 0.6) and (mean of the mean - median NxN differences = 0.1).

Figure 5.a. **Release-Year 2004-2016 HxH and NxN Mean Date of PIT-Tagged Smolt Detected passing McNary that were previously Detected leaving Clark Flat Acclimation Site**

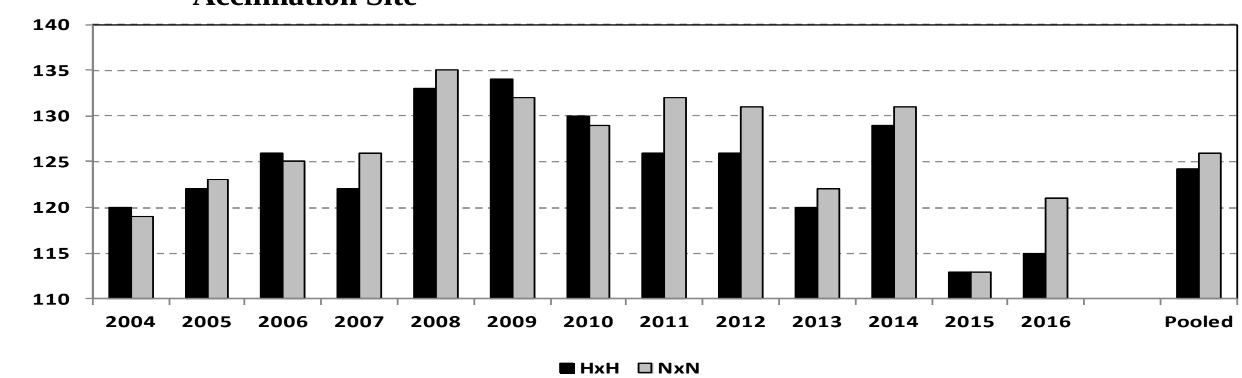

Figure 5.b. **Release-Year 2004-2016 HxH and NxN Median Date of PIT-Tagged Smolt Detected passing McNary that were previously Detected leaving Clark Flat Acclimation Site**

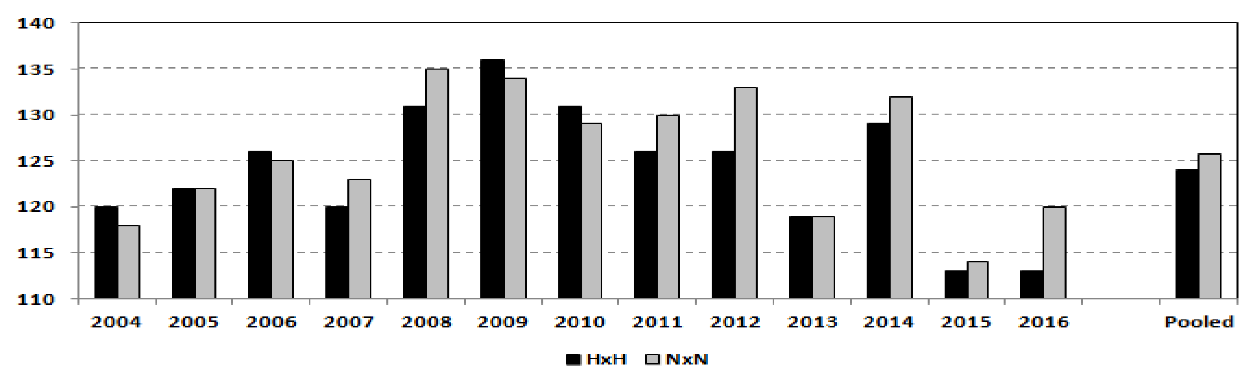

Table 5.a. Release-Year 2004-2016 HxH and NxN Mean Date of PIT-Tagged Smolt Detected passing McNary that were previously Detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	Detection Date	120	122	126	122	133	134	130	126	126	120	129	113	115	124.2
	Expanded Detections	521	364	867	765	1,203	1,942	1,242	1,537	1,549	1,471	1,459	2,268	1,609	16,798
NxN	Detection Date	119	123	125	126	135	132	129	132	131	122	131	113	121	126.0
	Expanded Detections	999	709	1,522	1,538	1,363	1,616	1,242	1,316	1,798	1,574	1,395	1,884	1,694	18,650
Difference (HxH - NxN)		1	-1	1	-4	-2	2	1	-6	-5	-2	-2	0	-6	-1.8

Table 5.b. Release-Year 2004-2016 HxH and NxN Median Date of PIT-Tagged Smolt Detected passing McNary that were previously Detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled
HxH	Detection Date	120	122	126	120	131	136	131	126	126	119	129	113	113	124.0
	Expanded Detections	521	364	867	765	1,203	1,942	1,242	1,537	1,549	1,471	1,459	2,268	1,609	16,798
NxN	Detection Date	118	122	125	123	135	134	129	130	133	119	132	114	120	125.7
	Expanded Detections	999	709	1,522	1,538	1,363	1,616	1,242	1,316	1,798	1,574	1,395	1,884	1,694	18,650
Difference (HxH - NxN)		2	0	1	-3	-4	2	2	-4	-7	0	-3	-1	-7	-2

* Number of McNary detections expanded by McNary detection efficiecy estimates

Table 5.c. Difference in Table 5.a. Mean and Table 5,b, Median McNary detection Dates

HxH	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Pooled	Adjusted*
HxH	Detection Date	0	0	0	2	2	-2	-1	0	0	1	0	0	2	0.2	0.6
NxN	Detection Date	1	1	0	3	0	-2	0	2	-2	3	-1	-1	1	0.3	0.1

Appendix A. Estimating Detection Rate Efficiencies and Expanding the Assessed dam Detections by those Efficiencies

For each dam down-stream of the dam for which detection efficiencies are being estimated, the joint assessed and downstream dams' joint detections at a downstream dam are obtained for each assessed dam's date and down-stream dam's date. Within each downstream-dam date, the detections are pooled over the assessed dam's dates to give the total assessed dam's detections on that downstream date. These joint totals are then divided by total downstream dam detections to get the estimated assessed dam's detection efficiency rate for that down-stream dam date. These detection rates are used as a dependent variable in a stepwise logistic regression. The dependent variables are indicator variables for the down-stream dam Julian detection dates. For a given downstream dam detection date, the indicator variable (IV) is assigned the value 0 if the actual down-stream dam date is less than the given IV Julian date and is 1 if that date is equal to or greater that IV date as illustrated below.

Table A.1. Variables used in getting stratified detection efficiencies

Lower Dam Julian Date	Assessed and Downstream Dam's Detections	Total Lower Downstream Detections	Upstream Dams Detection Rate	…	Indicator Variables IV-40	IV-4s	IV-4s	IV-43	IV-44	IV-45	IV-46	IV-47	IV-48	IV-49	IV-50	IV-5s	IV-5s	IV-53	IV-54	IV-55	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
40	25	205	0.1219512	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
41	25	154	0.1623377	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
42	35	244	0.1434426	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
43	50	208	0.2403846	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
44	75	280	0.2678571	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
45	220	420	0.5238095	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
46	90	380	0.2368421	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
47	220	490	0.4489796	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
48	220	424	0.5188679	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
49	250	624	0.400641	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
50	275	670	0.4104478	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
51	220	460	0.4782609	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
52	225	520	0.4326923	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
53	95	372	0.2553763	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
54	70	289	0.2422145	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
55	80	330	0.2424242	…	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Using the total lower dam's total detections at the downstream dam as the weight, a weighted stepwise logistic regression of the assessed dam's detection rate is run on the indicator variables. The regression output will be the list of out down-stream dam Julian dates which will establish strata boundaries. The detection rates for the sorted listed date and all the dates up to but not including the next listed sorted date are pooled together as a stratum of reasonably homogeneous detection rates. The dates preceding the first sorted listed date are also pooled into a separate stratum.

A smolt passing the assessed dam during that period could pass the down-stream dam during any of the down-stream dam strata[11]. It is necessary to proportionately assign down-stream strata

[11] For hatchery Spring Chinook, McNary passage periods the following passage periods were established were established: Pre-April , Early April through April 15, Late April, Early May through May 15, Late April, Early June through Jun 15, Late June, Post-June.

detection efficiencies to the assessed dam’s passage periods for the purpose of expanding the assessed dam counts within those periods.

Referring to Table A.2., the number of the joint detections (x in Table A.2.) within a lower dam stratum that came from the assessed dam time period was computed for each lower dam stratum. For each stratum, the period’s number of joint detections was divided by the period’s joint detections over all periods, giving the period’s relative frequency within the stratum (P in Table A.2.). The stratum’s total downstream-dam detections (n in Table A.3) were multiplied by the relative frequency proportions to assign those stratum totals to the periods. Within the period, the stratums’ detection efficiencies were weighted by the stratum downstream totals assigned to the period to obtain the mean detection efficiency for the period (example highlighted in yellow at the bottom of Table A.3).

Table A.2. Allocation of proportions of Joint Assessed and Downstream Dams’ Detections over Assessed Dam’s Periods within Downstream Dam’s Strata

		Joint Number (x) of Downstream Dam and Assessed Dam Detections					
Stratum	**Measure**	**Period a**	**Period b**	**Period c**	**...**	**Period p**	**Total**
1	Joint Detections	x(a,1)	x(b,1)	x(c,1)	...	x(p,1)	x(1)
	Proportional Distribution	P(a,1)=x(a,1)/x(1)	P(b,1)=x(b,1)/x(1)	P(a,1)=x(a3)/x(1)	...	P(p,1)=x(p,1)/x(1)	
2	Joint Detections	x(a,2)	x(b,2)	x(c,2)		x(p,2)	x(2)
	Proportional Distribution	P(a,2)=x(a,2)/x(2)	P(b,2)=x(b,2)/x(2)	P(a,2)=x(a3)/x(2)	...	P(p,2)=x(p,2)/x(2)	
3	Joint Detections	x(a,3)	x(b,3)	x(c,3)		x(p,3)	x(3)
	Proportional Distribution	P(a,3)=x(a,3)/x(3)	P(b,3)=x(b,3)/x(3)	P(a,3)=x(a3)/x(3)	...	P(p,3)=x(p,3)/x(3)	
...	...	...	...	...	...	...	...
s	Joint Detections	x(a,s)	x(b,s)	x(c,s)		x(p,s)	x(s)
	Proportional Distribution	P(a,s)=x(a,s)/x(s)	P(b,s)=x(b,s)/x(s)	P(a,s)=x(as)/x(s)	...	P(p,s)=x(p,s)/x(s)	

Table A.3. Allocation of Total Downstream Dams’ Detections over Assessed Dam’s Periods within Downstream Dam’s Strata and Estimation of Assessed Dam’s Period Detection Efficiencies

			Number (n) of Downstream Detections*				
Stratum	**Downstream Detections**	**Detection Efficiencies***	**Period a**	**Period b**	**Period c**	**...**	**Period p**
1	n(1)	de(1)=x(1)/n(1)	n(a,1) = n(1)*P(a,1)	n(b,1) = n(1)*P(b,1)	n(c,1) = n(1)*P(c,1)	...	n(p,1) = n(1)*P(p,1)
2	n(2)	de(2)=x(2)/n(2)	n(a,2) = n(2)*P(a,s)	n(b,2) = n(2)*P(b,s)	n(c,2) = n(2)*P(c,s)	...	n(p,2) = n(2)*P(p,s)
3	n(3)	de(3)=x(3)/n(3)	n(a,3) = n(3)*P(a,3)	n(b,3) = n(3)*P(b,3)	n(c,3) = n(3)*P(c,3)	...	n(p,3) = n(3)*P(p,3)
	...	...	...	...	...	...	...
s	n(s)	de(s)=x(4)/n(4)	n(a,s) = n(s)*P(a,s)	n(b,s) = n(s)*P(b,s)	n(c,s) = n(s)*P(c,s)	...	n(p,s) = n(s)*P(p,s)
Total			n(a)	n(b)	n (c)	...	n(p)

Example of detection efficiency for Period b: [n(b,1)*de(1) +n(b,2)*de(2) +n(b,3)*de(3)+...+n(b,s)*de(s)]/n(b)

This estimation procedure is separately performed for each of the down-stream dams, and then the within period detection rate estimates are weighted by the total allocated to the period (the row labeled “Total” in Table A.3. taken from each of the downstream dam’s tables) While subject to bias, there is evidence that this procedure gives a less-biased detection-efficiency estimator application than just using the assessed dam and down-stream dam detections divided by the total down-stream dam detections ignoring strata and periods.

