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 is 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 2001-2018 average of over 10,200 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 summer/fall Chinook at Prosser Dam has increased from a 1983-1999 average of just over 1,000 fish to a 2000-2018 average of over 4,300 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. Approximately 440 summer-run Chinook were estimated to pass above Prosser Dam in 2018. In 2018, over 2,100 coho returned above Prosser Dam. Coho returns to Prosser Dam averaged over 5,400 fish from 1997-2018 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging over 800 fish annually 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 smolt migration years 2000 to present, annual abundance estimates of juvenile smolts migrating downstream at Prosser Dam averaged 219,400 wild/natural spring Chinook, 329,700 CESRF-origin spring Chinook, 44,200 wild/natural-origin coho, and 260,400 hatchery-origin coho. Preliminary smolt-to-adult survival indices averaged approximately 2.7% and 3.0% 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 57 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 220 redds enumerated annually on average in tributaries in the upper watersheds since 2004. In 2018, 100 coho redds were observed in tributaries in the Naches and Upper Yakima Subbasins.

Monitoring and evaluation of diversity metrics is primarily 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.

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 59% 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 (2005-2018) 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 an 18-year mean annual PNI of 65%. 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. 2017) 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 and CRITFC (2009-009-00) to address fish propagation, predation, harvest, and monitoring and evaluation methodology uncertainties including:

Fish Propagation Question 1. Are current propagation efforts successfully meeting harvest and conservation objectives while managing risks to natural populations?

> 1.2. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?

1.4. 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?

1.5. 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, and the proportion of natural origin adults in the hatchery broodstock?

Predation Question 1. Are the current efforts to address predation and reduce numbers of predators effective?

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 to measure productivity adequate to cost effectively inform decisions?

Monitoring and evaluation methods Question 2. Are there innovative methods for counting fish and measuring their productivity that would better inform decisions?

YKFP-related project research in the Yakima River Basin has resulted in the publication of over 60 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).

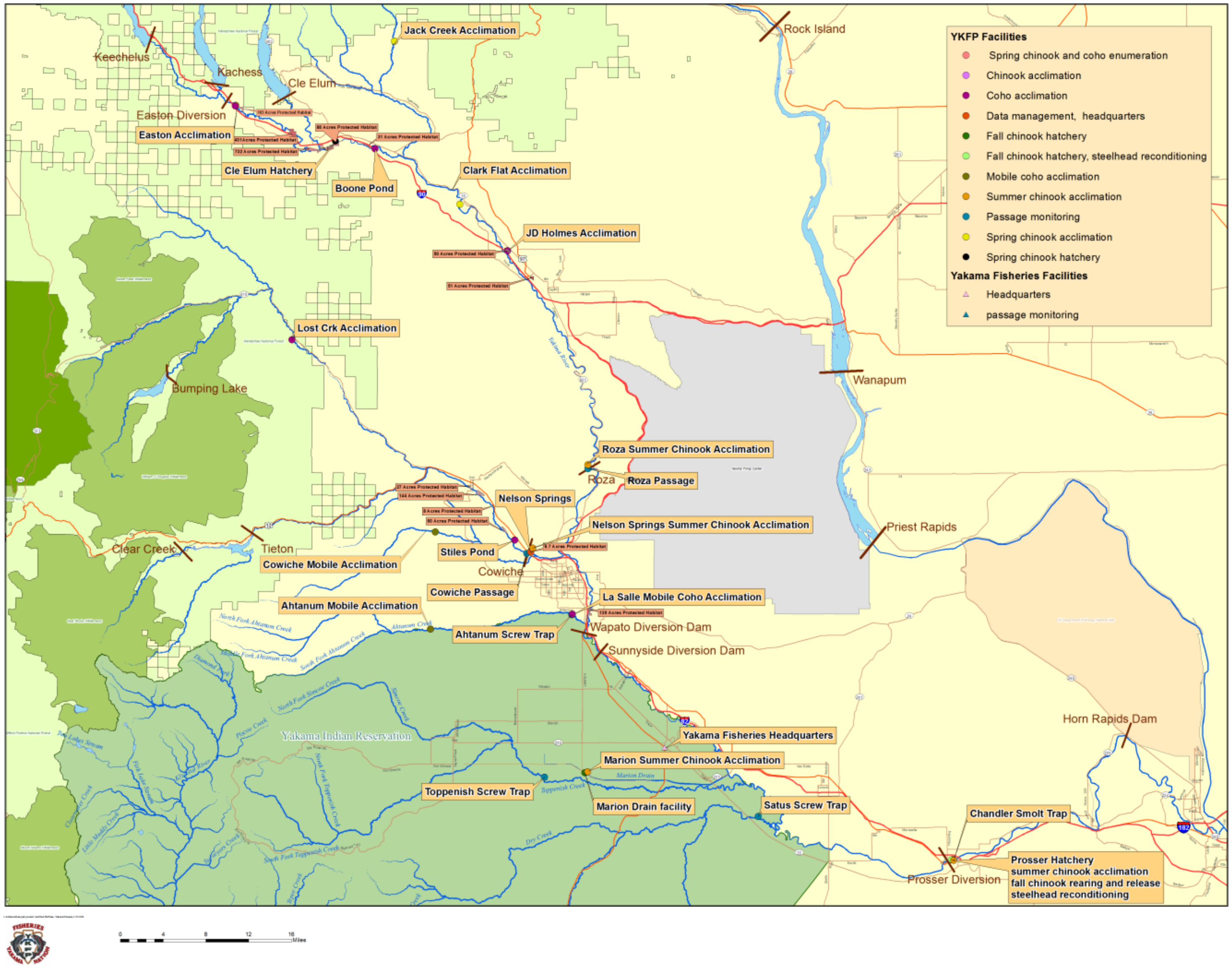


Figure 1. Yakima River Basin and Yakama Nation/YKFP-related artificial production and monitoring facilities (map provided by Paul Huffman).

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 (monitoringresources.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 (monitoringresources.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 (monitoringresources.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 available at: http://dashboard.yakamafish-star.net/DataQuery. Similarly at Roza Dam, adult trap data are entered into a Microsoft Access database, and daily dam count reports (with video counts integrated) are available at: http://dashboard.yakamafish-star.net/DataQuery. Post-season, counts are reviewed and adjusted for data gaps and knowledge about adult and jack lengths from sampling activities with corrections made to our master data sets. In addition to adult abundance data, Yakima Basin adult trap sampling (login required) data for the Prosser and Roza data sets are available at: http://dashboard.yakamafish-star.net/DataQuery.

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:

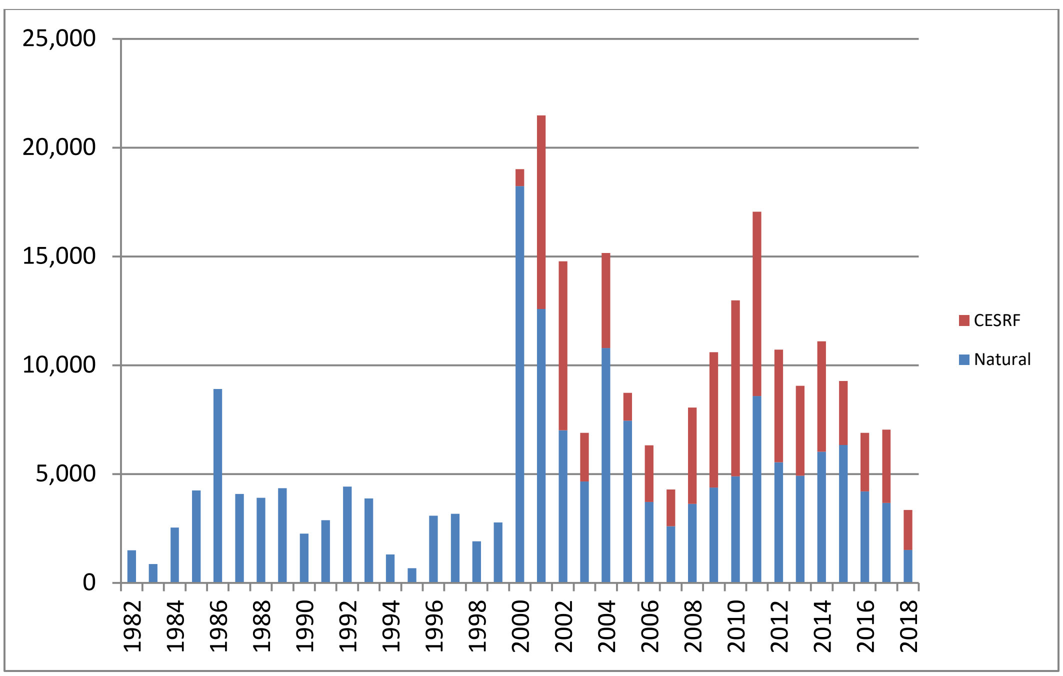


Figure 2. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Prosser Dam, 1982-present.

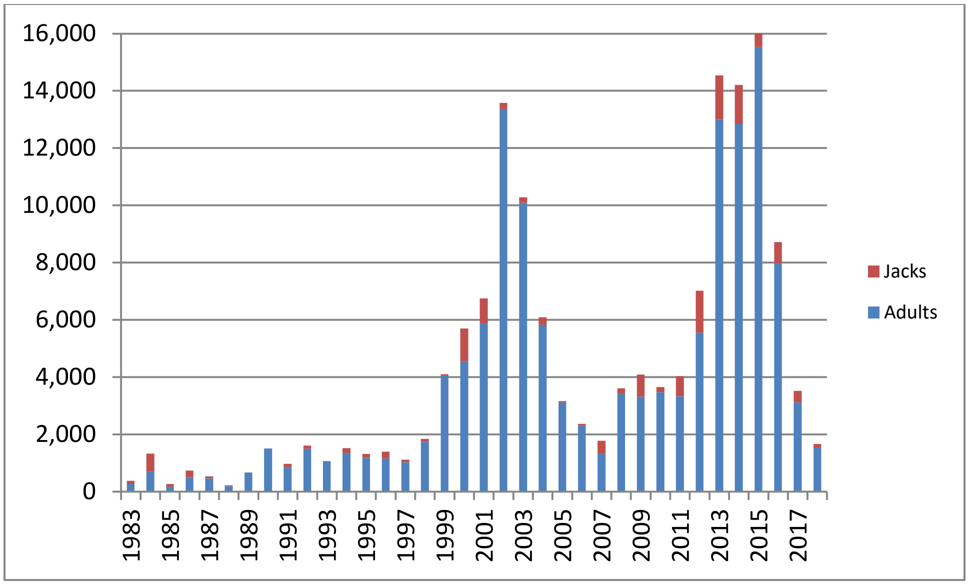


Figure 3. Estimated returns of adult and jack summer- and fall-run Chinook to the Yakima River mouth, 1983-present.

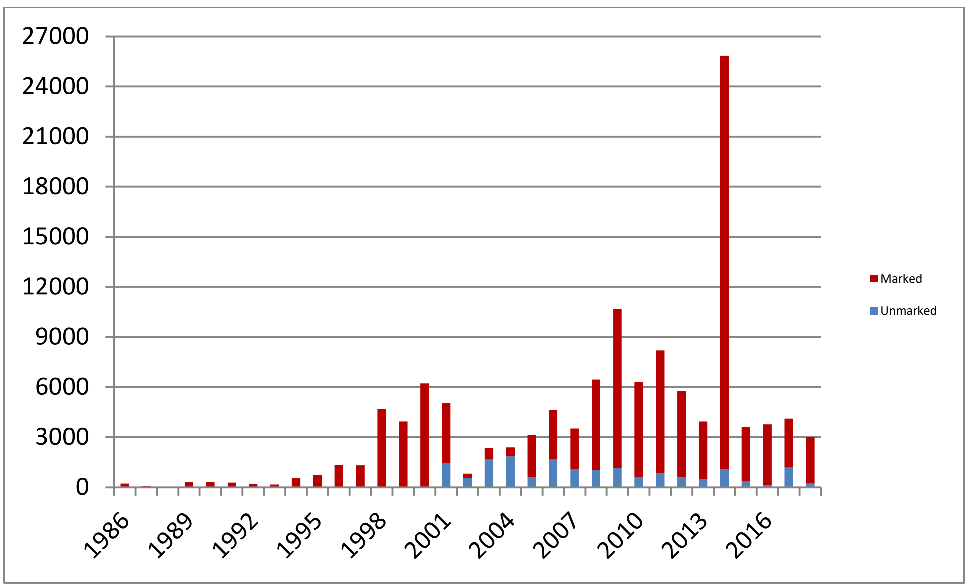


Figure 4. Estimated counts of marked (presumed hatchery-origin) and unmarked (presumed natural-origin) Coho (adults and jacks) at Prosser Dam 1986-present.

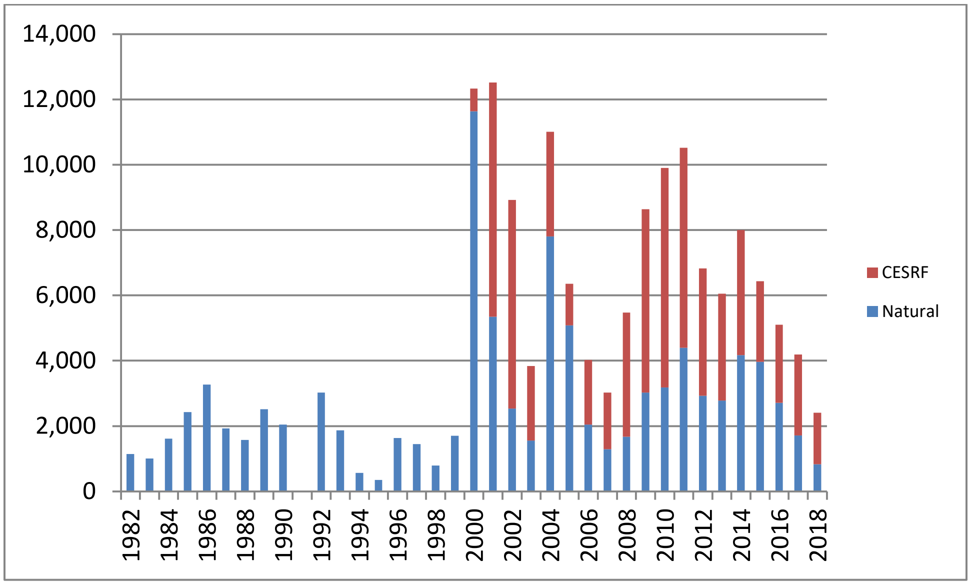


Figure 5. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Roza Dam, 1982-present.

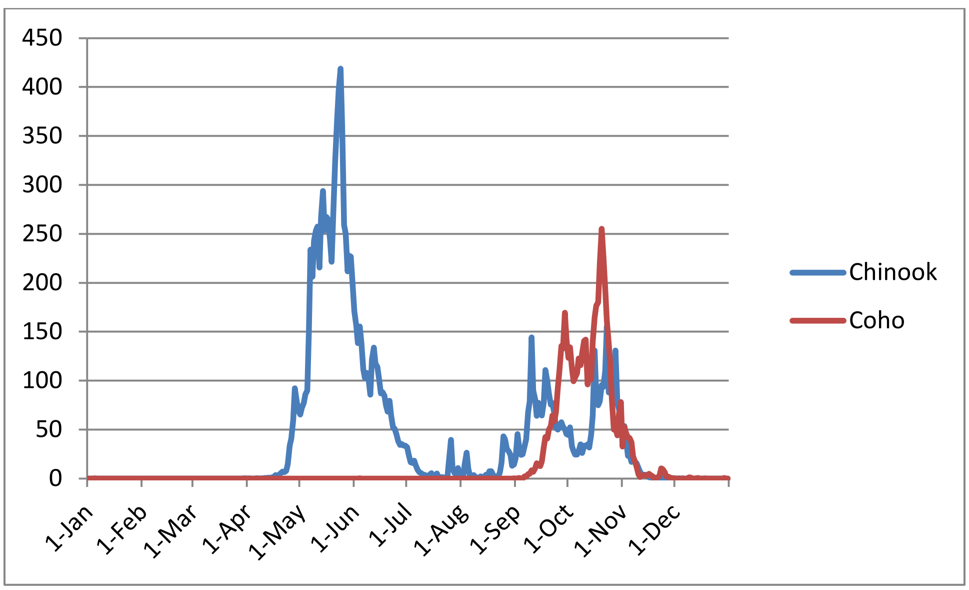


Figure 6. Average daily passage of Chinook and Coho (adults and jacks) at Prosser Dam, 2009-2018.

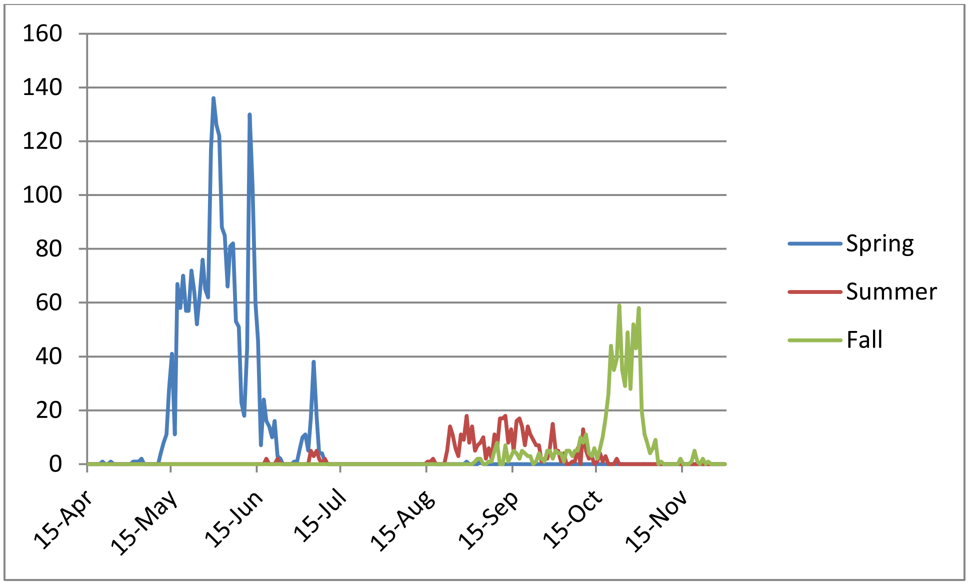


Figure 7. Passage timing of adult and jack Chinook at Prosser Dam in 2018 by run (see Methods).

Discussion:

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2018 average of about 10,200 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 2001-2018 average of approximately 6,800 fish (Figure 5). These increases beginning in 2001 coincide with the first adult returns from the Cle Elum supplementation program. However, freshwater passage conditions, marine survival, and habitat restoration and enhancement work also affect survival and return rates. The lower adult returns observed in 2003 and 2007 coincide with notable droughts during the corresponding smolt outmigration years of 2001 and 2005. Returns in 2015, 2018, and to a lesser extent 2017 were affected by thermal barriers in the lower Yakima River during the adult migration timeframe. 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 2000-2018 average of over 4,300 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). Approximately 440 summer-run Chinook were estimated to pass above Prosser Dam in 2018 (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 over 5,400 fish from 1997-2018 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging over 800 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 resources.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 resources.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	20	2,662	0.49
2013	4,984	299	1,622	10	1,931	0.39
2014	6,751	241	840			
2015	5,466	66				
2016	4,281					
2017	3,342					
2018	1,817					
Mean	4,170	344	2,803	111	3,336	1.56

1. The mean jack proportion of spawning escapement from 1999-2018 was 0.22 (geometric mean 0.17).

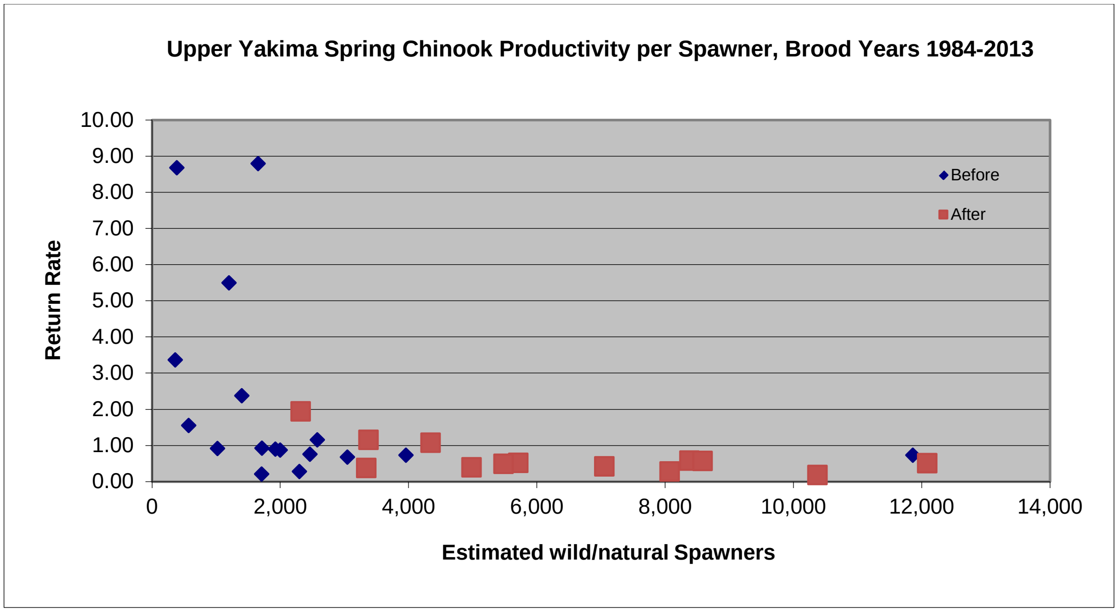


Figure 8. Upper Yakima wild/natural spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2013) commencement of supplementation.

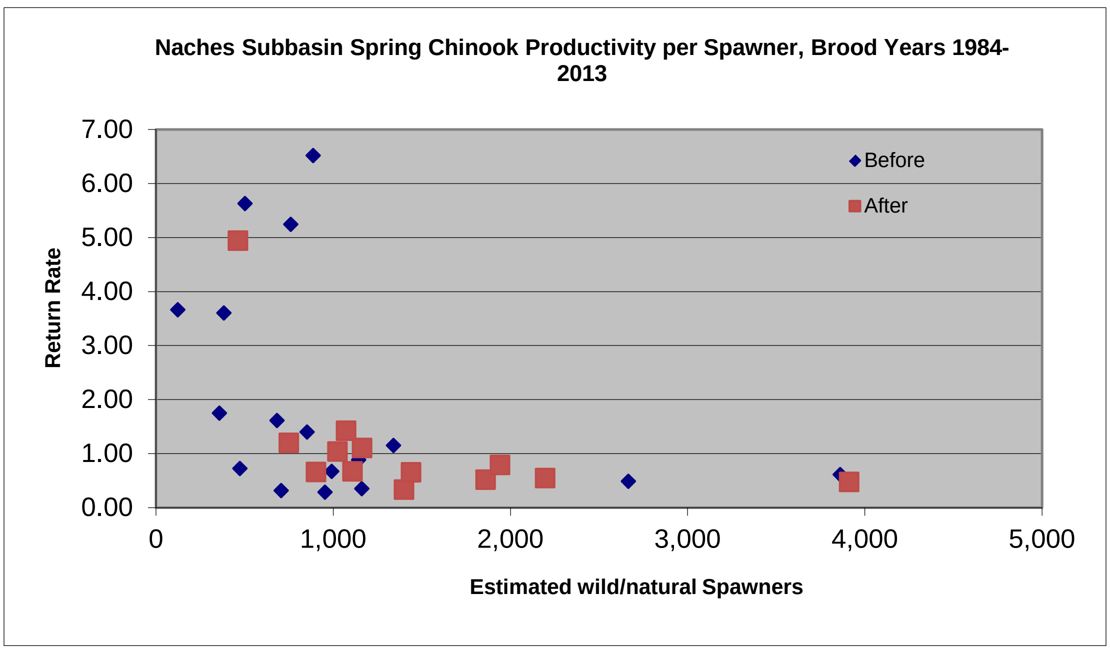


Figure 9. Naches subbasin spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2013) commencement of supplementation in the Upper Yakima River.

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	1,199	0.55
2005	1,439	167	653	116	0	936	0.65
2006	1,163	192	838	254	0	1,283	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	0	1,530	0.79
2012	1,110	64	419	260		743	0.67
2013	750	110	660	127		898	1.20
2014	746	142	397				
2015	1,285	26					
2016	790						
2017	971						
2018	500						
Mean	1,182	106	866	369	3	1,360	1.64

1. The mean jack proportion of spawning escapement from 1999-2018 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				Returns/ Spawner
		Age-3	Age-4	Age-5	Total	
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	10	1,723	4.61
2013	398	802	1,993	0	2,795	7.02
2014	384	1,008	1,451		2,458	6.40
2015	442	315				
2016	376					
2017	382					
2018	294					
Mean	451	968	3,245	98	4,341	7.56[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
2017	1162	15	1.07	1.07
2018	88	38	0.34	0.24
Mean	820	97	0.85	0.88

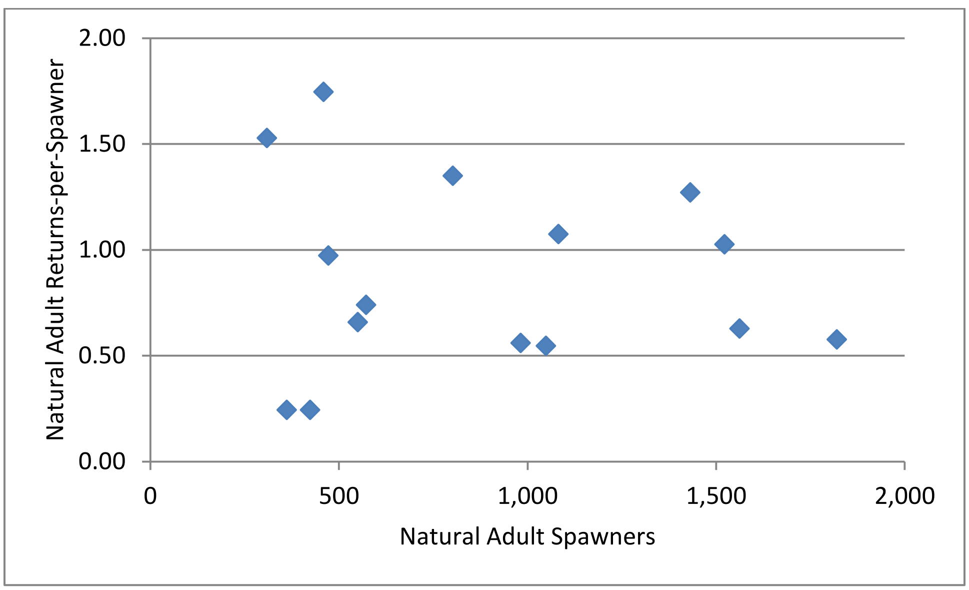


Figure 10. Productivity indices for age-3 natural-origin coho, brood years 2001-2015.

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 monitoringresources.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 detection efficiencies as described in Appendix C. These methods were generally consistent with monitoringresources.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
2016	339,816	329,392	230,490	218,676	220,042	669,208
2017	351,656	359,013	244,236	233,449	232,984	710,669
Mean	362,359	359,098	242,874	238,773	248,064	717,899

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 brood year, life stage, and brood source.

Brood	Smolts			Parr		Local Brood		Non-Loc	Total
Year	UppYak	Naches	Prosser	UppYak	Naches	Smolts	Parr	Smolts	Smolts
1997	436,000	1,257,000							1,693,000
1998	502,155	502,239							1,004,394
1999	498,872	429,318							928,190
2000	187,659	379,904							567,563
2001	263,288	357,530							620,818
2002	403,000	407,002							810,002
2003	313,207	291,494							604,701
2004	322,417	332,455							654,872
2005	338,127	554,784	50,000						942,911
2006	426,632	516,753	81,114						1,024,499
2007	358,412	440,783	219,098						1,018,293
2008	304,638	269,936	182,719	12,000	25,000	324,598	37,000	432,695	757,293
2009	407,184	341,414	245,455	13,000	12,000	610,423	25,000	383,630	994,053
2010	443,030	131,972	190,836	15,000	15,000	522,027	30,000	243,811	765,838
2011	311,102	359,067	322,100	365,035	73,572	992,269	438,607		992,269
2012	339,034	305,197	221,567	10,555	29,565	446,295	40,120	419,503	865,798
2013	353,139	373,072	367,382	9,000	18,232	524,967	27,232	568,626	1,093,593
2014	408,112	298,619	267,830	93,525	92,023	974,561	185,548		974,561
2015	141,000	141,000	204,358			204,358		282,000	486,358
2016	407,196	369,521	205,967			205,967		776,717	982,684
2017	438,331	267,211	470,000	114,141	138,624	641,589	252,765	533,953	1,175,542
Mean[1]	355,277	285,701	267,821	63,226	40,402	544,705	103,627	364,094	908,799

[1] 2008-2017 average.

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
2017	1,789,400		423,920	159,470				2,213,320
2018	1,638,300		328,620	208,660				1,966,920

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		Stiles Pond		Nelson			Total
Year	Prosser	Subyrl	Yrlng	Springs	Wapatox	Roza	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
2017	169,499					75,000	244,499
2018					44,000	30,000	74,000

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 219,400 wild/natural spring Chinook, 329,700 CESRF-origin spring Chinook, 44,200 wild/natural-origin coho, and 260,400 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.

	Smolt	Spring Chinook		Coho	
Brood Year	Migr. Year	Wild/ Natural	Hatchery (CESRF)	Wild/ Natural	Hatchery
1998	2000	199,416	303,688	37,359	331,503
1999	2001	148,460	281,256	40,605	134,574
2000	2002	467,359	366,950	19,859	155,814
2001	2003	308,959	154,329	9,092	139,135
2002	2004	169,397	290,950	18,787	148,810
2003	2005	134,859	236,443	31,631	204,728
2004	2006	133,238	300,508	8,298	204,602
2005	2007	99,341	351,359	18,772	260,455
2006	2008	120,013	265,485	40,170	416,708
2007	2009	237,228	415,923	23,858	496,594
2008	2010	220,950	382,878	33,408	341,145
2009	2011	304,322	442,564	22,908	333,891
2010	2012	258,106	391,446	17,667	244,503
2011	2013	365,486	372,079	56,947	483,122
2012	2014	263,266	408,222	159,642	337,988
2013	2015	125,150	332,715	20,757	134,084
2014	2016	185,442	403,938	227,163	233,374
2015	2017	208,929	273,248	8,011	85,458
2016	2018	218,880	290,644		
	Mean	219,411	329,717	44,163	260,360

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 (monitoringresources.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 monitoringresources.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 19 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.

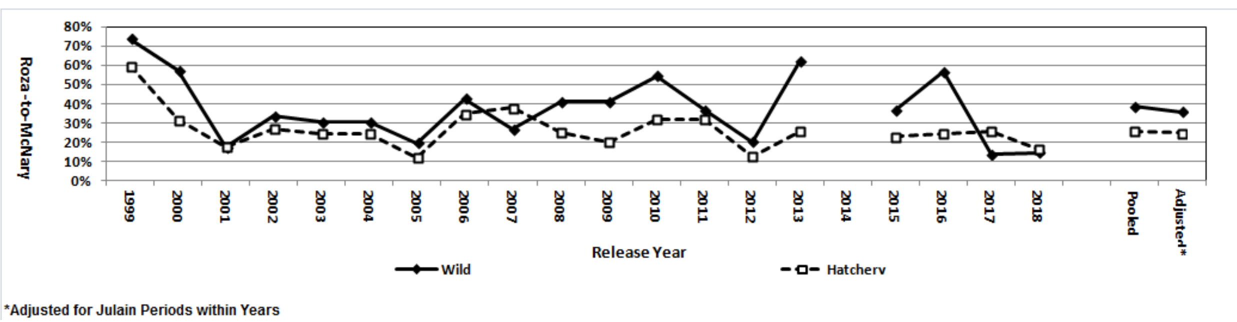


Figure 11. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for late-migrating (>March 15) Natural- (solid lines and filled diamonds) and Hatchery-origin (dashed lines and clear diamonds) Smolts adjusted for release period effects. No releases occurred in 2014 because of another study conducted 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 2018. Summer-run Chinook subyearlings were released from various sites in outmigration-years 2009 through 2018. Estimates and discussion of release-to-McNary survival for these releases are presented in Appendix G. Data for subyearling fall-run Chinook suggest that smolt survival was reduced in the most recent four years compared to 2008-2014 (Figure 12).

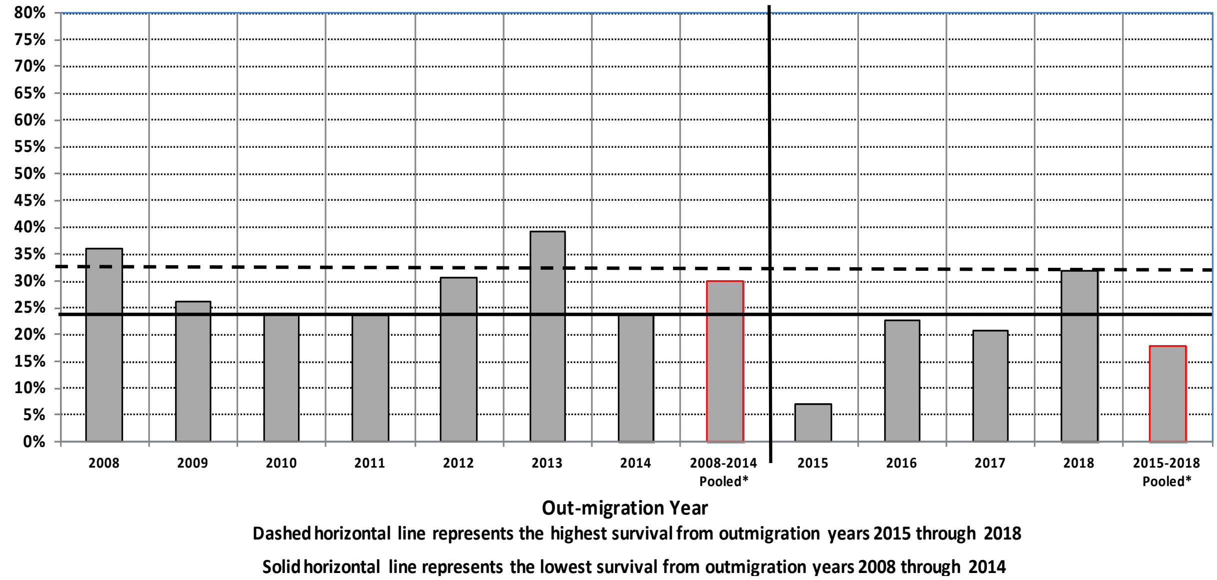


Figure 12. Pooled Prosser-to-McNary Survival for Yakima Stock Subyearling Fall Chinook Releases made in 2008 through 2018.

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 2016-18 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.

We also queried the PTAGIS database for PIT-tagged summer- and fall-run Chinook and Coho that were released in the Yakima Subbasin in recent years and produced McNary Dam juvenile (smolt) to Bonneville Dam adult SAR indices using juvenile detections at or downstream of McNary and adult detections at or upstream of Bonneville Dams.

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.

Brood Year	Smolt Migr. Year	Mean Flow[1] at Prosser Dam	Estimated Smolt Passage at Chandler: Wild/ Natural[2]	Estimated Smolt Passage at Chandler: CESRF Total	CESRF smolt-to-smolt survival[3]	Yakima R. Mouth Adult Returns[4]: Wild/ Natural[2]	Yakima R. Mouth Adult Returns[4]: CESRF Total	Smolt-to-Adult Return Index[4]: Wild/ Natural[2]	Smolt-to-Adult Return Index[4]: 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	205,065	53.1%	12,855	8,670	2.0%	4.2%
1998	2000[5]	4946	159,950	243,585	41.3%	8,240	9,782	5.2%	4.0%
1999	2001	1321	175,917	333,273	43.9%	1,764	864	1.0%	0.3%
2000	2002	5015	532,726	418,273	50.1%	11,434	4,819	2.1%	1.2%
2001	2003	3504	326,666	163,174	44.1%	8,597	1,251	2.6%	0.8%
2002	2004	2439	162,673	279,400	33.4%	3,743	2,557	2.3%	0.9%
2003	2005	1285	172,267	302,028	36.6%	2,746	1,020	1.6%	0.3%
2004	2006	5652	203,250	458,415	58.4%	2,802	4,482	1.4%	1.0%
2005	2007	4551	112,504	397,912	46.3%	4,295	5,004	3.8%	1.3%
2006	2008	4298	137,784	304,797	47.4%	6,004	10,577	4.4%	3.5%
2007	2009	5784	278,780	488,774	63.4%	7,952	7,604	2.9%	1.6%
2008	2010	3592	215,683	373,751	44.0%	7,385	8,036	3.4%	2.2%
2009	2011	9414	326,180	474,352	56.9%	3,766	3,606	1.2%	0.8%
2010	2012	8556	429,896	651,983	82.0%	6,602	5,592	1.5%	0.9%
2011	2013	4875	357,347	363,793	47.3%	7,343	4,160	2.1%	1.1%
2012	2014	4923	268,598	416,489	51.9%	3,969	1,932	1.5%	0.5%
2013	2015	1555	120,786	321,114	49.7%	3,368	3,139	2.8%	1.0%
2014	2016	5765	185,442	403,938	58.9%	1,787[6]	2,855[6]	1.0%[6]	0.7%[6]
2015	2017[6]	7804	301,022	393,691	60.1%				
2016	2018[6]	5652	86,478	140,255	21.0%				

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 1988-2018.

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%
2017	2,348,973	1,613	0.07%
2018	2,527,520	546	0.02%
Mean	1,968,415	2,775	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 Prosser-to-Prosser smolt-to-adult survival (SAR) indices for adult returns from hatchery- and natural-origin coho for the Yakima reintroduction program, juvenile migration years 2000-2017.

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%
2016	233,374	1,889	0.8%	227,163	1,162	0.5%
2017	85,458	831	1.0%	8,011	88	1.1%
Mean	260,360	3,970	1.3%	44,163	820	3.0% [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.

Table 13. Preliminary McNary Dam smolt to Bonneville Dam adult SAR-indices for hatchery-origin PIT-tagged summer and fall-run chinook released in the Yakima subbasin by brood year and life stage at release, 2006-2015 (PTAGIS query run May 6, 2019).

Brood	Subyearlings		Yearlings	
Year	Summer	Fall	Summer	Fall
2006		0.0%		8.5%
2007		2.3%		1.2%
2008	2.1%	0.5%		3.0%
2009	2.0%	1.1%		0.7%
2010	3.8%	0.0%	1.9%	1.6%
2011	1.7%	1.2%		1.6%
2012	1.3%	0.9%		
2013	1.1%	0.4%		
2014	0.0%	0.0%		
2015	0.2%	0.4%		
Pooled Mean	1.8%	1.1%	1.9%	1.7%

Table 14. Preliminary McNary Dam smolt to Bonneville Dam age-3 adult return (SAR) indices for hatchery-origin PIT-tagged coho released as smolt (sm) or parr[a] in Lower Yakima (LY), Naches (Na), and Upper Yakima (UY) mainstem or tributary areas, brood years 2003-2014 (PTAGIS queries run April 16, 2019).

	LY_sm	Na_sm	UY_sm	Na_parr	UY_parr
2003	3.78%	6.14%	2.92%		
2004	2.28%	3.16%	3.67%	1.09%	
2005	3.11%	3.31%	2.36%	1.41%	1.96%
2006	9.76%	6.81%	4.17%	5.52%	7.84%
2007	8.16%	2.84%	4.35%	0.52%	3.16%
2008	4.10%	7.59%	8.80%	5.84%	8.30%
2009	0.20%	1.89%	3.37%	1.99%	3.20%
2010	1.67%	1.80%	1.76%	0.98%	3.23%
2011	6.57%	7.15%	11.64%	6.11%	10.49%
2012	1.15%	1.48%	2.58%	1.01%	2.59%
2013	3.35%	2.33%	4.91%		3.03%
2014	0.66%	3.01%	3.05%	3.73%	6.74%
Average	3.73%	3.96%	4.46%	2.82%	5.05%
Geomean	2.46%	3.40%	3.85%	2.03%	4.33%

[a] PIT-tagged fish released as parr in brood year 2003, 2004 (Upp. Yak.), and 2013 (Naches) experienced very poor (<1%) survival to McNary Dam as juvenile smolts and were omitted from this analysis.

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 10-14 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 (monitoringresources.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:

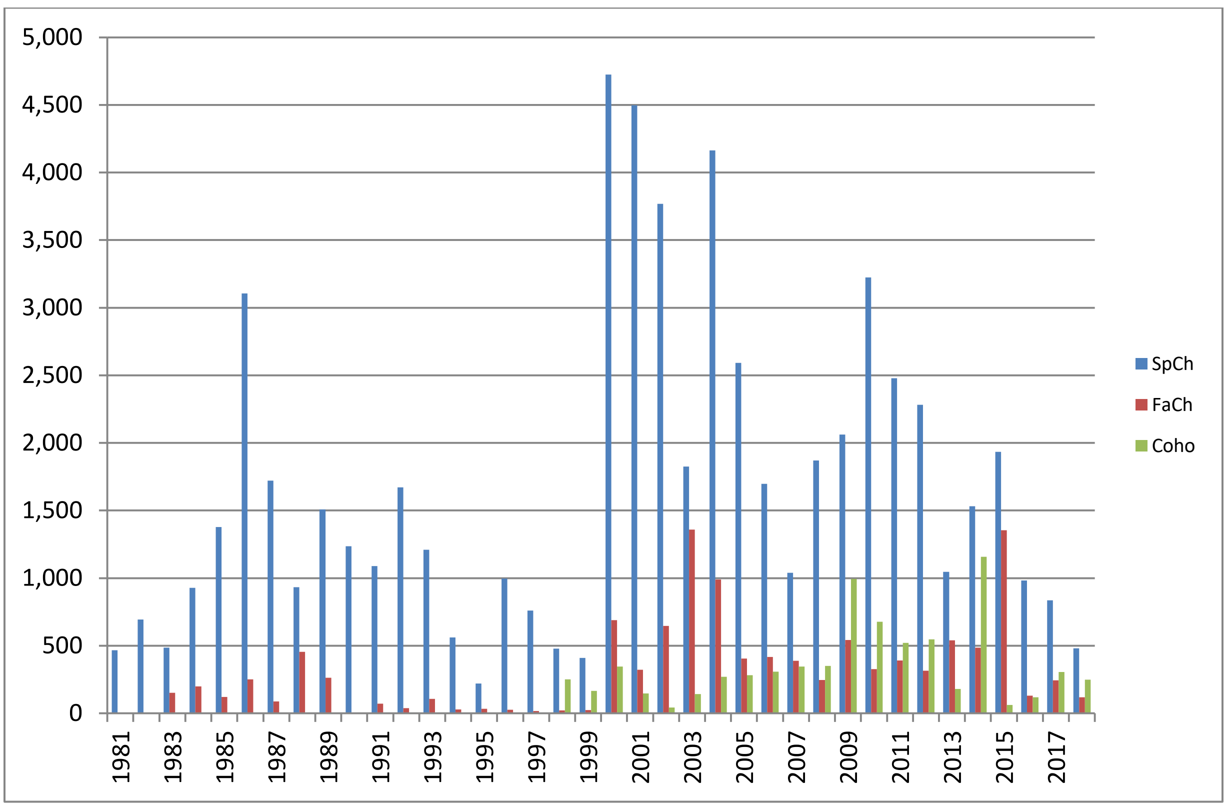


Figure 13. Redd Counts upstream of Prosser Dam in the Yakima River Basin by species, 1981-present.

Table 15. 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
2017	402	118	23	543	123	84	56	30	293
2018	339	13	0	352	27	56	44	1	128
Mean	1,022	123	27	1,171	160	165	112	47	484

[1] Including minor tributaries.

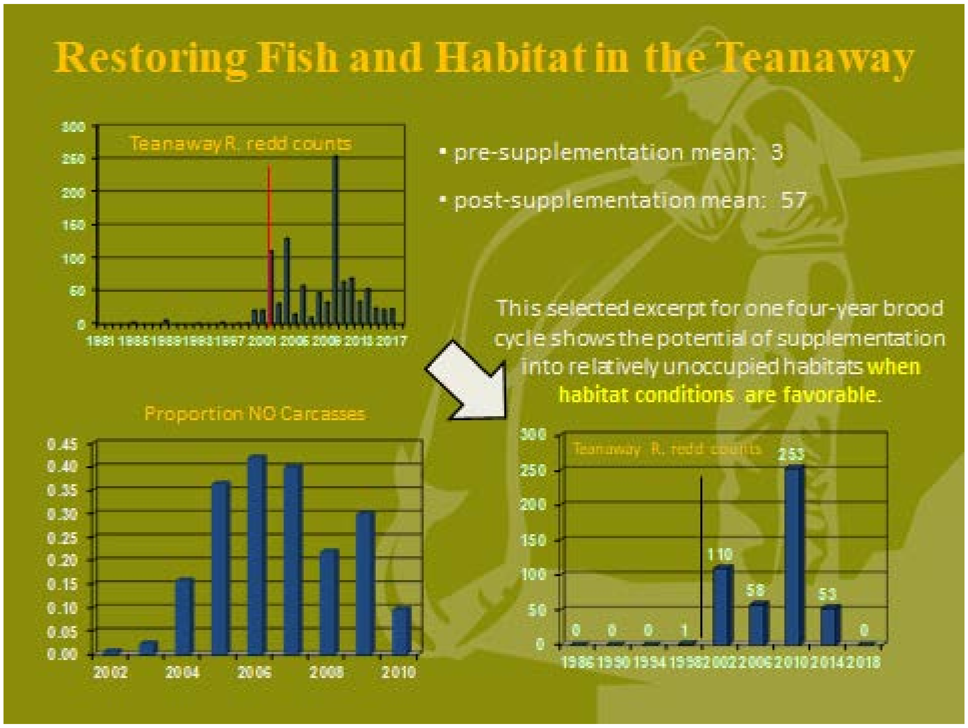


Figure 14. Teanaway River Spring Chinook redd counts, 1981-2018 (vertical lines denote pre- and post-supplementation periods) and the proportion of natural-origin (NO) carcasses observed in intensive spawning ground surveys, 2002-2010.

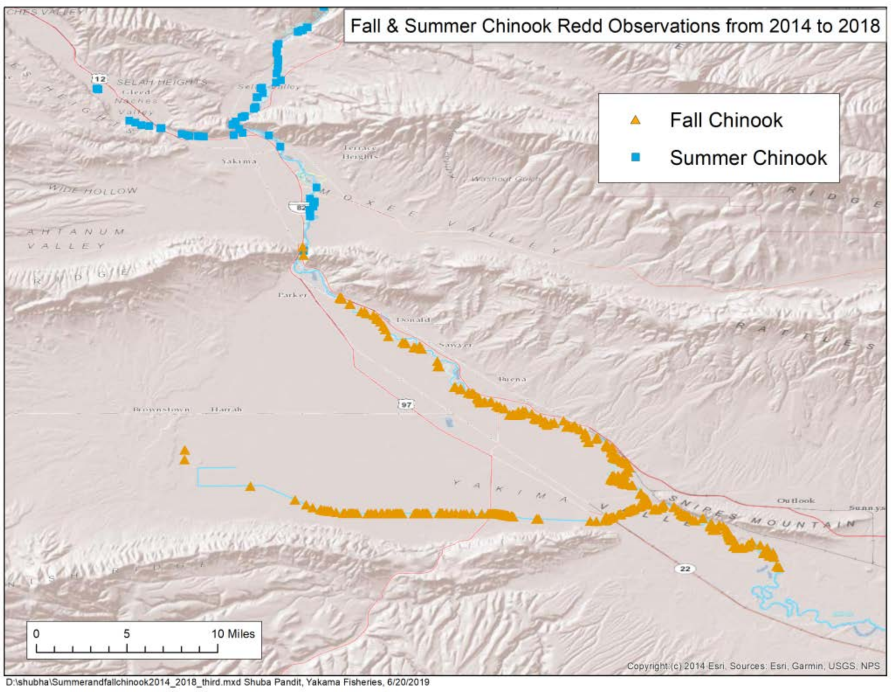


Figure 15. Distribution of summer and fall run Chinook redds in the Yakima River Basin (above Prosser Dam) 2014-2018.

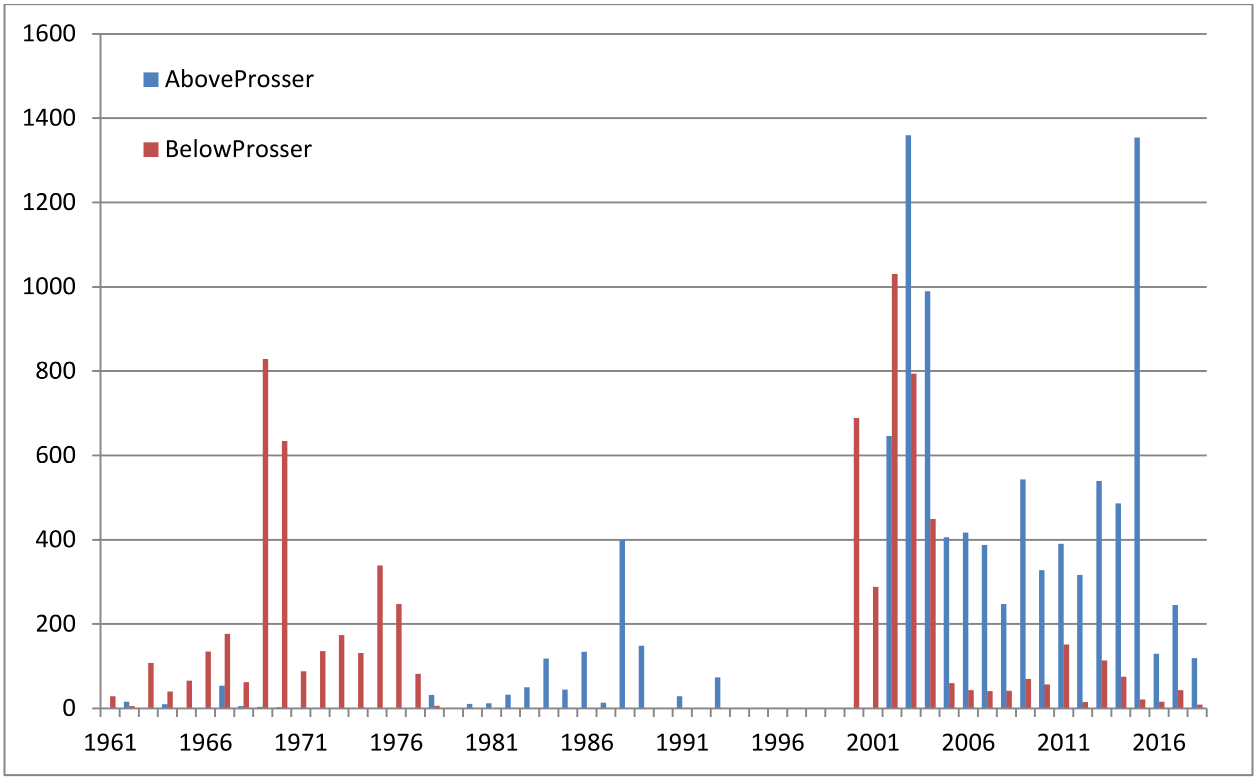


Figure 16. Fall Chinook redd counts above and below Prosser Dam, 1961-present, for years in which surveys were conducted and data are available. Data from YN, WDFW, and Pacific Northwest National Laboratory files. Note that survey completeness is highly variable due to annual flow and turbidity conditions; survey data are partial or incomplete for most years prior to 2000.

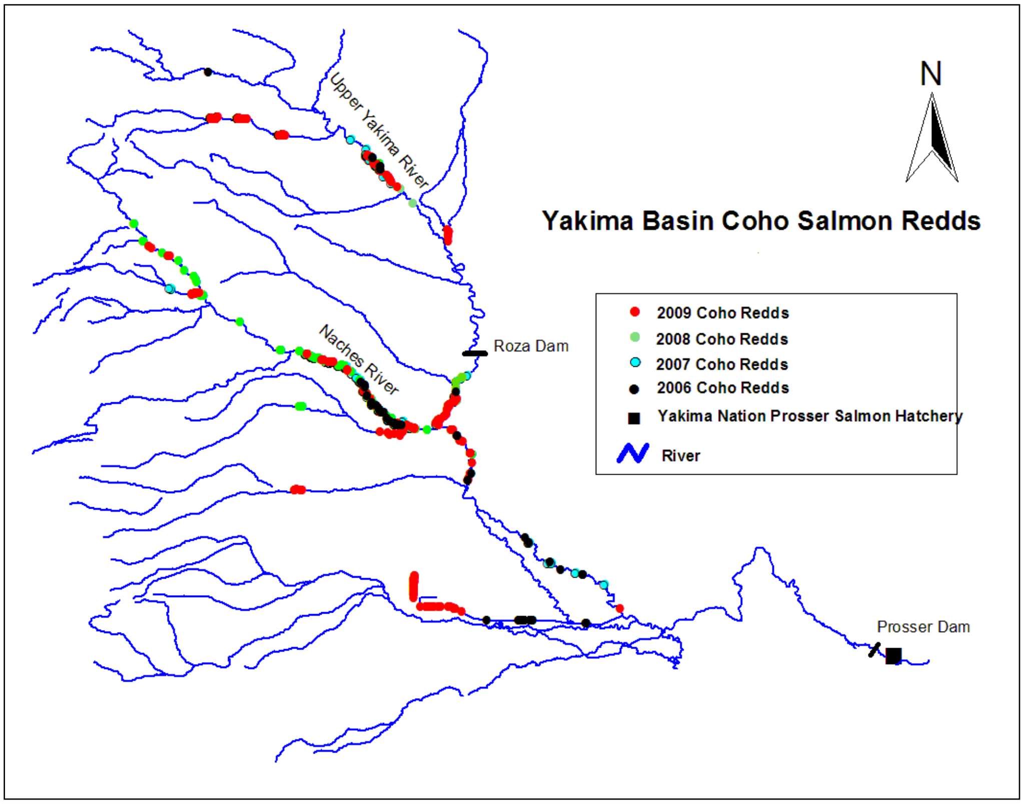


Figure 17. Distribution of coho redds in the Yakima River Basin.

Table 16. 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	16	0	47	63
2016	27	37	54	118
2017	92	36	177	305
2018	46	103	100	249

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 14). 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 57 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, including 2018, 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 16). 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 15; Yakama Nation 2012). Summer-run Chinook have now spawned naturally in these habitats since 2013 after an absence of over 40 years.

Coho redd counts and spawner distribution have increased substantially since reintroduction efforts began (Table 16 and Figure 17). 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 16). 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 2018 redd count was again below the recent average at 100 (Table 16). However, Coho continue to volunteer into many tributaries, and the fidelity of adults from summer parr plants has shown good results.

Adult Coho plants have also been used to evaluate the feasibility of increasing fish abundance in several tributaries. To determine the spawning success and effects on resident trout of these adult outplants, an intensive monitoring program was conducted in Taneum Creek for brood/spawn years 2007-2014. The results of this evaluation indicate that Coho spawned successfully and have the potential to produce large numbers of returning adult offspring per smolt that survive to McNary Dam as juveniles (Table 17). The total biomass of all salmonids in the stream increased and there were no discernable impacts to resident trout (Temple et al. 2012).

Table 17. Results from Taneum Creek adult out-plant study.

Year	Number of Adult Females Outplanted	Redds	Number of Juvenile coho PIT Tagged	McNary Juvenile PIT Detections	McNary Juvenile & Adult PIT Detections	McNary Juvenile-Adult SAR
2007	150	75	1,299	94		
2008	150	50	1,868	82	7	8.5%
2009	150	130	4,515	177	4	2.3%
2010	150	134	1,054	73	3	4.1%
2011	150	100	743	30	4	13.3%
2012	60	54	1,941	70		
2013	9	5	231	0		
2014	360	200	752	12		
Pooled			12,403	538	18	3.3%

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 (monitoringresources.org methods 454, 1454, 1548, 1549, 1551, 4008, 4041). We also queried the PTAGIS database for PIT-tagged summer- and fall-run Chinook that were released in the Yakima Subbasin in recent years and used PIT-detection data at Bonneville Dam for upstream migrants to estimate age composition and run timing of returning fish.

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 18-21. Age composition of summer- and fall-run Chinook are presented in Table 22 and run timing in Figure 18. 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 renaturalization can be detected in just a few generations after outplanting of hatchery-origin fish in the wild.

Table 18. 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
2017	122	67	66	64.9%	47.8%	09/13/17	12/05/17
2018	78	23	114	40.6%	36.3%	09/12/18	11/05/18
			Mean	51.0%	44.7%		

Table 19. 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
2017	122	74.6	58.8	10.8	66	73.9	57.1	10.4
2018	78	72.3	54.4	9.6	114	67.2	48.9	7.5
Mean		76.1	60.7	12.1		72.6	56.5	10.4

Table 20. 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
2017	694	132	752	48.0%	44.0%	09/13/17	12/19/17
2018	343	318	308	52.7%	35.4%	09/06/18	11/05/18
			Mean	53.5%	46.9%		

Table 21. 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
2017	694	64.5	49.6	6.4	752	63.6	47.8	5.9
2018	343	66.6	51.0	6.8	308	66.0	49.2	6.4
Mean		67.0	53.2	7.6		66.5	51.1	7.0

Table 22. Age composition of returning hatchery-origin PIT-tagged summer and fall-run chinook released in the Yakima subbasin as subyearling or yearling fish (data from PTAGIS query run May 1, 2019).

Brood Year	Age at Return 2	3	4	5	6
Summer Chinook Subyearlings					
2008	12.5%	12.5%	50.0%	25.0%	0.0%
2009	5.4%	16.3%	63.6%	14.7%	0.0%
2010	0.2%	27.5%	61.4%	10.6%	0.2%
2011	0.0%	12.1%	67.5%	20.4%	0.0%
2012	1.0%	50.0%	40.8%	8.2%	0.0%
2013	5.6%	11.1%	77.8%	5.6%	0.0%
Mean	4.1%	21.6%	60.2%	14.1%	0.0%
Fall Chinook Subyearlings					
2007	9.7%	47.9%	35.8%	6.6%	
2008	13.3%	53.3%	33.3%	0.0%	
2009	18.9%	40.5%	32.4%	8.1%	
2010	0.0%	66.7%	16.7%	16.7%	
2011	11.6%	34.9%	50.0%	3.5%	
2012	9.7%	61.1%	26.4%	2.8%	
Mean	10.6%	50.7%	32.4%	6.3%	
Summer Chinook Yearlings					
2010[1]	13.6%	31.2%	44.2%	3.9%	0.6%
Fall Chinook Yearlings					
2006	96.4%	0.0%	3.6%	0.0%	0.0%
2007	63.2%	16.2%	8.8%	11.8%	0.0%
2008	30.9%	36.2%	27.1%	5.8%	0.0%
2009	20.4%	19.4%	40.8%	19.4%	0.0%
2010	39.4%	26.8%	27.8%	6.1%	0.0%
2011	6.4%	16.7%	57.1%	14.7%	5.1%
Mean	42.8%	19.2%	27.5%	9.6%	0.9%

[1] 10 of 154 (6.5%) of detections occurred about 90 days post-release in adult ladders at Bonneville Dam and were assumed to be age-1 returns. However, only 2 of these 10 were confirmed as upstream detections based on later detections at dams upstream of Bonneville. The other 8 detections at Bonneville could have been late-migrating juveniles.

