YAKIMA/KLICKITAT FISHERIES PROJECT MONITORING AND EVALUATION
Yakima Subbasin

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

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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	7,329	5.47	5.00	5.99	5.69	5.20	6.21
2001	3,578	0.89	0.64	1.18	1.15	0.86	1.46
2002	4,236	2.31	1.92	2.75	2.38	1.99	2.82
2003	8,002	1.67	1.43	1.92	1.91	1.65	2.15
2004	4,912	2.63	2.25	3.02	2.85	2.46	3.27
2005	2,491	1.28	0.91	1.67	1.37	0.98	1.76
2006	2,632	1.67	1.28	2.12	2.13	1.66	2.63
2007	1,066	1.50	0.92	2.08	1.50	0.92	2.08
2008	2,795	4.69	3.97	5.41	5.80	5.03	6.58
2009	2,111	4.36	3.63	5.16	4.78	4.02	5.61
2010	3,338	1.38	1.05	1.73	1.86	1.46	2.29
2011	3,180	0.85	0.58	1.13	0.97	0.69	1.27
2012	1,944	2.78	2.15	3.46	3.24	2.55	4.00
2013	2,244	1.65	1.22	2.11	2.05	1.56	2.59
2014	1,489	2.08	1.48	2.74	2.35	1.72	3.10
2015	1,730	1.45	0.91	2.03	1.73	1.14	2.39
2016	241	0.41	0.00	1.23	0.41	0.00	1.23
2017	464	1.29	0.48	2.24	1.72	0.76	2.80
2018	474	1.05	0.38	1.86	1.05	0.38	1.86
2019	780	2.18	1.30	3.12	2.57	1.58	3.62
2020	857	2.57	1.42	3.71	3.03	1.73	4.41
2021[B]	1,302	1.15	0.54	1.99	1.46	0.69	2.50
Arithmetic mean (incl. zeros)		2.06			2.36		
Geometric mean (excl. zeros)		1.74			2.00		

[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 both the juvenile detector at McNary Dam, as well as PIT-tags on bird colonies in the Columbia River estuary (when applicable), PIT-tag detections at estuary pilings (when applicable), and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[B] Incomplete, 2-salt returns through September 25, 2023.

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Acknowledgements

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

Executive Summary

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

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

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

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

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2022 average of about 9,100 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 summer/fall Chinook at the Yakima River mouth has increased from a 1983-1999 average of about 1,200 fish to a 2000-2022 average of about 6,200 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, and improvements in spawning and rearing protocols. Approximately 370 summer-run Chinook were estimated to pass above Prosser Dam in 2022. Adult passage of Coho Salmon at Prosser Dam in 2022 was approximately 6,370 fish. Coho returns to Prosser averaged over 6,000 fish from 1998-2022 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging over 800 fish annually since 2001.

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

For smolt migration years 2000 to present, annual abundance estimates of juvenile smolts migrating downstream at Prosser Dam averaged 201,770 wild/natural spring Chinook, 323,920 CESRF-origin spring Chinook, 41,600 wild/natural-origin coho, and

269,900 hatchery-origin coho. Preliminary smolt-to-adult survival indices averaged approximately 2.3% and 2.8% 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 49 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 2022, 432 coho redds were observed in tributaries in the Naches and Upper Yakima Subbasins.

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

Overall average fine sediment levels in the Naches and Upper Yakima River subbasins over many years of sampling continue to trend downward.

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

Supplementation has increased spring Chinook redd abundance in the Upper Yakima relative to the Naches control system. We observed an average proportionate increase in redd counts in the upper Yakima nearly 5 times 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 (2005-2022) are trending downward relative to the pre-supplementation period (1982-2004) in both the Upper Yakima and Naches Rivers. Alarmingly, natural-origin return abundance in the Naches River (combined Naches and American populations) declined to an estimated 160 fish in 2019, a population level considered "at high risk of extinction" in a seminal publication that led to the ESA-listing of many Columbia River populations in the early 1990s. After several 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 out-planting in the wild. However, our study results also confirm a point made in many scientific reports and publications: long-term success of hatchery production projects and the sustained health of natural populations requires large-scale, ecosystem-level habitat recovery programs.

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 22-year mean annual PNI of 65%. The project is thus far meeting or exceeding most other established objectives related to hatchery reform.

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

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

Introduction

The Yakima-Klickitat Fisheries Project (YKFP) is a joint project of the Yakama Nation (lead entity) and the Washington State Department of Fish and Wildlife (WDFW) and is sponsored in large part by the Bonneville Power Administration (BPA) with oversight and guidance from the Northwest Power and Conservation Council (NPCC). It is among the largest and most complex fisheries management projects in the Columbia Basin in terms of experimental design and research on fisheries resources, physical facilities, habitat enhancement and restoration, and data collection and management. Consistent with Wy-Kan-Ush-Mi Wah-Kish-Wit (CRITFC 1995) and using principles of adaptive management (BPA 1996; Salafsky et al. 2001), the YKFP is attempting to evaluate all stocks historically present in the Yakima Subbasin and apply a combination of habitat restoration and hatchery supplementation or reintroduction, to restore the Yakima Subbasin ecosystem with sustainable and harvestable populations of salmon, steelhead and other at-risk species.

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

Supplementation is envisioned as a means to enhance and sustain the abundance of wild and naturally-spawning populations at levels exceeding the cumulative mortality burden imposed on those populations by habitat degradation and by natural cycles in environmental conditions. A supplementation hatchery is properly operated as an adjunct to the natural production system in a watershed. By fully integrating the hatchery with a naturally-producing population, high survival rates for the component of the population in the hatchery can raise the average abundance of the total population (hatchery component plus naturally-producing component) to a level that compensates for the high mortalities imposed by human development activities and fully seeds the natural environment. However, it is important to recognize that "rebuilding natural populations will ultimately depend on improving habitat quality and quantity" (ISRP 2011, Venditti et al. 2017) of which habitat connectivity is an essential component (CRITFC 1995, Milbrink et al. 2011). Hatchery programs, even "state of the art" integrated supplementation programs designed to follow all of the best management practice recommendations (Cuenco et al. 1993, Mobrand et al. 2005), do not directly affect any of these habitat parameters which are vital to improving natural productivity. Therefore, the YKFP is working with partners in multiple forums to implement habitat restoration and water resource management projects designed to address factors limiting productivity (see Yakima Subbasin, Recovery, and Integrated plans).

The objectives of the YKFP are to: enhance existing stocks; re-introduce extirpated stocks; protect and restore habitat in the Yakima Subbasin; operate using a scientifically rigorous process that will foster application of the knowledge gained about hatchery supplementation and habitat restoration throughout the Columbia River Basin; and use Ecosystem Diagnosis and Treatment (EDT) and other modeling tools to facilitate planning for project activities. In strictly scientific terms the stated purpose of the project is, "to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining the long-term genetic fitness of the fish population being supplemented and keeping adverse genetic and ecological interactions with non-target species or stocks within acceptable limits" (RASP 1992, BPA 1996). WDFW is addressing some critical uncertainties (see Columbia River Basin Research Plan and Critical Uncertainties for the Columbia River Basin Fish and Wildlife Program) related to genetic and ecological interactions under project 1995-064-25. We are working jointly with WDFW and CRITFC (2009-009-00) to address fish propagation, predation, harvest, and monitoring and evaluation methodology uncertainties including:

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

> 1.2. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?
>
> 1.4. What is the magnitude of any demographic benefit or detriment to the production of natural-origin juveniles and adults from natural spawning of hatchery-origin supplementation adults?

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

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

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

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

Monitoring and evaluation methods Question 1. Are current methods to … count fish and to measure productivity adequate to cost effectively inform decisions?

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

Data and research findings are presented in peer-reviewed scientific publications as information matures and time and resources allow. YKFP-related project research in the Yakima River Basin has resulted in the publication of over 60 manuscripts in the peer-reviewed literature (see References and Project-Related Publications). A number of Yakima Basin studies have already been published relating to elements of the Regional Assessment of Supplementation Project (RASP) definition of supplementation. These include: discussion and establishment of ecological risk guidelines (Pearsons and Hopley 1999; Ham and Pearsons 2001; Temple and Pearsons 2012); competition, predation, and other species interactions (McMichael and Pearsons 1998; McMichael et al. 1999b; Fritts and Pearsons 2004, 2006, 2008; Major et al. 2005; Murdoch et al. 2005; Fritts et al. 2007; Pearsons and Temple 2007; Pearsons et al. 2007; Pearsons and Temple 2010; Temple et al. 2017); precocial maturation in males (Beckman et al. 2000; Larsen et al. 2004, 2006, 2010, 2013; Pearsons et al. 2009; Galbreath et al. 2021); homing (Dittman et al. 2010); straying (Fast et al. 2015); fitness and relative reproductive success (Busack et al. 2007; Beckman et al. 2008; Knudsen et al. 2006, 2008; Schroder et al. 2008, 2010, 2012; Koch et al. 2022; Bosch et al. 2023); and genetic divergence (Waters et al. 2015, 2018, 2020). A science conference is held annually to present study findings to other agencies and interested members of the public. Study results and conference materials are stored on the web. The status of ongoing research relative to the above uncertainties is presented as part of this report.

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

Study Area

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

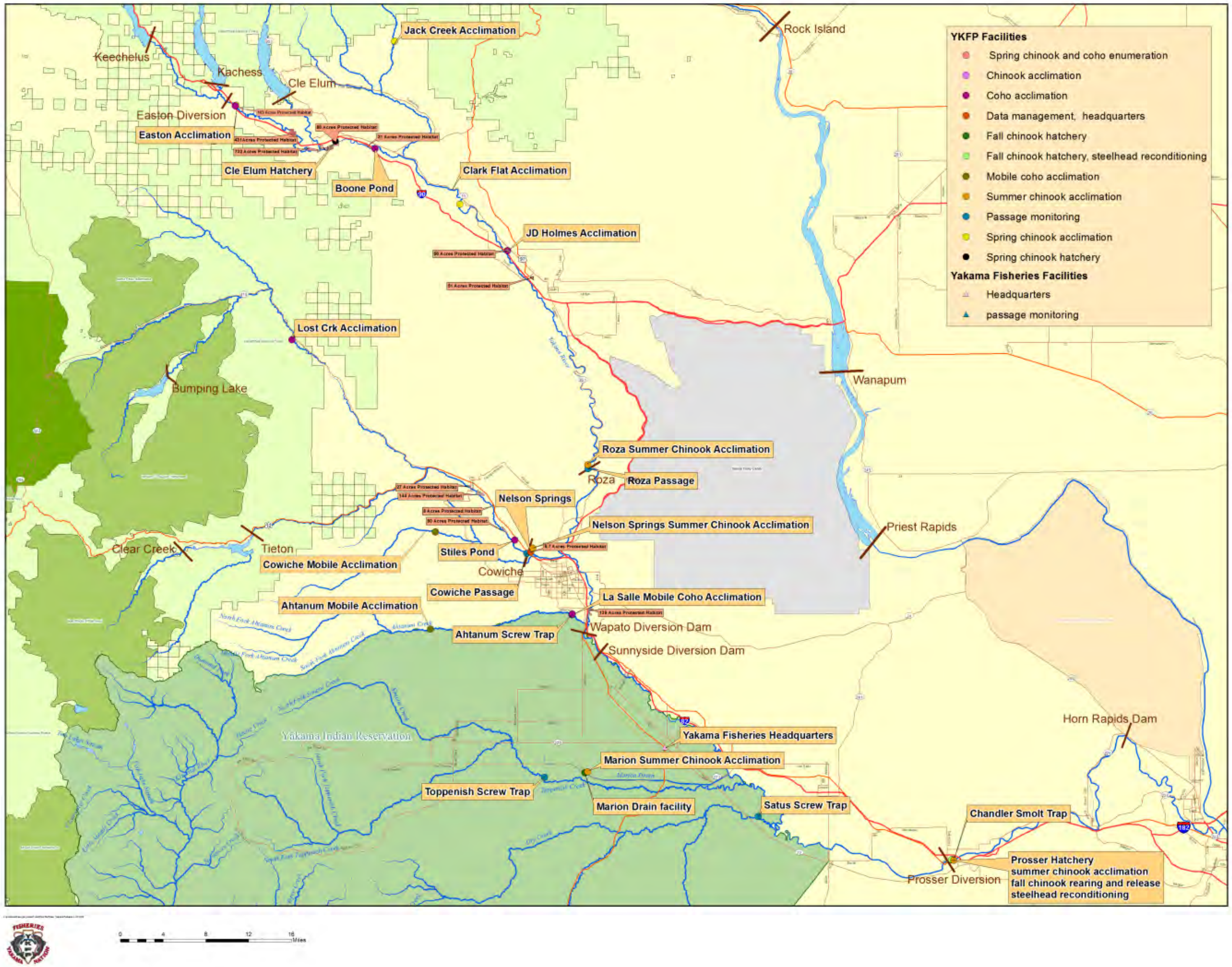


Figure 1. Yakima River Basin and Yakama Nation/YKFP-related artificial production and monitoring facilities (map provided by Paul Huffman).

Fish Population Status Monitoring

Status and Trend of Adult Fish Populations (Abundance)

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

At Prosser Dam, time-lapse video recorders (VHS) and a video camera were used in prior years at viewing windows at each of the three fishways. Digital video recorders (DVR) and surveillance software systems (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 systems provide the ability to filter digital video for just images of fish moving through the viewing window so that data are more easily downloaded to the viewing stations in Toppenish, allowing technicians in Toppenish to provide more timely and accurate fish counts. The technicians review the images and record various types of data for each fish that migrates upstream via the ladders. For each fish, technicians record passage date, passage time, facility/ladder, and species in a database.

Similarly, adult trap sample data for operations at both Prosser and Roza Dams are entered into databases. These databases are automatically uploaded daily so that integrated (trap and video) count and Yakima Basin adult trap sampling (login required) data for the Prosser and Roza data sets can be viewed at: https://yakamafish-nsn.gov/fish-data. Count data for these facilities are also mirrored on the Columbia River DART (Data Access in Real Time) web site. Counts are regularly reviewed and adjusted for data gaps and knowledge about adult and jack lengths from sampling activities with corrections made to our master data sets during the course of the season and post-season.

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 2019). Thus, enumeration of hatchery- and natural-origin summer/fall run Chinook adult returns is not presently available but will be available in the future. New marking protocols made it possible to distinguish hatchery- and natural-origin coho beginning with return year 2001.

Results:

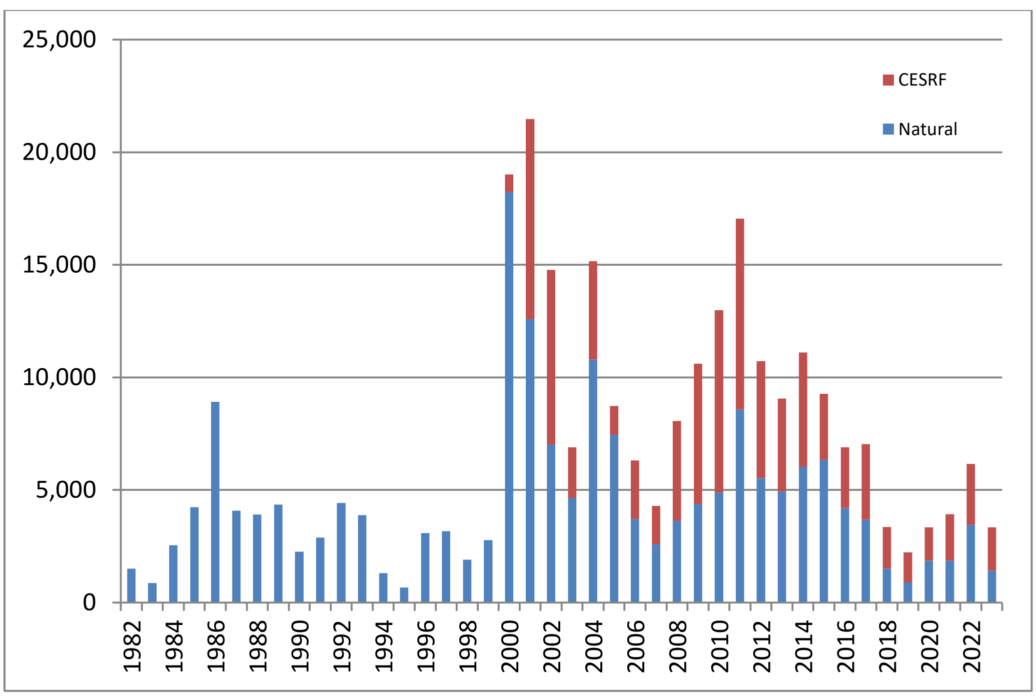


Figure 2. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Prosser Dam, 1982-present.

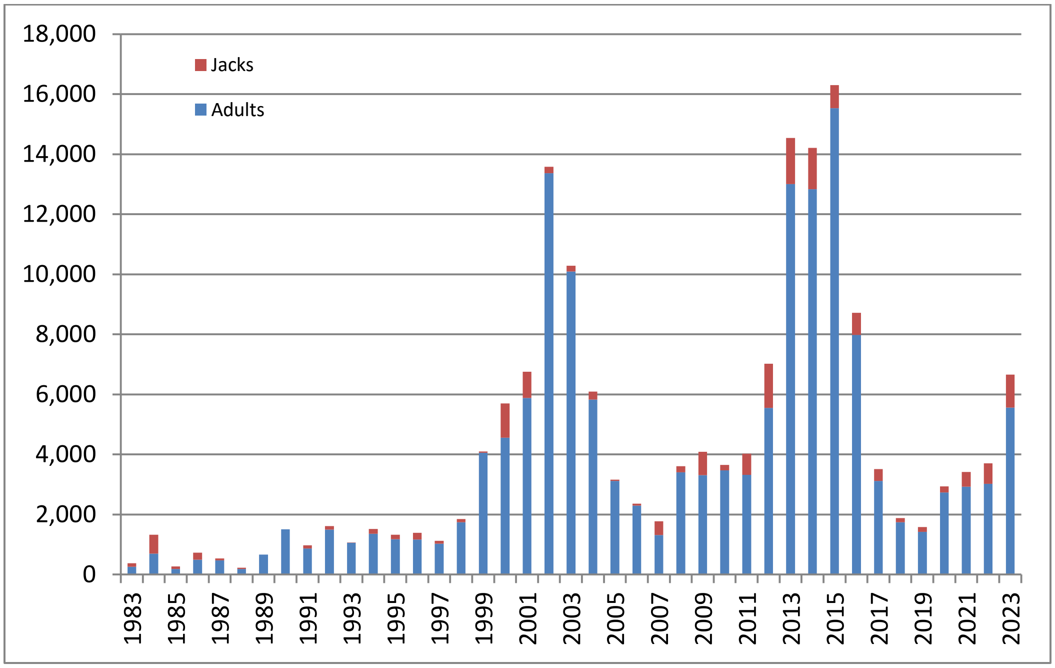


Figure 3. Estimated returns of adult and jack summer- and fall-run Chinook to the Yakima River mouth, 1983-present.

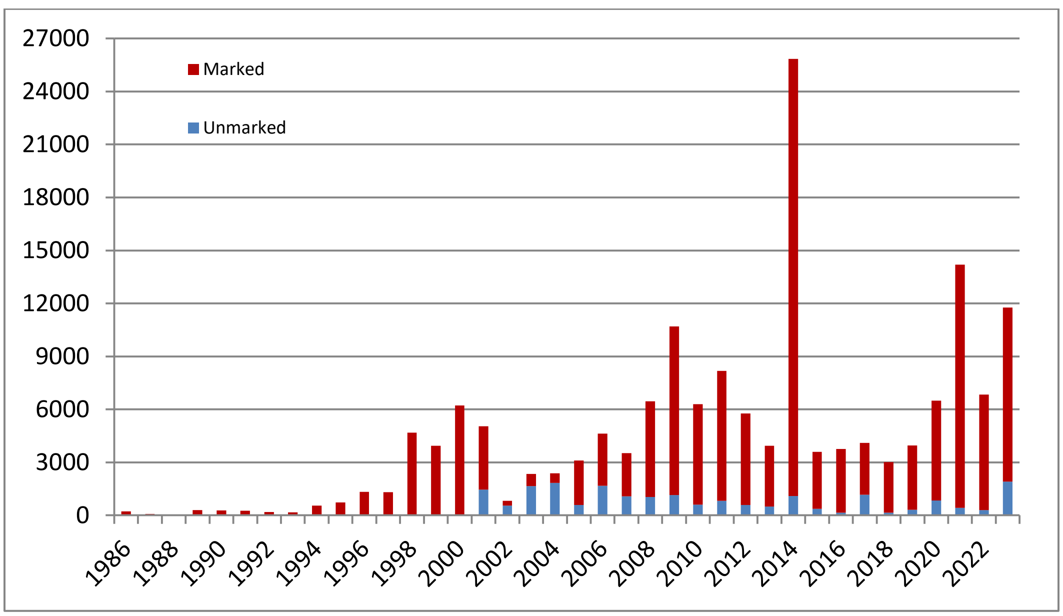


Figure 4. Estimated counts of marked (presumed hatchery-origin) and unmarked (presumed natural-origin) Coho (adults and jacks) at Prosser Dam 1986-present.

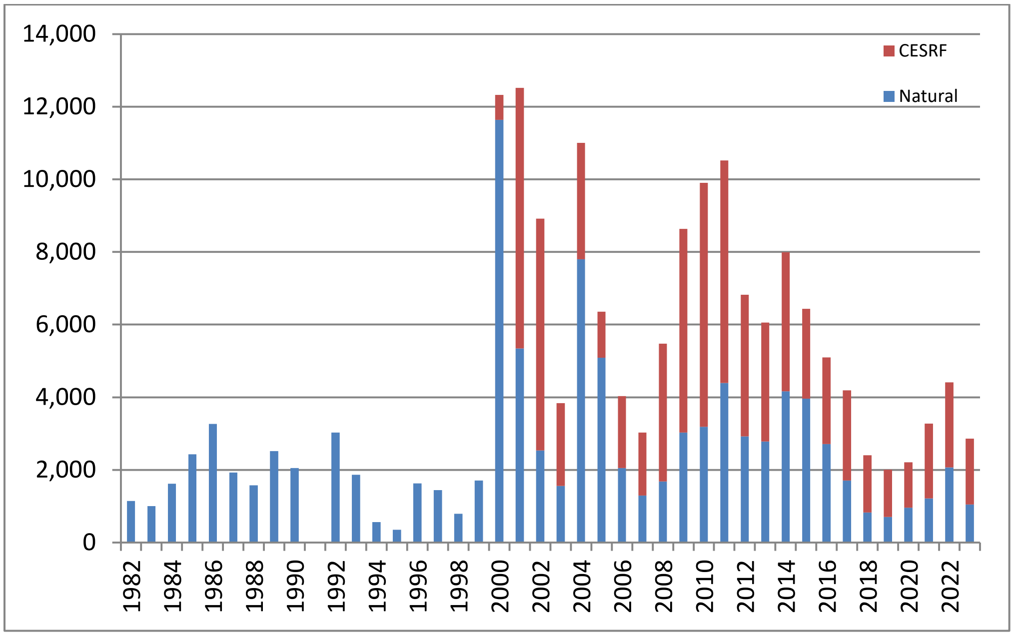


Figure 5. Estimated counts of natural- and Cle Elum Supplementation and Research Facility (CESRF-) origin spring Chinook (adults and jacks) at Roza Dam, 1982-present.

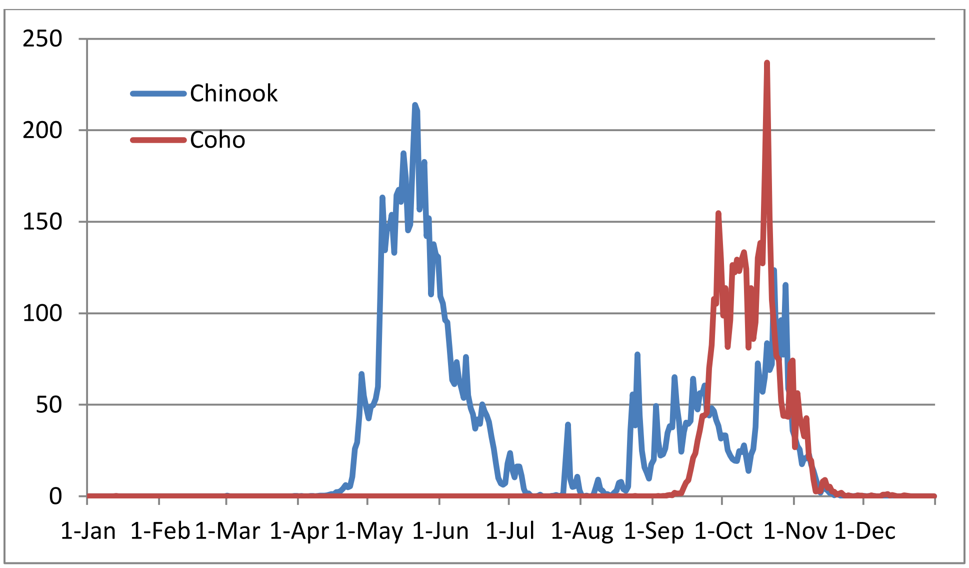


Figure 6. Average daily passage of Chinook and Coho (adults and jacks) at Prosser Dam, 2014-2023.

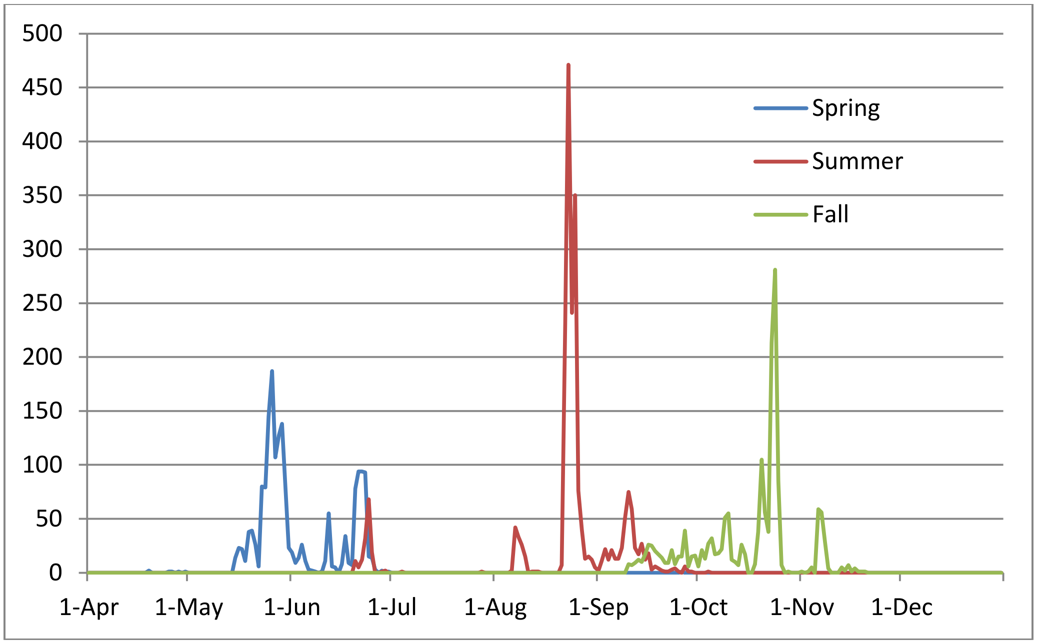


Figure 7. Passage timing of adult and jack Chinook at Prosser Dam in 2023 by run (see Methods).

Discussion:

Annual abundance of spring Chinook at Prosser Dam has increased from a 1982-2000 average of about 4,000 fish to a 2001-2022 average of about 9,100 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 2001-2023 average of approximately 6,100 fish (Figure 5). These increases beginning in 2001 coincide with the first adult returns from the Cle Elum supplementation program. However, freshwater passage conditions, marine survival, and habitat restoration and enhancement work also affect survival and return rates. The lower adult returns observed in 2003 and 2007 coincide with notable droughts during the corresponding smolt outmigration years of 2001 and 2005. Returns in several recent years (beginning in 2015) were affected by thermal barriers in the lower Yakima River during the adult migration timeframe. Discussion of uncertainties relating to the Cle Elum spring Chinook supplementation program is included under Hatchery Monitoring later in this report. Additional data and detail on the Cle Elum spring Chinook supplementation program and the status of natural- and CESRF-origin spring Chinook in the Yakima River Basin are provided in Appendix B.

Although some natural production is occurring, adult returns of fall Chinook to the Yakima River Basin consist mostly of hatchery-origin fish returning from annual releases of Upriver Brights from the Prosser Hatchery which have occurred since 1983 and averaged about 1.9 million since 1999 (Yakama Nation 2019). 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 the Yakima River mouth has increased from a 1983-1999 average of about 1,200 fish to a 2000-2023 average of about 6,200 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, 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 2019). Approximately 370 summer-run Chinook were estimated to pass above Prosser Dam in 2023 (Figure 7).

Coho were extirpated from the Yakima Subbasin by the early 1980s. Pursuant to *U.S. v. Oregon* court-mandated agreements, substantial numbers (annual average > 700,000) of hatchery-reared coho salmon were released into the Yakima River since the mid-1980s. Prior to 1996 the primary purpose of releases was harvest augmentation and fish were released in sub-optimal spawning and rearing areas below Wapato Dam. With the inception of the YKFP in 1996, the objective of the coho program became "to determine the feasibility of reestablishing a naturally spawning coho population" and releases were moved upriver to more suitable habitats for natural coho. Monitoring of these efforts to re-introduce a sustainable, naturally spawning coho population in the Yakima Basin have indicated that coho returns averaged 6,000 fish from 1998-2023 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging over 800 fish annually since 2001 (Figure 4).

Status and Trend of Adult Productivity

Methods:

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

Spring Chinook

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

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

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

Coho

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

Summer/Fall Run Chinook

Adult fall Chinook returning to the Yakima Basin consist of hatchery-origin returns from releases at and above Prosser Dam and natural-origin returns from fish spawning naturally in the Yakima River. Due to fiscal, physical, logistical, and policy considerations, only a small proportion of hatchery-origin releases have been externally marked. Therefore, it is impossible at present to know the origin of unmarked adult fall Chinook counted at Prosser. Additional marking is proposed for hatchery-origin releases as part of the Master Plan (Yakama Nation 2019), which will allow development of a comprehensive brood/cohort age at return table for natural- and hatchery-origin returns. Methods and results for evaluating adult productivity of summer/fall run

Chinook will be included in future reports and publications as the data become available.

Results:

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

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Total	Returns/ Spawner
1984	1,715	92	1,348	139	1,578	0.92
1985	2,578	114	2,746	105	2,965	1.15
1986	3,960	171	2,574	149	2,893	0.73
1987	2,003	53	1,571	109	1,733	0.87
1988	1,400	53	3,138	132	3,323	2.37
1989	2,466	68	1,779	9	1,856	0.75
1990	2,298	79	566	0	645	0.28
1991	1,713	9	326	22	358	0.21
1992	3,048	87	1,861	95	2,043	0.67
1993	1,925	66	1,606	57	1,729	0.90
1994	573	60	737	92	890	1.55
1995	364	59	1,036	129	1,224	3.36
1996	1,657	1,059	12,882	630	14,571	8.79
1997	1,204	621	5,837	155	6,613	5.49
1998	390	434	2,803	145	3,381	8.68
1999	1,021[1]	164	722	45	930	0.91
2000	11,864	856	7,689	127	8,672	0.73
2001	12,087	775	5,074	222	6,071	0.50
2002	8,073	224	1,875	148	2,247	0.28
2003	3,341	158	1,036	63	1,257	0.38
2004	10,377	207	1,547	75	1,828	0.18
2005	5,713	293	2,630	14	2,936	0.51
2006	3,378	868	2,887	133	3,888	1.15
2007	2,322	456	3,976	65	4,498	1.94
2008	4,343	1,135	3,410	123	4,668	1.07
2009	7,056	283	2,572	109	2,964	0.42
2010	8,383	923	3,854	59	4,836	0.58
2011	8,584	832	3,908	144	4,883	0.57
2012	5,483	197	2,445	20	2,662	0.49
2013	4,984	299	1,622	36	1,957	0.39
2014	6,751	241	814	12	1,067	0.16
2015	5,466	66	620	14	701	0.13
2016	4,281	99	905	52	1,056	0.25
2017	3,342	75	994	14	1,082	0.32
2018	1,817	201	2,012	42[2]	2,255[2]	1.24[2]
2019	1,508	136	1,010[2]			
2020	1,664	79[2]				

2021	2,763					
2022	3,574					
2023	2,153[2]					
Mean	3,941	313	2,567	100	2,984	1.38

1. The geometric mean jack (age-3) proportion of spawning escapement from 1999-2021 was mean 0.17.
2. Preliminary.

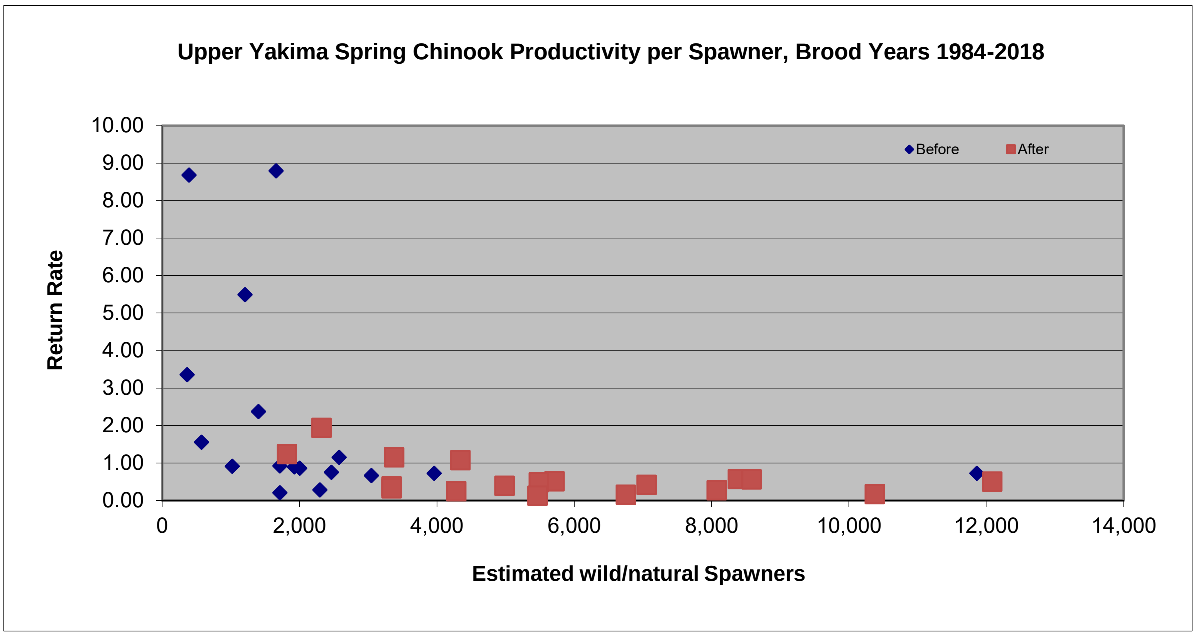


Figure 8. Upper Yakima wild/natural spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2018) commencement of supplementation.

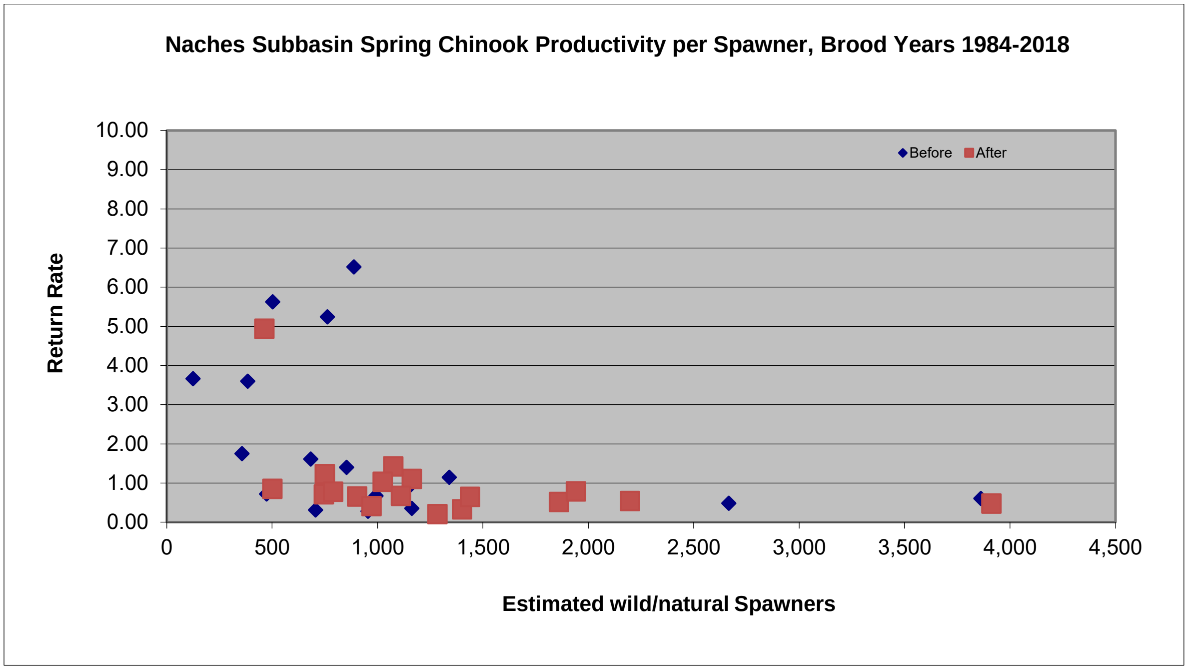


Figure 9. Naches subbasin spring Chinook return rate per spawner, before (brood years 1984-2000) and after (brood years 2001-2018) commencement of supplementation in the Upper Yakima River.

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

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Age-6	Total	Returns/ Spawner
1984	383	110	706	564	0	1,381	3.60
1985	683	132	574	396	0	1,102	1.61
1986	2,666	68	712	499	15	1,294	0.49
1987	1,162	27	183	197	0	407	0.35
1988	1,340	32	682	828	0	1,542	1.15
1989	992	28	331	306	0	665	0.67
1990	954	24	170	74	0	269	0.28
1991	706	7	37	121	57	222	0.31
1992	852	29	877	285	0	1,191	1.40
1993	1,145	45	593	372	0	1,010	0.88
1994	474	14	164	164	0	343	0.72
1995	124	40	164	251	0	455	3.66
1996	887	179	3,983	1,620	0	5,782	6.52
1997	762	207	3,081	708	0	3,996	5.24
1998	503	245	1,460	1,128	0	2,833	5.63
1999	358[1]	113	322	190	0	626	1.75
2000	3,862	71	2,060	215	0	2,346	0.61
2001	3,912	126	1,254	471	0	1,850	0.47
2002	1,861	59	753	153	0	965	0.52
2003	1,400	52	237	175	0	464	0.33
2004	2,197	107	875	218	0	1,199	0.55
2005	1,439	167	653	116	0	936	0.65
2006	1,163	192	838	254	0	1,283	1.10
2007	463	125	1,649	514	0	2,288	4.94
2008	1,074	414	827	290	0	1,531	1.42
2009	903	84	448	65	0	597	0.66
2010	1,024	209	653	198	0	1,059	1.03
2011	1,942	137	1,088	305	0	1,530	0.79
2012	1,110	64	419	260	0	743	0.67
2013	750	110	660	148	0	919	1.23
2014	746	142	376	13	0	532	0.71
2015	1,285	26	34	206	0	266	0.21
2016	790	6	523	89	0	617	0.78
2017	971	32	225	139	0	396	0.41
2018	500	37	353	37[2]		427[2]	0.85[2]
2019	51	27	94[2]				
2020	740	13[2]					
2021	415						
2022	872						
2023	1,792						

Mean	1,091	95	779	330	3	1,230	1.49

1. The geometric mean jack (age-3) proportion of spawning escapement from 1999-2021 was 0.09.
2. Preliminary.

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

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Total	Returns/ Spawner
1997	261	741	7,753	176	8,670	33.22
1998	408	1,242	7,939	602	9,782	23.98
1999	738[1]	134	714	16	864	1.17
2000	567	1,103	3,647	70	4,819	8.50
2001	595	396	845	9	1,251	2.10
2002	629	345	1,886	69	2,300	3.66
2003	441	121	800	12	932	2.11
2004	597	805	3,101	116	4,022	6.74
2005	510	1,305	3,052	21	4,378	8.58
2006	419	3,038	5,812	264	9,114	21.75
2007	449	1,277	5,174	108	6,558	14.61
2008	457	2,344	4,567	65	6,976	15.27
2009	486	461	2,663	58	3,181	6.55
2010	336	1,495	3,183	30	4,707	14.01
2011	377	1,233	2,340	34	3,607	9.57
2012	374	221	1,492	10	1,723	4.61
2013	398	802	1,993	0	2,795	7.02
2014	384	1,008	1,447	7	2,463	6.41
2015	442	314	877	0	1,191	2.70
2016	376	287	771	41	1,099	2.92
2017	382	349	1,188	0	1,537	4.02
2018	294	546	1,701	0[2]	2,248[2]	7.65[2]
2019	306	450	1,103[2]		1,554[2]	5.08[2]
2020	405	480[2]				
2021	412					
2022	377					
2023	428[2]					
Mean	439	854	2,785	78	3,729	6.64[3]

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

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

	Prosser Dam Counts		Return per Spawner Indices	
Return Year	Adults	Jacks	With Jacks	Without Jacks
2001	1,432	21		
2002	309	245		
2003	1,523	135		
2004	1,820	25	1.27	1.27
2005	472	120	1.07	1.53
2006	1,562	114	1.01	1.03
2007	1,049	32	0.59	0.58
2008	459	587	1.77	0.97
2009	982	173	0.69	0.63
2010	573	37	0.56	0.55
2011	802	24	0.79	1.75
2012	550	33	0.50	0.56
2013	424	79	0.83	0.74
2014	1,082	18	1.33	1.35
2015	362	9	0.64	0.66
2016	103	45	0.29	0.24
2017	1,162	15	1.07	1.07
2018	125	32	0.42	0.35
2019	301	8	2.09	2.92
2020	744	107	0.72	0.64
2021	422	8	2.74	3.38
2022	290	17	0.99	0.96
2023	1,745	172	2.25	2.35
Mean	795	89	1.08	1.18

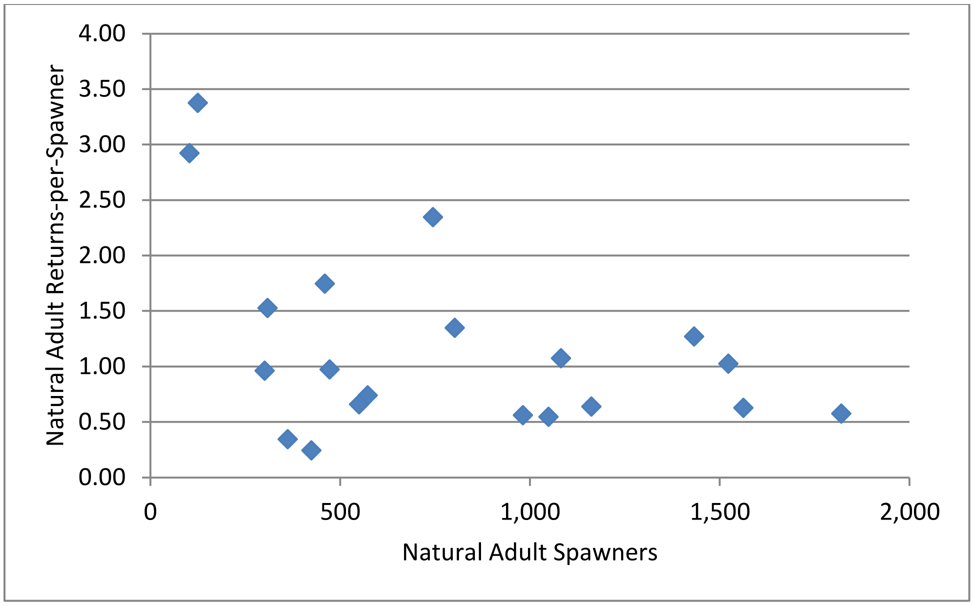


Figure 10. Productivity indices for age-3 natural-origin coho, brood years 2001-2020.

Discussion:

Recruit per spawner data for the Upper Yakima and Naches spring Chinook populations are highly correlated (Tables 1 and 2; Pearson's correlation coefficient=0.87) and analysis of variance indicates the means (± one standard error) in the 33-year data set are not different (Upper Yakima=1.43±0.38; Naches=1.54±0.30; *P*=0.82). Trends in adult productivity indices for Yakima Basin natural-origin spring Chinook are also very similar for both Upper Yakima (Figure 8) and Naches (Figure 9) populations. 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). 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. 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 in Appendix C; see also monitoringresources.org methods 32 and 3875.

Paired releases of PIT-tagged smolts were made in order to estimate the fish entrainment and canal survival rates in relation to river conditions and canal operations. For outmigration years 1999 through 2014, these data were used to generate a multi-variate river flow/canal entrainment relationship (D. Neeley 2010 and 2012a; Appendix C). Over a range of flow diversion rates, juvenile fish entrainment rates generally fit a logistic curve: at low diversion rates, the entrainment rate is lower than the diversion rate, and at high diversion rates the entrainment rate is higher than the diversion rate. In recent years it became difficult to adapt the model to higher winter and spring flows and to river channel changes, partly because at low diversion rates it was difficult to capture enough fish to get many point estimates of entrainment rate. The releases that were made, however, still tended to support a low entrainment rate relative to diversion rate at high river flows. For some years, Prosser smolt passage estimates produced by this model were outside of what were considered reasonable bounds (e.g., entrainment-based Prosser passage estimates approached or even exceeded known releases for hatchery-origin spring Chinook far upstream). This required us to reevaluate and change our methodology. The proportions of all PIT- tagged smolts released above Prosser and detected at mid-Columbia dams that were previously detected in the Chandler Canal bypass now serve as estimates of bypass-detection efficiency. Expanded Prosser passage estimates were then derived using the juvenile sample counts and detection efficiencies as described in Appendix C. These methods were generally consistent with monitoringresources.org methods 134, 271, 1636 and 6786.

Results and Discussion:

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

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

Brood Year	Control[1]	Treatment[2]	Acclimation Site[3] CFJ	ESJ	JCJ	Total
1997	207,437	178,611	229,290	156,758		386,048
1998[4]	284,673	305,010	221,460	230,860	137,363	589,683
1999	384,563	374,226	232,563	269,502	256,724	758,789
2000	424,554	409,731	285,954	263,061	285,270	834,285
2001[5]	183,963	186,273	80,782	39,106	250,348	370,236
2002	420,764	416,140	266,563	290,552	279,789	836,904
2003	414,175	410,517	273,377	267,711	283,604	824,692
2004[6]	378,740	406,708	280,598	273,440	231,410	785,448
2005	431,536	428,466	287,127	281,150	291,725	860,002
2006	351,063	291,732	209,575	217,932	215,288	642,795

2007	387,055	384,210	265,907	254,540	250,818	771,265
2008	421,290	428,015	280,253	287,857	281,195	849,305
2009	418,314	414,627	279,123	281,395	272,423	832,941
2010	395,455	399,326	264,420	264,362	265,999	794,781
2011	382,195	386,987	255,290	248,454	265,438	769,182
2012	401,059	401,657	256,732	276,210	269,774	802,716
2013	No Experiment		215,933	214,745	216,077	646,755
2014	337,548	347,682	232,440	226,257	226,533	685,230
2015	331,316	323,631	208,239	218,225	228,483	654,947
2016	339,816	329,392	230,490	218,676	220,042	669,208
2017	351,656	359,013	244,236	233,449	232,984	710,669
2018	322,219	320,201	213,833	206,619	221,968	642,420
2019	270,242	280,156	153,575	193,042	203,781	550,398
2020	376,302	384,886	261,643	244,378	255,167	761,188
2021		809,010	268,064	276,969	263,977	809,010
2022	91,554	758,496	284,502	289,319	276,230	850,051
Mean	346,145	434,719	241,614	239,407	247,296	718,806

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. JCJ raceway 3 suffered mechanical failures resulting in the loss of about 45,000 high-growth (control) fish.

Table 6. Total releases of Coho by brood year, life stage, and brood source.

	Smolts			Parr		Local Brood		Total Smolts	
Brood Year	UppYak	Naches	Prosser	UppYak	Naches	Smolts	Parr	Non-Local	Local
1997	436,000	1,257,000							1,693,000
1998	502,155	502,239							1,004,394
1999	498,872	429,318							928,190
2000	187,659	379,904							567,563
2001	263,288	357,530							620,818
2002	403,000	407,002							810,002

2003	313,207	291,494							604,701
2004	322,417	332,455							654,872
2005	338,127	554,784	50,000						942,911
2006	426,632	516,753	81,114						1,024,499
2007	358,412	440,783	219,098						1,018,293
2008	304,638	269,936	182,719	12,000	25,000	324,598	37,000	432,695	757,293
2009	407,184	341,414	245,455	13,000	12,000	610,423	25,000	383,630	994,053
2010	443,030	131,972	190,836	15,000	15,000	522,027	30,000	243,811	765,838
2011	311,102	359,067	322,100	365,035	73,572	992,269	438,607		992,269
2012	339,034	305,197	221,567	10,555	29,565	446,295	40,120	419,503	865,798
2013	353,139	373,072	367,382	9,000	18,232	524,967	27,232	568,626	1,093,593
2014	408,112	298,619	267,830	93,525	92,023	974,561	185,548		974,561
2015	141,000	141,000	204,358			204,358		282,000	486,358
2016	407,196	369,521	205,967			205,967		776,717	982,684
2017	438,331	267,211	470,000	114,141	138,624	641,589	252,765	533,953	1,175,542
2018			929,388	139,925	114,735	400,000	254,660	528,388	929,388
2019			897,233	3,000	3,000	354,000	6,000	543,233	897,233
2020	210,000		915,197	215,000	0	400,000	215,000	610,000	1,125,197
2021	210,429		937,916	325,571	0	425,000	325,571	635,429	1,148,345
2022	240,000		915,197	215,483	0	610,000	215,483	825,483	1,125,197
2023	197,589		887,492	375,571	10,000	547,589	375,571	547,589	1,085,081
Mean	338,422	396,489	447,939	135,914	28,001	511,478	167,223	523,719	935,840

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
2016	1,593,090		562,472					2,155,562
2017	1,789,399		434,096	159,468				2,382,963

2018	1,638,298		338,727	208,664	2,185,689
2019	0		158,046	224,961	682,652
2020	2,315,627	82,679	0		2,398,306
2021	1,601,273		536,000	210,000	2,397,273
2022	1,099,834	565,767	384,000	115,490	2,165,091
2023	1,100,000				1,990,875

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/Prosser[2] Subyrl	Yrlng	Nelson Springs	Wapatox	Roza	Total Release
2009		180,911					180,911
2010		200,747					200,747
2011			176,364	39,406			215,770
2012	98,300			98,803			197,103
2013				88,208		48,355	136,563
2014				179,901		74,980	254,881
2015	55,000			99,600		122,848	277,448
2016						37,000	37,000
2017	169,499					75,000	244,499
2018				44,000		30,000	74,000
2019	581,000			75,000	100,000	75,000	831,000
2020	932,843[3]			100,000	100,000	175,000	1,307,843
2021	198,398				30,830	50,366	279,594
2022	434,712		19,081	74,616	68,469	111,661	708,539
2023	650,000		215,000	98,636	69,209	136,280	954,125

1. All fish released as subyearlings unless otherwise noted.
2. 2009-2010: Stiles Pond/Naches R.; 2022: Prosser.
3. Includes Marion Drain facility acclimation

For smolt migration years 2000 to present, annual abundance estimates of juvenile smolts migrating downstream at Prosser Dam averaged 201,767 wild/natural spring Chinook, 323,920 CESRF-origin spring Chinook, 41,600 wild/natural-origin coho, and 269,900 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.

	Smolt	Spring Chinook		Coho	
Brood Year	Migr. Year	Wild/ Natural	Hatchery (CESRF)	Wild/ Natural	Hatchery
1997	1999	584,016	187,669		
1998	2000	199,416	303,688	37,359	331,503
1999	2001	148,460	281,256	40,605	134,574
2000	2002	467,359	366,950	19,859	155,814
2001	2003	308,959	154,329	9,092	139,135
2002	2004	169,397	290,950	18,787	148,810
2003	2005	134,859	236,443	31,631	204,728
2004	2006	133,238	300,508	8,298	204,602
2005	2007	99,341	351,359	18,772	260,455
2006	2008	120,013	265,485	40,170	416,708
2007	2009	237,228	415,923	23,858	496,594
2008	2010	220,950	382,878	33,408	341,145
2009	2011	304,322	442,564	22,908	333,891
2010	2012	258,106	391,446	17,667	244,503
2011	2013	365,386	372,079	56,947	483,122
2012	2014	263,266	408,222	159,642	337,988
2013	2015	125,150	332,715	20,757	129,084
2014	2016	185,442	403,938	227,163	233,371
2015	2017	208,929	273,248	12,031	108,570
2016	2018	131,489	290,644	38,451	299,535
2017	2019	175,427	319,579	41,696	246,178
2018	2020	151,265	371,069	10,000	396,000
2019	2021	106,092	212,000	20,092	323,493
2020	2022	126,537	282,878	26,432	237,548
2021	2023	141,216	270,555	37,057	222,529
	Mean	201,767	323,920	40,528	268,120

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. For most releases, PIT-tag detectors were located in or near the exit(s) from the release sites and allowed estimation of the number of PIT-tagged fish leaving the release sites (monitoringresources.org 6572). 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. Our methods are described in detail in Appendix C and are generally consistent with Sandford and Smith (2002) and the Columbia Basin Comparative Survival Studies (McCann et al. 2022). 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 D (spring Chinook), E (coho), and F (summer-run Chinook). There were no PIT-tagged releases of fall-run Chinook in 2020; the latest results for this species were presented in Appendix G of Fiander et al. (2019).

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 from Roza Dam to McNary Dam was generally better for late-migrating natural-origin relative to hatchery-origin spring Chinook smolts and for late-migrating relative to early-migrating natural-origin smolts (Figure 11; Appendix D). However, these general patterns are reversed in several of the most recent years (Appendix D, Figure 4). This may be due to hatchery-origin fish trending toward larger size at release over time (Bosch et. al. 2023), or the survival estimation methodology changing from a weighted-average method to use of a Cormack-Jolly-Seber (CJS) method or some of both (Appendix D).

For coho, we estimated survival from acclimation site release to McNary Dam based on life stage, brood source, location, and timing of the releases (Appendix E). The average survival probability of Coho Salmon smolts from the release sites to McNary Dam in 2022 was 14.17 ± 3.55 %, which was lower than the 2021 (40.34 ± 6.02 %) and 2020 estimates (47.31 ± 5.79%), but similar to the 2019 estimate (14.27 ± 2.64%) and higher than the 2015 estimate (10.12 ± 1.14%). The annual variation in survival rate might be associated with annual variation in river flow, water temperature as well as differing release locations. Comparing broodstocks, the survival probability in 2023 was higher for the Eagle Creek stock (25.37 ± 11.68%) than the Yakima stock (19.28 ± 7.13%), but both were significantly lower and in reverse order compared to 2021 (Eagle Creek: 35.27 ± 8.21%; Yakima: 39.10 ± 8.80%).

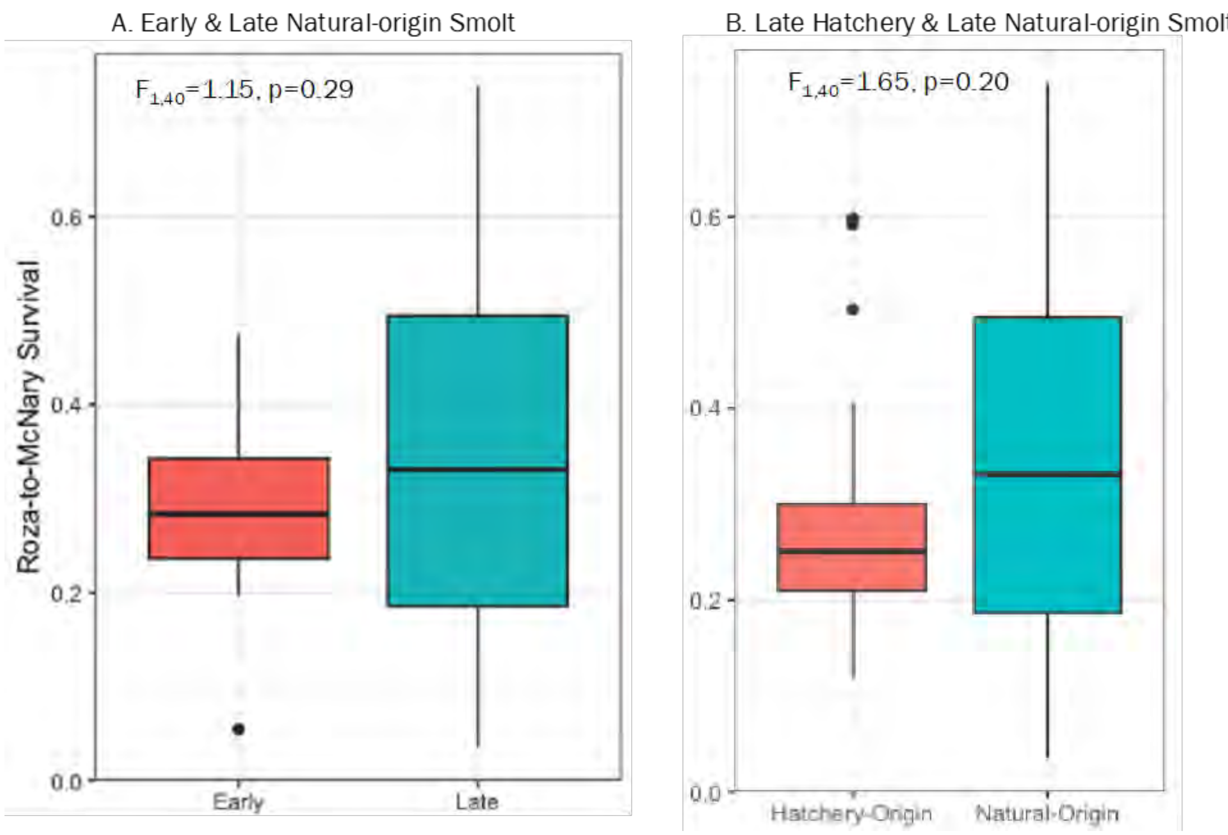


Figure 11. Box plot showing the 24-year average survival probabilities of natural-origin (Natural) and hatchery-origin (Hatchery) spring Chinook Salmon smolts (S. Pandit, Appendix D). A. is the comparison between Early- and Late-migrating natural-origin smolts; and B. is the comparison of Late hatchery- and natural-origin smolts.

Juvenile survival rates to Prosser and McNary Dams for summer-run Chinook varied by year over migration years from 2010 through 2023. The highest average annual survival rate to McNary Dam was in 2011 (40.15%±1.94%) and the lowest was in 2015 (0.73%±0.47%). The same trend was observed at Prosser Dam (73.64±7.47 in 2011 and 1.95±0 in 2015). These years represent the flow extremes over the study period. Evaluation indicated that release month and fish sizes are also important factors in fish survival. A complete report of our study of juvenile outmigration survival of Yakima Basin Summer Chinook to Prosser and McNary dams is provided in 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 2019). To derive rough smolt-to-adult return indices for fall Chinook, aggregate (marked and unmarked combined) smolt passage estimates for the age-3, -4, and -5 components for a given return year were averaged and the aggregate adult passage estimate for that return year was divided by this average smolt passage estimate. For example, the "Prosser Average Smolts" for adult return year 1988 is the average of marked and unmarked Prosser smolt estimates for juvenile migration years 1983-1985.

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

Results:

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

			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
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	n/a	109,002			2,597		2.4%	
1990	1992	1960	128,457			1,178		0.9%	
1991	1993	3397	92,912			544		0.6%	
1992	1994	1926	167,477			3,790		2.3%	
1993	1995	4882	172,375			3,202		1.9%	
1994	1996	6231	218,578			1,238		0.6%	
1995	1997	12608	52,028			1,995		3.8%	
1996	1998	5466	491,584			21,151		4.3%	
1997	1999	5925	584,016	187,669	48.6%	12,855	8,670	2.2%	4.6%
1998	2000[5]	4946	199,416	303,688	51.5%	8,240	9,782	4.1%	3.2%
1999	2001	1321	148,460	281,256	37.1%	1,764	864	1.2%	0.3%
2000	2002	5015	467,359	366,950	44.0%	11,434	4,819	2.4%	1.3%
2001	2003	3504	308,959	154,329	41.7%	8,597	1,251	2.8%	0.8%
2002	2004	2439	169,397	290,950	34.8%	3,743	2,557	2.2%	0.9%
2003	2005	1285	134,859	236,443	28.7%	2,746	1,020	2.0%	0.4%

2004	2006	5652	133,238	300,508	38.3%	2,802	4,482	2.1%	1.5%
2005	2007	4551	99,341	351,359	40.9%	4,295	5,004	4.3%	1.4%
2006	2008	4298	120,013	265,485	41.3%	6,004	10,577	5.0%	4.0%
2007	2009	5784	237,228	415,923	53.9%	7,952	7,604	3.4%	1.8%
2008	2010	3592	220,950	382,878	45.1%	7,385	8,036	3.3%	2.1%
2009	2011	9414	304,322	442,564	53.1%	3,766	3,606	1.2%	0.8%
2010	2012	8556	258,106	391,446	49.3%	6,602	5,592	2.6%	1.4%
2011	2013	4875	365,386	372,079	48.4%	7,343	4,160	2.0%	1.1%
2012	2014	4923	263,266	408,222	50.9%	3,969	1,932	1.5%	0.5%
2013	2015	1555	125,150	332,715	51.4%	3,415	3,139	2.7%	0.9%
2014	2016	5765	185,442	403,938	58.9%	1,800	2,865	1.0%	0.7%
2015	2017	7804	208,929	273,248	41.7%	1,185	1,321	0.6%	0.5%
2016	2018	5652	131,489	290,644	43.4%	1,931	1,263	1.5%	0.4%
2017	2019	3595	175,427	319,579	45.0%	1,919	1,700	1.1%	0.5%
2018	2020[6]	2864	151,265	371,069	57.8%	3,087[6]	2,910[6]	2.0%[6]	0.8%[6]
2019	2021[6]	3815	106,092	212,000	38.5%				
2020	2022[6]	6738	126,537	282,878	37.2%				
2021	2023		141,216	270,555	52.19%				

1. Mean flow (cfs) approaching Prosser Dam March 29-July 4 of juvenile migration year. In high flow years (flows at or > 5000 cfs) operation of the Chandler smolt sampling facility may be precluded during portions of the outmigration. Data courtesy of U.S. BOR hydromet.
2. Aggregate of Upper Yakima, Naches, and American wild/natural populations.
3. Estimated smolt-to-smolt (release from upper Yakima River acclimation sites to Chandler) survival for CESRF juveniles.
4. Includes combined age-3 through age-5 returns. CESRF adult returns and smolt-to-adult survival values are understated relative to wild/natural values since these figures are not adjusted for differential harvest rates in mark selective fisheries in marine and lower Columbia River fisheries.

5. Available data were not sufficient to estimate juvenile flow-entrainment and passage of wild/natural fish.
6. Data for most recent year are preliminary; return data do not include age-5 adult fish.

Table 11. Average combined hatchery- and natural-origin smolt counts at Prosser for fish returning at age-3, -4, and -5, combined adult returns to Prosser Dam of all age classes, and estimated Prosser smolt-to-adult return indices for Yakima River fall-run Chinook for adult return years 1988-2023.

Adult Return Year	Prosser Average Smolts[1]	Prosser Total Adults	Prosser Smolt-to-Adult Return Index (SAR)
1988	1,029,429	224	0.02%
1989	1,469,019	670	0.05%
1990	1,664,378	1,504	0.09%
1991	1,579,989	971	0.06%
1992	1,811,088	1,612	0.09%
1993	2,034,865	1,065	0.05%
1994	1,976,301	1,520	0.08%
1995	1,329,664	1,322	0.10%
1996	1,023,053	1,392	0.14%
1997	1,097,032	1,120	0.10%
1998	1,533,093	1,148	0.07%
1999	1,786,511	1,896	0.11%
2000	1,716,156	2,293	0.13%
2001	1,867,966	4,311	0.23%
2002	1,946,676	6,241	0.32%
2003	2,108,238	4,875	0.23%
2004	2,653,056	2,947	0.11%
2005	2,707,132	1,942	0.07%
2006	2,724,824	1,528	0.06%
2007	2,312,562	1,132	0.05%
2008	2,450,308	2,863	0.12%
2009	2,353,675	2,972	0.13%
2010	2,118,702	2,888	0.14%
2011	1,780,670	2,718	0.15%
2012	1,806,572	4,477	0.25%
2013	1,939,754	7,706	0.40%
2014	2,411,076	7,792	0.32%
2015	2,476,483	7,380	0.30%
2016	2,436,111	5,355	0.22%
2017	2,348,973	1,613	0.07%
2018	2,527,520	763	0.03%
2019	2,544,821	691	0.03%
2020	2,479,388	1,724	0.07%
2021	2,300,953	1,411	0.06%

2022	1,797,957	1,777	0.10%
2023	1,791,115	1,660	0.09%
Mean	1,998,197	2,597	0.13%

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

Table 12. Preliminary estimates of Prosser-to-Prosser smolt-to-adult survival (SAR) indices for adult returns from hatchery- and natural-origin coho for the Yakima reintroduction program, juvenile migration years 2000-2021.

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	2,418	1.6%	18,787	472	2.5%
2005	204,728	2,898	1.4%	31,631	1,562	4.9%
2006	204,602	2,404	1.2%	8,298	1,049	12.6%
2007	260,455	4,131	1.6%	20,131	459	2.3%
2008	416,708	8,835	2.1%	43,046	982	2.3%
2009	496,594	5,153	1.0%	25,108	573	2.3%
2010	341,145	7,216	2.1%	35,158	802	2.3%
2011	333,891	4,948	1.5%	24,108	550	2.3%
2012	244,503	2,703	1.1%	17,667	424	2.4%
2013	483,122	24,178	5.0%	56,947	1,082	1.9%
2014	337,988	2,943	0.9%	159,642	362	0.2%
2015	129,084	3,280	2.5%	18,415	103	0.6%
2016	233,371	2,693	1.2%	227,163	1,162	0.5%
2017	108,570	2,083	1.9%	12,031	125	1.0%
2018	299,535	3,566	1.2%	38,451	301	0.8%
2019	246,178	2,530	1.0%	41,969	744	1.8%
2020	396,000	12,053	3.0%	10,000	422	4.2%
2021	323,493	6,079	1.9%	20,092	454	2.3%
Mean	269,885	4,773	1.6%	41,616	760	2.8% [d]

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

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

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

[d] Excludes migration year 2003.

