# YAKIMA/KLICKITAT FISHERIES PROJECT MONITORING AND EVALUATION
## Yakima Subbasin

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## FINAL REPORT
**For the Performance Period**
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THE CONFEDERATED TRIBES AND BANDS OF
THE YAKAMA NATION
Toppenish, WA 98948


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# Acknowledgements

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## Executive Summary

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

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

Adult returns of fall Chinook to the Yakima River Basin consist mostly of hatchery-origin fish returning from releases averaging 1.6 million Upriver Brights annually from the Prosser Hatchery which have occurred since 1983. Summer-run Chinook were extirpated from the Yakima Basin by 1970. To increase the temporal and spatial distribution of summer/fall run Chinook in the Yakima River Subbasin, the program began releases of Wells Hatchery summer-run Chinook in the Yakima River Basin in 2009. Coho were extirpated from the Yakima Subbasin by the early 1980s. Pursuant to *U.S. v. Oregon* court-mandated agreements, substantial numbers (annual average > 700,000) of hatchery-reared coho salmon were released into the Yakima River since the mid-1980s. Prior to 1996 the primary purpose of releases was harvest augmentation and fish were released in sub-optimal spawning and rearing areas below Wapato Dam. With the inception of the YKFP in 1996, the objective of the coho program became "to determine the feasibility of reestablishing a naturally spawning coho population" and releases were moved upriver to more suitable habitats for natural coho.

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2015 average of approximately 11,100 fish. These increases can be attributed to returns from the Cle Elum supplementation program beginning in 2001, improved freshwater passage conditions, improved marine survival, and habitat restoration and enhancement work. Annual abundance of fall Chinook at Prosser Dam has increased from a 1983-1999 average of just over 1,000 fish to a 2000-2015 average of about 4,000 fish. While this increase coincides with improved ocean conditions, some of the increase may also be due to improved passage in the mainstem Columbia River, changes in the lower Yakima River that are making fish seek more amenable spawning areas further upriver, and improvements in spawning and rearing protocols. Over 1,800 summer-run Chinook passed above Prosser Dam in 2015, among the first such fish to return to the Yakima Basin in over 40 years. The coho return in 2015 was poor with only about 2,200 Coho passing above Prosser Dam. Adult Coho returns to Prosser Dam averaged about 4,600 fish from 1997-2015 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging about 1,000 fish since 2001.

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

For juvenile migration years 2000-present, annual abundance estimates of juvenile smolts migrating downstream at Prosser Dam averaged 248,730 wild/natural spring Chinook, 355,300 CESRF-origin spring Chinook, 35,930 wild/natural-origin coho, and 268,700 hatchery-origin coho. Preliminary smolt-to-adult survival indices averaged approximately 2.6% and 3.4% 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 66 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 nearly 250 redds enumerated annually on average in tributaries in the upper watersheds since 2004. With the poor return in 2015, only 59 coho redds were observed in tributaries in the Naches and Upper Yakima Subbasins.

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

Overall average fine sediment levels in the Naches and Upper Yakima River subbasins 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 70% 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 (2005-2015) were maintained or increased in the supplemented Upper Yakima River and appear to be declining in the Naches control system relative to the pre-supplementation period (1982-2004). After three generations of study, the results (many of which are published in the peer-reviewed literature) from the spring chinook supplementation program in the Upper Yakima River demonstrate that a well-designed and carefully managed integrated hatchery program using 100% natural-origin broodstock can produce fish for harvest and return fish to the natural spawning grounds with minimal negative impacts to the target ecosystem. Coho re-introduction research in the published literature suggests that hatchery-origin coho, with a legacy of as many as 10 to 30 generations of hatchery-influence, can reestablish a naturalized population after as few as 3 to 5 generations of outplanting in the wild.

YKFP efforts to monitor and evaluate hatchery reform focus on the CESRF spring Chinook program which was designed explicitly for this purpose from its inception. By designing the program to use only natural-origin fish for brood-stock, the program has demonstrated reduced genetic divergence for the integrated program compared to a traditional segregated hatchery program. The CESRF is also meeting or exceeding scientific recommendations for proportionate natural influence (PNI) on an annual basis with a 15-year mean annual PNI of 66%. The project is thus far meeting or exceeding most other established objectives related to hatchery reform.

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

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

## Introduction

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

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

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

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

Fish Propagation Critical Uncertainty 2. What is the magnitude of any demographic benefit to the production of natural-origin juveniles and adults from the natural spawning of hatchery-origin supplementation adults?

Fish Propagation Critical Uncertainty 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, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock?

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

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

*Study Area*

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

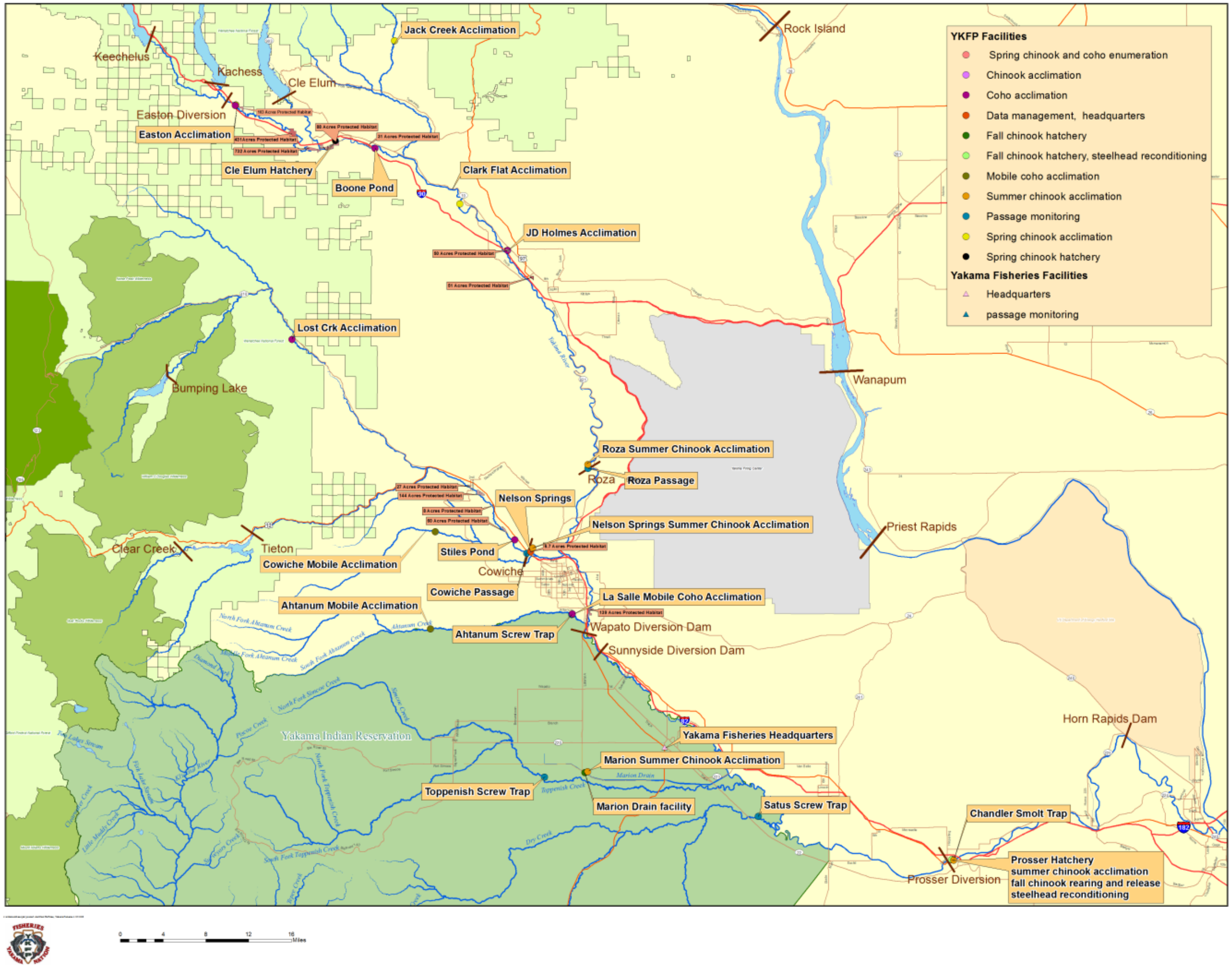


**Figure 1. Yakima River Basin and Yakama Nation/YKFP-related artificial production and monitoring facilities (map provided by Paul Huffman).**

# Fish Population Status Monitoring

## *Status and Trend of Adult Fish Populations (Abundance)*

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

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

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

**Results:**

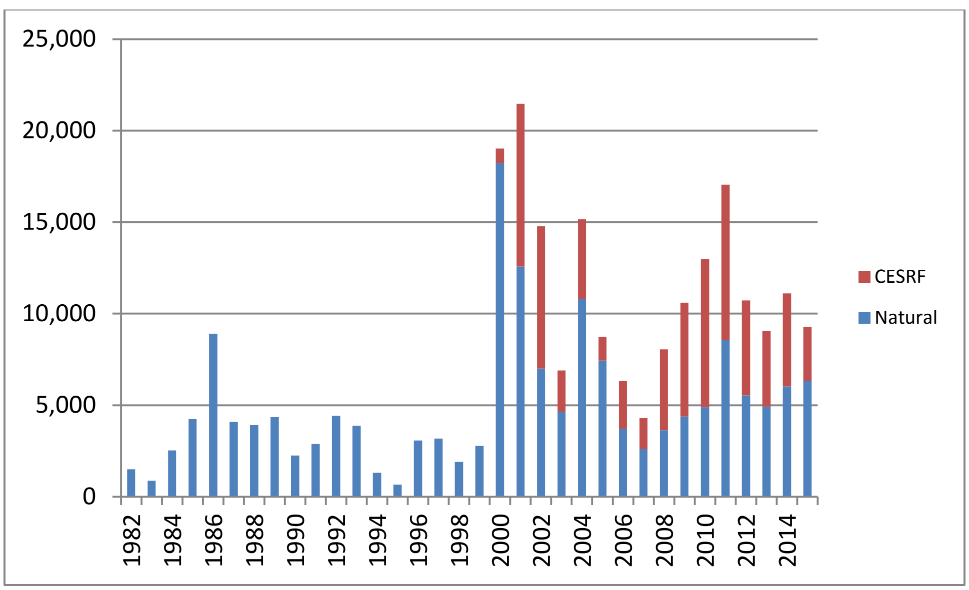


**Figure 2. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Prosser Dam, 1982-present.**

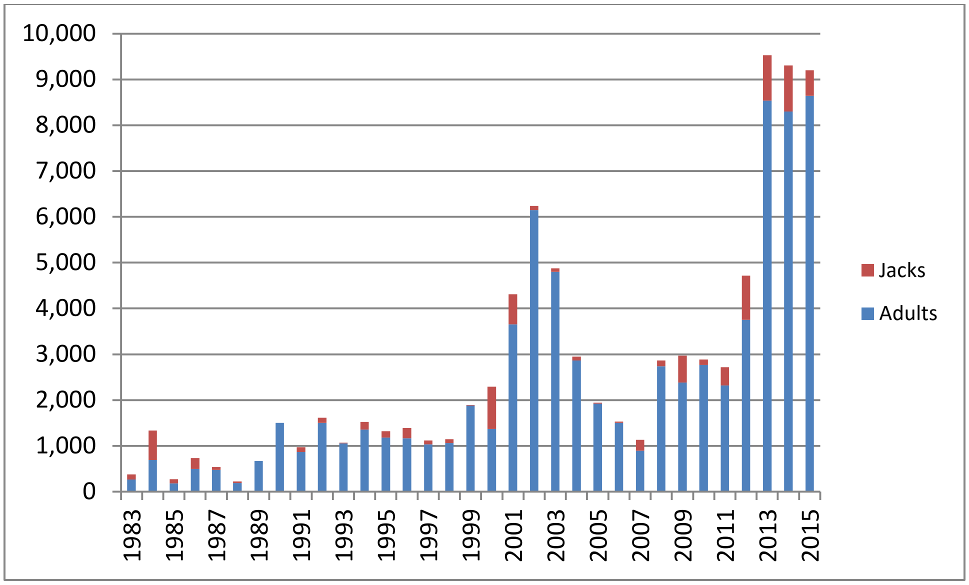


**Figure 3. Estimated counts of adult and jack summer/fall run Chinook at Prosser Dam, 1983-present.**

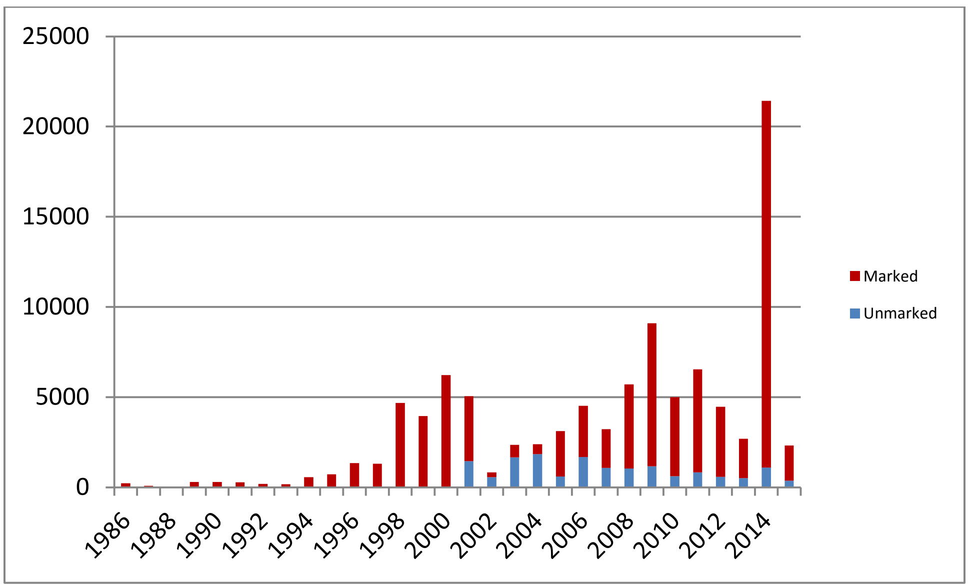


**Figure 4. Estimated counts of marked (presumed hatchery-origin) and unmarked (presumed natural-origin) Coho (adults and jacks) at Prosser Dam 1986-present.**

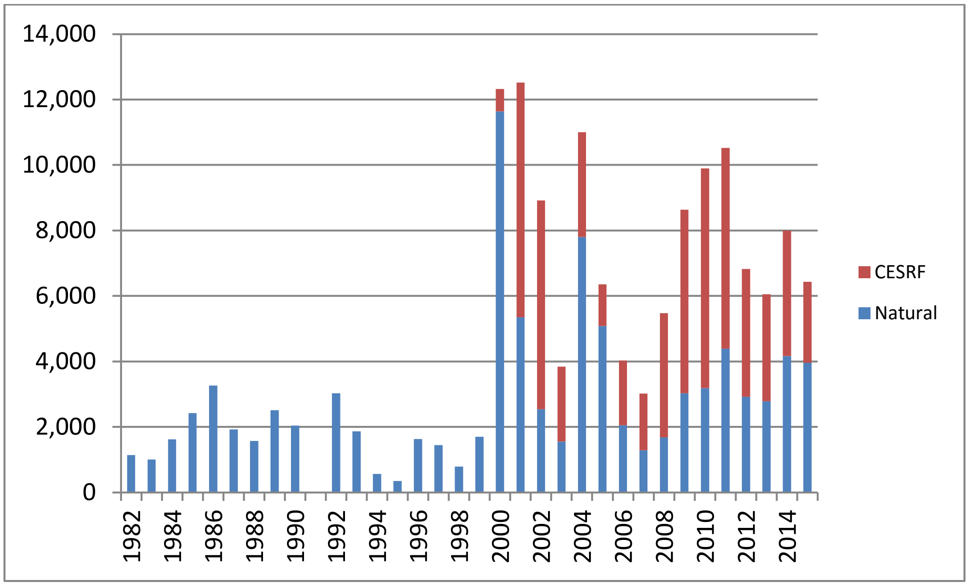


**Figure 5. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Roza Dam, 1982-present.**

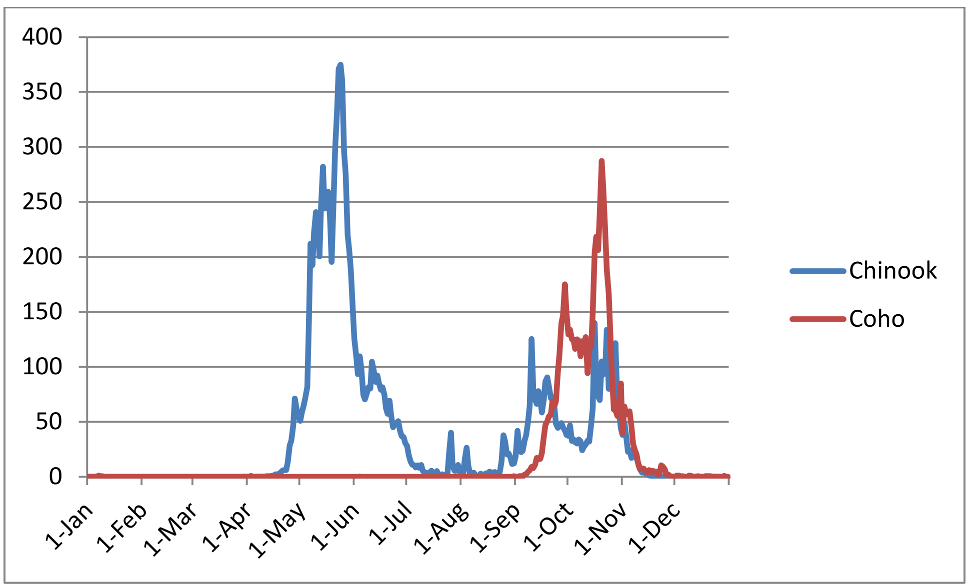


**Figure 6. Average daily passage of Chinook and Coho (adults and jacks) at Prosser Dam, 2006-2015.**

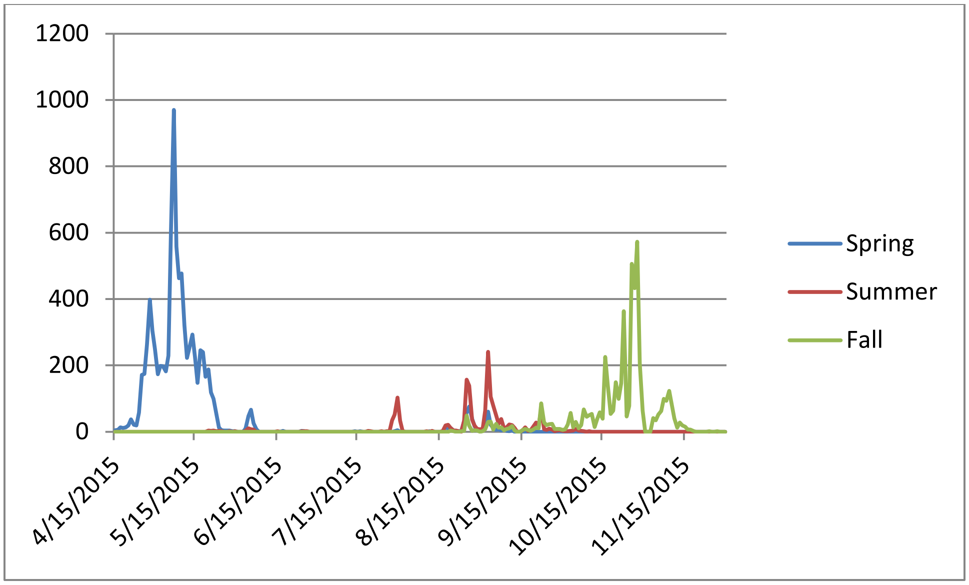


**Figure 7. Passage timing of adult and jack Chinook at Prosser Dam in 2015 by run (see Methods).**

## Discussion:

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2015 average of approximately 11,100 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 2001-2015 average of approximately 7,400 fish (Figure 5). These increases can be attributed to returns from the Cle Elum supplementation program beginning in 2001, improved freshwater passage conditions, improved marine survival, and habitat restoration and enhancement work. The lowest adult returns since 2000 followed two years after the notable droughts which occurred during smolt outmigration years 2001 and 2005. Discussion of uncertainties relating to the Cle Elum spring Chinook supplementation program is included under Hatchery Monitoring later in this report. Additional data and detail on the Cle Elum spring Chinook supplementation program and the status of natural- and CESRF-origin spring Chinook in the Yakima River Basin are provided in Appendix B.

Although some natural production is occurring, adult returns of fall Chinook to the Yakima River Basin consist mostly of hatchery-origin fish returning from annual releases of Upriver Brights from the Prosser Hatchery which have occurred since 1983 and averaged about 1.9 million since 1999 (Yakama Nation 2012). In addition, the Yakama Nation has a goal of re-establishing Summer-run Chinook which were extirpated from the Yakima Basin by 1970. Pursuant to this goal we began releases of Wells Hatchery summer-run Chinook in the Yakima River Basin in 2009. Annual abundance of summer/fall Chinook at Prosser Dam has increased from a 1983-1999 average of just over 1,000 fish to a 2000-2015 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). Over 1,800 summer-run Chinook were estimated to pass above Prosser Dam in 2015 (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 adult coho returns averaged about 4,600 fish from 1997-2015 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging about 1,000 fish annually since 2001 (Figure 4).

## *Status and Trend of Adult Productivity*

### Methods:

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

*Spring Chinook*

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

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

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

*Coho*

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

*Summer/Fall Run Chinook*

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

## Results:

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

| Brood Year | Estimated Spawners | Estimated Yakima R. Mouth Returns Age-3 | Age-4 | Age-5 | Total | Returns/ Spawner |
|---|---|---|---|---|---|---|
| 1984 | 1,715 | 92 | 1,348 | 139 | 1,578 | 0.92 |
| 1985 | 2,578 | 114 | 2,746 | 105 | 2,965 | 1.15 |
| 1986 | 3,960 | 171 | 2,574 | 149 | 2,893 | 0.73 |
| 1987 | 2,003 | 53 | 1,571 | 109 | 1,733 | 0.87 |
| 1988 | 1,400 | 53 | 3,138 | 132 | 3,323 | 2.37 |
| 1989 | 2,466 | 68 | 1,779 | 9 | 1,856 | 0.75 |
| 1990 | 2,298 | 79 | 566 | 0 | 645 | 0.28 |
| 1991 | 1,713 | 9 | 326 | 22 | 358 | 0.21 |
| 1992 | 3,048 | 87 | 1,861 | 95 | 2,043 | 0.67 |
| 1993 | 1,925 | 66 | 1,606 | 57 | 1,729 | 0.90 |
| 1994 | 573 | 60 | 737 | 92 | 890 | 1.55 |
| 1995 | 364 | 59 | 1,036 | 129 | 1,224 | 3.36 |
| 1996 | 1,657 | 1,059 | 12,882 | 630 | 14,571 | 8.79 |
| 1997 | 1,204 | 621 | 5,837 | 155 | 6,613 | 5.49 |
| 1998 | 390 | 434 | 2,803 | 145 | 3,381 | 8.68 |
| 1999 | 1,021[1] | 164 | 722 | 45 | 930 | 0.91 |
| 2000 | 11,864 | 856 | 7,689 | 127 | 8,672 | 0.73 |
| 2001 | 12,087 | 775 | 5,074 | 222 | 6,071 | 0.50 |
| 2002 | 8,073 | 224 | 1,875 | 148 | 2,247 | 0.28 |
| 2003 | 3,341 | 158 | 1,036 | 63 | 1,257 | 0.38 |
| 2004 | 10,377 | 207 | 1,547 | 75 | 1,828 | 0.18 |
| 2005 | 5,713 | 293 | 2,630 | 14 | 2,936 | 0.51 |
| 2006 | 3,378 | 868 | 2,887 | 133 | 3,888 | 1.15 |
| 2007 | 2,322 | 456 | 3,976 | 65 | 4,498 | 1.94 |
| 2008 | 4,343 | 1,135 | 3,410 | 123 | 4,668 | 1.07 |
| 2009 | 7,056 | 283 | 2,572 | 109 | 2,964 | 0.42 |
| 2010 | 8,383 | 923 | 3,854 | 59 | 4,836 | 0.58 |
| 2011 | 8,584 | 832 | 3,908 | | | |
| 2012 | 5,483 | 197 | | | | |
| 2013 | 4,984 | | | | | |
| 2014 | 6,751 | | | | | |
| 2015 | 5,466 | | | | | |
| Mean | 4,266 | 358 | 2,928 | 117 | 3,356 | 1.68 |

1. The mean jack proportion of spawning escapement from 1999-2015 was 0.22 (geometric mean 0.16).

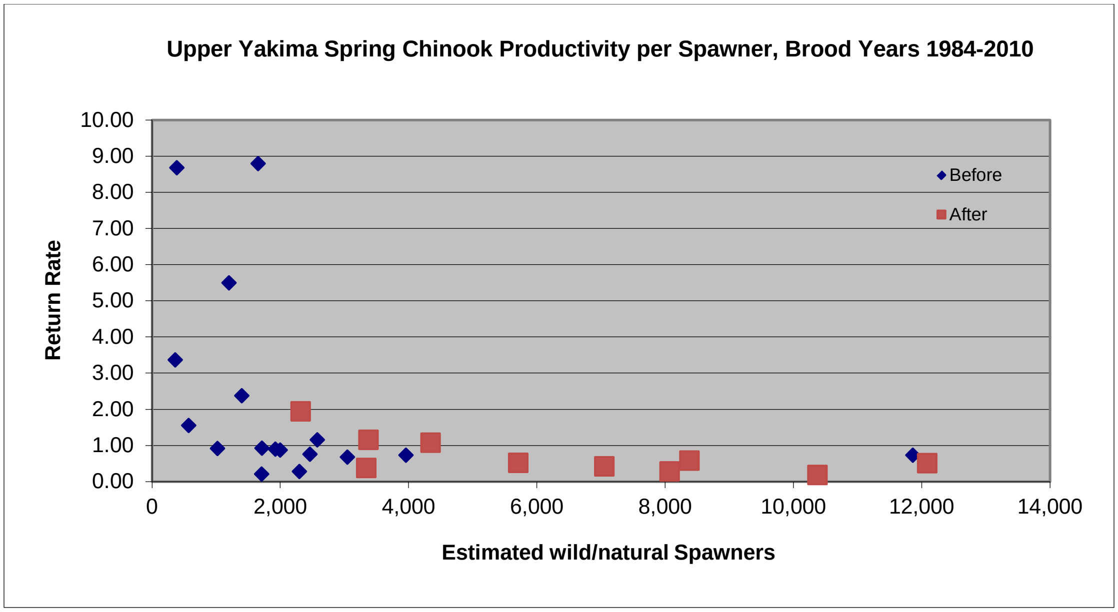


**Figure 8. Upper Yakima wild/natural spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2010) commencement of supplementation.**

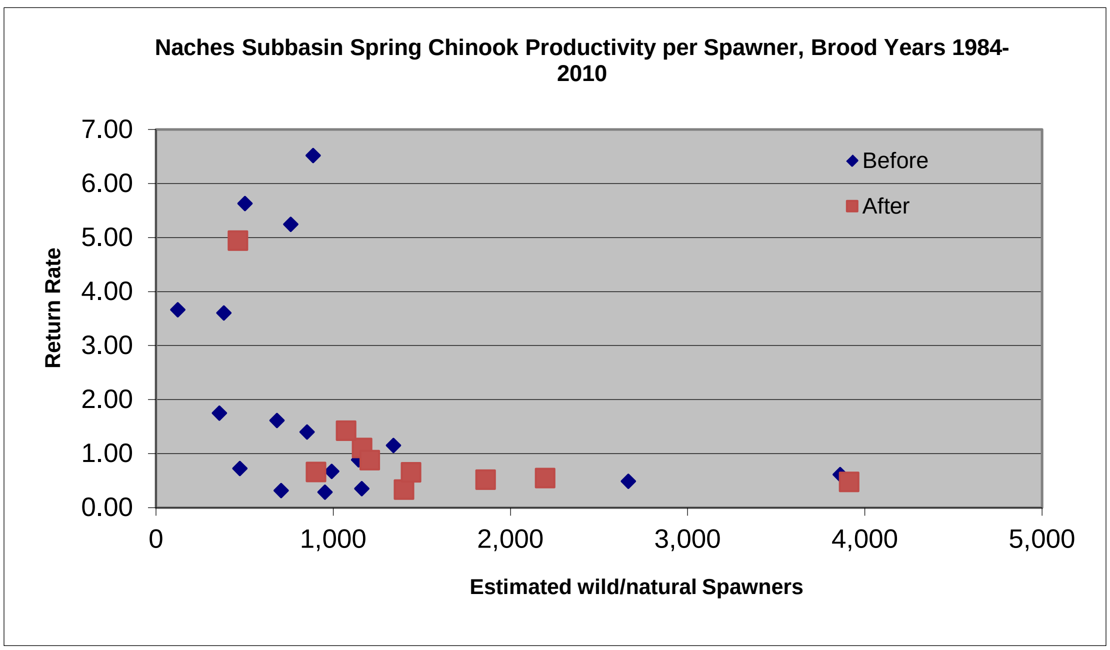


**Figure 9. Naches subbasin spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2010) commencement of supplementation in the Upper Yakima River.**

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

| Brood Year | Estimated Spawners | Estimated Yakima R. Mouth Returns | | | | | 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 | 1,200 | 0.55 |
| 2005 | 1,439 | 167 | 653 | 119 | 0 | 940 | 0.65 |
| 2006 | 1,163 | 192 | 834 | 254 | 0 | 1,280 | 1.10 |
| 2007 | 463 | 125 | 1,649 | 514 | 0 | 2,288 | 4.94 |
| 2008 | 1,074 | 414 | 827 | 290 | 0 | 1,531 | 1.42 |
| 2009 | 903 | 84 | 448 | 65 | 0 | 597 | 0.66 |
| 2010 | 1,207 | 209 | 653 | 198 | | 1,059 | 0.88 |
| 2011 | 2,476 | 137 | 1,088 | | | | |
| 2012 | 1,537 | 64 | | | | | |
| 2013 | 1,107 | | | | | | |
| 2014 | 915 | | | | | | |
| 2015 | 1,702 | | | | | | |
| Mean | 1,288 | 107 | 906 | 384 | 3 | 1,394 | 1.72 |

1. The mean jack proportion of spawning escapement from 1999-2015 was 0.12 (geometric mean 0.09).

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

| Brood Year | Estimated Spawners | Estimated Yakima R. Mouth Returns Age-3 | Age-4 | Age-5 | Total | Returns/ Spawner |
|---|---|---|---|---|---|---|
| 1997 | 261 | 741 | 7,753 | 176 | 8,670 | 33.22 |
| 1998 | 408 | 1,242 | 7,939 | 602 | 9,782 | 23.98 |
| 1999 | 738[1] | 134 | 714 | 16 | 864 | 1.17 |
| 2000 | 567 | 1,103 | 3,647 | 70 | 4,819 | 8.50 |
| 2001 | 595 | 396 | 845 | 9 | 1,251 | 2.10 |
| 2002 | 629 | 345 | 1,886 | 69 | 2,300 | 3.66 |
| 2003 | 441 | 121 | 800 | 12 | 932 | 2.11 |
| 2004 | 597 | 805 | 3,101 | 116 | 4,022 | 6.74 |
| 2005 | 510 | 1,305 | 3,052 | 21 | 4,378 | 8.58 |
| 2006 | 419 | 3,038 | 5,812 | 264 | 9,114 | 21.75 |
| 2007 | 449 | 1,277 | 5,174 | 108 | 6,558 | 14.61 |
| 2008 | 457 | 2,344 | 4,567 | 65 | 6,976 | 15.27 |
| 2009 | 486 | 461 | 2,663 | 58 | 3,181 | 6.55 |
| 2010 | 336 | 1,495 | 3,183 | 30 | 4,707 | 14.01 |
| 2011 | 377 | 1,233 | 2,340 | | | |
| 2012 | 374 | 221 | | | | |
| 2013 | 398 | | | | | |
| 2014 | 384 | | | | | |
| 2015 | 442 | | | | | |
| Mean | 468 | 1,016 | 3,565 | 115 | 4,825 | 7.84[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 |
| Mean | 893 | 110 | 0.92 | 0.97 |

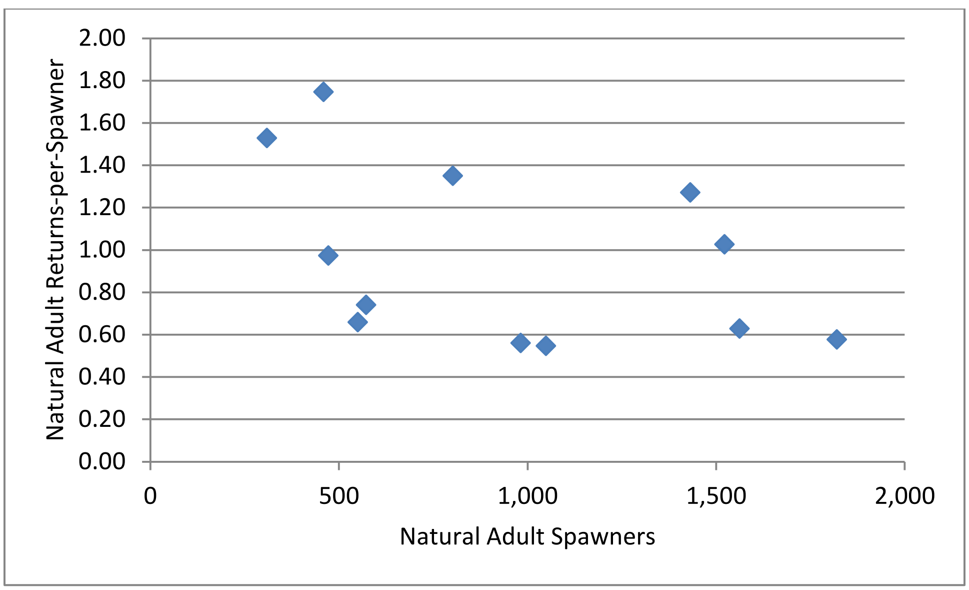


**Figure 10. Productivity indices for age-3 natural-origin coho, brood years 2001-2012.**

## Discussion:

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

### *Status and Trend of Juvenile Abundance*

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

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

Paired releases of PIT-tagged smolts were made in order to estimate the fish entrainment and canal survival rates in relation to river conditions and canal operations. These data were used to generate a multi-variate river flow/canal entrainment relationship (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 adjust passage estimates using PIT-based estimates of hatchery-origin fish survival from acclimation site release to Prosser. These methods were generally consistent with monitoringmethods.org methods 435, 623 and 1743.

**Results and Discussion:**

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

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

| Brood Year | Control[1] | Treatment[2] | Acclimation Site[3] CFJ | ESJ | JCJ | Total |
|---|---|---|---|---|---|---|
| 1997 | 207,437 | 178,611 | 229,290 | 156,758 | | 386,048 |
| 1998[4] | 284,673 | 305,010 | 221,460 | 230,860 | 137,363 | 589,683 |
| 1999 | 384,563 | 374,226 | 232,563 | 269,502 | 256,724 | 758,789 |
| 2000 | 424,554 | 409,731 | 285,954 | 263,061 | 285,270 | 834,285 |
| 2001[5] | 183,963 | 186,273 | 80,782 | 39,106 | 250,348 | 370,236 |
| 2002 | 420,764 | 416,140 | 266,563 | 290,552 | 279,789 | 836,904 |
| 2003 | 414,175 | 410,517 | 273,377 | 267,711 | 283,604 | 824,692 |
| 2004[6] | 378,740 | 406,708 | 280,598 | 273,440 | 231,410 | 785,448 |
| 2005 | 431,536 | 428,466 | 287,127 | 281,150 | 291,725 | 860,002 |
| 2006 | 351,063 | 291,732 | 209,575 | 217,932 | 215,288 | 642,795 |
| 2007 | 387,055 | 384,210 | 265,907 | 254,540 | 250,818 | 771,265 |
| 2008 | 421,290 | 428,015 | 280,253 | 287,857 | 281,195 | 849,305 |
| 2009 | 418,314 | 414,627 | 279,123 | 281,395 | 272,423 | 832,941 |
| 2010 | 395,455 | 399,326 | 264,420 | 264,362 | 265,999 | 794,781 |
| 2011 | 382,195 | 386,987 | 255,290 | 248,454 | 265,438 | 769,182 |
| 2012 | 401,059 | 401,657 | 256,732 | 276,210 | 269,774 | 802,716 |
| 2013 | No Experiment | | 215,933 | 214,745 | 216,077 | 646,755 |
| 2014 | 337,548 | 347,682 | 232,440 | 226,257 | 226,533 | 685,230 |
| Mean | 366,140 | 362,936 | 245,410 | 241,327 | 251,752 | 724,503 |

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 and acclimation site.**

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

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

| Release Year | Prosser On-Station Release LWH[1] | PRH[1] | Subyrl[2] | Yrlng[2] | Billy's Pond[2] | Stiles Pond[2] | Marion Drain | Total 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 |

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

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

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

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 239,950 wild/natural spring Chinook, 343,230 CESRF-origin spring Chinook, 35,930 wild/natural-origin coho, and 268,700 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 and coho.**

| Brood Year | Smolt Migr. Year | Spring Chinook Wild/ Natural | Spring Chinook Hatchery (CESRF) | Coho Wild/ Natural | Coho Hatchery |
|---|---|---|---|---|---|
| 1998 | 2000 | 165,159 | 243,367 | 37,359 | 331,503 |
| 1999 | 2001 | 183,045 | 322,475 | 40,605 | 134,574 |
| 2000 | 2002 | 538,772 | 398,909 | 19,859 | 155,814 |
| 2001 | 2003 | 327,520 | 147,514 | 9,092 | 139,135 |
| 2002 | 2004 | 162,673 | 266,380 | 18,787 | 148,810 |
| 2003 | 2005 | 172,267 | 287,777 | 31,631 | 204,728 |
| 2004 | 2006 | 203,250 | 437,166 | 8,298 | 204,602 |
| 2005 | 2007 | 114,906 | 387,961 | 18,772 | 260,455 |
| 2006 | 2008 | 134,511 | 286,357 | 40,170 | 416,708 |
| 2007 | 2009 | 294,760 | 473,931 | 23,858 | 496,594 |
| 2008 | 2010 | 151,646 | 241,290 | 33,408 | 341,145 |
| 2009 | 2011 | 326,180 | 453,716 | 22,908 | 333,891 |
| 2010 | 2012 | 429,896 | 620,208 | 17,667 | 244,503 |
| 2011 | 2013 | 357,347 | 345,754 | 56,947 | 483,122 |
| 2012 | 2014 | 268,598 | 396,588 | 159,642 | 337,988 |
| 2013 | 2015 | 149,203 | 375,372 | | 65,636 |
| | Mean | 248,733 | 355,298 | 35,934 | 268,701 |

## *Status and Trend of Juvenile Migration Survival to McNary Dam*

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

**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 13 of the 16 outmigration years (Figure 11). The pooled survival and weighted survival estimates over years were significantly higher for the natural-origin smolts (Appendix C). Survival analyses for additional spring Chinook treatments are presented in Appendix D of this report.

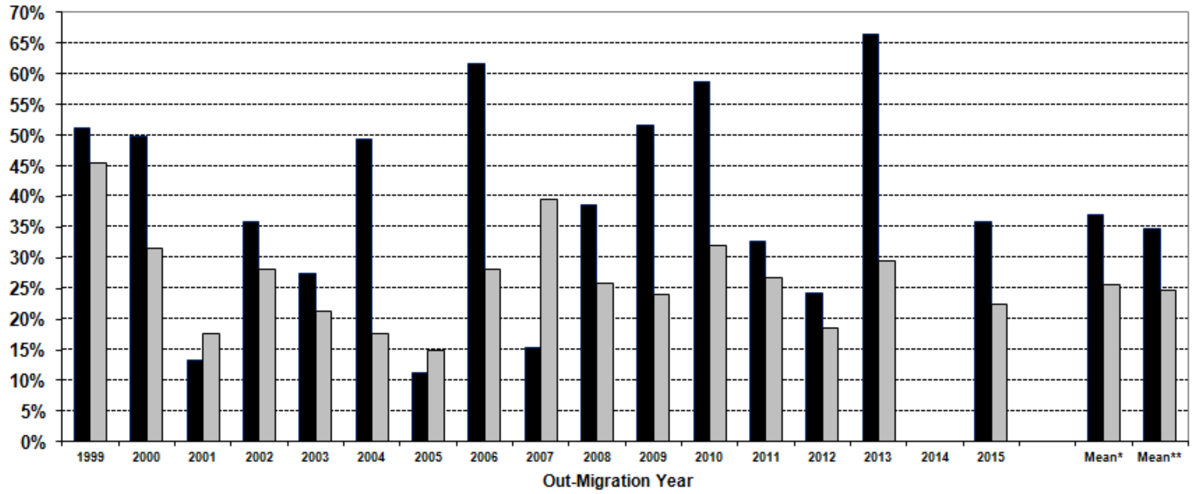


**Figure 11. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for late-migrating (>March 15) Natural- (dark-colored bars) and Hatchery-origin (light-colored bars) Smolts. No releases occurred in 2014 because of another study conducted at Roza in that year.**

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 2015. Summer-run Chinook subyearlings were released from Stiles pond in outmigration-years 2009 through 2011, from Nelson Springs (Buckskin Slough) in 2011 through 2015, from Prosser and Marion Drain in 2012, and from Roza Dam in 2013-14 (for locations see Figure 1). Estimates of release-to-McNary survival for yearling and subyearling fall Chinook released from Prosser and for subyearling summer-run Chinook from the Naches (Stiles and Nelson Springs) and from Roza are presented in Figure 12. Complete results for all summer- and fall-run Chinook releases are presented in Appendix E.

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.

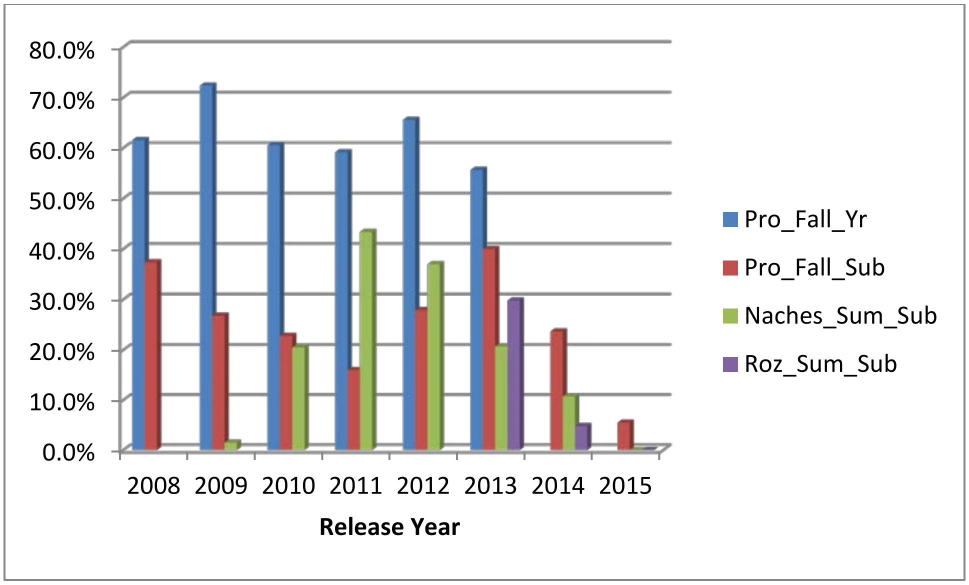


**Figure 12. Estimated smolt survival to McNary Dam of summer- and fall-run Chinook that were PIT-tagged and detected at release from various sites in the Yakima River, 2008-2015. Data source: Appendix E, Tables 1.a and 2.a (Neeley 2015).**

For coho, we estimated survival (Appendix F) from acclimation site release to McNary Dam for fish that were the progeny of local (Yakima) and Eagle Creek National Fish Hatchery (Eagle Creek) brood stock as well as a cross of the two brood stocks (2011 only). Yakima stock survival was higher than that of the Eagle Creek stock for all 18 paired-releases (Appendix F).

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

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

### Methods:

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

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

## Results:

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

| | | | Estimated Smolt Passage at Chandler | | | Yakima R. Mouth Adult Returns[4] | | Smolt-to-Adult Return Index[4] | |
|---|---|---|---|---|---|---|---|---|---|
| Brood Year | Smolt Migr. Year | Mean Flow[1] at Prosser Dam | Wild/ Natural[2] | CESRF Total | CESRF smolt-to-smolt survival[3] | Wild/ Natural[2] | CESRF Total | Wild/ Natural[2] | CESRF Total |
| 1982 | 1984 | 4134 | 381,857 | | | 6,753 | | 1.8% | |
| 1983 | 1985 | 3421 | 146,952 | | | 5,198 | | 3.5% | |
| 1984 | 1986 | 3887 | 227,932 | | | 3,932 | | 1.7% | |
| 1985 | 1987 | 3050 | 261,819 | | | 4,776 | | 1.8% | |
| 1986 | 1988 | 2454 | 271,316 | | | 4,518 | | 1.7% | |
| 1987 | 1989 | 4265 | 76,362 | | | 2,402 | | 3.1% | |
| 1988 | 1990 | 4141 | 140,218 | | | 5,746 | | 4.1% | |
| 1989 | 1991 | | 109,002 | | | 2,597 | | 2.4% | |
| 1990 | 1992 | 1960 | 128,457 | | | 1,178 | | 0.9% | |
| 1991 | 1993 | 3397 | 92,912 | | | 544 | | 0.6% | |
| 1992 | 1994 | 1926 | 167,477 | | | 3,790 | | 2.3% | |
| 1993 | 1995 | 4882 | 172,375 | | | 3,202 | | 1.9% | |
| 1994 | 1996 | 6231 | 218,578 | | | 1,238 | | 0.6% | |
| 1995 | 1997 | 12608 | 52,028 | | | 1,995 | | 3.8% | |
| 1996 | 1998 | 5466 | 491,584 | | | 21,151 | | 4.3% | |
| 1997 | 1999 | 5925 | 633,805 | 182,622 | 47.3% | 12,855 | 8,670 | 2.0% | 4.7% |
| 1998 | 2000[5] | 4946 | 165,159 | 243,367 | 41.3% | 8,228 | 9,782 | 5.0% | 4.0% |
| 1999 | 2001 | 1321 | 183,045 | 322,475 | 42.5% | 1,764 | 864 | 1.0% | 0.3% |
| 2000 | 2002 | 5015 | 538,772 | 398,909 | 47.8% | 11,434 | 4,819 | 2.1% | 1.2% |
| 2001 | 2003 | 3504 | 327,520 | 147,514 | 39.8% | 8,597 | 1,251 | 2.6% | 0.8% |
| 2002 | 2004 | 2439 | 162,673 | 266,380 | 31.8% | 3,743 | 2,300 | 2.3% | 0.9% |
| 2003 | 2005 | 1285 | 172,267 | 287,777 | 34.9% | 2,746 | 932 | 1.6% | 0.3% |
| 2004 | 2006 | 5652 | 203,250 | 437,166 | 55.7% | 2,802 | 4,022 | 1.4% | 0.9% |
| 2005 | 2007 | 4551 | 114,906 | 387,961 | 45.1% | 4,201 | 4,378 | 3.7% | 1.1% |
| 2006 | 2008 | 4298 | 134,511 | 286,357 | 44.5% | 6,099 | 9,114 | 4.5% | 3.2% |
| 2007 | 2009 | 5784 | 294,760 | 473,931 | 61.4% | 7,952 | 6,558 | 2.7% | 1.4% |
| 2008 | 2010 | 3592 | 151,646 | 241,290 | 28.4% | 7,385 | 6,976 | 4.9% | 2.9% |
| 2009 | 2011 | 9414 | 326,180 | 453,716 | 54.5% | 3,766 | 3,181 | 1.2% | 0.7% |
| 2010 | 2012 | 8556 | 429,896 | 620,208 | 78.0% | 6,602 | 4,707 | 1.5% | 0.8% |
| 2011 | 2013 | 4875 | 357,347 | 345,754 | 45.0% | 6,640[6] | 3,573[6] | 1.9%[6] | 1.0%[6] |
| 2012 | 2014 | 4923 | 268,598 | 396,588 | 49.4% | | | | |
| 2013 | 2015[6] | 1555 | 149,203 | 375,372 | 58.0% | | | | |

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 Chinook for adult return years 1988-2015.**

| 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 | 1,866,876 | 4,477 | 0.24% |
| 2013 | 2,066,973 | 7,706 | 0.37% |
| 2014 | 2,610,219 | 7,792 | 0.30% |
| 2015 | 2,681,023 | 7,380 | 0.28% |
| Mean | 1,939,267 | 2,804 | 0.14% |

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

**Table 12. Preliminary estimates of smolt-to-adult survival (SAR) indices for adult returns from hatchery- and natural-origin coho for the Yakima reintroduction program, juvenile migration years 2000-2014.**

| 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% | 20,131 | 459 | 2.3%[c] |
| 2008 | 416,708 | 8,835 | 2.1% | 43,046 | 982 | 2.3%[c] |
| 2009 | 496,594 | 5,153 | 1.0% | 25,108 | 573 | 2.3%[c] |
| 2010 | 341,145 | 7,216 | 2.1% | 35,158 | 802 | 2.3%[c] |
| 2011 | 333,891 | 4,948 | 1.5% | 24,108 | 550 | 2.3%[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% |
| Mean | 282,238 | 4,476 | 1.3% | 36,496 | 893 | 3.4% |

[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.

## 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 flow data and estimated Chandler entrainment rates. Chandler smolt passage estimates are prepared primarily for the purpose of comparing relative marked versus unmarked passage estimates and not for making survival comparisons. While these Chandler smolt passage estimates represent the best available data, there may be a high degree of error associated with these estimates due to inherent complexities, assumptions, and uncertainties in the statistical expansion process. Therefore, these estimates are subject to revision.

2) Large numbers of Yakima Basin salmonid releases (all CESRF spring Chinook) are adipose-fin clipped and subjected to higher harvest rates than unmarked wild/natural fish in marine and Columbia River mark-selective fisheries. No adjustments have yet been made in the above SAR estimates to account for differential harvest rates in these mark-selective fisheries.

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

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

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

### *Status and Trend of Spatial Distribution (Redd Counts)*

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

**Results:**

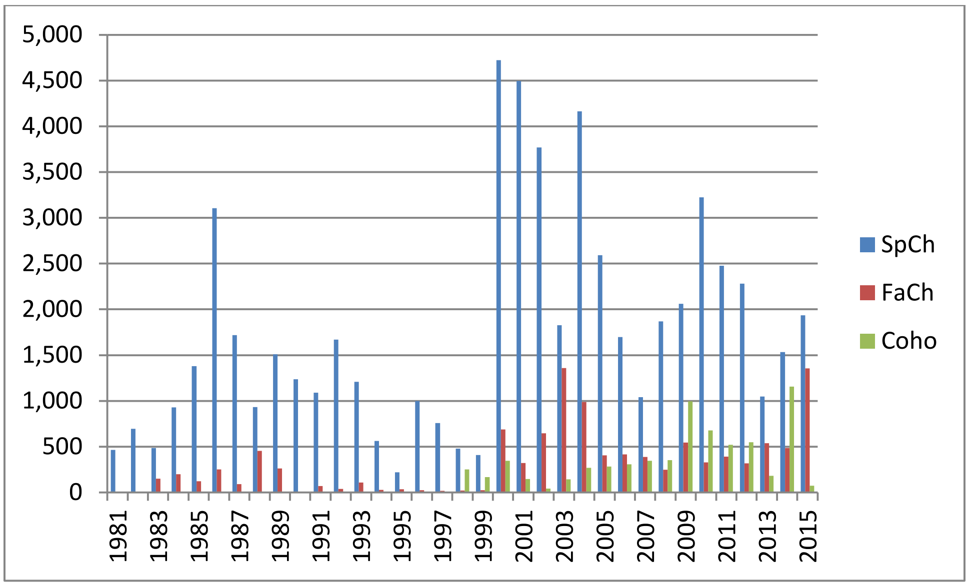


**Figure 13. Redd Counts upstream of Prosser Dam in the Yakima River Basin by species, 1981-present.**

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

| | Upper Yakima River System | | | | Naches River System | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Mainstem[1] | Cle Elum | Teanaway | Total | American | Naches[1] | Bumping | Little Naches | Total |
| 1981 | 237 | 57 | 0 | 294 | 72 | 64 | 20 | 16 | 172 |
| 1982 | 610 | 30 | 0 | 640 | 11 | 25 | 6 | 12 | 54 |
| 1983 | 387 | 15 | 0 | 402 | 36 | 27 | 11 | 9 | 83 |
| 1984 | 677 | 31 | 0 | 708 | 72 | 81 | 26 | 41 | 220 |
| 1985 | 795 | 153 | 3 | 951 | 141 | 168 | 74 | 44 | 427 |
| 1986 | 1,716 | 77 | 0 | 1,793 | 464 | 543 | 196 | 110 | 1,313 |
| 1987 | 968 | 75 | 0 | 1,043 | 222 | 281 | 133 | 41 | 677 |
| 1988 | 369 | 74 | 0 | 443 | 187 | 145 | 111 | 47 | 490 |
| 1989 | 770 | 192 | 6 | 968 | 187 | 200 | 101 | 53 | 541 |
| 1990 | 727 | 46 | 0 | 773 | 143 | 159 | 111 | 51 | 464 |
| 1991 | 568 | 62 | 0 | 630 | 170 | 161 | 84 | 45 | 460 |
| 1992 | 1,082 | 164 | 0 | 1,246 | 120 | 155 | 99 | 51 | 425 |
| 1993 | 550 | 105 | 1 | 656 | 214 | 189 | 88 | 63 | 554 |
| 1994 | 226 | 64 | 0 | 290 | 89 | 93 | 70 | 20 | 272 |
| 1995 | 105 | 12 | 0 | 117 | 46 | 25 | 27 | 6 | 104 |
| 1996 | 711 | 100 | 3 | 814 | 28 | 102 | 29 | 25 | 184 |
| 1997 | 364 | 56 | 0 | 420 | 111 | 108 | 72 | 48 | 339 |
| 1998 | 123 | 24 | 1 | 148 | 149 | 104 | 54 | 23 | 330 |
| 1999 | 199 | 24 | 1 | 224 | 27 | 95 | 39 | 25 | 186 |
| 2000 | 3,349 | 466 | 21 | 3,836 | 54 | 483 | 278 | 73 | 888 |
| 2001 | 2,910 | 374 | 21 | 3,305 | 392 | 436 | 257 | 107 | 1,192 |
| 2002 | 2,441 | 275 | 110 | 2,826 | 366 | 226 | 262 | 89 | 943 |
| 2003 | 772 | 87 | 31 | 890 | 430 | 228 | 216 | 61 | 935 |
| 2004 | 2,985 | 330 | 129 | 3,444 | 91 | 348 | 205 | 75 | 719 |
| 2005 | 1,717 | 287 | 15 | 2,019 | 140 | 203 | 163 | 68 | 574 |
| 2006 | 1,092 | 100 | 58 | 1,250 | 136 | 163 | 115 | 33 | 447 |
| 2007 | 665 | 51 | 10 | 726 | 166 | 60 | 60 | 27 | 313 |
| 2008 | 1,191 | 137 | 47 | 1,375 | 158 | 165 | 102 | 70 | 495 |
| 2009 | 1,349 | 197 | 33 | 1,579 | 92 | 159 | 163 | 68 | 482 |
| 2010 | 2,199 | 219 | 253 | 2,671 | 173 | 171 | 168 | 40 | 552 |
| 2011 | 1,663 | 171 | 64 | 1,898 | 212 | 145 | 175 | 48 | 580 |
| 2012 | 1,276 | 125 | 69 | 1,470 | 337 | 196 | 189 | 89 | 811 |
| 2013 | 552 | 85 | 34 | 671 | 170 | 66 | 85 | 55 | 376 |
| 2014 | 962 | 138 | 53 | 1,153 | 129 | 65 | 158 | 27 | 379 |
| 2015 | 1,258 | 39 | 24 | 1,321 | 239 | 177 | 152 | 46 | 614 |
| Mean | 1,073 | 127 | 28 | 1,228 | 165 | 172 | 117 | 49 | 503 |

[1] Including minor tributaries.

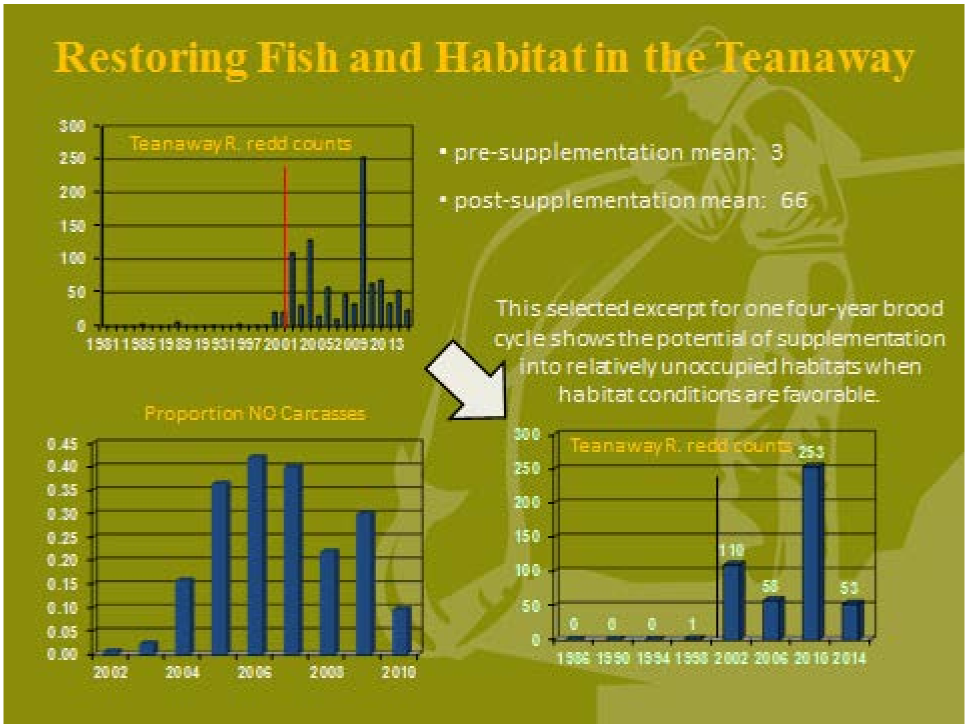


**Figure 14. Teanaway River Spring Chinook redd counts, 1981-2015 (vertical lines denote pre- and post-supplementation periods) and the proportion of natural-origin (NO) carcasses observed in intensive spawning ground surveys, 2002-2010.**

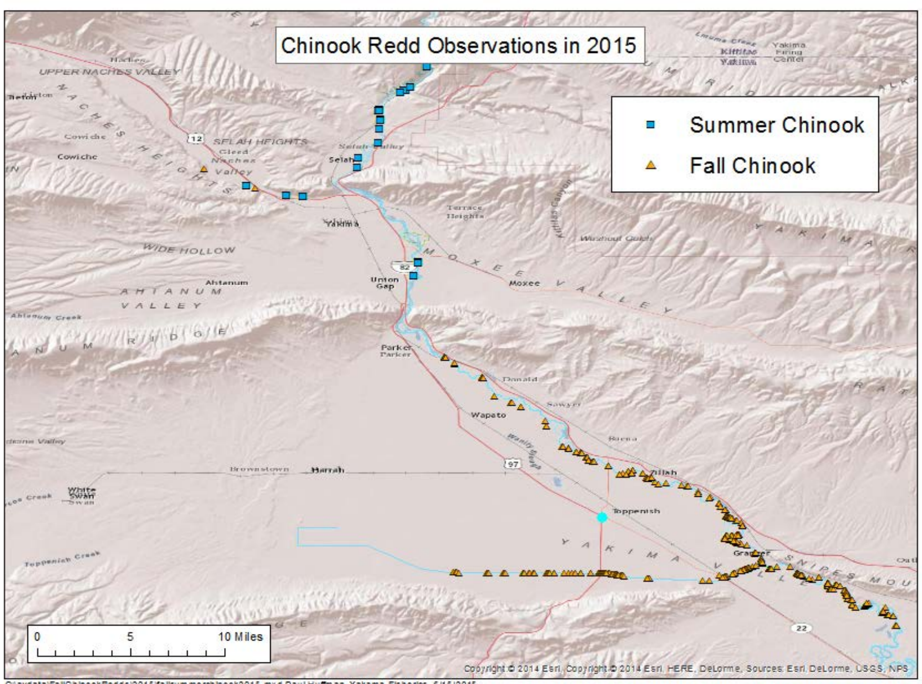


**Figure 15. Distribution of summer and fall run Chinook redds in the Yakima River Basin (above Prosser Dam) in 2015.**

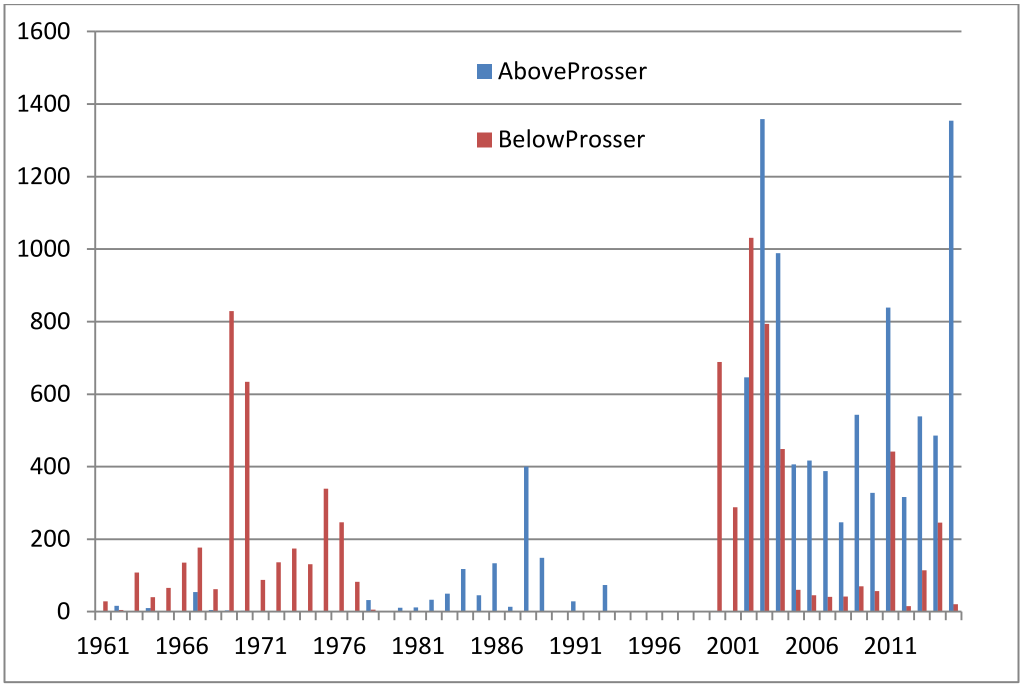


**Figure 16. Fall Chinook redd counts above and below Prosser Dam, 1961-present, for years in which surveys were conducted and data are available. Data from YN, WDFW, and Pacific Northwest National Laboratory files; survey data are partial or incomplete for most years prior to 2000.**

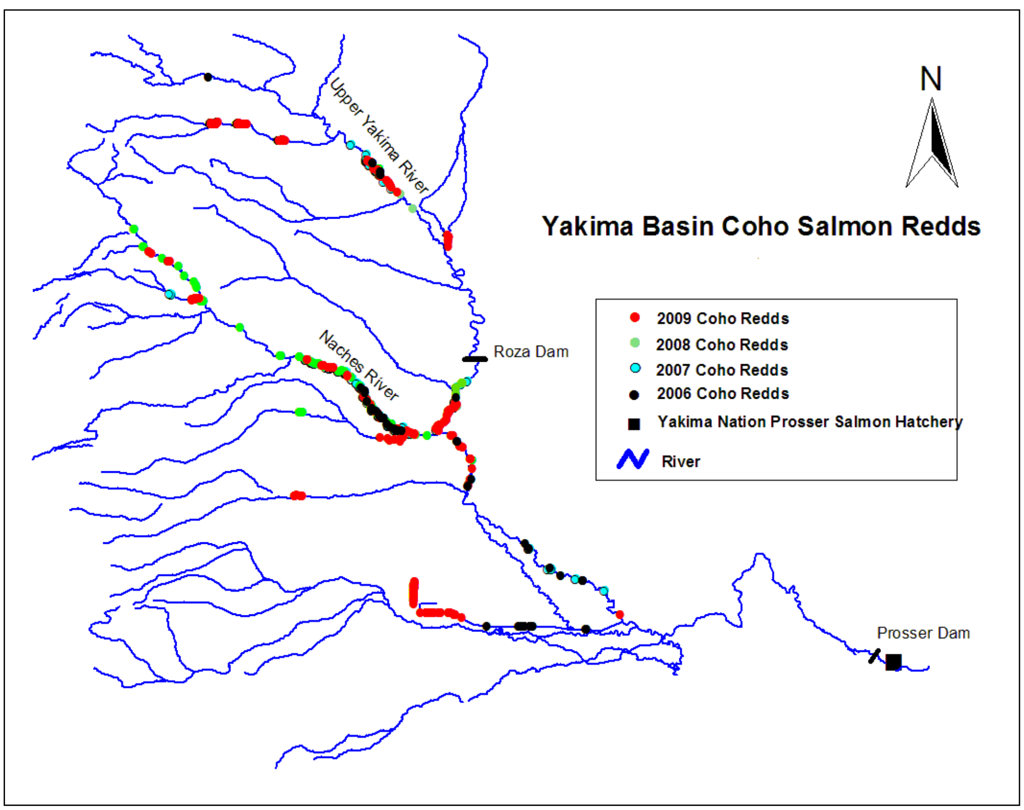


**Figure 17. Distribution of coho redds in the Yakima River Basin.**

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

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

## 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 66 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.

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). Figure 15 indicates a good distribution of reintroduced summer-run spawners into the intended habitats above Parker Dam in 2015, primarily age-4 fish returning from subyearling releases in 2012. This is the third year of substantial natural summer-run Chinook spawning in these habitats in over 40 years.

Coho redd counts and spawner distribution have increased substantially over the past 16 years (Table 14 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 14). Although, there were large numbers of potential spawners in 2014 (~9,000 females), river conditions were very unfavorable for finding redds. Winter anchor ice in early December kept surveys to a minimum. This was followed by winter freshets that reduced visibility in the Naches River to the point where visibility was near zero. River conditions were again unfavorable for successful spawner surveys in 2015. However, coho continue to volunteer into many tributaries, and the fidelity of adults from summer parr plants has shown good results. The tributary redd counts we observed in Cowiche Creek and Ahtanum Creek in 2014 were very encouraging. We continue to find natural returns from the Taneum Creek adult out-plant study (Table 15). The study in Taneum Creek was set up to test reintroduction and interactions (Temple et al. 2012); it was not set up for full reintroduction. With implementation of the Coho Master Plan, we expect to double adult out plant numbers, increase escapement into Taneum Creek, and fully seed the available habitat.

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

| Year | Number of Adult Females Outplanted | Redds | Number of Juvenile coho PIT Tagged | Juvenile Migration Year | Juvenile Survival to McNary | Natural-Origin Adults to McNary |
|---|---|---|---|---|---|---|
| 2007 | 150 | 75 | 1300 | 2009 | 16% | 1 |
| 2008 | 150 | 50 | 1812 | 2010 | 10% | 16 |
| 2009 | 150 | 130 | 4515 | 2011 | 13% | 13 |
| 2010 | 150 | 134 | 1054 | 2012 | 26% | 7 |
| 2011 | 150 | 100 | 743 | 2013 | 13% | 9 |
| 2012 | 60 | 54 | 1941 | 2014 | 12% | 1 |
| 2013 | 9 | 5 | 231 | 2015 | 12% | |
| 2014 | 360 | 200 | 1941 | 2016 | | |

## *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) and the project's "Supplementation Monitoring Plan" (Chapter 7 in 2005 annual report on project genetic studies), and numerous manuscripts in the published literature (see Results and References).