Appendix B. Analyses of Variation for the Analyzed Measures

Appendix B.1. Analysis of Variance of Pre-Release Smolt Weight

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (SS/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	276.5	12	23.04	13.705	**0.0000**	Error
Stock (HxH vs NxN)	2.9	1	2.90	0.491	**0.4969**	Year x Stock
Year x Stock	70.9	12	5.91	3.514	**0.0105**	Error
Error	26.9	16	1.68			

Note: Yellow shaded boldfaced significant at 5% level

Appendix B.2. Logistic Analysis of Variation Release-to-McNary Smolt-to-Smolt Survival

	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P	Denominatpr Source
Year	2907.79	12	242.32	39.542	**0.0000**	Error
Stook (HxH vs NxN)	33.74	1	33.74	1.721	0.2141	Year x Stock
Year x Stock	235.21	12	19.60	3.199	**0.0161**	Error
Error	98.05	16	6.13			

Note: Yellow shaded boldfaced significant at 5% level

Appendix B.3. Logistic Analysis of Percent of PIT-Tagged Smolt Detected leaving the Acclimation Site

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	514.01	12	42.83	6.778	**0.0003**	Error
Stock (HxH vs NxN)	188	1	188.00	13.202	**0.0034**	Year x Stock
Year x Stock	170.88	12	14.24	2.253	0.0653	Error
Error	101.11	16	6.32			

Note: Yellow shaded boldfaced significant at 5% level, not boldfaced significant at 10% level

Appendix B.4. Analysis of Variance of Volitional Release Dates

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (SS/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	6,962,941	12	580,245	56.250	**0.0000**	Error
Stock (HxH vs NxN)	86,366	1	86,366	1.687	0.2184	Year x Stock
Year x Stock	614,368	12	51,197	4.963	**0.0018**	Error
Error	165,047	16	10,315			

Note: Yellow shaded boldfaced significant at 5% level

Appendix B.5. Analysis of Variance of Mean McNary-Dam Juvenile-Passage Dates

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (SS/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	1,523,231	12	126,936	106.764	**0.0000**	Error
Stock (HxH vs NxN)	37,041	1	37,041	7.401	**0.0186**	Year x Stock
Year x Stock	60,056	12	5,005	4.209	**0.0044**	Error
Error	19,023	16	1,189			

Note: Yellow shaded boldfaced significant at 5% level

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Appendix F
Annual Report: Comparison of Pro-Feed and BioVita Feed Treatments evaluated on Natural-Origin Hatchery-Reared Upper-Yakima Spring Chinook Smolt released in 2016

Doug Neeley, Consultant to Yakama Nation

Introduction

2016 hatchery releases of smolt spawned from wild Upper Yakima Spring Chinook (brood year 2014), two feed treatments were allocated to raceways within adjacent raceway pairs. Within the pairs of raceways, one raceway from each pair was allocated BioVita feed as a control treatment and the other was allocated PRO feed as a test treatment. These experimental treatments have been given or are being given for brood years 2015 and 2016. The treatment effects the following five juvenile measures were compared for brood year 2014:

1) Mean and median volitional release (acclimation pond outfall detection) date;
2) Mean and median McNary Dam (McNary) smolt-passage date;
3) Mean proportion of PIT-tagged fish detected leaving the acclimation ponds;
4) Mean smolt-to-smolt survival from volitional release to McNary; and
5) Mean fish weight.

The current methodology of estimating detection efficiencies needed for 3) and 4) above is given in Appendix A[1].

Volitional Release Date

The main effect PRO on mean release date over years was significantly earlier than the control at the 5% level (P = 0.049, Appendix Table B.1), and the individual site Pro release dates were earlier than the

[1] **In Appendix A. "Assessed Dam' is McNary, "Downstream Dams" are Bonneville and John Day, and "Periods" are Pre-April, Early April (through April 15), Late April, Early May (through May 15), Late May, Early June (through June 15), Late June, and after June**

Control at all sites (Table 1.a). The median dates showed a similar pattern to that of the mean dates with the median dates[2] showing a generally larger Pro-Control difference than did the mean date difference (Table 1.b.). Note that the median release dates (Table 1.b.) tended to be earlier than the mean release dates (Table 1.a), as summarized in Table 1.c., indicating a positive skewness in the release timing distributions. At this point there is not enough information to permit formal analyses of the median and mean-mean data.

Table 1.a. **Brood-Year 2014 <u>Release Mean Julian Detection Date</u> for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation given Pro and BioVita (Control) feeds**

		Site			
Feed	**Measure**	**Clark Flat**	**Easton**	**Jack Creek**	**Pooled Mean**
Tested	**Survival**	**101**	**94**	**85**	**92**
Pro	**Released**	**3,838**	**5,646**	**5,744**	**15,228**
Control	**Survival**	**103**	**98**	**87**	**95**
BioVita	**Released**	**3,815**	**5,696**	**5,777**	**15,288**
	Tested - Control Survival	**-2**	**-4**	**-2**	**-3**

Table 1.b. **Brood-Year 2014 <u>Release Median Julian Detection Date</u> for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation given Pro and BioVita (Control) feeds**

		Site			
Feed	**Measure**	**Clark Flat**	**Easton**	**Jack Creek**	**Pooled Mean**
Tested	**Mean Detection Date**	**94**	**89**	**85**	**89**
Pro	**Expanded Detections**	**3,838**	**5,646**	**5,744**	**15,228**
Control	**Mean Detection Date**	**101**	**95**	**86**	**93**
BioVita	**Expanded Detections**	**3,815**	**5,696**	**5,777**	**15,288**
Tested - Control Mean Detection Date		**-7**	**-6**	**-1**	**-4**

[2] Excluding the equalities in the PRO and Control median dates, Type 1 Error p = 0.016 based on a two-sided binomial-based sign test based on all 7 raceway pairs having earlier Pro-treatment volitional release dates.

Table 1.c. **Brood-Year 2014 Release Median – Mean Julian Detection Date Difference for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation given Pro and BioVita (Control) feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested	Survival	-7	-5	0	-4
Pro	Released	3,838	5,646	5,744	15,228
Control	Survival	-2	-3	-1	-2
BioVita	Released	3,815	5,696	5,777	15,288

McNary Detection Date

Tables 2.a. and 2.b. respectively give mean and median Pro and Bio estimated McNary passage dates and their differences. The level of significance in the McNary-detection date main effect Pro – BioVita mean difference did not quite reach the 5% significance level (P = 0.077, Appendix Table B.2). The fact that it reached that level of significance is remarkable because there were negligible Pro-BioVita differences at any of the sites for either the mean or median.

Table 2.a. **Brood-Year 2014 Mean McNary Julian Detection Date for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation given Pro and BioVita (Control) feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested	Survival	121	119	115	118
Pro	Released	1,694	1,873	1,569	5,136
Control	Survival	121	120	116	119
BioVita	Released	1,616	1,844	1,621	5,082
	Tested - Control Survival	0	-1	-1	-1

Table 2.b. **Brood-Year 2014 Median McNary Julian Detection Date for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation given Pro and BioVita (Control) feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested	Survival	120	118	115	118
Pro	Released	1,694	1,873	1,569	5,136
Control	Survival	121	119	116	119
BioVita	Released	1,616	1,844	1,621	5,082
	Tested - Control Survival	-1	-1	-1	-1

Table 2.c. **Brood-Year 2014 Median – Mean McNary Julian Detection Date Difference for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation given Pro and BioVita (Control) feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested	Survival	-1	-1	0	-1
Pro	Released	1,694	1,873	1,569	5,136
Control	Survival	0	-1	0	0
BioVita	Released	1,616	1,844	1,621	5,082

Proportion of PIT-tagged Fish Detected Leaving Acclimation Ponds

The main-effect mean Pro-BioVita difference in the pooled proportions of PIT-tagged smolt detected at release was small and not significant (P = 0.59, Appendix Table B.3) and the individual site differences were less than 1% (Table 3).

Table 3. **Brood-Year 2014 Proportion of Spring Chinook Smolt leaving Acclimation Sites (Clark Flat, Easton and Jack Creek) given Pro and BioVita (Control) feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested	Survival	95.4%	94.9%	96.3%	95.6%
Pro	Released	3,999	6,000	6,000	15,999
Control	Survival	96.0%	94.1%	95.7%	95.2%
BioVita	Released	4,000	6,000	6,000	16,000
	Tested - Control Survival	-0.6%	0.8%	0.6%	0.4%

Smolt-to-Smolt Survival to McNary Dam

Referring to Table 4, there was neither a substantial nor significant difference in the smolt-to-smolt survival means of Pro and BioVita feed treatments over years (P = 0.77, Appendix Table B.4). The mean survival estimates are given in Table 4.

Table 4. **Brood-Year 2014 <u>Mean Release-to-McNary Smolt-to-Smolt Survival</u> for Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation Sites given Pro and BioVita (Control) feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested Pro	Survival	42.4%	32.4%	28.1%	33.3%
	Released	3,838	5,646	5,744	15,228
Control BioVita	Survival	44.1%	33.2%	27.3%	33.7%
	Released	3,815	5,696	5,777	15,288
Tested - Control Survival		-1.8%	-0.8%	0.7%	-0.4%

Juvenile Fish Weight prior to Release

Juveniles were bulk weighed prior to release. Referring to Table 5, there was neither a substantial nor significant Pro-BioVita mean difference in the weights (grams per fish; P = 0.67, Appendix Table B.5). The mean weights are given in Table 5.

Table 5. **Brood-Year 2014 <u>Mean pre-release Juvenile Weight</u> (grams/fish) of Spring Chinook Smolt from Clark Flat, Easton and Jack Creek Acclimation Sites given Pro and BioVita feeds**

		Site			
Feed	Measure	Clark Flat	Easton	Jack Creek	Pooled Mean
Tested*	Survival	20	17	17	18
Control**	Survival	21	19	16	19
Tested - Control Survival		-1	-2	1	-1

*Pro
** BIOVita

Appendix A. Estimating Detection Rate Efficiencies and Expanding the Assessed dam Detections by those Efficiencies

For each dam down-stream of the dam for which detection efficiencies are being estimated, the joint assessed and downstream dams' joint detections at a downstream dam are obtain for each assessed dam's date and down-stream dam's date. Within each downstream-dam date, the detections are pooled over the assessed dam's dates to give the total assessed dam's detections on that downstream date. These joint totals are then divided by total downstream dam detections to get the estimated assessed dam's detection efficiency rate for that down-stream dam date. These detection rates are used as a dependent variable in a stepwise logistic regression. The dependent variables are indicator variables for the down-stream dam Julian detection dates. For a given downstream dam detection date, the indicator variable (IV) is assigned the value 0 if the actual down-stream dam date is less than the given IV Julian date and is 1 if that date is equal to or greater that IV date as illustrated below.

Table A.1. Variables used in getting stratified detection efficiencies

Lower Dam Julian Date	Assessed and Downstream Dam's Detections	Total Lower Downstream Detections	Upstream Dams Detection Rate	…	Indicator Variables																…
					IV-40	IV-4s	IV-4s	IV-43	IV-44	IV-45	IV-46	IV-47	IV-48	IV-49	IV-50	IV-5s	IV-5s	IV-53	IV-54	IV-55	
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
40	25	205	0.1219512	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
41	25	154	0.1623377	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
42	35	244	0.1434426	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
43	50	208	0.2403846	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
44	75	280	0.2678571	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
45	220	420	0.5238095	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
46	90	380	0.2368421	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
47	220	490	0.4489796	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
48	220	424	0.5188679	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
49	250	624	0.400641	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
50	275	670	0.4104478	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
51	220	460	0.4782609	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
52	225	520	0.4326923	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
53	95	372	0.2553763	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
54	70	289	0.2422145	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
55	80	330	0.2424242	…	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Using the total lower dam's total detections at the downstream dam as the weight, a weighted stepwise logistic regression of the assessed dam's detection rate is run on the indicator variables. The regression output will be the list of out down-stream dam Julian dates which will establish strata boundaries. The detection rates for the sorted listed date and all the dates up to but not including the next listed sorted date are pooled together as a stratum of reasonably homogeneous detection rates. The dates preceding the first sorted listed date are also pooled into a separate stratum.