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

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

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

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

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

Discussion:

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

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

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

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

Given these complicating factors, Tables 10-14 present available smolt-to-adult survival indices for Yakima River spring and summer/fall Chinook and coho. Because of the complexities noted above, these data are useful for analysis of trends but should not be used as direct citations of, or for comparisons of marked and unmarked, smolt-to-adult survival rates. The reader is encouraged to contact Yakama Nation technical staff to discuss these and other issues prior to any use of these data or any other estimation of Yakima Basin SARs that may be available through data obtained from public web sites such as RMPC, PTAGIS, DART, FPC or others.

Substantial juvenile mortality of subyearling releases of summer- and fall-run Chinook occurs in the Yakima River between their release sites and McNary Dam (Neeley 2012b). Strategies have been proposed to address limiting factors (YSFWPB 2004) and improve survival of these releases (Yakama Nation 2019). 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 2019). Additional discussion and results for Yakima Basin spring Chinook SARs are presented in Appendix B.

Status and Trend of Spatial Distribution (Redd Counts)

Methods: Regular foot and/or boat surveys (monitoringresources.org methods 29, 131, 211, 285) were conducted within the established geographic range for each species (this is increasing for coho as acclimation sites are located upriver and as the run increases in size). Redds were individually marked during each survey and carcasses were sampled to collect egg retention, scale sample, sex, and body length information and to check for possible experimental marks. River conditions vary from year to year and preclude complete accounting, especially for fall Chinook and Coho. Other agencies (WDFW, Pacific Northwest National Laboratory, and private contractors) have also conducted foot, boat, or aerial surveys for fall Chinook redds in the Yakima River Basin and we have attempted to incorporate available information from those surveys here.

Results:

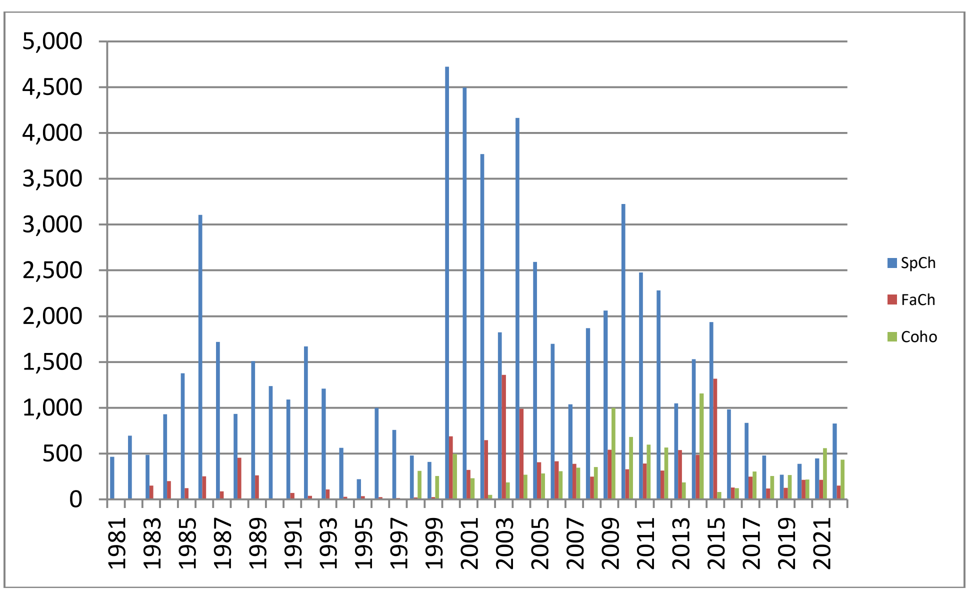


Figure 12. Redd Counts upstream of Prosser Dam in the Yakima River Basin by species, 1981-present.

Table 15. Yakima Basin spring Chinook redd counts and distribution, 1981 – present.

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

2010	2,199	219	253	2,671	173	171	168	40	552
2011	1,663	171	64	1,898	212	145	175	48	580
2012	1,276	125	69	1,470	337	196	189	89	811
2013	552	85	34	671	170	66	85	55	376
2014	962	138	53	1,153	129	65	158	27	379
2015	1,258	39	24	1,321	239	177	152	46	614
2016	512	83	22	617	149	106	74	37	366
2017	402	118	23	543	123	84	56	30	293
2018	339	13	0	352	27	56	44	1	128
2019	185	44	9	238	21	1	2	7	31
2020	189	44	8	241	44	25	71	6	146
2021	237	18	5	260	79	59[2]	49[2]	0	187
2022	426	40	32	498	198	85	45	2	330
2023	273	65	3	341	29	12	20	0	61
Mean	933	113	25	1,072	150	150	104	42	445

[1] Including minor tributaries.
[2] Surveys in the Bumping R., Rattlesnake Cr., and upper Nile watershed precluded due to fire; used recent 5-yr average.

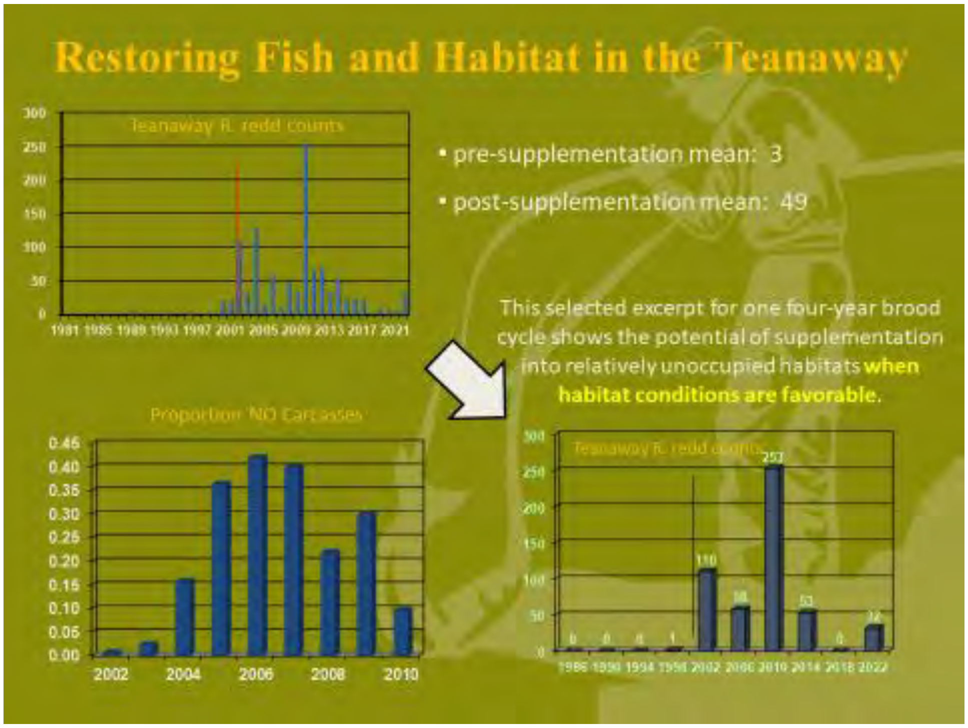


Figure 13. Teanaway River Spring Chinook redd counts, 1981-2022 (vertical lines denote pre- and post-supplementation periods) and the proportion of natural-origin (NO) carcasses observed in intensive spawning ground surveys, 2002-2010.

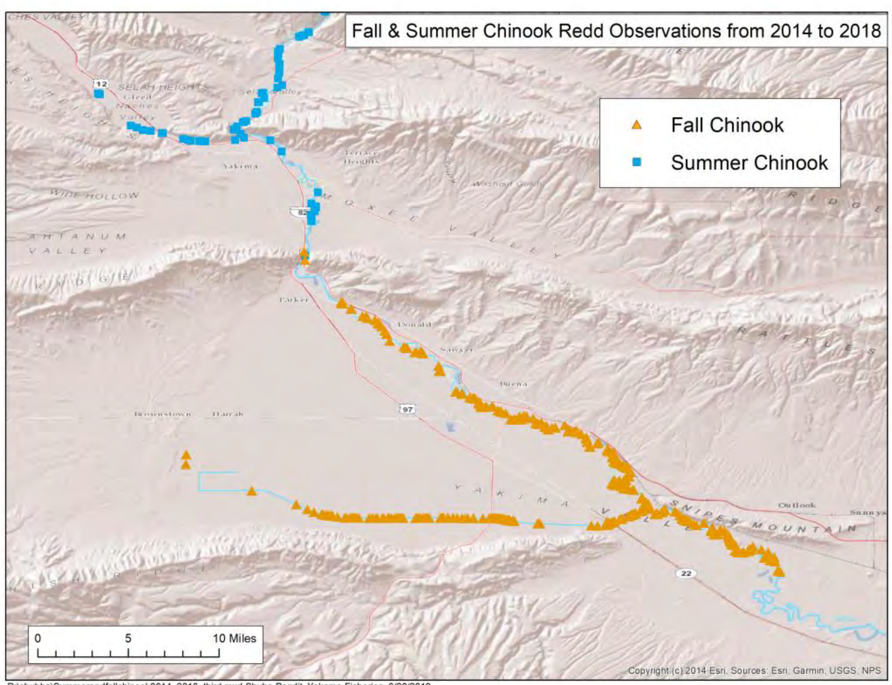


Figure 14. Distribution of summer and fall run Chinook redds in the Yakima River Basin (above Prosser Dam) based on redd observations from 2014 to 2018.

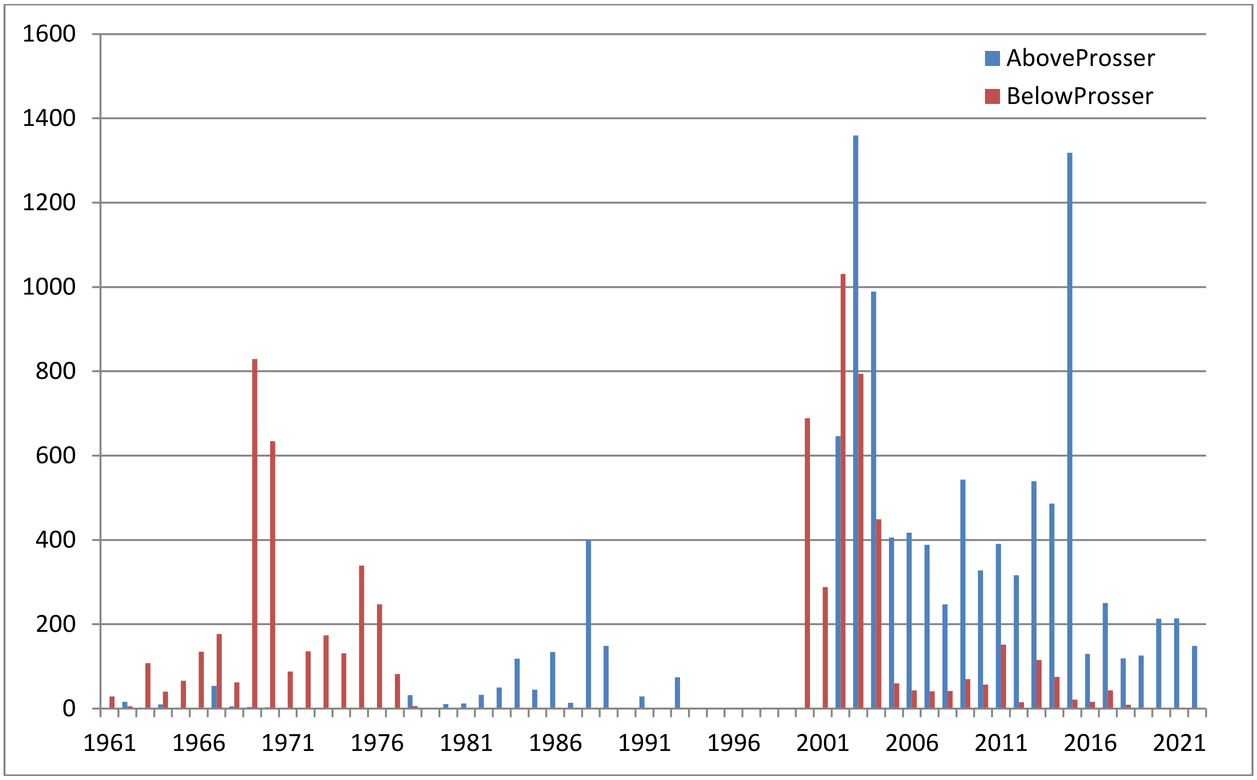


Figure 15. Fall Chinook redd counts above and below Prosser Dam, 1961-present, for years in which surveys were conducted and data are available. Data from YN, WDFW, and Pacific Northwest National Laboratory files. Note that survey completeness is highly variable due to annual flow and turbidity conditions;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

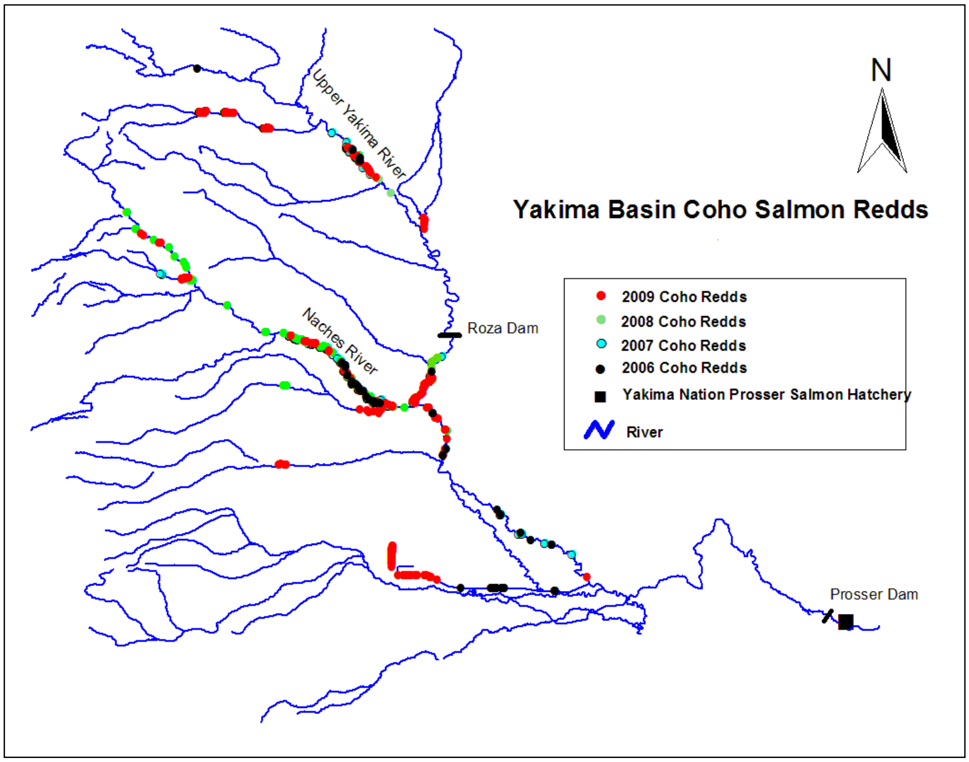


Figure 16. Distribution of coho redds in the Yakima River Basin.

Table 16. Yakima Basin coho redd counts and distribution, 1998 – present.

	Yakima River	Lower Yakima	Naches River	Tributaries	Total
1998	53	59	6	193	311
1999	104	108		43	255
2000	142	119	137	97	495
2001	27	32	95	77	231
2002	4	8	23	16	51
2003	32	48	56	50	186
2004	33	38	87	112	270
2005	57	50	72	103	282
2006	76	33	44	154	307
2007	63	7	87	188	345
2008	49	14	60	230	353
2009	163	66	281	488	998
2010	75	47	276	282	680
2011	82	37	243	235	597
2012	148	18	228	172	566
2013	45	20	69	52	186
2014	320	256	86	495	1157
2015	13	0	0	69	82
2016	37	0	27	59	123
2017	92	37	36	138	303

2018	46	7	103	99	255
2019	62	8	80	116	266
2020	71	0	50	95	216
2021	62	26	32	440	560
2022	111	19	24	278	432

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 49 redds per year. The proportion of natural-origin carcasses increased from less than one percent in 2002 (when CESRF fish first returned to the natural spawning grounds) to 42% in 2006 when the progeny of the 110 redds produced in 2002 (virtually 100% of which were produced by CESRF-origin fish) returned. These data clearly indicate that naturally-spawning CESRF spring Chinook were successful in returning natural-origin adults back to the Teanaway River. However, redd counts in the Teanaway River remain at or below pre-supplementation levels in some years, including 2018, indicating that habitat factors (primarily low late-summer and fall season flows) continue to deter returning fish and these fish are likely spawning in nearby mainstem and tributary reaches more conducive to survival of progeny (Fast et al. 2015).

Fall Chinook redd distribution in the Yakima River Basin appears to be experiencing a major transition in recent years. Historical redd survey data indicates that a substantial number of fall Chinook spawned below Prosser Dam in the lower Yakima River. However, from 2003-present, an average of approximately 80 percent (range 62 to 90 percent) of surveyed fall Chinook redds have been located above Prosser Dam (Figure 16). Biologists and habitat experts in the subbasin at least partially attribute this change in spawning distribution to the invasion of water stargrass (see Wise et al. 2009) in the lower 43 miles of the Yakima River. With the reintroduction of summer run Chinook, the Yakama Nation is expanding the distribution of summer/fall run Chinook spawners and redds into the middle reaches of the Yakima Basin between the town of Wapato upstream to the confluence with the Tieton River in the Naches subbasin and to Roza Dam in the Upper Yakima subbasin (Figures 1 and 15; Yakama Nation 2012). Summer-run Chinook have now spawned naturally in these habitats since 2013 after an absence of over 40 years.

Coho redd counts and spawner distribution have increased substantially since reintroduction efforts began (Table 16 and Figure 17). Many redds in the mainstem were located intermixed with fall chinook redds, tucked under cut banks or were found in side channels. Tributary redd enumeration and identification continues to be accurate due to the fall low water levels, improving interagency cooperation, and relatively good weather. One of the overall goals during the present implementation phase (Phase II) of the coho program is to evaluate the transition of redds from the mainstem river into historic tributaries. With the beginning of Phase II of the Coho Program we observed large increases in tributary spawning, with an annual average of approximately 200 redds counted in tributaries since 2004 (Table 16). We continue to transport returning adults via tankers to historic spawning habitats. These fish are helping to produce consistently robust redd counts (Table 16). Coho continue to volunteer into many tributaries, and the fidelity of adults from summer parr and adult out-plants have shown good results.

Adult Coho plants have also been used to evaluate the feasibility of increasing fish abundance in several tributaries. To determine the spawning success and effects on resident trout of these adult outplants, an intensive monitoring program was conducted in Taneum Creek for brood/spawn years 2007-2014. The results of this evaluation indicate that Coho spawned successfully and have the potential to produce large numbers of returning adult offspring per smolt that survive to McNary Dam as juveniles (Table 17). The total biomass of all salmonids in the stream increased and there were no discernable impacts to resident trout (Temple et al. 2012, 2017). Adult out-plants began again with brood year 2021. Additionally, releases of hatchery raised coho parr from the newly constructed MRS facility are targeted for Taneum Creek. The adults and the parr smolt to adult survival will be closely evaluated using PIT tags in the coming years.

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

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

Status and Trend of Diversity Metrics

Methods:

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

Diversity metrics for returning adult summer/fall Chinook and coho collected at the Prosser Dam denil fish trap include sex ratios, lengths, and weights (monitoringresources.org methods 454, 1548, 1549, 1551, 1577, 1747, 4041, 6723). We also queried the PTAGIS database for PIT-tagged summer- and fall-run Chinook that were released in the Yakima Subbasin in recent years and used PIT-detection data at Bonneville Dam for upstream migrants to estimate age composition and run timing of returning fish.

Results and Discussion:

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

Sex ratios, lengths, and weight data for fall Chinook and coho salmon sampled at the Prosser denil adult sampling facility from 2001-present are presented in Tables 18-21. Age composition of summer- and fall-run Chinook are presented in Table 22 and run timing in Figure 18. In addition, preliminary results of some diversity metrics relating to the effort to reestablish a natural spawning coho population in the Yakima Basin were published in Bosch et al. (2007). That study observed divergence in some diversity traits between hatchery- and natural-origin fish suggesting that some re-naturalization can be detected in just a few generations after outplanting of hatchery-origin fish in the wild.

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

Return Year	Sample Size F	J	M	Female Adult %	Female Total %	Sample Date Range First	Last
2001	186	80	213	46.6%	38.8%	09/10/01	11/19/01
2002	389	61	512	43.2%	40.4%	09/09/02	11/25/02
2003	396	24	224	63.9%	61.5%	09/07/03	11/17/03
2004	185	40	201	47.9%	43.4%	09/06/04	11/23/04
2005	201	8	233	46.3%	45.5%	09/06/05	11/14/05
2006	107	11	84	56.0%	53.0%	09/13/06	11/06/06
2007	42	44	39	51.9%	33.6%	09/10/07	11/06/07
2008	81	23	101	44.5%	39.5%	09/08/08	11/13/08
2009	110	132	95	53.7%	32.6%	09/08/09	11/07/09
2010	239	4	162	59.6%	59.0%	09/08/10	11/03/10
2011	67	10	34	66.3%	60.4%	09/07/11	11/09/11
2012	249	109	264	48.5%	40.0%	09/04/12	11/06/12
2013	272	86	460	37.2%	33.3%	09/16/13	11/22/13
2014	681	78	725	48.4%	45.9%	09/04/14	12/10/14
2015	1047	69	1374	43.2%	42.0%	09/09/15	11/16/15
2016	158	22	128	55.2%	51.3%	09/09/16	11/12/16
2017	122	67	66	64.9%	47.8%	09/13/17	12/05/17
2018	78	23	114	40.6%	36.3%	09/12/18	11/05/18
2019	36	7	22	62.1%	55.4%	09/22/19	11/15/19
2020	20		25	44.4%	44.4%	09/23/20	11/20/20
2021	30	9	31	49.2%	42.9%	09/20/21	10/20/21
2022	21	9	61	25.6%	23.1%	09/15/22	11/02/22
2023	68	6	43	61.3%	58.1%	09/21/23	11/04/23
			Mean	50.5%	44.7%		

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

Run Year	Females N	Fork	POH	Weight	Males (excluding Jacks) N	Fork	POH	Weight
2001	186	72.7	60.1	11.0	213	71.5	57.8	9.3
2002	389	78.4	63.9	13.5	512	76.1	60.2	12.1
2003	396	83.4	68.5	15.6	224	83.7	67.0	16.3
2004	185	82.3	67.8	15.1	201	73.9	60.0	11.2
2005	201	80.5	66.3	14.2	233	75.1	60.6	11.5
2006	107	81.5	66.3	15.6	84	81.3	64.6	15.3
2007	42	79.9	64.4	14.8	39	72.8	56.8	11.7
2008	81	70.1	56.5	9.8	101	67.8	54.0	8.9
2009	110	74.1	57.8	11.2	95	69.4	52.5	9.6
2010	239	73.3	57.8	11.3	162	70.9	54.7	9.7
2011	67	76.5	60.4	12.4	34	74.2	57.7	11.3

2012	249	70.1	53.3	9.5	264	66.4	49.6	7.9
2013	272	72.5	56.1	10.1	460	69.8	52.9	8.7
2014	681	76.1	60.8	11.9	725	69.0	53.2	8.6
2015	1047	76.2	59.5	11.4	1374	71.4	54.8	9.2
2016	158	75.3	59.5	9.7	128	71.6	55.3	8.1
2017	122	74.6	58.8	10.8	66	73.9	57.1	10.4
2018	78	72.3	54.4	9.6	114	67.2	48.9	7.5
2019	36	70.2	55.3	8.7	22	68.4	54.2	7.9
2020	20	71.9	51.7	9.1	25	71.4	51.9	8.5
2021	30	73.5	57.5	8.8	31	73.2	56.4	9.6
2022	21	65.8	51.0	7.6	61	64.6	49.6	6.7
2023	68	72.2	55.0	9.9	43	68.4	54.0	8.3
Mean		74.9	59.2	11.4		71.8	55.8	9.9

Table 20. Sex ratio of upstream migrating coho sampled at the Prosser Dam right bank denil ladder and fish trap, 2001-present.

Return Year	Sample Size F	J	M	Female Adult %	Female Total %	Sample Date Range First	Last
2001	1147	44	1024	52.8%	51.8%	09/11/01	11/22/01
2002	72	201	71	50.3%	20.9%	09/11/02	11/25/02
2003	473	89	452	51.1%	46.6%	09/11/03	11/21/03
2004	586	49	509	53.5%	51.2%	09/07/04	11/16/04
2005	531	146	405	56.7%	49.1%	09/13/05	11/15/05
2006	826	97	586	58.5%	54.7%	09/17/06	11/19/06
2007	676	34	538	55.7%	54.2%	09/11/07	11/20/07
2008	666	930	514	56.4%	31.6%	09/08/08	12/04/08
2009	1644	76	1576	51.1%	49.9%	09/09/09	11/20/09
2010	999	35	673	59.7%	58.5%	09/08/10	11/19/10
2011	907	12	776	53.9%	53.5%	09/16/11	11/17/11
2012	1156	108	961	54.6%	52.0%	09/08/12	11/17/12
2013	523	146	528	49.8%	43.7%	09/20/13	11/22/13
2014	4302	135	3668	54.0%	53.1%	09/03/14	12/23/14
2015	656	67	683	49.0%	46.7%	09/13/15	12/09/15
2016	310	101	249	55.5%	47.0%	09/13/16	11/16/16
2017	694	132	752	48.0%	44.0%	09/13/17	12/19/17
2018	343	318	308	52.7%	35.4%	09/06/18	11/05/18
2019	758	28	692	52.3%	51.3%	09/04/19	12/31/19
2020	357	115	180	66.5%	54.8%	09/22/20	11/25/20
2021	567	116	509	52.7%	47.6%	09/20/21	11/06/21
2022	447	19	438	50.5%	49.4%	09/17/22	11/08/22
2023	853	201	768	52.6%	46.8%	09/20/23	12/19/23
			Mean	53.8%	47.6%		

Table 21. Sample size (N), mean fork and mid-eye to hypural plate (MEH) lengths (cm), and weights (pounds) of upstream migrating coho sampled at the Prosser Dam right bank denil ladder and fish trap, 2001-present.

Run	Females				Males (excluding Jacks)			
Year	N	Fork	POH	Weight	N	Fork	POH	Weight
2001	1147	65.4	53.7	6.7	1024	65.6	52.4	6.5
2002	72	68.1	54.9	8.5	71	69.4	54.0	8.1
2003	473	65.3	52.9	7.0	452	65.7	51.4	6.8
2004	586	68.8	56.4	8.0	509	67.8	53.9	7.4
2005	531	67.5	54.9	8.0	405	67.6	53.5	7.8
2006	826	71.6	58.2	10.0	586	71.3	55.8	9.4
2007	676	66.3	52.1	7.0	538	65.5	49.9	6.6
2008	666	69.9	56.7	9.6	516	69.8	54.6	9.0
2009	1644	68.1	52.4	7.9	1576	67.2	49.7	7.2
2010	999	69.7	54.2	8.7	673	68.5	51.5	7.8
2011	907	68.6	53.7	8.2	776	68.5	51.7	7.7
2012	1156	64.3	49.5	6.8	961	62.6	46.4	6.0
2013	523	66.2	51.9	6.9	528	64.0	48.4	5.9
2014	4302	65.6	52.6	7.0	3668	63.5	49.8	6.1
2015	656	63.5	50.1	6.0	683	61.9	47.5	5.2
2016	310	66.9	52.7	6.9	249	67.4	51.6	6.4
2017	694	64.5	49.6	6.4	752	63.6	47.8	5.9
2018	343	66.6	51.0	6.8	308	66.0	49.2	6.4
2019	758	64.8	49.7	5.7	692	63.7	47.7	5.2
2020	357	67.4	49.8	7.9	180	66.4	47.9	7.0
2021	567	65.6	51.6	6.9	509	64.0	49.5	6.1
2022	447	66.2	50.5	7.1	438	64.8	48.4	6.5
2023	853	65.2	48.7	7.1	768	63.3	45.8	6.1
Mean		66.8	52.5	7.4		66.0	50.4	6.8

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

Brood	Age at Return				
Year	2	3	4	5	6
Summer Chinook Subyearlings					
2008	12.5%	12.5%	50.0%	25.0%	0.0%
2009	5.4%	16.3%	63.6%	14.7%	0.0%
2010	0.2%	27.5%	61.4%	10.6%	0.2%
2011	0.0%	12.1%	67.5%	20.4%	0.0%
2012	1.0%	50.0%	40.8%	8.2%	0.0%
2013	5.6%	11.1%	77.8%	5.6%	0.0%
Mean	4.1%	21.6%	60.2%	14.1%	0.0%
Fall Chinook Subyearlings					
2007	9.7%	47.9%	35.8%	6.6%	
2008	13.3%	53.3%	33.3%	0.0%	

2009	18.9%	40.5%	32.4%	8.1%	
2010	0.0%	66.7%	16.7%	16.7%	
2011	11.6%	34.9%	50.0%	3.5%	
2012	9.7%	61.1%	26.4%	2.8%	
Mean	10.6%	50.7%	32.4%	6.3%	
Summer Chinook Yearlings					
2010[1]	13.6%	31.2%	44.2%	3.9%	0.6%
Fall Chinook Yearlings					
2006	96.4%	0.0%	3.6%	0.0%	0.0%
2007	63.2%	16.2%	8.8%	11.8%	0.0%
2008	30.9%	36.2%	27.1%	5.8%	0.0%
2009	20.4%	19.4%	40.8%	19.4%	0.0%
2010	39.4%	26.8%	27.8%	6.1%	0.0%
2011	6.4%	16.7%	57.1%	14.7%	5.1%
Mean	42.8%	19.2%	27.5%	9.6%	0.9%

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

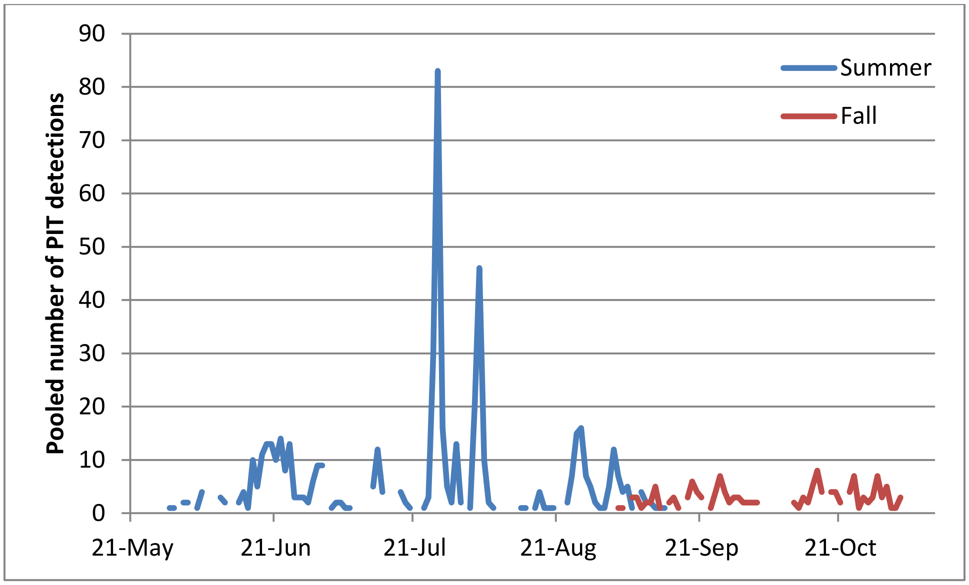


Figure 17. Adult return timing at Prosser Dam of PIT-tagged summer- and fall-run Chinook reared at the Marion Drain and Prosser Hatcheries and released as subyearlings, pooled for return years 2009-2018.

Habitat Monitoring

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

Status and Trend of Fine Sediment

Methods: Representative gravel samples (McNiel core samples, monitoring resources 199) were collected from various reaches in the Little Naches and Upper Yakima Rivers in the fall of 2022. 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 100 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 38 years for the two historical reaches, and 31 years for the expanded sampling area that includes several tributary streams.

The average percent fine sediment less than 0.85mm for the entire Little Naches drainage in 2022 was 11.3%, greater than the recent 2012-2021 ten-year average of 9.2%, but improved from averages observed prior to 2008 (Figure 19). The overall trend remains downward and similar trends can be seen when looking at individual reach conditions over the longer term monitoring period since 1992.

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

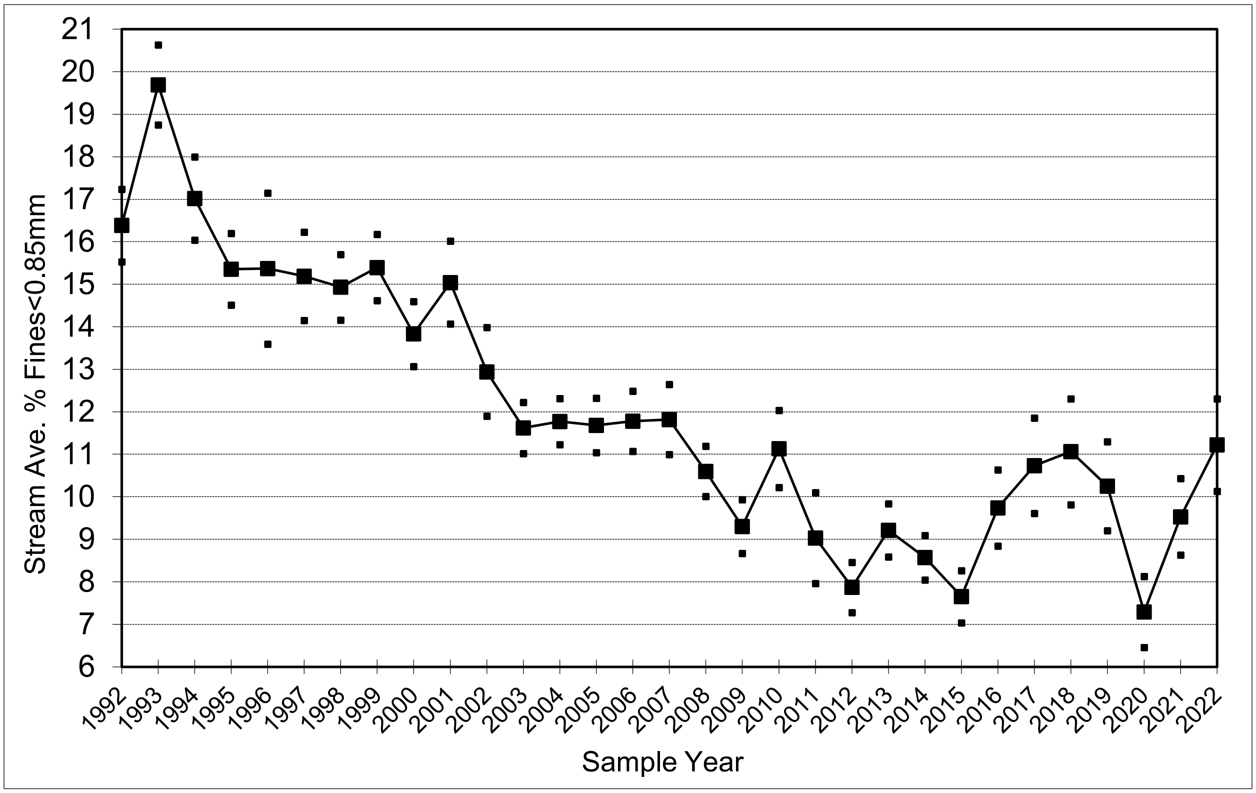


Figure 18. Overall Fine Sediment (<0.85mm) Trends with 95% confidence bounds in the Little Naches River Drainage, 1992-2022.

South Fork Tieton

One reach on the South Fork Tieton River (in the vicinity of Minnie Meadows) has been sampled in the past by the U.S. Forest Service. To the best of our knowledge this reach has not been sampled since 2015. This stream reach typically receives significant bull trout spawning activity and the monitoring efforts provide valuable information on their spawning conditions. Average fine sediment in this reach was 8.9% in 2015, matching the previous low observed in 1999, and is well below the mean for sediment levels for the 17 years that were sampled (Figure 20).

Upper Yakima

A total of 60 samples were collected and processed from the Upper Yakima River drainage this past year (5 reaches, 12 samples from each reach). The same reaches (Stampede Pass, Easton, Camelot to Ensign Ranch, Elk Meadows, and Cle Elum) have been sampled annually for the past 26 years. The 26-year trend in average percent fine sediment less than 0.85mm for the combined Upper Yakima drainage remains downward, although 2022 was the greatest observed average percent fine gravels since 2008 (Figure 21). At this time, we do not know what might have caused increased fine sediment levels in the Upper Yakima system.

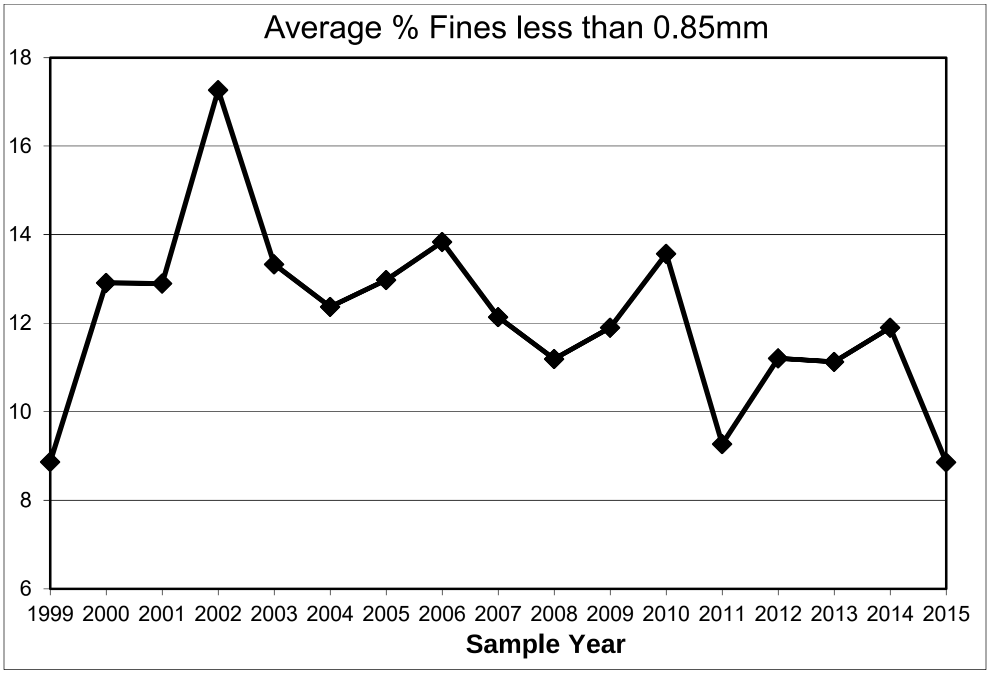


Figure 19. Fine Sediment Trends in the South Fork Tieton River, 1999-2015. Note: Data for 2007 were collected from only 1 Riffle. Data courtesy of U.S. Forest Service.

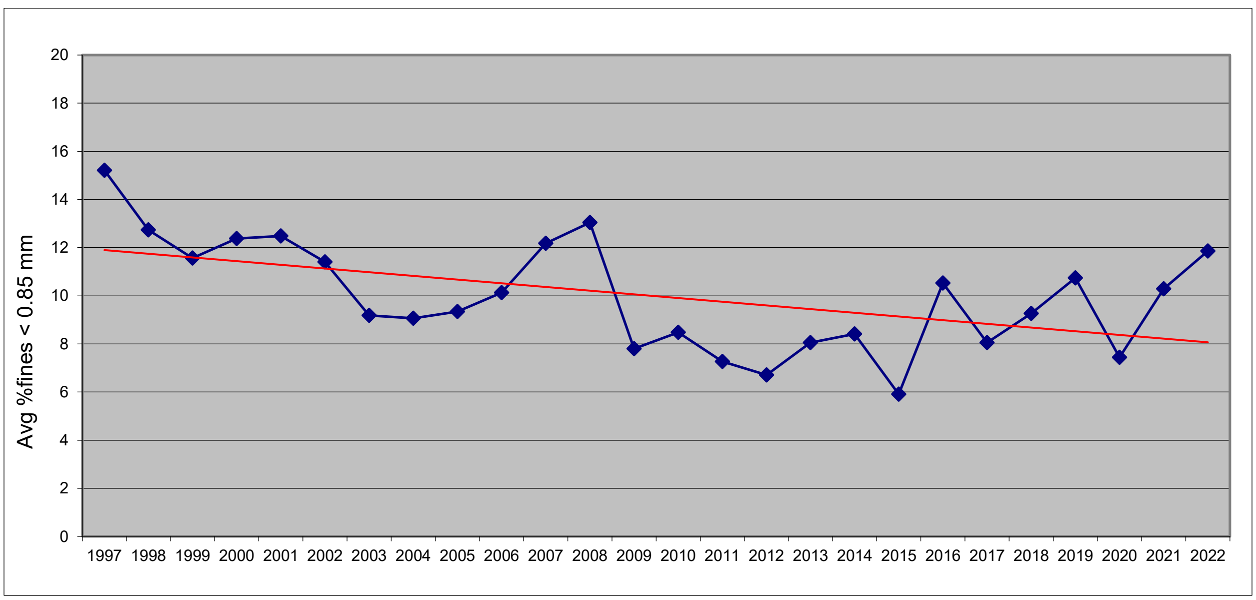


Figure 20. Overall average percent fine sediment (< 0.85 mm) in spawning gravels of the Upper Yakima River, 1997-2022.

Summary

Low rates of fine sediment improve egg and alevin survival and favor salmonid spawning success. The overall trend in average fine sediment levels in the Little Naches and Upper Yakima drainages is decreasing. However, we have observed increases in some recent years in both drainages that may have been due to effects from the large fires the region has experienced in these years as well as other factors.

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

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

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 generally consistent with monitoringresources.org methods 4056 and 4231.

Results:

Table 23. Spring Chinook harvest in the Yakima River Basin, 1983-present.

	Tribal		Non-Tribal		River Totals			Harvest
Year	CESRF	Natural	CESRF	Natural	CESRF	Natural	Total	Rate[1]
1983		84		0		84	84	5.8%
1984		289		0		289	289	10.9%
1985		865		0		865	865	19.0%
1986		1,340		0		1,340	1,340	14.2%
1987		517		0		517	517	11.6%
1988		444		0		444	444	10.5%
1989		747		0		747	747	15.2%
1990		663		0		663	663	15.2%
1991		32		0		32	32	1.1%
1992		345		0		345	345	7.5%
1993		129		0		129	129	3.3%
1994		25		0		25	25	1.9%
1995		79		0		79	79	11.9%
1996		475		0		475	475	14.9%
1997		575		0		575	575	18.1%
1998		188		0		188	188	9.9%
1999		604		0		604	604	21.7%
2000	53	2,305		100	53	2,405	2,458	12.9%
2001	572	2,034	1,252	772	1,825	2,806	4,630	19.9%
2002	1,373	1,207	492	36[2]	1,865	1,243	3,108	20.6%
2003	134	306	0	0	134	306	440	6.3%
2004	289	712	569	109[2]	858	820	1,679	11.0%
2005	46	428	0	0	46	428	474	5.4%
2006	246	354	0	0	246	354	600	9.5%
2007	123	156	0	0	123	156	279	6.5%
2008	521	414	586	11[2]	1,107	426	1,532	17.8%
2009	1,089	715	541	8[2]	1,630	722	2,353	19.4%
2010	345	194	1,154	48[2]	1,499	241	1,741	13.2%
2011	1,361	1,261	1,579	179[2]	2,940	1,440	4,380	24.4%
2012	1,220	1,302	735	63[2]	1,955	1,364	3,320	27.5%
2013	846	975	786	46[2]	1,632	1,021	2,653	25.9%
2014	576	715	826	54[2]	1,402	769	2,171	19.2%
2015	121	271	385	38[2]	506	309	815	8.7%
2016	103	185	132	24[2]	235	209	444	6.4%
2017	217	201	750	104[2]	967	305	1,272	17.8%
2018	154	115	259	20[2]	413	136	548	15.2%
2019	24	16	0	0	24	16	40	1.8%
2020	26	42	0	0	26	42	68	2.0%
2021	9	7	0	0	9	7	16	0.4%
2022	61	85	300	25	361	110	471	7.7%

2023	61	58	52	6	113	64	177	5.3%
Mean	414	511	452	67	866	583	1,095	12.3%

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 24. Estimated summer- and fall-run Chinook return, escapement, and harvest in the Yakima River, 1998-2023. Data from WDFW and YN databases.

			Escapement						
	Total Return		Above Prosser		Below Prosser		WA Recreational Harvest		
Year	Adult	Jack	Adult	Jack	Adult	Jack	Adult	Jack	Rate
1998	1,743	106	1,064	84	645	22	34	0	1.8%
1999	4,056	43	1,876	20	2,046	23	134	0	3.3%
2000	4,557	1,138	1,371	922	2,931	194	255	22	4.9%
2001	5,886	869	3,651	660	1,293	151	942	58	14.8%
2002	13,369	211	6,146	95	4,923	116	2,300	0	16.9%
2003	10,092	193	4,796	79	3,874	73	1,422	41	14.2%
2004	5,825	271	2,862	85	2,231	140	732	46	12.8%
2005	3,121	45	1,920	22	491	7	710	16	22.9%
2006	2,299	67	1,499	29	363	10	437	28	19.7%
2007	1,318	460	892	240	194	26	232	194	24.0%
2008	3,403	208	2,739	124	137	17	527	67	16.4%
2009	3,315	772	2,381	591	424	106	510	75	14.3%
2010	3,474	176	2,763	125	270	12	441	39	13.2%
2011	3,325	705	2,318	400	470	81	537	224	18.9%
2012	5,553	1,468	3,751	963	1098	211	704	294	14.2%
2013	13,005	1,541	8,537	995	1936	194	2,532	352	19.8%
2014	12,839	1,371	8,302	1,003	2,969	302	1,568	66	11.5%
2015	15,533	769	8,644	559	5,224	156	1,665	54	10.5%
2016	7,982	735	5,688	585	1,372	119	922	31	10.9%
2017	3,116	399	1,927	278	719	105	470	16	13.8%
2018	1,739	147	1,137	76	397	46	205	25	12.2%
2019	1,420	161	869	78	406	21	145	62	13.1%
2020	2,734	200	1,873	105	631	40	230	55	9.7%
2021	2,924	497	1,875	153	754	273	295	71	10.7%
2022	3,022	683	1,700	446	820	151	502	86	15.9%
2023	5,563	1,092	3,502	325	1,610	613	451	154	9.1%

Table 25. Estimated Coho return, escapement, and harvest in the Yakima River, 1999-2023. Data from WDFW and YN databases.

	Escapement								
	Total Return		Prosser Dam		Hatchery Denil		WA Recreational Harvest		
Year	Adult	Jack	Adult	Jack	Adult	Jack	Adult	Jack	Rate
1999	3,906	91	3,852	91			54	0	1.4%
2000	4,444	1,841	4,390	1,826			54	15	1.1%
2001	5,032	68	4,978	68			54	0	1.1%
2002	515	343	475	343			40	0	4.7%
2003	2,192	162	2,192	162			0	0	0.0%
2004	2,367	74	2,325	64			42	10	2.1%
2005	2,897	225	2,890	225			7	0	0.2%
2006	4,478	175	4,335	175	125	0	18	0	0.4%
2007	3,461	64	3,153	60	300	4	8	0	0.2%
2008	4,636	1,917	3,890	1,809	700	58	46	50	1.5%
2009	9,843	873	8,517	573	1300	300	26	0	0.2%
2010	5,776	567	4,811	183	915	384	50	0	0.8%
2011	8,073	171	6,424	121	1594	50	55	0	0.7%
2012	5,511	264	4,298	164	1200	100	13	0	0.2%
2013	3,173	848	2,290	395	837	412	46	41	2.2%
2014	25,368	584	20,997	427	4263	157	108	0	0.4%
2015	3,314	300	2,210	105	1095	195	9	0	0.2%
2016	3,383	374	1,693	188	1690	186	0	0	0.0%
2017	3,920	274	3,051	222	804	34	65	18	2.0%
2018	2,236	835	1,690	440	518	365	28	30	1.9%
2019	3,921	105	2,506	52	1361	46	54	7	1.5%
2020	3,274	3,228	2,303	524	971	2704	0	0	0.0%
2021	12,654	1,745	4,129	269	8,346	1,450	179	26	1.4%
2022	6,425	469	2,395	62	3,974	393	56	14	1.0%
2023	8,885	2,922	4,247	422	4,518	2,469	120	31	1.3%

Discussion:

Adult returns of spring Chinook from the CESRF have substantially increased fishing opportunity for all fishers in the Yakima Basin (Table 25) and returned recreational fisheries to the Basin after a 40-year absence. This has contributed to improved relationships between all the Basin's stakeholders and increased opportunities for collaboration.

Recreational fishers enjoy a successful annual fall Chinook fishery situated primarily near the mouth of the Yakima River (Table 26). Tribal fishers harvest a substantial, but unquantified number of Yakima Basin-destined fall Chinook (Figure 22) and coho in commercial gillnet fisheries in the Zone 6 fishing area. Because of the quantity and relatively higher quality of fall Chinook and coho available to tribal fishers in Zone 6 Columbia and Klickitat River fisheries, Yakima River tribal harvest is typically at or near zero even though regulations allowing fall season fisheries in the Yakima River are propagated annually by the Yakama Nation.

Hatchery Research

Effect of Artificial Production on the Viability of Natural Fish Populations

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

> 1.2. Can hatchery production programs meet adult production and harvest goals (integrated and segregated) while protecting naturally spawning populations?
>
> 1.4. What is the magnitude of any demographic benefit or detriment to the production of natural-origin juveniles and adults from natural spawning of hatchery-origin supplementation adults?
>
> 1.5. What are the range, magnitude and rates of change of natural spawning fitness of integrated (supplemented) populations, and how are these related to management rules including the proportion of hatchery fish permitted on the spawning grounds, and the proportion of natural origin adults in the hatchery broodstock?

Methods:

The YKFP began a spring Chinook salmon hatchery program at the CESRF near Cle Elum on the upper Yakima River (river kilometer 297, measuring from the confluence with the Columbia River; Figures 1 and 23) in 1997. This program is a supplementation effort targeting the upper Yakima River population and is designed to test whether artificial propagation can be used to increase natural production and harvest opportunities while limiting ecological and genetic impacts (RASP 1992). It is an integrated hatchery program (Mobrand et al. 2005) because only natural-origin brood-stock are used and returning hatchery-origin adults are allowed to spawn in the wild. The program employs “best practice” hatchery management principles (see Cuenco et al. 1993, Mobrand et al. 2005) including reduced pond densities, strict disease management protocols, random brood-stock selection, and factorial mating (Busack and Knudsen 2007) to maximize effective population size. Fish are reared at the central facility, but released from three acclimation sites located near the central facility at: Easton approximately 25km upstream of the central facility, Clark Flat about 25km downstream of the central facility, and Jack Creek about 12km upstream from the Teanaway River's confluence with the Yakima River (Figure 23). The CESRF collected its first spring Chinook brood-stock in 1997, released its first fish in 1999, and age-4 adults have been returning since 2001. The first generation of offspring of CESRF and wild fish spawning in the wild returned as adults in 2005. The program uses the adjacent, un-supplemented Naches River population as an environmental and wild control system.

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

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

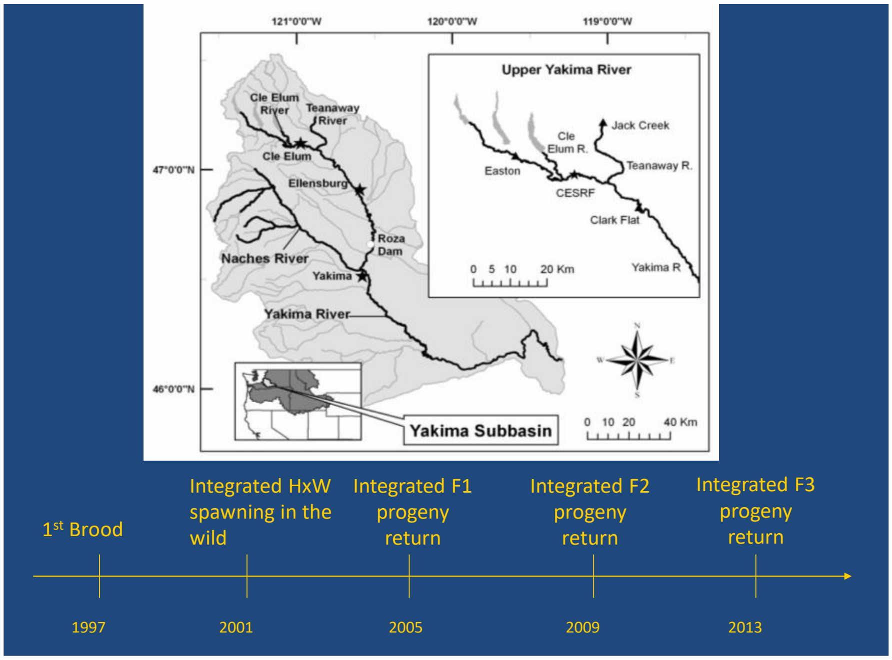


Figure 21. Map of the Yakima River Basin, Cle Elum Supplementation and Research Facility (CESRF) locations, and timeline of the spring Chinook supplementation program.

Results:

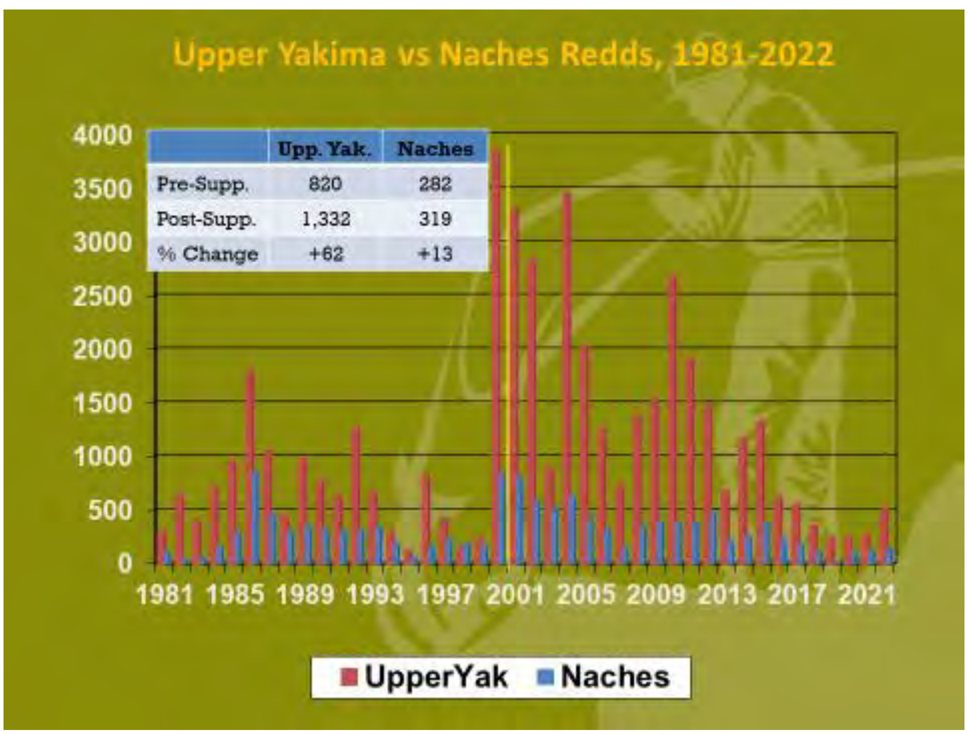


Figure 22. Spring Chinook redd counts in the supplemented Upper Yakima (red bar) relative to the un-supplemented Naches (control; blue bar) for the pre- (1981-2000) and post-supplementation (2001-2022) periods.

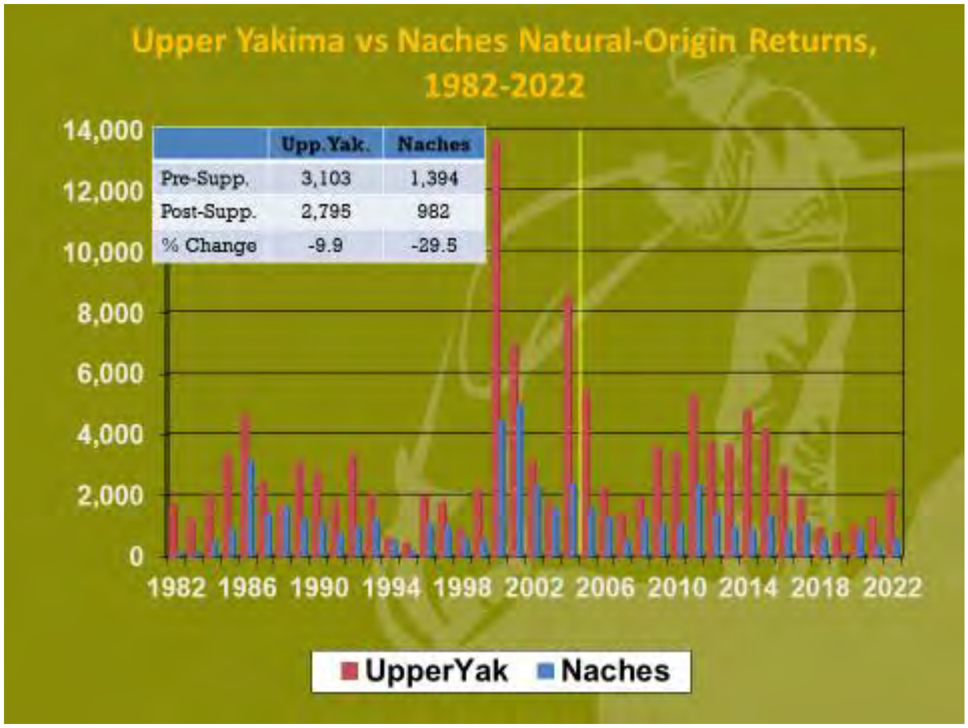


Figure 23. Natural-Origin returns of Spring Chinook in the supplemented Upper Yakima (red bar) relative to the un-supplemented Naches (control; blue bar) for the pre- (1982-2004) and post-supplementation (2005-2022) periods.

Discussion:

Spring Chinook redd abundance is greater for both the supplemented Upper Yakima and Naches control populations in the post- relative to pre-supplementation periods (Figure 24). Redd counts in the post-supplementation period (2001-2022) increased in the supplemented Upper Yakima (+62.4%; P=0.08) and in the un-supplemented Naches control system (+13.1%; P=0.57) relative to the pre-supplementation period (1981-2000); however, neither change was statistically significant. As noted above, spatial distribution of spring Chinook has also increased as a result of supplementation with dramatic increases in redd abundance observed in the Teanaway River (Figure 14) in some years.

Changes in mean natural-origin return abundance in the post-supplementation period (2005-2022) relative to the pre-supplementation period (1982-2004) were not significant in either the supplemented upper Yakima River (-9.9%; P=0.69; Figure 25) or the unsupplemented Naches River system (-29.5%; P=0.21; Figure 25). However, natural-origin return abundance in the Naches River (combined Naches and American populations) declined to an estimated 160 fish in 2019. Nehlsen et al. (1991) identified “populations having recent (within the past 1 to 5 years) escapements under 200, in the absence of evidence that they were historically small”, as populations “at high risk of extinction". As we have noted, many factors, unrelated to hatchery production actions, appear to be inhibiting natural productivity (see status and trend of adult productivity) throughout the Yakima Basin.

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, evaluation of RRS for all integrated hatchery- and natural-origin spawners above Roza Dam for brood years 2007-2011 has been completed (Koch et al. 2022).

The YKFP is presently studying the release of over 1.0 million coho smolts annually from acclimation sites in the Naches and Upper Yakima subbasins. These fish are a combination of in-basin production from brood-stock collected in the vicinity of Prosser Dam plus out-of-basin stock generally reared at Willard or Eagle Creek National Fish Hatcheries and moved to the Yakima Subbasin for final rearing and release. Monitoring of these efforts to re-introduce a sustainable, naturally spawning coho population in the Yakima Basin have indicated that coho returns averaged over 6,000 fish from 1997-2022 (an order of magnitude improvement from the average for years prior to the project) including estimated returns of wild/natural coho averaging over 800 fish annually since 2001 (Figure 4). Coho re-introduction research has demonstrated that hatchery-origin coho, with a legacy of as many as 10 to 30 generations of hatchery-influence, can reestablish a naturalized population after as few as 3 to 5 generations of outplanting in the wild (Bosch et al. 2007). The project is working to further develop a locally adapted brood-stock and to establish specific release sites and strategies that optimize natural reproduction and survival.

Effectiveness of Hatchery Reform

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

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

YKFP efforts to monitor and evaluate hatchery reform focus on the CESRF spring Chinook program which was designed explicitly for this purpose from its inception (BPA 1996). To the extent that is practical, we will evaluate similar metrics for the summer/fall run Chinook and coho programs and publish those results in future reports as the Master Plan (Yakama Nation 2019) is implemented and the programs mature over time.

In addition to the integrated (supplementation-S) hatchery program described above for the CESRF, this facility also introduced a segregated "hatchery control" (HC) program in 2002 as recommended by independent scientific review. To protect the integrity of the integrated program evaluation described above, returning HC line fish were either harvested or trapped and removed at the Roza Adult Monitoring Facility (RAMF); no HC line fish were allowed to escape to the spawning grounds (determination of fish origin was based on a differential marking strategy for S and HC fish; unmarked fish were presumed wild). CESRF-project scientists hypothesized that

HC-line fish, which use only returning hatchery-origin fish as brood source, would increasingly diverge in phenotypic and genetic characteristics from wild (WC or wild control) fish with increasing generations of hatchery influence, whereas S-line fish, which use only wild or natural-origin fish for brood source, would remain relatively close in characteristics to wild fish (Figure 26). These hypothetical outcomes were based on hatchery reform theory which suggests that, by using only wild or natural-origin parents to spawn successive generations of fish in the hatchery environment, mean fitness of an integrated population in the natural environment can be maintained relatively close to that of a wild population (Mobrand et al. 2005).

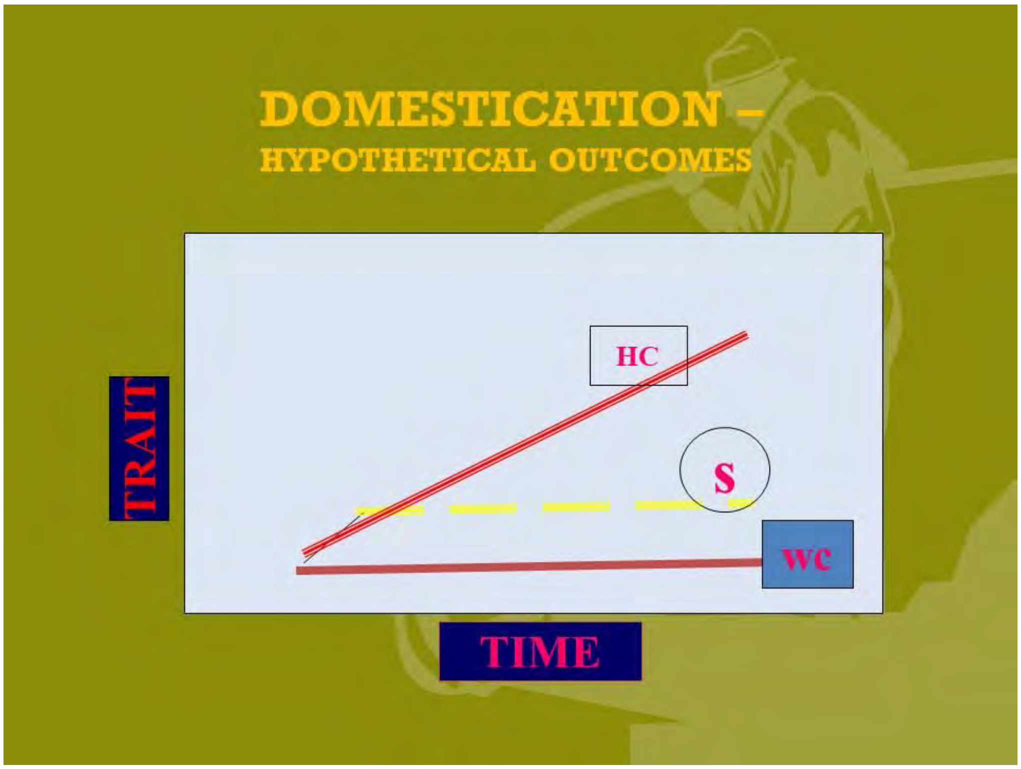


Figure 24. Hypothetical outcomes of trait divergence (domestication effects) over time for a segregated (hatchery-control or HC) line of fish, compared to an integrated (supplementation or S) line of fish and a wild (wild-control or WC) line of fish (D. Fast, Yakama Nation).

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

Methods:

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

A recently developed parameter to monitor the mean fitness of an integrated population in the natural environment is called Proportionate Natural Influence (PNI). PNI is an approximation of the rate of gene flow between the natural environment and the hatchery environment (Busack et al. 2008). The equation describing PNI is

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

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

Results and Discussion:

For CESRF integrated program return years 2001-2022, PNI averaged 65% while pHOS averaged 54% (Table 28). As stated in the introduction to this report and in the final Environmental Impact Statement for the Yakima Fisheries Project (BPA 1996), one of the explicit purposes of the project is to test the assumption that new artificial propagation or hatchery reform techniques (Cuenco et al. 1993, Mobrand et al. 2005) can be used to increase natural production without causing significant impacts to existing natural populations. Therefore, it has always been the intent of this project to purposely allow integrated hatchery-origin fish to escape to the natural spawning grounds, i.e., we intentionally maintained a relatively high pHOS rate. Even with a high pHOS relative to recommendations, PNI for the CESRF integrated program remained in the "low hatchery influence for conservation of natural populations" category described by the HSRG (Paquet et al. 2011).

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

Table 26. Escapement (Roza Dam counts less brood-stock collection and harvest above Roza) of natural- (NoR) and hatchery-origin (HoR) spring Chinook to the upper Yakima subbasin, 1982 – present.