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

**Results and Discussion:**

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

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

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

| Return | Sample Size | | | Female | Female | Sample Date Range | |
|---|---|---|---|---|---|---|---|
| Year | F | J | M | Adult % | Total % | First | Last |
| 2001 | 186 | 80 | 213 | 46.6% | 38.8% | 09/10/01 | 11/19/01 |
| 2002 | 389 | 61 | 512 | 43.2% | 40.4% | 09/09/02 | 11/25/02 |
| 2003 | 396 | 24 | 224 | 63.9% | 61.5% | 09/07/03 | 11/17/03 |
| 2004 | 185 | 40 | 201 | 47.9% | 43.4% | 09/06/04 | 11/23/04 |
| 2005 | 201 | 8 | 233 | 46.3% | 45.5% | 09/06/05 | 11/14/05 |
| 2006 | 107 | 11 | 84 | 56.0% | 53.0% | 09/13/06 | 11/06/06 |
| 2007 | 42 | 44 | 39 | 51.9% | 33.6% | 09/10/07 | 11/06/07 |
| 2008 | 81 | 23 | 101 | 44.5% | 39.5% | 09/08/08 | 11/13/08 |
| 2009 | 110 | 132 | 95 | 53.7% | 32.6% | 09/08/09 | 11/07/09 |
| 2010 | 239 | 4 | 162 | 59.6% | 59.0% | 09/08/10 | 11/03/10 |
| 2011 | 67 | 10 | 34 | 66.3% | 60.4% | 09/07/11 | 11/09/11 |
| 2012 | 249 | 109 | 264 | 48.5% | 40.0% | 09/04/12 | 11/06/12 |
| 2013 | 272 | 86 | 460 | 37.2% | 33.3% | 09/16/13 | 11/22/13 |
| 2014 | 681 | 78 | 725 | 48.4% | 45.9% | 09/04/14 | 12/10/14 |
| 2015 | 1047 | 69 | 1374 | 43.2% | 42.0% | 09/09/15 | 11/16/15 |
| | | | Mean | 50.5% | 44.6% | | |

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

| Run | Females | | | | Males (excluding Jacks) | | | |
|---|---|---|---|---|---|---|---|---|
| Year | N | Fork | POH | Weight | N | Fork | POH | Weight |
| 2001 | 186 | 72.7 | 60.1 | 11.0 | 213 | 71.5 | 57.8 | 9.3 |
| 2002 | 389 | 78.4 | 63.9 | 13.5 | 512 | 76.1 | 60.2 | 12.1 |
| 2003 | 396 | 83.4 | 68.5 | 15.6 | 224 | 83.7 | 67.0 | 16.3 |
| 2004 | 185 | 82.3 | 67.8 | 15.1 | 201 | 73.9 | 60.0 | 11.2 |
| 2005 | 201 | 80.5 | 66.3 | 14.2 | 233 | 75.1 | 60.6 | 11.5 |
| 2006 | 107 | 81.5 | 66.3 | 15.6 | 84 | 81.3 | 64.6 | 15.3 |
| 2007 | 42 | 79.9 | 64.4 | 14.8 | 39 | 72.8 | 56.8 | 11.7 |
| 2008 | 81 | 70.1 | 56.5 | 9.8 | 101 | 67.8 | 54.0 | 8.9 |
| 2009 | 110 | 74.1 | 57.8 | 11.2 | 95 | 69.4 | 52.5 | 9.6 |
| 2010 | 239 | 73.3 | 57.8 | 11.3 | 162 | 70.9 | 54.7 | 9.7 |
| 2011 | 67 | 76.5 | 60.4 | 12.4 | 34 | 74.2 | 57.7 | 11.3 |
| 2012 | 249 | 70.1 | 53.3 | 9.5 | 264 | 66.4 | 49.6 | 7.9 |
| 2013 | 272 | 72.5 | 56.1 | 10.1 | 460 | 69.8 | 52.9 | 8.7 |
| 2014 | 681 | 76.1 | 60.8 | 11.9 | 725 | 69.0 | 53.2 | 8.6 |
| 2015 | 1047 | 76.2 | 59.5 | 11.4 | 1374 | 71.4 | 54.8 | 9.2 |
| Mean | | 76.5 | 61.3 | 12.5 | | 72.9 | 57.1 | 10.8 |

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

| Return Year | Sample Size F | J | M | Female Adult % | Female Total % | Sample Date Range First | Last |
|---|---|---|---|---|---|---|---|
| 2001 | 1147 | 44 | 1024 | 52.8% | 51.8% | 09/11/01 | 11/22/01 |
| 2002 | 72 | 201 | 71 | 50.3% | 20.9% | 09/11/02 | 11/25/02 |
| 2003 | 473 | 89 | 452 | 51.1% | 46.6% | 09/11/03 | 11/21/03 |
| 2004 | 586 | 49 | 509 | 53.5% | 51.2% | 09/07/04 | 11/16/04 |
| 2005 | 531 | 146 | 405 | 56.7% | 49.1% | 09/13/05 | 11/15/05 |
| 2006 | 826 | 97 | 586 | 58.5% | 54.7% | 09/17/06 | 11/19/06 |
| 2007 | 676 | 34 | 538 | 55.7% | 54.2% | 09/11/07 | 11/20/07 |
| 2008 | 666 | 930 | 514 | 56.4% | 31.6% | 09/08/08 | 12/04/08 |
| 2009 | 1644 | 76 | 1576 | 51.1% | 49.9% | 09/09/09 | 11/20/09 |
| 2010 | 999 | 35 | 673 | 59.7% | 58.5% | 09/08/10 | 11/19/10 |
| 2011 | 907 | 12 | 776 | 53.9% | 53.5% | 09/16/11 | 11/17/11 |
| 2012 | 1156 | 108 | 961 | 54.6% | 52.0% | 09/08/12 | 11/17/12 |
| 2013 | 523 | 146 | 528 | 49.8% | 43.7% | 09/20/13 | 11/22/13 |
| 2014 | 4302 | 135 | 3668 | 54.0% | 53.1% | 09/03/14 | 12/23/14 |
| 2015 | 654 | 67 | 682 | 49.0% | 46.6% | 09/13/15 | 11/15/15 |
| | | | Mean | 53.8% | 47.8% | | |

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

| Run Year | Females N | Fork | POH | Weight | Males (excluding Jacks) 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 | 654 | 63.5 | 50.1 | 6.0 | 682 | 61.9 | 47.4 | 5.2 |
| Mean | | 67.3 | 53.6 | 7.8 | | 66.6 | 51.4 | 7.2 |

# Habitat Monitoring

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

### *Status and Trend of Fine Sediment*

**Methods:** Representative gravel samples (McNiel core samples, monitoring methods 1504) were collected from various reaches in the Little Naches, South Fork Tieton, and Upper Yakima Rivers in the fall of 2015. Each sample was analyzed to estimate the percentage of fine or small particles present (<0.85 mm). The Washington State Timber, Fish, and Wildlife program established guidelines that specify the impacts that estimated sedimentation levels can have on salmonid egg-to-smolt survival. These impact guidelines will inform future analyses of "extrinsic" factors on natural production in the Yakima Basin.

**Results and Discussion:**

Little Naches

A total of 108 McNiel core samples were collected and processed from 9 spawning reaches in the Little Naches drainage this past year. Pyramid Creek has not been sampled since 2009 when the main road going into this reach was decommissioned. Other means to access this sampling site is needed. With this year's monitoring work, the data set for the Little Naches drainage now covers a time period of 31 years for the two historical reaches, and 24 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 was the lowest in our 24-year data set (Figure 18; cumulative average of 7.7% for 2015 compared to 12.9% for 1992-2014 and 9.2% for 2010-2014). Similar trends can be seen when looking at individual reach conditions over the longer term monitoring period since 1992. Most reaches have had a declining level of fine sediment in recent years.

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.

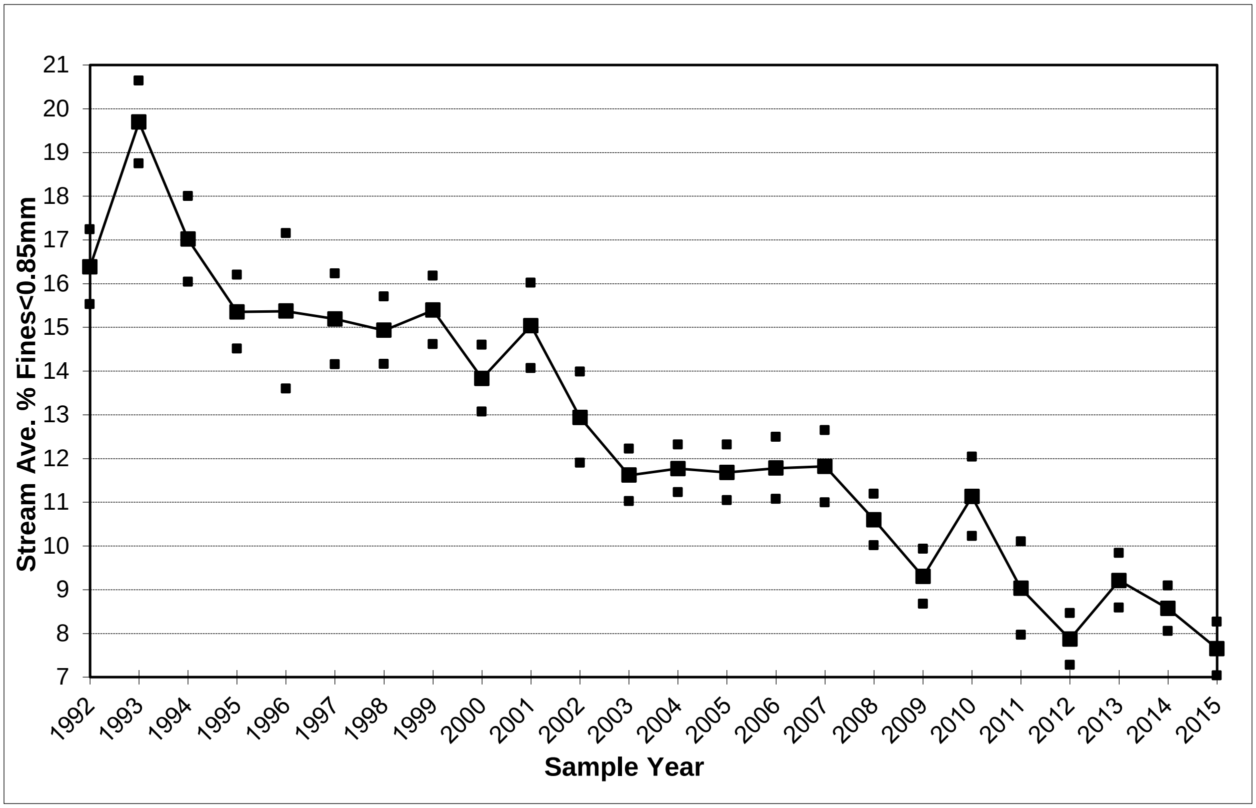


**Figure 18. Overall Fine Sediment (<0.85mm) Trends with 95% confidence bounds in the Little Naches River Drainage, 1992-2015.**

South Fork Tieton

One reach on the South Fork Tieton River (in the vicinity of Minnie Meadows) was sampled again this past season by the U.S. Forest Service. This marks 17 years that the USFS has been sampling this area. 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-year sampling period (Figure 19).

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 19 years. Overall average percent fine sediment less than 0.85mm for the combined Upper Yakima drainage declined to the lowest level in our 19-year data set (Figure 20).

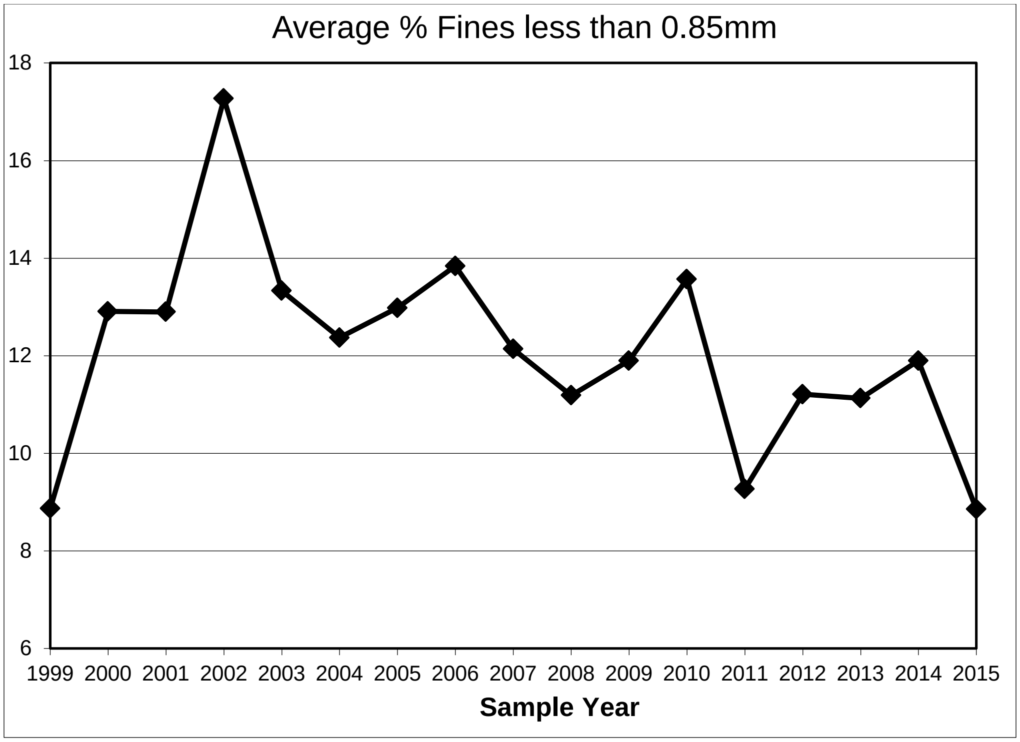


**Figure 19. Fine Sediment Trends in the South Fork Tieton River, 1999-2015. Note: Data for 2007 were collected from only 1 Riffle.**

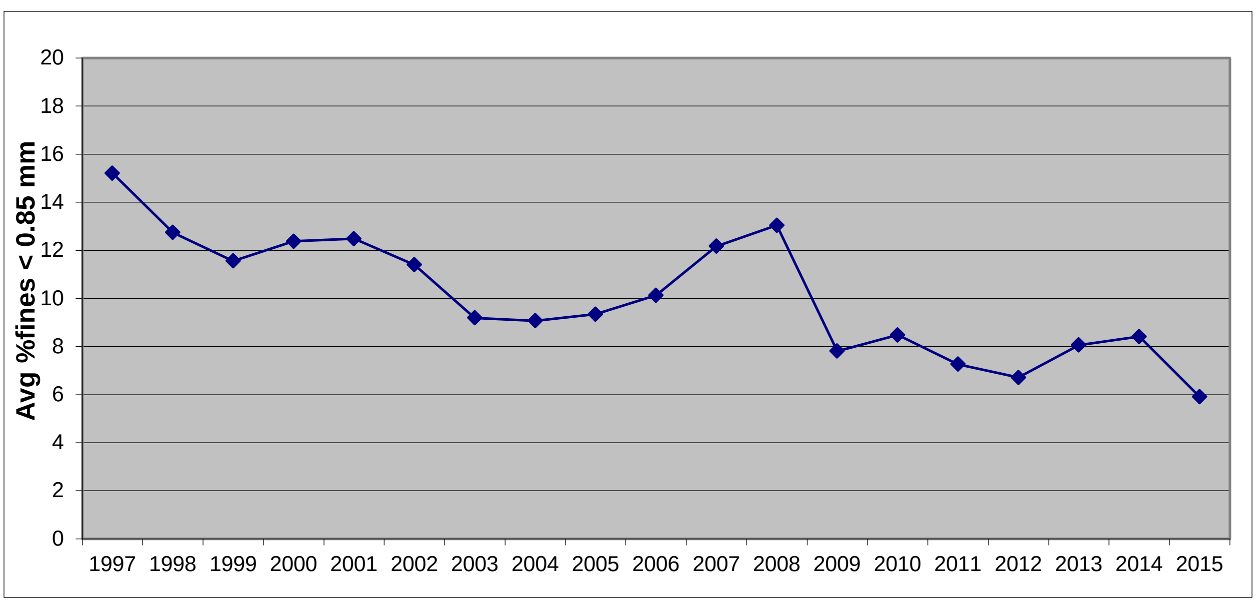


**Figure 20. Overall average percent fine sediment (< 0.85 mm) in spawning gravels of the Upper Yakima River, 1997-2015.**

Summary

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

The results of the USFS sampling in the South Fork Tieton River were also very low and below mean sediment levels for the 17-year sampling period. These conditions should be favorable for early life history survival of bull trout.

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

## Harvest Monitoring

### *Marine and Mainstem Columbia Fisheries*

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

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

## Results:

**Table 20. Marine and freshwater recoveries of CWTs from brood year 1997-2010 releases of spring Chinook from the CESRF as reported to the Regional Mark Information System (RMIS) 3 Dec 2015.**

| 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 | 1165 | 1.4% |
| 2007 | 8 | 145 | 5.2% | 13 | 1142 | 1.1% |
| 2008 | 5 | 245 | 2.0% | 7 | 1633 | 0.4% |
| 2009 | 3 | 90 | 3.2% | 5 | 554 | 0.9% |
| 2010[1] | 4 | 137 | 2.8% | 9 | 670 | 1.3% |

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 2010 are considered preliminary or incomplete.

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

| Year | Columbia R. Mouth Run Size | Col. R. Mouth to BON Harvest | BON to McNary Harvest | Yakima R. Mouth Run Size | Yakima River Harvest | Columbia Basin Harvest Summary | | | Col. Basin Harvest Rate | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total | Wild | CESRF | Total | Wild |
| 1983 | 2,452 | 118 | 99 | 1,441 | 84 | 300 | 300 | 0 | 12.3% | 12.3% |
| 1984 | 3,868 | 134 | 257 | 2,658 | 289 | 680 | 680 | 0 | 17.6% | 17.6% |
| 1985 | 5,248 | 191 | 178 | 4,560 | 865 | 1,234 | 1,234 | 0 | 23.5% | 23.5% |
| 1986 | 13,514 | 280 | 783 | 9,439 | 1,340 | 2,403 | 2,403 | 0 | 17.8% | 17.8% |
| 1987 | 6,140 | 96 | 371 | 4,443 | 517 | 984 | 984 | 0 | 16.0% | 16.0% |
| 1988 | 5,631 | 360 | 372 | 4,246 | 444 | 1,177 | 1,177 | 0 | 20.9% | 20.9% |
| 1989 | 8,869 | 212 | 663 | 4,914 | 747 | 1,621 | 1,621 | 0 | 18.3% | 18.3% |
| 1990 | 6,908 | 350 | 453 | 4,372 | 663 | 1,465 | 1,465 | 0 | 21.2% | 21.2% |
| 1991 | 4,620 | 183 | 278 | 2,906 | 32 | 493 | 493 | 0 | 10.7% | 10.7% |
| 1992 | 6,196 | 102 | 373 | 4,599 | 345 | 820 | 820 | 0 | 13.2% | 13.2% |
| 1993 | 5,117 | 44 | 311 | 3,919 | 129 | 484 | 484 | 0 | 9.5% | 9.5% |
| 1994 | 2,225 | 86 | 107 | 1,302 | 25 | 219 | 219 | 0 | 9.8% | 9.8% |
| 1995 | 1,384 | 1 | 68 | 666 | 79 | 149 | 149 | 0 | 10.7% | 10.7% |
| 1996 | 5,773 | 6 | 303 | 3,179 | 475 | 783 | 783 | 0 | 13.6% | 13.6% |
| 1997 | 5,196 | 3 | 348 | 3,173 | 575 | 926 | 926 | 0 | 17.8% | 17.8% |
| 1998 | 2,839 | 3 | 143 | 1,903 | 188 | 333 | 333 | 0 | 11.7% | 11.7% |
| 1999 | 3,918 | 4 | 180 | 2,781 | 604 | 789 | 789 | 0 | 20.1% | 20.1% |
| 2000 | 28,862 | 58 | 1,755 | 19,100 | 2,458 | 4,271 | 4,147 | 123 | 14.8% | 14.8% |
| 2001 | 31,004 | 948 | 4,050 | 23,265 | 4,630 | 9,629 | 5,528 | 4,101 | 31.1% | 29.7% |
| 2002 | 23,898 | 1,234 | 2,547 | 15,099 | 3,108 | 6,888 | 2,569 | 4,320 | 28.8% | 24.7% |
| 2003 | 9,727 | 274 | 764 | 6,957 | 440 | 1,478 | 890 | 588 | 15.2% | 14.3% |
| 2004 | 21,910 | 964 | 1,894 | 15,289 | 1,679 | 4,536 | 2,515 | 2,021 | 20.7% | 16.1% |
| 2005 | 11,903 | 326 | 741 | 8,758 | 474 | 1,542 | 1,214 | 328 | 13.0% | 12.2% |
| 2006 | 11,560 | 299 | 760 | 6,314 | 600 | 1,658 | 942 | 716 | 14.3% | 12.8% |
| 2007 | 4,981 | 170 | 343 | 4,303 | 279 | 791 | 382 | 410 | 15.9% | 13.8% |
| 2008 | 11,419 | 1,151 | 1,507 | 8,598 | 1,532 | 4,190 | 1,181 | 3,008 | 36.7% | 26.5% |
| 2009 | 12,804 | 1,168 | 934 | 10,701 | 2,353 | 4,455 | 1,237 | 3,218 | 34.8% | 25.7% |
| 2010 | 17,366 | 1,563 | 2,286 | 13,142 | 1,741 | 5,590 | 1,302 | 4,288 | 32.2% | 21.4% |
| 2011 | 22,171 | 1,059 | 1,396 | 17,960 | 4,380 | 6,834 | 2,373 | 4,461 | 30.8% | 22.2% |
| 2012 | 16,641 | 842 | 1,427 | 12,053 | 3,320 | 5,588 | 2,252 | 3,336 | 33.6% | 27.3% |
| 2013 | 14,234 | 847 | 761 | 10,245 | 2,653 | 4,261 | 1,686 | 2,575 | 29.9% | 23.3% |
| 2014 | 16,292 | 691 | 1,759 | 11,322 | 2,171 | 4,621 | 1,836 | 2,784 | 28.4% | 21.6% |
| 2015[1] | 11,211 | 455 | 1,250 | 9,351 | 815 | 2,520 | 1,312 | 1,208 | 22.5% | 17.6% |
| Mean | 10,784 | 431 | 893 | 7,665 | 1,213 | 2,537 | 1,401 | 1,136 | 20.2% | 17.8% |

1. Preliminary.

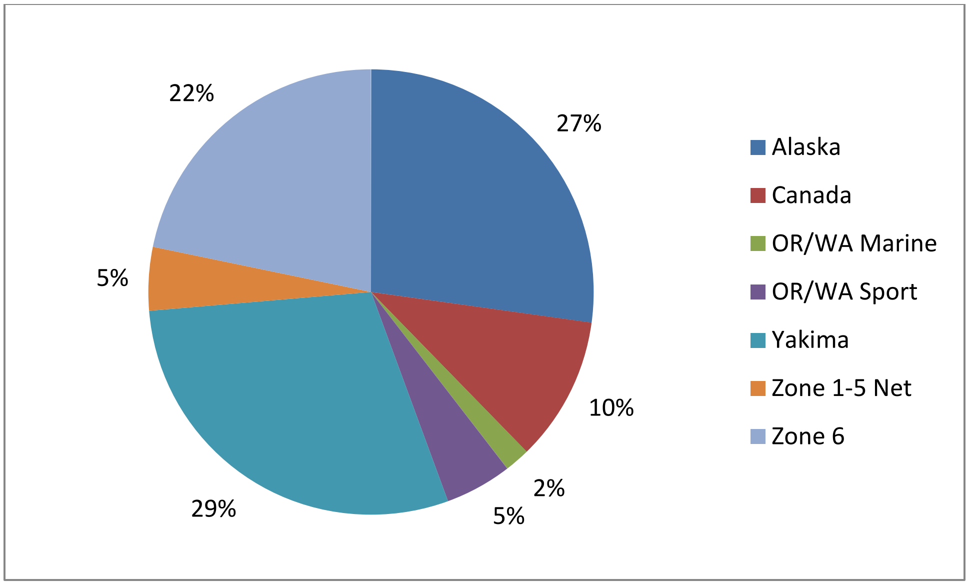


**Figure 21. Distribution of coded-wire tag recoveries of Yakima Basin summer/fall run Chinook releases in marine, mainstem Columbia River, and Yakima Basin fisheries. Data retrieved from the regional mark information system (RMIS) for brood year 1997-2007 recoveries.**

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

## Discussion:

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

Yakima Basin summer/fall Chinook are harvested in marine fisheries from Alaska to southern Oregon, and in Columbia River fisheries from the mouth to the Hanford Reach (Figure 21). Approximately 71% of harvest recoveries from Yakima Basin fall Chinook releases for brood years 1997-2007 occurred in marine (44%) and mainstem

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

### *Yakima Subbasin Fisheries*

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

## Results:

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

| | Tribal | | Non-Tribal | | River Totals | | | Harvest |
|---|---|---|---|---|---|---|---|---|
| Year | CESRF | Natural | CESRF | Natural | CESRF | Natural | Total | Rate[1] |
| 1983 | | 84 | | 0 | | 84 | 84 | 5.8% |
| 1984 | | 289 | | 0 | | 289 | 289 | 10.9% |
| 1985 | | 865 | | 0 | | 865 | 865 | 19.0% |
| 1986 | | 1,340 | | 0 | | 1,340 | 1,340 | 14.2% |
| 1987 | | 517 | | 0 | | 517 | 517 | 11.6% |
| 1988 | | 444 | | 0 | | 444 | 444 | 10.5% |
| 1989 | | 747 | | 0 | | 747 | 747 | 15.2% |
| 1990 | | 663 | | 0 | | 663 | 663 | 15.2% |
| 1991 | | 32 | | 0 | | 32 | 32 | 1.1% |
| 1992 | | 345 | | 0 | | 345 | 345 | 7.5% |
| 1993 | | 129 | | 0 | | 129 | 129 | 3.3% |
| 1994 | | 25 | | 0 | | 25 | 25 | 1.9% |
| 1995 | | 79 | | 0 | | 79 | 79 | 11.9% |
| 1996 | | 475 | | 0 | | 475 | 475 | 14.9% |
| 1997 | | 575 | | 0 | | 575 | 575 | 18.1% |
| 1998 | | 188 | | 0 | | 188 | 188 | 9.9% |
| 1999 | | 604 | | 0 | | 604 | 604 | 21.7% |
| 2000 | 53 | 2,305 | | 100 | 53 | 2,405 | 2,458 | 12.9% |
| 2001 | 572 | 2,034 | 1,252 | 772 | 1,825 | 2,806 | 4,630 | 19.9% |
| 2002 | 1,373 | 1,207 | 492 | 36[2] | 1,865 | 1,243 | 3,108 | 20.6% |
| 2003 | 134 | 306 | 0 | 0 | 134 | 306 | 440 | 6.3% |
| 2004 | 289 | 712 | 569 | 109[2] | 858 | 820 | 1,679 | 11.0% |
| 2005 | 46 | 428 | 0 | 0 | 46 | 428 | 474 | 5.4% |
| 2006 | 246 | 354 | 0 | 0 | 246 | 354 | 600 | 9.5% |
| 2007 | 123 | 156 | 0 | 0 | 123 | 156 | 279 | 6.5% |
| 2008 | 521 | 414 | 586 | 11[2] | 1,107 | 426 | 1,532 | 17.8% |
| 2009 | 1,089 | 715 | 541 | 8[2] | 1,630 | 722 | 2,353 | 19.4% |
| 2010 | 345 | 194 | 1,154 | 48[2] | 1,499 | 241 | 1,741 | 13.2% |
| 2011 | 1,361 | 1,261 | 1,579 | 179[2] | 2,940 | 1,440 | 4,380 | 24.4% |
| 2012 | 1,220 | 1,302 | 735 | 63[2] | 1,955 | 1,364 | 3,320 | 27.5% |
| 2013 | 846 | 975 | 786 | 46[2] | 1,632 | 1,021 | 2,653 | 25.9% |
| 2014 | 576 | 715 | 826 | 54[2] | 1,402 | 769 | 2,171 | 19.2% |
| 2015 | 121 | 271 | 385 | 38 | 506 | 309 | 815 | 8.7% |
| Mean | 591 | 736 | 594 | 91 | 1,185 | 674 | 1,171 | 13.7% |

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

**Table 23. Estimated fall Chinook return, escapement, and harvest in the Yakima River, 1998-2015. Data from WDFW and YN databases.**

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

**Table 24. Estimated Coho return, escapement, and harvest in the Yakima River, 1999-2015. 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% |

**Discussion:**

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

Recreational fishers enjoy a successful annual fall Chinook fishery situated primarily near the mouth of the Yakima River (Table 23). Tribal fishers harvest a substantial, but unquantified number of Yakima Basin-destined fall Chinook (Figure 21) 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:

Fish Propagation Critical Uncertainty 2. What is the magnitude of any demographic benefit to the production of natural-origin juveniles and adults from the natural spawning of hatchery-origin supplementation adults?

Fish Propagation Critical Uncertainty 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, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock?

**Methods:**

The YKFP began a spring Chinook salmon hatchery program at the CESRF near Cle Elum on the upper Yakima River (river kilometer 297, measuring from the confluence with the Columbia River; Figures 1 and 22) 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 22). 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).

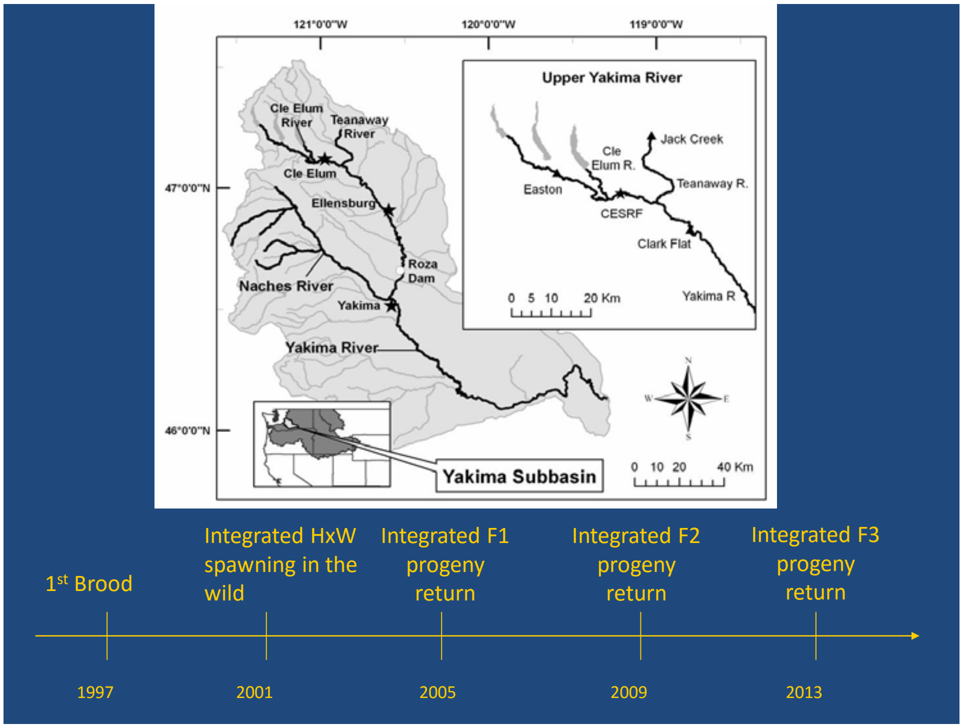


**Figure 22. Map of the Yakima River Basin, Cle Elum Supplementation and Research Facility (CESRF) locations, and timeline of the spring Chinook supplementation program.**

## Results:

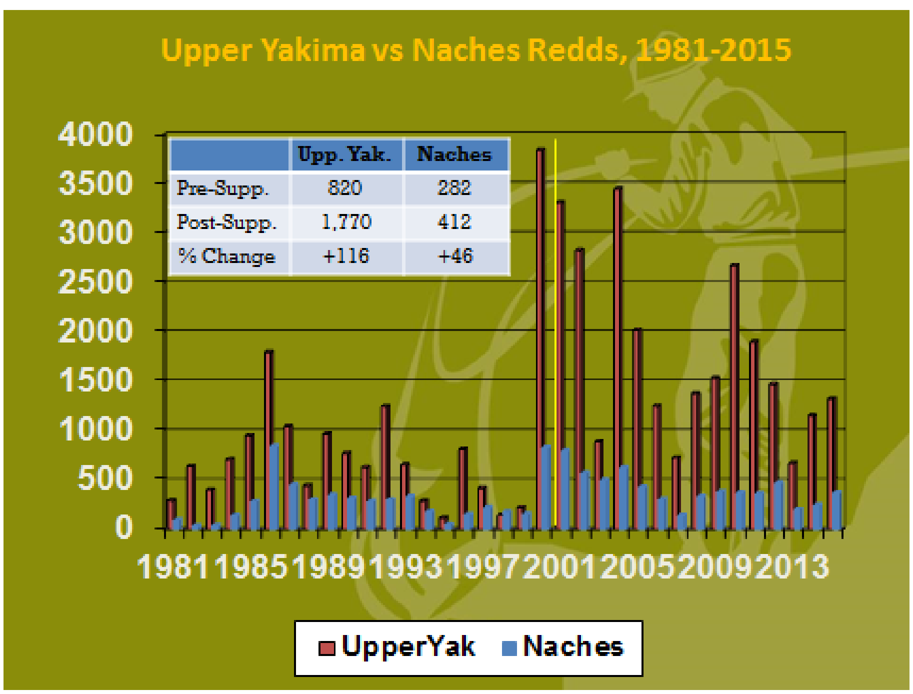


**Figure 23. Spring Chinook redd counts in the supplemented Upper Yakima (red bar) relative to the un-supplemented Naches (control; blue bar) for the pre- (1981-2000) and post-supplementation (2001-2015) periods.**

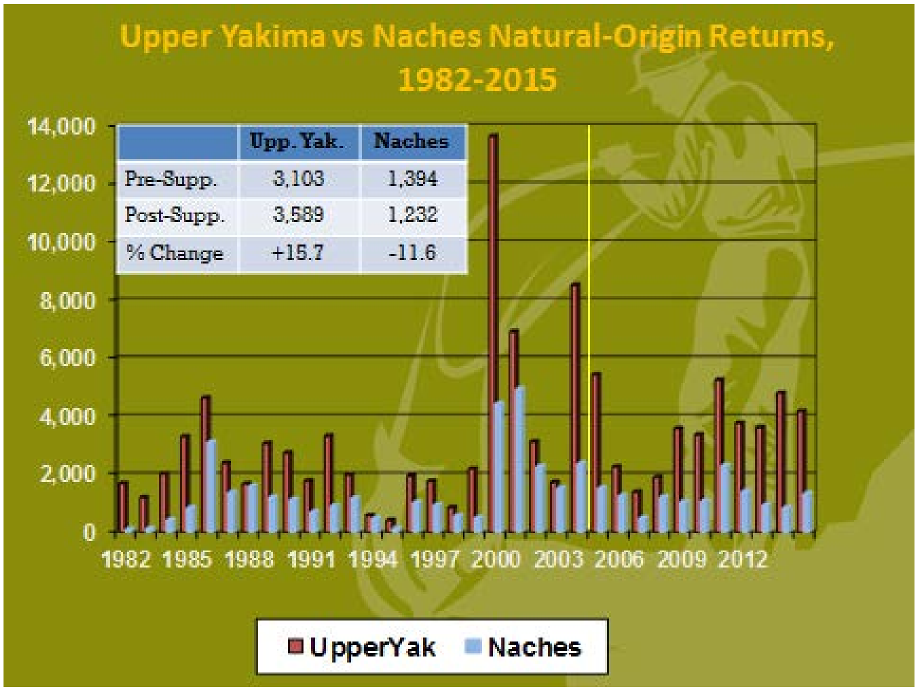


**Figure 24. Natural-Origin returns of Spring Chinook in the supplemented Upper Yakima (blue bar) relative to the un-supplemented Naches (control; yellow bar) for the pre- (1982-2004) and post-supplementation (2005-2015) periods.**

## Discussion:

Supplementation has increased spring Chinook redd abundance in the Upper Yakima relative to the Naches control system (Figure 23). Redd counts in the post-supplementation period (2001-2015) increased in the supplemented Upper Yakima (+116%; P=0.003) but the change observed in the un-supplemented Naches control system relative to the pre-supplementation period (1981-2000) was not significant (+46%; P=0.068). 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).

Changes in mean natural-origin return abundance in the post-supplementation period (2005-2015) relative to the pre-supplementation period (1982-2004) were not significant in either the supplemented upper Yakima River (+15.7%; P=0.609; Figure 24) or the unsupplemented Naches River system (-11.6%; P=0.689; Figure 24). We have already noted that limiting factors appear to be inhibiting natural productivity (see status and trend of adult productivity) throughout the Yakima Basin. It may also be that the post-supplementation time period is not yet long enough to detect a significant change in this natural production parameter. Given the short post-supplementation time series, these findings are preliminary. We will continue to incorporate additional years of data and out-of-basin control populations into this evaluation and publish more complete findings at a later date.

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

The YKFP is presently studying the release of over 1.0 million coho smolts annually from acclimation sites in the Naches and Upper Yakima subbasins. These fish are a combination of in-basin production from brood-stock collected in the vicinity of Prosser Dam plus out-of-basin stock generally reared at Willard or Eagle Creek National Fish Hatcheries and moved to the Yakima Subbasin for final rearing and release. Monitoring of these efforts to re-introduce a sustainable, naturally spawning coho population in the Yakima Basin have indicated that adult coho returns averaged about 4,600 fish from 1997-2015 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging about 1,000 fish annually since 2001 (Figure 4). Coho re-introduction research has demonstrated that hatchery-origin coho, with a legacy of as many as 10 to 30 generations of hatchery-influence, can reestablish a naturalized population after as few as 3 to 5 generations of outplanting in the wild (Bosch et al. 2007). The project is working to further develop a locally adapted brood-stock and to establish specific release sites and strategies that optimize natural reproduction and survival.

### *Effectiveness of Hatchery Reform*

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

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

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

In addition to the integrated (supplementation-S) hatchery program described above for the CESRF, this facility also introduced a segregated “hatchery control” (HC) program in 2002 as recommended by independent scientific review. To protect the integrity of the integrated program evaluation described above, returning HC line fish were either harvested or trapped and removed at the Roza Adult Monitoring Facility (RAMF); no HC line fish were allowed to escape to the spawning grounds (determination of fish origin was based on a differential marking strategy for S and HC fish; unmarked fish were presumed wild). CESRF-project scientists hypothesized that HC-line fish, which use only returning hatchery-origin fish as brood source, would increasingly diverge in phenotypic and genetic characteristics from wild (WC or wild control) fish with increasing generations of hatchery influence, whereas S-line fish, which use only wild or natural-origin fish for brood source, would remain relatively close in characteristics to wild fish (Figure 25). 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).

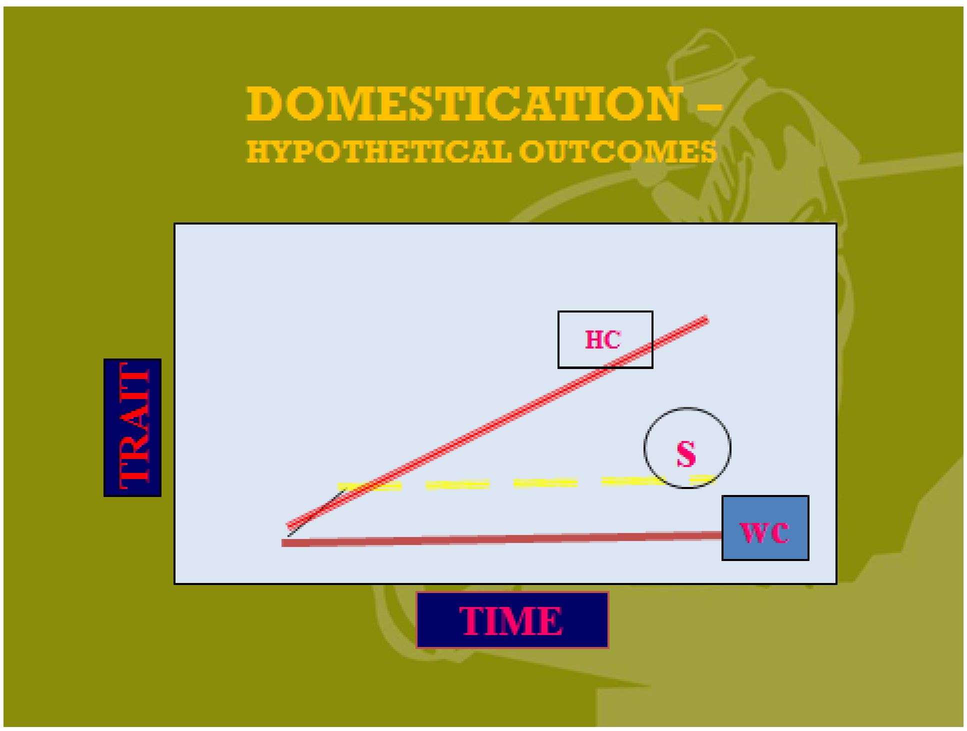


**Figure 25. Hypothetical outcomes of trait divergence (domestication effects) over time for a segregated (hatchery-control or HC) line of fish, compared to an integrated (supplementation or S) line of fish and a wild (wild-control or WC) line of fish (D. Fast, Yakama Nation).**

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

## Methods:

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

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

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

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 2001-2015, PNI averaged 66% while pHOS averaged 54% (Table 25). As stated in the introduction to this report and in the final Environmental Impact Statement for the Yakima Fisheries Project (BPA 1996), one of the explicit purposes of the project is to test the assumption that new artificial propagation or hatchery reform techniques (Cuenco et al. 1993, Mobrand et al. 2005) can be used to increase natural production without causing significant impacts to existing natural populations. Therefore it has always been the intent of this project to purposely allow integrated hatchery-origin fish to escape to the natural spawning grounds, i.e., we intentionally maintained a relatively high pHOS rate. Even with a high pHOS relative to recommendations, PNI for the CESRF integrated program remained in the "low hatchery influence for conservation of natural populations" category described by the HSRG (Paquet et al. 2011).

The project will continue to monitor PNI considering factors such as: policy input regarding controlling the number and types of fish allowed to escape to natural spawning areas, meeting overall production goals of the project, guidance from the literature relative to percentage of hatchery fish on the spawning grounds with fitness loss, considerations about what risk is acceptable in a project designed to evaluate impacts from that risk, and the numerous risk containment measures already in place in the project. The State of Washington is using mark-selective fisheries in the lower Columbia River and, when possible, in the lower Yakima River in part as a tool to manage escapement proportions. In 2011, the project implemented an effort to transfer some returning hatchery-origin CESRF adults from Roza Dam to Lake Cle

Elum for the purpose of returning marine derived nutrients and salmon to the watersheds that feed the lake. These measures will also increase PNI in the major spawning areas of the Upper Yakima Basin. Additional adaptive management measures will be considered when and if monitoring and evaluation indicates a need.

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

| | Wild/Natural (NoR) | | | CESRF (HoR) | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Adults | Jacks | Total | Adults | Jacks | Total | Adults | Jacks | Total | PHOS[1] | PNI[1] |
| 1982 | | | 1,146 | | | | | | | | |
| 1983 | | | 1,007 | | | | | | | | |
| 1984 | | | 1,535 | | | | | | | | |
| 1985 | | | 2,331 | | | | | | | | |
| 1986 | | | 3,251 | | | | | | | | |
| 1987 | | | 1,734 | | | | | | | | |
| 1988 | | | 1,340 | | | | | | | | |
| 1989 | | | 2,331 | | | | | | | | |
| 1990 | | | 2,016 | | | | | | | | |
| 1991 | | | *1,583*[2] | | | | | | | | |
| 1992 | | | 3,009 | | | | | | | | |
| 1993 | | | 1,869 | | | | | | | | |
| 1994 | | | 563 | | | | | | | | |
| 1995 | | | 355 | | | | | | | | |
| 1996 | | | 1,631 | | | | | | | | |
| 1997 | 1,141 | 43 | 1,184 | | | | | | | | |
| 1998 | 369 | 18 | 387 | | | | | | | | |
| 1999 | 498 | 468 | 966 | | | | | | | | |
| 2000 | 10,491 | 481 | 10,972 | | 688 | 688 | 10,491 | 1,169 | 11,660 | 5.9% | |
| 2001 | 4,454 | 297 | 4,751 | 6,065 | 982 | 7,047 | 10,519 | 1,279 | 11,798 | 59.7% | 62.6% |
| 2002 | 1,820 | 89 | 1,909 | 6,064 | 71 | 6,135 | 7,884 | 160 | 8,044 | 76.3% | 56.7% |
| 2003 | 394 | 723 | 1,117 | 1,036 | 1,105 | 2,141 | 1,430 | 1,828 | 3,258 | 65.7% | 60.3% |
| 2004 | 6,536 | 671 | 7,207 | 2,876 | 204 | 3,080 | 9,412 | 875 | 10,287 | 29.9% | 77.0% |
| 2005 | 4,401 | 175 | 4,576 | 627 | 482 | 1,109 | 5,028 | 657 | 5,685 | 19.5% | 83.7% |
| 2006 | 1,510 | 121 | 1,631 | 1,622 | 111 | 1,733 | 3,132 | 232 | 3,364 | 51.5% | 66.0% |
| 2007 | 683 | 161 | 844 | 734 | 731 | 1,465 | 1,417 | 892 | 2,309 | 63.4% | 61.2% |
| 2008 | 988 | 232 | 1,220 | 2,157 | 957 | 3,114 | 3,145 | 1,189 | 4,334 | 71.9% | 58.2% |
| 2009 | 1,843 | 701 | 2,544 | 2,234 | 2,260 | 4,494 | 4,077 | 2,961 | 7,038 | 63.9% | 61.0% |
| 2010 | 2,436 | 413 | 2,849 | 4,524 | 1,001 | 5,525 | 6,960 | 1,414 | 8,374 | 66.0% | 60.2% |
| 2011 | 3,092 | 926 | 4,018 | 3,162 | 1,404 | 4,566 | 6,254 | 2,330 | 8,584 | 53.2% | 65.3% |
| 2012 | 2,359 | 191 | 2,550 | 2,661 | 265 | 2,926 | 5,020 | 456 | 5,476 | 53.4% | 65.2% |
| 2013 | 1,708 | 678 | 2,386 | 1,587 | 840 | 2,427 | 3,295 | 1,518 | 4,813 | 50.4% | 66.5% |
| 2014 | 3,099 | 685 | 3,784 | 2,150 | 794 | 2,944 | 5,249 | 1,479 | 6,728 | 43.8% | 69.6% |
| 2015 | 3,357 | 163 | 3,520 | 1,779 | 167 | 1,946 | 5,136 | 330 | 5,466 | 35.6% | 73.7% |
| Mean[3] | 2,694 | 381 | 3,074 | 2,619 | 758 | 3,377 | 5,197 | 1,173 | 6,371 | 53.6% | 65.8% |

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 25 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 26). 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 25), 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. 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).

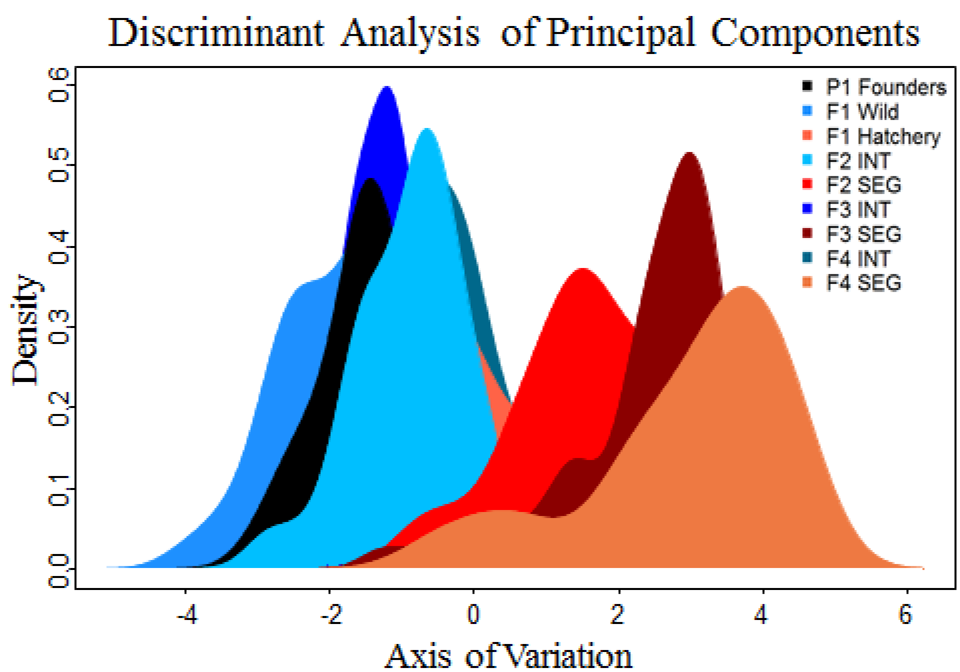


**Figure 26. Estimated genetic divergence (variation) for integrated (INT blue), segregated (SEG red), and wild founder (black) spring Chinook in the CESRF program after 4 parental-generations of the hatchery program (P1=1998, F1=2002, F2=2006, F3=2010, F4=2014; updated from Figure 4 in Waters et al. 2015).**

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

## Predation Management and Predator Control

### *Avian Predation Index*

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

### *Methods:*

#### River Reach Surveys

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

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

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

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

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

**Acclimation Site Surveys**

Three Spring Chinook acclimation sites in upper Yakima River (Clark Flat, Jack Creek, and Easton) and one Coho site (JD Holmes) were surveyed for piscivorous birds from 2004 through 2015 (Figure 1). Surveys were conducted between January 23 and June 10, though dates varied for each site. Three surveys were conducted at the Spring Chinook sites each day, at 8:00 am, 12:00 noon, and 4:00 pm. The Coho site was surveyed once or twice on days hatchery personnel were feeding smolts. Surveys were conducted on foot. All piscivorous birds within the acclimation facility, along the length of the artificial acclimation stream, and 50 meters above and 150 meters below the acclimation stream outlet, into the main stem of the Yakima River or its tributaries, were recorded.

**Salmon PIT Tag Surveys at Great Blue Heron Rookeries**

A Passive Integrated Transponder (PIT) tag reader was used to survey for PIT tags deposited in various Yakima River Great Blue Heron Rookeries (Figure 27). Methods were generally consistent with Evans and Hostetter (2012) and with monitoringmethods.org method 255.

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

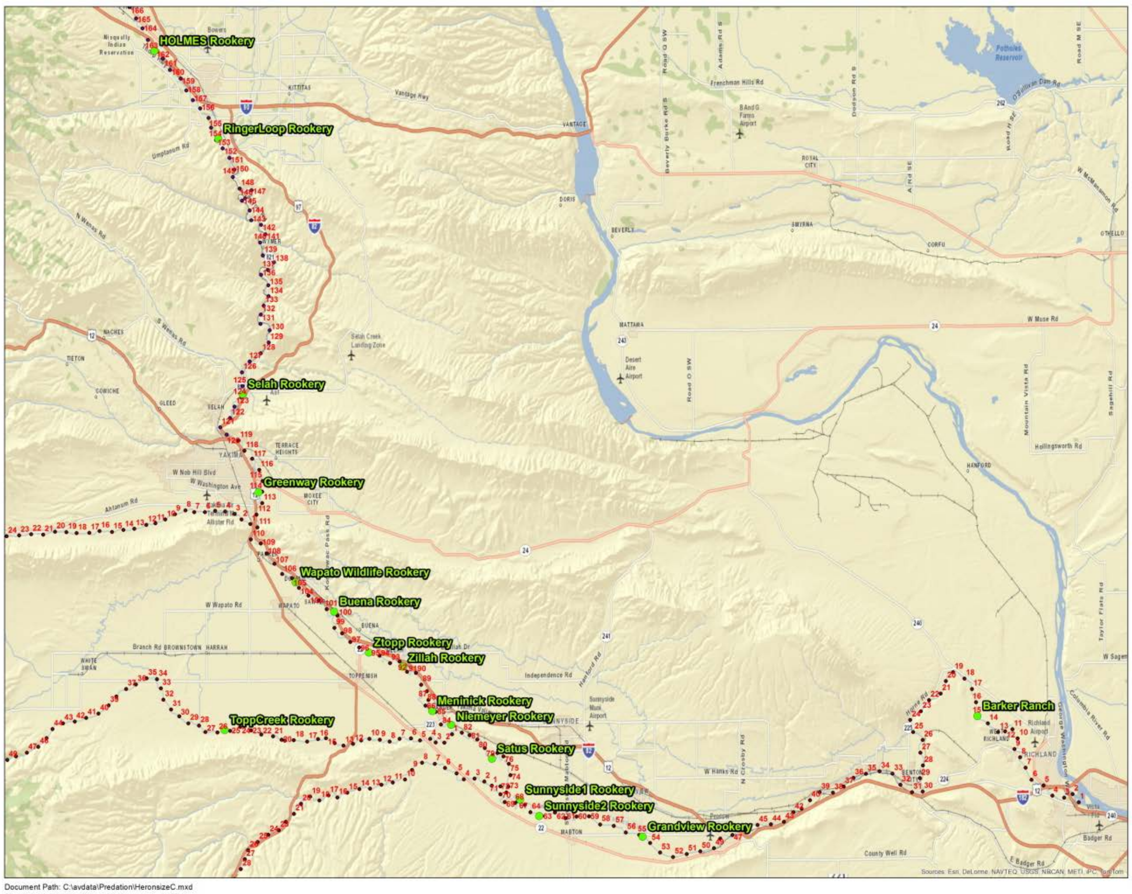


**Figure 27. Map of Yakima Basin Heron Rookeries.**

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

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

The objectives for the study were:

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

## Results and Discussion:

River Reach Surveys

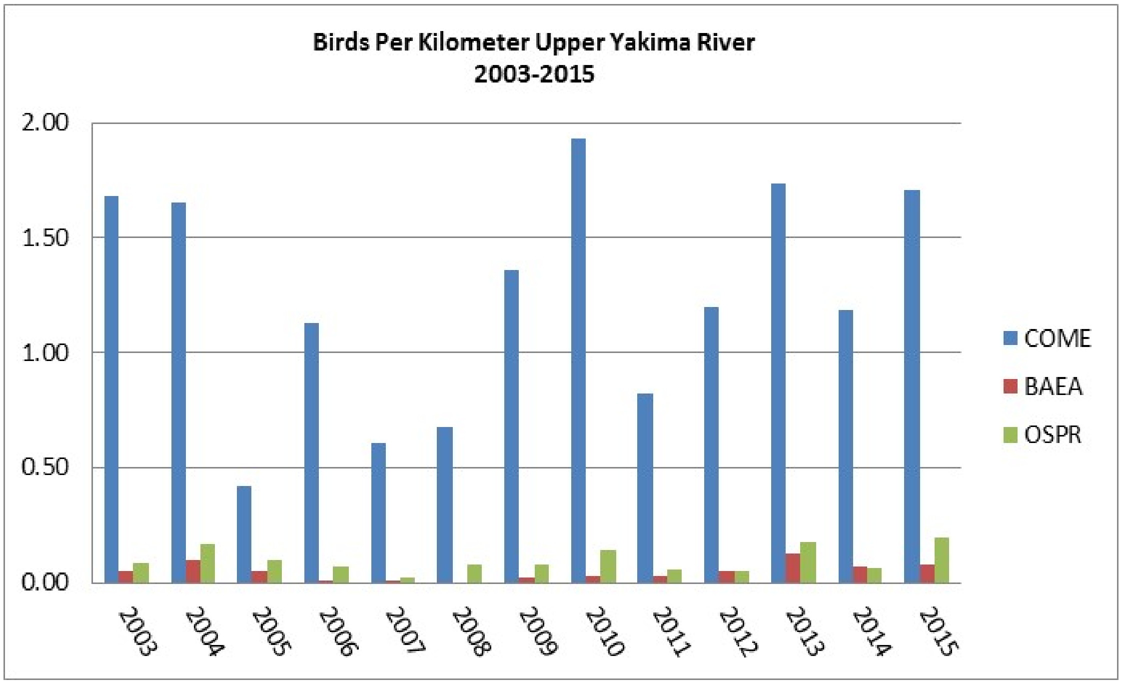


**Figure 28. Upper Yakima piscivorous birds per kilometer (Common Merganser-COME, Bald Eagle-BAEA, and Osprey-OSPR).**

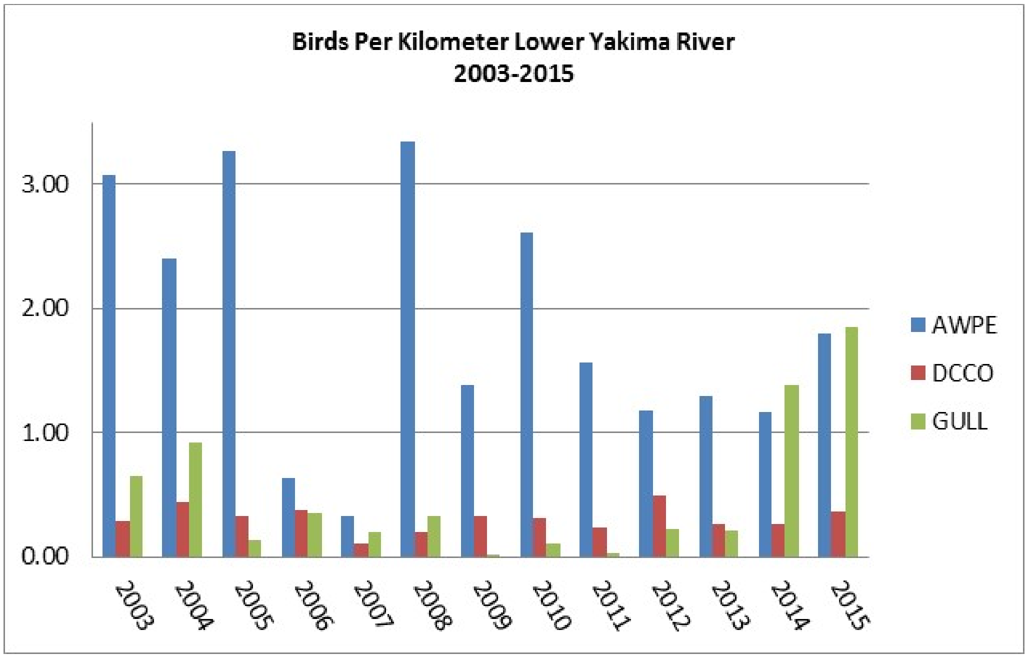


**Figure 29. Lower Yakima piscivorous birds per kilometer (American White Pelican-AWPE, Double Crested Cormorant-DCCO, and Gulls-GULL).**

Thirteen different piscivorous bird species were observed on the Yakima River. These included: American White Pelican, Bald Eagle, Black-crowned Night Heron, Belted Kingfisher, Caspian Tern, Common Merganser, Double-crested Cormorant, Forster's Tern, Great Egret, Great Blue Heron, Gull species, Hooded Merganser, and Osprey. These same 13 species were observed in most survey years. Graph data for river reach surveys represents a combined view of the upper Yakima River (surveys above Wapato Dam; Figure 28) and the lower Yakima River (surveys below Wapato Dam; Figure 29). The three top bird predators within these bisected areas were chosen for graph representation.

Osprey, Great Blue Heron, and Belted Kingfisher were the only species found on all six reaches in the spring, and Common Mergansers were observed on all reaches except the Vangie reach. Common Mergansers were most abundant in the upper reaches of the river (Easton and Cle Elum reaches) which was the case in all years surveyed (Figure 28).

Gull numbers in the lower Yakima River rose again in 2015 (Figure 29). Double Crested Cormorant numbers surveyed remained consistent with prior years. This species remains a concern due to takeover of Great Blue Heron Rookeries in various areas along the Yakima River. Monitoring of the Double Crested Cormorant on the river and in rookeries will be a priority in upcoming years as the Army Corp of Engineers culls and removes breeding habitat at the estuary of the Columbia River in efforts to reduce juvenile salmon predation (USACE 2014). These actions may result in displacement and searching out of new habitat for the Cormorants and lead to impacts on salmon in other rivers and basins. The American White Pelicans numbers remain consistently high in the lower Yakima River. In the Yakima River pelicans can be seen in groups of over 100 in the Wapato Reach of the river along the borders of the Yakama Indian Reservation.

Acclimation Sites Surveys

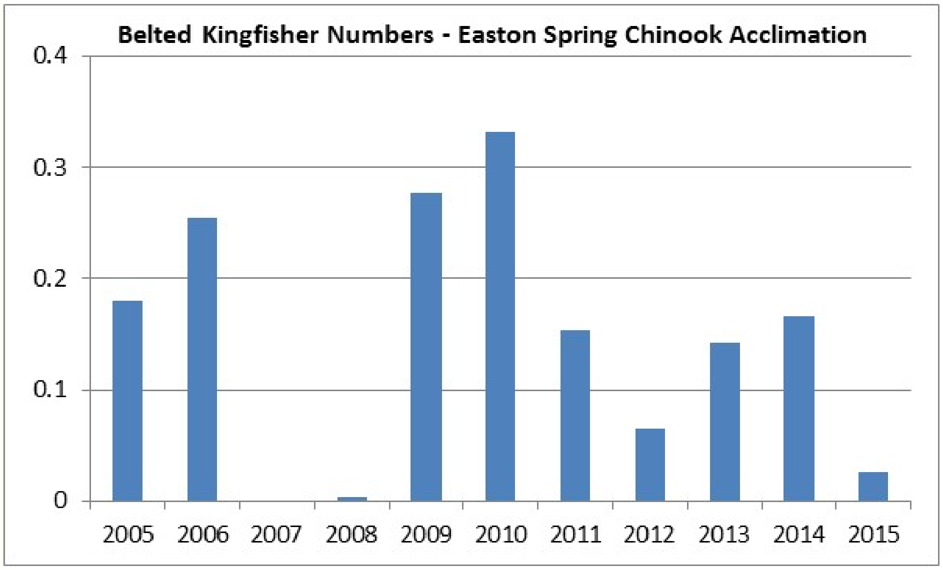


**Figure 30. Average number of Belted King Fishers observed per day at the Easton spring Chinook acclimation site between 2005 and 2015 when fish were present.**

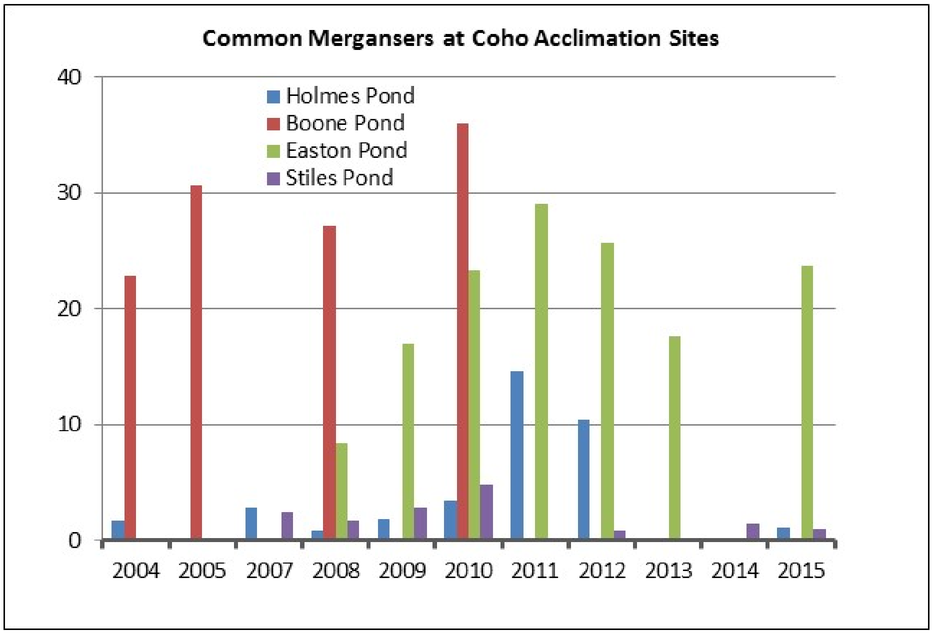


**Figure 31. Average number of Common Mergansers observed per day at the JD Holmes, Boone, Easton, and Stiles Pond Coho acclimation sites between 2004 and 2015 when fish were present.**

Acclimation site avian abundance varied greatly between manmade concrete structures and natural or manmade ponds. Spring Chinook from the CESRF were acclimated in concrete raceways in three different locations in the Upper Yakima Basin. The raceways were covered with guide wires to control access to fish by piscivorous birds and provide a deterrent to predation. The Belted Kingfisher, due to its small size and fishing style, was the dominant predator in these acclimation sites, but numbers per day remained below any level of concern for management strategies to be implemented (Figure 30).

Coho acclimation was conducted in natural or manmade ponds which were highly accessible to piscivorous birds. The Common Merganser was the most common predator at these Coho acclimation sites (Figure 31). From 2004 to 2015 various ponds were used in alternation as Coho acclimation sites. Boone pond in the upper Yakima Basin showed a tendency to draw large numbers of Common Mergansers during coho acclimation and during recent years has been abandoned as a site of acclimation. Easton pond was used consistently as a Coho acclimation site from 2004 to 2015 (however, no data were available for this pond in 2014). Recent years have shown a steady growth in Common Mergansers utilizing Holmes pond during Coho acclimation; this may be due to the fact of lack of fish at Boone pond.

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

For the Spring Chinook sites (Clark Flat, Easton and Jack Creek), it was estimated that these bird species together consumed 402 smolts at Clark Flat, 581 smolts at Easton and 283 smolts at Jack Creek. A few Osprey were observed consuming smolts at the Jack Creek site.

At the Coho acclimation sites (Lost Creek, Stiles, Easton Pond and Holmes), it was estimated that these bird species together consumed 337 juvenile Coho at Lost Creek. Common Mergansers were the most common bird observed. Common Mergansers were observed on ten days with the highest count of four Common Mergansers on 03/21/15 and 04/30/15, consuming 246 juvenile Coho. At Stiles, 1,489 juvenile Coho were consumed. The most common birds observed were Belted Kingfishers and Common Mergansers. Belted Kingfishers were observed on seventeen days, consuming 26 juvenile Coho. Common Mergansers were observed on thirty-four days with the highest count of ten Common Mergansers on 02/18/15, consuming 1,453 juvenile Coho. At Easton Pond, 50,070 juvenile Coho were consumed. Common Mergansers were the most common birds observed with the highest count of seventy-five Common Mergansers on 03/20/15 and they consumed 46,166 juvenile Coho. At Holmes, 5,634 juvenile Coho were consumed. Great Blue Herons consumed 3,785 juvenile Coho, with the highest count of twenty-one Great Blue Herons on 03/22/15. Six Common Mergansers were observed on 03/20/15 and 03/22/15, they consumed 1,737 juvenile Coho.