A smolt passing the assessed dam during that period could pass the down-stream dam during any of the down-stream dam strata[3]. It is necessary to proportionately assign down-stream strata detection efficiencies to the assessed dam's passage periods for the purpose of expanding the assessed dam counts within those periods.

Referring to Table A.2., the number of the joint detections (x in Table A.2.) within a lower dam stratum that came from the assessed dam time period was computed for each lower dam stratum. For each stratum, the period's number of joint detections was divided by the period's joint detections over all periods, giving the period's relative frequency within the stratum (P in Table A.2.). The stratum's total downstream-dam detections (n in Table A.3) were multiplied by the relative frequency proportions to assign those stratum totals to the periods. Within the period, the stratums' detection efficiencies were weighted by the stratum downstream totals assigned to the period to obtain the mean detection efficiency for the period (example highlighted in yellow at the bottom of Table A.3).

Table A.2. Allocation of proportions of Joint Assessed and Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata

		Joint Number (x) of Downstream Dam and Assessed Dam Detections					
Stratum	Measure	Period a	Period b	Period c	...	Period p	Total
1	Joint Detections	x(a,1)	x(b,1)	x(c,1)	...	x(p,1)	x(1)
	Proportional Distribution	P(a,1)=x(a,1)/x(1)	P(b,1)=x(b,1)/x(1)	P(a,1)=x(a3)/x(1)	...	P(p,1)=x(p,1)/x(1)	
2	Joint Detections	x(a,2)	x(b,2)	x(c,2)		x(p,2)	x(2)
	Proportional Distribution	P(a,2)=x(a,2)/x(2)	P(b,2)=x(b,2)/x(2)	P(a,2)=x(a3)/x(2)	...	P(p,2)=x(p,2)/x(2)	
3	Joint Detections	x(a,3)	x(b,3)	x(c,3)		x(p,3)	x(3)
	Proportional Distribution	P(a,3)=x(a,3)/x(3)	P(b,3)=x(b,3)/x(3)	P(a,3)=x(a3)/x(3)	...	P(p,3)=x(p,3)/x(3)	
...	...	...	...	...	...	...	...
s	Joint Detections	x(a,s)	x(b,s)	x(c,s)		x(p,s)	x(s)
	Proportional Distribution	P(a,s)=x(a,s)/x(s)	P(b,s)=x(b,s)/x(s)	P(a,s)=x(as)/x(s)	...	P(p,s)=x(p,s)/x(s)	

Table A.3. Allocation of Total Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata and Estimation of Assessed Dam's Period Detection Efficiencies

			Number (n) of Downstream Detections*				
Stratum	Downstream Detections	Detection Efficiencies*	Period a	Period b	Period c	...	Period p
1	n(1)	de(1)=x(1)/n(1)	n(a,1) = n(1)*P(a,1)	n(b,1) = n(1)*P(b,1)	n(c,1) = n(1)*P(c,1)	...	n(p,1) = n(1)*P(p,1)
2	n(2)	de(2)=x(2)/n(2)	n(a,2) = n(2)*P(a,s)	n(b,2) = n(2)*P(b,s)	n(c,2) = n(2)*P(c,s)	...	n(p,2) = n(2)*P(p,s)
3	n(3)	de(3)=x(3)/n(3)	n(a,3) = n(3)*P(a,3)	n(b,3) = n(3)*P(b,3)	n(c,3) = n(3)*P(c,3)	...	n(p,3) = n(3)*P(p,3)
	...	...	...	...	...	...	...
s	n(s)	de(s)=x(4)/n(4)	n(a,s) = n(s)*P(a,s)	n(b,s) = n(s)*P(b,s)	n(c,s) = n(s)*P(c,s)	...	n(p,s) = n(s)*P(p,s)
Total			n(a)	n(b)	n (c)	...	n(p)

Example of detection efficiency for Period b: [n(b,1)*de(1) +n(b,2)*de(2) +n(b,3)*de(3)+...+n(b,s)*de(s)]/n(b)

---

[3] For hatchery Spring Chinook, McNary passage periods the following passage periods were established were established: Pre-April , Early April through April 15, Late April, Early May through May 15, Late April, Early June through Jun 15, Late June, Post-June.

This estimation procedure is separately performed for each of the down-stream dams, and then the within period detection rate estimates are weighted by the total allocated to the period (the row labeled "Total" in Table A.3. taken from each of the downstream dam's tables)   While subject to bias, there is evidence that this procedure gives a less-biased detection-efficiency estimator application than just using the assessed dam and down-stream dam detections divided by the total down-stream dam detections ignoring strata and periods.

Appendix B. Statistical Analysis Tables for the Measures presented in the Text

Table B.1. **Weighted Least Squares Analysis of Variance of Julian Volitional-Release Date for Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Number of fish detected volitionally leaving the raceways)

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	**1,285,452**	**2**	**642,726**	**68.57**	**0.0000**	**Error**
Feed*	**47,273**	**1**	**47,273**	**5.04**	**0.0485**	**Error**
Feed x Site	5,304	2	2,652	0.28	0.7594	Error
Error	93,730	10	9,373			

*Pro vs BioVita

Note: Yellow shaded boldfaced significant at 5% level

Table B.2. **Weighted Least Squares Analysis of Variance of Expanded Mean Julian McNary-Dam Passage Date for Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Expanded number of smolt passing McNary Dam)

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	**58,399.98**	**2**	**29,199.99**	**62.06**	**0.0000**	**Error**
Feed*	1,824.32	1	1,824.32	3.88	0.0773	Error
Feed x Site	84.18	2	42.09	0.09	0.9152	Error
Error	4,705.42	10	470.54			

*Pro vs BioVita

Note: Yellow shaded boldfaced significant at 5% level; Yellow not boldfaced significant at 10% level

Table B.3. **Weighted* Logistic Analysis of Variation of Proportion of PIT-Tagged Fish detected leaving Acclimation Ponds for Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Number of fish tagged)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	32.04	2	16.02	1.97	0.1900	Error
Feed*	2.47	1	2.47	0.30	0.5937	Error
Feed x Site	5.67	2	2.84	0.35	0.7140	Error
Error	81.34	10	8.13			

*Pro vs BioVita

Table B.4. **Weighted* Logistic Analysis of the Smolt-to-Smolt Survival to McNary Dam of those PIT-Tagged Fish detected leaving Acclimation Ponds for Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Number of fish detected volitionally leaving the raceways)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	**497.26**	**2**	**248.63**	**29.43**	**0.0001**	**Error**
Feed*	0.73	1	0.73	0.09	0.7748	Error
Feed x Site	3.35	2	1.675	0.20	0.8233	Error
Error	84.49	10	8.449			

*Pro vs BioVita

Note: Yellow shaded boldfaced significant at 5% level

Table B.5. **Least Squares Analysis of Variance of given Pro and BioVita fed Pre-Release weights (grams) of Juvenile Smolt sampled prior to release**

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	**37.32**	**2**	**18.66**	**4.35**	**0.0436**	**Error**
Feed*	0.80	1	0.80	0.19	0.6749	Error
Feed x Site	4.47	2	2.24	0.52	0.6089	Error
Error	42.86	10	4.29			

*Pro vs BioVita

Note: Yellow shaded boldfaced significant at 5% level

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Appendix G
Annual Report: 2008-2016 Fall and 2009-2016 Summer Chinook Smolt-to-Smolt Survival to McNary Dam of Releases into the Yakima Basin

Doug Neeley, Consultant to Yakama Nation

Introduction

Errors in the estimation of McNary Dam (McNary) detection efficiencies were discovered; therefore Fall and Summer Chinook 2008-2016 survival-index estimates (survival) from time-of-tagging-to-McNary detection were re-estimated and re-analyzed. The results are presented in this report. Methods of estimation are presented in Appendix A. It is noted that the survivals given in this report are almost always higher than those given in previous reports.

Summary

Both Fall and Summer Chinook 2015 releases experienced abysmal survivals because of extremely poor in-river conditions resulting from a low snow pack in the Cascades, high summer water temperatures, and an associated early run-off. Because of the river conditions that year, the decision was made to make releases from two sites[1] located in Yakima River further down-stream than had been made in recent years.

For Fall Chinook, Prosser was a third release site which has been standard release site over many years. With the exception of one release, the Fall Chinook McNary survivals of early May[2], late May, and early June releases were less than 8%, the exception being a May 29th release into the mouth of the Yakima with a 37.9% survival. And as an indication of the rapidly deteriorating conditions, a release into the mouth three days later (June 2nd) had a survival of only 7.2%.

In 2016, early-May, late-May, and late-June releases were made. The early-May release survivals from Prosser and Wanawish were both 23%; the late-June release survivals from both sites were either at or near 0%. With one site exception, other late-May and late-June releases were extremely low, the

[1] Near Wanawish Dam and into the mouth of the Yakima
[2] An early release was made at Prosser, not at Lower Yakima release sites.

exception being   moderate late-May and late-June survivals (respectively 35% and 24%) released from the mouth of the Yakima.

The situation was worse for Summer Chinook in 2015. Releases were made in early-May and mid-May from below Roza Dam, Buckskin Slough, and Prosser, and the highest survival realized was only 2.6%. Since the initiation of Summer Chinook releases in 2009, with one exception, no mid-May or later release attained a McNary survival of 5%. The exception was the single 2016 mid-May release, which was made into the mouth of the Yakima, for which the survival was 34.5%.

Because of the survival re-estimation, the Prosser survivals of paired yearling and subyearling releases from 2008 through 2013 were reanalyzed. The conclusions presented in the 2013 Annual Report was not altered in the reanalysis which again were: 1) The survival of Yearling releases were higher than that of the Subyearling within each year; 2) The Yearling survival when pooled[3] over years was substantially and significantly higher than the pooled Subyearling survival (Type 1 Error P = 0.011 based on analysis of the re-estimated survival estimates).

Subyearling Fall Chinook Smolt-to-Smolt Survival

Table 1 and Figure 1 present McNary survivals of Fall Chinook releases made in 2015, a year which experienced extremely poor in-river conditions resulting from a low snow pack in the Cascades, high summer water temperatures, and associate early run-off. Because poor in-river Yakima and Columbia River conditions existed when an early release was made at Prosser, the decision was made to make a later release at that site and to make additional late releases downstream of Prosser to see if survival would improve with a decrease in the distance and travel time to McNary Dam.

All survivals were abysmally low except for the May 29th release into the mouth of the Yakima. The May 29th release into the mouth of the Yakima had a relatively much higher survival (37.9%) than other late releases; however, the June 2nd release into the mouth of the Yakima had a survival of only 7.2%, representing a 30% decrease in survival from the site with only a three-day difference in the dates of release. This suggests that the conditions in the mouth of the Yakima and in the Columbia River had rapidly deteriorated.   It is interesting to note that the 6.7% survival from the June 2nd release at Prosser, located at river mile 47, was not much lower than 7.2% survival of that final June 2nd release into the mouth of the Yakima.

[3] The term pooled refers computing an average by weighting the releases' estimates going into the average by the numbers of tagged fish going into those estimates.