	Wild/Natural (NoR)			CESRF (HoR)			Total				
Year	Adults	Jacks	Total	Adults	Jacks	Total	Adults	Jacks	Total	pHOS[1]	PNI[1]
1982			1,146								
1983			1,007								
1984			1,535								
1985			2,331								
1986			3,251								
1987			1,734								
1988			1,340								
1989			2,331								
1990			2,016								
1991			*1,583*[2]								
1992			3,009								
1993			1,869								
1994			563								
1995			355								
1996			1,631								
1997	1,141	43	1,184								
1998	369	18	387								
1999	498	468	966								
2000	10,491	481	10,972		688	688	10,491	1,169	11,660	5.9%	
2001	4,454	297	4,751	6,065	982	7,047	10,519	1,279	11,798	59.7%	62.6%
2002	1,820	89	1,909	6,064	71	6,135	7,884	160	8,044	76.3%	56.7%
2003	394	723	1,117	1,036	1,105	2,141	1,430	1,828	3,258	65.7%	60.3%
2004	6,536	671	7,207	2,876	204	3,080	9,412	875	10,287	29.9%	77.0%
2005	4,401	175	4,576	627	482	1,109	5,028	657	5,685	19.5%	83.7%
2006	1,510	121	1,631	1,622	111	1,733	3,132	232	3,364	51.5%	66.0%
2007	683	161	844	734	731	1,465	1,417	892	2,309	63.4%	61.2%
2008	988	232	1,220	2,157	957	3,114	3,145	1,189	4,334	71.9%	58.2%

2009	1,843	701	2,544	2,234	2,260	4,494	4,077	2,961	7,038	63.9%	61.0%
2010	2,436	413	2,849	4,524	1,001	5,525	6,960	1,414	8,374	66.0%	60.2%
2011	3,092	926	4,018	3,162	1,404	4,566	6,254	2,330	8,584	53.2%	65.3%
2012	2,359	191	2,550	2,661	265	2,926	5,020	456	5,476	53.4%	65.2%
2013	1,708	678	2,386	1,587	840	2,427	3,295	1,518	4,813	50.4%	66.5%
2014	3,099	685	3,784	2,150	794	2,944	5,249	1,479	6,728	43.8%	69.6%
2015	3,357	163	3,520	1,779	167	1,946	5,136	330	5,466	35.6%	73.7%
2016	2,070	266	2,336	1,198	705	1,903	3,268	971	4,239	44.9%	69.0%
2017	1,135	194	1,329	1,328	660	1,988	2,463	854	3,317	59.9%	62.5%
2018	500	33	533	1,033	233	1,266	1,533	266	1,799	70.4%	58.7%
2019	316	81	397	828	266	1,094	1,144	347	1,491	73.4%	57.7%
2020	497	56	553	746	341	1,087	1,243	397	1,640	66.3%	60.1%
2021	618	184	802	1,190	734	1,924	1,808	918	2,726	70.6%	58.6%
2022	1,575	120	1,695	1,521	333	1,854	3,096	453	3,549	52.2%	65.7%
Mean[3]	2,227	314	2,541	2,142	667	2,715	4,039	904	4,943	54.3%	64.5%

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

Both the CESRF integrated and segregated programs have now proceeded for several generations and we can evaluate actual outcomes relative to the hypothetical outcomes given in Figure 26 above. Results were presented in Waters et al. (2015) and empirically demonstrate that using managed gene flow (i.e, using only natural-origin fish for brood stock) reduced genetic divergence over time in the CESRF integrated (S-line) fish compared to the segregated (HC-line; hatchery-origin parents) fish (Figure 27). The actual results are remarkably consistent with the projected outcomes demonstrating that there is considerable merit to the concepts behind hatchery reform. While some detractors of hatchery supplementation choose to highlight the differences the CESRF program has found between hatchery and natural-origin fish such as those documented in Knudsen et al. (2006 and 2008), it is important to note that integrated hatchery-origin fish were never expected to be identical to wild fish (Figure 26), but rather similar enough to increase demographic abundance of natural spawners while minimizing risk, which is exactly what the results to date for this project demonstrate (Fast et al. 2015; Koch et al. 2022). Additional monitoring is required to understand and fully evaluate biological costs and benefits relative to using this type of management over the long-term (Fraser 2008). The YKFP is continuing its collaboration with University of Washington and NOAA scientists to further evaluate and associate genetic divergence results from Waters et al. (2015) with the phenotypic trait analyses in Knudsen et al. (2006 and 2008).

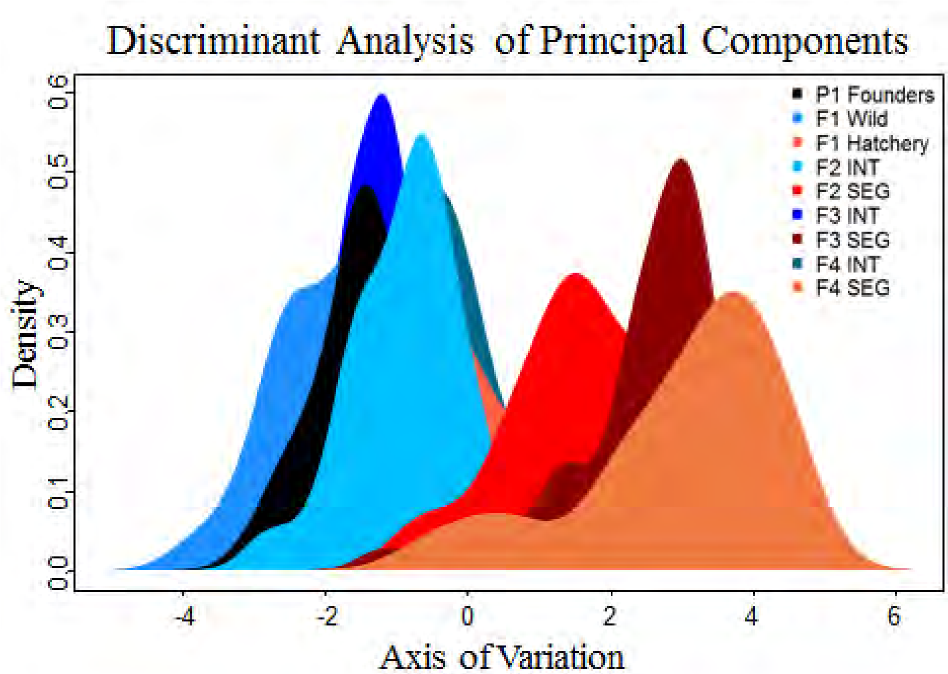


Figure 25. Estimated genetic divergence (variation) for integrated (INT blue), segregated (SEG red), and wild founder (black) spring Chinook in the CESRF program after 4 parental-generations of the hatchery program (P1=1998, F1=2002, F2=2006, F3=2010, F4=2014; updated from Figure 4 in Waters et al. 2015).

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

Predation Management and Predator Control

Avian Predation Index

Avian predators are capable of significantly depressing smolt production. The loss of wild spring Chinook salmon juveniles to various types of avian predators has long been suspected as a significant constraint on production and could limit the success of supplementation. Therefore, a long-standing objective of the YKFP has been to monitor, evaluate, and index the impact of avian predation on annual salmon and steelhead smolt production in the Yakima River basin. Accurate methods of indexing avian predation across years have been developed through river reach surveys (monitoringmethods.org; method 1151) within six reaches which cover approximately 70 miles of collecting point count estimates of piscivorous avian species in the lower portion of the Yakima River (see [2020 BPA annual report]). In 2023, additional effort was used to haze and collect observational count data primarily at two known avian hotspots on the Yakima River, Wanawish dam and Chandler fish bypass outfall pipe (Figure 1).

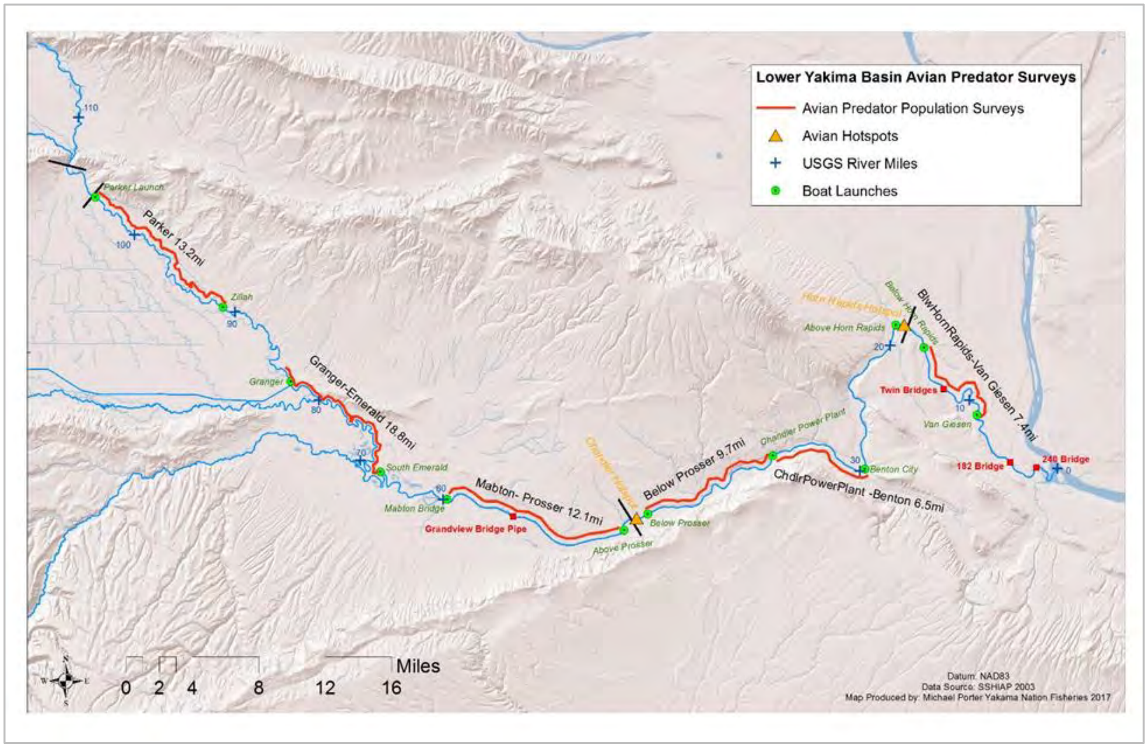


Figure 26. Avian "hotspot" locations and previous year's predator survey locations.

Methods:

In 2023, Yakama Nation staff observed then hazed piscivorous birds at two "hotspot" locations within the Yakima River basin including Chandler fish bypass outfall pipe (Chandler) and Wanawish Dam (Figure 1). Periodic counts were taken at Roza Dam throughout the season, but no hazing was conducted. Staff hazed at Wanawish and Chandler 3-5 days a week from mid-April through June during the smolt outmigration and 1-2 days a week in March, early April, and early July when few birds were in the area. Upon arrival on site, staff observed visually, or with 10x42 Vortex binoculars, piscivorous birds within study zones. Study sites were divided into distinct zones to monitor initial avian location and avian movement post hazing. Common piscivorous birds observed at these sites were: American white pelican, double-crested cormorant and California gull/ring-billed gulls; though many other avian species are observed in the Yakima River (Table 1). Data recorded included: date, site, observer, observer bank, and a total count of birds by species and behavior within each zone prior to hazing. Sex and age of birds were recorded if distinguishable. Next, staff would use various hazing methods in attempt to discourage birds from being in the area, then conduct a count of species within each zone. Hazing and harassment techniques included bangers, screamers, and whistler pyro technics, a green laser, and physical presence. Pyro technics were fired either at a 45° angle over the river or in a safe direction away from wildlife, persons or property. The green laser was flashed on and around the birds and physical presence was simply arriving on site and observing if birds reacted.

Table 1. Yakima River avian predators.

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

Hotspots and zones

Wanawish Dam on the Yakima River (rkm 30) is located in Benton County northwest of the town of West Richland. This dam was built to divert water for irrigation and spans over 150m wide with a 1-2m drop from the forebay to the spillway depending on flows conditions. In this study, Wanawish Dam study area was divided into six distinct zones and determined by orientation to the dam (Figure 2). Forebay 1 (FB1) was the zone 0-100 m upstream of the dam left bank to right bank. Forebay 2 (FB2) was the zone 100-200 m upstream of the dam from left bank to right bank. Spillway 1 LB (SW1 LB) was the zone 0-100 m downstream of the dam from center channel to left bank. Spillway 1 RB (SW1 RB) was the zone 0-100 m downstream of the dam from center channel to right bank. Spillway 2 (SW2) was the zone 100-460 m downstream of the dam from left bank to right bank. Any birds seen, but not listed in one of the above zones was recorded as outside the survey area (OSA).

Figure 27. Wanawish Dam hotspot zones.

Another significant avian hotspot is near Prosser Dam located on the Yakima River (rkm 74) in Yakima County, in the city of Prosser, and diverts water for irrigation. Fish moving downstream either navigate over the dam or are diverted down the Chandler canal into a juvenile fish monitoring facility, sampled on site, and released back into the river through a large 1m diameter pipe which spills into the river. The Chandler study area was divided into six distinct zones and determined by orientation to the juvenile outfall pipe (Figure 3). Above pipe 1 (AP1) was the zone 0-100 m upstream of the outfall pipe from left bank to right bank. Above pipe 2 (AP2) was the zone 100-200 m upstream of the outfall pipe from left bank to right bank. Below pipe 1 LB (BP1 LB) was the zone 0-100 m downstream of the outfall pipe from center channel to left bank; the outflow pipe spills into this zone. Below pipe 1 RB (BP1 RB) was the zone 0-100 m downstream of the outfall pipe from center channel to right bank. Below pipe 2 (BP2) was the zone 100-500 m downstream of the outfall pipe from left bank to right bank. Any birds seen, but not listed in one of the above zones was recorded as outside the survey area (OSA).

Figure 30. Chandler hotspot zones. Circle represents juvenile bypass outfall pipe.

In the upper Yakima River, there is another notable avian hotspot at Roza Dam. It is located on the Yakima River (rkm 206) in Kittitas County 16 km north of Yakima. The dam is 20 m tall and nearly 150 m wide and was built to divert water for irrigation and generate electricity. The Roza Dam study area was divided into three distinct zones and determined by orientation to the dam (Figure 4). Above dam (AD) was the zone 0-275 m upstream of the dam to the tip of the island from left bank to right bank. Below dam (BD) was the zone 0-200 m downstream of the dam to the train bridge from left bank to right back. Any birds seen, but not listed in one of the above zones was recorded as outside the survey area (OSA).

Figure 31. Roza dam hotspot zones.

Relationship between river flow and avian predation

Following the fish survey in the hotspot, we conducted additional investigations to ascertain whether the increased presence of avian predators in this area was linked to the river's flow. To do this, we acquired the daily river flow data for the Yakima River and the corresponding daily total avian predator counts, then analyzed their linear relationship.

Results and Discussion:
Avian distribution

Within 54 days of sampling at each site from March 1st through July 11th, 2023, a total of 1370 piscivorous avian species were observed and hazed at Yakima basin hotspots. Among them, 684 birds were observed at Wanawish while 684 were observed at Chandler (Table 2). The most dominant species observed in both locations was the American White Pelican with 576 and 430 respectively. Throughout the study period in 2023, the daily peak count at Wanawish, Chandler were 66, 40, respectively (Figure 5). Other species also present, but in smaller numbers at Chandler include: California Gull, Common Merganser, Double-crested Cormorant, Great Blue Heron, Black-crowned Night Heron, and Belted Kingfisher. Species at Wanawish in small numbers included all species seen at Chandler except the Black-crowned Night Heron, and Belted

Kingfisher. Peak observations of piscivorous avian species at Wanawish and Chandler were in the month of May where 52% and 40% of the total were seen throughout the study period (Table 3).

Table 27. Total piscivorous avian species observed at Chandler juvenile bypass and Wanawish Dam.

Area	AWPE	BAEA	BCHE	BEKI	COME	DCCO	GBHE	GREG	GULL	OSPR	Total
Chandler Pipe	430	1	5	1	119	40	79	2	7	2	686
Wanawish	576	2	0	0	23	33	2	3	39	6	684
Total	1006	3	5	1	142	73	81	5	46	8	1370

Table 28. **Total monthly piscivorous avian species observed at Chandler juvenile bypass and Wanawish Dam**.

Area	**Month**	**AWPE**	**BAEA**	**BCHE**	**BEKI**	**COME**	**DCCO**	**GBHE**	**GREG**	**GULL**	**OSPR**	**total**	**%**
Chandler Pi	March	0	0	0	0	42	0	9	0	0	0	51	7.434402
Chandler Pi	April	10	0	2	0	75	17	38	2	0	2	146	21.2828
Chandler Pi	May	83	1	1	1	1	14	21	0	0	0	122	17.78426
Chandler Pi	June	329	0	2	0	0	9	11	0	7	1	359	52.33236
Chandler Pi	July	8	0	0	0	0	0	0	0	0	0	8	1.166181
Total												686	
Area	**Month**	**AWPE**	**BAEA**	**BCHE**	**BEKI**	**COME**	**DCCO**	**GBHE**	**GREG**	**GULL**	**OSPR**	**Total**	**%**
Wanawish	March	13	0	0	0	5	0	0	0	0	0	18	2.635432
Wanawish	April	210	2	0	0	10	8	0	0	0	1	231	33.82138
Wanawish	May	256	0	0	0	0	5	1	0	14	1	277	40.55637
Wanawish	June	97	0	0	0	8	18	1	3	23	3	153	22.40117
Wanawish	July	0	0	0	0	0	2	0	0	1	1	4	0.585652
Total												683	

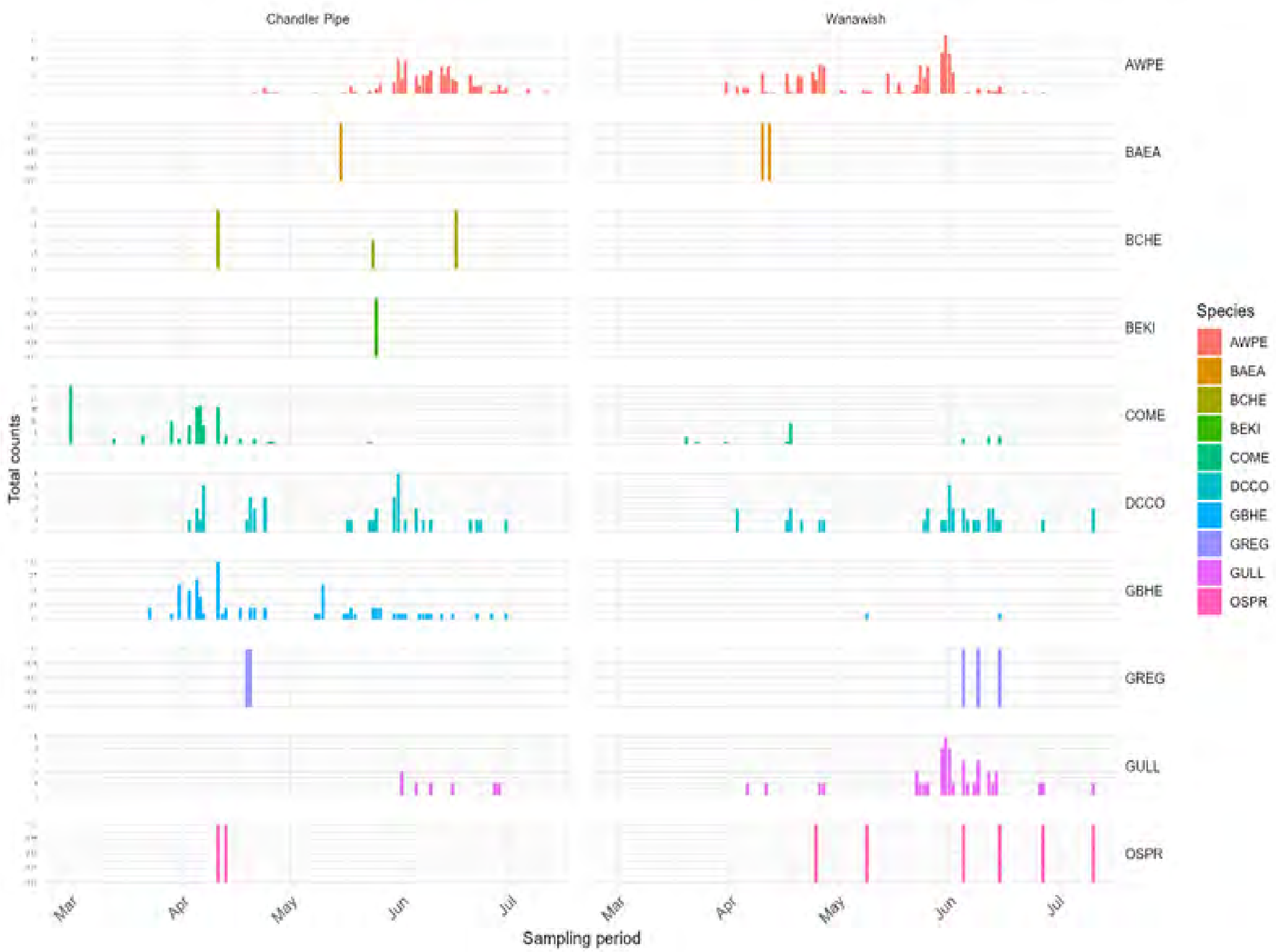


Figure 32. Daily bird count in the sampling period in both sampling areas for 2023

Relationship between bird counts and river flow

The overall bird counts varied between 0 and 66, while the river flow spanned from approximately 500 to 12000 cfs. Notably, higher bird counts were observed when the river flow was within a lower range with a slight peak at roughly 2500 cfs and continuing until river flow reached 4000 cfs for both areas. (Figure 6).

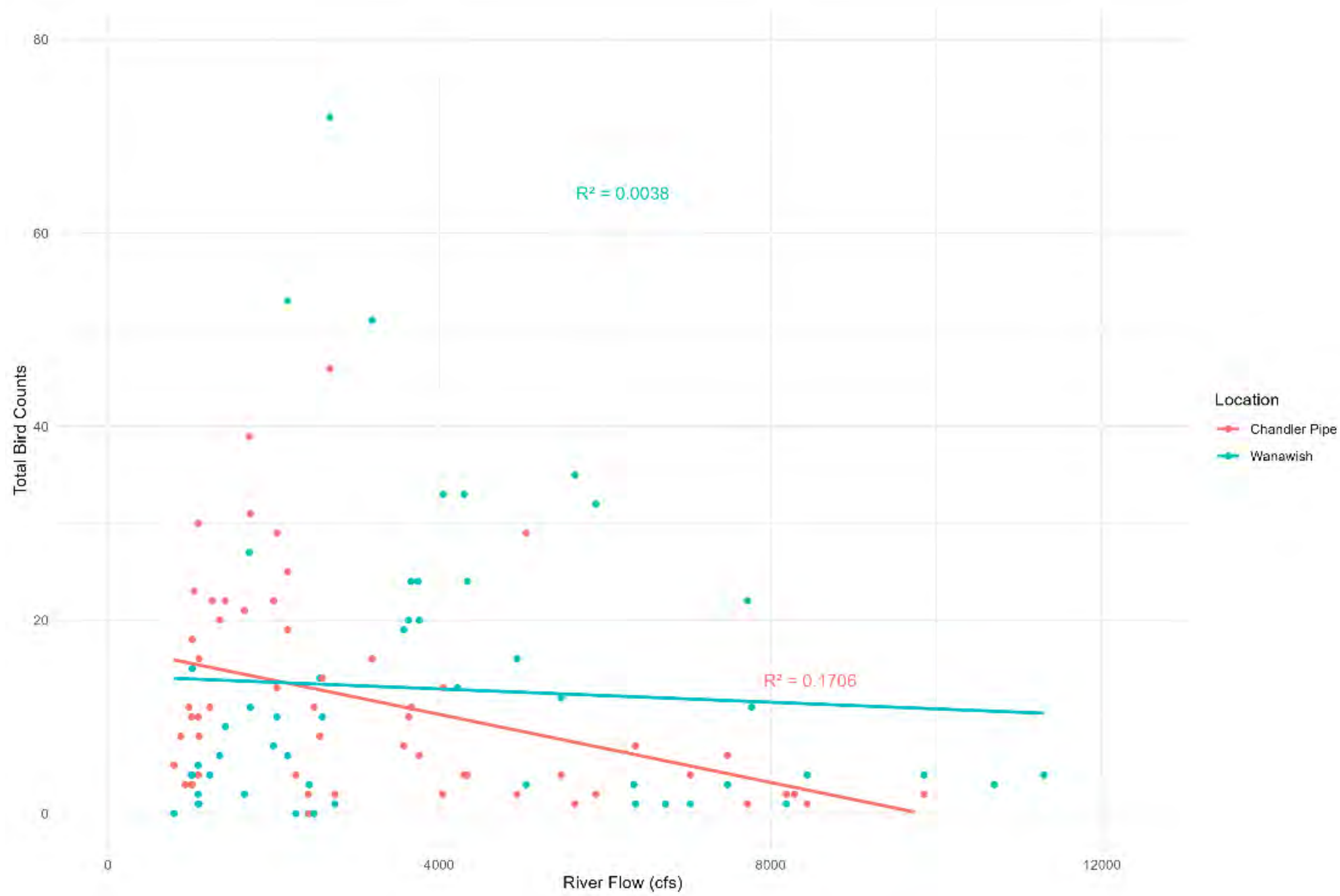


Figure 33. Relationship between river flow and avian species observed at study sites.

Smolts Consumed at Acclimation Sites

In addition to monitoring birds at the different hotspot locations Yakama Nation staff also periodically recorded observations of several different avian predatory species at the three Spring Chinook salmon acclimation sites in the upper Yakima River and its tributaries. Piscivorous bird surveys were conducted over a 3–5-month period in the winter and spring of 2023. The most common species of birds surveyed at acclimation sites were the Bald Eagle, Belted Kingfisher, Common Merganser, Great Blue Heron and Osprey. Due to the data being based on average observational counts which can vary by timing, day and location we only report the total estimated daily consumption of fish by each individual species encountered throughout the study period. Using the assumption that birds frequenting acclimation ponds are only consuming acclimating juvenile salmon, an average consumption rate can be determined. The average consumption rate can be calculated using the average number of birds at each site, daily energy requirements of the birds and the average size of juvenile salmon. For the Spring Chinook sites (Clark Flat, Easton and Jack Creek), it was estimated that these bird species together consumed 100 juvenile Chinook at Clark Flat. The birds observed were Bald Eagle, Belted Kingfisher, Great Blue Heron, and Osprey. Great Blue Herons had the highest consumption rate, consuming 42 juvenile Chinook. At Easton, it was estimated that 100 juvenile Chinook were consumed. The birds observed were Bald Eagle, Belted Kingfisher, Common Merganser, Great Blue Heron, and Osprey. Great Blue Herons had the highest consumption rates, consuming 50 juvenile Chinook. At Jack Creek, there were no birds observed and it was estimated that no juvenile Chinook were consumed. In 2023, these bird species together consumed 100 juvenile Chinook at Clark Flat, 100 juvenile Chinook at Easton, and no consumption of juvenile Chinook at Jack Creek. Table(4).

Table 29. **Total daily average bird counts and estimate of fish consumed (Note: No birds were consumed at jack creek in 2023)**

2023 SPRING CHINOOK ACCLIMATION SITES						
CLARK FLAT						
	AVG. # OF BIRDS	# FISH EATEN BY SPECIES	% OF FISH EATING BY SPECIES	% OF TOTAL FISH EATEN BY SITE	# DAYS OBSERVED	DAILY AVERAGE # OF BIRDS
BAEA	0.089868421	6.730785263	20.66608439	0.002511974	6	7
BEKI	1.612894737	11.70477711	35.93814123	0.004368302	41	122
GBHE	0.265789474	13.56722368	41.65656437	0.005063379	18	20
OSPR	0.013157895	0.566447368	1.739210012	0.000211402	1	1
TOTAL	*1.981710526*	*32.56923342*	*100*	*0.012155057*	*66*	*150*
EASTON						
	AVG. # OF BIRDS	# FISH EATEN BY SPECIES	% OF FISH EATING BY SPECIES	% OF TOTAL FISH EATEN BY SITE	# DAYS OBSERVED	DAILY AVERAGE # OF BIRDS
BAEA	0.037244898	2.789493878	22.45806049	0.001039007	7	4
BEKI	0.133979592	0.980194694	7.891493114	0.000365094	21	13
COME	0.032142857	1.8135	14.60038791	0.000675477	4	3
GBHE	0.121428571	6.248714286	50.30805213	0.002327467	16	12
OSPR	0.013571429	0.589	4.742006331	0.000219386	2	2
TOTAL	*0.338367347*	*12.42090286*	*99.99999998*	*0.004626431*	*50*	*34*
JACK CREEK						
	AVG. # OF BIRDS	# FISH EATEN BY SPECIES	% OF FISH EATING BY SPECIES	% OF TOTAL FISH EATEN BY SITE	# DAYS OBSERVED	DAILY AVERAGE # OF BIRDS
COME	0	0	0	0	0	0
TOTAL	*0*	*0*	*0*	*0*	*0*	*0*

Fish Predation Index and Predator Control

Fish predators are also identified as a significant factor contributing to the decline in 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 River basin 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:

In previous years, Yakama Nation conducted surveys in six river reaches (Figure 7), encompassing approximately 50 miles of the lower Yakima River. Among these reaches, Below Prosser and lower Yakima (Snively) were notable for having the highest abundance of piscivorous fish. Consequently, in 2022 and 2023 our survey efforts were focused to those specific reaches. Staff utilized jet boat and raft-based electrofishing through time to assess the spatial and temporal variations in fish abundance and distribution within these reaches. Additionally, sampling was conducted just above the Yakima River delta (above delta) and the east and west causeway of Bateman Island near the confluence at the Columbia River, however the above delta reach was not included in further analysis due to the small sample size. Each reach had two transects, or segments within each reach, and reaches were determined by dams, boat launches, or other distinguishing river features.

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

Data collected during each sampling event consisted of:

- Water Temperature, Dissolved Oxygen, Specific Conductivity gathered by a HACH 30qd water multi-meter
- Water Turbidity gathered by a HACH TSS Handheld Instrument
- River CFS gathered from Bureau of Reclamation gaging stations
- GPS transect start and end locations
- Electrode start and end times

- Numbers and species (Table 5) of all fish observed and their size class greater than or less than 100mm

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

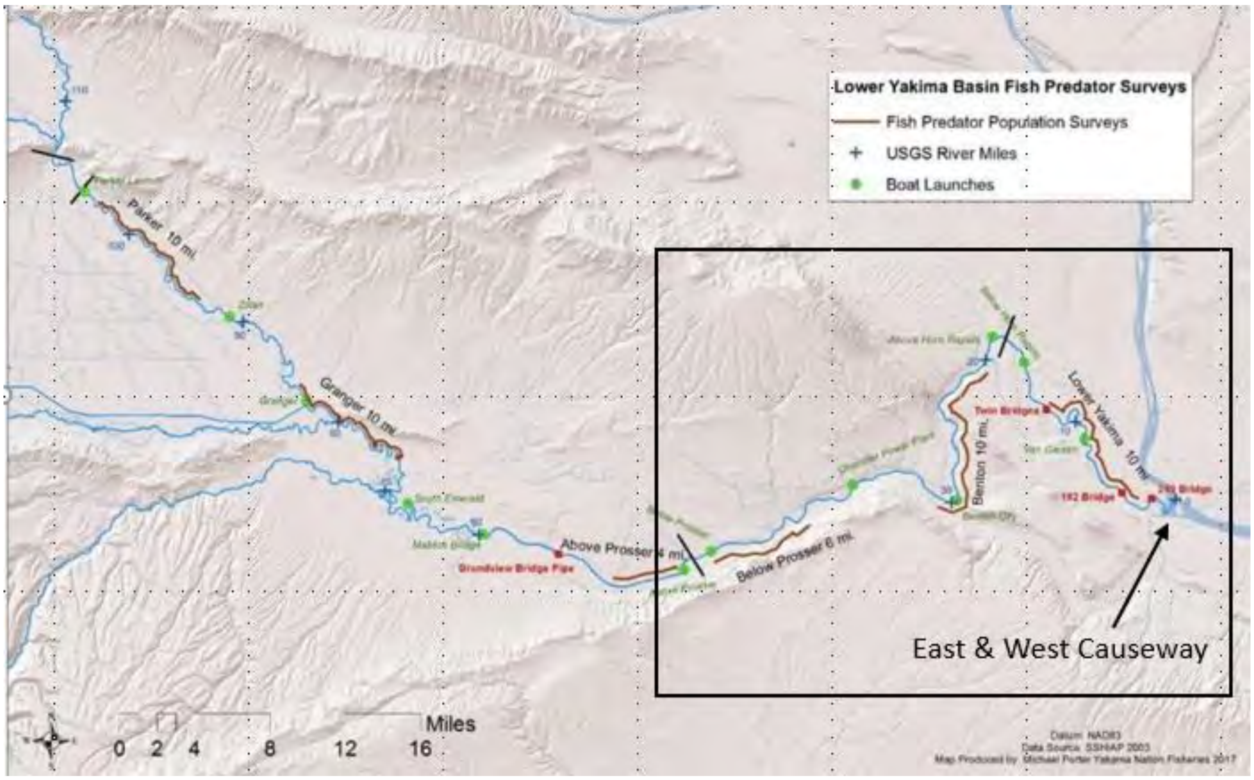


Figure 34. Fish Predator Survey Locations.

Beginning April 12th, crews sampled weekly as environmental conditions permitted until June 27th (Fish Predators Schei, monitoring methods 47 and Predator Reduction Mclellan, monitoring methods 438). Sampling was conducted using three different types of vessels and electrofishers. The Smith Root SR-16H electrofishing boat equipped with the 7.5 GPP electrofishing unit powered by a 6,000-W Kohler boat generator or a 16-foot aluminum jet boat equipped with a Smith Root VVP-15B electrofisher powered by a Honda EM3500S generator were used in the Snively reach, east causeway and west causeway reaches. Within the reach below Prosser, sampling was conducted with a 12-foot raft equipped with a Smith Root 1.5-KVA electrofisher powered by Honda EU2200i generator. Electrofishing settings were adjusted to continuous DC for an output of approximately 700 V and 9–12 A. These methods will be used to monitor native and nonnative species fish populations and abundance in the Yakima River.

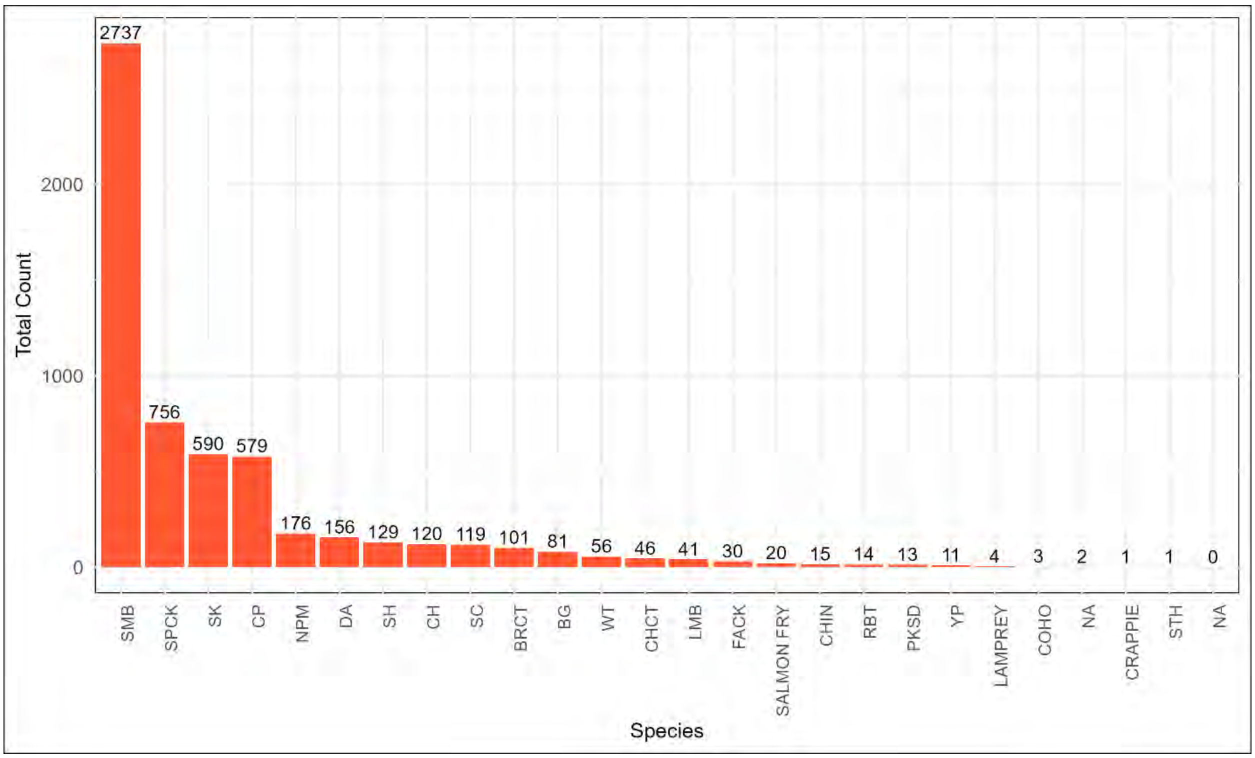
Table 5. Yakima River Fish Species

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

Results and Discussion:

During the sampling period in 2023, the below Prosser and Snively reaches were each sampled a total of 15 times and the west and east causeway were each sampled 6 times each. A total of 24 species were observed, including 8 fish predator species. The most encountered species of non-predatory fish was spring chinook with a total observed of (756). The species of predatory fish with the highest density was Smallmouth Bass (2,768). Considering the significant number of salmonid species naturally produced and those released by Yakama Nation Fisheries (spring Chinook, summer Chinook, fall Chinook, Coho, and Sockeye), there is reasonable concern of piscivorous fish predation impacts on anadromous salmonids. We expected to observe higher densities of salmonid species compared to predator species, however this did not appear to be the case for the locations sampled during our study period. The presence of predator fish species such as Smallmouth Bass and Northern Pikeminnow were seen in high densities (Figure 8).

Figure 35. Species abundance in 2023. Values displayed represent total abundance of each species.



When comparing predator-prey densities in the Yakima River by reach (Figure 34), we consistently found high densities of Smallmouth Bass in all four sampling areas while the Spring Chinook were concentrated only two of the four (below Prosser, and Snively. All four reaches saw densities of fish predator species higher that of salmonid species. For example, in the below Prosser reach the total abundance of SMB was 1448, whereas the abundance of spring chinook was only 516. In the Snively Reach, the abundance of SMB (1041) was much higher than the total abundance of spring chinook (219), which may indicate significant predation pressure on the salmonid species.

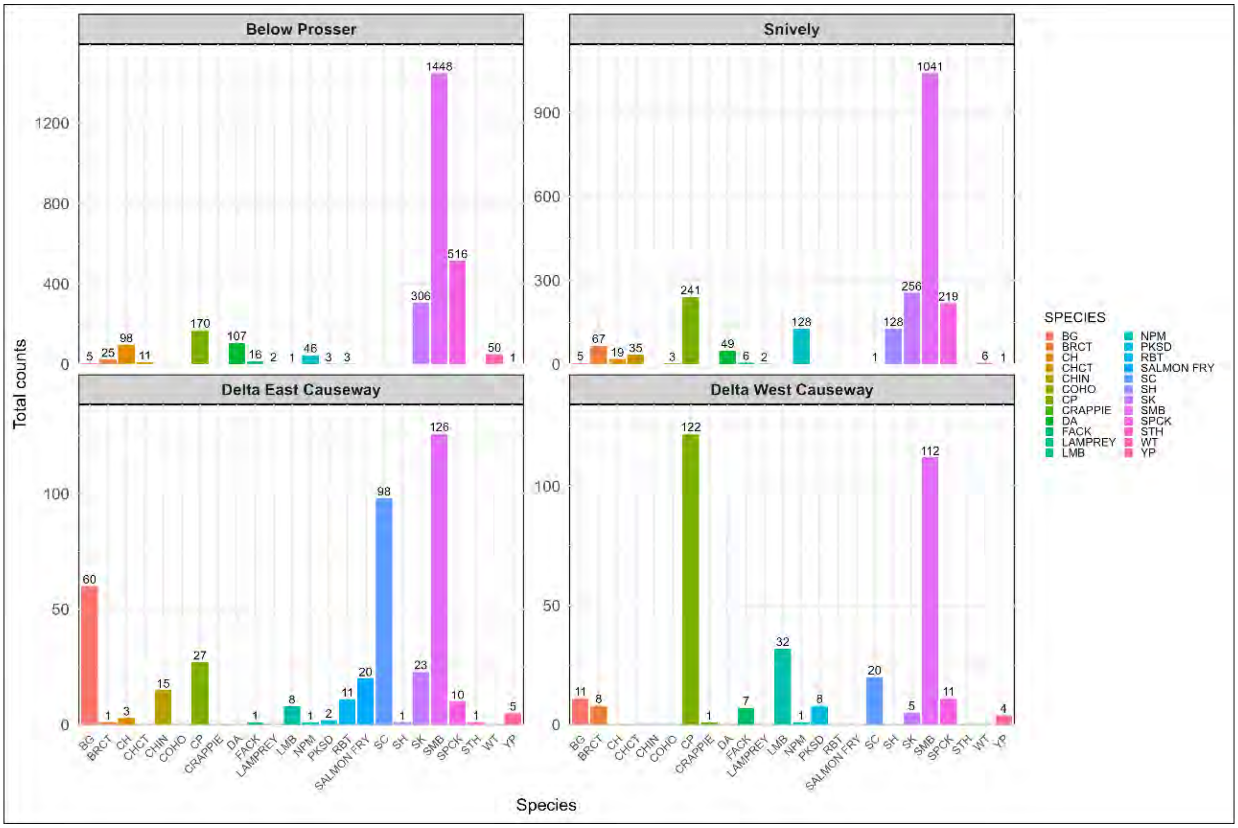


Figure 36. Reach specific species abundance during sampling period 2023.

Throughout the spring sampling period until early July, the three most abundant predatory species Smallmouth Bass, Northern Pikeminnow, and Channel Catfish were observed consistently in the Yakima River basin (Figure 10), with a higher presence observed as the season progressed. These findings of consistent piscivorous fish presence during the smolt migration highlight the importance of understanding and managing predator-prey dynamics in the Yakima River basin to ensure the successful survival of salmonid species. Further analysis and consideration of these predator-prey interactions are necessary for effective conservation and management strategies.

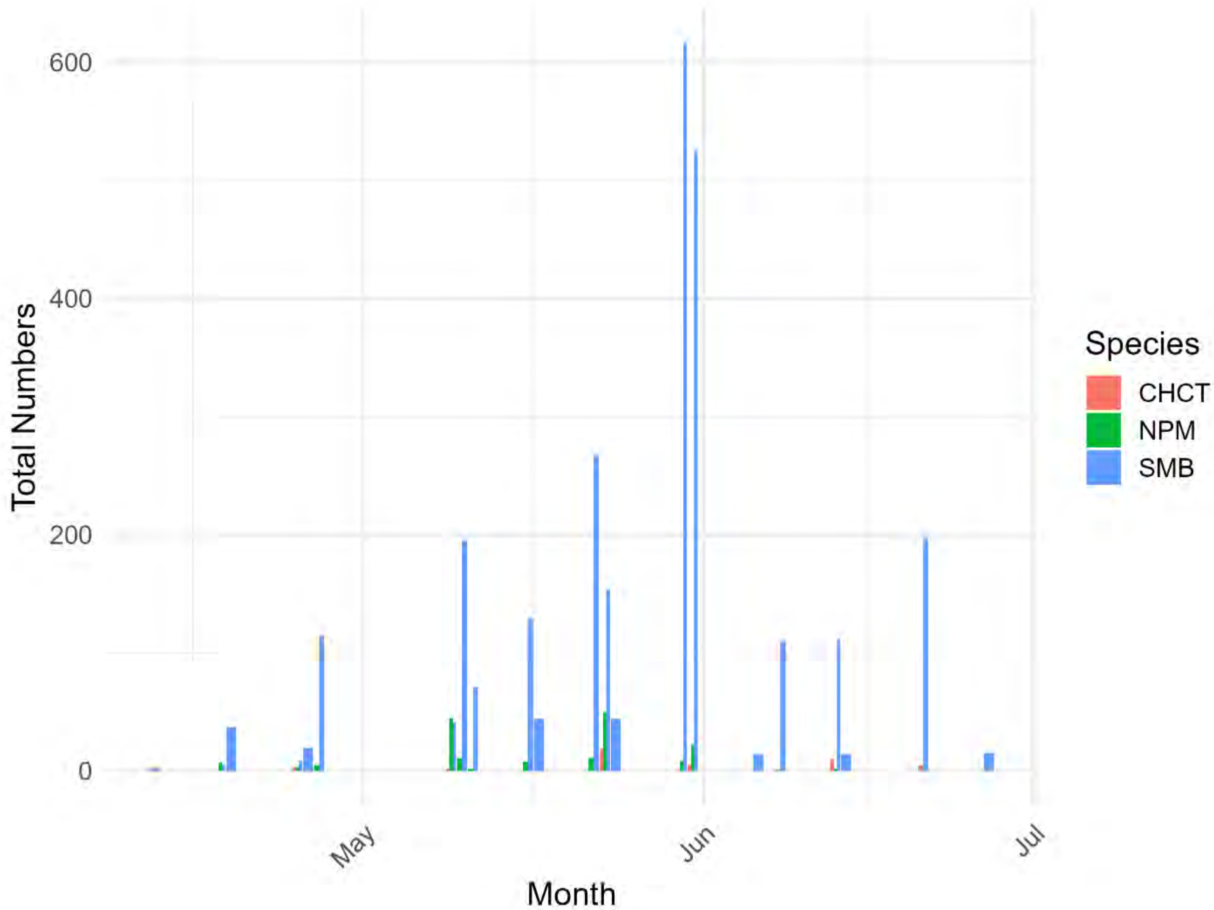


Figure 37. Total abundance of primary predatory fish species observed by the sampling date in 2023.

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 (Cone and Ridlington 1996) that the region knew exactly what it was doing to natural salmon productivity when settlement and development of the region began to increase, even as early as the middle 1800s.

3. We need to be patient. Hatchery reform is a relatively new concept and results for longer term 20-25 year efforts such as the Idaho Supplementation Studies (ISS;

Venditti et al. 2017) and CESRF program (Fast et al. 2015) are only now becoming available. These programs empirically support the idea that hatchery reform principles can provide additional fish to fisheries and improve fitness over traditional hatchery rearing concepts.

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.

8. Finally, we concur with the ISRP (ISRP 2022-1) that there are "implications of flat funding on projects being able to implement their proposed actions". The Yakama Nation will prioritize available funding to implement actions that have the best potential for improving fish survival and returning fish to fisheries and to spawning grounds. While we fully intend to continue our monitoring and evaluation efforts to inform future actions, limited funding will limit our future ability to report on actions to the extent we have in this report in prior years.

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APPENDICES

A. Use of Data and Products

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

C. 2022 Annual Chandler Certification for Out-migrating Spring (Yearling) Chinook Smolts

D. Juvenile Coho outmigration survival and adult Coho returns to the Yakima Basin, 1999-2022

E. Juvenile Outmigration Survival of Yakima Basin Summer Chinook Smolts to Prosser and McNary Dams, 2009-2022

Appendix A: Use of Data & Products

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

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

Fish Passage Center
Yakama Nation Fisheries website
RMIS - Regional Mark Information System
Columbia River DART
StreamNet Database
cbfish.org (see projects 1995-063-25 and 1988-120-25)
PTAGIS Website
Washington State SaSI

A system has been developed that serves Yakima Basin adult abundance and trap sampling (requires login) data for the Prosser and Roza data sets. This system can be accessed at: https://www.yakamafish-nsn.gov/fish-data.

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

- Prosser and Roza dam daily count and trap sample (requires login) data https://www.yakamafish-nsn.gov/fish-data.
- Integration of PIT and CWT release and recovery data with PTAGIS, RMIS, and Fish Passage Center databases (available to the public)
- BPA quarterly and annual reports (e.g., PISCES, available to the public via CBfish.org)
- NPCC project proposals (available to the public via nwcouncil.org)
- Yakima Basin conference presentations and project technical reports (available to the public)
- Yakima Basin Status and Trends Annual Reports (available to the public)

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

Appendix B: Summary of Data Collected by the Yakama Nation

relative to
Yakima River Spring Chinook Salmon and the
Cle Elum Spring Chinook Supplementation and Research Facility

2023 Annual Report

Draft, May. 14, 2024

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

The core project team includes the following individuals: Mark Johnston, Bill Bosch, Shubha Pandit, Andrew Matala, Daylen Isaac, Chris Frederiksen, Michael Porter, Joe Hoptowit, and a number of technicians from the YN; Charles Strom and a number of assistants from the CESRF; Anthony Fritts, Gabe Temple, Christopher Johnson, and a number of assistants from the WDFW; the USFWS for fish health related analyses; 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, Dave Fast, David Lind, Paul Huffman, Bruce Watson, Joel Hubble, Bill Hopley, Todd Pearsons, Steve Schroder, Curt Knudsen, Doug Neeley and Craig Busack. These individuals put in countless hours of hard work during the planning, design, and implementation of this project. Their contributions helped to lay a solid foundation for this project and our monitoring and evaluation efforts. Dan Barrett (retired) served as the manager of the CESRF from 1997-2002. He helped to lay a solid foundation for the critical work done day in and day out at the Cle Elum facility.

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

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

Abstract

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

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

This report documents data collected from Yakama Nation tasks related to monitoring and evaluation of the CESRF and its effect on natural populations of spring Chinook in the Yakima Basin through 2021. 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 create a release target range of 720,000-810,000 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. Subsequent broods have generally tested survival using different types of feed treatment or used a standard treatment in all raceways. With guidance and input from the NPCC and the Independent Scientific Review Panel (ISRP) in 2001, the Naches subbasin population of spring Chinook was established as a wild/natural control. A hatchery control line at the CESRF was also established with the first brood production for this line collected in 2002. Please refer to the project's "Supplementation Monitoring Plan" (Chapter 7 in 2005 annual report on project genetic studies) for additional information regarding these control lines.

Facility Descriptions

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

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

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

Yakima River Basin Overview

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

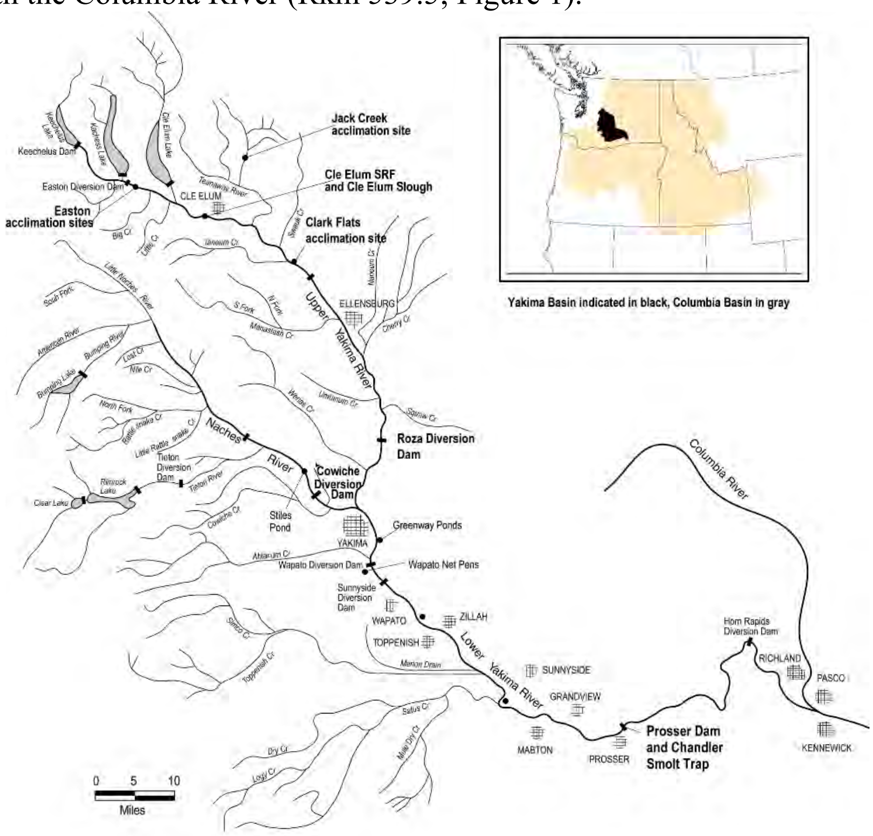


Figure 28. Yakima River Basin.

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, and the Yakima Basin Integrated Plan 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).

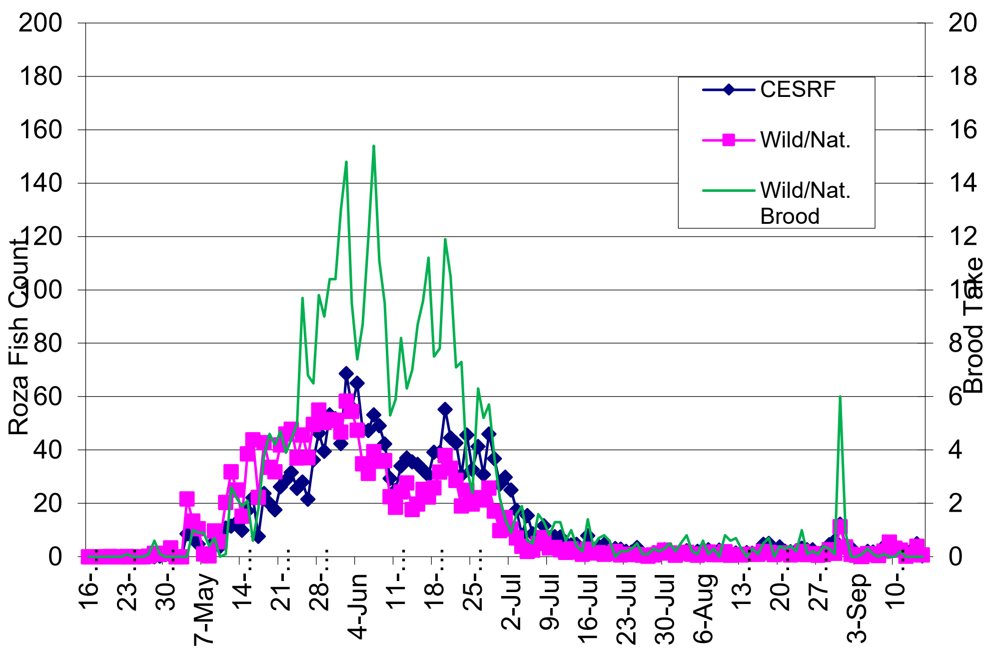


Figure 29. Mean spring Chinook run timing and broodstock collection at Roza Dam, 2014-2023.

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. Since 2015, the spring Chinook return has been impeded by thermal barriers in the lower Yakima River as warmer air temperatures combined with reduced summer and fall flows have increased water temperatures. Mean daily water temperatures near Prosser (rkm 76 from the mouth of the Yakima R.) have exceeded 68° F on several days between June and September during these years (source U.S. BOR hydromet database). This may have caused a large number of fish to stray or be delayed in their migration above Roza Dam.

Table 30. Counts of wild/natural spring Chinook (including jacks), brood collection, and brood representation of wild/natural run at Roza Dam, 1997 – present.

				Portion of run collected:[1]			Portion of collection from:[2]		
Year	Trap Count	Brood Take	Brood %	Early[3]	Middle[3]	Late[3]	Early[3]	Middle[3]	Late[3]
1997	1,445	261	18.1%	26.4%	17.6%	17.7%	7.3%	83.1%	9.6%
1998	795	408	51.3%	51.1%	51.3%	51.9%	5.6%	84.3%	10.0%
1999	1,704	738	43.3%	44.6%	44.1%	35.9%	5.6%	86.3%	8.1%
2000	11,639	567	4.9%	10.7%	4.5%	4.4%	12.5%	77.8%	9.7%
2001	5,346	595	11.1%	6.9%	11.4%	10.7%	3.0%	87.7%	9.2%
2002	2,538	629	24.8%	15.7%	25.2%	26.1%	3.2%	86.3%	10.5%
2003	1,558	441	28.3%	52.5%	25.9%	36.4%	9.5%	77.8%	12.7%
2004	7,804	597	7.6%	2.6%	7.4%	12.8%	2.0%	81.6%	16.4%
2005	5,086	510	10.0%	2.2%	9.5%	21.9%	1.3%	77.0%	21.7%
2006	2,050	419	20.4%	48.5%	22.2%	41.0%	9.1%	75.1%	15.8%
2007	1,293	449	34.7%	25.0%	34.4%	60.6%	3.2%	80.0%	16.9%
2008	1,677	457	27.3%	57.7%	26.7%	32.4%	9.3%	79.0%	11.6%
2009	3,030	486	16.0%	10.0%	14.1%	35.9%	3.5%	73.9%	22.6%
2010	3,185	336	10.5%	6.4%	15.0%	22.5%	2.0%	82.6%	15.3%
2011	4,395	377	8.6%	11.3%	9.2%	21.3%	5.6%	73.2%	21.2%
2012	2,924	374	12.8%	1.9%	12.3%	27.4%	1.1%	79.9%	19.0%
2013	2,784	398	14.3%	18.5%	13.0%	22.0%	9.5%	75.1%	15.3%
2014	4,168	384	9.2%	4.8%	8.6%	16.9%	2.3%	80.5%	17.1%
2015	3,962	442	11.2%	3.1%	8.2%	40.6%	2.0%	59.9%	38.1%
2016	2,712	376	13.9%	5.3%	14.8%	18.6%	2.5%	84.7%	12.9%
2017	1,711	382	22.3%	53.6%	19.0%	45.4%	11.4%	69.9%	18.7%
2018	827	294	35.6%	3.0%	33.7%	87.6%	0.3%	75.1%	24.6%
2019	703	306	43.5%	48.1%	46.3%	29.1%	8.3%	84.3%	7.3%
2020	958	405	42.3%	47.7%	48.1%	15.9%	4.9%	91.1%	4.0%
2021	1,214	412	33.9%	49.3%	40.8%	0.0%	7.7%	92.3%	0.0%
2022	2,072	377	18.2%	16.4%	20.3%	10.4%	5.2%	88.5%	6.3%
2023	1,046	428	40.9%	32.5%	45.6%	4.5%	3.0%	95.8%	1.2%

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

	Wild/Natural (NoR)			CESRF (HoR)			Total				
Year	Adults	Jacks	Total	Adults	Jacks	Total	Adults	Jacks	Total	pHOS[1]	PNI[1]
1982			1,146								
1983			1,007								
1984			1,535								
1985			2,331								
1986			3,251								
1987			1,734								
1988			1,340								
1989			2,331								
1990			2,016								
1991			*1,583*[2]								
1992			3,009								
1993			1,869								
1994			563								
1995			355								
1996			1,631								
1997	1,141	43	1,184								
1998	369	18	387								
1999	498	468	966								
2000	10,491	481	10,972		688	688	10,491	1,169	11,660	5.9%	
2001	4,454	297	4,751	6,065	982	7,047	10,519	1,279	11,798	59.7%	62.6%
2002	1,820	89	1,909	6,064	71	6,135	7,884	160	8,044	76.3%	56.7%
2003	394	723	1,117	1,036	1,105	2,141	1,430	1,828	3,258	65.7%	60.3%
2004	6,536	671	7,207	2,876	204	3,080	9,412	875	10,287	29.9%	77.0%
2005	4,401	175	4,576	627	482	1,109	5,028	657	5,685	19.5%	83.7%
2006	1,510	121	1,631	1,622	111	1,733	3,132	232	3,364	51.5%	66.0%
2007	683	161	844	734	731	1,465	1,417	892	2,309	63.4%	61.2%
2008	988	232	1,220	2,157	957	3,114	3,145	1,189	4,334	71.9%	58.2%
2009	1,843	701	2,544	2,234	2,260	4,494	4,077	2,961	7,038	63.9%	61.0%

2010	2,436	413	2,849	4,524	1,001	5,525	6,960	1,414	8,374	66.0%	60.2%
2011	3,092	926	4,018	3,162	1,404	4,566	6,254	2,330	8,584	53.2%	65.3%
2012	2,359	191	2,550	2,661	265	2,926	5,020	456	5,476	53.4%	65.2%
2013	1,708	678	2,386	1,587	840	2,427	3,295	1,518	4,813	50.4%	66.5%
2014	3,099	685	3,784	2,150	794	2,944	5,249	1,479	6,728	43.8%	69.6%
2015	3,357	163	3,520	1,779	167	1,946	5,136	330	5,466	35.6%	73.7%
2016	2,070	266	2,336	1,198	705	1,903	3,268	971	4,239	44.9%	69.0%
2017	1,135	194	1,329	1,328	660	1,988	2,463	854	3,317	59.9%	62.5%
2018	500	33	533	1,033	233	1,266	1,533	266	1,799	70.4%	58.7%
2019	316	81	397	828	266	1,094	1,144	347	1,491	73.4%	57.7%
2020	497	56	553	746	341	1,087	1,243	397	1,640	66.3%	60.1%
2021	618	184	802	1,190	734	1,924	1,808	918	2,726	70.6%	58.6%
2022	1,575	120	1,695	1,521	333	1,854	3,096	453	3,549	52.2%	65.7%
2023	565	53	618	1,014	483	1,497	1,579	536	2,115	70.8%	58.6%
Mean[3]	2,165	305	2,470	2,093	659	2,665	3,948	890	4,838	54.9%	64.3%

4. Proportion Natural Influence (including jacks) 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).
5. This is a rough estimate since Roza counts are not available for 1991.
6. 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 32. Yakima River spring Chinook run (CESRF and wild, adults and jacks combined) reconstruction, 1993-present.

Year	River Mouth Run Size[1] Adults	Jacks	Total	Harvest Below Prosser	Prosser Count	Harvest Above Prosser	Spawners Below Roza[2]	Roza Count	Roza Removals[3]	Est. Escapement Upper Y.R.[4]	Naches[5]	Redd Counts Upper Y.R.	Naches
1993	3,800	119	3,919	44	3,875	85	56	1,869	0	1,869	1,865	637	554
1994	1,282	20	1,302	0	1,302	25	10	563	0	563	704	285	272
1995	526	140	666	0	666	79	9	355	0	355	223	114	104
1996	3,060	119	3,179	100	3,079	375	26	1,631	0	1,631	1,047	801	184
1997	3,092	81	3,173	0	3,173	575	20	1,445	261	1,184	1,133	413	339
1998	1,771	132	1,903	0	1,903	188	3	795	408	387	917	147	330
1999	1,513	1,268	2,781	8	2,773	596	55	1,704	738	966	418	212	186
2000	17,519	1,582	19,101	90	19,011	2,368	204	12,327	667	11,660	4,112	3,770	888
2001	21,225	2,040	23,265	1,793	21,472	2,838	286	12,516	718	11,798	5,829	3,226	1,192
2002	14,616	483	15,099	328	14,771	2,780	29	8,922	878	8,044	3,041	2,816	943
2003	4,868	2,089	6,957	59	6,898	381	83	3,842	584	3,258	2,592	868	935
2004	13,974	1,315	15,289	135	15,154	1,544	90	11,005	718	10,287	2,515	3,414	719
2005	8,059	699	8,758	34	8,724	440	28	6,352	667	5,685	1,904	2,009	574
2006	5,951	363	6,314	0	6,314	600	14	4,028	664	3,364	1,672	1,245	447
2007	2,968	1,335	4,303	10	4,293	269	13	3,025	716	2,309	986	722	313
2008	6,615	1,983	8,598	539	8,059	993	9	5,478	1,144	4,334	1,578	1,372	495
2009	7,441	4,679	12,120	1,517	10,603	836	18	8,633	1,595	7,038	1,117	1,575	482
2010	11,027	2,114	13,142	156	12,986	1,585	9	9,900	1,526	8,374	1,491	2,668	552
2011	13,398	4,561	17,960	909	17,051	3,471	0	10,520	1,936	8,584	3,060	1,898	580
2012	11,083	970	12,053	1,331	10,722	1,989	7	6,826	1,350	5,476	1,900	1,468	811
2013	7,101	3,144	10,245	1,191	9,054	1,462	171	6,053	1,240	4,813	1,369	648	376
2014	8,850	2,472	11,322	221	11,101	1,950	23	7,997	1,269	6,728	1,130	1,149	379
2015	8,795	556	9,351	83	9,268	732	0	6,433	967	5,466	2,103	1,321	614
2016	5,517	1,399	6,916	24	6,892	420	42	5,098	859	4,239	1,332	611	366
2017	5,462	1,701	7,163	122	7,041	1,150	25	4,193	876	3,317	1,673	539	293
2018	3,156	448	3,605	251	3,353	297	18	2,404	605	1,799	634	348	128
2019	1,756	466	2,222	0	2,222	40	17	2,007	516	1,491	158	235	31
2020	2,833	529	3,362	24	3,338	44	24	2,211	571	1,640	1,059	237	146
2021	2,924	998	3,922	0	3,922	16	37	3,274	548	2,726	594	256	188
2022	5,431	724	6,155	0	6,155	471	26	4,410	861	3,549	1,248	470	330
2023	2,673	661	3,334	0	3,334	177	38	2,862	747	2,115	257	335	61

Mean[6]	4,740	995	5,735	73	5,663	530	25	4,089	782	3,307	1,019	553	254

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.
6. Recent 10-year average (2014-2023).