Great Blue Heron Rookeries

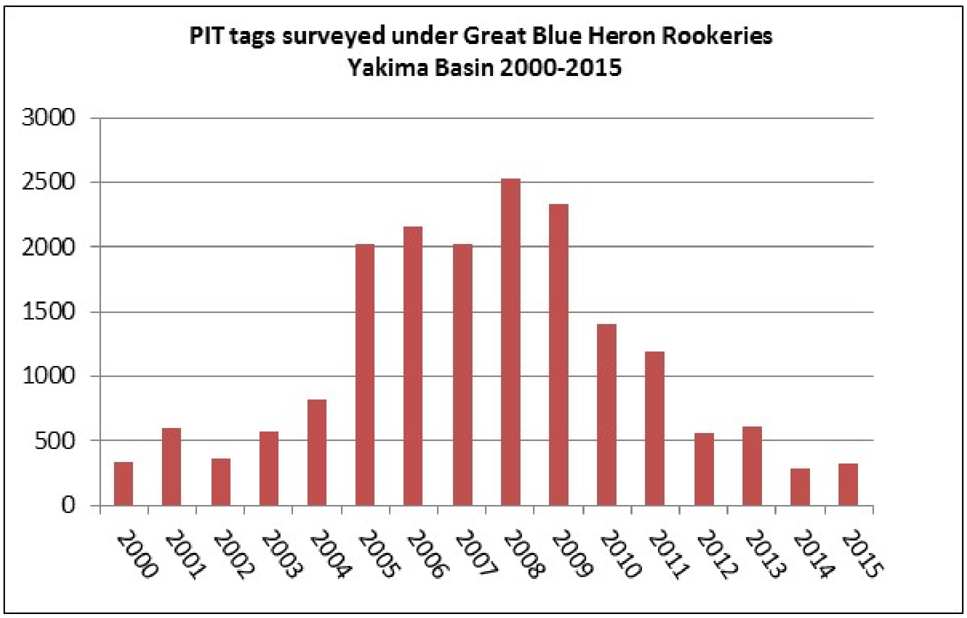


**Figure 32. Number of PIT tags recovered at Yakima Basin Great Blue Heron rookery sites during surveys conducted from 2008-2015. Tags were from juvenile salmonids migrating downstream between 2000 and 2015. Total PIT tags recovered are shown by their corresponding migration year.**

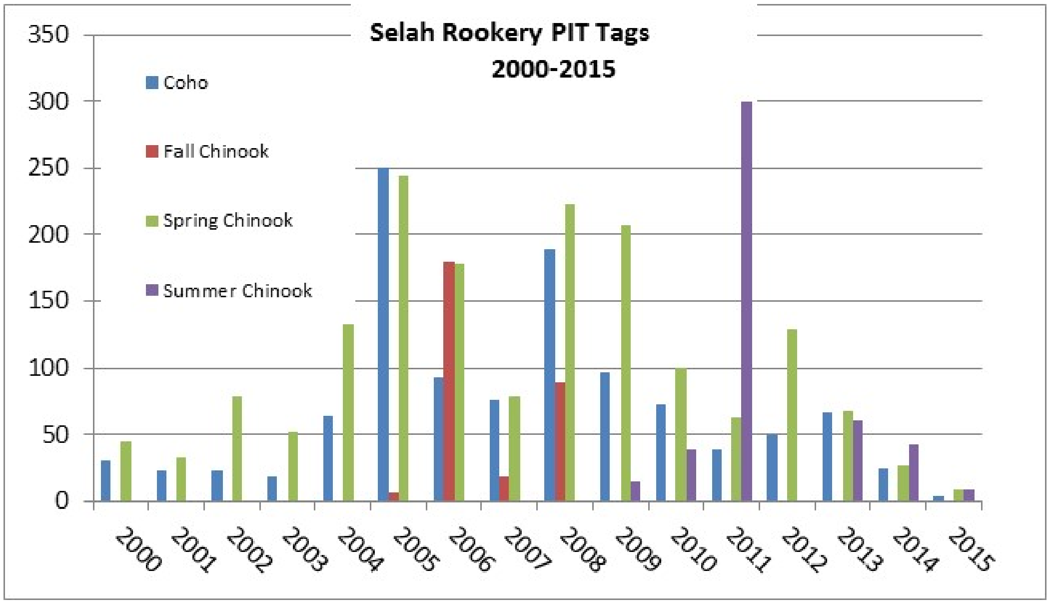


**Figure 33. Number of PIT tags recovered at the Selah Great Blue Heron rookery during surveys conducted from 2008-2015. Tags were from juvenile salmonids migrating downstream between 2000 and 2015. Total PIT tags recovered are shown by species and their corresponding migration year.**

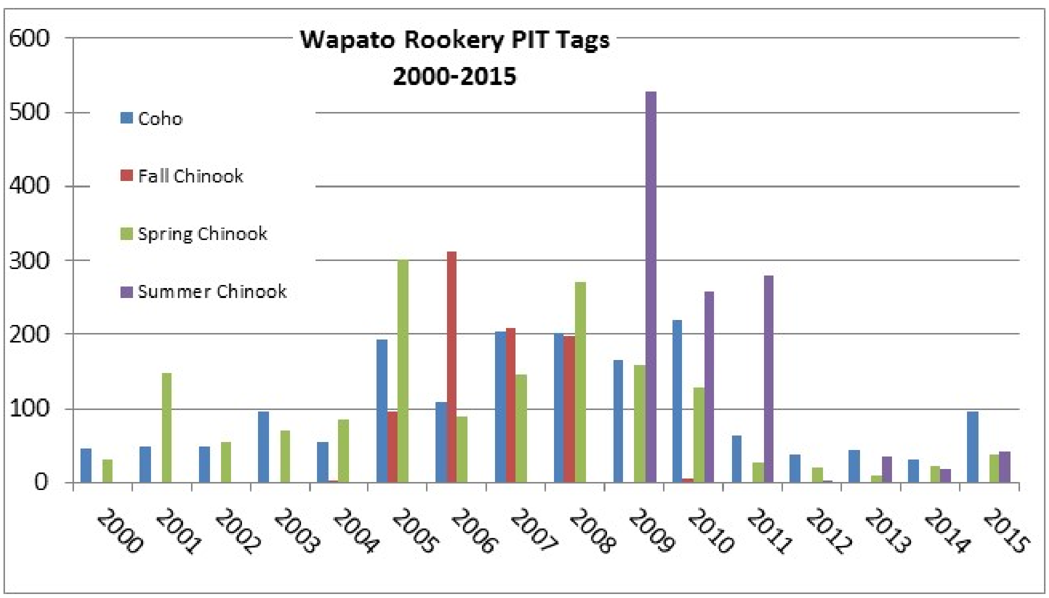


**Figure 34. Number of PIT tags recovered at the Wapato Wildlife Area Great Blue Heron rookery during surveys conducted from 2008-2015. Tags were from juvenile salmonids migrating downstream between 2000 and 2015. Total PIT tags recovered are shown by species and their corresponding migration year.**

Surveys of the Yakima Basin Great Blue Heron rookery sites between 2008 and 2015 recovered approximately 18,000 salmonid related PIT tags (Figure 32). Heron rookery PIT recoveries, when sorted by migration year, show higher mortality rates for juvenile migration years 2005 to 2009. This may correspond to river conditions (e.g., lower flows, low turbidity) that are likely conducive to increased smolt mortalities. For example, the migration year of 2008 was the most prevalent in PIT recoveries which could be related to drought conditions in 2007 when many 2008 migrants were released.

PIT recoveries in the Selah Heron Rookery may show the highest correlation to increases in predation opportunities due to low water flows in the Yakima River (Figure 33). Spring Chinook, released in Yakima River waters upriver of the rookery, exhibited the high numbers of PIT recoveries for migration years 2005 and 2007 which were years of relatively low flows in the Yakima River. The Selah Rookery is located near the Roza reach of the Yakima River below Roza Dam which generally produces flows lower than most Yakima River reaches during poor water years. These low flows may inhibit fish passage and increase predation opportunities.

Large numbers of summer Chinook tags have been recovered over the last few years in the Selah Rookery (Figure 33). Beginning in 2013, some summer Chinook were released from a portable acclimation raceway at the Roza juvenile sampling facility (upstream of Selah; Figure 1). It is also possible that summer Chinook, acclimated at the nearby Stiles pond on the Naches River, could migrate to the Yakima River near the Selah rookery. Anecdotal evidence from the owner of the acclimation pond indicates that Herons congregate at the pond's release channel to the Naches River. These Herons are most likely from the Selah rookery.

The Wapato Wildlife area Great Blue Heron Rookery has produced the highest number of PIT recoveries when compared to all other Yakima Basin Rookeries. While Heron numbers in the rookery are high the overall difference in the Heron numbers when compared with other rookeries in the Basin is minimal. The high numbers of PIT recoveries in this rookery may be due to its location which is near to irrigation diversions and fish screening facilities. Fish diverted into these facilities are subjected to unfavorable flow conditions before being diverted back to the Yakima River via an underground pipe. Fish may become disoriented or severely injured during the diversion process making them susceptible to predation from the nearby Herons. PIT recoveries for summer Chinook migrating downstream in 2010 and 2011 were noticeably high at this rookery (Figure 34). Late release dates, low flows, and release location are the most likely factors related to the high mortality rates of these summer Chinook at the Wapato Rookery.

### *Fish Predation Index and Predator Control*

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

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

**Methods:**

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

During this project year, monthly multi-pass predator removal efforts (generally consistent with monitoringmethods.org methods 438) were conducted from March through August at Selah Gap to Union Gap (Section 1-4), Parker Dam to Toppenish (Sections 5-8), Toppenish to Granger (Sections 9-13), Benton (14-18), and Vangie (19-22) (Figure 35). Transects were approximately 1 mile sections separated by up to 1 mile and were chosen based on river flows (CFS) and ability to continue to survey these areas during low river water flows. Entire transects were sampled for presence of piscivorous fish. A comparative analysis of the multi-pass numbers for each transect was used to determine population numbers of piscivorous fish.

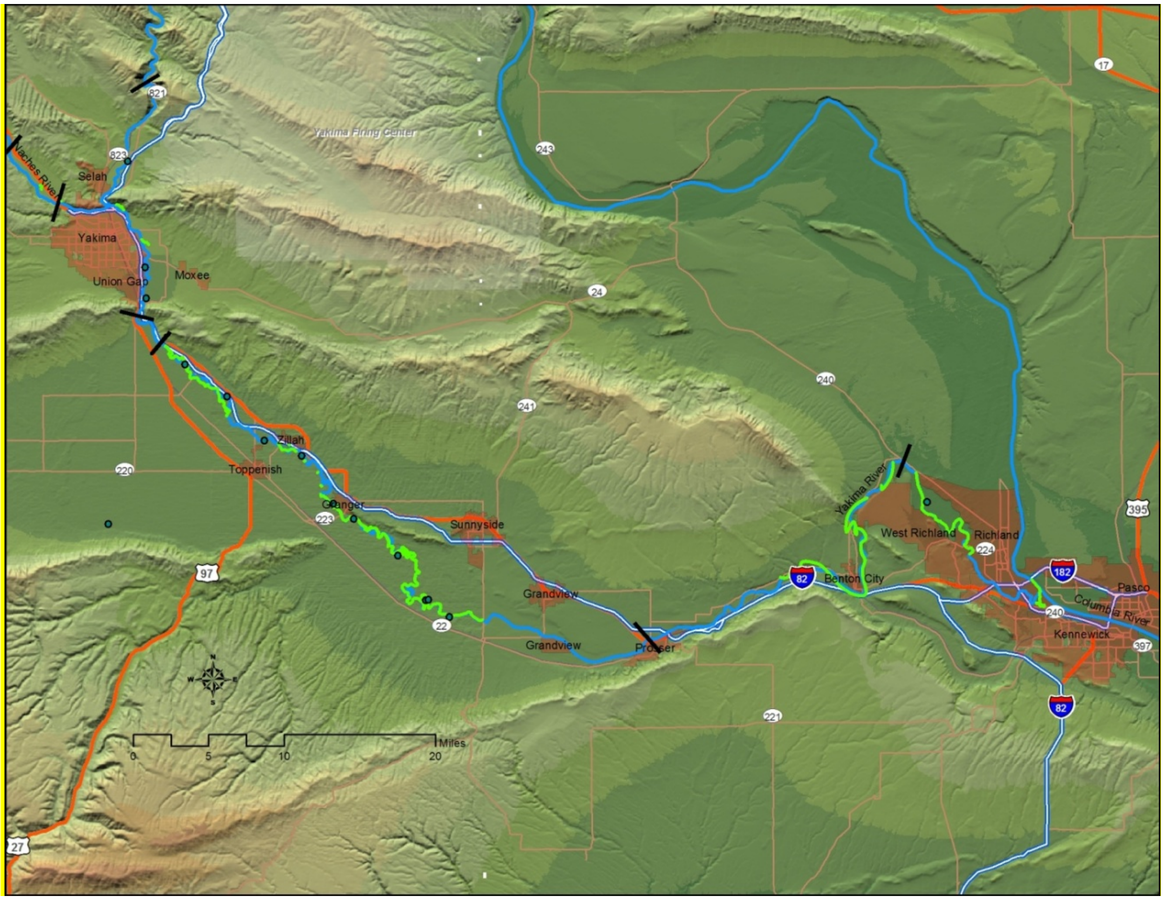


**Figure 35. Map of Yakima River Piscivorous Fish Populations Study Areas.**

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

Survey efforts for 2011 to present also included recording all fish species and their corresponding catch per unit effort for select areas of importance on the Yakima River. Included for the inclusive species monitoring is the Wapato reach, a section of the Yakima River, designated as the area (for the purpose of this report) between Union Gap at USGS River mile 107 to the boundary of the Yakama Indian

Reservation at USGS River mile 60. Additional sections of the Yakima River which the species monitoring incorporates are three sections at the Yakima River Delta which include an area of the Yakima River at USGS river mile 1 to the confluence at the Columbia River, and the Delta sections to the East and West of the Bateman Island Causeway (Figure 36).

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 36. Yakima River Delta Survey Areas.**

## Results and Discussion:

Wapato Reach fish species included the piscivorous Northern Pikeminnow and 10 other species of fish (Table 27). Relative catch numbers of the Northern Pikeminnow, for 2010 to present, were small compared to other fish species. Fish from the family *Catostomidae*, or suckers, were the highest relative catch for the Wapato reach (Figure 37). Salmonids were found in high abundance in the Wapato reach; catch abundance was dependent on time of year and is highest during the salmon smolt out-migration through the reach.

**Table 27. Wapato Reach of the Yakima River - Fish Species identified during surveys 2010-2015.**

Wapato Reach Fish Species

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

Northern Pike Minnow were the dominant piscivorous fish in reaches of the Yakima River above Prosser Dam. Catch and CPUE of Northern Pikeminnow can vary widely over time periods in this reach (Figure 38). While numbers vary over seasons it is evident that Northern Pikeminnow populations remain in high numbers over the course of the year.

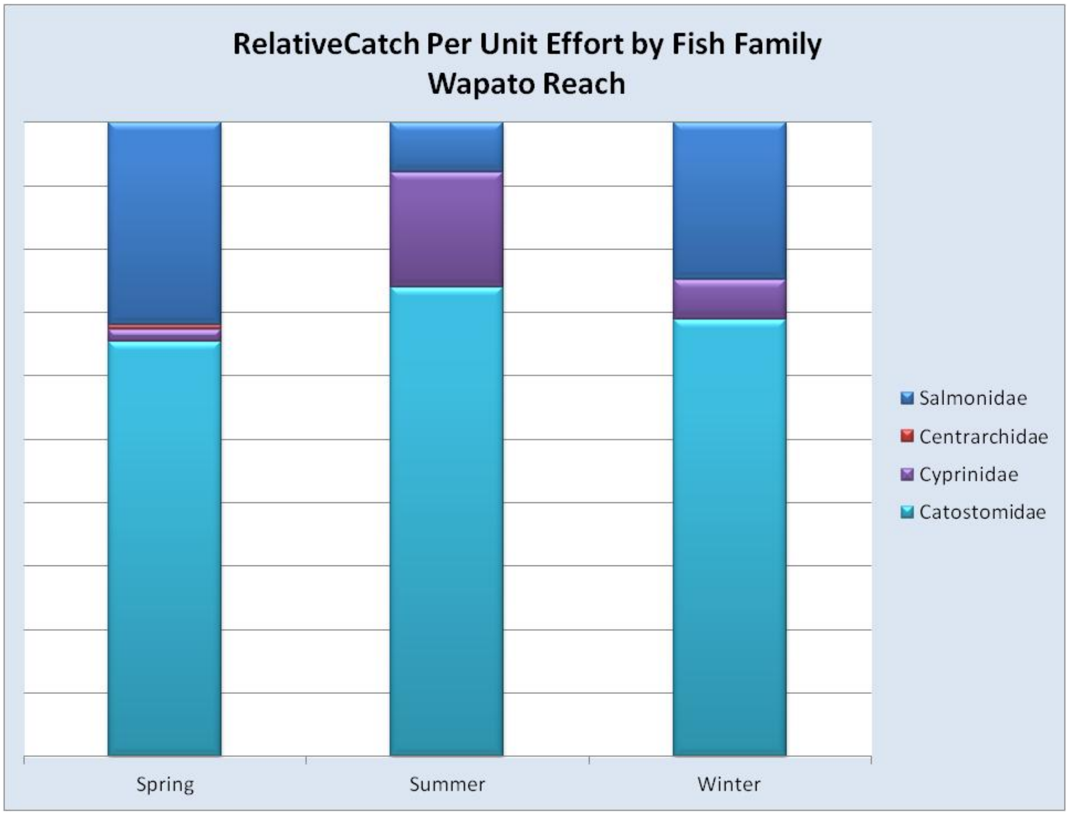


**Figure 37. Wapato Reach of the Yakima River – Relative catch per unit effort by fish family.**

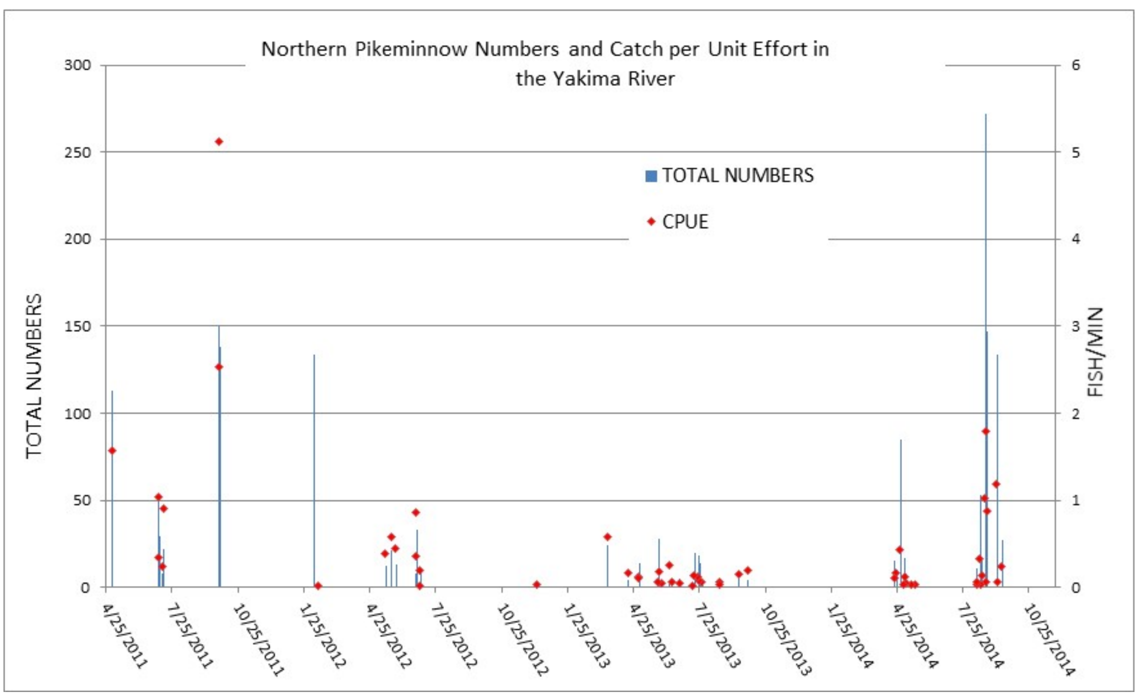


**Figure 38. Number and Catch per Unit Effort (CPUE) of Northern Pike Minnow observed in surveys of the Yakima River Wapato Reach. Data are from 2011-2014 surveys and display NPM presence over varying seasons.**

Large amounts of piscivorous fish were found to inhabit the Lower Yakima River, which is defined as that portion of the river between Prosser Dam and the confluence of the Yakima River with the Columbia River. During winter months high amounts of piscivorous fish, in particular NPM, were found in irrigation drains along the Yakima River. These drains remain highly productive over the winter months as their temperatures typically remain higher than the Yakima River and may range up to 10 degrees Celsius higher.

With increased catch success during the late summer months electro-fishing efforts were increased to maximize management efforts of introduced piscivorous fish species in the lower Yakima River. Smallmouth Bass were found in higher numbers in the lower river with a spike in presence during their spawning periods, between April 1 and July 1. Because of their abundance, Smallmouth Bass continue to be a target for population management to increase smolt survival. Catch and catch per unit effort (Figure 39) begins to rise in May and June as Smallmouth bass begin their migration from the Columbia River upstream in the Yakima River to spawn. The catch numbers for Smallmouth Bass in the Yakima River decreased in 2015 and Catch per unit effort fell to 3.1 fish per minute; this is down from 2014 with high of over 329 fish catch day and catch per unit effort near 3 fish per minute. 2015 was a year of extremely low flows which limited catch effort.

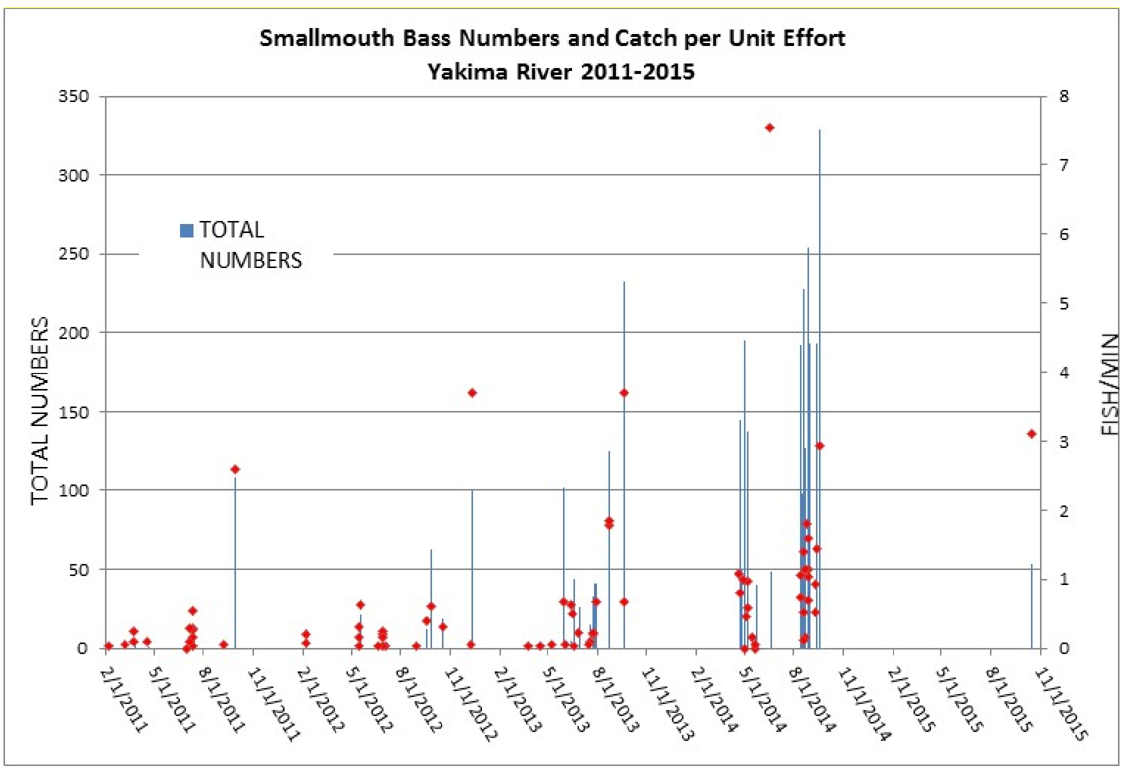


**Figure 39. Number and Catch per Unit Effort (CPUE) of Smallmouth Bass observed in surveys of the Lower Yakima River.**

Yakima River Delta surveys from 2010 to 2015 found 23 different fish species occupied the delta at varying temporal and spatial distributions (Table 28). This is twice the number of fish species in the Delta when compared to the fish species of the Wapato Reach. Many of the fish species in the delta are introduced, non-native fish and are a warm-water species of fish. These introduced fish are adapted to the highly altered water conditions, of increased temperatures and low dissolved oxygen, which the Yakima delta displays. Water temperatures may reach highs of 80 degrees Fahrenheit in the late summer months. Relative catch abundance in the Yakima Delta for the surveys shows a high number of fish from the families of: *Centrarchidae*, *Cyprinidae*, and *Ictaluridae* (Figure 40). These families are highly represented because of large numbers of piscivorous fish present in the delta. Smallmouth Bass, Largemouth Bass, and numerous catfish are present here and use the area for spawning and rearing of juveniles.

**Table 28. Yakima River Delta - Fish Species identified during surveys 2010-2015.**

Yakima River Delta Fish Species

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

When comparing the Wapato Reach Species/Relative Catch Abundance (Figure 37) to the Yakima Delta Species/Relative Catch Abundance (Figure 40) a glaring dissimilarity in the type of fish and their abundance between the two sections of the Yakima River is obvious. In the upper portion of the Yakima River, where natural attributes such as water temperature, riparian cover, nutrient loading, and flow that is closer to historical values the fish species consist of native species which are adapted to cold water conditions. In the lower section of the Yakima River and the Yakima River delta river attributes have been highly altered by: dams, irrigation diversions, water drawn for power, lowered flows, little riparian cover, irrigation water returned loaded with nutrients, and a blocked section of the river delta, fish species consist of a high number of introduced species many of which are piscivorous.

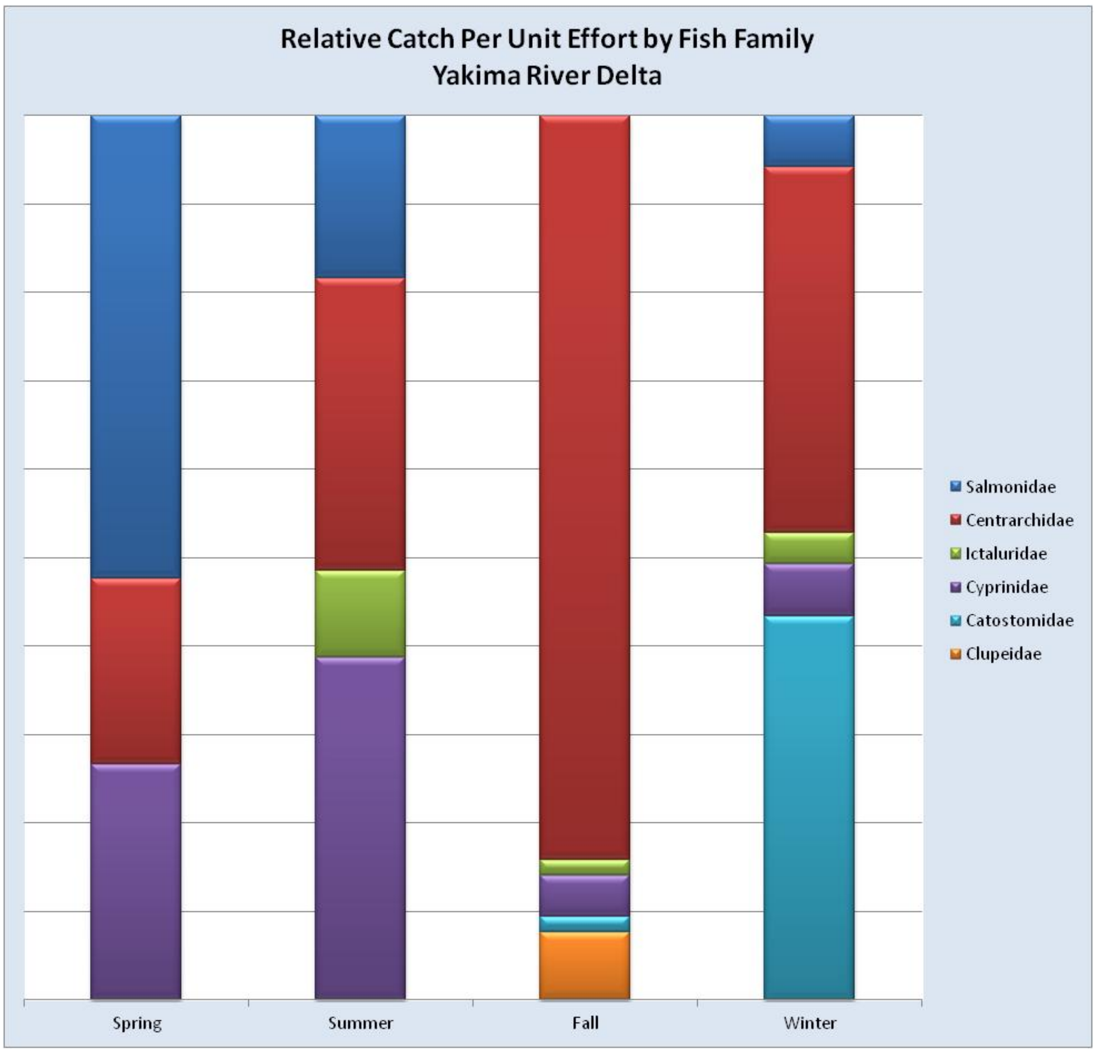


**Figure 40. Yakima River Delta – Relative catch per unit effort by fish family.**

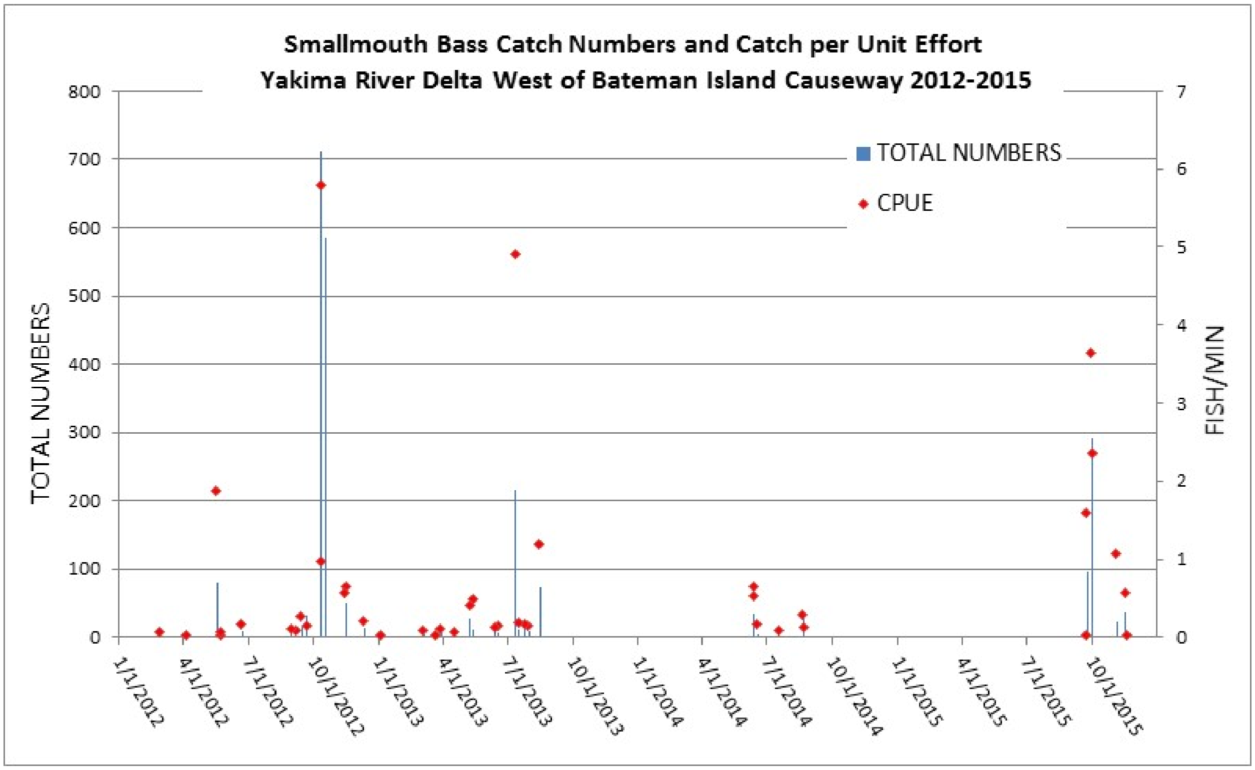


**Figure 41. Number and Catch per Unit Effort (CPUE) of Smallmouth Bass observed in surveys of the Yakima River Delta area (West of the Bateman Island Causeway).**

Smallmouth Bass in the delta of the Yakima River have been found in surprisingly high numbers. The Yakima delta at all times of the year contains some presence of Smallmouth Bass and during rearing times it becomes a haven for rearing Smallmouth Bass juveniles. In the autumn, times of extreme low water in the Delta have resulted in extremely high abundance and CPUE's of Smallmouth Bass (Figure 41).

Smallmouth Bass in the delta of the Yakima River, on the disconnected (east) side of the River by Bateman Island, were also found in high numbers (Figure 42), though considerably less than their presence on the west side of the causeway. Numbers on this side of the delta rise as temperatures in the Yakima River drop and Columbia River temperatures remain higher (as this side of delta is connected to the Columbia). Total catch numbers of smallmouth bass rise during the early winter months and CPUE can rise to near 1.5 fish per minute. This disconnected area of the Yakima River also rears large numbers of juvenile Largemouth bass during the fall and winter months. Also present is a significant spawning population of Brown Bullhead catfish.

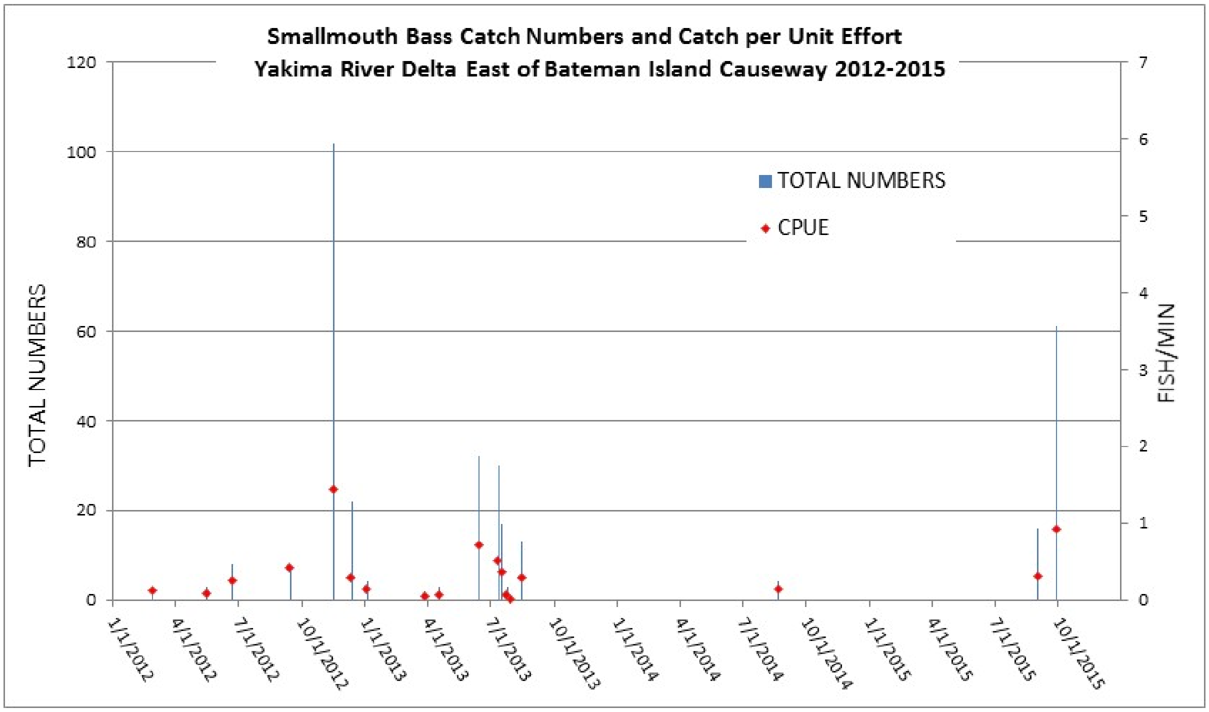


**Figure 42. Number and Catch per Unit Effort (CPUE) of Smallmouth Bass observed in surveys of the Yakima River Delta area (East of the Bateman Island Causeway).**

## Adaptive Management and Lessons Learned

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

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

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

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

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

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

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

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

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

7. Hatchery programs should be regularly evaluated at the local level using expertise across disciplines to collaboratively and iteratively develop appropriate solutions that address the unique problems and limiting factors encountered in each

subbasin or tributary that hosts a hatchery program. In the Yakima Basin, this is achieved with the annual Yakima Basin Aquatic Science and Management Conference, and we use the results to evaluate existing goals, objectives, and strategies and to adaptively manage projects in response to new information.

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# APPENDICES

A. Use of Data and Products

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

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

D. IntSTATS, Inc. Annual Report: Comparisons between Smolt-Trait Measures of Hatchery x Hatchery- and Natural x Natural-Brood Stock for Brood-Years 2002-2015 Upper Yakima Spring Chinook

E. IntSTATS, Inc. 2015 Annual Report: Smolt-to-Smolt Survival to McNary Dam of Yakima Fall and Summer Chinook

F. IntSTATS, Inc. Annual Report: 2015 Coho Smolt-to-Smolt Survival of Releases into the Yakima Basin

G. IntSTATS, Inc. Spring Chinook Release-to-Roza-Dam Smolt-to-Adult Survival: Comparison of Hatchery and Natural Origin Brood Stock

H. IntSTATS, Inc. Comparison of Salt-Water-Transfer Supplemented-Feed and Unsupplemented-Feed Treatments evaluated on Upper-Yakima Spring Chinook Natural Brood Smolt-to-Adult Survival for Smolt released in 2009 through 2011

# Appendix A: Use of Data & Products

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

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

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

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

- Automated integration of Prosser and Roza dam daily count data with Data Access in Real-Time (DART)
- Integration of PIT and CWT release and recovery data with PTAGIS, RMIS, and Fish Passage Center databases
- Production and support of data bases necessary to support BPA quarterly and annual reports (available via PISCES and BPA reports web site)
- Production and support of data bases necessary to support NPCC project proposals (available via CBfish.org)

Additional data is available on the ykfp.org web site and by email contact through the data managers (Yakima Basin, contact Bill Bosch, bbosch@yakama.com; Klickitat Basin, contact Michael Babcock, mbabcock@ykfp.org). Project data managers participated in the Coordinated Assessments process to develop pilot exchange templates for adult and juvenile abundance and productivity parameters. However, as documented in a letter from Phil Rigdon, Director of Natural Resources for the Yakama Nation to Phil Anderson Director of the Washington Department of Fish and Wildlife, dated 7Nov2012, the Yakama Nation would like to see the region develop strong, enforceable data sharing agreements before we can support broad population and unlimited use of and access to these regional databases with data from YN/YKFP projects. We remain concerned about the potential for misuse of project data obtained from existing regional databases.

# 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

2015 Annual Report

May 27, 2016

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# Acknowledgments

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

The core project team includes the following individuals: Dave Fast, Mark Johnston, Bill Bosch, David Lind, Paul Huffman, Joe Hoptowit, and a number of technicians from the YN; Charles Strom and a number of assistants from the CESRF; Andrew Murdoch, Steve Schroder, 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; Ray Brunson 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, 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. Patricia Smith is BPA's contracting officer and technical representative (COTR) for this project. David Byrnes preceded Patricia 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 2015. 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.

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).

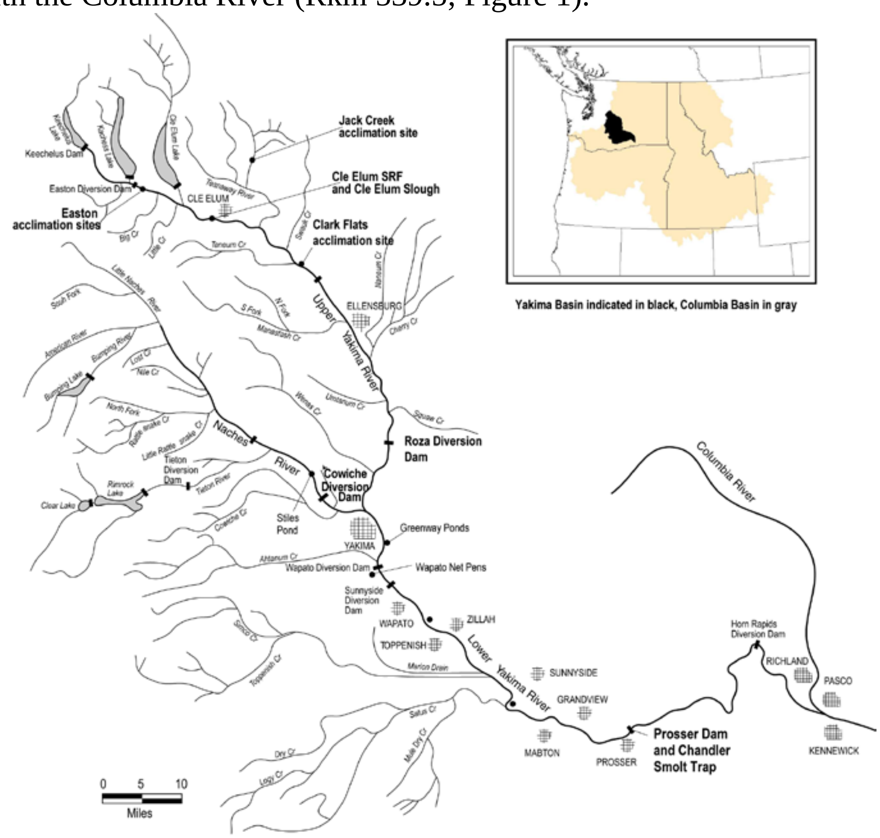


**Figure 1. Yakima River Basin.**

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).

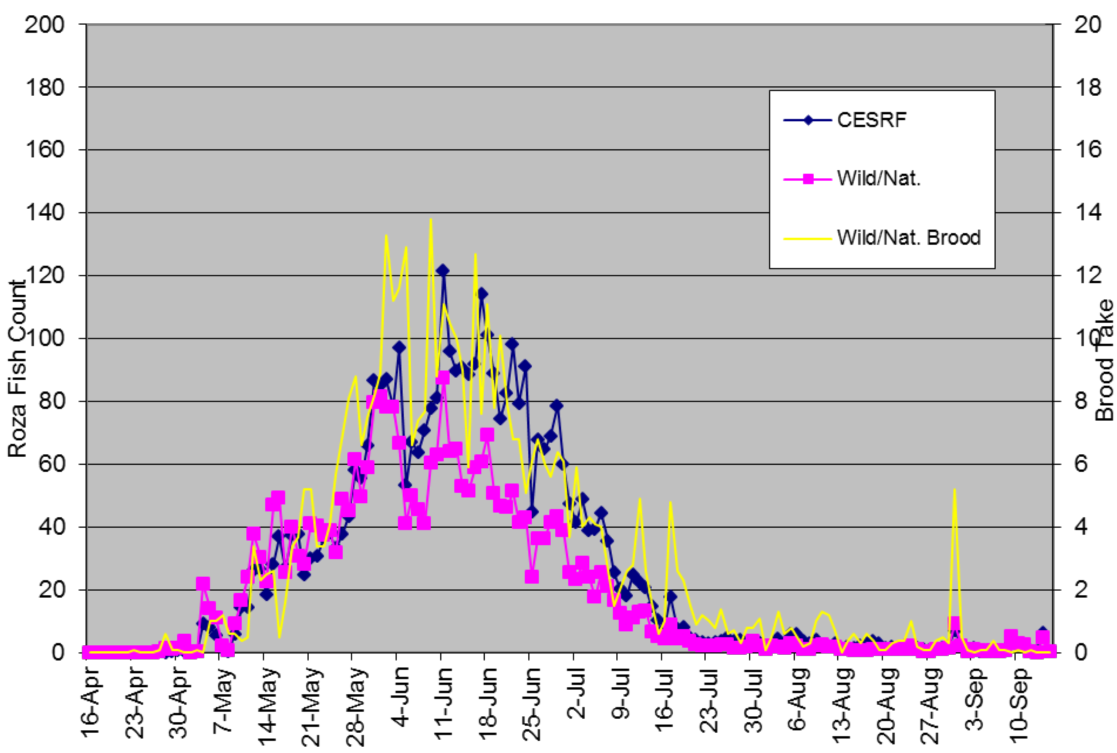


**Figure 2. Mean spring Chinook run timing and broodstock collection at Roza Dam, 2006-2015.**

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 migration period.

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

| | 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% |

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% |
| Mean[3] | 2,694 | 381 | 3,074 | 2,619 | 758 | 3,377 | 5,197 | 1,173 | 6,371 | 53.6% | 65.8% |

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

## Adult-to-adult Returns

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

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

| | River Mouth Run Size[1] | | | Harvest Below Prosser | Prosser Count | Harvest Above Prosser | Spawners Below Roza[2] | Roza Count | Roza Removals[3] | Est. Escapement | | Redd Counts | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Adults | Jacks | Total | | | | | | | Upper Y.R.[4] | Naches[5] | Upper Y.R. | Naches |
| 1988 | 3,919 | 327 | 4,246 | 333 | 3,913 | 111 | 60 | 1,575 | 235 | 1,340 | 2,167 | 424 | 490 |
| 1989 | 4,640 | 274 | 4,914 | 560 | 4,354 | 187 | 135 | 2,515 | 184 | 2,331 | 1,517 | 915 | 541 |
| 1990 | 4,280 | 92 | 4,372 | 131 | *2,255* | 532 | 282 | 2,047 | 31 | 2,016 | *1,380* | 678 | 464 |
| 1991 | 2,802 | 104 | 2,906 | 27 | 2,879 | 5 | 131 | | 40 | *1,583* | *1,121* | 582 | 460 |
| 1992 | 4,492 | 107 | 4,599 | 184 | 4,415 | 161 | 39 | 3,027 | 18 | 3,009 | 1,188 | 1,230 | 425 |
| 1993 | 3,800 | 119 | 3,919 | 44 | 3,875 | 85 | 56 | 1,869 | 0 | 1,869 | 1,865 | 637 | 554 |
| 1994 | 1,282 | 20 | 1,302 | 0 | 1,302 | 25 | 10 | 563 | 0 | 563 | 704 | 285 | 272 |
| 1995 | 526 | 140 | 666 | 0 | 666 | 79 | 9 | 355 | 0 | 355 | 223 | 114 | 104 |
| 1996 | 3,060 | 119 | 3,179 | 100 | 3,079 | 375 | 26 | 1,631 | 0 | 1,631 | 1,047 | 801 | 184 |
| 1997 | 3,092 | 81 | 3,173 | 0 | 3,173 | 575 | 20 | 1,445 | 261 | 1,184 | 1,133 | 413 | 339 |
| 1998 | 1,771 | 132 | 1,903 | 0 | 1,903 | 188 | 3 | 795 | 408 | 387 | 917 | 147 | 330 |
| 1999 | 1,513 | 1,268 | 2,781 | 8 | 2,773 | 596 | 55 | 1,704 | 738 | 966 | 418 | 212 | 186 |
| 2000 | 17,519 | 1,582 | 19,101 | 90 | 19,011 | 2,368 | 204 | 12,327 | 667 | 11,660 | 4,112 | 3,770 | 888 |
| 2001 | 21,225 | 2,040 | 23,265 | 1,793 | 21,472 | 2,838 | 286 | 12,516 | 718 | 11,798 | 5,829 | 3,226 | 1,192 |
| 2002 | 14,616 | 483 | 15,099 | 328 | 14,771 | 2,780 | 29 | 8,922 | 878 | 8,044 | 3,041 | 2,816 | 943 |
| 2003 | 4,868 | 2,089 | 6,957 | 59 | 6,898 | 381 | 83 | 3,842 | 584 | 3,258 | 2,592 | 868 | 935 |
| 2004 | 13,974 | 1,315 | 15,289 | 135 | 15,154 | 1,544 | 90 | 11,005 | 718 | 10,287 | 2,515 | 3,414 | 719 |
| 2005 | 8,059 | 699 | 8,758 | 34 | 8,724 | 440 | 28 | 6,352 | 667 | 5,685 | 1,904 | 2,009 | 574 |
| 2006 | 5,951 | 363 | 6,314 | 0 | 6,314 | 600 | 14 | 4,028 | 664 | 3,364 | 1,672 | 1,245 | 447 |
| 2007 | 2,968 | 1,335 | 4,303 | 10 | 4,293 | 269 | 13 | 3,025 | 716 | 2,309 | 986 | 722 | 313 |
| 2008 | 6,615 | 1,983 | 8,598 | 539 | 8,059 | 993 | 9 | 5,478 | 1,144 | 4,334 | 1,578 | 1,372 | 495 |
| 2009 | 7,441 | 4,679 | 12,120 | 1,517 | 10,603 | 836 | 18 | 8,633 | 1,595 | 7,038 | 1,117 | 1,575 | 482 |
| 2010 | 11,027 | 2,114 | 13,142 | 156 | 12,986 | 1,585 | 9 | 9,900 | 1,526 | 8,374 | 1,491 | 2,668 | 552 |
| 2011 | 13,398 | 4,561 | 17,960 | 909 | 17,051 | 3,471 | 0 | 10,520 | 1,936 | 8,584 | 3,060 | 1,898 | 580 |
| 2012 | 11,083 | 970 | 12,053 | 1,331 | 10,722 | 1,989 | 7 | 6,826 | 1,350 | 5,476 | 1,900 | 1,468 | 811 |
| 2013 | 7,101 | 3,144 | 10,245 | 1,191 | 9,054 | 1,462 | 171 | 6,053 | 1,240 | 4,813 | 1,369 | 648 | 376 |
| 2014 | 8,850 | 2,472 | 11,322 | 221 | 11,101 | 1,950 | 23 | 7,997 | 1,269 | 6,728 | 1,130 | 1,149 | 379 |
| 2015 | 8,795 | 556 | 9,351 | 83 | 9,268 | 732 | 0 | 6,433 | 967 | 5,466 | 2,103 | 1,321 | 614 |
| Mean[6] | 8,323 | 2,218 | 10,541 | 596 | 9,945 | 1,389 | 26 | 6,889 | 1,241 | 5,649 | 1,641 | 1,407 | 505 |

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 (2006-2015).

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 | | | |
| 2012 | 5,483 | 197 | | | | |
| 2013 | 4,984 | | | | | |
| 2014 | 6,751 | | | | | |
| 2015 | 5,466 | | | | | |
| Mean | 4,266 | 358 | 2,928 | 117 | 3,356 | 1.68 |

1. The mean jack proportion of spawning escapement from 1999-2015 was 0.22 (geometric mean 0.16).

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

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

| Brood Year | Estimated Spawners | Estimated Yakima R. Mouth Returns Age-3 | Age-4 | Age-5 | Age-6 | Total | Returns/ Spawner |
|---|---|---|---|---|---|---|---|
| 1984 | 383 | 110 | 706 | 564 | 0 | 1,381 | 3.60 |
| 1985 | 683 | 132 | 574 | 396 | 0 | 1,102 | 1.61 |
| 1986 | 2,666 | 68 | 712 | 499 | 15 | 1,294 | 0.49 |
| 1987 | 1,162 | 27 | 183 | 197 | 0 | 407 | 0.35 |
| 1988 | 1,340 | 32 | 682 | 828 | 0 | 1,542 | 1.15 |
| 1989 | 992 | 28 | 331 | 306 | 0 | 665 | 0.67 |
| 1990 | 954 | 24 | 170 | 74 | 0 | 269 | 0.28 |
| 1991 | 706 | 7 | 37 | 121 | 57 | 222 | 0.31 |
| 1992 | 852 | 29 | 877 | 285 | 0 | 1,191 | 1.40 |
| 1993 | 1,145 | 45 | 593 | 372 | 0 | 1,010 | 0.88 |
| 1994 | 474 | 14 | 164 | 164 | 0 | 343 | 0.72 |
| 1995 | 124 | 40 | 164 | 251 | 0 | 455 | 3.66 |
| 1996 | 887 | 179 | 3,983 | 1,620 | 0 | 5,782 | 6.52 |
| 1997 | 762 | 207 | 3,081 | 708 | 0 | 3,996 | 5.24 |
| 1998 | 503 | 245 | 1,460 | 1,128 | 0 | 2,833 | 5.63 |
| 1999 | 358[1] | 113 | 322 | 190 | 0 | 626 | 1.75 |
| 2000 | 3,862 | 71 | 2,060 | 215 | 0 | 2,346 | 0.61 |
| 2001 | 3,912 | 126 | 1,254 | 471 | 0 | 1,850 | 0.47 |
| 2002 | 1,861 | 59 | 753 | 153 | 0 | 965 | 0.52 |
| 2003 | 1,400 | 52 | 237 | 175 | 0 | 464 | 0.33 |
| 2004 | 2,197 | 107 | 875 | 218 | 0 | 1,200 | 0.55 |
| 2005 | 1,439 | 167 | 653 | 119 | 0 | 940 | 0.65 |
| 2006 | 1,163 | 192 | 834 | 254 | 0 | 1,280 | 1.10 |
| 2007 | 463 | 125 | 1,649 | 514 | 0 | 2,288 | 4.94 |
| 2008 | 1,074 | 414 | 827 | 290 | 0 | 1,531 | 1.42 |
| 2009 | 903 | 84 | 448 | 65 | 0 | 597 | 0.66 |
| 2010 | 1,207 | 209 | 653 | 198 | | 1,059 | 0.88 |
| 2011 | 2,476 | 137 | 1,088 | | | | |
| 2012 | 1,537 | 64 | | | | | |
| 2013 | 1,107 | | | | | | |
| 2014 | 915 | | | | | | |
| 2015 | 1,702 | | | | | | |
| Mean | 1,288 | 107 | 906 | 384 | 3 | 1,394 | 1.72 |

1. The mean jack proportion of spawning escapement from 1999-2015 was 0.12 (geometric mean 0.09).

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

| Brood Year | Estimated Spawners | Estimated Yakima R. Mouth Returns Age-3 | Age-4 | Age-5 | Age-6 | Total | Returns/ Spawner |
|---|---|---|---|---|---|---|---|
| 1984 | 187 | 54 | 301 | 458 | 0 | 813 | 4.36 |
| 1985 | 337 | 81 | 149 | 360 | 0 | 590 | 1.75 |
| 1986 | 1,457 | 36 | 134 | 329 | 11 | 509 | 0.35 |
| 1987 | 567 | 12 | 71 | 134 | 0 | 216 | 0.38 |
| 1988 | 827 | 19 | 208 | 661 | 5 | 892 | 1.08 |
| 1989 | 524 | 11 | 69 | 113 | 0 | 193 | 0.37 |
| 1990 | 425 | 15 | 113 | 84 | 0 | 213 | 0.50 |
| 1991 | 414 | 3 | 5 | 22 | 0 | 30 | 0.07 |
| 1992 | 335 | 23 | 157 | 237 | 0 | 417 | 1.24 |
| 1993 | 721 | 8 | 218 | 405 | 8 | 639 | 0.89 |
| 1994 | 230 | 7 | 36 | 16 | 0 | 59 | 0.26 |
| 1995 | 98 | 33 | 32 | 98 | 0 | 163 | 1.65 |
| 1996 | 159 | 30 | 176 | 760 | 0 | 967 | 6.07 |
| 1997 | 371 | 13 | 1,543 | 610 | 0 | 2,166 | 5.84 |
| 1998 | 414 | 120 | 766 | 1,136 | 0 | 2,022 | 4.88 |
| 1999 | 61 | 72 | 99 | 163 | 0 | 334 | 5.50 |
| 2000 | 250 | 60 | 163 | 110 | 0 | 333 | 1.33 |
| 2001 | 1,917 | 18 | 364 | 256 | 0 | 638 | 0.33 |
| 2002 | 1,180 | 19 | 279 | 257 | 0 | 555 | 0.47 |
| 2003 | 1,192 | 23 | 183 | 440 | 0 | 646 | 0.54 |
| 2004 | 318 | 121 | 52 | 33 | 0 | 206 | 0.65 |
| 2005 | 464 | 79 | 173 | 263[1] | 0 | 515 | 1.11 |
| 2006 | 509 | 45 | 172[1] | 451 | 0 | 668 | 1.31 |
| 2007 | 523 | 57[1] | 645 | 493 | 0 | 1,194 | 2.28 |
| 2008 | 504 | 239 | 461 | 465 | 0 | 1,165 | 2.31 |
| 2009 | 213 | 60 | 143 | 44 | 0 | 247 | 1.16 |
| 2010 | 285 | 172 | 326 | 173 | | 671 | 2.36 |
| 2011 | 584 | 71 | 646 | | | | |
| 2012 | 363 | 41 | | | | | |
| 2013 | 261 | | | | | | |
| 2014 | 216 | | | | | | |
| 2015 | 401 | | | | | | |
| Mean | 510 | 53 | 274 | 317 | 1 | 632 | 1.82 |

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

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

| Brood Year | Estimated Spawners | Estimated Yakima R. Mouth Returns Age-3 | Age-4 | Age-5 | Age-6 | Total | Returns/ Spawner |
|---|---|---|---|---|---|---|---|
| 1984 | 570 | 164 | 1,109 | 1,080 | 0 | 2,354 | 4.13 |
| 1985 | 1,020 | 213 | 667 | 931 | 0 | 1,811 | 1.77 |
| 1986 | 4,123 | 103 | 670 | 852 | 31 | 1,657 | 0.40 |
| 1987 | 1,729 | 39 | 231 | 400 | 0 | 669 | 0.39 |
| 1988 | 2,167 | 51 | 815 | 1,557 | 11 | 2,434 | 1.12 |
| 1989 | 1,517 | 39 | 332 | 371 | 0 | 741 | 0.49 |
| 1990 | 1,380 | 40 | 326 | 168 | 0 | 533 | 0.39 |
| 1991 | 1,121 | 10 | 32 | 144 | 127 | 314 | 0.28 |
| 1992 | 1,188 | 52 | 1,034 | 661 | 0 | 1,747 | 1.47 |
| 1993 | 1,865 | 53 | 603 | 817 | 17 | 1,489 | 0.80 |
| 1994 | 704 | 21 | 160 | 167 | 0 | 348 | 0.49 |
| 1995 | 223 | 73 | 201 | 498 | 0 | 771 | 3.46 |
| 1996 | 1,047 | 209 | 4,010 | 2,359 | 0 | 6,579 | 6.29 |
| 1997 | 1,133 | 220 | 4,644 | 1,377 | 0 | 6,241 | 5.51 |
| 1998 | 917 | 364 | 2,167 | 2,316 | 12 | 4,859 | 5.30 |
| 1999 | 418[1] | 185 | 369 | 279 | 0 | 833 | 1.99 |
| 2000 | 4,112 | 131 | 2,286 | 346 | 0 | 2,762 | 0.67 |
| 2001 | 5,829 | 144 | 1,598 | 785 | 0 | 2,526 | 0.43 |
| 2002 | 3,041 | 78 | 975 | 443 | 0 | 1,496 | 0.49 |
| 2003 | 2,592 | 75 | 387 | 1,028 | 0 | 1,489 | 0.57 |
| 2004 | 2,515 | 227 | 514 | 232 | 0 | 973 | 0.39 |
| 2005 | 1,904 | 246 | 845 | 174[2] | 0 | 1,264 | 0.66 |
| 2006 | 1,672 | 237 | 1,215[2] | 759 | 0 | 2,211 | 1.32 |
| 2007 | 986 | 182[2] | 2,239 | 1,033 | 0 | 3,454 | 3.50 |
| 2008 | 1,578 | 653 | 1,262 | 803 | 0 | 2,718 | 1.72 |
| 2009 | 1,117 | 144 | 542 | 116 | 0 | 802 | 0.72 |
| 2010 | 1,491 | 381 | 972 | 412 |  | 1,766 | 1.18 |
| 2011 | 3,060 | 208 | 1,693 |  |  |  |  |
| 2012 | 1,900 | 105 |  |  |  |  |  |
| 2013 | 1,369 |  |  |  |  |  |  |
| 2014 | 1,130 |  |  |  |  |  |  |
| 2015 | 2,103 |  |  |  |  |  |  |
| Mean | 1,798 | 160 | 1,139 | 745 | 8 | 2,031 | 1.70 |

1. The mean jack proportion of spawning escapement from 1999-2015 was 0.12 (geometric mean 0.09).
2. Age composition using only Naches survey samples in 2010 return year.

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

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

| Brood 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 | | | |
| 2012 | 374 | 221 | | | | |
| 2013 | 398 | | | | | |
| 2014 | 384 | | | | | |
| 2015 | 442 | | | | | |
| Mean | 468 | 1,016 | 3,565 | 115 | 4,825 | 7.84[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 2015, age composition of American River spring Chinook has averaged 1, 44, 54, and 1 percent age-3, -4, –5, and -6, respectively (Table 9). Naches system spring Chinook averaged 2, 61, 36 and 0.5 percent age-3, -4, –5 and -6, respectively (Table 10). The upper Yakima River natural origin fish averaged 8, 88, and 4 percent age-3, -4, and –5, respectively (Table 11). While these ages are biased toward the older age classes, we believe the bias is approximately equal across populations and is a good relative indicator of differences in age composition between populations. The data show distinct differences with the American River population having the oldest age of maturation, followed closely by the Naches system and then the upper Yakima River which has significantly more age-3's, fewer age-5's and no age-6 fish.

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

| Return | Males | | | | | Females | | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 3 | 4 | 5 | 6 | n | 3 | 4 | 5 | 6 | n | 3 | 4 | 5 | 6 |
| 1986 | | 23.8 | 76.2 | | 21 | | 8.9 | 86.7 | 4.4 | 45 | | 13.6 | 83.3 | 3.0 |
| 1987 | | 70.8 | 25.0 | 4.2 | 24 | | 42.9 | 57.1 | | 21 | | 57.8 | 40.0 | 2.2 |
| 1988 | | | 100.0 | | 1 | | 100.0 | | | 1 | | 33.3 | 66.7 | |
| 1989 | | 39.6 | 60.4 | | 48 | | 10.0 | 90.0 | | 50 | | 24.5 | 75.5 | |
| 1990 | 2.5 | 25.0 | 72.5 | | 40 | | 28.3 | 71.7 | | 46 | 1.2 | 26.7 | 72.1 | |
| 1991 | | 23.8 | 76.2 | | 42 | | 13.3 | 86.7 | | 60 | | 17.6 | 82.4 | |
| 1992 | | 71.2 | 23.1 | 5.8 | 52 | | 45.8 | 54.2 | | 48 | | 59.0 | 38.0 | 3.0 |
| 1993 | 4.8 | 14.3 | 81.0 | | 21 | | 8.0 | 92.0 | | 75 | 1.0 | 9.4 | 89.6 | |
| 1994 | | 44.4 | 55.6 | | 18 | | 50.0 | 46.7 | 3.3 | 30 | | 49.0 | 49.0 | 2.0 |
| 1995 | 14.3 | 14.3 | 71.4 | | 7 | | | 100.0 | | 13 | 5.0 | 5.0 | 90.0 | |
| 1996 | | 100.0 | | | 2 | | 83.3 | 16.7 | | 6 | | 87.5 | 12.5 | |
| 1997 | | 40.0 | 60.0 | | 5 | | 22.2 | 64.4 | 13.3 | 45 | | 24.0 | 64.0 | 12.0 |
| 1998 | | 12.1 | 87.9 | | 33 | | 6.6 | 93.4 | | 76 | | 8.3 | 91.7 | |
| 1999 | | 100.0 | | | 2 | | 40.0 | 40.0 | 20.0 | 5 | | 57.1 | 28.6 | 14.3 |
| 2000 | | 66.7 | 33.3 | | 15 | | 61.5 | 38.5 | | 13 | | 64.3 | 35.7 | |
| 2001 | | 65.6 | 34.4 | | 90 | | 67.9 | 32.1 | | 106 | | 67.0 | 33.0 | |
| 2002 | 1.7 | 53.4 | 44.8 | | 58 | | 56.4 | 43.6 | | 110 | 0.6 | 55.4 | 44.0 | |
| 2003 | | 8.1 | 91.9 | | 74 | | 7.9 | 92.1 | | 151 | | 8.0 | 92.0 | |
| 2004 | | 100.0 | | | 3 | | 20.0 | 80.0 | | 5 | | 50.0 | 50.0 | |
| 2005 | | 64.7 | 35.3 | | 17 | | 84.0 | 16.0 | | 25 | | 76.7 | 23.3 | |
| 2006 | | 61.5 | 38.5 | | 13 | | 48.6 | 51.4 | | 35 | | 52.1 | 47.9 | |
| 2007 | 10.5 | 31.6 | 57.9 | | 19 | | 43.8 | 56.3 | | 48 | 3.0 | 40.3 | 56.7 | |
| 2008 | | 8.7 | 91.3 | | 23 | | 11.9 | 88.1 | | 42 | | 10.6 | 89.4 | |
| 2009 | 30.8 | 69.2 | | | 13 | | 75.0 | 25.0 | | 16 | 13.8 | 72.4 | 13.8 | |
| 2010 | | | | | | | No carcasses were sampled | | | | | | | |
| 2011 | | 40.0 | 60.0 | | 10 | | 63.2 | 36.8 | | 19 | | 58.8 | 41.2 | |
| 2012 | | 50.0 | 50.0 | | 14 | | 47.8 | 52.2 | | 16 | | 48.3 | 51.7 | |
| 2013 | 11.1 | 11.1 | 77.8 | | 9 | | 26.9 | 73.1 | | 26 | 2.9 | 22.9 | 74.3 | |
| 2014 | 5.6 | 77.8 | 16.7 | | 18 | | 90.9 | 9.1 | | 33 | 2.0 | 86.3 | 11.8 | |
| 2015 | 7.4 | 74.1 | 18.5 | | 27 | | 78.3 | 21.7 | | 46 | 2.7 | 76.7 | 20.5 | |
| Mean | 3.1 | 47.0 | 49.6 | 0.3 | | | 42.9 | 55.7 | 1.4 | | 1.1 | 43.5 | 54.1 | 1.3 |

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

| Return | Males | | | | | Females | | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 3 | 4 | 5 | 6 | n | 3 | 4 | 5 | 6 | n | 3 | 4 | 5 | 6 |
| 1986 | 5.0 | 60.0 | 30.0 | 5.0 | 20 | | 33.3 | 64.3 | 2.4 | 42 | 1.6 | 41.9 | 53.2 | 3.2 |
| 1987 | 5.9 | 76.5 | 11.8 | 5.9 | 17 | | 69.0 | 31.0 | | 42 | 1.7 | 71.7 | 25.0 | 1.7 |
| 1988 | | 50.0 | 50.0 | | 8 | 5.6 | 38.9 | 55.6 | | 18 | 3.3 | 46.7 | 50.0 | |
| 1989 | | 70.2 | 29.8 | | 47 | | 34.9 | 63.5 | 1.6 | 63 | | 50.0 | 49.1 | 0.9 |
| 1990 | 9.1 | 60.6 | 30.3 | | 33 | 10.7 | 57.1 | 32.1 | | 28 | 11.1 | 57.1 | 31.7 | |
| 1991 | 4.3 | 52.2 | 43.5 | | 23 | | 13.3 | 86.7 | | 45 | 1.5 | 26.5 | 72.1 | |
| 1992 | 4.0 | 80.0 | 12.0 | 4.0 | 25 | | 70.6 | 29.4 | | 34 | 1.7 | 75.0 | 21.7 | 1.7 |
| 1993 | | 42.3 | 57.7 | | 26 | | 18.6 | 81.4 | | 43 | | 28.6 | 71.4 | |
| 1994 | | 50.0 | 50.0 | | 4 | | 30.0 | 70.0 | | 10 | | 35.7 | 64.3 | |
| 1995 | | 25.0 | 75.0 | | 4 | | 28.6 | 71.4 | | 7 | | 33.3 | 66.7 | |
| 1996 | | 100.0 | | | 17 | | 75.0 | 25.0 | | 16 | | 87.9 | 12.1 | |
| 1997 | 2.9 | 70.6 | 20.6 | 5.9 | 34 | | 57.1 | 36.7 | 6.1 | 49 | 1.2 | 62.7 | 30.1 | 6.0 |
| 1998 | | 29.4 | 70.6 | | 17 | | 27.9 | 72.1 | | 43 | | 30.6 | 69.4 | |
| 1999 | 12.5 | 62.5 | 25.0 | | 8 | | 33.3 | 66.7 | | 9 | 5.9 | 47.1 | 47.1 | |
| 2000 | 1.7 | 94.9 | 3.4 | | 59 | | 92.2 | 7.8 | | 77 | 0.7 | 93.4 | 5.9 | |
| 2001 | 1.7 | 72.9 | 25.4 | | 59 | | 61.0 | 39.0 | | 118 | 0.6 | 65.2 | 34.3 | |
| 2002 | 2.1 | 78.7 | 19.1 | | 47 | | 63.3 | 36.7 | | 98 | 0.7 | 66.9 | 32.4 | |
| 2003 | 7.8 | 25.0 | 67.2 | | 64 | 1.1 | 18.9 | 80.0 | | 95 | 3.8 | 21.4 | 74.8 | |
| 2004 | 7.5 | 87.5 | 5.0 | | 40 | | 91.3 | 8.7 | | 92 | 2.3 | 89.5 | 8.3 | |
| 2005 | | 81.8 | 18.2 | | 11 | | 83.8 | 16.2 | | 37 | | 83.7 | 16.3 | |
| 2006 | | 61.5 | 38.5 | | 13 | | 61.5 | 38.5 | | 13 | | 61.5 | 38.5 | |
| 2007 | | 75.0 | 25.0 | | 4 | | 57.9 | 42.1 | | 19 | | 60.9 | 39.1 | |
| 2008 | 36.4 | 45.5 | 18.2 | | 11 | | 87.0 | 13.0 | | 23 | 11.8 | 73.5 | 14.7 | |
| 2009 | 7.1 | 71.4 | 21.4 | | 14 | | 76.9 | 23.1 | | 26 | 2.4 | 73.2 | 24.4 | |
| 2010 | | 100.0 | | | 9 | | 81.8 | 18.2 | | 22 | 3.0 | 84.8 | 12.1 | |
| 2011 | 11.5 | 80.8 | 7.7 | | 26 | | 78.9 | 21.1 | | 19 | 6.3 | 81.3 | 12.5 | |
| 2012 | 11.8 | 41.2 | 47.1 | | 17 | | 64.4 | 33.3 | | 45 | 4.8 | 58.7 | 36.5 | |
| 2013 | 15.4 | 53.8 | 30.8 | | 13 | | 56.3 | 43.8 | | 16 | 6.7 | 56.7 | 36.7 | |
| 2014 | | 86.7 | 13.3 | | 15 | | 92.3 | 7.7 | | 26 | | 90.9 | 9.1 | |
| 2015 | | 100.0 | | | 10 | | 75.0 | 25.0 | | 16 | | 84.6 | 15.4 | |
| Mean | 4.9 | 66.2 | 28.2 | 0.7 | | 0.7 | 57.7 | 41.3 | 0.3 | | 2.4 | 61.4 | 35.8 | 0.4 |

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

| Return | Males | | | | Females | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 3 | 4 | 5 | n | 3 | 4 | 5 | n | 3 | 4 | 5 |
| 1986 | | 100.0 | | 12 | | 94.1 | 5.9 | 51 | | 95.2 | 4.8 |
| 1987 | 10.8 | 81.5 | 7.7 | 65 | | 77.8 | 22.2 | 126 | 3.7 | 79.1 | 17.3 |
| 1988 | 22.5 | 70.0 | 7.5 | 40 | 10.4 | 75.0 | 14.6 | 48 | 15.6 | 73.3 | 11.1 |
| 1989 | 0.8 | 93.1 | 6.2 | 130 | 0.4 | 95.5 | 4.1 | 246 | 0.5 | 94.7 | 4.8 |
| 1990 | 6.3 | 88.4 | 5.3 | 95 | 2.1 | 94.8 | 3.1 | 194 | 3.4 | 92.8 | 3.8 |
| 1991 | 9.1 | 87.3 | 3.6 | 55 | | 89.2 | 10.8 | 111 | 3.0 | 88.6 | 8.4 |
| 1992 | 2.4 | 91.6 | 6.0 | 167 | | 98.1 | 1.9 | 315 | 0.8 | 95.9 | 3.3 |
| 1993 | 4.0 | 90.0 | 6.0 | 50 | 0.9 | 92.0 | 7.1 | 112 | 1.9 | 91.4 | 6.8 |
| 1994 | | 100.0 | | 16 | | 98.0 | 2.0 | 50 | | 98.5 | 1.5 |
| 1995 | 20.0 | 80.0 | | 5 | | 100.0 | | 12 | 5.6 | 94.4 | |
| 1996 | 9.1 | 89.6 | 1.3 | 154 | 0.7 | 98.2 | 1.1 | 282 | 3.7 | 95.2 | 1.1 |
| 1997 | | 96.7 | 3.3 | 61 | | 96.3 | 3.7 | 136 | | 96.4 | 3.6 |
| 1998 | 14.3 | 85.7 | | 21 | 5.3 | 86.8 | 7.9 | 38 | 8.5 | 86.4 | 5.1 |
| 1999 | 61.8 | 38.2 | | 34 | | 94.4 | 5.6 | 36 | 31.0 | 66.2 | 2.8 |
| 2000 | 2.8 | 97.2 | | 72 | | 100.0 | | 219 | 1.0 | 99.0 | |
| 2001 | 2.7 | 89.2 | 8.1 | 37 | | 83.6 | 16.4 | 122 | 0.6 | 85.0 | 14.4 |
| 2002 | 2.4 | 58.5 | 39.0 | 41 | 3.6 | 87.5 | 8.9 | 56 | 5.1 | 73.7 | 21.2 |
| 2003 | 60.5 | 39.5 | | 38 | 4.3 | 82.6 | 13.0 | 23 | 39.3 | 55.7 | 4.9 |
| 2004 | 6.5 | 93.5 | | 108 | 0.0 | 99.5 | 0.5 | 198 | 2.3 | 97.4 | 0.3 |
| 2005 | 9.2 | 90.0 | | 120 | 1.4 | 97.2 | 1.4 | 214 | 4.2 | 94.7 | 1.2 |
| 2006 | 23.7 | 74.6 | | 59 | 2.3 | 96.5 | 1.2 | 86 | 11.0 | 87.6 | 1.4 |
| 2007 | 17.1 | 82.9 | | 76 | 0.9 | 93.8 | 5.4 | 112 | 7.4 | 89.4 | 3.2 |
| 2008 | 11.8 | 88.2 | | 34 | 0.0 | 95.8 | 4.2 | 24 | 6.9 | 91.4 | 1.7 |
| 2009 | 47.7 | 52.3 | | 111 | 2.2 | 95.6 | 2.2 | 45 | 34.6 | 64.7 | 0.6 |
| 2010 | 27.7 | 72.3 | | 47 | | 100.0 | | 71 | 11.0 | 89.0 | |
| 2011 | 37.5 | 62.5 | | 16 | | 100.0 | | 27 | 13.6 | 86.4 | |
| 2012 | 25.0 | 75.0 | | 8 | 7.7 | 92.3 | | 13 | 14.3 | 85.7 | |
| 2013 | | | | | | 100.0 | | 8 | | 100.0 | |
| 2014 | 3.3 | 96.7 | | 30 | | 100.0 | | 59 | 1.1 | 98.9 | |
| 2015 | | | | | | no surveys | | | | | |
| 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 2001-2015 compared to 11, 86, and 3.5 percent respectively for their wild/natural counterparts in the upper Yakima for the same years (Table 11). The observed difference in age distribution between wild/natural and CESRF sampled on the spawning grounds may be due in part to the carcass recovery bias described above. A better comparison of age distribution between upper Yakima wild/natural and CESRF fish is from samples collected at Roza Dam which are displayed in Tables 13 and 14. However, it must be noted that jacks (age-3 males) were collected at Roza in proportion to run size from 1997 to 1999, but from 2000-present we have attempted to collect them at their mean brood representation rate (approximately 7% of the spawning population). Age-3 females do occur rarely in the Upper Yakima population, but it is likely that the data in Table 13 slightly over-represent the proportion of age-3 females due to human error associated with scale collection, handling, processing, and management and entry of these data.