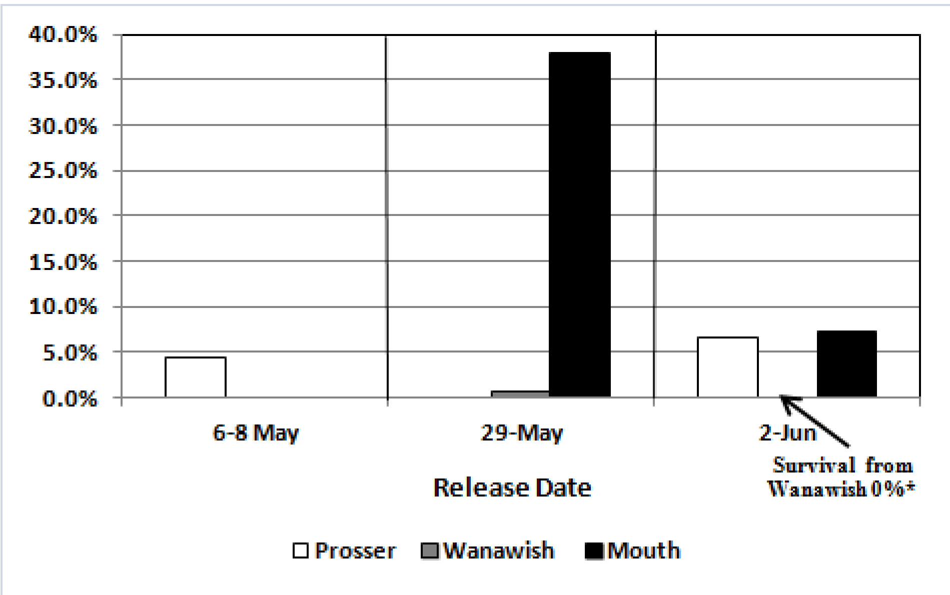
Table 1. **2015 Yakima Stock Release-to-McNary Fall Chinook Survival-Index Estimates from Release Sites**

Release Site	Release Date >	6-8 May	29-May	2-Jun
Prosser	Survival	4.5%		6.7%
	Number Tagged	4,021		14,156
Wanawish	Survival		0.7%	0.0% *
	Number Tagged		2,014	2,004
Mouth	Survival		37.9%	7.2%
	Number Tagged		1,668	1,018

* In addition to no detections at McNary, there were also no detections at Bonneville or John Day

Yellow highlighted survivals < 8%

Figure 1. **2015 Yakima Stock Release-to-McNary Fall Chinook Survival-Index Estimates from Release Sites**



* In addition to no detections at McNary, there were no detections at Bonneville and John Day

The decision was made to continue making later releases at Prosser and Lower Yakima sites as well as early releases in 2016. The survival estimates are given in Table and Figure 2. Early May release survivals from Prosser and Wanawish were moderate (23%), but late release at these and other up-river sites were extremely low. The only late releases with moderate survivals to McNary were those made into the mouth of the Yakima. However, absent information on Yakima returns, there may be concern about the degree to which releases into the mouth of the Yakima will home back to target spawning areas in the Yakima River Basin.

Table 2. 2016 Yakima Stock Release-to-McNary Fall Chinook Survival-Index Estimates from Release Sites

Release Site	Release Date >	4-5*** May	25-May	23-26**** June
Prosser	Survival	22.8%	1.8%	0.0% *
	Number Tagged	2,531	2,122	2,105
Benton City	Survival			0.0%
	Number Tagged			2,113
Wanawish	Survival	23.0%		0.2%
	Number Tagged	1,056		2,104
Mouth	Survival		35.3%	21.9%
	Number Tagged		2,199	1,151

* In addition to no detections at McNary, there were also no detections at Bonneville or John Da

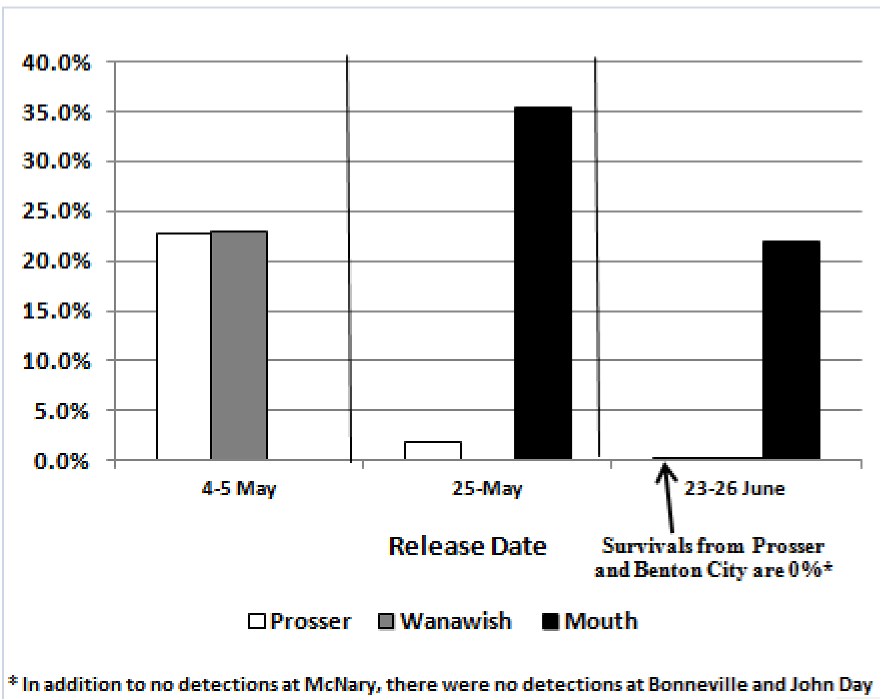
** Not graphed

*** Prosser release made on May 5; Wanawish releases made on June 23

**** Benton City release made on June 26; other sites' releases made on June 23

Yellow highlighted survivals < 2%

Table 2. 2016 Yakima Stock Release-to-McNary Fall Chinook Survival-Index Estimates from Release Sites



Summer Chinook Smolt-to-Smolt Survival

Table 3 gives McNary survival for all releases made into the Yakima basin. As with Fall Chinook releases, 2015 Summer Chinook releases experienced abysmal survivals. It is also worth nothing that, with the exception of the single 2013 release below Roza Dam, all late releases of Summer Chinook for all years had survivals less than 5%. And, with the exception of the 2015 releases, release made before May 25th had survival that exceed 18%.

Table 3. 2009-2016 Release-to-McNary Summer Chinook Survival-Index Estimates from Release Sites

Release Site →	Stiles		Prosser		Buckskin			Marion Drain	Below Roza Dam			Yakima Mouth
Release Period →	Mid	Late	Early	Mid	Early	Mid	Late	Mid	Early	Mid	Late	Mid
Release Date → Release Year ↓	May 10 < Day ≤ May 25	May 25 < Day	Day ≤ May 10	May 10 < Day ≤ May 25	Day ≤ May 10	May 10 < Day ≤ May 25	May 25 < Day	May 10 < Day ≤ May 25	Day ≤ May 10	May 10 < Day ≤ May 25	May 25 < Day	May 10 < Day ≤ May 25
2009		1.5% 30,037 06/12/09										
2010	19.7% 29,865 05/14/10											
2011	39.7%* 20,000 5/16				43.7% 29,894 4/29-5/2							
2012				20.8% 9,999 5/16		37.2% 9,999 5/21		35.8% 9,998 5/24				
2013											21.6% 7,882 5/29/13	
2014						18.3% 10,086 5/12	3.2% 10,102 6/2				4.3% 16,346 6/3	
2015**			2.6% 4,031 5/6			0.0% 10,266 5/13			0.1% 10,034 4/29-5/1	0.0% 5,002 5/16		
2016												34.5% 19,974 5/13

* In 2011, the Stiles site utlilized Wenatchee Eastbank Hatchry stock; the 2011 Buckskin site utilized Wells Hatchery stock as did all sites in all other years.

** For the two 0.0% McNayy Survival estimates given in 2015: Not only were there no detections at McNary, there were no detections at Bonneville and John Day

Note: Yellow-highlighted Survivals < 5%

Time-of tagging-to-McNary Survival of Paired Yearling and Subyearling Fall Chinook

From 2009 through 2013 there were paired releases of yearling and subyearling Yakima-stock smolt from the Prosser site. The yearling McNary smolt survivals exceed those of the subyearling smolt in each year (Table 4.a. and Figure 4.). The difference in survival estimates when pooled over years was significant (Type 1 Error P = 0.011, Table 4.b.)

Table 4.a. 2008-2013 Yakima Stock Prosser-Release-to-McNary Yearling and Subyearling Fall Chinook Survival-Index Estimates (Releases made in April and Early May)

		Release Year								
Age	Measure	2008	2009	2010	2011	2012	2013	2014	2015	2016
Yearling	Survival	46.8%	79.1%	61.5%	62.3%	53.8%	47.8%			
	Tagged	1,831	7,516	12,167	22,754	29,805	22,815			
SubYearling	Survival	38.9%	26.3%	24.0%	17.9%	30.5%	39.3%	23.7%	4.5%	22.8%
	Tagged	10,005	7,565	13,685	22,790	9,264	22,966	4,025	4,021	2,531
Survival Difference		7.9%	52.8%	37.5%	44.4%	23.3%	8.5%			

Figure 4. 2008-2013 Yakima Stock Prosser-Release-to-McNary Yearling and Subyearling Fall Chinook Survival-Index Estimates (Releases made in April and Early May)

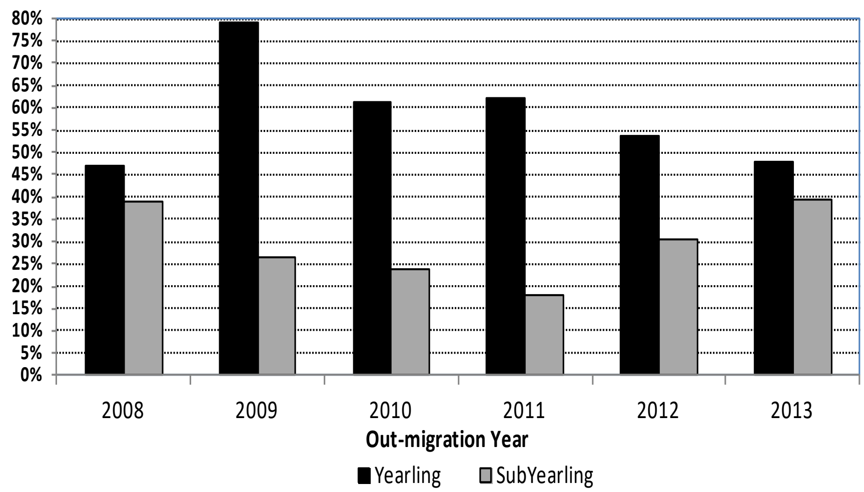


Table 4.b. Logistic Analysis of Variation of 2008-2013 Yakima Stock Prosser-Release-to-McNary Yearling and Subyearling Fall Chinook Survival-Index Estimates

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-ratio	Type 1 Error P	Denominator Source
Year	1248.36	5	249.67	0.24	0.9281	Error
Yearling vs Sub-Yearling	16171.70	1	16171.70	15.57	0.0109	Error
Error	5194.70	5	1038.94			

Appendix A. Estimating Detection Rate Efficiencies and Expanding the Assessed dam Detections by those Efficiencies

Below is a general description of the methodology. The assessed dam is McNary, the downstream dams are Bonneville and John Day, and the periods are pre-May, early May (through May 15), late May, early June (through June 15), and after June 15.

For each dam down-stream of the dam for which detection efficiencies are being estimated, the assessed and downstream dams' joint detections at a downstream dam are obtain for each assessed dam's date and down-stream dam's date. Within each downstream-dam date, the detections are pooled over the assessed dam's dates to give the total assessed dam's detections on that downstream date. These joint totals are then divided by total downstream dam detections to get the estimated assessed dam's detection efficiency rate for that down-stream dam date. These detection rates are used as a dependent variable in a stepwise logistic regression. The dependent variables are indicator variables for the down-stream dam Julian detection dates. For a given downstream dam detection date, the indicator variable (IV) is assigned the value 0 if the actual down-stream dam date is less than the given IV Julian date and is 1 if that date is equal to or greater that IV date as illustrated below.