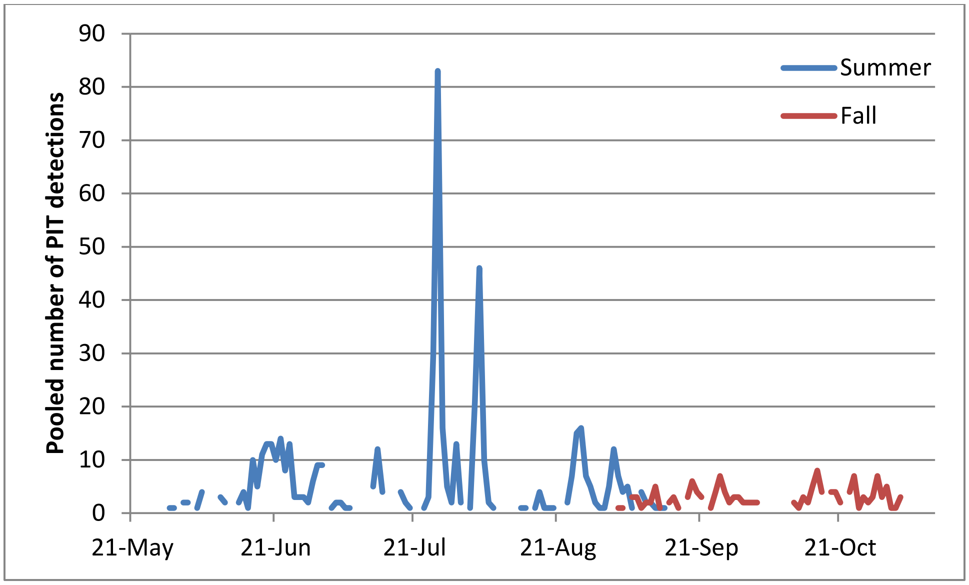


Figure 18. Adult return timing at Prosser Dam of PIT-tagged summer- and fall-run Chinook reared at the Marion Drain and Prosser Hatcheries and released as subyearlings, pooled for return years 2009-2018.

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 resources 1504) were collected from various reaches in the Little Naches and Upper Yakima Rivers in the fall of 2018. 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 96 McNiel core samples were collected and processed from 8 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 34 years for the two historical reaches, and 27 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 2018 was 11.1% which continued the increase observed since a low in 2015, but is still below the watershed average observed every year from 1992-2007 (Figure 19). 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.

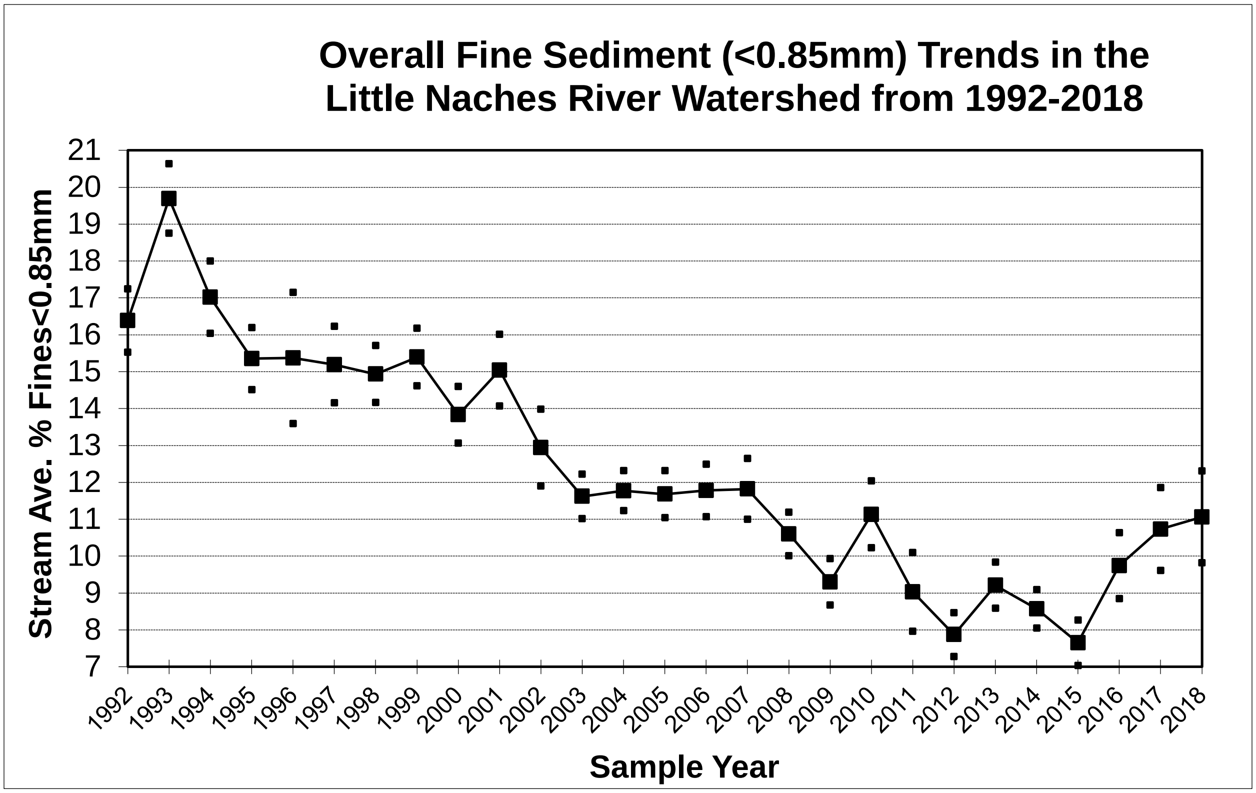


Figure 19. Overall Fine Sediment (<0.85mm) Trends with 95% confidence bounds in the Little Naches River Drainage, 1992-2018.

South Fork Tieton

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 has not been sampled since 2015. 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 20).

Upper Yakima

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 22 years. The 22-year trend in average percent fine sediment less than 0.85mm for the combined Upper Yakima drainage remains downward, although observed fine sediments the past three years have been at or above the average observed since 2009 (Figure 21).

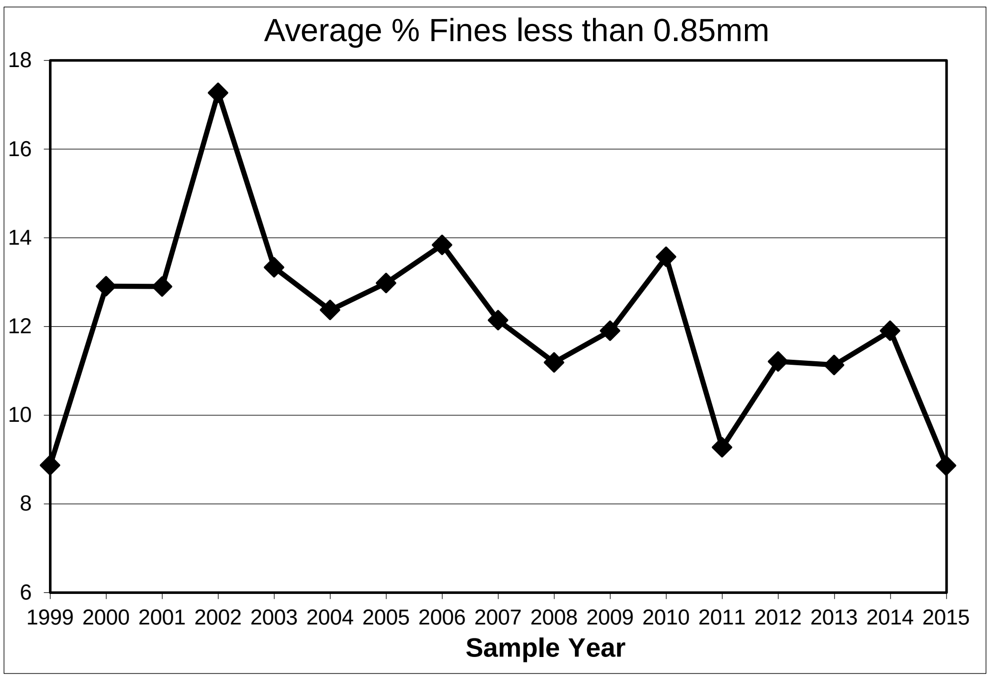


Figure 20. Fine Sediment Trends in the South Fork Tieton River, 1999-2015. Note: Data for 2007 were collected from only 1 Riffle. Data courtesy of U.S. Forest Service.

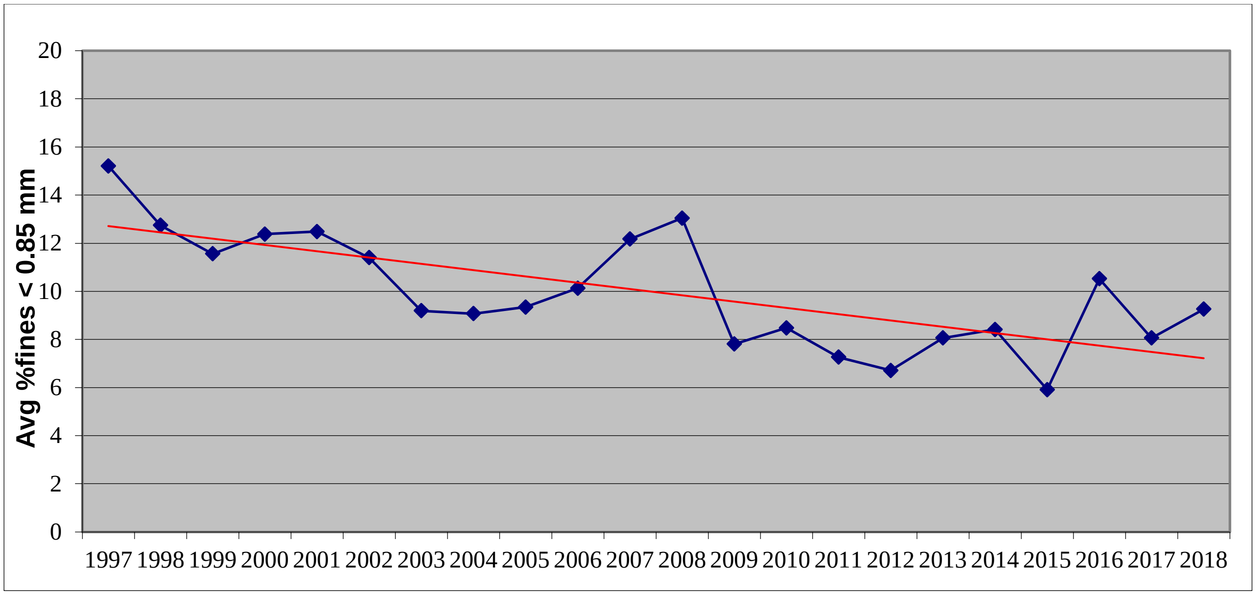


Figure 21. Overall average percent fine sediment (< 0.85 mm) in spawning gravels of the Upper Yakima River, 1997-2018.

<u>Summary</u>

We continue to observe a general decreasing trend in average fine sediment levels in the Little Naches and Upper Yakima drainages. The slight increases observed since 2016 in both drainages could mean that we are experiencing some effect from the large fires in recent years. Overall, the generally 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 Matthews, 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 23. Marine and freshwater recoveries of CWTs from brood year 1997-2013 releases of spring Chinook from the CESRF as reported to the Regional Mark Information System (RMIS) 06 Nov 2018.

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	942	0.9%
2011	5	186	2.6%	5	1019	0.5%
2012	4	73	5.2%	2	308	0.6%
2013[1]	9	50	15.3%	20	204	8.9%

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 2013 are considered preliminary or incomplete.

Table 24. 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	2,460	118	113	1,441	84	316	316	0	12.8%	12.8%
1984	3,911	135	290	2,658	289	714	714	0	18.3%	18.3%
1985	5,276	192	197	4,560	865	1,254	1,254	0	23.8%	23.8%
1986	13,624	282	858	9,439	1,340	2,479	2,479	0	18.2%	18.2%
1987	6,204	97	420	4,443	517	1,034	1,034	0	16.7%	16.7%
1988	5,718	366	442	4,246	444	1,252	1,252	0	21.9%	21.9%
1989	8,981	214	743	4,914	747	1,704	1,704	0	19.0%	19.0%
1990	6,990	354	514	4,372	663	1,531	1,531	0	21.9%	21.9%
1991	4,675	185	315	2,906	32	533	533	0	11.4%	11.4%
1992	6,233	103	405	4,599	345	853	853	0	13.7%	13.7%
1993	5,155	44	337	3,919	129	510	510	0	9.9%	9.9%
1994	2,265	88	126	1,302	25	239	239	0	10.6%	10.6%
1995	1,410	1	86	666	79	166	166	0	11.8%	11.8%
1996	5,909	6	320	3,179	475	801	801	0	13.6%	13.6%
1997	5,224	3	379	3,173	575	957	957	0	18.3%	18.3%
1998	2,889	3	165	1,903	188	356	356	0	12.3%	12.3%
1999	4,174	4	212	2,781	604	820	820	0	19.6%	19.6%
2000	28,825	58	1,824	19,101	2,458	4,340	4,214	126	15.1%	15.1%
2001	32,610	980	4,566	24,157	4,630	10,177	5,862	4,314	31.2%	29.3%
2002	25,751	1,300	3,333	15,828	3,108	7,740	2,946	4,794	30.1%	25.2%
2003	10,454	291	1,069	7,231	440	1,799	1,097	702	17.2%	16.1%
2004	24,644	1,041	2,716	16,847	1,679	5,436	3,166	2,269	22.1%	17.5%
2005	13,579	361	1,145	9,605	474	1,980	1,581	399	14.6%	13.7%
2006	12,457	318	1,191	6,600	600	2,108	1,230	878	16.9%	15.2%
2007	5,311	177	539	4,460	279	995	496	499	18.7%	16.4%
2008	13,269	1,273	2,479	9,311	1,532	5,284	1,629	3,655	39.8%	28.6%
2009	14,389	1,271	1,695	11,423	2,353	5,319	1,571	3,748	37.0%	27.1%
2010	19,676	1,728	3,755	13,782	1,741	7,224	1,897	5,327	36.7%	25.7%
2011	23,940	1,127	2,373	18,535	4,380	7,880	2,883	4,997	32.9%	24.3%
2012	17,622	871	1,914	12,626	3,320	6,105	2,518	3,587	34.6%	27.8%
2013	15,815	932	1,783	10,623	2,653	5,368	2,256	3,111	33.9%	27.3%
2014	16,985	703	1,927	11,857	2,171	4,801	1,936	2,865	28.3%	21.2%
2015	11,759	466	1,228	9,838	815	2,509	1,308	1,200	21.3%	16.3%
2016	10,372	465	1,273	7,290	444	2,182	1,146	1,036	21.0%	17.8%
2017	12,489	504	1,187	7,553	1,272	2,963	993	1,970	23.7%	15.3%
2018[1]	6,273	250	695	3,738	548	1,493	485	1,008	23.8%	17.3%
Mean	11,314	453	1,184	7,803	1,175	2,812	1,520	1,291	21.5%	18.6%

1. Preliminary.

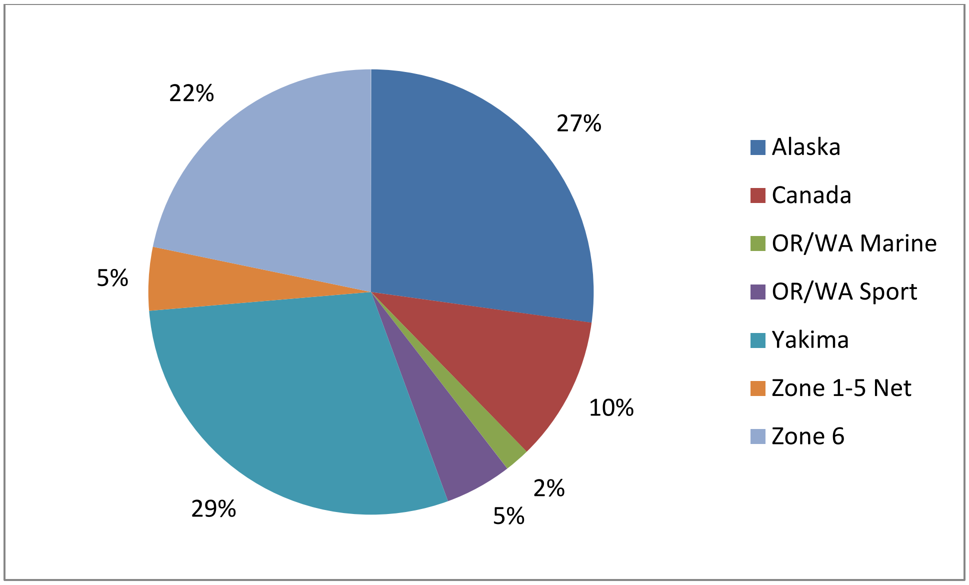


Figure 22. Distribution of coded-wire tag recoveries of Yakima Basin summer/fall run Chinook releases in marine, mainstem Columbia River, and Yakima Basin fisheries. Data retrieved from the regional mark information system (RMIS) for brood year 1997-2007 recoveries.

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 23). Adult returns of spring Chinook from the CESRF appear to be making substantial contributions to Columbia Basin fisheries (Table 24).

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 22). 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 monitoringresources.org methods 404 and 960.

Results:

Table 25. 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[2]	506	309	815	8.7%
2016	103	185	132	24[2]	235	209	444	6.4%
2017	217	201	750	104[2]	967	305	1,272	17.8%
2018	154	115	259	20[2]	413	136	548	15.2%
Mean	519	641	558	84	1,077	630	1,155	13.6%

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 26. Estimated fall Chinook return, escapement, and harvest in the Yakima River, 1998-2018. 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	271	2,862	85	2,231	140	732	46	12.8%
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	5,553	1,468	3,751	963	1098	211	704	294	14.2%
2013	13,005	1,541	8,537	995	1936	194	2,532	352	19.8%
2014	12,839	1,371	8,302	1,003	2,969	302	1,568	66	11.5%
2015	15,533	769	8,644	559	5,224	156	1,665	54	10.5%
2016	7,982	735	5,688	585	1,372	119	922	31	10.9%
2017	3,116	399	1,927	278	719	105	470	16	13.8%
2018	1,539	124	937	53	397	46	205	25	13.8%

Table 27. Estimated Coho return, escapement, and harvest in the Yakima River, 1999-2018. 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%
2017	3,920	274	3,051	222	804	34	65	18	2.0%
2018	2,218	835	1,672	440	518	365	28	30	1.9%

Discussion:

Adult returns of spring Chinook from the CESRF have substantially increased fishing opportunity for all fishers in the Yakima Basin (Table 25) 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 26). Tribal fishers harvest a substantial, but unquantified number of Yakima Basin-destined fall Chinook (Figure 22) 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:

> 1.2. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?
>
> 1.4. 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?
>
> 1.5. 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, 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 23) 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 23). 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).

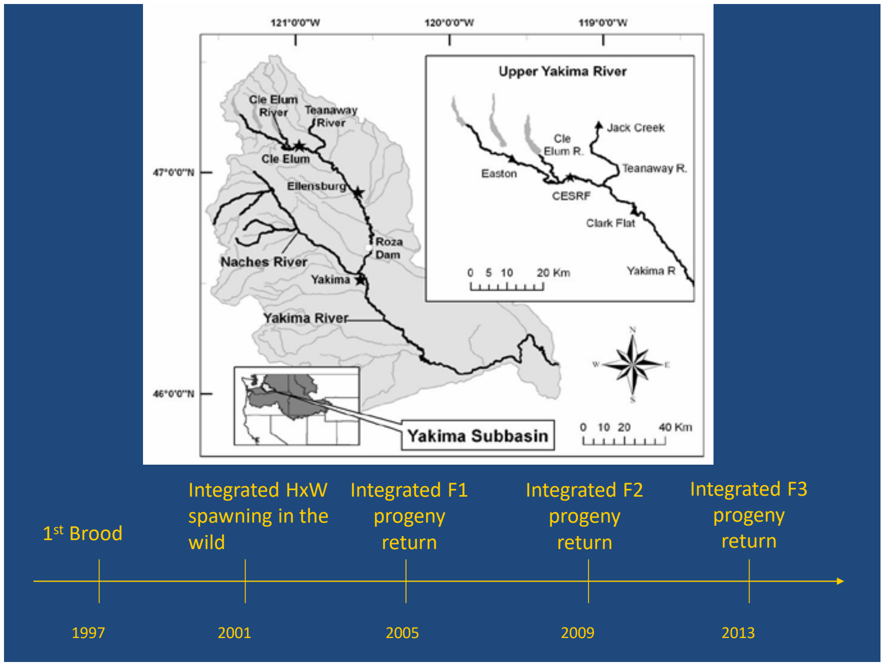


Figure 23. Map of the Yakima River Basin, Cle Elum Supplementation and Research Facility (CESRF) locations, and timeline of the spring Chinook supplementation program.

Results:

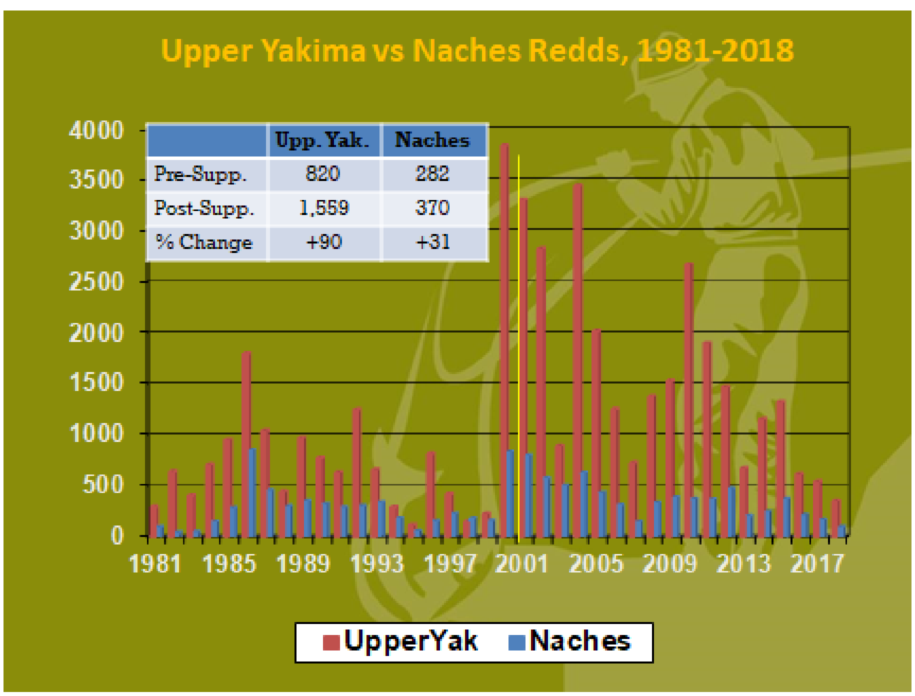


Figure 24. Spring Chinook redd counts in the supplemented Upper Yakima (red bar) relative to the un-supplemented Naches (control; blue bar) for the pre- (1981-2000) and post-supplementation (2001-2018) periods.

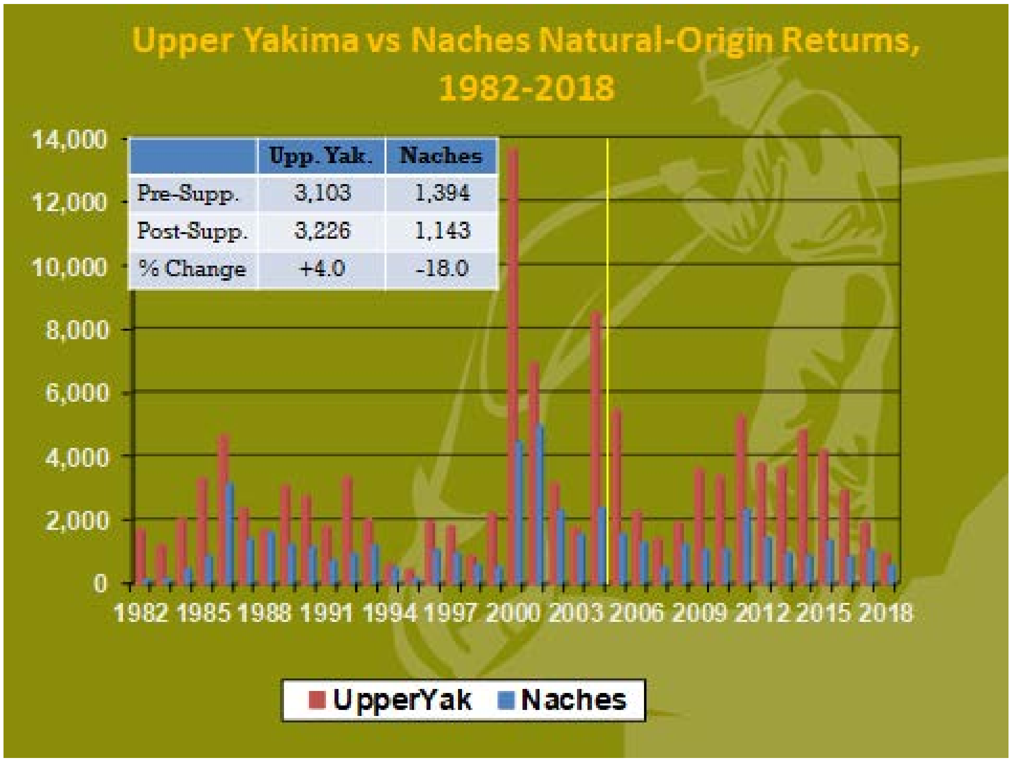


Figure 25. Natural-Origin returns of Spring Chinook in the supplemented Upper Yakima (blue bar) relative to the un-supplemented Naches (control; yellow bar) for the pre- (1982-2004) and post-supplementation (2005-2018) periods.

Discussion:

Supplementation has increased spring Chinook redd abundance in the Upper Yakima relative to the Naches control system (Figure 24). Redd counts in the post-supplementation period (2001-2018) increased in the supplemented Upper Yakima (+90%; P=0.014) but the change observed in the un-supplemented Naches control system relative to the pre-supplementation period (1981-2000) was not significant (+31%; P=0.191). 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 14) in some years.

Changes in mean natural-origin return abundance in the post-supplementation period (2005-2018) relative to the pre-supplementation period (1982-2004) were not significant in either the supplemented upper Yakima River (+4.0%; P=0.89; Figure 25) or the unsupplemented Naches River system (-18.0%; P=0.49; Figure 25). 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 relatively 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/P159280 for the latest progress report on this project). We expect to complete genotyping for this work this year 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 coho returns averaged over 5,400 fish from 1997-2018 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging over 900 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). To the extent that is practical, 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 26). 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).

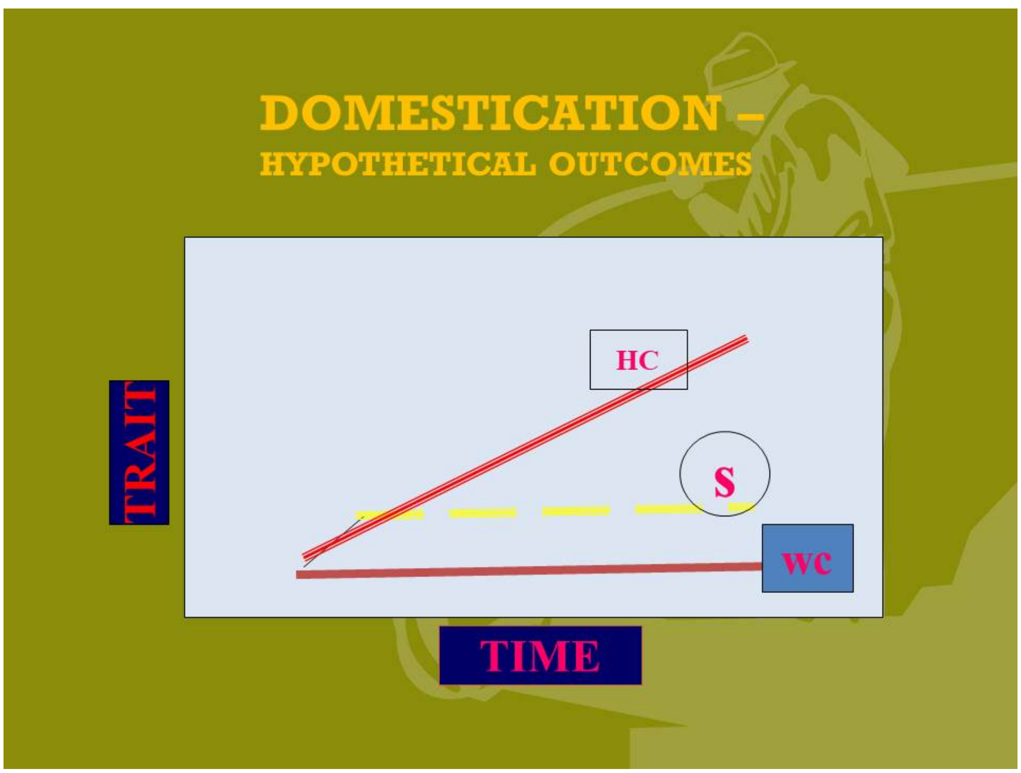


Figure 26. Hypothetical outcomes of trait divergence (domestication effects) over time for a segregated (hatchery-control or HC) line of fish, compared to an integrated (supplementation or S) line of fish and a wild (wild-control or WC) line of fish (D. Fast, Yakama Nation).

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. 2008). The equation describing PNI is

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

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 2001-2018, PNI averaged 65% while pHOS averaged 54.4% (Table 28). 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 28. 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%
2017	1,135	194	1,329	1,328	660	1,988	2,463	854	3,317	59.9%	62.5%
2018	500	33	533	1,033	233	1,266	1,533	266	1,799	70.4%	58.7%
Mean[3]	2,495	351	2,846	2,380	721	3,101	4,735	1,094	5,829	54.4%	65.4%

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 26 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 27). The actual results are remarkably consistent with the projected outcomes in Figure 25 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 26), 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).

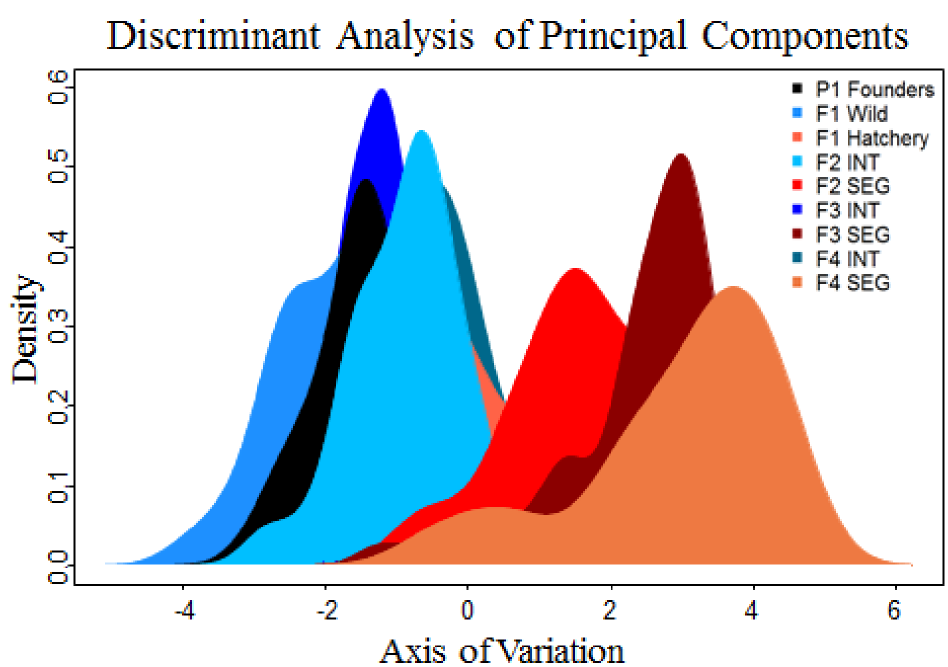


Figure 27. Estimated genetic divergence (variation) for integrated (INT blue), segregated (SEG red), and wild founder (black) spring Chinook in the CESRF program after 4 parental-generations of the hatchery program (P1=1998, F1=2002, F2=2006, F3=2010, F4=2014; updated from Figure 4 in Waters et al. 2015).

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 survey accounts for coverage of approximately 100 miles of the lower portion of the Yakima River.

Table 29. Avian predation river reach survey start and end locations and total reach length.

Survey Name	*River Mile Start*	*River Mile End*	*Survey Distance*
Parker	107.0	93.8	13.2
Granger-Emerald	85.3	66.5	18.8
Mabton- Prosser	60.6	48.5	12.1
Below Prosser	46.4	36.6	9.7
Chandler Power Plant -Benton	36.6	30.2	6.5
Below Horn Rapids-Van Giesen	16.8	9.4	7.4

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.

Table 30. Yakima River Avian Predators.

Common Name	*Scientific Name*	Acronym
Common Merganser	*Mergus merganser*	COME
American White Pelican	*Pelecanus erythrorhynchos*	AWPE
California Gull	*Larus californicus*	GULL
Ring-billed Gull	*Larus delawarensis*	GULL
Belted Kingfisher	*Ceryle alcyon*	BEKI
Great Blue Heron	*Ardea herodias*	GBHE
Double-crested Cormorant	*Phalacrocorax auritus*	DCCO
Black-crowned Night-Heron	*Nycticorax nycticorax*	BCHE
Forster's Tern	*Sterna forsteri*	FOTE
Great Egret	*Ardea alba*	GREG
Hooded Merganser	*Lophodytes cucullatus*	HOME
Bald Eagle	*Haliaeetus leucocephalus*	BAEA
Osprey	*Pandion haliaetus*	OSPR
Caspian Tern	*Sterna caspia*	CATE

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.

Avian Predator Hotspot Surveys

Two "hotspots" of avian predators have been identified within the Lower Yakima River (Figure 28). These "hotspots" consist of an area below the Chandler fish bypass outfall pipe and below Wanawish Dam. To include data about these hotspots weekly bird counts will be conducted at each of these "hotspots" by YN personnel and BOR personnel. Data will be single day counts of piscivorous birds during the early morning.

Acclimation Site Surveys

Three Spring Chinook acclimation sites in upper Yakima River (Clark Flat, Jack Creek, and Easton) were surveyed for piscivorous birds from 2004 through 2018 (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. 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.

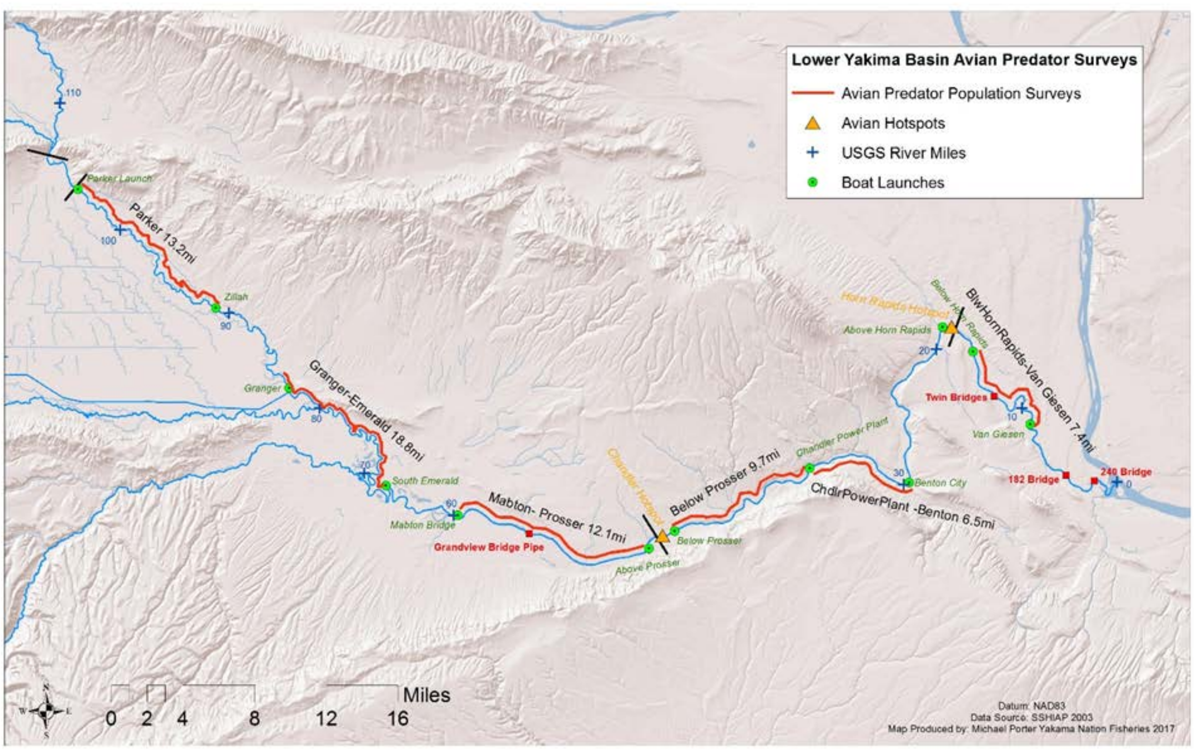


Figure 28. Avian Predator Survey Locations.

Results and Discussion:

River Reach Surveys

Twelve 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, Great Egret, Great Blue Heron, Gull species (California and Ringbill), Hooded Merganser, and Osprey. These same 12 species were observed in most survey years. Graph Data (Figure 29) for river reach surveys represents Avian Predator totals by reach of the lower Yakima River (surveys below Wapato Dam). The total avian predators in the Parker Reach by week are represented in (Figure 30) and numbers increased as river flows decreased. The avian predator counts within the Parker, Granger, Below Prosser, Benton, and Lower Yakima reaches are represented in the bar graphs by their survey acronyms (Figures 31-35).

The American White Pelican, Osprey, Great Blue Heron, Common Merganser, Double Crested Cormorant, and Belted Kingfisher were observed within all six reaches. Common Mergansers and American White Pelicans were most abundant Avian Predators in the upper surveyed reaches of the river. The American White Pelicans numbers were greatest in the Parker and Granger Reaches of the Yakima River (Figures 31 and 32). American White Pelican numbers remained consistently high throughout the study period with an increase in abundance with decreasing river stage.

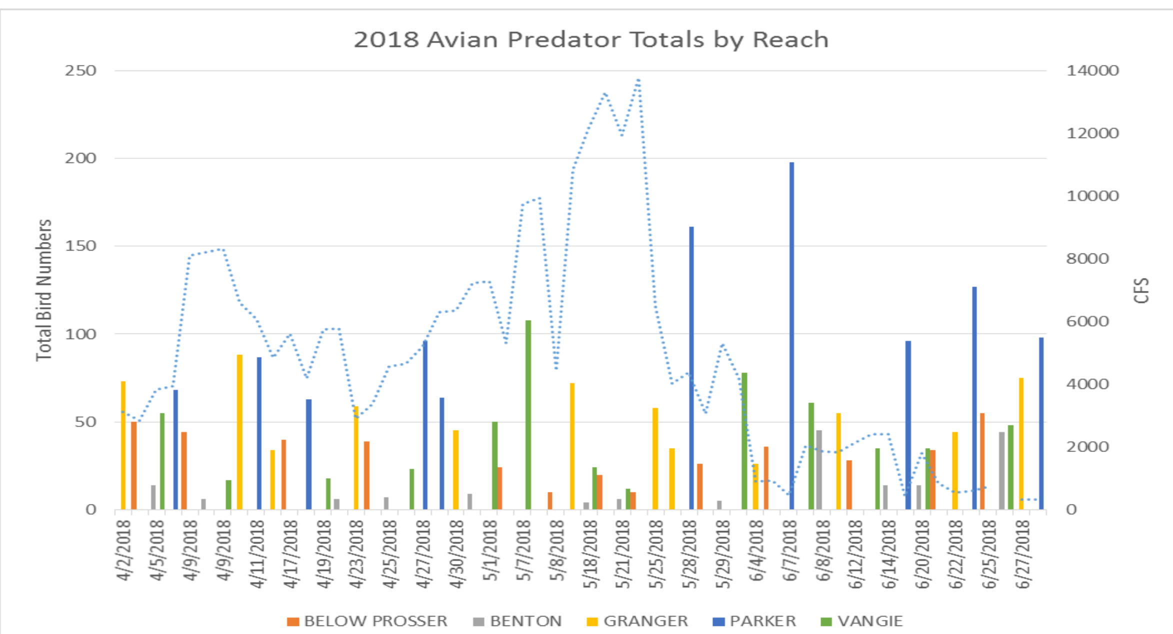


Figure 29. Avian Predator Totals by Reach.

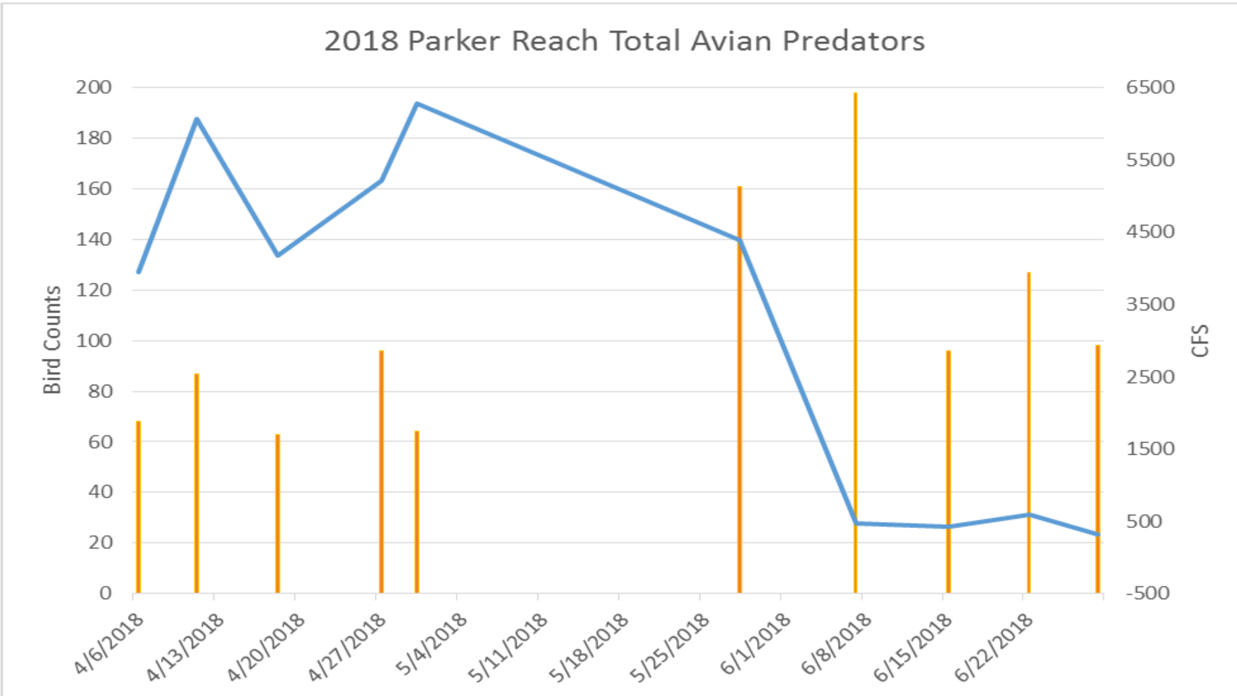


Figure 30. Parker Reach Total Avian Predators by Week.

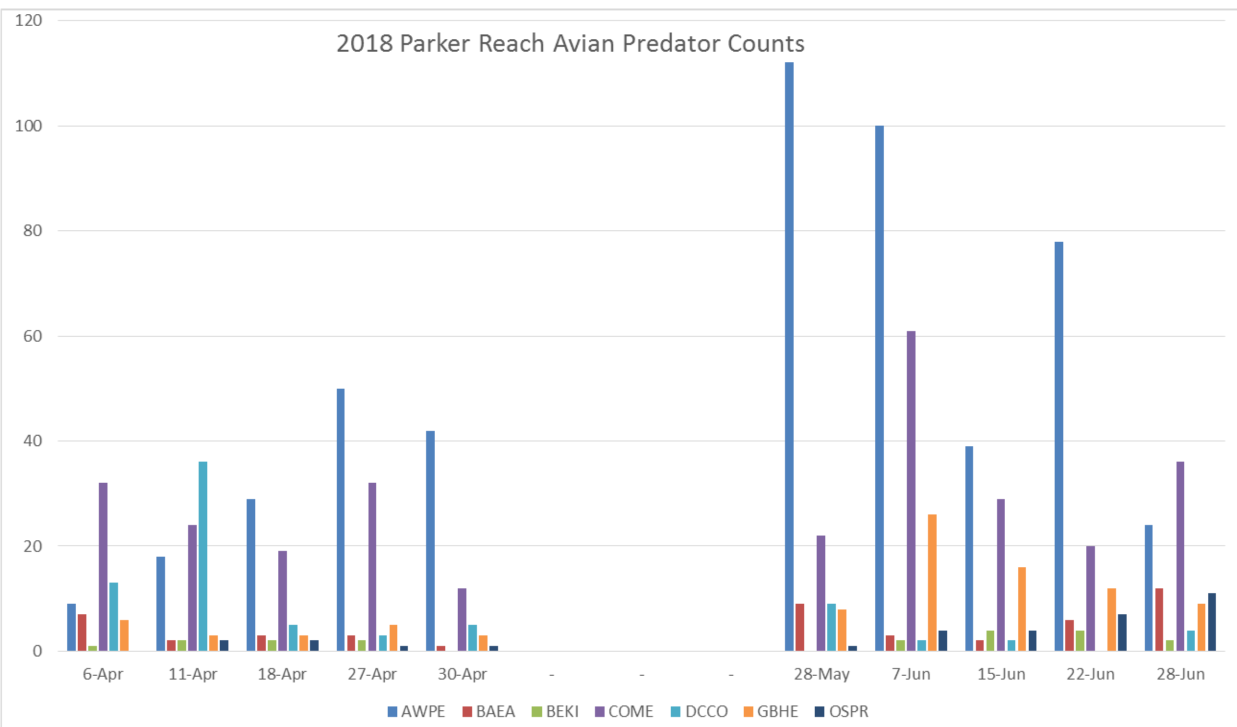


Figure 31. Parker Reach Avian Predator Species Counts.

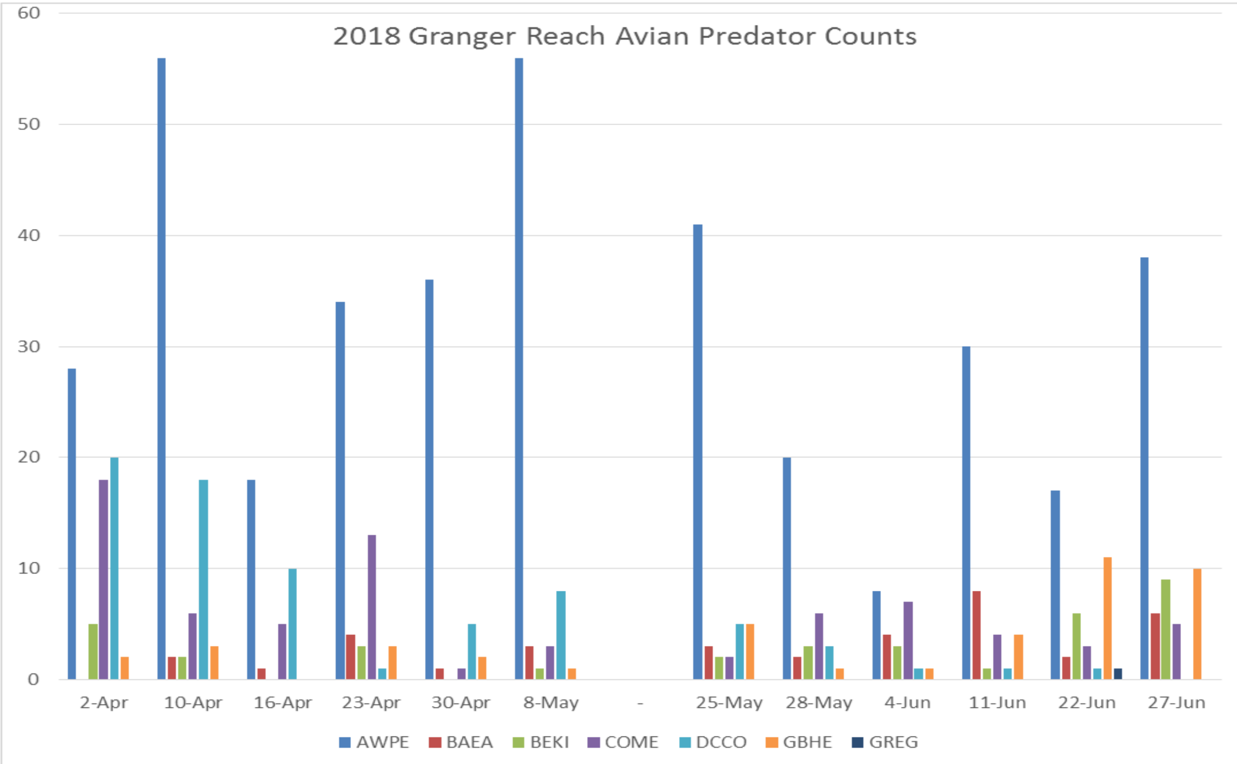


Figure 32. Granger Reach Avian Predator Species Counts.

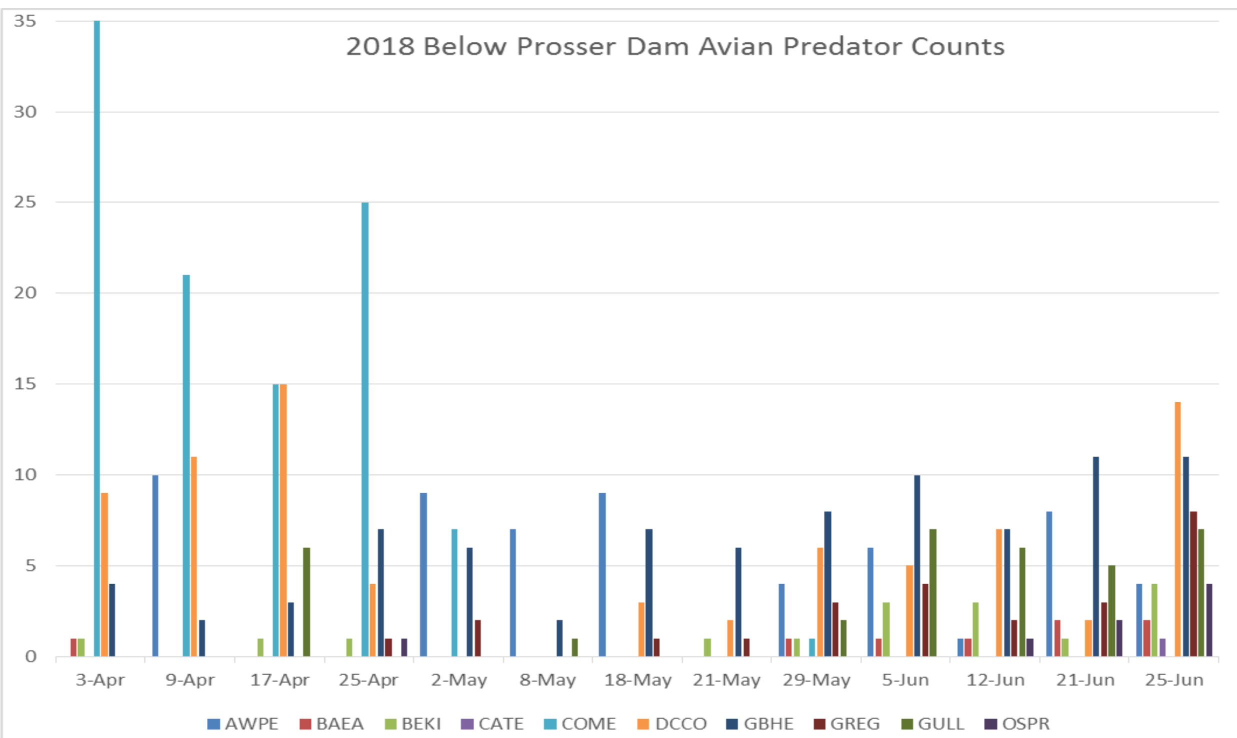


Figure 33. Below Prosser Avian Predator Species Counts.

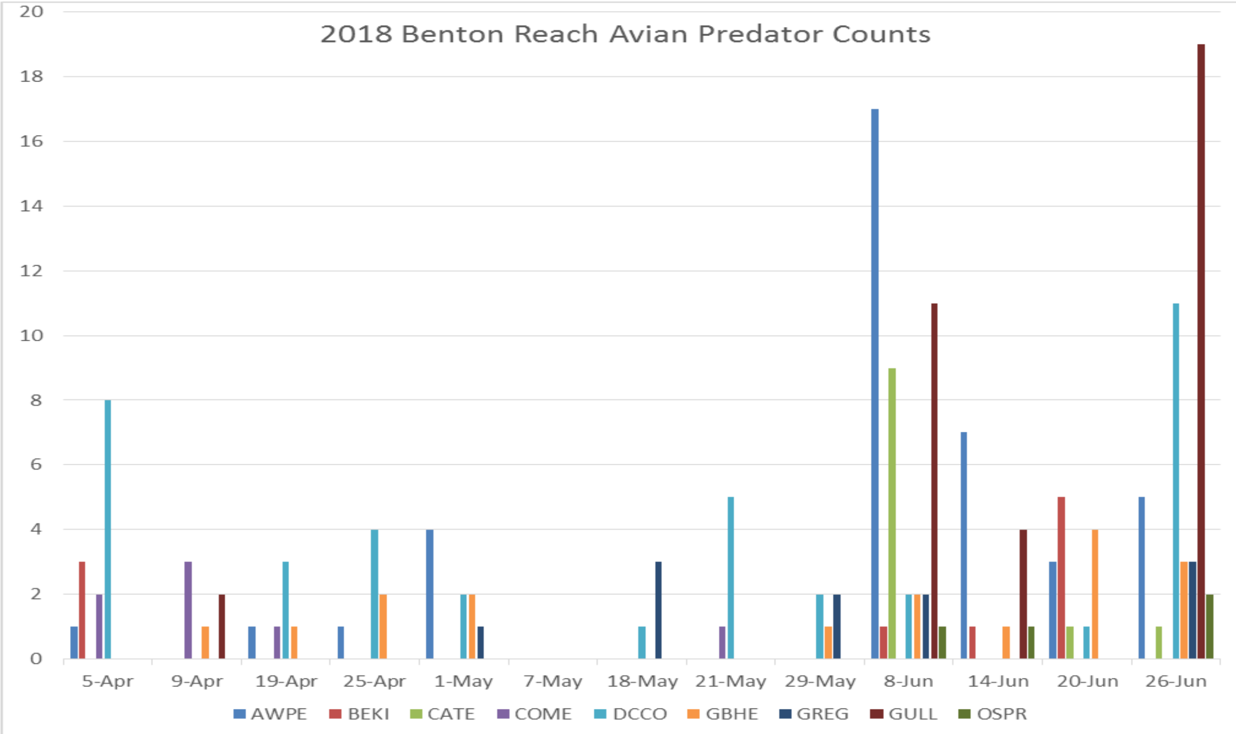


Figure 34. Benton Reach Avian Predator Species Counts.

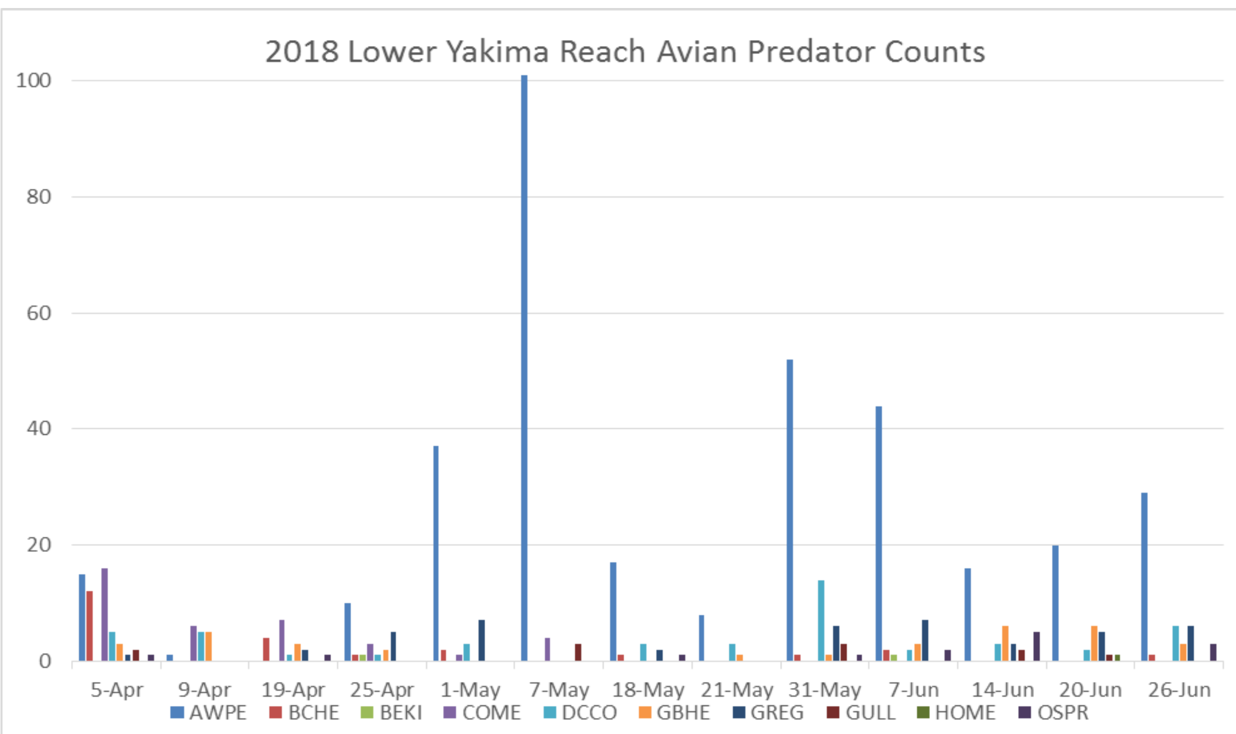


Figure 35. Lower Yakima Reach Avian Predator Species Counts.

Hotspot Surveys

Avian predator surveys were conducted at the Chandler fish bypass pipe (river mile ~46) and Wanawish Dam (river mile ~18.5) hotspots. At both sites American White Pelicans, Belted Kingfishers, Common Mergansers, Double Crested Cormorants, Great Blue Herons, and Gull species were observed. Graph Data (Figures 36 and 37) for hotspot surveys represents avian predator counts at these sites.