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

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Total	Returns/ Spawner
1986	3,960	171	2,574	149	2,893	0.73
1987	2,003	53	1,571	109	1,733	0.87
1988	1,400	53	3,138	132	3,323	2.37
1989	2,466	68	1,779	9	1,856	0.75
1990	2,298	79	566	0	645	0.28
1991	1,713	9	326	22	358	0.21
1992	3,048	87	1,861	95	2,043	0.67
1993	1,925	66	1,606	57	1,729	0.90
1994	573	60	737	92	890	1.55
1995	364	59	1,036	129	1,224	3.36
1996	1,657	1,059	12,882	630	14,571	8.79
1997	1,204	621	5,837	155	6,613	5.49
1998	390	434	2,803	145	3,381	8.68
1999	1,021[1]	164	722	45	930	0.91
2000	11,864	856	7,689	127	8,672	0.73
2001	12,087	775	5,074	222	6,071	0.50
2002	8,073	224	1,875	148	2,247	0.28
2003	3,341	158	1,036	63	1,257	0.38
2004	10,377	207	1,547	75	1,828	0.18
2005	5,713	293	2,630	14	2,936	0.51
2006	3,378	868	2,887	133	3,888	1.15
2007	2,322	456	3,976	65	4,498	1.94
2008	4,343	1,135	3,410	123	4,668	1.07
2009	7,056	283	2,572	109	2,964	0.42
2010	8,383	923	3,854	59	4,836	0.58
2011	8,584	832	3,908	144	4,883	0.57
2012	5,483	197	2,445	20	2,662	0.49
2013	4,984	299	1,622	36	1,957	0.39
2014	6,751	241	814	12	1,067	0.16
2015	5,466	66	620	14	701	0.13
2016	4,281	99	905	52	1,056	0.25
2017	3,342	75	994	14	1,082	0.32
2018	1,817	201	2,012	42[2]	2,255[2]	1.24[2]

2019	1,508	136	1,010[2]			
2020	1,664	79[2]				
2021	2,763					
2022	3,574					
2023	2,153[2]					
Mean	3,941	313	2,567	100	2,984	1.38

3. The geometric mean jack (age-3) proportion of spawning escapement from 1999-2023 was 0.17.
4. Preliminary.

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

Brood	Estimated	Estimated Yakima R. Mouth Returns					Returns/
Year	Spawners	Age-3	Age-4	Age-5	Age-6	Total	Spawner
1987	1,162	27	183	197	0	407	0.35
1988	1,340	32	682	828	0	1,542	1.15
1989	992	28	331	306	0	665	0.67
1990	954	24	170	74	0	269	0.28
1991	706	7	37	121	57	222	0.31
1992	852	29	877	285	0	1,191	1.40
1993	1,145	45	593	372	0	1,010	0.88
1994	474	14	164	164	0	343	0.72
1995	124	40	164	251	0	455	3.66
1996	887	179	3,983	1,620	0	5,782	6.52
1997	762	207	3,081	708	0	3,996	5.24
1998	503	245	1,460	1,128	0	2,833	5.63
1999	358[1]	113	322	190	0	626	1.75
2000	3,862	71	2,060	215	0	2,346	0.61
2001	3,912	126	1,254	471	0	1,850	0.47
2002	1,861	59	753	153	0	965	0.52
2003	1,400	52	237	175	0	464	0.33
2004	2,197	107	875	218	0	1,199	0.55
2005	1,439	167	653	116	0	936	0.65
2006	1,163	192	838	254	0	1,283	1.10
2007	463	125	1,649	514	0	2,288	4.94
2008	1,074	414	827	290	0	1,531	1.42
2009	903	84	448	65	0	597	0.66
2010	1,024	209	653	198	0	1,059	1.03
2011	1,942	137	1,088	305	0	1,530	0.79
2012	1,110	64	419	260	0	743	0.67
2013	750	110	660	148	0	919	1.23
2014	746	142	376	13	0	532	0.71
2015	1,285	26	34	206	0	266	0.21
2016	790	6	523	89	0	617[2]	0.78
2017	971	32	225	139	0	396	0.41
2018	500	37	353	37[2]		427[2]	0.85[2]
2019	51	27	94[2]				

2020	740	13[2]					
2021	415						
2022	872						
2023	1,792						
Mean	1,091	95	779	330	3	1,230	1.49

1. The geometric mean jack (age-3) proportion of spawning escapement from 1999-2022 was 0.09.
2. Preliminary.

Table 35. Adult-to-adult productivity indices for American River wild/natural stock.

Brood	Estimated	Estimated Yakima R. Mouth Returns					Returns/
Year	Spawners	Age-3	Age-4	Age-5	Age-6	Total	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	127	0	378	0.81
2006	509	45	308	451	0	805	1.58
2007	523	57	645	493	0	1,194	2.28
2008	504	239	461	465	0	1,165	2.31
2009	213	60	143	44	0	247	1.16
2010	467	172	326	173	0	671	1.44
2011	1,118	71	646	236	0	953	0.85
2012	789	41	261	253	0	555	0.70
2013	619	76	412	53	0	542	0.88
2014	385	103	87	37	0	227	0.59
2015	819	7	61	120	0	188	0.23
2016	542	12	195	84	0	291	0.54
2017	703	14	144	280	0	438	0.62
2018	134	27	457	45[1]		529[1]	3.95[1]
2019	107	40	74[1]				
2020	319	11[1]					
2021	179						
2022	376						
2023	77[1]						
Mean	521	49	264	273	1	594	1.61

3. Preliminary.

Table 36. Adult-to-adult productivity indices for Naches/American aggregate (wild/natural) population.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns Age-3	Age-4	Age-5	Age-6	Total	Returns/ Spawner
1984	570	164	1,109	1,080	0	2,354	4.13
1985	1,020	213	667	931	0	1,811	1.77
1986	4,123	103	670	852	31	1,657	0.40
1987	1,729	39	231	400	0	669	0.39
1988	2,167	51	815	1,557	11	2,434	1.12
1989	1,517	39	332	371	0	741	0.49
1990	1,380	40	326	168	0	533	0.39
1991	1,121	10	32	144	127	314	0.28
1992	1,188	52	1,034	661	0	1,747	1.47
1993	1,865	53	603	817	17	1,489	0.80
1994	704	21	160	167	0	348	0.49
1995	223	73	201	498	0	771	3.46
1996	1,047	209	4,010	2,359	0	6,579	6.29
1997	1,133	220	4,644	1,377	0	6,241	5.51
1998	917	364	2,167	2,316	12	4,859	5.30
1999	418[1]	185	369	279	0	833	1.99
2000	4,112	131	2,286	346	0	2,762	0.67
2001	5,829	144	1,598	785	0	2,526	0.43
2002	3,041	78	975	443	0	1,496	0.49
2003	2,592	75	387	1,028	0	1,489	0.57
2004	2,515	227	514	232	0	973	0.39
2005	1,904	246	845	268	0	1,359	0.71
2006	1,672	237	1,120	759	0	2,117	1.27
2007	986	182	2,239	1,033	0	3,454	3.50
2008	1,578	653	1,262	803	0	2,718	1.72
2009	1,117	144	542	116	0	802	0.72
2010	1,491	381	972	412	0	1,766	1.18
2011	3,060	208	1,693	559	0	2,459	0.80
2012	1,900	105	662	540	0	1,307	0.69
2013	1,369	186	1,046	226	0	1,459	1.07
2014	1,130	245	439	49	0	733	0.65
2015	2,103	33	96	355	0	484	0.23
2016	1,332	18	688	169	0	875	0.66
2017	1,673	46	372	418[2]	0	8372	0.50[2]
2018	634	64	811[2]	85[2]		960	1.51
2019	158	66	165				
2020	1,059	24[2]					
2021	594						
2022	1,249						
2023	257						
Mean	1,612	144	1,002	646	6	1,827	1.49

1. The geometric mean jack (age-3) proportion of spawning escapement from 1999-2022 was 0.09.

2. Preliminary.

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

Brood	Estimated	Estimated Yakima R. Mouth Returns				Returns/
Year	Spawners	Age-3	Age-4	Age-5	Total	Spawner
1997	261	741	7,753	176	8,670	33.22
1998	408	1,242	7,939	602	9,782	23.98
1999	738[1]	134	714	16	864	1.17
2000	567	1,103	3,647	70	4,819	8.50
2001	595	396	845	9	1,251	2.10
2002	629	345	1,886	69	2,300	3.66
2003	441	121	800	12	932	2.11
2004	597	805	3,101	116	4,022	6.74
2005	510	1,305	3,052	21	4,378	8.58
2006	419	3,038	5,812	264	9,114	21.75
2007	449	1,277	5,174	108	6,558	14.61
2008	457	2,344	4,567	65	6,976	15.27
2009	486	461	2,663	58	3,181	6.55
2010	336	1,495	3,183	30	4,707	14.01
2011	377	1,233	2,340	34	3,607	9.57
2012	374	221	1,492	10	1,723	4.61
2013	398	802	1,993	0	2,795	7.02
2014	384	1,008	1,447	7	2,463	6.41
2015	442	314	877	0	1,191	2.70
2016	376	287	771	41	1,099	2.92
2017	382	349	1,188	0	1,537	4.02
2018	294	546	1,701	0[2]	2,248	7.65
2019	306	450	1,103[2]		1,554[2]	5.08[2]
2020	405	480[2]				
2021	412					
2022	377					
2023	428[2]					
Mean	439	854	2,785	78	3,729	6.64[3]

4. 357 or 48% of these fish were jacks.
5. Preliminary.
6. 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 2022 (there were no or very few carcass recoveries in 2017 through 2020), age composition of American River spring Chinook has averaged 2, 47, 52, 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. Maybe just keep Tables 13 and 19?

Table 38. Percentage by sex and age of American River wild/natural spring Chinook carcasses sampled on the spawning grounds and sample size (n), 1986-present.

Return	Males					Females					Total			
Year	3	4	5	6	n	3	4	5	6	n	3	4	5	6
1986		23.8	76.2		21		8.9	86.7	4.4	45		13.6	83.3	3.0
1987		70.8	25.0	4.2	24		42.9	57.1		21		57.8	40.0	2.2
1988			100.0		1		100.0			1		33.3	66.7	
1989		39.6	60.4		48		10.0	90.0		50		24.5	75.5	
1990	2.5	25.0	72.5		40		28.3	71.7		46	1.2	26.7	72.1	
1991		23.8	76.2		42		13.3	86.7		60		17.6	82.4	
1992		71.2	23.1	5.8	52		45.8	54.2		48		59.0	38.0	3.0
1993	4.8	14.3	81.0		21		8.0	92.0		75	1.0	9.4	89.6	
1994		44.4	55.6		18		50.0	46.7	3.3	30		49.0	49.0	2.0
1995	14.3	14.3	71.4		7			100.0		13	5.0	5.0	90.0	
1996		100.0			2		83.3	16.7		6		87.5	12.5	
1997		40.0	60.0		5		22.2	64.4	13.3	45		24.0	64.0	12.0
1998		12.1	87.9		33		6.6	93.4		76		8.3	91.7	
1999		100.0			2		40.0	40.0	20.0	5		57.1	28.6	14.3
2000		66.7	33.3		15		61.5	38.5		13		64.3	35.7	
2001		65.6	34.4		90		67.9	32.1		106		67.0	33.0	
2002	1.7	53.4	44.8		58		56.4	43.6		110	0.6	55.4	44.0	
2003		8.1	91.9		74		7.9	92.1		151		8.0	92.0	
2004		100.0			3		20.0	80.0		5		50.0	50.0	
2005		64.7	35.3		17		84.0	16.0		25		76.7	23.3	
2006		61.5	38.5		13		48.6	51.4		35		52.1	47.9	
2007	10.5	31.6	57.9		19		43.8	56.3		48	3.0	40.3	56.7	
2008		8.7	91.3		23		11.9	88.1		42		10.6	89.4	
2009	30.8	69.2			13		75.0	25.0		16	13.8	72.4	13.8	
2010	6.3	56.3	37.5		16		75.0	25.0		32	2.0	69.4	28.6	
2011		40.0	60.0		10		63.2	36.8		19		58.8	41.2	
2012		50.0	50.0		14		47.8	52.2		16		48.3	51.7	
2013	11.1	11.1	77.8		9		26.9	73.1		26	2.9	22.9	74.3	
2014	5.6	77.8	16.7		18		90.9	9.1		33	2.0	86.3	11.8	
2015	7.4	74.1	18.5		27		78.3	21.7		46	2.7	76.7	20.5	
2016		28.6	71.4		14		65.4	34.6		26		52.5	47.5	
2017	No carcasses were sampled													
2018	No carcasses were sampled													
2019	Only 1 carcass sampled due to low run size													
2020	50.0	50.0			2		100.0			3	20.0	80.0		
2021		62.5	37.5		8		63.6	36.4		11		63.2	36.8	
2022		76.9	23.1		13		76.2	23.8		21		77.1	22.9	
2023														
Mean	4.3	48.1	47.3	0.3			47.8	51.0	1.2		1.6	47.2	51.6	1.1

Table 39. Percentage by sex and age of Naches River wild/natural spring Chinook carcasses sampled on the spawning grounds and sample size (n), 1986-present.

Return	Males					Females					Total			
Year	3	4	5	6	n	3	4	5	6	n	3	4	5	6
1986	5.0	60.0	30.0	5.0	20		33.3	64.3	2.4	42	1.6	41.9	53.2	3.2
1987	5.9	76.5	11.8	5.9	17		69.0	31.0		42	1.7	71.7	25.0	1.7
1988		50.0	50.0		8	5.6	38.9	55.6		18	3.3	46.7	50.0	
1989		70.2	29.8		47		34.9	63.5	1.6	63		50.0	49.1	0.9
1990	9.1	60.6	30.3		33	10.7	57.1	32.1		28	11.1	57.1	31.7	
1991	4.3	52.2	43.5		23		13.3	86.7		45	1.5	26.5	72.1	
1992	4.0	80.0	12.0	4.0	25		70.6	29.4		34	1.7	75.0	21.7	1.7
1993		42.3	57.7		26		18.6	81.4		43		28.6	71.4	
1994		50.0	50.0		4		30.0	70.0		10		35.7	64.3	
1995		25.0	75.0		4		28.6	71.4		7		33.3	66.7	
1996		100.0			17		75.0	25.0		16		87.9	12.1	
1997	2.9	70.6	20.6	5.9	34		57.1	36.7	6.1	49	1.2	62.7	30.1	6.0
1998		29.4	70.6		17		27.9	72.1		43		30.6	69.4	
1999	12.5	62.5	25.0		8		33.3	66.7		9	5.9	47.1	47.1	
2000	1.7	94.9	3.4		59		92.2	7.8		77	0.7	93.4	5.9	
2001	1.7	72.9	25.4		59		61.0	39.0		118	0.6	65.2	34.3	
2002	2.1	78.7	19.1		47		63.3	36.7		98	0.7	66.9	32.4	
2003	7.8	25.0	67.2		64	1.1	18.9	80.0		95	3.8	21.4	74.8	
2004	7.5	87.5	5.0		40		91.3	8.7		92	2.3	89.5	8.3	
2005		81.8	18.2		11		83.8	16.2		37		83.7	16.3	
2006		61.5	38.5		13		61.5	38.5		13		61.5	38.5	
2007		75.0	25.0		4		57.9	42.1		19		60.9	39.1	
2008	36.4	45.5	18.2		11		87.0	13.0		23	11.8	73.5	14.7	
2009	7.1	71.4	21.4		14		76.9	23.1		26	2.4	73.2	24.4	
2010	4.5	90.9	4.5		22		83.3	16.7		42	2.9	85.3	11.8	
2011	11.5	80.8	7.7		26		78.9	21.1		19	6.3	81.3	12.5	
2012	11.8	41.2	47.1		17		64.4	33.3		45	4.8	58.7	36.5	
2013	15.4	53.8	30.8		13		56.3	43.8		16	6.7	56.7	36.7	
2014		86.7	13.3		15		92.3	7.7		26		90.9	9.1	
2015		100.0			10		75.0	25.0		16		84.6	15.4	
2016		25.0	75.0		4		64.3	35.7		14		57.9	42.1	
2017	No carcasses were sampled													
2018	No carcasses were sampled													
2019	No carcasses were sampled													
2020		100.0			1		100.0			1		100.0		
2021	Only 1 male carcass sampled; age not available													
2022		100.0			1									
2023														
Mean	4.9	64.6	29.9	0.7		0.6	57.9	41.1	0.3		2.3	61.3	36.0	0.4

Table 40. Percentage by sex and age of upper Yakima River wild/natural spring Chinook carcasses sampled on the spawning grounds and sample size (n), 1986-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
1986		100.0		12		94.1	5.9	51		95.2	4.8
1987	10.8	81.5	7.7	65		77.8	22.2	126	3.7	79.1	17.3
1988	22.5	70.0	7.5	40	10.4	75.0	14.6	48	15.6	73.3	11.1
1989	0.8	93.1	6.2	130	0.4	95.5	4.1	246	0.5	94.7	4.8
1990	6.3	88.4	5.3	95	2.1	94.8	3.1	194	3.4	92.8	3.8
1991	9.1	87.3	3.6	55		89.2	10.8	111	3.0	88.6	8.4
1992	2.4	91.6	6.0	167		98.1	1.9	315	0.8	95.9	3.3
1993	4.0	90.0	6.0	50	0.9	92.0	7.1	112	1.9	91.4	6.8
1994		100.0		16		98.0	2.0	50		98.5	1.5
1995	20.0	80.0		5		100.0		12	5.6	94.4	
1996	9.1	89.6	1.3	154	0.7	98.2	1.1	282	3.7	95.2	1.1
1997		96.7	3.3	61		96.3	3.7	136		96.4	3.6
1998	14.3	85.7		21	5.3	86.8	7.9	38	8.5	86.4	5.1
1999	61.8	38.2		34		94.4	5.6	36	31.0	66.2	2.8
2000	2.8	97.2		72		100.0		219	1.0	99.0	
2001	2.7	89.2	8.1	37		83.6	16.4	122	0.6	85.0	14.4
2002	2.4	58.5	39.0	41	3.6	87.5	8.9	56	5.1	73.7	21.2
2003	60.5	39.5		38	4.3	82.6	13.0	23	39.3	55.7	4.9
2004	6.5	93.5		108	0.0	99.5	0.5	198	2.3	97.4	0.3
2005	9.2	90.0		120	1.4	97.2	1.4	214	4.2	94.7	1.2
2006	23.7	74.6		59	2.3	96.5	1.2	86	11.0	87.6	1.4
2007	17.1	82.9		76	0.9	93.8	5.4	112	7.4	89.4	3.2
2008	11.8	88.2		34	0.0	95.8	4.2	24	6.9	91.4	1.7
2009	47.7	52.3		111	2.2	95.6	2.2	45	34.6	64.7	0.6
2010	27.7	72.3		47		100.0		71	11.0	89.0	
2011	37.5	62.5		16		100.0		27	13.6	86.4	
2012	25.0	75.0		8	7.7	92.3		13	14.3	85.7	
2013						100.0		8		100.0	
2014	3.3	96.7		30		100.0		59	1.1	98.9	
2015	carcass surveys discontinued as Roza samples deemed adequate										
Mean	15.7	80.9	3.4		1.5	93.6	4.9		7.9	87.8	4.3

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

Table 41. Percentage by sex and age of upper Yakima River CESRF spring Chinook carcasses sampled on the spawning grounds and sample size (n), 2001-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
2001	23.5	76.5		34	0.9	99.1		108	6.3	93.7	
2002	8.0	81.3	10.7	75		88.6	11.4	140	2.8	86.2	11.1
2003	100.0			1		100.0		1	50.0	50.0	
2004	9.5	90.5		21		98.0	2.0	51	2.8	95.8	1.4
2005	42.9	57.1		21		90.9	4.5	22	23.3	74.4	2.3
2006	26.7	73.3		15		100.0		43	6.9	93.1	
2007	66.7	33.3		6		100.0		11	23.5	76.5	
2008				0		100.0		1		100.0	
2009	60.0	40.0		5				0	60.0	40.0	
2010	28.6	71.4		7		100.0		11	11.1	88.9	
2011	37.5	62.5		16	4.5	95.5		22	18.4	81.6	
2012		100.0		4	5.3	94.7		19	4.3	95.7	
2013		100.0		1		100.0		7		100.0	
2014		100.0		20		100.0		62	1.2	98.8	
2015	carcass surveys discontinued as Roza samples deemed adequate										
Mean[1]	25.3	73.8	0.9		0.5	97.2	1.8		13.4	85.4	1.2

1. **Excludes years where sample size < 5.**

Table 42. Percentage by sex and age of upper Yakima River wild/natural spring Chinook collected for brood stock at Roza Dam and sample size (n), 1997-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
1997	4.5	92.0	3.4	88		94.6	5.4	111	2.0	93.5	4.5
1998	22.4	73.1	4.5	134		91.6	8.4	179	9.6	83.7	6.7
1999	71.1	26.1	2.8	425		92.6	7.4	215	48.8	47.0	4.2
2000	17.8	81.7	0.4	230		98.7	1.3	313	7.5	91.5	0.9
2001	12.4	77.4	10.3	234	0.9	90.5	8.5	328	5.7	85.2	9.2
2002	16.4	78.3	5.3	226	0.6	94.8	4.7	343	6.9	88.2	4.9
2003	27.4	60.2	12.4	201		83.3	16.7	228	12.8	72.6	14.7
2004	15.1	84.5	0.4	239	0.3	99.0	0.7	305	6.8	92.6	0.6
2005	15.5	82.3	2.2	181	0.4	97.1	2.5	276	6.3	91.2	2.4
2006	11.1	77.4	11.5	226		89.4	10.6	255	5.2	83.8	11.0
2007	13.6	74.7	11.7	162		87.8	12.2	255	5.3	82.7	12.0
2008	20.0	77.4	2.6	190		95.6	4.4	252	8.6	87.8	3.6
2009	17.4	81.2	1.4	207	0.8	96.1	3.1	258	8.2	89.5	2.4
2010	20.0	79.4	0.6	155	0.4	99.3	0.4	285	7.3	92.3	0.5
2011	18.1	81.3	0.5	182	0.8	95.3	3.8	236	8.4	89.2	2.4
2012	12.5	86.5	1.0	104		97.4	2.6	189	4.4	93.5	2.0
2013	18.0	77.6	4.3	161	0.0	96.2	3.8	183	8.4	87.5	4.1
2014	20.9	76.3	2.8	177	0.0	97.8	2.2	184	10.2	87.3	2.5
2015	9.3	89.4	1.2	161	0.0	98.7	1.3	231	3.8	94.9	1.3
2016	12.5	81.6	5.9	152	0.5	95.2	4.3	210	5.5	89.5	5.0
2017	13.7	84.9	1.4	146	1.0	97.9	1.0	194	6.5	92.4	1.2
2018	17.6	79.4	2.9	102	0.0	95.8	4.2	144	7.3	89.0	3.7
2019	13.2	86.8	0.0	76	0.7	97.3	2.0	149	4.9	93.8	1.3
2020	9.6	89.6	0.8	125	0.0	97.8	2.2	183	3.9	94.5	1.6
2021	6.3	91.9	1.9	160	0.4	93.0	6.6	227	2.8	92.5	4.7
2022	7.8	91.3	0.9	115	0.0	99.4	0.6	171	3.1	96.2	0.7
2023	13.0	84.4	2.6	154	0.5	95.0	4.5	220	5.6	90.6	3.7
Mean	16.9	79.5	3.6		0.3	95.1	4.6		8.0	87.9	4.1

Table 43. Percentage by sex and age of upper Yakima River CESRF spring Chinook collected for research or brood stock at Roza Dam and sample size (n), 2001-present.

Return	Males				Females				Total		
Year	3	4	5	n	3	4	5	n	3	4	5
2001	12.5	87.5		40		100.0		75	5.1	94.9	
2002	14.7	83.8	1.5	68		98.3	1.7	115	5.5	92.9	1.6
2003	36.1	34.7	29.2	72		61.2	38.8	67	18.7	47.5	33.8
2004	19.6	80.4		46		100.0		60	8.5	91.5	
2005	17.8	75.6	6.7	45		88.1	11.9	59	7.7	82.7	9.6
2006	18.3	80.0	1.7	60		100.0		65	8.8	90.4	0.8
2007	33.3	60.8	5.9	51		87.5	12.5	56	15.9	74.8	9.3
2008	50.0	50.0		40		100.0		56	20.8	79.2	
2009	25.4	71.2	3.4	59	1.2	97.6	1.2	84	11.2	86.7	2.1
2010	27.9	72.1		61		99.0	1.0	100	10.6	88.8	0.6
2011	21.2	72.7	6.1	66	0.9	97.2	1.9	107	8.7	87.9	3.5
2012	13.0	85.2	1.9	54		97.0	3.0	101	4.5	92.9	2.6
2013	17.9	80.6	1.5	67	1.1	96.7	2.2	92	8.2	89.9	1.9
2014	31.9	66.0	2.1	47	0.0	100.0	0.0	33	18.8	80.0	1.3
2015	33.3	66.7	0.0	27	0.0	97.9	2.1	48	12.0	86.7	1.3
2016	26.5	69.4	4.1	49	0.0	100.0	0.0	47	13.5	84.4	2.1
2017	43.6	56.4	0.0	39	0.0	100.0	0.0	66	16.2	83.8	
2018	28.9	71.1	0.0	38	0.0	100.0	0.0	38	14.5	85.5	
2019	26.3	73.7	0.0	19	3.5	96.5	0.0	57	9.2	90.8	
2020	12.5	87.5	0.0	8	0.0	100.0	0.0	14	4.5	95.5	
2021[1]				0	0.0	50.0	50.0	2	0.0	50.0	50.0
2022[1]											
2023[1]											
Mean	25.5	71.3	3.2		0.3	95.9	3.8		11.1	85.3	3.5

[1] 2 fish sampled in 2021; 0 fish in 2022 and 2023.

Sex Composition

In the American River, the mean proportion of males to females in wild/natural carcasses sampled on the spawning grounds from 1986-2022 was 40:60 for age-4 and 34:66 for age-5 spring Chinook (Table 15). In the Naches River, the mean proportion of males to females was 41:59 for age-4 and 27:73 for age-5 fish (Table 16). In the upper Yakima River, the mean proportion of males to females was 33:67 for age-4 and 23:77 for age-5 fish (Table 17). Collection of carcass samples from the spawning grounds throughout the Yakima Basin did not occur in 2017-2019 and very few carcasses were sampled in 2020.

For upper Yakima fish collected at Roza Dam for brood stock or research purposes from 1997-2020, the mean proportion of males to females was 38:62 and 35:65 for age-4 fish from the wild/natural and CESRF populations, respectively (Tables 19 and 20). For these same samples, the mean proportion of males to females was 35:65 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 44. Percent of American River wild/natural spring Chinook carcasses sampled on the spawning grounds by age and sex, 1986-present.

Return	Age-3		Age-4		Age-5		Age-6	
Year	M	F	M	F	M	F	M	F
1986			55.6	44.4	29.1	70.9		100.0
1987			65.4	34.6	33.3	66.7	100.0	
1988			0.0	100.0	100.0	0.0		
1989			79.2	20.8	39.2	60.8		
1990	100.0		43.5	56.5	46.8	53.2		
1991			55.6	44.4	38.1	61.9		
1992			62.7	37.3	31.6	68.4	100.0	
1993	100.0		33.3	66.7	19.8	80.2		
1994			34.8	65.2	41.7	58.3		100.0
1995	100.0		100.0	0.0	27.8	72.2		
1996			28.6	71.4	0.0	100.0		
1997			16.7	83.3	9.4	90.6		100.0
1998			44.4	55.6	29.0	71.0		
1999			50.0	50.0	0.0	100.0		100.0
2000			55.6	44.4	50.0	50.0		
2001			45.0	55.0	47.7	52.3		
2002	100.0		33.3	66.7	35.1	64.9		
2003			33.3	66.7	32.9	67.1		
2004			75.0	25.0	0.0	100.0		
2005			34.4	65.6	60.0	40.0		
2006			32.0	68.0	21.7	78.3		
2007	100.0		22.2	77.8	28.9	71.1		
2008			28.6	71.4	36.2	63.8		
2009			42.9	57.1	0.0	100.0		
2010			27.3	72.7	42.9	57.1		
2011			25.0	75.0	46.2	53.8		
2012			24.1	75.9	22.6	77.4		
2013			12.5	87.5	26.9	73.1		
2014			31.8	68.2	50.0	50.0		
2015			35.7	64.3	33.3	66.7		
2016			19.0	81.0	52.6	47.4		
2017			No carcasses were sampled					
2018			No carcasses were sampled					
2019			Only 1 carcass sampled; low return					
2020	100.0		25.0	75.0				
2021			41.7	58.3	42.9	57.1		
2022			38.5	61.5	37.5	62.5		
2023								
mean			39.8	60.2	33.7	66.3		

Table 45. Percent of Naches River wild/natural spring Chinook carcasses sampled on the spawning grounds by age and sex, 1986-present.

Return	Age-3		Age-4		Age-5		Age-6	
Year	M	F	M	F	M	F	M	F
1986	100.0		46.2	53.8	18.2	81.8	50.0	50.0
1987	100.0		31.0	69.0	13.3	86.7	100.0	
1988		100.0	36.4	63.6	28.6	71.4		
1989			60.0	40.0	25.9	74.1		100.0
1990	50.0	50.0	55.6	44.4	52.6	47.4		
1991	100.0		66.7	33.3	20.4	79.6		
1992	100.0		45.5	54.5	23.1	76.9	100.0	
1993			57.9	42.1	30.0	70.0		
1994			40.0	60.0	22.2	77.8		
1995			33.3	66.7	37.5	62.5		
1996			58.6	41.4		100.0		
1997	100.0		46.2	53.8	28.0	72.0	40.0	60.0
1998			29.4	70.6	27.9	72.1		
1999	100.0		62.5	37.5	25.0	75.0		
2000	100.0		44.1	55.9	25.0	75.0		
2001	100.0		37.4	62.6	24.6	75.4		
2002	100.0		37.4	62.6	20.0	80.0		
2003	83.3	16.7	47.1	52.9	36.1	63.9		
2004	100.0		29.4	70.6	20.0	80.0		
2005			22.5	77.5	25.0	75.0		
2006			50.0	50.0	50.0	50.0		
2007			21.4	78.6	11.1	88.9		
2008	100.0		20.0	80.0	40.0	60.0		
2009	100.0		33.3	66.7	33.3	66.7		
2010	100.0		36.4	63.6	12.5	87.5		
2011	100.0		58.3	41.7	33.3	66.7		
2012	66.7	33.3	19.4	80.6	34.8	65.2		
2013	100.0		43.8	56.3	36.4	63.6		
2014			35.1	64.9	50.0	50.0		
2015			45.5	54.5		100.0		
2016			10.0	90.0	37.5	62.5		
2017			No carcasses were sampled					
2018			No carcasses were sampled					
2019			No carcasses were sampled					
2020			50.0	50.0				
2021			Only 1 male carcass sampled; age not available					
2022			Only 1 male carcass sampled; age-4					
2023								
mean			40.6	59.4	27.2	72.8		

Table 46. Percent of Upper Yakima River wild/natural spring Chinook carcasses sampled on the spawning grounds by age and sex, 1986-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
1986			20.0	80.0		100.0
1987	100.0		35.1	64.9	15.2	84.8
1988	64.3	35.7	43.8	56.3	30.0	70.0
1989	50.0	50.0	34.0	66.0	44.4	55.6
1990	60.0	40.0	31.3	68.7	45.5	54.5
1991	100.0		32.7	67.3	14.3	85.7
1992	100.0		33.1	66.9	62.5	37.5
1993	66.7	33.3	30.4	69.6	27.3	72.7
1994			24.6	75.4		100.0
1995	100.0		25.0	75.0		
1996	87.5	12.5	33.3	66.7	40.0	60.0
1997			31.1	68.9	28.6	71.4
1998	60.0	40.0	35.3	64.7		100.0
1999	100.0		27.7	72.3		100.0
2000	100.0		24.2	75.8		
2001	100.0		24.4	75.6	13.0	87.0
2002	33.3	66.7	32.9	67.1	76.2	23.8
2003	95.8	4.2	44.1	55.9		100.0
2004	100.0		33.9	66.1		100.0
2005	78.6	21.4	34.2	65.8	25.0	75.0
2006	87.5	12.5	34.6	65.4	50.0	50.0
2007	92.9	7.1	37.5	62.5		100.0
2008	100.0		56.6	43.4		100.0
2009	98.1	1.9	57.4	42.6		100.0
2010	100.0		32.4	67.6		
2011	100.0		27.0	73.0		
2012	66.7	33.3	33.3	66.7		
2013				100.0		
2014	100.0	0.0	33.0	67.0		
2015	carcass surveys discontinued as Roza samples deemed adequate					
mean	85.7	14.3	33.0	67.0	22.5	77.5

Table 47. Percent of upper Yakima River CESRF spring Chinook carcasses sampled on the spawning grounds by age and sex, 2001-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
2001	88.9	11.1	19.5	80.5		
2002	100.0		33.0	67.0	33.3	66.7
2003	100.0			100.0		
2004	100.0		27.5	72.5		100.0
2005	90.0	10.0	37.5	62.5		100.0
2006	100.0		20.4	79.6		
2007	100.0		15.4	84.6		
2008				100.0		
2009	100.0		100.0			
2010	100.0		31.3	68.8		
2011	85.7	14.3	32.3	67.7		
2012			18.2	81.8		
2013			12.5	87.5		
2014			24.4	75.6		
2015	carcass surveys discontinued as Roza samples deemed adequate					
mean	96.5	3.5	26.6	73.4		

Table 48. Percent of upper Yakima River wild/natural spring Chinook collected for brood stock at Roza Dam by age and sex, 1997-present.

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

2017	90.9	9.1	39.5	60.5	50.0	50.0
2018	100.0		37.0	63.0	33.3	66.7
2019	90.9	9.1	31.3	68.7	0.0	100.0
2020	100.0		38.5	61.5	20.0	80.0
2021	90.9	9.1	41.1	58.9	16.7	83.3
2022	100.0		38.2	61.8	50.0	50.0
2023	95.2	4.8	38.3	61.7	28.6	71.4
mean	97.3	2.7	38.0	62.0	34.8	65.2

Table 49. Percent of Upper Yakima River CESRF spring Chinook collected for research or brood stock at Roza Dam by age and sex, 2001-present.

Return	Age-3		Age-4		Age-5	
Year	M	F	M	F	M	F
2001	100.0	0.0	31.8	68.2		
2002	100.0	0.0	33.5	66.5	33.3	66.7
2003	100.0	0.0	37.9	62.1	44.7	55.3
2004	100.0	0.0	38.1	61.9		
2005	100.0	0.0	39.5	60.5	30.0	70.0
2006	100.0	0.0	42.5	57.5	100.0	
2007	100.0	0.0	38.8	61.3	30.0	70.0
2008	100.0	0.0	26.3	73.7		
2009	93.8	6.3	33.9	66.1	66.7	33.3
2010	100.0	0.0	30.8	69.2		100.0
2011	93.3	6.7	31.6	68.4	66.7	33.3
2012	100.0		31.9	68.1	25.0	75.0
2013	92.3	7.7	37.8	62.2	33.3	66.7
2014	100.0	0.0	48.4	51.6	100.0	0.0
2015	100.0	0.0	27.7	72.3		
2016	100.0	0.0	42.0	58.0	100.0	0.0
2017	100.0	0.0	25.0	75.0		
2018	100.0	0.0	41.5	58.5		
2019	71.4	28.6	20.3	79.7		
2020	100.0	0.0	33.3	66.7		
2021[1]			0.0	100.0	0.0	100.0
2022[1]						
2023[1]						
mean	97.5	2.5	34.6	65.4	41.2	58.8

[1] 2 fish sampled in 2021; 0 fish in 2022 and 2023.

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 75 cm for age-3, -4, and -5 males, and averaged 63 and 72 cm for age-4 and -5 females, respectively, from carcasses sampled on the spawning grounds in the American River from 1996-2022 (Table 21). In the Naches River, mean POHP lengths averaged 42, 60, and 76 cm for age-3, -4, and -5 males, and averaged 61 and 72 cm for age-4 and -5 females, respectively (Table 22). For wild/natural spring Chinook sampled on the spawning grounds in the upper Yakima River, mean POHP lengths averaged 44, 60, and 72 cm for age-3, -4, and -5 males, and averaged 59 and 69 cm for age-4 and -5 females, respectively (Table 23). Beginning in 2012, carcass sampling in the Upper Yakima was scaled back considerably as large numbers of escaping fish are sampled at Roza Dam (Tables 27-28). From 2001-2023, CESRF fish returning to the upper Yakima have been generally smaller in size-at-age than their wild/natural counterparts (Tables 25-28).

Table 50. 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, 1989-present.

	Males								Females					
	Age 3		Age 4		Age 5		Age 6		Age 4		Age 5		Age 6	
Return Year	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP	Count	MEHP
1990	1	41.0	10	63.6	29	77.3			13	62.5	33	73.6		
1991			10	59.5	32	77.1			8	65.1	52	73.4		
1992			37	60.6	12	76.2	3.0	86.7	22	64.1	26	76.4		
1993	1	47.0	3	64.0	17	80.2			6	63.7	69	75.5		
1994			8	67.3	10	83.0			15	70.8	14	76.4	1	85.0
1995	1	44.4	1	70.0	4	83.5					12	76.4		
		POHP		POHP		POHP		POHP		POHP		POHP		POHP
1996			2	56.3					5	59.0	1	67.0		
1997[1]			2	62.0	1	63.0			4	62.8	14	64.4	5	71.0
1998			4	58.3	29	79.1			5	64.0	71	73.4		
1999			2	50.5					2	61.0	2	73.0	1	77.0
2000			10	57.9	5	83.2			8	63.9	5	76.2		
2001			59	65.9	31	77.6			72	63.6	34	73.0		
2002	1	40.0	31	63.0	26	77.3			62	64.4	48	74.7		
2003			6	63.0	68	79.4			12	64.3	139	76.7		
2004			3	56.0					1	58.0	4	77.5		
2005			11	60.6	6	80.2			21	62.6	4	74.8		
2006			8	60.8	5	75.4			17	61.8	18	71.7		
2007	2	37.0	6	62.8	11	76.5			21	60.0	27	73.3		
2008			2	67.5	21	83.1			5	67.4	37	78.9		
2009	4	44.0	9	68.3					12	62.6	4	69.8		
2010	1	38.0	9	70.1	6	75.7			24	65.1	8	73.0		
2011			4	65.5	6	82.8			12	65.8	7	75.9		
2012			7	64.1	7	77.3			22	63.7	24	74.3		
2013	1	34.0	1	56.0	7	70.1			7	65.7	18	70.3		
2014	1	36.0	14	61.1	3	66.7			30	61.2	3	63.3		
2015	2	42.0	20	63.4	5	77.4			36	61.3	10	71.2		
2016			4	65.0	10	71.5			17	59.7	9	67.6		

2017-19				No samples				No samples				
2020	1	38.0	1	52.0			3	65.7				
2021			4	54.8	3	64.0	5	60.5	4	63.8		
2022			10	62.7	3	60.0	16	57.6	5	66.2		
2023												
Mean[2]		38.6		61.1		74.7		62.6		71.7		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 1996-2021 post-eye to hypural plate lengths.

Table 51. 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, 1989-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	M
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		PO
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	
1998			5	57.8	12	75.0					12	61.1	31	71.6		
1999	1	40.0	5	61.2	2	73.0					3	58.7	6	75.0		
2000	1	35.0	56	58.2	2	84.0					71	59.5	6	72.8		
2001	1	45.0	43	61.4	15	73.4					72	62.2	46	74.5		
2002	1	40.0	37	63.6	9	77.3					62	62.4	36	71.8		
2003	5	41.4	16	62.2	43	79.4			1	41.0	18	62.8	76	75.6		
2004	3	46.0	35	59.8	2	74.5					84	61.5	8	75.8		
2005			9	60.1	2	78.0					31	61.7	6	71.7		
2006			8	56.9	5	76.0					8	63.8	5	71.2		
2007			3	61.3	1	67.0					11	56.9	8	72.1		
2008	4	42.0	5	59.6	2	81.5					20	62.0	3	78.7		
2009	1	43.0	10	67.9	3	76.3					20	63.9	6	73.2		
2010	1	40.0	20	60.5	1	77.0					35	61.7	7	71.4		
2011	3	44.3	21	61.9	2	78.0					15	60.4	4	76.8		
2012	2	51.5	7	67.3	8	75.8			1	41.0	29	61.6	15	71.1		
2013	2	37.0	7	56.1	4	75.0					9	58.7	7	71.3		
2014			13	61.8	2	71.0					24	56.7	2	67.5		
2015			10	59.3							12	60.4	4	65.8		
2016			1	47.0	3	77.0					9	53.9	5	68.8		
2017-19				No samples								No samples				

2020			1	50.0							1	53.0		
2021	1 carcass sampled; unknown age; POHP = 58.0													
2022			1	59.0										
2023														
Mean[2]		41.9		60.1		75.8		78.0		41.0		60.5		72.1

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

Table 52. Counts and mean mid-eye (MEHP) or post-orbital (POHP) to hypural plate lengths (cm) of upper Yakima River wild / natural spring Chinook from carcasses sampled on the spawning grounds by sex and age, 1986-present.

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

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

Table 53. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River CESRF spring Chinook from carcasses sampled on the spawning grounds by sex and age, 2001-present.

	Males						Females					
Return	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
2001	8	40.5	25	59.0	1	69.5	1	41.0	107	59.0		
2002	6	47.7	61	61.2	8	68.9			124	60.6	16	71.2
2003	1	42.0							1	69.0		
2004	2	52.0	19	60.8					50	57.9	1	68.0
2005	8	41.8	12	59.9			1	46.0	20	59.6	1	72.0
2006	4	42.3	11	54.0					43	57.0		
2007	4	44.3	2	58.5					11	60.1		
2008	0		0						1	58.0		
2009	3	47.7	2	---								
2010	2	44.0	5	61.8					11	55.5		
2011	6	40.7	10	59.1			1	46.0	21	59.0		
2012			4	63.0			1	50.0	18	57.3		
2013			1	---					7	53.6		
2014			20	60.8					62	59.0		
2015	carcass surveys discontinued as Roza samples deemed adequate											
Mean		44.3		59.8		69.2				58.9		70.4

Table 54. 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
2016	16	45.9	110	61.4	8	68.9			159	60.4	7	68.0
2017	18	43.2	115	61.0	2	66.0	2	47.7	167	62.1	2	64.9
2018	17	40.5	77	59.2	3	66.0			132	58.9	6	62.9
2019	6	39.8	55	55.2			1	39.5	120	56.2	1	63.5
2020	12	39.7	105	55.9	1	71.1			173	55.9	4	62.3
2021	8	40.5	92	56.0	2	65.9	1	53.9	171	56.8	14	60.7
2022	9	41.2	92	57.0	1	61.0			150	56.7	1	58.5
Mean		42.7		59.2		69.4				59.4		66.8

Table 55. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River CESRF spring Chinook from carcasses sampled at the CESRF prior to spawning by sex and age, 2001-present.

	Males						Females					
Return	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
2001			4	61.3					33	60.4		
2002	2	40.2	25	59.6					63	59.4	2	66.1
2003	17	42.6	16	57.8	15	74.0			31	59.7	19	70.4
2004	6	39.4	9	57.1					42	59.3		
2005	6	37.9	21	58.4	2	68.7			38	58.6	5	68.0
2006[1]			3	57.2					3	56.3		
2007	8	40.4	18	59.3	1	71.4			35	58.2	5	67.6
2008	17	43.8	9	59.1					28	59.4		
2009	5	43.8	11	61.1					32	60.1	1	67.5
2010	11	41.8	18	59.2					40	61.0		
2011	4	43.4	10	62.7	1	79.2			32	60.4	2	71.7
2012	3	39.0	23	59.3	1	73.7			43	59.4	1	67.2
2013	2	45.7	24	60.3					32	57.3		
2014	7	39.2	21	61.8	1	70.2			32	60.5		
2015	7	38.9	17	58.5					42	59.2	1	66.7
2016	2	42.8	22	61.4	2	75.0			34	60.8		
2017	11	44.1	20	59.9					36	61.9		
2018	8	38.4	22	59.5					34	59.4		
2019	3	37.3	14	56.2					25	55.8		
2020	1	37.4	7	54.9					13	54.6		
2021[1]									1	57.1		
2022[1]												
2023[1]												
Mean		40.9		59.2		73.2				59.0		68.2

1 Few length samples were collected for spawning or research in 2006, and 2021-2022.

Table 56. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River wild/natural spring Chinook from fish sampled at Roza Dam by sex[1] and age, 1997-present.

Return	Males						Females					
	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
1997	4	39.6	81	60.6	2	73.3			121	60.5	10	70.6
1998	36	42.4	108	58.3	11	67.7	1	58.5	201	59.4	13	67.0
1999	350	40.7	80	59.4	11	67.5	2	46.8	256	60.3	19	68.3
2000	40	41.3	145	60.5	1	77.0	1	46.0	354	60.2	4	72.1
2001	32	42.9	111	61.9	28	73.8			371	61.2	24	70.7
2002	43	41.6	146	61.2	21	71.4	2	52.5	379	60.7	8	70.3
2003	54	43.3	52	64.6	18	75.3	1	51.0	262	61.9	45	71.2
2004	41	43.4	121	61.1	1	69.0			394	59.4	2	69.5
2005	35	43.2	134	61.1	5	74.2			307	60.8	6	68.3
2006	27	41.3	77	59.1	22	72.6	1	47.0	336	58.8	27	69.5
2007	31	42.9	83	60.8	18	69.8	1	50.0	280	60.5	34	69.7
2008	38	45.8	101	61.7	8	72.4			293	60.7	8	69.1
2009	36	45.3	125	63.4	4	71.5	3	52.7	297	61.9	8	69.9
2010	39	43.7	129	62.6	1	74.0	1	51.0	298	62.8	1	70.0
2011	42	46.7	154	61.2	3	77.3	2	53.0	235	61.9	10	75.3
2012	27	43.6	113	60.5	1	63.0			202	60.3	5	68.0
2013	31	45.4	132	59.9	8	70.6			181	59.8	7	70.6
2014	38	44.7	138	62.2	5	72.2			181	61.2	4	65.5
2015	16	44.0	150	61.2	3	72.0			245	61.2	3	71.7
2016	21	46.0	130	62.3	10	71.4			210	61.6	10	69.8
2017	21	43.3	128	61.3	2	66.5	2	48.0	195	62.5	2	66.0
2018	21	40.9	86	59.3	3	67.3			140	59.2	7	64.4
2019	11	40.9	67	57.7			1	42.0	148	58.6	4	70.3
2020	13	41.7	127	58.5	1	75.0			192	58.3	4	66.3
2021	11	42.5	146	59.1	3	67.7	1	57.0	215	59.7	16	64.6
2022	9	40.7	112	59.6	1	65.0			179	59.4	1	62.0
2023	16	43.4	129	58.8	4	67.8	1	51.0	209	58.3	10	66.5
Mean		43.0		60.7		71.0		50.5		60.4		68.8

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

Table 57. Counts and mean post-orbital to hypural plate (POHP) lengths (cm) of upper Yakima River CESRF spring Chinook from fish sampled at Roza Dam by sex[1] and age, 2001-present.

	Males						Females					
Return	Age 3		Age 4		Age 5		Age 3		Age 4		Age 5	
Year	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP	Count	POHP
2001	473	39.9	548	59.5			1	58.0	1795	59.2		
2002	26	38.7	383	59.5	19	67.7			1152	59.1	15	66.1
2003	392	41.8	48	61.8	61	73.0	2	47.0	207	60.3	154	70.8
2004	48	40.3	100	60.5			1	44.0	351	59.2	2	71.0
2005	98	40.4	58	60.1	6	73.0			160	59.1	12	68.7
2006	26	40.4	89	58.0					318	57.4	2	70.5
2007	174	41.4	46	60.7	6	71.7	1	47.0	185	59.0	13	69.8
2008	93	44.8	60	60.7			2	54.5	191	60.1	1	67.0
2009	254	43.6	78	62.8	5	65.0	1	50.0	212	61.8	6	69.5
2010	106	42.5	196	61.0	1	67.0	1	60.0	361	61.8	1	72.0
2011	155	42.9	146	60.9	8	73.5	2	57.5	265	61.5	13	73.4
2012	45	40.6	131	59.3	3	65.7	1	45.0	250	59.9	6	69.2
2013	92	44.4	122	59.0	3	70.0			163	58.8	4	69.3
2014	78	42.8	111	61.0	2	71.0			163	60.5	3	71.7
2015	19	41.2	90	59.5					146	60.3	3	72.0
2016	86	44.5	73	61.1	3	77.3	2	48.0	102	61.2	1	65.0
2017	83	43.9	47	61.6					160	62.3	1	67.0
2018	24	39.3	56	58.4			1	41.0	86	59.4		
2019	18	41.4	35	57.5			1	46.0	84	57.7	1	76.0
2020	35	41.7	25	57.4					52	57.7		
2021	39	42.9	31	57.9	1	68.0	1	50.0	56	59.8	2	61.5
2022	18	41.2	20	58.7					35	58.2		
2023	21	40.3	19	57.4			1	50.0	27	56.2	1	68.0
Mean		41.6		59.7		70.2		49.9		59.6		69.4

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).

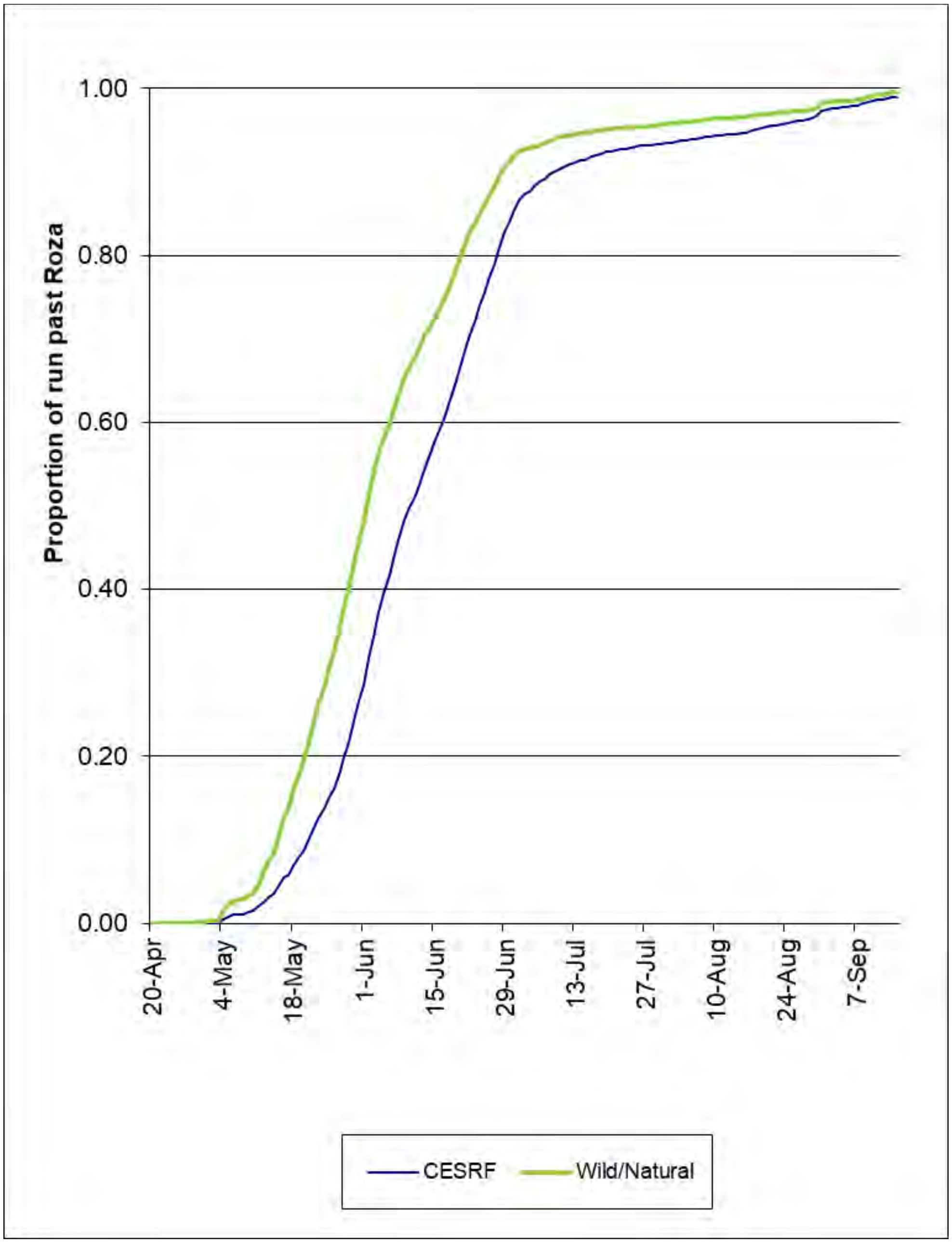


Figure 30. Proportionate passage timing at Roza Dam of wild/natural and CESRF adult spring Chinook (including jacks), 2014-2023.

Table 58. Comparison of 5%, median (50%), and 95% passage dates of wild/natural and CESRF adult spring Chinook (including jacks) at Roza Dam, 1997-Present.

	Wild/Natural Passage			CESRF Passage		
Year	5%	Median	95%	5%	Median	95%
1997	10-Jun	17-Jun	21-Jul			
1998	22-May	10-Jun	10-Jul			
1999	31-May	24-Jun	4-Aug			
2000	12-May	24-May	12-Jul	21-May[1]	15-Jun[1]	27-Jul[1]
2001	4-May	23-May	11-Jul	8-May	28-May	15-Jul
2002	16-May	10-Jun	6-Aug	20-May	13-Jun	12-Aug
2003	13-May	11-Jun	19-Aug	13-May	10-Jun	24-Aug
2004	4-May	20-May	24-Jun	5-May	22-May	26-Jun
2005	9-May	22-May	23-Jun	15-May	31-May	2-Jul
2006	1-Jun	14-Jun	18-Jul	3-Jun	18-Jun	19-Jul
2007	16-May	5-Jun	9-Jul	24-May	14-Jun	19-Jul
2008	27-May	9-Jun	9-Jul	31-May	17-Jun	14-Jul
2009	31-May	14-Jun	17-Jul	2-Jun	19-Jun	17-Jul
2010	11-May	30-May	5-Jul	12-May	2-Jun	9-Jul
2011	6-Jun	23-Jun	16-Jul	9-Jun	24-Jun	15-Jul
2012	30-May	14-Jun	9-Jul	30-May	13-Jun	8-Jul
2013	22-May	4-Jun	3-Jul	24-May	8-Jun	8-Jul
2014	15-May	1-Jun	2-Jul	18-May	5-Jun	8-Jul
2015[2]	4-May	16-May	31-Aug	5-May	18-May	31-Aug
2016	17-May	29-May	28-Jun	21-May	4-Jun	20-Jul
2017	1-Jun	14-Jun	3-Jul	6-Jun	20-Jun	14-Jul
2018	1-Jun	8-Jun	18-Jul	2-Jun	14-Jun	16-Jul
2019	22-May	31-May	29-Jul	25-May	5-Jun	20-Aug
2020	21-May	11-Jun	9-Aug	27-May	23-Jun	23-Aug
2021	19-May	5-Jun	9-Aug	23-May	14-Jun	30-Aug
2022	23-May	20-Jun	8-Jul	16-May	26-Jun	29-Jul
2023	25-May	4-Jun	28-Jun	27-May	6-Jun	3-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 70º 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 59. Median spawn[1] dates for spring Chinook in the Yakima Basin.

Year	American	Naches	Upper Yakima	CESRF
1989	14-Aug	7-Sep	19-Sep	
1990	14-Aug	12-Sep	25-Sep	
1991	12-Aug	12-Sep	24-Sep	
1992	11-Aug	10-Sep	22-Sep	
1993	9-Aug	8-Sep	27-Sep	
1994	16-Aug	14-Sep	26-Sep	
1995	14-Aug	7-Sep	1-Oct	
1996	20-Aug	18-Sep	23-Sep	
1997	12-Aug	11-Sep	23-Sep	23-Sep
1998	11-Aug	15-Sep	30-Sep	22-Sep
1999	24-Aug	8-Sep	27-Sep	21-Sep
2000	7-Aug	20-Sep	19-Sep	19-Sep
2001	14-Aug	13-Sep	25-Sep	18-Sep
2002	12-Aug	11-Sep	23-Sep	24-Sep
2003	11-Aug	14-Sep	28-Sep	23-Sep
2004	17-Aug	12-Sep	27-Sep	21-Sep
2005	15-Aug	15-Sep	27-Sep	20-Sep
2006	15-Aug	14-Sep	26-Sep	19-Sep
2007	14-Aug	12-Sep	25-Sep	25-Sep
2008	11-Aug	12-Sep	23-Sep	23-Sep
2009	17-Aug	10-Sep	23-Sep	28-Sep
2010	17-Aug	12-Sep	21-Sep	21-Sep
2011	23-Aug	8-Sep	21-Sep	20-Sep
2012	21-Aug	11-Sep	24-Sep	25-Sep
2013	19-Aug	11-Sep	25-Sep	23-Sep
2014	19-Aug	18-Sep	29-Sep	24-Sep
2015	20-Aug	17-Sep	28-Sep	23-Sep
2016	16-Aug	16-Sep	27-Sep	20-Sep
2017[2]	16-Aug		26-Sep	19-Sep
2018	15-Aug	20-Sep	1-Oct	25-Sep
2019	15-Aug	9-Sep	1-Oct	24-Sep
2020	31-Aug	23-Sep	29-Sep	22-Sep
2021	23-Aug	22-Sep	27-Sep	21-Sep
2022	16-Aug	21-Sep	26-Sep	20-Sep
2023	15-Aug	12-Sep	2-Oct	19-Sep

Mean	15-Aug	13-Sep	25-Sep	21-Sep

1. Approximately one-half of the redds in the system were counted by this date and one-half were counted after this date. For the CESRF, approximately one-half of the total broodstock were spawned by this date and one-half were spawned after this date.
2. Spawner surveys impacted by fires; especially in the Naches system.

Redd Counts and Distribution

Table 60. Yakima Basin spring Chinook redd count summary, 1981 – present.

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

2009	1,349	197	33	1,579	92	159	163	68	482
2010	2,199	219	253	2,671	173	171	168	40	552
2011	1,663	171	64	1,898	212	145	175	48	580
2012	1,276	125	69	1,470	337	196	189	89	811
2013	552	85	34	671	170	66	85	55	376
2014	962	138	53	1,153	129	65	158	27	379
2015	1,258	39	24	1,321	239	177	152	46	614
2016	512	83	22	617	149	106	74	37	366
2017	402	118	23	543	123	84	56	30	293
2018	339	13	0	352	27	56	44	1	128
2019	185	44	9	238	21	1	2	7	31
2020	189	44	8	241	44	25	71	6	146
2021	237	18	5	260	79	59[2]	49[2]	0	187
2022	426	40	32	498	198	85	45	2	330
2023	273	65	3	341	29	12	20	0	61
Mean	933	113	25	1,072	150	150	104	42	445

[1] Including minor tributaries.

[2] Surveys in the Bumping R., Rattlesnake Cr., and upper Nile watershed precluded due to fire; used recent 5-yr average.

Homing

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

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

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 61. Cle Elum Supplementation and Research Facility spawning and survival statistics (NoR brood only), 1999 - 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
1999	738[5]	24	96.7%	213	222	2.7%	818,816	777,984	5.0%	781,872	97.3%	758,789	97.0%	94.5%
2000	567	61	89.2%	170	278	9.2%	916,292	851,128	7.1%	870,328	97.3%	834,285	95.9%	93.4%
2001	595	171	71.3%	145	223	53.2%	341,648	316,254	7.4%	380,880	98.6%	370,236	97.2%	96.1%
2002	629	89	85.9%	125	261	10.0%	919,776	817,841	11.1%	783,343	98.0%	749,067	95.6%	93.6%
2003	441	54	87.8%	115	200	0.0%	856,574	787,933	8.0%	761,990	98.4%	735,959	96.6%	95.0%
2004	597	70	88.3%	125	245	0.4%	873,815	806,375	7.7%	776,941	97.8%	691,109[6]	89.0%	87.0%
2005	526	57	89.2%	136	241	0.0%	907,199	835,890	7.9%	796,559	98.1%	769,484	96.6%	94.7%
2006	519	45	91.3%	122	239	1.7%	772,357	703,657	8.9%	631,691	97.3%	574,361[7]	90.9%	88.3%
2007	473	49	89.6%	149	216	0.9%	798,729	760,189	4.8%	713,814	98.9%	676,602	94.8%	93.7%
2008	480	38	92.1%	151	253	2.0%	915,563	832,938	9.0%	809,862	99.0%	752,109[8]	97.3%	96.3%
2009	486	57	88.3%	142	219	1.4%	850,404	848,339	0.2%	770,706	98.2%	744,170	96.6%	94.6%
2010	483	20	95.9%	102	193	0.5%	787,953	753,464	4.4%	726,325	98.9%	702,751	96.8%	95.6%
2011	455	28	93.8%	103	197	0.0%	798,229	765,221	4.1%	721,197	98.1%	684,481	94.9%	93.0%
2012	363	14	96.1%	111	209	0.0%	819,775	788,605	3.8%	737,705	98.2%	712,036	96.5%	94.7%
2013	385	15	96.1%	153	179	0.6%	683,484	658,796	3.6%	613,493	98.9%	575,156	93.8%	92.6%
2014	384	39	89.8%	133	188	0.0%	679,374	639,989	5.8%	636,092	96.5%	599,908	94.3%	91.1%
2015	436	116	73.4%	128	182	0.5%	654,361	615,189	6.0%	613,796	97.0%	594,736	96.9%	94.1%
2016	394	57	85.5%	142	173	0.0%	687,218	652,110	5.1%	593,514	96.2%	588,139	99.1%	95.2%
2017	396	27	93.2%	152	193	2.1%	707,232	671,605	5.0%	642,836	95.7%	634,390	98.7%	94.5%
2018	305	6	98.0%	122	166	0.0%	565,221	534,753	5.4%	515,596	98.2%	498,011	96.6%	94.8%
2019	313	25	92.0%	103	174	2.3%	541,760	504,630	6.9%	482,177	94.7%	450,377	93.4%	88.5%
2020	423	29	93.1%	144	230	1.7%	708,208	676,954	4.4%	674,954	97.5%	666,173	98.7%	96.3%
2021	412	19	95.4%	146	244	0.8%	759,164	740,294	2.5%	727,234	98.2%	725,578	99.8%	98.0%
2022	377	23	93.9%	144	205	15.6%	578,557	561,322	3.0%	548,553	97.7%	498,996	91.0%	88.9%
2023	375	35	90.7%	138	194	33.5%	387,016	364,351	5.9%	355,529	98.4%			
Mean	453	47	90.0%	136	209	5.3%	724,788	681,255	5.9%	655,840	97.8%	637,023	95.6%	93.4%

1. Total collected minus total mortalities does not equal total spawned. This is because some fish are used in the spawning channel, some have been released back to the river, and some have not been used.
2. Includes jacks.

3. All documented egg loss at spawn time plus dead eggs counted at shock divided by the estimated total egg take.
4. Based on physical counts at mark time and all documented rearing mortality from ponding to release, except for BY2013 it is live eggs (est.) minus fry loss.
5. Approximately one-half of these were jacks, many of which were not used in spawning.
6. Approximately 45,000 smolts lost at Jack Creek due to frozen equipment in February, 2006.
7. EWOS feed treatment had high mortality and was discontinued in May 2007; resulted in lower survival to release.
8. Approximately 36,000 NoR (Table 33) and 12,000 HoR (Table 34) fish were culled in July 2009 to reduce pond densities; these fish were added back in to fry-smolt and live-egg-smolt survival calculations.

Table 62. 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	238,152	7.8%	91,300	98.2%	87,837	96.2%	94.4%
2003	143	12	91.6%	30	51	0.0%	219,901	203,784	7.3%	91,204	98.8%	88,733	97.3%	96.1%
2004	126	19	84.9%	22	49	0.0%	187,406	176,292	5.9%	100,567	98.3%	94,339	93.8%	92.2%
2005	109	6	94.5%	26	45	0.0%	168,160	147,628	12.2%	92,903	98.1%	90,518	97.4%	95.6%
2006	136	21	84.6%	28	41	2.4%	112,576	102,889	8.6%	74,735	97.6%	68,434	91.6%	89.4%
2007	110	15	86.4%	26	35	0.0%	125,755	121,755	3.2%	96,912	99.2%	94,663	97.7%	96.9%
2008	194	10	94.8%	51	67	1.5%	247,503	234,780	5.1%	111,797	98.9%	97,196	97.4%	96.4%
2009	164	24	85.4%	30	38	0.0%	148,593	147,458	0.8%	91,221	98.3%	88,771	97.3%	95.6%
2010	162	9	94.4%	29	55	1.8%	215,814	197,587	8.4%	96,144	97.9%	92,030	95.7%	93.7%
2011	166	7	95.8%	28	49	0.0%	188,075	179,650	4.5%	88,852	98.4%	84,701	95.3%	93.8%
2012	140	8	94.3%	29	42	0.0%	148,932	145,985	2.0%	94,031	98.8%	90,680	96.4%	95.3%
2013	186	5	97.3%	38	43	0.0%	155,383	150,853	2.9%	75,842	98.2%	71,599	94.4%	92.7%
2014	86	11	87.2%	21	29	0.0%	104,121	102,431	1.6%	91,702	97.2%	85,322	93.0%	90.4%
2015	61	23	62.3%	15	22	13.6%	66,238	64,646	2.4%	62,625	96.9%	60,211	96.1%	93.1%
2016	114	25	78.1%	33	35	0.0%	129,355	121,466	6.1%	85,910	95.8%	81,069	94.4%	90.4%
2017	127	8	93.7%	46	55	0.0%	195,070	187,173	4.0%	88,905	97.9%	76,279	85.8%	84.0%
2018	101	6	94.1%	33	54	0.0%	179,083	172,211	3.8%	150,126[11]	96.1%	144,409	96.2%	92.4%
2019	126	12	90.5%	43	46	0.0%	128,677	115,667	10.1%	120,071[11]	92.6%	100,021	83.3%	77.1%
2020	131	18	86.3%	43	50	4.0%	133,970	124,494	7.1%	97,324	97.3%	95,015	97.6%	95.0%
2021	118	13	89.0%	37	49	0.0%	124,346	120,825	2.8%	93,976	98.8%	83,432	88.8%	87.7%
2022	233	37	84.1%	67	111	6.3%	271,279	263,871	2.7%	103,510	97.0%	91,863	88.7%	86.1%

2023	144	17	88.2%	46	57	31.6%	93,034	86,718	6.8%	85,041	98.1%			
Mean	140	15	88.5%	34	50	3.0%	163,704	154,832	5.3%	94,759	97.7%	88,911	94.0%	91.8

Continued from footnotes for Table 33 above.

9. Table 34 -- From 2002 to present this is the estimated total egg take from all HxH crosses.
10. Table 34 – Estimated live eggs of total egg take. Due to the large surplus of eggs over the approximately 100K needed for the HxH line in many years, surplus fry were either planted in nearby land-locked lakes or were destroyed.
11. The number of segregated, hatchery-control line brood raceways was increased from 2 to 4 for this brood due to overall brood shortages.

Female BKD Profiles

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

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

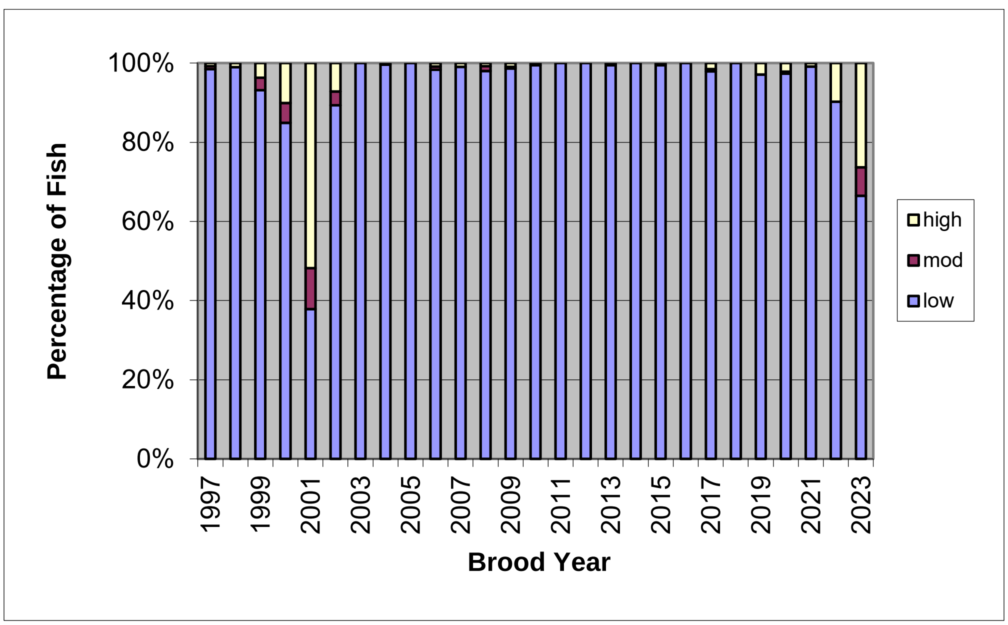


Figure 31. Proportion of wild/natural females spawned at CESRF by BKD rank, 1997 – present.