Table A.1. Variables used in getting stratified detection efficiencies

					Indicator Variables																
Lower Dam Julian Date	Assessed and Downstream Dam's Detections	Total Lower Downstream Detections	Upstream Dams Detection Rate	…	IV-40	IV-4s	IV-4s	IV-43	IV-44	IV-45	IV-46	IV-47	IV-48	IV-49	IV-50	IV-5s	IV-5s	IV-53	IV-54	IV-55	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
40	25	205	0.1219512	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
41	25	154	0.1623377	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
42	35	244	0.1434426	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
43	50	208	0.2403846	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
44	75	280	0.2678571	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
45	220	420	0.5238095	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
46	90	380	0.2368421	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
47	220	490	0.4489796	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
48	220	424	0.5188679	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
49	250	624	0.400641	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
50	275	670	0.4104478	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
51	220	460	0.4782609	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
52	225	520	0.4326923	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
53	95	372	0.2553763	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
54	70	289	0.2422145	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
55	80	330	0.2424242	…	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Using the total lower dam's total detections at the downstream dam as the weight, a weighted stepwise logistic regression of the assessed dam's detection rate is run on the indicator variables. The regression output will be the list of out down-stream dam Julian dates which will establish strata boundaries. The detection rates for the sorted listed date and all the dates up to but not including the next listed sorted date are pooled together as a stratum of reasonably homogeneous detection rates. The dates preceding the first sorted listed date are also pooled into a separate stratum.

A smolt passing the assessed dam during that period could pass the down-stream dam during any of the down-stream dam strata[4]. It is necessary to proportionately assign down-stream strata detection efficiencies to the assessed dam's passage periods for the purpose of expanding the assessed dam counts within those periods.

Referring to Table A.2., the number of the joint detections (x in Table A.2.) within a lower dam stratum that came from the assessed dam time period was computed for each lower dam stratum. For each stratum, the period's number of joint detections was divided by the period's joint detections over all periods, giving the period's relative frequency within the stratum (P in Table A.2.). The stratum's total downstream-dam detections (n in Table A.3) were multiplied by the relative frequency proportions to assign those stratum totals to the periods. Within the period, the stratums' detection efficiencies were weighted by the stratum downstream totals assigned to the period to obtain the mean detection efficiency for the period (example highlighted in yellow at the bottom of Table A.3).

Table A.2. Allocation of proportions of Joint Assessed and Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata

		Joint Number (x) of Downstream Dam and Assessed Dam Detections					
Stratum	Measure	Period a	Period b	Period c	...	Period p	Total
1	Joint Detections	x(a,1)	x(b,1)	x(c,1)	...	x(p,1)	x(1)
	Proportional Distribution	P(a,1)=x(a,1)/x(1)	P(b,1)=x(b,1)/x(1)	P(a,1)=x(a3)/x(1)	...	P(p,1)=x(p,1)/x(1)	
2	Joint Detections	x(a,2)	x(b,2)	x(c,2)		x(p,2)	x(2)
	Proportional Distribution	P(a,2)=x(a,2)/x(2)	P(b,2)=x(b,2)/x(2)	P(a,2)=x(a3)/x(2)	...	P(p,2)=x(p,2)/x(2)	
3	Joint Detections	x(a,3)	x(b,3)	x(c,3)		x(p,3)	x(3)
	Proportional Distribution	P(a,3)=x(a,3)/x(3)	P(b,3)=x(b,3)/x(3)	P(a,3)=x(a3)/x(3)	...	P(p,3)=x(p,3)/x(3)	
...	...	...	...	...	...	...	...
s	Joint Detections	x(a,s)	x(b,s)	x(c,s)		x(p,s)	x(s)
	Proportional Distribution	P(a,s)=x(a,s)/x(s)	P(b,s)=x(b,s)/x(s)	P(a,s)=x(as)/x(s)	...	P(p,s)=x(p,s)/x(s)	

Table A.3. Allocation of Total Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata and Estimation of Assessed Dam's Period Detection Efficiencies

			Number (n) of Downstream Detections*				
Stratum	Downstream Detections	Detection Efficiencies*	Period a	Period b	Period c	...	Period p
1	n(1)	de(1)=x(1)/n(1)	n(a,1) = n(1)*P(a,1)	n(b,1) = n(1)*P(b,1)	n(c,1) = n(1)*P(c,1)	...	n(p,1) = n(1)*P(p,1)
2	n(2)	de(2)=x(2)/n(2)	n(a,2) = n(2)*P(a,s)	n(b,2) = n(2)*P(b,s)	n(c,2) = n(2)*P(c,s)	...	n(p,2) = n(2)*P(p,s)
3	n(3)	de(3)=x(3)/n(3)	n(a,3) = n(3)*P(a,3)	n(b,3) = n(3)*P(b,3)	n(c,3) = n(3)*P(c,3)	...	n(p,3) = n(3)*P(p,3)
	...	...	...	...	...	...	...
s	n(s)	de(s)=x(4)/n(4)	n(a,s) = n(s)*P(a,s)	n(b,s) = n(s)*P(b,s)	n(c,s) = n(s)*P(c,s)	...	n(p,s) = n(s)*P(p,s)
Total			n(a)	n(b)	n (c)	...	n(p)

Example of detection efficiency for Period b: [n(b,1)*de(1) +n(b,2)*de(2) +n(b,3)*de(3)+...+n(b,s)*de(s)]/n(b)

[4] For hatchery Spring Chinook, McNary passage periods the following passage periods were established were established: Pre-April , Early April through April 15, Late April, Early May through May 15, Late April, Early June through Jun 15, Late June, Post-June.

This estimation procedure is separately performed for each of the down-stream dams, and then the within period detection rate estimates are weighted by the total allocated to the period (the row labeled “Total” in Table A.3. taken from each of the downstream dam’s tables). While subject to bias, there is evidence that this procedure gives a less-biased detection-efficiency estimator application than just using the assessed dam and down-stream dam detections divided by the total down-stream dam detections ignoring strata and periods.

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Appendix H
Annual Report: 2016 Coho Smolt-to-Smolt Survival of Releases into the Yakima Basin

Doug Neeley, Consultant to Yakama Nation

Introduction

Errors in the estimation of McNary Dam (McNary) detection efficiencies were discovered; therefore all 1999-2016 Coho-release survival-index estimates (survival) from time-of-tagging-to-McNary detection were re-estimated and re-analyzed. The results are presented in this report. Methods of estimation are presented in Appendix A[1].

Summary

Time-of-release trials conducted from 1999 through 2002 indicated no significant smolt survival differences between early and late release times when pooled[2] over years (Type 1 Error p = 0.63).

In all years except 2000, 2004, 2013, and 2016[3], there were designated sites from which two or more stocks were released from the same designated sites, making paired comparisons possible.

> In 1999, Yakima and Cascade stock were released from the same sites. The Cascade stock had a significantly higher survival than the Yakima stock when pooled over sites (Type 1 Error p = 0.032), the Cascade stock's survivals exceeding those of the Yakima stock for all four designated sites.

[1] In Appendix A. "Assessed Dam' is McNary, "Downstream Dams" are Bonneville and John Day, and "Periods" are Pre-May, Early May (through May 15), Late May, Early June (through June 15), and after Early June

[2] The term pooled refers computing an average by weighting the releases' estimates going into the average by the numbers of tagged fish going into those estimates.

[3] In 2000 only Willard stock releases were made from the designated sites, and in 2006 and 20016 only Yakima stock were released from designated sites. In 2013 both Eagle Creek and Yakima stock were released, but the releases were from different sites. There were other years where some sites had only one stock release but other sites had two or more stock releases.

In release years[4] 2001 through 2003 there were sites from which both Yakima and Willard stock were released. Based on an analysis of these sites, the Yakima stock had significantly higher survival than the Willard stock when pooled over sites and years (Type 1 Error p = 0.025), with no statistically significant evidence of survival differences interacting with either sites or years.

From 2007 through 2012 and in 2014 and 2015, Yakima stock and Eagle Creek Hatchery stock (Clackamas River basin) were released from the same Yakima-basin sites. Those stocks' survival difference were pooled over sites and years, the difference between the stocks' averages was small and far from significant (Type 1 Error p = 0.965). However in 2011, there was only one release site from which both stock were released, but in that year there were three sites from which both Yakima stock and a Yakima x Eagle Creek crosses were released (one site of the three is the site of the Eagle Creek stock release). The three Yakima x Eagle Creek cross survival estimates and the single Eagle Creek survival estimate were substantially higher than those of the associated Yakima stock releases in that year, the 2011 Yakima x Eagle Creek Cross stock's survival being significantly higher than that of the Yakima stock (Type 1 Error p = 0.012).

In 2005 there were two paired Yakima smolt and Washougal parr releases and one paired Eagle Creek smolt and Washougal parr release. There was no significant difference between the stock survivals (Type 1 Error p = 0.48). The comparison confounds stock (Yakima and Willard) with juvenile age (smolt and parr). Data summaries are presented in the main text only for reference because there are Washougal smolt releases being made in 2017.

There were two sets of paired experimental releases of Yakima stock, the pairs being: 1) a control treatment with Yakima smolt reared within the Yakima basin and released from a given Yakima site and 2) a test treatment with Yakima smolt reared at Eagle Creek Hatchery within the Clackamas basin but released at the same Yakima site. One set was the 2012 releases from the Easton release site, and the other set was the 2013 releases from the Stiles release site. The Yakima reared smolt had a higher survival rate in both years, and even though there was only one degree of freedom associated with the statistical test, the difference was statistically significant at the 5% level (1-sided Type 1 Error p = 0.047 under the hypothesis that the Yakima-reared smolt would have a higher survival than the Eagle Creek-reared smolt).

Early versus Late Releases

Table 1.a. gives the estimated survivals for paired early and late releases pooled over years, sites, and stock. When adjusted for the effects of year and site and their interactions, the survival difference was not significant (Type 1 Error p = 0.63, Table 1.c.). Table 1.b. gives the estimates by year, site, and stock. It should be noted that there was only a 10 day difference between the release dates in 1999, but in the subsequent years the late release dates were at least 18 days later than the early release dates. Since

[4] **In 2002, Willard sock was used in all but one designated site, but for that single-release site smolt were not identified by stock. There were no paired releases.**

stocks and sites of release differ from year to year, the pooled means are given within stock and years in Table 1.b. It is noted here that the stock differences significantly interacted with both years and sites at the 10% level (respective Type 1 Error p = 0.094 and p =0.099, Table 1.c.). Stock differences are discussed in subsequent sections.

Table 1.a. Time-of-Tagging-to-McNary-Passage Survival for early and late of 1999-2002 Coho Smolt Releases into the Yakima Basin

Release Period	Measure	1999-2002 Releases
Early	Survival	26.2%
	Tagged	36,366
Late	Survival	23.6%
	Tagged	39,196
Early - Late Survival		2.7%

Table 1.b. Individual release Time-of-Tagging-to-McNary-Passage Survival for Coho Smolt early and late Yakima Basin Releases into the Yakima River made from 1999 through 2002

			Cascade Stock: Release Site					Yakima Stock: Release Site						Willard Stock: Release Site				
Year	Treatment	Measure	Cle Elum	Jack Creek	Lost Creek	Stiles	Pooled*	Cle Elum	Easton	Jack Creek	Lost Creek	Stiles	Pooled*	Cle Elum	Easton	Lost Creek	Stiles	Pooled*
1999	Early	Survival	49.3%	52.3%	32.1%	64.9%	49.0%	47.1%		32.7%	13.4%	43.2%	34.7%					
	17-May	Tagged	799	1,246	1,160	1,248	4,548	1,158		1,229	1,047	1,240	4,674					
	Late	Survival	44.2%	63.5%	6.7%	51.3%	41.4%	36.9%		37.2%	1.1%	39.0%	29.0%					
	27-May	Tagged	809	1,245	1,220	1,274	4,548	1,181		1,243	1,144	1,244	4,812					
	Early - Late Survival		5.1%	-11.2%	25.4%	13.7%	7.6%	10.2%		-4.5%	12.3%	4.2%	5.7%					
2000	Early	Survival												16.0%	32.6%	31.2%	30.4%	27.6%
	7-May	Tagged												2,487	2,476	2,489	2,488	9,919
	Late	Survival												2.3%	21.4%	17.2%	41.8%	20.7%
	31-May	Tagged												2,462	2,476	2,488	2,493	9,919
	Early - Late Survival													13.7%	11.2%	14.0%	-11.4%	6.9%
2001	Early	Survival						1.2%	12.5%		25.6%	40.0%	20.0%	1.2%	1.2%	2.6%	19.9%	6.3%
	7-May	Tagged						1,207	1,249		1,250	1,249	4,955	1,197	1,234	1,240	1,236	4,935
	Late	Survival						1.8%	4.7%		18.7%	43.9%	17.3%	1.4%	7.2%	2.8%	15.9%	6.8%
	25-May	Tagged						1,240	1,247		1,251	1,249	4,987	1,219	1,234	1,245	1,237	4,935
	Early - Late Survival							-0.6%	7.8%		6.9%	-3.9%	2.7%	-0.2%	-6.0%	-0.1%	4.1%	-0.6%
2002	Early	Survival									26.3%		26.3%		5.9%	24.6%	37.6%	17.0%
	6-May	Tagged									1,192		1,192		1,248	1,249	1,249	4,995
	Late	Survival									41.4%		41.4%		19.4%	12.8%	35.7%	21.8%
	25-May	Tagged									1,250		1,250		2,497	1,247	1,251	4,995
	Early - Late Survival										-15.1%		-15.1%		-13.5%	11.9%	1.9%	-4.8%