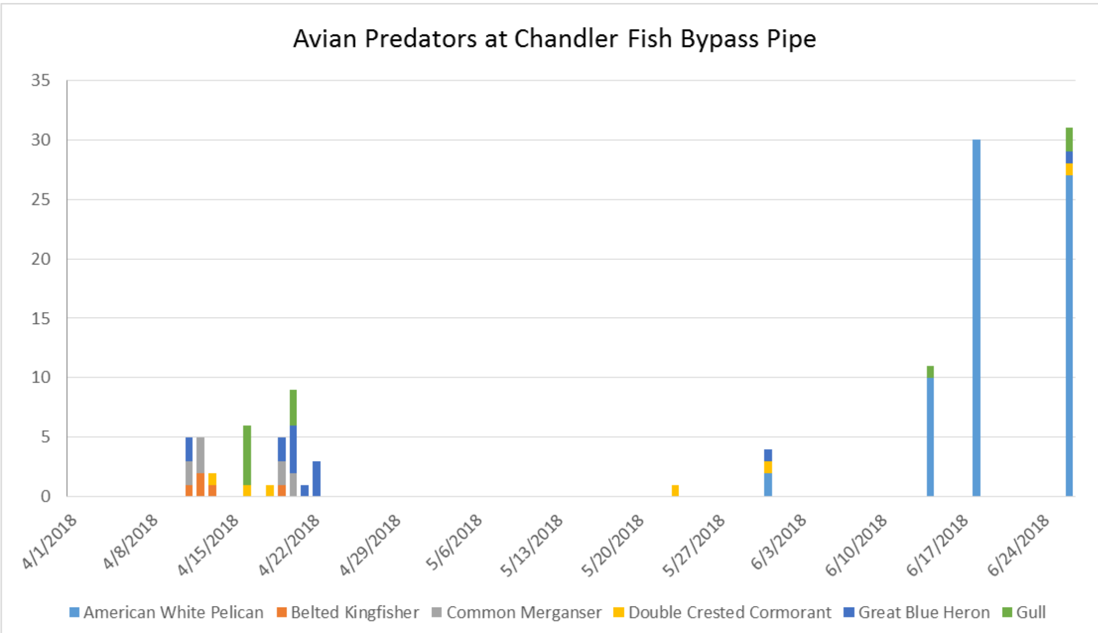


Figure 36. Avian Predator Counts at Chandler "hotspot".

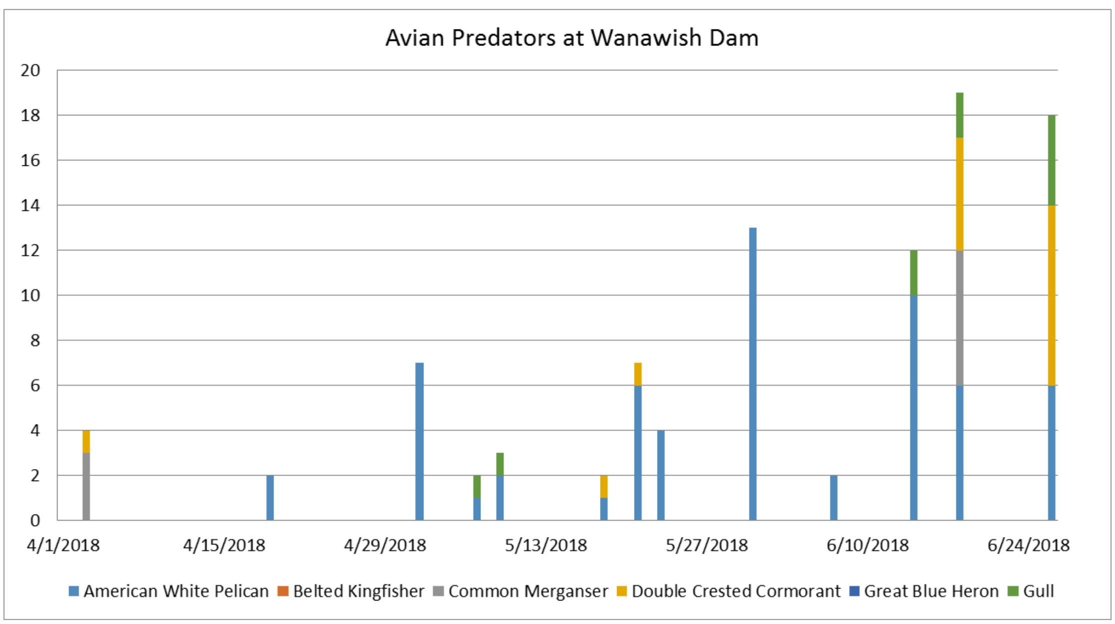


Figure 37. Avian Predator Counts at Wanawish Dam "hotspot".

Acclimation Sites Surveys

At the three Spring Chinook salmon acclimation sites in the upper Yakima River and its tributaries piscivorous bird surveys were conducted over a 3-5 month period in the winter and spring of 2018. The most common species of birds observed at acclimation sites were Bald Eagle, Belted Kingfisher, Common Merganser, Great Blue Heron and Osprey. Using the assumption that birds frequenting acclimation ponds are only consuming acclimating juvenile salmon, an average consumption rate can be determined. The average consumption rate can be calculated using the average number of birds at each site, daily energy requirements of the birds and the average size of juvenile salmon.

It was estimated that these bird species together consumed 950 juvenile Chinook at Clark Flat. The most common birds observed were Bald Eagles, Belted Kingfishers, and Great Blue Herons. Great Blue Herons had the highest consumption rate, consuming 774 juvenile Chinook. At Easton, it was estimated that 339 juvenile Chinook were consumed. The most common birds observed were Bald Eagles, Belted Kingfishers, Common Mergansers, Great Blue Herons, and Ospreys. Great Blue Herons and Bald Eagles had the highest consumption rates. Great Blue Herons consumed 157 juvenile Chinook and Bald Eagles consumed 100 juvenile Chinook. Only Belted Kingfishers and Common Mergansers were observed at Jack Creek, it was estimated that they consumed 961 juvenile Chinook. Common Mergansers consumed 928 juvenile Chinook. In 2017, these bird species together consumed 1,002 juvenile Chinook at Clark Flat, 1,802 juvenile Chinook at Easton and 329 juvenile Chinook at Jack Creek.

Table 31. Yakima River Avian Predators.

CLARK FLAT

	AVG. # OF BIRDS	~ FISH CONSUMED*	% BREAKDOWN CONSUMED	% OF TOTAL FISH CONSUMED BY SITE
BAEA	0.036821705	127	13.36842105	0.055094507
BEKI	0.146317829	49	5.157894737	0.021256936
GBHE	0.326550388	774	81.47368421	0.33577282
TOTAL	*0.509689922*	*950*	*100*	*0.412124262*

EASTON

	AVG. # OF BIRDS	~ FISH CONSUMED*	% BREAKDOWN CONSUMED	% OF TOTAL FISH CONSUMED BY SITE
BAEA	0.02827381	100	29.49852507	0.04572871
BEKI	0.017857143	6	1.769911504	0.002743723
COME	0.007440476	20	5.899705015	0.009145742
GBHE	0.064732143	157	46.31268437	0.071794074
OSPR	0.027529762	56	16.51917404	0.025608078
TOTAL	*0.145833333*	*339*	*100*	*0.155020326*

JACK CREEK

	AVG. # OF BIRDS	~ FISH CONSUMED*	% BREAKDOWN CONSUMED	% OF TOTAL FISH CONSUMED BY SITE
BEKI	0.13030303	33	3.433922997	0.014996864
COME	0.478787879	928	96.566077	0.421730002
TOTAL	*0.609090909*	*961*	*100*	*0.436726866*

*Fish consumption numbers derived by assumption smolts were sole food source

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:

Data was collected on piscivorous fish from six electrofishing sites within the Yakima River (Figure 38). Sites were sampled via boat electrofishing through time to assess spatial and temporal patterns of fish abundance and distribution. Each sampling segment was defined by river features of dams and boat launches. The partitioned sample locations consist of four ten mile surveys, one four mile survey, and one six mile survey (Table 32). Total river mile distance of the combined Yakima River surveys is 50 miles. Survey locations were marked by GPS unit (Garmin GPSmap 78; Garmin International, Olathe, Kansas). After marking sampling reaches, we sample weekly beginning April 2nd and ending June 22nd (dates may vary depending on river stage). (Fish Predators Schei, monitoring methods 47), (Predator Reduction Mclellan, monitoring methods 438).

Sampling was conducted using three different types of vessels and electrofishers. Five of the Yakima River surveys were conducted using two boats; one Smith Root SR-16H Electrofishing boat equipped with the 7.5 GPP electrofishing unit powered by a

6,000-W Kohler boat generator, and one 16 foot aluminum jet boat equipped with a Smith Root VVP-15B electrofisher powered by a Honda EM3500S generator. The Yakima River survey below Prosser was conducted with a 13 foot raft equipped with a smith root 1.5-KVA electrofisher powered by Honda EU2000i generator; 3. Electro-fishing settings were adjusted to continuous DC for an output of approximately 700 V and 9–12 A. 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.

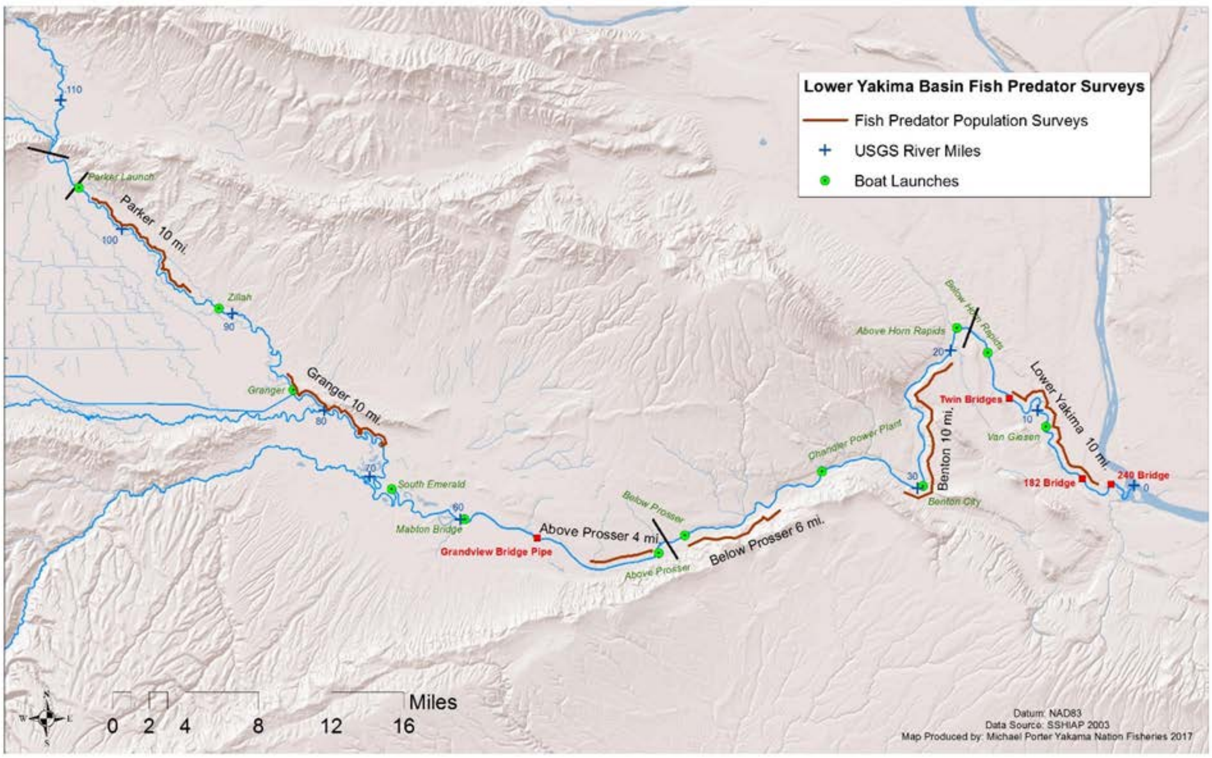


Figure 38. Fish Predator Survey Locations.

Table 32. Fish Predator Survey River Miles and Distances.

Survey Name	*River Mile Start*	*River Mile End*	*Survey Distance Miles*
Parker	106.1	96.1	10
Granger	85.3	75.3	10
Above Prosser	52.4	48.4	4
Below Prosser	46.4	40.4	6
Benton	31.1	21.1	10
Lower Yakima	13.8	3.8	10

Sampling was conducted continuously along river margins when possible. As river stage changes, limiting access to areas within survey segments, continuous electro-fishing was not always possible. The start and endpoints of shocker operation within the segment at low river stages was marked, resulting in discontinuous, marked sub-segments of electrofisher operation within each survey area.

Data collected during each sampling event consisted of:

- Water Temperature, Dissolved Oxygen, Specific Conductivity gathered by a HACH 30qd water multi-meter
- Water Turbidity gathered by a HACH TSS Handheld Instrument
- River CFS gathered from Bureau of Reclamation gaging stations
- Electrode start and end times
- Numbers and species (Table 5) of all fish observed and their size class greater than or less than 100mm

At the start of each sampling event a small group of fish were caught and examined to insure that electro-fishing settings were not causing visible injuries. To further insure injuries to fish were minimized sampling procedures by the National Marine Fisheries Service, "Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act," were followed.

Table 33. Yakima River Fish Species (Note: Spring Chinook and Coho total counts are combined in results as SP+CO).

Family	Common Name	*Scientific Name*	Acronym
Salmonidae:			
	Steelhead/Rainbow trout	*Oncorhynchus mykiss*	STH
	Coho Salmon	*Oncorhynchus kisutch*	COHO*
	Chinook Salmon	*Oncorhynchus tshawytscha*	SPCK/FACK*
	Mountain Whitefish	*Prosopium williamsoni*	WT
Cyprinidae:			
	Chiselmouth	*Acrocheilus alutaceus*	CH
	Carp	*Cyprinus carpio*	CP
	Peamouth	*Mylocheilus caurinus*	PEA
	Speckled Dace	*Rhinichthys osculus*	SPDA
	Northern Pikeminnow	*Ptychocheilus oregonensis*	NPM
	Redside Shiner	*Richardsonius balteatus*	SH
Catostomidae:			
	Sucker	*Catostomus columbianus*	SK
		Catostomus catostomus	
Ictaluridae:			
	Brown Bullhead	*Ameiurus nebulosus*	BRCT
	Channel Catfish	*Ictalurus punctatus*	CHCT
Centrarchidae:			
	Pumpkin Seed	*Lepomis gibbosus*	PKSC
	Blue Gill	*Lepomis macrochirus*	BG
	Smallmouth Bass	*Micropterus dolomieui*	SMB
	Large Mouth Bass	*Micropterus salmoides*	LMB
	Black Crappie	*Pomoxis nigromaculatus*	CRAP
Percidae:			
	Walleye	*Stizostedion vitreum vitreum*	WALLEYE
	Yellow Perch	*Perca flavescens*	YP
Cottidae:			
	Sculpin	*Cottus bairdi*	SC
Clupeidae:			
	Shad	*Alosa sapidissima*	SHAD

Results and Discussion:

Piscivorous fish were identified in all 6 survey reaches of the Yakima River. Smallmouth Bass was the most abundant fish predator observed during the 2018 surveys (Figure 39).

Northern Pike Minnow are the dominate fish piscivorous of the upper portion of the 2018 surveyed reaches of Yakima River (reaches above Prosser Dam). They were the fish predator found in the highest abundance in the upper survey reaches during electro-fishing surveys of 2018. Fish counts for all species observed during the 2018 surveys are given for all reaches in figures 40 through 45.

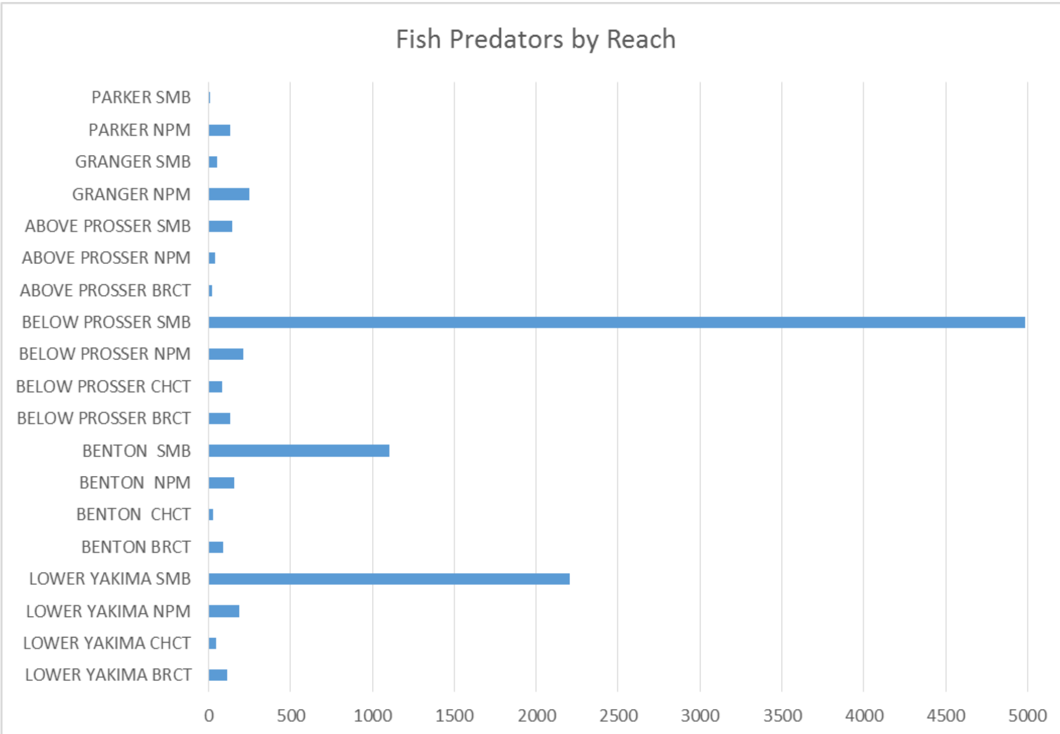


Figure 39. Fish Predator Counts by Reach and Species.

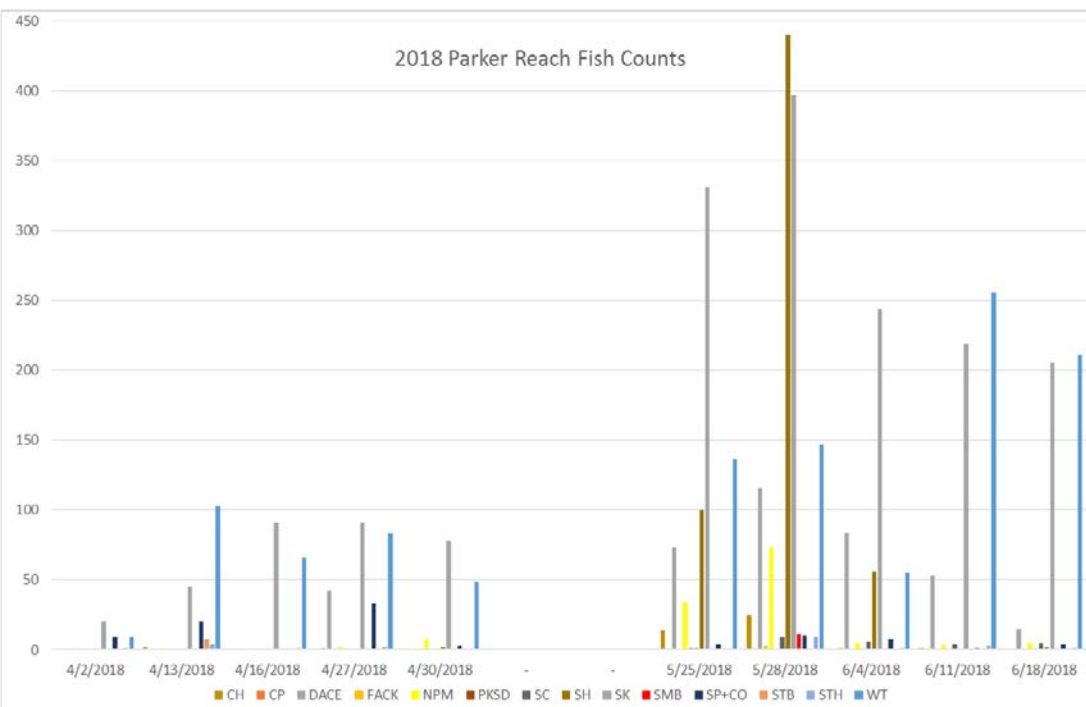


Figure 40. Parker Reach Fish Counts by Species.

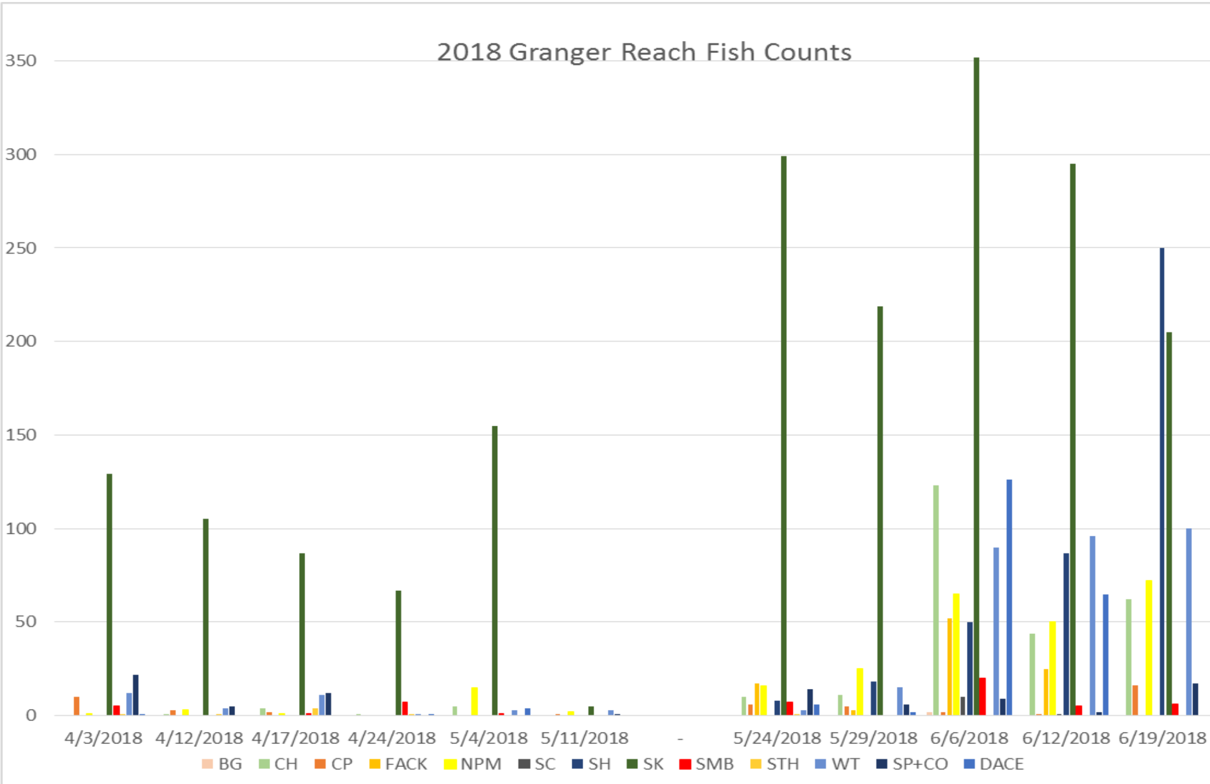


Figure 41. Granger Reach Fish Counts by Species.

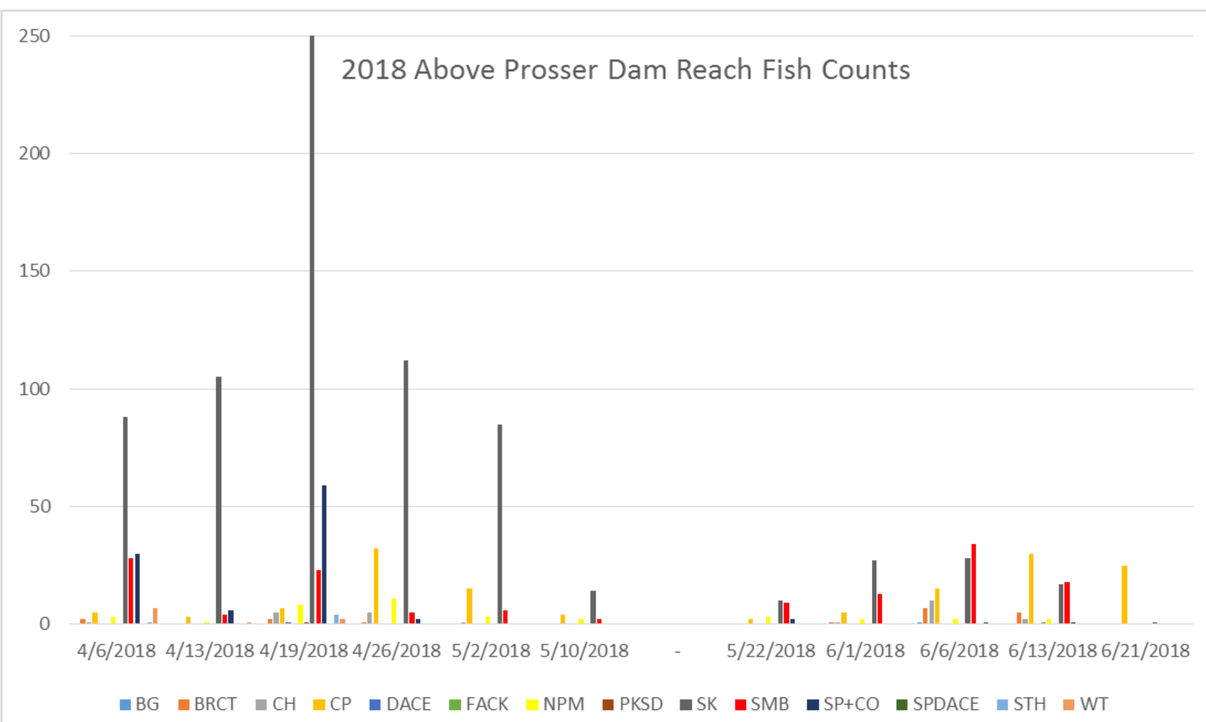


Figure 42. Above Prosser Dam Fish Counts by Species.

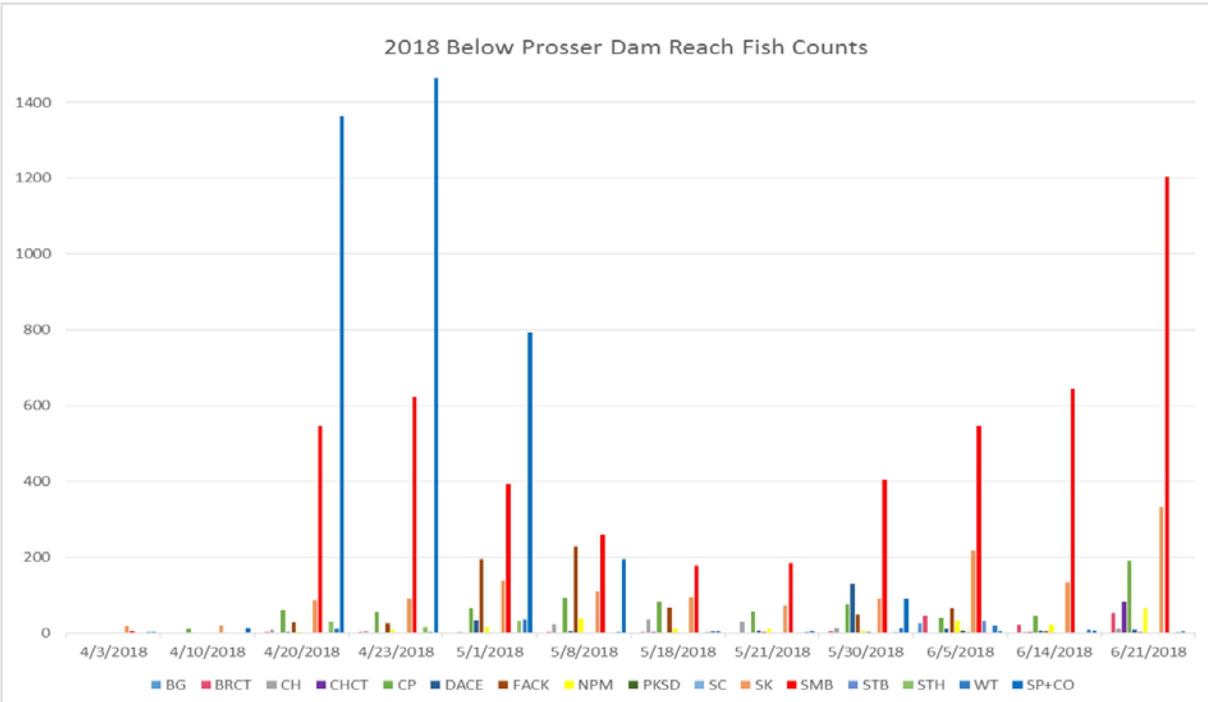


Figure 43. Below Prosser Dam Fish Counts by Species.

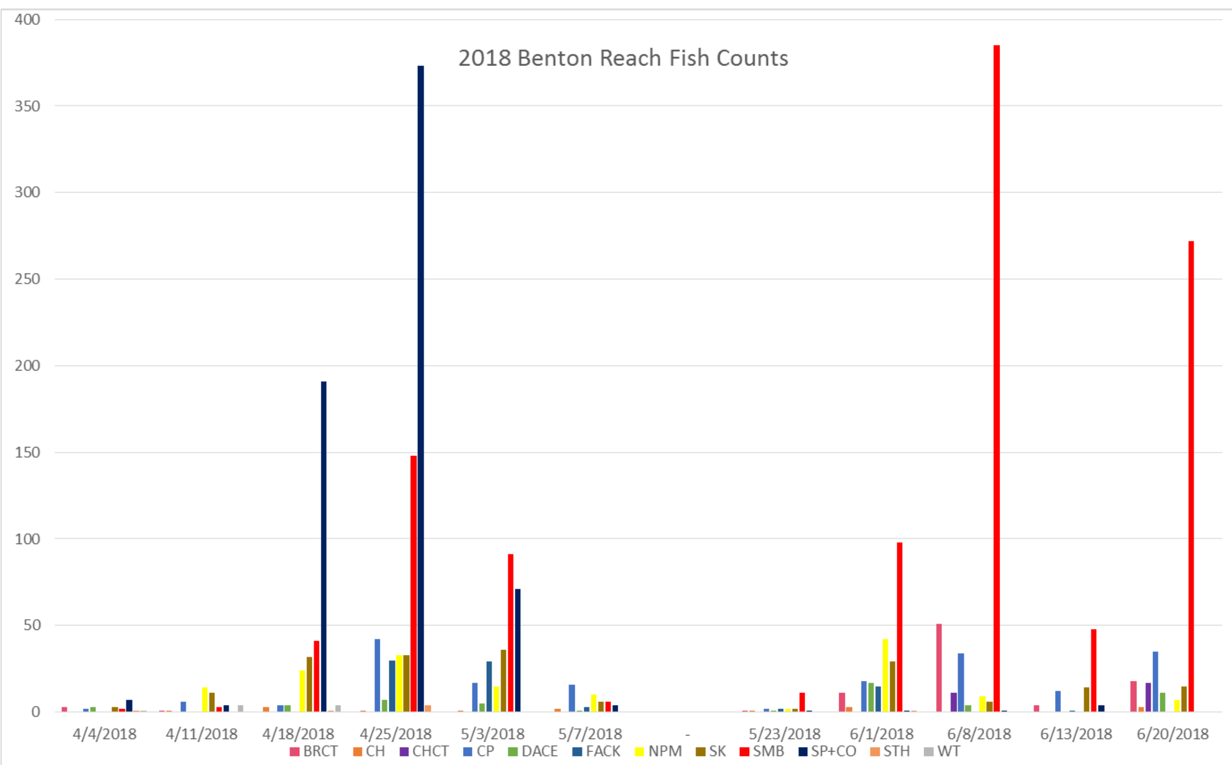


Figure 44. Benton Reach Fish Counts by Species.

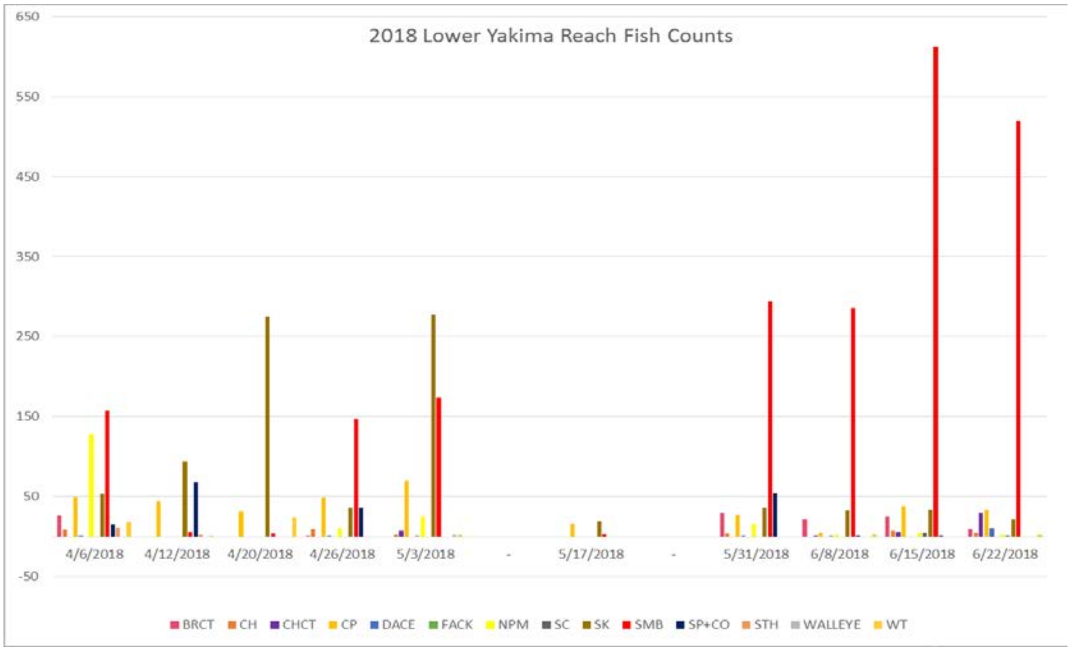
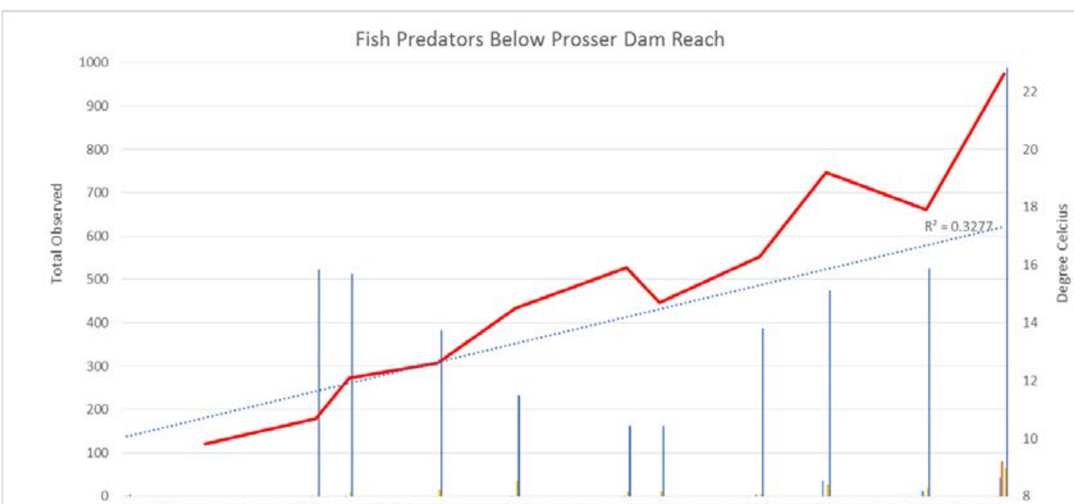


Figure 45. Lower Yakima Reach Fish Counts by Species.

Large amounts of introduced fish predators inhabit the Lower Yakima River. During the 2018 surveys the highest abundance of non-native fish predators were found in the lowest reaches of the Yakima River. Smallmouth Bass and Channel Catfish were found in increased abundance during the later weeks of the 2018 surveys (Figure 46). These two predators are often considered to consume large amounts of salmonids.



	4/3/18	4/10/18	4/20/18	4/23/18	5/1/18	5/8/18	5/18/18	5/21/18	5/30/18	6/5/18	6/14/18	6/21/18
BRCT			2	1		1	1		4	36	12	44
CHCT							1				2	81
LMB	1									1		
NPM			1	8	16	36	10	10	5	27	20	66
SMB	4		524	513	382	233	162	162	388	474	525	989
River Temp C°		9.8	10.7	12.1	12.6	14.5	15.9	14.7	16.3	19.2	17.9	22.6

Figure 46. Total Count of Fish Predators below Prosser Dam.

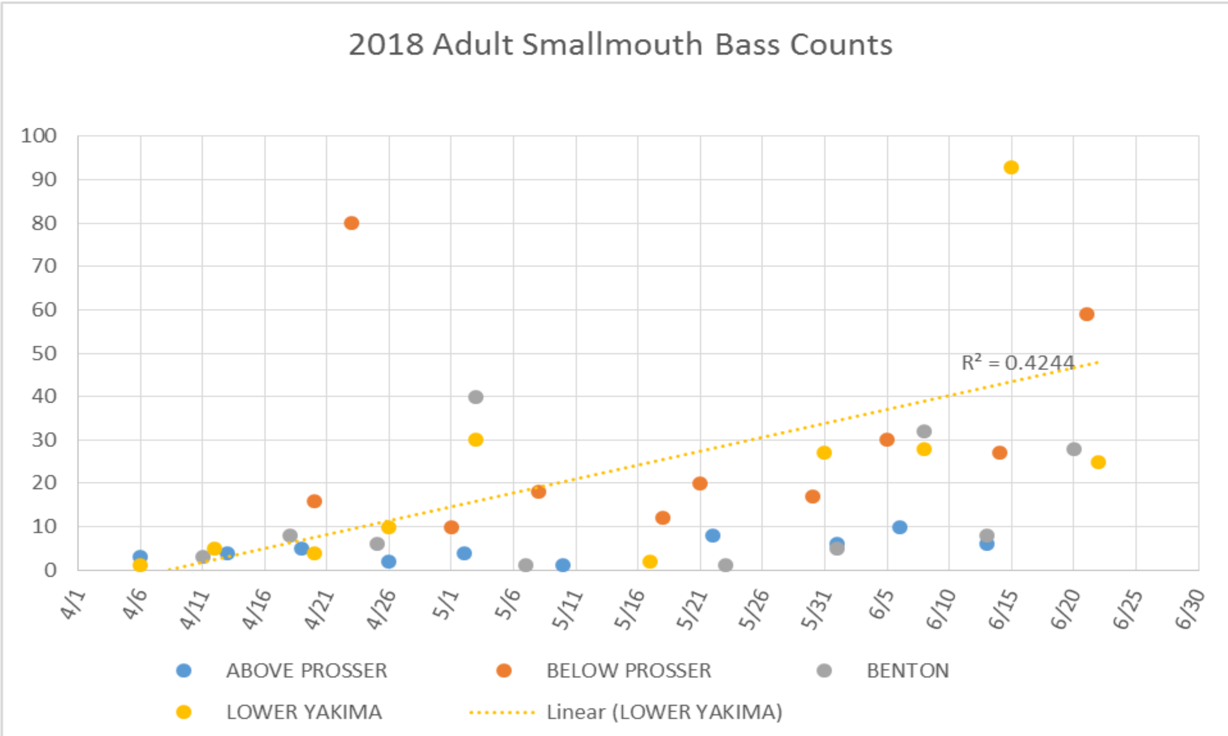


Figure 47. Adult Smallmouth Bass Totals by Reach.

Smallmouth Bass have been found to exhibit a spike in abundance during their spawning periods in the Lower Yakima River. Spawning for Smallmouth Bass is typically between April 1 and July 1. This time period coincides with juvenile salmonid outmigration. This timing provides a readily available prey source for the adult spawning bass and their young recruits. Catch and catch per unit effort for adult Smallmouth Bass begins to rise in the May and June survey periods (Figure 47) as Smallmouth Bass 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 (Figure 48).

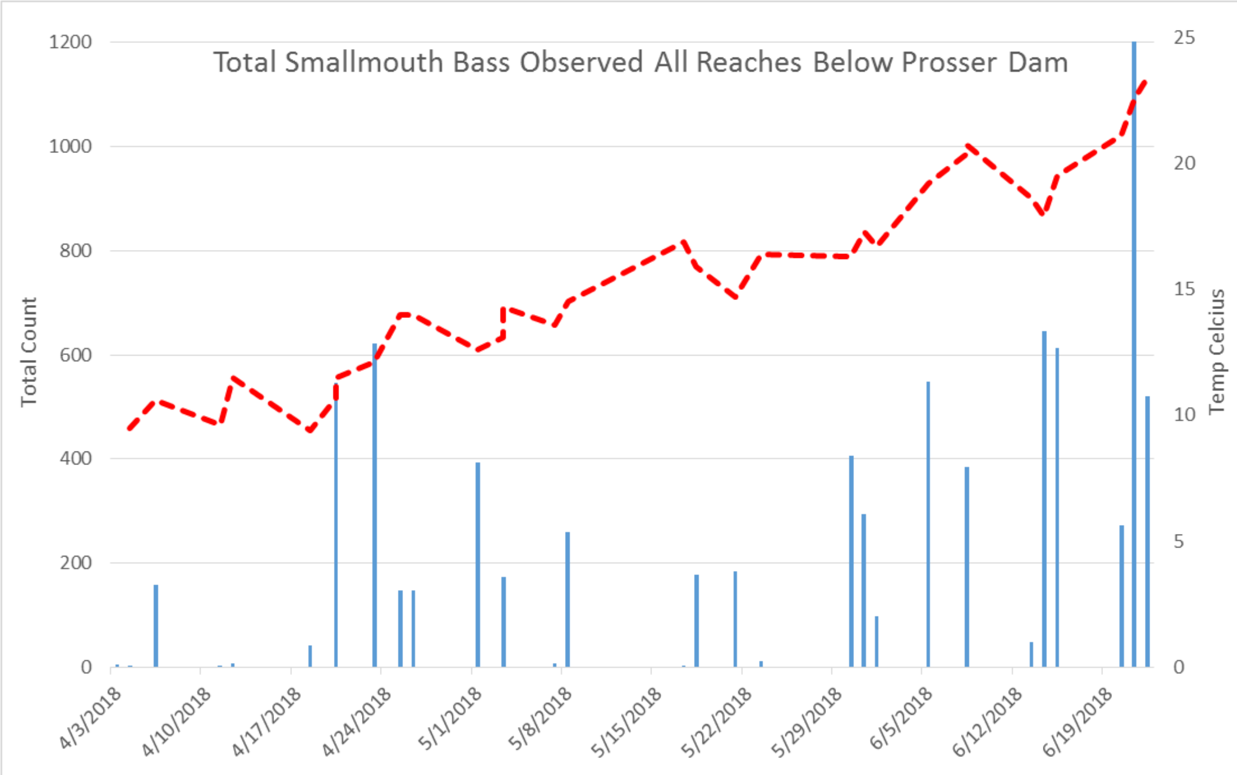


Figure 48. Adult and Juvenile Smallmouth Bass Total below Prosser Dam.

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. 2017) 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

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D. IntSTATS, Inc. Annual Report: Smolt Survival to McNary Dam of 1999-2013 and 2015-2018 PIT-tagged Spring Chinook released at Roza Dam

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G. IntSTATS, Inc. Annual Report: 2008-2018 Fall and 2009-2018 Summer Chinook Smolt-to-Smolt Survival to McNary Dam of Releases into the Yakima Basin

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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
RMIS - Regional Mark Information System
Yakima-Klickitat Fisheries Project website
StreamNet Database
cbfish.org
PTAGIS Website
Washington State SaSI

A system has been developed that serves Yakima Basin adult abundance and trap sampling (requires login) data for the Prosser and Roza data sets. This system can be accessed at: http://dashboard.yakamafish-star.net/FishData.

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

- Prosser and Roza dam daily count and trap sample (requires login) data http://dashboard.yakamafish-star.net/FishData.
- 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 (e.g., PISCES, available via CBfish.org)
- 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 system we have developed 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

2018 Annual Report

May 31, 2019

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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 2017. 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).

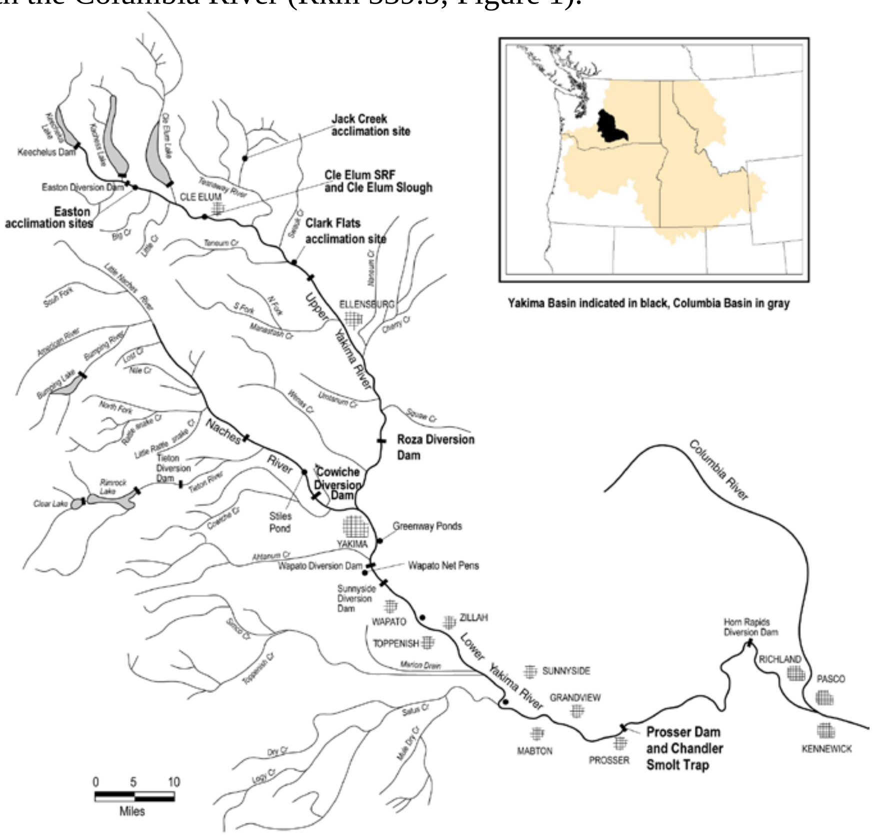

Figure 1. Yakima River Basin.

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).

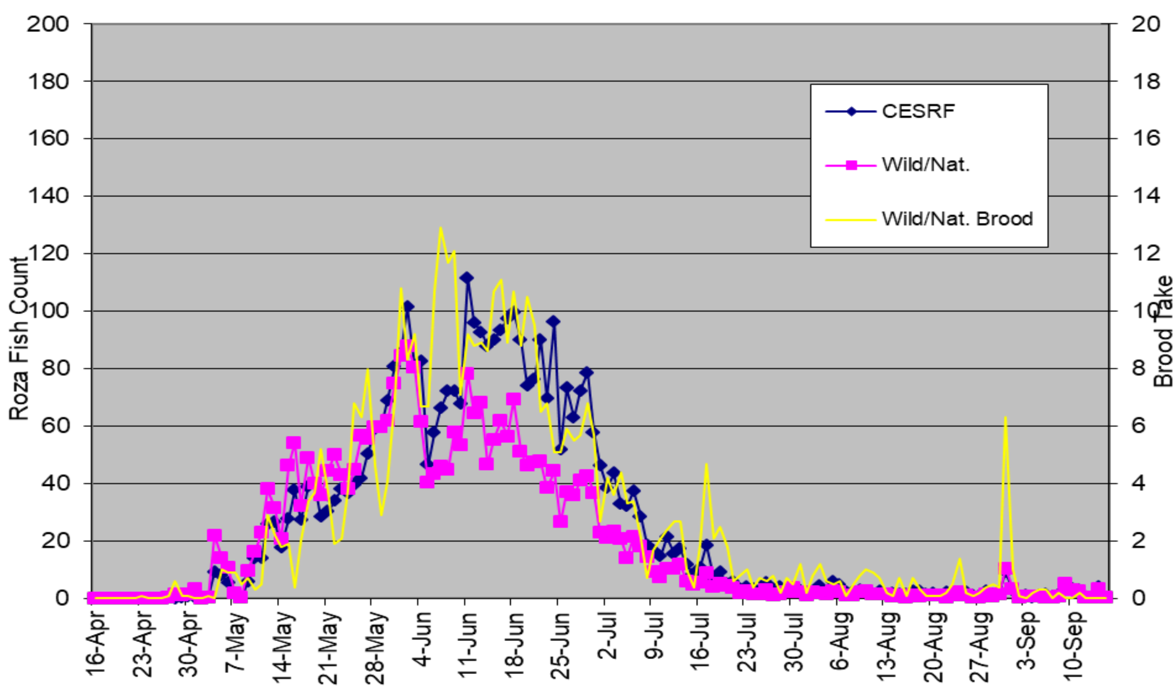

Figure 2. Mean spring Chinook run timing and broodstock collection at Roza Dam, 2009-2018.

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. Similarly warm river conditions occurred again in the Yakima Basin during the spring/summer of 2018.

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

	Trap	Brood	Brood	Portion of run collected:[1]			Portion of collection from:[2]		
Year	Count	Take	%	Early[3]	Middle[3]	Late[3]	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%
2017	1,711	382	22.3%	53.6%	19.0%	45.4%	11.4%	69.9%	18.7%
2018	827	294	35.6%	3.0%	33.7%	87.6%	0.3%	75.1%	24.6%

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%
2017	1,135	194	1,329	1,328	660	1,988	2,463	854	3,317	59.9%	62.5%
2018	500	33	533	1,033	233	1,266	1,533	266	1,799	70.4%	58.7%
Mean[3]	2,495	351	2,846	2,380	721	3,101	4,735	1,094	5,829	54.4%	65.4%

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, 1989-present.

Year	River Mouth Run Size[1] Adults	Jacks	Total	Harvest Below Prosser	Prosser Count	Harvest Above Prosser	Spawners Below Roza[2]	Roza Count	Roza Removals[3]	Est. Escapement Upper Y.R.[4]	Naches[5]	Redd Counts Upper Y.R.	Naches
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
2017	5,462	1,701	7,163	122	7,041	1,150	25	4,193	876	3,317	1,673	539	293
2018	3,155	449	3,605	251	3,353	297	18	2,404	605	1,799	634	348	128
Mean[6]	8,183	2,204	10,388	580	9,807	1,389	31	6,806	1,222	5,583	1,581	1,224	458

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 (2009-2018).

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	20	2,662	0.49
2013	4,984	299	1,622	36	1,957	0.39
2014	6,751	241	814			
2015	5,466	66				
2016	4,281					
2017	3,342					
2018	1,817					
Mean	4,170	344	2,802	112	3,337	1.56

1. The mean jack proportion of spawning escapement from 1999-2018 was 0.22 (geometric mean 0.17).

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					Returns/ Spawner
		Age-3	Age-4	Age-5	Age-6	Total	
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	116	0	936	0.65
2006	1,163	192	838	254	0	1,283	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	0	1,530	0.79
2012	1,110	64	419	260		743	0.67
2013	750	110	660	127		898	1.20
2014	746	142	397				
2015	1,285	26					
2016	790						
2017	971						
2018	500						
Mean	1,182	106	866	369	3	1,360	1.64

1. The mean jack proportion of spawning escapement from 1999-2018 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					Returns/ Spawner
		Age-3	Age-4	Age-5	Age-6	Total	
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	127	0	378	0.81
2006	509	45	308	451	0	805	1.58
2007	523	57	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	0	953	0.85
2012	789	41	261	253		555	0.70
2013	619	76	412	49		537	0.87
2014	385	103	92				
2015	819	7					
2016	542						
2017	703						
2018	134						
Mean	565	54	277	299	1	637	1.68

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	268	0	1,359	0.71
2006	1,672	237	1,120	759	0	2,117	1.27
2007	986	182	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	0	2,459	0.80
2012	1,900	105	662	540		1,307	0.69
2013	1,369	186	1,046	204		1,437	1.05
2014	1,130	245	461				
2015	2,103	33					
2016	1,332						
2017	1,673						
2018	635						
Mean	1,747	160	1,096	717	7	2,001	1.62

1. The mean jack proportion of spawning escapement from 1999-2018 was 0.09.

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	10	1,723	4.61
2013	398	802	1,993	0	2,795	7.02
2014	384	1,008	1,451		2,458	6.40
2015	442	315				
2016	376					
2017	382					
2018	294					
Mean	451	968	3,245	98	4,341	7.56[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 (there were no carcass recoveries in 2017 or 2018), 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	6.3	56.3	37.5		16		75.0	25.0		32	2.0	69.4	28.6	
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	
2017						No carcasses were sampled								
2018						No carcasses were sampled								
Mean	3.1	46.7	50.0	0.3			44.6	54.0	1.3		1.1	44.7	53.1	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	4.5	90.9	4.5		22		83.3	16.7		42	2.9	85.3	11.8	
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	
2017							No carcasses were sampled							
2018							No carcasses were sampled							
Mean	4.9	64.6	29.9	0.7		0.6	57.9	41.1	0.3		2.3	61.3	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	carcass surveys discontinued as Roza samples deemed adequate										
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	carcass surveys discontinued as Roza samples deemed adequate										
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
2017	13.7	84.9	1.4	146	1.0	97.9	1.0	194	6.5	92.4	1.2
2018	17.6	79.4	2.9	102	0.0	95.8	4.2	144	7.3	89.0	3.7
Mean	18.5	77.4	4.1		0.3	94.8	5.0		8.9	86.6	4.5

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
2017	43.6	56.4	0.0	39	0.0	100.0	0.0	66	16.2	83.8	
2018	28.9	71.1	0.0	38	0.0	100.0	0.0	38	14.5	85.5	
Mean	26.2	70.2	3.5		0.2	95.6	4.2		11.6	84.5	3.9

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). Collection of carcass samples from the spawning grounds throughout the Yakima Basin did not occur in 2017 or 2018.

For upper Yakima fish collected at Roza Dam for brood stock or research purposes from 1997-2017, the mean proportion of males to females was 38:62 and 35:65 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 38:62 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			27.3	72.7	42.9	57.1		
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		
2017			No carcasses were sampled					
2018			No carcasses were sampled					
mean			40.2	59.8	33.3	66.7		

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	100.0		36.4	63.6	12.5	87.5		
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		
2017			No carcasses were sampled					
2018			No carcasses were sampled					
mean			40.6	59.4	27.2	72.8		

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	carcass surveys discontinued as Roza samples deemed adequate					
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	carcass surveys discontinued as Roza samples deemed adequate					
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
2017	90.9	9.1	39.5	60.5	50.0	50.0
2018	100.0		37.0	63.0	33.3	66.7
mean	97.8	2.2	38.2	61.8	37.5	62.5

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
2017	100.0	0.0	25.0	75.0		
2018	100.0	0.0	41.5	58.5		
mean	98.9	1.1	35.5	64.5	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 2001-2018, CESRF fish returning to the upper Yakima have been generally smaller in size-at-age than their wild/natural counterparts (Tables 25-28).

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	1	38.0	9	70.1	6	75.7			24	65.1	8	73.0		
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		
2017-18				No samples						No samples				
Mean[2]		38.7		61.8		76.2				62.8		72.4		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	1	40.0	20	60.5	1	77.0					35	61.7	7	71.4		
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		
2017-18				No samples								No samples				
Mean[2]		41.9		60.1		75.8		78.0		41.0		60.5		72.1		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	carcass surveys discontinued as Roza samples deemed adequate											
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.

	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	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	carcass surveys discontinued as Roza samples deemed adequate											
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
2017	18	43.2	115	61.0	2	66.0	2	47.7	167	62.1	2	64.9
2018	17	40.5	77	59.2	3	66.0			132	58.9	6	62.9
Mean		43.2		59.8		69.9				59.9		67.9

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		
2017	11	44.1	20	59.9					36	61.9		
2018	8	38.4	22	59.5					34	59.4		
Mean		41.3		59.6		73.2				59.5		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
2017	21	43.3	128	61.3	2	66.5	2	48.0	195	62.5	2	66.0
2018	21	40.9	86	59.3	3	67.3			140	59.2	7	64.4
Mean		43.3		61.1		71.4		50.6		60.8		69.4

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

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.

	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	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
2017	83	43.9	47	61.6					160	62.3	1	67.0
2018	24	39.3	56	58.4			1	41.0	86	59.4		
Mean		41.7		60.3		70.4		50.2		60.0		69.6

[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).

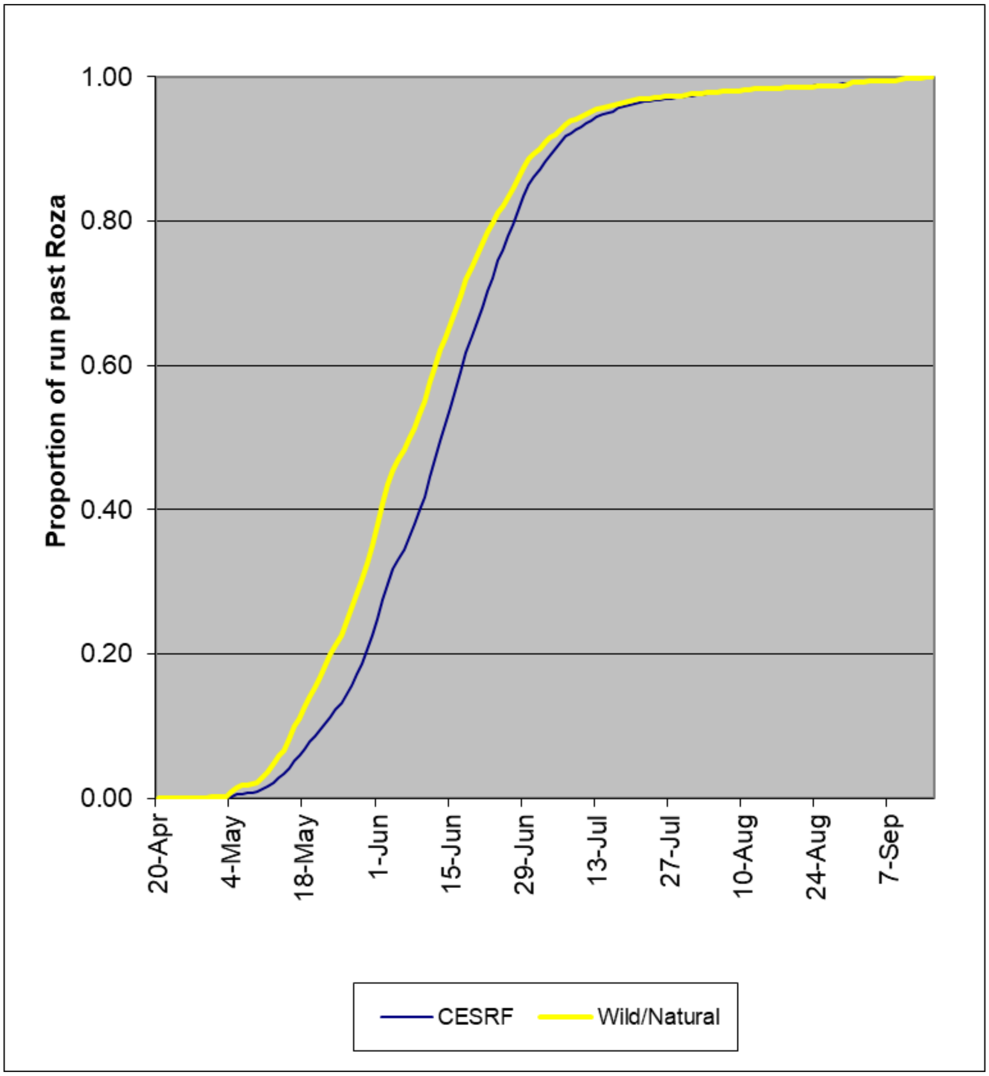

Figure 3. Proportionate passage timing at Roza Dam of wild/natural and CESRF adult spring Chinook (including jacks), 2009-2018.