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

| Return | Males | | | | Females | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 3 | 4 | 5 | n | 3 | 4 | 5 | n | 3 | 4 | 5 |
| 2001 | 23.5 | 76.5 | | 34 | 0.9 | 99.1 | | 108 | 6.3 | 93.7 | |
| 2002 | 8.0 | 81.3 | 10.7 | 75 | | 88.6 | 11.4 | 140 | 2.8 | 86.2 | 11.1 |
| 2003 | 100.0 | | | 1 | | 100.0 | | 1 | 50.0 | 50.0 | |
| 2004 | 9.5 | 90.5 | | 21 | | 98.0 | 2.0 | 51 | 2.8 | 95.8 | 1.4 |
| 2005 | 42.9 | 57.1 | | 21 | | 90.9 | 4.5 | 22 | 23.3 | 74.4 | 2.3 |
| 2006 | 26.7 | 73.3 | | 15 | | 100.0 | | 43 | 6.9 | 93.1 | |
| 2007 | 66.7 | 33.3 | | 6 | | 100.0 | | 11 | 23.5 | 76.5 | |
| 2008 | | | | 0 | | 100.0 | | 1 | | 100.0 | |
| 2009 | 60.0 | 40.0 | | 5 | | | | 0 | 60.0 | 40.0 | |
| 2010 | 28.6 | 71.4 | | 7 | | 100.0 | | 11 | 11.1 | 88.9 | |
| 2011 | 37.5 | 62.5 | | 16 | 4.5 | 95.5 | | 22 | 18.4 | 81.6 | |
| 2012 | | 100.0 | | 4 | 5.3 | 94.7 | | 19 | 4.3 | 95.7 | |
| 2013 | | 100.0 | | 1 | | 100.0 | | 7 | | 100.0 | |
| 2014 | | 100.0 | | 20 | | 100.0 | | 62 | 1.2 | 98.8 | |
| 2015 | | | | | | no surveys | | | | | |
| 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 |
| Mean | 19.1 | 76.7 | 4.2 | | 0.2 | 94.5 | 5.3 | | 9.3 | 86.0 | 4.7 |

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

| Return | Males | | | | Females | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 3 | 4 | 5 | n | 3 | 4 | 5 | n | 3 | 4 | 5 |
| 2001 | 12.5 | 87.5 | | 40 | | 100.0 | | 75 | 5.1 | 94.9 | |
| 2002 | 14.7 | 83.8 | 1.5 | 68 | | 98.3 | 1.7 | 115 | 5.5 | 92.9 | 1.6 |
| 2003 | 36.1 | 34.7 | 29.2 | 72 | | 61.2 | 38.8 | 67 | 18.7 | 47.5 | 33.8 |
| 2004 | 19.6 | 80.4 | | 46 | | 100.0 | | 60 | 8.5 | 91.5 | |
| 2005 | 17.8 | 75.6 | 6.7 | 45 | | 88.1 | 11.9 | 59 | 7.7 | 82.7 | 9.6 |
| 2006 | 18.3 | 80.0 | 1.7 | 60 | | 100.0 | | 65 | 8.8 | 90.4 | 0.8 |
| 2007 | 33.3 | 60.8 | 5.9 | 51 | | 87.5 | 12.5 | 56 | 15.9 | 74.8 | 9.3 |
| 2008 | 50.0 | 50.0 | | 40 | | 100.0 | | 56 | 20.8 | 79.2 | |
| 2009 | 25.4 | 71.2 | 3.4 | 59 | 1.2 | 97.6 | 1.2 | 84 | 11.2 | 86.7 | 2.1 |
| 2010 | 27.9 | 72.1 | | 61 | | 99.0 | 1.0 | 100 | 10.6 | 88.8 | 0.6 |
| 2011 | 21.2 | 72.7 | 6.1 | 66 | 0.9 | 97.2 | 1.9 | 107 | 8.7 | 87.9 | 3.5 |
| 2012 | 13.0 | 85.2 | 1.9 | 54 | | 97.0 | 3.0 | 101 | 4.5 | 92.9 | 2.6 |
| 2013 | 17.9 | 80.6 | 1.5 | 67 | 1.1 | 96.7 | 2.2 | 92 | 8.2 | 89.9 | 1.9 |
| 2014 | 31.9 | 66.0 | 2.1 | 47 | 0.0 | 100.0 | 0.0 | 33 | 18.8 | 80.0 | 1.3 |
| 2015 | 33.3 | 66.7 | 0.0 | 27 | 0.0 | 100.0 | 0.0 | 33 | 12.0 | 86.7 | 1.3 |
| Mean | 24.9 | 71.2 | 4.0 | | 0.2 | 94.8 | 4.9 | | 11.0 | 84.4 | 4.6 |

## Sex Composition

In the American River, the mean proportion of males to females in wild/natural carcasses sampled on the spawning grounds from 1986-2015 was 41:59 for age-4 and 32:68 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 26:74 for age-5 fish (Table 16). In the upper Yakima River, the mean proportion of males to females was 33:67 for age-4 and 23:77 for age-5 fish (Table 17).

For upper Yakima fish collected at Roza Dam for brood stock or research purposes from 1997-2015, the mean proportion of males to females was 38:62 and 36:64 for age-4 fish from the wild/natural and CESRF populations, respectively (Tables 19 and 20). For these same samples, the mean proportion of males to females was 36:64 and 41:59 for age-5 fish from the wild/natural and CESRF populations (excluding years with very small age-5 sample sizes), respectively (Tables 19 and 20). For adult fish, the mean proportion of males to females in spawning ground carcass recoveries was substantially lower than the ratio found at RAMF (Tables 17 and 19), indicating that sex ratios estimated from hatchery origin carcass recoveries were biased due to female carcasses being recovered at higher rates than male carcasses (Knudsen et al, 2003 and 2004). Again, despite these biases, we believe these data are good relative indicators of differences in sex composition between populations and between years.

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

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

| Return | Age-3 | | Age-4 | | Age-5 | | Age-6 | |
|---|---|---|---|---|---|---|---|---|
| Year | M | F | M | F | M | F | M | F |
| 1986 | | | 55.6 | 44.4 | 29.1 | 70.9 | | 100.0 |
| 1987 | | | 65.4 | 34.6 | 33.3 | 66.7 | 100.0 | |
| 1988 | | | 0.0 | 100.0 | 100.0 | 0.0 | | |
| 1989 | | | 79.2 | 20.8 | 39.2 | 60.8 | | |
| 1990 | 100.0 | | 43.5 | 56.5 | 46.8 | 53.2 | | |
| 1991 | | | 55.6 | 44.4 | 38.1 | 61.9 | | |
| 1992 | | | 62.7 | 37.3 | 31.6 | 68.4 | 100.0 | |
| 1993 | 100.0 | | 33.3 | 66.7 | 19.8 | 80.2 | | |
| 1994 | | | 34.8 | 65.2 | 41.7 | 58.3 | | 100.0 |
| 1995 | 100.0 | | 100.0 | 0.0 | 27.8 | 72.2 | | |
| 1996 | | | 28.6 | 71.4 | 0.0 | 100.0 | | |
| 1997 | | | 16.7 | 83.3 | 9.4 | 90.6 | | 100.0 |
| 1998 | | | 44.4 | 55.6 | 29.0 | 71.0 | | |
| 1999 | | | 50.0 | 50.0 | 0.0 | 100.0 | | 100.0 |
| 2000 | | | 55.6 | 44.4 | 50.0 | 50.0 | | |
| 2001 | | | 45.0 | 55.0 | 47.7 | 52.3 | | |
| 2002 | 100.0 | | 33.3 | 66.7 | 35.1 | 64.9 | | |
| 2003 | | | 33.3 | 66.7 | 32.9 | 67.1 | | |
| 2004 | | | 75.0 | 25.0 | 0.0 | 100.0 | | |
| 2005 | | | 34.4 | 65.6 | 60.0 | 40.0 | | |
| 2006 | | | 32.0 | 68.0 | 21.7 | 78.3 | | |
| 2007 | 100.0 | | 22.2 | 77.8 | 28.9 | 71.1 | | |
| 2008 | | | 28.6 | 71.4 | 36.2 | 63.8 | | |
| 2009 | | | 42.9 | 57.1 | 0.0 | 100.0 | | |
| 2010 | | | No carcasses were sampled | | | | | |
| 2011 | | | 25.0 | 75.0 | 46.2 | 53.8 | | |
| 2012 | | | 24.1 | 75.9 | 22.6 | 77.4 | | |
| 2013 | | | 12.5 | 87.5 | 26.9 | 73.1 | | |
| 2014 | | | 31.8 | 68.2 | 50.0 | 50.0 | | |
| 2015 | | | 35.7 | 64.3 | 33.3 | 66.7 | | |
| mean | | | 41.4 | 58.6 | 32.3 | 67.7 | | |

**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 | | | 33.3 | 66.7 | | 100.0 | | |
| 2011 | 100.0 | | 58.3 | 41.7 | 33.3 | 66.7 | | |
| 2012 | 66.7 | 33.3 | 19.4 | 80.6 | 34.8 | 65.2 | | |
| 2013 | 100.0 | | 43.8 | 56.3 | 36.4 | 63.6 | | |
| 2014 | | | 35.1 | 64.9 | 50.0 | 50.0 | | |
| 2015 | | | 45.5 | 54.5 | | 100.0 | | |
| mean | | | 41.6 | 58.4 | 26.4 | 73.6 | | |

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

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

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

| Return | Age-3 | | Age-4 | | Age-5 | |
|---|---|---|---|---|---|---|
| Year | M | F | M | F | M | F |
| 2001 | 88.9 | 11.1 | 19.5 | 80.5 | | |
| 2002 | 100.0 | | 33.0 | 67.0 | 33.3 | 66.7 |
| 2003 | 100.0 | | | 100.0 | | |
| 2004 | 100.0 | | 27.5 | 72.5 | | 100.0 |
| 2005 | 90.0 | 10.0 | 37.5 | 62.5 | | 100.0 |
| 2006 | 100.0 | | 20.4 | 79.6 | | |
| 2007 | 100.0 | | 15.4 | 84.6 | | |
| 2008 | | | | 100.0 | | |
| 2009 | 100.0 | | 100.0 | | | |
| 2010 | 100.0 | | 31.3 | 68.8 | | |
| 2011 | 85.7 | 14.3 | 32.3 | 67.7 | | |
| 2012 | | | 18.2 | 81.8 | | |
| 2013 | | | 12.5 | 87.5 | | |
| 2014 | | | 24.4 | 75.6 | | |
| 2015 | | | no surveys | | | |
| 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 |
| mean | 98.2 | 1.8 | 38.2 | 61.8 | 36.4 | 63.6 |

**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 | 35.3 | 64.7 | | |
| mean | 98.6 | 1.4 | 35.9 | 64.1 | 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 77 cm for age-3, -4, and -5 males, and averaged 63 and 73 cm for age-4 and -5 females, respectively, from carcasses sampled on the spawning grounds in the American River from 1996-2015 (Table 21). In the Naches River, mean POHP lengths averaged 42, 61, 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 2001-2015, CESRF fish returning to the upper Yakima have been generally smaller in size-at-age than their wild/natural counterparts (Tables 23-28).

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

| | Males | | | | | | | | Females | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Return | Age 3 | | Age 4 | | Age 5 | | Age 6 | | Age 4 | | Age 5 | | Age 6 | |
| Year | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP |
| 1986 | | | 5 | 57.1 | 16 | 80.9 | | | 4 | 65.8 | 39 | 75.2 | 2 | 74.0 |
| 1987 | | | 17 | 58.0 | 6 | 80.8 | 1.0 | 86.0 | 9 | 64.5 | 12 | 76.9 | | |
| 1988 | | | | | 1 | 79.0 | | | 1 | 63.0 | | | | |
| 1989 | | | 19 | 61.1 | 29 | 77.4 | | | 5 | 63.0 | 45 | 73.5 | | |
| 1990 | 1 | 41.0 | 10 | 63.6 | 29 | 77.3 | | | 13 | 62.5 | 33 | 73.6 | | |
| 1991 | | | 10 | 59.5 | 32 | 77.1 | | | 8 | 65.1 | 52 | 73.4 | | |
| 1992 | | | 37 | 60.6 | 12 | 76.2 | 3.0 | 86.7 | 22 | 64.1 | 26 | 76.4 | | |
| 1993 | 1 | 47.0 | 3 | 64.0 | 17 | 80.2 | | | 6 | 63.7 | 69 | 75.5 | | |
| 1994 | | | 8 | 67.3 | 10 | 83.0 | | | 15 | 70.8 | 14 | 76.4 | 1 | 85.0 |
| 1995 | 1 | 44.4 | 1 | 70.0 | 4 | 83.5 | | | | | 12 | 76.4 | | |
| | | POHP | | POHP | | POHP | | POHP | | POHP | | POHP | | POHP |
| 1996 | | | 2 | 56.3 | | | | | 5 | 59.0 | 1 | 67.0 | | |
| 1997[1] | | | 2 | 62.0 | 1 | 63.0 | | | 4 | 62.8 | 14 | 64.4 | 5 | 71.0 |
| 1998 | | | 4 | 58.3 | 29 | 79.1 | | | 5 | 64.0 | 71 | 73.4 | | |
| 1999 | | | 2 | 50.5 | | | | | 2 | 61.0 | 2 | 73.0 | 1 | 77.0 |
| 2000 | | | 10 | 57.9 | 5 | 83.2 | | | 8 | 63.9 | 5 | 76.2 | | |
| 2001 | | | 59 | 65.9 | 31 | 77.6 | | | 72 | 63.6 | 34 | 73.0 | | |
| 2002 | 1 | 40.0 | 31 | 63.0 | 26 | 77.3 | | | 62 | 64.4 | 48 | 74.7 | | |
| 2003 | | | 6 | 63.0 | 68 | 79.4 | | | 12 | 64.3 | 139 | 76.7 | | |
| 2004 | | | 3 | 56.0 | | | | | 1 | 58.0 | 4 | 77.5 | | |
| 2005 | | | 11 | 60.6 | 6 | 80.2 | | | 21 | 62.6 | 4 | 74.8 | | |
| 2006 | | | 8 | 60.8 | 5 | 75.4 | | | 17 | 61.8 | 18 | 71.7 | | |
| 2007 | 2 | 37.0 | 6 | 62.8 | 11 | 76.5 | | | 21 | 60.0 | 27 | 73.3 | | |
| 2008 | | | 2 | 67.5 | 21 | 83.1 | | | 5 | 67.4 | 37 | 78.9 | | |
| 2009 | 4 | 44.0 | 9 | 68.3 | | | | | 12 | 62.6 | 4 | 69.8 | | |
| 2010 | | | No samples | | | | | | | No samples | | | | |
| 2011 | | | 4 | 65.5 | 6 | 82.8 | | | 12 | 65.8 | 7 | 75.9 | | |
| 2012 | | | 7 | 64.1 | 7 | 77.3 | | | 22 | 63.7 | 24 | 74.3 | | |
| 2013 | 1 | 34.0 | 1 | 56.0 | 7 | 70.1 | | | 7 | 65.7 | 18 | 70.3 | | |
| 2014 | 1 | 36.0 | 14 | 61.1 | 3 | 66.7 | | | 30 | 61.2 | 3 | 63.3 | | |
| 2015 | 2 | 42.0 | 20 | 63.4 | 5 | 77.4 | | | 36 | 61.3 | 10 | 71.2 | | |
| Mean[2] | | 38.8 | | 61.2 | | 76.6 | | | | 62.8 | | 72.6 | | 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 1996-2015 post-eye to hypural plate lengths.

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

| | Males | | | | | | | | Females | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Return | Age 3 | | Age 4 | | Age 5 | | Age 6 | | Age 3 | | Age 4 | | Age 5 | | Age 6 | |
| Year | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP | Count | MEHP |
| 1986 | 1 | 45.0 | 12 | 62.7 | 6 | 74.3 | 1.0 | 80.0 | | | 14 | 64.5 | 27 | 73.6 | 1 | 83.5 |
| 1987 | 1 | 37.0 | 12 | 64.2 | 2 | 80.5 | 1.0 | 94.0 | | | 29 | 67.9 | 13 | 75.7 | | |
| 1988 | | | 4 | 62.0 | 4 | 74.6 | | | 1 | 45.0 | 7 | 69.1 | 10 | 73.6 | | |
| 1989 | | | 33 | 58.4 | 14 | 77.5 | | | | | 22 | 61.7 | 40 | 73.2 | 1 | 75.0 |
| 1990 | 3 | 53.0 | 20 | 59.4 | 10 | 75.9 | | | 3 | 51.7 | 16 | 60.9 | 9 | 73.7 | | |
| 1991 | 1 | 31.0 | 12 | 56.3 | 10 | 72.8 | | | | | 6 | 62.5 | 39 | 71.1 | | |
| 1992 | 1 | 42.0 | 20 | 58.8 | 3 | 72.3 | 1.0 | 83.0 | | | 24 | 62.4 | 10 | 71.7 | | |
| 1993 | | | 11 | 60.0 | 15 | 77.7 | | | | | 8 | 63.3 | 35 | 72.5 | | |
| 1994 | | | 2 | 62.5 | 2 | 77.0 | | | | | 3 | 63.7 | 7 | 73.1 | | |
| 1995 | | | 1 | 59.0 | 3 | 73.0 | | | | | 2 | 64.0 | 5 | 73.8 | | |
| | | POHP | | POHP | | POHP | | POHP | | POHP | | POHP | | POHP | | POHP |
| 1996 | | | 17 | 58.1 | | | | | | | 12 | 60.3 | 4 | 69.6 | | |
| 1997[1] | 1 | 39.0 | 24 | 59.8 | 4 | 71.5 | 2.0 | 78.0 | | | 28 | 60.0 | 15 | 68.6 | 1 | 75.0 |
| 1998 | | | 5 | 57.8 | 12 | 75.0 | | | | | 12 | 61.1 | 31 | 71.6 | | |
| 1999 | 1 | 40.0 | 5 | 61.2 | 2 | 73.0 | | | | | 3 | 58.7 | 6 | 75.0 | | |
| 2000 | 1 | 35.0 | 56 | 58.2 | 2 | 84.0 | | | | | 71 | 59.5 | 6 | 72.8 | | |
| 2001 | 1 | 45.0 | 43 | 61.4 | 15 | 73.4 | | | | | 72 | 62.2 | 46 | 74.5 | | |
| 2002 | 1 | 40.0 | 37 | 63.6 | 9 | 77.3 | | | | | 62 | 62.4 | 36 | 71.8 | | |
| 2003 | 5 | 41.4 | 16 | 62.2 | 43 | 79.4 | | | 1 | 41.0 | 18 | 62.8 | 76 | 75.6 | | |
| 2004 | 3 | 46.0 | 35 | 59.8 | 2 | 74.5 | | | | | 84 | 61.5 | 8 | 75.8 | | |
| 2005 | | | 9 | 60.1 | 2 | 78.0 | | | | | 31 | 61.7 | 6 | 71.7 | | |
| 2006 | | | 8 | 56.9 | 5 | 76.0 | | | | | 8 | 63.8 | 5 | 71.2 | | |
| 2007 | | | 3 | 61.3 | 1 | 67.0 | | | | | 11 | 56.9 | 8 | 72.1 | | |
| 2008 | 4 | 42.0 | 5 | 59.6 | 2 | 81.5 | | | | | 20 | 62.0 | 3 | 78.7 | | |
| 2009 | 1 | 43.0 | 10 | 67.9 | 3 | 76.3 | | | | | 20 | 63.9 | 6 | 73.2 | | |
| 2010 | | | 9 | 60.3 | | | | | | | 18 | 62.6 | 4 | 72.0 | | |
| 2011 | 3 | 44.3 | 21 | 61.9 | 2 | 78.0 | | | | | 15 | 60.4 | 4 | 76.8 | | |
| 2012 | 2 | 51.5 | 7 | 67.3 | 8 | 75.8 | | | 1 | 41.0 | 29 | 61.6 | 15 | 71.1 | | |
| 2013 | 2 | 37.0 | 7 | 56.1 | 4 | 75.0 | | | | | 9 | 58.7 | 7 | 71.3 | | |
| 2014 | | | 13 | 61.8 | 2 | 71.0 | | | | | 24 | 56.7 | 2 | 67.5 | | |
| 2015 | | | 10 | 59.3 | | | | | | | 12 | 60.4 | 4 | 65.8 | | |
| Mean[2] | | 42.0 | | 60.7 | | 75.7 | | 78.0 | | 41.0 | | 60.9 | | 72.3 | | 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 1996-2015 post-eye to hypural plate lengths.

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

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

[1] Mean of mean values for 1996-2015 post-eye to hypural plate lengths.

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

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

| 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 | 39.7 | 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 |
| Mean | | 43.2 | | 59.7 | | 70.4 | | | | 59.8 | | 68.3 |

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

| Return | Males | | | | | | Females | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age 3 | | Age 4 | | Age 5 | | Age 3 | | Age 4 | | Age 5 | |
| Year | Count | POHP | Count | POHP | Count | POHP | Count | POHP | Count | POHP | Count | POHP |
| 2001 | | | 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 |
| Mean | | 41.2 | | 59.5 | | 72.9 | | | | 59.3 | | 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.**

| | 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 | 39.6 | 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 |
| Mean | | 43.2 | | 61.1 | | 71.8 | | 50.8 | | 60.7 | | 69.9 |

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

| | 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 |
| Mean | | 41.5 | | 60.3 | | 69.8 | | 51.4 | | 59.9 | | 70.1 |

[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).

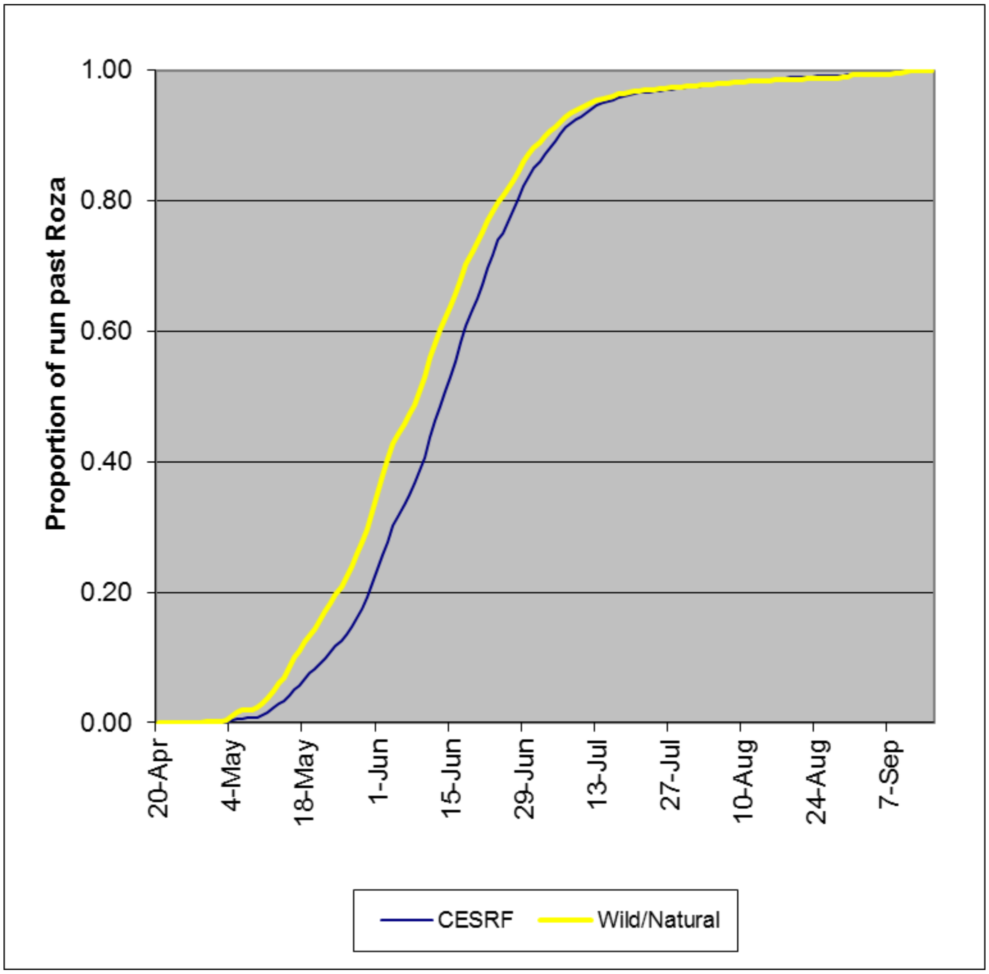


**Figure 3. Proportionate passage timing at Roza Dam of wild/natural and CESRF adult spring Chinook (including jacks), 2006-2015.**

**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 |

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 |
| Mean | 15-Aug | 12-Sep | 25-Sep | 22-Sep |

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

## Redd Counts and Distribution

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

| | Upper Yakima River System | | | | Naches River System | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Mainstem[1] | Cle Elum | Teanaway | Total | American | Naches[1] | Bumping | Little Naches | Total |
| 1981 | 237 | 57 | 0 | 294 | 72 | 64 | 20 | 16 | 172 |
| 1982 | 610 | 30 | 0 | 640 | 11 | 25 | 6 | 12 | 54 |
| 1983 | 387 | 15 | 0 | 402 | 36 | 27 | 11 | 9 | 83 |
| 1984 | 677 | 31 | 0 | 708 | 72 | 81 | 26 | 41 | 220 |
| 1985 | 795 | 153 | 3 | 951 | 141 | 168 | 74 | 44 | 427 |
| 1986 | 1,716 | 77 | 0 | 1,793 | 464 | 543 | 196 | 110 | 1,313 |
| 1987 | 968 | 75 | 0 | 1,043 | 222 | 281 | 133 | 41 | 677 |
| 1988 | 369 | 74 | 0 | 443 | 187 | 145 | 111 | 47 | 490 |
| 1989 | 770 | 192 | 6 | 968 | 187 | 200 | 101 | 53 | 541 |
| 1990 | 727 | 46 | 0 | 773 | 143 | 159 | 111 | 51 | 464 |
| 1991 | 568 | 62 | 0 | 630 | 170 | 161 | 84 | 45 | 460 |
| 1992 | 1,082 | 164 | 0 | 1,246 | 120 | 155 | 99 | 51 | 425 |
| 1993 | 550 | 105 | 1 | 656 | 214 | 189 | 88 | 63 | 554 |
| 1994 | 226 | 64 | 0 | 290 | 89 | 93 | 70 | 20 | 272 |
| 1995 | 105 | 12 | 0 | 117 | 46 | 25 | 27 | 6 | 104 |
| 1996 | 711 | 100 | 3 | 814 | 28 | 102 | 29 | 25 | 184 |
| 1997 | 364 | 56 | 0 | 420 | 111 | 108 | 72 | 48 | 339 |
| 1998 | 123 | 24 | 1 | 148 | 149 | 104 | 54 | 23 | 330 |
| 1999 | 199 | 24 | 1 | 224 | 27 | 95 | 39 | 25 | 186 |
| 2000 | 3,349 | 466 | 21 | 3,836 | 54 | 483 | 278 | 73 | 888 |
| 2001 | 2,910 | 374 | 21 | 3,305 | 392 | 436 | 257 | 107 | 1,192 |
| 2002 | 2,441 | 275 | 110 | 2,826 | 366 | 226 | 262 | 89 | 943 |
| 2003 | 772 | 87 | 31 | 890 | 430 | 228 | 216 | 61 | 935 |
| 2004 | 2,985 | 330 | 129 | 3,444 | 91 | 348 | 205 | 75 | 719 |
| 2005 | 1,717 | 287 | 15 | 2,019 | 140 | 203 | 163 | 68 | 574 |
| 2006 | 1,092 | 100 | 58 | 1,250 | 136 | 163 | 115 | 33 | 447 |
| 2007 | 665 | 51 | 10 | 726 | 166 | 60 | 60 | 27 | 313 |
| 2008 | 1,191 | 137 | 47 | 1,375 | 158 | 165 | 102 | 70 | 495 |
| 2009 | 1,349 | 197 | 33 | 1,579 | 92 | 159 | 163 | 68 | 482 |
| 2010 | 2,199 | 219 | 253 | 2,671 | 173 | 171 | 168 | 40 | 552 |
| 2011 | 1,663 | 171 | 64 | 1,898 | 212 | 145 | 175 | 48 | 580 |
| 2012 | 1,276 | 125 | 69 | 1,470 | 337 | 196 | 189 | 89 | 811 |
| 2013 | 552 | 85 | 34 | 671 | 170 | 66 | 85 | 55 | 376 |
| 2014 | 962 | 138 | 53 | 1,153 | 129 | 65 | 158 | 27 | 379 |
| 2015 | 1,258 | 39 | 24 | 1,321 | 239 | 177 | 152 | 46 | 614 |
| Mean | 1,073 | 127 | 28 | 1,228 | 165 | 172 | 117 | 49 | 503 |

[1] Including minor tributaries.

**Homing**

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

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

## Straying

The regional PTAGIS (PIT tag) and RMIS (CWT) databases were queried in late December 2015 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% | 3,123 | | | 2,663 | 1 | 0.04% |
| 2010[2] | 207 | 5 | 2.42% | 4,735 | 2 | 0.04% | 3,241 | | |
| 2011[3] | 179 | 28 | 15.64% | | | | | | |
| 2012[4] | 10 | | | | | | | | |

[1] All marked fish observed in spawning ground carcass surveys in the Naches Basin are assumed to be CESRF fish.
[2] Age 5 data are preliminary.
[3] Through age 4 only and data are preliminary. Water temperature in the lower Yakima River was greater than 70$^{o}$ F on average from May 29 to Aug. 29, 2015 which likely caused many fish to seek cooler water in other parts of the Columbia Basin.
[4] Through age 3 only and data are preliminary.

## CESRF Spawning and Survival

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

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

where

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

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

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

| Brood Year | Total Collected | Total Morts. | PreSpawn Survival | No. Fish Spawned[1] Males[2] | Females | % BKD Loss | Total Egg Take | Live Eggs | % Egg Loss[3] | Fry Ponded[4] | Live-Egg-Fry Survival | Smolts Released | Fry-Smolt Survival | Live-Egg-Smolt Survival |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 261 | 23 | 91.2% | 106 | 132 | 2.6% | 500,750 | 463,948 | 7.3% | 413,211 | 98.5% | 386,048 | 93.4% | 91.9% |
| 1998 | 408 | 70 | 82.8% | 140 | 198 | 1.4% | 739,802 | 664,125 | 10.2% | 627,481 | 98.7% | 589,648 | 94.0% | 92.7% |
| 1999 | 738[5] | 24 | 96.7% | 213 | 222 | 2.7% | 818,816 | 777,984 | 5.0% | 781,872 | 97.3% | 758,789 | 97.0% | 94.5% |
| 2000 | 567 | 61 | 89.2% | 170 | 278 | 9.2% | 916,292 | 851,128 | 7.1% | 870,328 | 97.3% | 834,285 | 95.9% | 93.4% |
| 2001 | 595 | 171 | 71.3% | 145 | 223 | 53.2% | 341,648 | 316,254 | 7.4% | 380,880 | 98.6% | 370,236 | 97.2% | 96.1% |
| 2002 | 629 | 89 | 85.9% | 125 | 261 | 10.0% | 919,776 | 817,841 | 11.1% | 783,343 | 98.0% | 749,067 | 95.6% | 93.6% |
| 2003 | 441 | 54 | 87.8% | 115 | 200 | 0.0% | 856,574 | 787,933 | 8.0% | 761,990 | 98.4% | 735,959 | 96.6% | 95.0% |
| 2004 | 597 | 70 | 88.3% | 125 | 245 | 0.4% | 873,815 | 806,375 | 7.7% | 776,941 | 97.8% | 691,109 | 89.0% | 87.0% |
| 2005 | 526 | 57 | 89.2% | 136 | 241 | 0.0% | 907,199 | 835,890 | 7.9% | 796,559 | 98.1% | 769,484 | 96.6% | 94.7% |
| 2006 | 519 | 45 | 91.3% | 122 | 239 | 1.7% | 772,357 | 703,657 | 8.9% | 631,691 | 97.3% | 574,361 | 90.9% | 88.3% |
| 2007 | 473 | 49 | 89.6% | 149 | 216 | 0.9% | 798,729 | 760,189 | 4.8% | 713,814 | 98.9% | 676,602 | 94.8% | 93.7% |
| 2008 | 480 | 38 | 92.1% | 151 | 253 | 2.0% | 915,563 | 832,938 | 9.0% | 809,862 | 99.0% | 752,109 | 97.3% | 96.3% |
| 2009 | 486 | 57 | 88.3% | 142 | 219 | 1.4% | 850,404 | 848,339 | 0.2% | 770,706 | 98.2% | 744,170 | 96.6% | 94.6% |
| 2010 | 483 | 20 | 95.9% | 102 | 193 | 0.5% | 787,953 | 753,464 | 4.4% | 726,325 | 98.9% | 702,751 | 96.8% | 95.6% |
| 2011 | 455 | 28 | 93.8% | 103 | 197 | 0.0% | 798,229 | 765,221 | 4.1% | 721,197 | 98.1% | 684,481 | 94.9% | 93.0% |
| 2012 | 363 | 14 | 96.1% | 111 | 209 | 0.0% | 819,775 | 788,605 | 3.8% | 737,705 | 98.2% | 712,036 | 96.5% | 94.7% |
| 2013 | 385 | 15 | 96.1% | 153 | 179 | 0.6% | 683,484 | 658,796 | 3.6% | 613,493 | 98.9% | 575,156 | 93.8% | 92.6% |
| 2014 | 384 | 39 | 89.8% | 133 | 188 | 0.0% | 679,374 | 639,989 | 5.8% | 636,092 | 96.5% | 599,908 | 94.3% | 91.1% |
| 2015 | 436 | 116 | 73.4% | 128 | 182 | 0.5% | 654,361 | 615,189 | 6.0% | 613,796 | 97.0% | | | |
| Mean | 486 | 55 | 88.9% | 135 | 214 | 4.6% | 770,258 | 720,414 | 6.4% | 693,015 | 98.1% | 661,456 | 95.1% | 93.3% |

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

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

| Brood Year | Total Collected | Total Morts. | PreSpawn Survival | No. Fish Spawned[1] Males[2] | Females | % BKD Loss | Total Egg Take[9] | Live Eggs[10] | % Egg Loss[3] | Fry Ponded[4] | Live-Egg-Fry Survival | Smolts Released | Fry-Smolt Survival | Live-Egg-Smolt Survival |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 201 | 22 | 89.1% | 26 | 72 | 4.2% | 258,226 | 100,011 | 7.8% | 91,300 | 98.2% | 87,837 | 96.2% | 94.4% |
| 2003 | 143 | 12 | 91.6% | 30 | 51 | 0.0% | 219,901 | 83,128 | 7.3% | 91,204 | 98.8% | 88,733 | 97.3% | 96.1% |
| 2004 | 126 | 19 | 84.9% | 22 | 49 | 0.0% | 187,406 | 94,659 | 5.9% | 100,567 | 98.3% | 94,339 | 93.8% | 92.2% |
| 2005 | 109 | 6 | 94.5% | 26 | 45 | 0.0% | 168,160 | 89,066 | 12.2% | 92,903 | 98.1% | 90,518 | 97.4% | 95.6% |
| 2006 | 136 | 21 | 84.6% | 28 | 41 | 2.4% | 112,576 | 80,121 | 8.6% | 74,735 | 97.6% | 68,434 | 91.6% | 89.4% |
| 2007 | 110 | 15 | 86.4% | 26 | 35 | 0.0% | 125,755 | 90,162 | 3.2% | 96,912 | 99.2% | 94,663 | 97.7% | 96.9% |
| 2008 | 194 | 10 | 94.8% | 51 | 67 | 1.5% | 247,503 | 106,122 | 5.1% | 111,797 | 98.9% | 97,196 | 97.4% | 96.4% |
| 2009 | 164 | 24 | 85.4% | 30 | 38 | 0.0% | 148,593 | 91,994 | 0.8% | 91,221 | 98.3% | 88,771 | 97.3% | 95.6% |
| 2010 | 162 | 9 | 94.4% | 29 | 55 | 1.8% | 215,814 | 94,925 | 8.4% | 96,144 | 97.9% | 92,030 | 95.7% | 93.7% |
| 2011 | 166 | 7 | 95.8% | 28 | 49 | 0.0% | 188,075 | 89,107 | 4.5% | 88,852 | 98.4% | 84,701 | 95.3% | 93.8% |
| 2012 | 140 | 8 | 94.3% | 29 | 42 | 0.0% | 148,932 | 95,438 | 2.0% | 94,031 | 98.8% | 90,680 | 96.4% | 95.3% |
| 2013 | 186 | 5 | 97.3% | 38 | 43 | 0.0% | 155,383 | 80,534 | 2.9% | 75,842 | 98.2% | 71,599 | 94.4% | 92.7% |
| 2014 | 86 | 11 | 87.2% | 21 | 29 | 0.0% | 104,121 | 74,843 | 1.6% | 91,702 | 97.2% | 85,322 | 93.0% | 90.4% |
| 2015 | 61 | 23 | 62.3% | 15 | 22 | 13.6% | 66,238 | 64,646 | 2.4% | 62,625 | 96.9% | | | |
| Mean | 142 | 14 | 88.8% | 29 | 46 | 1.7% | 167,620 | 158,135 | 5.2% | 89,988 | 98.2% | 87,294 | 95.7% | 94.1% |

See footnotes for Table 33 above.

**Female BKD Profiles**

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

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

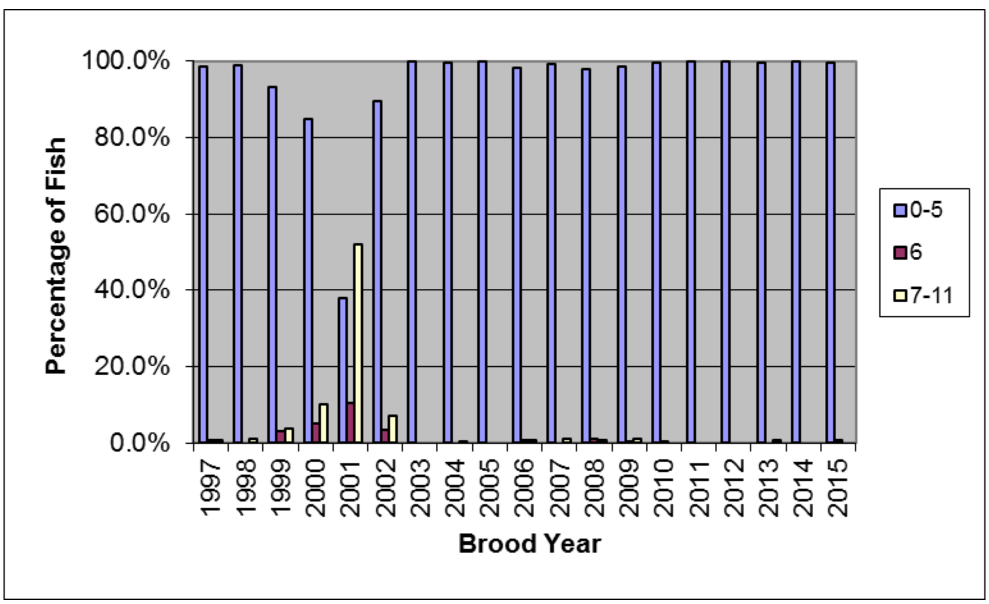


**Figure 4. Proportion of wild/natural females spawned at CESRF by BKD rank, 1997 – present.**

### Fecundity

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

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

| | Wild/Natural (SN) | | | | | | CESRF (HC) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brood | Age-3 | | Age-4 | | Age-5 | | Age-3 | | Age-4 | | Age-5 | |
| Year | N | Fecundity | N | Fecundity | N | Fecundity | N | Fecundity | N | Fecundity | N | Fecundity |
| 1997 | | | 105 | 3,842.0 | 4 | 4,069.9 | | | | | | |
| 1998 | 2[1] | 3,908.9 | 161 | 3,730.3 | 15 | 4,322.5 | | | | | | |
| 1999 | 3[1] | 4,470.4 | 183 | 3,968.1 | 14 | 4,448.6 | | | | | | |
| 2000 | | | 224 | 3,876.5 | 2 | 5,737.9 | | | | | | |
| 2001 | | | 72 | 3,966.9 | 9 | 4,991.2 | | | 18 | 4,178.9 | | |
| 2002 | 1 | 1,038.0 | 205 | 3,934.7 | 7 | 4,329.4 | | | 60 | 3,820.0 | 1 | 4,449.0 |
| 2003 | | | 163 | 4,160.2 | 31 | 5,092.8 | | | 30 | 3,584.1 | 19 | 5,459.9 |
| 2004 | | | 224 | 3,555.4 | 2 | 4,508.3 | | | 42 | 3,827.2 | | |
| 2005 | 1 | 1,769.0 | 218 | 3,815.5 | 5 | 4,675.1 | | | 38 | 3,723.9 | 5 | 4,014.7 |
| 2006 | | | 196 | 3,396.4 | 24 | 4,338.9 | | | 36 | 3,087.3 | | |
| 2007 | | | 178 | 3,658.3 | 24 | 4,403.3 | | | 33 | 3,545.2 | 2 | 4,381.9 |
| 2008 | | | 207 | 3,814.0 | 10 | 4,139.9 | | | 58 | 3,898.0 | | |
| 2009 | 1 | 2,498.2 | 195 | 4,018.9 | 6 | 4,897.1 | | | 34 | 3,920.3 | | |
| 2010 | | | 185 | 4,103.0 | | | | | 54 | 3,996.6 | | |
| 2011 | 1[1] | 3,853.1 | 179 | 4,000.1 | 4 | 5,692.1 | | | 41 | 3,843.3 | 2 | 4,098.2 |
| 2012 | | | 186 | 3,901.0 | 5 | 4,982.8 | | | 41 | 3,537.4 | 1 | 3,900.5 |
| 2013 | | | 159 | 3,760.3 | 6 | 5,068.0 | | | 36 | 3,498.7 | 2 | 4,955.3 |
| 2014 | | | 171 | 3,889.4 | 4 | 4,599.5 | | | 25 | 3,627.1 | 1 | 5,335.8 |
| 2015 | | | 153 | 3,922.5 | 2 | 5,249.3 | | | 14 | 3,975.1 | 1 | 3,793.3 |
| Mean | | | | 3,858.6 | | 4,752.6 | | | | 3,736.7 | | 4,487.6 |

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 | Apr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 2.2 | | 1.1 | 0.8 | 1.2 | 0.8 | 1.5 | 1.5 | | 1.9 | | 5.3 | 0.7 |
| 1998 | | 1.0 | 0.9 | 1.0 | 0.9 | 0.8 | 2.4 | 1.4 | 2.1 | -0.3 | 1.0 | 1.2 | 0.8 |
| 1999 | | 1.0 | 1.1 | 1.1 | 1.2 | 1.5 | 1.8 | 1.0 | | -0.5 | 0.3 | 1.7 | 0.7 |
| 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 | 0.4 |
| 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 | 0.5 |
| 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 | 0.7 |
| Mean | 0.8 | 0.9 | 1.1 | 1.0 | 1.2 | 1.1 | 2.0 | 1.1 | 1.6 | 0.4 | 1.2 | 1.2 | 0.6 |

## Length and Weight Growth Profiles

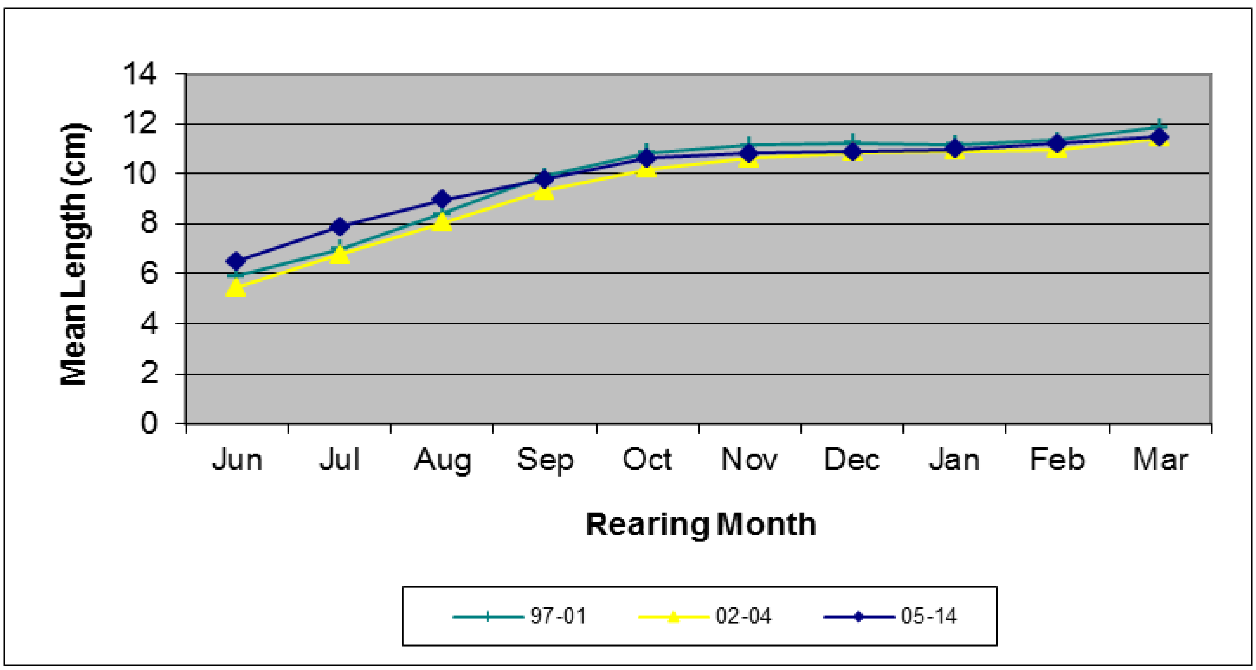


**Figure 5. Mean length (cm) of "standard growth treatment (Hi)" CESRF juveniles by brood year and growth month, 1997 - present.**

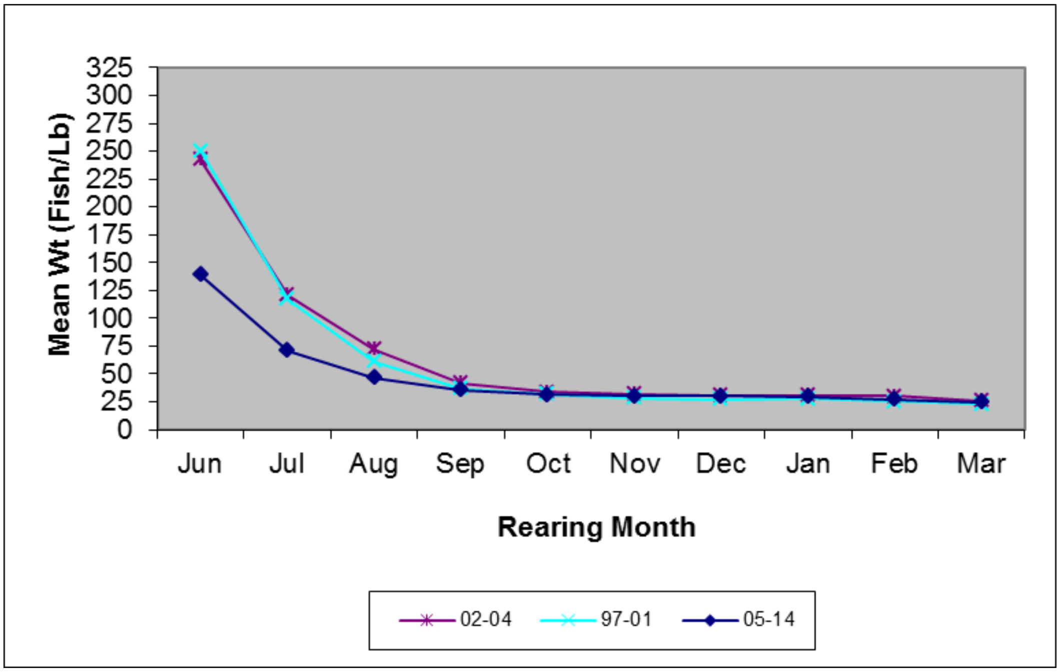


**Figure 6. Mean Weight (fish/lb) of "standard growth treatment (Hi)" CESRF juveniles by brood year and growth month, 1997 - present.**

## 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 15 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 |

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

## Incidence of Precocialism

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

<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.

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

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

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

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

## CESRF Smolt Releases

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

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

| Brood | | | 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 |
| Mean | 366,140 | 362,936 | 245,410 | 241,327 | 251,752 | 724,503 |

**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 |
| Mean | 43,216 | 42,743 | 42,398 | 40,947 | 42,632 |

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: 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.

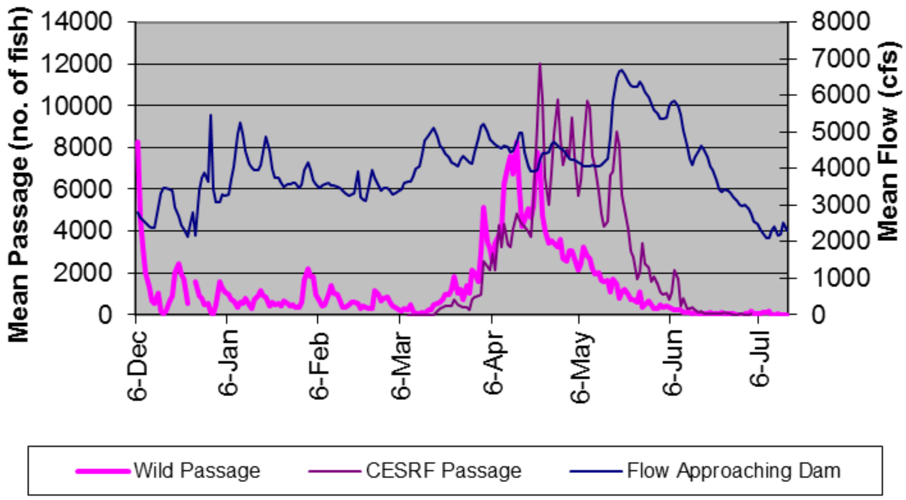


**Figure 7. Mean flow approaching Prosser Dam versus mean estimated smolt passage at Prosser of aggregate wild/natural and CESRF spring Chinook for outmigration years 1999-2015.**

## Smolt-to-Smolt Survival

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

Results of this experiment have been published:

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

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

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

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

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

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

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

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

**Smolt-to-Adult Survival**

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

1) Downstream of the confluence of the Yakima and Naches rivers the three populations of spring Chinook (Upper Yakima, Naches, and American) are aggregated. A subsample of the

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

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

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

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

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

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

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

8) The ISAB has indicated that "more attention should be given to the apparent documentation that PIT-tagged fish do not survive as well as untagged fish. This point has major implications for all uses of PIT-tagged fish as surrogates for untagged fish." Our data appear

to corroborate this point (Tables 45-46). However, these data are not corrected for tag loss. If a fish loses its PIT tag after detection upon leaving the acclimation site, but before it returns as an adult to Roza Dam, it would be included only as a release in Table 45 and only as an adult return in Table 46. Knudsen et al. (2009) found that smolt-to-adult return rates (SARS) based on observed PIT tag recoveries were significantly underestimated by an average of 25% and that after correcting for tag loss, SARS of PIT-tagged fish were still 10% lower than SARS of non-PIT-tagged fish. Thus, the data in Table 45 under-represent "true" SARS for PIT-tagged fish and SARS for PIT-tagged and non-PIT-tagged fish are likely closer than those reported in Tables 45 and 46.

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

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

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

| | | | Estimated Smolt Passage at Chandler | | | Yakima R. Mouth Adult Returns[4] | | Smolt-to-Adult Return Index[4] | |
|---|---|---|---|---|---|---|---|---|---|
| Brood Year | Smolt Migr. Year | Mean Flow[1] at Prosser Dam | Wild/ Natural[2] | CESRF Total | CESRF smolt-to-smolt survival[3] | Wild/ Natural[2] | CESRF Total | Wild/ Natural[2] | CESRF Total |
| 1982 | 1984 | 4134 | 381,857 | | | 6,753 | | 1.8% | |
| 1983 | 1985 | 3421 | 146,952 | | | 5,198 | | 3.5% | |
| 1984 | 1986 | 3887 | 227,932 | | | 3,932 | | 1.7% | |
| 1985 | 1987 | 3050 | 261,819 | | | 4,776 | | 1.8% | |
| 1986 | 1988 | 2454 | 271,316 | | | 4,518 | | 1.7% | |
| 1987 | 1989 | 4265 | 76,362 | | | 2,402 | | 3.1% | |
| 1988 | 1990 | 4141 | 140,218 | | | 5,746 | | 4.1% | |
| 1989 | 1991 | | 109,002 | | | 2,597 | | 2.4% | |
| 1990 | 1992 | 1960 | 128,457 | | | 1,178 | | 0.9% | |
| 1991 | 1993 | 3397 | 92,912 | | | 544 | | 0.6% | |
| 1992 | 1994 | 1926 | 167,477 | | | 3,790 | | 2.3% | |
| 1993 | 1995 | 4882 | 172,375 | | | 3,202 | | 1.9% | |
| 1994 | 1996 | 6231 | 218,578 | | | 1,238 | | 0.6% | |
| 1995 | 1997 | 12608 | 52,028 | | | 1,995 | | 3.8% | |
| 1996 | 1998 | 5466 | 491,584 | | | 21,151 | | 4.3% | |
| 1997 | 1999 | 5925 | 633,805 | 182,622 | 47.3% | 12,855 | 8,670 | 2.0% | 4.7% |
| 1998 | 2000[5] | 4946 | 165,159 | 243,367 | 41.3% | 8,228 | 9,782 | 5.0% | 4.0% |
| 1999 | 2001 | 1321 | 183,045 | 322,475 | 42.5% | 1,764 | 864 | 1.0% | 0.3% |
| 2000 | 2002 | 5015 | 538,772 | 398,909 | 47.8% | 11,434 | 4,819 | 2.1% | 1.2% |
| 2001 | 2003 | 3504 | 327,520 | 147,514 | 39.8% | 8,597 | 1,251 | 2.6% | 0.8% |
| 2002 | 2004 | 2439 | 162,673 | 266,380 | 31.8% | 3,743 | 2,300 | 2.3% | 0.9% |
| 2003 | 2005 | 1285 | 172,267 | 287,777 | 34.9% | 2,746 | 932 | 1.6% | 0.3% |
| 2004 | 2006 | 5652 | 203,250 | 437,166 | 55.7% | 2,802 | 4,022 | 1.4% | 0.9% |
| 2005 | 2007 | 4551 | 114,906 | 387,961 | 45.1% | 4,201 | 4,378 | 3.7% | 1.1% |
| 2006 | 2008 | 4298 | 134,511 | 286,357 | 44.5% | 6,099 | 9,114 | 4.5% | 3.2% |
| 2007 | 2009 | 5784 | 294,760 | 473,931 | 61.4% | 7,952 | 6,558 | 2.7% | 1.4% |
| 2008 | 2010 | 3592 | 151,646 | 241,290 | 28.4% | 7,385 | 6,976 | 4.9% | 2.9% |
| 2009 | 2011 | 9414 | 326,180 | 453,716 | 54.5% | 3,766 | 3,181 | 1.2% | 0.7% |
| 2010 | 2012 | 8556 | 429,896 | 620,208 | 78.0% | 6,602 | 4,707 | 1.5% | 0.8% |
| 2011 | 2013 | 4875 | 357,347 | 345,754 | 45.0% | 6,640[6] | 3,573[6] | 1.9%[6] | 1.0%[6] |
| 2012 | 2014 | 4923 | 268,598 | 396,588 | 49.4% | | | | |
| 2013 | 2015[6] | 1555 | 149,203 | 375,372 | 58.0% | | | | |

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

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

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

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

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

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

**Table 43. Overall wild/natural smolt-to-adult return rates (SAR) based on juvenile and adult detections of fish PIT-tagged and released at Roza Dam (Table B.49 in McCann et al. 2015). 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 | | %SAR Estimate | Non-parametric CI | |
| | | | 90% LL | 90% UL | | 90% LL | 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[B] | 710 | 1.27 | 0.64 | 2.02 | 1.41 | 0.73 | 2.19 |
| Geometric mean | | 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] Incomplete with 2-salt returns through September 14, 2015.
[C] No PIT-tagged smolts released in 2010.

**Table 44. Overall CESRF smolt-to-adult return rates (SAR) based on juvenile and adult detections of PIT tagged fish (Table B.53 in McCann et al. 2015). 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 | | %SAR Estimate | Non-parametric CI | |
| | | | 90% LL | 90% UL | | 90% LL | 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[B] | 13,243 | 1.37 | 1.18 | 1.53 | 1.94 | 1.72 | 2.16 |
| Geometric mean | | 1.21 | | | 1.60 | | |

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.
[B] Incomplete with 2-salt returns through September 14, 2015.

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

| Brood Year | Number Tagged[1] | Adult Detections at Bonn. Dam | | | | | Adult Detections at Roza Dam | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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% | 186 | 263 | 11 | 460 | 1.19% |
| 2007 | 38,618 | 73 | 279 | 3 | 355 | 0.92% | 53 | 182 | 3 | 238 | 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% | 61 | 142 | 3 | 206 | 0.53% |
| 2011 | 38,165 | 77 | 191 | | | | 57 | 122 | | | |
| 2012 | 38,343 | 33 | | | | | 10 | | | | |

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 | 2,384 | 6,428 | 287 | 9,098 | 1.51% |
| 2007 | 732,647 | 1,026 | 5,645 | 87 | 6,758 | 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 | 722 | 3,618 | 28 | 4,367 | 0.58% |
| 2011 | 731,017 | 780 | 2,318 | | | |
| 2012 | 764,373 | 172 | | | | |

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

# Harvest Monitoring

## Yakima Basin Fisheries

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

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

| | Tribal | | Non-Tribal | | River Totals | | | Harvest |
|---|---|---|---|---|---|---|---|---|
| Year | CESRF | Wild | CESRF | Wild | CESRF | Wild | Total | Rate[1] |
| 1983 | | 84 | | 0 | | 84 | 84 | 5.8% |
| 1984 | | 289 | | 0 | | 289 | 289 | 10.9% |
| 1985 | | 865 | | 0 | | 865 | 865 | 19.0% |
| 1986 | | 1,340 | | 0 | | 1,340 | 1,340 | 14.2% |
| 1987 | | 517 | | 0 | | 517 | 517 | 11.6% |
| 1988 | | 444 | | 0 | | 444 | 444 | 10.5% |
| 1989 | | 747 | | 0 | | 747 | 747 | 15.2% |
| 1990 | | 663 | | 0 | | 663 | 663 | 15.2% |
| 1991 | | 32 | | 0 | | 32 | 32 | 1.1% |
| 1992 | | 345 | | 0 | | 345 | 345 | 7.5% |
| 1993 | | 129 | | 0 | | 129 | 129 | 3.3% |
| 1994 | | 25 | | 0 | | 25 | 25 | 1.9% |
| 1995 | | 79 | | 0 | | 79 | 79 | 11.9% |
| 1996 | | 475 | | 0 | | 475 | 475 | 14.9% |
| 1997 | | 575 | | 0 | | 575 | 575 | 18.1% |
| 1998 | | 188 | | 0 | | 188 | 188 | 9.9% |
| 1999 | | 604 | | 0 | | 604 | 604 | 21.7% |
| 2000 | 53 | 2,305 | | 100 | 53 | 2,405 | 2,458 | 12.9% |
| 2001 | 572 | 2,034 | 1,252 | 772 | 1,825 | 2,806 | 4,630 | 19.9% |
| 2002 | 1,373 | 1,207 | 492 | 36[2] | 1,865 | 1,243 | 3,108 | 20.6% |
| 2003 | 134 | 306 | 0 | 0 | 134 | 306 | 440 | 6.3% |
| 2004 | 289 | 712 | 569 | 109[2] | 858 | 820 | 1,679 | 11.0% |
| 2005 | 46 | 428 | 0 | 0 | 46 | 428 | 474 | 5.4% |
| 2006 | 246 | 354 | 0 | 0 | 246 | 354 | 600 | 9.5% |
| 2007 | 123 | 156 | 0 | 0 | 123 | 156 | 279 | 6.5% |
| 2008 | 521 | 414 | 586 | 11[2] | 1,107 | 426 | 1,532 | 17.8% |
| 2009 | 1,089 | 715 | 541 | 8[2] | 1,630 | 722 | 2,353 | 19.4% |
| 2010 | 345 | 194 | 1,154 | 48[2] | 1,499 | 241 | 1,741 | 13.2% |
| 2011 | 1,361 | 1,261 | 1,579 | 179[2] | 2,940 | 1,440 | 4,380 | 24.4% |
| 2012 | 1,220 | 1,302 | 735 | 63[2] | 1,955 | 1,364 | 3,320 | 27.5% |
| 2013 | 846 | 975 | 786 | 46[2] | 1,632 | 1,021 | 2,653 | 25.9% |
| 2014 | 576 | 715 | 826 | 54[2] | 1,402 | 769 | 2,171 | 19.2% |
| 2015 | 121 | 271 | 385 | 38 | 506 | 309 | 815 | 8.7% |
| Mean | 591 | 736 | 594 | 91 | 1,185 | 674 | 1,171 | 13.7% |

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

## Columbia Basin Fisheries

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

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

| | | | | | | Columbia Basin Harvest Summary | | | Col. Basin Harvest Rate | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Columbia R. Mouth Run Size | Col. R. Mouth to BON Harvest | BON to McNary Harvest | Yakima R. Mouth Run Size | Yakima River Harvest | Total | Wild | CESRF | Total | Wild |
| 1983 | 2,452 | 118 | 99 | 1,441 | 84 | 300 | 300 | 0 | 12.3% | 12.3% |
| 1984 | 3,868 | 134 | 257 | 2,658 | 289 | 680 | 680 | 0 | 17.6% | 17.6% |
| 1985 | 5,248 | 191 | 178 | 4,560 | 865 | 1,234 | 1,234 | 0 | 23.5% | 23.5% |
| 1986 | 13,514 | 280 | 783 | 9,439 | 1,340 | 2,403 | 2,403 | 0 | 17.8% | 17.8% |
| 1987 | 6,140 | 96 | 371 | 4,443 | 517 | 984 | 984 | 0 | 16.0% | 16.0% |
| 1988 | 5,631 | 360 | 372 | 4,246 | 444 | 1,177 | 1,177 | 0 | 20.9% | 20.9% |
| 1989 | 8,869 | 212 | 663 | 4,914 | 747 | 1,621 | 1,621 | 0 | 18.3% | 18.3% |
| 1990 | 6,908 | 350 | 453 | 4,372 | 663 | 1,465 | 1,465 | 0 | 21.2% | 21.2% |
| 1991 | 4,620 | 183 | 278 | 2,906 | 32 | 493 | 493 | 0 | 10.7% | 10.7% |
| 1992 | 6,196 | 102 | 373 | 4,599 | 345 | 820 | 820 | 0 | 13.2% | 13.2% |
| 1993 | 5,117 | 44 | 311 | 3,919 | 129 | 484 | 484 | 0 | 9.5% | 9.5% |
| 1994 | 2,225 | 86 | 107 | 1,302 | 25 | 219 | 219 | 0 | 9.8% | 9.8% |
| 1995 | 1,384 | 1 | 68 | 666 | 79 | 149 | 149 | 0 | 10.7% | 10.7% |
| 1996 | 5,773 | 6 | 303 | 3,179 | 475 | 783 | 783 | 0 | 13.6% | 13.6% |
| 1997 | 5,196 | 3 | 348 | 3,173 | 575 | 926 | 926 | 0 | 17.8% | 17.8% |
| 1998 | 2,839 | 3 | 143 | 1,903 | 188 | 333 | 333 | 0 | 11.7% | 11.7% |
| 1999 | 3,918 | 4 | 180 | 2,781 | 604 | 789 | 789 | 0 | 20.1% | 20.1% |
| 2000 | 28,862 | 58 | 1,755 | 19,100 | 2,458 | 4,271 | 4,147 | 123 | 14.8% | 14.8% |
| 2001 | 31,004 | 948 | 4,050 | 23,265 | 4,630 | 9,629 | 5,528 | 4,101 | 31.1% | 29.7% |
| 2002 | 23,898 | 1,234 | 2,547 | 15,099 | 3,108 | 6,888 | 2,569 | 4,320 | 28.8% | 24.7% |
| 2003 | 9,727 | 274 | 764 | 6,957 | 440 | 1,478 | 890 | 588 | 15.2% | 14.3% |
| 2004 | 21,910 | 964 | 1,894 | 15,289 | 1,679 | 4,536 | 2,515 | 2,021 | 20.7% | 16.1% |
| 2005 | 11,903 | 326 | 741 | 8,758 | 474 | 1,542 | 1,214 | 328 | 13.0% | 12.2% |
| 2006 | 11,560 | 299 | 760 | 6,314 | 600 | 1,658 | 942 | 716 | 14.3% | 12.8% |
| 2007 | 4,981 | 170 | 343 | 4,303 | 279 | 791 | 382 | 410 | 15.9% | 13.8% |
| 2008 | 11,419 | 1,151 | 1,507 | 8,598 | 1,532 | 4,190 | 1,181 | 3,008 | 36.7% | 26.5% |
| 2009 | 12,804 | 1,168 | 934 | 10,701 | 2,353 | 4,455 | 1,237 | 3,218 | 34.8% | 25.7% |
| 2010 | 17,366 | 1,563 | 2,286 | 13,142 | 1,741 | 5,590 | 1,302 | 4,288 | 32.2% | 21.4% |
| 2011 | 22,171 | 1,059 | 1,396 | 17,960 | 4,380 | 6,834 | 2,373 | 4,461 | 30.8% | 22.2% |
| 2012 | 16,641 | 842 | 1,427 | 12,053 | 3,320 | 5,588 | 2,252 | 3,336 | 33.6% | 27.3% |
| 2013 | 14,234 | 847 | 761 | 10,245 | 2,653 | 4,261 | 1,686 | 2,575 | 29.9% | 23.3% |
| 2014 | 16,292 | 691 | 1,759 | 11,322 | 2,171 | 4,621 | 1,836 | 2,784 | 28.4% | 21.6% |
| 2015[1] | 11,211 | 455 | 1,250 | 9,351 | 815 | 2,520 | 1,312 | 1,208 | 22.5% | 17.6% |
| Mean | 10,784 | 431 | 893 | 7,665 | 1,213 | 2,537 | 1,401 | 1,136 | 20.2% | 17.8% |

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 Dec. 3, 2015 for CESRF spring Chinook CWTs released in brood years 1997-2010. Based on the information reported to RMIS to date, it is believed that marine harvest accounts for about 0-3% of the total harvest of Yakima Basin spring Chinook. CWT recovery data for brood year 2011 were considered too incomplete to report at this time.