*Estimates weighted by number of tagged smolt

Table 1.c Logistic Analysis of Variation of the Effect of Early and Late Releases (Treatment) on 1999-2002 Coho Time-of-Tagging-to-McNary Survival

(Note that the significant differences in stock survival involve more than two stock over the four years; stock differences will be discussed later.)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	3,527.40	3	1175.80	22.56	**0.0000**	Error*
Site	3,838.16	4	959.54	2.34	0.1534	Site x Year
Site x Year	2,865.40	7	409.34	7.85	**0.0004**	Error*
Stock	**1,443.90**	**3**	**481.30**	**14.95**	**0.0034**	**Stock x Year**
Stock x Year	95.41	1	95.41	1.83	0.1961	Error*
Stock x Site	193.19	6	32.20	0.62	0.7134	Error*
Stock x Site x Year	28.05	1	28.05	0.54	0.4745	Error*
Treatment	**37.44**	**1**	**37.44**	**0.28**	**0.6330**	**Treat x Year**
Treat x Year	400.33	3	133.44	2.56	0.0939	Error*
Treat x Site	494.17	4	123.54	2.37	0.0991	Error*
Stock x Site	127.71	3	42.57	0.82	0.5045	Error*
Error*	781.85	15	52.12			

* Includes three factor interactions involving treatment

Yellow shaded cells significant at the 10% level if not boldfaced and at the 5% level if boldfaced

Stock Comparisons

Yakima Stock versus Cascade Stock

Paired releases of Cascade and Yakima stock from the same sites were made in 1999. Since there were no substantial or significant differences in early and late releases made in 1999 through 2002, the decision was made to combine the early and late release data within the 1999 release sites[5]. The estimated McNary survivals are summarized in Table 2.a. The Cascade stock had a higher survival than the Yakima stock for all four sites and Cascade stock's survival when pooled over sites was significant at the 5% level (Type 1 Error p = 0.032, Table 2.b.).

Table 2.a. 1999 Time-of-Tagging-to-McNary-Passage Survival for Yakima and Cascade stock of Coho Smolt Releases into the Yakima Basin

		Site				
	Measure	**Cle Elum**	**Jack Creek**	**Lost Creek**	**Stiles**	**Pooled***
Yakima	**Survival**	**42.0%**	**35.0%**	**7.0%**	**41.1%**	**31.8%**
	Tagged	**2,339**	**2,472**	**2,191**	**2,484**	**9,486**
Cascade	**Survival**	**46.7%**	**57.9%**	**19.1%**	**58.0%**	**44.6%**
	Tagged	**2,491**	**1,608**	**2,380**	**2,522**	**9,001**
Yakima-Cascade Survival		**-4.8%**	**-23.0%**	**-12.1%**	**-17.0%**	**-12.8%**

***Estimates weighted by number of tagged smolt**

[5] The pooling of the early- and late-treatment release estimates over sites has some potential of bias since the treatment x site interaction F-test in Table 1.c. was significant at the 10% level.

Table 2.b. Logistic Analysis of Variation of the Treatment Effect (Yakima versus Cascade stock) on 1999 Coho Time-of-Tagging-to-McNary Survival

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	1867.01	3	622.34	19.02	**0.0187**	Error
Stock	**471.45**	**1**	**471.45**	**14.41**	**0.0321**	**Error**
Error	98.16	3	32.72			

Yellow highlighted boldfaced Type 1 Error P significant at the 5% level

Yakima Stock versus Willard Stock

Paired releases of Yakima and Willard smolt were made from 2001 through 2003[6]. Since there were no substantial or significant differences in early and late releases made in 2001 through 2002, the decision was made to combine the early and late release data within the release sites for 2001 and 2002[7]. The estimated tagging–to-McNary survivals are summarized in Table 3.a. The Yakima stock had a statistically significant higher survival than the Willard stock for all three years when pooled over sites (Type 1 Error p = 0.025, Table 3.b.).

Table 3.a. 2001-2003 Time-of-Tagging-to-McNary-Passage Survival for Yakima and Willard stock of Coho Smolt Releases into the Yakima Basin

		Year			
Stock	Measure	2001	2002	2003	Pooled*
Yakima	Survival	18.6%	42.4%	23.3%	26.3%
	Tagged	72	44	51	167
Willard	Survival	6.6%	27.7%	16.6%	13.9%
	Tagged	102	44	51	197
Yakima-Willard Survival		12.1%	14.7%	6.8%	12.5%

*Estimates weighted by number of tagged smolt

6 The releases in 2000 were only of Willard parr. There were both Yakima and Willard stock releases in 2004, but they were released from different sites. For this reason, the 2000 and 2004 data were not included in the analysis. The summaries of the 2000 Willard survival estimates and of the 2004 Yakima and Willard survival estimates are given in Appendix Table B.1.

7 The pooling of the early- and late-treatment release estimates over sites has some potential of bias since the treatment x site and treatment x year interaction F-tests in Table 1.c. were significant at the 10% level.

Table 3.b. Logistic Analysis of Variation of the Treatment Effect (Yakima versus Willard stock) on 2001-2003 Coho Time-of-Tagging-to-McNary Survival

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	1963.21	2	981.61	50.61	**0.0194**	Error
Site	2481.03	3	827.01	23.17	**0.0417**	Site x Year
Site x Year	71.39	2	35.70	1.84	0.3521	Error
Stock	**908.66**	**1**	**908.66**	**7.32**	**0.0245**	**Stock x Year**
Site x Stock	94.67	3	31.56	1.63	0.4026	Error
Stock x Year	248.16	2	124.08	6.40	0.1352	Error
Error	38.79	2	19.40			

Yellow highlighted boldfaced Type 1 Error P significant at the 5% level

*** In 2000 only Willard stock released, in 2004 both Willard and Yakima stock released but not from same sites so paired comparisons not possible**

Yakima Stock versus Eagle Creek Stock

Paired releases of Yakima and Eagle Creek smolt were made in 2000 through 2012 and 2014 and 2015[8]; in 2011 there were also releases of a Yakima x Eagle Creek stock. The estimated tagging–to-McNary survivals are summarized in Table 4.a. The Yakima and Eagle Creek stock did not differ significantly in their survivals (Type 1 Error p = 0.965, Table 4.b.). However, the Yakima x Eagle Creek cross's survival was substantially and significantly higher than that of the Yakima in the year (2011) when the cross was released (Type 1 Error p = 0.012, Table 4.b.). Note from Table 4.a. within the 2011 release groups, in all four comparisons the survivals of the Eagle Creek stock and the Yakima x Eagle cross were greater than the associated Yakima stock survivals.

Table 4.a. 2001-2012 and 2014-2015 Time-of-Tagging-to-McNary-Passage Survival for Yakima and Eagle Creek Stock and and 2011 Yakima x Eagle Creek Cross of Coho Smolt Releases into the Yakima Basin

Stock	Site*-Year >	St-2007	Ho-2007	Pr-2007	St-2008	Ho-2008	St-2009	Ho-2009	St-2010	Ho-2010
Yakima (Ya)	Survival	25.0%	10.7%	62.7%	30.1%	10.6%	47.6%	9.6%	18.7%	2.1%
	Tagged	2,449	2,460	2,499	2,492	2,493	2,515	2,512	2,501	2,516
Eagle Creek (EC)	Survival	30.8%	6.9%	48.7%	33.9%	17.7%	39.9%	14.7%	15.4%	4.3%
	Tagged	2,513	2,504	1,246	2,453	2,508	3,755	3,951	2,608	2,504
	Ya - EC Survival Difference	-5.7%	3.8%	14.0%	-3.8%	-7.1%	7.7%	-5.1%	3.3%	-2.2%

Stock	Site-Year >	Lo-2011	Ea-2011	Ho-2011	2011**	St-2012	Ea-2012	Ho-2012	St-2014	St-2015	Pooled***
Yakima (Ya)	Survival	22.8%	6.6%	3.4%	11.7%	38.0%	21.8%	2.4%	44.9%	0.0817601	19.2%
	Tagged	2,500	1,272	2,516	6,288	2,526	2,524	2,508	2,505	2520	43,804
Eagle Creek (EC)	Survival		22.1%			38.6%	19.6%	1.2%	28.1%	0.1649595	23.6%
	Tagged		2,561			2,543	2,553	4,963	2,529	2498	36,630
Yakima x	Survival	39.6%	27.0%	7.3%	24.6%						
Eagle Creek	Tagged	2,514	2,524	2,506	7544						
	Ya - EC Survival Difference		-15.5%			-0.7%	2.1%	1.2%	16.8%	-0.0831994	-4.4%
	Ya - YaxEC Survival Difference	-16.8%	-20.4%	-3.9%	-12.9%						

* St- Stiles Pond, Lo- Lost Creek Pond, Ho- Holmes Pond, Pr- Prosser Pond, Ea- Easton Pond

** Estimates weighted by number of tagged smolt over all sites within 2011

*** Estimates weighted by number of tagged smolt over all sites and years

[8] The releases in 2013 and 2016 were only of Yakima stock. The summaries of the 2013 and 2016 Yakima survival estimates are given in Appendix Table B.1.

Table 4.b. Logistic Analysis of Variation of the Treatment Effects (Yakima versus Eagle Creek stock released in 2007-2012 and 2014-2015 and Yakima Cross versus Yakima x Eagle Creek Cross) on Coho Time-of-Tagging-to-McNary Survival

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year*	2712.84	7	387.55	11.98	**0.0151**	Pooled Error*
Site*	7589.55	3	2529.85	11.93	**0.0183**	Site x Year*
Site x Year*	848.39	4	212.10	6.56	**0.0222**	Error
Yakima (Ya) vs Eagle Creek (EC)*	**0.17**	**1**	**0.17**	**0.00**	**0.9653**	**Stock x Year**
Site x Stock (Ya vs EC)*	145.16	3	48.39	1.50	0.3081	Error
Year x (Ya vs EC)*	399.41	7	57.06	1.76	0.2532	Error
Ya vs Ya x EC cross	**412.51**	**1**	**412.51**	**12.75**	**0.0118**	**Error**
Pooled Error*	194.06	6	32.34			

Yellow highlighted boldfaced Type 1 Error P significant at the 5% level
* Excluding Yakima x Eagle Creek data
** adjusted for only 2011 sites excluding Eagkle Creek Stock
*** from 2007-2016 Ya vs EC and 2011 Ya vs Ya X EC analyses

In 2012 when both the Yakima and Eagle Creek stock were being released and in 2013 when only the Yakima stock was released, there were release sites from which Yakima stock reared within the Yakima River basin and Yakima stock reared within the Clackamas River basin (Eagle Creek Hatchery) were released. The survival estimates of those releases are summarized in Table 5.a. The Yakima basin reared smolt survival is substantially greater than that of the Eagle Creek Hatchery reared smolt. While the pooled survival difference is significant at the 10% level and not the 5% level, (Type 1 Error p = 0.0942[9], Table 5.b.), the test is not powerful because it is only based on 1 degree of freedom. It is likely that the Yakima-basin rearing results in higher survival than the Eagle Creek rearing.

Table 5.a. Coho 2012-2013 Time-of-Tagging-to-McNary Survival of smolt reared in the Yakima River Basin and in the Clackamas River Basin

		Year		
Rearing Site	Measure	2012	2013	Pooled
Within Yakima River	Survival	21.8%	78.3%	49.9%
Basin*	Released	2,524	2,504	5,028
Within Clackamas	Survival	13.6%	34.1%	23.8%
River Basin Basin**	Released	2,547	2,505	5,052
	Survival Difference	8.2%	44.2%	26.2%

*Rearing Stites - Easton Site in 2012, Prosser in 2013
* Eagle Creek Hatchery

9 If the assumption were that the Yakima-reared stock had the highest survival, then a one-sided test would have been appropriate, in which case the test would have been significant at the 5% level (P = 0.047).