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

Brood	Wild/Natural (SN)						CESRF (HC)					
	Age-3		Age-4		Age-5		Age-3		Age-4		Age-5	
Year	N	Fecundity	N	Fecundity	N	Fecundity	N	Fecundity	N	Fecundity	N	Fecundity
1997			105	3,842.0	4	4,069.9						
1998	2[1]	3,908.9	161	3,730.3	15	4,322.5						
1999	3[1]	4,470.4	183	3,968.1	14	4,448.6						
2000			224	3,876.5	2	5,737.9						
2001			72	3,966.9	9	4,991.2			18	4,178.9		
2002	1	1,038.0	205	3,934.7	7	4,329.4			60	3,820.0	1	4,449.0
2003			163	4,160.2	31	5,092.8			30	3,584.1	19	5,459.9
2004			224	3,555.4	2	4,508.3			42	3,827.2		
2005	1	1,769.0	218	3,815.5	5	4,675.1			38	3,723.9	5	4,014.7
2006			196	3,396.4	24	4,338.9			36	3,087.3		
2007			178	3,658.3	24	4,403.3			33	3,545.2	2	4,381.9
2008			207	3,814.0	10	4,139.9			58	3,898.0		
2009	1	2,498.2	195	4,018.9	6	4,897.1			34	3,920.3		
2010			185	4,103.0					54	3,996.6		
2011	1[1]	3,853.1	179	4,000.1	4	5,692.1			41	3,843.3	2	4,098.2
2012			186	3,901.0	5	4,982.8			41	3,537.4	1	3,900.5
2013			159	3,760.3	6	5,068.0			36	3,498.7	2	4,955.3
2014			171	3,889.4	4	4,599.5			25	3,627.1	1	5,335.8
2015			166	3,963.0	2	5,249.3			14	3,975.1	1	3,793.3
2016			159	3,969.1	7	4,959.4			34	3,675.9	1	4,375.5
2017	2	2,150.6	161	4,013.8	1	3,805.5	1	1,645.0	53	3,609.1		
2018			130	3,452.4	6	3,643.9			49	3,348.3		
2019	1	1,500.8	129	3,573.2	2	3,519.3	2	1,520.5	40	3,466.3	1	3,204.0
2020			165	3,413.9	4	3,772.2			39	3,393.3	1	5,008.6
2021	1	3,351.8	197	3,674.5	14	3,989.3			38	3,217.4	2	2,770.2
2022			127	3,793.6	1	2,469.6			71	3,426.2		
2023	1	2,332.4	110	3,407.1	2	4,253.5			25	3,380.7		
Mean				3,801.9		4,460.0				3,633.4		4,288.2

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

Brood Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1997	2.2		1.1	0.8	1.2	0.8	1.5	1.5		1.9		5.3
1998		1.0	0.9	1.0	0.9	0.8	2.4	1.4	2.1	-0.3	1.0	1.2
1999		1.0	1.1	1.1	1.2	1.5	1.8	1.0		-0.5	0.3	1.7
2000	0.8	0.8	1.0	1.5	1.2	1.4	2.2	2.0	1.6	2.1	2.5	2.4
2001	1.1	1.1	2.6	1.1	1.3	1.2	1.6	2.0	2.3	2.5	2.8	0.9
2002	0.9	1.0	1.4	1.2	1.4	1.1	1.5	2.2	4.0	-1.4	2.9	1.0
2003	0.6	1.0	0.9	1.4	1.2	1.2	4.6	0.7	0.9	-0.2	1.8	1.0
2004	0.9	1.0	1.2	1.6	2.4	1.2	1.7	2.0	2.8	0.9	-2.6	1.1
2005	0.8	0.7	1.3	1.0	1.3	1.2	1.5	-0.8	0.4	-0.4	2.2	
2006	0.8	0.7	0.6	0.9	0.8	1.0	1.6	-1.0		-2.6	0.6	0.6
2007	0.7	0.7	0.9	0.9	1.0	0.8	2.2	-1.6	1.9	2.0	0.7	0.9
2008	0.5	0.6	0.9	0.9	1.0		0.8	1.7	-1.1	0.9	0.9	0.6
2009	0.5	1.2	1.0	0.7	1.1	1.0	1.5	4.1	0.6	-2.8	0.8	0.9
2010	0.6	0.8	1.3	0.8	0.8	1.8	2.8	1.3		0.8	0.8	0.7
2011	0.9	0.6	0.8	0.7	1.1	0.9		0.7		0.6	0.9	1.0
2012	0.8	1.4	1.1	0.8	1.3	1.4	1.0	1.1		1.0	3.1	1.2
2013	0.6	0.9	0.7	0.9	1.0	1.1	2.7	1.4		0.4	0.8	2.5
2014	0.5	2.2	0.7	1.0	2.4	0.7	4.3	0.5		1.7	0.9	0.8
2015	0.8	0.9	0.8	1.0	1.3	0.9	-1.8	0.7	-0.8	1.0	0.5	0.9
2016	0.6	0.9	0.8	1.0	1.1	1.1	2.1	1.8	1.0	0.6	0.4	0.8
2017	0.8	0.8	0.9	0.9	1.7	0.8	2.1	2.9	3.8	0.4	0.1	0.6
2018	0.7	0.8	0.9	0.9	1.3	1.1		0.9		0.6	1.3	1.6
2019	0.8	1.7	1.1	0.8	1.3	1.5	1.1	1.6	3.3	0.6	1.5	0.9
2020	0.6	1.2	0.7	0.8	3.0	0.9	2.4	1.2	-1.6	0.4	1.6	1.0
2021	0.5	1.1	0.7	0.7	1.2	0.8		0.6			1.6	1.0
2022	0.9	1.1	1.6	1.0	2.1	0.8	2.1	0.8		0.7	1.4	1.0
Mean	0.8	1.0	1.0	1.0	1.4	1.1	1.9	1.2	1.4	0.4	1.2	1.1

Length and Weight Growth Profiles

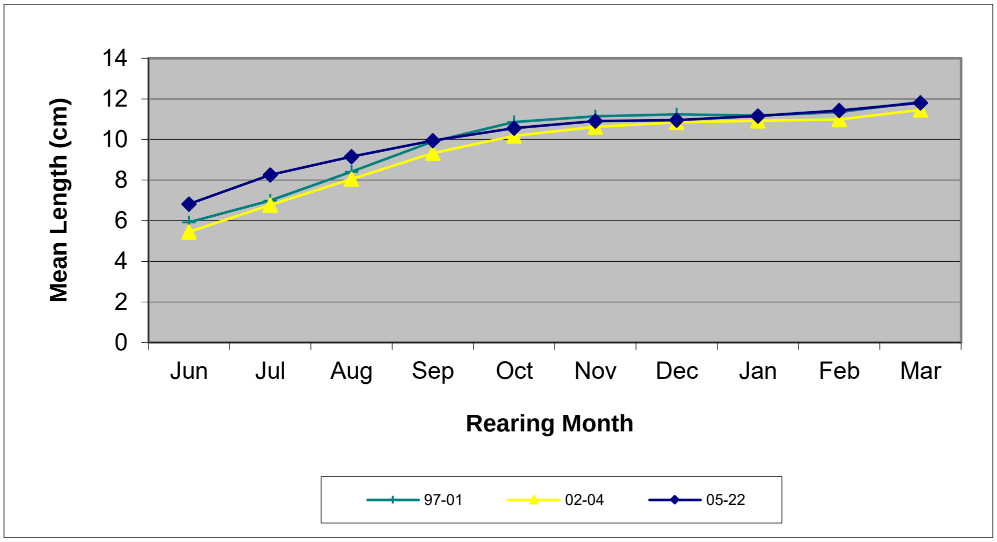


Figure 32. Mean fork length (cm) of CESRF juveniles by brood year and growth month, 1997 - present.

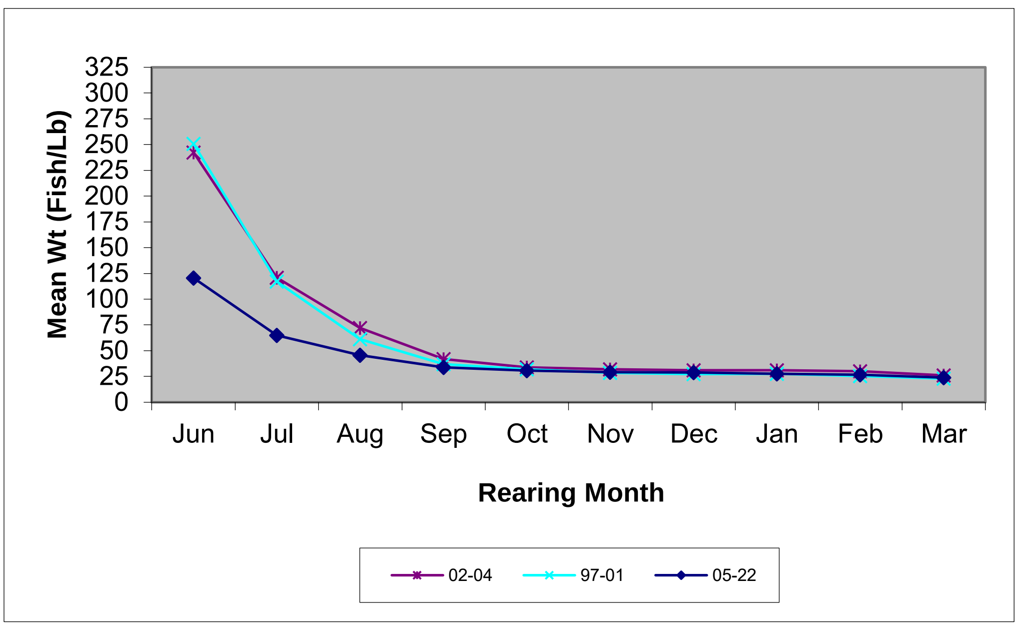
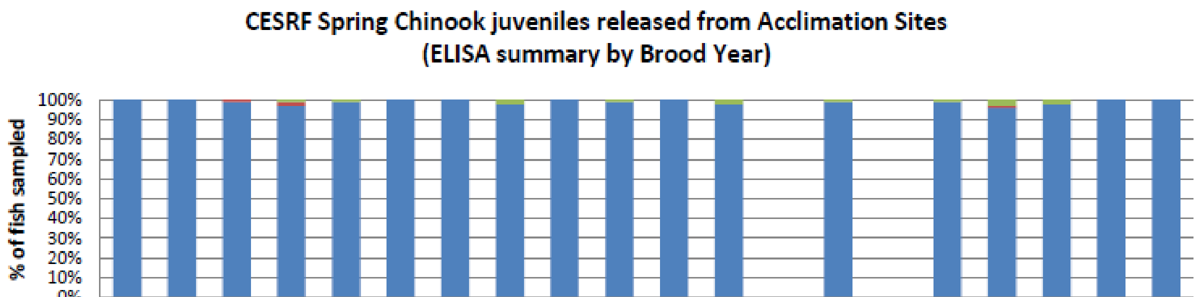


Figure 33. Mean Weight (fish/lb) of CESRF juveniles by brood year and growth month, 1997 - present.

Juvenile Fish Health Profile

Approximately 50-100 juveniles 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 high, moderate, or low (risk) based on the relative amounts of BKD in the tissue samples of the tested fish. These relative risk levels assume a good fish culture and rearing environment (i.e., water temperature and flows, nutrition, densities, etc. all must be conducive to good fish health). As indicated in Figure 7, juvenile fish released from the CESRF are largely in the low risk category for all brood years sampled to date. Due to budget issues and the low incidence observed over twenty years of testing, the USFWS discontinued testing of juveniles beginning with brood year 2017.

Figure 34. ELISA-risk profile of CESRF juveniles by brood year, 1997 – present (data source: USFWS).



	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997
High	0%	0%	0%	1%	1%	0%	0%	2%	0%	1%	0%	2%	0	1%	0	1%	3%	2%	0%	0%
Mod	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	0	0%	1%	0%	0%	0%
Low	100%	100%	99%	97%	99%	99%	99%	98%	100%	99%	100%	98%	0	99%	0	99%	96%	98%	100%	100%

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.

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.

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.

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

Brood Year	Control[1]	Treatment[2]	Acclimation Site CFJ	ESJ	JCJ	Total
1997	207,437	178,611	229,290	156,758		386,048
1998[3]	284,673	305,010	221,460	230,860	137,363	589,683
1999	384,563	374,226	232,563	269,502	256,724	758,789
2000	424,554	409,731	285,954	263,061	285,270	834,285
2001[4]	183,963	186,273	80,782	39,106	250,348	370,236
2002	420,764	416,140	266,563	290,552	279,789	836,904
2003	414,175	410,517	273,377	267,711	283,604	824,692
2004[5]	378,740	406,708	280,598	273,440	231,410	785,448
2005	431,536	428,466	287,127	281,150	291,725	860,002
2006	351,063	291,732	209,575	217,932	215,288	642,795
2007	387,055	384,210	265,907	254,540	250,818	771,265
2008	421,290	428,015	280,253	287,857	281,195	849,305
2009	418,314	414,627	279,123	281,395	272,423	832,941
2010	395,455	399,326	264,420	264,362	265,999	794,781
2011	382,195	386,987	255,290	248,454	265,438	769,182
2012	401,059	401,657	256,732	276,210	269,774	802,716
2013	No Experiment		215,933	214,745	216,077	646,755
2014	337,548	347,682	232,440	226,257	226,533	685,230
2015	331,316	323,631	208,239	218,225	228,483	654,947
2016	339,816	329,392	230,490	218,676	220,042	669,208
2017	351,656	359,013	244,236	233,449	232,984	710,669
2018	322,219	320,201	213,833	206,619	221,968	642,420
2019	270,242	280,156	153,575	193,042	203,781	550,398
2020	376,302	384,886	261,643	244,378	255,167	761,188
2021		809,010	268,064	276,969	263,977	809,010

2022		590,859	155,432	182,655	129,208	590,859
Mean	357,215	382,683	236,650	235,304	241,416	708,837[6]

Table 66. CESRF average pond densities at release by brood year, treatment, and acclimation site.

Brood	Treatment		Acclimation Site		
Year	Control[1]	Treatment[2]	CFJ	ESJ	JCJ
1997	41,487	35,722	38,215	39,190	
1998[3]	35,584	38,126	36,910	38,477	34,341
1999	42,729	41,581	38,761	44,917	42,787
2000	47,173	45,526	47,659	43,844	47,545
2001[4]	41,116	41,667	40,391	6,518	41,725
2002	46,752	46,238	44,427	48,425	46,632
2003	46,019	45,613	45,563	44,619	47,267
2004[5]	42,082	45,190	46,766	45,573	38,568
2005	47,948	47,607	47,855	46,858	48,621
2006	39,007	32,415	34,929	36,322	35,881
2007	43,006	42,690	44,318	42,423	41,803
2008	46,810	47,557	46,709	47,976	46,866
2009	46,479	46,070	46,521	46,899	45,404
2010	43,939	44,370	44,070	44,060	44,333
2011	42,466	42,999	42,548	41,409	44,240
2012	44,562	44,629	42,789	46,035	44,962
2013	No Experiment		35,989	35,791	36,013
2014	37,505	38,631	38,740	37,710	37,756
2015	36,813	35,959	34,707	36,371	38,081
2016	37,757	36,599	38,415	36,446	36,674
2017	39,073	39,890	40,706	38,908	38,831
2018	35,802	35,578	35,639	34,437	36,995
2019	30,027	31,128	25,596	32,174	33,964
2020	41,811	42,765	43,607	40,730	42,528
2021		44,945	44,677	46,162	43,996
2022		33,378	38,858	30,443	32,302
Mean	41,563	41,075	40,976	39,720	41,125

7. 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.
8. 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; BY2014-2021: BioPRO vs BioVIT diet. Brood Year 2006: EWS diet at CESRF through May 3, 2007; BY2022: BioVIT.
9. 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.
10. 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.

11. At the Jack Creek acclimation site raceway 3 suffered mechanical failures resulting in the loss of about 45,000 high-growth (control) fish.
12. 123564 BY 2022 forced Parr released into rivers in Nov/Dec 2023 included.

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 (Pandit 2020). 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.

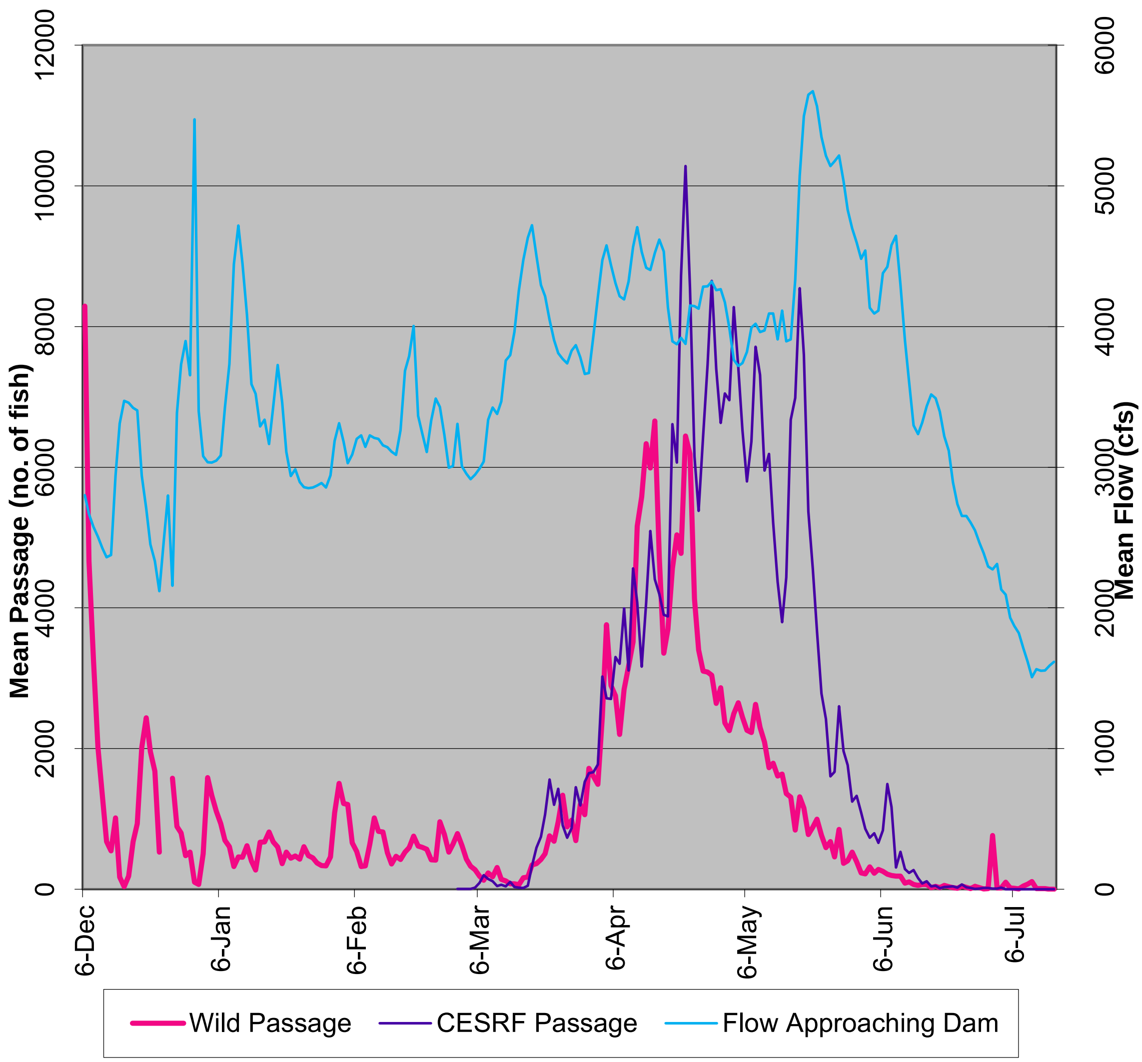


Figure 35. Mean flow approaching Prosser Dam versus mean estimated smolt passage at Prosser of aggregate wild/natural and CESRF spring Chinook for outmigration years 1999-2023.

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. See also:

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., 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 142:540–555.

Feed Treatments (Brood Years 2005, 2007- 2010; Migration Years 2007, 2009- 2018)

Prior to releases in 2007, and 2009- 2018, two feed treatments were allocated to raceways within adjacent raceway pairs. The feeds tested included Bio-Oregon's BioPro, BioVita, and BioTransfer diets (see https://www.bio-oregon.com/). The intent of the experiments was to determine whether any of the various feeds conferred any life-stage survival advantages. Preliminary analyses indicated no significant or substantial differences between the feeds when averaged over years. See Appendix H of our [2015 annual report] and Appendix F of our [2019 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 for other studies described above with standard Bio-Oregon pellets fed to half of the rearing ponds and an EWOS (https://www.cargill.com/animal-nutrition/brands/ewos) 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 continuing to develop 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 44-45). 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 44 and 45.

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 39-45 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 67. 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
1986	1988	2454	271,316			4,518		1.7%	
1987	1989	4265	76,362			2,402		3.1%	
1988	1990	4141	140,218			5,746		4.1%	
1989	1991		109,002			2,597		2.4%	
1990	1992	1960	128,457			1,178		0.9%	
1991	1993	3397	92,912			544		0.6%	
1992	1994	1926	167,477			3,790		2.3%	
1993	1995	4882	172,375			3,202		1.9%	
1994	1996	6231	218,578			1,238		0.6%	
1995	1997	12608	52,028			1,995		3.8%	
1996	1998	5466	491,584			21,151		4.3%	
1997	1999	5925	584,016	187,669	48.6%	12,855	8,670	2.2%	4.6%
1998	2000[5]	4946	199,416	303,688	51.5%	8,240	9,782	4.1%	3.2%
1999	2001	1321	148,460	281,256	37.1%	1,764	864	1.2%	0.3%
2000	2002	5015	467,359	366,950	44.0%	11,434	4,819	2.4%	1.3%
2001	2003	3504	308,959	154,329	41.7%	8,597	1,251	2.8%	0.8%
2002	2004	2439	169,397	290,950	34.8%	3,743	2,557	2.2%	0.9%
2003	2005	1285	134,859	236,443	28.7%	2,746	1,020	2.0%	0.4%
2004	2006	5652	133,238	300,508	38.3%	2,802	4,482	2.1%	1.5%
2005	2007	4551	99,341	351,359	40.9%	4,295	5,004	4.3%	1.4%
2006	2008	4298	120,013	265,485	41.3%	6,004	10,577	5.0%	4.0%
2007	2009	5784	237,228	415,923	53.9%	7,952	7,604	3.4%	1.8%
2008	2010	3592	220,950	382,878	45.1%	7,385	8,036	3.3%	2.1%
2009	2011	9414	304,322	442,564	53.1%	3,766	3,606	1.2%	0.8%
2010	2012	8556	258,106	391,446	49.3%	6,602	5,592	2.6%	1.4%
2011	2013	4875	365,386	372,079	48.4%	7,343	4,160	2.0%	1.1%
2012	2014	4923	263,266	408,222	50.9%	3,969	1,932	1.5%	0.5%
2013	2015	1555	125,150	332,715	51.4%	3,415	3,139	2.7%	0.9%
2014	2016	5765	185,442	403,938	58.9%	1,800	2,865	1.0%	0.7%
2015	2017	7804	208,929	273,248	41.7%	1,185	1,321	0.6%	0.5%
2016	2018	5652	131,489	290,644	43.4%	1,931	1,263	1.5%	0.4%
2017	2019	3595	175,427	319,579	45.0%	1,919	1,700	1.1%	0.5%
2018	2020	2864	151,265	371,069	57.8%	3,214	2,915	2.1%	0.8%
2019	2021[6]	3815	106,092	212,000	38.5%	1,377[6]	1,887[6]	1.3%[6]	0.9%[6]
2020	2022[6]	6738	126,537	282,878	37.2%	103[6]	253[6]	0.1%[6]	0.1%[6]
2021	2023[6]	4319	63,681	230,463	28.5%				

2022	2024[6]

7. 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.
8. Aggregate of Upper Yakima, Naches, and American wild/natural populations.
9. Estimated smolt-to-smolt (release from upper Yakima River acclimation sites to Chandler) survival for CESRF juveniles.
10. 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.
11. Available data were not sufficient to estimate juvenile flow-entrainment and passage of wild/natural fish.
12. Data for most recent years are preliminary; return data do not include age-5 adult fish.

Table 68. Estimated wild/natural smolt-to-adult return rates (SAR) based on adult detections of PIT tagged fish. Roza tagged smolts to Bonneville Dam adult returns. Footnotes follow Table 41.

		Wild/Natural smolts tagged at Roza				
Brood	Number	Adult Returns at Age[1]				
Year	Tagged	Age 3	Age 4	Age 5	Total	SAR[1]
1997	310	0	1	0	1	0.32%[2]
1998	6,209	15	171	14	200	3.22%
1999	2,179	2	8	0	10	0.46%
2000	8,718	1	51	1	53	0.61%
2001	7,804	9	52	3	64	0.82%
2002	3,931	2	46	4	52	1.32%
2003	1,733	0	6	1	7	0.40%
2004	2,333	1	8	1	10	0.43%
2005	1,200	0	8	0	8	0.67%
2006	1,675	12	33	2	47	2.81%
2007	3,795[a]	6	47	2	55	1.45%
2008	105	0	1	0	1	0.95%
2009	2,087	0	3	1	4	0.19%
2010	2,647	4	22	1	27	1.02%
2011	2,473	1	9	1	11	0.44%
2012			No Releases			
2013	524	1	5	0	6	1.15%
2014	136	0	0	0	0	0.00%
2015	181	0	0	0	0	0.00%
2016	382	0	1	0	1	0.26%
2017	292	2	0	0	2	0.68%
2018	253	0	3	1	4	1.58%
2019	1,259	2	6	1	9	0.71%
2020	341	0				

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

Table 69. Estimated CESRF smolt-to-adult return rates (SAR) based on adult detections of PIT tagged fish. Roza tagged smolts to Bonneville Dam adult returns.

		CESRF smolts tagged at Roza				
Brood	Number	Adult Returns at Age[1]				
Year	Tagged	Age 3	Age 4	Age 5	Total	SAR[1]
1997	407	0	2	0	2	0.49%[2]
1998	2,999	5	42	2	49	1.63%
1999	1,744	1	0	0	1	0.06%
2000	1,503	0	1	0	1	0.07%
2001	2,146	0	4	0	4	0.19%
2002	2,201	4	5	0	9	0.41%
2003	1,418	0	3	1	4	0.28%
2004	4,194	3	13	0	16	0.38%
2005	2,358	0	3	0	3	0.13%
2006	4,130	32	31	2	65	1.57%
2007	3,736	10	21	0	31	0.83%
2008	1,071	4	3	0	7	0.65%
2009	3,641	2	4	0	6	0.16%
2010	4,064	4	13	1	18	0.44%
2011	513	0	0	0	0	0.00%
2012	201	0	0	0	0	0.00%
2013	1,432	0	0	0	0	0.00%
2014	1,104	0	3	0	3	0.27%
2015	1,783	2	2	0	4	0.22%
2016	2,578	1	0	0	1	0.04%
2017	2,238	2	4	0	6	0.27%
2018	2,386	6	8	0	14	0.59%
2019	2,238	1	2		3	0.13%
2020	4,465	5	1			

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 70. Overall McNary Dam (MCN) smolt to Bonneville Dam adult (BOA) return rates (SAR) based on juvenile and adult detections of wild/natural Yakima R. spring Chinook PIT-tagged and released at Roza Dam (Table B.77 in McCann et al. 2023).

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	7,329	5.47	5.00	5.99	5.69	5.20	6.21
2001	3,578	0.89	0.64	1.18	1.15	0.86	1.46
2002	4,236	2.31	1.92	2.75	2.38	1.99	2.82
2003	8,002	1.67	1.43	1.92	1.91	1.65	2.15
2004	4,912	2.63	2.25	3.02	2.85	2.46	3.27
2005	2,491	1.28	0.91	1.67	1.37	0.98	1.76
2006	2,632	1.67	1.28	2.12	2.13	1.66	2.63
2007	1,066	1.50	0.92	2.08	1.50	0.92	2.08
2008	2,795	4.69	3.97	5.41	5.80	5.03	6.58
2009	2,111	4.36	3.63	5.16	4.78	4.02	5.61
2010	3,338	1.38	1.05	1.73	1.86	1.46	2.29
2011	3,180	0.85	0.58	1.13	0.97	0.69	1.27
2012	1,944	2.78	2.15	3.46	3.24	2.55	4.00
2013	2,244	1.65	1.22	2.11	2.05	1.56	2.59
2014	1,489	2.08	1.48	2.74	2.35	1.72	3.10
2015	1,730	1.45	0.91	2.03	1.73	1.14	2.39
2016	241	0.41	0.00	1.23	0.41	0.00	1.23
2017	464	1.29	0.48	2.24	1.72	0.76	2.80
2018	474	1.05	0.38	1.86	1.05	0.38	1.86
2019	780	2.18	1.30	3.12	2.57	1.58	3.62
2020	857	2.57	1.42	3.71	3.03	1.73	4.41
2021[B]	1,302	1.15	0.54	1.99	1.46	0.69	2.50
Arithmetic mean (incl. zeros)		2.06			2.36		
Geometric mean (excl. zeros)		1.74			2.00		

[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 both the juvenile detector at McNary Dam, as well as PIT-tags on bird colonies in the Columbia River estuary (when applicable), PIT-tag detections at estuary pilings (when applicable), and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[B] Incomplete, 2-salt returns through September 25, 2023.

Table 71. Overall McNary Dam smolt (MCN) to Bonneville Dam adult (BOA) return rates (SAR) based on juvenile and adult detections of CESRF PIT-tagged spring Chinook (Table B.83 in McCann et al. 2023).

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA without Jacks			MCN-to-BOA with Jacks		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	14,416	3.61	3.34	3.91	3.95	3.65	4.26
2001	9,269	0.28	0.20	0.37	0.29	0.20	0.38
2002	11,753	1.36	1.18	1.54	1.72	1.52	1.91
2003	11,974	0.59	0.48	0.71	0.86	0.72	1.00
2004	7,986	1.54	1.31	1.78	1.85	1.60	2.11
2005	5,789	0.66	0.48	0.84	0.78	0.59	0.98
2006	10,285	1.23	1.06	1.43	1.59	1.39	1.81
2007	12,654	1.01	0.87	1.16	1.51	1.32	1.69
2008	11,752	3.15	2.86	3.43	5.03	4.64	5.39
2009	15,386	1.82	1.64	2.00	2.29	2.08	2.50
2010	12,479	1.51	1.33	1.71	2.53	2.27	2.78
2011	11,886	0.93	0.79	1.08	1.20	1.03	1.37
2012	15,736	1.22	1.08	1.37	1.76	1.57	1.94
2013	13,230	1.39	1.22	1.59	1.97	1.76	2.19
2014	12,856	0.58	0.48	0.70	0.84	0.72	0.98
2015	10,614	1.02	0.86	1.18	1.87	1.65	2.11
2016	13,850	0.87	0.74	1.01	1.52	1.34	1.70
2017	11,202	0.62	0.49	0.75	0.74	0.61	0.88
2018	11,805	0.54	0.43	0.66	0.84	0.70	0.98
2019	10,270	0.77	0.62	0.93	1.15	0.96	1.34
2020	11,678	1.20	0.97	1.41	1.77	1.48	2.05
2021[B]	10,579	0.90	0.63	1.15	1.22	0.95	1.53
Arithmetic mean (incl. zeros)		1.22			1.70		
Geometric mean (excl. zeros)		1.03			1.43		

[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 both the juvenile detector at McNary Dam, as well as PIT-tags on bird colonies in the Columbia River estuary (when applicable), PIT-tag detections at estuary pilings (when applicable), and adult detections to augment the NOAA Trawl detections below BON and the Logit link.

[B] Incomplete, 2-salt returns through September 25, 2023.

Table 72. 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				
		Age 3	Age 4	Age 5	Total	SAR	Age 3	Age 4	Age 5	Total	SAR
1997[2]	39,892	18	182	4	204	0.51%	65	517	16	598	1.50%
1998	37,388	49	478	48	575	1.54%	54	310	34	398	1.06%
1999	38,793	1	25	1	27	0.07%	1	22	0	23	0.06%
2000	37,582	42	159	2	203	0.54%	37	112	1	150	0.40%
2001	36,523	32	71	0	103	0.28%	22	58	0	80	0.22%
2002[3]	39,003	25	119	4	148	0.38%	15	80	2	97	0.25%
2003	38,916	7	37	1	45	0.12%	3	27	1	31	0.08%
2004	36,426	37	123	4	164	0.45%	24	98	3	125	0.34%
2005	39,119	63	126	2	191	0.49%	44	96	2	142	0.36%
2006	38,595	221	354	15	590	1.53%	187	264	11	462	1.20%
2007	38,618	73	279	3	355	0.92%	55	182	3	240	0.62%
2008	39,013	135	192	3	330	0.85%	81	132	2	215	0.55%
2009	36,239	32	110	3	145	0.40%	23	85	2	110	0.30%
2010	38,737	85	187	6	278	0.72%	62	142	3	207	0.53%
2011	38,165	77	191	2	270	0.71%	57	122	2	181	0.47%
2012	38,343	33	75	0	108	0.28%	10	59	0	69	0.18%
2013	38,278	90	110	0	200	0.52%	68	84	0	152	0.40%
2014	38,119	92	121	1	214	0.56%	64	66	1	131	0.34%
2015	38,029	15	69	0	84	0.22%	6	51	0	57	0.15%
2016	38,061	34	64	1	99	0.26%	20	42	0	62	0.16%

2017	37,709	39	86	1	126	0.33%	26	67	0	93	0.25%
2018	35,886	68	145	1	214	0.60%	47	90	1	138	0.38%
2019	37,005	34	96	1	131	0.35%	24	77		101	0.27%
2020	37,152	35	33				24				
2021	35,476	2									

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

Brood Year	Number Tagged[1]	Adult Returns to Roza Dam				
		Age3	Age4	Age5	Total	SAR
1997[2]	346,156	623	5,663	120	6,406	1.85%
1998	552,295	936	5,834	534	7,304	1.32%
1999	719,996	103	652	13	768	0.11%
2000	796,703	1,005	2,764	69	3,837	0.48%
2001	333,713	290	791	9	1,091	0.33%
2002[3]	797,901	332	1,771	135	2,238	0.28%
2003	785,776	115	1,568	14	1,696	0.22%
2004	749,022	683	3,688	202	4,574	0.61%
2005	820,883	1,012	5,302	22	6,336	0.77%
2006	604,200	2,383	6,427	287	9,096	1.51%
2007	732,647	1,024	5,645	87	6,756	0.92%
2008	810,292	1,552	3,680	76	5,308	0.66%
2009	796,702	389	3,106	67	3,562	0.45%
2010	756,044	721	3,618	28	4,368	0.58%
2011	731,017	780	2,318	51	3,149	0.43%
2012	764,373	172	2,274	12	2,458	0.32%
2013	608,477	718	2,386	0	3,104	0.51%
2014	647,111	644	1,511	10	2,165	0.33%
2015	616,918	237	1,242	0	1,479	0.24%
2016	631,147	158	1,211	69	1,438	0.23%
2017	672,960	366	1,924	0	2,290	0.34%
2018	606,534	587	2,248	0	2,834	0.47%
2019	513,393	465	1,739		2,204	0.43%
2020	724,036	526				

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). Results are presented in Table 46.

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. Results are presented in Table 47.

Table 74. Spring Chinook harvest in the Yakima River Basin, 1985-present.

	Tribal		Non-Tribal		River Totals			Harvest
Year	CESRF	Wild	CESRF	Wild	CESRF	Wild	Total	Rate[1]
1985		865		0		865	865	19.0%
1986		1,340		0		1,340	1,340	14.2%
1987		517		0		517	517	11.6%
1988		444		0		444	444	10.5%
1989		747		0		747	747	15.2%
1990		663		0		663	663	15.2%
1991		32		0		32	32	1.1%
1992		345		0		345	345	7.5%
1993		129		0		129	129	3.3%
1994		25		0		25	25	1.9%
1995		79		0		79	79	11.9%
1996		475		0		475	475	14.9%
1997		575		0		575	575	18.1%
1998		188		0		188	188	9.9%
1999		604		0		604	604	21.7%
2000	53	2,305		100	53	2,405	2,458	12.9%
2001	572	2,034	1,252	772	1,825	2,806	4,630	19.9%
2002	1,373	1,207	492	36[2]	1,865	1,243	3,108	20.6%
2003	134	306	0	0	134	306	440	6.3%
2004	289	712	569	109[2]	858	820	1,679	11.0%
2005	46	428	0	0	46	428	474	5.4%
2006	246	354	0	0	246	354	600	9.5%
2007	123	156	0	0	123	156	279	6.5%
2008	521	414	586	11[2]	1,107	426	1,532	17.8%
2009	1,089	715	541	8[2]	1,630	722	2,353	19.4%
2010	345	194	1,154	48[2]	1,499	241	1,741	13.2%
2011	1,361	1,261	1,579	179[2]	2,940	1,440	4,380	24.4%
2012	1,220	1,302	735	63[2]	1,955	1,364	3,320	27.5%
2013	846	975	786	46[2]	1,632	1,021	2,653	25.9%
2014	576	715	826	54[2]	1,402	769	2,171	19.2%
2015	121	271	385	38[2]	506	309	815	8.7%
2016	103	185	132	24[2]	235	209	444	6.4%
2017	217	201	750	104[2]	967	305	1,272	17.8%
2018	154	115	259	20[2]	413	136	548	15.2%
2019	24	16	0	0	24	16	40	1.8%
2020	26	42	0	0	26	42	68	2.0%
2021	9	7	0	0	9	7	16	0.4%
2022	61	85	300	25	361	110	471	7.7%
2023	61	58	52	6	113	64	177	5.3%
Mean	414	511	452	67	866	583	1,095	12.3%

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 75. Estimated run size, harvest, and harvest rates of Yakima Basin spring Chinook in Columbia River mainstem and terminal area fisheries, 1986-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 Total	Wild	CESRF	Col. Basin Harvest Rate Total	Wild
1986	13,567	280	802	9,439	1,340	2,423	2,423	0	17.9%	17.9%
1987	6,160	96	378	4,443	517	991	991	0	16.1%	16.1%
1988	5,674	363	401	4,246	444	1,208	1,208	0	21.3%	21.3%
1989	8,919	213	683	4,914	747	1,642	1,642	0	18.4%	18.4%
1990	6,954	352	480	4,372	663	1,495	1,495	0	21.5%	21.5%
1991	4,650	184	291	2,906	32	507	507	0	10.9%	10.9%
1992	6,207	103	380	4,599	345	827	827	0	13.3%	13.3%
1993	5,132	44	315	3,919	129	488	488	0	9.5%	9.5%
1994	2,251	87	113	1,302	25	225	225	0	10.0%	10.0%
1995	1,394	1	69	666	79	149	149	0	10.7%	10.7%
1996	5,898	6	309	3,179	475	790	790	0	13.4%	13.4%
1997	5,192	3	348	3,173	575	926	926	0	17.8%	17.8%
1998	2,867	3	143	1,903	188	333	333	0	11.6%	11.6%
1999	4,160	4	198	2,781	604	806	806	0	19.4%	19.4%
2000	28,783	58	1,782	19,101	2,458	4,298	4,174	124	14.9%	14.9%
2001	32,253	969	4,230	24,147	4,630	9,830	5,654	4,176	30.5%	28.6%
2002	25,307	1,278	2,923	15,815	3,108	7,309	2,757	4,551	28.9%	24.0%
2003	10,277	286	902	7,227	440	1,628	987	641	15.8%	14.7%
2004	24,212	1,023	2,329	16,820	1,679	5,031	2,876	2,154	20.8%	16.2%
2005	13,302	354	893	9,588	474	1,721	1,363	358	12.9%	12.1%
2006	12,149	310	898	6,593	600	1,808	1,038	770	14.9%	13.2%
2007	5,218	174	477	4,457	279	930	460	470	17.8%	15.5%
2008	12,553	1,204	1,870	9,273	1,532	4,607	1,360	3,247	36.7%	25.2%
2009	13,693	1,210	1,089	11,395	2,353	4,651	1,318	3,333	34.0%	23.9%
2010	18,568	1,631	2,778	13,746	1,741	6,150	1,517	4,633	33.1%	21.8%
2011	23,322	1,098	1,794	18,520	4,380	7,272	2,590	4,682	31.2%	22.4%
2012	17,202	850	1,622	12,612	3,320	5,792	2,364	3,428	33.7%	26.7%
2013	14,924	879	1,035	10,602	2,653	4,567	1,849	2,718	30.6%	23.7%
2014	17,303	716	2,208	11,868	2,171	5,095	2,089	3,006	29.4%	22.4%
2015	11,992	476	1,437	9,848	815	2,727	1,454	1,273	22.7%	17.8%
2016	10,110	454	961	7,281	444	1,859	950	910	18.4%	15.1%
2017	12,196	493	924	7,544	1,272	2,688	855	1,833	22.0%	13.5%
2018	6,236	248	638	3,737	548	1,435	460	976	23.0%	16.4%
2019	3,756	68	259	2,250	40	367	130	237	9.8%	8.6%
2020	5,770	62	342	3,413	68	472	273	199	8.2%	7.6%
2021	5,616	173	333	4,026	16	522	191	331	9.3%	7.2%
2022	8,412	289	800	6,387	471	1,560	619	940	18.5%	13.1%
2023[1]	5,264	115	495	3,383	177	787	293	494	14.9%	13.2%
Mean	10,986	425	998	7,669	1,101	2,524	1,327	1,197	19.6%	16.6%

1. Preliminary.

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Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2022.

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

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

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

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

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

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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 2006-2022.

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.

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2010	CLE01	CFJ05	STF	WW	4.2	Right	Red	Snout	3/15/2012	5/14/2012	190256	2,000	40,221	41,972
2010	CLE02	CFJ06	BIO	WW	4.2	Left	Red	Snout	3/15/2012	5/14/2012	190257	2,000	40,845	42,664
2010	CLE03	CFJ03	STF	HH	4.0	Right	Red	Posterior Dorsal	3/15/2012	5/14/2012	190258	4,000	43,725	47,415
2010	CLE04	CFJ04	BIO	HH	4.0	Left	Red	Posterior Dorsal	3/15/2012	5/14/2012	190259	4,000	40,976	44,615
2010	CLE05	ESJ01	STF	WW	4.2	Right	Green	Snout	3/15/2012	5/14/2012	190260	2,000	40,710	42,374
2010	CLE06	ESJ02	BIO	WW	4.2	Left	Green	Snout	3/15/2012	5/14/2012	190261	2,000	40,419	42,157
2010	CLE07	JCJ01	STF	WW	4.0	Right	Orange	Snout	3/15/2012	5/14/2012	190262	2,000	43,833	45,471
2010	CLE08	JCJ02	BIO	WW	4.0	Left	Orange	Snout	3/15/2012	5/14/2012	190263	2,000	43,815	45,573
2010	CLE09	ESJ03	STF	WW	4.1	Right	Green	Snout	3/15/2012	5/14/2012	190264	2,000	42,528	44,257
2010	CLE10	ESJ04	BIO	WW	4.1	Left	Green	Snout	3/15/2012	5/14/2012	190265	2,000	42,649	44,443
2010	CLE11	ESJ05	STF	WW	4.2	Right	Green	Snout	3/15/2012	5/14/2012	190266	2,000	43,878	45,633
2010	CLE12	ESJ06	BIO	WW	4.2	Left	Green	Snout	3/15/2012	5/14/2012	190267	2,000	43,750	45,498
2010	CLE13	JCJ03	STF	WW	4.2	Right	Orange	Snout	3/15/2012	5/14/2012	190268	2,000	41,816	43,473
2010	CLE14	JCJ04	BIO	WW	4.2	Left	Orange	Snout	3/15/2012	5/14/2012	190269	2,000	41,052	42,772
2010	CLE15	JCJ05	STF	WW	4.1	Right	Orange	Snout	3/15/2012	5/14/2012	190270	2,000	42,894	44,603
2010	CLE16	JCJ06	BIO	WW	4.1	Left	Orange	Snout	3/15/2012	5/14/2012	190271	2,000	42,371	44,107
2010	CLE17	CFJ01	STF	WW	4.2	Right	Red	Snout	3/15/2012	5/14/2012	190272	2,000	42,329	44,128
2010	CLE18	CFJ02	BIO	WW	4.2	Left	Red	Snout	3/15/2012	5/14/2012	190273	2,000	41,829	43,626

[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 2006-2022.

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

[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 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 2006-2022.

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 2006-2022.

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

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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 2006-2022.

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

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

Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2022.

Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2015	CLE01	ESJ01	PRO	WN	2.9	Right	Green	Snout	3/15/2017	5/15/2017	190457	2,000	32,798	34,620
2015	CLE02	ESJ02	VIT	WN	2.9	Left	Green	Snout	3/15/2017	5/15/2017	190458	2,000	32,700	34,552
2015	CLE03	JCJ03	PRO	WN	2.9	Right	Orange	Snout	3/15/2017	5/15/2017	190459	2,000	38,469	40,305
2015	CLE04	JCJ04	VIT	WN	2.9	Left	Orange	Snout	3/15/2017	5/15/2017	190460	2,000	34,615	36,415
2015	CLE05	CFJ05	PRO	WN	2.9	Right	Red	Snout	3/15/2017	5/15/2017	190461	2,000	33,149	35,007
2015	CLE06	CFJ06	VIT	WN	2.9	Left	Red	Snout	3/15/2017	5/15/2017	190462	2,000	32,516	34,357
2015	CLE07	CFJ01	PRO	HC	2.6	Right	Red	Posterior Dorsal	3/15/2017	5/15/2017	190463	4,000	28,055	31,894
2015	CLE08	CFJ02	VIT	HC	2.6	Left	Red	Posterior Dorsal	3/15/2017	5/15/2017	190464	4,000	24,464	28,317
2015	CLE09	JCJ01	PRO	WN	3.0	Right	Orange	Snout	3/15/2017	5/15/2017	190465	2,000	38,098	39,927
2015	CLE10	JCJ02	VIT	WN	3.0	Left	Orange	Snout	3/15/2017	5/15/2017	190466	2,000	35,807	37,611
2015	CLE11	ESJ03	PRO	WN	2.8	Right	Green	Snout	3/15/2017	5/15/2017	190467	2,000	33,136	34,968
2015	CLE12	ESJ04	VIT	WN	2.8	Left	Green	Snout	3/15/2017	5/15/2017	190468	2,000	34,248	36,014
2015	CLE13	ESJ05	PRO	WN	2.8	Right	Green	Snout	3/15/2017	5/15/2017	190469	2,000	37,837	39,669
2015	CLE14	ESJ06	VIT	WN	2.8	Left	Green	Snout	3/15/2017	5/15/2017	190470	2,000	36,564	38,402
2015	CLE15	JCJ05	PRO	WN	2.9	Right	Orange	Snout	3/15/2017	5/15/2017	190471	2,000	34,354	36,206
2015	CLE16	JCJ06	VIT	WN	2.9	Left	Orange	Snout	3/15/2017	5/15/2017	190472	2,000	36,156	38,019
2015	CLE17	CFJ03	PRO	WN	2.8	Right	Red	Snout	3/15/2017	5/15/2017	190473	2,000	36,915	38,720
2015	CLE18	CFJ04	VIT	WN	2.8	Left	Red	Snout	3/15/2017	5/15/2017	190474	2,000	38,105	39,944

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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 2006-2022.

Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2016	CLE01	CFJ05	PRO	WN	2.4	Right	Red	Snout	3/15/2018	5/15/2018	190490	2,000	35,447	37,354
2016	CLE02	CFJ06	VIT	WN	2.4	Left	Red	Snout	3/15/2018	5/15/2018	190491	2,000	35,568	37,468
2016	CLE03	ESJ05	PRO	WN	2.4	Right	Green	Snout	3/15/2018	5/15/2018	190492	2,000	36,330	38,195
2016	CLE04	ESJ06	VIT	WN	2.4	Left	Green	Snout	3/15/2018	5/15/2018	190493	2,000	35,002	36,943
2016	CLE05	CFJ01	PRO	HC	2.7	Right	Red	Posterior Dorsal	3/15/2018	5/15/2018	190494	4,000	36,189	40,043
2016	CLE06	CFJ02	VIT	HC	2.7	Left	Red	Posterior Dorsal	3/15/2018	5/15/2018	190495	4,000	37,147	41,026
2016	CLE07	JCJ03	PRO	WN	2.4	Right	Orange	Snout	3/15/2018	5/15/2018	190496	2,000	36,599	38,400
2016	CLE08	JCJ04[3]	VIT	WN	2.4	Left	Orange	Snout	3/15/2018	5/15/2018	190497	2,000	34,080	54,569
2016	CLE09	JCJ01	PRO	WN	2.5	Right	Orange	Snout	3/15/2018	5/15/2018	190498	2,000	34,189	36,048
2016	CLE10	JCJ02[3]	VIT	WN	2.5	Left	Orange	Snout	3/15/2018	5/15/2018	190499	2,000	32,004	52,475
2016	CLE11	CFJ03	PRO	WN	2.6	Right	Red	Snout	3/15/2018	5/15/2018	190501	2,000	36,470	38,334
2016	CLE12	CFJ04	VIT	WN	2.6	Left	Red	Snout	3/15/2018	5/15/2018	190502	2,000	34,372	36,265
2016	CLE13	ESJ03	PRO	WN	2.5	Right	Green	Snout	3/15/2018	5/15/2018	190503	2,000	31,448	33,380
2016	CLE14	ESJ04	VIT	WN	2.5	Left	Green	Snout	3/15/2018	5/15/2018	190504	2,000	31,093	33,025
2016	CLE15	JCJ05	PRO	WN	2.5	Right	Orange	Snout	3/15/2018	5/15/2018	190505	2,000	36,688	38,550
2016	CLE16	JCJ06[3]	VIT	WN	2.5	Left	Orange	Snout	3/15/2018	5/15/2018	190506	2,000	35,244	0
2016	CLE17	ESJ01	PRO	WN	2.5	Right	Green	Snout	3/15/2018	5/15/2018	190507	2,000	37,553	39,512
2016	CLE18	ESJ02	VIT	WN	2.5	Left	Green	Snout	3/15/2018	5/15/2018	190508	2,000	35,689	37,621

[1] All fish are progeny of wild/natural parents unless denoted as HC which designates the hatchery control line beginning with brood year 2002. “Avg BKD” denotes the average BKD ELISA ranking of the female parents whose progeny were in these ponds. PRO=BioPro diet, VIT=BioVita diet, Bio-Oregon products.

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

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

Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2022.

Brood Year	C.E. Pond	Accl. Pond	Treatment[1] /Avg BKD			Tag Information			First Release	Last Release	CWT Code	No. PIT	No. CWT	Est. Tot. Release[2]
2017	CLE01	CFJ01	PRO	WN	3.4	Right	Red	Snout	3/15/2019	5/9/2019	190535	2,000	38,689	40,527
2017	CLE02	CFJ02	VIT	WN	3.4	Left	Red	Snout	3/15/2019	5/9/2019	190536	2,000	39,792	41,650
2017	CLE03	ESJ05	PRO	WN	3.5	Right	Green	Snout	3/15/2019	5/9/2019	190537	2,000	34,646	36,556
2017	CLE04	ESJ06	VIT	WN	3.5	Left	Green	Snout	3/15/2019	5/9/2019	190538	2,000	35,655	37,493
2017	CLE05	JCJ05[3]	PRO	WN	3.1	Right	Orange	Snout			190539	2,000	35,118	0
2017	CLE06	JCJ06[3]	VIT	WN	3.1	Left	Orange	Snout			190540	2,000	36,475	0
2017	CLE07	ESJ03	PRO	WN	3.3	Right	Green	Snout	3/15/2019	5/9/2019	190541	2,000	37,843	39,737
2017	CLE08	ESJ04	VIT	WN	3.3	Left	Green	Snout	3/15/2019	5/9/2019	190542	2,000	38,689	40,579
2017	CLE09	CFJ03	PRO	WN	3.4	Right	Red	Snout	3/15/2019	5/9/2019	190543	2,000	40,551	42,423
2017	CLE10	CFJ04	VIT	WN	3.4	Left	Red	Snout	3/15/2019	5/9/2019	190544	2,000	41,529	43,357
2017	CLE11	JCJ03[3]	PRO	WN	3.3	Right	Orange	Snout	3/15/2019	5/7/2019	190545	2,000	38,702	58,941
2017	CLE12	JCJ04[3]	VIT	WN	3.3	Left	Orange	Snout	3/15/2019	5/7/2019	190546	2,000	39,368	60,266
2017	CLE13	ESJ01	PRO	WN	3.3	Right	Green	Snout	3/15/2019	5/9/2019	190547	2,000	37,502	39,385
2017	CLE14	ESJ02	VIT	WN	3.3	Left	Green	Snout	3/15/2019	5/9/2019	190548	2,000	37,829	39,699
2017	CLE15	CFJ05	PRO	HC	3.2	Right	Red	Posterior Dorsal	3/15/2019	5/9/2019	190549	4,000	33,390	37,153
2017	CLE16	CFJ06	VIT	HC	3.2	Left	Red	Posterior Dorsal	3/15/2019	5/9/2019	190550	4,000	35,413	39,126
2017	CLE17	JCJ01[3]	PRO	WN	3.3	Right	Orange	Snout	3/15/2019	5/7/2019	190551	2,000	36,661	56,934
2017	CLE18	JCJ02[3]	VIT	WN	3.3	Left	Orange	Snout	3/15/2019	5/7/2019	190552	2,000	35,946	56,843

[1] All fish are progeny of wild/natural parents unless denoted as HC which designates the hatchery control line beginning with brood year 2002. "Avg BKD" denotes the average BKD ELISA ranking of the female parents whose progeny were in these ponds. PRO=BioPro diet, VIT=BioVita diet, Bio-Oregon products.

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

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

Appendix A. Tag and Release Information by Cle Elum Pond Id, Brood Years 2006-2022.

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]
2018	CLE01	ESJ01	Pro	WN	4.2	Left	Green	Snout	3/15/2020	5/15/2020	190573	2,773	31,833	34,524
2018	CLE02	ESJ02	Vit	WN	4.2	Right	Green	Snout	3/15/2020	5/15/2020	190574	2,000	31,213	33,105
2018	CLE03	CFJ01	Pro	HC	3.2	Left	Red	Posterior Dorsal	3/15/2020	5/15/2020	190575	2,000	35,285	37,228
2018	CLE04	CFJ02	Vit	HC	3.2	Right	Red	Posterior Dorsal	3/15/2020	5/15/2020	190576	2,000	34,672	36,594
2018	CLE05	ESJ03	Pro	WN	4.0	Left	Green	Snout	3/15/2020	5/15/2020	190577	2,000	33,397	35,301
2018	CLE06	ESJ04	Vit	WN	4.0	Right	Green	Snout	3/15/2020	5/15/2020	190578	2,000	33,772	35,692
2018	CLE07	CFJ05	Pro	HC	3.1	Left	Red	Posterior Dorsal	3/15/2020	5/15/2020	190579	2,000	32,461	34,384
2018	CLE08	CFJ06	Vit	HC	3.1	Right	Red	Posterior Dorsal	3/15/2020	5/15/2020	190580	2,000	34,276	36,203
2018	CLE09	JCJ03	Pro	WN	3.9	Left	Orange	Snout	3/15/2020	5/15/2020	190581	2,000	39,166	41,015
2018	CLE10	JCJ04	Vit	WN	3.9	Right	Orange	Snout	3/15/2020	5/15/2020	190582	2,000	38,910	40,780
2018	CLE11	JCJ05	Pro	WN	4.2	Left	Orange	Snout	3/15/2020	5/15/2020	190583	2,000	32,561	34,449
2018	CLE12	JCJ06	Vit	WN	4.2	Right	Orange	Snout	3/15/2020	5/15/2020	190584	2,000	32,726	34,621
2018	CLE13	JCJ01	Pro	WN	3.2	Left	Orange	Snout	3/15/2020	5/15/2020	190585	2,000	34,595	36,473
2018	CLE14	JCJ02	Vit	WN	3.2	Right	Orange	Snout	3/15/2020	5/15/2020	190586	2,000	32,739	34,630
2018	CLE15	CFJ04	Pro	WN	4.1	Left	Red	Snout	3/15/2020	5/15/2020	190587	4,000	30,681	34,579
2018	CLE16	CFJ03	Vit	WN	4.1	Right	Red	Snout	3/15/2020	5/15/2020	190588	4,000	30,934	34,845
2018	CLE17	ESJ05	Pro	WN	4.0	Left	Green	Snout	3/15/2020	5/15/2020	190589	2,000	32,347	34,266
2018	CLE18	ESJ06	Vit	WN	4.0	Right	Green	Snout	3/15/2020	5/15/2020	190590	2,000	31,802	33,731

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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 2006-2022.

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]
2019	CLE01	ESJ05	VIT	WN	3.8	Left	Green	Snout	3/15/2021	5/13/2021	190632	2,000	33,560	35,472
2019	CLE02	ESJ06	PRO	WN	3.8	Right	Green	Snout	3/15/2021	5/13/2021	190631	2,000	30,989	32,896
2019	CLE03	CFJ01	VIT	HC	3.6	Left	Red	Posterior Dorsal	3/15/2021	5/13/2021	190630	2,000	28,346	30,283
2019	CLE04	CFJ02	PRO	HC	3.6	Right	Red	Posterior Dorsal	3/15/2021	5/13/2021	190629	2,000	26,327	28,236
2019	CLE05	JCJ05	VIT	WN	3.4	Left	Orange	Snout	3/15/2021	5/13/2021	190628	2,000	30,806	32,703
2019	CLE06	JCJ06	PRO	WN	3.4	Right	Orange	Snout	3/15/2021	5/13/2021	190627	2,000	32,103	33,984
2019	CLE07	ESJ03	VIT	WN	3.6	Left	Green	Snout	3/15/2021	5/13/2021	190626	2,000	33,106	34,985
2019	CLE08	ESJ04	PRO	WN	3.6	Right	Green	Snout	3/15/2021	5/13/2021	190625	2,000	31,724	33,590
2019	CLE09	JCJ03	VIT	WN	3.7	Left	Orange	Snout	3/15/2021	5/13/2021	190624	2,000	33,462	35,333
2019	CLE10	JCJ04	PRO	WN	3.7	Right	Orange	Snout	3/15/2021	5/13/2021	190623	2,000	34,274	36,137
2019	CLE11	CFJ03	VIT	WN	3.9	Left	Red	Snout	3/15/2021	5/13/2021	190622	4,000	22,653	26,457
2019	CLE12	CFJ04	PRO	WN	3.9	Right	Red	Snout	3/15/2021	5/13/2021	190621	4,000	23,275	27,097
2019	CLE13	JCJ01	VIT	WN	3.5	Left	Orange	Snout	3/15/2021	5/13/2021	190620	2,000	33,085	34,904
2019	CLE14	JCJ02	PRO	WN	3.5	Right	Orange	Snout	3/15/2021	5/13/2021	190619	2,000	28,839	30,720
2019	CLE15	CFJ05	VIT	HC	3.9	Left	Red	Posterior Dorsal	3/15/2021	5/13/2021	190618	2,000	19,755	21,678
2019	CLE16	CFJ06	PRO	HC	3.9	Right	Red	Posterior Dorsal	3/15/2021	5/13/2021	190617	2,000	17,875	19,824
2019	CLE17	ESJ01	VIT	WN	3.7	Left	Green	Snout	3/15/2021	5/13/2021	190616	2,000	26,511	28,341
2019	CLE18	ESJ02	PRO	WN	3.7	Right	Green	Snout	3/15/2021	5/13/2021	190615	2,000	26,240	27,758

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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 2006-2022.

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]
2020	CLE01	CFJ01	VIT	HC	4.0	Left	Red	Posterior Dorsal	3/15/2022	5/12/2022	190645	4,000	44,756	48,581
2020	CLE02	CFJ02	PRO	HC	4.0	Right	Red	Posterior Dorsal	3/15/2022	5/12/2022	190646	4,000	42,622	46,434
2020	CLE03	CFJ03	VIT	WN	4.1	Left	Red	Snout	3/15/2022	5/12/2022	190647	2,000	40,189	42,021
2020	CLE04	CFJ04	PRO	WN	4.1	Right	Red	Snout	3/15/2022	5/12/2022	190648	2,000	39,357	41,186
2020	CLE05	CFJ05	VIT	WN	4.0	Left	Red	Snout	3/15/2022	5/12/2022	190649	2,000	40,853	42,670
2020	CLE06	CFJ06	PRO	WN	4.0	Right	Red	Snout	3/15/2022	5/12/2022	190650	2,000	39,001	40,751
2020	CLE07	ESJ01	VIT	WN	4.1	Left	Green	Snout	3/15/2022	5/12/2022	190651	2,000	42,493	44,357
2020	CLE08	ESJ02	PRO	WN	4.1	Right	Green	Snout	3/15/2022	5/12/2022	190652	2,000	40,536	42,394
2020	CLE09	JCJ03	VIT	WN	4.1	Left	Orange	Snout	3/15/2022	5/12/2022	190653	2,000	41,247	43,055
2020	CLE10	JCJ04	PRO	WN	4.1	Right	Orange	Snout	3/15/2022	5/12/2022	190654	2,000	40,415	42,228
2020	CLE11	JCJ01	VIT	WN	4.1	Left	Orange	Snout	3/15/2022	5/12/2022	190655	2,000	40,961	42,830
2020	CLE12	JCJ02	PRO	WN	4.1	Right	Orange	Snout	3/15/2022	5/12/2022	190656	2,000	40,027	41,849
2020	CLE13	ESJ03	VIT	WN	4.1	Left	Green	Snout	3/15/2022	5/12/2022	190657	2,000	36,833	38,657
2020	CLE14	ESJ04	PRO	WN	4.1	Right	Green	Snout	3/15/2022	5/12/2022	190658	2,000	36,444	38,339
2020	CLE15	JCJ05	VIT	WN	4.1	Left	Orange	Snout	3/15/2022	5/12/2022	190659	2,000	40,500	42,310
2020	CLE16	JCJ06	PRO	WN	4.1	Right	Orange	Snout	3/15/2022	5/12/2022	190660	2,000	41,120	42,895
2020	CLE17	ESJ05	VIT	WN	4.2	Left	Green	Snout	3/15/2022	5/12/2022	190661	2,000	38,590	40,405
2020	CLE18	ESJ06	PRO	WN	4.2	Right	Green	Snout	3/15/2022	5/12/2022	190662	2,000	38,442	40,226

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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 2006-2022.

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]
2021	CLE01	JCJ03	VIT	WN	4.0	Left	Orange	Snout	2/6/2023	2/23/2023	190680	2,000	40,397	42,309
2021	CLE02	JCJ04	VIT	WN	4.0	Right	Orange	Snout	2/6/2023	2/24/2023	190681	2,000	41,964	43,800
2021	CLE03	ESJ05	VIT	WN	3.9	Left	Green	Snout	3/15/2023	5/15/2023	190682	2,000	45,305	47,165
2021	CLE04	ESJ06	VIT	WN	3.9	Right	Green	Snout	3/15/2023	5/15/2023	190683	2,000	43,730	45,609
2021	CLE05	JCJ01	VIT	WN	4.0	Left	Orange	Snout	2/6/2023	2/23/2023	190684	2,000	41,884	43,728
2021	CLE06	JCJ02	VIT	WN	4.0	Right	Orange	Snout	2/6/2023	2/23/2023	190685	2,000	41,625	43,509
2021	CLE07	ESJ03	VIT	WN	3.9	Left	Green	Snout	3/15/2023	5/15/2023	190686	2,000	45,127	46,983
2021	CLE08	ESJ04	VIT	WN	3.9	Right	Green	Snout	3/15/2023	5/15/2023	190687	2,000	45,627	47,537
2021	CLE09	CFJ01	VIT	WN	3.9	Left	Red	Snout	3/15/2023	5/15/2023	190688	2,000	43,041	44,944
2021	CLE10	CFJ02	VIT	WN	3.9	Right	Red	Snout	3/15/2023	5/15/2023	190689	2,000	43,877	45,728
2021	CLE11	ESJ01	VIT	WN	3.9	Left	Green	Snout	3/15/2023	5/15/2023	190690	2,000	42,767	44,646
2021	CLE12	ESJ02	VIT	WN	3.9	Right	Green	Snout	3/15/2023	5/15/2023	190691	2,000	43,152	45,029
2021	CLE13	JCJ05	VIT	WN	4.1	Left	Orange	Snout	2/6/2023	2/24/2023	190692	2,000	43,775	45,653
2021	CLE14	JCJ06	VIT	WN	4.1	Right	Orange	Snout	2/6/2023	2/24/2023	190693	2,000	43,078	44,978
2021	CLE15	CFJ03	VIT	WN	3.9	Left	Red	Snout	3/15/2023	5/15/2023	190694	2,000	44,467	46,327
2021	CLE16	CFJ04	VIT	WN	3.9	Right	Red	Snout	3/15/2023	5/15/2023	190695	2,000	45,768	47,633
2021	CLE17	CFJ05	VIT	HC	4.1	Left	Red	Posterior Dorsal	3/15/2023	5/15/2023	190696	4,000	38,624	42,489
2021	CLE18	CFJ06	VIT	HC	4.1	Right	Red	Posterior Dorsal	3/15/2023	5/15/2023	190697	4,000	37,090	40,943

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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 2006-2022.