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
2017	1-Jun	14-Jun	3-Jul	6-Jun	20-Jun	14-Jul
2018	1-Jun	8-Jun	18-Jul	2-Jun	14-Jun	16-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
2017[2]	16-Aug		26-Sep	19-Sep
2018	15-Aug	20-Sep	1-Oct	25-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.
2. Spawner surveys impacted by fires; especially in the Naches system.

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
2017	402	118	23	543	123	84	56	30	293
2018	339	13	0	352	27	56	44	1	128
Mean	1,022	123	27	1,171	160	165	112	47	484

[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 November 2018 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%	3,607	15	0.42%	2,340		
2012[2]	69	13	18.84%	1,723	19	1.10%	1,492		
2013	152	4	2.63%	2,795			1,993		
2014[2]	130	14	10.77%	2,458			1,451		

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

[2] Water temperatures in the lower Yakima River were greater than 70^{o} F for much of the late spring/summer migration in 2015 and 2018 which likely caused many fish returning in those years 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[6]	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[7]	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[8]	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%	588,139	99.1%	95.2%
2017	396	27	93.2%	152	193	2.1%	707,232	671,605	5.0%	642,836	95.7%	634,390	98.7%	94.5%
2018	305	6	98.0%	132	173	0.0%	565,221	534,753	5.4%	515,596	98.2%			
Mean	469	51	89.3%	136	210	4.1%	754,299	706,651	6.3%	678,147	97.9%	653,498	95.5%	93.4%

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%	85,910	95.8%	81,069	94.4%	90.4%
2017	127	8	93.7%	46	55	0.0%	195,070	187,173	4.0%	88,905	97.9%	76,279	85.8%	84.0%
2018	101	6	94.1%	33	54	0.0%	179,083	172,211	3.8%	137,961[11]	95.7%			
Mean	137	14	88.7%	30	46	1.4%	167,658	158,514	5.1%	92,507	97.9%	84,524	95.0%	93.1%

See footnotes for Table 33 above.

[11] The number of segregated, hatchery-control line brood raceways was increased from 2 to 4 for this brood due to overall brood shortages.

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.

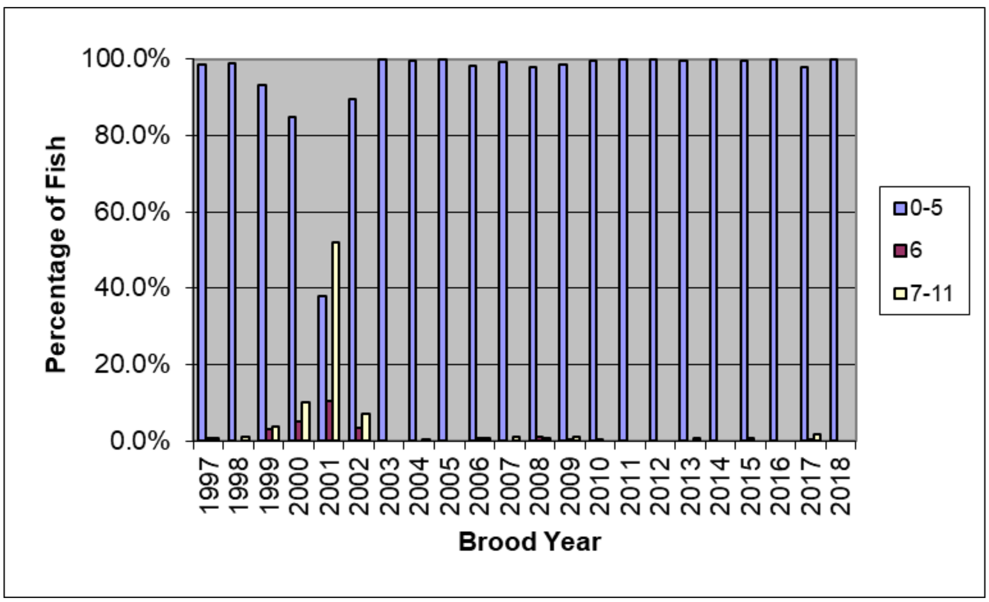

Figure 4. Proportion of wild/natural females spawned at CESRF by BKD rank, 1997 – present.

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
2017	2	2,150.6	161	4,013.8	1	3,805.5	1	1,645.0	53	3,609.1		
2018			130	3,452.4	6	3,643.9			48	3,358.6	1	2,853.4
Mean				3,854.1		4,664.6				3,705.3		4,328.9

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
2016	0.6	0.9	0.8	1.0	1.1	1.1	2.1	1.8	1.0	0.6	0.4	0.8
2017	0.8	0.8	0.9	0.9	1.7	0.8	2.1	2.9	3.8	0.4	0.1	0.6
Mean	0.8	0.9	1.0	1.0	1.3	1.1	1.9	1.2	1.6	0.4	1.1	1.1

Length and Weight Growth Profiles

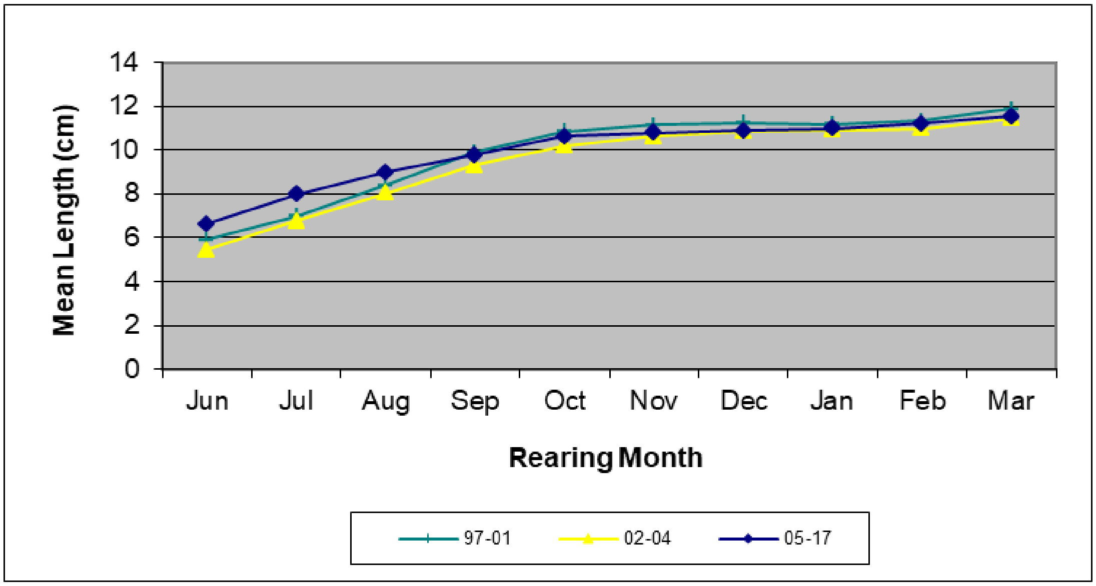

Figure 5. Mean length (cm) of "standard growth treatment (Hi)" CESRF juveniles by brood year and growth month, 1997 - present.

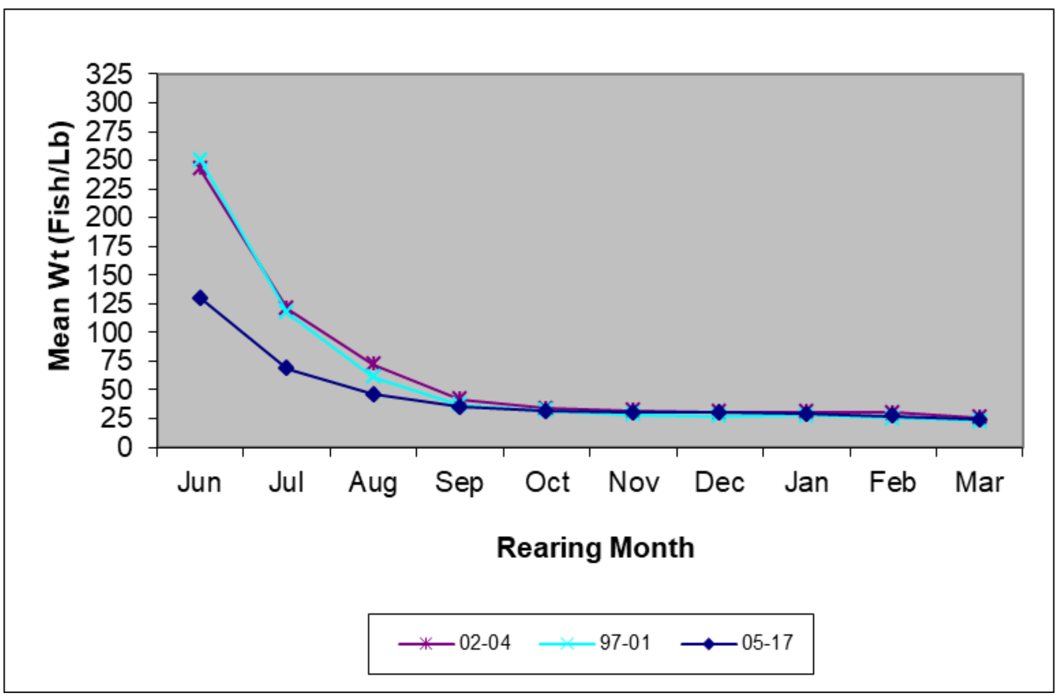

Figure 6. Mean Weight (fish/lb) of "standard growth treatment (Hi)" CESRF juveniles by brood year and growth month, 1997 - present.

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 17 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 Year	Acclimation Site Clark Flat	Easton	Jack Cr.	Pooled 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
2016	3.00	2.60	2.43	2.68

1. For the 1999, 2004 and 2005 broods, antibody problems were encountered and the USFWS was unable to process the samples.

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.

<u>Relevant Publications:</u>

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.

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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			Acclimation Site			
Year	Control[1]	Treatment[2]	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
2016	339,816	329,392	230,490	218,676	220,042	669,208
2017	351,656	359,013	244,236	233,449	232,984	710,669
Mean	362,359	359,098	242,874	238,773	248,064	717,899

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
2016	37,757	36,599	38,415	36,446	36,674
2017	39,073	39,890	40,706	38,908	38,831
Mean	42,415	41,954	41,761	40,418	41,916

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.

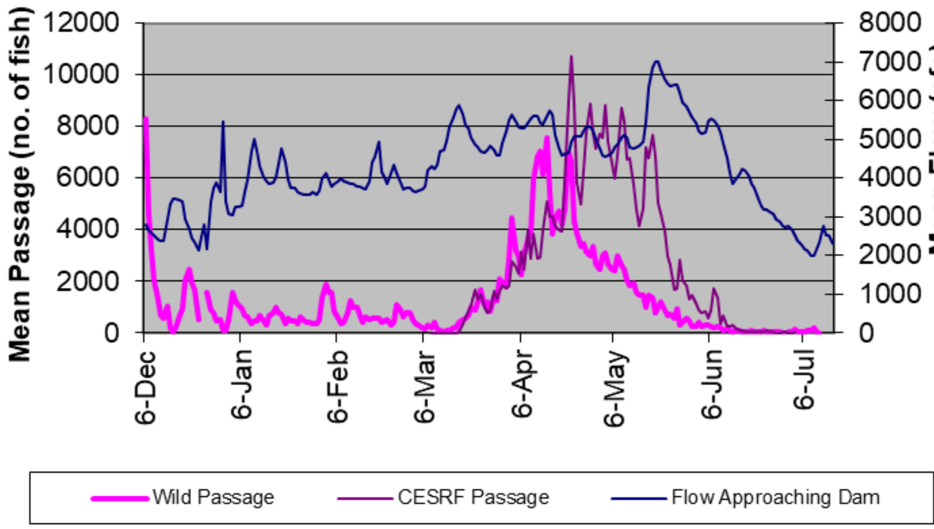

Figure 7. Mean flow approaching Prosser Dam versus mean estimated smolt passage at Prosser of aggregate wild/natural and CESRF spring Chinook for outmigration years 1999-2018.

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	584,016	187,669	48.6%	12,855	8,670	2.2%	4.6%
1998	2000[5]	4946	199,416	303,688	51.5%	8,240	9,782	4.1%	3.2%
1999	2001	1321	148,460	281,256	37.1%	1,764	864	1.2%	0.3%
2000	2002	5015	467,359	366,950	44.0%	11,434	4,819	2.4%	1.3%
2001	2003	3504	308,959	154,329	41.7%	8,597	1,251	2.8%	0.8%
2002	2004	2439	169,397	290,950	34.8%	3,743	2,557	2.2%	0.9%
2003	2005	1285	134,859	236,443	28.7%	2,746	1,020	2.0%	0.4%
2004	2006	5652	133,238	300,508	38.3%	2,802	4,482	2.1%	1.5%
2005	2007	4551	99,341	351,359	40.9%	4,295	5,004	4.3%	1.4%
2006	2008	4298	120,013	265,485	41.3%	6,004	10,577	5.0%	4.0%
2007	2009	5784	237,228	415,923	53.9%	7,952	7,604	3.4%	1.8%
2008	2010	3592	220,950	382,878	45.1%	7,385	8,036	3.3%	2.1%
2009	2011	9414	304,322	442,564	53.1%	3,766	3,606	1.2%	0.8%
2010	2012	8556	258,106	391,446	49.3%	6,602	5,592	2.6%	1.4%
2011	2013	4875	365,486	372,079	48.4%	7,343	4,160	2.0%	1.1%
2012	2014	4923	263,266	408,222	50.9%	3,969	1,932	1.5%	0.5%
2013	2015	1555	125,150	332,715	51.4%	3,368	3,139	2.7%	0.9%
2014	2016	5765	185,442	403,938	58.9%	1,787[6]	2,855[6]	1.0%[6]	0.7%[6]
2015	2017[6]	7804	208,929	273,248	41.7%				
2016	2018[6]	5652	218,880	290,644	43.4%				

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. Footnotes follow Table 42.

		Wild/Natural smolts tagged at Roza				
		Adult Returns at Age[1]				
Brood Year	Number 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	5	0	6	1.15%
2014	136	0	0		0	0.00%
2015	181	0				

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 Year	Number Tagged	Adult Returns at Age[1] 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	0	0	0.00%
2013	1,432	0	0	0	0	0.00%
2014	1,104	0	3		3	0.27%
2015	1,784	2				

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.74 in McCann et al. 2018). 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			MCN-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%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	0	--	--	--	--	--	--
2015	238	2.10	0.50	4.09	2.52	0.65	4.52
2016[B]	--	--	--	--	--	--	--
Arithmetic mean (incl. zeros)		2.91			3.32		
Geometric mean (excl. zeros)		2.43			2.69		

[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] Too few PIT-tags released to obtain reliable estimate of smolts arriving at MCN. Therefore, estimate of SAR not possible.
[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.78 in McCann et al. 2018). McNary smolts to Bonneville Dam adult returns.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks			MCN-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%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	12,855	0.58	0.48	0.69	0.84	0.72	0.98
2015	10,639	1.02	0.85	1.19	1.86	1.62	2.11
2016[B]	13,822	0.87	0.74	1.00	1.52	1.35	1.69
Arithmetic mean (incl. zeros)		1.34			1.86		
Geometric mean (excl. zeros)		1.13			1.55		

[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, 2-salt returns through September 15, 2018.

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	0	108	0.28%	10	59	0	69	0.18%
2013	38,278	90	110	0	200	0.52%	68	84	0	152	0.40%
2014	38,119	92	121		213	0.56%	64	66		130	0.34%
2015	38,029	15					6				

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 Year	Number Tagged[1]	Adult Returns to Roza Dam 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	51	3,149	0.43%
2012	764,373	172	2,274	12	2,458	0.32%
2013	608,477	718	2,386	0	3,104	0.51%
2014	647,111	644	1,511		2,155	0.33%
2015	616,918	219				

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, 1985-present.

	Tribal		Non-Tribal		River Totals			Harvest
Year	CESRF	Wild	CESRF	Wild	CESRF	Wild	Total	Rate[1]
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%
2017	217	201	750	104[2]	967	305	1,272	17.8%
2018	154	115	259	20[2]	413	136	548	15.2%
Mean	519	641	558	84	1,077	630	1,155	13.6%

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, 1985-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
1985	5,276	192	197	4,560	865	1,254	1,254	0	23.8%	23.8%
1986	13,624	282	858	9,439	1,340	2,479	2,479	0	18.2%	18.2%
1987	6,204	97	420	4,443	517	1,034	1,034	0	16.7%	16.7%
1988	5,718	366	442	4,246	444	1,252	1,252	0	21.9%	21.9%
1989	8,981	214	743	4,914	747	1,704	1,704	0	19.0%	19.0%
1990	6,990	354	514	4,372	663	1,531	1,531	0	21.9%	21.9%
1991	4,675	185	315	2,906	32	533	533	0	11.4%	11.4%
1992	6,233	103	405	4,599	345	853	853	0	13.7%	13.7%
1993	5,155	44	337	3,919	129	510	510	0	9.9%	9.9%
1994	2,265	88	126	1,302	25	239	239	0	10.6%	10.6%
1995	1,410	1	86	666	79	166	166	0	11.8%	11.8%
1996	5,909	6	320	3,179	475	801	801	0	13.6%	13.6%
1997	5,224	3	379	3,173	575	957	957	0	18.3%	18.3%
1998	2,889	3	165	1,903	188	356	356	0	12.3%	12.3%
1999	4,174	4	212	2,781	604	820	820	0	19.6%	19.6%
2000	28,825	58	1,824	19,101	2,458	4,340	4,214	126	15.1%	15.1%
2001	32,610	980	4,566	24,157	4,630	10,177	5,862	4,314	31.2%	29.3%
2002	25,751	1,300	3,333	15,828	3,108	7,740	2,946	4,794	30.1%	25.2%
2003	10,454	291	1,069	7,231	440	1,799	1,097	702	17.2%	16.1%
2004	24,644	1,041	2,716	16,847	1,679	5,436	3,166	2,269	22.1%	17.5%
2005	13,579	361	1,145	9,605	474	1,980	1,581	399	14.6%	13.7%
2006	12,457	318	1,191	6,600	600	2,108	1,230	878	16.9%	15.2%
2007	5,311	177	539	4,460	279	995	496	499	18.7%	16.4%
2008	13,269	1,273	2,479	9,311	1,532	5,284	1,629	3,655	39.8%	28.6%
2009	14,389	1,271	1,695	11,423	2,353	5,319	1,571	3,748	37.0%	27.1%
2010	19,676	1,728	3,755	13,782	1,741	7,224	1,897	5,327	36.7%	25.7%
2011	23,940	1,127	2,373	18,535	4,380	7,880	2,883	4,997	32.9%	24.3%
2012	17,622	871	1,914	12,626	3,320	6,105	2,518	3,587	34.6%	27.8%
2013	15,815	932	1,783	10,623	2,653	5,368	2,256	3,111	33.9%	27.3%
2014	16,985	703	1,927	11,857	2,171	4,801	1,936	2,865	28.3%	21.2%
2015	11,759	466	1,228	9,838	815	2,509	1,308	1,200	21.3%	16.3%
2016	10,372	465	1,273	7,290	444	2,182	1,146	1,036	21.0%	17.8%
2017	12,489	504	1,187	7,553	1,272	2,963	993	1,970	23.7%	15.3%
2018[1]	6,273	250	695	3,738	548	1,493	485	1,008	23.8%	17.3%
Mean	11,314	453	1,184	7,803	1,175	2,812	1,520	1,291	21.5%	18.6%

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. 6, 2018 for CESRF spring Chinook CWTs released in brood years 1997-2013 and Figure 8 shows recovery locations for CWTs recovered in marine fisheries 2008-2012. 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. The apparent increase for brood year 2013 may be attributable to a number of factors including: preliminary data or changes in fish distribution, ecological conditions, or sampling rates. CWT recovery data for brood year 2014 were considered too incomplete to report at this time.

Table 49. Marine and freshwater recoveries of CWTs from brood year 1997-2013 releases of spring Chinook from the CESRF as reported to the Regional Mark Information System (RMIS) 06 Nov, 2018.

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	942	0.9%
2011	5	186	2.6%	5	1019	0.5%
2012	4	73	5.2%	2	308	0.6%
2013[1]	9	50	15.3%	20	204	8.9%

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 2013 are considered preliminary or incomplete.

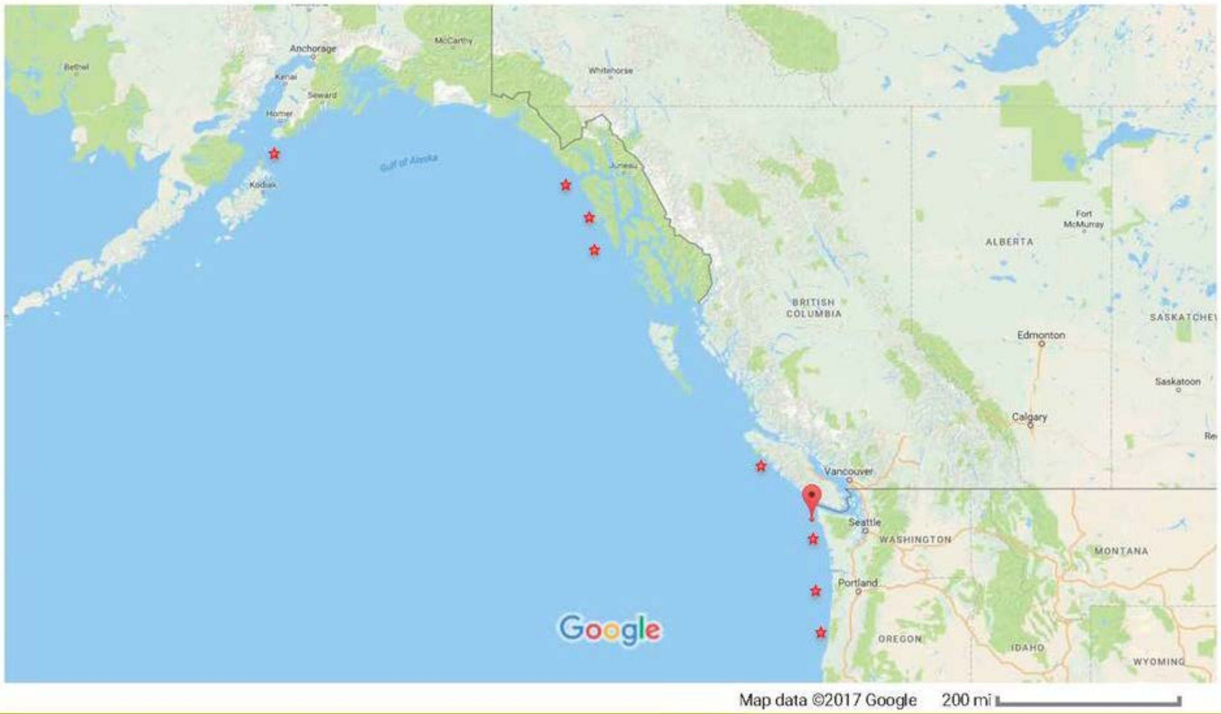

Figure 8. Marine recovery locations of coded-wire-tagged CESRF spring Chinook, recovery years 2008-2012.

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Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2017.

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.

Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2017.

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

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[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]
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

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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

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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

[1] All fish are progeny of wild/natural parents unless denoted as HC 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 2006-2017.

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

[1] All fish are progeny of wild/natural parents unless denoted as HC 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. PRO=BioPro diet, VIT=BioVita diet, Bio-Oregon products.

[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]
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

[1] All fish are progeny of wild/natural parents unless denoted as HC 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. PRO=BioPro diet, VIT=BioVita diet, Bio-Oregon products.

[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]
2016	CLE01	CFJ05	PRO	WN	2.4	Right	Red	Snout	3/15/2018	5/15/2018	190490	2,000	35,447	37,354
2016	CLE02	CFJ06	VIT	WN	2.4	Left	Red	Snout	3/15/2018	5/15/2018	190491	2,000	35,568	37,468
2016	CLE03	ESJ05	PRO	WN	2.4	Right	Green	Snout	3/15/2018	5/15/2018	190492	2,000	36,330	38,195
2016	CLE04	ESJ06	VIT	WN	2.4	Left	Green	Snout	3/15/2018	5/15/2018	190493	2,000	35,002	36,943
2016	CLE05	CFJ01	PRO	HC	2.7	Right	Red	Posterior Dorsal	3/15/2018	5/15/2018	190494	4,000	36,189	40,043
2016	CLE06	CFJ02	VIT	HC	2.7	Left	Red	Posterior Dorsal	3/15/2018	5/15/2018	190495	4,000	37,147	41,026
2016	CLE07	JCJ03	PRO	WN	2.4	Right	Orange	Snout	3/15/2018	5/15/2018	190496	2,000	36,599	38,400
2016	CLE08	JCJ04[3]	VIT	WN	2.4	Left	Orange	Snout	3/15/2018	5/15/2018	190497	2,000	34,080	54,569
2016	CLE09	JCJ01	PRO	WN	2.5	Right	Orange	Snout	3/15/2018	5/15/2018	190498	2,000	34,189	36,048
2016	CLE10	JCJ02[3]	VIT	WN	2.5	Left	Orange	Snout	3/15/2018	5/15/2018	190499	2,000	32,004	52,475
2016	CLE11	CFJ03	PRO	WN	2.6	Right	Red	Snout	3/15/2018	5/15/2018	190501	2,000	36,470	38,334
2016	CLE12	CFJ04	VIT	WN	2.6	Left	Red	Snout	3/15/2018	5/15/2018	190502	2,000	34,372	36,265
2016	CLE13	ESJ03	PRO	WN	2.5	Right	Green	Snout	3/15/2018	5/15/2018	190503	2,000	31,448	33,380
2016	CLE14	ESJ04	VIT	WN	2.5	Left	Green	Snout	3/15/2018	5/15/2018	190504	2,000	31,093	33,025
2016	CLE15	JCJ05	PRO	WN	2.5	Right	Orange	Snout	3/15/2018	5/15/2018	190505	2,000	36,688	38,550
2016	CLE16	JCJ06[3]	VIT	WN	2.5	Left	Orange	Snout	3/15/2018	5/15/2018	190506	2,000	35,244	0
2016	CLE17	ESJ01	PRO	WN	2.5	Right	Green	Snout	3/15/2018	5/15/2018	190507	2,000	37,553	39,512
2016	CLE18	ESJ02	VIT	WN	2.5	Left	Green	Snout	3/15/2018	5/15/2018	190508	2,000	35,689	37,621

[1] All fish are progeny of wild/natural parents unless denoted as HC 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. PRO=BioPro diet, VIT=BioVita diet, Bio-Oregon products.

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

[3] Due to problems at the acclimation site, Jack Creek raceway 6 was closed and all fish transferred and split between raceways 2 and 4 in February 2018.

Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2017.

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]
2017	CLE01	CFJ01	PRO	WN	3.4	Right	Red	Snout	3/15/2019	5/9/2019	190535	2,000	38,689	40,527
2017	CLE02	CFJ02	VIT	WN	3.4	Left	Red	Snout	3/15/2019	5/9/2019	190536	2,000	39,792	41,650
2017	CLE03	ESJ05	PRO	WN	3.5	Right	Green	Snout	3/15/2019	5/9/2019	190537	2,000	34,646	36,556
2017	CLE04	ESJ06	VIT	WN	3.5	Left	Green	Snout	3/15/2019	5/9/2019	190538	2,000	35,655	37,493
2017	CLE05	JCJ05	PRO	WN	3.1	Right	Orange	Snout			190539	2,000	35,118	0
2017	CLE06	JCJ06	VIT	WN	3.1	Left	Orange	Snout			190540	2,000	36,475	0
2017	CLE07	ESJ03	PRO	WN	3.3	Right	Green	Snout	3/15/2019	5/9/2019	190541	2,000	37,843	39,737
2017	CLE08	ESJ04	VIT	WN	3.3	Left	Green	Snout	3/15/2019	5/9/2019	190542	2,000	38,689	40,579
2017	CLE09	CFJ03	PRO	WN	3.4	Right	Red	Snout	3/15/2019	5/9/2019	190543	2,000	40,551	42,423
2017	CLE10	CFJ04	VIT	WN	3.4	Left	Red	Snout	3/15/2019	5/9/2019	190544	2,000	41,529	43,357
2017	CLE11	JCJ03	PRO	WN	3.3	Right	Orange	Snout	3/15/2019	5/7/2019	190545	2,000	38,702	58,941
2017	CLE12	JCJ04	VIT	WN	3.3	Left	Orange	Snout	3/15/2019	5/7/2019	190546	2,000	39,368	60,266
2017	CLE13	ESJ01	PRO	WN	3.3	Right	Green	Snout	3/15/2019	5/9/2019	190547	2,000	37,502	39,385
2017	CLE14	ESJ02	VIT	WN	3.3	Left	Green	Snout	3/15/2019	5/9/2019	190548	2,000	37,829	39,699
2017	CLE15	CFJ05	PRO	HC	3.2	Right	Red	Posterior Dorsal	3/15/2019	5/9/2019	190549	4,000	33,390	37,153
2017	CLE16	CFJ06	VIT	HC	3.2	Left	Red	Posterior Dorsal	3/15/2019	5/9/2019	190550	4,000	35,413	39,126
2017	CLE17	JCJ01	PRO	WN	3.3	Right	Orange	Snout	3/15/2019	5/7/2019	190551	2,000	36,661	56,934
2017	CLE18	JCJ02	VIT	WN	3.3	Left	Orange	Snout	3/15/2019	5/7/2019	190552	2,000	35,946	56,843

[1] All fish are progeny of wild/natural parents unless denoted as HC 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. PRO=BioPro diet, VIT=BioVita diet, Bio-Oregon products.

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

[3] Due to problems at the acclimation site, Jack Creek raceways 5&6 were closed and all fish transferred and split between raceways 1-4 in February 2019.

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Appendix C
2018 Annual Chandler Certification for
Yearling Outmigrating Spring Chinook Smolt

Doug Neeley, Consultant to the Yakama Nation

Introduction

Beginning in 1999, Upper Yakima hatchery smolt were released from three different acclimation sites within the Upper Yakima Subbasin. Smolt released from these sites were spawned from adults returning to the Upper Yakima and sampled from the Roza Dam (Roza) fish ladders. All released hatchery smolt were either tagged with elastomer tags or with Passive Integrated Transponders (PIT). A monitoring site was set up at the bypass system directing fish diverted above Prosser Dam (Prosser) on the main-stem Yakima River into Chandler Irrigation Canal and back into the river.

The purpose of this monitoring effort was to determine what effect, if any, the production and release of hatchery smolt into the Upper Yakima had on the production of wild smolt and on the relative frequency of the three stock sources of wild smolt (Naches, American, and Upper Yakima Rivers).

Methods of estimating smolt production (the number of smolt passing Prosser) are discussed in a later section entitled *Methodology*.

Passage Estimates

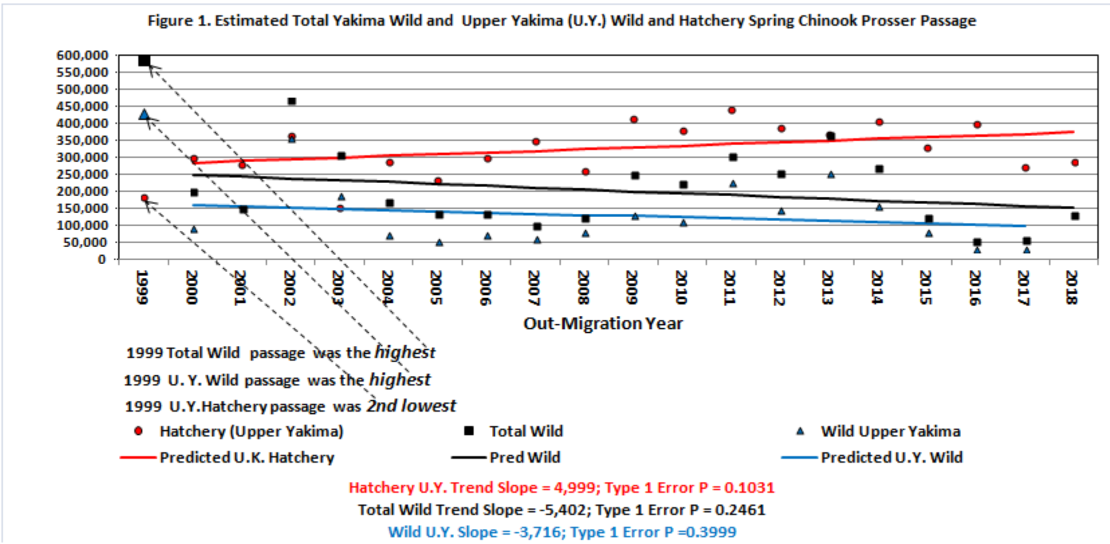
Juvenile Prosser-passage estimates are given in Table 1. by stock of wild origin (Naches, American, and Upper Yakima Rivers) and of hatchery Upper Yakima River origin.

Table 1. Estimated Wild Stock and Hatchery-Origin Stock Smolt Passage at Prosser Dam

Brood Year (BY)	Outmigration Year	Wild Stock Estimates: Total Wild	Naches	American	Upper Yakima	Hatchery Upper Yakima Estimates	Total = Total Wild & Hatchery
1997	1999	584,016	93,427	63,000	427,588	187,669	771,685
1998	2000	199,416	55,724	50,934	92,757	303,688	503,104
1999	2001	148,460	genetic samples not taken			281,256	429,716
2000	2002	467,359	92,323	17,835	357,201	366,950	834,309
2001	2003	308,959	74,498	42,867	191,594	154,329	463,288
2002	2004	169,397	59,978	35,800	73,619	290,950	460,347
2003	2005	134,859	45,321	35,564	53,974	236,443	371,301
2004	2006	133,238	49,947	7,882	75,409	300,508	433,746
2005	2007	99,341	26,684	11,103	61,554	351,359	450,700
2006	2008	120,013	32,589	6,811	80,613	265,485	385,499
2007	2009	237,228	80,756	27,498	128,974	415,923	653,151
2008	2010	220,950	77,397	30,354	113,198	382,878	603,828
2009	2011	304,322	58,904	17,882	227,536	442,564	746,886
2010	2012	258,106	81,483	23,609	153,014	391,446	649,552
2011	2013	365,486	85,577	25,681	254,228	372,079	737,565
2012	2014	263,266	79,450	28,622	155,194	408,222	671,488
2013	2015	125,150	29,885	13,769	81,496	332,715	457,865
2014	2016	185,442	57,657	15,378	112,407	403,938	589,380
2015	2017	208,929	62,190	24,455	122,285	273,248	482,178
2016	2018	205,679	genetic samples not yet available			290,644	496,323

Hatchery versus Wild Prosser Passage and Hatchery Survival

Figure 1. presents total wild, Upper Yakima wild, and Upper Yakima hatchery juvenile Prosser-passage estimates from Table 1 with predicted trends based on linear regressions of the passage estimates on out-migration years. The estimates from the first year, 1999, were omitted from the passage-trend estimates. That year had the highest wild passage estimates and the second lowest hatchery passage estimate for the years analyzed. In that year, only of 14 of the 18[1] raceways were used for hatchery production; this may explain why the Prosser hatchery-passage estimate in 1999 was so low.



The hatchery estimated trend (red in Figure 1.) shows a positive average increase in smolt passage of a 4,999/year which is not significant at the five-percent significance level based on a two-sided test (Type 1 Error P = 0.1031, Appendix Table D.1.a.). A concern would be whether a true positive increase in hatchery smolt passage would have an associated true negative decrease in wild passage. The one-sided test for a positive hatchery trend has a significance level of nearly 5% (Type 1 Error P = 0.0516 = 0.1031/2). However, the wild estimated Prosser passage trends, while negative (-5,402/year for total wild stock and -3,716 for Upper Yakima wild stock), were far from significant (respective Type 1 Errors = 0.2461 and 0.3999 from respective Appendix Tables D.1.b. and D.1.c.)

Probably a better assessment of wild and hatchery trends is to examine the hatchery and wild percentages changes over years (hatchery plus wild). Table 2. presents the hatchery juvenile percentages of total Prosser passage [Hatchery/(Hatchery + Total Wild)] and of Upper Yakima Prosser passage [Hatchery/(Hatchery + Upper Yakima Wild)] estimated from Table 1, the wild survivals being 1 – Hatchery Survivals. Figure 2, presents the hatchery survival estimates in graphical form along with trend estimates based on least squares regression of the percentages on out-migration years.

[1] **There were two other release years in which releases were made from less than 18 raceways, 2000 and 2005 with releases from 16 and 14 raceways, respectively.**

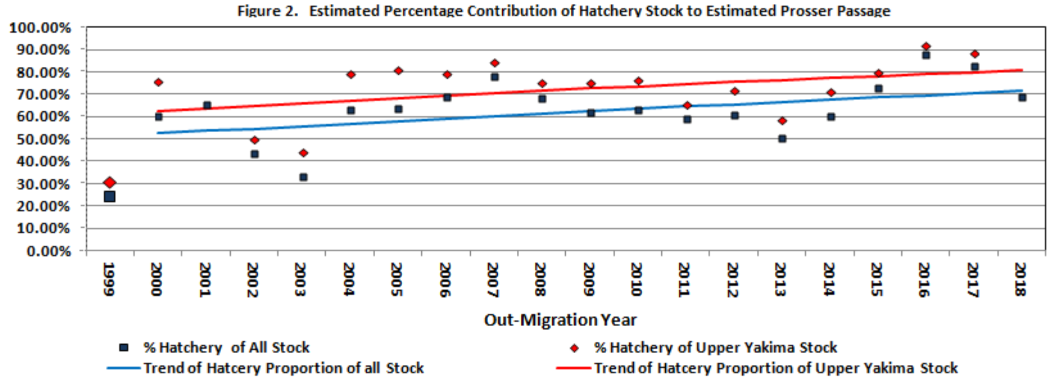
Table 2. Percentages of Wild and Hatchery* Juvenile Prosser-Passage Estimates

		Total Yakima Return		Upper Yakima Return	
Brood Year (BY)	Release Year	% Hatchery of All Stock	% Wild** Yakima of All Stock	% Hatchery of Upper Yakima Stock	% Wild of Upper Yakima
1997	2005	24.32%	75.7%	30.5%	69.5%
1998	2000	60.4%	39.6%	76.6%	23.4%
1999	2001	65.5%	34.5%	genetic samples not taken	
2000	2002	44.0%	56.0%	50.7%	49.3%
2001	2003	33.3%	66.7%	44.6%	55.4%
2002	2004	63.2%	36.8%	79.8%	20.2%
2003	2005	63.7%	36.3%	81.4%	18.6%
2004	2006	69.3%	30.7%	79.9%	20.1%
2005	2007	78.0%	22.0%	85.1%	14.9%
2006	2008	68.2%	31.8%	76.0%	24.0%
2007	2009	62.4%	37.6%	75.7%	24.3%
2008	2008	63.4%	36.6%	77.2%	22.8%
2009	2011	59.3%	40.7%	66.1%	33.9%
2010	2012	60.8%	39.2%	72.4%	27.6%
2011	2013	50.4%	49.6%	59.4%	40.6%
2012	2014	60.4%	39.6%	72.1%	27.9%
2013	2015	73.0%	27.0%	80.6%	19.4%
2014	2016	88.3%	11.7%	92.6%	7.4%
2015	2017	82.7%	17.3%	89.1%	10.9%
2016	2018	68.9%	31.1%	Not yet available	

* All Hatchery smolt are Upper-Yakima Stock

** Includes American, Naches, and Upper-Yakima Stock

Figure 2. Estimated Percentage Contribution of Hatchery Stock to Estimated Prosser Passage



Red line: Significant trend of Hatchery Percentage of Upper Yakima Stock from BY 1998 (1.05%/year, Type 1 Error P = 0.0483)*

Blue line: Non-significant trend of Hatchery Percentage of All Stock from BY 1998 (1.02%/Year, Type 1 Error P = 0.1069)

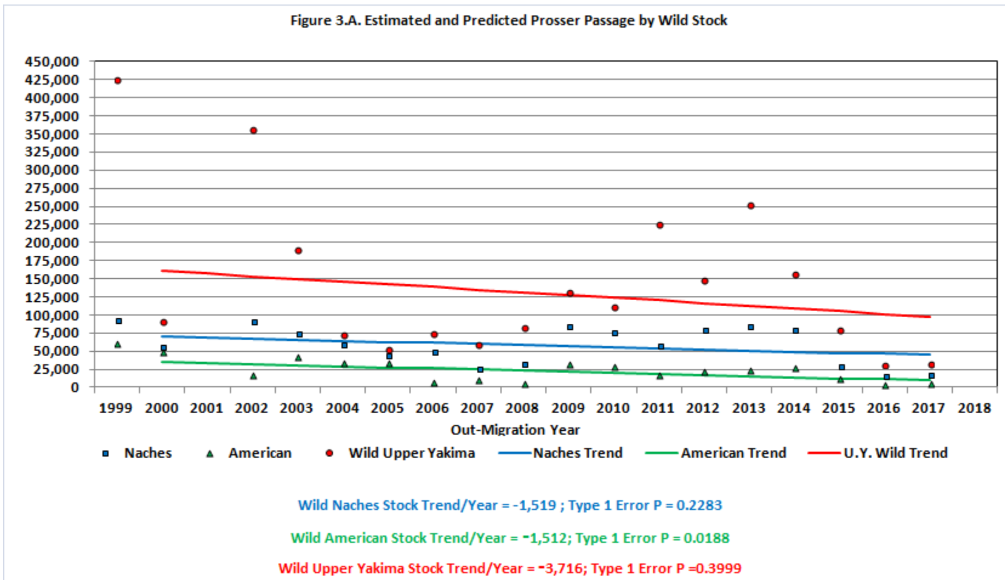
* Note: 2018 data on Wild Stock composition not yet available

Again the out-migration year 1999 survivals are left out of the trend assessment over years, and it can be seen from Figure 1. that the 1999 estimates are clearly lower than the percentages in subsequent years. The trend estimates are based on performing a weighted logistic analysis of variance of the survival on outmigration year, the weights being the respective totals (wild plus hatchery). As with the increase in hatchery passage in Figure 1., the hatchery percentages in Figure 2. are trending upward over time. The trend increases per year are slightly more than one percent (1.05%/year based on Upper Yakima Prosser Passage and 1.02%/year based on Total Yakima Prosser passage); and, as shown in the Figure 2., the positive trend survival is significant at the 5% level based on Upper Yakima wild stock but is not quite significant at the 10% level based on all total wild passage (Appendix Tables D.2.a. and D.2.b.). (Note: For the Upper Yakima survival trend analysis, the 2018 estimates were not available because genetic analysis for stock assignment was not yet available, and the 2001 estimates were not available because of a freezer malfunction rendering the samples unsuitable for genetic assignment.)

Comparisons among the Survivals of Three Yakima Basin Wild Stock

Another concern expressed in the introduction of a hatchery program into the Upper Yakima basin is whether the stock distribution of wild smolt production would be affected, either by a relative decrease in the wild production or a relative ultimate increase in the wild production in the Upper Yakima.

Figure 3.A. summarizes in graphical form the three wild stock's juvenile Prosser passage estimates from Table 1. and presents trends over years based on least squares regressions of the wild stock's passages on out-migration year[2].



Referring to the figure and statistical summary given above, all three stock experienced an estimated average yearly reduction in smolt passage. The wild Upper Yakima stock's average trend of -3,716/year was the largest of the three wild, but the estimate was not significantly different from a no trend hypotheses (Type 1 Error of 0.3999, Appendix D.1.c.), reflecting the large variation of red data points around the red trend line[3]. The Naches and American stock trend lines were nearly equal (respectively -1,519 and -1,512 per year); however, only the American stock's average reduction was significant different from a zero trend (Appendix Tables D.1.d.and D.1.e. for respective American and Naches analyses with respective Type 1 Error probability estimates of 0.0188 and 0.2283).

A better assessment of relative wild-stock assessment over time would be the change in their percent composition. Table 3. presents passage estimates of wild Naches, American, and Upper Yakima stock as percentages of total wild juvenile Prosser Passage. Figure 3.B. presents these percentages in graphical form as well as presenting trends estimated by weighted logistic regression of each stock's survival percentages on out-migration years, the weights being the total yearly wild passages with Release-Year 1999 excluded. The estimated yearly trends are given below the figure along with estimated Type 1 Error probabilities based on the hypothesis no true linear trend.

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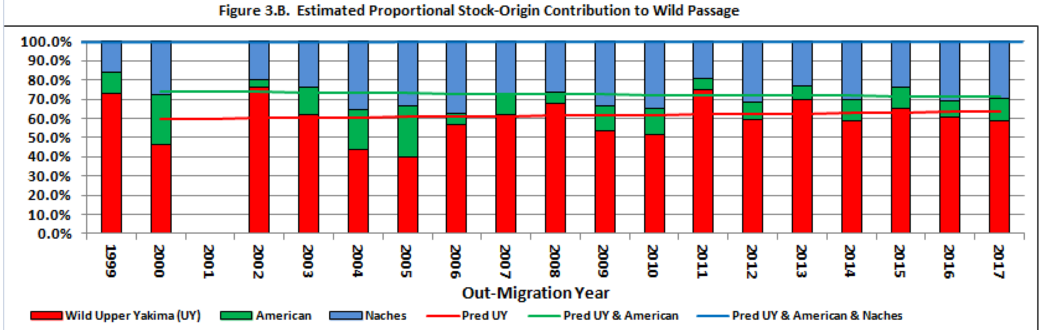
[2] For the purposes of comparing wild stock, the 1999 release year was included.

[3] With the juvenile-passage year of 1999 inclusion, the average trend line estimate is greater (-4.479 and nearly significantly near 0, Type 1 Error of 0.0801)

Table 3. American, Naches, Upper-Yakima Stock Percentages of Prosser Passage of Wild Stock

Brood Year (BY)	Outmigration Year	Naches	American	Upper Yakima
1997	1999*	16.0%	10.8%	73.2%
1998	2000	27.9%	25.5%	46.5%
1999	2001		no DNA testing	
2000	2002	19.8%	3.8%	76.4%
2001	2003	24.1%	13.9%	62.0%
2002	2004	35.4%	21.1%	43.5%
2003	2005	33.6%	26.4%	40.0%
2004	2006	37.5%	5.9%	56.6%
2005	2007	26.9%	11.2%	62.0%
2006	2008	27.2%	5.7%	67.2%
2007	2009	34.0%	11.6%	54.4%
2008	2010	35.0%	13.7%	51.2%
2009	2011	19.4%	5.9%	74.8%
2010	2012	31.6%	9.1%	59.3%
2011	2013	23.4%	7.0%	69.6%
2012	2014	30.2%	10.9%	58.9%
2013	2015	23.9%	11.0%	65.1%
2014	2016	31.1%	8.3%	60.6%
2015	2017	29.8%	11.7%	58.5%
2016	2018		Not yet available	

Figure 3.B. Estimated Proportional Stock-Origin Contribution to Wild Passage



Area between bottom border (0%) and red line, decreases over years for Upper Yakima stock (0.22%/year, two-sided Type 1 Error P = 0.7004)
Area bewteen red line and green line decreases over time for American stock (-0.39%/year, two-sided Type 1 Error P = 0.2291)
Area between green line and top (100%) border increases for Naches stock (0.18%/year, two-sided Type 1 Error P = 0.5885)

Referring to the above figure's text, no trend is even approaching the 5% significance level under the hypothesized zero trend (Appendix Tables D.3.a. through D.3.c.). The positive 0.22% change/year in the Upper Yakima corresponds to a negative 0.22% change/year in the combined American and Naches proportions, the low trends indicating that the hatchery program in the Upper Yakima has had no or very little effect on the stock distribution of wild juveniles from outside the Upper Yakima basin after the first year of hatchery release.

Methodology

The four steps listed in the summary are detailed below:

Step 1: A timer gate, when opened, directs the Prosser bypass flow from Chandler Canal into the monitoring facility in which smolt are tallied. The timer-gate rate (TR) settings vary over days based on the number of the sampled smolt entering the 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 the 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.

Step 2: The proportions of all PIT- tagged smolt released above Prosser and detected at mid-Columbia dams that were previously detected in the Chandler Canal bypass serve as estimates of bypass-detection efficiency. The method of estimating detection efficiency is presented in this report as Appendix B: *Methods of Estimating Smolt Survival and Passage*. Note: Four estimators were used, and the one chosen is a pooling of stratified estimates from the detection efficiencies from McNary, John Day, and Bonneville Dams on the Columbia Rivers, the strata being established for each of these dams by combining daily estimates that are deemed similar using Logistic stepwise regression of the daily detection efficiencies on Julian-date indicators that take the value 1 if the estimate is from a given date or a later date or 0 if the estimate was from an earlier date.

Step 3: On a daily basis the sampled Spring Chinook smolt were tallied as to source (hatchery-spawned or wild). On those days when the facility was shut down, linear interpolation was used to impute values to the missing information. The daily actual and imputed tallies were divided by the sample rates from Step 1. The sample-rate-adjusted tallies for each source were added over days within each of five time periods (discussed later in Step 4) and were then divided by the respective period's detection efficiencies from Step 2. The wild and hatchery smolt were tallied separately. The wild smolt were identified by the lack of a coded-wire tag. The hatchery smolt were identified by the presence of an elastomer tag. Expanded elastomer-tagged tallies were then divided by the proportion of hatchery smolt that were elastomer tagged to obtain estimates of the passage of all hatchery smolt.

Step 4: Within five time periods (pre-March, March, April, May, post-May), the tallied sample wild smolt from Step 3. were subsampled and genetically classified by the Molecular Genetics Lab of the Washington Department of Fish and Wildlife (WDFW) as to brood origin (stock from the American, Naches, and Upper Yakima Rivers). Within each period, the brood-origin proportions of those sampled smolt were computed by WDFW (Appendix Table B.). The wild passage estimates within each period from Step 3 were multiplied by each of the period's brood-source proportions. The brood's time-period wild passage estimates were then added over the time periods to estimate brood's total passages as were the hatchery passage estimates.

Step 5. The estimates of hatchery passage were clearly biased in a couple of years. And all expanded passage estimates were calibrated to adjust for the potential bias for all stock in all years. Daily PIT-tag detection counts of hatchery smolt in the Chandler bypass were tallied within the five time-strata and were expanded by the detection efficiencies. Since the bypass detector was located above the timer gate, both sampled and non-sampled smolt were detected and no sample-rate expansion was required[4]. The PIT-tag estimates were divided by the proportion of smolt PIT-Tagged at the hatchery to provide a second estimate of hatchery Prosser passage. (Note: Hatchery smolt were either elastomer-tagged or PIT-tagged but not both.)

Step 6. The PIT-tagged passage estimate from Step 5 was divided by elastomer-tagged estimate from Step 3 to estimate a calibration number. And the wild estimates from Step 3 were multiplied by this number to obtain the calibrated wild estimate used in this report. The hatchery estimate from Step 5 served as the hatchery estimates used in this report.

Wild Juvenile Passage Estimators' Correlations with Adult Returns

Table 4 serves as a definitional reference in evaluating Pearson's correlation estimates between wild juvenile passage and adult return.

Table 4. 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 effect of the spawner number on wild juvenile Prosser passage and return is assessed.

[4] This method was actually performed for all brood-year tallies. The elastomer-tag basis was selected over the PIT-tad basis based on correlating juvenile-passage estimates with returns. The elastomer-based estimates for all other years of passage were used except for 2016 when the estimates were clearly biased.

Upper Yakima Wild Juvenile Prosser Passage and Adult Return to Roza

Table 5.A. presents the brood-year Upper Yakima Roza escapement[5] of the parental generation in addition to Upper Yakima Prosser juvenile passage and Roza return. Tables 5.B. and 5.B. present the Pearson's Correlation estimates among these three variables.

Table 5.A. Wild Upper-Yakima Escapement , Wild Upper Yakima Juvenile Prosser Passage and Return to Roza

Brood Year	Out-migration Year	Roza Escapement*	Upper Yakima Juvenile Prosser Passage	Roza Returns**
1997.00	1999	1,184	427,588	5,540
1998.00	2000	387	92,795	2,741
1999.00	2001	966		917
2000.00	2002	11,660	357,201	7,867
2001.00	2003	11,798	191,594	5,587
2002.00	2004	8,044	73,619	2,116
2003.00	2005	3,258	53,974	1,245
2004.00	2006	10,287	75,399	1,611
2005.00	2007	5,685	61,498	2,552
2006.00	2008	3,364	83,711	3,488
2007.00	2009	2,309	133,569	3,877
2008.00	2010	4,334	113,372	3,655
2009.00	2011	7,038	227,072	2,294
2010.00	2012	8,374	149,038	4,155
2011.00	2013	8,584	254,261	4,498
2012.00	2014	5,476	157,679	2,618
2013.00	2015	4,813	80,284	1,773
2014.00	2016	6,728	32,420	986
2015	2017	5,466	33,328	60
2016	2018	4,239		

Note: Shaded cells reflect no or incomplete estimates

* Table 6) in Bosch B.2018, Run Size Forcast for Yakima River Adult Spring Chinook 2019

** Table 4) in Bosch B.2018, Run Size Forecast for Yakima River Adult Spring Chinook 2019

Table 5.B. BY 1997-2000,2002-2011 Wild Upper Yakima Spawner, Juvenile Passage, and Roza Return Correlations

	Upper-Yakima Escapement	Juvenile Prosser Passage	Upper-Yakima Returns
Escapement	1.000		
Passage	0.140	1.000	
Returns	0.291	0.802	1.000
Type 1 p*	0.1396	<0.0001	

Table 5.C. BY 1997-2000,2002-2011 Wild Juvenile Passage and Roza Return Correlations adjusted for Escapement

	Juvenile Prosser Passage	Upper-Yakima Returns
Passage	1.000	
Returns	0.803	1.000
Type 1 p*	<0.0001	

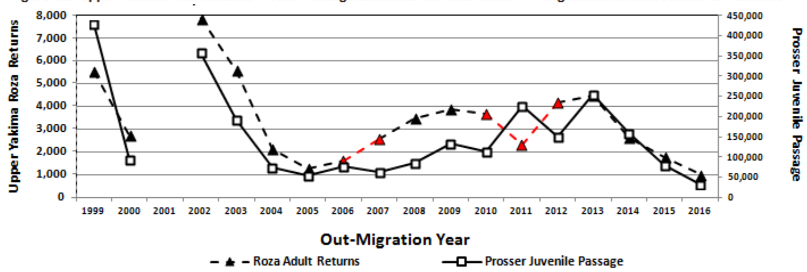
* 1-sided test for correlation > 0

From Table 5.B., it can be seen that Upper Yakima return has a low correlation with escapement (correlation with Upper Yakima escapement correlation = 0.291, Type 1 Error P <0.1396) and has a significantly and moderately high correlation with Prosser juvenile passage (correlation = 0.802, Type 1 Error P < 0.0001). The question arises as to what degree, if any, is the contribution with juvenile passage affected by the brood's spawner[5] number. Table 5.C. is an attempt to answer that question. The table adjusts Juvenile passage correlation with return for the correlation between juvenile passage and escapement and for the correlation between return and escapement. The adjusted correlation of juvenile passage with return number is hardly affected by spawner number, the rounded moderately-high unadjusted correlation being 0.802 (Table 5.B.) and the adjusted estimate being 0.803 (Table 5.C.). This indicates that the moderately high Upper Yakima juvenile Roza passage correlation with return is not indirectly tied to the number of naturally spawning brood fish that produced those juveniles. The Upper Yakima juvenile-passage/adult-return scatter diagram (Figure 4.A.) indicates a rather consistent positive linear relation over the ranges of the data points.

[5] **Escapement measures are taken as a surrogate of spawner number**

Figure 4.B. presents the Upper Yakima juvenile passage and return trends over years. As can be seen, the year to year trends are quite consistent with only three year-to-year trend sets (indicated in red) differing in direction.

Figure 4.B. Upper-Yakima Wild Juvenile Prosser-Passage Estimates and Roza-Return* Assignments and associated correlations



* From Table 4) in Bosch B. 2018, Run Size Forecast for Yakima River Adult Spring Chinook 2019 from where Jacks are assigned to Brood Year + 3 and Adults to Brood Year + 4

NOTE: Red adult trend lines have opposite directions than do associated juvenile passage trend lines

Sign test of same directional trends	
Same Yearly Trends	12
Total Yearly Trends	15
Percentage	80.0%
1-sided P	0.1051

Total Wild Juvenile Prosser Passage and Adult Return to Prosser

Table 6.A. presents the brood-year Prosser escapement[6] of the parental generation in addition to Total Juvenile Prosser Passage and Prosser return. Total Tables 5.B. and 5.B. present the Pearson's Correlation estimates among these three variables. Prosser estimates include all three wild stock (Upper Yakima, Naches, and American River stock).

Referring to Tables 6.A. through 6.C., the findings for Prosser juvenile passage and return of the combined Naches, American, and Upper Yakima wild stock are similar to those for the Upper Yakima Prosser passage and Roza returns (Table 5.A.through through 5.C.).

Table 6.A. Total Wild Escapement, Juvenile Passage and Return to Prosser

Brood Year	Out-migration Year	Prosser Escapement*	Total Juvenile Prosser Passage	Prosser Returns**
1997	1999	2,337	584,016	12,808
1998	2000	1,307	199,476	7,283
1999	2001	1,439	148,460	4,090
2000	2002	15,976	467,359	11,128
2001	2003	17,916	308,959	7,731
2002	2004	11,113	169,397	3,850
2003	2005	5,933	134,859	2,195
2004	2006	12,893	133,218	3,687
2005	2007	7,617	99,265	4,089
2006	2008	5,050	123,735	5,118
2007	2009	3,308	250,846	7,610
2008	2010	5,922	221,228	6,739
2009	2011	8,172	303,711	4,167
2010	2012	9,875	252,029	6,148
2011	2013	11,644	365,468	7,002
2012	2014	7,383	267,433	3,941
2013	2015	6,352	123,289	3,736
2014	2016	7,882	53,478	1,928
2015	2017	7,569	57,051	72
2016	2018	5,613	131,489	

Note: Red font entries indicate estimates resulting in high correlations between juvenile and adult return passages which both have the two highest brood returns and juvenile passage

Note: Shaded cells reflect no or incomplete estimates

* Table 10) in Bosch B.2018, Run Size Forecact for Yakima River Adult Spring Chinook 2019

** Table 3) in Bosch B.2018, Run Size Forecast for Yakima River Adult Spring Chinook 2019

[6] Escapement measures are taken as a surrogate of spawner number

Table 6.B. BY 1997-2014 Upper Yakima Spawner, Hatchery Juvenile Passage, and Prosser Return Correlations

	Prosser Escapement	Juvenile Prosser Passage	Prosser Returns
Escapement	1.000		
Passage	0.180	1.000	
Returns	0.070	0.879	1.000
Type 1 p*	0.462	<0.0001	
BY 1997 and 2002 Removed		0.676	
Type 1 p*		0.0005	

Table 6.C. BY 1997-2014 Hatchery Juvenile Passage and Prosser Return Correlations adjusted for Escapement

	Juvenile Prosser Passage	Prosser Returns
Passage	1.000	
Returns	0.883	1.000
Type 1 p*	<0.0001	

* 1-sided test for correlation > 0

While the Table 6.B. correlation between escapement and juvenile passage is far from significantly different than and very nearly 0, unlike that for the Upper Yakima stock (Table 5.B.); the Table 6.B. and 6.C. estimated total wild juvenile-passage adult-return correlations are actually higher than those of Upper-Yakima estimates (Table 5.B. and 5.C). However, two out-migration years, 1999 and 2001, are driving these higher correlations in Figure 6.A and 6.B. Removing these two out-migration year's estimates (red text estimates in Table 6.A.) resulted in a reduced juvenile-passage adult-return correlation in Figure 6.B. from the moderately highly value of 0.879 to a moderate estimate of 0.676, and a reduced juvenile-passage adult-return correlation in Figure 6.C. from the moderately highly value of 0.883 to a moderate estimate of 0.692.