Table 5.b. Logistic Analysis of Variation Coho 2012-2013 Time-of-Tagging-to-McNary Survival of smolt reared in the Yakima River Basin and in the Clackamas River Basin

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	583.99	1	583.99	238.36	**0.0412**	Stock
Stock	110.16	1	110.16	44.96	0.0942	Error
Error	2.45	1	2.45			

Yellow shaded cells significant at the 10% level if not boldfaced and at the 5% level if boldfaced

Washougal Parr versus Control

In 2005 Washougal parr were released from three sites. The survival estimates of these releases are summarized in Table 6.a. The "Control" treatments are Eagle Creek at the Holmes site and Yakima at the Lost Creek sites[10]. Omitting the Holmes site resulted in an estimate of 0 for the estimate error deviance which would have resulted in an "infinite" F-test in the logistic analysis of variance. Since there was no substantial or significant difference in mean survivals of the Eagle Creek and Yakima stock when pooled over paired releases in later years (Table 4.b.), the Eagle Creek stock is used as a Boone-site surrogate for the Yakima stock. Even if the Eagle Creek stock were a suitable surrogate for the Yakima stock, meaningful stock comparisons are not possible because of the confounding of the stock with age of smolt (the "Controls" are smolt releases and Washougal are parr releases[11]). A logistic analysis of variation is given in Table 6.b. but should not be used to make any conclusion because of inherent potential biases associate with the surrogate assumption and the confounding effect of age of juveniles at release.

The only reason that these summaries are given is that the Washougal stock smolt are being used for some releases in 2017 because of poor adult returns to the Yakima basin; however, the 2017 releases of Washougal stock juveniles will be smolt instead of the parr used in 2005.

Table 6.a. 2005 Time-of-Tagging-to-McNary-Passage Survival for Coho Yakima/Eagle Creek Smolt and Washougal Parr Releases into the Yakima Basin

Stock	Site	Site: Holmes	Lost Creek	Boone	Pooled*
Control** -	Smolt Survival	0.2%	3.4%	0.9%	1.8%
	Tagged	2,527	5,232	5,052	12,811
Washougal -	Parr Survival	17.7%	0.2%	0.0%	8.8%
	Tagged	4,958	2,529	2,529	10,016
Yakima - Wahsougal Difference***		-17.5%	3.3%	0.9%	-7.0%

* Estimates weighted by number of tagged smolt

** Control: Eagle Creek at Holmes, Yakima at Lost Creek and Boone

*** Stock difference completely confounded with age (smolt versus parr)

[10] Note that the control smolt estimates are given in the Appendix B.1. table but the Washougal Parr estimates are given in the lower right-hand corner of the Appendix B.2. table

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Table 6.b. Logistic Analysis of Variation of the Treatment Effect (Yakima Smolt versus Washougal Parr) on Coho 2005 Time-of-Tagging-to-McNary Survival

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Site	1153.06	2	576.53	1.79	0.3586	Error*
Stock	**235.48**	**1**	**235.48**	**0.73**	**0.4828**	**Error***
Error*	644.8	2	322.4			

* The "Error" would include Site x Stock interactions if they existed"

Appendix A. Estimating Detection Rate Efficiencies and Expanding the Assessed dam Detections by those Efficiencies

For each dam down-stream of the dam for which detection efficiencies are being estimated, the joint assessed and downstream dams' joint detections at a downstream dam are obtain for each assessed dam's date and down-stream dam's date. Within each downstream-dam date, the detections are pooled over the assessed dam's dates to give the total assessed dam's detections on that downstream date. These joint totals are then divided by total downstream dam detections to get the estimated assessed dam's detection efficiency rate for that down-stream dam date. These detection rates are used as a dependent variable in a stepwise logistic regression. The dependent variables are indicator variables for the down-stream dam Julian detection dates. For a given downstream dam detection date, the indicator variable (IV) is assigned the value 0 if the actual down-stream dam date is less than the given IV Julian date and is 1 if that date is equal to or greater that IV date as illustrated below.

Table A.1. Variables used in getting stratified detection efficiencies

Lower Dam Julian Date	Assessed and Downstream Dam's Detections	Total Lower Downstream Detections	Upstream Dams Detection Rate	…	Indicator Variables																…
					IV-40	IV-4s	IV-4s	IV-43	IV-44	IV-45	IV-46	IV-47	IV-48	IV-49	IV-50	IV-5s	IV-5s	IV-53	IV-54	IV-55	
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
40	25	205	0.1219512	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
41	25	154	0.1623377	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
42	35	244	0.1434426	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
43	50	208	0.2403846	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
44	75	280	0.2678571	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
45	220	420	0.5238095	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
46	90	380	0.2368421	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
47	220	490	0.4489796	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
48	220	424	0.5188679	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
49	250	624	0.400641	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
50	275	670	0.4104478	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
51	220	460	0.4782609	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
52	225	520	0.4326923	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
53	95	372	0.2553763	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
54	70	289	0.2422145	…	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	…
55	80	330	0.2424242	…	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Using the total lower dam's total detections at the downstream dam as the weight, a weighted stepwise logistic regression of the assessed dam's detection rate is run on the indicator variables. The regression output will be the list of out down-stream dam Julian dates which will establish strata boundaries. The detection rates for the sorted listed date and all the dates up to but not including the next listed sorted date are pooled together as a stratum of reasonably homogeneous detection rates. The dates preceding the first sorted listed date are also pooled into a separate stratum.

A smolt passing the assessed dam during that period could pass the down-stream dam during any of the down-stream dam strata[12]. It is necessary to proportionately assign down-stream strata detection efficiencies to the assessed dam's passage periods for the purpose of expanding the assessed dam counts within those periods.

Referring to Table A.2., the number of the joint detections (x in Table A.2.) within a lower dam stratum that came from the assessed dam time period was computed for each lower dam stratum. For each stratum, the period's number of joint detections was divided by the period's joint detections over all periods, giving the period's relative frequency within the stratum (P in Table A.2.). The stratum's total downstream-dam detections (n in Table A.3) were multiplied by the relative frequency proportions to assign those stratum totals to the periods. Within the period, the stratums' detection efficiencies were weighted by the stratum downstream totals assigned to the period to obtain the mean detection efficiency for the period (example highlighted in yellow at the bottom of Table A.3).

Table A.2. Allocation of proportions of Joint Assessed and Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata

		Joint Number (x) of Downstream Dam and Assessed Dam Detections					
Stratum	Measure	Period a	Period b	Period c	...	Period p	Total
1	Joint Detections	x(a,1)	x(b,1)	x(c,1)	...	x(p,1)	x(1)
	Proportional Distribution	P(a,1)=x(a,1)/x(1)	P(b,1)=x(b,1)/x(1)	P(a,1)=x(a3)/x(1)	...	P(p,1)=x(p,1)/x(1)	
2	Joint Detections	x(a,2)	x(b,2)	x(c,2)		x(p,2)	x(2)
	Proportional Distribution	P(a,2)=x(a,2)/x(2)	P(b,2)=x(b,2)/x(2)	P(a,2)=x(a3)/x(2)	...	P(p,2)=x(p,2)/x(2)	
3	Joint Detections	x(a,3)	x(b,3)	x(c,3)		x(p,3)	x(3)
	Proportional Distribution	P(a,3)=x(a,3)/x(3)	P(b,3)=x(b,3)/x(3)	P(a,3)=x(a3)/x(3)	...	P(p,3)=x(p,3)/x(3)	
...	...	...	...	...	...	...	...
s	Joint Detections	x(a,s)	x(b,s)	x(c,s)		x(p,s)	x(s)
	Proportional Distribution	P(a,s)=x(a,s)/x(s)	P(b,s)=x(b,s)/x(s)	P(a,s)=x(as)/x(s)	...	P(p,s)=x(p,s)/x(s)	

Table A.3. Allocation of Total Downstream Dams' Detections over Assessed Dam's Periods within Downstream Dam's Strata and Estimation of Assessed Dam's Period Detection Efficiencies

			Number (n) of Downstream Detections*				
Stratum	Downstream Detections	Detection Efficiencies*	Period a	Period b	Period c	...	Period p
1	n(1)	de(1)=x(1)/n(1)	n(a,1) = n(1)*P(a,1)	n(b,1) = n(1)*P(b,1)	n(c,1) = n(1)*P(c,1)	...	n(p,1) = n(1)*P(p,1)
2	n(2)	de(2)=x(2)/n(2)	n(a,2) = n(2)*P(a,s)	n(b,2) = n(2)*P(b,s)	n(c,2) = n(2)*P(c,s)	...	n(p,2) = n(2)*P(p,s)
3	n(3)	de(3)=x(3)/n(3)	n(a,3) = n(3)*P(a,3)	n(b,3) = n(3)*P(b,3)	n(c,3) = n(3)*P(c,3)	...	n(p,3) = n(3)*P(p,3)
	...	...	...	...	...	...	...
s	n(s)	de(s)=x(4)/n(4)	n(a,s) = n(s)*P(a,s)	n(b,s) = n(s)*P(b,s)	n(c,s) = n(s)*P(c,s)	...	n(p,s) = n(s)*P(p,s)
Total			n(a)	n(b)	n (c)	...	n(p)

Example of detection efficiency for Period b: [n(b,1)*de(1) +n(b,2)*de(2) +n(b,3)*de(3)+...+n(b,s)*de(s)]/n(b)

[12] For hatchery Spring Chinook, McNary passage periods the following passage periods were established were established: Pre-April , Early April through April 15, Late April, Early May through May 15, Late April, Early June through Jun 15, Late June, Post-June.

This estimation procedure is separately performed for each of the down-stream dams, and then the within period detection rate estimates are weighted by the total allocated to the period (the row labeled "Total" in Table A.3. taken from each of the downstream dam's tables).   While subject to bias, there is evidence that this procedure gives a less-biased detection-efficiency estimator application than just using the assessed dam and down-stream dam detections divided by the total down-stream dam detections ignoring strata and periods.