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]
2022	CLE01	ESJ05	VIT	WN	low	Left	Green	Snout	1/10/2024	1/10/2024	190014	2,000	29,310	31,248
2022	CLE02	ESJ06	VIT	WN	low	Right	Green	Snout	1/10/2024	1/10/2024	190015	2,000	31,222	33,147
2022	CLE03	JCJ01	VIT	WN	low	Left	Red	Snout	2/12/2024	2/12/2024	190016	2,000	29,503	31,372
2022	CLE04	JCJab[3,4,]	VIT	WN	low	Right	Red	Snout	11/28/2023	11/28/2023	190017	2,000	29,347	31,279
2022	CLE05	JCJ02	VIT	WN	low	Left	Orange	Snout	2/12/2024	2/12/2024	190018	2,000	34,587	36,511
2022	CLE06	JCJab[3]	VIT	WN	low	Right	Orange	Snout	12/7/2023	12/7/2023	190019	2,000	31,554	33,504
2022	CLE07	CFJ03	VIT	HC	low	Left	Red	Posterior Dorsal	1/22/2024	1/22/2024	190020	4,000	41,180	45,066

2022	CLE08	CFJ04	VIT	HC	low	Right	Red	Posterior Dorsal	1/22/2024	1/22/2024	190NULL	4,000	43,143	46,995
2022	CLE09	ESJ01	VIT	WN	low	Left	Green	Snout	1/10/2024	1/10/2024	190022	2,000	28,472	30,419
2022	CLE10	ESJ02	VIT	WN	low	Right	Green	Snout	1/10/2024	1/10/2024	190023	2,000	27,700	29,666
2022	CLE11	CFJ01	VIT	WN	low	Left	Red	Snout	1/23/2024*	1/23/2024	190024	2,000	31,208	33,174
2022	CLE12	CFJ02	VIT	WN	low	Right	Red	Snout	1/22/2024*	1/22/2024	190027	2,000	28,595	30,565
2022	CLE13	JCJ03	VIT	WN	low	Left	Orange	Snout	2/12/2024	2/12/2024	190NULL	2,000	27,415	29,370
2022	CLE14	JCJbe[3]	VIT	WN	low	Right	Orange	Snout	11/29/2023	11/29/2023	190025	2,000	28,063	30,046
2022	CLE15	ESJ03	VIT	WN	low	Left	Green	Snout	1/11/2024	1/11/2024	190028	2,000	27,196	29,156
2022	CLE16	ESJ04	VIT	WN	low	Right	Green	Snout	2/2/2024	2/2/2024	190029	2,000	27,365	29,313
2022	CLE17	JCJ04	VIT	WN	low	Left	Orange	Snout	2/12/2024	2/12/2024	190030	2,000	30,075	32,013
2022	CLE18	JCJNF[3]	VIT	WN	low	Right	Orange	Snout	11/30/2023	11/30/2023	190031	2,000	26,754	28,735

[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. (Release to Accl Pond or parr[3] release to rivers)

[3] Parr release to Jack Creek (above/below/North Fork)

[4] Accidental release of CLE04 pond fish to Jack Creek

Appendix C: 2023 Annual Chandler Certification for Outmigrating Spring (Yearling) Chinook Smolts

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August 14, 2024

Executive Summary

Outmigrating smolts have been monitored since 1983 at the Chandler Diversion Canal in the Yakima River at Prosser, Washington. Chandler Juvenile Monitoring Facility (CJMF) improvements over the years have made it possible to count all species entering the juvenile bypass system each year from January into July, encompassing the entire juvenile outmigration period. Winter operations are made possible by the dual purpose of the canal, which supplies a hydroelectric plant as well as an irrigation district. The diversion is located downstream from all Spring Chinook, Summer Chinook, Coho and Steelhead spawning and juvenile rearing areas in the Yakima River Basin.

Numerous projects to restore and protect channel and riparian habitat, along with fish reintroduction programs, have been implemented in the Yakima Basin since the 1990s. The population status and trends for the different species in their freshwater life stages are important measures of management success, and the data collected at the facility have allowed us to answer several management questions that can help to improve these programs. This report provides estimates of 2023 outmigrating Spring (yearling) Chinook smolt populations (hatchery and wild) past Prosser Dam; its temporal (annual) trend from 1999 through 2023; and evaluation of whether the production and releases of hatchery smolts into the upper Yakima had an effect on the production of wild smolts and on the relative abundance of the three stock sources of wild smolts (Naches, American, and Upper Yakima rivers). This evaluation is part of an ongoing study that was initiated in 1999 with the first release of hatchery Spring Chinook smolts.

The entire bypass flow leaving the juvenile screens enters the counting facility but only a portion is manually counted. A timer gate on an hourly cycle directs bypass flow to a holding tank for a portion of each hour that can be adjusted as often as once per day to compensate for fluctuations in fish abundance so as to not overwhelm the capacity of the staff to tally those smolts by species and stock.

In 2023, In 2023 the CJMF was operated from January 4th to July 15th (193 days total). There were three timer gate settings (TR) for sampling, representing the percentage of time in each hourly cycle that bypassed fish were directed into the sample tank. Over the sampling period, the timer gate setting (TR) was 33% for 165 days, 50% for 3 days, and 100% for 25 days. Several statistical methods/approaches were applied for expanding the subsample data and analyzing them. To address the objectives of the study, we answered the following research questions:

1. **Which species and runs were captured during the 2023 sampling period and what were the relative abundances of each group?**

During the 2023 sampling period, a total of 56,419 individuals (raw, unadjusted value) of 17 species and runs were captured in the sampling room. Among salmonids, Wild Summer/Fall Chinook (20,203) comprised more than 52% of the total count. The second highest count was hatchery Spring Chinook (17,469) comprised about 30% of the total count; and the third highest count was wild coho (3,728).

2. What was the PIT-tag detection efficiency of the monitoring facility and did the efficiencies vary among the sampling periods (pre-March, March, April, May, Post-May)?

In 2023, the overall detection rate at Prosser (pooled 27.01% ± 1.9%) was lower compared to 2022 (30±1.5%), 2021 (32.87% ± 1.06%) and 2020 (43.96% ± 1.0%). It's important to note that the detection rate exhibited variation across the years. When examining the sampling periods, the peak detections were observed in April and May. 0.27±0.019.

3. How many wild and hatchery Spring Chinook smolts were estimated to pass Prosser Dam during 2023 and was there any temporal trend from the 1999 through 2023 juvenile migration years?

Wild (natural-origin) spring chinook can be separated genetically into three stocks: Upper Yakima, from the Yakima River and tributaries above the Naches River confluence; American River, a tributary of the Naches River; and Naches River, from the Naches River and tributaries exclusive of the American River. Only the Upper Yakima stock receives hatchery supplementation.

The estimated number of wild Spring Chinook smolts passing Prosser Dam during the 2023 migration period ranged from 102,791 to 131,942, while the hatchery smolt estimates for 2023 ranged from 165,938 to 218,683. The total number of wild outmigrating smolts as well as the upper Yakima component stock seemed to be decreasing over time, whereas the population of Upper Yakima hatchery smolts seemed to be increasing but none of these trends were statistically significant.

4. What proportions of wild Spring Chinook populations that outmigrated from Prosser were contributed by different stocks (Naches, American, Upper Yakima) in the Yakima Basin? Did the proportions of these stocks in the outmigrating smolt population vary by migration year?

About 61% of the total count of wild outmigrating Spring Chinook smolts was contributed by the Upper Yakima stock; while 28% and 11% of the total wild outmigration were contributed by the

Naches and American river stocks, respectively. The rate of decline in the wild Upper Yakima stock averaged -1916/year, which was the highest of the three wild populations (Naches, American, Upper Yakima), but the estimated decline was not significant (Upper Yakima; $R^2 = 0.026$, $p = 0.48$). The rate of decrease for Naches stock was -1126/year, it was also not significant; however, only the American stock average reduction was significant (Slope= -1110/year, $R^2 = 0.313$, $p = 0.008$).

5. Did the production and release of hatchery smolts into the upper Yakima affect the production of wild smolts?

To evaluate whether the hatchery program affected wild production, we tested a hypothesis that the rate of decline of outmigration should be higher in Upper Yakima wild Spring Chinook, because only the Upper Yakima stock receives hatchery supplementation. We found that there was no significant negative linear trend in the relative proportions of the three stocks of outmigrating smolt populations with the outmigration year, indicating that there was no influence of hatchery supplementation on the wild abundance as measured by outmigrating smolt abundance at Prosser in the lower Yakima River. If the proportion of wild Upper Yakima smolts would have decreased significantly over time, this could represent a hatchery effect, environmental effects, or a combination of the two.

1. Introduction

Conservation and management of culturally and economically important species rely on monitoring programs to provide accurate and robust estimates of population size. Numerous projects to restore and protect channel and riparian habitat have been implemented on the Yakima River in coordination with reintroduction/supplementation programs. Quantifying and understanding whether juvenile outmigration or Smolt-to-Adult-Return (SAR) are increased/decreased over time, or which stocks perform better, are fundamental questions in determining whether species management and production goals are being reached.

Outmigrating smolts have been monitored since 1983 at the Chandler Diversion Canal in the Yakima River at Prosser, Washington (Figures 2 -4). The diversion canal is located downstream from all Spring Chinook, Summer Chinook, Coho and Steelhead spawning and juvenile rearing areas in the Yakima River Basin. Improvements at the Chandler Juvenile Monitoring Macility (CJMF) over the years have made it possible to count all species entering the juvenile bypass system each year from January into July, encompassing the entire juvenile (smolt) outmigration period. Winter operations are made possible by the dual purpose of the canal, which supplies a hydroelectric plant as well as an irrigation district. Chandler Diversion canal typically conveys 1000 cfs with a maximum of 1500 cfs over the course of a year. Water not used for irrigation is returned to the Yakima River eleven miles downstream at the Chandler Powerhouse. The Yakima River at Prosser is characterized by a high spring runoff peaking in March, and low summer flows reaching a minimum in August, but there is wide variation in this flow pattern and the timing of high and low flows from year to year.

At the CJMF, fish are counted from the portion of river flow that is diverted into the irrigation canal and then into the juvenile fish bypass system. The monitoring data collected at the facility over the 6-month outmigration period can be useful to determine the status and trends of different species and runs at the outmigrating smolt stage, identify potential life-cycle bottlenecks, and evaluate the effectiveness of ongoing reintroduction and habitat improvement actions on population dynamics. The number of smolts of different species that outmigrate from the river basin are influenced by the numbers and fecundity of spawners and by the conditions their progeny encounter before and during outmigration, including river water temperature and river flows. Yakima River flow is modified by storage and releases from five large reservoirs in the upper Yakima Basin, and by irrigation and hydropower withdrawals and return flow. Under various agreements, minimum flows below storage and diversion dams are maintained to sustain ecological processes during periods of low natural runoff. Snowmelt exacerbated by occasional rain-on-snow events causes considerable variation in the flow of unregulated tributaries and in the Yakima River itself from November through June. When irrigation demand exceeds this runoff during the fish outmigration period, unnatural delays and poor outmigration survival can result. Studies of the relationship of river flow and outmigration have shown that river flow pulses from natural events and reservoir releases can accelerate smolt movement downstream and enhance survival to the ocean. Relying entirely on annual outmigration totals may obscure the role of in-season flow fluctuations and the importance of flow pulses during this critical period.

The main objectives of the study were to estimate prior-year (2022) outmigrating smolt populations (hatchery and wild) of spring Chinook; assess its temporal trend from 1999 through 2022; determine whether the production and releases of hatchery smolts into the upper Yakima had an effect on the production of wild smolts and on the relative abundances of the three stock sources of wild smolts (Naches, American, and Upper Yakima rivers); evaluate whether outmigration is higher in years of high river flow; and within years, on days with greater flow. To address the objectives, we answered the following research questions:

- Which species and runs were captured during the 2023 sampling period and what were the relative abundances of each group?
- What was the PIT-tag detection efficiency of the monitoring facility, and did the efficiencies vary among the sampling periods (pre-March, March, April, May, Post-May) in 2023?
- How many wild and hatchery Spring Chinook smolts emigrated from Prosser during 2023 and was there any temporal trend from 1999 through the 2023 juvenile migration year?
- What proportions of wild Spring Chinook populations that outmigrated from Prosser were contributed by different stocks (Naches, American, Upper Yakima) in the Yakima Basin? Did the proportions of these stocks in the outmigrating smolt population vary by migration year?
- Did the production and release of hatchery smolts into the upper Yakima affect the production of wild smolts?

- What was the effect of river flow (daily as well as annual flow) on the number of outmigrating Spring Chinook smolts?

2.0 Methodology

The CJMF is located on the fish bypass outlet of Chandler Canal at Prosser Dam (Figure 1), which is about 76 river km (47 river miles) upstream from the mouth of the Yakima River. The canal supplies water for irrigation and to generate power. The Chandler Canal typically conveys 1000 cfs with a maximum of 1500 cfs over the course of a year (Pyper and Smith, 2005). The proportion of river flow diverted, and thus the proportion of smolts entrained, varies widely during the outmigration season, due mostly to fluctuations in river flow. Juvenile fish screens (Figure 2) allow fish to exit the canal. The bypass flow enters a juvenile counting facility before returning to the river, where a portion of the fish are manually counted. A timer gate on an hourly cycle directs bypass flow to a holding tank for a portion of each hour that can be adjusted as often as once per day to compensate for fluctuations in fish abundance and avoid overwhelming the capacity of the staff to tally those smolts by species and stock. For this study, several methods were used to enumerate smolts and are outlined in Figure 3.

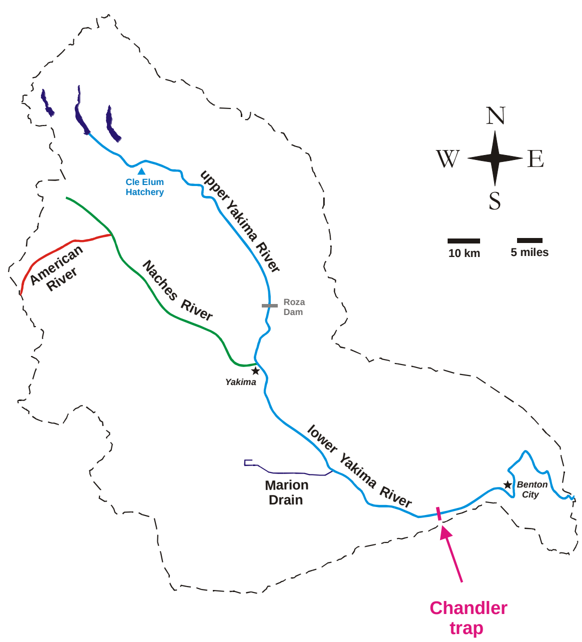

Figure 1. Yakima basin and the location of the Chandler Juvenile Monitoring Facility at Prosser and different sub-basins or genetic stocks (Naches, Upper Yakima River and American River).

Figure 2. Composite photo depicting the Chandler canal location and the key sampling components at the Chandler Juvenile Monitoring Facility (CJMF).

2.1. Estimating Sample Rate and Calibration

Figure 4 is a schematic of the CJMF layout and the details of the sampling area. The sampling period was continuous from January 04^{h} to July 15th in 2023 except for one days in which the facility was shut down due to adverse river conditions.

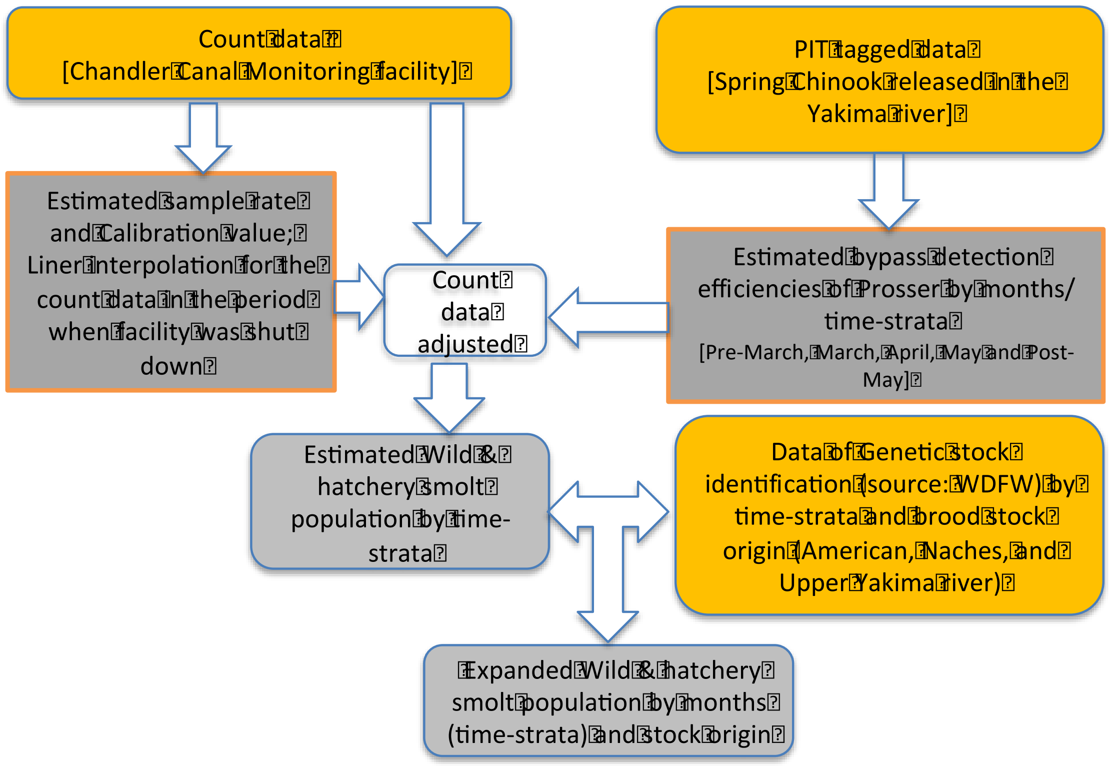

Figure 3. Outline of the methodology used for data analysis in this report

In 2023, three timer-gate settings (TR) were used to control the proportion of bypassed smolts that were manually counted: 33% (20 minutes per hour), 50% (30 minutes per hour), and 100%. There are two PIT-tag detectors in the bypass system (Figure 4): one upstream of the timer gate and one in the exit from the counting facility downstream of the timer gate where the daily subsamples of smolts are tallied. Along with detectors in the Prosser adult ladders, these detectors comprise site PRO in the PIT Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission.

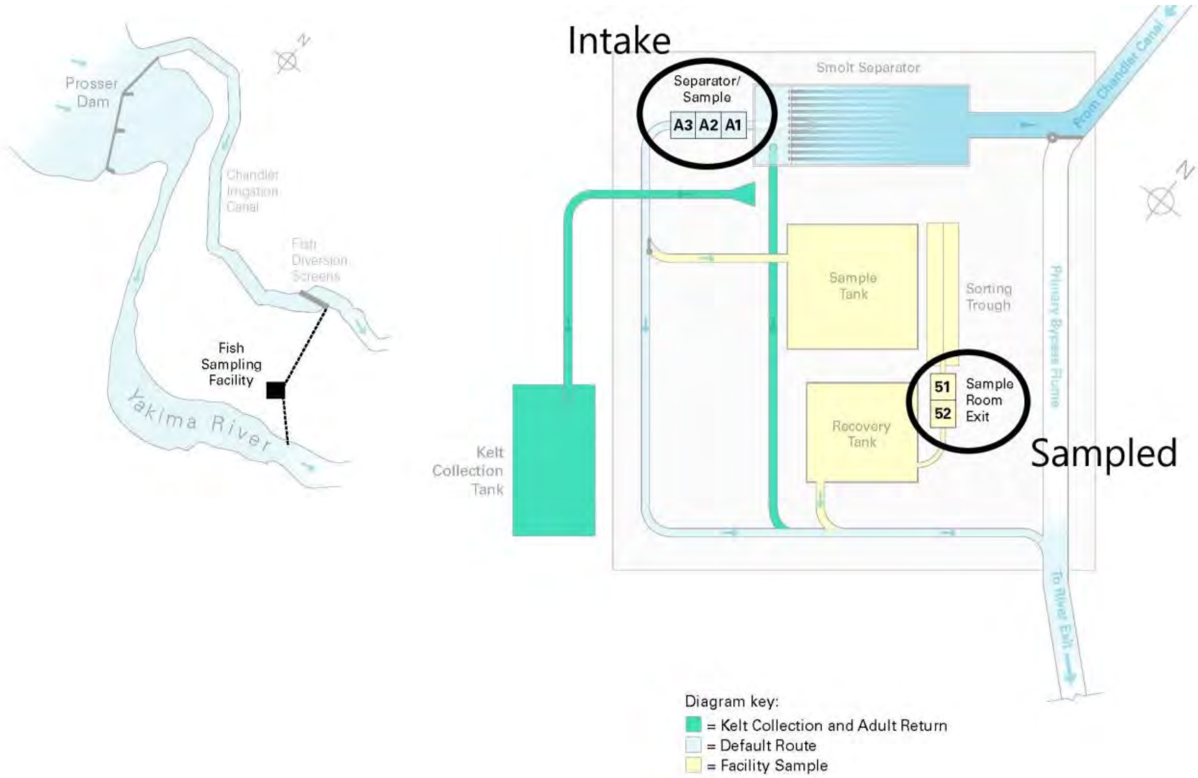

Figure 4. Site Overview of Chandler Juvenile Monitoring Facility at Prosser. The layout was adapted from the site configuration at https://www.ptagis.org/.

The timer gate, when opened, directs the Prosser bypass flow from Chandler Canal into the sample tank where smolts are tallied. Data regarding species, life stage, and abundance were tallied and counted daily during the sampling period. The timer gate setting has to be corrected because some bypassed fish swim against the bypass flow and may not enter the counting facility in strict proportion to the gate setting. For a given daily TR setting, the observed sample rate was computed as:

SR_{ti}: $\frac{\text{the number of PIT−tagged Spring Chinook smolts detected leaving the counting facility}}{\text{the total number detected by the bypass detector located upstream of the timer gate } (TG_i)}$; or

$SR_{ti}=\frac{\text{n[counting facility]}}{\text{n[bypass (TR)]}}$; Where t_i is the timer setting.

Once we estimated the daily sample rate, the calibration value was computed as:

$$\text{Calibration value (CV)} = w(33\%) \times [SR(TR=33\%)/33\%]+w(50\%)\times [SR(TR=50\%)/50\%]$$

Where w(33%) and w(50%) are the weight, which are the proportion of bypass detections within the TR setting 0.33 and 0.50, respectively. The weights being the proportions of bypass detections within the TR setting and estimated as (see, Neeley 2012):

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

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

2.2. Missing data imputation

Spring Chinook smolts were tallied each day as to source (hatchery-spawned or wild) on the basis of external marks. However, the sampling facility was shut down for a few days due to flow conditions or other technical problems. Data were missing for those days in which the sampling facility was closed. Linear interpolation was used to impute counts for days with missing information.

2.3. PIT-tag data

We queried the PTAGIS database (https://www.ptagis.org/) in July 2024 to retrieve available PIT-tag detection information for all tagged hatchery Spring Chinook smolts released upstream from Prosser Dam. About 6% of the total release hatchery Spring Chinook were tagged and released in the acclimation sites, but not all the tagged fish were detected at the acclimation site exits, either because of mortality and tag shedding over the 3-to-5-month period between tagging and volitional release, or detection failure on exit. We used only those fish which were detected on exit from acclimation sites or captured, tagged and released in the Roza Dam bypass in the upper Yakima River. A total of 45,139 PIT-tagged smolts were used for this analysis. An encounter history for each fish with detection events (date and detection site) was constructed for further analysis.

2.4. Genetic information

During the sampling period each year, tissue samples were taken from subsamples of wild smolts passing through the counting facility. In order to minimize bias, samples of smolts were distributed proportionally among five time strata (January-February, March, April, May and June). These tissue samples were processed in the Molecular Genetics Laboratory of the Washington Department of Fish and Wildlife (WDFW). Results of the molecular samples are available (Seamons and Bowman, 2022) and this information was used to estimate 2022 outmigrating smolts.

2.5. Estimating Prosser bypass detection rate

The proportions of all PIT- tagged smolts released above Prosser and detected at mid-Columbia dams that were previously detected in the Chandler Canal bypass serve as estimates of bypass-detection rate. Detections at the three downstream sites with juvenile PIT tag detection (McNary, John Day, and Bonneville dams) were pooled to estimate the Prosser bypass detection rate. Daily estimates of Prosser detection rate from downstream dams are not possible because smolts migrate at different rates between Prosser and downstream dams, and one day's detections in the Prosser bypass are detected at a given downstream dam over several subsequent days. For this study, the detection rate was estimated for five strata over the outmigration period (pre-March, March, April, May and post-May) based on McNary Dam alone, or pooled over the three Columbia River dams. The detection efficiency (DE) was estimated as:

DE = n(daily joint site detections)/n(total site detections)

These detection rates based on upper Yakima hatchery Spring Chinook were also applied to the three stocks of wild Spring Chinook smolts, few of which were tagged. The wild Spring Chinook were made up of Naches, American, and Upper-Yakima stock (See fig. 1). All hatchery Spring Chinook smolts were coded-wire tagged and most were elastomer tagged in addition to about 6% being PIT-tagged. Elastomer tags allowed visual separation of hatchery smolts and adults by acclimation site, with fish released from the Clark Flat, Easton, and Jack Creek sites, receiving red, green, and orange elastomer tags, respectively. Elastomer-tagged smolts were also tallied by elastomer color. PIT-tagged hatchery smolts were not elastomer-tagged.

The wild and elastomer-tagged hatchery tallies were expanded by four different estimates of Prosser detection rates as mentioned above.

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

Detailed methodology is given in Neeley (2019). Of these four estimators, the one chosen for further analysis was a pooling of stratified estimates from the detection efficiencies from McNary, John Day, and Bonneville Dams on the Columbia Rivers; the strata being established for each of these dams by combining daily estimates that were deemed similar using Logistic stepwise regression of the daily detection efficiencies on Julian-date indicators that take the value 1 if the estimate was from a given date or a later date or 0 if the estimate was from an earlier date (see, Neeley (2019) for further details).

2.6. Wild and hatchery passage estimate

On a daily basis the sampled Spring Chinook smolts were tallied as to source (hatchery-spawned or wild). On those days when the facility was shut down, linear interpolation was used to impute values to the missing information as mentioned above. The daily actual and imputed tallies were divided by the sample rates in use on those days (SR). The sample-rate-adjusted tallies for each source were added over days within each of five time periods and were then divided by the respective period's detection rate. The wild and hatchery smolts were tallied separately. Wild smolts were identified by the lack of a coded-wire tag or external mark. Hatchery smolts could be identified by the presence of an elastomer tag, a coded wire tag, an adipose fin clip and a PIT tag if there was no elastomer tag. Expanded elastomer-tagged tallies were then divided by the proportion of hatchery smolts to obtain estimates of the passage of all hatchery smolts.
Within each of the five time periods (pre-March, March, April, May, post-May), the tallied sample of wild smolts was subsampled and genetically classified as to brood origin (American, Naches, or Upper Yakima rivers) by the Washington Department of Fish and Wildlife Molecular Genetics Laboratory so that brood-origin proportions could be estimated for each stratum. The wild passage estimates within each period were multiplied by each of the period's brood-source proportions. Each wild brood's time-period passage estimates were then added over the time periods to estimate the brood's total passage, as were the hatchery passage estimates. The detailed methodology can be found in Neeley (2019).

2.7. Model validation (estimates comparisons)

The estimates of the number of smolts passing Prosser Dam can vary slightly with different entrainment-based estimation methods. To ascertain which of these passage estimates is the best to report and use for further analysis, we compared flow/entrainment-based estimates of hatchery Spring Chinook smolts at Prosser to another estimate that was derived using a PIT-tag-based survival rate from release site to Prosser Dam. Since we know the total number of hatchery Spring Chinook smolts released in the upper Yakima, we multiplied the survival rate by the total release, which provided the total hatchery smolt population passing Prosser. This estimate can be viewed as an independent estimate but it can also be biased because we assumed there was no variation in the survival rate among the sampling days' time strata. If detection rate is not homogeneous, survival rate cannot be homogeneous. However, this survival-based estimator has value because it is independent of the flow/entrainment-based method.

In addition to the survival-based method, each of the flow/entrainment methods' estimates of hatchery juvenile passage (see section 2.5 above) was also compared with hatchery adult returns at Prosser (Bosch, 2022). If the estimate is a reasonable value, it should be highly correlated with the hatchery adult returns from that outmigration.

2.8. Estimated Daily smolt outmigration from Prosser

One of our objectives was to determine whether river flows influence the size of the population of outmigrating smolts If larger number of smolts outmigrated during high river flow, the rate of outmigration would be a function of river flow. To estimate daily passage at Prosser Dam, daily counts of each species in the live box at the (CJMF) were expanded by the canal entrainment, canal survival (from prior paired releases), and sub-sampling rates using the following formula (Neeley, 2012).

$Entrainment\ rate\ (ER) = 1/1 + \exp(-5.60081 + 13.5861 * \text{diversion rate})$ ..eq. 1

$Survival\ Probability =$
$1/1 + \exp(-2.84815 + 0.0154 * Juliandate - 0.00017 * (canalflow + 132)$..eq.2
Estimated daily count: $\text{Count}/(\text{Survival Probability} * \text{sample.rate}(SR) * \text{ER})$ .. eq.3

The model for the Entrainment Rate (ER) was based on the logistic regression using the daily proportion of Yakima River flow diverted into the canal. The Entrainment Rate (ER) is the predicted daily proportion of fish passing Prosser that are entrained into Chandler Canal, the Canal-Survival Rate (Survival probability) is the daily predicted proportion of those entrained fish that survive the canal from below the head-gate down the canal and into the bypass to a point just above the sampling station, and Sampling Rate (SR) is the estimated proportion of fish that are sampled from the bypass and enumerated.

2.8.1. Relationship between river flow and estimated daily count

To determine whether high river flow helped to increase the rate of smolt outmigration from Prosser, we built univariate relationships using two datasets (annual and daily).

A. Annual total estimates: A univariate linear relationship between the estimated total annual number of hatchery Spring Chinook smolts passing Prosser (2000-2022 outmigration years) and the average March-June river flows (corresponding to the

March-June volitional exit of hatchery Spring Chinook from acclimation sites) for each year from 2000 through 2023.

B. Daily estimates: A univariate linear relationship between the estimated daily count of wild Spring Chinook and daily river flow above Prosser Dam, which is the sum of the daily flows measured at the Bureau of Reclamation gaging stations CHCW (Chandler Canal) and YRPW (Yakima River below Chandler Canal). River flow data were accessed in June, 2024 from

https://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html.

3.0 Results and discussion

In 2023 the CJMF was operated from January 4th to July 15th (193 days total). There were three timer gate settings (TR) for sampling, representing the percentage of time in each hourly cycle that bypassed fish were directed into the sample tank. Over the sampling period, the timer gate setting (TR) was 33% for 165 days, 50% for 3 days, and 100% for 25 days. As noted earlier, adjustments are applied to timer gate settings because some bypassed fish swim against the bypass flow upstream from the gate and may not enter the counting facility in strict proportion to the gate setting, unless there is no alternative, i.e. the gate is set to sample 100% of bypass flow. This occurs at the end of the season when lethal lower river conditions require transportation of entrained smolts to the Columbia River instead of discharge past the sample room detector to the Yakima River.

The SR is usually less than the TR, indicating not all fish passing through the bypass when the timer gate is open are actually entering and being detected in the counting facility. In 2023, when TR was 33%, sample rate (SR) was 25.5%, and at the 50% TR setting the SR was 38.6% (Table 1).

Table 1. Sample-room sample rates for given timer-gate settings. Timer Gate Rate (TR) is the proportion of time that the bypass gate is opened to Sample Room.

Out-Migration Year	Calibration Value	Estimated Sample Rates (SR) for different Timer-Gate Rates								
		Timer-Gate Rate (TR)								
		0.05	0.1	0.2	0.25	0.33	0.4	0.45	0.5	0.75
1998	0.778	0.039	0.078	0.156	0.194	0.257	0.311	0.350	0.389	0.583
1999	0.833	0.042	0.083	0.167	0.208	0.275	0.333	0.375	0.417	0.625
2000	0.794	0.040	0.079	0.159	0.198	0.262	0.318	0.357	0.397	0.595
2001	0.278	0.014	0.028	0.056	0.070	0.092	0.111	0.125	0.139	0.209
2002	0.838	0.042	0.084	0.168	0.209	0.277	0.335	0.377	0.419	0.628
2003	0.669	0.033	0.067	0.134	0.167	0.221	0.267	0.301	0.334	0.501
2004	0.693	0.035	0.069	0.139	0.173	0.229	0.277	0.312	0.346	0.520
2005	0.776	0.039	0.078	0.155	0.194	0.256	0.310	0.349	0.388	0.582
2006	1.000	0.050	0.100	0.200	0.250	0.330	0.400	0.450	0.500	0.750
2007	0.800	0.040	0.080	0.160	0.200	0.264	0.320	0.360	0.400	0.600
2008	0.651	0.033	0.065	0.130	0.163	0.215	0.260	0.293	0.326	0.488
2009	0.770	0.038	0.077	0.154	0.192	0.254	0.308	0.346	0.385	0.577
2010	0.584	0.029	0.058	0.117	0.146	0.193	0.234	0.263	0.292	0.438
2011	1.000	0.050	0.100	0.200	0.250	0.330	0.400	0.450	0.500	0.750
2012	0.979	0.049	0.098	0.196	0.245	0.323	0.391	0.440	0.489	0.734
2013	0.973	0.049	0.097	0.195	0.243	0.321	0.389	0.438	0.486	0.729

2014	0.903	0.045	0.090	0.181	0.226	0.298	0.361	0.407	0.452	0.678
2015	0.830	0.041	0.083	0.166	0.207	0.274	0.332	0.373	0.415	0.622
2016	0.873	0.044	0.087	0.175	0.218	0.288	0.349	0.393	0.437	0.655
2017	0.819	0.041	0.082	0.164	0.205	0.270	0.327	0.368	0.409	0.614
2018	0.910	0.046	0.091	0.182	0.228	0.300	0.364	0.410	0.455	0.683
2019	0.906	0.045	0.091	0.181	0.226	0.299	0.362	0.408	0.453	0.679
2020	0.794	0.040	0.079	0.158	0.199	0.261	0.318	0.357	0.397	0.596
2021	0.806	0.035	0.071	0.141	0.176	0.233	0.282	0.317	0.353	0.529
2022	0.921	0.037	0.085	0.152	0.217	0.250	0.367	0.395	0.452	0.687
2023	0.771	0.039	0.078	0.155	0.193	0.255	0.309	0.347	0.386	0.578

Note: Estimates for the year 1998-2018 were adopted from Neeley (2019)

3.1. Species composition and daily counts in the counting facility

During the 2023 sampling period, a total of 56,419 individuals (raw, unadjusted value) of 17 species and runs were captured in the sampling room (Table 2, Figure 5). Among salmonids, Wild Summer/Fall Chinook (20,203) comprised more than 52% of the total count. The second highest count was hatchery Spring Chinook (17,469) comprised about 30% of the total count; and the third highest count was wild coho (3,728).

Table 2. Total counts by species in the sample-room for 2019 and 2023.

Species	2019	2020	2021	2022	2023
Bass	84	87	43	170	93
BigMthM	187	131	294	145	308
Bluegill	68	113	144	80	103
Carp	22	176	31	50	37
Catfish	809	757	174	2320	1752
Chisel	2393	280	781	140	2355
Crappie	19	47	115	29	7
Dace	3	0	0	0	1
Eel	3654	138	4539	2167	4872
Hat.SpChk1	29532	39047	27746	21202	17469
Perch	17	24	32	8	13
Pumpkinseed	1	0	0	0	0
Shiner	33	11	48	11	15
Sockeye	32	5593	151	15481	1509
Sucker	1079	590	525	505	1042
Whitefish	357	215	124	332	1048
Wild.Chk0	13411	26497	72108	27956	13398
Wild.Chk1	13507	14925	14094	8789	6805
Wild.Coho	8075	1850	3668	4695	3728
Wild.Sth	5440	4946	6048	1924	1864

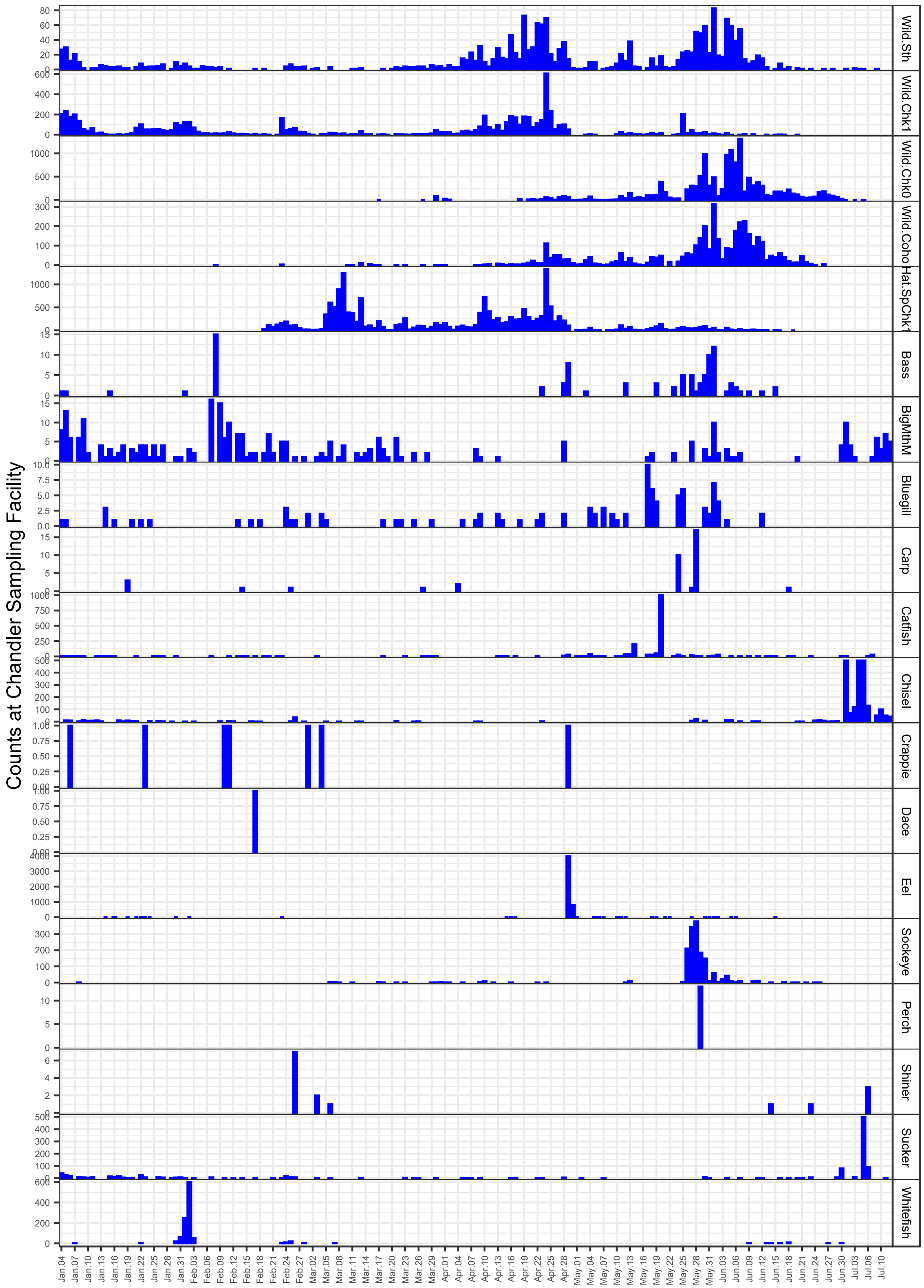

Figure 5: Daily catch (raw count) of different species from January through July 2023 (sampling period). Number in green color is the total counts in the sampled during the sampling period.

3.2. Counts of wild and hatchery Spring Chinook

Daily raw counts of the hatchery and wild Spring Chinook were divided by the daily sampling rate (adjusted with Timer Gate Rate) to derive the total number bypassed each sampling day. Missing counts were estimated by linear interpolation for those days in which no sampling was done as mentioned in methodology. After the adjustments, total counts of bypassed hatchery and wild spring Chinook during the sampling period in the sampling facility were estimated to be 91,952 and 38,3252, respectively (Table 3).

Regarding the outmigration timing, wild Spring Chinook passed Prosser Dam earlier than their hatchery counterparts, starting with the January initiation of sampling, while hatchery Spring Chinook were not observed until after their volitional release from acclimation sites began in mid-March. The outmigration of both groups was nearly complete by the end of May and ending in late June but peaked in April (Table 3).

Table 3. Adjusted total count (raw count ∗ sample rate (SR)) of bypassed hatchery and wild Spring Chinook smolts in the Chandler Juvenile Monitoring Facility over 5 temporal strata from 2019 through 2023.

Migration year	Origin	Counts					
		Pre-March	March	April	May	Post-May	Total
	Wild	15489	3937	10596	23290	63	53,374
2019	Hatchery	0	904	24775	76824	198	102701
	Wild	8,843	2,602	30,737	10,851	58	53,092
2020	Hatchery	8	1,419	64,446	82,305	789	148,967
	Wild	12,482	3,849	34,195	11,816	1,365	63,706
2021	Hatchery	0	11,730	56,272	46,835	4,334	119,172
	Wild	11,352	1,821	21,730	2,444	208	37,378
2022	Hatchery	0	3,608	63,724	23,512	31	91,052
2023	Wild	12,310	7,946	16,863	1,130	3	38,252
	Hatchery	0	20,669	57,505	12,851	27	91,952

3.2. Detection rate of the sampling facility and downstream Dams (MCJ, John Day, BON)

Table 4. Detection efficiencies of Prosser (PRO) and joint detection of hatchery Spring Chinook smolts between PRO and McNary (MCJ), PRO and John Day (JDJ), PRO and Bonneville (B2J/BCC); and PRO and the pooled detections at MCJ and downstream sites. Detection at Bonneville included the juvenile (smolt) population of hatchery Spring Chinook detected by B2J at BCC antennas, which cover different passage routes. The pooled (ALL) estimate represents the detection probability at Prosser based on detection at one or more downstream dams (MCJ, JDJ and BON).

Migration year	Joint Detection of PRO with	Months Pre. March	March	April	May	Post May	Total Joint	Rate of Detection
2019	McNary (MCN)	0	6	143	220	0	369	0.2709±0.012
	John Day (JD)	0	2	94	224	0	320	0.2946±0.014
	Bonneville (BON)	0	4	174	287	0	465	0.2704±0.018
	Pooled (All)	0	12	411	731	0	1154	0.2785±0.007
2020	McNary (MCN)	0	7	117	116	0	240	0.3344±0.018
	John Day (JD)	0	4	146	252	1	402	0.4620±0.018
	Bonneville (BON)	0	5	295	342	2	644	0.4666±0.014
	Pooled (All)	0	16	558	710	3	1286	0.4396±0.010
2021	McNary (MCN)	0	32	125	41	1	199	0.364±0.019
	John Day (JD)	0	1	38	18	3	60	0.245±0.026
	Bonneville (BON)	0	15	107	100	5	227	0.283±0.015
	Pooled (All)	0	48	270	159	9	486	0.3287±0.016
2022	McNary (MCN)	0	8	111	18	0	137	0.325±0.021
	John Day (JD)	0	22	50	46	0	118	0.264±0.025
	Bonneville (BON)	0	5	98	86	0	189	0.292±0.017
	Pooled (All)	0	35	259	150	0	444	0.301±0.015
2023	McNary (MCN)	0	15	118	20	0	153	0.204±0.0136
	John Day (JD)	0	20	42	50	0	112	0.104±0.0917
	Bonnevile (BON)	0	4	78	59	0	141	0.203±0.0524
	Pooled (All)	0	39	238	129	0	406	0.27±0.019

Table 5. Detection rate of hatchery Spring Chinook smolts at Prosser Dam based on strata (Un-stratified and Stratified) with the reference of McNary Dam and pooled over the three Columbia River dams (MCJ, JDJ and B2J/BCC) from 2019 through 2023. The redistributed detection rate was estimated by pooling the five time periods into two groups: pre-March through April, and May through Post-May.

Migration Year	Reference	stratified/unstratified	Pre-March	March	April	May	Post-May
2019	Based on McNary Dam	Un-stratified	27.61%	27.61%	27.61%	27.61%	27.61%
		Stratified	0.00%	19.38%	17.72%	39.63%	0.00%
		Stratified (Redistributed)	18.47%	18.47%	18.47%	39.63%	39.63%
	Based on pooled Dams (McN, JD and BON)	Un-stratified	27.93%	27.93%	27.93%	27.93%	27.93%
		Stratified	0.00%	24.64%	20.27%	36.13%	0.00%
		Stratified (Redistributed)	20.07%	20.07%	20.06%	35.88%	35.88%
2020	Based on McNary Dam	Un-stratified	33.44%	33.44%	33.44%	33.44%	33.44%
		Stratified	0.00%	11.85%	22.72%	57.96%	0.00%
		Stratified (Redistributed)	23.68%	23.68%	23.68%	57.96%	57.96%
	Based on pooled Dams (McN, JD and BON)	Un-stratified	43.96%	43.96%	43.96%	43.96%	43.96%
		Stratified	0.00%	14.87%	33.21%	59.30%	0.00%
		Stratified (Redistributed)	32.26%	32.26%	33.30%	59.23%	59.23%
2021	Based on McNary Dam	Un-stratified	27.09%	27.09%	27.09%	27.09%	27.09%
		Stratified	0.00%	19.38%	17.72%	39.63%	0.00%
		Stratified (Redistributed)	18.47%	18.47%	18.47%	39.63%	39.63%
	Based on pooled Dams (McN, JD and BON)	Un-stratified	27.93%	27.93%	27.93%	27.93%	27.93%
		Stratified	0.00%	20.36%	20.06%	35.88%	0.00%
		Stratified (Redistributed)	20.07%	20.07%	20.06%	35.88%	35.88%
2022	Based on McNary Dam	Un-stratified	35.28%	35.28%	35.28%	35.28%	35.28%
		Stratified	0.000%	44.521%	29.326%	29.762%	0.000%
		Stratified (Redistributed)	36.834%	36.834%	36.834%	30.268%	30.268%
	Based on pooled Dams (McN, JD and BON)	Un-stratified	30.06%	30.06%	30.06%	30.06%	30.06%
		Stratified	0.00%	40.59%	28.20%	29.92%	0.00%
		Stratified (Redistributed)	29.54%	29.54%	28.20%	31.08%	31.08%
2023	Based on McNary Dam	Un-stratified	36.50%	36.50%	36.50%	36.50%	36.50%
		Stratified	37.400%	37.400%	37.400%	37.400%	37.400%
		Stratified (Redistributed)	37.400%	37.400%	37.400%	31.500%	31.500%

Based on pooled Dams (McN, JD and BON)	Un-stratified	31.50%	31.50%	31.50%	31.50%	31.50%
	Stratified	29.60%	29.60%	28.20%	31.50%	0.00%
	Stratified (Redistributed)	18.70%	18.70%	25.14%	60.07%	60.07%

3.3. Predicted number of outmigrating wild and hatchery Spring Chinook smolts

The total number of hatchery Spring Chinook smolts passing Prosser Dam in all four migration years (2019-2023) was way higher than the wild (natural-origin) populations (Table 6). Applying the detection rates derived from hatchery Spring Chinook to their wild counterparts (Table 5), the estimates of wild Spring Chinook smolts passing Prosser Dam varied between years. In the case of the 2023 out-migration year, depending on the estimation method used, the estimates for wild outmigration ranged from 102,791 to 131,942, while the hatchery smolt estimates for 2023 ranged from 165,938 to 218,683 (see table 6). The details of the juvenile Spring Chinook passage estimate at Prosser Dam based on different estimators from 1999-2023 are given in Appendix A of this report. The estimates based on the method with temporal strata Pre-May, May, June, Post-June was found to be slightly higher than the estimates based on non-stratified detection rates.

Table 6. The estimated number of wild and hatchery Spring Chinook smolts migrating past Prosser Dam in each year from 2019 through 2023 using four estimation methods.

		Estimates of outmigration population based on different methods			
Migration Year	Origin	McN_UnStr (Method1)	McN_Str (Method2)	Pooled_UnStr (Method3)	Pooled_Str (Method4)
2019	Wild	168,119	154,848	175,427	154,530
	Hatchery	310,836	353,803	319,579	343,212
2020	Wild	201,313	168,124	151,254	115,300
	Hatchery	456,852	500,195	371,069	380,494
2021	Wild	180,396	180,554	218,874	211,829
	Hatchery	353,239	365,831	437,370	429,200
	Wild	102,936	105,936	126,537	120,247
2022	Hatchery	282,878	279,511	333,868	317,270
2023	Wild	102,791	104,799	131,942	120,247
	Hatchery	270,555	270,196	341,427	458,706

Choosing the best estimate was challenging. We compared these estimates with another independent estimate derived from the CJS model (Table 7). In migration year 2023, the average survival rate from the three acclimation sites to Prosser Dam was 36.81±1.97% (based on the CJS model) and the total number of released hatchery Spring Chinook smolts during 2023 was 865,875. Multiplying the survival rate by the released population, the total outmigration of hatchery Spring Chinook from Prosser was estimated to be 285,210 ± 33,518 (mean ± SE, see table 7). This estimate was almost similar with the estimates derived from the method using method 3 but lower than the method 4 (Tables 6 and 7).

Table 7. Number of Spring Chinook (hatchery) smolts release at Acclimation sites and its survival rate from the acclimation sites to Below Prosser based on CJS model and the estimated outmigration smolts from Prosser Dam for each migration year from 2019 through 2023.

Migration Year	No. of smolts at Acclimation sites	Survival rate from the acclimation site to below Prosser		Estimated outmigration smolt from Prosser	
		Average	SE	Average	SE [95% CI]
2019	673,218	50.82	2.2	342,129	29,103 [285,087 - 399,171]
2020	624,200	61.22	3.91	382,135	47,958 [288137 - 476,133]
2021	550,398	41.92	2.21	230,727	24,764 [182,124 - 279,270]
2022	706,924	38.19	1.19	269,975	8,412 [261,562 - 278,387]
2023	865,875	36.81	1.97	318,729	33,518 [285,210-352,247]

However, the estimates based on the CJS models may still have some bias because the survival rate may not be homogeneous among the sampling months, especially due to variation in river flow at Prosser within the sampling period.

3.4. Annual trend of juvenile Prosser-passage estimates (hatchery and wild) by stock

Annual juvenile Prosser-passage estimates from outmigration years 1999 through 2023 are given in Table 8 by stock of wild/Natural origin (Naches, American, and Upper Yakima rivers) plus hatchery Upper Yakima River origin. It showed that Prosser juvenile estimates for both wild (natural) and hatchery vary among the outmigration year.

Table 8. Annual estimated wild and hatchery-origin smolt passage at Prosser Dam from 1999 through 2023. Estimates for the outmigration years from 1998 through 2018 were adopted from Neeley (2019).

Brood Year (BY)	Outmigration Year	Wild Stock Estimates				Hatchery (Upper Yakima)	Total Wild & Hatchery
		Total Wild	Naches	American	Upper Yakima		
1997	1999	584,016	93,427	63,000	427,588	187,669	771,685
1998	2000	199,416	55,737	50,944	92,795	303,688	503,104
1999	2001	148,460	Genetic samples not taken			281,256	429,716
2000	2002	467,359	92,323	17,835	357,201	366,950	834,309
2001	2003	308,959	74,498	42,867	191,594	154,329	463,288
2002	2004	169,397	59,978	35,800	73,619	290,950	460,347
2003	2005	134,859	45,321	35,564	5,374	236,443	371,302
2004	2006	133,238	49,947	7,882	75,409	300,508	433,746
2005	2007	99,341	26,684	11,103	61,554	351,359	450,700
2006	2008	120,013	32,589	6,811	80,613	265,485	385,498
2007	2009	237,228	80,756	26,498	128,974	415,923	653,151
2008	2010	220,950	77,397	30,354	113,198	382,878	603,828

2009	2011	304,322	58,904	17,882	227,536	442,564	746,886
2010	2012	258,106	81,483	23,609	153,014	391,446	649,552
2011	2013	365,386	85,577	25,681	254,228	372,079	737,465
2012	2014	263,266	79,450	28,622	155,194	408,222	671,488
2013	2015	125,150	29,885	13,769	81,496	332,715	457,865
2014	2016	185,442	57,657	15,378	112,407	403,938	589,380
2015	2017	208,929	62,190	24,455	122,285	273,248	482,177
2016	2018	131,489	37,500	9,824	76,150	290,644	422,133
2017	2019	175,427	41,690	22,379	127,176	319,579	495,006
2018	2020	151,265	34,770	5,007	115,288	371,069	522,333
2019	2021	106,092	24,279	7,610	80,859	212,000	318,092
2020	2022	126,537	58,802	8,263	59,472	282,878	409,416
2021	2023	141,216	61,404	10,152	69,660	270,555	402,497
Average/year		215,154	58,691	22,539	137,452	316,335	531,118
Standard Error (SE)		23,487	4,822	3,046	19,299	14,881	28,127

Because the smolt passage estimates for the three largest stock groupings (Total wild, Upper Yakima wild, and Upper Yakima hatchery) varied by outmigration year, we further estimated whether the outmigration smolt decreased over years (temporal trends) and whether there were differences among stocks. In 1999, only 14 of 18 raceways were used for hatchery production. As a result, the Prosser passage estimates for hatchery smolts in 1999 were low, which might not compare well with other years' hatchery estimates. Two relationships were developed using the data with and without 1999's passage estimates for all three groups (total wild, Upper Yakima wild, and Upper Yakima hatchery). In both datasets, the total number of out-migrating wild smolts and the number of wild upper Yakima smolts seemed to be decreasing over time, whereas the population of hatchery in Upper Yakima sub-basin seemed to be increasing; but neither trend was statistically significant.

Table 9. Percentage of wild and hatchery spring Chinook stocks in juvenile Prosser passage estimates, comparing the hatchery stock to all wild stocks and to the Upper Yakima wild stock by itself.

		Total Yakima Basin		Only Upper Yakima River	
Brood Year (BY)	Out-migration Year	% Hatchery of Total	% Wild of Total	% Hatchery of Upper Yakima Stock	% Wild of Upper Yakima stock
1997	1999	24.32%	75.68%	30.50%	69.50%
1998	2000	60.36%	39.64%	76.60%	23.40%
1999	2001	65.45%	34.55%	Genetic samples not taken	
2000	2002	43.98%	56.02%	50.67%	49.33%
2001	2003	33.31%	66.69%	44.61%	55.39%
2002	2004	63.20%	36.80%	79.81%	20.19%
2003	2005	63.68%	36.32%	97.78%	2.22%
2004	2006	69.28%	30.72%	79.94%	20.06%
2005	2007	77.96%	22.04%	85.09%	14.91%
2006	2008	68.87%	31.13%	76.71%	23.29%
2007	2009	63.68%	36.32%	76.33%	23.67%
2008	2010	63.41%	36.59%	77.18%	22.82%
2009	2011	59.25%	40.75%	66.04%	33.96%
2010	2012	60.26%	39.74%	71.90%	28.10%
2011	2013	50.45%	49.55%	59.41%	40.59%
2012	2014	60.79%	39.21%	72.45%	27.55%
2013	2015	72.67%	27.33%	80.33%	19.67%
2014	2016	68.54%	31.46%	78.23%	21.77%
2015	2017	56.67%	43.33%	69.08%	30.92%
2016	2018	68.85%	31.15%	79.24%	20.76%
2017	2019	64.56%	35.44%	71.53%	28.47%
2018	2020	71.04%	28.96%	76.30%	23.70%
2019	2021	66.65%	33.35%	72.39%	27.61%
2020	2022	69.09%	30.91%	82.63%	17.37%
2021	2023	65.71%	34.29%	79.52%	20.48%

Note: Estimates for the outmigration years from 1998 through 2018 were adopted from Neeley (2019)

We found that while the rate of change in out-migrating hatchery smolt population over years seemed to be positive and the trend for wild stocks were negative, the relationship of hatchery passage to wild passage (all wild stocks or only the Upper Yakima wild stock) was not statistically significant. This indicates that the production and releases of spring Chinook hatchery smolts into the upper Yakima do not have an effect on the production of wild smolts. The reduction of the production of wild smolts could be influenced by many factors including habitat loss that limits the carrying capacity and it eventually reduces the survival rate and the total outmigration.

3.5. Genetic variation among stocks (Upper Yakima, Naches, American)

As discussed above, wild Yakima Basin Spring Chinook are comprised of multiple stocks, of which Upper Yakima River, Naches River, and American River stocks have been identified by demographic characteristics and supported by genetic analysis. Reproductively isolated populations usually differ in productivity. We, therefore, further evaluated whether the rate of outmigration of these genetic stocks has changed over time. Because no hatchery program has been implemented in the American and Naches rivers, we hypothesized that the rate of decline should be higher in the Upper Yakima's wild Spring Chinook, if the hatchery program affected wild productivity.

The annual outmigration estimates showed that the wild Spring Chinook smolt population declined over the 2000-2023 outmigration years (Figure 6) for all three stocks. The rate of decline of the smolt in the Wild Upper Yakima stock was -1916 smolts/year (see figure 9 and 11), but the trend was not significant ($R^2 = 0.026$, $p = 0.48$), nor was the rate of decline for the Naches River stock (Slope=1126/year, R^2=0.114, $p = 0.135$, Figure 11). Only the American stock declined significantly (Slope= -1110/year, $R^2 = 0.313$, p=0.008); there has been no introduction of hatchery smolts into the American River.

In fact, the American River seems to have suffered a relatively low anthropogenic effect compared to the other rivers. It is also the coldest and has entirely natural flow that persists through the summer. If hatchery or other local anthropogenic factors had a negative influence, the American River stock should have declined the least, but the opposite was true in terms of outmigrant abundance.

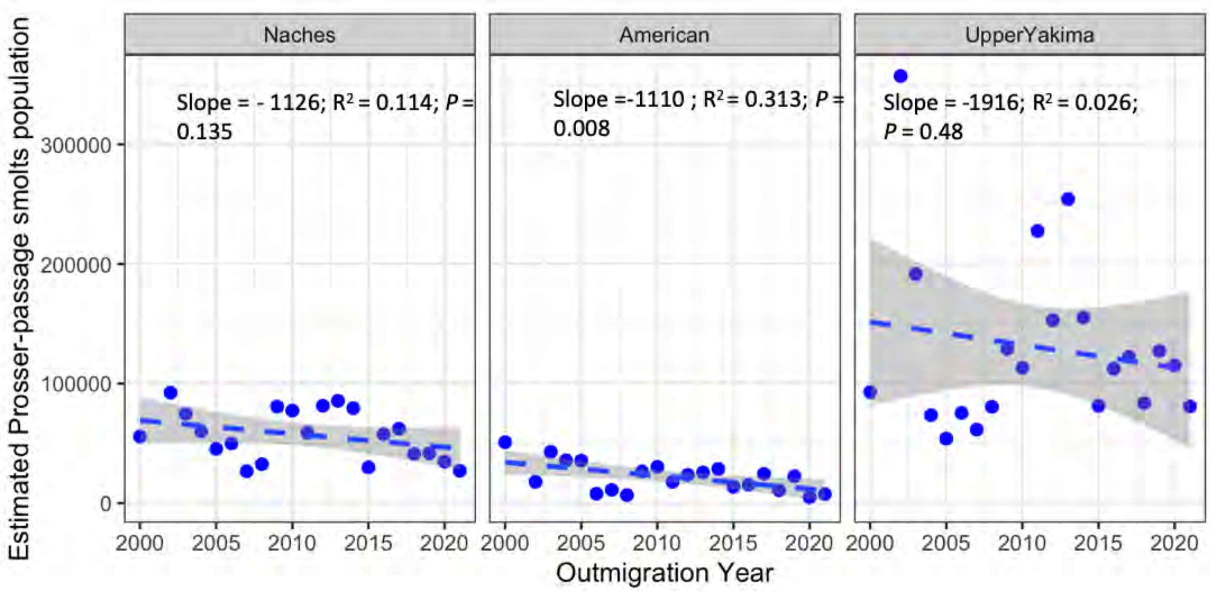

Figure 6. The relationship between estimated smolt passage of Wild Spring Chinook of Naches, American, and Upper Yakima stock by outmigration year.

3.6. Contribution of each stock to outmigration

For outmigration years 1999-2023, about 62% of the total wild outmigration was contributed by the Upper Yakima wild stock; while 28% and 11% were contributed by Naches and American River stocks, respectively (Table 10).

Table 10. American, Naches and Upper Yakima Percentages of Prosser passage of wild Spring Chinook smolts at Prosser Dam. Data for outmigration years 1998 through 2017 were adopted from Neeley (2018).

Brood Year	Outmigration Year	Naches	American	Upper Yakima
1997	1999	16.00%	10.79%	73.22%
1998	2000	27.95%	25.55%	46.53%
1999	2001			
2000	2002	19.75%	3.82%	76.43%
2001	2003	24.11%	13.87%	62.01%
2002	2004	35.41%	21.13%	43.46%
2003	2005	33.61%	26.37%	40.02%
2004	2006	37.49%	5.92%	56.60%
2005	2007	26.86%	11.18%	61.96%
2006	2008	27.15%	5.68%	67.17%
2007	2009	34.04%	11.17%	54.37%
2008	2010	35.03%	13.74%	51.23%
2009	2011	19.36%	5.88%	74.77%
2010	2012	31.57%	9.15%	59.28%
2011	2013	23.42%	7.03%	69.58%
2012	2014	30.18%	10.87%	58.95%

2013	2015	23.88%	11.00%	65.12%
2014	2016	31.09%	8.29%	60.62%
2015	2017	29.77%	11.70%	58.53%
2016	2018	28.52%	7.47%	57.91%
2017	2018	23.76%	12.76%	72.50%
2018	2020	22.99%	3.31%	76.22%
2019	2021	22.89%	7.17%	69.94%
2020	2022	26.47%	6.53%	67.00%
2021	2023	43.48%	7.19%	49.33%
Mean		28.12%	10.73%	61.36%
SE		1.31%	1.16%	2.13%

Table 11. Estimated Wild Spring Chinook stock distributions (American, Naches and Upper Yakima River) within the genetic sampling periods (Pre-March through Post-May). The data were provided by WDFW.

migration year	American					Naches					U. Yakima				
	Pre-March	March	April	May	Post-May	Pre-March	March	April	May	Post-May	Pre-March	March	April	May	Post-May
1999	8.08%	8.08%	8.08%	12.00%	28.00%	6.06%	6.06%	6.06%	29.00%	33.00%	85.86%	85.86%	85.86%	59.00%	39.00%
2000	16.18%	16.18%	22.14%	46.94%	46.94%	22.06%	22.06%	30.99%	36.73%	36.73%	61.76%	61.76%	46.88%	16.33%	16.33%
2002	3.81%	3.81%	3.81%	3.86%	3.86%	19.68%	19.68%	19.68%	20.29%	20.29%	76.51%	76.51%	76.51%	75.85%	75.85%
2003	13.43%	13.43%	13.43%	16.03%	16.03%	21.64%	21.64%	21.64%	34.24%	34.24%	64.93%	64.93%	64.93%	49.73%	49.73%
2004	6.46%	4.27%	21.50%	34.72%	31.25%	33.84%	29.27%	36.47%	34.03%	18.75%	59.70%	66.46%	42.03%	31.25%	50.00%
2005	21.39%	18.87%	29.57%	32.14%	0.00%	35.32%	7.55%	35.36%	23.21%	17.86%	43.28%	73.58%	35.07%	44.64%	82.14%
2006	7.36%	0.00%	5.52%	5.45%	2.27%	39.88%	25.96%	35.95%	39.11%	15.91%	52.76%	74.04%	58.53%	55.45%	81.82%
2007	9.10%	14.50%	6.81%	16.75%	11.54%	18.20%	32.30%	24.72%	29.78%	26.07%	72.70%	53.20%	68.47%	53.47%	62.39%
2008	8.33%	0.00%	5.22%	5.00%	14.81%	8.33%	14.29%	25.22%	31.11%	51.85%	83.33%	85.71%	69.57%	63.89%	33.33%
2009	9.80%	10.93%	12.06%	10.95%	36.29%	35.60%	32.43%	29.25%	40.78%	28.23%	54.60%	56.64%	58.69%	48.27%	35.48%
2010	30.31%	0.00%	14.16%	11.88%	0.00%	7.35%	19.50%	37.13%	33.63%	75.49%	62.34%	80.50%	48.71%	54.49%	24.51%
2011	8.64%	0.00%	3.49%	5.92%	16.65%	18.19%	19.75%	23.96%	13.10%	0.00%	73.17%	80.25%	72.55%	80.98%	83.35%
2012	10.99%	5.31%	6.17%	13.65%	23.46%	31.62%	29.60%	29.32%	38.48%	29.45%	57.39%	65.09%	64.51%	47.87%	47.09%
2013	8.23%	2.30%	5.72%	16.96%	6.39%	17.43%	20.59%	27.50%	29.53%	7.85%	74.34%	77.11%	66.78%	53.51%	85.76%
2014	11.65%	12.03%	9.09%	11.95%	13.86%	41.19%	21.74%	30.16%	38.12%	0.00%	47.16%	66.23%	60.74%	49.93%	86.14%
2015	13.86%	11.62%	8.92%	14.74%	14.74%	16.80%	26.32%	23.13%	24.09%	24.09%	69.34%	62.06%	67.96%	61.17%	61.17%
2016	5.69%	7.42%	9.44%	13.00%	3.71%	26.41%	23.18%	38.42%	34.52%	0.00%	67.90%	69.40%	52.13%	52.49%	96.29%
2017	10.20%	11.21%	15.80%	10.78%	37.16%	31.70%	27.73%	27.10%	29.57%	11.47%	58.10%	61.06%	57.10%	59.65%	51.37%
2018	8.80%	3.30%	5.82%	10.40%	25.00%	23.20%	33.00%	35.11%	41.94%	25.00%	68.00%	63.70%	59.08%	47.66%	50.00%
2019	9.90%	12.44%	14.70%	14.71%	0.00%	17.82%	21.89%	23.32%	35.29%	0.00%	72.28%	65.67%	61.98%	50.00%	100.0%
2020	3.78%	6.50%	2.84%	3.60%	0.00%	3.78%	6.50%	2.84%	3.60%	0.00%	76.22%	73.17%	74.47%	66.19%	100.0%
2021	5.87%	3.72%	6.62%	11.11%	11.11%	31.05%	12.56%	23.69%	31.82%	7.41%	63.08%	83.72%	69.69%	57.07%	81.48%
2022	7.93%	7.02%	5.88%	5.13%	0.00%	47.39%	46.78%	45.63%	50.00%	0.00%	44.68%	46.20%	48.48%	44.87%	100.00%
2023	10.96%	11.52%	9.66%	12.90%	0.00%	25.11%	20.42%	28.77%	51.61%	0.00%	63.93%	68.06%	61.57%	35.48%	100.00%

3.7. Relationship between Wild Juvenile passage estimates and estimated Adult Returns

Since the number of smolts outmigrating from Prosser (Prosser-passage estimates) varied among years, we further evaluated whether this variation corresponded to adult returns. Or in other words, does the fluctuation of annual wild juvenile passage at Prosser synchronize with the fluctuation of the adult returns at Prosser? To answer the question, we built a univariate relationship between the total Juvenile Prosser estimates of wild Spring Chinook and the predicted adult return to Prosser. Table 12 presents the brood year Prosser escapement (the escapement measures are taken as a surrogate of spawner number) of the parental generation in addition to total juvenile Prosser passage and Prosser return. The relationship between juvenile-to-adult correlation of total wild juvenile passage to adult return from each outmigration was significantly high, with an R^2 of 69% and p value<0.01, indicating that estimated number of outmigration smolts are reasonably accurate.