Figure 5.A. presents a scatter diagram of combined-stock juvenile passage at Prosser and adult return to Prosser.

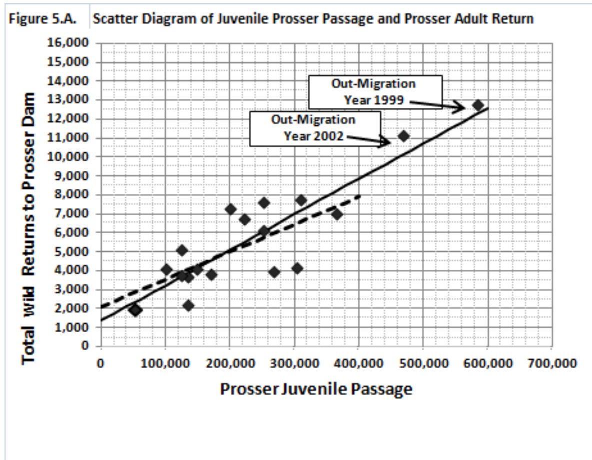
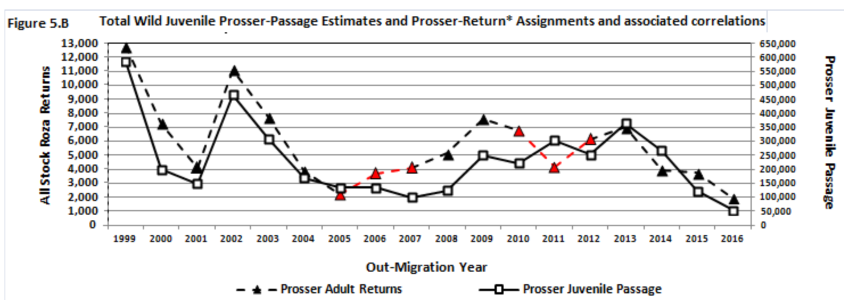


Figure 5.B. presents the combined-stock juvenile Prosser passage and Prosser return trends over years. The year-to-year trends are quite not quite as consistent as those for the Upper Stock presented in Figure 4.B., with 4 instead of 3 trend sets differing in direction.



* From Table 3) in Bosch B. 2018, Run Size Forecast for Yakima River Adult Spring Chinook 2019 from where Jacks are assigned to Brood Year + 3 and Adults to Brood Year + 4

NOTE: Red adult trend lines have opposite directions than do associated juvenile passage trend lines

Sign test of same directional trends	
Same Yearly Trends	13
Total Yearly Trends	17
Percentage	76.5%
1-sided P	0.0245

It should be noted that the Total wild smolt trend estimates used include 17 data sets; whereas the Table 5. estimates include 15 data sets, the non-genetic sampling in 2001 eliminating the 2000-2001 and the 2002-2003 trends.

In spite of the fewer data points, the Upper Yakima measures of escapement (Tables 5.A. and 5.B.) are more accurate measure than those of combined escapement of Upper Yakima, Naches, and American (Tables 6.A. and 6.B.) because the former is based on actual total adults passing Rosa Dam whereas the latter is based on reconstructed counts.

The magnitudes of the juvenile passage and return correlations in Tables 5.B and 5.C and in Tables 6.B. and 6.C are worth emphasizing. All correlation measures between juvenile passage and adult return indicate over 64% than of the wild-stock variance in returns are associated with the number of those fish outmigrating as juveniles (respective percentages are the squares of the correlations given in Table 5.C and 6.C. multiplied by 100; i.e. R-square values).

Appendix A (of Appendix C)

The following appendix tables are referenced in the text:

Table A. Sample room sample rates for the various timer-gate rate setting.

Table B. Genetic distributions provided by the Molecular Genetics Lab at WDFW.

Table C. Sample rate expanded Juvenile tallies at Prosser by Prosser periods, associated detection efficiency estimates, Table B.'s stock distributions, and resulting Expanded and Calibrated Passage estimates with the calibration index[7].

Table D. Statistical analyses referred to the main text.

There were four estimates of detection efficiencies:

The first being the total joint detections of smolt jointly detected at Prosser and McNary Dam (unstratified, McNary)

The second involving a stratification in which adjacent detection dates having similar detection efficiencies were grouped together, different groups having different detection rates (stratified, McNary).

The third involving the separate estimation of Prosser detection efficiency for McNary, John Day and Bonneville Dams in the same manner as the first method, the estimates being then pooled over the three Columbia River Dams (unstratified, Pooled)

The fourth involving the separate estimation of Prosser detection efficiency for McNary, John Day and Bonneville Dams in the same manner as the second method, the estimates being pooled over the three Columbia River Dams (stratified, Pooled)

In Appendix Table C. McNary is identified as "McN", Pooled as "Pooled", Stratified as "Str" and Unstratified as "UnStr".

All estimates are presented in Table C. The stratified estimate pooled over the three dams was selected. The detection efficiencies estimated from each of three Columbia River Dams were assigned to the five genetic sampling periods based on proportion of the joint downstream dams' counts that were detected within the Prosser's time periods; within each time period, those three dams' detection assigned detection efficiency estimates were pooled over the three dams.

The Calibrated passage estimates used in this report are highlighted in yellow in Appendix C.

Table A. Sample-Room Sample Rates for given Timer-Gate settings[8]

		Estimated Sample Rates** (SR) for different Timer-Gate Rates										
Out-Migration Year	SR/TR Calibration Value*	Timer-Gate Rate (TR)									Number of Detection Days	Total Number of Detections
		5%	10%	20%	25%	33%	45%	50%	75%	100%		
1998	0.778	3.9%	7.8%	15.6%	19.4%	25.7%	35.0%	38.9%	58.3%	97.8%	37	1,984
1999	0.833	4.2%	8.3%	16.7%	20.8%	27.5%	37.5%	41.7%	62.5%	97.8%	76	4,413
2000	0.794	4.0%	7.9%	15.9%	19.8%	26.2%	35.7%	39.7%	59.5%	97.8%	64	8,482
2001***	0.278	1.4%	2.8%	5.6%	7.0%	9.2%	12.5%	13.9%	20.9%	97.8%	30	9,103
2002	0.838	4.2%	8.4%	16.8%	20.9%	27.7%	37.7%	41.9%	62.8%	97.8%	39	950
2003	0.669	3.3%	6.7%	13.4%	16.7%	22.1%	30.1%	33.4%	50.1%	97.8%	77	17,360
2004	0.693	3.5%	6.9%	13.9%	17.3%	22.9%	31.2%	34.6%	52.0%	97.8%	100	12,079
2005	0.776	3.9%	7.8%	15.5%	19.4%	25.6%	34.9%	38.8%	58.2%	97.8%	76	3,476
2006****	1.000	5.0%	10.0%	20.0%	25.0%	33.0%	45.0%	50.0%	75.0%	97.8%	65	5,960
2007	0.800	4.0%	8.0%	16.0%	20.0%	26.4%	36.0%	40.0%	60.0%	97.8%	75	7,723
2008	0.651	3.3%	6.5%	13.0%	16.3%	21.5%	29.3%	32.6%	48.8%	97.8%	74	6,125
2009	0.770	3.8%	7.7%	15.4%	19.2%	25.4%	34.6%	38.5%	57.7%	97.8%	88	4,809
2010	0.584	2.9%	5.8%	11.7%	14.6%	19.3%	26.3%	29.2%	43.8%	97.8%	79	13,227
2011****	1.000	5.0%	10.0%	20.0%	25.0%	33.0%	45.0%	50.0%	75.0%	97.8%	84	7,722
2012	0.979	4.9%	9.8%	19.6%	24.5%	32.3%	44.0%	48.9%	73.4%	97.8%	106	3,175
2013	0.973	4.9%	9.7%	19.5%	24.3%	32.1%	43.8%	48.6%	72.9%	97.8%	114	8,471
2014	0.903	4.5%	9.0%	18.1%	22.6%	29.8%	40.7%	45.2%	67.8%	97.8%	96	2,643
2015	0.830	4.1%	8.3%	16.6%	20.7%	27.4%	37.3%	41.5%	62.2%	97.8%	96	11,256
2016	0.873	4.4%	8.7%	17.5%	21.8%	28.8%	39.3%	43.7%	65.5%	97.8%	121	620
2017	0.819	4.1%	8.2%	16.4%	20.5%	27.0%	36.8%	40.9%	61.4%	97.8%	141	403
2018	0.910	4.5%	9.1%	18.2%	22.7%	30.0%	40.9%	45.5%	68.2%	97.8%	177	586

* The calibration value = (total of TR-33% and TR-50% sample-facility detections)/(total of TR-33% and TR-50% bypass detections) These two settings were use because they were the most commomly used setting othe than than the 100% setiingings

** SR estimate = (Calibration Rate) * (Column header TR) except for TR = 1.0 which is actual sample-room estimates pooled over years

*** When SR estimates exceed 33% for TR = 33%, SR is equated to TR

[7] Calibrated passage estimate = (Expanded passage estimate)*(calibration Index)

[8] Timer Gate Rate (TG) is proportion of time that the bypass gate is opened to Sample Room

Table B. Estimated Stock Distributions within Genetic Sampling Periods [9]

Out-migration Year	Brood	Sampling Period: 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%
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	5.69%	7.42%	9.44%	13.00%	3.71%
	Naches	26.41%	23.18%	38.42%	34.52%	0.00%
	U. Yakima	67.90%	69.40%	52.13%	52.49%	96.29%
2017	American	10.20%	11.21%	15.80%	10.78%	37.16%
	Naches	31.70%	27.73%	27.10%	29.57%	11.47%
	U. Yakima	58.10%	61.06%	57.10%	59.65%	51.37%
2018	American	American				
	Naches	genetic assignment to Upper Yakima Stock not yet available				
	U. Yakima					

[9] **Provided by the Washington Department of Fish and Wildlife's Molecular Genetics Lab**

Table C. Detailed Passage-Estimation Table

1999	Brood-Year 1997	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
Wild	Prosser Wild Tally	41,233	407	29,431	51,920	1,577	124,569	124,569			
	American DFW Percent	8.1%	8.1%	8.1%	12.0%	28.0%					
	Estimated Prosser Tally	3,332	33	2,378	6,230	442	12415	12,415			
	Naches DFW Percent	6.1%	6.1%	6.1%	29.0%	33.0%					
	Estimated Prosser Tally	2,499	25	1,784	15,057	520	19885	19,885			
	Upper YakimaDFW Percent	85.9%	85.9%	85.9%	59.0%	39.0%					
	Estimated Prosser Tally	35,402	350	25,269	30,633	615	92269	92,269			
	Yakima Passage Wild Tally	41,233	407	29,431	51,920	1,577	124569	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	18.5%	18.5%	18.5%	25.5%	5.0%					
	Total Passage	222,873	2,201	159,082	203,681	31,262	619,099	619,099	571,397		0.9229
	American Passage	18,010	178	12,855	24,442	8,753	64,238	64,238	59,288		
	Naches Passage	13,507	133	9,641	59,067	10,316	92,666	92,666	85,526		
	American & Naches Passage	31,517	311	22,496	83,509	19,070	156,904	156,904	144,815		
	Upper Yakima Passage	191,355	1,890	136,586	120,172	12,192	462,195	462,195	426,583		
McN UnStr Wild	Estimate b. :ion Efficiency	23.0%	23.0%	23.0%	23.0%	23.0%					
	Total Passage	179,338	1,771	128,008	225,822	6,860	541,799	541,799	502,917		0.9282
	American Passage	14,492	143	10,344	27,099	1,921	53,998	53,998	50,123		
	Naches Passage	10,869	107	7,758	65,488	2,264	86,486	86,486	80,280		
	American & Naches Passage	25,361	251	18,102	92,587	4,184	140,485	140,485	130,403		
	Upper Yakima Passage	153,977	1,521	109,906	133,235	2,675	401,314	401,314	372,514		
Pooled Str Wild	Estimate c. :ion Efficiency	19.4%	19.4%	19.4%	23.0%	3.8%					
	Total Passage	212,650	2,101	151,786	225,518	41,751	633,805	633,805	584,016		0.9214
	American Passage	17,184	170	12,266	27,062	11,690	68,371	68,371	63,000		
	Naches Passage	12,888	127	9,199	65,400	13,778	101,392	101,392	93,427		
	American & Naches Passage	30,072	297	21,465	92,462	25,468	169,764	169,764	156,428		
	Upper Yakima Passage	182,579	1,803	130,321	133,056	16,283	464,042	464,042	427,588		
Pooled UnStr Wild	Estimate e. :ion Efficiency	20.3%	20.3%	20.3%	20.3%	20.3%					
	Total Passage	203,022	2,005	144,913	255,644	7,766	613,350	613,350	569,333		0.9282
	American Passage	16,406	162	11,710	30,677	2,174	61,130	61,130	56,743		
	Naches Passage	12,304	122	8,783	74,137	2,563	97,908	97,908	90,882		
	American & Naches Passage	28,710	284	20,493	104,814	4,737	159,038	159,038	147,624		
	Upper Yakima Passage	174,312	1,722	124,420	150,830	3,029	454,312	454,312	421,709		
Hatchery	Prosser Hatchery Tally	0	7	1,812	31,529	1,371	34,719	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	39	9,796	123,685	27,175	160,696	179,215	165,406	0.1033	0.9229
McN-UnStr Hatch	Estimate b. Total Passage	0	32	7,883	137,130	5,963	151,007	168,410	156,324		0.9282
Pooled Str Hatch	Estimate c. Total Passage	0	38	9,347	136,946	36,292	182,622	203,668	187,669		0.9214
Pooled UnStr Hatch	Estimate e. Total Passage	0	36	8,924	155,240	6,750	170,950	190,650	176,968		0.9282

2000	Brood-Year 1998	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
Wild	Prosser Wild Tally	12,637	252	11,172	19,815	814	44,690	44,690			
	American DFW Percent	16.2%	16.2%	22.1%	46.9%	46.9%					
	Estimated Prosser Tally	2,044	41	2,473	9,301	382	14241	14,241			
	Naches DFW Percent	22.1%	22.1%	31.0%	36.7%	36.7%					
	Estimated Prosser Tally	2,788	56	3,462	7,279	299	13883	13,883			
	Upper YakimaDFW Percent	61.8%	61.8%	46.9%	16.3%	16.3%					
	Estimated Prosser Tally	7,805	156	5,237	3,235	133	16566	16,566			
	Yakima Passage Wild Tally	12,637	252	11,172	19,815	814	44690	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	12.5%	12.5%	31.6%	52.6%	31.0%					
	Total Passage	100,754	2,008	35,311	37,686	2,627	178,387	178,387	222,645		1.2481
	American Passage	16,298	325	7,816	17,689	1,233	43,362	43,362	54,120		
	Naches Passage	22,225	443	10,943	13,844	965	48,420	48,420	60,433		
	American & Naches Passage	38,524	768	18,759	31,533	2,199	91,782	91,782	114,553		
	Upper Yakima Passage	62,231	1,240	16,552	6,153	429	86,605	86,605	108,091		
McN UnStr Wild	Estimate b. :ion Efficiency	41.7%	41.7%	41.7%	41.7%	41.7%					
	Total Passage	30,333	605	26,818	47,564	1,955	107,274	107,274	132,166		1.2320
	American Passage	4,907	98	5,936	22,326	918	34,184	34,184	42,116		
	Naches Passage	6,691	133	8,311	17,472	718	33,326	33,326	41,059		
	American & Naches Passage	11,598	231	14,247	39,798	1,636	67,510	67,510	83,175		
	Upper Yakima Passage	18,735	373	12,571	7,765	319	39,764	39,764	48,991		
Pooled Str Wild	Estimate c. :ion Efficiency	15.9%	15.9%	30.0%	51.1%	30.0%					
	Total Passage	79,697	1,589	37,229	38,770	2,713	159,998	159,998	199,476		1.2467
	American Passage	12,892	257	8,241	18,198	1,273	40,862	40,862	50,944		
	Naches Passage	17,580	350	11,537	14,242	997	44,707	44,707	55,737		
	American & Naches Passage	30,472	607	19,778	32,440	2,270	85,568	85,568	106,681		
	Upper Yakima Passage	49,224	981	17,451	6,330	443	74,430	74,430	92,795		
Pooled UnStr Wild	Estimate e. Total Passage	41.2%	41.2%	41.2%	41.2%	41.2%					
	Total Passage	30,699	612	27,141	48,137	1,979	108,568	108,568	133,760		1.2320
	American Passage	4,966	99	6,008	22,595	929	34,596	34,596	42,624		
	Naches Passage	6,772	135	8,411	17,683	727	33,728	33,728	41,554		
	American & Naches Passage	11,738	234	14,419	40,278	1,656	68,324	68,324	84,178		
	Upper Yakima Passage	18,961	378	12,722	7,859	323	40,244	40,244	49,582		
Hatchery	Prosser Hatchery Tally	0	11	12,187	59,659	21,234	93,091	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	91	38,517	113,466	68,501	220,575	235,507	293,937	0.0634	1.2481
McN-UnStr Hatch	Estimate b. Total Passage	0	27	29,253	143,206	50,971	223,458	238,585	293,946		1.2320
Pooled Str Hatch	Estimate c. Total Passage	0	72	40,610	116,731	70,728	228,141	243,585	303,688		1.2467
Pooled UnStr Hatch	Estimate e. Total Passage	0	28	29,606	144,933	51,586	226,152	241,461	297,490		1.2320

Genetic Sample Analysis not Performed

2001		Brood-Year 1999	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	4,679	3,236	101,993	27,763	1,307	138,977	138,977			
	American	DFW Percent										
		Estimated Prosser Tally							0			
	Naches	DFW Percent										
		Estimated Prosser Tally	genetic assignment to Upper Yakima Stock not possible						0			
	Upper Yakima	DFW Percent										
		Estimated Prosser Tally							0			
		Yakima Passage Wild Tally						138977	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	:ion Efficiency	76.1%	76.1%	76.1%	86.8%	91.9%					
		Total Passage	6,150	4,253	134,076	31,992	1,421	177,893	177,893	149,124		0.8383
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
McN UnStr Wild	Estimate b.	:ion Efficiency	83.9%	83.9%	83.9%	83.9%	83.9%					
		Total Passage	5,577	3,857	121,571	33,092	1,558	165,654	165,654	143,613		0.8669
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
Pooled Str Wild	Estimate c.	:ion Efficiency	77.3%	77.3%	77.3%	85.9%	90.9%					
		Total Passage	6,052	4,185	131,931	32,310	1,438	175,917	175,917	148,460		0.8439
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
Pooled UnStr Wild	Estimate e.	:ion Efficiency	83.7%	83.7%	83.7%	83.7%	83.7%					
		Total Passage	5,589	3,865	121,828	33,162	1,561	166,004	166,004	143,917		0.8669
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
Hatchery		Prosser Hatchery Tally	0	4	96,207	148,783	16,931	261,925	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	5	126,468	171,448	18,415	316,337	333,380	279,467	0.0511	0.8383
McN-UnStr Hatch	Estimate b.	Total Passage	0	5	114,674	177,343	20,181	312,202	329,022	285,245		0.8669
Pooled Str Hatch	Estimate c.	Total Passage	0	5	124,446	173,151	18,633	316,235	333,273	281,256		0.8439
Pooled UnStr Hatch	Estimate e.	Total Passage	0	5	114,916	177,717	20,223	312,862	329,717	285,847		0.8669

2002		Brood-Year 2000	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	66,506	26,080	101,052	40,512	62	234,213	234,213			
	American	DFW Percent	3.8%	3.8%	3.8%	3.9%	3.9%					
		Estimated Prosser Tally	2,534	994	3,850	1,566	2	8945	8,945			
	Naches	DFW Percent	19.7%	19.7%	19.7%	20.3%	20.3%					
		Estimated Prosser Tally	13,090	5,133	19,890	8,220	13	46345	46,345			
	Upper Yakima	DFW Percent	76.5%	76.5%	76.5%	75.8%	75.8%					
		Estimated Prosser Tally	50,883	19,954	77,313	30,726	47	178922	178,922			
		Yakima Passage Wild Tally	66,506	26,080	101,052	40,512	62	234213	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	:ion Efficiency	31.7%	31.7%	56.3%	65.9%	25.2%					
		Total Passage	209,858	82,295	179,367	61,477	247	533,244	533,244	466,904		0.8756
		American Passage	7,995	3,135	6,833	2,376	10	20,348	20,348	17,817		
		Naches Passage	41,305	16,198	35,304	12,474	50	105,331	105,331	92,227		
		American & Naches Passage	49,300	19,333	42,137	14,850	60	125,679	125,679	110,044		
		Upper Yakima Passage	160,558	62,963	137,230	46,628	187	407,565	407,565	356,861		
McN UnStr Wild	Estimate b.	:ion Efficiency	59.5%	59.5%	59.5%	59.5%	59.5%					
		Total Passage	111,740	43,819	169,781	68,066	104	393,510	393,510	349,322		0.8877
		American Passage	4,257	1,669	6,468	2,631	4	15,028	15,028	13,341		
		Naches Passage	21,993	8,625	33,417	13,810	21	77,867	77,867	69,123		
		American & Naches Passage	26,250	10,294	39,885	16,441	25	92,895	92,895	82,464		
		Upper Yakima Passage	85,490	33,525	129,896	51,625	79	300,615	300,615	266,858		
Pooled Str Wild	Estimate c.	:ion Efficiency	32.8%	32.8%	53.9%	65.2%	7.9%					
		Total Passage	202,911	79,571	187,367	62,093	784	532,726	532,726	467,359		0.8773
		American Passage	7,730	3,031	7,138	2,400	30	20,329	20,329	17,835		
		Naches Passage	39,938	15,662	36,879	12,599	159	105,236	105,236	92,323		
		American & Naches Passage	47,668	18,693	44,016	14,998	189	125,565	125,565	110,158		
		Upper Yakima Passage	155,243	60,878	143,350	47,095	595	407,161	407,161	357,201		
Pooled UnStr Wild	Estimate e.	Total Passage	57.6%	57.6%	57.6%	57.6%	57.6%					
		Total Passage	115,447	45,272	175,414	70,324	108	406,565	406,565	360,912		0.8877
		American Passage	4,398	1,725	6,682	2,718	4	15,527	15,527	13,784		
		Naches Passage	22,723	8,911	34,526	14,269	22	80,450	80,450	71,416		
		American & Naches Passage	27,121	10,635	41,208	16,986	26	95,977	95,977	85,200		
		Upper Yakima Passage	88,326	34,637	134,206	53,337	82	310,588	310,588	275,712		
Hatchery		Prosser Hatchery Tally	5	2,254	126,919	101,160	171	230,509	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	16	7,111	225,281	153,510	680	386,599	404,834	354,470	0.0450	0.8756
McN-UnStr Hatch	Estimate b.	Total Passage	9	3,786	213,241	169,962	288	387,287	405,555	360,015		0.8877
Pooled Str Hatch	Estimate c.	Total Passage	16	6,876	235,328	155,049	2,164	399,432	418,273	366,950		0.8773
Pooled UnStr Hatch	Estimate e.	Total Passage	9	3,912	220,316	175,601	298	400,136	419,010	371,959		0.8877

2003	Brood-Year 2001	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	30,359	16,582	98,537	33,294	272	179,045	179,045			
	American DFW Percent	13.4%	13.4%	13.4%	16.0%	16.0%					
	Estimated Prosser Tally	4,078	2,227	13,236	5,338	44	24923	24,923			
	Naches DFW Percent	21.6%	21.6%	21.6%	34.2%	34.2%					
	Estimated Prosser Tally	6,570	3,589	21,325	11,400	93	42977	42,977			
	Upper YakimaDFW Percent	64.9%	64.9%	64.9%	49.7%	49.7%					
	Estimated Prosser Tally	19,711	10,766	63,975	16,557	135	111144	111,144			
	Yakima Passage Wild Tally	30,359	16,582	98,537	33,294	272	179045	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion 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	308,309		0.9450
	American Passage	9,047	4,941	21,378	9,767	326	45,461	45,461	42,961		
	Naches Passage	14,576	7,961	34,443	20,859	697	78,536	78,536	74,218		
	American & Naches Passage	23,624	12,903	55,821	30,626	1,023	123,997	123,997	117,180		
	Upper Yakima Passage	43,729	23,884	103,328	30,295	1,012	202,248	202,248	191,129		
McN UnStr Wild	Estimate b. :ion 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	289,106		0.9447
	American Passage	6,970	3,807	22,624	9,124	75	42,600	42,600	40,244		
	Naches Passage	11,230	6,134	36,450	19,485	159	73,458	73,458	69,395		
	American & Naches Passage	18,201	9,941	59,073	28,609	234	116,058	116,058	109,640		
	Upper Yakima Passage	33,691	18,401	109,349	28,299	232	189,971	189,971	179,466		
Pooled Str Wild	Estimate c. :ion 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	308,959		0.9458
	American Passage	8,613	4,704	21,600	10,314	93	45,324	45,324	42,867		
	Naches Passage	13,877	7,579	34,800	22,026	487	78,768	78,768	74,498		
	American & Naches Passage	22,490	12,283	56,400	32,339	579	124,091	124,091	117,365		
	Upper Yakima Passage	41,630	22,737	104,400	31,990	1,819	202,575	202,575	191,594		
Pooled UnStr Wild	Estimate e. :ion 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	296,392		0.9447
	American Passage	7,146	3,903	23,194	9,354	77	43,674	43,674	41,259		
	Naches Passage	11,513	6,288	37,368	19,976	163	75,309	75,309	71,145		
	American & Naches Passage	18,659	10,191	60,562	29,330	240	118,983	118,983	112,403		
	Upper Yakima Passage	34,540	18,865	112,105	29,013	237	194,760	194,760	183,989		
Hatchery	Prosser Hatchery Tally	0	2,058	67,386	15,896	233	85,573	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	4,565	108,836	29,087	1,743	144,230	160,014	151,217	0.0986	0.9450
McN-UnStr Hatch	Estimate b. Total Passage	0	3,517	115,178	27,170	399	146,264	162,271	153,297		0.9447
Pooled Str Hatch	Estimate c. Total Passage	0	4,346	109,965	30,714	2,054	147,078	163,174	154,329		0.9458
Pooled UnStr Hatch	Estimate e. Total Passage	0	3,605	118,081	27,855	409	149,950	166,361	157,161		0.9447

2004	Brood-Year 2002	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	5,652	7,240	70,520	19,028	346	102,786	102,786			
	American DFW Percent	6.5%	4.3%	21.5%	34.7%	31.3%					
	Estimated Prosser Tally	365	309	15,160	6,607	108	22549	22,549			
	Naches DFW Percent	33.8%	29.3%	36.5%	34.0%	18.8%					
	Estimated Prosser Tally	1,913	2,119	25,721	6,475	65	36292	36,292			
	Upper YakimaDFW Percent	59.7%	66.5%	42.0%	31.3%	50.0%					
	Estimated Prosser Tally	3,374	4,812	29,639	5,946	173	43944	43,944			
	Yakima Passage Wild Tally	5,652	7,240	70,520	19,028	346	102786	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion 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	171,641		1.0398
	American Passage	626	529	25,963	7,580	124	34,822	34,822	36,206		
	Naches Passage	3,276	3,629	44,049	7,429	74	58,457	58,457	60,781		
	American & Naches Passage	3,901	4,158	70,012	15,009	198	93,280	93,280	96,987		
	Upper Yakima Passage	5,778	8,241	50,759	6,822	198	71,799	71,799	74,653		
McN Str Wild	Estimate b. :ion 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	170,539		1.0706
	American Passage	566	479	23,495	10,239	167	34,947	34,947	37,413		
	Naches Passage	2,964	3,284	39,862	10,034	100	56,245	56,245	60,215		
	American & Naches Passage	3,531	3,763	63,357	20,274	268	91,192	91,192	97,628		
	Upper Yakima Passage	5,229	7,458	45,934	9,215	268	68,104	68,104	72,910		
McN UnStr Wild	Estimate c. :ion Efficiency	59.4%	59.4%	59.4%	86.8%	86.8%					
	Total Passage	9,511	12,183	118,664	21,916	398	162,673	162,673	169,397		1.0413
	American Passage	615	520	25,510	7,610	124	34,379	34,379	35,800		
	Naches Passage	3,219	3,566	43,281	7,458	75	57,597	57,597	59,978		
	American & Naches Passage	3,833	4,086	68,791	15,068	199	91,976	91,976	95,778		
	Upper Yakima Passage	5,678	8,097	49,873	6,849	199	70,696	70,696	73,619		
Pooled Str Wild	Estimate e. :ion Efficiency	66.8%	66.8%	66.8%	66.8%	66.8%					
	Total Passage	8,465	10,843	105,611	28,496	518	153,933	153,933	164,797		1.0706
	American Passage	547	463	22,704	9,894	162	33,770	33,770	36,153		
	Naches Passage	2,865	3,174	38,520	9,697	97	54,352	54,352	58,188		
	American & Naches Passage	3,412	3,636	61,224	19,591	259	88,122	88,122	94,341		
	Upper Yakima Passage	5,053	7,207	44,387	8,905	259	65,811	65,811	70,456		
Pooled UnStr Wild	Prosser Hatchery Tally	0	1,662	99,011	83,912	283	184,868	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	2,847	169,565	96,276	324	269,013	282,162	293,378	0.0466	1.0398
McN-UnStr Hatch	Estimate b. Total Passage	0	2,576	153,446	130,045	438	286,505	300,510	321,719		1.0706
Pooled Str Hatch	Estimate c. Total Passage	0	2,797	166,606	96,651	326	266,380	279,400	290,950		1.0413
Pooled UnStr Hatch	Estimate e. Total Passage	0	2,490	148,280	125,667	423	276,860	290,392	310,888		1.0706

2005	Brood-Year 2003	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	37,617	3,569	66,596	6,246	63	114,092	114,092			
	American DFW Percent	21.4%	18.9%	29.6%	32.1%	0.0%					
	Estimated Prosser Tally	8,047	673	19,689	2,008	0	30418	30,418			
	Naches DFW Percent	35.3%	7.5%	35.4%	23.2%	17.9%					
	Estimated Prosser Tally	13,288	269	23,550	1,450	11	38568	38,568			
	Upper YakimaDFW Percent	43.3%	73.6%	35.1%	44.6%	82.1%					
	Estimated Prosser Tally	16,282	2,626	23,357	2,789	52	45106	45,106			
	Yakima Passage Wild Tally	37,617	3,569	66,596	6,246	63	114092	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion 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	131,650		0.7737
	American Passage	13,249	1,109	27,561	2,902	0	44,820	44,820	34,679		
	Naches Passage	21,876	443	32,965	2,096	16	57,396	57,396	44,410		
	American & Naches Passage	35,125	1,552	60,525	4,998	16	102,216	102,216	79,090		
	Upper Yakima Passage	26,806	4,324	32,694	4,030	75	67,930	67,930	52,560		
McN UnStr Wild	Estimate b. :ion 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	125,864		0.7724
	American Passage	11,494	962	28,121	2,868	0	43,444	43,444	33,556		
	Naches Passage	18,978	385	33,635	2,071	16	55,085	55,085	42,548		
	American & Naches Passage	30,472	1,346	61,757	4,939	16	98,530	98,530	76,104		
	Upper Yakima Passage	23,255	3,751	33,360	3,983	74	64,422	64,422	49,760		
Pooled Str Wild	Estimate c. :ion 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	134,859		0.7828
	American Passage	13,392	1,121	27,398	3,518	0	45,429	45,429	35,564		
	Naches Passage	22,113	448	32,770	2,541	20	57,892	57,892	45,321		
	American & Naches Passage	35,506	1,569	60,168	6,059	20	103,321	103,321	80,885		
	Upper Yakima Passage	27,096	4,370	32,501	4,886	91	68,946	68,946	53,974		
Pooled UnStr Wild	Estimate e. :ion 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	128,846		0.7724
	American Passage	11,766	985	28,788	2,936	0	44,474	44,474	34,351		
	Naches Passage	19,428	394	34,432	2,120	17	56,390	56,390	43,556		
	American & Naches Passage	31,194	1,378	63,220	5,056	17	100,864	100,864	77,907		
	Upper Yakima Passage	23,806	3,840	34,150	4,077	76	65,949	65,949	50,939		
Hatchery	Prosser Hatchery Tally	21	8	159,590	37,455	16	197,090	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	35	13	223,388	54,132	24	277,593	291,340	225,424	0.0472	0.7737
McN-UnStr Hatch	Estimate b. Total Passage	31	11	227,934	53,495	23	281,494	295,434	228,194		0.7724
Pooled Str Hatch	Estimate c. Total Passage	36	13	222,070	65,629	29	287,777	302,028	236,443		0.7828
Pooled UnStr Hatch	Estimate e. Total Passage	31	11	233,334	54,762	24	288,163	302,433	233,600		0.7724

2006	Brood-Year 2004	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	10,379	400	21,517	9,248	45	41,588	41,588			
	American DFW Percent	7.4%	0.0%	5.5%	5.4%	2.3%					
	Estimated Prosser Tally	764	0	1,187	504	1	2456	2,456			
	Naches DFW Percent	39.9%	26.0%	36.0%	39.1%	15.9%					
	Estimated Prosser Tally	4,139	104	7,736	3,617	7	15602	15,602			
	Upper YakimaDFW Percent	52.8%	74.0%	58.5%	55.4%	81.8%					
	Estimated Prosser Tally	5,476	296	12,593	5,127	37	23530	23,530			
	Yakima Passage Wild Tally	10,379	400	21,517	9,248	45	41588	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	21.0%	21.0%	21.0%	23.7%	23.7%					
	Total Passage	49,335	1,901	102,278	38,999	191	192,705	192,705	126,524		0.6566
	American Passage	3,632	0	5,644	2,124	4	11,404	11,404	7,488		
	Naches Passage	19,673	494	36,772	15,252	30	72,222	72,222	47,419		
	American & Naches Passage	23,305	494	42,416	17,376	35	83,626	83,626	54,906		
	Upper Yakima Passage	26,029	1,408	59,862	21,623	156	109,079	109,079	71,618		
McN UnStr Wild	Estimate b. :ion Efficiency	20.5%	20.5%	20.5%	20.5%	20.5%					
	Total Passage	50,510	1,947	104,715	45,005	220	202,397	202,397	131,973		0.6520
	American Passage	3,719	0	5,779	2,451	5	11,953	11,953	7,794		
	Naches Passage	20,142	505	37,648	17,601	35	75,932	75,932	49,511		
	American & Naches Passage	23,861	505	43,427	20,052	40	87,885	87,885	57,305		
	Upper Yakima Passage	26,650	1,441	61,288	24,953	180	114,512	114,512	74,667		
Pooled Str Wild	Estimate c. :ion Efficiency	20.1%	20.1%	20.1%	22.0%	22.0%					
	Total Passage	51,735	1,994	107,254	42,031	206	203,220	203,220	133,218		0.6555
	American Passage	3,809	0	5,919	2,289	5	12,021	12,021	7,880		
	Naches Passage	20,631	518	38,561	16,438	33	76,180	76,180	49,939		
	American & Naches Passage	24,439	518	44,480	18,727	37	88,201	88,201	57,819		
	Upper Yakima Passage	27,296	1,476	62,774	23,304	168	115,019	115,019	75,399		
Pooled UnStr Wild	Estimate e. :ion Efficiency	20.7%	20.7%	20.7%	20.7%	20.7%					
	Total Passage	50,065	1,930	103,791	44,608	218	200,612	200,612	130,809		0.6520
	American Passage	3,686	0	5,728	2,429	5	11,847	11,847	7,725		
	Naches Passage	19,964	501	37,316	17,446	35	75,262	75,262	49,075		
	American & Naches Passage	23,650	501	43,044	19,875	40	87,110	87,110	56,800		
	Upper Yakima Passage	26,415	1,429	60,747	24,733	179	113,502	113,502	74,009		
Hatchery	Prosser Hatchery Tally	3	9	46,130	45,561	19	91,722	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	14	43	219,277	192,140	81	411,555	431,559	283,348	0.0464	0.6566
McN-UnStr Hatch	Estimate b. Total Passage	15	44	224,500	221,728	93	446,380	468,077	305,209		0.6520
Pooled Str Hatch	Estimate c. Total Passage	15	45	229,944	207,074	87	437,166	458,415	300,508		0.6555
Pooled UnStr Hatch	Estimate e. Total Passage	15	44	222,520	219,773	92	442,444	463,950	302,518		0.6520

2007	Brood-Year 2005	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	542	523	17,147	11,159	189	29,559	29,559			
	American DFW Percent	9.1%	14.5%	6.8%	16.7%	11.5%					
	Estimated Prosser Tally	49	76	1,167	1,869	22	3183	3,183			
	Naches DFW Percent	18.2%	32.3%	24.7%	29.8%	26.1%					
	Estimated Prosser Tally	99	169	4,239	3,323	49	7879	7,879			
	Upper YakimaDFW Percent	72.7%	53.2%	68.5%	53.5%	62.4%					
	Estimated Prosser Tally	394	278	11,740	5,967	118	18497	18,497			
	Yakima Passage Wild Tally	542	523	17,147	11,159	189	29559	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	30.2%	30.2%	30.2%	21.9%	21.9%					
	Total Passage	1,791	1,728	56,711	51,048	866	112,144	112,144	99,769		0.8897
	American Passage	163	251	3,860	8,550	100	12,924	12,924	11,498		
	Naches Passage	326	558	14,022	15,200	226	30,332	30,332	26,985		
	American & Naches Passage	489	809	17,882	23,750	326	43,256	43,256	38,483		
	Upper Yakima Passage	1,302	920	38,829	27,297	540	68,888	68,888	61,287		
McN UnStr Wild	Estimate b. :ion Efficiency	26.3%	26.3%	26.3%	26.3%	26.3%					
	Total Passage	2,058	1,986	65,172	42,413	719	112,349	112,349	98,319		0.8751
	American Passage	187	288	4,436	7,104	83	12,098	12,098	10,588		
	Naches Passage	375	642	16,114	12,629	188	29,946	29,946	26,207		
	American & Naches Passage	562	930	20,550	19,733	271	42,045	42,045	36,794		
	Upper Yakima Passage	1,496	1,057	44,622	22,680	449	70,304	70,304	61,525		
Pooled Str Wild	Estimate c. :ion Efficiency	28.3%	28.3%	28.3%	23.7%	23.7%					
	Total Passage	1,916	1,849	60,674	47,178	800	112,417	112,417	99,265		0.8830
	American Passage	174	268	4,130	7,902	92	12,567	12,567	11,097		
	Naches Passage	349	597	15,001	14,048	209	30,204	30,204	26,670		
	American & Naches Passage	523	865	19,131	21,950	301	42,771	42,771	37,767		
	Upper Yakima Passage	1,393	984	41,543	25,228	499	69,646	69,646	61,498		
Pooled UnStr Wild	Estimate e. :ion Efficiency	26.2%	26.2%	26.2%	26.2%	26.2%					
	Total Passage	2,068	1,996	65,477	42,611	723	112,874	112,874	98,779		0.8751
	American Passage	188	289	4,457	7,137	83	12,155	12,155	10,637		
	Naches Passage	376	645	16,189	12,688	188	30,087	30,087	26,329		
	American & Naches Passage	565	934	20,646	19,825	272	42,241	42,241	36,967		
	Upper Yakima Passage	1,503	1,062	44,831	22,786	451	70,633	70,633	61,813		
Hatchery	Prosser Hatchery Tally	0	629	61,236	37,776	281	99,922	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	2,079	202,534	172,814	1,285	378,712	396,759	352,979	0.0455	0.8897
McN-UnStr Hatch	Estimate b. Total Passage	0	2,389	232,752	143,581	1,068	379,790	397,889	348,202		0.8751
Pooled Str Hatch	Estimate c. Total Passage	0	2,224	216,687	159,714	1,188	379,813	397,912	351,359		0.8830
Pooled UnStr Hatch	Estimate e. Total Passage	0	2,400	233,841	144,253	1,073	381,568	399,751	349,831		0.8751

2008	Brood-Year 2006	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	7,037	1,052	44,603	16,505	443	69,641	69,641			
	American DFW Percent	8.3%	0.0%	5.2%	5.0%	14.8%					
	Estimated Prosser Tally	586	0	2,327	825	66	3804	3,804			
	Naches DFW Percent	8.3%	14.3%	25.2%	31.1%	51.9%					
	Estimated Prosser Tally	586	150	11,248	5,135	230	17349	17,349			
	Upper YakimaDFW Percent	83.3%	85.7%	69.6%	63.9%	33.3%					
	Estimated Prosser Tally	5,864	902	31,028	10,545	148	48487	48,487			
	Yakima Passage Wild Tally	7,037	1,052	44,603	16,505	443	69641	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	71.4%	71.4%	71.4%	35.6%	10.8%					
	Total Passage	9,857	1,473	62,485	46,346	4,094	124,254	124,254	107,901		0.8684
	American Passage	821	0	3,260	2,317	606	7,005	7,005	6,083		
	Naches Passage	821	210	15,757	14,419	2,123	33,330	33,330	28,944		
	American & Naches Passage	1,643	210	19,017	16,736	2,729	40,335	40,335	35,027		
	Upper Yakima Passage	8,214	1,263	43,468	29,610	1,365	83,919	83,919	72,874		
McN UnStr Wild	Estimate b. :ion Efficiency	46.1%	46.1%	46.1%	46.1%	46.1%					
	Total Passage	15,257	2,281	96,703	35,784	961	150,986	150,986	130,742		0.8659
	American Passage	1,271	0	5,045	1,789	142	8,248	8,248	7,142		
	Naches Passage	1,271	326	24,386	11,133	498	37,614	37,614	32,571		
	American & Naches Passage	2,543	326	29,431	12,922	641	45,863	45,863	39,714		
	Upper Yakima Passage	12,715	1,955	67,272	22,862	320	105,123	105,123	91,029		
Pooled Str Wild	Estimate c. :ion Efficiency	48.8%	48.8%	66.7%	31.2%	7.9%					
	Total Passage	14,422	2,156	66,892	52,920	5,644	142,034	142,034	123,735		0.8712
	American Passage	1,202	0	3,490	2,646	836	8,174	8,174	7,121		
	Naches Passage	1,202	308	16,868	16,464	2,927	37,769	37,769	32,903		
	American & Naches Passage	2,404	308	20,358	19,110	3,763	45,943	45,943	40,024		
	Upper Yakima Passage	12,018	1,848	46,534	33,810	1,881	96,091	96,091	83,711		
Pooled UnStr Wild	Estimate e. :ion Efficiency	41.4%	41.4%	41.4%	41.4%	41.4%					
	Total Passage	16,979	2,538	107,612	39,821	1,069	168,019	168,019	145,492		0.8659
	American Passage	1,415	0	5,615	1,991	158	9,179	9,179	7,948		
	Naches Passage	1,415	363	27,137	12,389	554	41,858	41,858	36,246		
	American & Naches Passage	2,830	363	32,752	14,380	713	51,037	51,037	44,194		
	Upper Yakima Passage	14,149	2,175	74,861	25,441	356	116,983	116,983	101,298		
Hatchery	Prosser Hatchery Tally	0	233	43,465	65,164	930	109,793	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	326	60,890	182,980	8,595	252,791	268,938	233,543	0.0600	0.8684
McN-UnStr Hatch	Estimate b. Total Passage	0	505	94,235	141,281	2,017	238,037	253,242	219,289		0.8659
Pooled Str Hatch	Estimate c. Total Passage	0	477	65,185	208,936	11,851	286,449	304,746	265,485		0.8712
Pooled UnStr Hatch	Estimate e. Total Passage	0	561	104,866	157,219	2,245	264,891	281,812	244,028		0.8659

2009	Brood-Year 2007	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	14,956	543	27,585	9,394	2,450	54,927	54,927			
	American DFW Percent	9.8%	10.9%	12.1%	10.9%	36.3%					
	Estimated Prosser Tally	1,466	59	3,327	1,029	889	6769	6,769			
	Naches DFW Percent	35.6%	32.4%	29.2%	40.8%	28.2%					
	Estimated Prosser Tally	5,324	176	8,068	3,831	691	18090	18,090			
	Upper YakimaDFW Percent	54.6%	56.6%	58.7%	48.3%	35.5%					
	Estimated Prosser Tally	8,166	307	16,191	4,534	869	30067	30,067			
	Yakima Passage Wild Tally	14,956	543	27,585	9,394	2,450	54927	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	28.4%	28.4%	21.2%	12.5%	12.5%					
	Total Passage	52,671	1,911	130,062	75,334	19,645	279,622	279,622	240,827		0.8613
	American Passage	5,162	209	15,686	8,249	7,129	36,434	36,434	31,379		
	Naches Passage	18,751	620	38,038	30,723	5,545	93,676	93,676	80,680		
	American & Naches Passage	23,912	828	53,724	38,972	12,674	130,111	130,111	112,059		
	Upper Yakima Passage	28,758	1,082	76,338	36,362	6,971	149,512	149,512	128,768		
McN UnStr Wild	Estimate b. :ion Efficiency	15.3%	15.3%	15.3%	15.3%	15.3%					
	Total Passage	98,002	3,555	180,751	61,551	16,051	359,910	359,910	318,180		0.8841
	American Passage	9,604	388	21,799	6,740	5,825	44,356	44,356	39,213		
	Naches Passage	34,889	1,153	52,863	25,102	4,530	118,537	118,537	104,793		
	American & Naches Passage	44,493	1,541	74,662	31,842	10,355	162,893	162,893	144,006		
	Upper Yakima Passage	53,509	2,014	106,089	29,710	5,695	197,017	197,017	174,173		
Pooled Str Wild	Estimate c. :ion Efficiency	26.2%	26.2%	21.3%	11.4%	11.4%					
	Total Passage	57,137	2,073	129,580	82,196	21,434	292,419	292,419	250,846		0.8578
	American Passage	5,599	226	15,628	9,000	7,778	38,232	38,232	32,797		
	Naches Passage	20,341	672	37,897	33,521	6,050	98,481	98,481	84,480		
	American & Naches Passage	25,940	899	53,525	42,521	13,828	136,713	136,713	117,277		
	Upper Yakima Passage	31,197	1,174	76,055	39,674	7,606	155,705	155,705	133,569		
Pooled UnStr Wild	Estimate e. :ion Efficiency	14.6%	14.6%	14.6%	14.6%	14.6%					
	Total Passage	102,487	3,718	189,022	64,368	16,785	376,379	376,379	332,739		0.8841
	American Passage	10,044	406	22,797	7,048	6,091	46,386	46,386	41,008		
	Naches Passage	36,485	1,206	55,282	26,251	4,738	123,961	123,961	109,588		
	American & Naches Passage	46,529	1,612	78,078	33,299	10,829	170,347	170,347	150,596		
	Upper Yakima Passage	55,958	2,106	110,943	31,069	5,956	206,032	206,032	182,143		
Hatchery	Prosser Hatchery Tally	31	42	23,787	39,531	303	63,695	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	111	148	112,155	317,029	2,431	431,874	454,638	391,561	0.0501	0.8613
McN-UnStr Hatch	Estimate b. Total Passage	206	276	155,865	259,027	1,986	417,360	439,358	388,416		0.8841
Pooled Str Hatch	Estimate c. Total Passage	120	161	111,739	345,905	2,653	460,577	484,854	415,923		0.8578
Pooled UnStr Hatch	Estimate e. Total Passage	216	288	162,997	270,879	2,077	436,457	459,463	406,189		0.8841

2010	Brood-Year 2008	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	3,862	3,204	70,483	24,871	637	103,056	103,056			
	American DFW Percent	30.3%	0.0%	14.2%	11.9%	0.0%					
	Estimated Prosser Tally	1,170	0	9,981	2,955	0	14106	14,106			
	Naches DFW Percent	7.4%	19.5%	37.1%	33.6%	75.5%					
	Estimated Prosser Tally	284	625	26,167	8,364	481	35921	35,921			
	Upper YakimaDFW Percent	62.3%	80.5%	48.7%	54.5%	24.5%					
	Estimated Prosser Tally	2,407	2,579	34,334	13,552	156	53029	53,029			
	Yakima Passage Wild Tally	3,862	3,204	70,483	24,871	637	103056	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	45.0%	45.0%	45.0%	59.2%	43.6%					
	Total Passage	8,584	7,122	156,665	42,045	1,459	215,875	215,875	221,188		1.0246
	American Passage	2,602	0	22,186	4,995	0	29,782	29,782	30,515		
	Naches Passage	631	1,389	58,163	14,140	1,101	75,424	75,424	77,281		
	American & Naches Passage	3,233	1,389	80,349	19,135	1,101	105,206	105,206	107,796		
	Upper Yakima Passage	5,351	5,733	76,316	22,910	358	110,668	110,668	113,392		
McN UnStr Wild	Estimate b. :ion Efficiency	52.2%	52.2%	52.2%	52.2%	52.2%					
	Total Passage	7,396	6,137	134,998	47,635	1,219	197,386	197,386	201,737		1.0220
	American Passage	2,242	0	19,117	5,659	0	27,018	27,018	27,614		
	Naches Passage	544	1,197	50,119	16,020	921	68,800	68,800	70,316		
	American & Naches Passage	2,785	1,197	69,236	21,679	921	95,818	95,818	97,930		
	Upper Yakima Passage	4,611	4,940	65,761	25,956	299	101,568	101,568	103,807		
Pooled Str Wild	Estimate c. :ion Efficiency	45.4%	45.4%	45.4%	57.4%	35.4%					
	Total Passage	8,507	7,058	155,261	43,333	1,796	215,955	215,955	221,228		1.0244
	American Passage	2,578	0	21,987	5,148	0	29,713	29,713	30,439		
	Naches Passage	625	1,377	57,642	14,573	1,356	75,572	75,572	77,418		
	American & Naches Passage	3,204	1,377	79,629	19,721	1,356	105,285	105,285	107,856		
	Upper Yakima Passage	5,303	5,682	75,632	23,612	440	110,669	110,669	113,372		
Pooled UnStr Wild	Estimate e. :ion Efficiency	51.3%	51.3%	51.3%	51.3%	51.3%					
	Total Passage	7,530	6,248	137,440	48,497	1,241	200,957	200,957	205,387		1.0220
	American Passage	2,282	0	19,463	5,761	0	27,507	27,507	28,113		
	Naches Passage	553	1,219	51,026	16,310	937	70,044	70,044	71,588		
	American & Naches Passage	2,836	1,219	70,489	22,071	937	97,551	97,551	99,702		
	Upper Yakima Passage	4,694	5,030	66,951	26,426	304	103,406	103,406	105,685		
Hatchery	Prosser Hatchery Tally	0	204	58,305	129,493	737	188,739	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	453	129,598	218,915	1,688	350,653	367,535	376,582	0.0459	1.0246
McN-UnStr Hatch	Estimate b. Total Passage	0	390	111,674	248,021	1,411	361,496	378,900	387,253		1.0220
Pooled Str Hatch	Estimate c. Total Passage	0	449	128,436	225,621	2,078	356,584	373,751	382,878		1.0244
Pooled UnStr Hatch	Estimate e. Total Passage	0	397	113,694	252,508	1,436	368,036	385,755	394,259		1.0220

2011	Brood-Year 2009	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	24,773	4,142	30,530	15,792	91	75,328	75,328			
	American DFW Percent	8.6%	0.0%	3.5%	5.9%	16.6%					
	Estimated Prosser Tally	2,140	0	1,066	935	15	4156	4,156			
	Naches DFW Percent	18.2%	19.8%	24.0%	13.1%	0.0%					
	Estimated Prosser Tally	4,506	818	7,316	2,069	0	14709	14,709			
	Upper YakimaDFW Percent	73.2%	80.3%	72.5%	81.0%	83.4%					
	Estimated Prosser Tally	18,126	3,324	22,149	12,788	75	56463	56,463			
	Yakima Passage Wild Tally	24,773	4,142	30,530	15,792	91	75328	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	17.5%	17.5%	28.7%	30.9%	30.9%					
	Total Passage	141,442	23,652	106,452	51,115	293	322,954	322,954	299,949		0.9288
	American Passage	12,221	0	3,716	3,027	49	19,012	19,012	17,657		
	Naches Passage	25,728	4,671	25,508	6,697	0	62,605	62,605	58,146		
	American & Naches Passage	37,949	4,671	29,224	9,724	49	81,617	81,617	75,803		
	Upper Yakima Passage	103,493	18,980	77,228	41,391	244	241,337	241,337	224,146		
McN UnStr Wild	Estimate b. :ion Efficiency	27.9%	27.9%	27.9%	27.9%	27.9%					
	Total Passage	88,870	14,861	109,524	56,652	325	270,231	270,231	254,125		0.9404
	American Passage	7,678	0	3,823	3,355	54	14,910	14,910	14,021		
	Naches Passage	16,165	2,935	26,245	7,423	0	52,768	52,768	49,623		
	American & Naches Passage	23,844	2,935	30,067	10,777	54	67,678	67,678	63,644		
	Upper Yakima Passage	65,026	11,926	79,457	45,875	271	202,554	202,554	190,481		
Pooled Str Wild	Estimate c. :ion Efficiency	17.6%	17.6%	28.3%	29.5%	29.5%					
	Total Passage	140,705	23,528	107,826	53,479	307	325,846	325,846	303,711		0.9321
	American Passage	12,157	0	3,764	3,167	51	19,138	19,138	17,838		
	Naches Passage	25,594	4,647	25,838	7,007	0	63,086	63,086	58,800		
	American & Naches Passage	37,751	4,647	29,601	10,174	51	82,224	82,224	76,639		
	Upper Yakima Passage	102,954	18,882	78,225	43,306	256	243,622	243,622	227,072		
Pooled UnStr Wild	Estimate e. :ion Efficiency	27.3%	27.3%	27.3%	27.3%	27.3%					
	Total Passage	90,699	15,166	111,779	57,819	332	275,795	275,795	259,357		0.9404
	American Passage	7,836	0	3,901	3,424	55	15,217	15,217	14,310		
	Naches Passage	16,498	2,995	26,785	7,576	0	53,854	53,854	50,644		
	American & Naches Passage	24,335	2,995	30,686	10,999	55	69,071	69,071	64,954		
	Upper Yakima Passage	66,365	12,171	81,093	46,819	276	206,724	206,724	194,403		
Hatchery	Prosser Hatchery Tally	70	4,100	57,391	66,684	580	128,824	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	398	23,409	200,108	215,843	1,877	441,635	461,721	428,831	0.0435	0.9288
McN-UnStr Hatch	Estimate b. Total Passage	250	14,708	205,884	239,222	2,080	462,144	483,164	454,365		0.9404
Pooled Str Hatch	Estimate c. Total Passage	396	23,287	202,692	225,825	1,963	454,164	474,820	442,564		0.9321
Pooled UnStr Hatch	Estimate e. Total Passage	255	15,011	210,123	244,147	2,123	471,659	493,111	463,720		0.9404

2012	Brood-Year 2010	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	15,922	6,786	14,719	5,327	993	43,746	43,746			
	American DFW Percent	11.0%	5.3%	6.2%	13.6%	23.5%					
	Estimated Prosser Tally	1,750	360	908	727	233	3978	3,978			
	Naches DFW Percent	31.6%	29.6%	29.3%	38.5%	29.4%					
	Estimated Prosser Tally	5,034	2,009	4,316	2,050	292	13700	13,700			
	Upper YakimaDFW Percent	57.4%	65.1%	64.5%	47.9%	47.1%					
	Estimated Prosser Tally	9,138	4,416	9,495	2,550	468	26067	26,067			
	Yakima Passage Wild Tally	15,922	6,786	14,719	5,327	993	43746	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	10.6%	10.6%	6.8%	6.4%	6.4%					
	Total Passage	149,599	63,757	215,132	82,800	15,434	526,721	526,721	301,173		0.5718
	American Passage	16,439	3,386	13,274	11,299	3,621	48,019	48,019	27,456		
	Naches Passage	47,298	18,874	63,077	31,863	4,545	165,658	165,658	94,721		
	American & Naches Passage	63,738	22,260	76,350	43,162	8,166	213,676	213,676	122,178		
	Upper Yakima Passage	85,861	41,497	138,782	39,638	7,267	313,045	313,045	178,995		
McN UnStr Wild	Estimate b. :ion Efficiency	6.8%	6.8%	6.8%	6.8%	6.8%					
	Total Passage	233,096	99,343	215,485	77,987	14,537	640,449	640,449	368,824		0.5759
	American Passage	25,615	5,276	13,295	10,642	3,411	58,239	58,239	33,539		
	Naches Passage	73,698	29,408	63,180	30,011	4,281	200,579	200,579	115,510		
	American & Naches Passage	99,312	34,684	76,476	40,654	7,692	258,818	258,818	149,049		
	Upper Yakima Passage	133,784	64,659	139,010	37,334	6,845	381,631	381,631	219,775		
Pooled Str Wild	Estimate c. :ion Efficiency	17.2%	12.0%	8.0%	6.2%	6.2%					
	Total Passage	92,790	56,530	184,609	86,385	16,102	436,417	436,417	252,029		0.5775
	American Passage	10,197	3,002	11,390	11,788	3,778	40,155	40,155	23,189		
	Naches Passage	29,337	16,735	54,127	33,243	4,742	138,184	138,184	79,801		
	American & Naches Passage	39,534	19,737	65,518	45,031	8,520	178,339	178,339	102,990		
	Upper Yakima Passage	53,256	36,794	119,091	41,354	7,582	258,077	258,077	149,038		
Pooled UnStr Wild	Estimate e. :ion Efficiency	7.4%	7.4%	7.4%	7.4%	7.4%					
	Total Passage	216,431	92,241	200,080	72,412	13,497	594,661	594,661	342,455		0.5759
	American Passage	23,783	4,898	12,345	9,881	3,167	54,075	54,075	31,141		
	Naches Passage	68,429	27,306	58,663	27,866	3,975	186,239	186,239	107,252		
	American & Naches Passage	92,212	32,204	71,008	37,747	7,142	240,314	240,314	138,393		
	Upper Yakima Passage	124,219	60,036	129,071	34,665	6,356	354,347	354,347	204,063		
Hatchery	Prosser Hatchery Tally	0	1,485	20,279	22,395	919	45,078	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	13,952	296,397	348,103	14,288	672,740	707,207	404,372	0.0487	0.5718
McN-UnStr Hatch	Estimate b. Total Passage	0	21,739	296,884	327,872	13,457	659,952	693,764	399,527		0.5759
Pooled Str Hatch	Estimate c. Total Passage	0	12,370	254,344	363,177	14,906	644,798	677,833	391,446		0.5775
Pooled UnStr Hatch	Estimate e. Total Passage	0	20,185	275,659	304,431	12,495	612,770	644,164	370,963		0.5759