Appendix B.1 1999-2016 Smolt Release Survival by Release Year, Site, and Stock

			Outmigration Year																	
Site	Stock	Site	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cle Elum	Yakima	Survival	42.0%		1.5%															
		Tagged	2,339		2,447															
	Cascade	Survival	46.7%																	
		Tagged	1,608																	
	Willard	Survival		9.2%	1.3%															
		Tagged		4,949	2,416															
Jack Creek	Yakima	Survival	35.0%																	
		Tagged	2,472																	
	Cascade	Survival	57.9%																	
		Tagged	2,491																	
Lost Creek	Yakima	Survival	7.0%		22.1%	34.1%	21.5%	68.9%	3.4%	40.6%	22.1%	28.7%	31.2%	20.0%	22.8%		68.2%		4.3%	7.8%
		Tagged	2,191		2,501	2,442	3,333	2,445	5,232	5,006	2,501	2,499	2,508	2,505	2,500		2,531		2,506	2,502
	Cascade	Survival	19.1%																	
		Tagged	2,380																	
	Willard	Survival		24.2%	2.7%	18.7%	9.4%													
		Tagged		4,977	2,485	2,496	2,497													
	Eagle Creek	Survival									15.9%	30.8%	27.4%	19.2%				22.0%		
		Tagged									2,511	2,524	2,331	2,528				2,523		
	Yakima x Eagle Creek	Survival													39.6%					
		Tagged													2,514					
Stiles	Yakima	Survival	41.1%		41.9%	50.6%	25.1%				25.0%	30.1%	47.6%	18.7%		38.0%		44.9%	8.2%	49.5%
		Tagged	2,484		2,498	2,500	3,332				2,449	2,492	2,515	2,501		2,526		2,505	2,520	3,756
	Cascade	Survival	58.0%																	
		Tagged	1																	
	Willard	Survival		36.1%	17.9%	36.6%	23.7%	73.1%												
		Tagged		4,981	2,473	2,500	2,501	1												
	Eagle Creek	Survival							24.9%		30.8%	33.9%	39.9%	15.4%		38.6%		28.1%	28.1%	
		Tagged							5,005		2,513	2,453	3,755	2,608		2,543		2,529	2,529	
	Yakima x Eagle Creek	Survival													27.0%					
		Tagged													2,524					
Easton	Yakima	Survival			8.6%										6.6%	21.8%	23.4%			20.2%
		Tagged			2,496										1,272	2,524	3,464			5,098
	Willard	Survival		27.0%	4.2%	14.9%	6.6%													
		Tagged		4,952	2,468	3,745	2,461													
	Eagle Creek	Survival											14.7%	9.7%	22.1%	19.6%		9.0%	2.6%	
		Tagged											2,524	2,532	2,561	2,553		2,586	3,751	
	Yakima x Eagle Creek	Survival													24.4%					
		Tagged													2,522					
Boone	Yakima	Survival						65.5%	0.9%	3.1%										
		Tagged						2,488	5,052	5,001										
	Eagle Creek	Survival												3.5%						
		Tagged												1,265						
Holmes	Yakima	Survival								11.6%	10.7%	10.6%	9.6%	2.1%	3.4%	2.4%	17.8%			34.7%
		Tagged								5,026	2,460	2,493	2,512	2,516	2,516	2,508	2,506			5,050
	Willard	Survival					13.5%	41.0%												
		Tagged					2,499	2,522												
	Eagle Creek	Survival							17.7%		6.9%	17.7%	14.7%	4.3%		1.2%		12.0%	8.6%	
		Tagged							4,958		2,504	2,508	3,951	2,504		4,963		2,502	2,501	
	Yakima x Eagle Creek	Survival													7.3%					
		Tagged													2,506					
Prosser	Yakima	Survival								58.3%	62.7%		71.9%	52.5%	37.2%	37.6%	67.2%	78.0%	37.2%	28.9%
		Tagged								2,257	2,499		2,506	1,371	5,036	1,285	2,520	3,004	1,265	2,501
	Eagle Creek	Survival									48.7%	30.3%								
		Tagged									1,246	854								

Appendix B.2. Tagging-to-McNary Survival of 2005-2016 Parr Releases by Site

Year	Ahtanum Creek	Survival	Tagged
2009	Ahtanum Cr	10.26%	3002
2010	Ahtanum Cr	20.41%	3050
2011	Ahtamum Cr	18.42%	3003
2012	Ahtanum below WIP Main Diversion	5.36%	4003
2013	Ahtanum Creek at La Salle	9.64%	600
2013	Ahtanum Creek WIP Diversion	6.71%	1213
2014	Ahtanum below buried section	0.62%	872
2014	Ahtanum on LaSalle	0.00%	672
2015	Ahtanum below buried section	0.00%	1349
2015	Ahtanum Cr	0.00%	231
2016	Ahtanum Creek at La Salle	26.22%	869
2016	Autanum Below WIP Diversion	1.51%	1648

Year	Big Creek	Survival	Tagged
2008	Big Cr	13.33%	3001
2009	Big Cr	12.45%	3003
2010	Big Cr	9.90%	3006
2011	Big Cr	15.63%	3003
2012	Big Cr	11.04%	3013
2013	Big Cr	8.10%	3028
2014	Big Cr	3.36%	3047
2015	Big Cr	0.30%	3003
2016	Big Cr	6.47%	3013

Year	Boone Pond	Survival	Tagged
2006	Boone Pond (unpaired Parr release)	1.87%	1026
2008	Boone Pond (unpaired Parr release)	3.37%	2519

Year	Buckskin Slough	Survival	Tagged
2007	Buckskin Slough	9.08%	1026
2011	Buckskin Slough	31.91%	216
2014	Buckskin Slough	50.00%	1572
2015	Buckskin Slough	12.57%	1247
2016	Buckskin Slough	30.91%	2501

Year	Bumping Reservoir	Survival	Tagged
2007	Bumping Reservoir	13.28%	3002

Year	Cle Elum Dam	Survival	Tagged
2005	Cle Elum Dam (below)	0.99%	3331
2005	Cle Elum Dam (flume)	0.00%	1001
2006	Cle Elum Dam (below)	31.96%	1001
2006	Cle Elum Dam (flume)	15.99%	1000
2007	Cle Elum Dam (below dam)	10.26%	999
2007	Cle Elum Dam (below dam)	0.00%	1011
2007	Cle Elum Dam (flume)	0.00%	1004
2007	Cle Elum Dam (flume)	4.11%	1000
2007	Cle Elum Dam at Tucquala Outlet	1.38%	2998
2008	Cle Elem Dam (forebay)	3.61%	5973

Year	Cle Elum Lake	Survival	Tagged
2006	Cle Elum Lake (from Net Pen)	0.06%	9998
2006	Cle Elum Lake (upper)	0.43%	3004
2007	Cle Elum Lake (from Net Pen)	4.22%	9999
2007	Cle Elum River (upper)	0.24%	3013
2008	Cle Elum Lake (Upper)	4.12%	5944
2009	Cle Elum Lake (Upper)	0.23%	11934
2016	Cle Elum Lake	0.43%	3015

Year	Cowiche Creek	Survival	Tagged
2008	Cowiche Cr	30.72%	3001
2009	Cowiche Cr (below dam)	23.34%	3001
2009	Cowiche Cr (catch and release)	No. Est.	
2010	Cowiche Cr	16.89%	3004
2011	Cowiche Cr (below dam)	19.56%	3021
2011	Cowiche Cr (below dam)	81.17%	28
2013	Cowiche Cr (below dam)	11.25%	3003
2014	Cowiche Cr (below dam)	3.57%	3014
2014	Cowiche Cr (from Mobile)	25.43%	1249
2015	Cowiche Cr	15.43%	1250
2015	Cowiche Cr (below dam)	0.00%	3017

Year	South fork Cowiche Creek	Survival	Tagged
2009	Cowiche Cr SF from Mobile	45.40%	817
2010	Cowiche Cr SF	25.01%	1248
2011	Cowiche Cr SF from Mobile	31.09%	1272
2012	Cowiche Cr SF	9.33%	3024
2012	Cowiche Cr SF from Mobile	40.39%	1277
2013	Cowiche Cr SF from Mobile	27.46%	2495
2016	Cowiche Cr SF	2.32%	3005

Year	Hanson Pond	Survival	Tagged
2005	Hanson Pond (below dam)	5.90%	994
2005	Hanson River (below dam)	0.95%	997
2006	Hanson Pond (below dam)	4.13%	2015
2007	Hanson Pond (below dam)	16.46%	1026

Year	Hundly Ponds	Survival	Tagged
2015	Hundly Ponds (near Nelson Spr siding	0.00%	1531

Year	Lost Creek	Survival	Tagged
2011	Lost Creek	56.82%	10

Year	Marion Drain	Survival	Tagged
2008	Marion Drain	26.96%	3013

Year	Mercer Creek	Survival	Tagged
2013	Mercer above Buried Section	15.37%	1502
2013	Mercer below Buried Section	16.35%	1502
2016	Mercer (Down Steam)	20.83%	1543
2016	Mercer (Upstream)	8.95%	1523

Year	Naches	Survival	Tagged
2016	Naches	7.92%	3017
2006	Naches	42.65%	30

Year	Little Naches	Survival	Tagged
2009	Little Naches	16.62%	3000
2010	Little Naches	18.29%	3072
2011	Little Naches	9.59%	3022
2012	Little Naches	20.25%	3014
2013	Little Naches	7.56%	3019
2014	Little Naches	6.61%	3012
2015	Little Naches	0.00%	3010
2015	Little Naches	0.00%	3026
2016	Little Naches	3.97%	3008

Year	North Fork Little Naches	Survival	Tagged
2008	Little Naches NF	12.10%	3001
2009	Little Naches NF	16.31%	3003
2010	Little Naches NF	19.44%	3014
2011	Little Naches NF	17.84%	3058
2012	Little Naches NF	15.43%	3028
2013	Little Naches NF	11.36%	3012
2014	Little Naches NF	5.68%	3034
2015	Little Naches NF	0.00%	3004

Year	Nile Creek	Survival	Tagged
2008	Nile Cr	17.23%	3000
2009	Nile Cr	8.32%	2999
2010	Nile Cr	13.86%	3055
2010	Nile Cr	54.10%	16
2011	Nile Cr	7.49%	3110
2011	Nile Cr	71.02%	16
2012	Nile Cr	7.12%	3017
2013	Nile Cr	4.92%	3033
2014	Nile Cr	6.40%	3026

Year	Quarts Creek	Survival	Tagged
2012	Quarts Cr	11.55%	3008
2013	Quarts Cr	5.37%	3007
2014	Quarts Cr	4.61%	3039
2015	Quarts Cr	0.00%	3012

Year	Rattle Snake Creek	Survival	Tagged
2010	Rattle Snake Cr	8.51%	1144
2010	Rattle Snake Cr	12.27%	3053
2011	Rattle Snake Cr	7.95%	3000
2012	Rattle Snake Cr	8.69%	3006
2012	Rattle Snake Cr from Mobile	15.70%	1274
2013	Rattle Snake Cr	3.85%	3002
2013	Rattle Snake Cr	21.85%	1263
2014	Rattle Snake Cr	6.08%	3011
2015	Rattle Snake Cr	5.81%	1249
2015	Rattle Snake Cr	0.56%	1606
2016	Rattle Snake Cr	5.61%	3032

Year	Little Rattle Snake Creek	Survival	Tagged
2009	Little Rattle Snake	2.28%	3005

Year	Reecer Creek	Survival	Tagged
2008	Reecer Cr	37.41%	3001
2009	Reecer Cr	25.21%	2965
2010	Reecer Cr	23.24%	3015
2011	Reecer Cr	29.24%	3004
2012	Reecer Cr	20.52%	3026
2013	Reecer Cr	13.35%	3032
2014	Reecer Cr	7.46%	3031
2015	Reecer Cr	3.26%	3026

Year	Rock Creek	Survival	Tagged
2010	Rock Cr	0.00%	78

Year	Roza Dam	Survival	Tagged
2005	Roza Dam (above)	1.70%	3334
2005	Roza Dam (below)	1.84%	3334
2013	Roza Dam (bypass)	46.71%	1221
2014	Roza Dam (below)	41.63%	1500
2016	Roza Dam (below)	25.04%	2500

Year	Taneum Creek	Survival	Tagged
2009	Taneum Cr	15.84%	1300
2010	Taneum Cr	9.09%	1867
2011	Taneum Cr	13.72%	4515
2012	Taneum Cr	24.56%	1054
2013	Taneum Cr	13.48%	743
2014	Taneum Cr	8.04%	1941

Year	Umtanum Creek	Survival	Tagged
2009	Umtanum Cr	35.09%	150
2010	Umtanum Cr	35.71%	42

Year	Wilson Creek	Survival	Tagged
2008	Wilson Cr	11.36%	3000
2009	Wilson Cr	15.51%	3007
2010	Wilson Cr	12.15%	3050
2011	Wilson Cr	16.44%	2522
2012	Wilson Cr	11.23%	3020
2013	Wilson Buried Section Above	4.89%	1518
2013	Wilson Buried Section Below	10.19%	1502
2014	Wilson Cr	8.19%	3024
2015	Wilson Cr	7.10%	3027
2016	Wilson Cr	21.05%	3011

Year	Holmes Pond	Survival	Tagged
2005	Yakima River	55.14%	1301
2007	Upper Yakima River at Holmes	0.00%	23
2007	Yakima River at Hanson Pond	7.71%	1026
2009	Yakima at Crystal Creek C.G.	9.99%	3003
2012	Yakima at Thorp Bridge	10.78%	2499
2016	Yakima (Keechelus Reach)	0.94%	952

Year	Washougal* Parr Releases	Survival	Tagged
2005	Holmes Pond - PARR	0.19%	2,527
2005	Lost Creek Pond - PARR	0.19%	2,529
2005	Boone Pond - PARR	0.00%	2,529

*Washougal Parr releases listed separately because they were released as part of a multi-site paired stock trial with Yakima stock released as smolt. Individual site release summaries given in text under the section "Paired Releases" where the two sock are compared