Table 12. Total estimated escapement (Estimated Spawners (wild/natural) at Yakima river mouth), juvenile passage and return to Prosser of each wild Spring Chinook brood for brood years 1997-2019. Estimated value for the Prosser escapement and Prosser return were adopted from Table 10 and Table 3 of Bosch (2023), respectively. The shaded yellow color and number with red color indicate that adult returns from these brood years are incomplete.

Brood Year	Out-migration Year	Estimated Spawners (wild/natural) at Yakima river mouth	Total Juvenile Prosser Passage	Prosser return
1997	1999	2,337	584,016	12,808
1998	2000	1,307	199,476	7,283
1999	2001	1,439	148,460	4,090
2000	2002	15,976	467,359	11,128
2001	2003	17,916	308,959	7,731
2002	2004	11,113	169,397	3,850
2003	2005	5,933	134,859	2,195
2004	2006	12,893	133,218	3,687
2005	2007	7,617	99,265	4,089
2006	2008	5,050	123,735	5,118
2007	2009	3,308	250,846	7,610
2008	2010	5,922	221,228	6,739
2009	2011	8,172	303,711	4,167
2010	2012	9,875	252,029	6,148
2011	2013	11,644	365,468	7,002
2012	2014	7,383	267,433	3,941
2013	2015	6,352	123,289	3,736
2014	2016	7,882	53,478	1,928
2015	2017	7,569	193,723	870
2016	2018	5,613	144,493	1,876
2017	2019	5,015	175,427	1,745
2018	2020	2,451	151,254	3,474
2019	2021	1,628	106,092	1466*
2020	2022	2,723	126,537	
2021	2023	3358	141,216	

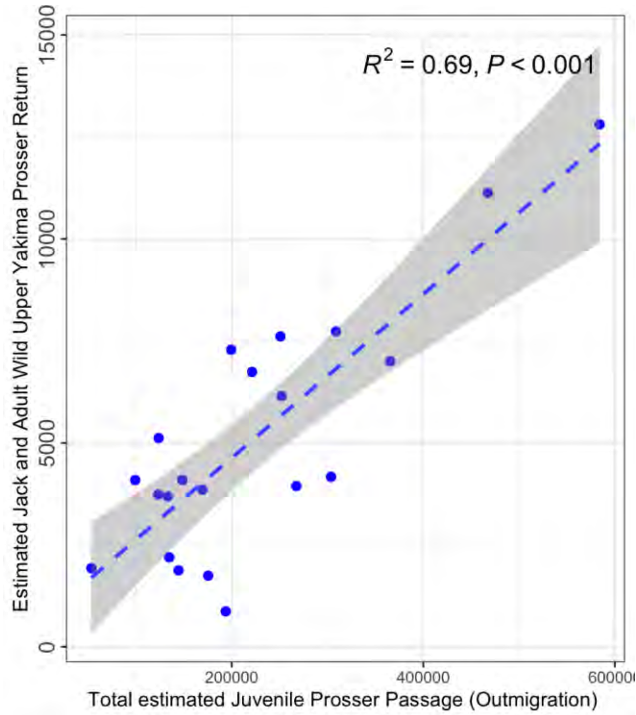

Figure 7. The relationship between total smolts outmigration and Prosser returns of progeny (adult returns) of wild Spring Chinook. Since the Spring Chinook can spend as many as 4 years in the ocean, the relationship was made for the populations that brood year from 1997 through 2021.

4. References

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5. Supplementary information: Detailed Passage-Estimates

Detailed Passage-Estimates for each year from 1998 through 2022

Supplementary information: Detailed Passage-Estimates for each year from 1998 through 2021

5.1.Year 1998

1998		Brood-Year 1996	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	0	10618	106253	6174	292	123337	123337			
	American	WDFW Percent	0	0.00	0.02	0.02	0.12					
		Estimated Prosser Tally	0	0.00	2125.06	124.72	35.06	2284.84	2284.84			
	Naches	WDFW Percent	0.21	0.21	0.24	0.24	0.51					
		Estimated Prosser Tally	0	2230	25501	1497	149	29376	29376			
	Upper Yakima	WDFW Percent	0.79	0.79	0.74	0.74	0.37					
		Estimated Prosser Tally	0	8388	78627	4552	108	91676	91676			
		Yakima Passage Wild Tally	0	10618	106253	6174	292	123337	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
	Estimate a.	Detection Efficiency										
		Total Passage										
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
	Estimate b.	Detection Efficiency										
		Total Passage										
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
	Estimate c.	Detection Efficiency										
*		Total Passage										
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
	Estimate e.	Detection Efficiency										

			Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
		Total Passage				
		American Passage				
		Naches Passage				
		American & Naches Passage				
		Upper Yakima Passage				
Hatchery		Prosser Hatchery Tally	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage				
McN-UnStr Hatch	Estimate b.	Total Passage				
Pooled Str Hatch	Estimate c.	Total Passage				
Pooled UnStr Hatch	Estimate e.	Total Passage				

5.2.Year 1999

1999		Brood-Year 1997	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	41232.89541	407	29431	51920	1577	124569	124569			
	American	WDFW Percent	0.08	0.08	0.08	0.12	0.28					
		Estimated Prosser Tally	3332	33	2378	6230	442	12415	12415			
	Naches	WDFW Percent	0.06	0.06	0.06	0.29	0.33					
		Estimated Prosser Tally	2499	25	1784	15057	520	19885	19885			
	Upper Yakima	WDFW Percent	0.86	0.86	0.86	0.59	0.39					
		Estimated Prosser Tally	35401.98091	350	25269	30633	615	92269	92269			
		Yakima Passage Wild Tally	41233	407	29431	51920	1577	124569	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	18.5%	18.5%	18.5%	25.5%	5.0%					
		Total Passage	222873	2201	159082	203681	31262	619099	619099	571397		0.9229
		American Passage	18010	178	12855	24442	8753	64238	64238	59288		
		Naches Passage	13507	133	9641	59067	10316	92666	92666	85526		
		American & Naches Passage	31517	311	22496	83509	19070	156904	156904	144815		
		Upper Yakima Passage	191355	1890	136586	120172	12192	462195	462195	426583		

McN UnStr Wild	Estimate b.	Detection Efficiency	23.0%	23.0%	23.0%	23.0%	23.0%					
		Total Passage	179338	1771	128008	225822	6860	541799	541799	502917		0.9282
		American Passage	14492	143	10344	27099	1921	53998	53998	50123		
		Naches Passage	10869	107	7758	65488	2264	86486	86486	80280		
		American & Naches Passage	25361	251	18102	92587	4184	140485	140485	130403		
		Upper Yakima Passage	153977	1521	109906	133235	2675	401314	401314	372514		
Pooled Str Wild	Estimate c.	Detection Efficiency	19.4%	19.4%	19.4%	23.0%	3.8%					
		Total Passage	212650	2101	151786	225518	41751	633805	633805	584016		0.9214
		American Passage	17184	170	12266	27062	11690	68371	68371	63000		
		Naches Passage	12888	127	9199	65400	13778	101392	101392	93427		
		American & Naches Passage	30072	297	21465	92462	25468	169764	169764	156428		
		Upper Yakima Passage	182579	1803	130321	133056	16283	464042	464042	427588		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	20.3%	20.3%	20.3%	20.3%	20.3%					
		Total Passage	203022	2005	144913	255644	7766	613350	613350	569333		0.9282
		American Passage	16406	162	11710	30677	2174	61130	61130	56743		
		Naches Passage	12304	122	8783	74137	2563	97908	97908	90882		
		American & Naches Passage	28710	284	20493	104814	4737	159038	159038	147624		
		Upper Yakima Passage	174312	1722	124420	150830	3029	454312	454312	421709		
Hatchery		Prosser Hatchery Tally	0	7	1812	31529	1371	34719	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estim a.	Total Passage	0	39	9796	123685	27175	160696	179215	165406	0.1033	0.9229
McN-UnStr Hatch	Estimate b.	Total Passage	0	32	7883	137130	5963	151007	168410	156324		0.9282
Pooled Str Hatch	Estimate c.	Total Passage	0	38	9347	136946	36292	182622	203668	187669		0.9214
Pooled UnStr Hatch	Estimate e.	Total Passage	0	36	8924	155240	6750	170950	190650	176968		0.9282

5.3. Year 2000

2000		Brood-Year 1998	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	12636.71089	252	11172	19815	814	44690	44690			
	American	WDFW Percent	0.16	0.16	0.22	0.47	0.47					
		Estimated Prosser Tally	2044	41	2473	9301	382	14241	14241			
	Naches	WDFW Percent	0.22	0.22	0.31	0.37	0.37					
		Estimated Prosser Tally	2788	56	3462	7279	299	13883	13883			
	Upper Yakima	WDFW Percent	0.62	0.62	0.47	0.16	0.16					
		Estimated Prosser Tally	7805	156	5237	3235	133	16566	16566			
		Yakima Passage Wild Tally	12637	252	11172	19815	814	44690	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	12.5%	12.5%	31.6%	52.6%	31.0%					
		Total Passage	100754	2008	35311	37686	2627	178387	178387	222645		1.2481
		American Passage	16298	325	7816	17689	1233	43362	43362	54120		
		Naches Passage	22225	443	10943	13844	965	48420	48420	60433		
		American & Naches Passage	38524	768	18759	31533	2199	91782	91782	114553		
		Upper Yakima Passage	62231	1240	16552	6153	429	86605	86605	108091		
McN UnStr Wild	Estimate b.	Detection Efficiency	41.7%	41.7%	41.7%	41.7%	41.7%					
		Total Passage	30333	605	26818	47564	1955	107274	107274	132166		1.2320
		American Passage	4907	98	5936	22326	918	34184	34184	42116		
		Naches Passage	6691	133	8311	17472	718	33326	33326	41059		
		American & Naches Passage	11598	231	14247	39798	1636	67510	67510	83175		
		Upper Yakima Passage	18735	373	12571	7765	319	39764	39764	48991		
Pooled Str Wild	Estimate c.	Detection Efficiency	15.9%	15.9%	30.0%	51.1%	30.0%					
		Total Passage	79697	1589	37229	38770	2713	159998	159998	199476		1.2467
		American Passage	12892	257	8241	18198	1273	40862	40862	50944		
		Naches Passage	17580	350	11537	14242	997	44707	44707	55737		
		American & Naches Passage	30472	607	19778	32440	2270	85568	85568	106681		
		Upper Yakima Passage	49224	981	17451	6330	443	74430	74430	92795		

			Pre-March	March	April	May	Post-May	Total	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
Pooled UnStr Wild	Estimate e.	Total Passage	41.2%	41.2%	41.2%	41.2%	41.2%					
		Total Passage	30699	612	27141	48137	1979	108568	108568	133760		1.2320
		American Passage	4966	99	6008	22595	929	34596	34596	42624		
		Naches Passage	6772	135	8411	17683	727	33728	33728	41554		
		American & Naches Passage	11738	234	14419	40278	1656	68324	68324	84178		
		Upper Yakima Passage	18961	378	12722	7859	323	40244	40244	49582		
Hatchery		Prosser Hatchery Tally	0	11	12187	59659	21234	93091	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	91	38517	113466	68501	220575	235507	293937	0.0634	1.2481
McN-UnStr Hatch	Estimate b.	Total Passage	0	27	29253	143206	50971	223458	238585	293946		1.2320
Pooled Str Hatch	Estimate c.	Total Passage	0	72	40610	116731	70728	228141	243585	303688		1.2467
Pooled UnStr Hatch	Estimate e.	Total Passage	0	28	29606	144933	51586	226152	241461	297490		1.2320

5.4.Year 2001

2001		Brood-Year 1999	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	4678.641782	3236	101993	27763	1307	138977	138977			
	American	WDFW Percent										
		Estimated Prosser Tally							0			
	Naches	WDFW Percent										
		Estimated Prosser Tally	genetic assignment to Upper Yakima Stock not possible						0			
	Upper Yakima	WDFW Percent										
		Estimated Prosser Tally							0			
		Yakima Passage Wild Tally						138977	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	76.1%	76.1%	76.1%	86.8%	91.9%					
		Total Passage	6150	4253	134076	31992	1421	177893	177893	149124		0.8383
		American Passage										

Genetic Sample Analysis not Performed

		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
McN UnStr Wild	Estimate b.	Detection Efficiency	83.9%	83.9%	83.9%	83.9%	83.9%					
		Total Passage	5577	3857	121571	33092	1558	165654	165654	143613		0.8669
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
Pooled Str Wild	Estimate c.	Detection Efficiency	77.3%	77.3%	77.3%	85.9%	90.9%					
		Total Passage	6052	4185	131931	32310	1438	175917	175917	148460		0.8439
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
Pooled UnStr Wild	Estimate e.	Detection Efficiency	83.7%	83.7%	83.7%	83.7%	83.7%					
		Total Passage	5589	3865	121828	33162	1561	166004	166004	143917		0.8669
		American Passage										
		Naches Passage										
		American & Naches Passage										
		Upper Yakima Passage										
Hatchery		Prosser Hatchery Tally	0	4	96207	148783	16931	261925	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	5	126468	171448	18415	316337	333380	279467	0.0511	0.8383
McN-UnStr Hatch	Estimate b.	Total Passage	0	5	114674	177343	20181	312202	329022	285245		0.8669
Pooled Str Hatch	Estimate c.	Total Passage	0	5	124446	173151	18633	316235	333273	281256		0.8439
Pooled UnStr Hatch	Estimate e.	Total Passage	0	5	114916	177717	20223	312862	329717	285847		0.8669

5.5. Year 2002

2002		Brood-Year 2000	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	66506.36024	26080	101052	40512	62	234213	234213			
	American	WDFW Percent	0.04	0.04	0.04	0.04	0.04					
		Estimated Prosser Tally	2534	994	3850	1566	2	8945	8945			
	Naches	WDFW Percent	0.20	0.20	0.20	0.20	0.20					
		Estimated Prosser Tally	13090	5133	19890	8220	13	46345	46345			
	Upper Yakima	WDFW Percent	0.77	0.77	0.77	0.76	0.76					
		Estimated Prosser Tally	50882.64387	19954	77313	30726	47	178922	178922			
		Yakima Passage Wild Tally	66506	26080	101052	40512	62	234213	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	31.7%	31.7%	56.3%	65.9%	25.2%					
		Total Passage	209858	82295	179367	61477	247	533244	533244	466904		0.8756
		American Passage	7995	3135	6833	2376	10	20348	20348	17817		
		Naches Passage	41305	16198	35304	12474	50	105331	105331	92227		
		American & Naches Passage	49300	19333	42137	14850	60	125679	125679	110044		
		Upper Yakima Passage	160558	62963	137230	46628	187	407565	407565	356861		
McN UnStr Wild	Estimate b.	Detection Efficiency	59.5%	59.5%	59.5%	59.5%	59.5%					
		Total Passage	111740	43819	169781	68066	104	393510	393510	349322		0.8877
		American Passage	4257	1669	6468	2631	4	15028	15028	13341		
		Naches Passage	21993	8625	33417	13810	21	77867	77867	69123		
		American & Naches Passage	26250	10294	39885	16441	25	92895	92895	82464		
		Upper Yakima Passage	85490	33525	129896	51625	79	300615	300615	266858		
Pooled Str Wild	Estimate c.	Detection Efficiency	32.8%	32.8%	53.9%	65.2%	7.9%					
		Total Passage	202911	79571	187367	62093	784	532726	532726	467359		0.8773
		American Passage	7730	3031	7138	2400	30	20329	20329	17835		

		Naches Passage	39938	15662	36879	12599	159	105236	105236	92323		
		American & Naches Passage	47668	18693	44016	14998	189	125565	125565	110158		
		Upper Yakima Passage	155243	60878	143350	47095	595	407161	407161	357201		
Pooled UnStr Wild	Estimate e.	Total Passage	57.6%	57.6%	57.6%	57.6%	57.6%					
		Total Passage	115447	45272	175414	70324	108	406565	406565	360912		0.8877
		American Passage	4398	1725	6682	2718	4	15527	15527	13784		
		Naches Passage	22723	8911	34526	14269	22	80450	80450	71416		
		American & Naches Passage	27121	10635	41208	16986	26	95977	95977	85200		
		Upper Yakima Passage	88326	34637	134206	53337	82	310588	310588	275712		
Hatchery		Prosser Hatchery Tally	5	2254	126919	101160	171	230509	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	16	7111	225281	153510	680	386599	404834	354470	0.0450	0.8756
McN-UnStr Hatch	Estimate b.	Total Passage	9	3786	213241	169962	288	387287	405555	360015		0.8877
Pooled Str Hatch	Estimate c.	Total Passage	16	6876	235328	155049	2164	399432	418273	366950		0.8773
Pooled UnStr Hatch	Estimate e.	Total Passage	9	3912	220316	175601	298	400136	419010	371959		0.8877

5.6. Year 2003

2003		Brood-Year 2001	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	30359.49166	16582	98537	33294	272	179045	179045
	American	WDFW Percent	0.13	0.13	0.13	0.16	0.16		
		Estimated Prosser Tally	4078	2227	13236	5338	44	24923	24923
	Naches	WDFW Percent	0.22	0.22	0.22	0.34	0.34		
		Estimated Prosser Tally	6570	3589	21325	11400	93	42977	42977
	Upper Yakima	WDFW Percent	0.65	0.65	0.65	0.50	0.50		
		Estimated Prosser Tally	19711.01324	10766	63975	16557	135	111144	111144

		Yakima Passage Wild Tally	30359	16582	98537	33294	272	179045	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	45.1%	45.1%	61.9%	54.7%	13.4%					
		Total Passage	67353	36787	159149	60921	2035	326245	326245	308309		0.9450
		American Passage	9047	4941	21378	9767	326	45461	45461	42961		
		Naches Passage	14576	7961	34443	20859	697	78536	78536	74218		
		American & Naches Passage	23624	12903	55821	30626	1023	123997	123997	117180		
		Upper Yakima Passage	43729	23884	103328	30295	1012	202248	202248	191129		
McN UnStr Wild	Estimate b.	Detection Efficiency	58.5%	58.5%	58.5%	58.5%	58.5%					
		Total Passage	51891	28342	168422	56908	466	306029	306029	289106		0.9447
		American Passage	6970	3807	22624	9124	75	42600	42600	40244		
		Naches Passage	11230	6134	36450	19485	159	73458	73458	69395		
		American & Naches Passage	18201	9941	59073	28609	234	116058	116058	109640		
		Upper Yakima Passage	33691	18401	109349	28299	232	189971	189971	179466		
Pooled Str Wild	Estimate c.	Detection Efficiency	47.3%	47.3%	61.3%	51.8%	11.4%					
		Total Passage	64119	35020	160800	64329	2398	326666	326666	308959		0.9458
		American Passage	8613	4704	21600	10314	93	45324	45324	42867		
		Naches Passage	13877	7579	34800	22026	487	78768	78768	74498		
		American & Naches Passage	22490	12283	56400	32339	579	124091	124091	117365		
		Upper Yakima Passage	41630	22737	104400	31990	1819	202575	202575	191594		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	57.1%	57.1%	57.1%	57.1%	57.1%					
		Total Passage	53199	29056	172667	58342	477	313743	313743	296392		0.9447
		American Passage	7146	3903	23194	9354	77	43674	43674	41259		
		Naches Passage	11513	6288	37368	19976	163	75309	75309	71145		
		American & Naches Passage	18659	10191	60562	29330	240	118983	118983	112403		

									Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
		Upper Yakima Passage	34540	18865	112105	29013	237	194760	194760	183989		
Hatchery		Prosser Hatchery Tally	0	2058	67386	15896	233	85573				
McN-Str Hatch	Estimate a.	Total Passage	0	4565	108836	29087	1743	144230	160014	151217	0.0986	0.9450
McN-UnStr Hatch	Estimate b.	Total Passage	0	3517	115178	27170	399	146264	162271	153297		0.9447
Pooled Str Hatch	Estimate c.	Total Passage	0	4346	109965	30714	2054	147078	163174	154329		0.9458
Pooled UnStr Hatch	Estimate e.	Total Passage	0	3605	118081	27855	409	149950	166361	157161		0.9447

5.7.Year 2004

2004		Brood-Year 2002	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	5652.21 5163	7240	70520	19028	346	102786	102786			
	American	WDFW Percent	0.06	0.04	0.21	0.35	0.31					
		Estimated Prosser Tally	365	309	15160	6607	108	22549	22549			
	Naches	WDFW Percent	0.34	0.29	0.36	0.34	0.19					
		Estimated Prosser Tally	1913	2119	25721	6475	65	36292	36292			
	Upper Yakima	WDFW Percent	0.60	0.66	0.42	0.31	0.50					
		Estimated Prosser Tally	3374.13 6048	4812	29639	5946	173	43944	43944			
		Yakima Passage Wild Tally	5652	7240	70520	19028	346	102786	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	58.4%	58.4%	58.4%	87.2%	87.2%					
		Total Passage	9680	12400	12077 1	21832	397	165079	165079	171641		1.0398
		American Passage	626	529	25963	7580	124	34822	34822	36206		
		Naches Passage	3276	3629	44049	7429	74	58457	58457	60781		
		American & Naches Passage	3901	4158	70012	15009	198	93280	93280	96987		
		Upper Yakima Passage	5778	8241	50759	6822	198	71799	71799	74653		
McN Str Wild	Estimate b.	Detection Efficiency	64.5%	64.5%	64.5%	64.5%	64.5%					
		Total Passage	8760	11221	10929 1	29489	536	159296	159296	170539		1.0706
		American Passage	566	479	23495	10239	167	34947	34947	37413		
		Naches Passage	2964	3284	39862	10034	100	56245	56245	60215		
		American & Naches Passage	3531	3763	63357	20274	268	91192	91192	97628		
		Upper Yakima Passage	5229	7458	45934	9215	268	68104	68104	72910		
McN UnStr Wild	Estimate c.	Detection Efficiency	59.4%	59.4%	59.4%	86.8%	86.8%					
		Total Passage	9511	12183	11866 4	21916	398	162673	162673	169397		1.0413
		American Passage	615	520	25510	7610	124	34379	34379	35800		
		Naches Passage	3219	3566	43281	7458	75	57597	57597	59978		

			Pre-March	March	April	May	Post-May	Total	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
		American & Naches Passage	3833	4086	68791	15068	199	91976	91976	95778		
		Upper Yakima Passage	5678	8097	49873	6849	199	70696	70696	73619		
Pooled Str Wild	Estimate e.	Detection Efficiency	66.8%	66.8%	66.8%	66.8%	66.8%					
		Total Passage	8465	10843	105611	28496	518	153933	153933	164797		1.0706
		American Passage	547	463	22704	9894	162	33770	33770	36153		
		Naches Passage	2865	3174	38520	9697	97	54352	54352	58188		
		American & Naches Passage	3412	3636	61224	19591	259	88122	88122	94341		
		Upper Yakima Passage	5053	7207	44387	8905	259	65811	65811	70456		
Pooled UnStr Wild		Prosser Hatchery Tally	0	1662	99011	83912	283	184868	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	2847	169565	96276	324	269013	282162	293378	0.0466	1.0398
McN-UnStr Hatch	Estimate b.	Total Passage	0	2576	153446	130045	438	286505	300510	321719		1.0706
Pooled Str Hatch	Estimate c.	Total Passage	0	2797	166606	96651	326	266380	279400	290950		1.0413
Pooled UnStr Hatch	Estimate e.	Total Passage	0	2490	148280	125667	423	276860	290392	310888		1.0706

5.8.Year 2005

2005		Brood-Year 2003	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	37617.03993	3569	66596	6246	63	114092	114092			
	American	WDFW Percent	0.21	0.19	0.30	0.32	0.00					
		Estimated Prosser Tally	8047	673	19689	2008	0	30418	30418			
	Naches	WDFW Percent	0.35	0.08	0.35	0.23	0.18					
		Estimated Prosser Tally	13288	269	23550	1450	11	38568	38568			
	Upper Yakima	WDFW Percent	0.43	0.74	0.35	0.45	0.82					
		Estimated Prosser Tally	16282.00236	2626	23357	2789	52	45106	45106			
		Yakima Passage Wild Tally	37617	3569	66596	6246	63	114092	Elastomer	Calibrated Total	PIT-Tag/Total		Calibration Index

McN Str Wild	Estimate a.	Detection Efficiency	60.7%	60.7%	71.4%	69.2%	69.2%					
		Total Passage	61931	5876	93219	9028	92	170146	170146	131650		0.7737
		American Passage	13249	1109	27561	2902	0	44820	44820	34679		
		Naches Passage	21876	443	32965	2096	16	57396	57396	44410		
		American & Naches Passage	35125	1552	60525	4998	16	102216	102216	79090		
		Upper Yakima Passage	26806	4324	32694	4030	75	67930	67930	52560		
McN UnStr Wild	Estimate b.	Detection Efficiency	70.0%	70.0%	70.0%	70.0%	70.0%					
		Total Passage	53727	5097	95116	8921	91	162952	162952	125864		0.7724
		American Passage	11494	962	28121	2868	0	43444	43444	33556		
		Naches Passage	18978	385	33635	2071	16	55085	55085	42548		
		American & Naches Passage	30472	1346	61757	4939	16	98530	98530	76104		
		Upper Yakima Passage	23255	3751	33360	3983	74	64422	64422	49760		
Pooled Str Wild	Estimate c.	Detection Efficiency	60.1%	60.1%	71.9%	57.1%	57.1%					
		Total Passage	62602	5939	92669	10945	111	172267	172267	134859		0.7828
		American Passage	13392	1121	27398	3518	0	45429	45429	35564		
		Naches Passage	22113	448	32770	2541	20	57892	57892	45321		
		American & Naches Passage	35506	1569	60168	6059	20	103321	103321	80885		
		Upper Yakima Passage	27096	4370	32501	4886	91	68946	68946	53974		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	68.4%	68.4%	68.4%	68.4%	68.4%					
		Total Passage	54999	5218	97370	9133	93	166813	166813	128846		0.7724
		American Passage	11766	985	28788	2936	0	44474	44474	34351		
		Naches Passage	19428	394	34432	2120	17	56390	56390	43556		
		American & Naches Passage	31194	1378	63220	5056	17	100864	100864	77907		
		Upper Yakima Passage	23806	3840	34150	4077	76	65949	65949	50939		
Hatchery		Prosser Hatchery Tally	21	8	159590	37455	16	197090	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	35	13	223388	54132	24	277593	291340	225424	0.0472	0.7737
McN-UnStr Hatch	Estimate b.	Total Passage	31	11	227934	53495	23	281494	295434	228194		0.7724

Pooled Str Hatch	Estimate c.	Total Passage	36	13	222070	65629	29	287777	302028	236443		0.7828
Pooled UnStr Hatch	Estimate e.	Total Passage	31	11	233334	54762	24	288163	302433	233600		0.7724

5.9.Year 2006

2006		Brood-Year 2004	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	10378.78788	400	21517	9248	45	41588	41588			
	American	WDFW Percent	7.36%	0.00%	5.52%	5.45%	2.27%					
		Estimated Prosser Tally	764	0	1187	504	1	2456	2456			
	Naches	WDFW Percent	39.88%	25.96%	35.95%	39.11%	15.91%					
		Estimated Prosser Tally	4139	104	7736	3617	7	15602	15602			
	Upper Yakima	WDFW Percent	52.76%	74.04%	58.53%	55.45%	81.82%					
		Estimated Prosser Tally	5475.924893	296	12593	5127	37	23530	23530			
		Yakima Passage Wild Tally	10379	400	21517	9248	45	41588	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	21.0%	21.0%	21.0%	23.7%	23.7%					
		Total Passage	49335	1901	102278	38999	191	192705	192705	126524		0.6566
		American Passage	3632	0	5644	2124	4	11404	11404	7488		
		Naches Passage	19673	494	36772	15252	30	72222	72222	47419		
		American & Naches Passage	23305	494	42416	17376	35	83626	83626	54906		
		Upper Yakima Passage	26029	1408	59862	21623	156	109079	109079	71618		
McN UnStr Wild	Estimate b.	Detection Efficiency	20.5%	20.5%	20.5%	20.5%	20.5%					
		Total Passage	50510	1947	104715	45005	220	202397	202397	131973		0.6520
		American Passage	3719	0	5779	2451	5	11953	11953	7794		
		Naches Passage	20142	505	37648	17601	35	75932	75932	49511		
		American & Naches Passage	23861	505	43427	20052	40	87885	87885	57305		
		Upper Yakima Passage	26650	1441	61288	24953	180	114512	114512	74667		

Pooled Str Wild	Estimate c.	Detection Efficiency	20.1%	20.1%	20.1%	22.0%	22.0%					
		Total Passage	51735	1994	107254	42031	206	203220	203220	133218		0.6555
		American Passage	3809	0	5919	2289	5	12021	12021	7880		
		Naches Passage	20631	518	38561	16438	33	76180	76180	49939		
		American & Naches Passage	24439	518	44480	18727	37	88201	88201	57819		
		Upper Yakima Passage	27296	1476	62774	23304	168	115019	115019	75399		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	20.7%	20.7%	20.7%	20.7%	20.7%					
		Total Passage	50065	1930	103791	44608	218	200612	200612	130809		0.6520
		American Passage	3686	0	5728	2429	5	11847	11847	7725		
		Naches Passage	19964	501	37316	17446	35	75262	75262	49075		
		American & Naches Passage	23650	501	43044	19875	40	87110	87110	56800		
		Upper Yakima Passage	26415	1429	60747	24733	179	113502	113502	74009		
Hatchery		Prosser Hatchery Tally	3	9	46130	45561	19	91722	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	14	43	219277	192140	81	411555	431559	283348	0.0464	0.6566
McN-UnStr Hatch	Estimate b.	Total Passage	15	44	224500	221728	93	446380	468077	305209		0.6520
Pooled Str Hatch	Estimate c.	Total Passage	15	45	229944	207074	87	437166	458415	300508		0.6555
Pooled UnStr Hatch	Estimate e.	Total Passage	15	44	222520	219773	92	442444	463950	302518		0.6520

5.10.Year 2007

2007		Brood-Year 2005	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	541.5116347	523	17147	11159	189	29559	29559
	American	WDFW Percent	9.10%	14.50%	6.81%	16.75%	11.54%		
		Estimated Prosser Tally	49	76	1167	1869	22	3183	3183
		WDFW Percent	18.20%	32.30%	24.72%	29.78%	26.07%		
	Naches	Estimated Prosser Tally	99	169	4239	3323	49	7879	7879

		WDFW Percent	72.70%	53.20 %	68.47 %	53.47 %	62.39 %					
	Upper Yakima	Estimated Prosser Tally	393.678 9584	278	11740	5967	118	18497	18497			
		Yakima Passage Wild Tally	542	523	17147	11159	189	29559	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	30.2%	30.2%	30.2%	21.9%	21.9%					
		Total Passage	1791	1728	56711	51048	866	112144	112144	99769		0.8897
		American Passage	163	251	3860	8550	100	12924	12924	11498		
		Naches Passage	326	558	14022	15200	226	30332	30332	26985		
		American & Naches Passage	489	809	17882	23750	326	43256	43256	38483		
		Upper Yakima Passage	1302	920	38829	27297	540	68888	68888	61287		
McN UnStr Wild	Estimate b.	Detection Efficiency	26.3%	26.3%	26.3%	26.3%	26.3%					
		Total Passage	2058	1986	65172	42413	719	112349	112349	98319		0.8751
		American Passage	187	288	4436	7104	83	12098	12098	10588		
		Naches Passage	375	642	16114	12629	188	29946	29946	26207		
		American & Naches Passage	562	930	20550	19733	271	42045	42045	36794		
		Upper Yakima Passage	1496	1057	44622	22680	449	70304	70304	61525		
Pooled Str Wild	Estimate c.	Detection Efficiency	28.3%	28.3%	28.3%	23.7%	23.7%					
		Total Passage	1916	1849	60674	47178	800	112417	112417	99265		0.8830
		American Passage	174	268	4130	7902	92	12567	12567	11097		
		Naches Passage	349	597	15001	14048	209	30204	30204	26670		
		American & Naches Passage	523	865	19131	21950	301	42771	42771	37767		
		Upper Yakima Passage	1393	984	41543	25228	499	69646	69646	61498		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	26.2%	26.2%	26.2%	26.2%	26.2%					
		Total Passage	2068	1996	65477	42611	723	112874	112874	98779		0.8751
		American Passage	188	289	4457	7137	83	12155	12155	10637		
		Naches Passage	376	645	16189	12688	188	30087	30087	26329		
		American & Naches Passage	565	934	20646	19825	272	42241	42241	36967		
		Upper Yakima Passage	1503	1062	44831	22786	451	70633	70633	61813		

Hatchery		Prosser Hatchery Tally	0	629	61236	37776	281	99922	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	2079	202534	172814	1285	378712	396759	352979	0.0455	0.8897
McN-UnStr Hatch	Estimate b.	Total Passage	0	2389	232752	143581	1068	379790	397889	348202		0.8751
Pooled Str Hatch	Estimate c.	Total Passage	0	2224	216687	159714	1188	379813	397912	351359		0.8830
Pooled UnStr Hatch	Estimate e.	Total Passage	0	2400	233841	144253	1073	381568	399751	349831		0.8751

5.11. Year 2008

2008		Brood-Year 2006	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	7037.374779	1052	44603	16505	443	69641	69641			
	American	WDFW Percent	8.33%	0.00%	5.22%	5.00%	14.81%					
		Estimated Prosser Tally	586	0	2327	825	66	3804	3804			
		WDFW Percent	8.33%	14.29%	25.22%	31.11%	51.85%					
	Naches	Estimated Prosser Tally	586	150	11248	5135	230	17349	17349			
		WDFW Percent	83.33%	85.71%	69.57%	63.89%	33.33%					
	Upper Yakima	Estimated Prosser Tally	5864.478983	902	31028	10545	148	48487	48487			
		Yakima Passage Wild Tally	7037	1052	44603	16505	443	69641	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	71.4%	71.4%	71.4%	35.6%	10.8%					
		Total Passage	9857	1473	62485	46346	4094	124254	124254	107901		0.8684
		American Passage	821	0	3260	2317	606	7005	7005	6083		
		Naches Passage	821	210	15757	14419	2123	33330	33330	28944		
		American & Naches Passage	1643	210	19017	16736	2729	40335	40335	35027		
		Upper Yakima Passage	8214	1263	43468	29610	1365	83919	83919	72874		
McN UnStr Wild	Estimate b.	Detection Efficiency	46.1%	46.1%	46.1%	46.1%	46.1%					
		Total Passage	15257	2281	96703	35784	961	150986	150986	130742		0.8659

		American Passage	1271	0	5045	1789	142	8248	8248	7142		
		Naches Passage	1271	326	24386	11133	498	37614	37614	32571		
		American & Naches Passage	2543	326	29431	12922	641	45863	45863	39714		
		Upper Yakima Passage	12715	1955	67272	22862	320	105123	105123	91029		
Pooled Str Wild	Estimate c.	Detection Efficiency	48.8%	48.8%	66.7%	31.2%	7.9%					
		Total Passage	14422	2156	66892	52920	5644	142034	142034	123735		0.8712
		American Passage	1202	0	3490	2646	836	8174	8174	7121		
		Naches Passage	1202	308	16868	16464	2927	37769	37769	32903		
		American & Naches Passage	2404	308	20358	19110	3763	45943	45943	40024		
		Upper Yakima Passage	12018	1848	46534	33810	1881	96091	96091	83711		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	41.4%	41.4%	41.4%	41.4%	41.4%					
		Total Passage	16979	2538	107612	39821	1069	168019	168019	145492		0.8659
		American Passage	1415	0	5615	1991	158	9179	9179	7948		
		Naches Passage	1415	363	27137	12389	554	41858	41858	36246		
		American & Naches Passage	2830	363	32752	14380	713	51037	51037	44194		
		Upper Yakima Passage	14149	2175	74861	25441	356	116983	116983	101298		
Hatchery		Prosser Hatchery Tally	0	233	43465	65164	930	109793	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	326	60890	182980	8595	252791	268938	233543	0.0600	0.8684
McN-UnStr Hatch	Estimate b.	Total Passage	0	505	94235	141281	2017	238037	253242	219289		0.8659
Pooled Str Hatch	Estimate c.	Total Passage	0	477	65185	208936	11851	286449	304746	265485		0.8712
Pooled UnStr Hatch	Estimate e.	Total Passage	0	561	104866	157219	2245	264891	281812	244028		0.8659

5.12.Year 2009

2009		Brood-Year 2007	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	14956	543	27585	9394	2450	54927	54927
	American	WDFW Percent	9.80%	10.93%	12.06%	10.95%	36.29%		

		Estimated Prosser Tally	1466	59	3327	1029	889	6769	6769			
		WDFW Percent	35.60%	32.43%	29.25%	40.78%	28.23%					
	Naches	Estimated Prosser Tally	5324	176	8068	3831	691	18090	18090			
		WDFW Percent	54.60%	56.64%	58.69%	48.27%	35.48%					
	Upper Yakima	Estimated Prosser Tally	8166.22 4368	307	16191	4534	869	30067	30067			
		Yakima Passage Wild Tally	14956	543	27585	9394	2450	54927	Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	28.4%	28.4%	21.2%	12.5%	12.5%					
		Total Passage	52671	1911	130062	75334	19645	279622	279622	240827		0.8613
		American Passage	5162	209	15686	8249	7129	36434	36434	31379		
		Naches Passage	18751	620	38038	30723	5545	93676	93676	80680		
		American & Naches Passage	23912	828	53724	38972	12674	130111	130111	112059		
		Upper Yakima Passage	28758	1082	76338	36362	6971	149512	149512	128768		
McN UnStr Wild	Estimate b.	Detection Efficiency	15.3%	15.3%	15.3%	15.3%	15.3%					
		Total Passage	98002	3555	180751	61551	16051	359910	359910	318180		0.8841
		American Passage	9604	388	21799	6740	5825	44356	44356	39213		
		Naches Passage	34889	1153	52863	25102	4530	118537	118537	104793		
		American & Naches Passage	44493	1541	74662	31842	10355	162893	162893	144006		
		Upper Yakima Passage	53509	2014	106089	29710	5695	197017	197017	174173		
Pooled Str Wild	Estimate c.	Detection Efficiency	26.2%	26.2%	21.3%	11.4%	11.4%					
		Total Passage	57137	2073	129580	82196	21434	292419	292419	250846		0.8578
		American Passage	5599	226	15628	9000	7778	38232	38232	32797		
		Naches Passage	20341	672	37897	33521	6050	98481	98481	84480		
		American & Naches Passage	25940	899	53525	42521	13828	136713	136713	117277		
		Upper Yakima Passage	31197	1174	76055	39674	7606	155705	155705	133569		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	14.6%	14.6%	14.6%	14.6%	14.6%					

		Total Passage	102487	3718	189022	64368	16785	376379	376379	332739		0.8841
		American Passage	10044	406	22797	7048	6091	46386	46386	41008		
		Naches Passage	36485	1206	55282	26251	4738	123961	123961	109588		
		American & Naches Passage	46529	1612	78078	33299	10829	170347	170347	150596		
		Upper Yakima Passage	55958	2106	110943	31069	5956	206032	206032	182143		
Hatchery		Prosser Hatchery Tally	31	42	23787	39531	303	63695	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	111	148	112155	317029	2431	431874	454638	391561	0.0501	0.8613
McN-UnStr Hatch	Estimate b.	Total Passage	206	276	155865	259027	1986	417360	439358	388416		0.8841
Pooled Str Hatch	Estimate c.	Total Passage	120	161	111739	345905	2653	460577	484854	415923		0.8578
Pooled UnStr Hatch	Estimate e.	Total Passage	216	288	162997	270879	2077	436457	459463	406189		0.8841

5.13.Year 2010

2010		Brood-Year 2008	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	3862	3204	70483	24871	637	103056	103056			
	American	WDFW Percent	30.31%	0.00%	14.16%	11.88%	0.00%					
		Estimated Prosser Tally	1170	0	9981	2955	0	14106	14106			
		WDFW Percent	7.35%	19.50%	37.13%	33.63%	75.49%					
	Naches	Estimated Prosser Tally	284	625	26167	8364	481	35921	35921			
		WDFW Percent	62.34%	80.50%	48.71%	54.49%	24.51%					
	Upper Yakima	Estimated Prosser Tally	2407.39006	2579	34334	13552	156	53029	53029			
		Yakima Passage Wild Tally	3862	3204	70483	24871	637	103056	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	45.0%	45.0%	45.0%	59.2%	43.6%					
		Total Passage	8584	7122	156665	42045	1459	215875	215875	221188		1.0246
		American Passage	2602	0	22186	4995	0	29782	29782	30515		

		Naches Passage	631	1389	58163	14140	1101	75424	75424	77281		
		American & Naches Passage	3233	1389	80349	19135	1101	105206	105206	107796		
		Upper Yakima Passage	5351	5733	76316	22910	358	110668	110668	113392		
McN UnStr Wild	Estimate b.	Detection Efficiency	52.2%	52.2%	52.2%	52.2%	52.2%					
		Total Passage	7396	6137	134998	47635	1219	197386	197386	201737		1.0220
		American Passage	2242	0	19117	5659	0	27018	27018	27614		
		Naches Passage	544	1197	50119	16020	921	68800	68800	70316		
		American & Naches Passage	2785	1197	69236	21679	921	95818	95818	97930		
		Upper Yakima Passage	4611	4940	65761	25956	299	101568	101568	103807		
Pooled Str Wild	Estimate c.	Detection Efficiency	45.4%	45.4%	45.4%	57.4%	35.4%					
		Total Passage	8507	7058	155261	43333	1796	215955	215955	221228		1.0244
		American Passage	2578	0	21987	5148	0	29713	29713	30439		
		Naches Passage	625	1377	57642	14573	1356	75572	75572	77418		
		American & Naches Passage	3204	1377	79629	19721	1356	105285	105285	107856		
		Upper Yakima Passage	5303	5682	75632	23612	440	110669	110669	113372		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	51.3%	51.3%	51.3%	51.3%	51.3%					
		Total Passage	7530	6248	137440	48497	1241	200957	200957	205387		1.0220
		American Passage	2282	0	19463	5761	0	27507	27507	28113		
		Naches Passage	553	1219	51026	16310	937	70044	70044	71588		
		American & Naches Passage	2836	1219	70489	22071	937	97551	97551	99702		
		Upper Yakima Passage	4694	5030	66951	26426	304	103406	103406	105685		
Hatchery		Prosser Hatchery Tally	0	204	58305	129493	737	188739	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	453	129598	218915	1688	350653	367535	376582	0.0459	1.0246
McN-UnStr Hatch	Estimate b.	Total Passage	0	390	111674	248021	1411	361496	378900	387253		1.0220
Pooled Str Hatch	Estimate c.	Total Passage	0	449	128436	225621	2078	356584	373751	382878		1.0244

Pooled UnStr Hatch	Estimate e.	Total Passage	0	397	113694	252508	1436	368036	385755	394259		1.0220

5.14.Year 2011

2011		Brood-Year 2009	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	24773	4142	30530	15792	91	75328	75328			
	American	WDFW Percent	8.64%	0.00%	3.49%	5.92%	16.65%					
		Estimated Prosser Tally	2140	0	1066	935	15	4156	4156			
		WDFW Percent	18.19%	19.75%	23.96%	13.10%	0.00%					
	Naches	Estimated Prosser Tally	4506	818	7316	2069	0	14709	14709			
		WDFW Percent	73.17%	80.25%	72.55%	80.98%	83.35%					
	Upper Yakima	Estimated Prosser Tally	18126.20455	3324	22149	12788	75	56463	56463			
		Yakima Passage Wild Tally	24773	4142	30530	15792	91	75328	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	17.5%	17.5%	28.7%	30.9%	30.9%					
		Total Passage	141442	23652	106452	51115	293	322954	322954	299949		0.9288
		American Passage	12221	0	3716	3027	49	19012	19012	17657		
		Naches Passage	25728	4671	25508	6697	0	62605	62605	58146		
		American & Naches Passage	37949	4671	29224	9724	49	81617	81617	75803		
		Upper Yakima Passage	103493	18980	77228	41391	244	241337	241337	224146		
McN UnStr Wild	Estimate b.	Detection Efficiency	27.9%	27.9%	27.9%	27.9%	27.9%					
		Total Passage	88870	14861	109524	56652	325	270231	270231	254125		0.9404
		American Passage	7678	0	3823	3355	54	14910	14910	14021		
		Naches Passage	16165	2935	26245	7423	0	52768	52768	49623		
		American & Naches Passage	23844	2935	30067	10777	54	67678	67678	63644		
		Upper Yakima Passage	65026	11926	79457	45875	271	202554	202554	190481		
Pooled Str Wild	Estimate c.	Detection Efficiency	17.6%	17.6%	28.3%	29.5%	29.5%					

			Pre-March	March	April	May	Post-May	Total	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
		Total Passage	140705	23528	107826	53479	307	325846	325846	303711		0.9321
		American Passage	12157	0	3764	3167	51	19138	19138	17838		
		Naches Passage	25594	4647	25838	7007	0	63086	63086	58800		
		American & Naches Passage	37751	4647	29601	10174	51	82224	82224	76639		
		Upper Yakima Passage	102954	18882	78225	43306	256	243622	243622	227072		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	27.3%	27.3%	27.3%	27.3%	27.3%					
		Total Passage	90699	15166	111779	57819	332	275795	275795	259357		0.9404
		American Passage	7836	0	3901	3424	55	15217	15217	14310		
		Naches Passage	16498	2995	26785	7576	0	53854	53854	50644		
		American & Naches Passage	24335	2995	30686	10999	55	69071	69071	64954		
		Upper Yakima Passage	66365	12171	81093	46819	276	206724	206724	194403		
Hatchery		Prosser Hatchery Tally	70	4100	57391	66684	580	128824	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	398	23409	200108	215843	1877	441635	461721	428831	0.0435	0.9288
McN-UnStr Hatch	Estimate b.	Total Passage	250	14708	205884	239222	2080	462144	483164	454365		0.9404
Pooled Str Hatch	Estimate c.	Total Passage	396	23287	202692	225825	1963	454164	474820	442564		0.9321
Pooled UnStr Hatch	Estimate e.	Total Passage	255	15011	210123	244147	2123	471659	493111	463720		0.9404

5.15.Year 2012

2012		Brood-Year 2010	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	15922	6786	14719	5327	993	43746	43746
	American	WDFW Percent	10.99%	5.31%	6.17%	13.65%	23.46%		
		Estimated Prosser Tally	1750	360	908	727	233	3978	3978
		WDFW Percent	31.62%	29.60%	29.32%	38.48%	29.45%		
	Naches	Estimated Prosser Tally	5034	2009	4316	2050	292	13700	13700
	Upper Yakima	WDFW Percent	57.39%	65.09%	64.51%	47.87%	47.09%		

		Estimated Prosser Tally	9138.041429	4416	9495	2550	468	26067	26067			
		Yakima Passage Wild Tally	15922	6786	14719	5327	993	43746	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	10.6%	10.6%	6.8%	6.4%	6.4%					
		Total Passage	149599	63757	215132	82800	15434	526721	526721	301173		0.5718
		American Passage	16439	3386	13274	11299	3621	48019	48019	27456		
		Naches Passage	47298	18874	63077	31863	4545	165658	165658	94721		
		American & Naches Passage	63738	22260	76350	43162	8166	213676	213676	122178		
		Upper Yakima Passage	85861	41497	138782	39638	7267	313045	313045	178995		
McN UnStr Wild	Estimate b.	Detection Efficiency	6.8%	6.8%	6.8%	6.8%	6.8%					
		Total Passage	233096	99343	215485	77987	14537	640449	640449	368824		0.5759
		American Passage	25615	5276	13295	10642	3411	58239	58239	33539		
		Naches Passage	73698	29408	63180	30011	4281	200579	200579	115510		
		American & Naches Passage	99312	34684	76476	40654	7692	258818	258818	149049		
		Upper Yakima Passage	133784	64659	139010	37334	6845	381631	381631	219775		
Pooled Str Wild	Estimate c.	Detection Efficiency	17.2%	12.0%	8.0%	6.2%	6.2%					
		Total Passage	92790	56530	184609	86385	16102	436417	436417	252029		0.5775
		American Passage	10197	3002	11390	11788	3778	40155	40155	23189		
		Naches Passage	29337	16735	54127	33243	4742	138184	138184	79801		
		American & Naches Passage	39534	19737	65518	45031	8520	178339	178339	102990		
		Upper Yakima Passage	53256	36794	119091	41354	7582	258077	258077	149038		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	7.4%	7.4%	7.4%	7.4%	7.4%					
		Total Passage	216431	92241	200080	72412	13497	594661	594661	342455		0.5759
		American Passage	23783	4898	12345	9881	3167	54075	54075	31141		
		Naches Passage	68429	27306	58663	27866	3975	186239	186239	107252		

		American & Naches Passage	92212	32204	71008	37747	7142	240314	240314	138393		
		Upper Yakima Passage	124219	60036	129071	34665	6356	354347	354347	204063		
Hatchery		Prosser Hatchery Tally	0	1485	20279	22395	919	45078	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	13952	296397	348103	14288	672740	707207	404372	0.0487	0.5718
McN-UnStr Hatch	Estimate b.	Total Passage	0	21739	296884	327872	13457	659952	693764	399527		0.5759
Pooled Str Hatch	Estimate c.	Total Passage	0	12370	254344	363177	14906	644798	677833	391446		0.5775
Pooled UnStr Hatch	Estimate e.	Total Passage	0	20185	275659	304431	12495	612770	644164	370963		0.5759

5.16.Year 2013

2013		Brood-Year 2011	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	28502	18683	50994	8258	336	106774	106774			
	American	WDFW Percent	8.23%	2.30%	5.72%	16.96%	6.39%					
		Estimated Prosser Tally	2346	429	2916	1401	22	7113	7113			
		WDFW Percent	17.43%	20.59%	27.50%	29.53%	7.85%					
	Naches	Estimated Prosser Tally	4968	3847	14023	2439	26	25303	25303			
		WDFW Percent	74.34%	77.11%	66.78%	53.51%	85.76%					
	Upper Yakima	Estimated Prosser Tally	21188.49724	14407	34055	4419	289	74358	74358			
		Yakima Passage Wild Tally	28502	18683	50994	8258	336	106774	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	26.7%	26.7%	37.1%	23.4%	23.4%					
		Total Passage	106741	69970	137366	35270	1437	350785	350785	358055		1.0207
		American Passage	8785	1608	7855	5982	92	24321	24321	24826		
		Naches Passage	18605	14408	37774	10415	113	81314	81314	82999		
		American & Naches Passage	27390	16016	45628	16397	205	105636	105636	107825		
		Upper Yakima Passage	79352	53955	91738	18873	1232	245149	245149	250230		

McN UnStr Wild	Estimate b.	Detection Efficiency	32.6%	32.6%	32.6%	32.6%	32.6%					
		Total Passage	87352	57260	156284	25309	1031	327236	327236	333839		1.0202
		American Passage	7189	1316	8936	4293	66	21800	21800	22240		
		Naches Passage	15225	11791	42976	7474	81	77546	77546	79111		
		American & Naches Passage	22415	13106	51912	11766	147	99346	99346	101351		
		Upper Yakima Passage	64938	44154	104372	13543	884	227890	227890	232489		
Pooled Str Wild	Estimate c.	Detection Efficiency	27.5%	27.5%	35.1%	21.1%	21.1%					
		Total Passage	103702	67978	145428	39056	1591	357755	357755	365468		1.0216
		American Passage	8535	1562	8316	6624	102	25139	25139	25680		
		Naches Passage	18075	13997	39991	11533	125	83721	83721	85526		
		American & Naches Passage	26610	15560	48306	18157	227	108860	108860	111206		
		Upper Yakima Passage	77092	52418	97122	20898	1365	248896	248896	254261		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	30.5%	30.5%	30.5%	30.5%	30.5%					
		Total Passage	93410	61231	167121	27064	1103	349929	349929	356990		1.0202
		American Passage	7688	1407	9556	4590	70	23312	23312	23782		
		Naches Passage	16281	12608	45956	7992	87	82924	82924	84597		
		American & Naches Passage	23969	14015	55512	12582	157	106235	106235	108379		
		Upper Yakima Passage	69441	47216	111609	14482	946	243693	243693	248611		
Hatchery		Prosser Hatchery Tally	0	13014	69719	20263	879	103874	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	48738	187807	86542	3753	326839	343892	351019	0.0496	1.0207
McN-UnStr Hatch	Estimate b.	Total Passage	0	39885	213671	62100	2693	318349	334959	341718		1.0202
Pooled Str Hatch	Estimate c.	Total Passage	0	47350	198830	95831	4155	346166	364227	372079		1.0216
Pooled UnStr Hatch	Estimate e.	Total Passage	0	42651	228489	66406	2879	340425	358187	365415		1.0202

5.17.Year 2014

2014		Brood-Year 2012	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	1589	4340	14949	11897	959	33735	33735			
	American	WDFW Percent	11.65%	12.03%	9.09%	11.95%	13.86%					
		Estimated Prosser Tally	185	522	1360	1421	133	3621	3621			
		WDFW Percent	41.19%	21.74%	30.16%	38.12%	0.00%					
	Naches	Estimated Prosser Tally	655	944	4509	4535	0	10643	10643			
		WDFW Percent	47.16%	66.23%	60.74%	49.93%	86.14%					
	Upper Yakima	Estimated Prosser Tally	749.6015614	2874	9080	5940	826	19471	19471			
		Yakima Passage Wild Tally	1589	4340	14949	11897	959	33735	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	13.9%	13.9%	13.9%	13.9%	6.0%					
		Total Passage	11447	31257	107660	85679	15923	251966	251966	250881		0.9957
		American Passage	1334	3760	9791	10236	2208	27329	27329	27211		
		Naches Passage	4715	6795	32474	32662	0	76646	76646	76317		
		American & Naches Passage	6049	10555	42266	42898	2208	103975	103975	103528		
		Upper Yakima Passage	5398	20701	65395	42781	13715	147991	147991	147354		
McN UnStr Wild	Estimate b.	Detection Efficiency	13.8%	13.8%	13.8%	13.8%	13.8%					
		Total Passage	11481	31349	107976	85931	6930	243667	243667	241676		0.9918
		American Passage	1338	3771	9820	10266	961	26156	26156	25942		
		Naches Passage	4729	6815	32570	32758	0	76872	76872	76244		
		American & Naches Passage	6066	10586	42390	43024	961	103027	103027	102186		
		Upper Yakima Passage	5414	20762	65587	42907	5969	140639	140639	139490		
Pooled Str Wild	Estimate c.	Detection Efficiency	13.1%	13.1%	13.1%	13.1%	5.0%					

		Total Passage	12091	33016	113718	90500	19031	268355	268355	267433		0.9966
		American Passage	1409	3972	10342	10812	2638	29173	29173	29073		
		Naches Passage	4980	7178	34302	34500	0	80959	80959	80681		
		American & Naches Passage	6389	11149	44644	45312	2638	110132	110132	109754		
		Upper Yakima Passage	5702	21866	69074	45188	16392	158223	158223	157679		
Pooled UnStr Wild	Estimate e.	Total Passage	13.0%	13.0%	13.0%	13.0%	13.0%					
		Total Passage	12197	33306	114717	91295	7363	258877	258877	256762		0.9918
		American Passage	1421	4007	10433	10907	1021	27788	27788	27561		
		Naches Passage	5024	7241	34603	34803	0	81670	81670	81003		
		American & Naches Passage	6445	11247	45036	45710	1021	109459	109459	108564		
		Upper Yakima Passage	5752	22058	69681	45585	6342	149419	149419	148198		
Hatchery		Prosser Hatchery Tally	0	1493	16126	30753	1114	49486	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	10749	116139	221480	18480	366847	385256	383598	0.0478	0.9957
McN-UnStr Hatch	Estimate b.	Total Passage	0	10781	116480	222131	8043	357434	375371	372304		0.9918
Pooled Str Hatch	Estimate c.	Total Passage	0	11354	122673	233942	22087	390056	409630	408222		0.9966
Pooled UnStr Hatch	Estimate e.	Total Passage	0	11454	123751	235997	8545	379747	398803	395545		0.9918

5.18. Year 2015

2015		Brood-Year 2013	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	2658	13541	35320	11639	4	63162	63162
	American	WDFW Percent	13.86%	11.62%	8.92%	14.74%	14.74%		
		Estimated Prosser Tally	368	1573	3149	1716	1	6807	6807
		WDFW Percent	16.80%	26.32%	23.13%	24.09%	24.09%		
	Naches	Estimated Prosser Tally	447	3564	8169	2804	1	14985	14985

		WDFW Percent	69.34%	62.06 %	67.96 %	61.17 %	61.17 %					
	Upper Yakima	Estimated Prosser Tally	1842.998005	8404	24002	7119	2	41370	41370			
		Yakima Passage Wild Tally	2658	13541	35320	11639	4	63162	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	52.9%	52.9%	52.9%	56.3%	56.3%					
		Total Passage	5028	25614	66809	20689	6	118146	118146	120848		1.0229
		American Passage	697	2976	5956	3050	1	12680	12680	12970		
		Naches Passage	845	6742	15451	4985	2	28024	28024	28665		
		American & Naches Passage	1541	9718	21408	8035	3	40704	40704	41635		
		Upper Yakima Passage	3486	15897	45401	12655	4	77442	77442	79213		
McN UnStr Wild	Estimate b.	Detection Efficiency	53.2%	53.2%	53.2%	53.2%	53.2%					
		Total Passage	4999	25468	66427	21890	7	118791	118791	121334		1.0214
		American Passage	693	2959	5922	3227	1	12802	12802	13076		
		Naches Passage	840	6703	15363	5274	2	28182	28182	28786		
		American & Naches Passage	1533	9662	21285	8501	3	40984	40984	41861		
		Upper Yakima Passage	3466	15806	45141	13389	4	77807	77807	79472		
Pooled Str Wild	Estimate c.	Detection Efficiency	37.1%	37.1%	62.1%	57.6%	57.6%					
		Total Passage	7170	36531	56858	20221	6	120786	120786	123289		1.0207
		American Passage	994	4244	5069	2981	1	13289	13289	13564		
		Naches Passage	1205	9615	13150	4872	2	28843	28843	29441		
		American & Naches Passage	2198	13859	18219	7853	2	42132	42132	43005		
		Upper Yakima Passage	4972	22671	38639	12368	4	78654	78654	80284		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	51.4%	51.4%	51.4%	51.4%	51.4%					
		Total Passage	5173	26355	68741	22653	7	122930	122930	125561		1.0214
		American Passage	717	3062	6129	3339	1	13248	13248	13531		
		Naches Passage	869	6937	15898	5458	2	29164	29164	29788		

			Pre-March	March	April	May	Post-May	Total				
		American & Naches Passage	1586	9999	22027	8797	3	42412	42412	43320		
		Upper Yakima Passage	3587	16356	46714	13856	4	80518	80518	82241		
Hatchery		Prosser Hatchery Tally	0	43016	90070	26254	11	159351	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	81366	170371	46668	19	298424	317197	324451	0.0592	1.0229
McN-UnStr Hatch	Estimate b.	Total Passage	0	80901	169397	49377	21	299696	318550	325368		1.0214
Pooled Str Hatch	Estimate c.	Total Passage	0	116043	144995	45612	19	306669	325961	332715		1.0207
Pooled UnStr Hatch	Estimate e.	Total Passage	0	83720	175300	51098	21	310139	329649	336705		1.0214

5.19. Year 2016

2016		Brood-Year 2014	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	2900	3922	4227	3478	73	14599	14599			
	American	WDFW Percent	5.69%	7.42%	9.44%	13.00%	3.71%					
		Estimated Prosser Tally	165	291	399	452	3	1310	1310			
	Naches	WDFW Percent	26.41%	23.18%	38.42%	34.52%	0.00%					
		Estimated Prosser Tally	766	909	1624	1200	0	4500	4500			
	Upper Yakima	WDFW Percent	67.90%	69.40%	52.13%	52.49%	96.29%					
		Estimated Prosser Tally	1968.880324	2722	2204	1825	70	8790	8790			
		Yakima Passage Wild Tally	2900	3922	4227	3478	73	14599	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	5.5%	5.5%	5.5%	22.8%	22.8%					
		Total Passage	52843	71469	77035	15257	320	216925	216925	51305		0.2365
		American Passage	3007	5304	7273	1983	12	17578	17578	4157		
		Naches Passage	13956	16568	29600	5266	0	65391	65391	15465		

		American & Naches Passage	16963	21872	36873	7250	12	82969	82969	19623		
		Upper Yakima Passage	35881	49598	40162	8008	308	133956	133956	31682		
McN UnStr Wild	Estimate b.	Detection Efficiency	9.6%	9.6%	9.6%	9.6%	9.6%					
		Total Passage	30115	40730	43902	36116	757	151620	151620	39037		0.2575
		American Passage	1714	3022	4145	4694	28	13603	13603	3502		
		Naches Passage	7953	9442	16869	12466	0	46731	46731	12031		
		American & Naches Passage	9667	12465	21014	17161	28	60334	60334	15534		
		Upper Yakima Passage	20448	28265	22888	18956	729	91286	91286	23503		
Pooled Str Wild	Estimate c.	Detection Efficiency	5.9%	5.9%	4.4%	21.5%	21.5%					
		Total Passage	49149	66473	96748	16177	339	228887	228887	53478		0.2336
		American Passage	2797	4933	9134	2103	13	18979	18979	4434		
		Naches Passage	12980	15410	37175	5584	0	71149	71149	16624		
		American & Naches Passage	15777	20343	46309	7687	13	90128	90128	21058		
		Upper Yakima Passage	33372	46131	50439	8491	326	138759	138759	32420		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	8.4%	8.4%	8.4%	8.4%	8.4%					
		Total Passage	34538	46712	50350	41421	868	173890	173890	44770		0.2575
		American Passage	1965	3466	4754	5384	32	15601	15601	4017		
		Naches Passage	9122	10829	19347	14297	0	53594	53594	13799		
		American & Naches Passage	11087	14295	24100	19681	32	69196	69196	17815		
		Upper Yakima Passage	23451	32417	26250	21740	836	104694	104694	26955		
Hatchery		Prosser Hatchery Tally	0	9155	14039	20515	66	136488	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	166846	255836	90006	289	1499037	1587340	375419	0.0556	0.2365
McN-UnStr Hatch	Estimate b.	Total Passage	0	95085	145799	213058	685	1417512	1501013	386455		0.2575
Pooled Str Hatch	Estimate c.	Total Passage	0	155183	321302	95434	307	1632683	1728859	403938		0.2336

Pooled UnStr Hatch	Estimate e.	Total Passage	0	109051	167214	244352	785	1625716	1721481	443217		0.2575

5.20.Year 2017

2017		Brood-Year 2015	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
Wild		Prosser Wild Tally	2542	458	993	1352	24	5369	5369			
	American	WDFW Percent	10.20%	11.21%	15.80%	10.78%	37.16%					
		Estimated Prosser Tally	296	440	668	375	27	1805	1805			
	Naches	WDFW Percent	31.70%	27.73%	27.10%	29.57%	11.47%					
		Estimated Prosser Tally	919	1087	1146	1028	8	4189	4189			
	Upper Yakima	WDFW Percent	58.10%	61.06%	57.10%	59.65%	51.37%					
		Estimated Prosser Tally	1684.712029	2395	2414	2074	37	8605	8605			
		Yakima Passage Wild Tally	2900	3922	4227	3478	73	14599	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	5.5%	5.5%	5.5%	9.3%	9.3%					
		Total Passage	45879	8257	17922	14554	258	86871	86871	60411		0.6954
		American Passage	4680	926	2832	1569	96	10102	10102	7025		
		Naches Passage	14544	2289	4857	4304	30	26024	26024	18097		
		American & Naches Passage	19223	3215	7688	5873	126	36125	36125	25122		
		Upper Yakima Passage	26656	5042	10233	8682	133	50745	50745	35289		
McN UnStr Wild	Estimate b.	Detection Efficiency	7.2%	7.2%	7.2%	7.2%	7.2%					
		Total Passage	35465	6383	13854	18862	335	74899	74899	49700		0.6636
		American Passage	3617	716	2189	2033	124	8679	8679	5759		
		Naches Passage	11242	1770	3754	5578	38	22383	22383	14853		
		American & Naches Passage	14860	2485	5943	7611	163	31062	31062	20612		
		Upper Yakima Passage	20605	3897	7910	11251	172	43836	43836	29088		

Pooled Str Wild	Estimate c.	Detection Efficiency	5.9%	5.9%	5.9%	9.7%	9.7%					
		Total Passage	43257	7785	16897	14009	249	82198	82198	57051		0.6941
		American Passage	4412	873	2670	1510	92	9557	9557	6633		
		Naches Passage	13712	2159	4579	4143	29	24622	24622	17089		
		American & Naches Passage	18125	3031	7249	5653	121	34179	34179	23723		
		Upper Yakima Passage	25132	4754	9648	8357	128	48019	48019	33328		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	7.6%	7.6%	7.6%	7.6%	7.6%					
		Total Passage	33442	6019	13064	17786	316	70627	70627	46866		0.6636
		American Passage	3411	675	2064	1917	117	8184	8184	5431		
		Naches Passage	10601	1669	3540	5260	36	21107	21107	14006		
		American & Naches Passage	14012	2344	5604	7177	154	29291	29291	19436		
		Upper Yakima Passage	19430	3675	7459	10609	162	41336	41336	27429		
Hatchery		Prosser Hatchery Tally	1	235	1943	5727	41	7947	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	18	4241	35067	61646	441	386839	412204	286652	0.061	0.6954
McN-UnStr Hatch	Estimate b.	Total Passage	9	3279	27108	79893	572	425176	453055	300633	0.1029	0.6636
Pooled Str Hatch	Estimate c.	Total Passage	12	3999	33063	59338	425	369465	393691	273248	0.1029	0.6941
Pooled UnStr Hatch	Estimate e.	Total Passage	9	3092	25561	75336	539	400926	427215	283486	0.1029	0.6636

5.21. Year 2018

2018		Brood-Year 2016	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	6091	1173	8517	1374	96	17251	17251
	American	WDFW Percent	8.80%	3.30%	5.82%	10.40 %	25.00 %	0.00	
		Estimated Prosser Tally	255	129	246	362	18	1010	1010
		WDFW Percent	31.70%	27.73 %	27.10 %	29.57 %	11.47 %	0.00	
	Naches	Estimated Prosser Tally	919	1087	1146	1028	8	4189	4189