**Table 49. Marine and freshwater recoveries of CWTs from brood year 1997-2010 releases of spring Chinook from the CESRF as reported to the Regional Mark Information System (RMIS) 3 Dec, 2015.**

| 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 | 1142 | 1.1% |
| 2008 | 5 | 245 | 2.0% | 7 | 1633 | 0.4% |
| 2009 | 3 | 90 | 3.2% | 5 | 554 | 0.9% |
| 2010[1] | 4 | 137 | 2.8% | 9 | 670 | 1.3% |

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 2010 are considered preliminary or incomplete.

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## *Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2005-2014.*

| 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] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | CLE01 | JCJ06 | STF | WW | 2.4 | Left | Orange | Snout | 3/15/2007 | 5/15/2007 | 613418 | 2,222 | 45,991 | 47,913 |
| 2005 | CLE02 | JCJ05 | CON | WW | 2.4 | Right | Orange | Snout | 3/15/2007 | 5/15/2007 | 613419 | 2,222 | 46,172 | 48,189 |
| 2005 | CLE03 | JCJ04 | STF | WW | 2.6 | Right | Orange | Snout | 3/15/2007 | 5/15/2007 | 613420 | 2,222 | 47,604 | 49,605 |
| 2005 | CLE04 | JCJ03 | CON | WW | 2.6 | Left | Orange | Snout | 3/15/2007 | 5/15/2007 | 613421 | 2,222 | 47,852 | 49,865 |
| 2005 | CLE05 | CFJ06 | CON | WW | 2.5 | Right | Red | Snout | 3/15/2007 | 5/15/2007 | 613422 | 2,222 | 46,258 | 48,282 |
| 2005 | CLE06 | CFJ05 | STF | WW | 2.5 | Left | Red | Snout | 3/15/2007 | 5/15/2007 | 613423 | 2,222 | 47,129 | 49,155 |
| 2005 | CLE07 | ESJ06 | CON | WW | 2.5 | Right | Green | Snout | 3/15/2007 | 5/15/2007 | 613424 | 2,222 | 41,808 | 43,871 |
| 2005 | CLE08 | ESJ05 | STF | WW | 2.5 | Left | Green | Snout | 3/15/2007 | 5/15/2007 | 613425 | 2,222 | 42,094 | 44,193 |
| 2005 | CLE09 | CFJ02 | CON | HH | 2.3 | Right | Red | Posterior Dorsal | 3/15/2007 | 5/15/2007 | 613431 | 2,222 | 43,580 | 45,616 |
| 2005 | CLE10 | CFJ01 | STF | HH | 2.3 | Left | Red | Posterior Dorsal | 3/15/2007 | 5/15/2007 | 613427 | 2,222 | 42,971 | 44,902 |
| 2005 | CLE11 | ESJ02 | CON | WW | 2.5 | Right | Green | Snout | 3/15/2007 | 5/15/2007 | 613428 | 2,222 | 50,108 | 52,186 |
| 2005 | CLE12 | ESJ01 | STF | WW | 2.5 | Left | Green | Snout | 3/15/2007 | 5/15/2007 | 613429 | 2,222 | 44,487 | 46,550 |
| 2005 | CLE13 | ESJ04 | CON | WW | 2.5 | Right | Green | Snout | 3/15/2007 | 5/15/2007 | 613430 | 2,222 | 45,040 | 47,132 |
| 2005 | CLE14 | ESJ03 | STF | WW | 2.5 | Left | Green | Snout | 3/15/2007 | 5/15/2007 | 613426 | 2,222 | 45,132 | 47,218 |
| 2005 | CLE15 | JCJ02 | STF | WW | 2.5 | Right | Orange | Snout | 3/15/2007 | 5/15/2007 | 613432 | 2,222 | 46,178 | 48,266 |
| 2005 | CLE16 | JCJ01 | CON | WW | 2.5 | Left | Orange | Snout | 3/15/2007 | 5/15/2007 | 613433 | 2,222 | 45,804 | 47,887 |
| 2005 | CLE17 | CFJ04 | CON | WW | 2.5 | Right | Red | Snout | 3/15/2007 | 5/15/2007 | 613434 | 2,222 | 46,476 | 48,508 |
| 2005 | CLE18 | CFJ03 | STF | WW | 2.4 | Left | Red | Snout | 3/15/2007 | 5/15/2007 | 613435 | 2,222 | 48,638 | 50,664 |

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

[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 2005-2014.*

| 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 2005-2014.*

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

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

[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 2005-2014.*

| 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 |

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

[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 2005-2014.*

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

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

[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 2005-2014.*

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

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

[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 2005-2014.*

| 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] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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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[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 2005-2014.*

| 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] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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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[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 2005-2014.*

| 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] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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.

[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 2005-2014.*

| Brood | C.E. Pond | Accl. | Treatment /Avg BKD | | | Tag Information | | | First Release | Last Release | CWT Code | No. PIT | No. CWT | Est. Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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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**Appendix C**

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

**Doug Neeley, Consultant to the Yakama Nation**

## Introduction and Summary

From 1999[1] through 2015, survival estimates to McNary Dam (McNary) of PIT-tagged hatchery-spawned Spring Chinook (hatchery) and naturally spawned (natural) smolt released into the Roza Dam (Roza) juvenile bypass system were made and compared. These releases were not made in 2014 because of another study conducted at Roza in that year.

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

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

## Methodology

All smolt releases included in the analyses were grouped into seven-day intervals; i.e., smolt released between Julian dates 1 and 7 were treated as one release group, those released between Julian dates 8 and 14 were treated as another group, etc. (these groups could be considered to be Julian weeks). This was primarily done to have consistency over years, but if there were not a sufficient number of smolt within a stratum, then adjacent seven-day groups were sometimes combined into a common group. Conceptual survival estimation procedures are discussed in Appendix A. Weighted logistic analyses of variation both within and over years were used to analyze the proportion surviving to McNary, there weights being the release numbers of fish

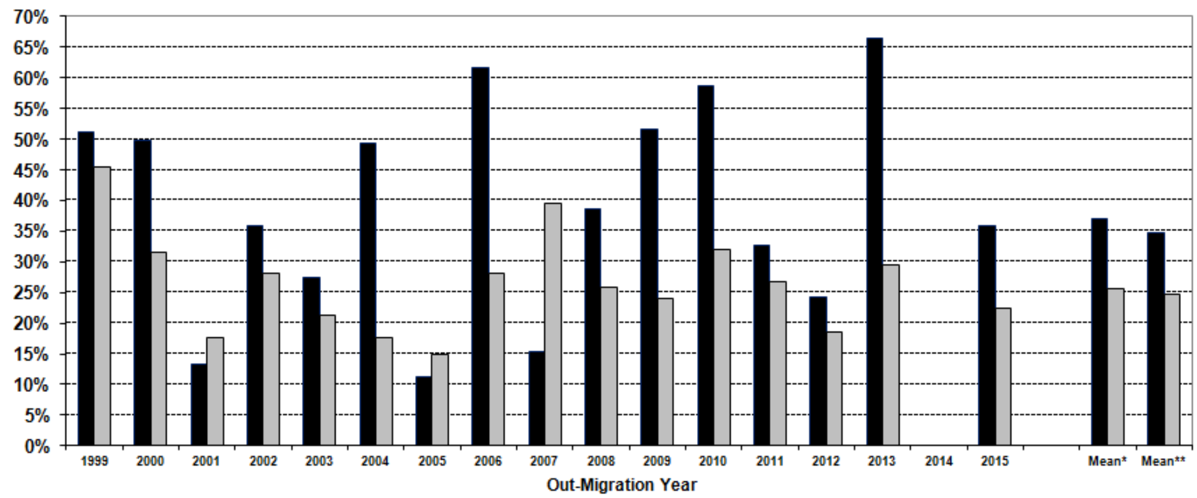
[1] The first outmigration year of Upper Yakima River hatchery-origin Spring Chinook

used to estimate the proportions[2]. Comparisons of late-natural and hatchery smolt were treated as paired comparisons with the Julian-date intervals treated as blocks. Comparisons between early and late natural smolt proportions were treated as independent comparisons since they involved different Julian-date intervals.

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

As was the case in most previous years, late naturally spawned smolt released at Roza in 2015 had a higher mean Roza-to-McNary survival rate than did hatchery smolt. Figure 1 presents the late-natural- and hatchery-smolt contemporaneous survivals.

**Figure 1. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival for Late Natural Smolt (black bars) and Hatchery Smolt (gray bars)**




*** Weighted mean using yearly release number as a weighting variable of survival percentages**
**** Weighted mean using release-number/mean deviance as a weighting variable of survival proportions**

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

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

were performed for the natural–hatchery differences in mean survivals based on the null hypotheses of no differences. Table 1 presents individual-year means and mean differences and their within-year statistical test summaries. Survival estimates combined over years with their associated statistical test summaries are also presented.

---

[2] A second method of weighting was used for over-year comparisons, the weight being the inverse of the estimated variance of the compared estimates to assure homogeneity of variation in the tests.

As can be seen from Figure 1 and Table 1, the late natural smolt survival exceeded that of the hatchery smolt in 13 or 81%[3] of the 16 outmigration years. Of those 13 years, 7 were significant at the 5% level (Table 1). The analyses on which individual-year significance levels in Table 1 are based are presented in Appendix B.2. The mean survival estimate based on combining all released smolt over years was also significantly higher[4] for the natural smolt (37% survival) than the later hatchery smolt (26% survival)

**Table 1. Upper-Yakima Spring Chinook Roza-to-McNary Smolt Survival[5] for Late Naturally-Spawned and Hatchery-Spawned Smolt**

| | | Outmigration Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stock** | **Measure** | **1999** | **2000** | **2001*** ** | **2002** | **2003** | **2004** | **2005*** ** | **2006** | **2007*** ** |
| **Natural** | **Survival** | **0.5122** | **0.4987** | **0.1339** | **0.3584** | **0.2750** | **0.4935** | **0.1122** | **0.6160** | **0.1529** |
| (Nat) | Released | 133 | 3196 | 1424 | 2114 | 1190 | 74 | 45 | 500 | 336 |
| **Hatchery** | **Survival** | **0.4540** | **0.3155** | **0.1759** | **0.2803** | **0.2137** | **0.1768** | **0.1494** | **0.2810** | **0.3955** |
| (Hat) | Released | 675 | 2999 | 1744 | 1503 | 2146 | 2201 | 1344 | 3802 | 2477 |
| **Difference** | **Nat-Hat** | **0.0582** | **0.1832** | **-0.0420** | **0.0781** | **0.0613** | **0.3167** | **-0.0371** | **0.3350** | **-0.2426** |
| | | **Type 1 Error P** | | | | | | | | |
| **(1-sided)** | **(Nat > Hat)** | 0.0755 | **0.0000** | 0.7377 | 0.0866 | 0.0749 | **0.0243** | 0.5295 | **0.0006** | 0.9824 |

| **Stock** | **Measure** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2015** | **Mean*** | **Mean**** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Natural** | **Survival** | **0.3857** | **0.5161** | **0.5874** | **0.3260** | **0.2419** | **0.6642** | **0.3594** | **0.3594** | **0.3474** |
| (Nat) | Released | 421 | 172 | 105 | 956 | 193 | 38 | 243 | 243 | |
| **Hatchery** | **Survival** | **0.2573** | **0.2405** | **0.3196** | **0.2679** | **0.1849** | **0.2939** | **0.2233** | **0.2233** | **0.2462** |
| (Hat) | Released | 4406 | 2334 | 1130 | 3103 | 4405 | 550 | 1503 | 1503 | |
| **Difference** | **Nat-Hat** | **0.1284** | **0.2756** | **0.2678** | **0.0581** | **0.0570** | **0.3703** | **0.1362** | **0.1146** | **0.1012** |
| | | | | | | | | | | |
| **(1-sided)** | **(Nat > Hat)** | **0.0096** | **0.0363** | **0.0216** | 0.1118 | 0.3196 | 0.1989 | **0.0486** | **0.0020** | **0.0056** |

*** Pooled using yearly release number as a weighting variable of survival proportions**

**** Pooled using yearly ratio (release-number)/(error-mean deviance) as a weighting variable of survival proportions**

***** The three years in which <u>late</u> Natural-brood Survival was less than that of the hatcherry-brood**

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

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

---

[3] The 81% is significantly greater than what would be expected by chance (P = 0.0106 based on a 1-sided binomial distribution sign test).

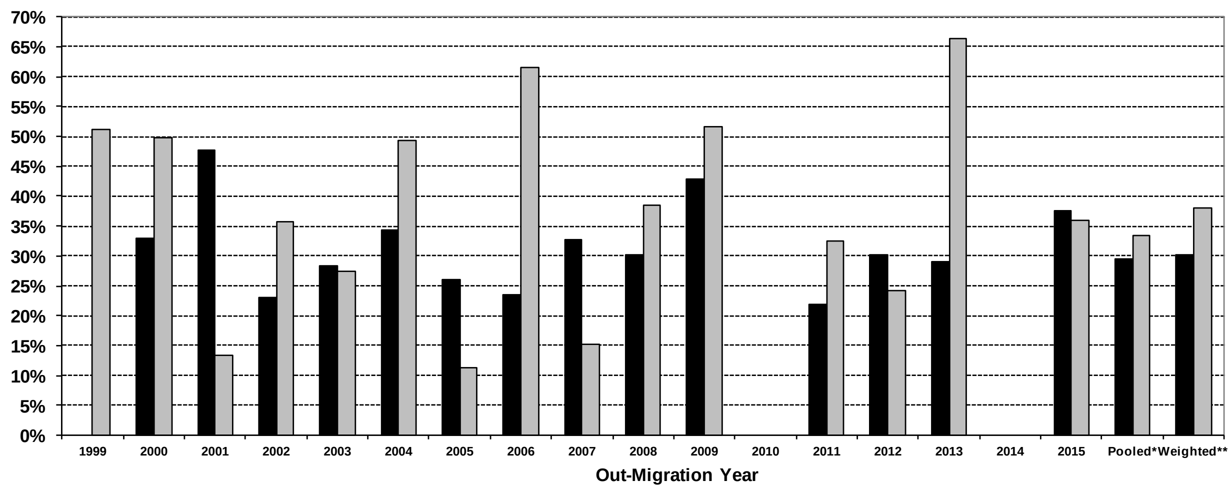
[4] P = 0.0020, Mean* in Table 1 and Appendix Table B.3.

[5] Refer to Appendix B.1. for a complete table of means.

Of the fourteen years with early releases, late releases had higher Roza-to-McNary survival in eight (57%[6]) of the years. Three of the four significant differences were years in which the late releases had a higher survival than that of the early releases. However, in those three years (2000, 2002, and 2006) as well as others, early releases of natural smolt began before January. It is quite possible that smolt passing McNary from the very early releases were not detected because the McNary smolt bypasses had not yet been watered up; therefore, in many years, the McNary survivals of the early natural smolt may be underestimated. The analyses on which these individual-year significance levels in Table 2 are based are presented in Appendix B.4. Figure 2.b. gives the Julian week's survivals for all natural and hatchery Julian week releases at Roza.

The mean survival estimate based on combining all released smolt over years was not significant (P = 0.1286, Mean* in Table 1 and Appendix Table B.3). The lower early smolt survival of 30% (versus the 33% for the later release) could have been higher if there were an earlier undetected McNary passage that could have been accounted for.

**Figure 2.a. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival[7] for Early (black bars) and Late (grey bars) Natural Smolt**




*** Weighted mean using yearly release number as a weighting variable of survival percentages**
**** Weighted mean using release-number/mean deviance as a weighting variable of survival proportions**

[6] The 57% is not significantly different than what would be expected by chance (P = 0.7906 based on a 2-sided binomial distribution sign test).

[7] Refer to Appendix B.1. for a complete table of means.

## Table 2. Upper-Yakima Spring-Chinook Roza-to-McNary Smolt Survival Indices for Early and Late Natural Smolt

| Natural Stock | Measure | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Outmigration Year | | | | | | | | |
| **Natural** | **Survival** | **no** | **0.3307** | **0.4771** | **0.2314** | **0.2837** | **0.3442** | **0.2608** | **0.2361** | **0.3273** |
| **Early** | Released | **release** | 3013 | 755 | 6604 | 6614 | 3857 | 1688 | 1833 | 1072 |
| **Natural** | **Survival** | 0.5122 | **0.4987** | 0.1339 | **0.3584** | **0.2750** | **0.4935** | **0.1122** | **0.6160** | **0.1529** |
| **Late** | Released | 133 | 3196 | 1424 | 2114 | 1190 | 74 | 45 | 500 | 336 |
| **Difference** | **Early-Late** | | **-0.1679** | **0.3432** | **-0.1270** | **0.0087** | **-0.1493** | **0.1485** | **-0.3799** | **0.1744** |
| | | **Type 1 Error P** | | | | | | | | |
| **(2-sided)** | **Early-Late** | | 0.0000 | 0.0001 | 0.0004 | 0.8230 | 0.4903 | 0.4035 | 0.0010 | 0.0889 |

| Stock | Measure | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2015 | Pooled* | Weighted** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Outmigration Year | | | | | | | | |
| **Natural** | **Survival** | **0.3020** | **0.4286** | **no** | **0.2200** | **0.3016** | **0.2912** | **0.3749** | **0.2954** | **0.3028** |
| **Early** | Released | 1254 | 1804 | **release** | 985 | 2482 | 2435 | 282 | 34678 | 0 |
| **Natural** | **Survival** | **0.3857** | **0.5161** | 0.5874 | **0.3260** | **0.2419** | **0.6642** | **0.3594** | **0.3338** | **0.3808** |
| **Late** | Released | 421 | 172 | 105 | 956 | 193 | 38 | 243 | 12165 | 0 |
| **Difference** | **Early-Late** | **-0.0837** | **-0.0875** | | **-0.1060** | **0.0597** | **-0.3730** | **0.0155** | **-0.0383** | **-0.0781** |
| | | | | | | | | | | |
| **(2-sided)** | **Early-Late** | 0.2458 | 0.7590 | | 0.2176 | 0.5212 | 0.3226 | 0.8986 | 0.6353 | 0.3917 |

*** Pooled using yearly release number as a weighting variable of survival proportions**

**** Pooled using yearly (release-number)/(error-mean deviance) as a weighting variable of survival proportions**

**NOTE: The years 1999 and 2010 are not used in the pooled estimates because no Early Natural were released**

**Figure 2.b. Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week (Natural Smolt - Green, Hatchery Smolt - Red)**

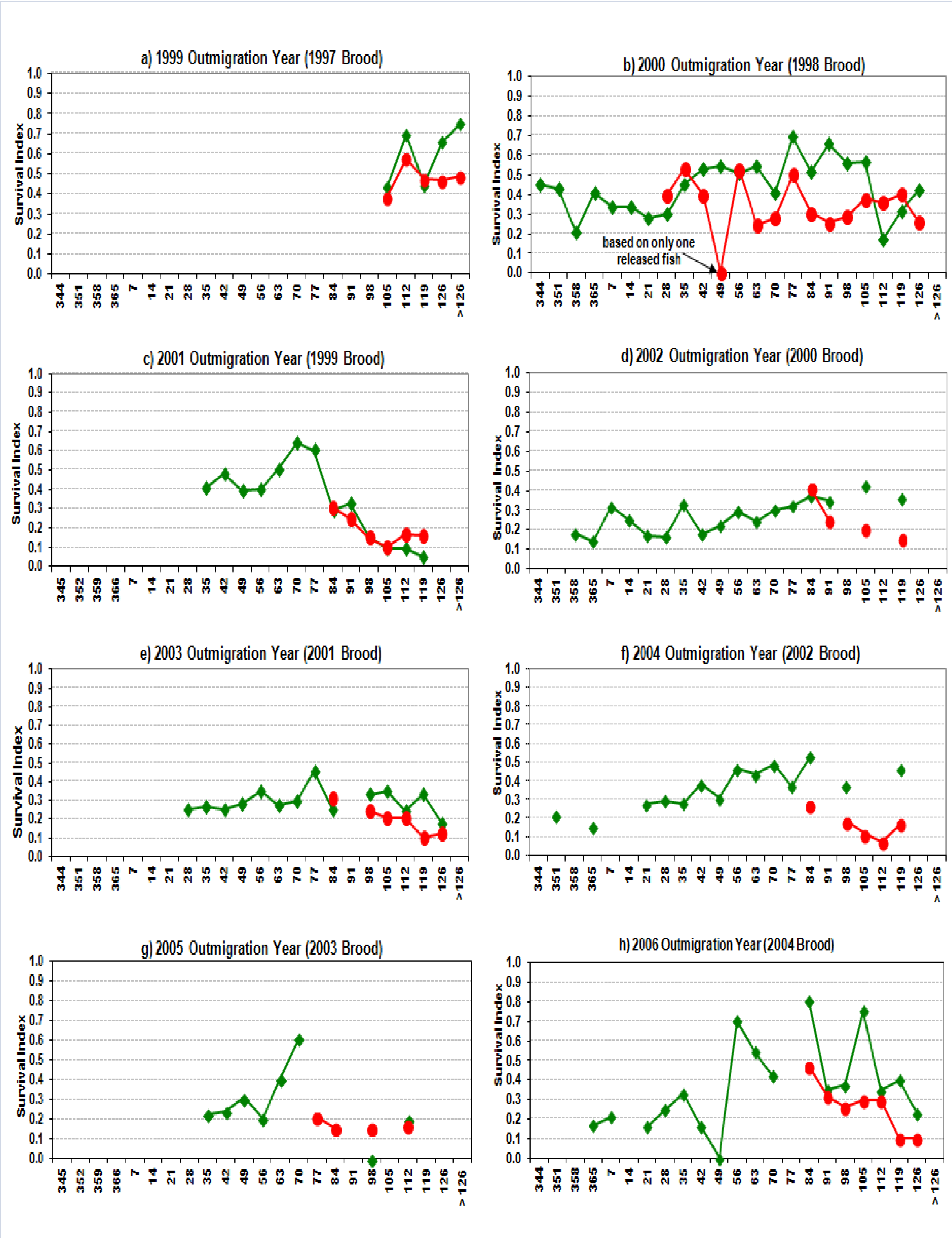
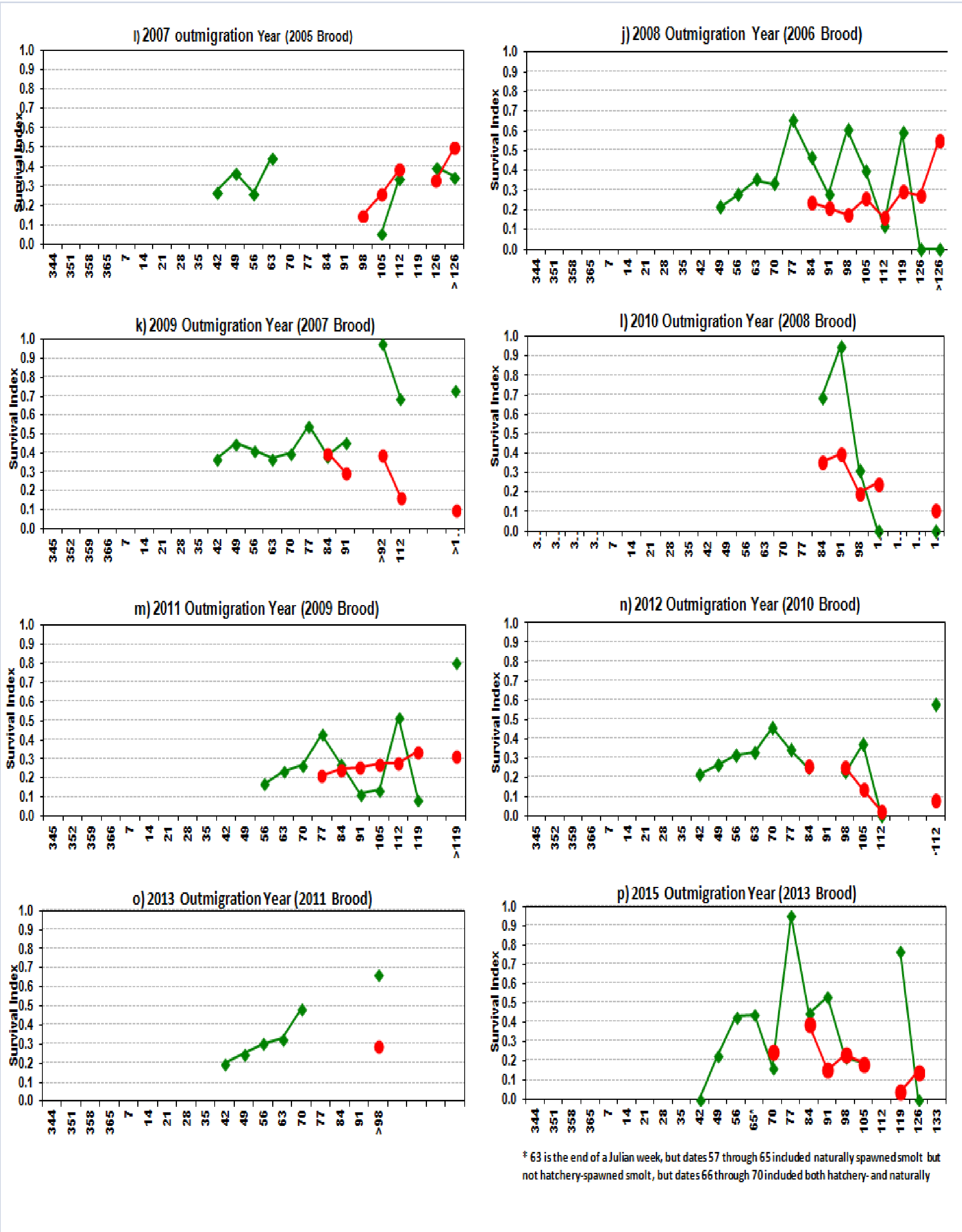


**Figure 2.b. (continued) Roza-Dam to McNary-Detection Smolt-to-Smolt Survival Index with respect to Julian Week (Natural Smolt - Green, Hatchery Smolt - Red)**



## Appendix A. Conceptual Computation

The smolt-to-smolt survival to McNary estimation method involves:

1. Identifying time-of-passage strata within which estimated daily McNary detection rates are reasonably homogeneous[8]. (Daily McNary detection rate is the estimated daily proportion of all[9] Yakima PIT-tagged Spring Chinook passing McNary Dam that were subsequently detected at McNary)

2. Estimating the McNary detection rate for each stratum

3. Expanding (dividing) each Roza group's release number of smolt detected at McNary during the stratum by the stratum's detection rate.

4. Totaling each group's release expanded McNary-detection numbers over all strata

5. Taking that release group's expanded total over strata and dividing it by the number of fish initially released at Roza

The steps given above can be summarized in the following equations:

Equation 1.

$$\text{Stratum McNary detection rate} = \frac{\text{number of joint detections at McNary and downstream dams within Stratum}}{\text{estimated total number of detections at downstream dams within Stratum}}$$

Equation 2.

$$\text{Smolt-to-Smolt Survival to McNary for a given group} = \frac{\sum_{\text{strata}} \text{For Stratum}\left[\frac{\text{Number McNary Detections from Group}}{\text{Stratum's McNary Detection Rate (Equation 1)}}\right]}{\text{Number of Smolt in Group Released at Roza}}$$

The methods of identifying strata and estimating the individual stratum detection rates at McNary are discussed in my annual report *Hatchery x Hatchery and Natural x Natural Smolt-to-Smolt Survivals and Mini-Jack Proportions of Upper Yakima Spring Chinook for Brood-Years 2002-2006*.

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8 These usually were the Julian weeks referred to in the main text; however in 2009 there were 6 groups used in the formal analysis but only 5 Julian weeks presented in main test Figure 2.b. and in 2013 there were 2 groups used in the formal analysis but only 1 presented in Figure 2..b.

9 All smolt PIT-tagged in the Yakima Basin, not only those PIT-tagged at Roza

# Appendix B. Statistical Tables

## Appendix B.1. Estimated Survival to McNary Dam of Roza-Released Upper-Yakima Natural- and Hatchery-Brood Spring Chinook Smolt

**a. 1999 Outmigration Year (Brood 1997)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | | 04/15/99 |
| Ending Week (ending date of week) | | | |
| **Natural Origin** | Number Released | | 133 |
| | Expanded McNary Passage Number | | 68.1 |
| | **Survival-Index Estimate** | | **0.5122** |
| **Hatchery Pooled** | Number Released | | 675 |
| | Expanded McNary Passage Number | | 306.4 |
| | **Survival-Index Estimate** | | **0.4540** |

**b. 2000 Outmigration Year (Brood 1998)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 12/10/99 | 01/28/00 |
| Ending Week (ending date of week) | | 01/27/00 | |
| **Natural Origin** | Number Released | 3013 | 3196 |
| | Expanded McNary Passage Number | 996.5 | 1593.8 |
| | **Survival-Index Estimate** | **0.3307** | **0.4987** |
| **Hatchery Pooled** | Number Released | | 2999 |
| | Expanded McNary Passage Number | | 946.1 |
| | **Survival-Index Estimate** | | **0.3155** |

**c. 2001 Outmigration Year (Brood 1999)**

| | | Hatchery | Hatchery |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/04/01 | 03/25/01 |
| Ending Week (ending date of week) | | 03/24/01 | |
| **Natural Origin** | Number Released | 755 | 1424 |
| | Expanded McNary Passage Number | 360.2 | 190.6 |
| | **Survival-Index Estimate** | **0.4771** | **0.1339** |
| **Hatchery Pooled** | Number Released | | 1744 |
| | Expanded McNary Passage Number | | 306.7 |
| | Survival-Index Estimate | | **0.1759** |

**d. 2002 Outmigration Year (Brood 2000)**

| | | Hatchery | Hatchery |
|---|---|---|---|
| Beginning Week (ending date of week) | | 12/24/01 | 03/25/02 |
| Ending Week (ending date of week) | | 03/24/02 | |
| **Natural Origin** | Number Released | 6604 | 2114 |
| | Expanded McNary Passage Number | 1528.3 | 757.6 |
| | **Survival-Index Estimate** | **0.2314** | **0.3584** |
| **Hatchery Pooled** | Number Released | | 1503 |
| | Expanded McNary Passage Number | | 421.3 |
| | Survival-Index Estimate | | 0.2803 |

**e. 2003 Outmigration Year (Brood 2001)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 01/28/03 | 03/25/03 |
| Ending Week (ending date of week) | | 03/24/03 | |
| **Natural Origin** | Number Released | 6614 | 1190 |
| | Expanded McNary Passage Number | 1876.5 | 327.2 |
| | **Survival-Index Estimate** | **0.2837** | **0.2750** |
| **Hatchery Pooled** | Number Released | | 2146 |
| | Expanded McNary Passage Number | | 458.5 |
| | **Survival-Index Estimate** | | **0.2137** |

**f. 2004 Outmigration Year (Brood 2002)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 12/10/03 | 03/24/04 |
| Ending Week (ending date of week) | | 03/17/04 | |
| **Natural Origin** | Number Released | 3857 | 74 |
| | Expanded McNary Passage Number | 1327.7 | 36.5 |
| | **Survival-Index Estimate** | **0.3442** | **0.4935** |
| **Hatchery Pooled** | Number Released | | 2201 |
| | Expanded McNary Passage Number | | 389.2 |
| | **Survival-Index Estimate** | | **0.1768** |

## Appendix B.1. (Continued)

**g. 2005 Outmigration Year (Brood 2003)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 12/24/04 | 03/18/05 |
| Ending Week (ending date of week) | | 03/11/05 | |
| **Natural Origin** | Number Released | 1688 | 45 |
| | Expanded McNary Passage Number | 440.2 | 5.1 |
| | **Survival-Index Estimate** | **0.2608** | **0.1122** |
| **Hatchery Pooled** | Number Released | | 1344 |
| | Expanded McNary Passage Number | | 200.7 |
| | **Survival-Index Estimate** | | **0.1494** |

**h. 2006 Outmigration Year (Brood 2004)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 12/31/05 | 03/18/06 |
| Ending Week (ending date of week) | | 03/11/06 | |
| **Natural Origin** | Number Released | 1833 | 500 |
| | Expanded McNary Passage Number | 432.8 | 308.0 |
| | **Survival-Index Estimate** | **0.2361** | **0.6160** |
| **Hatchery Pooled** | Number Released | | 3802 |
| | Expanded McNary Passage Number | | 1068.2 |
| | **Survival-Index Estimate** | | **0.2810** |

**i. 2007 Outmigration Year (Brood 2005)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/11/07 | 04/08/07 |
| Ending Week (ending date of week) | | 03/04/07 | |
| **Natural Origin** | Number Released | 1072 | 336 |
| | Expanded McNary Passage Number | 350.9 | 51.4 |
| | **Survival-Index Estimate** | **0.3273** | **0.1529** |
| **Hatchery Pooled** | Number Released | | 2477 |
| | Expanded McNary Passage Number | | 979.6 |
| | **Survival-Index Estimate** | | **0.3955** |

**j. 2008 Outmigration Year (Brood 2006)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/18/08 | 03/24/08 |
| Ending Week (ending date of week) | | 03/17/08 | |
| **Natural Origin** | Number Released | 1254 | 421 |
| | Expanded McNary Passage Number | 378.7 | 162.4 |
| | **Survival-Index Estimate** | **0.3020** | **0.3857** |
| **Hatchery Pooled** | Number Released | | 4406 |
| | Expanded McNary Passage Number | | 1133.7 |
| | **Survival-Index Estimate** | | **0.2573** |

**k. 2009 Outmigration Year (Brood 2007)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/11/09 | 03/25/09 |
| Ending Week (ending date of week) | | 03/18/09 | |
| **Natural Origin** | Number Released | 1804 | 172 |
| | Expanded McNary Passage Number | 773.2 | 88.8 |
| | **Survival-Index Estimate** | **0.4286** | **0.5161** |
| **Hatchery Pooled** | Number Released | | 2334 |
| | Expanded McNary Passage Number | | 561.3 |
| | **Survival-Index Estimate** | | **0.2405** |

**l. 2010 Outmigration Year (Brood 2008)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | | 03/25/10 |
| Ending Week (ending date of week) | | | |
| **Natural Origin** | Number Released | | 105 |
| | Expanded McNary Passage Number | | 61.7 |
| | **Survival-Index Estimate** | | **0.5874** |
| **Hatchery Pooled** | Number Released | | 1130 |
| | Expanded McNary Passage Number | | 361.2 |
| | **Survival-Index Estimate** | | **0.3196** |

## Appendix B.1. (Continued)

**m. 2011 Outmigration Year (Brood 2009)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/25/12 | 03/17/12 |
| Ending Week (ending date of week) | | 03/10/12 | |
| **Natural Origin** | Number Released | 985 | 956 |
| | Expanded McNary Passage Number | 216.7 | 311.7 |
| | **Survival-Index Estimate** | **0.2200** | **0.3260** |
| **Hatchery Pooled** | Number Released | | 3103 |
| | Expanded McNary Passage Number | | 831.4 |
| | **Survival-Index Estimate** | | **0.2679** |

**n. 2012 Outmigration Year (Brood 2010)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/25/12 | 03/17/12 |
| Ending Week (ending date of week) | | 03/10/12 | |
| **Natural Origin** | Number Released | 2482 | 193 |
| | Expanded McNary Passage Number | 748.5 | 46.7 |
| | **Survival-Index Estimate** | **0.3016** | **0.2419** |
| **Hatchery Pooled** | Number Released | | 4405 |
| | Expanded McNary Passage Number | | 814.3 |
| | **Survival-Index Estimate** | | **0.1849** |

**0. 2013 Outmigration Year (Brood 2011)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/11/13 | 04/08/13 |
| Ending Week (ending date of week) | | 04/01/13 | |
| **Natural Origin** | Number Released | 2435 | 38 |
| | Expanded McNary Passage Number | 709.1 | 25.2 |
| | **Survival-Index Estimate** | **0.2912** | **0.6642** |
| **Hatchery Pooled** | Number Released | | 550 |
| | Expanded McNary Passage Number | | 161.6 |
| | **Survival-Index Estimate** | | **0.2939** |

**p. 2015 Outmigration Year (Brood 2013)**

| | | Before Hatchery Passage | During Hatchery Passage |
|---|---|---|---|
| Beginning Week (ending date of week) | | 02/11/13 | 04/08/13 |
| Ending Week (ending date of week) | | 04/01/13 | |
| **Natural Origin** | Number Released | 282 | 243 |
| | Expanded McNary Passage Number | 105.7 | 87.3 |
| | **Survival-Index Estimate** | **0.3749** | **0.3594** |
| **Hatchery Pooled** | Number Released | | 1503 |
| | Expanded McNary Passage Number | | 335.6 |
| | **Survival-Index Estimate** | | **0.2233** |

## Appendix B.2. Weighted* Logistic Analyses of Variance for Roza-to-McNary Survival of Hatchery** Spawned Smolt Passing Roza Contemporaneously with Late Naturally-Spawned Smolt (non-shaded-analysis is basis of test)

### a) 1999 Outmigration (1997 Brood)

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 32.55 | 4 | 8.14 | 0.93 | 0.4943 | |
| Natural Origin versus Hatchery Origin[1] | 20.15 | 1 | 20.15 | 2.29 | 0.1683 | |
| Tagged vs Untagged Hatchery Origin1 | 8.26 | 1 | 8.26 | 0.94 | 0.3606 | |
| Error(1) | 70.26 | 8 | 8.7825 | | | |
| Natural Origin versus Hatchery Origin[2] | 20.15 | 1 | 20.15 | 2.35 | 0.1511 | 0.0755 |
| Tagged vs Untagged Hatchery Origin[2] | 8.26 | 1 | 8.26 | 0.96 | 0.3455 | |
| Error(2)[3] | 102.81 | 12 | 8.57 | | | |

### b) 2000 Outmigration (1998 Brood)

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 177.90 | 14 | 12.71 | 3.90 | 0.0017 | |
| Natural Origin versus Hatchery Origin[1] | 135.38 | 1 | 135.38 | 41.51 | 0.0000 | 0.0000 |
| Tagged vs Untagged Hatchery Origin[1] | 0.16 | 1 | 0.16 | 0.05 | 0.8266 | |
| Error(1) | 78.27 | 24 | 3.26 | | | |
| Natural Origin versus Hatchery Origin[2] | 135.38 | 1 | 135.38 | 20.08 | 0.0001 | |
| Tagged vs Untagged Hatchery Origin[2] | 0.16 | 1 | 0.16 | 0.02 | 0.8784 | |
| Error(2)[3] | 256.17 | 38 | 6.74 | | | |

### c) 2001 Outmigration (1999 Brood)

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 119.01 | 5 | 23.80 | 11.89 | 0.0006 | |
| Natural Origin versus Hatchery Origin[1] | 0.87 | 1 | 0.87 | 0.43 | 0.5246 | 0.2623 |
| Tagged vs Untagged Hatchery Origin[1] | 1.78 | 1 | 1.78 | 0.89 | 0.3679 | |
| Error(1) | 20.02 | 10 | 2.002 | | | |
| Natural Origin versus Hatchery Origin[2] | 0.87 | 1 | 0.87 | 0.09 | 0.7635 | |
| Tagged vs Untagged Hatchery Origin[2] | 1.78 | 1 | 1.78 | 0.19 | 0.6675 | |
| Error(2)[3] | 139.03 | 15 | 9.27 | | | |

* Weight is Number Released, Block being Late-Release Week

** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival

[1] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(1)

[2] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(2)

[3] Error (2) is pooling of Error(1) and Block. Analysis is based on Error(1) if Block Type 1 Error P < 0.2, otherwise analysis based on Error(2) is used

[4] One-sided test for Hatchery Survival < Wild Survival

## Appendix B.2. (continued)

**d) 2002 Outmigration (2000 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 41.93 | 4 | 10.48 | 1.34 | 0.3553 | |
| Natural Origin versus Hatchery Origin[1] | 19.10 | 1 | 19.10 | 2.45 | 0.1689 | |
| Tagged vs Untagged Hatchery Origin1 | 3.00 | 1 | 3 | 0.38 | 0.5582 | |
| Error(1) | 46.86 | 6 | 7.81 | | | |
| Natural Origin versus Hatchery Origin[2] | 19.10 | 1 | 19.1 | 2.15 | 0.1732 | 0.0866 |
| Tagged vs Untagged Hatchery Origin[2] | 3.00 | 1 | 3.00 | 0.34 | 0.5739 | |
| Error(2)[3] | 88.79 | 10 | 8.88 | | | |

**e) 2003 Outmigration (2001 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 46.25 | 5 | 9.25 | 1.83 | 0.1953 | |
| Natural Origin versus Hatchery Origin[1] | 12.33 | 1 | 12.33 | 2.43 | 0.1498 | 0.0749 |
| Tagged vs Untagged Hatchery Origin[1] | 0.62 | 1 | 0.62 | 0.12 | 0.7337 | |
| Error(1) | 50.65 | 10 | 5.07 | | | |
| Natural Origin versus Hatchery Origin[2] | 12.33 | 1 | 12.33 | 1.91 | 0.1873 | |
| Tagged vs Untagged Hatchery Origin[2] | 0.62 | 1 | 0.62 | 0.10 | 0.7610 | |
| Error(2)[3] | 96.90 | 15 | 6.46 | | | |

**f) 2004 Outmigration (2002 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 87.14 | 4 | 21.79 | 6.15 | 0.0257 | |
| Natural Origin versus Hatchery Origin[1] | 21.55 | 1 | 21.55 | 6.08 | 0.0487 | 0.0243 |
| Tagged vs Untagged Hatchery Origin[1] | 21.85 | 1 | 21.85 | 6.17 | 0.0476 | |
| Error(1) | 21.25 | 6 | 3.54 | | | |
| Natural Origin versus Hatchery Origin[2] | 21.55 | 1 | 21.55 | 1.99 | 0.1889 | |
| Tagged vs Untagged Hatchery Origin[2] | 21.85 | 1 | 21.85 | 2.02 | 0.1861 | |
| Error(2)[3] | 108.39 | 10 | 10.84 | | | |

* Weight is Number Released, Block being Late-Release Week

** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival

1 Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(1)

2 Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(2)

3 Error (2) is pooling of Error(1) and Block. Analysis is based on Error(1) if Block Type 1 Error P < 0.2, otherwise analysis based on Error(2) is used

4 One-sided test for Hatchery Survival < Wild Survival

## Appendix B.2. (continued)

**g) 2005 Outmigration (2003 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 15.16 | 3 | 5.05 | 0.98 | 0.4845 | |
| Natural Origin versus Hatchery Origin[1] | 0.03 | 1 | 0.03 | 0.01 | 0.9427 | |
| Tagged vs Untagged Hatchery Origin[1] | 0.01 | 1 | 0.01 | 0.00 | 0.9669 | |
| Error(1) | 20.54 | 4 | 5.135 | | | |
| Natural Origin versus Hatchery Origin[2] | 0.03 | 1 | 0.03 | 0.01 | 0.9410 | 0.5295 |
| Tagged vs Untagged Hatchery Origin[2] | 0.01 | 1 | 0.01 | 0.00 | 0.9659 | |
| Error(2)[3] | 35.70 | 7 | 5.10 | | | |

**h) 2006 Outmigration (2004 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 378.21 | 6 | 63.04 | 10.55 | 0.0003 | |
| Natural Origin versus Hatchery Origin[1] | 105.84 | 1 | 105.84 | 17.71 | 0.0012 | 0.0006 |
| Tagged vs Untagged Hatchery Origin[1] | 0.16 | 1 | 0.16 | 0.03 | 0.8727 | |
| Error(1) | 71.71 | 12 | 5.98 | | | |
| Natural Origin versus Hatchery Origin[2] | 105.84 | 1 | 105.84 | 4.23 | 0.0544 | |
| Tagged vs Untagged Hatchery Origin[2] | 0.16 | 1 | 0.16 | 0.01 | 0.9371 | |
| Error(2)[3] | 449.92 | 18 | 25.00 | | | |

**i) 2007 Outmigration (2005 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 236.27 | 4 | 59.07 | 12.32 | 0.0028 | |
| Natural versus Hatchery[1] | 32.50 | 1 | 32.50 | 6.78 | 0.0352 | 0.0176 |
| Tagged vs Untagged Hatchery | 25.61 | 1 | 25.61 | 5.34 | 0.0541 | |
| Error(1) | 33.56 | 7 | 4.79 | | | |
| **Natural versus Hatchery[2]** | 32.50 | 1 | 32.5 | 1.32 | 0.2741 | |
| **Tagged vs Untagged Hatchery[2]** | 25.61 | 1 | 25.61 | 1.04 | 0.3288 | |
| **Error(2)3** | 269.83 | 11 | 24.53 | | | |

* Weight is Number Released, Block being Late-Release Week

** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival

[1] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(1)

[2] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(2)

[3] Error (2) is pooling of Error(1) and Block. Analysis is based on Error(1) if Block Type 1 Error P < 0.2, otherwise analysis based on Error(2) is used

[4] One-sided test for Hatchery Survival < Wild Survival

## Appendix B.2. (continued)

**j) 2008 Outmigration (2006 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 272.61 | 7 | 38.94 | 5.84 | 0.0025 | |
| Natural Origin versus Hatchery Origin[1] | 46.66 | 1 | 46.66 | 7.00 | 0.0192 | 0.0096 |
| Tagged vs Untagged Hatchery Origin[1] | 0.78 | 1 | 0.78 | 0.12 | 0.7374 | |
| Error(1) | 93.33 | 14 | 6.67 | | | |
| Natural Origin versus Hatchery Origin[2] | 46.66 | 1 | 46.66 | 2.68 | 0.1167 | |
| Tagged vs Untagged Hatchery Origin[2] | 0.78 | 1 | 0.78 | 0.04 | 0.8345 | |
| Error(2)[3] | 365.94 | 21 | 17.43 | | | |

**k) 2009 Outmigration (2007 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 152.80 | 5 | 30.56 | 4.44 | 0.0258 | |
| Natural Origin versus Hatchery Origin[1] | 28.47 | 1 | 28.47 | 4.13 | 0.0726 | 0.9637 |
| Tagged vs Untagged Hatchery Origin[1] | 8.52 | 1 | 8.52 | 1.24 | 0.2950 | |
| Error(1) | 62.01 | 9 | 6.89 | | | |
| Natural Origin versus Hatchery Origin[2] | 28.47 | 1 | 28.47 | 1.86 | 0.1947 | |
| Tagged vs Untagged Hatchery Origin[2] | 8.52 | 1 | 8.52 | 0.56 | 0.4685 | |
| Error(2)[3] | 214.81 | 14 | 15.34 | | | |

**l) 2010 Outmigration (2008 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided Type 1 p[4] |
|---|---|---|---|---|---|---|
| Block[1] | 68.48 | 4 | 17.12 | 3.10 | 0.0913 | |
| Natural Origin versus Hatchery Origin[1] | 33.57 | 1 | 33.57 | 6.08 | 0.0431 | 0.0216 |
| Tagged vs Untagged Hatchery Origin[1] | 1.92 | 1 | 1.92 | 0.35 | 0.5739 | |
| Error(1) | 38.65 | 7 | 5.52 | | | |
| Natural Origin versus Hatchery Origin[2] | 33.57 | 1 | 33.57 | 3.45 | 0.0903 | |
| Tagged vs Untagged Hatchery Origin[2] | 1.92 | 1 | 1.92 | 0.20 | 0.6656 | |
| Error(2)[3] | 107.13 | 11 | 9.74 | | | |

* Weight is Number Released, Block being Late-Release Week

** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival

[1] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(1)

[2] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(2)

[3] Error (2) is pooling of Error(1) and Block. Analysis is based on Error(1) if Block Type 1 Error P < 0.2, otherwise analysis based on Error(2) is used

[4] One-sided test for Hatchery Survival < Wild Survival

## Appendix B.2. (continued)

**m) 2011 Outmigration (2009 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided[4] Type 1 p |
|---|---|---|---|---|---|---|
| Block[1] | 32.96 | 6 | 5.49 | 0.39 | 0.8684 | |
| Natural Origin versus Hatchery Origin[1] | 17.51 | 1 | 17.51 | 1.25 | 0.2867 | |
| Tagged vs Untagged Hatchery Origin[1] | 28.31 | 1 | 28.31 | 2.03 | 0.1822 | |
| Error(1) | 153.60 | 11 | 13.96 | | | |
| Natural Origin versus Hatchery Origin[2] | 17.51 | 1 | 17.51 | 1.60 | 0.2236 | 0.1118 |
| Tagged vs Untagged Hatchery Origin[2] | 28.31 | 1 | 28.31 | 2.58 | 0.1267 | |
| Error(2)[3] | 186.56 | 17 | 10.97 | | | |

**n) 2012 Outmigration (20010 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Analysis of Variation Type 1 P | 1-sided[4] Type 1 p |
|---|---|---|---|---|---|---|
| Block[1] | 323.24 | 4 | 80.81 | 19.51 | 0.0030 | |
| Natural Origin versus Hatchery Origin[1] | 1.03 | 1 | 1.03 | 0.25 | 0.6392 | 0.3196 |
| Tagged vs Untagged Hatchery Origin[1] | 2.70 | 1 | 2.70 | 0.65 | 0.4561 | |
| Error(1) | 20.71 | 5 | 4.14 | | | |
| Natural Origin versus Hatchery Origin[2] | 1.03 | 1 | 1.03 | 0.03 | 0.8732 | |
| Tagged vs Untagged Hatchery Origin[2] | 2.70 | 1 | 2.70 | 0.07 | 0.7964 | |
| Error(2)[3] | 343.95 | 9 | 38.22 | | | |

**o) 2013 Outmigration (2011 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | 1-sided[4] Type 1 p |
|---|---|---|---|---|---|---|
| Block1 | 26.82 | 1 | 26.82 | 0.97 | 0.5051 | |
| Wild versus All Hatchery[1] | 27.70 | 1 | 27.70 | 1.03 | 0.4949 | |
| Error(1) | 26.82 | 1 | 26.82 | | | |
| Wild versus All Hatchery[2] | 20.59 | 1 | 20.59 | 1.14 | 0.3978 | 0.1989 |
| Error(2)[3] | 36.19 | 2 | 18.10 | | | |

NOTE: In 2013 there too few Tagged for comparison to Untagged Hatchery-Origin Fish

**p) 2015 Outmigration (2013 Brood)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | 1-sided[4] Type 1 p |
|---|---|---|---|---|---|---|
| Block1 | 108.17 | 6 | 18.03 | 2.45 | 0.1497 | |
| Wild versus All Hatchery[1] | 15.69 | 1 | 15.69 | 2.13 | 0.1943 | 0.0972 |
| Error(1) | 44.11 | 6 | 7.35 | | | |
| Wild versus All Hatchery[2] | 19.63 | 1 | 19.63 | 1.59 | 0.2316 | |
| Error(2)[3] | 148.34 | 12 | 12.36 | | | |

*** Weight is Number Released, Block being Late-Release Week**

**** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival**

**[1] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(1)**

**[2] Block, Wild versus Hatchery, Tagged versus Untagged Hatchery tested against Error(2)**

**[3] Error (2) is pooling of Error(1) and Block. Analysis is based on Error(1) if Block Type 1 Error P < 0.2, other analysis based on Error(2) is used**

**[4] One-sided test for Hatchery Survival < Wild Survival**

## Appendix B.3. Weighted* Logistic Analyses of Variance Pooled over Years of Roza-to-McNary Survival of Contemporaneous Naturally-Spawned (Nat) and Hatchery-Spawned (Hat) Smolt Passing Roza

**(Weight = number of given stock released in given year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P (Nat ≠ Hat) | Type 1 Error P (Nat > Hat) |
|---|---|---|---|---|---|---|
| Nat vs Hat Stock (adjusted for Years) | 335.87 | 1 | 335.87 | 11.54 | 0.0040 | 0.0020 |
| Among Years (adjusted for stock) | 1377.35 | 15 | 91.82 | 3.15 | 0.0165 | |
| Stock x Year Interaction | 436.68 | 15 | 29.11 | | | |

**(Weight = measure of inverse of variation* of estimate)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error (Nat ≠ Hat) | Type 1 Error (Nat > Hat) |
|---|---|---|---|---|---|---|
| Nat vs Hat Stock (adjusted for Years) | 59.06 | 1 | 59.06 | 8.36 | 0.0112 | 0.0056 |
| Among Years (adjusted for stock) | 407.17 | 15 | 27.14 | 3.84 | 0.0066 | |
| Stock x Year Interaction | 105.97 | 15 | 7.06 | | | |

$$^{*}\ \text{Weight} = \frac{\text{Expanded Number of Released Fish Detected at McNary for Group}}{\left[\dfrac{\text{Error Mean Deviance for Year (Appendix C.1)}}{\text{Number of Released (for group)}}\right]}$$

## Appendix B.4. Weighted* Logistic Analyses of Variance for Roza-to-McNary Survival of Naturally-Spawned Smolt Passing Roza Before (Early) and Contemporaneously (Late) with Hatchery-Spawned Smolt

**a) 1999 Outmigration (1997 Brood Year)**
**[No Roza Tagging prior to Hatchery-Release Passage at Roza]**

**b) 2000 Outmigration (1998 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Type 1 Error | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 181.10 | 1 | 181.10 | 31.62 | 0.0000 | Late |
| Error | 114.54 | 20 | 5.73 | | | |

**c) 2001 Outmigration (1999 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 297.69 | 1 | 297.69 | 34.62 | 0.0001 | Early |
| Error | 94.60 | 11 | 8.60 | | | |

**d) 2002 Outmigration (2000 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 161.77 | 1 | 161.77 | 20.03 | 0.0004 | Late |
| Error | 121.16 | 15 | 8.08 | | | |

**e) 2003 Outmigration (2001 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 0.38 | 1 | 0.38 | 0.05 | 0.8230 | Early |
| Error | 87.28 | 12 | 7.27 | 0.00 | | |

**f) 2004 Outmigration (2002 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 6.81 | 1 | 6.81 | 0.51 | 0.4903 | Late |
| Error | 161.35 | 12 | 13.45 | | | |

* Weight is Number Released

** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival

*** "Late" Outmigrating means migrating contemporaneously w ith Hatchery-produced Fish and "Early" means oumigrating before Hatchery-produced Fish

## Appendix B.4. (Continued)

**g) 2005 Outmigration (2003 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 5.98 | 1 | 5.98 | 0.81 | 0.4035 | Early |
| Error | 44.43 | 6 | 7.41 | | | |

**h) 2006 Outmigration (2004 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 246.57 | 1 | 246.57 | 17.31 | 0.0010 | Late |
| Error | 199.40 | 14 | 14.24 | | | |

**i) 2007 Outmigration (2005 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural-Origin Early versus Late | 41.69 | 1 | 41.69 | 4.11 | 0.0889 | Early |
| Error | 60.82 | 6 | 10.14 | | | |

**j) 2008 Outmigration (2006 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 9.91 | 1 | 9.91 | 1.50 | 0.2458 | Late |
| Error | 72.51 | 11 | 6.59 | | | |

**k) 2009 Outmigration (2007 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Natural Origin Early versus Late | 0.42 | 1 | 0.42 | 0.10 | 0.7590 | Late |
| Error | 37.78 | 9 | 4.20 | | | |

**l) 2010 Outmigration (2008 Brood Year)**
**[No Roza Tagging prior to Hatchery-Release Passage at Roza]**

* Weight is Number Released
** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival
*** "Late" Outmigrating means migrating contemporaneously w ith Hatchery-produced Fish and "Early" means oumigrating before Hatchery-produced Fish

## Appendix B.4. (Continued)

**n) 2011 Outmigration (2009 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Devivance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Wild Early versus Late | 27.63 | 1 | 27.63 | 1.79 | 0.2176 | Late |
| Error | 123.43 | 8 | 15.43 | | | |

**n) 2012 Outmigration (2010 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Devivance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Wild Early versus Late | 3.17 | 1 | 3.17 | 0.45 | 0.5212 | Early |
| Error | 64.04 | 9 | 7.12 | | | |

**o) 2013 Outmigration (2011 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Devivance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Wild Early versus Late | 22.16 | 1 | 22.16 | 1.20 | 0.3226 | Late |
| Error | 92.06 | 5 | 18.41 | | | |

**p) 2015 Outmigration (2013 Brood Year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Devivance (Dev/DF) | F-Ratio | P | Highest Survival Estimate: |
|---|---|---|---|---|---|---|
| Wild Early versus Late | 0.13 | 1 | 0.13 | 0.02 | 0.8986 | Late |
| Error | 68.04 | 9 | 7.56 | | | |

* Weight is Number Released

** Roza-Dam-Release to McNary-Dam -Detection Smolt-to-Smolt Survival

*** "Late" Outmigrating means migrating contemporaneously w ith Hatchery-produced Fish and "Early" means oumigrating before Hatchery-produced Fish

## Appendix B.5. Weighted Logistic Analyses of Variance over Years for Pooled Roza-to-McNary Survival of Early and Late Naturally-Spawned Smolt Passing Roza

**(Weight = number of given stock released in given year)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P |
|---|---|---|---|---|---|
| Early vs Late Natually Spaw ned Brood (adjusted for Years) | 164.38 | 1 | 164.38 | 2.6334 | 0.1286 |
| Among Years (adjusted for Brood) | 667.19 | 13 | 51.32 | 0.8222 | 0.6353 |
| Brood x Year Interaction | 811.47 | 13 | 62.42 | | |

**(Weight = measure of inverse of variation* of estimate)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P |
|---|---|---|---|---|---|
| Early vs Late Natually Spaw ned Brood (adjusted for Years) | 21.99 | 1 | 21.99 | 3.2084 | 0.0966 |
| Among Years (adjusted for Brood) | 104.09 | 13 | 8.01 | 1.1682 | 0.3917 |
| Brood x Year Interaction | 89.1 | 13 | 6.85 | | |

Note: Nat denotes Natural-Origin Stock, Hat denotes Hatchery-Origin Stock
Year and Stock Tested against Interaction (Denominator Mean Deviance).
Note: In release years 2009 and 2010 there w ere no early Natural releasease

$$* \quad \text{Weight} = \frac{\text{Expanded Number of Released Fish Detected at McNary for Group}}{\left[\dfrac{\text{Error Mean Deviance for Year (Appendix D.1)}}{\text{Number of Released (for group)}}\right]}$$

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## Appendix D
## Annual Report: Comparisons between Smolt-Trait Measures of Hatchery x Hatchery- and Natural x Natural-Brood Stock for Brood-Years 2002-2015 Upper Yakima Spring Chinook

**Doug Neeley, Consultant to the Yakama Nation**

### Summary

Hatchery x Hatchery (HxH or Hatchery Control - HC) and Natural x Natural (NxN or Supplemental Hatchery -SH) stock[1] reared at the Cle Elum Facility were allocated to Clark Flat acclimation-site raceway pairs. With the exception of the 2013 brood (released as smolt in 2015), the raceways within each pair were assigned different feed treatments. This report focuses on the stock comparisons and their interactions with other factors.

For brood-years 2002 through 2013 (release-years 2004 through 2015, respectively), the following juvenile traits are analyzed:

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

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

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

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

## Introduction

In previous years' annual reports, analyses were summarized for the following traits.

1) Pre-release weight
2) Volitional-release-to-McNary survival
3) Percent of fish detected leaving pond
4) Mean and median acclimation-pond volitional-release date
5) Mean and median McNary passage date
6) Pre-release length
7) Pre-release Percent of juveniles that are males
8) Pre-release Percent of males that are precocial (mini-jacks)

NOAA Fisheries had taken pre-release fish samples from which individual fish measures were made on the following of the above: 1) Pre-release weight, 6) Pre-release length, 7) Pre-release percent of juveniles that were males, and 8) Pre-release percent of males that were precocial. NOAA ceased taking samples from the Cle Elum acclimation ponds beginning with the 2012 brood released in 2014 (they ceased taking samples at two other acclimation sites, Easton and Jack Creek, the year before). However, the hatchery staff has been taking pre-release measures of the weight on a bulk measure, computing number-of-fish/pound. These measures, converted to an average grams/fish are now being used for 1) Pre-release weight assessment.

## Design of Experiment and Analysis Procedures

The HxH stock assignment was superimposed at only the Clark Flat Acclimation Site at which there were three pairs of raceways[2] with two feed treatments[3] allocated to the different raceways within each pair. The HxH Stock was allocated to one of the three pairs of raceways, and the NxN Stock to the other two pairs[4]. Thus there were twice as many raceways at Clark Flat assigned to the NxN Stock than to the HxH Stock. The design was effectively a Split-Plot design at both the hatchery at Cle Elum and at the acclimation site, Clark Flat, with the Stock assigned to the raceway pairs (main-plot), and the feed levels assigned to raceways within raceway pairs (subplot).

---

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

[3] In every year, two treatments were evaluated. In BY 2002- BY 2004, they were Low and High Nutrition Feed levels (LO and HI) of the feed, Bio-Vita, the High (HI) Feed level being the standard feed or Control over all years. The Low (LO) Nutrition Feed was tested to determine whether it would reduce the proportion of male smolt that were sexually mature (precocial and mini-jacks). In BY 2005 and 2007 through 2012, the standard feed (Bio-Vita) was either supplemented or not supplemented with Salt-water Transfer Feed (STF) to test whether supplementation with STF increased the rate of smoltification. In BY 2006, two feeds (Bio-Vita and EWOS) were evaluated. In BY 2013 only the standard feed was used.

[4] NxN stock was the only stock used at the other two acclimation sites (i.e., allocated to all three pairs of raceways at both Easton and Jack Creek).

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

Both main effect HxH–NxN differences and the interactions among yearly stock differences within years were tested at the 5% significance level using either a weighted-least-squares analysis of variance or a weighted-logistic-analysis of variation[5]. The analyses of variation are presented in Appendix A. Year was taken to be a random effect; therefore, the weighted mean HxH - NxN main-effect difference over years was usually tested against the Stock x Year interaction, and that interaction was tested against the variation among raceway-pairs within-years. More detailed analyses were undertaken when there were significant Stock x Feed-Level x Year interactions.

## Data Summary Differences from the Previous Report

There have been some traits for which there were significant interactions between feed treatment, year, and stock effects. In the 2014 report, rather than try to interpret these interactions, the decision was made to use the fish data from only those raceways receiving the standard feed. In absence of such interaction, comparisons between the stocks' means for only the Control treatment estimates would be less powerful than estimates based on pooling data from the two treatments because fewer smolt would be involved in the analysis. For each trait analyzed in this report, the pooled means over feed treatments are presented. Whenever any Stock x Feed-Level or Stock x Feed-Level x Year interactions are significant at the 10% significance level[6], the stocks' means are also compared separately for two treatments.

Errors in estimation of previous years' studies were discovered. Whenever a presented mean or median pooled over treatments differs from that presented in the 2013 annual report or whenever a mean for the Control treatment differs from that presented in the 2014 annual report, that mean or median is underlined in this report.

In tables of means, in addition to significant levels for HxH – NxN main-effect comparisons over years, significance levels for Mean HxH – NxN comparisons within year are presented; however, the power of these tests is week because the degrees of freedom associated with the test is small. Within the text, main effect mean comparisons over years are the only ones evaluated in terms of significance.

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

[6] Interactions are less powerfully measured than main effect means. For this reason the lower 10% rather than the 5% significance level was chosen as a basis for making stock comparisons within feed-treatment levels.

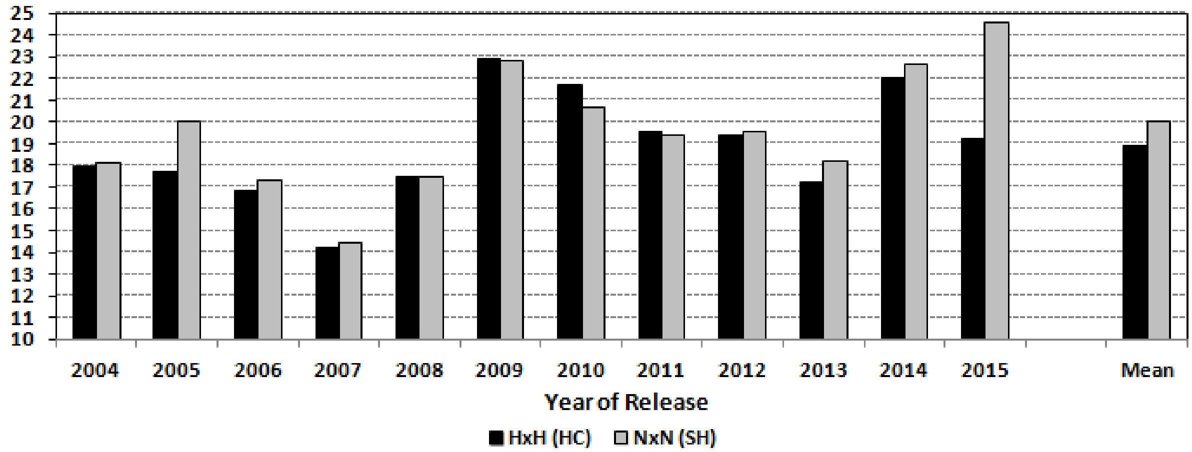
Methods of estimating McNary passage and survival are presented in Appendix B.

## Mean Pre-Release Smolt Weight

Figure 1. and Table 1.a. present the individual release-year HxH and NxN stock pre-release fish-weight means. The main-effect-mean difference between stock was not significant at the 5% level (P = 0.2881, Appendix Table A.1.), and all interactions involving stock with feed level were not significant at the 10% level (Appendix Table A.1.).