2013	Brood-Year 2011	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	28,502	18,683	50,994	8,258	336	106,774	106,774			
	American DFW Percent	8.2%	2.3%	5.7%	17.0%	6.4%					
	Estimated Prosser Tally	2,346	429	2,916	1,401	22	7113	7,113			
	Naches DFW Percent	17.4%	20.6%	27.5%	29.5%	7.9%					
	Estimated Prosser Tally	4,968	3,847	14,023	2,439	26	25303	25,303			
	Upper YakimaDFW Percent	74.3%	77.1%	66.8%	53.5%	85.8%					
	Estimated Prosser Tally	21,188	14,407	34,055	4,419	289	74358	74,358			
	Yakima Passage Wild Tally	28,502	18,683	50,994	8,258	336	106774	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	26.7%	26.7%	37.1%	23.4%	23.4%					
	Total Passage	106,741	69,970	137,366	35,270	1,437	350,785	350,785	358,055		1.0207
	American Passage	8,785	1,608	7,855	5,982	92	24,321	24,321	24,826		
	Naches Passage	18,605	14,408	37,774	10,415	113	81,314	81,314	82,999		
	American & Naches Passage	27,390	16,016	45,628	16,397	205	105,636	105,636	107,825		
	Upper Yakima Passage	79,352	53,955	91,738	18,873	1,232	245,149	245,149	250,230		
McN UnStr Wild	Estimate b. :ion Efficiency	32.6%	32.6%	32.6%	32.6%	32.6%					
	Total Passage	87,352	57,260	156,284	25,309	1,031	327,236	327,236	333,839		1.0202
	American Passage	7,189	1,316	8,936	4,293	66	21,800	21,800	22,240		
	Naches Passage	15,225	11,791	42,976	7,474	81	77,546	77,546	79,111		
	American & Naches Passage	22,415	13,106	51,912	11,766	147	99,346	99,346	101,351		
	Upper Yakima Passage	64,938	44,154	104,372	13,543	884	227,890	227,890	232,489		
Pooled Str Wild	Estimate c. :ion Efficiency	27.5%	27.5%	35.1%	21.1%	21.1%					
	Total Passage	103,702	67,978	145,428	39,056	1,591	357,755	357,755	365,468		1.0216
	American Passage	8,535	1,562	8,316	6,624	102	25,139	25,139	25,680		
	Naches Passage	18,075	13,997	39,991	11,533	125	83,721	83,721	85,526		
	American & Naches Passage	26,610	15,560	48,306	18,157	227	108,860	108,860	111,206		
	Upper Yakima Passage	77,092	52,418	97,122	20,898	1,365	248,896	248,896	254,261		
Pooled UnStr Wild	Estimate e. :ion Efficiency	30.5%	30.5%	30.5%	30.5%	30.5%					
	Total Passage	93,410	61,231	167,121	27,064	1,103	349,929	349,929	356,990		1.0202
	American Passage	7,688	1,407	9,556	4,590	70	23,312	23,312	23,782		
	Naches Passage	16,281	12,608	45,956	7,992	87	82,924	82,924	84,597		
	American & Naches Passage	23,969	14,015	55,512	12,582	157	106,235	106,235	108,379		
	Upper Yakima Passage	69,441	47,216	111,609	14,482	946	243,693	243,693	248,611		
Hatchery	Prosser Hatchery Tally	0	13,014	69,719	20,263	879	103,874	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	48,738	187,807	86,542	3,753	326,839	343,892	351,019	0.0496	1.0207
McN-UnStr Hatch	Estimate b. Total Passage	0	39,885	213,671	62,100	2,693	318,349	334,959	341,718		1.0202
Pooled Str Hatch	Estimate c. Total Passage	0	47,350	198,830	95,831	4,155	346,166	364,227	372,079		1.0216
Pooled UnStr Hatch	Estimate e. Total Passage	0	42,651	228,489	66,406	2,879	340,425	358,187	365,415		1.0202

2014	Brood-Year 2012	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	1,589	4,340	14,949	11,897	959	33,735	33,735			
	American DFW Percent	11.7%	12.0%	9.1%	11.9%	13.9%					
	Estimated Prosser Tally	185	522	1,360	1,421	133	3621	3,621			
	Naches DFW Percent	41.2%	21.7%	30.2%	38.1%	0.0%					
	Estimated Prosser Tally	655	944	4,509	4,535	0	10643	10,643			
	Upper YakimaDFW Percent	47.2%	66.2%	60.7%	49.9%	86.1%					
	Estimated Prosser Tally	750	2,874	9,080	5,940	826	19471	19,471			
	Yakima Passage Wild Tally	1,589	4,340	14,949	11,897	959	33735	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	13.9%	13.9%	13.9%	13.9%	6.0%					
	Total Passage	11,447	31,257	107,660	85,679	15,923	251,966	251,966	250,881		0.9957
	American Passage	1,334	3,760	9,791	10,236	2,208	27,329	27,329	27,211		
	Naches Passage	4,715	6,795	32,474	32,662	0	76,646	76,646	76,317		
	American & Naches Passage	6,049	10,555	42,266	42,898	2,208	103,975	103,975	103,528		
	Upper Yakima Passage	5,398	20,701	65,395	42,781	13,715	147,991	147,991	147,354		
McN UnStr Wild	Estimate b. :ion Efficiency	13.8%	13.8%	13.8%	13.8%	13.8%					
	Total Passage	11,481	31,349	107,976	85,931	6,930	243,667	243,667	241,676		0.9918
	American Passage	1,338	3,771	9,820	10,266	961	26,156	26,156	25,942		
	Naches Passage	4,729	6,815	32,570	32,758	0	76,872	76,872	76,244		
	American & Naches Passage	6,066	10,586	42,390	43,024	961	103,027	103,027	102,186		
	Upper Yakima Passage	5,414	20,762	65,587	42,907	5,969	140,639	140,639	139,490		
Pooled Str Wild	Estimate c. :ion Efficiency	13.1%	13.1%	13.1%	13.1%	5.0%					
	Total Passage	12,091	33,016	113,718	90,500	19,031	268,355	268,355	267,433		0.9966
	American Passage	1,409	3,972	10,342	10,812	2,638	29,173	29,173	29,073		
	Naches Passage	4,980	7,178	34,302	34,500	0	80,959	80,959	80,681		
	American & Naches Passage	6,389	11,149	44,644	45,312	2,638	110,132	110,132	109,754		
	Upper Yakima Passage	5,702	21,866	69,074	45,188	16,392	158,223	158,223	157,679		
Pooled UnStr Wild	Estimate e. Total Passage	13.0%	13.0%	13.0%	13.0%	13.0%					
	Total Passage	12,197	33,306	114,717	91,295	7,363	258,877	258,877	256,762		0.9918
	American Passage	1,421	4,007	10,433	10,907	1,021	27,788	27,788	27,561		
	Naches Passage	5,024	7,241	34,603	34,803	0	81,670	81,670	81,003		
	American & Naches Passage	6,445	11,247	45,036	45,710	1,021	109,459	109,459	108,564		
	Upper Yakima Passage	5,752	22,058	69,681	45,585	6,342	149,419	149,419	148,198		
Hatchery	Prosser Hatchery Tally	0	1,493	16,126	30,753	1,114	49,486	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	10,749	116,139	221,480	18,480	366,847	385,256	383,598	0.0478	0.9957
McN-UnStr Hatch	Estimate b. Total Passage	0	10,781	116,480	222,131	8,043	357,434	375,371	372,304		0.9918
Pooled Str Hatch	Estimate c. Total Passage	0	11,354	122,673	233,942	22,087	390,056	409,630	408,222		0.9966
Pooled UnStr Hatch	Estimate e. Total Passage	0	11,454	123,751	235,997	8,545	379,747	398,803	395,545		0.9918

2015	Brood-Year 2013	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	2,658	13,541	35,320	11,639	4	63,162	63,162			
	American DFW Percent	13.9%	11.6%	8.9%	14.7%	14.7%					
	Estimated Prosser Tally	368	1,573	3,149	1,716	1	6807	6,807			
	Naches DFW Percent	16.8%	26.3%	23.1%	24.1%	24.1%					
	Estimated Prosser Tally	447	3,564	8,169	2,804	1	14985	14,985			
	Upper YakimaDFW Percent	69.3%	62.1%	68.0%	61.2%	61.2%					
	Estimated Prosser Tally	1,843	8,404	24,002	7,119	2	41370	41,370			
	Yakima Passage Wild Tally	2,658	13,541	35,320	11,639	4	63162	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	52.9%	52.9%	52.9%	56.3%	56.3%					
	Total Passage	5,028	25,614	66,809	20,689	6	118,146	118,146	120,848		1.0229
	American Passage	697	2,976	5,956	3,050	1	12,680	12,680	12,970		
	Naches Passage	845	6,742	15,451	4,985	2	28,024	28,024	28,665		
	American & Naches Passage	1,541	9,718	21,408	8,035	3	40,704	40,704	41,635		
	Upper Yakima Passage	3,486	15,897	45,401	12,655	4	77,442	77,442	79,213		
McN UnStr Wild	Estimate b. :ion Efficiency	53.2%	53.2%	53.2%	53.2%	53.2%					
	Total Passage	4,999	25,468	66,427	21,890	7	118,791	118,791	121,334		1.0214
	American Passage	693	2,959	5,922	3,227	1	12,802	12,802	13,076		
	Naches Passage	840	6,703	15,363	5,274	2	28,182	28,182	28,786		
	American & Naches Passage	1,533	9,662	21,285	8,501	3	40,984	40,984	41,861		
	Upper Yakima Passage	3,466	15,806	45,141	13,389	4	77,807	77,807	79,472		
Pooled Str Wild	Estimate c. :ion Efficiency	37.1%	37.1%	62.1%	57.6%	57.6%					
	Total Passage	7,170	36,531	56,858	20,221	6	120,786	120,786	123,289		1.0207
	American Passage	994	4,244	5,069	2,981	1	13,289	13,289	13,564		
	Naches Passage	1,205	9,615	13,150	4,872	2	28,843	28,843	29,441		
	American & Naches Passage	2,198	13,859	18,219	7,853	2	42,132	42,132	43,005		
	Upper Yakima Passage	4,972	22,671	38,639	12,368	4	78,654	78,654	80,284		
Pooled UnStr Wild	Estimate e. :ion Efficiency	51.4%	51.4%	51.4%	51.4%	51.4%					
	Total Passage	5,173	26,355	68,741	22,653	7	122,930	122,930	125,561		1.0214
	American Passage	717	3,062	6,129	3,339	1	13,248	13,248	13,531		
	Naches Passage	869	6,937	15,898	5,458	2	29,164	29,164	29,788		
	American & Naches Passage	1,586	9,999	22,027	8,797	3	42,412	42,412	43,320		
	Upper Yakima Passage	3,587	16,356	46,714	13,856	4	80,518	80,518	82,241		
Hatchery	Prosser Hatchery Tally	0	43,016	90,070	26,254	11	159,351	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	81,366	170,371	46,668	19	298,424	317,197	324,451	0.0592	1.0229
McN-UnStr Hatch	Estimate b. Total Passage	0	80,901	169,397	49,377	21	299,696	318,550	325,368		1.0214
Pooled Str Hatch	Estimate c. Total Passage	0	116,043	144,995	45,612	19	306,669	325,961	332,715		1.0207
Pooled UnStr Hatch	Estimate e. Total Passage	0	83,720	175,300	51,098	21	310,139	329,649	336,705		1.0214

2016	Brood-Year 2014	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	2,900	3,922	4,227	3,478	73	14,599	14,599			
	American DFW Percent	5.7%	7.4%	9.4%	13.0%	3.7%					
	Estimated Prosser Tally	165	291	399	452	3	1310	1,310			
	Naches DFW Percent	26.4%	23.2%	38.4%	34.5%	0.0%					
	Estimated Prosser Tally	766	909	1,624	1,200	0	4500	4,500			
	Upper YakimaDFW Percent	67.9%	69.4%	52.1%	52.5%	96.3%					
	Estimated Prosser Tally	1,969	2,722	2,204	1,825	70	8790	8,790			
	Yakima Passage Wild Tally	2,900	3,922	4,227	3,478	73	14599	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	5.5%	5.5%	5.5%	22.8%	22.8%					
	Total Passage	52,843	71,469	77,035	15,257	320	216,925	216,925	51,305		0.2365
	American Passage	3,007	5,304	7,273	1,983	12	17,578	17,578	4,157		
	Naches Passage	13,956	16,568	29,600	5,266	0	65,391	65,391	15,465		
	American & Naches Passage	16,963	21,872	36,873	7,250	12	82,969	82,969	19,623		
	Upper Yakima Passage	35,881	49,598	40,162	8,008	308	133,956	133,956	31,682		
McN UnStr Wild	Estimate b. :ion Efficiency	9.6%	9.6%	9.6%	9.6%	9.6%					
	Total Passage	30,115	40,730	43,902	36,116	757	151,620	151,620	39,037		0.2575
	American Passage	1,714	3,022	4,145	4,694	28	13,603	13,603	3,502		
	Naches Passage	7,953	9,442	16,869	12,466	0	46,731	46,731	12,031		
	American & Naches Passage	9,667	12,465	21,014	17,161	28	60,334	60,334	15,534		
	Upper Yakima Passage	20,448	28,265	22,888	18,956	729	91,286	91,286	23,503		
Pooled Str Wild	Estimate c. :ion Efficiency	5.9%	5.9%	4.4%	21.5%	21.5%					
	Total Passage	49,149	66,473	96,748	16,177	339	228,887	228,887	53,478		0.2336
	American Passage	2,797	4,933	9,134	2,103	13	18,979	18,979	4,434		
	Naches Passage	12,980	15,410	37,175	5,584	0	71,149	71,149	16,624		
	American & Naches Passage	15,777	20,343	46,309	7,687	13	90,128	90,128	21,058		
	Upper Yakima Passage	33,372	46,131	50,439	8,491	326	138,759	138,759	32,420		
Pooled UnStr Wild	Estimate e. :ion Efficiency	8.4%	8.4%	8.4%	8.4%	8.4%					
	Total Passage	34,538	46,712	50,350	41,421	868	173,890	173,890	44,770		0.2575
	American Passage	1,965	3,466	4,754	5,384	32	15,601	15,601	4,017		
	Naches Passage	9,122	10,829	19,347	14,297	0	53,594	53,594	13,799		
	American & Naches Passage	11,087	14,295	24,100	19,681	32	69,196	69,196	17,815		
	Upper Yakima Passage	23,451	32,417	26,250	21,740	836	104,694	104,694	26,955		
Hatchery	Prosser Hatchery Tally	0	9,155	14,039	20,515	66	136,488	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	166,846	255,836	90,006	289	1,499,037	1,587,340	375,419	0.0556	0.2365
McN-UnStr Hatch	Estimate b. Total Passage	0	95,085	145,799	213,058	685	1,417,512	1,501,013	386,455		0.2575
Pooled Str Hatch	Estimate c. Total Passage	0	155,183	321,302	95,434	307	1,632,683	1,728,859	403,938		0.2336
Pooled UnStr Hatch	Estimate e. Total Passage	0	109,051	167,214	244,352	785	1,625,716	1,721,481	443,217		0.2575

2017	Brood-Year 2015	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	2,542	458	993	1,352	24	5,369	5,369			
	American DFW Percent	10.2%	11.2%	15.8%	10.8%	37.2%					
	Estimated Prosser Tally	296	440	668	375	27	1805	1,805			
	Naches DFW Percent	31.7%	27.7%	27.1%	29.6%	11.5%					
	Estimated Prosser Tally	919	1,087	1,146	1,028	8	4189	4,189			
	Upper YakimaDFW Percent	58.1%	61.1%	57.1%	59.6%	51.4%					
	Estimated Prosser Tally	1,685	2,395	2,414	2,074	37	8605	8,605			
	Yakima Passage Wild Tally	2,900	3,922	4,227	3,478	73	14599	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	5.5%	5.5%	5.5%	9.3%	9.3%					
	Total Passage	45,879	8,257	17,922	14,554	258	86,871	86,871	60,411		0.6954
	American Passage	4,680	926	2,832	1,569	96	10,102	10,102	7,025		
	Naches Passage	14,544	2,289	4,857	4,304	30	26,024	26,024	18,097		
	American & Naches Passage	19,223	3,215	7,688	5,873	126	36,125	36,125	25,122		
	Upper Yakima Passage	26,656	5,042	10,233	8,682	133	50,745	50,745	35,289		
McN UnStr Wild	Estimate b. :ion Efficiency	7.2%	7.2%	7.2%	7.2%	7.2%					
	Total Passage	35,465	6,383	13,854	18,862	335	74,899	74,899	49,700		0.6636
	American Passage	3,617	716	2,189	2,033	124	8,679	8,679	5,759		
	Naches Passage	11,242	1,770	3,754	5,578	38	22,383	22,383	14,853		
	American & Naches Passage	14,860	2,485	5,943	7,611	163	31,062	31,062	20,612		
	Upper Yakima Passage	20,605	3,897	7,910	11,251	172	43,836	43,836	29,088		
Pooled Str Wild	Estimate c. :ion Efficiency	5.9%	5.9%	5.9%	9.7%	9.7%					
	Total Passage	43,257	7,785	16,897	14,009	249	82,198	82,198	57,051		0.6941
	American Passage	4,412	873	2,670	1,510	92	9,557	9,557	6,633		
	Naches Passage	13,712	2,159	4,579	4,143	29	24,622	24,622	17,089		
	American & Naches Passage	18,125	3,031	7,249	5,653	121	34,179	34,179	23,723		
	Upper Yakima Passage	25,132	4,754	9,648	8,357	128	48,019	48,019	33,328		
Pooled UnStr Wild	Estimate e. :ion Efficiency	7.6%	7.6%	7.6%	7.6%	7.6%					
	Total Passage	33,442	6,019	13,064	17,786	316	70,627	70,627	46,866		0.6636
	American Passage	3,411	675	2,064	1,917	117	8,184	8,184	5,431		
	Naches Passage	10,601	1,669	3,540	5,260	36	21,107	21,107	14,006		
	American & Naches Passage	14,012	2,344	5,604	7,177	154	29,291	29,291	19,436		
	Upper Yakima Passage	19,430	3,675	7,459	10,609	162	41,336	41,336	27,429		
Hatchery	Prosser Hatchery Tally	1	235	1,943	5,727	41	7,947	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	18	4,241	35,067	61,646	441	386,839	412,204	286,652	0.0615	0.6954
McN-UnStr Hatch	Estimate b. Total Passage	9	3,279	27,108	79,893	572	425,176	453,055	300,633	0.1029	0.6636
Pooled Str Hatch	Estimate c. Total Passage	12	3,999	33,063	59,338	425	369,465	393,691	273,248	0.1029	0.6941
Pooled UnStr Hatch	Estimate e. Total Passage	9	3,092	25,561	75,336	539	400,926	427,215	283,486	0.1029	0.6636

Genetic Sample Analysis not yet available

2018	Brood-Year 2016	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild	Prosser Wild Tally	6,091	1,173	8,517	1,374	96	17,251	17,251			
	American DFW Percent										
	Estimated Prosser Tally	0	0	0	0	0	0	0			
	Naches DFW Percent										
	Estimated Prosser Tally	0	0	0	0	0	0	0			
	Upper YakimaDFW Percent										
	Estimated Prosser Tally	0	0	0	0	0	0	0			
	Yakima Passage Wild Tally	0	0	0	0	0	0	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a. :ion Efficiency	9.8%	9.8%	9.8%	4.9%	4.9%					
	Total Passage	62,211	11,978	86,996	27,928	1,951	191,064	191,064	128,380		0.6719
	American Passage	0	0	0	0	0	0	0	0		
	Naches Passage	0	0	0	0	0	0	0	0		
	American & Naches Passage	0	0	0	0	0	0	0	0		
	Upper Yakima Passage	0	0	0	0	0	0	0	0		
McN UnStr Wild	Estimate b. :ion Efficiency	8.4%	8.4%	8.4%	8.4%	8.4%					
	Total Passage	72,640	13,986	101,579	16,386	1,145	205,735	205,735	122,910		0.5974
	American Passage	0	0	0	0	0	0	0	0		
	Naches Passage	0	0	0	0	0	0	0	0		
	American & Naches Passage	0	0	0	0	0	0	0	0		
	Upper Yakima Passage	0	0	0	0	0	0	0	0		
Pooled Str Wild	Estimate c. :ion Efficiency	13.7%	13.7%	9.3%	4.4%	4.4%					
	Total Passage	44,443	8,557	91,787	30,928	2,161	177,875	177,875	131,489		0.7392
	American Passage	0	0	0	0	0	0	0	0		
	Naches Passage	0	0	0	0	0	0	0	0		
	American & Naches Passage	0	0	0	0	0	0	0	0		
	Upper Yakima Passage	0	0	0	0	0	0	0	0		
Pooled UnStr Wild	Estimate e. :ion Efficiency	8.2%	8.2%	8.2%	8.2%	8.2%					
	Total Passage	74,408	14,326	104,052	16,785	1,173	210,744	210,744	136,769		0.6490
	American Passage	0	0	0	0	0	0	0	0		
	Naches Passage	0	0	0	0	0	0	0	0		
	American & Naches Passage	0	0	0	0	0	0	0	0		
	Upper Yakima Passage	0	0	0	0	0	0	0	0		
Hatchery	Prosser Hatchery Tally	0	1,470	15,058	2,640	392	19,560	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a. Total Passage	0	15,011	153,802	53,661	7,968	386,839	411,667	276,607	0.0603	0.6719
McN-UnStr Hatch	Estimate b. Total Passage	0	17,527	179,584	31,484	4,675	425,176	452,465	270,311		0.5974
Pooled Str Hatch	Estimate c. Total Passage	0	10,724	162,273	59,425	8,824	369,465	393,178	290,644		0.7392
Pooled UnStr Hatch	Estimate e. Total Passage	0	17,954	183,956	32,251	4,789	400,926	426,658	276,892		0.6490

Analyses of Variation for Passage Trends over Years

Table D.1.a. Linear Regession of Upper Yakima Hatchery Prosser Passage on Year

	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS =SS/DF)	F-Ratio	Two-Sided Type 1 Error P	Two-Sided Type 1 Error P
Regression	1	1.424E+10	1.424E+10	2.97	0.1031	0.0516
Residual	17	8.157E+10	4.798E+09			
Total	18	9.582E+10				

Table D.1.b. Linear Regession of Total Wild Prosser Passage on Year

	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS =SS/DF)	F-Ratio	Two-Sided Type 1 Error P	Two-Sided Type 1 Error P
Regression	1	1.6630E+10	1.663E+10	1.44	0.2461	0.1231
Residual	17	1.959E+11	1.152E+10			
Total	18	2.125E+11				

Table D.1.c. Linear Regession of Upper Yakima Wild Prosser Passage on Year

	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS =SS/DF)	F-Ratio	Two-Sided Type 1 Error P	Two-Sided Type 1 Error P
Regression	1	5.867E+09	5.867E+09	0.75	0.3999	0.2000
Residual	15	1.172E+11	7.816E+09			
Total	16	1.231E+11				

Table D.1.d. Linear Regession of American Wild Prosser Passage on Year

	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS =SS/DF)	F-Ratio	Two-Sided Type 1 Error P	Two-Sided Type 1 Error P
Regression	1	9.711E+08	9.711E+08	6.94	0.0188	0.0094
Residual	15	2.099E+09	1.399E+08			
Total	16	3.070E+09				

Table D.1.e. Linear Regession of Naches Wild Prosser Passage on Year

	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS =SS/DF)	F-Ratio	Two-Sided Type 1 Error P	Two-Sided Type 1 Error P
Regression	1	9.807E+08	9.807E+08	1.58	0.2283	0.1142
Residual	15	9.323E+09	6.215E+08			
Total	16	1.030E+10				

Proportion Trend of Hatchery Stock over Years

Table D.2.a. Weighted* Logistic Regression of Proportion of Prosser Upper Yakima Stock Passage

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P
Regression	135505	1	135505	4.53	0.0483
Error	508702	17	29924		

*** Total Prosser Passage (Total Wild and Upper Yakima Passage)**

Table D.2.b. Weighted* Logistic Regression of Proportion of Prosser Upper Yakima Stock Passage that is of Hatchery Upper-Yakima Stock

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P
Regression	98285	1	98285	2.94	0.1069
Error	501198	15	33413		

*** Total Prosser Passage of Upper Yakima Stock**

Table D.3.a. Weighted* Logistic Regression of Proportion of total Wild Passage that is Upper-Yakima Stock

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P
Regression	1,725	1	1,725	0.15	0.7004
Error	168,205	15	11,214		

* Total Prosser Wild Passage

Table D.3.b. Weighted* Logistic Regression of Proportion of total Wild Passage that is American Stock

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P
Regression	12,787	1	12,787	1.57	0.2291
Error	122,020	15	8,135		

* Total Prosser Wild Passage

Table D.3.c. Weighted* Logistic Regression of Proportion of total Wild Passage that is Naches Stock

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P
Regression	1191	1	1191	0.31	0.5885
Error	58456	15	3897		

* Total Prosser Wild Passage

Appendix B (of Appendix C)

Methods of Estimating Smolt Survival and Passage

Doug Neeley, Consultant to the Yakama Nation

In general, for a given cohort, an estimate of smolt passage at a given upstream monitoring site is based on the expansion (division) of that site's sample tallies by the proportion of PIT-tagged smolt detected at the site (detection efficiency). For a given cohort, the detection efficiency is based on sampling these fish at a downstream site, the estimate being a given downstream number of detections at that site that were previously detected at the upstream site (this number is herein referred to as joint detections) divided by the total number detected at the downstream site (the number is herein referred as total detections).

Smolt Survival to McNary

For YKFP cohort releases of Coho and Spring, Summer, and Fall Chinook survival to McNary, detection efficiency estimates are based on all[10] of the given cohort's PIT-tagged smolt released above McNary. A given release's passage is then the tally of the release's detections at McNary divided by the cohort's detection efficiency, and the release-to-survival estimate is that passage estimate divided by the number released.

The specific estimation procedure of the passage/survival is discussed in two parts. The first is the estimation of the detection efficiencies and the second is the application of those detection efficiencies to the McNary tallies.

Estimation of the Detection McNary Efficiencies

There are two downstream-detection sites used to estimate McNary's detection efficiency--John Day and Bonneville Dams. A given downstream-dam's daily McNary detection efficiency is unlikely to be homogeneous over days because the detections are from a mixture of daily passages from McNary, and the McNary detection efficiency is unlikely to be constant over the McNary passage time.

For each downstream dam, the detection efficiencies are stratified over the downstream passage time. The stratification is done separately for the John Day and Bonneville sites in a manner that creates relatively homogeneous detection efficiency estimates among contiguous days within the downstream dam's strata. The stratification procedures for a given downstream dam are as follows:

The McNary daily detection efficiency (DE) estimated at the downstream site is

$$DE = n(\text{daily joint site and McNary detections})/n(\text{total site detections})$$

A stepwise logistic regression is performed on the downstream dam's daily detection efficiency estimates as the dependent variable on indicator variables (IV) that are unique to each downstream dam's date of passage using the following model:

$$\text{logit}[DE] = B(0)+B(i)*IV(i) + B(i+1)*IV(i+1) + B(i+2)*IV(i+2) + \ldots$$

The logit is the logistic transformation of the daily detection efficiency,

$$\text{logit}(DE) = \ln[DE/(1-DE)],$$

[10] **This includes the Cohort's PIT-tagged smolt released at the hatchery or released from sites downstream of the hatchery but sufficiently up-river of the upstream site so as be well mixed with hatchery released smolt prior to reaching the upstream site.**

"ln" being the natural log and the IV's being sequential Julian date indicator variables. B(0) is the "intercept", and the B(i),…B(i+1), B(i+2)… coefficients associated with IV indicator variables for sequential Julian passage dates beginning with Julian date i. For a given passage date, the indicator variable associated with that date takes on the value 0 for any day previous to that date and 1 for that date and any day subsequent to that date, as indicated in the following table:

Julian Date	DR	IV(i)	IV(i+1)	IV(i+2)	IV(i+3)	IV(i+4)	IV(i+5)
i-3	DR(i-3)	0	0	0	0	0	0
i-2	DR(i-2)	0	0	0	0	0	0
i-1	DR(i-1)	0	0	0	0	0	0
i	DR(i)	1	0	0	0	0	0
i+1	DR(i+1)	1	1	0	0	0	0
i+2	DR(i+2)	1	1	1	0	0	0
i+3	DR(i+3)	1	1	1	1	0	0
i+4	DR(i+4)	1	1	1	1	1	0
i+5	DR(i+5)	1	1	1	1	1	1
i+6	DR(i+6)	1	1	1	1	1	1
i+7	DR(i+7)	1	1	1	1	1	1
i+8	DR(i+8)	1	1	1	1	1	1
…	…	…	…	…	…	…	…

Since the detection facilities at the downstream dams are not usually watered up until mid-march, the choice of first Julian date, i, is somewhat arbitrary. The first date used in the analysis has been taken to be the first date that the number of joint detections has reached or exceeded 20. Likewise, the choice of last Julian date used has been taken to be the date that the number of reverse cumulative joint detections reached or exceeded 20[11].

The stepwise regression creates the strata. Say that two coefficients were indicator variables selected from the stepwise analysis giving estimates for B(j) and B(k). These two coefficients create three strata within which the detection rates are relatively homogeneous. The estimated detection efficiencies can be estimated by a careful weighting of the B(0), B(j), and B(k) estimates, and then by retransforming the logit estimate, for the weighted estimates:

$$DE(\text{stratum}) = 1/[1+\exp(-\text{logit estimate})].$$

However, a conceptually easier way is: For the first stratum, pool (add) all the daily joint detections from the first day of detection through day j-1 [j referenced by B(j)] and do the same for the total detections, the cumulative joint-detection pooled number divided by the total pooled number being the detection efficiency for the first stratum; then, similarly, for the second stratum, pool over detection dates j through k-1 [k referenced by B(k)]; and for the third stratum, pool over detection dates k through the last day of detection.

It is emphasized that this procedure is done separately for the two lower-stream dams, John Day and Bonneville. The strata dates will most probably be different for the two dams, and the number of strata may differ as well. The combining of the information from the two dams will be discussed later.

Using this process, there were occasional cases in which a stratum was comprised of only one day with an unusually high or low value compared to the estimates from the adjacent strata. Even though the stepwise procedure identified

[11] **Inclusion of all detection dates would have resulted in a singularity in the analysis**

that single-day stratum as having a significantly[12] different detection efficiency than those adjacent strata, the estimate was usually pooled with the adjacent stratum that had the efficiency estimate that differed least from the single-day's estimate. This was done because of concern that a single day's estimate may have been the result of a statistical Type 2 error based on only that single day's worth of information (an outlier).

Assignment of Lower Dam Detection-Rate Estimates to McNary Dates of Passage

A lower-dam's stratum estimate of the McNary detection rate was from fish that were detected at various dates of McNary passage. And fish passing on a given date at McNary could have passed during different step-wise-regression-based-time strata at the lower dam. To make assignments of the lower dam's statum's estimated detection efficiency to a McNary passage date, the passage dates at McNary were themselves stratified independently of the lower dam stratification procedures. The 2002 Coho releases will serve as an example. The McNary strata that were been used for Coho are pre-May, mid-May through May 15, late May, early June through June 15 and post early June[13].

The stratified Bonneville-based McNary detection strata along with the number of tallied joint Bonneville detections with McNary and the total Bonneville detections within strata are given in Table A.1. **(Note: Highlighted cells in Table A.1. indicates respective numbers found in subsequent tables)**

Table A.1. Bonneville-based Stratum Totals and McNary Detection Efficiencies

Beginning Julian Date	Ending Julian Date	Total Joint* Detections	Total Detections	Detection Efficiency
Begin Run	05/18/02	35	66	0.5303
05/19/02	End Run	91	549	0.1658
	Total	126	615	0.2049

***Bonneville Detections of smolt previously detected at McNary**

The joint detections frequencies within strata were also tallied within in the McNary strata and are presented in Table A.2.

Table A.2. Distribution of Table A.1 Bonneville Detections previously Detected at McNary over McNary Strata within Bonneville Strata

Beginning	Ending	Joint Detections Allocated to McNary Strata					
Julian Date	Julian Date	Pre May	Early May	Late May	Early June	Later	Total
Begin Run	05/18/02	14	21	0	0	0	35
05/19/02	End Run	0	2	77	10	2	91
	Total	14	23	77	10	2	126

[12] 5% significance level for adding a consecutive date to the stratum (forward step) or subtracting a consecutive day from the stratum (backward step)

[13] These generally served as strata for Fall Chinook as well. For Spring Chinook, earlier strata were used for the McNary strata, because of Spring Chinook's earlier out-migration.

Table A.2. detection tallies are put into relative frequency[14] form within strata in Table B.3.

Table A.3. Relative Distribution of Table 2 Joint Bonneville and McNary Joint Detection Totals over McNary Strata within Bonneville Strata

Beginning	Ending	Proportions of Joint Detections to McNary Strata					
Julian Date	Julian Date	Pre May	Early May	Late May	Early June	Later	Total
Begin Run	05/18/02	0.4000	0.6000	0.0000	0.0000	0.0000	1.0000
05/19/02	End Run	0.0000	0.0220	0.8462	0.1099	0.0220	1.0000
Pooled Efficiencies		0.1111	0.1825	0.6111	0.0794	0.0159	1.0000

These relative frequencies are then multiplied by the number of given in the “Total Detections” column of Table A.1. to assign those detections to McNary strata within Bonneville strata, the results[15] being presented in Table A.4.

Table A.4. Distribution of Table A.1 of Total Detections over McNary Strata within Bonneville Strata

Beginning	Ending	Allocated Total Detections					
Julian Date	Julian Date	Pre May	Early May	Late May	Early June	Later	Total
Begin Run	05/18/02	26.4	39.6	0.0	0.0	0.0	66.00
05/19/02	End Run	0.0	12.1	464.5	60.3	12.1	549.00
	Total	26.4	51.7	464.5	60.3	12.1	615.00

The joint-detection column total from Table A.2. is divided by the total-detection column total from Table A.4. to estimate the McNary strata detection efficiencies which are given in the first row of Table A.5.[16]

In that table statistical comparisons are made between adjacent strata to determine whether there is sufficient evidence to pool McNary strata. The standard error is that for the binomial comparison between binomial detection-efficiency differences[17], and the z-ratio is the adjacent strata difference in detection efficiencies divided by the associated standard error. The z-ratios between all but the Early and Late May strata is small which justifies the pooling, but the z-ratio between Early and Late May is large; therefore the Pre-May and Early May estimates are pooled and the subsequent strata are pooled giving two pooled strata estimates. Note that blue highlighted Pooled detection efficiency of Tables A.1. and A.5. is McNary’s unstratified estimate.

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[14] **As an example, within a Bonneville stratum’s row, divide the McNary stratum’s column joint totals in Table A.2. by that row’s total; e.g. for the first row Bonneville stratum ending 05/18/02 in Table A.2., McNary’s Pre-May stratum’s cell’s passage detection number divided by the row’s total detection number, 14/35 = 0.4, is given the corresponding cell in Table A.3.**

[15] **There are inherent biases associated with this procedure. The procedure assumes that the distributions of detection efficiencies at Bonneville are uniform over days within the Bonneville Strata which they probably are not. Also the method assumes that the distribution of a lower dam’s joint and total detection relative frequency distributions over McNary Dam strata are the same. The reason for the stratification assumes that they are not the same. The question is whether these estimates and better than the non-stratified pooled estimate like that given “Pooled” column shaded detection efficiency given in Table A.5. This will be discussed in a subsequent section.**

[16] **For example, the Early-May detection efficiency is 23 (the Early-May total from Table A.2.) divided by 51.7 (the corresponding entry in Table A.4 total), 23/51.7 = 0.4452 (corresponding Early-May entry in first row of Table A.5).**

[17] ***Estimated standard error between proportions p(j) and p(j+1) is square root of {[p(j)*(1-p(j))/n(j)]+ {[p(j+1)*(1-p(j+1))/n(j+1)]}***

Table A.5. Individual Bonneville-Based McNary-Strata Detection Efficiencies

	Allocated Total Detections					
	Pre May	Early May	Late May	Early June	Later	Pooled
Detection Efficiencies*	0.5303	0.4452	0.1658	0.1658	0.1658	0.2049
Adjacent Strata Difference		-0.0851	-0.2794117	0	0	
Standard Error (Difference)		0.1192	0.0713	0.0509	0.1173	
z-ratio		-0.7141	-3.9209	0.0000	0.0000	
	Pre May	Early May	Late May	Early June	Later	Pooled
Pooled Efficiencies		0.4483	0.1658			0.2049

* ***For example the Pre-May total in Table A.2. divided by the Pre-May total in Table A.4. gives the Pre-May detection efficiency in Table A.5. (14/26.4) = 0.5030***

The same procedure is followed for John Day detections; these procedures are given in Tables B.1 through B.5. Note: the stepwise logistic regression procedure produced three John Day strata; whereas the Bonneville procedure discussed above produced two.

Table B.1. John Day-based Stratum Totals and McNary

Beginning Julian	Ending Julian	Total Joint Detections	Total Detections	Detection Efficiency
Begin Run	05/14/02	24	57	0.4211
05/15/02	06/02/02	54	242	0.2231
06/03/02	End Run	33	283	0.1166
Total		111	582	0.1907

Table B.2. Distribution of Table A.1 John Day Detection Detections previously Detected at McNary over McNary Strata within John Day Strata

Beginning	Ending	Joint Detections Allocated to McNary Strata					
Julian	Julian	Pre May	Early May	Late May	Early June	Later	Total
Begin Run	05/14/02	13	11	0	0	0	24
05/15/02	06/02/02	1	1	52	0	0	54
06/03/02	End Run	0	0	10	20	3	33
Total		14	12	62	20	3	111

Table B.3. Relative Distribution of Table 2 Joint John Day and McNary Joint Detection Totals over McNary Strata within John Day Strata

Beginning	Ending	Proportions of Joint Detections to McNary Strata					
Julian	Julian	Pre May	Early May	Late May	Early June	Later	Total
Begin Run	05/14/02	0.5417	0.4583	0.0000	0.0000	0.0000	1.0000
05/15/02	06/02/02	0.0185	0.0185	0.9630	0.0000	0.0000	1.0000
06/03/02	End Run	0.0000	0.0000	0.3030	0.6061	0.0909	1.0000
Detection Efficiencies		0.1261	0.1081	0.5586	0.1802	0.0270	1.0000

Table B.4. Distribution of Table A.1 of Total Detections over McNary Strata within John Day Strata.

Beginning	Ending	Allocated Total Detections					
Julian Date	Julian Date	Pre May	Early May	Late May	Early June	Later	Total
Begin Run	05/14/02	30.9	26.1	0.0	0.0	0.0	57
05/15/02	06/02/02	4.5	4.5	233.0	0.0	0.0	242
06/03/02	End Run	0.0	0.0	85.8	171.5	25.7	283
Total		35.4	30.6	318.8	171.5	25.7	582

Table B.5. Individual John Day-Based McNary-Strata Detection Efficiencies.

	Allocated Total Detections					
	Pre May	Early May	Late May	Early June	Later	Pooled
Detection Efficiencies*	0.3960	0.3921	0.1945	0.1166	0.1166	0.1907
Adjacent Strata Difference		0.0039	0.1976	0.0779	0.0000	
Standard Error (Difference)		0.1206	0.0910	0.0330	0.0679	
z-ratio		0.0323	**2.1716**	**2.3566**	0.0000	
	Pre May	Early May	Late May	Early June	Later	Pooled
Pooled Efficiencies		0.3942	0.1945	0.1166		0.1907

Pooling Detection Efficiency Estimates over Downstream Sites

The pooling of estimates over sites is simply adding the Bonneville and John Day total joint detections with McNary together ("Total" rows in Tables A.2. and B.2. added together) and the McNary assigned total detection together ("Total" row in Tables A.4. and B.4. added together), and then dividing the former by the latter. The results are given in Table C.

Table C. McNary Detections and Detection Efficiencies pooled over lower Detection Sites

	Allocated Total Detections					Pooled over
	Pre May	Early May	Late May	Early June	Later	McNary Strata
Pooled Joint Detections Tables A.2 and B.2	28	35	139	30	5	237
Pooled Total Detections Tables A.4 and B.4	61.8	82.3	783.3	231.8	37.8	1197.0
Pooled Efficiencies (1st Row/2nd Row)	0.4534	0.4254	0.1774	0.1294	0.1323	0.1980
Adjacent Strata Difference		0.0280	0.2480	0.0480	-0.0029	
Standard Error (Difference)		0.0836	0.0562	0.0259	0.0594	
z-ratio		0.3348	4.4130	1.8532	-0.0489	
	Pre May	Early May	Late May	Early June	Later	Pooled
Pooled Efficiencies		0.4374	0.1774	0.1298		0.1980

The McNary detection tallies for a given release within the McNary strata are then divided by the lower dam detection efficiencies to obtain total within-stratum passage estimates, and these estimates are then totaled over McNary strata to estimate total McNary passage. The resulting total when divided by the number released is the estimated smolt-to-smolt survival index from release to McNary. These values were also pooled over strata based on the z-values.

Spring Chinook Smolt Passage at Prosser Dam

A portion of the Yakima River flow above Prosser Diversion Dam Smolt is diverted into Chandler Irrigation Canal immediately above the dam on the left bank. The canal is screened, and canal-diverted smolt are directed into a bypass system carrying 132 ft/sec of canal flow back to the river. The bypass passes through the Chandler Juvenile Monitoring Facility within which a timer gate directs a portion of the bypass flow into counting facility wherein the timer-directed smolt are tallied by species and by origin--wild or hatchery source.

There are two steps in the expansion of the tallies of the fish counted in the sampling facility: Expanding the number of tallied the species of interest by the sample rate to estimated total smolt bypassed, and then expanding that number by Prosser's bypass detection efficiency.

Estimating the sample rate

There are two PIT-tag detectors: One in the bypass upstream of the timer gate and one in the facility through which the diverted-flow sampled smolt are sent and tallied. For a given species on a daily basis, the PIT-tagged number of all Spring Chinook smolt released above Prosser Dam that detected in the counting facility is divided the number detected in the bypass as an estimated daily sample rate (SR) from the bypass for a given timer-gate setting.

The timer gate directs the bypass flow into the counting facility by opening the gate to counting facility for a set percentage of the time. That percentage, referred to herein as the timer-gate rate (TR), can be changed to accommodate the capability of staff to manage and tally the number of smolt.

The daily sample rate (SR) of smolt is proportion of canal bypassed smolt that are directed to the counting facility. For a given daily TR-setting, the sample rate was computed as

$$SR(TR) = n[facility(TR)]/n[bypass(TR)],$$

n[facility(TR)] and n[bypass(TR)] respectively being the total number detected in the facility and the total detected in the bypass.

In almost all cased, the SR is less than the TR, indicating not all fish passing through the bypass when the timer gate is open are actually entering and being detected in the facility. There were three common time gate settings, TR = 33%, TR = 50%, and TR = 100%, but there were several less commonly used settings for which precise estimates of the sample rates were not possible. The decision was made to calibrate the sample rates for the less common settings using the SR/TR ratios based on the more common TR=33%, and in most years the TR=50%. The TR = 100% rate was not used in the calibration because of the uniqueness of having all flow directed into the facility.

The ratios SR(TR)/TR for the TR=33% and the TR = 50% were used for the calibration value (CV), specifically the CV value was the weighted TR = 33% and TR = 50% estimates of SR/TR ratios ,

$$CV = w(33\%)*[SR(TR=33\%)/33\%]+w(50\%)*[SR(TR=50\%)/50\%],$$

The weights being the proportions of bypass detections within the TR setting.

$$w(33)\% = n[bypass(TR=33\%)]/\{n[bypass(TR=33\%)] + n[bypass(TR=50\%)]\}$$

$$w(50)\% = n[bypass(TR=33\%)]/\{n[bypass(TR=33\%)] + n[bypass(TR=50\%)]\},$$

the greater weighting given to the greater number of bypassed smolt.

In outmigration years 2004, 2006, 2009, 2012, and 2015-2017, there were very few or no days for which the TR setting was 50%, in which case the calibration value was equated to the SR/TR ratio for 33%.

For consistency sr values for a given TR value (TR*) were estimated as

$$SR(TR^*) = CVxTR^*$$

Within an outmigration year, the same CV value was applied to all TR values less than 100%, including.

In two of the outmigration years (2006 and 2011), the SR value exceeded the TR=33% values, the sample rate rates were equated to the TR values. This was because almost all SR values tended to be lower than their TR values, and a sample rate estimate greater than 33% was taken to be an outlier. In one of those two years, 2006, there were no TR = 50% settings, and in the other, 2011, there was only 1 day when there the setting was 50% and 84 days of the TR = 33% settings, therefore the decision was to used only the 33% setting for the CV value.

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, all bypassed smolt are usually transported without running them through the sample-facility detector.

The SR values used through release year 2017 are given in Table D.

Table D. Estimate sampling rates (SR) for given timer-gate-rate (TR) settings

		Estimated Sample Rates* (SR) for different Timer-Gate Rates										Total TR .33 & .5	
Out-Migration Year	Calibration Value	Timer-Gate Rate (TR) 0.05	0.1	0.2	0.25	0.33	0.4	0.45	0.5	0.75	1	Number of Detection Days	Total Number of Detections
1998	0.778	3.89%	7.78%	15.56%	19.45%	25.67%	31.12%	35.01%	38.90%	58.35%	97.85%	37	1,984
1999	0.833	4.17%	8.33%	16.67%	20.83%	27.50%	33.33%	37.50%	41.66%	62.50%	97.85%	76	4,413
2000	0.794	3.97%	7.94%	15.88%	19.85%	26.20%	31.76%	35.73%	39.70%	59.55%	97.85%	64	8,482
2001*	0.278	1.39%	2.78%	5.56%	6.95%	9.18%	11.13%	12.52%	13.91%	20.86%	97.85%	30	9,103
	actual estimate					10.08%			11.97%			0	0
2002	0.838	4.19%	8.38%	16.76%	20.95%	27.65%	33.52%	37.71%	41.90%	62.84%	97.85%	39	950
2003	0.669	3.34%	6.69%	13.37%	16.72%	22.06%	26.75%	30.09%	33.43%	50.15%	97.85%	77	17,360
2004	0.693	3.46%	6.93%	13.85%	17.32%	22.86%	27.71%	31.17%	34.63%	51.95%	97.85%	100	12,079
2005	0.776	3.88%	7.76%	15.52%	19.40%	25.61%	31.04%	34.92%	38.80%	58.21%	97.85%	76	3,476
2006**	1.000	5.00%	10.00%	20.00%	25.00%	33.00%	40.00%	45.00%	50.00%	75.00%	97.85%	65	5,960
	actual estimate					34.50%			no estimate			0	0
2007	0.800	4.00%	8.00%	16.00%	20.01%	26.41%	32.01%	36.01%	40.01%	60.02%	97.85%	75	7,723
2008	0.651	3.26%	6.51%	13.02%	16.28%	21.49%	26.04%	29.30%	32.55%	48.83%	97.85%	74	6,125
2009	0.770	3.85%	7.70%	15.39%	19.24%	25.40%	30.79%	34.64%	38.49%	57.73%	97.85%	88	4,809
2010	0.584	2.92%	5.84%	11.68%	14.61%	19.28%	23.37%	26.29%	29.21%	43.82%	97.85%	79	13,227
	actual estimate					0.192**			0.348**			0	0
2011***	1.000	5.00%	10.00%	20.00%	25.00%	33.00%	40.00%	45.00%	50.00%	75.00%	97.85%	84	7,722
	actual estimate				25.72%	37.10%			44.23%			0	0
2012	0.979	4.89%	9.79%	19.57%	24.46%	32.29%	39.14%	44.04%	48.93%	73.39%	97.85%	106	3,175
2013	0.973	4.86%	9.73%	19.45%	24.32%	32.10%	38.90%	43.77%	48.63%	72.95%	97.85%	114	8,471
2014	0.903	4.52%	9.03%	18.07%	22.59%	29.81%	36.14%	40.66%	45.17%	67.76%	97.85%	96	2,643
2015	0.830	4.15%	8.30%	16.60%	20.75%	27.39%	33.20%	37.35%	41.50%	62.25%	97.85%	96	11,256
2016	0.873	4.37%	8.73%	17.46%	21.83%	28.81%	34.93%	39.29%	43.66%	65.49%	97.85%	121	620
2017	0.819	4.09%	8.19%	16.37%	20.46%	27.01%	32.74%	36.83%	40.93%	61.39%	97.85%	79	1,492

*** the actual SR ratios were extremely low for both the TR = 33% and 5% settings.**

**** the actual SR ratio was somewhat than the TR = 33% settings, the TR setting was used instead of the SR estimates**

***** the SR esimate was higher than the TR estimate for TR = 33% but lower for the TR = 45% setting, however, the TR = 45% setting was based only on one day's setting, the TR setting was used instead of the SR estimates**

Estimation of the Prosser Bypass Detection Efficiencies

The Prosser estimation procedures are the same as those described under the McNary detection efficiency sections, except that there are three downstream detection sites instead of two (Bonneville, John Day, and McNary Dams). Detection efficiencies for outmigration years 1998 through 2017 are presented in the YKFP report *2017 Annual Chandler Certification for Yearling Outmigrating Spring Chinook smolt* (within Appendix B. Detailed Passage-Estimation Table). These detection efficiencies are again assigned to McNary strata[18] and then applied to both wild and hatchery sources.

[18] In the case of Prosser, The strata used were pre-March, March, April, May, and post-May because these are strata used by the Washington Department of Fish and Wildlife's Molecular Genetics Laboratory to genetically allocate wild stock sampled from the

The wild stock are tallied smolt that are not coded-wire tagged. The wild Spring Chinook are made up of Naches, American, and Upper-Yakima stock. All and only hatchery smolt are coded-wire tagged and are of Upper Yakima stock. Most hatchery smolt are also elastomer tagged by acclimation site, acclimation sites Clark Flat, Easton, and Jack Creek respectively receiving red, green, and orange elastomer tags. These tags are also tallied and pooled. The hatchery smolt that are not elastomer-tagged are PIT-tagged prior to release.

The wild and elastomer-tagged[19] hatchery tallies are expanded by four different estimates of McNary detection rates.

1. McNary-based un-stratified detection rate estimate
2. McNary-based stratified detection rate estimate
3. Pooled-lower-dam[20]-based un-stratified detection rate estimate
4. Pooled-lower-dam-based stratified detection rate estimate

The detection-efficiency-expanded tallied elastomer-tagged smolt are further expanded by the proportion of released hatchery smolt that are elastomer tagged. Smolt that are PIT-tagged prior to release are used for estimating smolt-to-smolt survival. These smolt are not elastomer tagged; therefore the proportion of fish that are elastomer-tagged is:

Proportion of released hatchery smolt that are elastomer tagged = 1 – proportion of smolt PIT-tagged before release.

Each of the above four method's estimates of hatchery juvenile passage was correlated with hatchery returns, and the one that gave the highest correlation was Number 4: Pooled-lower-dam-based stratified detection rate estimate.

There was an alternative method of estimation based on the detected number of all Chandler-bypassed smolt PIT-tagged at the hatchery instead of the number of elastomer-tagged smolt sampled from the bypass. These by-pass-detected PIT-tagged smolt were tallied within each Prosser stratum and then divided by the proportion of hatchery-released smolt that were PIT-tagged. Since this alternative was based on all bypassed smolt, there was no expansion by the sampling rate from the bypass. These by-passed smolt estimates based of passage on all-Chandler-bypassed smolt gave lower correlations for all four of the above estimators than those based on the timer-gate sampled smolt.

However, there was an issue when the methods based on timer-gate sampled smolt was applied to the 2016 juvenile passage for which there are only Age-3 returns at this writing, and this issue is discussed in the YKFP report *2017 Annual Chandler Certification for Yearling Outmigrating Spring Chinook Smolt.* For this outmigration year, the by-passed smolt estimate may have to be used applied in some fashion.

Prosser Juvenile Monitoring Facility to brood source. The allocations are brood origin: Naches, American, and Upper-Yakima River. Within these strata, the expanded wild passage estimates expanded by the genetically assigned proportions to the three wild stock.

[19] The tallied elastomer hatchery smolt are expanded by the proportion of released hatchery smolt that are not elastomer tagged. These are smolt that are PIT-tagged prior to release and are used for estimating smolt-to-smolt survival.

[20] Pooled over Bonneville, John Day, and McNary Dams

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Appendix D
Annual Report: Smolt Survival to McNary Dam of 1999-2013 and 2015-2018
PIT-tagged Spring Chinook released at Roza Dam

Doug Neeley, Consultant to the Yakama Nation

Introduction and Summary

From 1999[1] through 2013 and 2015 through 2018, survival estimates to McNary Dam (McNary) of PIT-tagged hatchery (hatchery-reared) and wild (naturally spawned and reared) Spring Chinook 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 wild smolt for a period beginning when hatchery juveniles were first found in samples taken from Roza Dam's bypass for PIT-tagging. Wild smolt sampled during this period are referred to as "late" wild smolt. Survival-estimate comparisons are also made between late and "early" wild smolt, the early wild smolt being those sampled and PIT-tagged before the first hatchery-smolt were sampleda.

For the late releases, the pooled[2] mean McNary survival of late wild smolt over years is highly significantly greater than that of hatchery smolt. The pooled survival of late-released wild smolt is greater than that of early-released wild smolt, but not significantly so; however, the survival of early-released smolt may be underestimated in some years if some of those smolt pass McNary before the McNary bypass is watered up, in which case those early wild smolt would not be detected.

Methodology

All smolt releases included in the analyses were grouped into seven-day periods; i.e., smolt released between Julian dates 1 and 7 were treated as one release period, those released between Julian dates 8 and 14 were treated as another release period, etc. These groups are referred to as Julian periods. Weighted logistic analyses of variation over years were used to analyze the proportion of Roza released smolt surviving[3] to McNary, their weights being the release numbers of fish used to estimate the proportions. Also the binomial-distribution-based sign test was used to assess whether the proportion of years that one group exceeded that of the other group exceeded 0.5 (the proportion expected by chance). Comparisons between early and late wild smolt proportions were treated as independent (unpaired) comparisons since they involved different Julian-week periods. Comparisons between late wild and hatchery survival were paired comparisons for Julian periods during which both stock were released (contemporaneous periods); Julian periods during which only one stock was release were removed from the analysis, although all survival estimates are given in the section entitled "Period Survivals Tables and Figures for all Julian".

Comparison of Wild and Hatchery Smolt Survival to McNary from Late Roza Releases

Yearly survival estimates based on all contemporaneous late-period smolt are given in Table and Figure 1. within which the pooled estimate is the total expanded recoveries at McNary divided by the total smolt released at Roza. The adjusted estimate is that adjusted for the effects of differences among yearly survivals.

Because wild 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 wild

[1] The first outmigration year of Upper Yakima River hatchery-reared Spring Chinook
[2] Pooled survival over years is the total of McNary passage estimates over years divided by the total released over years.
[3] Estimation procedures for survival are discussed and illustrated in the report Methods of Estimating Smolt Survival and Passage.

smolt would be greater than that of hatchery-spawned smolt even though the hatchery smolt tend to be larger. Therefore, one-sided tests have been the basis for wild versus hatchery comparisons. The wild survival percentage exceeded that of the hatchery in 14 of the 19 (or 74%) of the years of the study, which is significantly greater than that based on chance at the 5% significance level (Type 1 Error P = 0.0318 based on a one-sided binomial sign test under assumption equal chance of survival). A weighted logistic analysis of variation of the survival estimates (Appendix A.1) indicates that the wild–hatchery survival difference is highly significantly greater than 0 (1-sided Type 1 Error P = 0.0019), based on a weighted[4] logistic analysis of variation, Appendix Table A.1.).

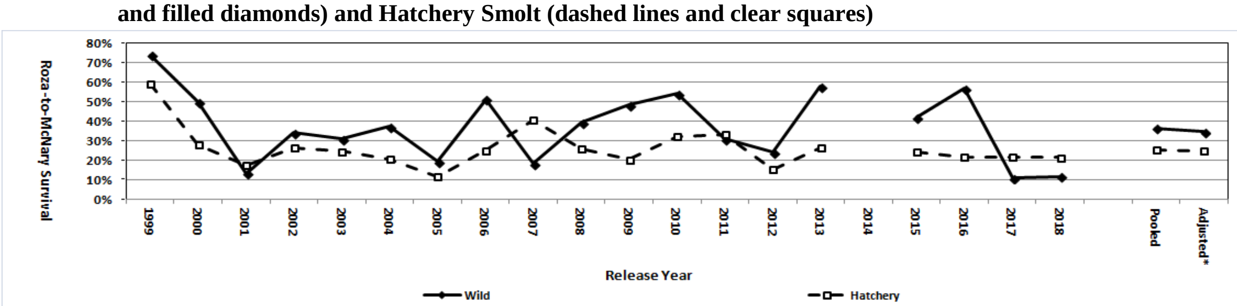
Table 1. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt-to-Smolt Survival for Late Wild and Hatchery Smolt

Stock	Measure	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
Wild	Survival	73.87%	49.82%	13.32%	34.22%	30.95%	37.49%	19.46%	51.26%	18.33%	39.57%	48.43%	54.02%	31.09%	24.06%	57.82%		41.96%	56.66%	11.06%	11.79%	36.57%	34.54%
	Released	312	3,196	1,424	2,588	1,190	232	25	500	336	498	239	105	904	191	38		358	39	181	274	12,630	
Hatchery	Survival	59.13%	27.93%	17.51%	26.28%	24.58%	20.41%	11.80%	25.05%	40.61%	25.99%	20.35%	32.03%	33.10%	15.26%	26.42%		24.32%	21.62%	21.62%	21.41%	25.35%	24.96%
	Released	1,082	2,999	1,744	1,503	2,146	1,509	701	3,689	2,477	4,911	3,931	1,130	3,051	4,424	550		1,503	575	1,869	2,550	42,344	
Survival Difference		14.74%	21.90%	-4.18%	7.95%	6.37%	17.08%	7.66%	26.21%	-22.27%	13.57%	28.07%	21.99%	-2.01%	8.80%	31.40%		17.64%	35.04%	-10.57%	-9.62%	11.22%	9.58%

* Ajusted for year effects

Negative Wild - Hartchery differences highlighted in grey

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



* Ajusted for year effects

However, within the late Roza passage, the differences between wild and hatchery survivals differ greatly over the Julian periods within years. To give a more valid paired comparison, the hatchery and wild late survival estimates were adjusted for survival differences among the those Julian periods within each year, and the adjusted survival estimates were analyzed over years. Table and Figure 2.a. give these adjusted survivals.