**Figure 1.** **Mean Smolt Weight (gr) of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared Smolt weighed before Leaving the Clark Flat Acclimation Site**

**(Averaged over Feed-Level Treatments)**




The Stock x Year interaction was significant at the 10% significance level (P = 0.0912, Appendix Table A.1.). This is because the NxN weight in release year 2015 was much higher than the HxH weight than in previous years. This appears to be an aberration. There was only one treatment level for that brood. The weights for all raceways in all acclimation sites are presented in Table 1.b. Note that the HxH weights at Clark Flat are comparable to the NxN weights at the other two acclimation sites (Easton and Jack Creek) where only NxN stock were reared, but the NxN weights at Clark Flat are much higher, not only than those for HxH at Clark Flat, but also are greater than NxN weights at the other sites.

**Table 1.b. 2015 Smolt Weight* (gr) for each Acclimation-Site Raceway**

| Clark Flat | | Easton | | Jack Creek | |
|---|---|---|---|---|---|
| Raceway-Stock | Weight | Raceway-Stock | Weight | Raceway-Stock | Weight |
| 1-HxH | 18.51 | 1-NxN | 18.29 | 1-NxN | 18.07 |
| 2-HxH | 19.89 | 2-NxN | **21.30** | 2-NxN | 18.29 |
| 3-NxN | **22.13** | 3-NxN | 16.38 | 3-NxN | 16.55 |
| 4-NxN | **23.02** | 4-NxN | 19.38 | 4-NxN | 13.11 |
| 5-NxN | **27.00** | 5-NxN | 18.90 | 5-NxN | 17.58 |
| 6-NxN | **26.22** | 6-NxN | 16.93 | 6-NxN | 18.07 |

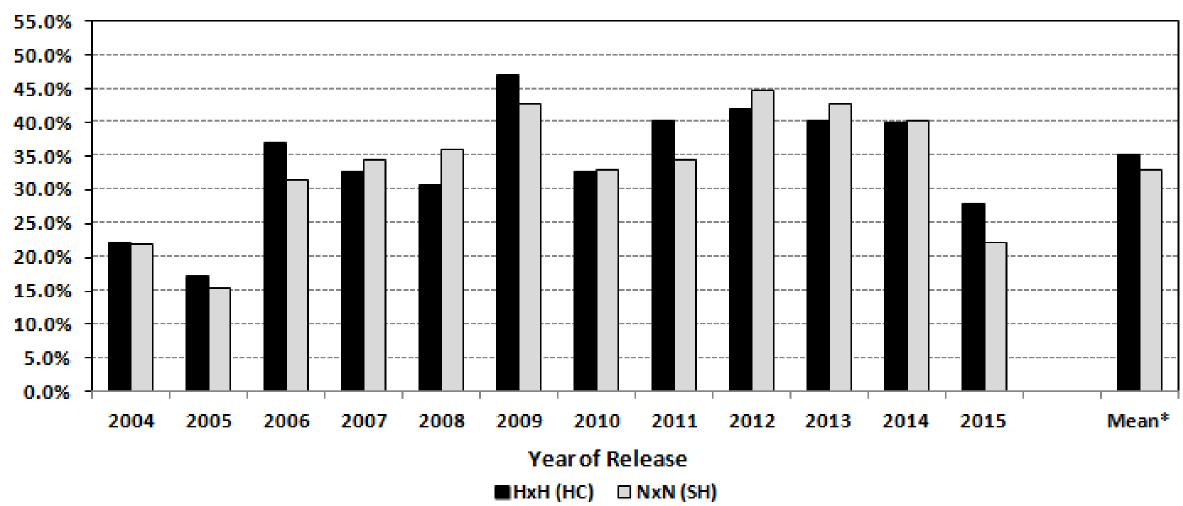
* Weights greater than 20 gr are boldfaced, all such weights at Clark Flat being greater than all weights at other acclimarion sites

## Release-to-McNary Smolt-to-Smolt Survival

The mean Release-to-McNary survival is the estimated percent of all PIT-Tagged fish detected leaving the acclimation site that pass McNary. Estimates are given in Figure and Table 2. Neither the HxH – NxN main-effect nor the HxH – NxN interaction with year were significant (P = 0.4781 and P = 0.2084, respectively, Appendix Table A.2.), and all interactions involving treatment and nutrition-feed level were not significant at the 10% level (Appendix Table A.2.).

We note that the 2015 release was associated with the record low snow packs in the Cascade Mountains and a severe drought year. The 2015 release survival to McNary was the lowest since the 2005 release.

Figure 2. Mean Survival to McNary of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Pooled* over Feed Levels)




* Averaged over all smolt detected at release

**Table 2. Mean Survival to McNary of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site**

**(Pooled* over Feed Levels)**

| | Brood Year > | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| | Release Year > | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Brood Stock | Feed-Level Treatments Assessed > | Low versus (vs) High Nutrition Level | | | STF +Bio-Vita vs Bio-Vita | EWOS vs Bio-Vita | STF +Bio-Vita vs Bio-Vita |
| HxH (HC) | Survival Percentage | 22.1% | 17.1% | 37.1% | 32.7% | 30.7% | 47.0% |
| | n (Detected at Release) | 4,286 | 4,269 | 4,311 | 4,322 | 7,508 | 7,395 |
| NxN (SH) | Survival Percentage | 22.0% | 15.4% | 31.4% | 34.4% | 35.9% | 42.7% |
| | n (Detected at Release) | 8,707 | 8,637 | 8,651 | 8,743 | 7,669 | 7,875 |
| | HxH - NxN Difference | 0.2% | 1.7% | 5.7% | -1.7% | -5.2% | 4.3% |
| | Type 1 Error P | 0.9489 | 0.5386 | 0.1177 | 0.6196 | 0.0983 | 0.1842 |

| | Brood Year > | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | Release Year > | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Pooled* |
| Brood Stock | Feed-Level Treatments Assessed > | STF +Bio-Vita vs Bio-Vita | | | | | Bio-Vita Only | over Years |
| HxH (HC) | Survival Percentage | 32.7% | 40.3% | 41.9% | 40.2% | 39.9% | 28.0% | 35.3% |
| | n (Detected at Release) | 7,855 | 7,836 | 7,743 | 7,381 | 7,562 | 7,379 | 77,847 |
| NxN (SH) | Survival Percentage | 33.0% | 34.5% | 44.8% | 42.9% | 40.3% | 22.2% | 33.0% |
| | n (Detected at Release) | 7,789 | 7,831 | 7,680 | 7,641 | 7,616 | 7,733 | 96,572 |
| | HxH - NxN Difference | -0.3% | 5.8% | -2.8% | -2.6% | -0.4% | 5.8% | 2.3% |
| | Type 1 Error P | 0.9114 | 0.0753 | 0.3756 | 0.4057 | 0.9092 | 0.9092 | 0.4781 |

*Averaged over all smolt detected at release

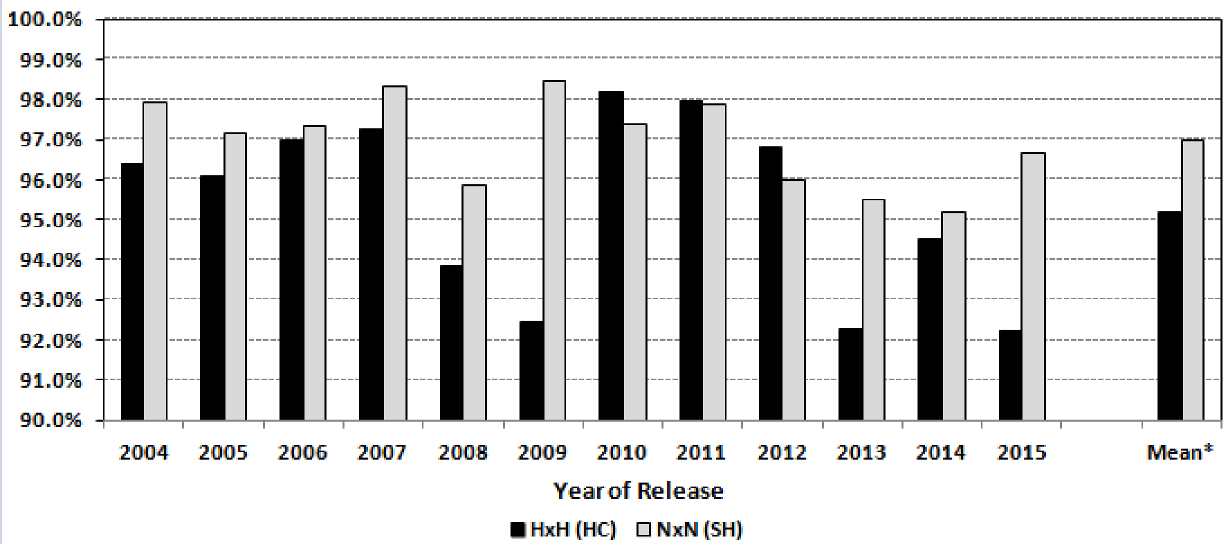
## Mean Percent of PIT-Tagged Smolt Detected leaving the Acclimation Site

Figure 3.and Table 3.a.present the individual release-year HxH and NxN stock percentages of fish detected leaving the acclimation site. The estimate is simply the ratio as a percentage[7] of the number of fish detected leaving the acclimation-site raceway to the total number of fish originally tagged; this percentage is used here as an index of pre-release survival. The HxH - NxN main-effect mean difference is negative and significant at the 5% level (P = 0.0131, Appendix Table A.3.a.), indicating a lower pre-release HxH survival compared to that for the NxN stock The stock comparisons' interactions with years was also significant at the 5% level (P = 0.0237, Appendix Table A.3.a). The HxH mean is lower in 9 of the 12 years thus far analyzed, the inconsistency over years being the source of the interaction. However, in 7 of those 9 years, the NxN stock's percent was 1% or more than that of HxH stock; thus far, the HxH stock's percent has never exceeded that of NxN stock by 1%.

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

Figure 3. Percent Detected at Release of Hatchery-Brood (HxH) and Natural Brood (NxN) Hatchery -reared PIT-Tagged Smolt from Clark Flat Acclimation Site

(Pooled over Feed Levels)




* Averaged over all tagged smolt

**Table 3.a.** Percent Detected at Release of Hatchery-Brood (HxH) and Natural Brood (NxN) Hatchery -reared PIT-Tagged Smolt from Clark Flat Acclimation Site

(Pooled* over Feed Levels)

| | Brood Year > | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| | Release Year > | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Brood Stock | Feed-Level Treatments Assessed > | Low versus (vs) High Nutrition Level | | | STF + Bio-Vita vs Bio-Vita | EWOS vs Bio-Vita | STF + Bio-Vita vs Bio-Vita |
| HxH (HC) | Percent Released | 96.4% | 96.1% | 97.0% | 97.2% | 93.9% | 92.4% |
| | n (Number Tagged) | 4,446 | 4,444 | 4,446 | 4,445 | 8,000 | 8,000 |
| NxN (SH) | Percent Released | 97.9% | 97.2% | 97.3% | 98.3% | 95.9% | 98.4% |
| | n (Number Tagged) | 8,892 | 8,889 | 8,889 | 8,894 | 8,000 | 8,000 |
| | HxH - NxN Difference | -1.5% | -1.1% | -0.4% | -1.1% | -2.0% | **-6.0%** |
| | Type 1 Error P | 0.1381 | 0.3152 | 0.7209 | 0.2333 | 0.1024 | **0.0003** |

| | Brood Year > | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 [1] | |
|---|---|---|---|---|---|---|---|---|
| | Release Year > | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Pooled* |
| Brood Stock | Feed-Level Treatments Assessed > | STF + Bio-Vita vs Bio-Vita | | | | | Bio-Vita Only | over Years |
| HxH (HC) | Percent Released | 98.2% | 98.0% | 96.8% | 92.3% | 94.5% | 92.2% | 95.2% |
| | n (Number Tagged) | 8,000 | 8,000 | 8,000 | 7,999 | 8,001 | 7,999 | 81,780 |
| NxN (SH) | Percent Released | 97.4% | 97.9% | 96.0% | 95.5% | 95.2% | 96.7% | 97.0% |
| | n (Number Tagged) | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 | 99,564 |
| | HxH - NxN Difference | 0.8% | 0.1% | 0.8% | **-3.2%** | -0.7% | -4.4% | **-1.8%** |
| | Type 1 Error P | 0.2987 | 0.9333 | 0.4263 | **0.0228** | 0.5552 | 0.5552 | **0.0131** |

* Averaged over all tagged smolt

For the 2004-2006 Low versus High nutrition level Bio-Vita treatment year comparisons, the Stock x Feed-Level x Year interaction was significant at the 1% significance level (P = 0.0065, Appendix Table A.3.a) and that interaction measure was significant at the 10% level for the STF versus Bio-Vita treatment comparisons for 2007, and 2009 through 2014 (P = 0.0737, Appendix Table A.3.a). Therefore Stock comparisons were made within treatment levels and are discussed below.

Table 3.b presents the means for the Control treatments (Bio-Vita or High). When viewed over all years, the Control treatment's HxH main-effect mean percent leaving the pond was again negative and significant at the 5% level (P=0.0064, Appendix A.3.b.). For the years when the tested treatment was the Low nutrition level, the Control treatment's HxH - NxN stock main-effect difference was significant at the 5% level (P=0.0380, Appendix A.3.b), but the stock's interaction with year is not (P=0.5658). For the years when the STF supplement was the tested treatment, HxH - NxN stock main effect was not significant at the 5% level (P = 0.2045, Appendix A.3.b), but the stock's interaction with year is significant at the 10% level (P = 0.0816). In spite of the inconsistent significance level for these two groups of multi-year tests, the main effect HxH percent detected leaving ponds was lower for NxN stock for both feed-level treatment sets; this was also the case for the year when EWOS was the tested treatment and for the year, 2015, when there was no tested treatment. This is consistent with the comparison where the Control and tested treatment data were polled together. In fact, the Control treatment comparisons were more consistent than those based on the pooling over treatments with 11 of the 12 years with a lower HxH percent detected leaving the acclimation site (Table 3.b.) compared to the 9 out of 12 in Table 3.a.

**Table 3.b. Percent Detected at Release of Hatchery-Brood (HxH) and Natural Brood (NxN) Hatchery -reared PIT-Tagged Smolt from the Clark Flat Acclimation Site**

**(Control Bio-Vita Feed Level)**

**Emphasis on HI versus LO Release Years 2004-2006 and STF vs Bio Years 2007, 2009-2014**

| Brood Stock | Brood Year > / Release Year > | 2002 / 2004 | 2003 / 2005 | 2004 / 2006 | Pooled* Over LO Years | 2006 / 2008 | 2013 / 2015 | Pooled* over all Years |
|---|---|---|---|---|---|---|---|---|
| HxH (HC) | Percent Released | 97.3% | 96.1% | 96.6% | 96.7% | 95.1% | 92.2% | 95.5% |
| | n (Number Tagged) | 2,223 | 2,222 | 2,222 | 6,667 | 4,000 | 7,999 | 71,108 |
| NxN (SH) | Percent Released | 97.9% | 97.7% | 97.7% | 97.8% | 96.2% | 96.7% | 97.3% |
| | n (Number Tagged) | 4,446 | 4,444 | 4,444 | 13,334 | 4,000 | 8,000 | 82,234 |
| | **0.001935209** | -1.6% | -1.6% | -1.1% | **-1.1%** | -1.0% | -4.4% | **-1.7%** |
| | **Type 1 Error P** | 0.6859 | 0.3491 | 0.5005 | **0.0380** | 0.5738 | 0.4722 | **0.0064** |

| Brood Stock | Brood Year > / Release Year > | 2005 / 2007 | 2007 / 2009 | 2008 / 2010 | 2009 / 2011 | 2010 / 2012 | 2011 / 2013 | 2012 / 2014 | Pooled* Over LO Years |
|---|---|---|---|---|---|---|---|---|---|
| HxH (HC) | Percent Released | 97.75% | 93.9% | 98.7% | 97.6% | 97.23% | 94.6% | 94.9% | 96.3% |
| | n (Number Tagged) | 2,222 | 4,000 | 4,000 | 4,000 | 4,000 | 3,999 | 4,000 | 26,221 |
| NxN (SH) | Percent Released | 98.07% | 98.5% | 97.3% | 98.2% | 96.97% | 96.0% | 96.2% | 97.3% |
| | n (Number Tagged) | 4,450 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 28,450 |
| | **HxH - NxN Difference** | -0.32% | **-4.6%** | -0.6% | -0.6% | 0.25% | -1.4% | -1.3% | -1.0% |
| | **Type 1 Error P** | 0.8271 | **0.0256** | 0.2843 | 0.6368 | 0.8663 | 0.4538 | 0.4722 | 0.2045 |

*** Averaged over all tagged smolt**

Table 3.c. presents the means for the tested treatments. Even when viewed over all years, the tested treatment's HxH main-effect mean percent leaving the pond was again negative but not quite significant at the 5% level (P=0.0533, Appendix A.3.c). For the years when the tested treatment was the Low nutrition level, the Low's HxH - NxN stock main-effect difference was far from significant (P=0.4238), and for the years when the STF supplement was the tested treatment, the negative HxH – NxN difference was also not significant (P=0.1818). Again, the main effect HxH percent detected leaving ponds was lower than NxN for both sets of years as it was for the EWOS-tested release year and the 2015 release year. The HxH stock had a lower percent of smolt detected leaving ponds in 7 of the 11 years involving tested treatments (2015 had no tested treatment). It should be noted that the four years with the highest absolute values in HxH - NxN treatment differences were years that had a lower HxH percent.

**Table 3.c. Percent Detected at Release of Hatchery-Brood (HxH) and Natural Brood (NxN) Hatchery -reared PIT-Tagged Smolt from the Clark Flat Acclimation Site**

**(Tested Nutrition Levels: LO - Low Nutrition Level of Bio-Vita Feed;**
**STF - Salt Water Transfer Supplement to Control Level; EWS - EWOS Feed)**
**Emphasis on HI versus LO Release Years 2004-2006 and STF vs Bio Years 2007, 2009-2014**

| | **Treatment** | **LO** | | | **Pooled*** | **EWS** | **Pooled*** |
|---|---|---|---|---|---|---|---|
| **Brood** | **Brood Year >** | **2002** | **2003** | **2004** | **0ver** | **2006** | **over** |
| **Stock** | **Release Year >** | **2004** | **2005** | **2006** | **LO Years** | **2008** | **all Years** |
| **HxH (HC)** | **Percent Released** | 95.5% | 96.0% | 97.3% | 96.3% | 92.6% | 94.8% |
| | **n (Number Tagged)** | 2,223 | 2,222 | 2,224 | 6,669 | 4,000 | 36,893 |
| **NxN (SH)** | **Percent Released** | 98.0% | 96.6% | 96.9% | 97.2% | 95.6% | 96.7% |
| | **n (Number Tagged)** | 4,446 | 4,445 | 4,445 | 13,336 | 4,000 | 45,780 |
| | **0.001935209** | -2.4% | -0.6% | 0.4% | -0.9% | -3.0% | **-1.9%** |
| | **Type 1 Error P** | 0.1295 | 0.7320 | 0.7862 | 0.4238 | 0.1181 | **0.0689** |

| | **Treatment** | **STF** | | | | | | | **Pooled*** |
|---|---|---|---|---|---|---|---|---|---|
| **Brood** | **Brood Year >** | **2005** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **0ver** |
| **Stock** | **Release Year >** | **2007** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **LO Years** |
| **HxH (HC)** | **Percent Released** | 96.7% | 91.0% | 97.6% | 98.3% | 96.3% | 90.0% | 94.1% | 94.7% |
| | **n (Number Tagged)** | 2,223 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,001 | 26,224 |
| **NxN (SH)** | **Percent Released** | 98.5% | 98.4% | 97.4% | 97.6% | 95.0% | 95.0% | 94.2% | 96.6% |
| | **n (Number Tagged)** | 4,444 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 28,444 |
| | **HxH - NxN Difference** | -1.8% | **-7.4%** | 0.3% | 0.7% | 1.3% | **-5.0%** | 0.0% | -1.9% |
| | **Type 1 Error P** | 0.1760 | **0.0022** | 0.8163 | 0.5103 | 0.3997 | **0.0277** | 0.9783 | 0.1818 |

*** Averaged over all tagged smolt**

## Volitional Release Dates

The mean and median dates of detections of smolt leaving acclimation ponds are given in Figures 4.a and 4.b and are presented in Table 4. Based on means, negative HxH – NxN Main-Effect comparison was significant at the 5% level (P = 0.0389, Appendix Table A.4) but the HxH – NxN interaction with years was not (P = 0.2334). There were also no significant interactions of HxH –NxN comparisons at the 10% level with any of the other factors. The less powerful sign test for differences in medians was also not significant (P = 0.3877 for two sided test for 9 of 12 of the years having NxN with the later date**).**

**Figure 4.a.** Mean Julian Release Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Averaged over Feed levels)

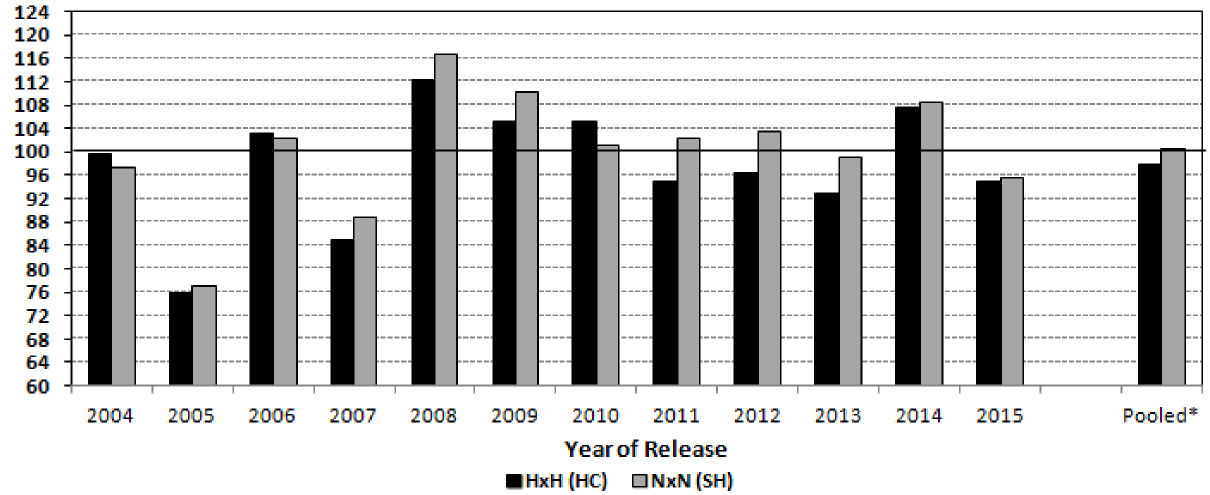
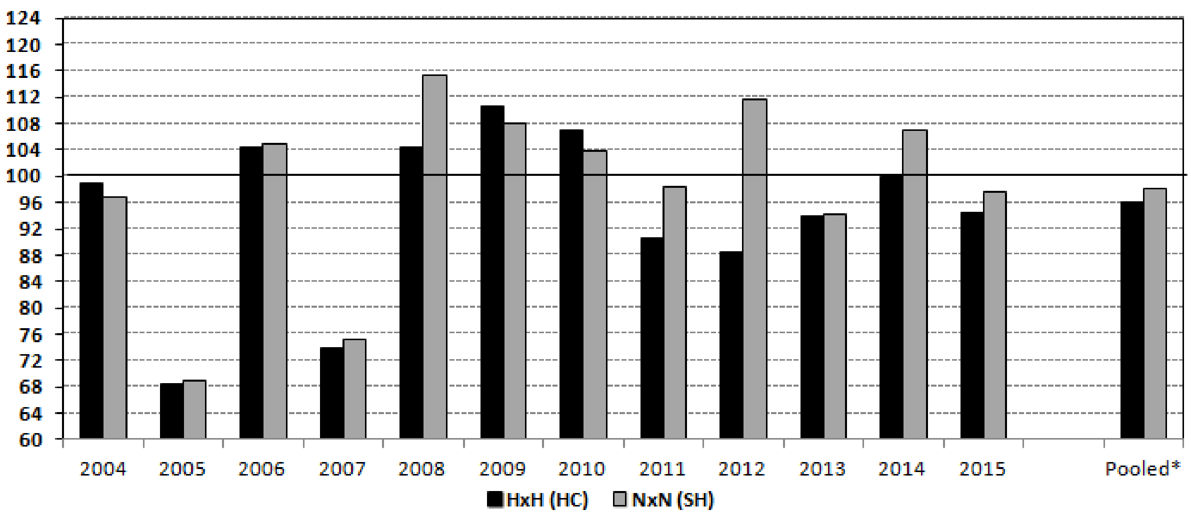



**Figure 4.b.** Median Julian Release Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Averaged over Feed levels)




* Averaged over all smolt detected at release

Table 4. Mean and Median Julian Release Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site

(Averaged over Feed levels)

| | Brood Year > | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| | Release Year > | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Brood Stock | Feed-Level Treatments Assessed > | Low versus (vs) High Nutrition Level | | | STF + VITA vs VITA | EWOS vs Vita | STF + VITA vs VITA |
| HxH (HC) | Mean Passage Date | 99.5 | 75.8 | 103.2 | 84.9 | 112.3 | 105.1 |
| | Median Passage Date | 99.0 | 68.5 | 104.5 | 74.0 | 104.5 | 110.5 |
| | n (McNary Passage) | 4,286 | 4,269 | 4,311 | 4,322 | 7,508 | 7,395 |
| NxN (SH) | Mean Passage Date | 97.3 | 77.0 | 102.2 | 88.8 | 116.7 | 110.1 |
| | Median Passage Date | 96.8 | 69.0 | 105.0 | 75.3 | 115.4 | 108.0 |
| | n (McNary Passage) | 8,707 | 8,637 | 8,651 | 8,743 | 7,669 | 7,875 |
| | HxH - NxN Mean Difference | 2.2 | -1.1 | 1.0 | **-3.9** | **-4.4** | -5.0 |
| | Two-Sided Type 1 Error P | 0.3504 | 0.6302 | 0.6736 | **0.1163** | **0.0489** | 0.0286 |
| | HxH - NxN Median Difference | 2.3 | -0.5 | -0.5 | -1.3 | -10.9 | 2.5 |

| | Brood Year > | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Pooled* |
|---|---|---|---|---|---|---|---|---|
| | Release Year > | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | |
| Brood Stock | Feed-Level Treatments Assessed > | STF + Bio-Vita vs Bio-Vita | | | | | Bio-Vita Only | over Years |
| HxH (HC) | Mean Passage Date | 105.2 | 95.0 | 96.5 | 92.8 | 107.5 | 95.0 | 98.0 |
| | Median Passage Date | 107.0 | 90.5 | 88.5 | 94.0 | 100.0 | 94.6 | 96.0 |
| | n (McNary Passage) | 7,855 | 7,836 | 7,743 | 7,381 | 7,562 | 7,379 | 77,847 |
| NxN (SH) | Mean Passage Date | 101.1 | 102.4 | 103.4 | 99.2 | 108.3 | 95.5 | 100.6 |
| | Median Passage Date | 103.8 | 98.3 | 111.7 | 94.2 | 107.0 | 97.5 | 98.0 |
| | n (McNary Passage) | 7,789 | 7,831 | 7,680 | 7,641 | 7,616 | 7,733 | 96,572 |
| | HxH - NxN Mean Difference | 4.2 | **-7.3** | **-6.8** | -6.4 | -0.9 | -0.5 | **-2.6** |
| | Two-Sided Type 1 Error P | 0.0581 | **0.0031** | **0.0050** | 0.0083 | 0.6746 | 0.7915 | 0.0389 |
| | HxH - NxN Median Difference | 3.2 | -7.8 | -23.3 | -0.3 | -7.0 | -2.9 | -2.0 |

* Averaged over all smolt detected at release

## Mean McNary-Dam Juvenile-Passage Dates

The mean and median Dates of McNary Passage are given in Figures 5.a. and 5.b and are presented in Table 5. Based on means, both the HxH – NxN Main-Effect difference and the HxH – NxN comparisons' interaction with year were significant (P = 0.0416 and P = 0.0088, respectively; Appendix Table A.5.a), the NxN stock having a later mean passage date in 9 out of the 12 years. The less powerful sign test for differences in medians over years was not significant (P = 0.1460), the median NxN passage date being later in 9 out of 12 years[8].

We note that, based on median and mean differences, there is no consistent evidence of skewness in passage time, the mean and medians being nearly similar for both stock when averaged over years.

[8] The sign (+/-) of the HxH - NxN differences were the same for means as they were for the medians in each of those years.

**Figure 5.a.1) McNary Dam Mean Julian Detection Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Pooled* over Feed Levels)**

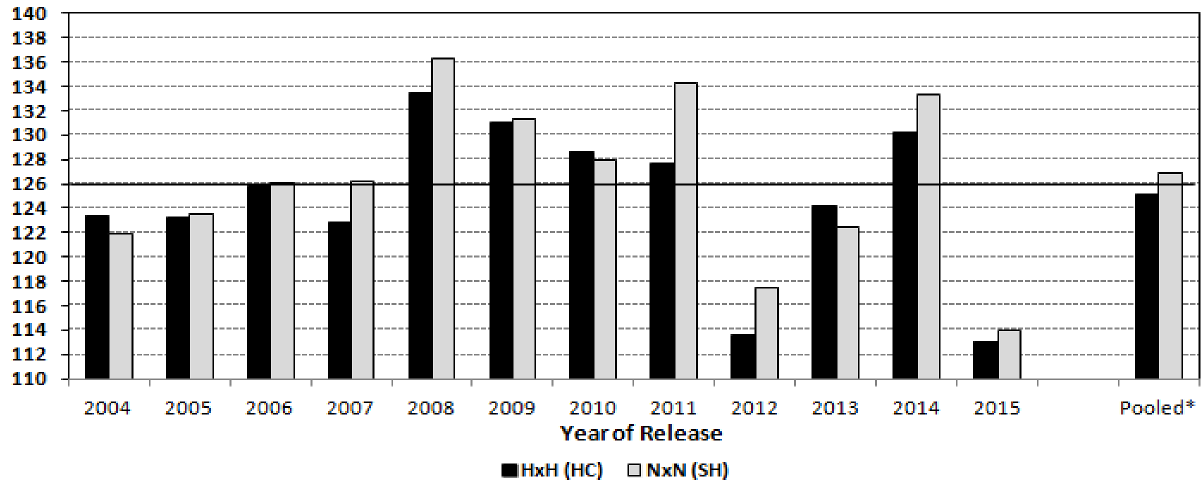
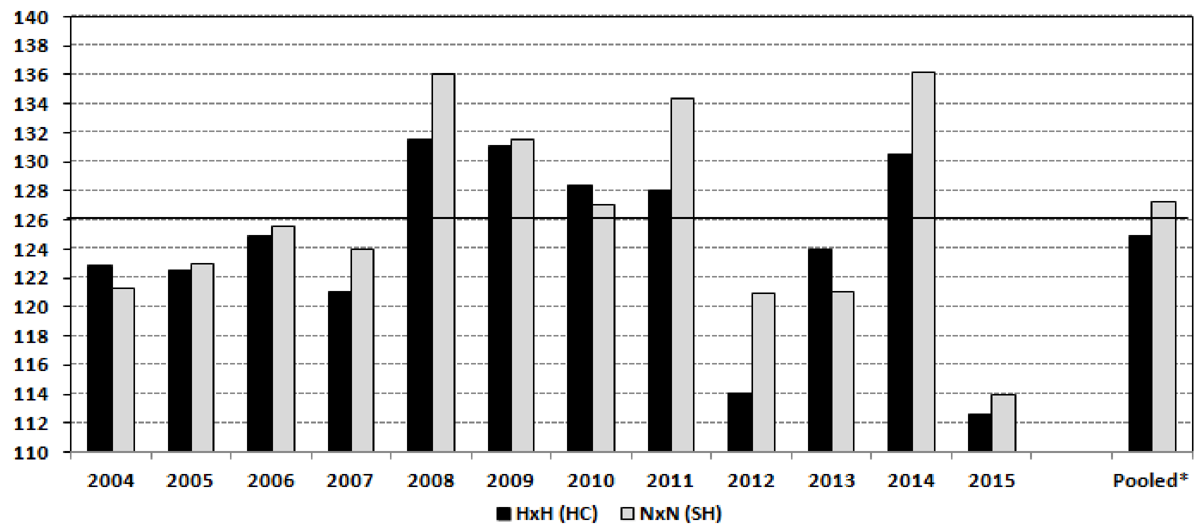



**Figure 5.b.2) McNary Dam Median Julian Detection Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Pooled* over Feed Levels)**




*** Averaged over Estimated McNary Passage**

**Table 5.a. McNary Dam Mean and Median Julian Detection Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Pooled* over Feed Levels)**

| | Brood Year > | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| | Release Year > | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Brood Stock | Feed-Level Treatments Assessed > | Low versus (vs) High Nutrition Level | | | STF + Bio-Vita vs Bio-Vita | EWOS vs Bio-Vita | STF + Bio-Vita vs Bio-Vita |
| HxH (HC) | Mean Passage Date | 123.3 | 123.2 | 125.8 | 122.9 | 133.4 | 131.0 |
| | Median Passage Date | 122.9 | 122.5 | 124.9 | 121.0 | 131.5 | 131.1 |
| | n (McNary Passage) | 949 | 728 | 1597 | 1413 | 2302 | 3476 |
| NxN (SH) | Mean Passage Date | 122.0 | 123.5 | 126.1 | 126.2 | 136.3 | 131.3 |
| | Median Passage Date | 121.3 | 123.0 | 125.5 | 124.0 | 136.0 | 131.5 |
| | n (McNary Passage) | 1911 | 1330 | 2716 | 3009 | 2753 | 3360 |
| | HxH - NxN Mean Difference | 1.4 | -0.3 | -0.2 | -3.3 | -2.9 | -0.2 |
| | Two-Sided Type 1 Error P | 0.5864 | 0.9207 | 0.9070 | 0.1282 | 0.1274 | 0.8780 |
| | HxH - NxN Median Difference | 1.6 | -0.5 | -0.6 | -3.0 | -4.5 | -0.4 |

| | Brood Year > | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | |
|---|---|---|---|---|---|---|---|---|
| | Release Year > | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Pooled* |
| Brood Stock | Feed-Level Treatments Assessed > | STF + Bio-Vita vs Bio-Vita | | | | | Bio-Vita Only | over Years |
| HxH (HC) | Mean Passage Date | 128.6 | 127.7 | 113.6 | 124.2 | 130.2 | 113.0 | 125.1 |
| | Median Passage Date | 128.4 | 128.1 | 114.1 | 124.0 | 130.5 | 112.5 | |
| | n (McNary Passage) | 2565 | 3157 | 3248 | 2967 | 3021 | 2065 | |
| NxN (SH) | Mean Passage Date | 128.0 | 134.2 | 117.5 | 122.5 | 133.4 | 114.0 | 126.8 |
| | Median Passage Date | 127.0 | 134.3 | 121.0 | 121.0 | 136.2 | 114.0 | |
| | n (McNary Passage) | 2569 | 2704 | 3437 | 3274 | 3069 | 1716 | |
| | HxH - NxN Mean Difference | 0.6 | **-6.5** | **-3.9** | 1.8 | -3.2 | -0.9 | **-1.7** |
| | Two-Sided Type 1 Error P | 0.7361 | **0.0019** | **0.0260** | 0.2854 | 0.0718 | 0.6602 | 0.0416 |
| | HxH - NxN Median Difference | 1.4 | -6.2 | -6.9 | 3.0 | -5.7 | -1.5 | |

*** Averaged over all smolt detected at release**

For the 2007/2009-2014 STF versus Control treatment-year comparisons, both the Stock x Feed-Level and the Stock x Feed-Level x Year interaction were significant (respectively P = 0.0150 and P = 0.0094, Appendix Table A.5.a). Tables 5.b. and 5.b present the means for the Control and Tested treatments separately for all years with emphasis on the STF treatment years.

For the Control treatment (Table 5.b.), the HxH - NxN stock main effect over all years was significant at the 5% level (P=0.0313, Appendix A.5.b). The Control treatment's HxH - NxN main effect over the STF years was not quite significant at the 5% level (P=0.0569, Appendix A.5.b). The difference in the significance levels between Control treatment's HxH - NxN comparison for the STF treatment years and that based on all years is primarily due the relative power of the test, there being 7 STF treatment years but a total of 12 years of HxH vs NxN comparisons. Though not significant, in 5 of the 7 years involving the STF treatment, the Control's HxH stock's median date of McNary passage was less than that of the NxN stock; over all years evaluated, the Control's HxH stock's median McNary-passage date was lower than that of the NxN stock in 8 of 12 years. The same was true for the means.

**Table 5.b.** McNary Dam Mean and Median Julian Detection Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site

(Control Bio-Vita Feed Level)

**Emphasis on STF vs Bio Years 2007, 2009-2014**

| Brood Stock | Brood Year > / Release Year > | 2002 / 2004 | 2003 / 2005 | 2004 / 2006 | 2006 / 2008 | 2013 / 2015 | Pooled over All Years |
|---|---|---|---|---|---|---|---|
| HxH (HC) | Mean Release Date | 122.4 | 122.5 | 125.0 | 134.4 | 113.0 | 124.1 |
| | Median Release Date | 122.0 | 122.0 | 124.0 | 132.0 | 112.5 | 123.6 |
| | Mean - Median | 0.4 | 0.5 | 1.0 | 2.4 | 0.5 | 0.6 |
| | n (McNary Passage) | 521 | 371 | 852 | 1,234 | 2,065 | 14,971 |
| NxN (SH) | Mean Release Date | 120.7 | 122.9 | 124.6 | 136.0 | 114.0 | 125.80 |
| | Median Release Date | 119.8 | 122.6 | 124.0 | 135.5 | 114.0 | 125.87 |
| | Mean - Median | 0.9 | 0.3 | 0.6 | 0.5 | 0.0 | -0.1 |
| | n (McNary Passage) | 987 | 721 | 1,522 | 1,383 | 1,716 | 16,856 |
| | HxH - NxN Mean Difference | 1.7 | -0.3 | 0.3 | -1.7 | -0.9 | **-1.7** |
| | Two-Sided Type 1 Error P | 0.4391 | 0.8926 | 0.8389 | 0.2917 | 0.4777 | **0.0313** |
| | HxH - NxN Median Difference | 2.2 | -0.6 | 0.0 | -3.5 | -1.5 | **-2.3** |

| Brood Stock | Brood Year > / Release Year > | 2005 / 2007 | 2007 / 2009 | 2008 / 2010 | 2009 / 2011 | 2010 / 2012 | 2011 / 2013 | 2012 / 2014 | Pooled* over STF Years |
|---|---|---|---|---|---|---|---|---|---|
| HxH (HC) | Mean Release Date | 123.0 | 132.4 | <u>130.3</u> | 126.7 | <u>112.4</u> | 120.5 | <u>129.6</u> | 125.2 |
| | Median Release Date | 121.0 | 132.0 | 131.0 | 127.0 | <u>112.0</u> | 119.0 | **130.0** | 124.9 |
| | Mean - Median | 2.0 | 0.4 | -0.7 | -0.3 | 0.4 | 1.5 | -0.4 | 0.3 |
| | n (McNary Passage) | 769 | 1,930 | 1,242 | 1,455 | 1,560 | 1,473 | 1,499 | 9,927 |
| NxN (SH) | Mean Release Date | 126.5 | 131.3 | 129.1 | 133.2 | <u>117.7</u> | 123.4 | <u>132.4</u> | 127.23 |
| | Median Release Date | 124.5 | 131.5 | 129.5 | 132.5 | <u>122.4</u> | 122.1 | 133.0 | 127.61 |
| | Mean - Median | 2.0 | -0.2 | -0.4 | 0.6 | -4.6 | 1.3 | -0.6 | -0.4 |
| | n (McNary Passage) | 1,545 | 1,606 | 1,242 | 1,312 | 1,782 | 1,592 | 1,449 | 10,527 |
| | HxH - NxN Mean Difference | -3.5 | 1.1 | 1.1 | **-6.4** | **-5.4** | -2.9 | -2.8 | **-2.0** |
| | Two-Sided Type 1 Error P | 0.0634 | 0.4014 | 0.4758 | **0.0009** | **0.0017** | 0.0567 | 0.0769 | **0.0684** |
| | HxH - NxN Median Difference | -3.5 | 0.5 | 1.5 | **-5.5** | **-10.4** | -3.1 | -3.0 | **-2.7** |

* Averaged over McNary Passage Estimates

Regarding HxH - NxN comparisons for the Tested treatments (Table 5.c), the HxH - NxN stock main-effect negative difference over all years is not significant at the 5% level (P = 0.1871) nor is the negative main-effect difference over the STF years (P=0.3706). The STF Tested treatment's HxH stock's <u>median</u> date of passage was lower than the NxN stock's in 6 of 7 years[9]; for all Tested treatments HxH stock's <u>median</u> date of passage was lower in 9 out of 11 years[10]. While levels of significance attained for the Tested treatment's HxH – NxN comparisons were not realized as they were for the Control treatment's comparisons or for the pooling of the Control and Tested treatment's, the number of years that the HxH stock's date of McNary Passage means and medians were less than that of the NxN stock for the Tested treatment equaled or exceeded the number for the Control treatment and for the pooled data from the Control and Tested treatments.

[9] The sign (+/-) of the HxH - NxN differences were the same for means as they were for the medians in each of those years.

[10] In the case of the means, 8 of the 12 had HxH - NxN differences of less than 0.

**Table 5.c.** McNary Dam Mean and Median Julian Detection Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared Smolt Detected Leaving the Clark Flat Acclimation Site

(Tested Nutrition Levels: LO - Low Nutrition Level Bio-Vita Feed; EWS - EWOS Feed;

STF - Salt Water Transfer Supplement to Control Level)

**Emphasis on STF vs Bio Years 2007, 2009-2014**

| | Treatment | LO | | | EWS | Pooled* |
|---|---|---|---|---|---|---|
| Brood | Brood Year > | 2002 | 2003 | 2004 | 2008 | over |
| Stock | Release Year > | 2004 | 2005 | 2006 | 2010 | All Years |
| HxH (HC) | Mean Detection Date | 124.5 | 124.0 | 126.8 | 132.3 | 126.46 |
| | Median Detection Date | 124.0 | 123.0 | 126.0 | 126.0 | 126.53 |
| | Mean - Median | 0.5 | 1.0 | 0.8 | 6.3 | -0.1 |
| | n (Number Detection) | 428 | 357 | 745 | 1,323 | 12,517 |
| NxN (SH) | Mean Detection Date | 123.3 | 124.3 | 127.9 | 126.9 | 127.84 |
| | Median Detection Date | 139.0 | 123.5 | 127.5 | 124.7 | 128.01 |
| | Mean - Median | -15.7 | 0.8 | 0.4 | 2.3 | -0.2 |
| | n (Number Detection) | 924 | 608 | 1,194 | 1,327 | 14,992 |
| | HxH - NxN Mean Difference | 1.2 | -0.3 | -1.1 | 5.3 | -1.4 |
| | Two-Sided Type 1 Error P | 0.6234 | 0.9048 | 0.5896 | 0.9526 | 0.1871 |
| | HxH - NxN Median Difference | -15.0 | -0.5 | -1.5 | 1.3 | -1.5 |

| | Treatment | STF | | | | | | | Pooled* |
|---|---|---|---|---|---|---|---|---|---|
| Brood | Brood Year > | 2005 | 2007 | 2006 | 2009 | 2010 | 2011 | 2012 | over |
| Stock | Detection Year > | 2007 | 2009 | 2008 | 2011 | 2012 | 2013 | 2014 | STF Years |
| HxH (HC) | Mean Detection Date | 123 | 129 | 127 | 129 | 115 | 128 | 131 | 126 |
| | Median Detection Date | 121 | 130 | 131 | 129 | 116 | 129 | 131 | 127 |
| | Mean - Median | 2 | -1 | -4 | 0 | -1 | -1 | 0 | -1 |
| | n (Number Detection) | 645 | 1546 | 1067 | 1702 | 1688 | 1495 | 1521 | 9665 |
| NxN (SH) | Mean Detection Date | 126 | 131 | 137 | 135 | 117 | 122 | 134 | 129 |
| | Median Detection Date | 124 | 131 | 136 | 136 | 119 | 120 | 139 | 129 |
| | Mean - Median | 2 | 0 | 0 | -1 | -2 | 2 | -5 | -1 |
| | n (Number Detection) | 1464 | 1753 | 1370 | 1392 | 1656 | 1683 | 1620 | 10939 |
| | HxH - NxN Mean Difference | -3.1 | -2.0 | **-9.5** | -6.7 | -2.5 | **6.4** | **-3.5** | -2.6 |
| | Two-Sided Type 1 Error P | 0.1433 | 0.2110 | **0.0307** | 0.0013 | 0.1151 | **0.0016** | **0.0410** | 0.3351 |
| | HxH - NxN Median Difference | -2.5 | -1.5 | -5.5 | -7.0 | -3.5 | 9.0 | -8.0 | -2.3 |

*** Averaged over McNary Passage Estimates**

## Appendix A. Analyses of Variation for the Analyzed Measures

Note that in the following tables, with the exception of interactions involving Stock, sources that have attained a significance level of $P \leq 0.05$ are bold-faced. In the case of interactions of stock with other factors (Stock x Year, Stock x Feed-Level, and Stock x Feed-Level x Year), those sources attaining a significance level of $P \leq 0.1$ are boldfaced.

## Appendix A.1. Mean Pre-Release Smolt Weight

**Table A.1. Analysis of Variance of Mean Smolt Weight (gr) of Hatchery-Brood (HxH) and Natural-Brood (NxN)Hatchery-reared PIT-tagged smolt weighed before Leaving the Clark Flat Acclimation Site**

| Source | Sums of Squares (SS) | Degrees of Freedom (DF) | Mean Square (DSS/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Square |
|---|---|---|---|---|---|---|
| **Year** | **550.20** | **11** | **50** | **30.31** | **0.0000** | **Among Raceway Pairs** |
| Stock | 4.60 | 1 | 5 | 1.25 | 0.2881 | Stock x Year |
| **Stock x Year** | **40.60** | **11** | **4** | **2.24** | **0.0912** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | **19.80** | **12** | **2** | **5.45** | **0.0042** | **Pooled Error over Trials** |
| **Low-High*** | **87.95** | **1** | **88** | **105.96** | **0.0093** | **Low-High x Year** |
| Stock x Low-High | 2.10 | 1 | 2 | 4.57 | 0.1661 | Stock x Low-High x Year |
| **Low-High x Year: 2004-2006** | **1.66** | **2** | **1** | **20.75** | **0.0175** | **Error from Low-High Trials** |
| **Stock x Low-High x Year: 2004-2006** | **0.92** | **2** | **0** | **11.50** | **0.0392** | **Error from Low-High Trials** |
| Error from Low-High Trials | 0.12 | 3 | 0 | | | |
| EWAS-BIO (2008) | 0.51 | 1 | 1 | 2.43 | 0.3632 | Error from EWAS - Bio Trial |
| Stock x EWAS-BIO | 0.25 | 1 | 0 | 1.19 | 0.4723 | Error from EWAS - Bio Trial |
| Error from EWAS - Bio Trial | 0.21 | 1 | 0 | | | |
| STF-BIO | 0.60 | 1 | 1 | 0.62 | 0.4608 | STF-BIO x Year |
| Stock x STF-BIO | 0.00 | 1 | 0 | 0.00 | 1.0000 | Stock x STF-BIO x Year |
| STF-BIO x Year: 2007,2009-2014 | 5.80 | 6 | 1 | 2.26 | 0.1556 | Error from STF - Bio Trials |
| Stock x STF-BIO x Year: 2007,2009-2014 | 2.60 | 6 | 0 | 1.01 | 0.4864 | Error from STF - Bio Trials |
| Error from STF - Bio Trials | 3.00 | 7 | 0 | | | |
| Pooled Error over Trials | 3.33 | 11 | 0.30 | | | |

## Appendix A.2. Release-to-McNary Smolt-to-Smolt Survival

**Table A.2. Logistic Analysis of Variation Table of Survival Percentage to McNary Dam of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Averaged over Feed Levels)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Deviance |
|---|---|---|---|---|---|---|
| **Year** | **5646.9** | **11** | **513.35** | **35.14** | **0.0000** | **Among Raceway Pairs** |
| **Stock** | 12.8 | 1 | 12.80 | 0.54 | 0.4781 | Stock x Year |
| **Stock x Year** | 261.07 | 11 | 23.73 | 1.62 | 0.2084 | Among Raceway Pairs |
| Among Raceway Pairs | 175.3 | 12 | 14.61 | 2.04 | 0.1234 | Pooled Error over Trials |
| **Low-High*** | **71.75** | **1** | **71.75** | **12.87** | **0.0697** | **Low-High x Year** |
| Stock x Low-High | 0.5 | 1 | 0.5 | 0.16 | 0.7254 | Stock x Low-High x Year |
| Low-High x Year: 2004-2006 | 11.15 | 2 | 5.575 | 1.04 | 0.4550 | Error from Low-High Trials |
| Stock x Low-High x Year: 2004-2006 | 6.13 | 2 | 3.065 | 0.57 | 0.6171 | Error from Low-High Trials |
| Error from Low-High Trials | 16.15 | 3 | 5.38 | | | |
| **EWAS-BIO (2008)** | 5.82 | 1 | 5.82 | 20.07 | 0.1398 | Error from EWAS - Bio Trial |
| **Stock x EWAS-BIO** | 5.73 | 1 | 5.73 | 19.76 | 0.1409 | Error from EWAS - Bio Trial |
| Error from EWAS - Bio Trial | 0.29 | 1 | 0.29 | | | |
| **STF-BIO** | 15.63 | 1 | 15.63 | 1.23 | 0.3101 | STF-BIO x Year |
| **Stock x STF-BIO** | 3.02 | 1 | 3.02 | 0.21 | 0.6639 | Stock x STF-BIO x Year |
| **STF-BIO x Year: 2007,2009-2014** | 76.34 | 6 | 12.72 | 1.43 | 0.3225 | Error from STF - Bio Trials |
| **Stock x STF-BIO x Year: 2007,2009-2014** | 86.85 | 6 | 14.48 | 1.63 | 0.2682 | Error from STF - Bio Trials |
| Error from STF - Bio Trials | 62.19 | 7 | 8.88 | | | |
| **Pooled Error over Trials** | 78.63 | 11 | 7.15 | | | |

# Appendix A.3. Mean Percent of PIT-Tagged Smolt Detected leaving the Acclimation Site

**Appendix A.3.a) Logistic Analysis of Variation Table of Released Proportion of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Averaged over Feed Levels)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Deviance |
|---|---|---|---|---|---|---|
| **Year** | **1011.21** | **11** | **91.93** | **8.77** | **0.0004** | **Among Raceway Pairs** |
| **Stock** | **308.39** | **1** | **308.39** | **8.73** | **0.0131** | **Stock x Year** |
| **Stock x Year** | **388.65** | **11** | **35.33** | **3.37** | **0.0237** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | **125.84** | **12** | **10.49** | **5.89** | **0.0031** | **Pooled Error over Trials** |
| **Low-High*** | **10.69** | **1** | **10.69** | **25.15** | **0.0375** | **Low-High x Year** |
| Stock x Low-High | 1.57 | 1 | 1.57 | 0.21 | 0.6889 | Stock x Low-High x Year |
| Low-High x Year: 2004-2006 | 0.85 | 2 | 0.425 | 2.41 | 0.2380 | Error from Low-High Trials |
| **Stock x Low-High x Year: 2004-2006** | **14.65** | **2** | **7.325** | **41.46** | **0.0065** | **Error from Low-High Trials** |
| Error from Low-High Trials | 0.53 | 3 | 0.18 | | | |
| EWAS-BIO (2008) | 20.13 | 1 | 20.13 | 5.01 | 0.2675 | Error from EWAS - Bio Trial |
| Stock x EWAS-BIO | 4.23 | 1 | 4.23 | 1.05 | 0.4919 | Error from EWAS - Bio Trial |
| Error from EWAS - Bio Trial | 4.02 | 1 | 4.02 | | | |
| **STF-BIO** | **99.67** | **1** | **99.67** | **27.84** | **0.0019** | **STF-BIO x Year** |
| Stock x STF-BIO | 3.37 | 1 | 3.37 | 0.48 | 0.5139 | Stock x STF-BIO x Year |
| STF-BIO x Year: 2007,2009-2014 | 21.48 | 6 | 3.58 | 1.67 | 0.2592 | Error from STF - Bio Trials |
| **Stock x STF-BIO x Year: 2007,2009-2014** | **42.04** | **6** | **7.01** | **3.26** | **0.0737** | **Error from STF - Bio Trials** |
| Error from STF - Bio Trials | 15.04 | 7 | 2.15 | | | |
| Pooled Error over Trials | 19.59 | 11 | 1.78 | | | |

**Table A.3.b) Logistic Analysis of Variation Table of Released Proportion of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Control Bio-Vita Feed Level)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Deviance |
|---|---|---|---|---|---|---|
| **2004-2014** | | | | | | |
| **Year** | **474.95** | **11** | **43.18** | **2.88** | **0.0413** | **Among Raceway Pairs** |
| **Stock** | **174.27** | **1** | **174.27** | **11.26** | **0.0064** | **Stock x Year** |
| Stock x Year | 170.19 | 11 | 15.47 | 1.03 | 0.4761 | **Among Raceway Pairs** |
| Among Raceway Pairs | 57.58 | 12 | 15.00 | | | |
| **2004-2006: LO vs HI** | | | | | | |
| Year | 3.33 | 2 | 1.665 | 1.32 | 0.3884 | Among Raceway Pairs |
| **Stock** | **21.73** | **1** | **21.73** | **24.83** | **0.0380** | **Stock x Year** |
| Stock x Year | 1.75 | 2 | 0.875 | 0.69 | 0.5658 | Among Raceway Pairs |
| Among Raceway Pairs | 3.79 | 3 | 1.26 | | | |
| **2007,2009-2014: STF vs Bio** | | | | | | |
| **Year** | 212.88 | 6 | 35.48 | **5.43** | **0.0214** | **Among Raceway Pairs** |
| Stock | 41.19 | 1 | 41.19 | 2.03 | 0.2045 | Stock x Year |
| **Stock x Year** | **122.01** | **6** | **20.34** | **3.11** | **0.0816** | **Among Raceway Pairs** |
| Among Raceway Pairs | 45.74 | 7 | 6.53 | | | |

## Appendix A.3. Mean Percent of PIT-Tagged Smolt Detected leaving the Acclimation Site (continued)

**Table A.3.c) Logistic Analysis of Variation Table of Released Proportion of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Tested Nutrition Levels: Release Year 2004-2006 LO - Low Nutrition Level of Bio-Vita Feed; 2007, 2009-2014 STF - Salt Water Transer Supplement to Control Level; 2008 EWS - EWOS Feed)**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Deviance (Dev/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Deviance |
|---|---|---|---|---|---|---|
| **2004-2014** | | | | | | |
| **Year** | **639.27** | **10** | **63.93** | **5.81** | **0.0038** | **Among Raceway Pairs** |
| **Stock** | **135.48** | **1** | **135.48** | **4.80** | **0.0533** | **Stock x Year** |
| **Stock x Year** | **282.24** | **10** | **28.22** | **2.57** | **0.0689** | **Among Raceway Pairs** |
| Among Raceway Pairs | 88.04 | 11 | 11.00 | | | |
| **2004-2006: LO vs HI** | | | | | | |
| Year | 6.72 | 2 | 3.36 | 1.80 | 0.3069 | Among Raceway Pairs |
| Stock | 10.41 | 1 | 10.41 | 0.99 | 0.4238 | Stock x Year |
| **Stock x Year** | **20.94** | **2** | **10.47** | **5.60** | **0.0971** | **Among Raceway Pairs** |
| Among Raceway Pairs | 5.61 | 3 | 1.87 | | | |
| **2007,2009-2014: STF vs Bio** | | | | | | |
| **Year** | **517.24** | **6** | **86.21** | **7.41** | **0.0092** | **Among Raceway Pairs** |
| Stock | 97.39 | 1 | 97.39 | 2.28 | 0.1818 | Stock x Year |
| **Stock x Year** | **256.36** | **6** | **42.73** | **3.67** | **0.0563** | **Among Raceway Pairs** |
| Among Raceway Pairs | 81.42 | 7 | 11.63 | | | |

## Appendix A.4. Volitional Release Dates

**Appendix A.4. Analysis of Variance of Mean Julian Release Date of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving the Clark Flat Acclimation Site (Averaged over Feed Levels)**

| Source | Sums of Squares (SS) | Degrees of Freedom (DF) | Mean Square (DSS/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Square |
|---|---|---|---|---|---|---|
| **Year** | **14,975,585** | **11** | **1361417** | **40.87** | **0.0000** | **Among Raceway Pairs** |
| **Stock** | **282,517** | **1** | **282517** | **5.49** | **0.0389** | **Stock x Year** |
| Stock x Year | 565,630 | 11 | 51421 | 1.54 | 0.2334 | Among Raceway Pairs |
| Among Raceway Pairs | 399,769 | 12 | 33314 | 1.83 | 0.1629 | Pooled Error over Trials |
| **Low-High*** | **119,981** | **1** | **119981** | **19.41** | **0.0479** | **Low-High x Year** |
| Stock x Low-High | 16,375 | 1 | 16375 | 0.51 | 0.5500 | Stock x Low-High x Year |
| Low-High x Year: 2004-2006 | 12,365 | 2 | 6183 | 0.29 | 0.7660 | Error from Low-High Trials |
| Stock x Low-High x Year: 2004-2006 | 64,496 | 2 | 32248 | 1.52 | 0.3498 | Error from Low-High Trials |
| Error from Low-High Trials | 63,585 | 3 | 21195 | | | |
| EWAS-BIO (2008) | 575 | 1 | 575 | 0.14 | 0.7701 | Error from EWAS - Bio Trial |
| Stock x EWAS-BIO | 13,135 | 1 | 13135 | 3.26 | 0.3221 | Error from EWAS - Bio Trial |
| Error from EWAS - Bio Trial | 4,031 | 1 | 4031 | | | |
| STF-BIO | 71,438 | 1 | 71438 | 3.83 | 0.0981 | STF-BIO x Year |
| Stock x STF-BIO | 1,186 | 1 | 1186 | 0.14 | 0.7223 | Stock x STF-BIO x Year |
| STF-BIO x Year: 2007,2009-2014 | 111,923 | 6 | 18654 | 0.99 | 0.4990 | Error from STF - Bio Trials |
| Stock x STF-BIO x Year: 2007,2009-2014 | 51,277 | 6 | 8546 | 0.45 | 0.8241 | Error from STF - Bio Trials |
| Error from STF - Bio Trials | 132,506 | 7 | 18929 | | | |
| Pooled Error over Trials | 200,122 | 11 | 18,192.93 | | | |

# Appendix A.5. Mean McNary-Dam Juvenile-Passage Dates

**Table A.5.a) Analysis of Variance of McNary Julian Detection Passage Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving Clark Flat Site (Averged over Feed Levels)**

| Source | Sums of Squares (SS) | Degrees of Freedom (DF) | Mean Square (DSS/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Square |
|---|---|---|---|---|---|---|
| **Year** | **2,374,166** | **11** | **215833** | **116.96** | **0.0000** | **Among Raceway Pairs** |
| **Stock** | **42,789** | **1** | **42789** | **5.32** | **0.0416** | **Stock x Year** |
| **Stock x Year** | **88,506** | **11** | **8046** | **4.36** | **0.0088** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | **22,145** | **12** | **1845** | **2.79** | **0.0500** | **Pooled Error over Trials** |
| **Low-High*** | **12,556** | **1** | **12556** | **37.91** | **0.0254** | **Low-High x Year** |
| **Stock x Low-High** | 309 | 1 | 309 | 2.92 | 0.2295 | Stock x Low-High x Year |
| Low-High x Year: 2004-2006 | 662 | 2 | 331 | 1.07 | 0.4469 | Error from Low-High Trials |
| Stock x Low-High x Year: 2004-2006 | 211 | 2 | 106 | 0.34 | 0.7359 | Error from Low-High Trials |
| Error from Low-High Trials | 932 | 3 | 311 | | | |
| EWAS-BIO (2008) | 499 | 1 | 499 | 2.85 | 0.3407 | Error from EWAS - Bio Trial |
| Stock x EWAS-BIO | 2,176 | 1 | 2176 | 12.40 | 0.1762 | Error from EWAS - Bio Trial |
| Error from EWAS - Bio Trial | 175 | 1 | 175 | | | |
| STF-BIO | 1,470 | 1 | 1470 | 0.27 | 0.6229 | STF-BIO x Year |
| Stock x STF-BIO | 3,570 | 1 | 3570 | 0.55 | 0.4864 | Stock x STF-BIO x Year |
| **STF-BIO x Year: 2007,2009-2014** | **32,849** | **6** | **5475** | **6.21** | **0.0150** | **Error from STF - Bio Trials** |
| **Stock x STF-BIO x Year: 2007,2009-2014** | **38,960** | **6** | **6493** | **7.36** | **0.0094** | **Error from STF - Bio Trials** |
| Error from STF - Bio Trials | 6,174 | 7 | 882 | | | |
| Pooled Error over Trials | 7,282 | 11 | 661.98 | | | |

**Table A.5.b) Analysis of Variance of McNary Julian Detection Passage Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving Clark Flat Site (Control Bio-Vita Feed Level)**

| Source | Sums of Squares (SS) | Degrees of Freedom (DF) | Mean Square (DSS/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Square |
|---|---|---|---|---|---|---|
| **2004-2014** | | | | | | |
| **Year** | **1541609.5** | **11** | **140,146** | **165.82** | **0.0000** | **Among Raceway Pairs** |
| **Stock** | **27305.3** | **1** | **27,305** | **6.09** | **0.0313** | **Stock x Year** |
| **Stock x Year** | **49332.6** | **11** | **4,485** | **5.31** | **0.0038** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | **10141.95** | **12** | **845** | | | |
| **2007,2009-2014: STF vs Bio** | | | | | | |
| **Year** | **704368.2** | **6** | **117,395** | **130.88** | **0.0000** | **Among Raceway Pairs** |
| Stock | 35001.6 | 1 | 35,002 | 5.53 | 0.0569 | Stock x Year |
| **Stock x Year** | **37978.28** | **6** | **6,330** | **7.06** | **0.0105** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | **6278.92** | **7** | **897** | | | |

**Table A.5.c) Analysis of Variance of McNary Julian Detection Passage Dates of Hatchery-Brood (HxH) and Natural-Brood (NxN) Hatchery-reared PIT-tagged Smolt Detected Leaving Clark Flat Site (Tested Nutrition Levels: Release Year 2004-2006 LO - Low Nutrition Level of Bio-Vita Feed; 2007, 2009-2014 STF - Salt Water Transfer Supplement to Control Level; 2008 EWS - EWOS Feed)**

| Source | Sums of Squares (SS) | Degrees of Freedom (DF) | Mean Square (DSS/DF) | F-Ratio | Estimated Type 1 Error P | Source of F-Ratio Denominator Mean Square |
|---|---|---|---|---|---|---|
| **2004-2014** | | | | | | |
| **Year** | 928,101 | 10 | 92,810 | 53.07 | **0.0000** | **Among Raceway Pairs** |
| Stock | 16,851 | 1 | 16,851 | 2.01 | 0.1871 | Stock x Year |
| **Stock x Year** | **84,022** | **10** | **8,402** | **4.80** | **0.0080** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | 19,238 | 11 | 1,749 | | | |
| **2007,2009-2014: STF vs Bio** | | | | | | |
| **Year** | **639353** | **6** | **106,559** | **43.30** | **0.0000** | **Among Raceway Pairs** |
| Stock | 11986.9 | 1 | 11,987 | 0.94 | 0.3706 | Stock x Year |
| **Stock x Year** | **76822.6** | **6** | **12,804** | **5.20** | **0.0240** | **Among Raceway Pairs** |
| **Among Raceway Pairs** | **17226.5** | **7** | **2,461** | | | |

## Appendix B. Method of Estimating Volitional Release-to-McNary Survival

For each individual raceway, the survival was based on dividing the total expanded McNary detections of PIT-tagged fish previously detected at acclimation sites by the release number (equation Eq.B.1):

Eq.B.1.

$$\text{Release - to - McNary Survival} = \frac{\text{Expanded Number of Released Fish Detected at McNary}}{\text{Release Number (detected at release)}}$$ [11]

The expanded number of fish detected at McNary (numerator of Eq.B.1) was computed using the following equation (Eq.B.2.)

Eq.B.2.

$$\text{Expanded Number} = \Sigma \frac{\text{Stratum Number Detected}}{\text{Stratum Detection Rate}}$$

The stratum being sequential McNary passage days during which the McNary detection rates are relatively homogeneous, and the Stratum's detection rate being computed by using the following equation (Eq,3)

Eq.B.3.

$$\text{Stratum Detection Rate} = \frac{\text{Number of Joint Detections at McNary and Downstream Sites within Sratum}}{\text{Total Downstream Detections within Stratum}}$$

The downstream sites being Bonneville and John Day Dams, and detections within each stratum being pooled over those dams. Note that the detection rates are based on all Yakima detected fish released into the Yakima River, not just those from the Clark Flat acclimation site.

Joint and Total Downstream Detections at Bonneville were included whether or not the fish were detected at McNary (sampling with replacement). A stratum was restricted by the imposition of the constraint that the numerator value of equation Eq.B.3 had to be at least 20. A further constraint was sequential stratum estimates for the separate Bonneville-based and John Day-based McNary detection rate estimates had to be consistent: If an estimate from one stratum to the next for Bonneville-based estimates increased, then the John Day-based estimates also had to increase, and if an estimate from one stratum to the next for Bonneville-based estimate decreased, then the John Day-based estimate also had to decrease.

[11] Expanded number is the number of fish passing McNary divided by the McNary detection rate. The McNary detection rate is the number of Yakima-origin PIT-tagged fish detected at both McNary and downstream dams (Bonneville and John Day dams) divided by the total number of Yakima-origin PIT-tagged fish detected by those down-stream dams.

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## Appendix E
## 2015 Annual Report: Smolt-to-Smolt Survival to McNary Dam of Yakima Fall and Summer Chinook

Doug Neeley, Consultant to Yakama Nation

### Introduction and Summary

Paired Subyearling and Yearling Yakima-stock Fall Chinook releases were made from Prosser Diversion Dam (Prosser) in out-migration years 2007 through 2013. The Yearling releases were discontinued in 2014. Subyearling Yakima-stock Fall Chinook continued to be released at Prosser. In 2015 Priest Rapids stock were also released from Prosser, and in that year Yakima stock were released at two sites well downstream of Prosser because there were concerns that poor in-stream conditions in the Yakima might affect survival, the downstream sites being at Wanawish (Horn Rapids) Dam at Yakima River mile 18 and at the mouth of the Yakima.

Summer Chinook Subyearlings were released from Stiles pond in outmigration-years 2009 through 2011. In 2012 the Stiles releases were discontinued and shifted to Prosser, and in 2013 the Prosser releases were discontinued and shifted to Roza Dam. Subyearlings were also released from Marion Drain in 2012 and from Buckskin Slough from 2011 through 2015.

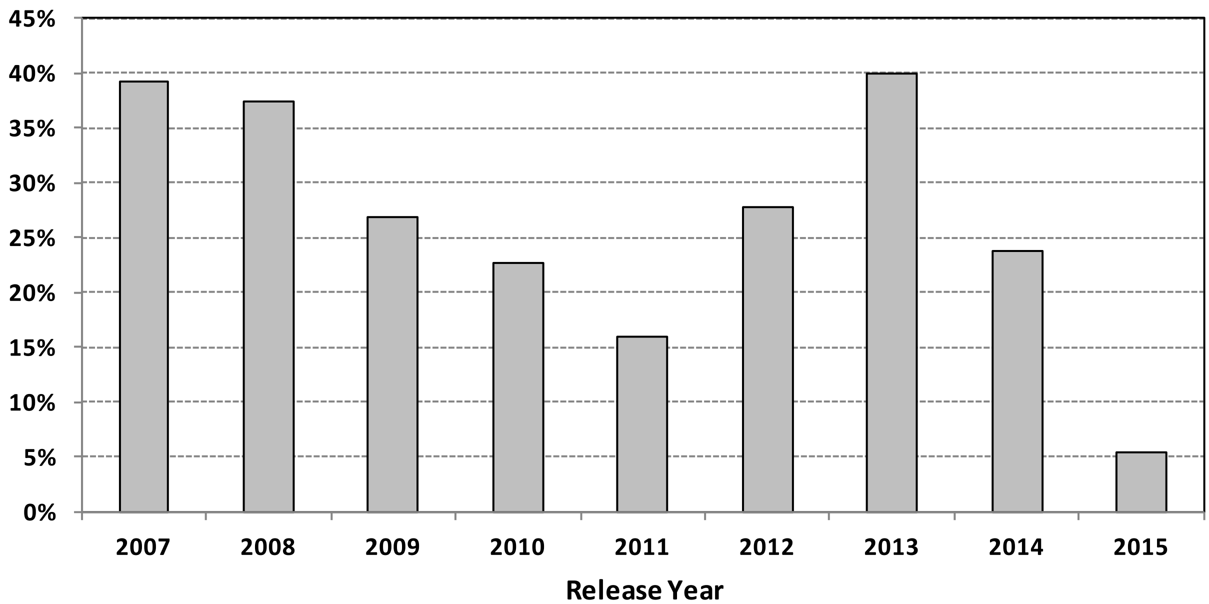
Estimates presented in this report are for 2007 through 2015 Fall Chinook and for 2009 through 2015 Summer Chinook time-of-tagging to McNary Dam (McNary) survival and mean dates of McNary passage. In previous years there were PIT-tag detectors at some of the release sites which permitted estimation of pre-release survival, mean date of volitional release, survival to McNary of smolt detected at release, and McNary passage date of those fish detected at release. These estimates were not available for the 2015 releases, and previous years' estimates are presented in the 2014 Annual Report.

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. In fact survival for releases made from all release sites and release dates in 2015 were abysmal except for the earliest release of Fall Chinook made into the mouth of Yakima.

## Fall Chinook

For the 2008 through 2015 releases, Figure 1. presents estimates for Fall Chinook subyearling Prosser releases. Prosser is the only site for which there have been estimates for a single stock for every year since 2007. The survival in 2015 (5.5%) was approximately one-third of the survival (16%) in 2011, which was the next lowest survival year.

**Figure 1. 2008-2015 Smolt Survival to McNary of all Tagged Subyearling Fall Chinook released from Prosser**




Tagging-to-McNary Survival estimates are given in Table 1.a. for all Fall Chinook releases since 2008. With one notable exception, the 2015 survival of all tagged smolt to McNary was less than 5%. The exception was the earlier release (May 29$^{th}$) at the mouth of the Yakima River. The survival to McNary (39.9%) for this release was more than 5 times greater than the survival (7.6%) of a release made only four days later from the same site. Part of that difference can be explained by pre-release mortality. The earlier release's detections of PIT-tags remaining at this site after release was 5.4% of the number of tagged smolt (90 of 1668 number before release) and that of the later release was 17.7% (181 out of 1018 tagged), the latter measure being 3.3 times that of the former. The difference is highly significant ($P < 0.0001$ based on a z-test). If these percentages are accurate indicators of pre-release mortality, then the dramatic decrease in survival between the two releases is partially due to changes in pre-release factors between the release dates.

On the same dates of the river-mouth releases, releases were made at Wanawish (Horn Rapids) Dam 18 miles upstream of the River's mouth. The survivals were dramatically less than those at the mouth (0.7% for the earlier release and 0.0% for the later release at Wanawish compared to the respective 39.9% and 7.6% at the mouth). The difference between Wanawish early and late release survivals are respectively based on unexpanded 2 and 0 detections at McNary and the earlier and later release numbers are nearly equal (respectively 2014 and 2004); the low McNary detection numbers are insufficiently different to suggest a true difference in survival between the early and late Wanawish survivals to McNary). The earlier release's detections of PIT-tags remaining at this site after release was 9.0% of the total tagged (182 of the 2014 tagged) and that of the later release was 11.3% (228 out of the 2004 tagged), the latter being only 1.26 times of the earlier, much less than the 3.3 magnitude from the Yakima mouth releases ; however the difference is significant at the 5% level (P = 0.0412 based on a z-test).

To the degree that the Wanawish and Yakima mouth releases are comparable, the short distance between the two contemporaneous sets of releases suggest the conditions were extremely poor in the Yakima and deteriorated rapidly in the Columbia over a four day period.

**Table 1.a. 2008-2015 Mean* Smolt Survival to McNary of PIT-tagged Subyearling Fall Chinook**

| | | Yearling | Subyearling | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Release Site > | Prosser | Prosser | | | | | | |
| Release Year | Measure/Stock | Yakima | Yakima | | | | | | |
| 2007 | Tagging-to-McNary Survival | | 39.3% | | | | | | |
| | Number Tagged | | 5002 | | | | | | |
| 2008 | Tagging-to-McNary Survival | 61.6% | 37.4% | | | | | | |
| | Number Tagged | 1,831 | 10,005 | | | | | | |
| 2009 | Tagging-to-McNary Survival | 72.4% | 26.8% | | | | | | |
| | Number Tagged | 7,516 | 7,565 | | | | | | |
| 2010 | Tagging-to-McNary Survival | 60.6% | 22.8% | | | | | | |
| | Number Tagged | 12,167 | 13,685 | | | | | | |
| 2011 | Tagging-to-McNary Survival | 59.2% | 16.0% | | | | | | |
| | Number Tagged | 22,754 | 22,790 | | | | | | |
| 2012 | Tagging-to-McNary Survival | 65.6% | 27.9% | | | | | | |
| | Number Tagged | 19,435 | 19,634 | | | | | | |
| 2013 | Tagging-to-McNary Survival | 55.7% | 40.0% | | | | | | |
| | Number Tagged | 13,685 | 22,966 | | | | | | |
| 2014 | Tagging-to-McNary Survival | | 23.7% | | | | | | |
| | Number Tagged | | 4,025 | | | | | | |
| | Release Site > | | Prosser | | | Wanawish | | Yakima River Mouth | |
| 2015 | Measure/Stock | | Yakima | | Priest Rapids | Yakima | | Yakima | |
| | Release Group | | Early | Late | Early | Early | Late | Early | Late |
| | Release Dates | | 05/06/15 05/08/15 | 06/02/15 06/02/15 | 05/06/15 05/08/15 | 05/29/15 | 06/02/15 | 05/29/15 | 06/02/15 |
| | Tagging-to-McNary Survival | | 7.31% | 4.94% | 7.10% | 7.10% | 0.00% | 39.87% | 7.56% |
| | Number Tagged | | 4,021 | 14,156 | 4,018 | 4,044 | 2,004 | 1,668 | 1,018 |
| | Pooled Tagging-to-McNary Survival | | 5.5% | | 7.1% | 7.1% | | 27.6% | |
| | Pooled Number Tagged | | 18,177 | | 4,018 | 4,044 | | 2,686 | |

* Weighted by Number Tagged

The mean dates of McNary passage of surviving smolt are presented in Table 1.b. The mean passage date of the 2015 subyearling Yakima stock released from Prosser are somewhat later /// than the than those of releases made prior to 2012 but are somewhat earlier than those from releases made in recent years ( 2012-2014). It is interesting to note that the 2015 mean passage date (Julian Date 161) pooled over the early and late Prosser releases is much later than 2011 date (Julian date 145) which is earliest passage date and is associated with the second lowest survival of the years studied.

The 2015 early and late Prosser release dates of Yakima subyearlings differ by more than 24 days; therefore, it is not surprising that the Mean Passage Dates of the earlier releases is earlier than those of the later releases (Julian Date 156 versus 163, a 7 day difference). Comparing 2015 Yakima subyearling mean passage dates over the three release sites (Prosser, Wanawish, and Yakima River mouth), the pooled dates over the early and late releases barely differ. Comparison across sites may not be particularly meaningful because later outmigrating smolt would not have contributed to the passage date due increasing mortality as conditions deteriorated and because Prosser released smolt would have been exposed to deteriorating in-stream conditions over a longer period, the mean date of passage may be less than what would have been the case had the conditions been more favorable.

**Table 1.b. 2008-2015 Mean* Passage Date at McNary Date for PIT-tagged Fall Chinook Smolt surviving to McNary**

| | | Yearling | Subyearling | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Release Site > | Prosser | Prosser | | | | | | |
| Release Year | Measure/Stock | Yakima | Yakima | | | | | | |
| 2007 | Mean Julian McNary Detection Date | | 151 | | | | | | |
| | Expanded McNary Passage | | 1483 | | | | | | |
| 2008 | Mean Julian McNary Detection Date | 112 | 151 | | | | | | |
| | Expanded McNary Passage | 1128 | 3744 | | | | | | |
| 2009 | Mean Julian McNary Detection Date | 114 | 154 | | | | | | |
| | Expanded McNary Passage | 5442 | 2030 | | | | | | |
| 2010 | Mean Julian McNary Detection Date | 128 | 153 | | | | | | |
| | Expanded McNary Passage | 7379 | 3117 | | | | | | |
| 2011 | Mean Julian McNary Detection Date | 136 | 145 | | | | | | |
| | Expanded McNary Passage | 13465 | 3635 | | | | | | |
| 2012 | Mean Julian McNary Detection Date | 113 | 164 | | | | | | |
| | Expanded McNary Passage | 12752 | 5474 | | | | | | |
| 2013 | Mean Julian McNary Detection Date | 101 | 170 | | | | | | |
| | Expanded McNary Passage | 12650 | 9188 | | | | | | |
| 2014 | Mean Julian McNary Detection Date | | 165 | | | | | | |
| | Expanded McNary Passage | | 955 | | | | | | |
| | Release Site > | | Prosser | | | Wanawish | | Yakima River Mouth | |
| 2015 | Measure/Stock | | Yakima | | Priest Rapids | Yakima | | Yakima | |
| | Release Group | | Early | Late | Early | Early | Late | Early | Late |
| | Release Dates | | 05/06/15 05/08/15 | 06/02/15 06/02/15 | 05/06/15 05/08/15 | 05/29/15 | 06/02/15 | 05/29/15 | 06/02/15 |
| | Mean Julian McNary Detection Date | | 156 | 163 | 159 | 159 | no | 160 | 161 |
| | Expanded McNary Passage | | 294 | 700 | 105 | 14 | detections | 665 | 77 |
| | Pooled Mean Julian McNary Detection Date | | 161 | | 159 | 159 | | 160 | |
| | Pooled Expanded McNary Passage | | 994 | | 105 | 14 | | 742 | |

* Weighted by Expanded McNary Passage

## Summer Chinook

Tagging-to-McNary Survival estimates are given in Table 2.a. and Mean McNary Passage Date of surviving Date are given in Table 2.b.

The 2015 survivals of Summer Chinook smolt were 0 or near 0 and were worse than those of the Fall Chinook. Survival estimates are based on the expansion of McNary detections by measures of McNary's detection efficiency. The non-zero survival of the Prosser release was based on only 6 unexpanded McNary-detection and that of the early Roza release was based on only 1 unexpanded McNary-detection. The detection efficiencies at McNary were based predominately on detections of Fall Chinook because of fewer detections at dams below McNary, detections needed to get the McNary detection rate.

If the 2.78% survival detection of 6 detections from the Prosser release does reflect a truly higher survival from Prosser than from the other sites, it probably reflects the fact that Prosser is located downstream of the other sites.

**Table 2.a. 2008-2015 Mean* Smolt Survival to McNary of PIT-tagged Subyearling Summer Chinook**

| | | Summer Chinook | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Release Year | Measure | Stiles | Buckskin Slough Release 1 | Buckskin Slough Release 2 | Marion | Prosser | Roza | |
| 2009 | Tagging-to-McNary Survival | 1.5% | | | | | | |
| | Number Tagged | 30,037 | | | | | | |
| 2010 | Tagging-to-McNary Survival | 20.5% | | | | | | |
| | Number Tagged | 29,865 | | | | | | |
| 2011 | Tagging-to-McNary Survival | 40.3% | 43.4% | | | | | |
| | Number Tagged | 20,000 | 29,894 | | | | | |
| 2012 | Tagging-to-McNary Survival | | 37.0% | | 35.7% | 20.7% | | |
| | Number Tagged | | 9,999 | | 9,998 | 9,999 | | |
| 2013 | Tagging-to-McNary Survival | | 20.7% | | | | 29.8% | |
| | Number Tagged | | 15,084 | | | | 15,065 | |
| 2014 | Tagging-to-McNary Survival | | 18.3% | 3.2% | | | 4.8% | |
| | Number Tagged | | 10,086 | 10,102 | | | 10,043 | |
| | Release Site | | Buckskin Slough | | | Prosser | Roza | |
| 2015 | Measure/Stock | | Wells Hatchery | | | Wells Hatchery | Wells Hatchery | |
| | Release Group | | Early | Late | | One Release | Early | Late |
| | Release Date - Replication 1 | | 05/13/15 | 05/15/15 | | 05/06/15 | 04/29/15 | 05/16/15 |
| | Release Date - Replication 1 | | | | | | 05/01/15 | 05/16/15 |
| | Tagging-to-McNary Survival | | 0.00% | 0.00% | | 2.78% | 0.07% | 0.00% |
| | Number Tagged | | 5,459 | 4,807 | | 4,031 | 10,034 | 10,027 |
| | Pooled Tagging-to-McNary Survival | | 0.0% | | | 2.8% | 0.03% | |
| | Pooled Number Tagged | | 10,266 | | | 4,031 | 20,061 | |

* Weighted by Number Tagged

## Table 2.b. Mean* 2008-2015 Mean Passage Date at McNary Date for PIT-tagged Summer Chinook Smolt surviving to McNary

| | | Summer Chinook | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Subyearling | | | | | | |
| | Release Site > | Stiles | Buckskin Slough | | Marion | Prosser | Roza | |
| Release Year | Measure/Stock | | Release 1 | Release 2 | | | | |
| 2009 | Mean Julian McNary Detection Date | 190 | | | | | | |
| | Expanded McNary Passage | 459 | | | | | | |
| 2010 | Mean Julian McNary Detection Date | 176 | | | | | | |
| | Expanded McNary Passage | 1735 | | | | | | |
| 2011 | Mean Julian McNary Detection Date | 155 | 171 | | | | | |
| | Expanded McNary Passage | 8065 | 12989 | | | | | |
| 2012 | Mean Julian McNary Detection Date | | 182 | | | | | |
| | Expanded McNary Passage | | 3704 | | | | | |
| 2013 | Mean Julian McNary Detection Date | | 171 | | | | 06/14/00 | |
| | Expanded McNary Passage | | 3115 | | | | 4,487 | |
| 2014 | Mean Julian McNary Detection Date | | 166 | 180 | | | 06/24/00 | |
| | Expanded McNary Passage | | 1845 | 321 | | | 487 | |
| | Release Site | | Buckskin Slough | | | Prosser | Rosa | |
| 2015 | Measure/Stock | | Wells Hatchery | | | Wells Hatchery | Wells Hatchery | |
| | Release Group | | Early | Late | | One Release | Early | Late |
| | Release Dates | | 05/13/15 | 05/15/15 | | 05/06/15 | 04/29/15 | 05/16/15 |
| | | | | | | | 05/01/15 | 05/16/15 |
| | Mean Julian McNary Detection Date | | no | no | | 161 | 155 | no |
| | Expanded McNary Passage | | detections | detections | | 112 | 10,034 | detections |
| | Pooled Mean Julian McNary Detection Date | | no | | | 161 | 155 | |
| | Pooled Expanded McNary Passage | | detections | | | 161 | 10,034 | |

*** Mean Julian Date weighted by Expanded Passage of all PIT-Tagged Smolt passing McNary**

* Weighted by Expanded McNary Passage

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# Appendix F
# Annual Report: 2015 Coho Smolt-to-Smolt Survival of Releases into the Yakima Basin

**Doug Neeley, Consultant to Yakama Nation**

## Introduction and Summary

With the exception of 2014, there have been joint Coho smolt releases of Yakima-Return (Yakima) and Eagle-Creek-Hatchery (Eagle Creek) stock from several sites in the Yakima Basin, most of which have been paired stock releases from common sites since 2006. In 2014 only Yakima-stock smolt were released. In 2011, joint releases of Yakima and Yakima x Eagle Creek Cross stock were made from four sites with one site also having an Eagle Creek stock release.

The 2006-2015 Eagle Creek stock pre-release survival was generally higher but its in-stream survival was always lower than those of the Yakima stock.

The 2015 release was associated with record low snow packs in the Cascade Mountains and a severe drought. Survival of all tagged smolt to McNary Dam (McNary) in 2015 was the lowest experienced and the mean date of McNary passage was the earliest since the 2005 release[1]. Comparison of previous years pre-release and in-stream survivals to the 2015 releases were not performed. This is because, during the 2015 volitional release period, there were failures in release sites' PIT-tag detectors and therefore comparisons with the previous years' measures based on release-site detections would be biased.

## Survival Estimates based on Smolt detected at Release

With PIT-tag detectors located in the outfalls from the release sites, it is possible to partition the survival of smolt from the time of tagging to the time of McNary (McNary) passage into:

[1] Releases of Eagle Creek stock were also made in 2005from two sites (Holmes and Lost Creek); there were no associated releases of Yakima stock smolt from those sites, but there was a joint release of Washougal stock from Holmes. There was also a joint release of Yakima and Washougal stock from Boone. There was a single-stock release of Eagle Creek stock from Stiles, and there were single-stock releases of Yakima stock into Hanson River and Lost Creek. The only 2005 release with a comparable stock and site to the 2015 release was the Eagle Creek Stock release from Stiles; the tagging-to-McNary survival estimate for that release was 27.2% which was greater than the 8.32% of the 2015 release (consistent with most other years), but the 2005 mean Julian date of McNary passage of 126 days was earlier than the 133 days of the 2015 release (not consistent with most other years). The 2005 data are not otherwise in included this report.

1) Survival from tagging to the time of release (Pre-release Survival); and 2) the in-stream survival from time of release to time of McNary passage (Release-to-McNary Survival).

## Pre-release Survival

Pre-release Survival is the estimated percentage of juveniles that survive from tagging to the time of Release. The estimate is the percent of PIT-tagged smolt detected leaving the pond divided by detection efficiency of the Prosser pond's PIT-tag detector; the detection efficiency being the ratio of the estimated passage at McNary of those tagged fish previously detected leaving the ponds and the estimated passage at McNary of all tagged fish. Pre-Release Survivals are presented in Figure and Table 1.

Of the 18 paired releases of Yakima and Eagle Creek stock from the same sites within years for which there were differences in the stocks' survivals, 16 or 89% of those differences had the Eagle Creek stock with the highest pre-release survival, 89% being significantly different than 50% at the 5% level (estimated Type 1 Error p = 0.0013 based on a binomial-distribution 2-sided sign test).

**Figure 1. Outmigration-Year 2006-2015 Pre-Release Survival of Tagged Smolt (Yakima, Eagle Creek, and Yakima x Eagle Creek stocks respectively shaded black, white, and gray) Acclimation Sites: Holmes (Ho), Taneam (Ta), Easton (Ea), Stiles (St), Lost Creek (LC), and Prosser (Pr)**

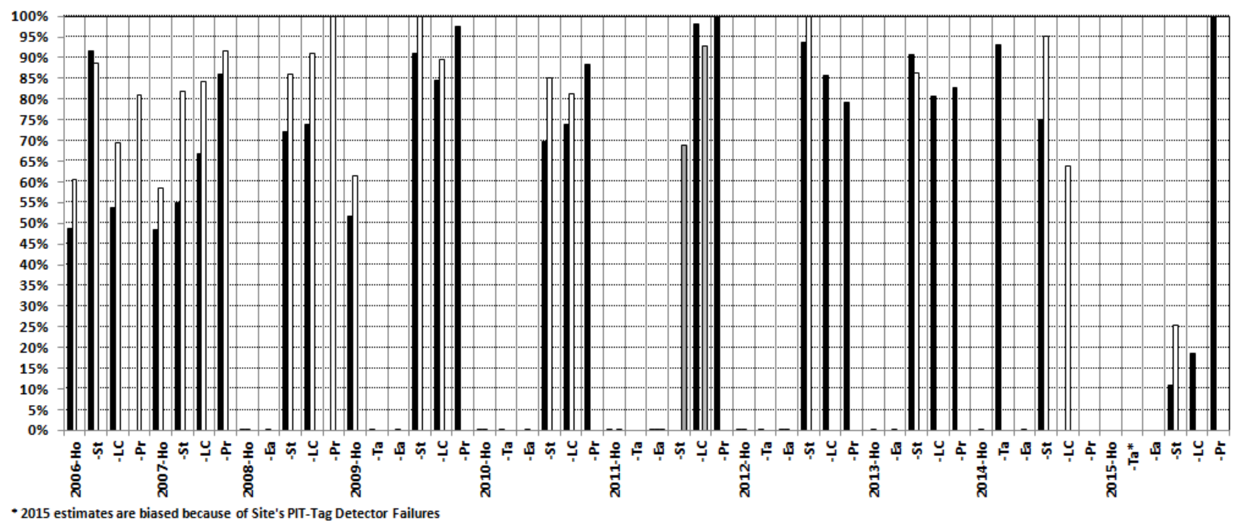


**Table 1. Outmigration-Year 2006-2015 Pre-release Survival of PIT-Tagged Coho Smolt**

| Release Year | Stock | Measure | Holmes | Boone | Cle Elum | Taneum Creek | Easton Pond | Stiles | Lost Creek | Prosser |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Release-Site Subbasin and Pond within Subbasin | | | | | | | |
| | | | Upper Yakima | | | | | Naches | | Main Stem Yakima |
| 2006 | Yakima | Pre-Release Survival | 48.69% | | | | | 91.75% | 53.84% | |
| | | Number Tagged | 2512 | | | | | 2490 | 2491 | |
| | Eagle Creek | Pre-Release Survival | 60.50% | | | | | 88.55% | 69.56% | 80.82% |
| | | Number Tagged | 2514 | | | | | 2506 | 2515 | 1231 |
| 2007 | Yakima | Pre-Release Survival | 48.40% | | | | | 54.99% | 66.81% | 85.88% |
| | | Number Tagged | 2460 | | | | | 2449 | 2501 | 2499 |
| | Eagle Creek | Pre-Release Survival | 58.62% | | | | | 81.81% | 84.26% | 91.67% |
| | | Number Tagged | 2504 | | | | | 2513 | 2511 | 1246 |
| 2008 | Yakima | Pre-Release Survival | | | | | | 71.98% | 73.82% | |
| | | Number Tagged | | | | | | 2492 | 2499 | |
| | Eagle Creek | Pre-Release Survival | | | | | | 86.02% | 91.13% | 100.00% |
| | | Number Tagged | | | | | | 2453 | 2524 | 854 |
| 2009 | Yakima | Pre-Release Survival | 51.59% | | | | | 91.12% | 84.60% | 97.56% |
| | | Number Tagged | 2512 | | | | | 2515 | 2508 | 2506 |
| | Eagle Creek | Pre-Release Survival | 61.49% | | | | | 100.00% | 89.56% | |
| | | Number Tagged | 1427 | | | | | 3755 | 2331 | |
| 2010 | Yakima | Pre-Release Survival | | | | | | 69.82% | 73.78% | 88.26% |
| | | Number Tagged | | | | | | 2501 | 2505 | 1371 |
| | Eagle Creek | Pre-Release Survival | | | | | | 85.03% | 81.33% | |
| | | Number Tagged | | | | | | 2581 | 2520 | |
| 2011 | Yakima | Pre-Release Survival | | | | * | | | 98.26% | 100.00% |
| | | Number Tagged | | | | 4515 | | | 2500 | 2522 |
| | Eagle Creek | Pre-Release Survival | | | | | | | | |
| | | Number Tagged | | | | | | | | |
| | Yakima x | Pre-Release Survival | | | | | | 68.98% | 92.86% | |
| | Eagle Creek | Number Tagged | | | | | | 1259 | 1262 | |
| 2012 | Yakima | Pre-Release Survival | | | | | | 93.59% | 85.71% | 79.06% |
| | | Number Tagged | | | | | | 2526 | 2526 | 1285 |
| | Yakima* | | | | | | | 0.04% | | |
| | | | | | | | | 2547 | | |
| | Eagle Creek | Pre-Release Survival | | | | | | 100.00% | | |
| | | Number Tagged | | | | | | 2543 | | |
| 2013 | Yakima | Pre-Release Survival | | | | | | 90.79% | 80.73% | 82.83% |
| | | Number Tagged | | | | | | 2504 | 2531 | 2520 |
| | Eagle Creek | Pre-Release Survival | | | | | | 86.19% | | |
| | | Number Tagged | | | | | | 2505 | | |
| 2014 | Yakima | Pre-Release Survival | | | | 92.97% | | 75.12% | | 0%* |
| | | Number Tagged | | | | 687 | | 2193 | | 12* |
| | Eagle Creek | Pre-Release Survival | | | | | | 95.04% | 63.71% | |
| | | Number Tagged | | | | | | 2054 | 1513 | |
| 2015 | Yakima | Pre-Release Survival* | | | | | | 10.95% | 18.68% | ** |
| | | Number Tagged | | | | | | 2520 | 2506 | 1265 |
| | Eagle Creek | Pre-Release Survival* | | | | | | 25.33% | | |
| | | Number Tagged | | | | | | 2498 | | |
| | WDFW | Pre-Release Survival* | | | | ** | | | | |
| | Tagging | Number* Tagged | | | | 231 | | | | |
| | | * Early PIT-Tag Detection Failures at site. Many smolt likely left the release sites after the failure. | | | | * Only 3.68% detected at pond and, of those, only 4 detected at McNary Dam<br>** None Detected at Release site | | | | * Only 12 Prosser detections, none of which were detected at McNary<br>** None Detected at Release site |

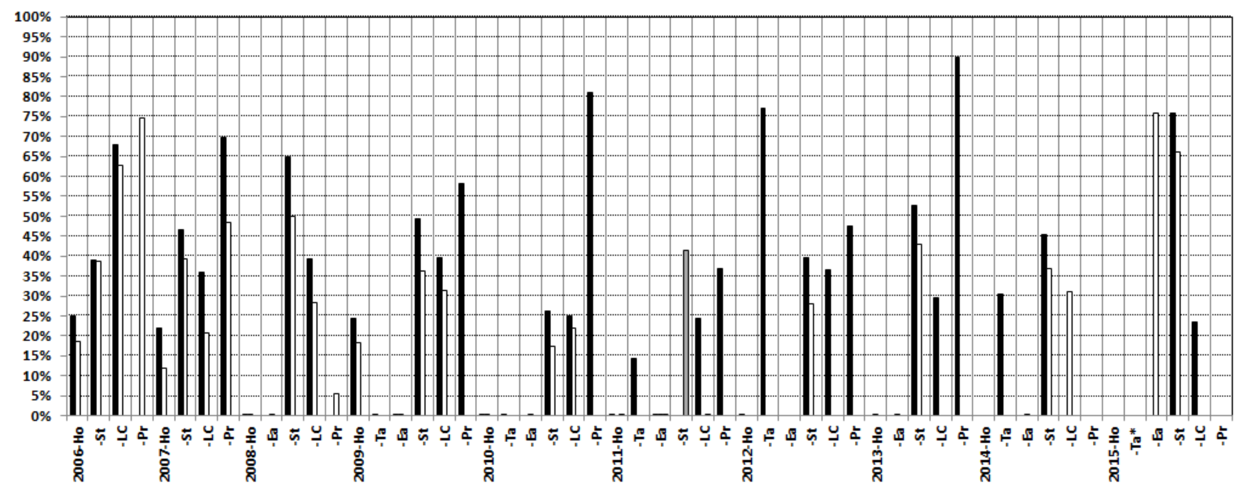
**Note: Highlighted sites are those having releases made in 2015.**

## Release-to-McNary Survival

Release-to-McNary Survival is the estimated in-stream survival of those smolt detected leaving the rearing pond that eventually pass McNary. The estimate[2] is basically the percent of those PIT-tagged smolt detected leaving the rearing pond that are later detected at McNary divided by McNary's detection efficiency[3]. That estimated McNary detection efficiency is the number of all PIT-tagged smolt released into the Yakima River that were detected at dams downstream[4] of McNary which were previously detected at McNary divided by the total number of the Yakima-released smolt detected at the downstream dams whether or not they were previously detected at McNary. This estimate is valid under the assumption that all Yakima-released PIT-Tagged Coho were well mixed prior to McNary passage.

Release-to-McNary Survivals are presented in Figure and Table 2. In all of the 18 paired releases of the Yakima and Eagle Creek stock from the same sites within years for which there were differences in the stocks' survivals, the Yakima stock had the highest Release-to-McNary survival. This 100% is highly significantly different than 50% (estimated Type 1 Error p < 0.0001 based on a binomial-distribution two-sided sign test).

**Figure 2. Outmigration-Year Coho 2006-2015 Release-to-McNary Smolt Survival (Yakima, Eagle Creek, and Yakima x Clear Creek stocks respectively shaded black, white, and gray)**
**Acclimation Sites: Holmes (Ho), Taneam (Ta), Easton (Ea), Stiles (St), Lost Creek (LC), and Prosser (Pr)**




* 2015 estimates are biased because of Site's PIT-Tag Detector Failures

Whereas the Eagle Creek stock tended to have a higher Pre-Release Survival in the hatchery environment, the Yakima stock had the highest in-stream survival to McNary.

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[2] The estimation is somewhat complicated in that detection efficiencies are estimated within time strata, within which there are relatively homogeneous daily detection efficiencies at McNary. Therefore the number of smolt detected at McNary is expanded within each stratum; these expanded stratum-passage numbers are then added over strata. The resulting total is then divided by the number of smolt detected leaving the rearing ponds.

[3] The proportion of smolt leaving the pond can be affected by pre-release mortality, pre-release tag-shedding, and the failure of the site's PIT-tag detectors to detect PIT-tagged fish exiting the rearing ponds. The detection efficiency is expected to adjust for differential detection failure but not for differential tag-shedding.

[4] The dams downstream of McNary dams are John Day and Bonneville Dams.

**Table 2. Outmigration-Year 2006-2015 Release-to-McNary-Passage Survival of PIT-Tagged Coho Smolt**

| Release Year | Stock | Measure | Release-Site Subbasin and Pond within Subbasin: Upper Yakima – Holmes | Upper Yakima – Boone | Upper Yakima – Cle Elum | Upper Yakima – Taneum Creek | Upper Yakima – Easton Pond | Naches – Stiles | Naches – Lost Creek | Main Stem Yakima – Prosser |
|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | Yakima | Survival from Release to McNary | 25.01% | | | | | 39.15% | 68.02% | |
| | | Number Detected at Release | 781 | | | | | 1598 | 1057 | |
| | Eagle Creek | Survival from Release to McNary | 18.62% | | | | | 38.81% | 62.66% | 74.78% |
| | | Number Detected at Release | 636 | | | | | 1974 | 1663 | 912 |
| 2007 | Yakima | Survival from Release to McNary | 22.01% | | | | | 46.76% | 35.83% | 69.75% |
| | | Number Detected at Release | 920 | | | | | 1204 | 1671 | 2112 |
| | Eagle Creek | Survival from Release to McNary | 12.02% | | | | | 39.39% | 20.68% | 48.35% |
| | | Number Detected at Release | 1293 | | | | | 1881 | 2092 | 1136 |
| 2008 | Yakima | Survival from Release to McNary | | | | | | 64.75% | 39.25% | |
| | | Number Detected at Release | | | | | | 1731 | 1633 | |
| | Eagle Creek | Survival from Release to McNary | | | | | | 50.09% | 28.37% | 5.53% |
| | | Number Detected at Release | | | | | | 2110 | 1956 | 507 |
| 2009 | Yakima | Survival from Release to McNary | 24.38% | | | | | 49.24% | 39.61% | 58.14% |
| | | Number Detected at Release | 48 | | | | | 696 | 2053 | 2299 |
| | Eagle Creek | Survival from Release to McNary | 18.29% | | | | | 36.23% | 31.32% | |
| | | Number Detected at Release | 130 | | | | | 908 | 1946 | |
| 2010 | Yakima | Survival from Release to McNary | | | | | | 26.24% | 25.10% | 81.15% |
| | | Number Detected at Release | 0 | | | 0 | | 1580 | 1519 | 1210 |
| | Eagle Creek | Survival from Release to McNary | | | | | | 17.41% | 21.88% | |
| | | Number Detected at Release | 0 | | | | 0 | 1836 | 1801 | |
| 2011 | Yakima | Survival from Release to McNary | | | | 14.46% | | | 24.31% | 36.92% |
| | | Number Detected at Release | 0 | | | 166 * | 0 | | 1488 | 2497 |
| | Eagle Creek | Survival from Release to McNary | | | | | | | | |
| | | Number Detected at Release | | | | | 0 | | | |
| | Yakima x | Survival from Release to McNary | | | | | 0.00% | 41.30% | | |
| | Eagle Creek | Number Detected at Release | 0 | | | | 1 | 1184 | | |
| 2012 | Yakima | Survival from Release to McNary | 0.00% | | | 76.94% | | 39.70% | 36.59% | 47.66% |
| | | Number Detected at Release | 1 | | | 92 | 0 | 929 | 1531 | 731 |
| | Yakima* | Survival from Release to McNary | | | | | 0.00% | | | |
| | | Number Detected at Release | | | | | 1 | | | |
| | Eagle Creek | | | | | | | 28.06% | | |
| | | | 0 | | | | 0 | 683 | | |
| 2013 | Yakima | Survival from Release to McNary | | | | | | 52.64% | 29.47% | 89.73% |
| | | Number Detected at Release | | | | | | 2240 | 1727 | 112* |
| | Eagle Creek | Survival from Release to McNary | | | | | | 42.84% | | |
| | | Number Detected at Release | 0 | | | | 0 | 2060 | | |
| 2014 | Yakima | Survival from Release to McNary | | | | 30.52% | | 45.44% | | 0%** |
| | | Number Detected at Release | | | | 687 | | 2193 | | 12** |
| | Yakima* | Survival from Release to McNary | | | | | | 37.00% | 31.10% | |
| | | Number Detected at Release | 0 | | | | 3 | 2054 | 1513 | |
| 2015 | Yakima | Survival from Release to McNary | | | | | | 75.94% | 23.37% | 0.00% |
| | | Number* Detected at Release | | | | | | 264 | 117 | 132 |
| | Eagle Creek | Survival from Release to McNary | | | | | 75.94% | 66.25% | | |
| | | Number* Detected at Release | 0 | | | | 264 | 564 | | |
| | WDFW | Survival from Release to McNary | | | | 0.00% | | | | |
| | Tagging | Number* Detected at Release | | | | 91 | | | | |
| | * Early PIT-Tag Detection Failures at site. Number detected at sites are the lowest at all sites. The period of detection was Probability the best for survival and not representative of the conditions for outmigration. Table 4.Time-of-Tagging-to-McNary Smolt Survival is better indication of survival | | | | * No detections at McNary | * Based on low unexpanded number (4) of pond-detected fish detected at McNary | | | | *Low detection number ** Only 12 Prosser detections, none of which were detected at McNary |

**Note: Highlighted sites are those having releases made in 2015.**

### Estimates based on all Tagged Smolt

Since not all release sites had PIT-tag detectors and since there were PIT-tag-detector failures at the release sites that had detectors, the overall Tagging-to-McNary smolt-to-smolt survival and the mean McNary-Passage Date were considered the most reliable measures for comparisons over sites and years.

### Tagging-to-McNary Survival

The Yakima stock had the highest Tagging-to-McNary Survival in 61% (or 14) of the 23 paired Yakima and Eagle Creek stock releases. This percent is not significantly different than 50% at the 5% level (estimated Type 1 Error p = 0.4049, based on a binomial-distribution 2-sided sign test). This is in contrast to the 100% of the paired releases with the Yakima stock having the highest Release-to-McNary Survival. The Yakima stock's Tagging-to-McNary Survival estimates relative those for the Eagle Creek stock pairs were differentially reduced by relatively higher Pre-Release Survival of the Eagle Creek stock.

Survivals are presented in Figures 3.a. through 3.f. and Table 3.a. for each stock within each site; in the figures a horizontal line connects the 2015 survival to those in previous years. There were only two sites which had the smallest survivals not associated with the 2015 releases. Those sites were Homes (Figure 3.a. and Table 3.) and Stiles (Figure 3,b. and Table 3.)

> Stiles: Of the total of 19 total releases made from Stiles, only one (the 2010 Eagle-Creek-stock release, Table 3.) had a lower survival than the 2015 releases.
>
> Holmes: In every year, Holmes's releases have had the lowest Tagging-to-McNary Survival estimates, a majority of which, including the 2015 release, were less than 10%. Holmes has an inherently low survival.

Figure 3.a. Coho 2006-2014 Releases' Tagging-to-McNary Survivals from Holmes compared to that for the 2015 Release

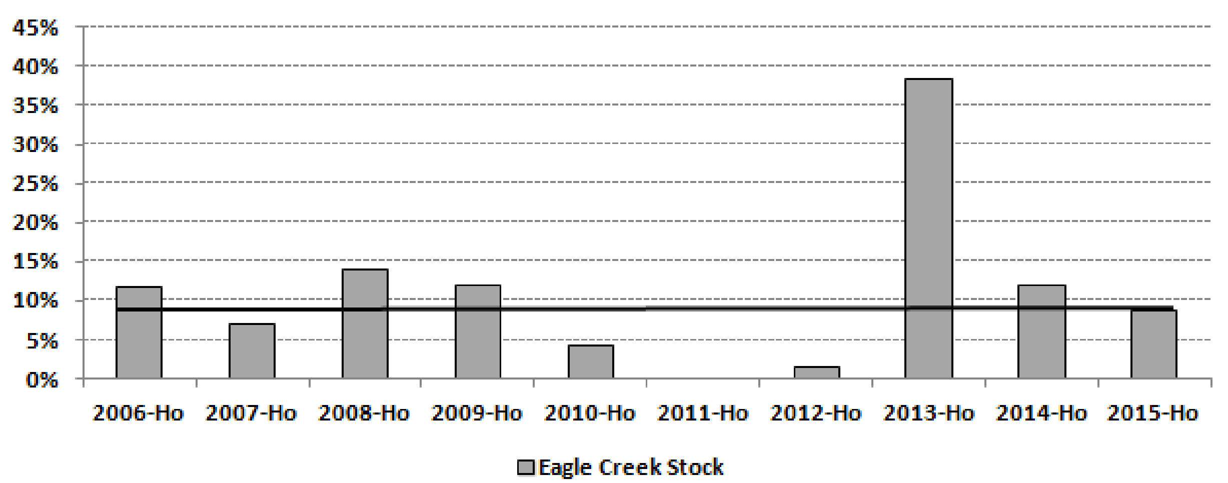


Figure 3.b. Coho 2006-2014 Releases' Tagging-to-McNary Survivals from Stiles compared to those for the 2015 Release

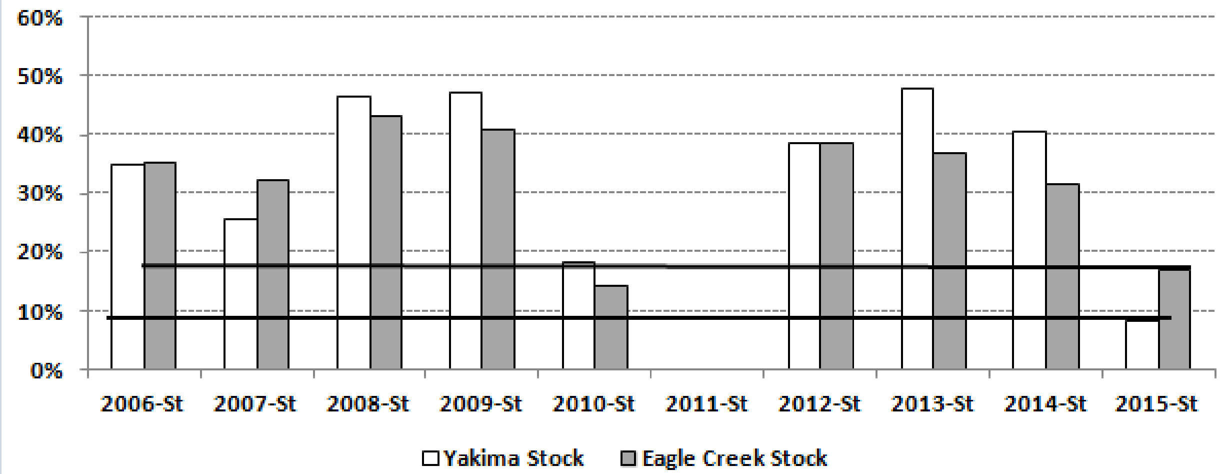



Figure 3.c. Coho 2006-2014 Releases' Tagging-to-McNary Survivals from Lost Creek compared to that for the 2015 Release

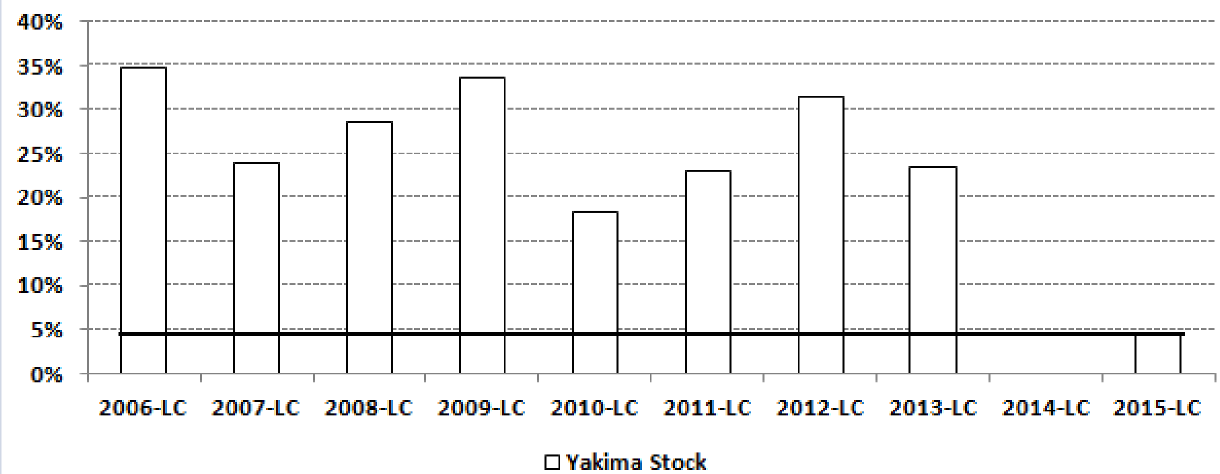



Figure 3.d. Coho 2006-2014 Releases' Tagging-to-McNary Survivals from Prosser compared to that for the 2015 Release

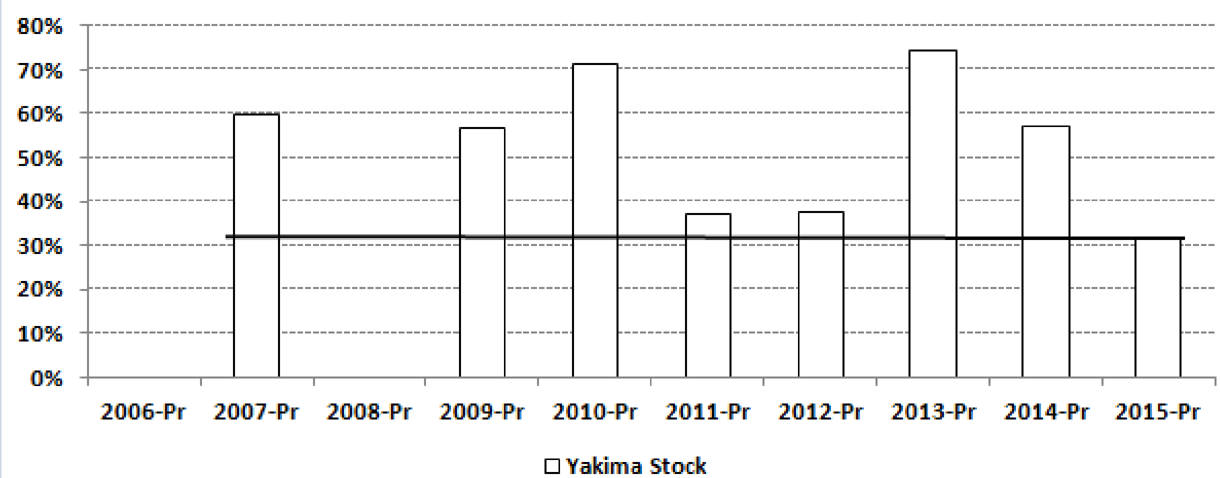


Figure 3.e. Coho 2006-2014 Releases' Tagging-to-McNary Survivals from Easton compared to that for the 2015 Release

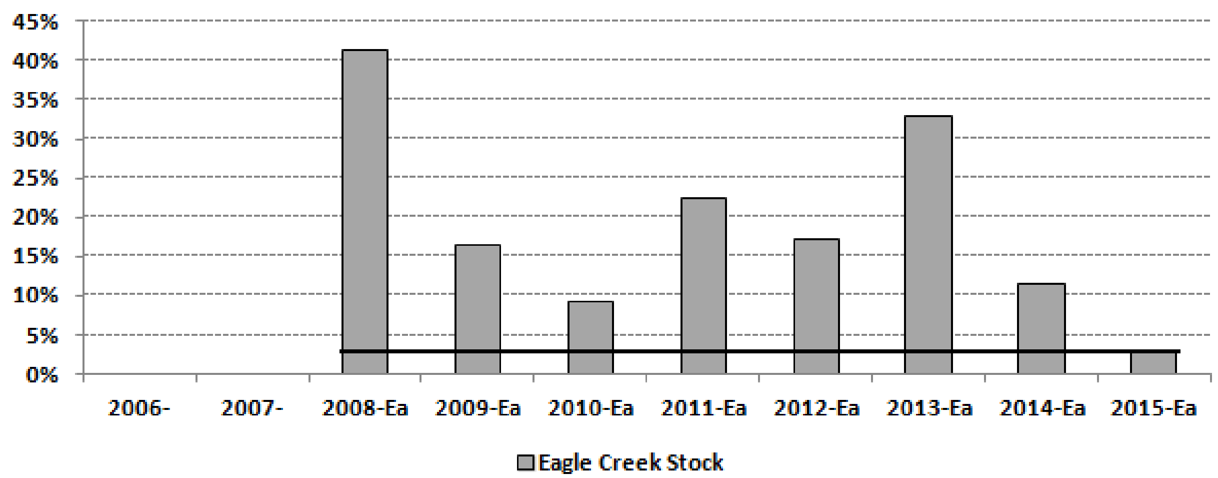



Figure 3.f. Coho 2006-2014 Releases' Tagging-to-McNary Survivals from Taneum compared to that for the 2015 Release

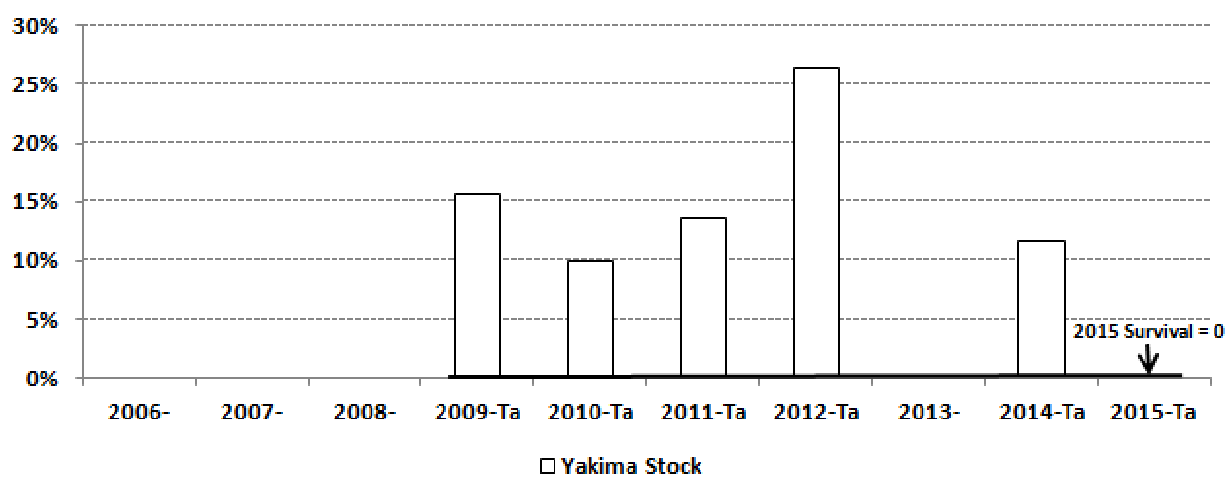


**Table 3.a. Outmigration-Year 2006-2015 Tagging-to-McNary Survival of PIT-Tagged Coho Smolt**

| | | | Release-Site Subbasin and Pond within Subbasin | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Upper Yakima | | | | | | Naches | | Main Stem Yakima |
| | Stock | Measure | Holmes | Boone | Cle Elum | Taneum Creek | Easton Pond | Rosa Dam | Stiles | Lost Creek | Prosser |
| 2006 | Yakima | Tagging-to-McNary Survival | 12.48% | 3.69% | | | | | 34.99% | 34.76% | |
| | | Number Tagged | 2512 | 2501 | | | | | 2490 | 2491 | |
| | Eagle Creek | Tagging-to-McNary Survival | 11.82% | 2.57% | | | | | 35.05% | 43.81% | 60.52% |
| | | Number Tagged | 2514 | 2500 | | | | | 2506 | 2515 | 1231 |
| 2007 | Yakima | Tagging-to-McNary Survival | 10.77% | | | | | | 25.65% | 23.94% | 59.84% |
| | | Number Tagged | 2460 | | | | | | 2449 | 2501 | 2499 |
| | Eagle Creek | Tagging-to-McNary Survival | 7.08% | | | | | | 32.07% | 17.39% | 44.30% |
| | | Number Tagged | 2504 | | | | | | 2513 | 2511 | 1246 |
| 2008 | Yakima | Tagging-to-McNary Survival | 11.17% | | | | | | 46.59% | 28.58% | |
| | | Number Tagged | 2493 | | | | | | 2492 | 2499 | |
| | Eagle Creek | Tagging-to-McNary Survival | 13.89% | | | | 41.45% | | 43.08% | 26.76% | 20.13% |
| | | Number Tagged | 2508 | | | | 2500 | | 2453 | 2524 | 854 |
| 2009 | Yakima | Tagging-to-McNary Survival | 9.19% | | 0.21% | 15.67% | | | 47.27% | 33.70% | 56.76% |
| | | Number Tagged | 2512 | | 11934 | 1300 | | | 2515 | 2508 | 2506 |
| | Eagle Creek | Tagging-to-McNary Survival | 12.01% | | | | 16.38% | | 40.80% | 27.76% | |
| | | Number Tagged | 1427 | | | | 2524 | | 3755 | 2331 | |
| 2010 | Yakima | Tagging-to-McNary Survival | 2.26% | | | 9.89% | | | 18.17% | 18.45% | 71.49% |
| | | Number Tagged | 2516 | | | 1867 | | | 2501 | 2505 | 1371 |
| | Eagle Creek | Tagging-to-McNary Survival | 4.29% | 3.41% | | | 9.10% | | 14.43% | 17.76% | |
| | | Number Tagged | 2504 | 1265 | | | 2532 | | 2581 | 2520 | |
| 2011 | Yakima | Tagging-to-McNary Survival | 3.46% | | | 13.64% | 6.74% | | | 23.10% | 37.19% |
| | | Number Tagged | 2516 | | | 4515 | 1272 | | | 2500 | 5036 |
| | Eagle Creek | Tagging-to-McNary Survival | | | | | 22.40% | | | | |
| | | Number Tagged | | | | | 2561 | | | | |
| | Yakima x | Tagging-to-McNary Survival | 7.42% | | | | 24.99% | | 28.42% | 39.85% | |
| | Eagle Creek | Number Tagged | 2506 | | | | 2522 | | 2524 | 2514 | |
| 2012 | Yakima(1) | Tagging-to-McNary Survival | 2.31% | | | 26.48% | 23.64% | | 38.38% | 31.36% | 37.68% |
| | | Number Tagged | 2508 | | | 1054 | 1258 | | 1285 | 2526 | 1285 |
| | Yakima(2) | Tagging-to-McNary Survival | | | | | 14.80% | | | | |
| | | Number Tagged | | | | | 2547 | | | | |
| | Eagle Creek | Tagging-to-McNary Survival | 1.40% | | | | 17.11% | | 38.49% | | |
| | | Number Tagged | 2453 | | | | 1294 | | 1260 | | |
| 2013 | Yakima | Tagging-to-McNary Survival | | | | | | 50.89% | 47.82% | 23.56% | 74.32% |
| | | Number Tagged | | | | | | 1221* | 2504 | 2531 | 2520 |
| | Eagle Creek | Tagging-to-McNary Survival | 38.39% | | | | 32.85% | | 36.70% | | |
| | | Number Tagged | 1263 | | | | 2495 | | 2505 | | |
| 2014 | Yakima | Tagging-to-McNary Survival | | | | 11.62% | | 31.86% | 40.39% | | 57.00% |
| | | Number Tagged | | | | 1941 | | 1500** | 2505 | | 3004 |
| | Eagle Creek | Tagging-to-McNary Survival | 11.86% | | | | 11.51% | | 31.62% | 29.27% | |
| | | Number Tagged | 2502 | | | | 2586 | | 2529 | 2523 | |
| 2015 | Yakima | Tagging-to-McNary Survival | | | | | | | 8.32% | 4.36% | 31.30% |
| | | Number Tagged | | | | | | | 2520 | 2506 | 1265 |
| | Eagle Creek | Tagging-to-McNary Survival | 8.75% | | | | 2.67% | | 16.78% | | |
| | | Number Tagged | 2501 | | | | 3751 | | 2498 | | |
| | WDFW | Tagging-to-McNary Survival | | | | 0.00% | | | | | |
| | Tagging | Number Tagged | | | | 231 | | | | | |
| | | | | | | | | * Bypass Release<br>** Below Dam Release | | | |

**Note: Highlighted sites are those having releases made in 2015.**

A more detailed analysis was performed. Appendix Table A.1 presents a logistic analysis of variation table. Of the sources in the table, the only ones that were significant at the 5% level[5] were Year and Site (both with p < 0.0001) and Year x Site interaction (P = 0.0019). Table 3.b. below presents the yearly survival means within site and the yearly means pooled over sites along with 2004-2014 mean differences from the 2015 means and their respective significance levels. Positive differences are boldfaced as are estimated Type 1 Error probabilities of P < 0.05. As can be seen, with the exception of Holmes, a vast majority of the individual 2006-2014 year survival means within sites are highly significantly greater than the 2015 estimates. When averaged over sites, all the 2015 mean survival estimates were greater than the 2015 estimate, the differences being highly significant for all nine comparisons (P < 0.0005).

**Table 3.b. Site x Year and Year Tagging-to-McNary Survival Means and Comparisons with 2015 Means**

| | Holmes | | | Taneum | | | Stiles | | |
|---|---|---|---|---|---|---|---|---|---|
| **Release Year** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** |
| 2006 | 12.2% | **3.4%** | 0.1518 | | | | 35.0% | **22.5%** | **0.0000** |
| 2007 | 8.9% | **0.2%** | 0.4776 | | | | 28.9% | **16.4%** | **0.0001** |
| 2008 | 12.5% | **3.8%** | 0.1300 | | | | 44.9% | **32.3%** | **0.0000** |
| 2009 | 10.2% | **1.5%** | 0.3234 | 15.7% | **15.7%** | **0.0000** | 43.4% | **30.9%** | **0.0000** |
| 2010 | 3.3% | -5.5% | 0.9837 | 9.9% | **9.9%** | **0.0000** | 16.3% | **3.7%** | 0.1096 |
| 2011 | 5.4% | -3.3% | 0.8943 | 13.6% | **13.6%** | **0.0000** | 28.4% | **15.9%** | **0.0006** |
| 2012 | 1.9% | -6.9% | 0.9962 | 26.5% | **26.5%** | **0.0000** | 38.4% | **25.9%** | **0.0000** |
| 2013 | 38.4% | 29.6% | **0.0001** | | | | 42.3% | **29.7%** | **0.0000** |
| 2014 | 11.9% | **3.1%** | 0.1994 | 11.6% | **11.6%** | **0.0000** | 36.0% | **23.4%** | **0.0000** |
| 2015 | 8.7% | | | 0.0% | | | 12.5% | | |

| | Lost Creek | | | Prosser | | | Easton | | |
|---|---|---|---|---|---|---|---|---|---|
| **Release Year** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** |
| 2006 | 39.3% | **34.9%** | **0.0000** | 60.5% | **29.2%** | **0.0017** | | | |
| 2007 | 20.7% | **16.3%** | **0.0005** | 54.7% | **23.4%** | **0.0020** | | | |
| 2008 | 27.7% | **23.3%** | **0.0001** | 20.1% | -11.2% | 0.9030 | 41.5% | **38.8%** | **0.0000** |
| 2009 | 16.3% | **11.9%** | **0.0023** | 56.8% | **25.5%** | **0.0016** | 16.4% | **13.7%** | **0.0005** |
| 2010 | 18.1% | **13.7%** | **0.0012** | 71.5% | **40.2%** | **0.0001** | 9.1% | **6.4%** | **0.0114** |
| 2011 | 31.5% | **27.1%** | **0.0000** | 37.2% | **5.9%** | 0.1819 | 20.3% | **17.6%** | **0.0001** |
| 2012 | 31.4% | **27.0%** | **0.0001** | 37.7% | **6.4%** | 0.2142 | 20.3% | **17.7%** | **0.0001** |
| 2013 | 23.6% | **19.2%** | **0.0004** | 74.3% | **43.0%** | **0.0000** | 32.9% | **30.2%** | **0.0000** |
| 2014 | 29.3% | **24.9%** | **0.0001** | 57.0% | **25.7%** | **0.0013** | 11.5% | **8.8%** | **0.0033** |
| 2015 | 4.4% | | | 31.3% | | | 2.7% | | |

| | Yearly Means pooled over Sites and Broods | | |
|---|---|---|---|
| **Release Year** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** |
| **2006** | 31.2% | **21.7%** | **0.0000** |
| **2007** | 26.5% | **17.0%** | **0.0000** |
| **2008** | 29.7% | **20.2%** | **0.0000** |
| **2009** | 27.7% | **18.2%** | **0.0000** |
| **2010** | 15.8% | **6.3%** | **0.0004** |
| **2011** | 22.3% | **12.8%** | **0.0000** |
| **2012** | 21.1% | **11.6%** | **0.0000** |
| **2013** | 42.6% | **33.1%** | **0.0000** |
| **2014** | 28.9% | **19.4%** | **0.0000** |
| **2015** | 9.5% | | |

*** 1-sided t-test for 2015 releases having a lower survival rate**

[5] **Since the poor conditions in 2015 were expected to result in a decreased survival, the tests were 1-sided tests for mean survival of each previous year being greater than that of 2015.**

It should be noted from Appendix Table A.1, that, while not significant at the 5% level, the Stock and Stock x Year interaction sources are nearly significant at the 10% level. The comparisons presented in Table 3.b. assume that there are no stock main or interaction effects. If there are, then the comparisons among years are confounded by these effects.

**Mean McNary-Passage Date**

Mean McNary-Passage Dates are presented in Figures 4.a. through 4.f. and in Table 4. for each stock within each site, a horizontal line connects the 2015 McNary Passage to those in previous years in the figures.. In 77 % (or 18) of the 23 paired releases of Yakima and Eagle Creek stock from the same sites within years for which there were differences in the stocks' survivals, the Yakima stock had an earlier mean date of McNary Passage. This 77% is significantly different than 50% at the 5% level (estimated Type 1 Error p = 0.0106, based on a binomial-distribution 2-sided sign test).

With the exceptionally low snow pack and drought in 2015, the higher mortality of smolt later in the run would be expected to result in an earlier passage. The 2015 passage date was the earliest for the Eagle Creek stock releases at Holmes and for the Yakima stock releases at Prosser. For four of the other release sets, 2015 was second earliest of the years presented with no consistency as to the years of the earliest passage. Since the McNary Survival estimate was 0% for the 2015 Taneum release, there was no estimated passage date.

Figure 4.a. 2006-2014 Coho McNary Mean Passage Dates from Holmes for compared to that for the 2015 Release

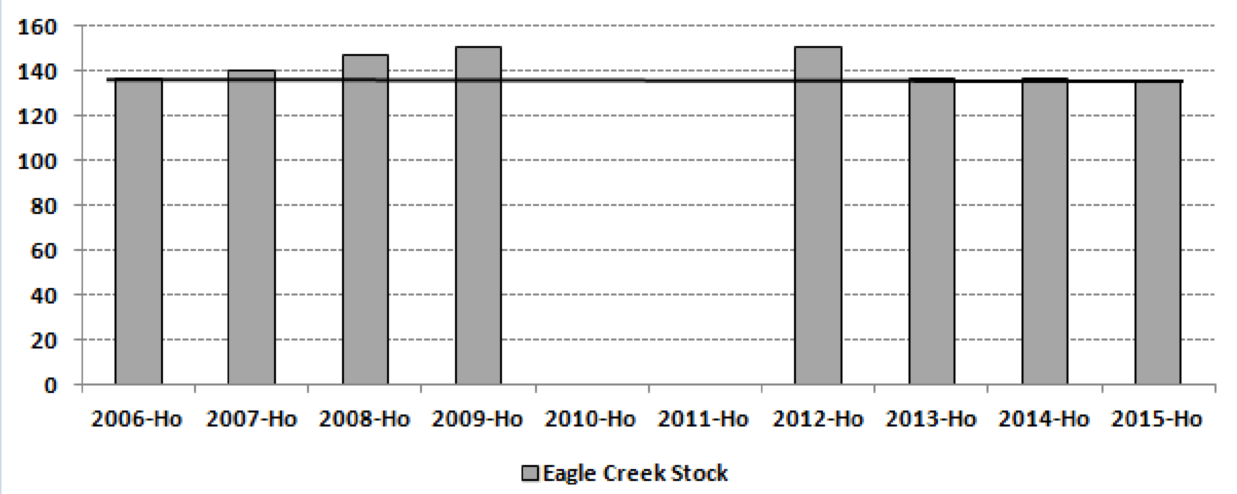


Figure 4.b. 2006-2014 Coho McNary Mean Passage Dates from Stiles for compared to those for the 2015 Release

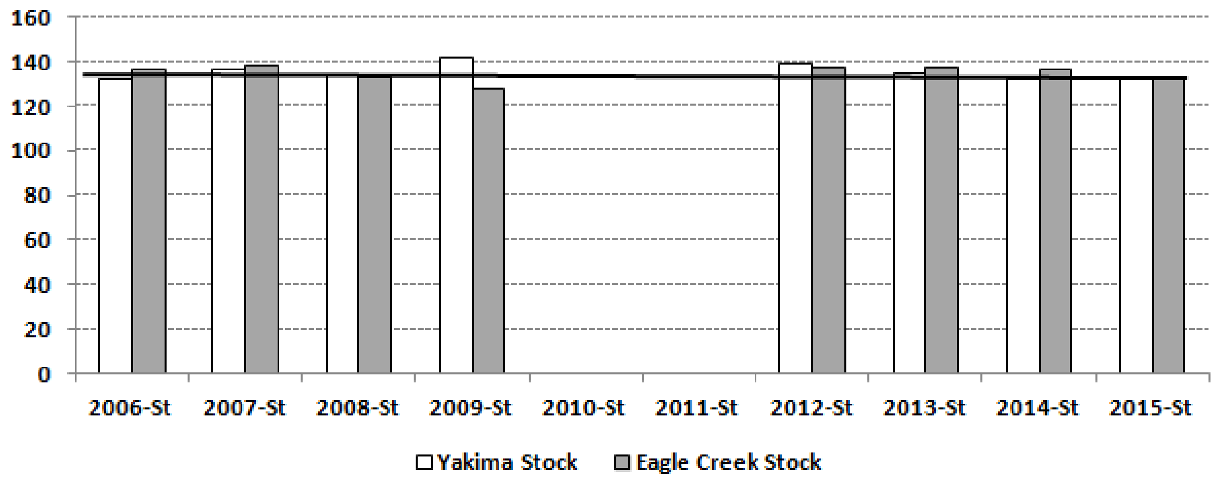



Figure 4.c. 2006-2014 Coho McNary Mean Passage Dates from Lost Creek for compared to that for the 2015 Release

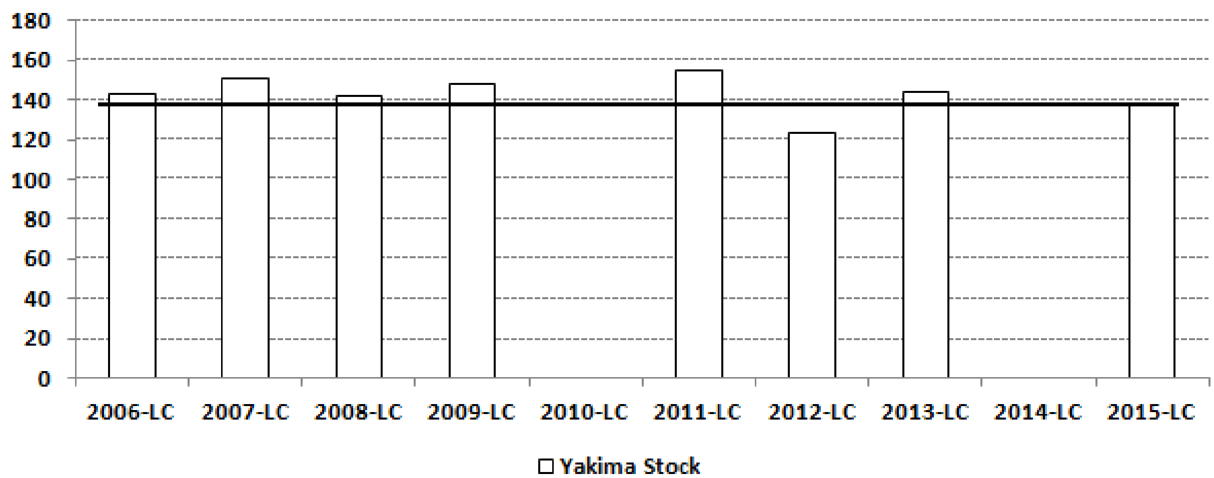
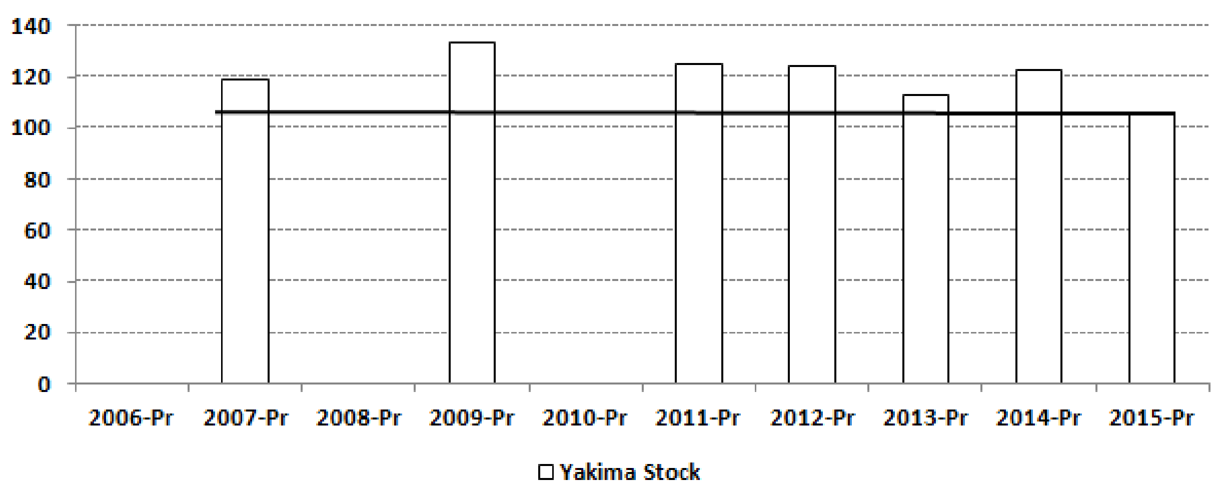



Figure 4.d. 2006-2014 Coho McNary Mean Passage Dates from Prosser for compared to that for the 2015 Release



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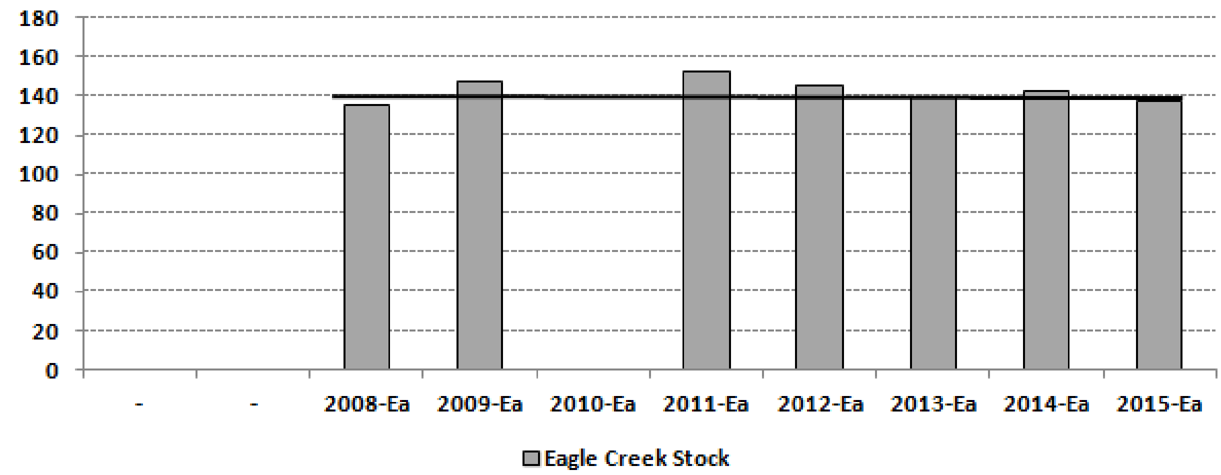


Figure 4.f. 2006-2014 Coho McNary Mean Passage Dates from Taneum for compared to that for the 2015 Release

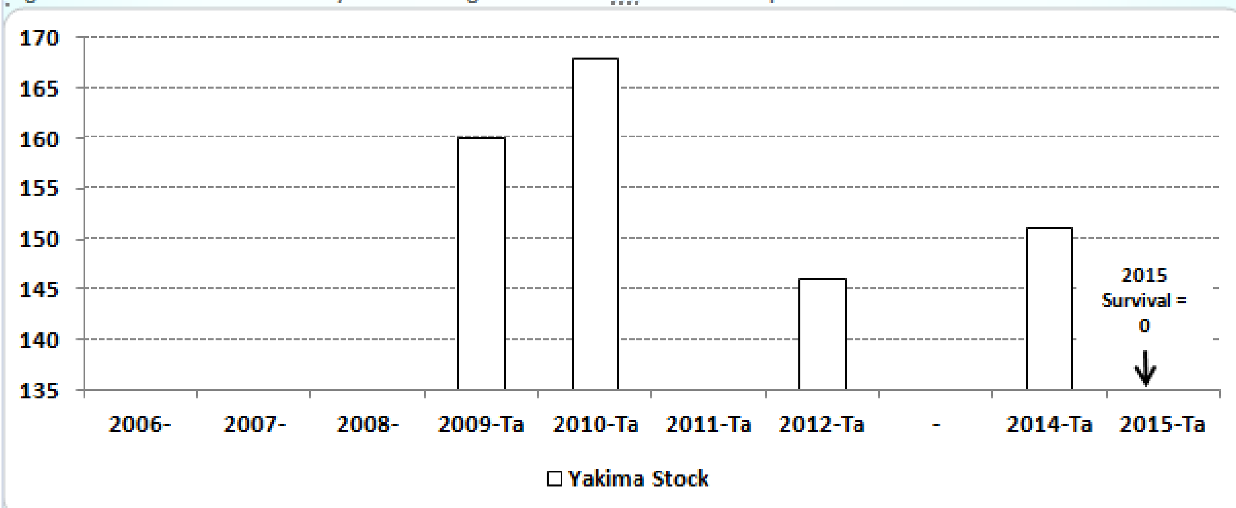

**Table 4.a. Outmigration-Year 2006-2015 Coho Mean McNary-Passage Julian Date (Yellow shaded sites are those stocked in 2015)**

| | | | Release-Site Subbasin and Pond within Subbasin | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Upper Yakima | | | | | | Naches | | Main Stem Yakima |
| Release Year | Stock | Measure | Holmes | Boone | Cle Elum | Taneum Creek | Easton Pond | Rosa Dam bypass | Stiles | Lost Creek | Prosser |
| 2006 | Yakima | Julian Passage Date | 124 | 133 | | | | | 132 | 143 | |
| | | Expanded McNary Passage | 313 | 92 | | | | | 871 | 865 | |
| | Eagle Creek | Julian Passage Date | 137 | 144 | | | | | 137 | 150 | 122 |
| | | Expanded McNary Passage | 297 | 64 | | | | | 878 | 110 | 744 |
| 2007 | Yakima | Julian Passage Date | 137 | | | | | | 137 | 151 | 119 |
| | | Expanded McNary Passage | 265 | | | | | | 628 | 598 | 1495 |
| | Eagle Creek | Julian Passage Date | 140 | | | | | | 138 | 148 | 122 |
| | | Expanded McNary Passage | 177 | | | | | | 805 | 436 | 552 |
| 2008 | Yakima | Julian Passage Date | 138 | | | | | | 134 | 142 | |
| | | Expanded McNary Passage | 278 | | | | | | 116 | 714 | |
| | Eagle Creek | Julian Passage Date | 147 | | | | 135 | | 133 | 148 | 142 |
| | | Expanded McNary Passage | 348 | | | | 1036 | | 105 | 675 | 171 |
| 2009 | Yakima | Julian Passage Date | 139 | | 164 | 160 | | | 142 | 148 | 133 |
| | | Expanded McNary Passage | 230 | | 25 | 204 | | | 1188 | 845 | 1422 |
| | Eagle Creek | Julian Passage Date | 151 | | | | 147 | | 128 | 153 | |
| | | Expanded McNary Passage | 171 | | | | 413 | | 1532 | 647 | |
| 2010 | Yakima | Julian Passage Date | 132 | | | 168 | | | 137 | 148 | 118 |
| | | Expanded McNary Passage | 57 | | | 185 | | | 454 | 462 | 980 |
| | Eagle Creek | Julian Passage Date | 145 | 155 | | | 144 | | 143 | 153 | |
| | | Expanded McNary Passage | 108 | 43 | | | 143 | | 372 | 447 | |
| 2011 | Yakima | Julian Passage Date | 148 | | | | 144 | | | 155 | 125 |
| | | Expanded McNary Passage | 87 | | | 616 | 86 | | | 577 | 1873 |
| | Eagle Creek | Julian Passage Date | | | | | 152 | | | | |
| | | Expanded McNary Passage | | | | | 574 | | | | |
| | Yakima x | Julian Passage Date | 146 | | | | 151 | | 144 | 156 | |
| | Eagle Creek | Expanded McNary Passage | 186 | | | | 630 | | 717 | 1002 | |
| 2012 | Yakima | Julian Passage Date | 149 | | | 146 | 146 | | 139 | 123 | 124 |
| | | Expanded McNary Passage | 58 | | | 279 | 538 | | 939 | 792 | 484 |
| | Yakima* | Julian Passage Date | | | | | 148 | | | | |
| | | Expanded McNary Passage | | | | | 377 | | | | |
| | Eagle Creek | Julian Passage Date | 150 | | | | 146 | | 137 | | |
| | | Expanded McNary Passage | 65 | | | | 496 | | 1001 | | |
| 2013 | Yakima | Julian Passage Date | | | | | | 124 | 134 | 144 | 113 |
| | | Expanded McNary Passage (reared at Prosser) | | | | | | 621 | 1197 | 596 | 1873 |
| | Eagle Creek | Julian Passage Date | 137 | | | | 140 | | 138 | | |
| | | Expanded McNary Passage (reared at Eagle Creek) | 485 | | | | 820 | | 919 | | |
| 2014 | Yakima | Julian Passage Date | | | | 151 | | 126 | 133 | | 123 |
| | | Expanded McNary Passage | | | | 226 | | 478 | 1012 | | 1712 |
| | Eagle Creek | Julian Passage Date | 137 | | | | 142 | | 137 | 139 | |
| | | Expanded McNary Passage | 297 | | | | 298 | | 800 | 739 | |
| 2015 | Yakima | Julian Passage Date | | | | | | | 133 | 137 | 105 |
| | | Expanded McNary Passage | | | | | | | 210 | 109 | 396 |
| | Eagle Creek | Julian Passage Date | 136 | | | | 137 | | 134 | | |
| | | Expanded McNary Passage | 219 | | | | 100 | | 419 | | |
| | WDFW | Julian Passage Date | | | | no survival | | | | | |
| | Tagging | Expanded McNary Passage | | | | 0 | | | | | |
| | | | | | | | | * Bypass Release<br>** Below Dam Release | | | |

**Note: Highlighted sites are those having releases made in 2015.**

As was the case for Tagging-to-McNary Survival, a more detailed analysis was performed for mean McNary-Passage Date. Appendix Table A.2 presents an analysis of variance table. Again, the only sources in table that were significant[6] at the 5% level were Year (p = 0.0002), Site (p < 0.0001) and Year x Site interaction (P = 0.0291). Table 4.b. below presents the yearly passage date means within site and the yearly means pooled over sites along with 2004-2014 mean differences from the 2015 means and their respective significance levels. Positive differences are boldfaced as are estimated Type 1 Error probabilities of P < 0.05. Out of the 43 within-site comparisons, 39 or 91% had the earlier 2015 mean date of passage associated with the 2015 release. When averaged over sites, all 2006-2014 years, all years had the earlier mean passage date associated with the 2015 releases, all but one comparison being significant, most being highly significant.