Table 2. Adjusted* Upper-Yakima Spring-Chinook Roza-to-McNary Smolt-to-Smolt Survivals for Late Wild and Hatchery Smolt

Adjusted* Smolt-to-Smolt Survival of Wild and McNary Spring Chinook Contemporaneously released at Roza Dam before (Early) or during (Late) Roza releases of MatcMery Smolt

Stock	Measure	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted**
Wild	Survival	72.00%	57.06%	17.19%	33.74%	30.37%	30.34%	19.46%	45.14%	26.74%	41.24%	41.06%	54.54%	36.50%	20.20%	62.16%		36.87%	48.80%	13.58%	14.47%	38.08%	35.36%
	Released	312	3,196	1,424	2,588	1,190	232	25	500	336	498	239	105	904	191	38		358	39	181	274	12,630	
Hatchery	Survival	57.70%	31.57%	17.34%	26.72%	24.22%	24.22%	11.80%	25.17%	37.75%	24.94%	19.86%	31.79%	31.94%	12.70%	25.33%		22.82%	21.14%	25.74%	16.12%	25.29%	24.44%
	Released	1,082	2,999	1,744	1,503	2,146	1,509	701	3,689	2,477	4,911	3,931	1,130	3,051	4,424	550		1,503	575	1,869	2,550	42,344	
Survival Difference		14.30%	25.48%	-0.15%	7.02%	6.15%	6.12%	7.66%	19.97%	-11.01%	16.30%	21.20%	22.76%	4.56%	7.51%	36.84%		14.04%	27.67%	-12.17%	-1.65%	12.79%	10.92%

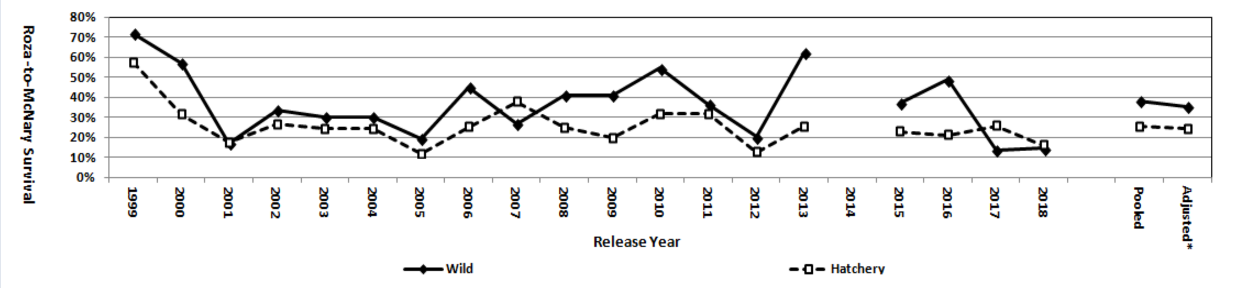
*Adjusted for Julain Periods within Years

** Adjusted for both the effects of Julian periods within years and for year effects

Negative Wild - Hartchery differences highlighted in grey

[4] **Weight = number of smolt released.**

Figure 2. **Upper-Yakima Spring-Chinook Roza-to-McNary Smolt-to-Smolt Survivals for Late Wild Smolt (solid lines and filled diamonds) and Hatchery Smolt (dashed lines and clear squares) adjusted for release period effects**



*Adjusted for Julain Periods within Years

The result of this analysis is that there was a slightly greater percentage of years with higher wild survivals (79%; Type 1 Error P = 0.0096 based on a one-sided binomial sign test under assumption equal chance of survival) and a higher level of significance in the pooled Wild – Hatchery late survival difference (Type 1 Error P < 0.0001 based on a logistic analysis of variation, Appendix Table A.2.) than compared to the analysis associated with Table and Figure 1.

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

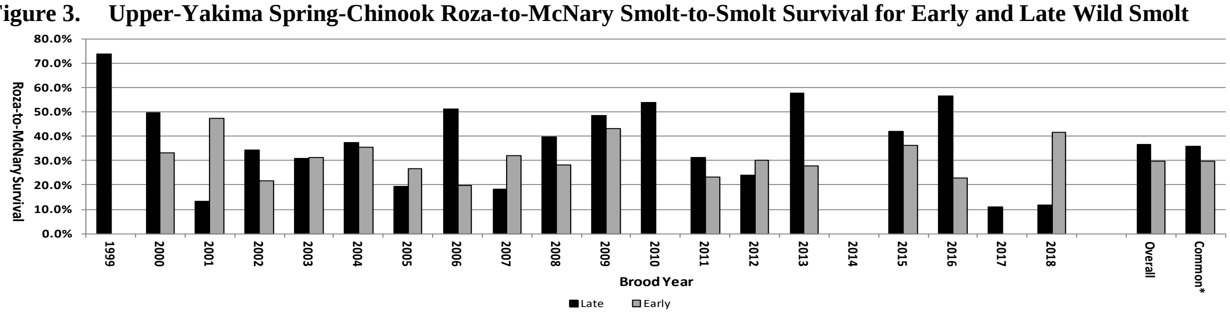
There were no early wild releases at Roza prior to Roza passage of hatchery smolt in 1999, 2010, and 2017; and, as stated earlier, there were no PIT-tagged releases in 2014. Table and Figure 3. present the wild early and late smolt survivals from Roza to McNary for all years. In the table and figure, the "overall" mean is the weighted survival over all years and the common mean is the weighted mean over those years within which both the early and late releases were made, the weights being the number of smolt released.

Table 3. **Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Early and Late[5] Wild Smolt**

																						Pooled over Years	
	Brood Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Overall*	Common*
Late	Survival	73.9%	49.8%	13.3%	34.2%	30.9%	37.5%	19.5%	51.3%	18.3%	39.6%	48.4%	54.0%	31.1%	24.1%	57.8%		42.0%	56.7%	11.1%	11.8%	36.6%	35.8%
	Released	312	3,196	1,424	2,588	1,190	232	25	500	336	498	239	105	904	191	38		358	39	181	274	12,630	12,032
Early	Survival		33.1%	47.5%	21.6%	31.4%	35.4%	26.8%	19.7%	31.9%	28.3%	43.0%		23.1%	30.1%	27.7%		36.3%	22.8%		41.5%	29.7%	29.7%
	Released		3,013	755	6,130	6,614	3,699	1,688	1,833	1,072	735	1,804		1,040	2,482	2,435		167	97		110	33,674	33,674
Survival Difference			16.8%	-34.2%	12.6%	-0.4%	2.1%	-7.4%	31.6%	-13.5%	11.2%	5.4%		7.9%	-6.1%	30.1%		5.7%	33.9%		-29.7%	6.9%	6.2%

* Overall is the release-weighted mean over all years; common is the weighted mean for those years withiin which there wer both late and esrly releases

Figure 3. **Upper-Yakima Spring-Chinook Roza-to-McNary Smolt-to-Smolt Survival for Early and Late Wild Smolt**



Of the 16 years with early releases, late releases had higher Roza-to-McNary survival in 10 (62.5%) of those years which is not significant different than expected by chance (Type 1 Error P = 0.4545 based on a two-sided binomial under assumption equal chance of survival). The mean late survival estimate was higher than that of the early but not quite significantly so at the 10% level (Type Error P = 0.1084 based a logistic analysis of variation, Appendix Table A.3); however the McNary Dam's bypass is generally watered up after Julian date 90. It may be that some of the early wild releases pass McNary before they could be detected in McNary's bypass, in which case the early-release wild survival estimates presented herein may be underestimated.

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

Period Survivals Tables and Figures for all Julian

Table 4. and Figure 4. present the individual year Prosser-to-McNary Dam Plots within Julian-week groupings for wild and hatchery releases at Prosser.

Table 4. Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week grouping

1999	Stock	Julian																			105	112	119	126	133		Early	Late	Over All
	Wild	Survival																			46.71%	88.49%	64.08%	85.38%	77.99%			73.87%	73.87%
		Released																			34	37	62	34	145			312	312
	Hatchery	Survival																			52.61%	70.31%	65.00%	60.10%	54.87%			59.13%	59.13%
		Released																			266	103	306	100	307			1082	1082
2000	Stock	Julian	345		359	366	7	14	21	28		42		56	63	70	77	84	91	98	105	112	119	126			Early	Late	Over All
	Wild	Survival	44.47%		20.26%	40.40%	33.87%	33.65%	27.90%	30.84%		48.74%		52.46%	54.23%	41.55%	69.01%	51.69%	65.28%	55.21%	56.02%	16.71%	32.98%	40.22%			33.05%	49.82%	41.68%
		Released	56		47	55	1575	845	435	243		847		506	723	235	46	248	156	92	17	19	23	41			3013	3196	6209
	Hatchery	Survival								39.68%		47.62%		50.71%	21.17%	24.24%	42.63%	26.86%	23.34%	25.89%	34.28%	31.98%	34.84%	22.63%				27.93%	27.93%
		Released								8		20		20	83	152	103	689	547	346	115	365	272	279				2999	2999
2001	Stock	Julian									35	42	49	56	63	70	77	84	91	98	105	112	119				Early	Late	Over All
	Wild	Survival									40.34%	47.76%	38.97%	40.06%	50.20%	63.78%	59.86%	28.85%	32.70%	14.99%	9.30%	9.13%	4.69%				47.49%	13.32%	25.16%
		Released									32	121	159	145	144	85	69	85	150	155	583	396	55				755	1424	2179
	Hatchery	Survival																30.31%	24.58%	14.79%	9.81%	16.74%	15.65%					17.51%	17.51%
		Released																132	465	288	500	293	66					1744	1744
2002	Stock	Julian			358	365	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105		119				Early	Late	Over All
	Wild	Survival			17.46%	13.83%	29.29%	19.99%	18.03%	16.22%	31.62%	16.24%	25.27%	27.55%	23.17%	31.96%	32.33%	36.28%	34.29%	33.26%	41.23%		34.95%				21.62%	34.22%	25.36%
		Released			500	501	295	761	960	533	178	388	328	804	398	484	617	665	277	750	47		232				6130	2588	8718
	Hatchery	Survival															51.40%	34.55%	21.22%	24.21%	20.37%		14.25%				0.00%	26.28%	26.28%
		Released															89	428	144	444	108		290				0	1503	1503
2003	Stock	Julian								28	35	42	49	56	63	70	77	84		98	105	112	119	126			Early	Late	Over All
	Wild	Survival								26.88%	29.19%	28.49%	31.37%	31.89%	33.26%	32.56%	50.59%	27.79%		38.76%	36.85%	27.12%	37.49%	18.68%			31.39%	30.95%	31.32%
		Released								515	1188	1600	639	794	1284	256	338	441		284	110	85	115	155			6614	1190	7804
	Hatchery	Survival																34.02%		27.73%	24.53%	25.36%	11.89%	13.38%				24.58%	24.58%
		Released																431		574	221	411	332	177				2146	2146
2004	Stock	Julian		351	358	365			21	28	35	42	49	56	63	70	77			98	105	112	119				Early	Late	Over All
	Wild	Survival		22.17%	20.15%	11.42%			28.67%	31.15%	16.25%	36.66%	32.94%	47.87%	45.08%	50.77%	40.71%			39.99%			0.00%				35.42%	37.49%	35.54%
		Released		184	156	153			301	603	43	889	276	352	398	344	195			19			18				3699	232	3931
	Hatchery	Survival															27.59%			21.66%	12.31%	11.33%	9.05%					17.85%	17.85%
		Released															220			1036	439	220	253					2168	2168
2005	Stock	Julian									35	42	49	56	63	70	77	84	91			112					Early	Late	Over All
	Wild	Survival									23.37%	25.14%	31.95%	20.81%	41.07%	62.56%						19.46%					26.84%	19.46%	26.73%
		Released									831	300	335	110	77	35						25					1688	25	1713
	Hatchery	Survival															24.92%	7.81%	15.62%			11.80%						14.05%	14.05%
		Released															205	187	327			701						1420	1420
2006	Stock	Julian				365	7		21	28	35	42		56	63	70		84	91	98	105	112	119	126			Early	Late	Pooled
	Wild	Survival				15.49%	16.70%		12.63%	20.62%	28.93%	14.49%		58.18%	46.81%	32.34%		62.06%	33.25%	34.77%	65.37%	39.23%	33.92%	26.75%			19.70%	51.26%	26.46%
		Released				351	551		215	250	200	125		18	67	56		269	21	32	31	70	41	36			1833	500	2333
	Hatchery	Survival																36.28%	25.38%	21.69%	25.62%	27.05%	12.94%	26.49%				25.05%	25.05%
		Released																450	686	827	601	639	356	130				0.2505	0.2505
2007	Stock	Julian										42	49		63						105		119		133	140	Early	Late	Over All
	Wild	Survival										26.98%	36.52%		31.92%						6.04%		52.64%		42.04%	51.54%	31.88%	18.33%	28.65%
		Released										453	476		143						233		31		62	10	1072	336	1408
	Hatchery	Survival																			22.99%		33.08%		40.34%	56.39%		40.61%	40.61%
		Released																			622		393		571	891		2477	2477
2008	Stock	Julian											49		63		77	84	91	98	105	112			133		Early	Late	Overall
	Wild	Survival											22.17%		33.41%		40.59%	45.69%	27.94%	64.00%	40.59%	11.19%			40.29%		28.33%	39.57%	32.87%
		Released											332		403		77	48	157	88	77	28			23		735	498	1233
	Hatchery	Survival															26.66%	24.47%	21.20%	17.82%	26.66%	15.90%			39.90%			25.99%	25.99%
		Released															505	467	879	316	505	1013			1226			4911	4911
2009	Stock	Julian										42	49	56	63	70	77	84		98		112	119			140	Early	Late	Over All
	Wild	Survival										36.26%	43.54%	43.32%	37.41%	41.44%	56.99%	40.31%		46.24%		51.91%	55.08%			78.24%	43.00%	48.43%	43.64%
		Released										450	321	160	179	379	315	81		39		74	37			8	1804	239	2043
	Hatchery	Survival																34.27%		25.38%		18.38%	27.46%			12.91%		20.35%	20.35%
		Released																413		712		920	448			1438		3931	3931
2010	Stock	Julian																84		98				126			Early	Late	Over All
	Wild	Survival																70.14%		45.36%				51.44%				54.02%	54.02%
		Released																33		57				15				105	105
	Hatchery	Survival																36.39%		32.09%				18.37%				32.03%	32.03%
		Released																318		707				105				1130	1130
2011	Stock	Julian												56	63	70	77	84	91	98	105		119		133		Early	Late	Over All
	Wild	Survival												18.32%	23.16%	51.90%	30.80%	25.66%	12.73%		40.92%		83.28%		63.71%		23.15%	31.09%	26.84%
		Released												430	538	72	113	473	126		109		58		25		1040	904	1944
	Hatchery	Survival															23.34%	27.58%	25.72%	21.41%	26.77%		24.59%		92.60%			32.86%	32.86%
		Released															521	710	465	63	381		634		340			3114	3114
2012	Stock	Julian										42	49	56	63	70	77	84	91	98	105	112	119		133	140	Early	Late	Over All
	Wild	Survival										21.52%	26.77%	30.97%	32.94%	46.49%	34.59%	25.01%		22.49%	35.66%	0.00%				75.00%	30.12%	24.06%	29.68%
		Released										469	650	383	548	202	230	106		35	24	22				4	2482	191	2673
	Hatchery	Survival																16.24%		18.18%	13.88%	3.02%				64.23%		15.26%	15.26%
		Released																839		1790	772	900				123		4424	4424
2013	Stock	Julian										42	49	56	63	70						112		126			Early	Late	Over All
	Wild	Survival										19.81%	24.54%	27.68%	29.99%	48.94%						34.87%		86.16%			27.69%	57.82%	28.15%
		Released										608	436	538	631	222						21		17			2435	38	2473
	Hatchery	Survival																				18.11%		30.53%				26.42%	26.42%
		Released																				182		368				550	550
2015	Stock	Julian											49	56		70		84	91	98	105				133		Early	Late	Over All
	Wild	Survival											16.84%	47.20%		42.38%		73.59%	58.28%	24.05%	21.04%				24.05%		36.29%	41.96%	40.16%
		Released											60	107		143		60	26	84	24				21		167	358	525
	Hatchery	Survival														27.85%		42.87%	17.02%	25.76%	20.76%				7.84%			24.32%	24.32%
		Released														272		271	89	451	73				347			1503	1503
2016	Stock	Julian															77			98				126			Early	Late	Over All
	Wild	Survival															22.78%			56.66%							22.78%	56.66%	32.49%
		Released															97			39							97	39	136
	Hatchery	Survival																		21.62%				69.93%				24.39%	24.39%
		Released																		575				35				610	610
2017	Stock	Julian																84	91	98		112	119	126			Early	Late	Over All
	Wild	Survival																0.00%	0.00%	0.00%		58.77%	0.00%	69.72%				11.06%	11.06%
		Released																48	58	31		21	12	11				181	181
	Hatchery	Survival																10.33%	7.25%	22.70%		65.10%	37.90%	0.00%				22.60%	22.60%
		Released																449	299	306		271	286	258				1869	1869
2018	Stock	Julian															77	84	91	98			119				Early	Late	Over All
	Wild	Survival															41.46%	9.04%	0.00%	14.38%			37.16%				41.46%	11.79%	20.29%
		Released															110	160	47	31			36				110	274	384
	Hatchery	Survival																4.58%	18.17%	14.76%			39.84%					21.41%	21.41%
		Released																753	576	317			904					2550	2550

Figure 4. Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week grouping

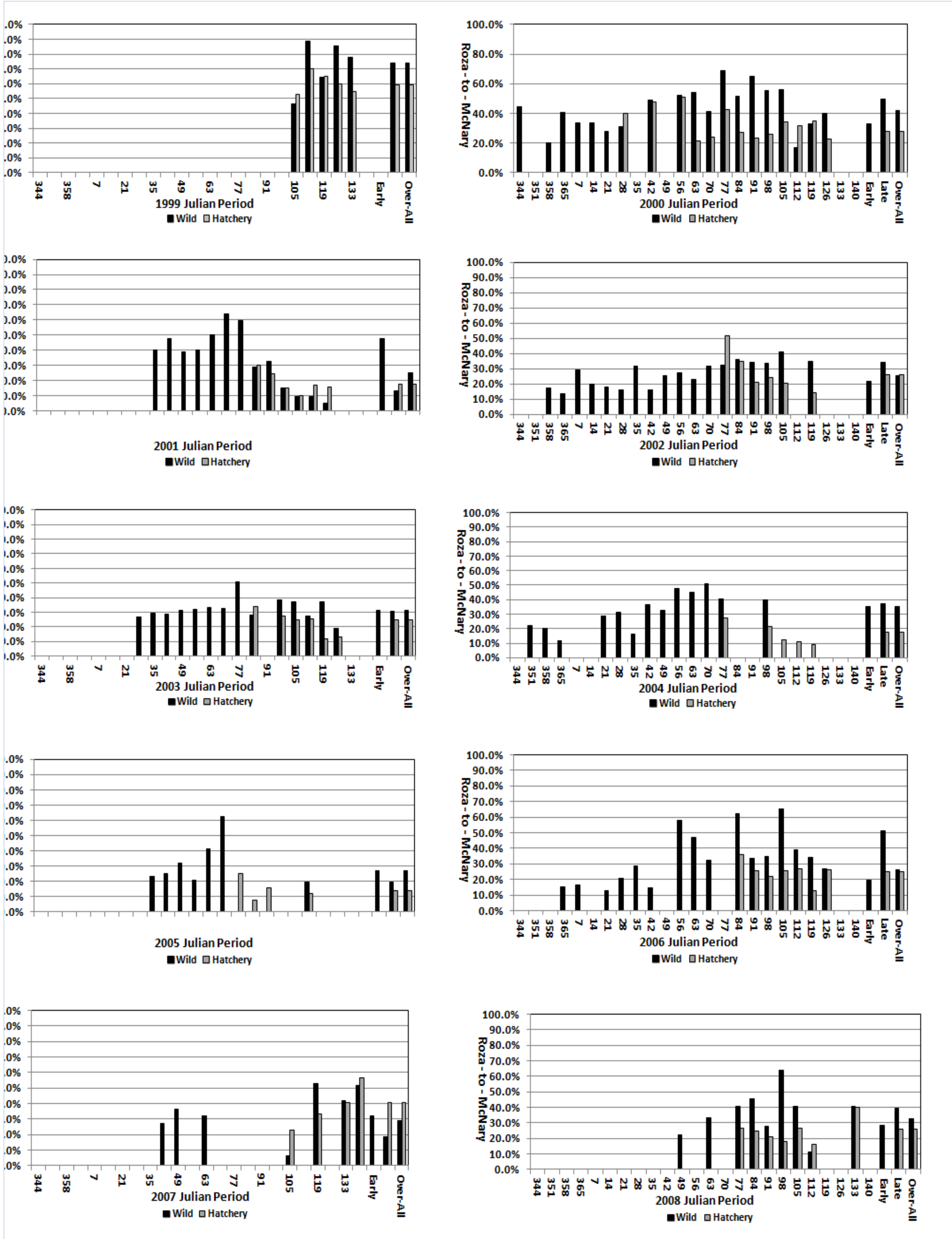
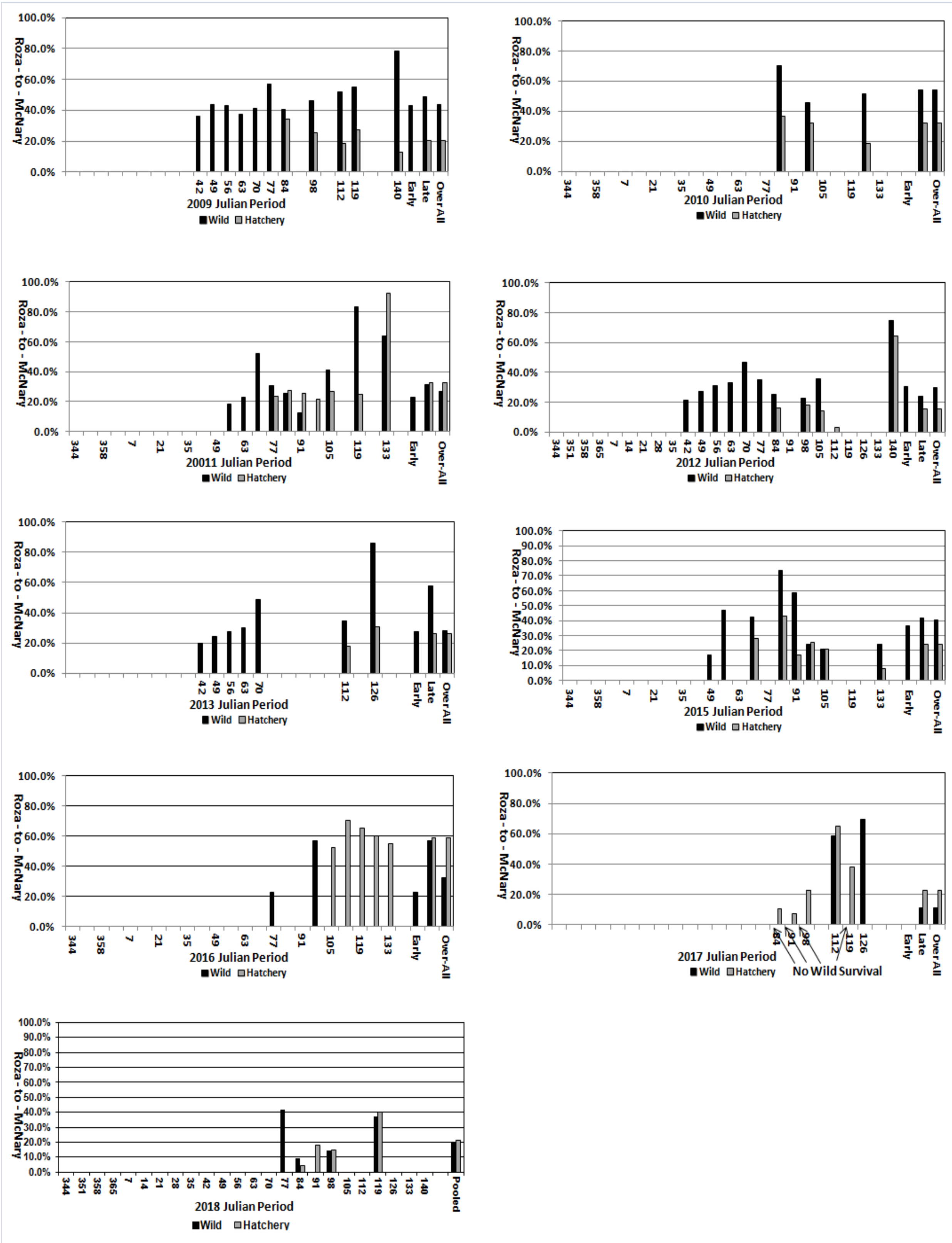


Figure 4. **(continued) Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week grouping**



Appendix: Logistic Analyses of Variation

Table A.1. **Logistic Analysis of Variation over Years of Upper-Yakima Spring-Chinook Roza-to-McNary Smolt-to-Smolt Survival for Late[6] Wild and Hatchery Smolt**

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	2,304.12	18	128.01	4.15	0.0021	Julian Period
Stock*	339.89	1	339.89	11.03	0.0038	Year x Stock
Year x Stock	554.75	18	30.82			

* Note: 1-sided Type 1 Error P = 0.0019 for Wild versus Hatchery comparisons

Table A.2. **Logistic Analysis of Variation over Years of Upper-Yakima Spring-Chinook Roza-to-McNary Period-within-Year adjusted Smolt-to-Smolt Survival for Late[7] Wild and Hatchery Smolt**

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	2,900.78	18	161.15	3.89	0.0000	Julian Period
Stock*	444.39	1	444.39	22.81	0.0002	Stock x Year
Stock x Year	350.74	18	19.49	0.47	0.9634	Julian Period
Julian Period	3,270.97	79	41.40	6.28	0.0000	Error
Error	521.14	79	6.60			

* Note: 1-sided Type 1 Error P < 0.0001 for Wild versus Hatchery comparisons

Table A.3. **Logistic Analysis of Variation over of Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Late[6] and Early[8] Wild Smolt**

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	778.18	15	51.88	5.46	0.0000	Residual
Stock	153.19	1	153.19	2.91	0.1084	Year x Stock
Year x Stock	788.62	15	52.57	5.54	0.0000	Residual
Residual	1,329.17	140	9.49			

[6] Passing Roza contemporaneously with hatchery smolt
[7] Passing Roza contemporaneously with hatchery smolt
[8] Passing Roza prior to hatchery smolt being sampled

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Appendix E
Annual Report: Comparisons between Smolt-Trait Measures of Hatchery x Hatchery- and Natural x Natural-Brood Stock for the 2002-2018 Upper Yakima Spring Chinook Broods

Doug Neeley, Consultant to Yakama Nation

Introduction

Hatchery x Hatchery Stock (HxH or Hatchery Control - HC) were allocated to one raceway pair and Natural x Natural (NxN or Supplemental Hatchery -SH) stock[1] were allocated to two raceway pairs at the Cle Elum hatchery and were later allocated to the Clark Flat acclimation-site from brood years 2002 through 2016 (associated smolt-release years 2004 through 2018). With the exception of Brood-Year 2013, one raceway from each raceway pair was allocated to a standard feed (control treatment) and the other to a test treatment (for the 2013 brood, all raceways received the standard feed). The test treatment changed over the course of the study. To avoid potential interaction with treatments that differed over years, only the standard treatment (standard level of BioVita feed) is used in this analysis. The following traits are analyzed in this report.

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

The above trait measures were based on smolt tagged with passive integrated transponders (PIT-tagged) which represented approximately 5% to 6% of the total hatchery smolt released. The current method of estimating survival to McNary and McNary passage date are discussed in a report entitled Methods of Estimating Smolt Survival and Passage.

[1] **HxH and NxN Stock are part of a domestication selection study. The original progenitors of both stocks were wild Upper-Yakima Stock. Both stock 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 are never spawned outside of the hatchery, and NxN progeny are never spawned in the hatchery.**

Smolt-to-Smolt Survival to McNary Dam

Table 1. presents smolt-to-smolt survivals from volitional release to McNary Dam of HxH and NxN smolt. There was neither a substantial nor significant difference in the main-effect smolt-to-smolt survival means of HxH and NxN stock over years (Type 1 Error P = 0.22, Appendix Table A.1.).

Table 1. Release-Year 2004 through 2018 Mean Release-to-McNary Smolt-to-Smolt Survival of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	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%	35.2%	30.2%	35.5%	35.2%
	Number*	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	3,787	3,866	54,297	
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%	35.7%	30.3%	33.2%	32.7%
	Number*	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	3,913	3,794	63,858	
HxH - NxN 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%	-0.4%	-0.1%	2.4%	2.5%

* Number detected at release

** Adjusted for Year

Percent of PIT-tagged Fish Detected Leaving Acclimation Ponds

The percent of PIT-tagged smolt detected leaving the acclimation site may give an indication of pre-release survival (from time-of-tagging to release-detection). Table 2. presents the HxH and NxN percent of PIT-tagged smolt detected leaving the acclimation ponds. There was a highly significant negative main-effect HxH – NxN difference in the percentages leaving the ponds over years (Type 1 Error P = 0.0067 Appendix Table A.2.). While the pooled main-effect mean difference is small, the HxH percentage of years within which the NxN survivals are less than those of the HxH is 80% (Type 1 Error P = 0.035 based on a binomial distribution with a hypothesized 50% chance).

Table 2. Release-Year 2004 through 2018 Percent detected leaving Clark Flat Acclimation Site of PIT-Tagged HxH and NxN Stock Spring Chinook Smolt

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted**
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%	94.7%	96.7%	95.5%	95.8%
	Number*	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	3,787	3,866	54,297	
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%	97.8%	94.8%	97.1%	97.2%
	Number*	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	3,913	3,794	63,858	
HxH - NxN Difference		-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%	-3.1%	1.9%	-1.6%	-1.4%

* Number detected at release

** Adjusted for Year

Volitional Release Dates

The mean volitional release days are given in Table 3.a. and the median release dates are given in Table 3.b. The pooled HxH – NxN negative mean difference (Table 3.a.) was small and had not quite attained significance at the 5% based on a least squares analysis of variance (Type 1 Error = 0.077, Appendix Table A.3.). Further, the HxH -NxN median differences (Table 3.b.) were not significant at even the 10% level based on non-parametric Wilcoxon Sign Ranked Sum Test[2] (Appendix Table A.5.a.).

Table 3.a.Release-Year 2004 through 2018 Julian Release-Date *Mean* of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
HxH	Detection Date	101	81	104	85	111	113	107	92	95	94	106	94	92	84	101	98	97.7
	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	3,787	3,866	54297	
NxN	Detection Date	100	76	103	93	112	109	100	100	103	97	108	95	101	95	106	99	100.3
	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	3,913	3,794	63858	
HxH - NxN Difference		1	5	1	-8	-1	4	7	-8	-8	-3	-2	-1	-9	-11	-5	-2	-2.6

* Adjusted for Year

Table 3.b.Release-Year 2004 through 2018 Julian Release-Date *Median* of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
HxH	Detection Date	102	69	103	75	105	112	108	91	86	94	100	94	82	75	99	94	93.2
	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	3,787	3,866	54,297	
NxN	Detection Date	98	69	105	77	110	111	103	94	112	95	100	97	94	76	91	95	96.2
	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	3,913	3,794	63,858	
HxH - NxN Difference		4	0	-2	-2	-5	1	5	-3	-26	-1	0	-3	-12	-1	8	-2	-3.0

* Adjusted for Year

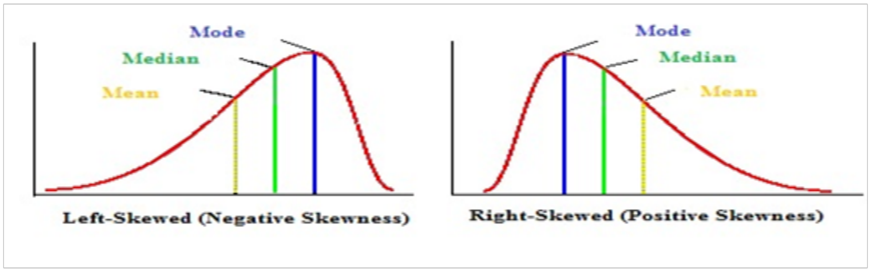
The differences between the median and the mean dates are given in Table 3.c. and indicate that the distribution of release dates for the HxH stock (first row of Table 3.c.) is significantly skewed to the left (Median – Mean < 0) at the 5% level based on the Wilcoxon Sign Ranked Sum Tests (Appendix Table A.5.b.). The Wilcoxon Sign Ranked Sum Test for skewness for the NxN stock (second row of Table 3.c.) is not significant at the 5% level but is at the 10% level (Appendix Table A.5.c.). Since the pooled means of two stocks are nearly equal (last two columns of the HxH and NxN rows in Table 3.a.) as are the medians (Table 3.b.), and since the difference between the HxH and NxN skewness measures (bottom row of Table 3.c) is not significant at the 10% level based on the Wilcoxon Sign Ranked Sum Test (Appendix Table A.5.d.); it is reasonable to assume an over-all negative skewness for both stock with insufficient evidence of a difference in the degree of skewness between the two stock.

[2] This may be because the non-parametric tests performed on the medians are less powerful that the least squares analyses of variance performed on the means. A least squares analysis of variance performed on the medians (not an appropriate test) was also not significant at the 10% level. It is noted that the Table 3.b. negative HxH – NxN median differences of 2012 and 2016 were by far the largest of the absolute values of the 15 years.

Table 3.c. Release-Year 2004 through 2018 Release-Date Median - Mean Release Date Difference (Skewness Measure) of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
HxH	Detection Date	1	-12	-1	-10	-6	-1	1	-1	-9	0	-6	0	-10	-9	-2	-4.3	-4.4
NxN	Detection Date	-2	-7	2	-16	-2	2	3	-6	9	-2	-8	2	-7	-19	-15	-4.4	-4.1
HxH - NxN Difference		3	-5	-3	6	-4	-3	-2	5	-18	2	2	-2	-3	10	13	0.1	-0.4

* Adjusted for Year



McNary Juvenile Passage Dates

The mean volitional McNary Passage Dates are given in Table 4.a. and the median dates are given in Table 4.b. The over HxH – NxN differences in the mean Passage Dates are highly significantly different than each other (Type 1 Error P = 0.0063, Appendix Table A.4.). The HxH – NxN differences in the median Passage Dates are significantly different at the 5% level based on the Wilcoxon Sign Ranked Sum Test (Appendix Table A.6.a.)

Table 4.a. Release-Year 2004 through 2018 Julian McNary-Passage Date *Mean* of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
HxH	Detection Date	120	122	126	122	133	134	130	126	126	120	129	113	115	118	124	123.8	124.1
	Expanded Detections	521	364	867	765	1,203	1,942	1,242	1,537	1,549	1,471	1,459	2,268	1,609	1,334	1,168	19,301	
NxN	Detection Date	119	123	125	126	135	132	129	132	131	122	131	113	121	125	126	125.9	126.6
	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	1,395	1,151	21,197	
HxH - NxN Difference		1	-1	1	-4	-2	2	1	-6	-5	-2	-2	0	-6	-7	-2	-2.2	-2.4

* Adjusted for Year

Table 4.b. Release-Year 2004 through 2018 Julian McNary-Passage Date *Median* of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock	Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
HxH	Detection Date	120	122	126	120	131	136	131	126	126	119	129	113	113	118	120	123.3	123.2
	Expanded Detections	521	364	867	765	1,203	1,942	1,242	1,537	1,549	1,471	1,459	2,268	1,609	1,334	1,168	19,301	
NxN	Detection Date	118	122	125	123	135	134	129	130	133	119	132	114	121	124	128	125.8	126.5
	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	1,395	1,151	21,197	
HxH - NxN Difference		2	0	1	-3	-4	2	2	-4	-7	0	-3	-1	-8	-6	-8	-2.5	-3.3

* Adjusted for Year

The differences between the median and the mean McNary Passage dates are given in Table 4.c. Neither the measures of skewness of the HxH stock (first of Table 4.c.) nor of the NxN stock (second row of Table 4.c.) nor the HxH – NxN skewness differences (bottom row of table 4.c.) are significant at the 10% level (Appendix Tables A.6.b., A.6.c, and A.6.c., respectively).

Table 4.c. Release-Year 2004 through 2018 <u>Median - Mean McNary-Passage Date Difference (Skewness Measure)</u> of HxH and NxN Spring Chinook Stock PIT-Tagged Smolt detected leaving Clark Flat Acclimation Site

Stock Measure	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Pooled	Adjusted*
HxH Detection Date	0	0	0	-2	-2	2	1	0	0	-1	0	0	-2	0	-4	-0.5	0.9
NxN Detection Date	-1	-1	0	-3	0	2	0	-2	2	-3	1	1	0	-1	2	-0.2	0.1
HxH - NxN Difference	1	1	0	1	-2	0	1	2	-2	2	-1	-1	-2	1	-6	-0.3	0.8

* Adjusted for Year

Appendix: Statistical Analysis Tables for the Measures presented in the Text

Measures of Means and Proportions

The means and proportions are based on large enough sample sizes to support the assumption that the Central Limit Theorem holds and that the use of weighted least squares analysis variance of means and the weighted logistic analysis of variation of proportions are appropriate, the weights being indicated in the following four tables within which Type 1 Error Probability estimates that exceed 0.05 (two-sided 5% significance level) are shaded in yellow.

Table A.1. Weighted Logistic Analysis of Variance of Volitional-Release-to-McNary Survival of PIT-tagged HxH and NxN Spring Chinook Smolt detected leaving Clark Flat Acclimation Site

(Weight = Number of PIT-tagged smolt detected volitionally leaving the raceways)

	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	2969.77	14	212.13	32.366	**0.0000**	Between Raceways*
Stock (HxH vs NxN)	27.83	1	27.83	1.615	0.2245	"Year x Stock"
"Year x Stock"	241.28	14	17.23	2.630	**0.0280**	Between Raceways*
Between Raceways*	117.97	18	6.55			

***Among Cle Elum Raceways assigned to NxN Stock within Years**

Yellow boldfaced significant at 5% level

Table A.2. Weighted Logistic Analysis of Variance of the Proportion of HxH and NxN Spring Chinook Smolt Spring Chinook Smolt detected leaving Clark Flat Acclimation Site

Site (Weight = Number PIT-tagged smolt)

	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	522.69	14	37.34	6.602	**0.0002**	Between Raceways*
Stock (HxH vs NxN)	181.27	1	181.27	10.098	**0.0067**	"Year x Stock"
"Year x Stock"	251.32	14	17.95	3.174	**0.0116**	Between Raceways*
Between Raceways*	101.79	18	5.66			

***Among Cle Elum Raceways assigned to NxN Stock within Years**

Yellow boldfaced significant at 5% level

Table A.3. Weighted Analysis of Variance of Mean Julian release Dates of PIT-tagged HxH and NxN Spring Chinook Smolt detected leaving Clark Flat Acclimation Site

(Weight = Number Detected at Release)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	7,664,127	14	547,438	68.478	**0.0000**	Between Raceways*
Stock (HxH vs NxN)	193,026	1	193,026	3.635	0.0773	"Year x Stock"
"Year x Stock"	743,474	14	53,105	6.643	**0.0002**	Between Raceways*
Between Raceways*	143,899	18	7,994			

***Among Cle Elum Raceways assigned to NxN Stock within Years**

Yellow boldfaced significant at 5% level, yellow not boldfaced signicant at 10% level

Table A.4. Weighted Analysis of Variance of Mean Julian dates of McNary Passage of PIT-tagged HxH and NxN Spring Chinook Smolt detected leaving Clark Flat Acclimation Site

(Weight = Expanded Number Detected at McNary)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	1,547,341	14	110,524	100.401	**0.0000**	etween Raceways*
Stock (HxH vs NxN)	58,952	1	58,952	10.321	**0.0063**	"Year x Stock"
"Year x Stock"	79,963	14	5,712	5.188	**0.0007**	etween Raceways*
Between Raceways*	19,815	18	1,101			

***Amomg Cle Elum Raceways assigned to NxN Stock within Years**

Yellow boldfaced significant at 5% level

Measures involving Medians

Medians are not expected to follow a normal distribution since the Central limit does not apply to medians. The non-parametric Wilcoxon Sign Ranked Sum Test is applied to raceway differences in the measures that involve medians. In the following tables two-sided critical values (C.V.) for the 5% and 10% levels are presented; if the actual ranked totals fall outside the critical boundaries (low value less than low critical value; high value greater than high critical value), they are highlighted in yellow.

Release Dates

Table A.5.a. Wilcoxon Sign Ranked Sum Test for Difference between HxH and NxN Median Volitional Release Dates

Total of Ranks excluding differences = 0	Negative	Positive	Total
Total	61	30	91
C.V. (P* = 0.05)	74	17	91
C.V. (P** = 0.10)	70	21	91

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

Table A.5.b. Wilcoxon Sign Ranked Sum Test for Difference between HxH Median and Mean[3] Volitional Release Dates

Total of Ranks excluding differences = 0	Negative	Positive	Total
Total	86	5	91
C.V. (P* = 0.05)	74	17	91
C.V. (P** = 0.10)	70	21	91

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

Yellow Highlighted indicates significance level

Table A.5.c. Wilcoxon Sign Ranked Sum Test for Difference between NxN Median and Mean[3] Volitional Release Dates

Total of Ranks excluding differences = 0	Negative	Positive	Total
Total	89	31	120
C.V. (P* = 0.05)	95	25	120
C.V. (P** = 0.10)	90	30	120

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

Yellow Highlighted indicates significance level

Table A.5.d. Wilcoxon Sign Ranked Sum Test for Difference between HxH and NxN Measures of Release Day Skewness[4]

Total of Ranks excluding differences = 0	Negative	Positive	Total
Total	60	60	120
C.V. (P* = 0.05)	25	95	120
C.V. (P** = 0.10)	30	90	120

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

[3] Measure of Skewness

[4] (HxH Median – HxH Mean) – (NxN Median – NxN Mean)

McNary Passage Dates

Table A.6.a. **Wilcoxon Sign Ranked Sum Test for Difference between HxH and NxN Median McNary-Passage Dates**

Total of Ranks excluding differences = 0			
	Negative	Positive	Total
Total	78	13	91
C.V. (P* = 0.05)	74	17	91
C.V. (P** = 0.10)	70	21	91

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

Yellow Highlighted indicates significance level

Table A.6.b. **Wilcoxon Sign Ranked Sum Test for Difference between HxH Median and Mean[5] McNary-Passage Release Dates**

Total of Ranks excluding differences = 0			
	Negative	Positive	Total
Total	22	6	28
C.V. (P* = 0.05)	26	2	28
C.V. (P** = 0.10)	24	4	28

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

Table A.6.c. **Wilcoxon Sign Ranked Sum Test for Difference between NxN Median and Mean[5] McNary-Passage Dates**

Total of Ranks excluding differences = 0			
	Negative	Positive	Total
Total	36	30	66
C.V. (P* = 0.05)	55	11	66
C.V. (P** = 0.10)	52	14	66

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

Table A.6.d. **Wilcoxon Sign Ranked Sum Test for Difference between HxH and NxN Measures of McNary-Passage Day Skewness[6]**

Total of Ranks excluding differences = 0			
	Negative	Positive	Total
Total	54	37	91
C.V. (P* = 0.05)	74	17	91
C.V. (P** = 0.10)	70	21	91

* 5% significance level (2-sided test)

** 10% significance level (2-sided test)

[5] **Median – Mean is a Measure of Skewness**

[6] **(HxH Median – HxH Mean) – (NxN Median – NxN Mean)**

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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 through 2018

Doug Neeley, Consultant to Yakama Nation

Introduction

Within the pairs of raceways at Cle Elum, one raceway from each of nine raceway-pairs was allocated BioVita feed as a control treatment and the other was allocated PRO feed as a test treatment in brood years 2014 through 2016 broods (release years 2016-2018). In this report, analyses are presented for these broods' smolt from crosses of natural-origin spawners released from three acclimation sites[1] for following juvenile characteristics:

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

The above trait measures were based on smolt tagged with passive integrated transponders (PIT-tagged) which represented approximately 5% to 6% of the total hatchery smolt released. The current method of estimating survival to McNary and McNary passage date are discussed in a report entitled Methods of Estimating Smolt Survival and Passage.

[1] Reared juveniles from the nine pairs of Cle Elum raceways were transferred to the Clark Flat, Easton and Jack Creek acclimations sites, three pairs to each acclimation site. One of the pairs of raceways transferred to Cle Elum was assigned to spawned hatchery broodstock. All other raceway pairs were assigned to naturally spawned broodstock. The decision was made to omit data for the hatchery broodstock from this analysis.

Smolt-to-Smolt Survival to McNary Dam

Table 1. presents the volitional-release-to-McNary Dam smolt-to-smolt survivals of Pro- and BioVita-fed smolt. There was neither a substantial nor significant difference in the main-effect smolt-to-smolt survival means of Pro and BioVita feed treatments over years based on a logistic analysis of variation (Type 1 Error P = 0.33, Appendix Table A.1.), and there were no substantial nor significant treatment interactions with years or sites (associated F-ratios less than 1, Appendix Table A.1.)

Table 1. Release-Year 2016 through 2018 <u>Mean Release-to-McNary Smolt-to-Smolt Survival</u> of Pro- and BioVita-Fed Smolt detected leaving Acclimation Sites

	Release Year →	2016				2017				2018				Pooled over
	Site →	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Years and
Feed	Measure ↓	Flat	Easton	Creek	2016 Sites	Flat	Easton	Creek	2017 Sites	Flat	Easton	Creek	2018 Sites	Sites
Pro	Survival	42.4%	32.4%	28.1%	33.2%	33.0%	28.7%	35.7%	32.5%	30.4%	31.4%	27.6%	29.7%	31.1%
	Released	3,815	5,696	5,777	15,288	3,853	5,553	5,841	15,247	3,819	5,625	5,747	15,191	45,726
BioVita	Survival	44.1%	33.2%	27.3%	33.7%	35.7%	33.2%	29.0%	32.3%	30.3%	30.3%	31.5%	30.8%	32.5%
Control	Released	3,838	5,646	5,744	15,228	3,913	5,646	5,514	15,073	3,794	5,661	5,661	15,116	45,417
Pro - BioVita Difference		1.8%	0.8%	-0.7%	0.5%	2.6%	4.5%	-6.7%	-0.2%	-0.1%	-1.1%	4.0%	1.1%	1.4%

Percent of PIT-tagged Fish Detected Leaving Acclimation Ponds

The percent of PIT-tagged smolt detected leaving the acclimation site may give an indication of pre-release survival (time-of-tagging to release-detection survival).

Table 2. presents Pro- and BioVita- fed percent of PIT-tagged smolt detected leaving the acclimation ponds. As with smolt survival, there was neither a substantial nor significant main-effect treatment difference in the percentages leaving the ponds over years based on a logistic analysis of variation (Type 1 Error P = 0.86 Appendix Table A.2.), and there were no substantial nor significant treatment interactions with year or sites (associated F-ratios less than 1, Appendix Table A.2.).

Table 2. Release-Year 2016 through 2018 <u>Percent detected leaving Acclimation Sites</u> of PIT-Tagged Pro- and BioVita-Fed Spring Chinook Smolt

	Release Year →	2016				2017				2018				Pooled over
	Site →	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Years and
Feed	Measure ↓	Flat	Easton	Creek	2016 Sites	Flat	Easton	Creek	2017 Sites	Flat	Easton	Creek	2017 Sites	Sites
Pro	Survival	95.4%	94.9%	96.3%	95.5%	96.3%	92.6%	97.8%	95.5%	95.5%	93.8%	95.6%	94.9%	95.5%
	Tagged	4,000	6,000	6,000	16,000	4,001	6,000	6,000	16,001	4,000	6,000	6,012	16,012	48,013
BioVita	Survival	96.0%	94.1%	95.7%	95.2%	97.8%	94.1%	91.9%	94.2%	94.8%	94.3%	96.3%	95.2%	95.2%
Control	Tagged	3,999	6,000	6,000	15,999	4,000	6,000	6,000	16,000	4,003	6,005	6,005	16,013	48,012
Pro - BioVita Difference		0.6%	-0.8%	-0.6%	-0.4%	1.5%	1.5%	-5.9%	-1.3%	-0.7%	0.5%	0.7%	0.3%	-0.3%

Volitional Release Dates

The mean volitional release dates are given in Table 3.a. and the median dates are given in Table 3.b. The main-effect difference between the Pro and BioVita <u>means</u> (Table 3.a) is not significant at the 5% level based on a least squares analysis of variance (Type 1 Error = 0.12, Appendix Table A.3.), and F-ratios of year and site interactions with treatment are less than 1. However, the PR0 Treatment's median volitional release date (Table 3.b.) was significantly later than that of the BioVita Treatment (significant at the 5% level based on the nonparametric Wilcoxon Sign Ranked Sum Test[2], Appendix Table A.5.a.).

Table 3.a. Release-Year 2016 through 2018 <u>Julian Release-Date *Mean*</u> of Pro- and BioVita-Fed Spring Chinook Smolt detected leaving Acclimation Sites

Feed	Release Year → / Site → / Measure ↓	2016 Clark Flat	2016 Easton	2016 Jack Creek	Pooled over 2016	2017 Clark Flat	2017 Easton	2017 Jack Creek	Pooled over 2017	2018 Clark Flat	2018 Easton	2018 Jack Creek	Pooled over 2018	Pooled over Years
Pro	Mean Release Detection Date	103	96	108	102	98	108	98	101	87	89	98	91	97.8
	Expanded Release Detections	3,815	3,853	3,819	11,487	5,696	5,553	5,625	16,874	5,777	5,841	5,747	17,365	45,726
BioVita Control	Mean Release Detection Date	101	95	106	101	94	99	101	98	85	91	95	90	95.8
	Expanded Release Detections	3,838	3,913	3,794	11,545	5,646	5,514	5,661	16,821	5,744	5,817	5,777	17,338	45,704
	Pro - BioVita Difference	2	1	2	2	4	9	-3	3	2	-2	3	1	2

Table 3.b. Release-Year 2016 through 2018 <u>Julian Release-Date *Median*</u> of Pro- and BioVita-Fed Spring Chinook Smolt detected leaving Acclimation Sites

Feed	Release Year → / Site → / Measure ↓	2016 Clark Flat	2016 Easton	2016 Jack Creek	2016 over 2016 Sites	2017 Clark Flat	2017 Easton	2017 Jack Creek	2017 over 2017 Sites	2018 Clark Flat	2018 Easton	2018 Jack Creek	2018 over 2018 Sites	Pooled over Years
Pro	Median Release Detection Date	101	92	109	101	95	112	94	100	86	75	92	84	94.3
	Expanded Release Detections	3,815	3,853	3,819	11,487	5,696	5,553	5,625	16,874	5,777	5,841	5,747	17,365	45,726
BioVita Control	Median Release Detection Date	94	76	91	87	89	100	99	96	85	76	91	84	89.1
	Expanded Release Detections	3,838	3,913	3,794	11,545	5,646	5,514	5,661	16,821	5,744	5,817	5,777	17,338	45,704
	Pro - BioVita Difference	7	16	18	14	6	12	-5	4	1	-1	1	0	5

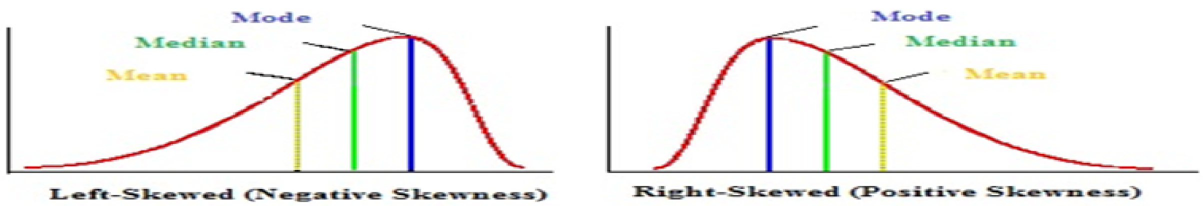
The differences between the median and the mean dates are given in Table 3.c. and indicate that the distributions in release dates are skewed to the left for both treatments (Median – Mean < 0), implying that smolt from both treatments tend to have prolonged release distribution (Table 3.c.). These skewness measures are significantly different than 0 at the 5% level based on the Wilcoxon Sign Ranked Sum Test (Appendix Table A.5.b. for the Pro treatment and Table A.5.c. for the BioVita treatment).

[2] An analysis of variance for the difference in the median main effect was not significance at the 5% but was significant at the 10% level (Type 1 Error = 0.070), but for reasons given in the Appendix, that analysis is not appropriate for medians.

The difference between the Pro and BioVita treatment skewness measures (bottom row of Table 3.c) does not differ significantly at the 5% level based on the Wilcoxon Sign Ranked Sum Test (Appendix Table A.5.d.).

Table 3.c. Release-Year 2016 through 2018 Release Date Median - Mean Release Date Difference (Skewness Measure) of Pro- and BioVita-Fed Spring Chinook Smolt detected leaving Acclimation Sites

	Release Year →	2016				2017				2018				over
	Site →	Clark		Jack	over 2016	Clark		Jack	over 2017			Jack	over 2018	Years
Feed	Measure ↓	Flat	Easton	Creek	Sites	Flat	Easton	Creek	Sites	Clark Flat	Easton	Creek	Sites	and
Pro	Median-Mean Difference	-2	-4	1	-2	-3	4	-4	-1	-1	-14	-6	-7	-3.5
BioVita	Median-Mean Difference	-7	-19	-15	-13.7	-5	1	-2	-2.0	0	-15	-4	-6.4	-6.6
Difference	Pro - BioVita Difference	5	15	16	12	2	3	-2	1	-1	1	-2	-1	3



McNary Juvenile Passage Dates

The mean volitional McNary Passage Dates are given in Table 4.a. As with the release dates, the main-effect mean McNary Passage Date difference between the Pro and BioVita means are not significant at the 5% level based on a least squares analysis of variance (Type 1 Error P = 0.24, Appendix Table A.4.), and the median passage dates (Table 4.b.) did not differ significantly at the 5% level based on the non-parametric Wilcoxon Sign Ranked Sum Test[3] (Appendix Table A.6.a).

Table 4.a. Release-Year 2016 through 2018 Mean Julian Date of McNary-Passage of Pro- and BioVita-Fed Spring Chinook Smolt detected leaving Acclimation Sites

	Release Year →	2016				2017				2018				Pooled
	Site →	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Clark		Jack	Pooled over	over Years
Feed	Measure ↓	Flat	Easton	Creek	2016 Sites	Flat	Easton	Creek	2017 Sites	Flat	Easton	Creek	2018 Sites	and Sites
Pro	Mean McNary Detection Date	122	126	126	124	120	133	128	127	116	125	127	123	125
	Expanded McNary Detections	1,616	1,272	1,161	4,049	1,844	1,592	1,767	5,203	1,621	1,643	1,583	4,847	14,099
BioVita	Mean McNary Detection Date	121	125	126	124	119	129	129	125	115	125	127	123	124
Control	Expanded McNary Detections	1,694	1,395	1,151	4,240	1,872	1,596	1,714	5,182	1,569	1,651	1,821	5,041	14,463
	Pro - BioVita Difference	1	1	0	1	1	4	-1	1	1	0	0	0	1

[3] **The Wilcoxon Sign Ranked Sum Test was significant at the 10% level (Appendix Table A.4), and the analysis of variance for the difference in the median main effect was near significance at the 5% level (Type 1 Error = 0.0507), but, again, for reasons given in the Appendix, the latter analysis of variance is not appropriate for medians. In any case, the Pro – BioVita differences in Table 4.a. for means and Table 4.b. for medians are small.**

Table 4.b. Release-Year 2016 through 2018 Median Julian Date of McNary-Passage of Pro- and BioVita-Fed Spring Chinook Smolt detected leaving Acclimation Sites

	Release Year →	2016				2017				2018				Pooled
	Site →	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Clark		Jack	Pooled over	over Years
Feed	Measure ↓	Flat	Easton	Creek	2016 Sites	Flat	Easton	Creek	2017 Sites	Flat	Easton	Creek	2018 Sites	and Sites
Pro	Median McNary Detection Date	122	125	127	124	121	136	137	131	115	123	126	121	126
	Expanded McNary Detections	1,616	1,272	1,161	4,049	1,844	1,592	1,767	5,203	1,621	1,643	1,583	4,847	14,099
BioVita	Median McNary Detection Date	121	124	128	124	119	130	132	127	114	123	124	121	124
Control	Expanded McNary Detections	1,694	1,395	1,151	4,240	1,872	1,596	1,714	5,182	1,569	1,651	1,821	5,041	14,463
	Pro - BioVita Difference	1	1	-1	0	2	6	5	4	1	0	2	1	2

The differences between the median and the mean dates are given in Table 4.c. These differences between the mean and median estimates were not significant over years for either treatment (Appendix Table A.6.b. for the Pro treatment and Appendix Table A.6.c. for the BioVita treatment), indicating no significant skewness at the 10% level in McNary Passage Dates for either treatment based on the Wilcoxon Sign Ranked Sum Test.

There is an anomaly in the differences in the Pro – BioVita skewness differences (bottom row in Table 4.c) in that the Wilcoxon Sign Ranked Sum Test is significant at the 10% level in spite of the small differences (Appendix Table A.6.d.). The test is a test of ranks of the differences and not of the magnitude of the differences. The absolute values in the bottom row of Table 4.c. are not great. Given that the differences between the two stock are small and the skewness measures for the individual stock are not significant, there is insufficient evidence to indicate that stocks differ in their skewness.

Table 4.c. Release-Year 2016 through 2018 Median - Mean McNary-Passage Date Difference (Skewness Measure) of Pro- and BioVita-Fed Spring Chinook Smolt detected leaving Acclimation Sites

	Release Year	2016				2017				2018				Pooled
	Site →	Clark		Jack	Pooled over	Clark		Jack	Pooled over	Clark		Jack	Pooled over	over Years
Feed	Measure ↓	Flat	Easton	Creek	2016 Sites	Flat	Easton	Creek	2017 Sites	Flat	Easton	Creek	2018 Sites	and Sites
Pro	Median Release Detection Date	0	1	-1	0	-1	-3	-9	-4	1	2	1	1	-1
BioVita	Median Release Detection Date	0	1	-2	0	0	-1	-3	-1	1	2	3	2	0
Difference	Pro - BioVita Difference	0	0	1	0	-1	-2	-6	-3	0	0	-2	-1	-1

Appendix: Statistical Analysis Tables for the Measures presented in the Text

Measures of Means and Proportions

The means and proportions are based on a large enough sample size to support the assumption that the Central Limit Theorem holds and that the use of weighted least squares analysis variance of means and the weighted logistic analysis of variation of proportions are appropriate, the weights being indicated in the following four tables within which Type 1 Error Probability estimates that exceed 0.05 (two-sided 5% significance level) are shaded in yellow.