**Table 4.b. Site x Year and Year Julian Date Means of McNary Passage and Comparisons with 2015 Means**

| | Holmes | | | Taneum | | | Stiles | | |
|---|---|---|---|---|---|---|---|---|---|
| **Release Year** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** |
| 2006 | 130 | -5 | 0.7447 | | | | 134 | **1** | 0.4025 |
| 2007 | 138 | **3** | 0.3825 | | | | 137 | **4** | 0.1959 |
| 2008 | 143 | **8** | 0.1830 | | | | 133 | 0 | 0.4904 |
| 2009 | 144 | **9** | 0.1656 | 160 | | | 134 | **1** | 0.4316 |
| 2010 | 140 | **5** | 0.3240 | 168 | | | 139 | **6** | 0.1232 |
| 2011 | 146 | **11** | 0.1228 | 162 | | | 144 | **11** | **0.0327** |
| 2012 | 149 | **14** | 0.1120 | 146 | | | 138 | **5** | 0.1465 |
| 2013 | 136 | **1** | 0.4600 | | | | 135 | **2** | 0.2988 |
| 2014 | 136 | **1** | 0.4461 | 151 | | | 134 | **1** | 0.4153 |
| 2015 | 135 | | | no estimated passage | | | 133 | | |

| | Lost Creek | | | Prosser | | | Easton | | |
|---|---|---|---|---|---|---|---|---|---|
| **Release Year** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** |
| 2006 | 143 | **6** | **0.2695** | 122 | **17** | **0.0072** | | | |
| 2007 | 149 | **12** | 0.1192 | 119 | **14** | **0.0080** | | | |
| 2008 | 144 | **7** | 0.2318 | 142 | **37** | **0.0003** | 135 | -2 | 0.5773 |
| 2009 | 150 | **13** | 0.1080 | 133 | **28** | **0.0000** | 147 | **10** | 0.1943 |
| 2010 | 150 | **13** | 0.1077 | 118 | **13** | **0.0240** | 144 | **7** | 0.3030 |
| 2011 | 155 | **18** | **0.0401** | 124 | **19** | **0.0009** | 151 | **14** | 0.0959 |
| 2012 | 122 | -15 | 0.9125 | 124 | **19** | **0.0057** | 145 | **8** | 0.2135 |
| 2013 | 144 | **7** | 0.2581 | 112 | **7** | 0.1097 | 139 | **2** | 0.4069 |
| 2014 | 139 | **2** | 0.4359 | 122 | **17** | **0.0025** | 142 | **5** | 0.3349 |
| 2015 | 137 | | | 105 | | | 137 | | |

| | Yearly Means pooled over Sites and Broods | | |
|---|---|---|---|
| **Release Year** | **Estimate** | **Difference from 2015** | **Type 1 Error P*** |
| **2006** | 133 | **7** | **0.0145** |
| **2007** | 132 | **6** | **0.0259** |
| **2008** | 140 | **14** | **0.0001** |
| **2009** | 139 | **13** | **0.0001** |
| **2010** | 137 | **11** | **0.0008** |
| **2011** | 144 | **18** | **0.0000** |
| **2012** | 136 | **10** | **0.0015** |
| **2013** | 129 | **3** | **0.1456** |
| **2014** | 132 | **6** | **0.0322** |
| **2015** | 126 | | |

*** 1-sided t-test for 2015 releases having a lower survival rate**

[6] **Since the poor conditions in 2015 were expected the result in a decreased survival for those fish leaving the release sites later, the 2015 McNary Passage Date was expected to be earlier; therefore the tests were 1-sided tests for mean passage date of each previous year being greater than that of 2015.**

There is much less concern about a confounding of the within-year comparisons with stock differences in Table 4.b. than in Table 3.b. because all source effects involving Stock had estimated Type 1 Error p values less than 0.25 (Appendix Table A.2).

## In-Stream and Mobile-Raceway Releases

Scatter-plants of parr and smolt directly into streams and rivers and Releases of smolt from mobile acclimation raceways began with outmigration year 2010. There was no PIT-tag detectors used at any of the release site. Tagging-to-McNary Survival estimates are given in Table A.5, and mean McNary-Passage Dates are given in Appendix Table A.6.

**Table 5.a. Outmigration-Year 2010-2015 Time-of-Tagging-to-McNary Juvenile Survival**

| Release Year | Stock | Measure | Little Rattlesnake | | Nile | | SF Cowiche | | Cowiche |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | Yakima | File Extender | MRS-Smolt | PRS-Parr | WNL-Wild O.Mykiss & Coho * | PNL-Parr | MCW-Smolt | PCW-Parr | |
| | | Tagging to McNary Survival | 8.18% | 12.06% | 69.42% | 13.79% | 23.29% | 17.25% | |
| | | Number Tagged | 1144 | 3053 | 16 | 3055 | 1248 | 3004 | |
| 2011 | Yakima | File Extender | | PLR-Parr | WNL-Parr * | PNL-Parr | MCW-Smolt | PCW-Parr | WCW-Parr* |
| | | Tagging to McNary Survival | | 7.97% | 69.45% | 7.46% | 31.50% | 19.54% | 81.99% |
| | | Number Tagged | | 3000 | 16 | 3110 | 1272 | 3021 | 28 |
| 2012 | Yakima | | Rattlesnake | | | | | | |
| | | File Extender | MRS-Smolt | PLR-Parr | | PNL-Parr | MCW-Smolt | PCS-Parr | |
| | | Tagging to McNary Survival | 16.22% | 8.39% | | 8.28% | 41.05% | 11.86% | |
| | | Number Tagged | 1274 | 3006 | | 3017 | 1277 | 3024 | |
| 2013 | Yakima | File Extender | MRA-Parr | PRS-Smolt | | PNL-Parr | MCW-Smolt | | PCW-Parr |
| | | Tagging to McNary Survival | 11.34% | 3.82% | | 4.72% | 19.87% | | 9.84% |
| | | Number Tagged | 2506 | 3002 | | 3033 | 3464 | | 3003 |
| 2014 | Yakima | File Extender | | PRC-Parr | | | MCW-Smolt | PCS-Smolt | |
| | | Tagging to McNary Survival | | 7.66% | | | 33.98% | 5.26% | |
| | | Number Tagged | | 3011 | | | 1249 | 3014 | |
| 2015 | Yakima | File Extender | MRS | PRI | | | MCW | PCS | |
| | | Tagging to McNary Survival | 6.85% | 0.57% | | | 16.04% | 0.00% | |
| | | Number Tagged | 1249 | 1606 | | | 1250 | 3017 | |

* High percent survival based on very small sample sizes

Table 5.b. Outmigration-Year 2010-2015 Time-of-Tagging-to-McNary Juvenile Survival (Continued)

| Release Year | Stock | Measure | Ahtanum | | Big Creek | Reecer | Lost Creek | Umtanum Creek | Wilson | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | Yakima | File Extender | | PAH-Parr | PBG-Parr | PRC-Parr | | UMT | PWL-Parr | |
| | | Tagging to McNary Survival | | 20.18% | 10.49% | 21.47% | | 44.32% | 11.32% | |
| | | Number Tagged | | 3050 | 3006 | 3015 | | 150 | 3050 | |
| 2011 | Yakima | File Extender | | PAH-Parr | PBG-Parr | PRC-Parr | WLC-Parr * | UMT-Parr * | PWL-Parr | |
| | | Tagging to McNary Survival | | 18.87% | 15.81% | 29.61% | 57.39% | 34.95% | 16.93% | |
| | | Number Tagged | | 3003 | 3003 | 3004 | 10 | 42 | 2522 | |
| 2012 | Yakima | File Extender | PAL-Parr | | PBG-Parr | PRE-Parr | | | PWI-Parr | |
| | | Tagging to McNary Survival | 5.42% | | 11.59% | 19.43% | | | 11.02% | |
| | | Number Tagged | 4003 | | 3013 | 3026 | | | 3020 | |
| | | | | | | | | | Burried Section-Parr | |
| | | | | | | | | | Above | Below |
| 2013 | Yakima | File Extender | PAL-Parr | PAM-Parr | PBG-Parr | PRE-Parr | | | PWA | PWB |
| | | Tagging to McNary Survival | 10.66% | 6.81% | 7.45% | 13.75% | | | 4.55% | 10.71% |
| | | Number Tagged | 600 | 1213 | 3028 | 3032 | | | 1518 | 1502 |
| 2014 | Yakima | File Extender | PAL-Parr | PAH-Parr | PBG-Parr | PRE-Parr | | | PWI-Parr | |
| | | Tagging to McNary Survival | 0.00% | 0.91% | 4.80% | 9.27% | | | 10.77% | |
| | | Number Tagged | 672 | 872 | 3047 | 3031 | | | 3024 | |
| 2015 | Yakima | File Extender | | PAH-Parr | PBG-Parr | PBG-Parr | | | PWI-Parr | |
| | | Tagging to McNary Survival | | 0.00% | 0.30% | 0.30% | | | 7.23% | |
| | | Number Tagged | | 1349 | 3003 | 3003 | | | 3027 | |

* 2011 WLC and UMT high percent based on very small sample size

Table 5.c. Outmigration-Year 2010-2015 Time-of-Tagging-to-McNary Juvenile Survival (Continued)

| Release Year | Stock | Measure | Rock Creek | Buckskin | Hudley | Quartz Creek | Yakima @ Thorp Bridge | Little Naches | NF Little Naches | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | Yakima | File Extender | WRK-Wild | | | | | PLN-Parr | PNF-Parr | | |
| | | Tagging to McNary Survival | 0.00% | | | | | 17.87% | 19.72% | | |
| | | Number Tagged | 78 | | | | | 3072 | 3014 | | |
| 2011 | Yakima | File Extender | | WBK-Parr | | | | PLN-Parr | PNF-Parr | | |
| | | Tagging to McNary Survival | | 37.95% | | | | 9.54% | 17.59% | | |
| | | Number Tagged | | 216 | | | | 3022 | 3058 | | |
| 2012 | Yakima | File Extender | | | | PQU-Parr | PYA-Parr | PLN-Parr | PNF-Parr | 2013 Mercer Creek | |
| | | Tagging to McNary Survival | | | | 12.09% | 10.68% | 21.91% | 19.12% | Burried Section-Parr | |
| | | Number Tagged | | | | 3008 | 2499 | 3014 | 3028 | Above | Below |
| 2013 | Yakima | File Extender | | | | PQU-Parr | | PLN-Parr | PNF-Parr | PMA | PMB |
| | | Tagging to McNary Survival | | | | 4.60% | | 7.48% | 10.90% | 15.61% | 16.46% |
| | | Number Tagged | | | | 3007 | | 3019 | 3012 | 1502 | 1502 |
| 2014 | Yakima | File Extender | | Smolt | | PQU-Parr | | PLN-Parr | | | |
| | | Tagging to McNary Survival | | 33.97% | | 6.50% | | 9.45% | | | |
| | | Number Tagged | | 1572 | | 3039 | | 3012 | | | |
| 2015 | Yakima | File Extender | | Smolt | PHU-Parr | PQU-Parr | | PLN-Parr | PNF-Parr | | |
| | | Tagging to McNary Survival | | 15.69% | 0.00% | 3.31% | | 0.00% | 0.00% | | |
| | | Number Tagged | | 1247 | 1531 | 3026 | | 6020 | 3004 | | |

* 2010 and 2011 WNL high percent based on very small sample size

Table 6.a. Outmigration-Year 2010-2015 Mean Juvenile McNary Passage Date

| Year | Stock | Measure | Little Rattlesnake | | Nile | | SF Cowiche | | Cowiche |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | Yakima | File Extender | Smolt | PRS-Parr | WNL-Parr | PNL-Parr | Smolt | PCW-Parr | |
| | | Mean McNary Passage Date | 166 | 155 | 171 | 159 | 149 | 166 | |
| | | Expanded McNary Passage | 94 | 368 | 11 | 421 | 291 | 518 | |
| 2011 | Yakima | File Extender | | PLR-Parr | WNL-Parr | PNL-Parr | Smolt | PCW-Parr | Parr |
| | | Mean McNary Passage Date | | 154 | 165 | 163 | 156 | 162 | 144 |
| | | Expanded McNary Passage | | 239 | 11 | 232 | 401 | 590 | 23 |
| | | | Rattlesnake | | | | | | |
| 2012 | Yakima | File Extender | MRS-Smolt | PLR-Parr | | PNL-Parr | MCW-Smolt | PCS-Smolt | |
| | | Mean McNary Passage Date | 147 | 155 | | 157 | 147 | 155 | |
| | | Expanded McNary Passage | 207 | 252 | | 250 | 524 | 359 | |
| 2013 | Yakima | File Extender | MRA | PRS | | PNL | MCW-Smolt | | PCW |
| | | Mean McNary Passage Date | 138 | 143 | | 156 | 143 | | 153 |
| | | Expanded McNary Passage | 2506 | 3002 | | 3033 | 3464 | | 3003 |
| 2014 | Yakima | File Extender | | PRC | | PLN | MCW | PCS | |
| | | Mean McNary Passage Date | | 144 | | 148 | 143 | 161 | |
| | | Expanded McNary Passage | | 231 | | 285 | 424 | 159 | |
| 2015 | 0.00% | File Extender | MRS | PRI | | | MCW | PCS | |
| | | Mean McNary Passage Date | 127 | 136 | | | 135 | n.a. | |
| | | Expanded McNary Passage | 86 | 9 | | | 200 | 0 | |

Table 6.b. Outmigration-Year 2010-2015 Mean Juvenile McNary Passage Date (continued)

| Release Year | Stock | Measure | Ahtanum | | Big Creek | Reecer | Lost Creek | Umtanum Creek | Wilson | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | Yakima | File Extender | PAH-Parr | | PBG-Parr | PRC-Parr | | Parr? | PWL-Parr | |
| | | Mean McNary Passage Date | 163 | | 160 | 145 | | 143 | 141 | |
| | | Expanded McNary Passage | 616 | | 315 | 647 | | 66 | 345 | |
| 2011 | Yakima | File Extender | PAH-Parr | | PBG-Parr | PRC-Parr | WLC-Parr | UMT-Parr? | PWL-Parr | |
| | | Mean McNary Passage Date | 156 | | 156 | 124 | 136 | 137 | 122 | |
| | | Expanded McNary Passage | 567 | | 475 | 890 | 6 | 15 | 427 | |
| 2012 | Yakima | File Extender | PAL-Parr | | PBG-Parr | PRE*-Parr | | | PWI-Parr | |
| | | Mean McNary Passage Date | 151 | | 152 | 145 | | | 144 | |
| | | Expanded McNary Passage | 217 | | 349 | 588 | | | 333 | |
| | | | | | | | | | Burried Section | |
| | | | | | | | | | Above | Below |
| 2013 | Yakima | File Extender | PAL-Parr | PAM | PBG | PRE | | | PWA | PWB |
| | | Mean McNary Passage Date | 121 | 146 | 147 | 140 | | | 152 | 147 |
| | | Expanded McNary Passage | 64 | 83 | 225 | 417 | | | 69 | 161 |
| 2014 | Yakima | File Extender | PAL-Parr | PAH-Parr | PBG-Parr | PRE-Parr | | | PWI-Parr | |
| | | Mean McNary Passage Date | n.a. | 141 | 143 | 139 | | | 140 | |
| | | Expanded McNary Passage | 0 | 8 | 146 | 281 | | | 326 | |
| 2015 | Yakima | File Extender | | PAH-Parr | PBG-Parr | PRE-Parr | | | PWI-Parr | |
| | | Mean McNary Passage Date | | n.a. | 130 | 139 | | | 137 | |
| | | Expanded McNary Passage | | 0 | 9 | 100 | | | 219 | |

Table 6.c. Outmigration-Year 2010-2015 Mean Juvenile McNary Passage Date (continued)

| Release Year | Stock | Measure | Rock Creek | Buckskin | Hudley | Quarts | Yakima @ Thorp Bridge | Little Naches | NF Little Naches | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | Yakima | File Extender | WRK-Wild | | | | | PLN-Parr | PNF-Parr | | |
| | | Mean McNary Passage Date | n.a. | | | | | 163 | 160 | | |
| | | Expanded McNary Passage | 0 | | | | | 549 | 594 | | |
| 2011 | Yakima | File Extender | | WBK-Parr | | | | PLN-Parr | PNF-Parr | | |
| | | Mean McNary Passage Date | | 135 | | | | 163 | 166 | | |
| | | Expanded McNary Passage | | 82 | | | | 288 | 538 | | |
| 2012 | Yakima | File Extender | | | | PQU-Parr | PYA-Parr | PLN-Parr | PNF-Parr | Mercer Creek | |
| | | Mean McNary Passage Date | | | | 154 | 148 | 152 | 146 | Burried Section-Parr | |
| | | Expanded McNary Passage | | | | 364 | 267 | 660 | 579 | Above | Below |
| 2013 | Yakima | File Extender | | | | | | PLN | PNF | PMA | PMB |
| | | Mean McNary Passage Date | | | | | | 153 | 156 | 150 | 140 |
| | | Expanded McNary Passage | | | | | | 3019 | 3012 | 234 | 247 |
| 2014 | Yakima | File Extender | | MBU-Smolt | | PQU-Parr | | PLN-Parr | | | |
| | | Mean Detection Date | | 118 | | 322 | | 154 | | | |
| | | Expanded McNary Passage | | 534 | | 197 | | 285 | | | |
| 2015 | Yakima | File Extender | | MBU-Smolt | PHU-Parr | PQU-Parr | | PLN-Parr | PNF-Parr | | |
| | | Mean Detection Date | | n.a. | n.a. | n.a. | | n.a. | n.a. | | |
| | | Expanded McNary Passage | | 196 | 0 | 0 | | 0 | 0 | | |

## Appendix

### Table A.1. Logistic Analysis of Variance of Tagging-to-McNary Survival

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev = Dev/DF | F-Ratio | Type 1 P | Denominator Source of Variation |
|---|---|---|---|---|---|---|
| **Year** | 6,475.57 | 9 | 719.51 | 37.78 | **0.0000** | Error |
| **Site** | 15,854.22 | 5 | 3,170.84 | 23.35 | **0.0000** | Year x Site |
| **Year x Site** | 5,295.41 | 39 | 135.78 | 7.13 | **0.0019** | Error |
| **Stock** | 264.17 | 2 | 132.09 | 2.89 | 0.1075 | Year x Stock |
| **Year x Stock** | 411.76 | 9 | 45.75 | 2.40 | 0.1039 | Error |
| **Site x Stock** | 87.82 | 6 | 14.64 | 0.77 | 0.6132 | Error |
| **Error** | 171.40 | 9 | 19.04 | | | |
| **Error & Site x Stock*** | 259.22 | 15 | 17.281333 | | | |

*** Mean Deviance used testing mean differences between years**

### Table A.2. Least Squares Analysis of Variance of Mean McNary-Passage Date

| Source | Sums of Squares (SS) | Degrees of Freedom (DF) | Mean Square = SS/DF | F-Ratio | Type 1 P | Denominator Source of Variation |
|---|---|---|---|---|---|---|
| **Year** | 1,140,469 | 9 | 126,719 | 15.11 | **0.0002** | Error |
| **Site** | 3,993,638 | 5 | 798,728 | 28.36 | **0.0000** | Year x Site |
| **Year x Site** | 1,070,259 | 38 | 28,165 | 3.36 | **0.0291** | Error |
| **Stock** | 14,226 | 2 | 7,113 | 0.57 | 0.5833 | Year x Stock |
| **Year x Stock** | 111,777 | 9 | 12,420 | 1.48 | 0.2841 | Error |
| **Site x Stock** | 66,360 | 6 | 11,060 | 1.32 | 0.3402 | Error |
| **Error** | 75,495 | 9 | 8,388 | | | |
| **Error & Site x Stock & Year x Stock & Stock*** | 267858 | 26 | 10,302 | | | |

*** Mean Square used testing mean differences between years**

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## Appendix G
## Spring Chinook Release-to-Roza-Dam Smolt-to-Adult Survival: Comparison of Hatchery and Natural Origin Brood Stock

Since the onset of the YKFP program, hatchery Spring Chinook of naturally spawned adults have been reared at the Cle Elum hatchery and subsequently transferred to and released from acclimation facilities at Clark Flat, Easton, and Jack Creek. In each year through Brood-Year 2012 two treatments have been allocated to raceways within adjacent raceway pairs, there being three pairs of raceways at each of the three acclimation sites. The experimental treatments have varied over years. The raceways pairs were similar, not only in that they were adjacent to each other, but also because the raceways within each pair received progeny from the same sets of diallele crosses.

Beginning in Brood-Year 2002, one pair of raceways at the Clark Flat acclimation site was assigned to progeny derived from hatchery-brood crosses (HxH or hatchery-control stock - HC) for the purpose of assessing the long-term effect of using the hatchery-brood progeny of each generation to serve as the brood-stock for the subsequent generation. All other raceways (including those located the Jack Creek and Easton acclimation sites) use crosses from naturally spawned parents (NxN or supplemented hatchery stock - SH). No HxH hatchery-produced returns are allowed to spawn in the wild.

In this report, only the HxH and NxN stock released from the Clark Flats acclimation site are being compared because survivals of releases from the other sites are known to differ from those at Cle Elum. Variables analyzed included are:

a) Survival from smolt release to Roza Dam return (Roza) of the coded-wire tagged (CWT) smolt;

b) Survival from smolt release to Roza of Passive Integrated Transponder tagged (PIT-tagged) smolt that were tagged prior to release; and

c) Age-3 percent of Roza returns.

Adult recoveries at Roza Dam were: 1) Assigned to brood years by age at recovery, 2) tallied within age groups within brood year, then 3) adjusted and divided by associated smolt release totals to estimate brood-year survivals using procedures described in Appendix B. It should be noted that the pre-release PIT-tagged smolt were also coded-wire tagged are included in the CWT analyses. Refer to Appendix A. as to why they were not excluded.

### Survival Comparisons between the Hatchery and Natural Crosses

Table[1] and Figure 1.a. present NxN and HxH survival to Roza of CWT smolt released from the Cle Elum acclimation site. Brood-Year 2010 estimates do not include Age-5 returns.

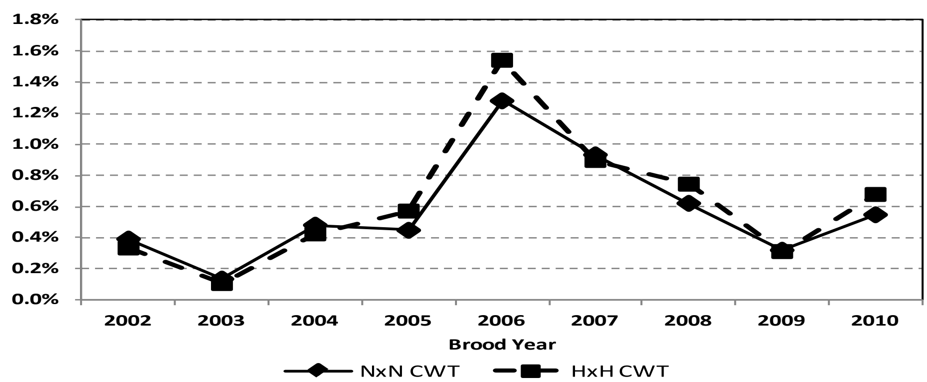
**Table 1.a. Comparisons between Naturally Spawned and Hatchery-Spawned Survival to Roza of Hatchery-reared CWT Smolt released from the Clark Flats Acclimation Site**

| | | a. CWT Survival | | |
|---|---|---|---|---|
| Brood Year | Measure | NxN | HxH | NxN - HxH |
| 2002 | Survival | 0.392% | 0.335% | 0.057% |
| | Weight* | 178,726 | 87,837 | |
| 2003 | Survival | 0.135% | 0.106% | 0.029% |
| | Weight* | 184,644 | 88,733 | |
| 2004 | Survival | 0.481% | 0.425% | 0.056% |
| | Weight* | 186,259 | 94,339 | |
| 2005 | Survival | 0.448% | 0.572% | -0.124% |
| | Weight* | 196,609 | 90,518 | |
| 2006 | Survival | 1.280% | 1.541% | -0.261% |
| | Weight* | 141,141 | 68,434 | |
| 2007 | Survival | 0.933% | 0.897% | 0.036% |
| | Weight* | 171,244 | 94,663 | |
| 2008 | Survival | 0.621% | 0.745% | -0.123% |
| | Weight* | 183,057 | 97,196 | |
| 2009 | Survival | 0.320% | 0.312% | 0.009% |
| | Weight* | 190,352 | 88,771 | |
| 2010 | Survival | 0.548% | 0.679% | -0.130% |
| | Weight* | 172,390 | 92,030 | |
| Pooled** Over Years | Survival | 0.550% | 0.603% | -0.053% |
| | Weight* | 1,604,422 | 802,521 | |

*** Number of all released CWT smolt**

**** Averaged over all CWT smolt released**

**Figure 1.a. Naturally Spawned and Hatchery-Spawned Survival to Roza of Hatchery-reared CWT Smolt released from the Clark Flats Acclimation Site**




[1] Table 1.a. highlighted differences for brood years 2007-2009 are discussed later.

Even though the CWT NxN stock's mean survival to Roza over years was less than that for the HxH stock (0.55% versus 0.60%), there was no significant[2] difference over years between CWT survivals of the NxN and HxH stock (P = 0.1775 based on logistic analysis of variation, Appendix Table A.1.a).

A subset of the CWT smolt was PIT-tagged pre-release for the purpose of estimating juvenile survival. This subset was separately analyzed to determine consistency with the CWT estimates. Table 1.b.and Figure 1.b. present NxN and HxH survival to Roza Dam return of PIT-tagged smolt detected at release from the Clark Flats acclimation site. Brood-year 2010 estimates do include Age-5 returns.

**Table 1.b. Comparisons between Naturally Spawned and Hatchery-Spawned Survival to Roza Return of Hatchery-reared PIT-tagged Smolt released from Clark Flats Acclimation Site**

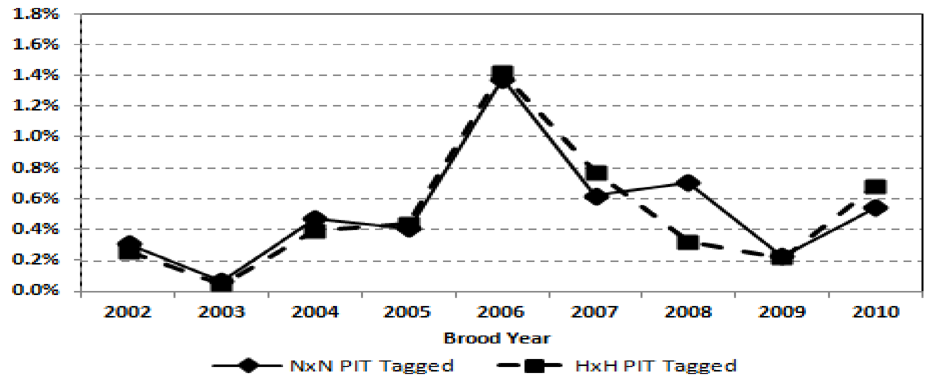
| Brood Year | Measure | NxN | HxH | NxN - HxH |
|---|---|---|---|---|
| 2002 | Survival | 0.310% | 0.257% | 0.053% |
| | Weight* | 8,707 | 4,286 | |
| 2003 | Survival | 0.069% | 0.047% | 0.023% |
| | Weight* | 8,637 | 4,269 | |
| 2004 | Survival | 0.474% | 0.394% | 0.080% |
| | Weight* | 8,651 | 4,311 | |
| 2005 | Survival | 0.412% | 0.440% | -0.028% |
| | Weight* | 8,743 | 4,322 | |
| 2006 | Survival | 1.382% | 1.425% | -0.043% |
| | Weight* | 7,669 | 7,508 | |
| 2007 | Survival | 0.622% | 0.771% | -0.149% |
| | Weight* | 7,875 | 7,395 | |
| 2008 | Survival | 0.706% | 0.496% | 0.210% |
| | Weight* | 7,789 | 7,855 | |
| 2009 | Survival | 0.230% | 0.345% | -0.115% |
| | Weight* | 7,831 | 7,836 | |
| 2010 | Survival | 0.547% | 0.684% | -0.138% |
| | Weight* | 7,680 | 7,743 | |
| Pooled** | Survival | 0.516% | 0.598% | -0.081% |
| Over Years | Weight* | 73,582 | 55,525 | |

*** Number of all released PIT-Tagged smolt**

**** Averaged over all PIT-Tagged smolt released**

[2] Significance is tested at the 5% level.

**Figure 1.b. Naturally Spawned and Hatchery-Spawned Survival to Roza Dam of Hatchery-reared PIT-tagged Smolt released from Clark Flats Acclimation Site**




The correlations between the CWT and PIT-tagged estimates are extremely high (0.98 for the NxN stock and 0.95 for the HxH stock, significantly greater than 0 with $P < 0.0001$ based one-sided t-tests), indicating a strong consistency in yearly CWT and PIT-tagged trends for both stock. As with the CWT estimates, the NxN stock mean over years was less than that of the HxH stock (0.52% versus 0.56%), again not significantly so ($P = 0.7000$ based on logistic analysis of variation, Appendix Table A.1.b.).

The CWT and PIT-tagged results do show some inconsistencies. The highlighted 2007 through 2009 brood differences from Tables 1.a. and 1.b. are of opposite signs. The 2007 and 2009 broods NxN – HxH CWT differences are positive, but the PIT-tagged differences are negative are negative; the converse is true for the 2008 brood. The magnitude of the NxN-HxH difference for the 2008 brood PIT-tagged smolt when compared to other years (Figure 1.b.) suggests a Year x Stock interaction; however the inclusion of other returns that were not PIT-tagged prior to release (Figure 1.a.) does not suggest a strong interaction. The 2008 brood PIT-tagged difference may have been simply due to sampling error resulting from the much smaller release numbers compared to CWT releases.

A more formal comparison between the two tag groups follows. Given the lack of significance in the stocks' over-year mean differences for both the CWT and PIT-tagged smolt and the high correlations in the two tag groups' yearly trends for both the NxN and HxH stock, the yearly HxH and NxN returns' estimates were pooled within the CWT and PIT-tagged groups; and these pooled estimates were formally analyzed. The estimates are presented in Table and Figure 1.c. The CWT survivals were consistently higher than those of the PIT-tagged group in 7 of the 9 brood years; however, the chance of this happening when there is no difference is not significant $P = 0.1797$ (based on a binomial distribution 2-sided sign test).

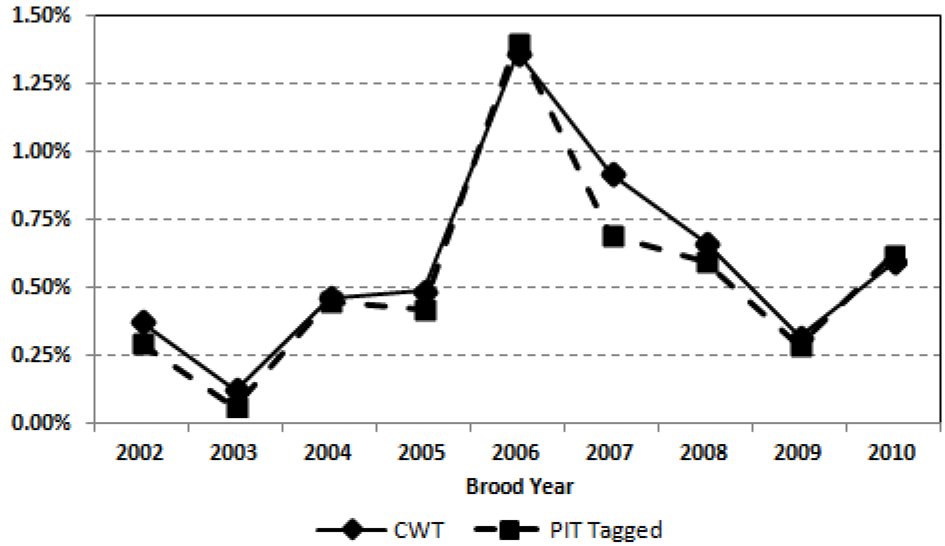
However, the magnitudes of the differences are not taken into account in that test. As a further test, the difference between the CWT and PIT means pooled over years was tested. The pooled difference over years and was not quite significantly different than 0 at the 5% level (the

CWT's 0.55% not significantly different than the PIT-tagged 0.52%, P = 0.0641 based on logistic analysis of variation, Appendix Table A.1.c.). There was no statistical evidence of a significant Year x Tag-group interaction (P= 0.7580, Appendix Table A.1.c.); the highlighted Brood Year 2006 and 2010 negative CWT-PIT survival differences and the other brood years' differences did not significantly differ from each other . Note that the within-year comparisons were not powerful enough to result in significance (Table 1.c.).

**Table 1.c. Comparison between CWT and PIT-Tagged Smolt-Release-to-Return Survival Estimates averaged over HxH and NxN Stock**

| | | c. CWT and PIT Estimates | | | |
|---|---|---|---|---|---|
| Brood Year | Measure | CWT | PIT | CWT - PIT | Type 1 Error P |
| 2002 | Survival | 0.373% | 0.292% | 0.081% | 0.3449 |
| | Weight* | 88,733 | 4,269 | | |
| 2003 | Survival | 0.126% | 0.062% | 0.064% | 0.2155 |
| | Weight* | 88,733 | 4,269 | | |
| 2004 | Survival | 0.462% | 0.447% | 0.015% | 0.8712 |
| | Weight* | 94,339 | 4,311 | | |
| 2005 | Survival | 0.487% | 0.421% | 0.066% | 0.4896 |
| | Weight* | 90,518 | 4,322 | | |
| 2006 | Survival | 1.365% | 1.403% | -0.038% | 0.7971 |
| | Weight* | 68,434 | 7,508 | | |
| 2007 | Survival | 0.920% | 0.694% | 0.226% | 0.0881 |
| | Weight* | 94,663 | 7,395 | | |
| 2008 | Survival | 0.664% | 0.601% | 0.063% | 0.5361 |
| | Weight* | 97,196 | 7,855 | | |
| 2009 | Survival | 0.318% | 0.287% | 0.030% | 0.6667 |
| | Weight* | 88,771 | 7,836 | | |
| 2010 | Survival | 0.594% | 0.616% | -0.022% | 0.8169 |
| | Weight* | 92,030 | 7,743 | | |
| Pooled** | Survival | 0.568% | 0.551% | 0.016% | 0.0641 |
| Over Years | Weight* | 803,417 | 55,508 | | |

**Figure 1.c. CWT and PIT-Tagged Smolt-Release-to-Return Survival Estimates averaged over HxH and NxN Stock**



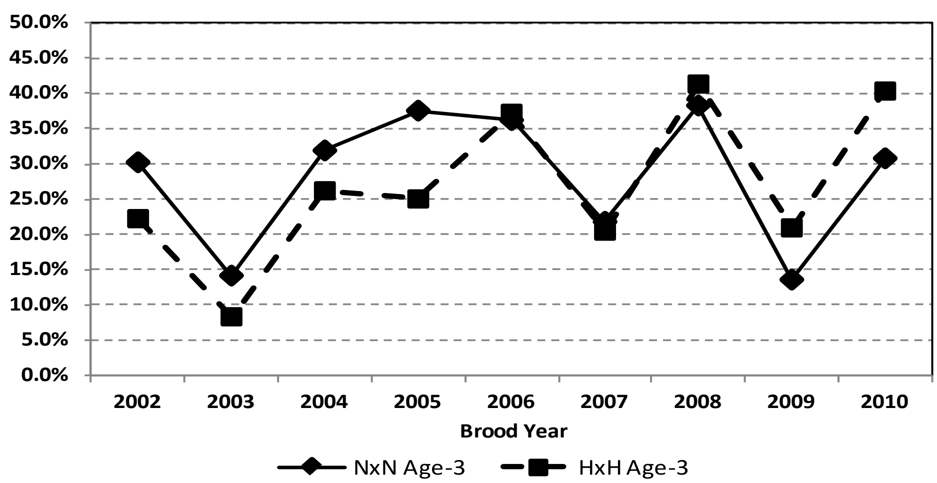

### Age-3 Percent Comparison between the Hatchery and Natural Crosses

Age-3 percentage estimates are presented in Table 2. and Figure 2. While there was large variation in the NxN – HxH differences over years, the Age-3 percent when pooled over years barely differed between the two stock (30.3% for NxN stock and 30.7% for HxH stock, Table 2 and Figure 2), consequently the difference between the pooled estimates was not statistically significant at any reasonable level (P = 0.8389 based on logistic analysis of variation, Appendix Table A.1.d).

**Table 2. Comparisons between Naturally Spawned and Hatchery-Spawned Age-3 Percent of Returns to Roza Dam of Hatchery-reared CWT Smolt released from Clark Flats Acclimation Site**

| Brood Year | Measure | NxN | HxH | NxN - HxH |
|---|---|---|---|---|
| 2002 | Survival | 30.2% | 22.2% | 8.0% |
| | Weight* | 701 | 294 | |
| 2003 | Survival | 14.2% | 8.3% | 5.8% |
| | Weight* | 249 | 94 | |
| 2004 | Survival | 31.9% | 26.2% | 5.7% |
| | Weight* | 897 | 401 | |
| 2005 | Survival | 37.6% | 25.0% | 12.5% |
| | Weight* | 881 | 518 | |
| 2006 | Survival | 36.2% | 37.2% | -1.0% |
| | Weight* | 1,807 | 1,055 | |
| 2007 | Survival | 21.8% | 20.5% | 1.3% |
| | Weight* | 1,598 | 849 | |
| 2008 | Survival | 38.3% | 41.3% | -3.0% |
| | Weight* | 1,138 | 724 | |
| 2009 | Survival | 13.6% | 20.9% | -7.3% |
| | Weight* | 610 | 277 | |
| 2010 | Survival | 30.8% | 40.3% | -9.5% |
| | Weight* | 945 | 625 | |
| Pooled** | Survival | 30.3% | 30.7% | -0.3% |
| Over Years | Weight* | 8,825 | 4,836 | |

**Figure 2. Naturally Spawned and Hatchery-Spawned Age-3 Percent of Returns to Roza Dam of Hatchery-reared CWT Smolt released from Clark Flats Acclimation Site**



## Appendix A. Logistic Analyses of Variation

The pre-released PIT-tagged smolt analyzed in Tables A.2.b. and A.2.b. were also coded-wire tagged (CWT) and are included as CWT returns in the analyses of Table's A.1.a. and Table A.1.c. The reason for not eliminating them was that there were also smolt that were CWT smolt that were PIT-tagged in-stream after release that could have subjected to the same survival challenges that the pre-release PIT tagged smolt were. There would have been no way for survival-estimation purposes to separate the in-stream PIT-tagged smolt from CWT smolt that were never PIT-tagged. There is an inherent bias in comparisons between the all CWT returns and smolt pre-release PIT-tagged smolt because of the latter group's inclusion with the former group's. However, since the proportion of the pre-release PIT-tagged smolt comprised less than 5% of the of released CWT smolt in brood years 2002 – 2005 and approximately 10% or less of the CWT smolt in subsequent brood years, the bias is would be minor.

The basic intent of comparing the CTW survival to the known-age pre-release PIT tagged smolt was to determine whether there was a major bias in the yearly HxH and NxN trends. This appeared not to be the case.

**Table A.1.a. Logistic Analysis of Variation of Naturally Spawned and Hatchery-Spawned Survival to Roza of Hatchery-reared CWT Smolt released from Clark Flats Acclimation Site**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P |
|---|---|---|---|---|---|
| Year | 4283.66 | 8 | 535.46 | 62.02 | 0.0000 |
| Stock | 18.88 | 1 | 18.88 | 2.19 | 0.1775 |
| Error | 69.07 | 8 | 8.63 | | |

**Table A.1.b. Logistic Analysis of Variation of Naturally Spawned and Hatchery-Spawned Survival to Roza of Hatchery-reared pre-release PIT-tagged Smolt released from Clark Flats Acclimation Site**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P |
|---|---|---|---|---|---|
| Year | 289.69 | 8 | 36.21 | 36.12 | 0.0000 |
| Stock | 0.16 | 1 | 0.16 | 0.16 | 0.7000 |
| Error | 8.02 | 8 | 1.00 | | |

**Table A.1.c. Logistic Analysis of Variation of CWT and pre-release PIT-Tagged Smolt-Release-to-Roza Survival Estimates averaged over HxH and NxN Stock**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P | F-Ratio Denominator Source |
|---|---|---|---|---|---|---|
| **Year** | 4554.83 | 8 | 569.35 | 263.13 | 0.0000 | Error |
| **Stock** | 17.8 | 1 | 17.80 | 2.38 | 0.1613 | Year x Stock* |
| PIT vs CWT | 7.35 | 1 | 7.35 | 4.61 | 0.0641 | Year x Tag |
| Stock X Tag | 0.22 | 1 | 0.22 | 0.10 | 0.7580 | Error |
| Year x Tag | 12.76 | 8 | 1.60 | 0.74 | 0.6618 | Error |
| Year x Stock* | 59.78 | 8 | 7.47 | 3.45 | **0.0494** | Error |
| Error | 17.31 | 8 | 2.16 | | | |

***** The significance associated with this source indicates that the yearly differences between NxN and HxH trends in Figure 1.a. significantly differs from year to year. The Figure 1.a, CWT data would dominate the Figure 2.b PIT-tagged data for this source because the former is based on a much larger number of released smolt. However tests of sources like this that don't include Tag (Tag = PIT vs CWT) may be biased because they treat CWT and PIT-tagged measures as if they were from different replicates which they are not, the measures are taken from the same raceways.

**Table A.2. Logistic Analysis of Variation of Naturally Spawned and Hatchery-Spawned Age-3 Percent of Returns to Roza of Hatchery-reared CWT Smolt released from Clark Flats Acclimation Site**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev (Dev/DF) | F-Ratio | Type 1 Error P |
|---|---|---|---|---|---|
| **Year** | 400.53 | 8 | 50.07 | 6.49 | 0.0079 |
| **Stock** | 0.34 | 1 | 0.34 | 0.04 | 0.8389 |
| **Error** | 61.70 | 8 | 7.71 | | |

## Appendix B. Procedures

A multivariate procedure (a modification of Hotelling's $T^2$ discriminant) was used to find a weighted index of fish fork-length (FL), post-orbital-to- hypural length (POH) length and weight (Wt) from known-age adult recoveries. This procedure is often used to compare two populations[3] to determine if they differ significantly using these weighted traits. However, the Age-3 and Age-4 populations and Age 4 and Age-5 populations are already known to differ in their traits' distributions. Instead, this index was developed using the measures of known-age[4] returns for the purpose of assigning unknown-age returns to age classes.

The intent of establishing the index is discussed: The index, once established, would be applied to each known-age fish's measures, the individual fish being flagged as to age; the index taking the form given in equation Eq.1.

Eq.1.a. $I = W(FL)*z(FL) + W(POH)*z(POH) + W(Wt)*z(Wt)$ wherein $W(FL)+ W(POH) + W(Wt) = 1$

For each measure, the z values in Equation Eq.1.a. were the standardized measures for known age fish given in Equation 1.b.

Eq.1.b. $z = (\text{Measure} - \text{Mean of Measure}) / (\text{Standard Deviation of Measure})$

The weights [W(FL), W(POH), W(Wt) in equation Eq.1.a.] were those that maximized Hotelling's $T^2$ difference (equation Eq.1.c) between the two populations

Eq. 1.c. $T^2 = \text{mean}^2(\text{difference}) / \text{Variance}(\text{difference})$, $\text{difference} = z(\text{age-j}) - z(\text{age-k})$

The index values would be sorted, and the sorted values that resulted in the equal numbers of age-j fish being misclassified as an age-j fish and of age-k fish being misclassified as an age-j returns would be determined. That discriminant value would be used to classify the unknown-age returns based on their individual index values.

The discriminant value estimates were based on returns from all acclimation-site releases, not from only the Clark Flats site. For Age-3 and Age-4 returns, discriminant values were estimated separately for each year. In the case of Age-4 and Age-5 returns, the number of known age-5 fish recovered per year was too small for yearly index-value estimation, and it was necessary to pool the age-4 and age-5 fish over years to obtain an estimate. This creates an unavoidable bias if the relative age-4/age-5 distributions differ over years. The weights are given in Table A.1.

[3] There are more than two populations (Age-3, Age-4, and Age-5 populations), however for the traits evaluated, the Age-3 and Age-5 populations' distributions never overlap. Therefore it was possible to separately apply Hotelling's $t^2$ to the Age-3 and Age-4 populations and to the Age-4 and Age-5 populations. Had all three populations overlapped, than another discriminant procedure would have to be used,

[4] Known-age fish based on returns of smolt PIT-tagged as smolt or based on scale-based aged adults (not PIT-tagged as smolt) sampled from all hatchery returns.

**Table B.1 Hotelling's $t^2$ Index Weights for Fork Length (Fl), Post-Orbital - Hypural Length (POH) and Weight (Wt)**

| Return | Age-3 and Age-4 | | |
|---|---|---|---|
| Year | Fl | POH | Fl |
| **2005** | 0.75 | 0.25 | 0.00 |
| **2006** | 0.72 | 0.28 | 0.00 |
| **2007** | 1.00 | 0.00 | 0.00 |
| **2008** | 0.41 | 0.59 | 0.00 |
| **2009** | 0.76 | 0.24 | 0.00 |
| **2010** | 1.00 | 0.00 | 0.00 |
| **2011** | 1.00 | 0.00 | 0.00 |
| **2012** | 0.63 | 0.37 | 0.00 |
| **2013** | 1.00 | 0.00 | 0.00 |
| **2014** | 1.00 | 0.00 | 0.00 |

| Return | Age-4 and Age-5 | | |
|---|---|---|---|
| Year | Fl | POH | Wt |
| **2005 - 2014** | 0.55 | 0.00 | 0.45 |

In no case were all three variables included in the index. In all cases fork length (FL) was included in the index; and in all but one case (Return Year 2008 for Age-3 and Age-4 returns) fork length had the highest weight. In five of the eleven cases, only Fork Length was included. The decision was made to use fork length only for all years.

The Fork-Length discriminant values, developed from known-aged returns and used to assign unknown age returns to ages within years, are given in Table B.2.along with the number of known age returns. Note: There were not enough known Age-5 returns within years[5] to permit assignments; therefore the data from all years were pooled to develop the index.

NOTE: There were a few known age returns that were less than 3 years of age. They were omitted from the analyses, and their fork lengths did not come anywhere near overlapping those of the Age-3 returns over all years combined. Based on the maximum fork length of the less-than-Age-3 returns and the minimum fork length of the Age-3 returns, unknown age returns with fork lengths less than 25 cm were also omitted under the assumption that those returns were less than 3 years of age.

[5] In fact there were less than five Age-5 returns in 2006, 2008, and 2010.

**Table B.2. Discriminant Values Numbers of known-age Fish and Misclassification Errors**

| Return Year | Discriminant Value (DV) Fork Length in cm | Number of Smolt | | Total Known-Age Returns | | Estimated Probability of Error in Classification | | |
|---|---|---|---|---|---|---|---|---|
| | | Age-3 ≤ DV* | Age-4 ≥ DV* | Age-3 | Age-4 | Age-3 | Age-4 | Total |
| **2005** | **62** | 5 | 5 | 98 | 220 | 0.051 | 0.023 | 0.031 |
| **2006** | **57.5** | 4 | 7 | 34 | 529 | 0.118 | 0.013 | 0.020 |
| **2007** | **59** | 2 | 2 | 211 | 306 | 0.009 | 0.007 | 0.008 |
| **2008** | **61.5** | 7 | 24 | 142 | 380 | 0.049 | 0.063 | 0.059 |
| **2009** | **63** | 8 | 8 | 363 | 438 | 0.022 | 0.018 | 0.020 |
| **2010** | **60** | 4 | 4 | 153 | 764 | 0.026 | 0.005 | 0.009 |
| **2011** | **61** | 8 | 8 | 213 | 589 | 0.038 | 0.014 | 0.020 |
| **2012** | **57** | 3 | 3 | 75 | 541 | 0.040 | 0.006 | 0.010 |
| **2013** | **59.5** | 8 | 7 | 160 | 385 | 0.050 | 0.018 | 0.028 |
| **2014** | **60.5** | 13 | 12 | 167 | 685 | 0.078 | 0.018 | 0.029 |

| Return Year | Discriminant Value (DV) in cm | Number of Fish | | Total Number of Fish | | Estimated Probability of Error in Classification | | |
|---|---|---|---|---|---|---|---|---|
| | | Age-4 ≤ DV* | Age-5 ≥ DV* | Age-4 | Age-5 | Age-4 | Age-5 | Total |
| **2004-2014** | **85** | 12 | 12 | 4,846 | 142 | 0.002 | 0.085 | 0.005 |

*** When the discriminant value is not a whole number, equality was not realized, the two fish sizes straddling the equality were averaged. When the discriminant value was applied to an unknown age fish, if the fish's fork length was exactly equal to the discriminant value (Age-3 = Age-4 = DV), then the fish was proportionately allocated to the two ages**

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## Appendix H
## Annual Report: Comparison of Salt-Water-Transfer Supplemented-Feed and Unsupplemented-Feed Treatments evaluated on Upper-Yakima Spring Chinook Natural Brood Smolt-to-Adult Survival for Smolt released in 2009 through 2011

**Doug Neeley, Consultant to Yakama Nation**

### Introduction and Summary

For hatchery releases of Spring Chinook smolt released in 2007 and 2009 through 2014, two feed treatments were allocated to raceways within adjacent raceway pairs. Fish from each raceway within the pairs were fed BioVita feed (Bio-Oregon Inc.) prior to smoltification, then one raceway from each pair was allocated the BioTransfer feed supplement (Bio-Oregon Inc.; designated “Saltwater Transfer Feed”, referred to as STF in this document) and the other was not. The intent of the experiment was to determine whether the STF-supplemented treatment increased the rate of smoltification and survival, the unsupplemented treatment serving as the control.

All juvenile smolt were coded-wire tagged as to parental source (hatchery spawned or naturally spawned parental source) and were elastomer tagged as to acclimation site (Clark Flat, Easton, and Jack Creek) and treatment (STF or Control). Since progeny of hatchery spawned parents were assigned to only one pair of raceways at Clark Flat but progeny of naturally spawned parents were assigned to two pairs at Clark Flat and to three pairs of raceways at the other two sites, the decision was to confine the analyses to the progeny of naturally spawned parents since the use of these progeny for supplementation of the Upper Yakima Spring Chinook population is the long term function of the hatchery program.

A portion of the smolt from each raceway was injected with a passive integrated transponder (PIT) tags which identified them as to raceway for the prime purpose of estimating outmigration juvenile passage traits.

In the 2014 report the elastomer assignment of Roza returns to treatment incorrectly assigned returns to the treatment for the 2008 through 2010 broods. This nullifies the conclusion in that report that the STF supplement results in a higher survival than the unsupplemented control. There are some CWT/elastomer assignment problems that remained to be resolved. In this report, analyses are based on only those Roza returns that were PIT-tagged prior to release from acclimation sites. Since the analyses presented do not yet include assessment on all CWT returns and since PIT-tag return data do not yet include all returns from the 2012 through 2014 releases, this report should be regarded as an interim report.

Based on the analyses of the pre-release PIT-tagged returns, there is no STF effect on either the release-to-Roza return survival or the age distribution.

**Smolt-Release-to-Roza-Return Smolt-to-Adult Survival and Age-3 Distribution**

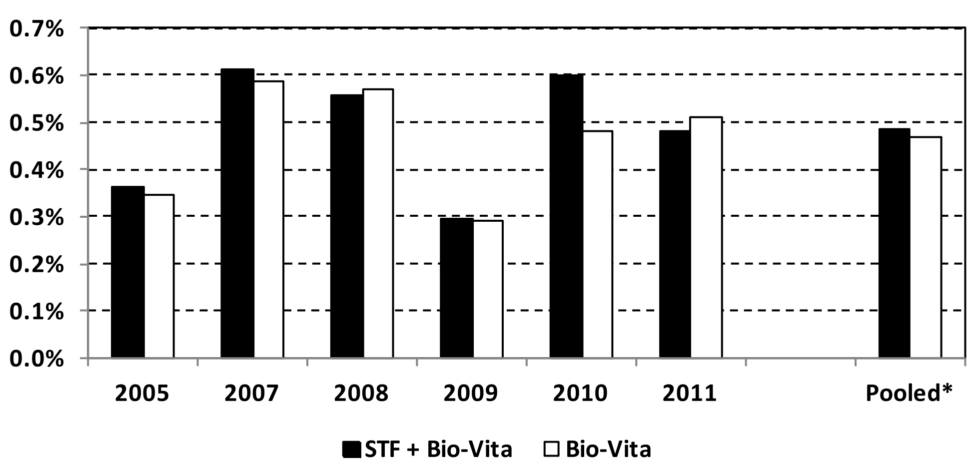
Table and Figure 1 present survivals by brood year[1]. The STF supplemented versus unsupplemented treatment differences are neither significant nor substantial. The respective treatment survivals pooled over all releases over years being 0.49% and 0.47%, differing by only 0.02% which not significant at 5% level (P = 0.1555, Appendix Table A.1.).

**Table 1. Brood Year 2005 and 2007-2011 Release-to-Roza Return Smolt-to-Adult Survival of Salt-Water Transfer Feed (STF) supplemented and unsupplemented to BioVita Fed Smolt based on pre-release PIT-tagged Smolt**

| Treatment | Measure | 2005 | 2007 | 2008 | 2009 | 2010 | 2011 | Pooled* |
|---|---|---|---|---|---|---|---|---|
| STF + BioVita | Survival | 0.362% | 0.613% | 0.558% | 0.294% | 0.601% | 0.483% | 0.486% |
| | Number Released | 17,396 | 15,650 | 15,579 | 13,941 | 15,474 | 15,329 | 93,369 |
| BioVita | Survival | 0.345% | 0.587% | 0.571% | 0.290% | 0.483% | 0.512% | 0.467% |
| | Number Released | 17,400 | 17,363 | 15,577 | 14,459 | 15,518 | 15,432 | 95,749 |
| | Difference due to STF | 0.017% | 0.026% | -0.013% | 0.004% | 0.118% | -0.029% | 0.019% |
| | Estimated Type 1 Error P | 0.7804 | 0.7973 | 0.1217 | 0.9489 | 0.2667 | 0.2730 | 0.1555 |

**Note: All tests in Table 1 are 1-sided test for The STF supplement increasing survival**

**Figure 1. Brood Year 2005 and 2007-2011 Release-to-Roza Return Smolt-to-Adult Survival of Salt-Water Transfer Feed (STF) supplemented and unsupplemented to BioVita Fed Smolt based on pre-release PIT-tagged Smolt**




*** Averaged over all pre-release PIT-tagged smolt released**

[1] Brood year precedes release year by two years

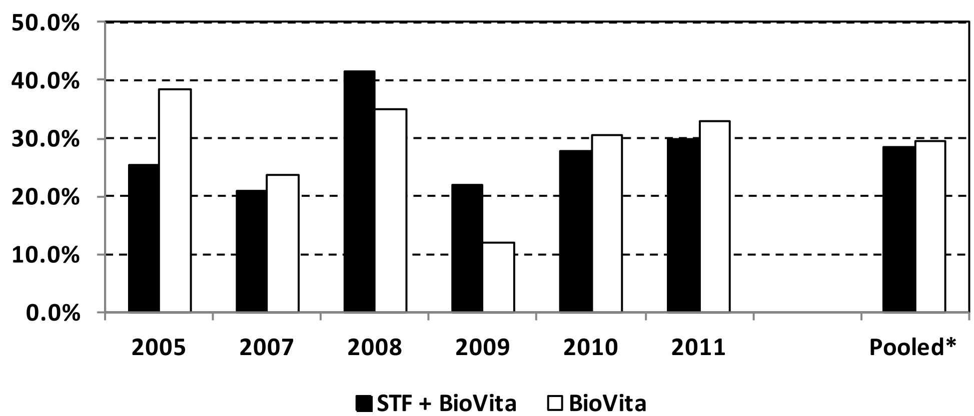
**Roza Return Age-3 Distribution**

Likewise, the respective age-3 proportions of the STF supplemented and unsupplemented treatment means of 28.4% and 29.5% differ by little more than 1% (not significant; P = 0.9220, Appendix Table A.2.).

**Table 2. Brood Year 2005 and 2007-2011 Roza Return Age-3 Percent of Salt-Water Transfer Feed (STF) supplemented and unsupplemented to BioVita Fed Smolt based on pre-release PIT-tagged Smolt**

| Treatment | Measure | 2005 | 2007 | 2008 | 2009 | 2010 | 2011 | Pooled* |
|---|---|---|---|---|---|---|---|---|
| STF + BioVita | Survival | 25.4% | 20.8% | 41.4% | 22.0% | 28.0% | 29.7% | 28.4% |
| | Number Recovered | 63 | 96 | 87 | 41 | 93 | 74 | 454 |
| BioVita | Survival | 38.3% | 23.5% | 34.8% | 11.9% | 30.7% | 32.9% | 29.5% |
| | Number Recovered | 60 | 102 | 89 | 42 | 75 | 79 | 447 |
| | Difference due to STF | -12.9% | -2.7% | 6.5% | 10.0% | -2.7% | -3.2% | -1.1% |
| | Estimated Type 1 Error P | 0.8192 | 0.2980 | 0.4410 | 0.1546 | 0.1769 | 0.2893 | 0.9220 |

**Figure 2. Brood Year 2005 and 2007-2011 Roza Return Age-3 Percent of Salt-Water Transfer Feed (STF) supplemented and unsupplemented to BioVita Fed Smolt based on pre-release PIT-tagged Smolt**




*** Averaged over all aged PIT-tagged smolt recovered at Roza**

## Appendix: Logistic Analyses of Variation

**Table A.1. Logistic Analysis of Variation of Brood Year 2005 and 2007-2011 Release-to-Roza Return Smolt-to-Adult Survival of Salt-Water Transfer Feed (STF) supplement to BioVita Feed based on pre-release PIT-tagged Smolt**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev = Dev/DF | F-Ratio | Type 1 P | 1-Sided* Type 1 P | Denominator Source |
|---|---|---|---|---|---|---|---|
| **Brood Year (Year)** | **53.39** | **5** | **10.68** | **7.45** | **0.0001** | | **Among Raceway Pairs** |
| **Site** | **17.72** | **2** | **8.86** | **5.42** | **0.0254** | | **Year x Site** |
| **Year x Site** | 16.34 | 10 | 1.63 | 1.14 | 0.3666 | | Among Raceway Pairs |
| **Among Raceway Pairs** | **42.97** | **30** | **1.43** | **1.36** | 0.2043 | | **Error** |
| **Treatment (Trt = STF effect)** | 0.5 | 1 | 0.50 | 1.27 | 0.3111 | 0.1555 | Year x Trt |
| **Site x Trt** | 0.12 | 2 | 0.06 | 0.03 | 0.9682 | | Year x Site x Trt |
| **Year x Trt** | 1.97 | 5 | 0.39 | 0.37 | 0.8630 | | Error |
| **Year x Site x Trt** | 18.51 | 10 | 1.85 | 1.75 | 0.1142 | | Error |
| **Error** | 31.68 | 30 | 1.056 | | | | |

* Test of the STF supplemented feed increasing survival over the unsupplemented feed

**Table A.2. Logistic Analysis of Variation of Brood Year 2005 and 2007-2011 Roza Return Age-3 Percent of Salt-Water Transfer Feed (STF) supplemented and unsupplemented to BioVita Fed Smolt based on pre-release PIT-tagged Smolt**

| Source | Deviance (Dev) | Degrees of Freedom (DF) | Mean Dev = Dev/DF | F-Ratio | Type 1 P | Denominator Source |
|---|---|---|---|---|---|---|
| **Brood Year (Year)** | **18.76** | **5** | **3.75** | **1.85** | **0.1329** | **Among Raceway Pairs** |
| **Site** | **2.86** | **2** | **1.43** | **1.38** | **0.2965** | **Year x Site** |
| **Year x Site** | 10.39 | 10 | 1.04 | 0.51 | 0.8676 | Among Raceway Pairs |
| **Among Raceway Pairs** | **60.8** | **30** | **2.03** | **1.72** | 0.0722 | **Error** |
| **Treatment (Trt = STF effect)** | 0.01 | 1 | 0.01 | 0.01 | 0.9220 | Year x Trt |
| **Site x Trt** | 0.44 | 2 | 0.22 | 0.12 | 0.8883 | Year x Site x Trt |
| **Year x Trt** | 4.72 | 5 | 0.94 | 0.80 | 0.5586 | Error |
| **Year x Site x Trt** | 18.36 | 10 | 1.84 | 1.56 | 0.1687 | Error |
| **Error** | 35.41 | 30 | 1.180 | | | |