Table A.1. **Weighted Logistic Analysis of Variance of Volitional-Release-to-McNary Survival for PIT-tagged Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Number of PIT-tagged smolt detected volitionally leaving the raceways)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	106.24	2	53.12	3.354	0.0625	Error
Site	363.43	2	181.72	3.142	0.1513	Year x Site
Year x Site	231.35	4	57.84	3.651	**0.0287**	Raceway Pairs
Raceway Pairs	237.6	15	15.84	2.086	0.0829	Error
Treatment* (Trt)	6.65	1	6.65	0.997	0.3293	Pooled Sources**
Trt x Year	0.77	2	0.39	0.051	0.9507	**Error**
Trt x Site	4.27	2	2.14	0.390	0.7001	Trt x Site x Year
Trt x Site x Year	21.88	4	5.47	0.720	0.5912	Error
Error	113.88	15	7.59			
Pooled Sources**	140.03	21	6.67	0.42		

* Pro versus BioVita Feed

** Basis of Test: Pooling of Treatment interactions and error because Treatment x Year interaction F-Ratio is unexpectantly small and using it as the denomiator for Treatment produced a highly signifant difference whereas the difference is only 1.4%

Yellow highlighted cells with boldfaced text significant at the 5% level or less, not boldface at the 10% level

Table A.2. **Weighted Logistic Analysis of Variance of Proportion of PIT-tagged Spring Chinook Smolt given Pro and BioVita Feeds that were detected leaving Acclimation Sites**

(Weight = Number PIT-tagged smolt)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	4.78	2	2.39	0.32	0.7342	Error
Site	334.12	2	167.06	5.20	0.0771	Year x Site
Year x Site	128.49	4	32.12	4.24	**0.0171**	Raceway Pairs
Raceway Pairs	113.64	15	7.58	0.86	0.6129	Error
Treatment* (Trt)	0.07	1	0.07	0.04	0.8646	Trt x Year
Trt x Year	3.75	2	1.88	0.21	0.8107	**Error**
Trt x Site	5.29	2	2.65	0.40	0.6952	Trt x Site x Year
Trt x Site x Year	26.54	4	6.64	0.75	0.5712	Error
Error	132.12	15	8.81			

* Pro versus BioVita Feed

Yellow highlighted cells with boldfaced text significant at the 5% level or less

Table A.3. **Weighted Analysis of Variance of Mean Julian dates of Volition Release of PIT-tagged Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Number Detected at Release)

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	**698,090**	**2**	**349,045**	**11.02**	**0.0011**	**Error**
Site	2,027,554	2	1,013,777	4.57	0.0927	Year x Site
Year x Site	**887,716**	**4**	**221,929**	**7.01**	**0.0022**	**Raceway Pairs**
Raceway Pairs	475,040	15	31,669	1.87	0.1193	Error
Treatment (Trt)	84,633	1	84,633	6.61	0.1238	Trt x Year
Trt x Year	25,614	2	12,807	0.75	0.4873	Error
Trt x Site	19,075	2	9,538	0.17	0.8521	Trt x Site x Year
Trt x Site x Year	**228,866**	**4**	**57,217**	**3.37**	**0.0371**	**Error**
Error	254,591	15	16,973	0.54	0.8807	

Pro versus BioVita Feed

Yellow highlighted cells with boldfaced text significant at the 5% level or less, not boldface at the 10% level

Table A.4. **Weighted Analysis of Variance of Mean Julian dates of McNary Passage of volitionally released PIT-tagged Spring Chinook Smolt given Pro and BioVita Feeds**

(Weight = Expanded Number of volitionally released smolt Detected at McNary)

Source	Sums of Squares (SS)	Degrees of Freedom (DF)	Mean Square (Dev/DF)	F-Ratio	Type 1 Error P	Denominator Source
Year	**464,889**	**2**	**232,445**	**58.17**	**0.0000**	**Error**
Site	82,411	2	41,206	2.37	0.2097	Year x Site
Year x Site	**69,619**	**4**	**17,405**	**4.36**	**0.0155**	**Raceway Pairs**
Raceway Pairs	59,936	15	3,996	1.95	0.1042	Error
Treatment (Trt)	5,723	1	5,723	2.67	0.2439	Trt x Year
Trt x Year	4,287	2	2,143	1.04	0.3761	Error
Trt x Site	1,602	2	801	0.33	0.7395	Trt x Site x Year
Trt x Site x Year	9,835	4	2,459	1.20	0.3520	Error
Error	30,782	15	2,052			

*** Pro versus BioVita Feed**

Yellow highlighted cells with boldfaced text significant at the 5% level or less

Measures involving Medians

Medians are not expected to follow a normal distribution since the Central limit does not apply to medians. The non-parametric Wilcoxon Sign Ranked Sum Test is applied to raceway differences in the measures that involve medians. In the following tables two-sided critical values (C.V.) for the 5% and 10% levels are presented; if the actual ranked totals fall outside the critical-level boundaries (low value less than low critical value; high value greater than high critical value) indicating significance, they are highlighted in yellow .

Release Dates

Table A.5.a. **Wilcoxon Sign Ranked Sum Test for Differences between Pro and BioVita Median Volitional Release Dates**

Total of Ranks of Measure			
	Negative	Positive	Total
Total	31	179	210
C.V. (P* = 0.05)	52	158	210
C.V. (P** = 0.10)	60	150	210

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)
Yellow Highlighted indicates significance level

Tables A.5.b. **Wilcoxon Sign Ranked Sum Test for Differences between Pro Mean and Median Volitional Release Dates**[4]

Total of Ranks of Measure			
	Negative	Positive	Total
Total	208	68	276
C.V. (P* = 0.05)	131	40	276
C.V. (P** = 0.10)	193	83	276

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)
Yellow Highlighted indicates significance level

Table A.5.c. **Wilcoxon Sign Ranked Sum Test for Differences between BioVita Mean and Median Volitional Release Dates**[4]

Total of Ranks of Measure			
	Negative	Positive	Total
Total	229	24	253
C.V. (P* = 0.05)	187	66	253
C.V. (P** = 0.10)	178	75	253

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)
Yellow Highlighted indicates significance level

Table A.5.d. **Wilcoxon Sign Ranked Sum Test for Differences between Pro and BioVita Measures of Release Day Skewness[5]**

Total of Ranks of Measure			
	Negative	Positive	Total
Total	83	170	253
C.V. (P* = 0.05)	66	187	253
C.V. (P** = 0.10)	75	178	253

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)

McNary Passage Dates

Table A.6.a. **Wilcoxon Sign Ranked Sum Test for Differences between Pro and BioVita Median McNary Passage Dates**

Total of Ranks of Measure			
	Negative	Positive	Total
Total	55	155	210
C.V. (P* = 0.05)	**52**	**158**	210
C.V. (P** = 0.10)	**60**	**150**	210

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)
Yellow Highlighted indicates significance level

Tables A.6.b. **Wilcoxon Sign Ranked Sum Test for Differences between Pro Mean and Median McNary Passage Dates[4]**

Total of Ranks of Measure			
	Negative	Positive	Total
Total	52	119	171
C.V. (P* = 0.05)	40	131	171
C.V. (P** = 0.10)	47	124	171

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)

Table A.6.c. **Wilcoxon Sign Ranked Sum Test for Differences between BioVita Mean and Median McNary Passage Dates[4]**

Total of Ranks of Measure			
	Negative	Positive	Total
Total	63	73	136
C.V. (P* = 0.05)	30	106	136
C.V. (P** = 0.10)	36	100	136

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)

Table A.6.d. **Wilcoxon Sign Ranked Sum Test for Differences between Pro and BioVita Measures of McNary Passage Day Skewness[5]**

Total of Ranks of Measure			
	Negative	Positive	Total
Total	30	106	136
C.V. (P* = 0.05)	30	106	136
C.V. (P** = 0.10)	36	100	136

* 5% significance level (2-sided test)
** 10% significance level (2-sided test)
Yellow Highlighted indicates significance level

[4] **Measure of Skewness**
[5] **(Pro Median – Pro Mean) – (BioVita Median – Bio-Vita Mean)**

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Appendix G
Annual Report: 2008-2018 Fall and 2009-2018 Summer Chinook Smolt-to-Smolt Survival to McNary Dam of Releases into the Yakima Basin

Doug Neeley, Consultant to Yakama Nation

Summary

From 2015 through 2018, Yakima-origin Fall Chinook smolt releases from Prosser, Wanawish Dam, and the mouth of the Yakima were made on various dates. Later releases have frequently had lower and sometimes much lower survivals[1] than releases made in earlier years. Standard early[2] Prosser releases of Fall Chinook made from 2015 through 2017 have experienced a drop in release-to-McNary Dam (McNary) survival (range: 6.9% to 20.7%) when compared to the standard early releases of Yakima-origin smolt made from 2008 through 2014 (range: 23.6% to 39.3%). The 2018 early-release survival of 32.0% fell within the 2008-2014 range. Analyses presented in this report suggest that late releases should generally be avoided, and there is some evidence that releases as early as April should be considered. Releases of Summer Chinook also support this conclusion.

Subyearling Fall Chinook Smolt-to-Smolt Survival

In 2015, poor Yakima and Columbia river conditions existed when the early[3] release was made from Prosser, and the decision was made to make later releases at that site and additional sites downstream of Prosser (below Wanawish Dam a short distance up-stream of the Mouth of the Yakima River and into the Mouth of the Yakima River) to determine whether survival would improve with a decrease in the distance and presumably in the travel time to McNary Dam. With the exception of the river mouth release, later 2015 survivals were even lower than early releases even though the early-release survivals were abysmal to low. In subsequent years, releases of Yakima stock were continued at these three sites; 2015-2018 release data summaries are presented in Table 1.A. and Figure. 1. The 2016 Early-May releases were much higher than in 2015; however, with the exception of the releases into the Yakima

[1] **Estimation procedures for survival are illustrated in the 2017 report Methods of Estimating Smolt Survival and Passage**
[2] **Standard early releases were those made in April or early May.**
[3] **In addition to the early-May 2015 release of the Yakima stock from Prosser, there was an early release from Prosser of the Priest Rapids stock. The 2015 survival to McNary of the Yakima and the Priest Rapids stock were nearly equal and extremely low (6.9% for Yakima stock and 6.7% for Priest Rapids Stock[3]).**

River's Mouth, the late-June Mouth of the Yakima, late-May and late-June release survivals were also abysmal. The later 2017 releases had higher survivals over earlier releases at all three release sites; whereas, the 2018 Prosser early-May release (the only site that had an early-May release) had a higher survival to McNary than the late-May release. All of the 2017 and 2018 releases have had moderate survivals, ranging from 20% to 33%.

Statistical comparisons among release-period comparisons were problematic for the 2017 and 2018 releases. There were actually two releases made on adjacent days within the 2018 late-May period, and the relative survival difference was large for the Yakima mouth adjacent-day releases (Table 1.b.). Unless the conditions in Columbia River deteriorated dramatically in one day, the single-day 23.7% relative river-mouth difference suggests that day-to-day survivals can vary dramatically, and it would be difficult to determine whether among-period differences exceed the within-period difference. Note from Table 1.a. that the 2015 river-mouth release survival dropped from 40% to 8.7%, a relative change of 78% ([40.0% - 8.7%]/40.0%), in a five day period; so a rapid deterioration of survival conditions in the Columbia is possible within a matter of a few days.

Table 1.a. Juvenile Survivals to McNary of Fall Chinook from Common Release Sites and associated Dates of Release, Mean McNary Passage, and Travel Times

2015* Yakima Stock McNary Survivals from Release Sites

Release Site	Release Period	Early May	Late May	Early June
Prosser	Release Date >	6 and 8 May		2-Jun
	Survival	6.9%		5.7%
	Number Tagged	4,021		11,640
	Travel Time	29		11
Wanawish	Release Date >		29-May	2-Jun
	Survival		0.7%	0.0% *
	Number Tagged		1,832	1,176
	Travel Time		33	no estimate
Mouth	Release Date >		29-May	2-Jun
	Survival		40.0%	8.7%
	Number Tagged		1,578	837
	Travel Time		33	8

* In addition to no detections at McNary, there were no detections at Bonneville and John Day. This is not necessarily an indication of no survival but of no detections within bypasses around dams

Red Texted survivals the highest within release site

Yellow highlighted survivals less than 5%

2016* Yakima Stock McNary Survivals from Release Sites

Release Site	Release Period	Early May	Late May	Late June
Prosser	Release Date >	5-May	25-May	23-Jun
	Survival	22.8%	1.8%	0.0%
	Number Tagged	2,531	2,122	2,105
	Travel Time	11	13	no estimate
Wanawish	Release Date >	4-May		23-Jun
	Survival	23.0%		0.2%
	Number Tagged	1,056		2,104
	Travel Time	9		8
Mouth	Release Date >	4-May		23-Jun
	Survival	35.3%		21.9%
	Number Tagged	2,199		1,151
	Travel Time	8		7

* In addition to no detections at McNary, there were no detections at Bonneville and John Day. This is not necessarily an indication of no survival but of no detectionswithin bypasses around dams

Red Texted survivals the highest within release site within year

Yellow highlighted survivals less than 5%

2017 Yakima Stock McNary Survivals from Release Sites

Release Site	Release Period	Early May	Late May	Early June
Prosser	Release Date >	5-May	30-May	5-Jun
	Survival	20.7%	26.3%	27.8%
	Number Tagged	2,503	2,020	2,026
	Travel Time	35	15	16
Wanawish	Release Date >		30-May	5-Jun
	Survival		22.0%	31.8%
	Number Tagged		1,047	1,030
	Travel Time		15	15
Mouth	Release Date >		30-May	5-Jun
	Survival		27.6%	28.9%
	Number Tagged		2,023	2,026
	Travel Time		17	15

2018 Yakima Stock McNary Survivals from Release Sites

Release Site	Release Period	Early May	Late May
Prosser	Release Date >	5-May	24-25-May
	Survival	32.0%	22.8%
	Number Tagged	2,502	4,013
	Travel Time	25	17-20
Wanawish	Release Date >		24-25-May
	Survival		29.7%
	Number Tagged		4,082
	Travel Time		15-14
Mouth	Release Date >		24-25-May*
	Survival		32.7%
	Number Tagged		2,017
	Travel Time		15-17

Figure 1.

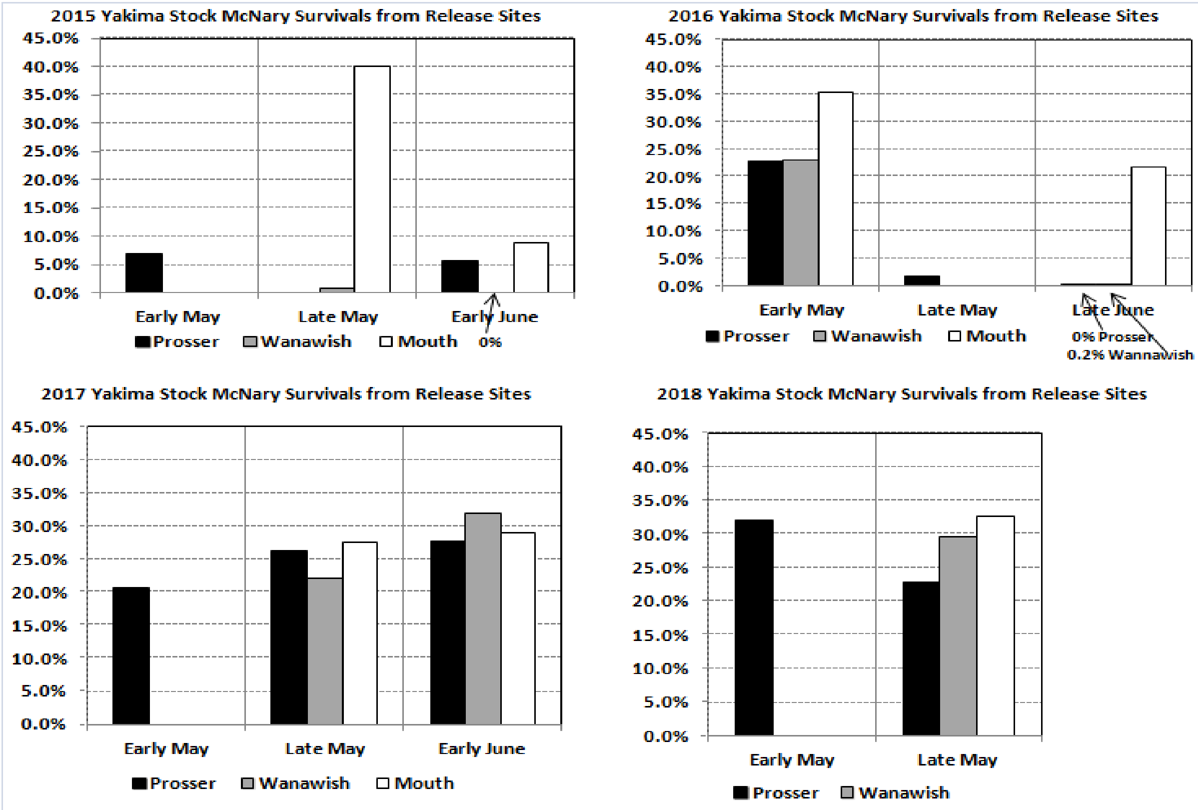


Table 1.b. 2018 Late May Yakima Stock McNary Survivals from Release Sites and associated Dates of Release, Mean McNary Passage, and Travel Times

2018 Late May Yakima Stock McNary Survivals from Release Sites

Release Site	Release Period	Late May		Relative Change*
Prosser	Release Date >	24-May	25-May	
	Survival	24.5%	21.0%	14.5%
	Number Tagged	2,006	2,007	
	Travel Time	17	20	
Wanawish	Release Date >	24-May	25-May	
	Survival	28.4%	30.9%	-8.7%
	Number Tagged	2,006	2,076	
	Travel Time	15	14	
Mouth	Release Date >	24-May	25-May	
	Survival	37.0%	28.3%	23.7%
	Number Tagged	1,009	1,008	
	Travel Time	15	17	

* (25 May - 24 May)/(24 May) as a percentage

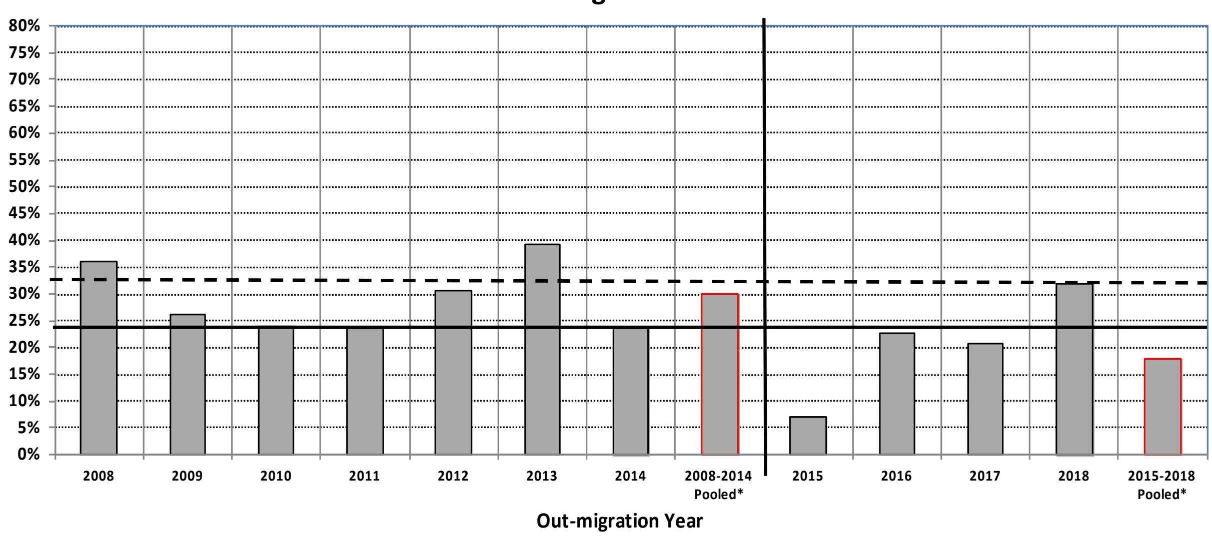
Table and Figure 2. present pooled early -release survival estimates from Prosser release to McNary passage for release years 2008 through 2018. The 2008 through 2014 release periods presented in the table are not necessarily the periods of highest survivals. The purpose of the table is to give a longer time series to permit comparisons of early-period survivals from the 2015 through 2018 era to early-period survivals before 2015 for which there is information.

A one-sided test for a reduction in survival from the 2008-2014 to 2015-2918 was not significant at the 5% level but was at the 10% level (1-sided Type 1 Error P = 0.0695, Table 3.a.) The analysis on the data set omitting the 2018 survival estimate was significant at the 5% level (1-sided Type 1 Error P = 0.0432, Table 3.b.). It should be noted from Figure 2. that the 2018 survival is exceed by two (2009 and 2013) of the 2008-2014 survivals; however, the first three of the four 2015-2018 survivals are less than that of the smallest survival (2011) from the 2008-2015 releases.

Table 2. Pooled Prosser-to-McNary Survival for Yakima Stock Subyearling Fall Chinook Releases made early in 2008 through 2018

	Release Year												
Measure	2008	2009	2010	2011	2012	2013	2014	Pooled 2008-2014	2015	2016	2017	2018	Pooled 2015-2018
Survival	38.9%	26.3%	24.0%	23.6%	28.9%	39.3%	23.7%	30.0%	6.9%	22.8%	20.7%	32.0%	17.9%
Tagged	10,005	7,565	13,685	22,790	19,634	22,966	4,025	100,670	4,998	2,531	2,503	2,502	12,534
Release Period	Late April	Early April	Late April-Early May	Early May	Late April-Early May	Late April-Early May	Early May		Early May	Early May	Early May	Early May	

Figure 2. Pooled Prosser-to-McNary Survival for Yakima Stock Subyearling Fall Chinook Releases made in 2008 through 2018



Dashed horizontal line represents the highest survival from outmigration years 2015 through 2018

Solid horizontal line represents the lowest survival from outmigration years 2008 through 2014

Table 3.a. Logistic Analysis of Variation comparing 2008-through-2014 Prosser-to-McNary Survival to 2015-through-2018 Prosser-to-McNary Survival for Yakima Stock Subyearling Fall Chinook

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P 2-side Test**	1-side Test**
Between Year Groupings*	865.59	1	865.59	2.63	0.1391	0.0695
Within Groupings	2958.14	9	328.68			

* 2008-2014 versus 2015-2018

**Test for 2015-2018 differing from the 2008-2014 Survival against the hypothesis of no difference

*** Test for 2015-2018 being less that the 2008-2014 Survival against the hypothesis of no difference

Table 3.b. Logistic Analysis of Variation comparing 2008-through-2014 Prosser-to-McNary Survival to 2015-through-2018 Prosser-to-McNary Survival for Yakima Stock Subyearling Fall Chinook

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Dev (Dev/DF)	F-Ratio	Type 1 Error P 2-side Test**	1-side Test**
Between Year Groupings*	1230.64	1	1230.64	3.82	0.0865	0.0432
Within Groupings	2579.28	8	322.41			

* 2008-2014 versus 2015-2017

**Test for 2015-2017 differing from the 2008-2014 Survival against the hypothesis of no difference

*** Test for 2015-2017 being less that the 2008-2014 Survival against the hypothesis of no difference

Summer Chinook Smolt-to-Smolt Survival

There were few release-time comparisons for Summer Chinook. Table 6. gives McNary survival for all releases made into the Yakima basin. As was the case for Fall Chinook releases, 2015 Summer Chinook releases experienced abysmal survivals for all release times and sites, and the two releases made in 2018 were also less than 5%. Other than the releases in 2015 (the year of poor survival for all up-river late Chinook releases), there was only one release made before May 10, and that was the 2011 release into Buckskin Slough. That release had the highest survival to McNary (44%) of all releases irrespective of release time and release site. With the exception of the 2013 release at Roza Dam, all Summer Chinook releases after May 25th had survivals less than 5%. Inclusive of two 2015 releases, four releases made after May 10 through May 25 were less than 5%. Of the two cases in which releases were made in two different periods at the same site within the same year (2014 releases into Buckskin Slough and 2015 releases at Roza), the survival of the earliest of the two releases had the highest survival (bordered in red in Figure 3.) All this suggests that releases of Summer Chinook should be made earlier than is currently the case.

Table 3. 2009-2018 Pooled Release-to-McNary Summer Chinook Survival-Index Estimates from Release Sites

Release Site		Stiles		Buckskin			Marion Drain	Roza Below Roza			Prosser		Yakima Mouth	Wapatox Bypass
Release Period		Mid**	Late***	Early*	Mid**	Late***	Mid**	Early*	Mid**	Late***	Early*	Mid**	Early *	Mid**
2009	Survival		1.5%											
	Tagged		30,037											
2010	Survival	19.7%												
	Tagged	29,865												
2011	Survival	39.7%		43.7%										
	Tagged	20,000		29,894										
2012	Survival				37.2%		35.8%					20.8%		
	Tagged				9,999		9,998					9,999		
2013	Survival				29.8%					20.9%				
	Tagged				15,065					14,907				
2014	Survival				18.3%	3.2%				4.8%				
	Tagged				10,086	10,102				10042				
2015	Survival				0.00%			0.07%	0.00%		2.6%			
	Tagged				10,266			10,012	9,520		4,031			
2016	Survival												31.2%	
	Tagged												35,619	
2017	Survival								19.4%			19.6%		
	Tagged								15,026			2,513		
2018	Survival								4.9%					0.3%
	Tagged								15,082					15,048

* Early: Through 10 May
** Mid: After 10 May through May 25
*** Late: After May 25
Yellow highlighted under 5% survival
Red Text is Wenatchee Hatchery Source, all others are Well Hatchery sources

Recommendation

Consideration should be given to have early releases made in April or early May for both Fall and Summer Chinook in addition to later releases. Up to 2016, the earliest Coho releases were made in April. In 2018 Coho releases were made in March which resulted in the tagging-to-McNary highest survivals by far than the later releases made in previous years. Recall that the 2011 early release into Buckskin had the highest survival of all Summer Chinook releases.

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Appendix H

Annual Report: 2018 Coho Smolt-to-Smolt Survival of Releases into the Yakima Basin

Doug Neeley, Consultant to Yakama Nation

Introduction

In 2018 there were early-March Yakima-stock smolt releases into the lower Yakima River at Prosser, into Buckskin Slough, and into Ahtanum Creek and the south fork of Cowiche Creek. There was also an earlier release of Washougal-stock smolt at Prosser as well as early releases of Eagle Creek stock from Styles and Easton ponds. In addition, there were parr releases made into the Upper Yakima and Little Naches Rivers and into Cowiche, Wilson, Squaw, and Ahtanum Creeks. Survival[1] estimates from date of tagging to McNary Dam (McNary) passage are presented for these releases as well as mean McNary passage dates and release-to-McNary travel times. The 2017 Yakima stock Prosser-release survival estimates exceeded the poor survival estimates of 2015 and 2016 and were well within the range of pre-2015 survival estimates, and the 2018 Prosser-to-McNary survival estimate exceeded 95%, much higher than any previous releases. The2017 and 2018 Prosser release dates were earlier than any of the previous earliest release dates of healthy smolt.   Although the 2017 Stiles-release survival was higher than those of the 2015 and the 2016 releases, it was lower than all but one of the pre-2015 releases. Appendix tables include 1999 through 2018 survival estimates from tagging to McNary of early Yakima-stock smolt releases from all release sites as well as of all parr releases.

Smolt Survival and McNary Passage Time

In 2015 there was an extremely low snow pack and an early snowmelt. In-stream conditions resulted in poor smolt-to-smolt survivals. Survivals were also poor in 2016 compared to pre-2015 releases. In-stream conditions were much better in 2017 and 2018, and, in the case of Prosser releases, the 2017 Prosser-release survival estimate was well within the range comparable of the pre-2015 releases, and the 2018 estimate exceeded those of all of the previous year estimates. The 2017 and 2018 Prosser release dates were earlier than those of previous years with the exception of the March 5th 2012 release which was made early because of high disease levels in rearing ponds.

Table 1.a. presents the smolt release survivals for all stock released in 2018 and the survivals of the 2015 through 2017 Yakima-stock releases. Note that the Prosser-release 2017-2018 survivals of Yakima Stock exceeded the poor survival years of 2015 and 2016 for all sites from which the Yakima stock was

[1] **Survival is time-of-tagging to McNary-passage survival**

released, and note that the 2017-2018 release dates from Prosser were earlier than those made in 2015-2016. The Yakima survival at Prosser was much higher than that of the Washougal stock release made at an earlier date than that at Prosser, but there is no information that would lead to a determination as to whether the Yakima – Washougal survival difference was due to a release-time or a stock effect[2].

Table 1.A. 2015-2018 Tagging-to-McNary Survival of early-release Yakima Stock* Smolt for those Sites from which 2018 Releases were made as well 2018 Survivals of other Stock Releases**

Release Site	Measure	2015: Yakima Stock	2016: Yakima Stock	2017: Yakima Stock	2018: Yakima Stock	2018: other Stock	
Stiles	Survival	8.2%	24.7%	27.4%		25.5%	Eagle Creek
	Tagged	2,520	3,756	5,007		5,008	
	Release Date	3/23	4/7	4/17		4/26	
	Mean Travel Time	51	35	31		17	
Prosser	Survival	37.2%	22.9%	66.5%	97.9%	32.1%	Washougal
	Tagged	1,265	2,501	2,876	2,509	4,254	
	Release Date	3/23	4/4	3/19	3/14	2/28	
	Mean Travel Time	21	19	34	48	51	
Easton	Survival		13.3%			9.2%	Eagle Creek
	Tagged		5,098			4,994	
	Release Date		4/7			4/3	
	Mean Travel Time		35			46	
Buckskin	Survival		20.4%		24.1%		
	Tagged		2,501		1,250		
	Release Date		3/28		5/1		
	Mean Travel Time		32		43168		
S.F. Cowiche	Survival				25.3%		
	Tagged				1,251		
	Release Date				3/13		
	Mean Travel Time				74		

*Highlighted in yellow

** Highlighted in blue

[2] **There were paired releases at Boone and Lost Creek ponds of Yakima and Washougal stock that out-migrated in 2005, but the Yakima stock was released as smolt in 2005 whereas the Washougal stock was released as Parr in the previous year. Stock and release-time effects would be confounded in any stock comparisons. There were no other Washougal releases.**

Table 1.B.1) presents Prosser-release Yakima stock survivals for all Prosser releases. The 2018 Prosser release's survival of 98%[3] is by far the highest over years, and the 2017 and 2018 release dates are the earliest with the exception of the 2012 release date (refer to green high-lighted release date and text in Table 1.B.1).

Table 1.B.1) Yakima-stock Prosser release survival to McNary for all years in which Yakima stock were released from Prosser

Release Year	2007	2009	2010	2011	2012*	2013	2014	2015	2016	2017	2018
Survival	62.7%	65.7%	52.5%	37.6%	33.9%	67.2%	78.0%	37.2%	22.9%	66.5%	97.9%
Number Released	2,499	2,506	1,371	5,036	3,811	2,520	3,004	1,265	2,501	2,876	2,509
Release Date (RD)	4/15	4/2	4/4	4/15	3/5	4/15	4/14	3/23	4/4	3/19	3/14
Travel Time (TT)	15	41	24	30	58	8	18	21	19	34	48

* While the 2012 release date was ealier than that in 2018, the smolt were released early because an elevated disease level detected in the pond

The other site with a post-2016 release and a reasonable number of pre-2017 releases of Yakima stock was Stiles Pond. Table 1.b.2) presents the relevant information for that site. As can be seen, the 2017 survival was greater than the poor survival years of 2015 and 2016 (only slightly greater than the 2016 release). However, the 27.4% survival of the 2017 release was less than all but two of the pre-2015 releases (the exceptions being the 2017 and 2010 release).

Table 1.B.2) Release-to-McNary Survival from Stiles Release of Yakima Stock

Release Year	2001	2003	2006	2007	2009	2010	2012	2013	2014	2015	2016	2017	2018
Survival	43.2%	40.0%	32.7%	25.0%	47.6%	18.7%	38.0%	44.2%	44.9%	8.2%	24.7%	27.4%	
Number Released	1,240	1,249	2,490	2,449	2,515	2,501	2,526	2,504	2,505	2,520	3,756	5,007	no
Release Date (RD)	5/17	5/7	4/3	4/5	4/15	4/12	4/16	4/15	4/16	3/23	4/7	4/17	releases
Travel Time (TT)	22	14	38	41	36	36	32	30	25	51	35	31	

[3] It is noted that detection efficiency estimates were very low in 2018 which contribute to the high survival estimate, there being only one previous year with such a low detection efficiency (refer to Appendix Table C.)

Parr Release Survivals

Table 2. presents survival to McNary of parr releases by release location and migration year for all releases sites having releases in 2018. Appendix B. presents tables for all parr.

Table 2. Estimated Release to McNary Dam survival of coho released as parr by release location and migration year.

Cowiche Creek

Year	Releases	Survival	Stock	Site
2008	3,001	30.7%	Yakima	Cowiche Creek - Parr
2009	6	0%*	Wild Parr?	Cowiche - Parr Capture and Release
2009	3,001	23.3%	Yakima	Cowiche - Parr
2010	3,004	16.9%	Yakima	Cowiche
2011	3,021	19.6%	Yakima	Cowiche - Parr
2011	28	81.2%**	Wild Parr	Cowiche - Parr
2011	3,049	20.1%		Cowiche - Parr
2013	3,003	11.3%	Yakima	Cowiche - Parr
2013	2,495	27.5%	Yakima	Cowiche from Mobile
2014	3,014	3.6%	Yakima	Cowiche - Parr
2014	1,249	25.4%	Yakima	Cowiche from Mobile
2015	3,017	0.0%	Yakima	Cowiche - Parr
2015	1,250	15.4%	Yakima	Cowiche from Mobile
2018	3,035	16.6%	Yakima	COWICC

* Only based on 6 juveniles released
* Only based on 28 juveniles released

Little Naches

Year	Releases	Survival	Stock	Site
2009	3,000	16.6%	Yakima	Little Naches - Parr
2010	3,072	18.3%	Yakima	Little Naches
2011	3,022	9.6%	Yakima	Little Naches
2012	3,014	20.3%	Yakima	Little Naches - Parr
2013	3,019	7.6%	Yakima	Little Naches - Parr
2014	3,012	6.6%	Yakima	Little Naches - Parr
2015	3,026	0.0%	Yakima	Little Naches - Parr
2015	3,004	0.0%	Yakima	Little Naches - Parr
2015	6,030	0.0%	Yakima	Little Naches - Parr
2016	3,008	2.6%	Yakima	Little Naches - Parr
2018	3,042	12.3%	Yakima	Little Naches - Parr

Reecer Creek

Year	Released	Survival	Stock	Site
2008	3,001	37.41%	Yakima	Reecer Creek - Parr
2009	2,965	25.21%	Yakima	Reecer Cr - Parr
2010	3,015	23.24%	Yakima	Reecer Cr
2011	3,004	29.24%	Yakima	Reecer Cr - Parr
2012	3,026	20.52%	Yakima	Reecer Cr - Parr
2013	3,032	13.35%	Yakima	Reecer Cr - Parr
2014	3,031	7.46%	Yakima	Reecer Cr - Parr
2015	3,026	3.26%	Yakima	Reecer Cr - Parr
2018	3,069	29.96%	Yakima	Reecer Cr - Parr

Swauk Creek Bridge

Year	Releases	Survival	Stock	Site
2018	3,024	2.85%	Yakima	Thorp Bridge - Parr

Upper Yakima

Year	Releases	Survival	Stock	Site
2018	3,046	8.5%	Yakima Parr	Upper Yakima (Location?)

Wilson Creek

Year	Releases	Survival	Stock	Site
2008	3,000	11.4%	Yakima	Wilson Creek - Parr
2009	3,007	15.5%	Yakima	Wilson - Parr
2010	3,050	12.1%	Yakima	Wilson
2011	3,008	13.8%	Yakima	Wilson - Parr
2012	3,020	11.2%	Yakima	Wilson - Parr
2013	1,518	4.9%	Yakima	Burried Section Above - Parr
	1,502	10.2%	Yakima	Burried Section Below - Parr
		Implies high mortality within burried section		
2014	3,024	8.2%	Yakima	Wilson - Parr
2015	3,027	7.1%	Yakima	Wilson - Parr
2016	3,011	11.6%	Yakima	Wilson - Parr
2018	3,019	48.5%	Yakima	Wilson - Parr

Appendix A. Earliest Smolt Releases of Yakima Stock over all Years and Release Sites
Outmigration Years 1999 through 2006

Release Year	Measure	Cle Elum	Jack Creek	Creek Pond	Holmes	Easton	Stiles	Boon Pond	Prosser Hatchery	Buckskin	Buckskin	SF Cowiche
1999	Released	1,158	1,229	1,047			1,240					
	Survival	47.1%	32.7%	13.4%			43.2%					
	Mean Passage Date	5/31/99	6/15/99	6/11/99			6/7/99					
	Release Date	5/17/99	5/17/99	5/17/99			5/17/99					
	Passage Time	14	30	25			22					
2000	Released	No releases made in 2000										
	Survival											
	Mean Passage Date											
	Release Date											
	Passage Time											
2001	Released	1,207		1,250		1,249	1,249					
	Survival	1.2%		25.6%		12.5%	40.0%					
	Mean Passage Date	5/12/01		5/22/01		5/29/01	5/21/01					
	Release Date	5/7/01		5/7/01		5/7/01	5/7/01					
	Passage Time	5		15		23	14					
2002	Released			1,192			1,250					
	Survival			26.3%			37.8%					
	Mean Passage Date			5/13/02			5/19/02					
	Release Date			05/06/02 00:00			05/06/02 00:00					
	Passage Time			7			14					
2003	Released			3,333	3,355	3,355	3,332					
	Survival			21.5%	11.6%	11.6%	25.1%					
	Mean Passage Date			6/3/03	5/26/03	5/26/03	5/22/03					
	Release Date			4/7/03	4/7/03	4/7/03	4/1/03					
	Passage Time			58	50	50	52					
2004	Released			2,445				2,488				
	Survival			34.4%				32.8%				
	Mean Passage Date			5/14/04				5/4/04				
	Release Date			4/5/04				4/5/04				
	Passage Time			39				29				
2005	Released			5,232				5,052				
	Survival			3.7%				0.5%				
	Mean Passage Date			5/6/05				5/8/05				
	Release Date			3/14/05				3/14/05				
	Passage Time			53				55				
2006	Released			2,491	2,512		2,490	2,501				
	Survival			35.0%	12.5%		32.7%	3.6%				
	Mean Passage Date			5/24/06	5/4/06		5/11/06	5/13/06				
	Release Date			4/3/06	4/3/06		4/3/06	4/3/06				
	Passage Time			51	31		38	40				

Appendix A. Earliest Smolt Releases of Yakima Stock over all Years and Release Sites Outmigration Years 2007 through 2014 (continued)

Release Year	Measure	Cle Elum	Jack Creek	Creek Pond	Holmes	Easton	Stiles	Boon Pond	Prosser Hatchery	Buckskin	Buckskin	SF Cowiche
2007	Released			2,501	2,460		2,449		2,499			
	Survival			22.1%	10.7%		25.0%		62.7%			
	Mean Passage Date			6/1/07	5/16/07		5/16/07		4/29/07			
	Release Date			4/5/07	4/5/07		4/5/07		4/15/07			
	Passage Time			57	41		41		15			
2008	Released			2,499	2,493	2,500	2,492					
	Survival			28.7%	10.6%	32.6%	30.1%					
	Mean Passage Date			5/22/08	5/19/08	5/16/08	5/15/08					
	Release Date			4/5/08	4/5/08	4/5/08	4/5/08					
	Passage Time			47	44	41	40					
2009	Released			2,508	2,512		2,515		2,506			
	Survival			31.2%	9.6%		47.6%		65.7%			
	Mean Passage Date			5/28/09	5/18/09		5/21/09		5/13/09			
	Release Date			4/15/09	4/15/09		4/15/09		4/2/09			
	Passage Time			43	33		36		41			
2010	Released			2,505	2,516		2,501		1,371			
	Survival			20.0%	2.1%		18.7%		52.5%			
	Mean Passage Date			5/28/10	5/13/10		5/18/10		4/28/10			
	Release Date			4/12/10	4/12/10		4/12/10		4/4/10			
	Passage Time			46	31		36		24			
2011	Released			2,500	2,516	1,272			5,036			
	Survival			22.8%	3.4%	6.6%			37.6%			
	Mean Passage Date			6/4/11	5/27/11	5/23/11			5/14/11			
	Release Date			4/14/11	4/15/11	4/15/11			4/15/11			
	Passage Time			51	43	38			30			
2012	Released				2,508	2,524	2,526		3,811			
	Survival				2.4%	21.8%	38.0%		33.9%			
	Mean Passage Date				5/28/12	5/24/12	5/18/12		5/1/12			
	Release Date				4/16/12	4/16/12	4/16/12		3/5/12			
	Passage Time				43	38	32		58			
2013	Released			2,531			2,504		2,520			
	Survival			24.0%			44.2%		67.2%			
	Mean Passage Date			5/24/13			5/14/13		4/22/13			
	Release Date			4/15/13			4/15/13		4/15/13			
	Passage Time			40			30		8			
2014	Released						2,505		3,004	1,572		
	Survival						44.9%		78.0%	50.0%		
	Mean Passage Date						5/10/14		5/1/14	4/27/14		
	Release Date						4/16/14		4/14/14	4/7/14		
	Passage Time						25		18	20		

Appendix A. Earliest Smolt Releases of Yakima Stock over all Years and Release Sites
Outmigration Years 2015 through 2018

Release Year	Measure	Cle Elum	Jack Creek	Creek Pond	Holmes	Easton	Stiles	Boon Pond	Prosser Hatchery	Buckskin	Buckskin	SF Cowiche
2015	Released			2,506			2,520		1,265			
	Survival			4.3%			8.2%		37.2%			
	Mean Passage Date			5/17/15			5/13/15		4/13/15			
	Release Date			3/23/15			3/23/15		3/23/15			
	Passage Time			55			51		21			
2016	Released			2,502	5,050	5,098	3,756		2,501	2,501		
	Survival			4.8%	19.2%	13.3%	24.7%		22.9%	20.4%		
	Mean Passage Date			5/16/16	5/7/16	5/11/16	5/12/16		4/22/16	4/28/16		
	Release Date			4/5/16	4/6/16	4/7/16	4/7/16		4/4/16	3/28/16		
	Passage Time			41	31	35	35		19	32		
2017	Released				5,002		5,007		2,876			
	Survival				14.8%		27.4%		66.5%			
	Mean Passage Date				5/19/17		5/17/17		4/21/17			
	Release Date				3/15/17		4/17/17		3/19/17			
	Passage Time				65		31		34			
2018	Released								2,509	1,250		1,251
	Survival								97.9%	24.1%		25.3%
	Mean Passage Date								5/1/18	5/1/18		5/20/18
	Release Date								3/14/18	3/9/18		3/8/18
	Passage Time								48	53		74

Note: There were smolt releases made at Ahtanum Creek in 2016 and 2017 but also a 2018 outmigration of a Parr release made in 2017. These are presented in Appendix B.

Appendix B. Parr Stream Releases (Year is outmigration year)

Ahtanum Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2009	PAH	3002	10.26%	Yakima	Ahtanum Cr - PARR
2010	PAH	3050	20.41%	Yakima	Ahtanum Cr
2011	PAH	3003	18.42%	Yakima	Ahtamum Cr - PARR
2012	PAL	4003	5.36%	Yakima	Ahtanum below WIP Main Diversion - PARR
2013	PAL	600	9.64%	Yakima	Ahtanum below WIP Main Diversion - PARR
2013	PAM	1213	6.71%	Yakima	Ahtanum below WIP Main Diversion - PARR
2013	PAL versus PAM	1813	2.94%	Yakima	Estimate may indicate no mortality in diversion
2014	PAL	672	0.00%	Yakima	Ahtanum La Salle - PARR
2014	PAH	872	0.62%	Yakima	Ahtanum below WIP Main Diversion - PARR
2015	RTA	231	0.00%	WDFW	Ahtanum Cr
2015	PAH	1349	0.00%	Yakima	Ahtanum below WIP Main Diversion - PARR
2016	YAL	869	18.77%	Yakima	Ahtanum Cr SMOLT release
2017	YAL	1527	31.05%	Yakima	La Salle SMOLT release
2018*	YAL	3009	21.97%	Yakima	Ahtanum Cr Parr

* 2017 Parr Release outmigrating in 2018

Big Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2008	BGY	3001	13.33%	Yakima	Big Creek - PARR
2009	PBG	3003	12.45%	Yakima	Big Cr - PARR
2010	PBG	3006	9.90%	Yakima	Big Cr
2011	PBG	3003	15.63%	Yakima	Big Cr - PARR
2012	PBG	3013	11.04%	Yakima	Big Cr - PARR
2013	PBG	3028	8.10%	Yakima	Big Cr - PARR
2014	PBG	3047	3.36%	Yakima	Big Cr - PARR
2015	PBG	3003	0.30%	Yakima	Big Cr - PARR

Boon Pond

Year	File Extension	Released	McNary Survival	Stock	Site
2008	BNY	2519	3.37%	Yakima	Boon Pond - PARR

Buckskin Slough

Year	File Extension			Stock	Site
2007	NSP	1026	9.08%	Yakima	Buckskin Slough - PARR
2011	WBK	216	31.91%	Wild Parr	Buckskin Slough - PARR
2014	MBU	1572	50.00%	Yakima	Buckskin Cr
2015	MBU	1247	12.57%	Yakima	Buckskin Slough
2016	MBU	2501	20.36%	Yakima	Buckskin Slough

Bumping Resevoir

Year	File Extension			Stock	Site
2007	BUB	3002	13.28%	Yakima	Bumping Resevoir - PARR

Appendix B. Parr Stream Releases (continued)

Cle Elum Dam

Year	File Extension			Stock	Site
2005	BLC	3331	3.12%		Lake Cle Elum Dam below dam
2005	FLU	1001	0.00%		Lake Cle Elum Dam Flume
2006	CLE	9998	0.06%	Coho	Cle Elum Lake from Net Pen
2006	UCW	3004	0.43%	Yakima	Upper Cle Elum Lake - PARR
2006	BLC	1001	31.96%	Hatchery	Cle Elum Dam below
2006	FLU	1000	15.99%	Coho	Cle Elum Dam Flume
2007	CLE	9999	4.22%	Lake CleElum	Cle Elum Lake from Net Pen
2007	UCW	3013	0.24%	Yakima	Upper Cle Elum River - PARR
2007	BLC	1011	0.00%		Lake Cle Elum Dam below dam
2007	BLC	999	10.26%		Cle Elum Dam below
2007	FLU	1004	0.00%		Lake Cle Elum Dam Flume
2007	FLU	1000	4.11%		Cle Elum Dam Flume
2007	BLC & BLC	2010	5.10%		Lake Cle Elum Dam below dam
2007	FLU & FLU	2004	2.05%		Lake Cle Elum Dam Flume
2007	UCE	2998	1.38%	Yakima	Cle Elum Dam at Tucquala Outlet - PARR
2008	UCL	5944	4.12%	Eagle Creek or Mixed Stock	Cle Elum Upper Lake
2008	CLN	5973	3.61%		Cle Elem Forebay
2009	CL1	4990	0.09%	Yakima	Cle Elum Lake
2009	CL2	6944	0.33%	Yakima	Cle Elum Lake
2009	CL1 & CL2	11934	0.23%	Yakima	Cle Elum Lake

Cowiche Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2008	CWY	3001	30.72%	Yakima	Cowiche Creek - PARR
2009	WCC	6	0.00%		Cowiche Cr - PARR Capture and Release
2009	PCW	3001	23.34%	Yakima	Cowiche Cr - PARR
2010	PCW	3004	16.89%	Yakima	Cowiche Cr
2011	PCW	3021	19.56%	Yakima	Cowiche Cr - PARR
2011	WCW	28	81.17%	Wild Parr	Cowiche Cr - PARR
2011	PCW & WCW	3049	20.13%		Cowiche Cr - PARR
2013	PCW	3003	11.25%	Yakima	Cowiche Cr - PARR
2013	MCW	2495	27.46%	Yakima	Cowiches Cr Moble
2014	PCS	3014	3.57%	Yakima	Cowiche Cr - PARR
2014	MCW	1249	25.43%	Yakima	Cowiche Cr from Mobile
2015	PCS	3017	0.00%	Yakima	Cowiche Cr - PARR
2015	MCW	1250	15.43%	Yakima	Cowiches Cr
2018	YPA	3035	0.165705656	Yakima	COWICC

Appendix B. Parr Stream Releases (continued)

South Fork Cowiche Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2009	MCW	817	45.40%	Yakima	Cowiche Cr SF from Mobile
2010	MCW	1248	25.01%	Yakima	Cowiche Cr SF
2011	MCW	1272	31.09%	Yakima	Cowiche Cr SF from Mobile
2012	MCW	1277	40.39%	Yakima	Cowiche Cr SF from Mobile
2012	PCS	3024	9.33%	Yakima	Cowiche Cr SF - PARR

Crystal Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2009	PCS	3003	9.99%	Yakima	Crystal Creek C.G. - PARR

Hanson River

Year	File Extension	Released	McNary Survival	Stock	Site
2005	HRY	997	2.37%	Yakima	Hanson River - PARR

Hanson Pond

Year	File Extension	Released	McNary Survival	Stock	Site
2005	HPY	994	9.12%	Yakima	Hanson Pond - PARR
2006	HPW	1006	3.82%	Coho	Hanson Pond - PARR
2006	HRW	1009	4.44%	Coho	Hanson Pond - PARR
2006	HPW & HRW	2015	4.13%	Coho	Hanson Pond - PARR
2007	HSP	1026	16.46%	Yakima	Hanson Pond - PARR
2007	HSR	1026	7.71%	Yakima	Yakima River Hanson reach- PARR

Holmes Pond

Year	File Extension	Released	McNary Survival	Stock	Site
2007	HLM	1025	6.98%	Yakima	Holmes Pond - PARR

Hundly Ponds

Year	File Extension	Released	McNary Survival	Stock	Site
2015	PHU	1531	0.00%	Yakima	Hundly Ponds - PARR

Keechelus Reach of Y.R.

Year	File Extension	Released	McNary Survival	Stock	Site
2016	PYK	952	0.42%	Wild	Keechelus Reach of Y.R.

Lost Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2007	LCK	1026	23.76%	Yakima	Lost Creek Pond

Marion Drain

Year	File Extension	Released	McNary Survival	Stock	Site
2008	MDE	3013	26.96%	Eagle Creek	Marion Drain

Appendix B. Parr Stream Releases (continued)

Mercer Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2013	PMA	1502	15.37%	Yakima	Mercer Cr Upstream of Burried Section - PARR
2013	PMB	1502	16.35%	Yakima	Mercer Downstream of Burried Section - PARR
2013	PMA versus PMB		-0.98%		Estimate may indicate little or no Mortailty in Burried Section
2016	PMA	1543	12.12%	Yakima	Mercer Cr Upstream of Burried Section - PARR
2016	PMB	1523	7.31%	Yakima	Mercer Cr Downstream of Burried Section - PARR
2016	PMA versus PMB		4.80%		Estimate may indicate no Mortailty in Burried Section

Naches

Year	File Extension	Released	McNary Survival	Stock	Site
2006	WNR	30	42.65%	Wild PARR	Naches - PARR
2016	PNA	3017	4.62%	Yakima	Naches Riv - PARR

Little Naches

Year	File Extension	Released	McNary Survival	Stock	Site
2009	PLN	3000	16.62%	Yakima	Little Naches - PARR
2010	PLN	3072	18.29%	Yakima	Little Naches
2011	PLN	3022	9.59%	Yakima	Little Naches
2012	PLN	3014	20.25%	Yakima	Little Naches - PARR
2013	PLN	3019	7.56%	Yakima	Little Naches - PARR
2014	PLN	3012	6.61%	Yakima	Little Naches - PARR
2015	PLN	3026	0.00%	Yakima	Little Naches - PARR
2015	PLN	3004	0.00%	Yakima	Little Naches - PARR
2015	PLN & PLN	6030	0.00%	Yakima	Little Naches - PARR
2016	PLN	3008.00	2.65%	PLN	Little Naches - PARR
2018	YPA	3042	12.28%		Little Naches - PARR

North Fork, Little Naches

Year	File Extension	Released	McNary Survival	Stock	Site
2008	LTY	3001	12.10%	Yakima	North Fork, Little Naches - PARR
2009	PNF	3003	16.31%	Yakima	Little Naches NF - PARR
2010	PNF	3014	19.44%	Yakima	Little Naches NF
2011	PNF	3058	17.84%	Yakima	Naches NF - PARR
2012	PNF	3028	15.43%	Yakima	Little Naches NF - PARR
2013	PNF	3012	11.36%	Yakima	NF Little Naches - PARR
2014	PNF	3034	5.68%	Yakima	Littl Naches NF - Parr
2015	PNF	3004	0.00%	Yakima	Little Naches NF - PARR

Appendix B. Parr Stream Releases (continued)

Nile Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2008	NLY	3000	17.23%	Yakima	Nile Creek - PARR
2010	PNL	3055	13.86%	Yakima	Nile Cr
2010	WNL	16	54.10%	Yakima	Nile Cr
2010	PNL & WNL	3071	14.07%	Yakima	Nile Cr
2009	PNL	2999	8.32%	Yakima	Nile Cr - PARR
2011	PNL	3110	7.49%	Yakima	Nile Cr - PARR
2011	WNL	16	71.02%	Wild Parr	Nile Cr - PARR
2011	PNL & WNL	3126	7.82%	Wild Parr	Nile Cr - PARR
2012	PNL	3017	7.12%	Yakima	Nile Cr - PARR
2013	PNL	3033	4.92%	Yakima	Nile Cr - PARR
2014	PNL	3026	6.40%	Yakima	Nile Cr - Parr

Quarts Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2012	PQU	3008	11.55%	Yakima	Quarts Cr - PARR
2013	PQU	3007	5.37%	Yakima	Quarts Cr - PARR
2014	PQU	3039	4.61%	Yakima	Quarts Cr - PARR
2015	PQU	3012	0.00%	Yakima	Quarts Cr - PARR

Rattle Snake Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2010	MRS	1144	8.51%	Yakima	Rattle Snake Cr Mobile
2010	PRS	3053	12.27%	Yakima	Rattle Snake Cr
2011	PLR	3000	7.95%	Yakima	Rattle Snake Cr - PARR
2012	MRS	1274	15.70%	Yakima	Rattle Snake Cr Mobile
2012	PLR	3006	8.69%	Yakima	Rattle Snake - PARR
2013	MRA	1263	21.85%	Yakima	Rattle Snake Cr Mobile
2013	PRS	3002	3.85%	Yakima	Rattle Snake - PARR
2014	PRC	3011	6.08%	Yakima	Rattle Snake Cr - PARR
2015	MRS	1249	5.81%	Yakima	Rattle Snake Cr Mobile
2015	PRI	1606	0.56%	Yakima	Rattle Snake Cr - PARR
2016	PRA	3032	3.81%	Yakima	Rattle Snake Cr - PARR

Little Rattle Snake

Year	File Extension	Released	McNary Survival	Stock	Site
2009	PLR	3005	2.28%	Yakima	Little Rattle Snake - PARR

Appendix B. Parr Stream Releases (continued)

Reecer Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2008	RCY	3001	37.41%	Yakima	Reecer Creek - PARR
2009	PRC	2965	25.21%	Yakima	Reecer Cr - PARR
2010	PRC	3015	23.24%	Yakima	Reecer Cr
2011	PRC	3004	29.24%	Yakima	Reecer Cr - PARR
2012	PRE	3026	20.52%	Yakima	Reecer Cr - PARR
2013	PRE	3032	13.35%	Yakima	Reecer Cr - PARR
2014	PRE	3031	7.46%	Yakima	Reecer Cr - PARR
2015	PRE	3026	3.26%	Yakima	Reecer Cr - PARR
2018	YPA	3069	29.96%	Yakima	Reecer Cr - PARR

Rock Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2010	WRK	78	0.00%	Yakima	Rock Cr

Roza Dam

Year	File Extension	Released	McNary Survival	Stock	Site
2005	ARD	3334	6.22%		Roza Dam above
2005	BRD	3334	4.81%		Roza Dam below
2013	YRP	1221	46.71%	Yakima	Roza Bypass
2014	MRZ	1500	41.63%	Yakima	Roza Dam below
2016	MRZ	2500	16.07%	Yakima	Roza Below Dam

Taneum Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2009	TAN	1300	15.84%	Wild	Taneum Cr
2010	TAN	1867	9.09%	Yakima	Taneum Cr
2011	TAN	4515	13.72%		Taneum Cr
2012	COT	1054	24.56%		Taneum Cr
2013	RTA	743	13.48%	Wild	Taneum
2014	RTA	1941	8.04%	Wild	Taneum Cr
2015	RTA	231	0.00%	WDFW Release	Taneum Cr

Swauk Creek Bridge

Year	File Extension	Released	McNary Survival	Stock	Site
2018	YPA	3024	2.85%	Yakima	Thorp Bridge - PARR

Thorp Bridge

Year	File Extension	Released	McNary Survival	Stock	Site
2012	PYA	2499	10.78%	Yakima	Thorp Bridge - PARR

Upper Yakima at Holmes

Year	File Extension	Released	McNary Survival	Stock	Site
2006	WYR	70	0.00%	Wild PARR	Upper Yakima River at Holmes - PARR
2007	WYR	23	0.00%	Wild	Upper Yakima River at Holmes - PARR

Upper Yakima

Year	File Extension	Released	McNary Survival	Stock	Site
2018	YPA	3046	8.49%	Yakima Parr	Upper Yakima (Location?)

Upper Yakima Tributaties

Year	File Extension	Released	McNary Survival	Stock	Site
2009	WCO	60	No. Est.		Upper Yakima Tributaties - PARR Capture and Release

Umtanum Cr

Year	File Extension	Released	McNary Survival	Stock	Site
2009	UMT	150	35.09%	Wild	Umtanum Cr
2010	UMT	42	35.71%	Yakima	Umtanum Cr

Wilson Creek

Year	File Extension	Released	McNary Survival	Stock	Site
2008	WLY	3000	11.36%	Yakima	Wilson Creek - PARR
2009	PWL	3007	15.51%	Yakima	Wilson Cr - PARR
2010	PWL	3050	12.15%	Yakima	Wilson Cr
2011	PWL	3008	13.78%	Yakima	Wilson Cr - PARR
2012	PWI	3020	11.23%	Yakima	Wilson Cr - PARR
2013	PWA	1518	4.89%	Yakima	Wilson Creek Burried Section Above - PARR
2013	PWB	1502	10.19%	Yakima	Wilson Creek Burried Section Below - PARR
2013	PWA versus PWB		-5.30%		Estimate may indicate Mortailty in Burried Setion
2014	PWI	3024	8.19%	Yakima	Wilson Cr - PARR
2015	PWI	3027	7.10%	Yakima	Wilson Cr - PARR
2016	PWI	3011	11.63%	Yakima	Wilson Cr - PARR
2018	YPA	3019	48.55%		Wilson Cr - PARR

Washougal Parr Releases Made in 2004, Reported in 2005 Out-Migration Yaer

Released	/IcN Surviva	Release Date	McN Passage Date	Site
2527.0	1.31%	7/26/04	5/18/05	Holmes Pond
2529.00	0.75%	7/26/04	5/19/05	Lost Creek Pond
2529.00	0.00%	7/26/04	NO SURVIVAL	Boone Pond

Appendix C: Unstratified* McNary Detection Efficiencies

Recovery Sites >	McNary (McN)Detection Efficiency by Recovery Site			Pooled detections over Bonneville and John	
	Bonneville	John Day	Pooled	Joint McN with lower Dams	Total Lower Dam
1999	28.74%	25.48%	26.56%	2171	8173
2000	19.00%	16.21%	17.59%	114	648
2001	53.74%	55.93%	54.81%	302	551
2002	20.49%	19.07%	19.80%	237	1197
2003	28.89%	25.54%	27.14%	456	1680
2004	4.94%	12.66%	7.37%	37	502
2005	17.26%	21.20%	20.12%	166	825
2006	26.45%	19.43%	21.08%	309	1466
2007	23.57%	21.42%	26.63%	679	2550
2008	16.89%	17.40%	17.17%	480	2795
2009	22.51%	19.44%	20.89%	712	3408
2010	13.30%	20.92%	15.32%	365	2383
2011	28.46%	20.93%	22.30%	479	2148
2012	17.77%	18.53%	18.17%	478	2631
2013	13.73%	14.36%	13.91%	268	1926
2014	17.42%	20.12%	18.58%	368	1981
2015	12.80%	16.44%	13.56%	94	693
2016	25.47%	24.54%	25.13%	420	1671
2017	10.15%	11.02%	10.65%	67	629
2018	6.84%	7.09%	6.96%	84	1207

Yellow highlighted years having detectionefficeicies < 10%

* The actual detection efficiencies are stratified but the the number of strata /year are to large for a meaningful presentation