		WDFW Percent	58.10%	61.06%	57.10%	59.65%	51.37%	0.00				
	Upper Yakima	Estimated Prosser Tally	1684.712029	2395	2414	2074	37	8605	8605			
		Yakima Passage Wild Tally	2859	3612	3805	3464	64	13804	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	9.8%	9.8%	9.8%	4.9%	4.9%					
		Total Passage	62211	11978	86996	27928	1951	191064	191064	128380		0.6719
		American Passage	5475	395	5061	2904	488	14323	14323	9624		
		Naches Passage	19721	3321	23576	8259	224	55101	55101	37024		
		American & Naches Passage	25196	3716	28637	11164	712	69424	69424	46647		
		Upper Yakima Passage	36145	7314	49674	16659	1002	110794	110794	74445		
McN UnStr Wild	Estimate b.	Detection Efficiency	8.4%	8.4%	8.4%	8.4%	8.4%					
		Total Passage	72640	13986	101579	16386	1145	205735	205735	122910		0.5974
		American Passage	6392	462	5909	1704	286	14753	14753	8814		
		Naches Passage	23027	3878	27528	4846	131	59410	59410	35493		
		American & Naches Passage	29419	4339	33437	6550	418	74163	74163	44307		
		Upper Yakima Passage	42204	8540	58001	9774	588	119107	119107	71157		
Pooled Str Wild	Estimate c.	Detection Efficiency	13.7%	13.7%	9.3%	4.4%	4.4%					
		Total Passage	44443	8557	91787	30928	2161	177875	177875	131489		0.7392
		American Passage	3911	282	5340	3216	540	13289	13289	9824		
		Naches Passage	14088	2373	24874	9147	248	50730	50730	37500		
		American & Naches Passage	17999	2655	30214	12363	788	64019	64019	47324		
		Upper Yakima Passage	25821	5225	52410	18448	1110	103015	103015	76150		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	8.2%	8.2%	8.2%	8.2%	8.2%					
		Total Passage	74408	14326	104052	16785	1173	210744	210744	136769		0.6490
		American Passage	6548	473	6053	1745	293	15112	15112	9808		
		Naches Passage	23587	3972	28198	4964	135	60856	60856	39495		

			Pre-March	March	April	May	Post-May	Total				
		American & Naches Passage	30135	4445	34251	6709	428	75969	75969	49302		
		Upper Yakima Passage	43231	8748	59413	10012	602	122007	122007	79180		
Hatchery		Prosser Hatchery Tally	0	1470	15058	2640	392	19560	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	15011	153802	53661	7968	386839	411667	276607	0.0603	0.6719
McN-UnStr Hatch	Estimate b.	Total Passage	0	17527	179584	31484	4675	425176	452465	270311		0.5974
Pooled Str Hatch	Estimate c.	Total Passage	0	10724	162273	59425	8824	369465	393178	290644		0.7392
Pooled UnStr Hatch	Estimate e.	Total Passage	0	17954	183956	32251	4789	400926	426658	276892		0.6490

5.22.Year 2019

2019		Brood-Year 2017	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	15489	3937	10596	23290	63	53374	53374			
	American	WDFW Percent	9.90%	12.44%	14.70%	14.71%	0.00%	0.00%				
		Estimated Prosser Tally	287	488	621	511	0	1908	1908			
		WDFW Percent	20.00%	20.33%	22.70%	30.22%	0.00%	0.00%				
	Naches	Estimated Prosser Tally	580	797	959	1051	0	3387	3387			
		WDFW Percent	76.22%	73.17%	74.47%	66.19%	100.0%	0.00%				
	Upper Yakima	Estimated Prosser Tally	2,210	2,870	3,148	2,302	73	10,602	10,602			
		Yakima Passage Wild Tally	3077	4154	4729	3864	73	15897	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	18.5%	18.5%	18.5%	39.6%	39.6%					
		Total Passage	83,879	21,319	57,385	58,761	158	221,503	221,503	168,119		0.7590
		American Passage	8,305	2,652	8,434	8,641	-	28,032	28,032	21,276		

		Naches Passage	16,776	4,333	13,024	17,755	-	51,888	51,888	39,382	
		American & Naches Passage	25,081	6,985	21,457	26,397	-	79,919	79,919	60,658	
		Upper Yakima Passage	63,930	15,600	42,734	38,892	158	161,313	161,313	122,435	
McN UnStr Wild	Estimate b.	Detection Efficiency	27.1%	27.1%	27.1%	27.1%	27.1%				
		Total Passage	57,169	14,530	39,111	85,963	231	197,005	197,005	154,848	0.7860
		American Passage	5,660	1,807	5,748	12,642	-	25,857	25,857	20,324	
		Naches Passage	11,434	2,953	8,876	25,974	-	49,238	49,238	38,701	
		American & Naches Passage	17,094	4,761	14,624	38,616	-	75,095	75,095	59,025	
		Upper Yakima Passage	43,572	10,632	29,126	56,896	231	140,457	140,457	110,401	
Pooled Str Wild	Estimate c.	Detection Efficiency	20.1%	20.1%	20.1%	35.9%	35.9%				
		Total Passage	77,184	19,618	52,827	64,908	175	214,712	214,712	175,427	0.8170
		American Passage	7,642	2,440	7,764	9,545	-	27,391	27,391	22,379	
		Naches Passage	15,437	3,987	11,989	19,613	-	51,026	51,026	41,690	
		American & Naches Passage	23,079	6,427	19,753	29,158	-	78,417	78,417	64,069	
		Upper Yakima Passage	58,827	14,354	39,340	42,961	175	155,656	155,656	127,176	
Pooled UnStr Wild	Estimate e.	Detection Efficiency	27.9%	27.9%	27.9%	27.9%	27.9%				
		Total Passage	55,458	14,095	37,941	83,390	224	191,108	191,108	154,530	0.8086
		American Passage	5,491	1,753	5,576	12,263	-	25,083	25,083	20,282	
		Naches Passage	11,092	2,865	8,611	25,197	-	47,764	47,764	38,622	
		American & Naches Passage	16,582	4,618	14,187	37,460	-	72,847	72,847	58,904	

			Pre-March	March	April	May	Post-May	Total				
		Upper Yakima Passage	42,268	10,314	28,254	55,193	224	136,253	136,253	110,174		
Hatchery		Prosser Hatchery Tally	-	904	24,775	76,824	198	102,701	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	-	4,897	134,169	193,833	500	386,839	409,539	310,836	0.0554	0.7590
McN-UnStr Hatch	Estimate b.	Total Passage	-	3,337	91,444	283,561	732	425,176	450,126	353,803		0.7860
Pooled Str Hatch	Estimate c.	Total Passage	-	4,506	123,513	214,108	552	369,465	391,145	319,579		0.8170
Pooled UnStr Hatch	Estimate e.	Total Passage	-	3,237	88,707	275,073	710	400,926	424,452	343,212		0.8086

5.23.Year 2020

2020		Brood-Year 2017	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	8843	2602	30737	10851	58	53092	53092			
	American	WDFW Percent	3.78%	6.50%	2.84%	3.60%	0.00%	0.00%				
		Estimated Prosser Tally	110	255	120	125	0	610	610			
	Naches	WDFW Percent	20.00%	20.33%	22.70%	30.22%	0.00%	0.00%				
		Estimated Prosser Tally	580	797	959	1051	0	3387	3387			
	Upper Yakima	WDFW Percent	76.22%	76.22%	76.22%	76.22%	76.2%	76.22%				
		Estimated Prosser Tally	2,210	2,989	3,222	2,650	56	11,127	11,127			
		Yakima Passage Wild Tally	2900	4041	4301	3826	56	15124	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	23.7%	23.7%	23.7%	58.0%	58.0%					
		Total Passage	37,350	10,991	129,819	18,722	101	196,983	196,983	201,313		1.0220
		American Passage	1,413	715	3,683	673	-	6,484	6,484	6,627		
		Naches Passage	7,470	2,234	29,463	5,657	-	44,824	44,824	45,809		
		American & Naches Passage	8,883	2,949	33,145	6,331	-	51,308	51,308	52,436		

		Upper Yakima Passage	28,467	8,377	98,943	14,269	77	150,133	150,133	153,433	
McN UnStr Wild	Estimate b.	Detection Efficiency	33.4%	33.4%	33.4%	33.4%	33.4%				
		Total Passage	26,445	7,782	91,916	32,450	174	158,767	158,767	168,133	1.0590
		American Passage	1,001	506	2,608	1,167	-	5,282	5,282	5,593	
		Naches Passage	5,289	1,582	20,860	9,805	-	37,536	37,536	39,750	
		American & Naches Passage	6,290	2,088	23,468	10,972	-	42,818	42,818	45,344	
		Upper Yakima Passage	20,155	5,931	70,055	24,732	133	121,007	121,007	128,145	
Pooled Str Wild	Estimate c.	Detection Efficiency	32.3%	20.1%	20.1%	35.9%	35.9%				
		Total Passage	27,409	8,065	92,297	18,321	98	146,190	146,190	151,265	1.0347
		American Passage	1,037	525	2,618	659	-	4,839	4,839	5,007	
		Naches Passage	5,482	1,639	20,947	5,536	-	33,604	33,604	34,770	
		American & Naches Passage	6,519	2,164	23,565	6,195	-	38,443	38,443	39,777	
		Upper Yakima Passage	20,890	6,147	70,345	13,963	75	111,420	111,420	115,288	
Pooled UnStr Wild	Estimate e.	Detection Efficiency	44.0%	44.0%	44.0%	44.0%	44.0%				
		Total Passage	20,117	5,919	69,920	24,685	133	120,773	120,773	115,300	0.9547
		American Passage	761	385	1,984	888	-	4,018	4,018	3,836	
		Naches Passage	4,023	1,203	15,868	7,459	-	28,553	28,553	27,259	
		American & Naches Passage	4,784	1,588	17,852	8,347	-	32,571	32,571	31,095	
		Upper Yakima Passage	15,332	4,512	53,290	18,814	101	92,049	92,049	87,877	

Hatchery		Prosser Hatchery Tally	8	1,419	64,446	82,305	789	148,967	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	32	5,995	272,195	142,004	1,361	421,586	447,027	456,852	0.0569	1.0220
McN-UnStr Hatch	Estimate b.	Total Passage	24	4,245	192,723	246,127	2,358	445,452	472,332	500,195		0.7860
Pooled Str Hatch	Estimate c.	Total Passage	24	4,399	193,521	138,959	1,331	338,210	358,619	371,069		0.8170
Pooled UnStr Hatch	Estimate e.	Total Passage	17	3,229	146,602	187,226	1,794	375,875	398,556	380,494		0.8086

5.24.Year 2021

2021		Brood-Year 2019	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer			
Wild		Prosser Wild Tally	12,482	3,849	34,195	11,816	1,365	0	0			
	American	WDFW Percent	5.9%	3.7%	6.6%	11.1%	11.1%	0.0%				
		Estimated Prosser Tally	732	143	2,264	1,313	152	4604	4,604			
	Naches	WDFW Percent	31.1%	12.6%	23.7%	31.8%	7.4%	0.0%				
		Estimated Prosser Tally	3,876	483	8,102	3,760	101	16322	16,322			
	Upper Yakima	WDFW Percent	76.2%	76.2%	76.2%	76.2%	76.2%	76.2%				
		Estimated Prosser Tally	9,513	2,933	26,062	9,006	1,040	48554	48,554			
		Yakima Passage Wild Tally	14,122	3,560	36,427	14,079	1,293	69480	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	36.9%	36.9%	36.9%	30.3%	30.3%					
		Total Passage	33,808	10,424	92,617	39,038	4,509	180,396	180,396	88,720		0.4918
		American Passage	1,984	388	6,131	4,338	501	13,342	13,342	6,562		
		Naches Passage	10,498	1,309	21,944	12,421	334	46,506	46,506	22,872		
		American & Naches Passage	12,482	1,697	28,076	16,759	835	59,848	59,848	29,434		
		Upper Yakima Passage	25,767	7,945	70,589	29,754	3,436	137,491	137,491	67,619		
McN UnStr Wild	Estimate b.	Detection Efficiency	35.3%	35.3%	35.3%	35.3%	35.3%					
		Total Passage	35,376	10,907	96,913	33,489	3,868	180,554	180,554	87,880		0.4867
		American Passage	2,076	406	6,416	3,721	430	13,048	13,048	6,351		
		Naches Passage	10,985	1,370	22,962	10,656	287	46,259	46,259	22,515		
		American & Naches Passage	13,061	1,776	29,378	14,377	716	59,307	59,307	28,866		
		Upper Yakima Passage	26,962	8,313	73,864	25,524	2,948	137,611	137,611	66,979		
Pooled Str Wild	Estimate c.	Detection Efficiency	29.6%	29.6%	28.2%	31.1%	31.1%					
		Total Passage	42,217	13,017	121,237	38,013	4,390	218,874	218,874	106,092		0.4847

		American Passage	2,477	484	8,026	4,224	488	15,699	15,699	7,610		
		Naches Passage	13,109	1,635	28,725	12,095	325	55,889	55,889	27,090		
		American & Naches Passage	15,586	2,119	36,751	16,319	813	71,588	71,588	34,700		
		Upper Yakima Passage	32,176	9,921	92,403	28,972	3,346	166,818	166,818	80,859		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	30.1%	30.1%	30.1%	30.1%	30.1%					
		Total Passage	41,504	12,797	113,700	39,290	4,538	211,829	211,829	103,103		0.4867
		American Passage	2,435	476	7,527	4,366	504	15,309	15,309	7,451		
		Naches Passage	12,888	1,607	26,939	12,501	336	54,272	54,272	26,415		
		American & Naches Passage	15,323	2,083	34,467	16,867	840	69,580	69,580	33,867		
		Upper Yakima Passage	31,633	9,753	86,658	29,946	3,459	161,448	161,448	78,581		
Hatchery		Prosser Hatchery Tally	0	11,730	56,272	46,835	4,334	119,172	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	31,772	152,416	154,734	14,317	353,239	382,605	188,167	0.0768	0.4918
McN-UnStr Hatch	Estimate b.	Total Passage	0	33,246	159,485	132,740	12,282	337,753	365,831	178,059		0.4867
Pooled Str Hatch	Estimate c.	Total Passage	0	39,674	199,514	150,671	13,941	403,801	437,370	212,000		0.4847
Pooled UnStr Hatch	Estimate e.	Total Passage	0	39,005	187,111	155,733	14,410	396,258	429,200	208,903		0.4867

5.25.Year 2022

2022		Brood-Year 2020	Pre-March	March	April	May	Post-May	Total	Expanded Elastomer
Wild		Prosser Wild Tally	11,352	1,821	21,730	2,444	31	37,378	37,378
	American	WDFW Percent	7.9%	7.0%	5.9%	5.1%	0.0%		
		Estimated Prosser Tally	900	128	1,278	125	0	2432	2,432

	Naches	WDFW Percent	47.4%	46.8%	45.6%	50.0%	0.0%					
		Estimated Prosser Tally	5,380	852	9,916	1,222	0	17369	17,369			
	Upper Yakima	WDFW Percent	44.7%	46.2%	48.5%	44.9%	100.0%					
		Estimated Prosser Tally	5,072	841	10,536	1,097	31	17577	17,577			
		Yakima Passage Wild Tally	11,352	1,821	21,730	2,444	31	37378	Expanded Elastomer	Calibrated Total	PIT-Tag/Total	Calibration Index
McN Str Wild	Estimate a.	Detection Efficiency	36.8%	36.8%	36.8%	30.3%	30.3%					
		Total Passage	30,820	4,944	58,994	8,074	103	102,936	102,936	273,284		2.6549
		American Passage	2,444	347	3,470	414	0	6,675	6,675	11,047		
		Naches Passage	14,605	2,313	26,921	4,037	0	47,876	47,876	79,230		
		American & Naches Passage	17,049	2,660	30,391	4,451	0	54,552	54,552	90,278		
		Upper Yakima Passage	13,771	2,284	28,603	3,623	103	48,384	48,384	80,071		
McN UnStr Wild	Estimate b.	Detection Efficiency	35.3%	35.3%	35.3%	35.3%	35.3%					
		Total Passage	32,174	5,162	61,586	6,927	88	105,936	105,936	69,036		0.6517
		American Passage	2,551	362	3,623	355	0	6,892	6,892	4,491		
		Naches Passage	15,247	2,415	28,103	3,463	0	49,228	49,228	32,081		
		American & Naches Passage	17,798	2,777	31,726	3,819	0	56,120	56,120	36,572		
		Upper Yakima Passage	14,375	2,385	29,860	3,108	88	49,816	49,816	32,464		
Pooled Str Wild	Estimate c.	Detection Efficiency	29.5%	29.5%	29.5%	29.5%	29.5%					
		Total Passage	38,431	6,165	73,562	8,274	105	126,537	126,537	82,462		0.6517
		American Passage	3,048	433	4,327	424	0	8,232	8,232	5,365		
		Naches Passage	18,212	2,884	33,569	4,137	0	58,802	58,802	38,320		
		American & Naches Passage	21,259	3,317	37,896	4,561	0	67,033	67,033	43,684		

		Upper Yakima Passage	17,171	2,848	35,667	3,713	105	59,504	59,504	38,777		
Pooled UnStr Wild	Estimate e.	Detection Efficiency	31.1%	31.1%	31.1%	31.1%	31.1%					
		Total Passage	36,520	5,859	69,905	7,862	100	120,247	120,247	78,362		0.6517
		American Passage	2,896	411	4,112	403	0	7,823	7,823	5,098		
		Naches Passage	17,306	2,741	31,900	3,931	0	55,878	55,878	36,415		
		American & Naches Passage	20,203	3,152	36,012	4,334	0	63,701	63,701	41,513		
		Upper Yakima Passage	16,317	2,707	33,893	3,528	100	56,546	56,546	36,850		
Hatchery		Prosser Hatchery Tally	0	3,608	63,724	23,512	208	91,052	Expanded Elastomer	Expanded PIT	PIT-Tag/Total	Calibration Index
McN-Str Hatch	Estimate a.	Total Passage	0	9,795	173,006	77,679	686	261,167	282,878	185,257	0.0786	1.6549
McN-UnStr Hatch	Estimate b.	Total Passage	0	10,226	180,606	66,638	588	258,058	279,511	182,152		0.6517
Pooled Str Hatch	Estimate c.	Total Passage	0	12,214	215,729	79,597	703	308,243	333,868	217,575		0.6517
Pooled UnStr Hatch	Estimate e.	Total Passage	0	11,607	205,004	75,640	668	292,919	317,270	206,758		0.6517

Appendix D: Juvenile Coho outmigration survival and adult Coho returns to the Yakima Basin, 1999-2023

Mobile Coho Salmon acclimation tank installed along Rattlesnake Creek, tributary to the Naches River in the Yakima River subbasin. Photo credit: Todd Newsome.

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1. Introduction

Prior to their extirpation in the early 1980's, Yakima Basin Coho salmon (*Oncorhynchus kisutch*) were once widely distributed among tributaries of the Yakima and Naches rivers (Fulton 1970; Chapman 1986), with annual adult returns numbering from 44,000 to 150,000 (Kreeger and McNeil 1993). Releases of hatchery reared Coho salmon in the Yakima Basin began in 1983 with the first release of 324,000 smolts originating from the Little White Salmon Hatchery (YN 1997). In 1988, the Yakama Nation (YN) and the Washington Department of Fish and Wildlife (WDFW) developed and implemented a reintroduction program that has shown evidence of successful natural production in both the Yakima and Naches rivers. The highest return of adults (2014) from hatchery releases and natural production was greater than 25,000 fish.

Several alternative release strategies have been utilized in the reintroduction program over time, informed and tested by long-term monitoring. Smolts were initially released in the mainstem of the Yakima River (Dunnigan et al. 2002), but subsequent releases have explored a range of different release locations to understand how geographically and hydrologically diverse habitats within the Yakima Basin affect outmigration survival and adult returns. Habitat capacity and quality have a significant impact on growth rate and survival, and within the Yakima River Basin human alterations to the environment continue to exacerbate naturally limiting conditions by reducing the quality and quantity of available spawning and rearing habitat. On the other hand, restoration programs are concurrently being implemented to improve habitat conditions in many Yakima Basin streams. Other exploratory release strategies have included variable life stages (parr vs. smolts) at release, different release times, and use of multiple brood sources. In past years, the primary sources of Coho outplants have been Yakima Basin returns, Eagle Creek National Fish Hatchery and WDFW's Washhougal Hatchery. In total, about 500,000 juvenile coho have been released each year from permanent acclimation sites on the Yakima and Naches rivers, and from temporary mobile acclimation facilities operated in tributary streams of the Naches and upper Yakima rivers.

Columbia River Coho typically spend one year in freshwater before out-migrating as yearling smolts (typically in April and May), then spend two growing seasons (about 18 months) in the ocean before returning as 3-year-old adults to spawn in their natal streams (Hassler 1987, Beamish et al. 2004). Precocious, sexually mature males (jacks) may also return to spawn after a summer in the ocean. Adult Coho generally migrate upstream at water temperature ranging from 7.2°C to 15.6°C (Reiser and Bjornn 1979 cited in Laufle et al. 1986) and spawn from late October to November, sometimes as late as December or January.

Spawning normally occurs in transitions from pools or runs to riffles, in minimum water depth of 0.18 m, at water temperatures ranging from 4.4°C to 9.4°C, and velocities ranging from 0.3 to 0.91 m/sec (Thompson 1972, BOR 2007). The optimum temperature for coho salmon egg incubation was 4°C to 11°C (Davidson and Hutchinson 1938, cited in Sandercock 1991). Juvenile coho salmon survive best in low-gradient habitats, typically tributaries having a stream gradient less than 3% with complex and deep pools or beaver ponds (Jones and Moore 1999, Bradford et al. 1997 and Reeves et al. 1989).

A long-term program is being conducted with the aim of monitoring progress towards project objectives and improving strategies by applying what is learned from the project experiments, monitoring and evaluation, and literature reviews, following the Yakima-Klickitat Fisheries Project adaptive management policy. This report is an annual update of an ongoing monitoring effort that began in 2001. It summarizes survival and return rates and downstream travel time estimates for Coho parr and smolts released from multiple locations in the Yakima Basin, with a focus on the following objectives:

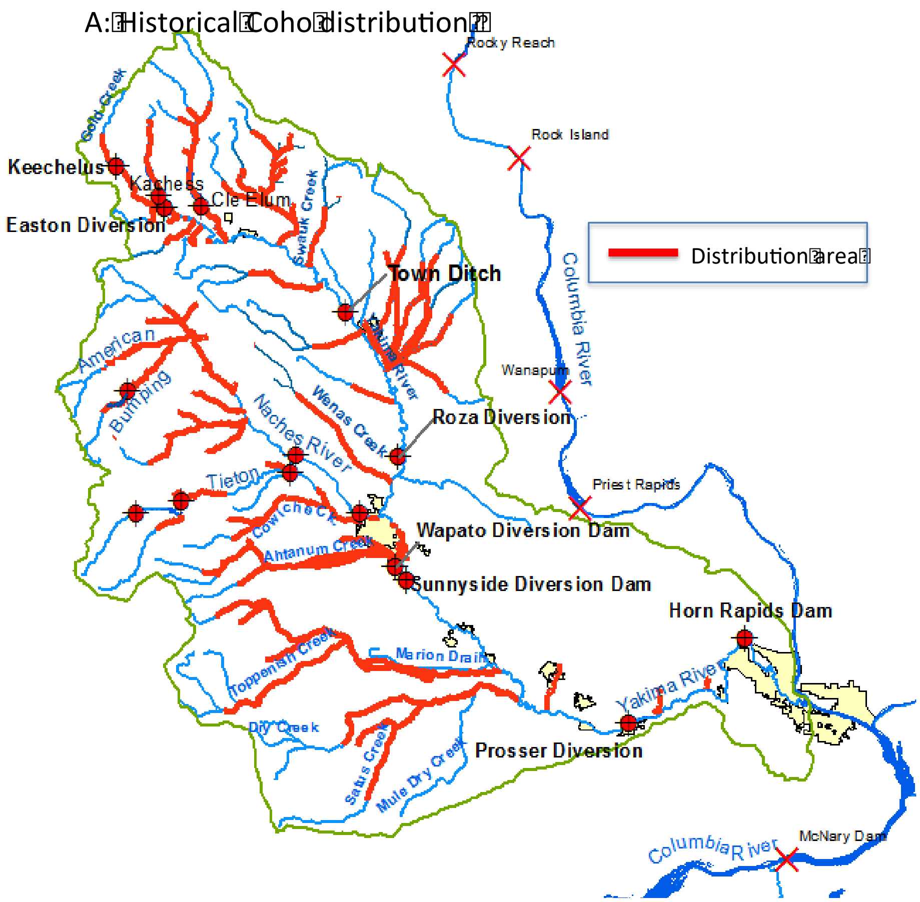
- Estimating survival rate and travel time of smolts released in 2023 and parr released in 2022 (migration year 2023)
- Comparing survival rates among different broodstock sources: Yakima returns and imported stocks from Eagle Creek National Fish Hatchery and Washougal Hatchery (Washington Department of Fish and Wildlife)
- Identifying watershed-specific survival rates among release locations and release months (February, March, April)
- Evaluating the effects of river flow on outmigration survival rate
- Determining the annual Smolt-Adult return rate (SAR) from 2004-2023 and age compositions of adult returns

2. Methodology

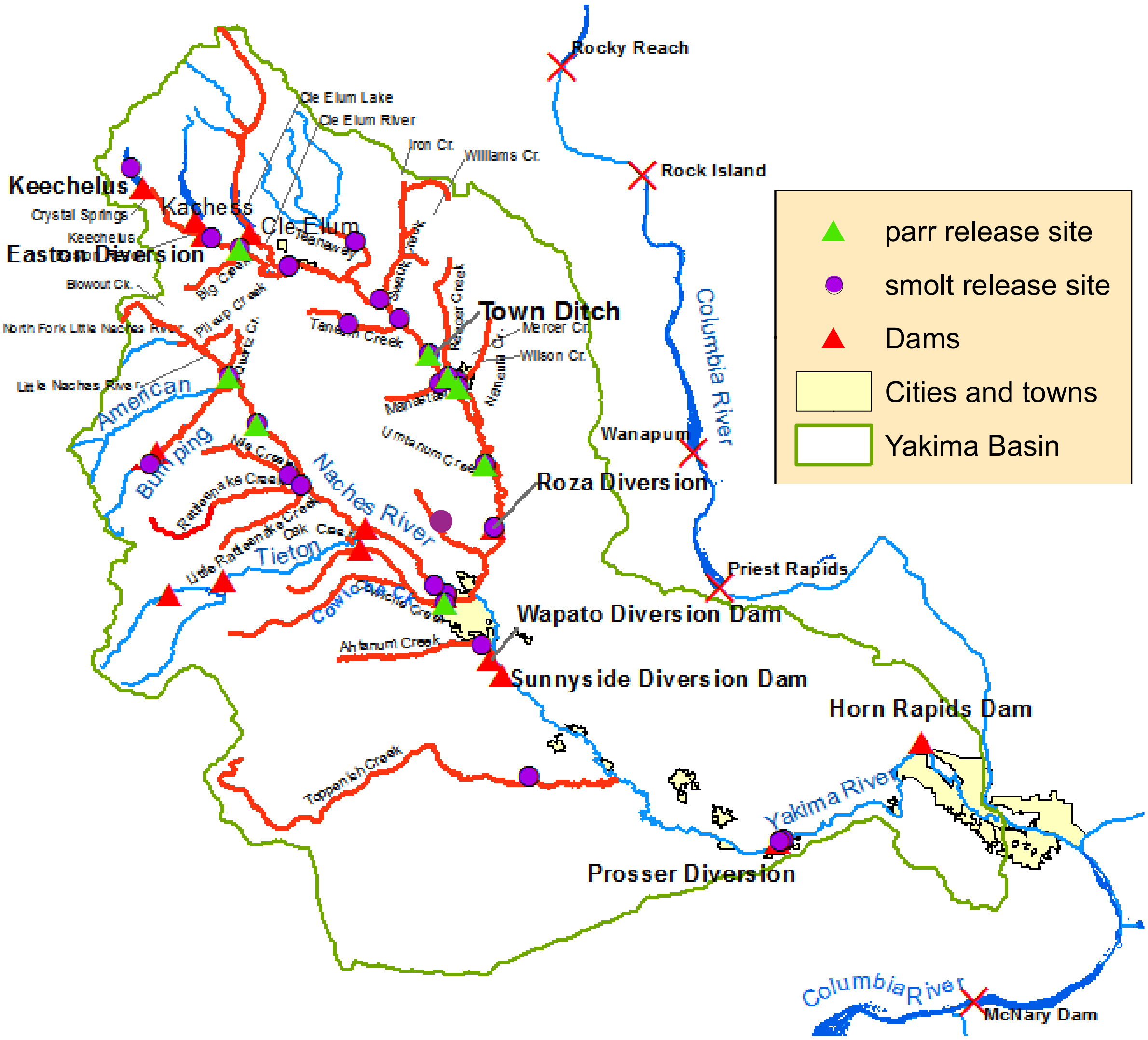
2.1 Geographical distribution: historical and current

Coho were widely distributed in lower-gradient tributaries of the Yakima and Naches rivers prior to passage impediments and habitat destruction caused by irrigation withdrawals, channel modifications and floodplain development (Wydoski and Whitney 2003; Tuck 1995; Haring 2001; Berg and Fast 2001; Figure 1A). As passage and habitat restoration projects enable coho to recolonize these habitats, acclimation and release sites developed in the reintroduction program overlap this historical geographical distribution (Figure 1B).

Figure 1. Historical Coho geographical distribution.



B. *Coho smolt and parr release sites, 2008-2023.*



2.2 PIT tag Data

We accessed the PTAGIS database (https://www.ptagis.org/) in April 2024 to gather PIT-tag detection information for all Coho Salmon smolts released at various locations within the Yakima Basin from 2015 to 2023 (Figure 1B). For migration year 2023, a total of 1,340,197 juveniles, including both parr and smolts, were released, a higher number compared to migration year 2021 (897,233). Within that total, approximately 62,000 fish with PIT tags were released (Table 1). Among these tagged fish, one-third (16,753) were released as smolts, while two-thirds (45,025) were released the prior calendar year as parr (Tables 1 & 2).

Table 2: Number of smolts and parr with PIT tags, name of release location, broodstock of origin and release date for outmigration year 2022 and 2023.

A. 2022

Life stage	Rearing hat.	Broodstocks	Session.Message	N	3/10/22	3/28/22	4/7/22	6/17/21	7/16/21	7/17/21
Parr	MRS	Yakima	COHO PARR RELEASED WILLIAMS CREEK MOBILE ACCLIMATION< SWAUK RELEASE	3031				3031		
Parr	MRS	Yakima	COHO PARR WILLIAMS CREEK MOBILE ACC RELEASE	1541				1541		
Parr	MRS	Yakima	COLEMAN CREEK COHO PAR RELEASE	4070						4070
Parr	MRS	Yakima	YN COHO PAR RELEASED BADGER CREEK	4011						4011
Parr	MRS	Yakima	YN COHO PAR RELEASED IN BIG CREEK	4016						4016
Parr	MRS	Yakima	YN COHO PAR RELEASED IN KEECHELUS/CRYSTAL SPRINGS	4024						4024
Parr	MRS	Yakima	YN COHO PAR RELEASED IN MASTASH CREEK	4034						4034
Parr	MRS	Yakima	YN COHO PAR RELEASED IN NORTH FORTH TEAWAY RIVER	4004						4004
Parr	MRS	Yakima	YN COHO PAR RELEASED IN REECER CREEK	4088					4088	
Parr	MRS	Yakima	YN COHO PAR RELEASED IN UPPER TANEUM CREEK	4040						4040
Parr	MRS	Yakima	YN COHO PAR RELEASED IN WILSON CREEK	4074						4074
Parr	MRS	Yakima	YN COHO PAR RELEASED LOWER TANEUM CREEK	2009					2009	
Parr	MRS	Yakima	YN COHO PAR RELEASED MAINSTEM TEAWAY RIVER	2083						2083
Smolt	Eagle Creek	Eagle Creek	EAGLE CREEK NFH COHO SMOLTS RELEASED AT PROSSER	4670		4670				
Smolt	MRS	Yakima	MRS HATCHERY COHO SMOLTS RELEASED NEAR HATCHERY	5002		5002				
Smolt	Prosser	Yakima	PROSSER COHO SMOLTS RELEASED AT JACK CREEK MOBILE ACCLIMATION SITE	2039			2039			
Smolt	Prosser	Yakima	YN COHO SMOLT RELEASED AT PROSSER	5042		5042				
Total Smolt				16753		14714	2039			
Total Parr				45025				4572	6097	34356

B. 2023

lifestage	Rearing hat.	Broodstocks	Session. Message	total	Release Date 5/26/22	6/28/22	7/11/22	7/12/22	7/13/22	7/14/22	7/17/22	10/24/22	10/31/22	3/9/23	4/14/23	4/19/23	4/3/23
Parr	MRS	Yakima	MRS COHO PARR	4285					4285								
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED AT CRYSTAL SPRINGS, 2022	4015					4015								
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN CLE ELUM RIVER, 2022	3975						3975							
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN BADGER CR, 2022	4059			4059										
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN BIG CR, 2022	4001				4001									
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN COLEMAN CR, 2022	4079				4079									
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN FIRST CR, 2022	1524							1524						
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN LOWER AHTANUM CR, 2022	1527	1527												
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN MANASTASH CR, 2022	4020					4020								
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN NF TEANAWAY RIVER, 2022	4027				4027									
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN REECER CR, 2022	4031			4031										
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN SWAUK CR, 2022	1498							1498						
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN WILLIAMS CR, 2022	1503		1503											
Parr	MRS	Yakima	YAKIMA COHO PARR RELEASED IN WILSON CR, 2022	4025			4025										
Parr	Wild Fish or Natural Production		Little Creek	1010									1010				
Parr	Wild Fish or Natural Production		Tucker Creek	688								688					
Smolt	MRS	Yakima	COHO SMOLTS RAISED AND RELEASED AT BOAT RAMP AT THOI	5002											5002		
Smolt	MRS	Yakima	COHO SMOLTS RELEASED IN COLEMAN CREEK.	2528												2528	
Smolt	Eagle Creek	Eagle Crre	EAGLE CREEK SMOLTS RELEASED AT PROSSER.	5104													5104
Smolt	MRS	Yakima	YAKIMA COHO Smolt RELEASED IN LOWER AHTANUM CR, 2022	978										978			
Smolt	MRS	Yakima	YN SMOLTS RELEASED AT PROSSER.	5161													5161
Total Smolt				18773										978	5002	2528	10265
Total Parr				48267	1527	1503	12115	12107	12320	3975	3022	688	1010				

2.3 Data analyses

Travel times and survival rates for both parr and smolt releases from each release location to McNary Dam were estimated for each outmigration year from 2015 to 2023. Travel time was calculated as the difference between the release date and the date of detection at McNary Dam. For outmigration years 2007 through 2018, a logistic regression model (Neeley 2012) was employed to estimate the survival probability of the groups. Starting in 2019 and in this report, survival probabilities from release locations to McNary Dam and the detection rates of PIT-tagged Coho smolts at McNary Dam were estimated using the Cormack-Jolly-Seber (CJS) mark-recapture model

(White and Burnham 1999; Lebreton et al. 1992; Williams et al. 2002; Conner et al. 2015). The CJS model has commonly been used within the Federal Columbia River Power System (FCRPS) to estimate survival rates for juvenile anadromous fish species (Tuomikoski et al. 2013).

One of the assumptions of the CJS model is the absence of immigration or emigration during the capture (tagging) and recapture (detection) intervals. This assumption holds true in the hydrosystem due to necessary passage at several hydroelectric dams and relatively consistent fish behavior as they move in one direction over a relatively short period of time (Conner et al. 2015). The CJS model was originally developed to calculate time-interval survival of tagged animals by estimating their survival and recapture probabilities through maximum likelihood. In our study, we used individual fish encounter histories to determine the likelihood of a fish surviving and being detected at each tag receiver facility (dams in this study; see Lebreton et al. 1992). The CJS model was applied to all smolts released at each location, based on an encounter history constructed from the number of fish released at different locations and subsequent detection events at McNary, John Day, and Bonneville dams on the Columbia River. Similar to previous studies (Neeley 2018), we estimated the survival and detection probability for each release group.

Several environmental factors, including river flow, have been identified as influential factors in downstream smolt survival (Raymond 1968; Connor et al. 2003; Tiffan et al. 2009). As early and late release groups are likely to experience different flow regimes in the lower Yakima River, their rates of survival can vary with temporal river conditions. Therefore, it was necessary to incorporate river flow and release month as covariates in the CJS model to estimate the survival rate of the releases. In our model, we utilized eight years of data (2015-2022) to enhance the overall sample size and increase confidence in our estimates. Coho smolts were released from February through April, with multiple releases occurring each year.

Flow data and water temperature for the Yakima River below Prosser Dam (YRPW) and at Kiona WA (KIOW) were accessed from the Bureau of Reclamation website at: https://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html, and water temperature at Kiona WA was accessed from the USGS website at https://waterdata.usgs.gov/nwis/uv?site_no=12510500. Based on the average travel time from Prosser to McNary Dam of approximately 20 days, a 20-day moving average of river flow data starting with the Prosser release date was assigned to each tag group to determine the effect of river flow on survival rate of the release group.

Several candidate CJS models were built using every possible combination of river flow and release month, with varying or constant survival and detection probabilities at dams in the CJS models. To determine the rank of the different candidate models we used the difference in the QAICc (ΔQAICc: Quasi-likelihood AICc Akaike's information criterion difference) relative to the top model. For models with ΔQAICc <2, we selected the model with the lowest QAIC and fewest parameters as the best model (Burnham and Anderson 2002). Selecting the best model, we estimated the effect of river flow on downstream survival rate for each release group. The CJS models were run within the RMark package (Laake and Rexstad 2019) in R statistical software, version 3.3.6 (R Core Team 2019). More information about the model is available in Pandit et al. (2021).

2.4 Smolt-to-Adult Returns (SAR)

SAR, which is the percentage of smolts that survive and return as an adult to spawn, is a metric that captures most of the cumulative impacts of the hydro-system and ocean conditions on anadromous fish, indicating how sustainable the returns of adults are over time. The SAR was estimated as the percentage of smolts detected at McNary Dam returning as adults to Bonneville Dam using the following equation for each year and release group:

$$U_{at\ \ McN\,\&\,BON} / J_{at\ McN}$$

Where, $U_{at\ MCN\ \&\ BON}$ is a total number of PIT tagged fish which were detected at McNary Dam (McN) as a juvenile and also detected at Bonneville Dam (BON) as a returning adult (joint detection). $J_{at\ McN}$ is the total number of fish detected at McNary Dam as juveniles. Since Coho can spend as many as 3 years in the ocean, we estimated SAR for the populations that out-migrated from 2004 through 2020 for both parr and smolt releases. Nonparametric 95% confidence intervals were computed around the estimated annual overall SARs for each group as described by McCann et al. (2020). The nonparametric bootstrapping approach of Efron and Tibshirani (1993) was used where first, the point estimates were calculated from the sample for each population, and then the data were re-sampled, with replacement, to create 1,000 simulated samples (Berggren et al. 2002, Chapter 4). These 1,000 iterations are used to produce a distribution of annual SARs from which the value in the 50th ranking is the lower limit and value in the 95th ranking is the upper limit of the resulting 95% nonparametric confidence interval.

2.5 Age composition of adult returns

The ocean age of each returning Coho was estimated by subtracting the date of detection at the Bonneville Adult passage from the date of release. Coho smolt and parr releases naturally show different outmigration behavior after release. Coho smolts start to migrate downstream immediately after release, while parr typically outmigrate as yearling smolts in the spring following release in summer or fall. Therefore, for parr release groups, ocean age was estimated as:

- Ocean age of smolt = date of detection of returning adult at Bonneville Dam –-release date
- Ocean age of parr= date of detection of returning adult at Bonneville Dam – release date-365

Return age composition was estimated as the proportion of each age class of adult return detected at Bonneville Dam for each brood year and life stage at release.

3. Results and Discussion

3.1 Fish length at the time of tagging and release

For migration year 2023, lengths of PIT tagged Coho were not measured. Over 6 prior outmigration years (2015-2020), about 7% of the PIT-tagged releases were measured. The average fork lengths for the groups released in March and April were 122.12 ± 3.54 mm (mean±SE) and 113.29 ± 3.44 mm, respectively (Table 4). Although this was not a significant difference, fish released in March tended to be larger at tagging than fish in the April release groups. This was most likely a hatchery effect, as March releases were largely comprised of fish reared at the Prosser hatchery where water temperatures are higher than at the other hatcheries used to rear Coho juveniles for this study.

Table 4: Smolt fork length by year, release location and release month, with sample size (N). Data are based on the limited number of lengths available from PTAGIS (n= 8605 out of 111,418 total tags).

Year	Location	Month	N	Mean (mm)	se	Range min	Range max
2015	Easton	March	431	133.76	0.47	94	166
2015	Holmes	March	377	126.15	0.48	95	157
2015	Stiles	March	585	119.78	0.60	72	168
2016	Easton	April	521	114.49	0.44	63	155
2016	Holmes	April	1074	112.82	0.29	63	144
2016	Stiles	April	558	122.07	0.54	82	160
2016	Prosser	April	303	133.06	0.46	104	155
2016	Ahtanum	March	520	127.28	0.62	75	220
2016	LostCr	April	85	129.96	0.79	110	150
2017	Holmes	March	292	115.83	0.48	85	136
2017	Stiles	April	600	116.08	0.35	88	140
2017	Prosser	March	414	126.72	0.52	91	160
2018	Easton	April	1108	108.56	0.23	83	140
2018	Stiles	April	800	107.40	0.25	83	151
2019	Easton	April	206	100.20	0.62	71	118
2019	Holmes	April	204	101.31	0.75	67	126
2019	Stiles	April	442	100.22	0.52	67	126
2020	Prosser	March	79	105.35	0.89	80	123
2021	NA	NA	NA	NA	NA	NA	NA
2022	NA	NA	NA	NA	NA	NA	NA
2023	NA	NA	NA	NA	NA	NA	NA

3.2 Travel Time from Release Locations to McNary Dam

In 2023, out of all the tagged smolts released, only 71 were detected at McNary Dam. The travel time from Prosser Dam to McNary Dam for the Eagle Creek broodstock release ranged from 24 to 67 days, with an average travel time of around 43 days (Table 5 and Table 6). For the Yakima broodstock release at Prosser, the travel time ranged from 11 to 75 days, with a mean travel time of 35 days. Despite both groups being released from the same location and on the same date, their travel times exhibited variation. This variation could be attributed to factors such as temperature differences or variations in food supply in the rearing hatchery, among others. The larger size of Prosser releases noted in prior years, and likely related to water temperature, may have contributed to faster travel times in outmigration year 2022. Numerous studies have indicated that fish size can influence travel times, with larger fish generally taking less time to migrate downstream.

Coho smolts released from Prosser Dam consistently have the shortest travel time to McNary Dam because Prosser Dam is closer than any other smolt release location to McNary Dam. Smolts released from the Jack Creek acclimation site had the longest travel time, with a mean of 81 days (76-85 days, min-max).

Parr releases took approximately 330 days from the release date to detection at McNary Dam. This was not only because they were released at an earlier life stage. In general, outmigration of hatchery parr releases occurs later than outmigration of hatchery smolts.

3.3 Detection rate of smolt and parr releases at McNary Dam

Travel time varies between the smolt and parr release groups, as well as among different broodstocks (Yakima and Eagle Creek), the detection rate at McNary Dam also exhibits variation. This variation can be attributed by several factors such as fish orientation at the antenna, river flow, and the operation of surface-passage structures. In recent years, there has been an increase in spill and the utilization of spillway weirs at dams as a primary management strategy to enhance the survival of juvenile fish passing through the Federal Columbia River Power System. However, greater spillway usage results in a lower proportion of fish entering juvenile bypass systems where PIT tags can be detected (Widener et al., 2018). Fluctuations in spill and flow can contribute to variable detection rates among years or within a migration season. During the period from 2016 through 2023, the detection rate at McNary Dam demonstrated year-to-year variation. The highest detection rate was observed in 2016, while the lowest detection rates were recorded in 2021 and 2023 (Tables 6 and 7).

Table 6. Summary of the total number of coho smolts/parr with PIT tags ("N"), detection and travel time for each release group in migration years (from 2020 through 2023). "Det.Prob%", "Surv. Prob%" and "travel time" are the detection probability at McNary Dam, survival probability from the release location to McNary Dam and the travel time (days) from the release location to McNary Dam, respectively. "PRO", "MCJ", "JDJ" and "BON" are the number of coho (PIT tags) detected at Prosser, McNary, John Day and Bonneville dams, respectively.

								No. of Fish detection at				McNary Dam	
Migration Year	Stock	Life Stage	Rearing	Release location	Release year	Release date	N	PRO	MCJ	JDJ	BON (B2J+B	Det. Prob.%	Surv.Prob.%
2020	Eagle Crk.	Smolt	Eagle Hat.	Prosser	2020	27-Mar-2020	9974		204	252	855	3.80± 0.5	53.79 ± 7.41
	Yakima	Smolt	Prosser Hat	Prosser	2020	27-Mar-2020	2952		78	86	156	6.75 ± 1.68	39.10 ± 8.80
	Yakima	Smolt	Prosser Hat	Ahtanum Crk. On LaSalle Gr.	2020	18-Feb-2020	939	4				NA	NA
	Yakima	Smolt	Prosser Hat	Mainstem YR near Holmes	2020	18-Feb-2020	1249	5			1	NA	NA
	Yakima	Parr	Prosser Hat	Mainstem Naches R near Tieton R	2019	8-Aug-2019	1289	40	2	1	3	0.15± 0.19	0.93 ± 1.5
2021	Yakima	Smolt	Prosser Hat	Prosser	2021	5-Apr-2021	5037		138	66	316	5.96 ± 1.21	42.92 ± 8.34
	Eagle Crk.	Smolt	Eagle Hat.	Prosser	2021	5-Apr-2021	4594		72	46	328	4.01 ± 1.05	35.27 ± 8.21
	Yakima	Parr	Prosser Hat	Ahtanum Crk.	2020	16-Jul-2020	996	7			1		
	Yakima	Parr	Prosser Hat	Above Barrier Tucker crk (up. Yakima)	2020	17-Jul-2020	502	19					
	Yakima	Parr	Prosser Hat	Below Barrier Tucker crk (up.Yakima)	2020	18-Jul-2020	491	18	1		1	100 ± 0	0.02 ± 0.02
	Yakima	Parr	Prosser Hat	Wapato Irri.Proj.(WIP) Diversion	2020	17-Jul-2020	308						
2022	Yakima	Parr	MRS	WILLIAMS CREEK MOBILE ACCL.< SWAUK RELEASE	2021	17-Jun-2021	3031	46	45	12	10	15±7.98	9.9±5.12
	Yakima	Parr	MRS	WILLIAMS CREEK MOBILE ACC RELEASE	2021	17-Jun-2021	1541	20	18	11	13	13.04±7.02	8.96±4.46
	Yakima	Parr	MRS	COLEMAN CREEK	2021	17-Jul-2021	4070	43	14	7	30	10.26±4.86	3.35±1.37
	Yakima	Parr	MRS	BADGER CREEK	2021	17-Jul-2021	4011	24	2	2	12	0.05±0.04	30±1.02
	Yakima	Parr	MRS	BIG CREEK	2021	17-Jul-2021	4016	41	32	11	20	15.62±6.42	5.1±1.96
	Yakima	Parr	MRS	KEECHELUS/CRYSTAL SPRINGS	2021	17-Jul-2021	4024	49	36	20	20	14.63±5.52	6.11±2.14
	Yakima	Parr	MRS	MANASTASH CREEK	2021	17-Jul-2021	4034	59	37	10	8	18.75±9.76	4.89±2.46
	Yakima	Parr	MRS	NORTH FORTH TEANAWAY RIVER	2021	17-Jul-2021	4004	19	15	4	3	16.67±15.21	2.4±2.13
	Yakima	Parr	MRS	REECER CREEK	2021	16-Jul-2021	4088	66	23	13	54	4.29±2.42	13.13±6.93
	Yakima	Parr	MRS	UPPER TANEUM CREEK	2021	17-Jul-2021	4040	39	26	16	7	27.27±9.5	2.36±0.76
	Yakima	Parr	MRS	WILSON CREEK	2021	17-Jul-2021	4074	83	13	19	43	1.49±1.48	21.38±20.4
	Yakima	Parr	MRS	LOWER TANEUM CREEK	2021	16-Jul-2021	2009	17	15	8	9	29.41±11.05	2.54±0.85
	Yakima	Parr	MRS	MAINSTEM TEANAWAY RIVER	2021	17-Jul-2021	2083	9	2	3	4	25±15.31	0.58±0.26
	Yakima	Smolt	Prosser Hat	PROSSER	2022	28-Mar-2022	5042	NA	41	25	114	4.23±1.69	19.25±7.13
	Yakima	Smolt	MRS	NEAR MRS HATCHERY	2022	28-Mar-2022	5002	140	6	16	45	1.64±1.63	7.32±6.63
	Yakima	Smolt	Prosser Hat	JACK CREEK MOBILE ACCLIMATION SITE	2022	7-Apr-2022	2039	30	4	10	11	10±6.71	1.96±0.98
	Eagle Crk.	Smolt	Eagle Hat.	Prosser (EAGLE CREEK NFH COHO smolt)	2022	28-Mar-2022	4670	NA	30	28	122	2.53±1.25	25.37±11.68
2023		Parr		MRS Coho Parr	2022	7/13/22	4285	58	2	3	11	33.33±13.51	2.63±0.2
		Parr		Crystal Springs	2022	7/13/22	4015	41	1	1	1	0.05±0.04	0.62±0.3
		Parr		CleElum River	2022	7/14/22	3975	28	0	1	2	0.03±0.03	0.31±0.024
		Parr		Badger Cr.	2022	7/11/22	4059	17	6	15	26	11.54±6.27	6.48±2.28
		Parr		Coleman Cr.	2022	7/12/22	4001	31	3	7	22	7.67±5.23	2.76±1.74
		Parr		First Cr.	2022	7/17/22	4079	21	1	0	1	0.01±0.007	0.82±0.05
		Parr		Manastash Cr.	2022	7/13/22	1527	49	1	2	2	7.85±8.2	0.934±1.7
		Parr		Big Cr.	2022	7/12/22	4001	45	2	2	4	0.1±0.02	1.25±0.1
		Parr		NF Teanaway River	2022	7/12/22	4020	49	1	2	2	0.1±0.03	0.934±1.5
		Parr		Reecer Cr.	2022	7/11/22	4027	32	4	13	35	0.42±0.01	5.29±2.4
		Parr		Swauk Cr.	2022	7/17/22	4031	31	0	0	4	0.1±0.04	3.34±1.2
		Smolt		Williams Cr.	2022	6/28/22	1498	11	0	0	0	NA	NA
		Parr		Wilson Cr.	2022	7/11/22	1503	18	10	15	32	9.38±5.15	7.78±3.44
		Parr	Wild	Little Cr.	2022	10/31/22	1010	9	1	1	0	0.5±0.03	2.48±0.1
		Parr	Wild	Tucker Cr.	2022	10/24/22	688	14	1	0	0	0.5±0.03	1.57±0.16
		Smot		Boat Ramp at Thorp	2023	4/14/23	5002	86	28	39	87	6.19±2.40	21.65±8.19
		Smolt		Coleman Cr.	2023	4/19/23	2528	71	30	82	148	6.19±2.40	45.43±10.40
	Eagle Crk.	Smolt	Eagle Hat.	Prosser	2023	4/3/23	5104		36	106	199	9.49±2.13	5.43±10.40
	Yakima	Smolt	MRS	Prosser	2023	4/3/23	5161		43	92	135	10.14±2.48	27.36±5.90

Table 7: Detection history (number of juvenile Coho detected/not detected at McNary and John Day/Bonneville dams) and detection rate during outmigration of smolt release groups (A) and parr release groups (B) over migration years 2015-2023. Enumeration of fish fate (Release/detection histories) is coded by detection (1) and no detection (0) such that "1.0.0." = no juvenile detection after release, "1.0.1" = not detected at McNary Dam but detected at John Day Dam or Bonneville Dam, "1.1.0" = detected at McNary Dam but not at John Day Dam or Bonneville Dam, and "1.1.1" = detected at McNary and either John Day or Bonneville.

A. Smolt releases

						Detection Rate		Survival Rate (%)	
Mig.Year	N	1.0.0	1.0.1	1.1.0	1.1.1	Mean	SE	Mean	SE
2015	18793	18167	392	179	55	12.3	1.51	10.12	1.14
2016	24777	23128	621	825	203	24.63	1.51	16.84	0.90
2017	14412	13601	337	431	43	11.31	1.62	29.06	3.40
2018	19266	18356	483	379	48	9.03	1.24	24.51	3.20
2019	20305	19775	338	168	24	6.23	1.31	14.27	2.64
2020	13865	12364	1219	227	55	4.31	0.58	47.31	5.79
2021	9443	8771	666	159	35	4.99	0.08	40.34	6.02
2022	16753	42337	368	68	13	3.41	0.93	14.17	3.55
2023	18773	17761	559	398	55	8.95	1.15	26.91	3.26

B. Parr releases (released parr typically outmigrate as yearling smolts). The year is the migration year. For example, number of fish in 2015 is the number of parr released in 2014.

						Detection Rate		Survival Rate	
Mig.Year	N	1.0.0	1.0.1	1.1.0	1.1.1	Mean	SE	Mean	SE
2015	28611	28547	19	41	4	17.39	7.90	0.90	0.39
2016	25815	25473	41	283	18	30.51	5.99	3.82	0.74
2017									
2018	21244	20614	333	260	37	9.23	3.59	13.98	2.05
2019	41275	41175	30	69	1	3.23	3.17	5.26	5.13
2020	2541	2532	4	4	1	25.00	21.65	0.93	0.71
2021	1989	1987	2	0	0	NA	NA	0.02*	115.47
2022	42942	42337	328	237	40	10.87	1.62	5.94	0.8
2023	49224	48923	163	120	18	9.94	2.22	2.81	0.59

Note: there was no parr release in 2016 (migration year 2017). NA indicates insufficient detections to estimate detection rate. * indicates the survival rate is not a precise estimate because of very few joint detections among dams.

3.5 Recovered PIT tags on Bird Islands

Figure 4 illustrates 13 bird nesting colonies where recoveries of PIT tags have played a crucial role in revealing the impact of avian predation on the survival of out-migrating juvenile salmonids. For the 2022 coho smolt release, the recovery of 405 PIT tags on avian nesting islands, compared to the detection of 359 PIT tags at McNary Dam, indicates that a significant portion of the total juvenile release in 2022 likely succumbed to avian predation.

Among the islands, the highest number of coho smolts were recaptured from Badger Island, with 250 out of the 405 recovered PIT tags originating from there. It is important to note that Badger Island is classified as an unmanaged island, lacking any structures or measures to reduce bird nesting. In contrast, nearby Crescent Island is categorized as a managed island, where several measures have been implemented to mitigate bird nesting. Only 23 out of the 405 recovered smolt tags were associated with Crescent Island (Table 8). It should be acknowledged that recovered PIT tags represent a fraction of the total predation on tagged smolts because tags can be blown off of the colony's nesting area during wind storms; washed away during high tides in the Columbia River estuary, rain storms, or high water events; otherwise damaged or lost during the course of the nesting season; or simply not detected.

Out of the 405 PIT tags recovered, 294 were from the parr group (0.65% of the total parr release) , while 111 were from the smolt group (0.66% of the total smolt release; Table 8). This similarity suggests that both groups had similar exposure to avian predation in the Columbia and lower Yakima rivers despite differences in migration timing.

Figure 4. Schematic of mark–recapture–recovery sites of PIT-tagged Coho released in Yakima Basin for the migration year 2021.

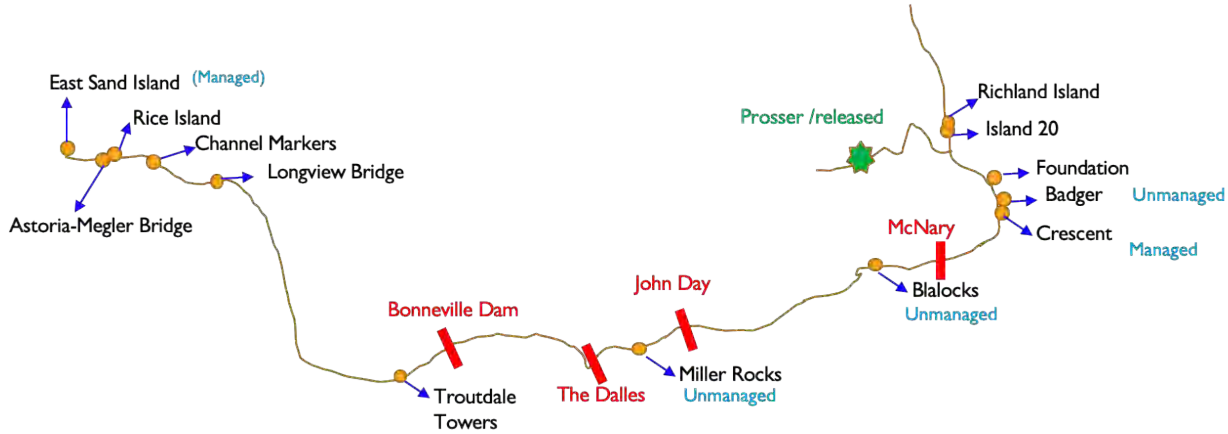


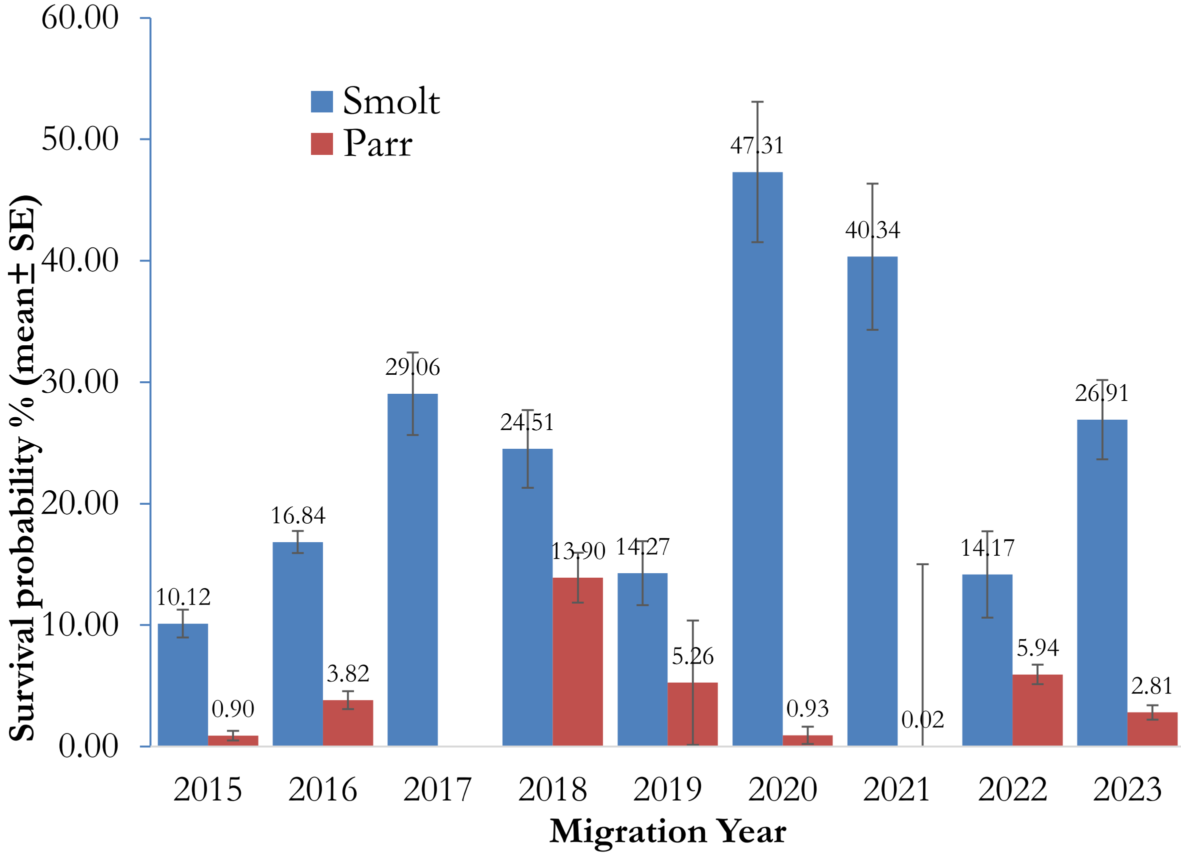
Table 8. The number of recaptured Coho Pit tags (released as smolt or parr for the migration year 2020, 2021 and 2023) on each bird nesting island. Recovery locations include "RICHIS" = Richland Island, "FOUNDI"= Foundation Island, "BADGER"= Badger Island, "CRESIS"= Crescent Island, "CBLAIS"=Central Blalock Island, "MLRSIN", = Miller Sands Island, "LMILS"= Little Miller Island, "ASMEBR"= Astonia-Megler-Bridge, "ESANIS"=East Sand Island, and "POTH"= Potholes Reservoir

Life stage (Parr/Smolt)	Mig. Year	N	Detection at Dams				Recaptured in Islands (AVIAN predation)											
			MCN	JD	BON	%	RICHIS	FOUNDI	BADGEI	CRESIS	CBLAIS	MLRSNI	LMILIS	ASMEBR	ESANIS	POTH	Total	% Recap
	2020	13865	282	338	1011	2.03	15	39	45	1			12	11	24		147	1.06
	2021	9443	210	112	664	2.22	10	15	50	2			14	13	13		117	1.24
Smolt	2022	11711	81	79	292	0.69	4	20	66	3	4	1	7	4	2	0	111	0.948
	2023	17795	137	319	569	0.77	12	32	168	9	6		21	34	16		298	1.67
	2020	1289	2	1	3	0.16			5								5	0.39
Parr	2021	1897	1	0	2	0.05	1		6								7	0.37
	2022	45025	278	136	233	0.62	8	27	184	20	8	0	19	14	14	0	294	0.653
	2023	50223	56	82	170	0.11	3	3	244	3	4	3	8	5	3		276	0.55

3.6 Survival Probability (Release Site to McNary Dam)

We estimated survival from release to McNary Dam based on life stage at release, brood source, location, and timing of release (Table 7 and Figure 5). When the 8 years from 2015 to 2023 were pooled (Figure 6), the highest survival rate was for Eagle Creek smolts (23.8%), followed by Yakima smolts (18.1%) and the lowest was for Washougal smolts (8.49%). Parr releases experienced over-winter mortality, migrated later than the smolt releases when river flow was lower and warmer, and traveled a longer distance to McNary Dam.

Figure 5. Overall smolt survival rate (± SE) from release site to McNary Dam for smolt and parr releases in migration years 2015-2023.

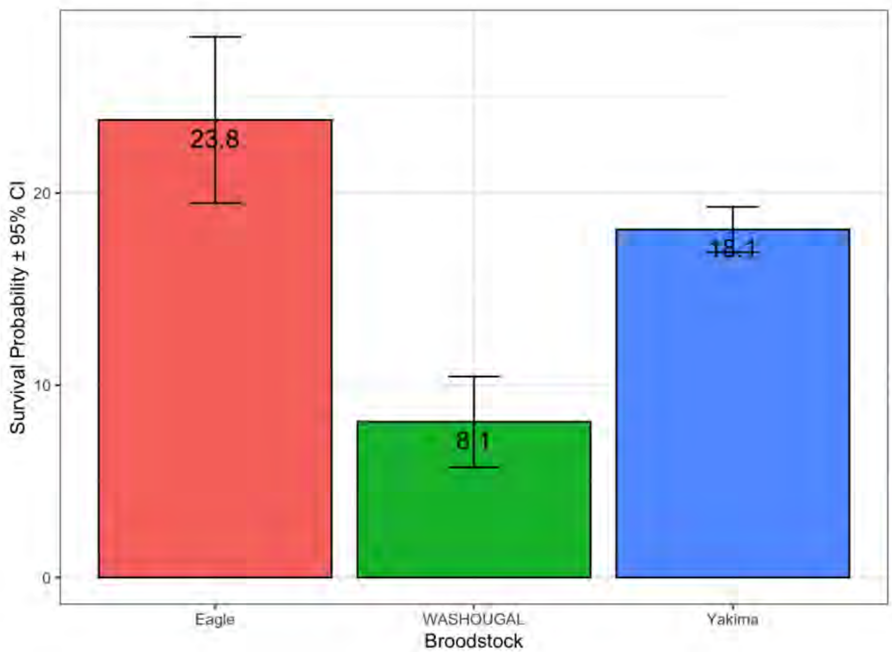


A. Evaluation of survival probability among broodstocks

Survival rate for different stocks are given in figure 6. When considering smolt releases from 2015 to 2023, the average survival rate differed among stocks, as depicted in Figure 6. Eagle Creek smolts exhibited the highest survival rate, while Washougal smolts had the lowest.

Initially, our expectation was that smolts from the Yakima stock would exhibit a higher survival rate compared to Eagle Creek imports. This expectation was met in a few years, or when considering the 7-year average. The variation in survival rates among hatcheries and years can be attributed to several factors, including water temperature and water quality at the hatchery. Although fish size data were unavailable for some years, previous studies conducted outside the Yakima Basin have indicated that fish size can impact juvenile survival rates. Additionally, the timing of outmigration and river flow may have also influenced the survival rates. The migration timing differs between the two groups, which means they might have encountered varying environmental conditions such as river flow or temperature. These environmental factors could contribute to the observed variation in survival rates between the Yakima stock and Eagle Creek imports.

Figure 6. Average Coho smolt survival rate (release to McNary Dam) and 95% confidence intervals by broodstock origin for the migration years 2015 through 2023.



B. Evaluation of survival probability by release location

B.1. Annual evaluation of survival rates for releases from Prosser Hatchery

The highest estimated survival rate for a Prosser release was in 2018 but as discussed above, the estimate is likely to be inaccurate, either because of a low detection rate at downstream dams or methodological errors. Ignoring 2018, the highest survival rate was in 2014 (78%) and the lowest was in 2016 (22.9%, Table 10).

Table 10. Survival to McNary Dam for Yakima-origin Coho released as smolts from Prosser Hatchery.

Year	Number released	Release Date	Travel days (Mean ± SE)	Survival Probability (Mean ± SE)
2007	2499	4/15	15	62.7
2008				
2009	2506	4/2	41	65.7
2010	1371	4/4	24	52.5
2011	5036	4/15	30	37.6
2012	3811	3/5	58	33.9
2013	2520	4/15	8	67.2
2014	3004	4/14	18	78.0
2015	1265	3/23	21	37.2
2016	2501	4/4	19	22.9
2017	2876	3/19	34	66.5
2018	2509	3/14	48	97.9
2019	2533	4/2	21.32 ± 8.54	25.19 ± 2.98
2020	2952	3/27	33.78±1.14	39.10± 8.80
2021	5037	4/5	19.50±1.4	42.92 ± 8.34
2022	5042	3/28	35 ± 4.9	19.25 ±1.4
2023	5161	4/03		27.34 ±5.9

Note: Estimates for the years prior to 2019 were obtained from Neeley (2018). Standard errors are available only starting from 2019.

B.1.2. Annual evaluation of survival rates for releases from Stiles Pond (Naches River)

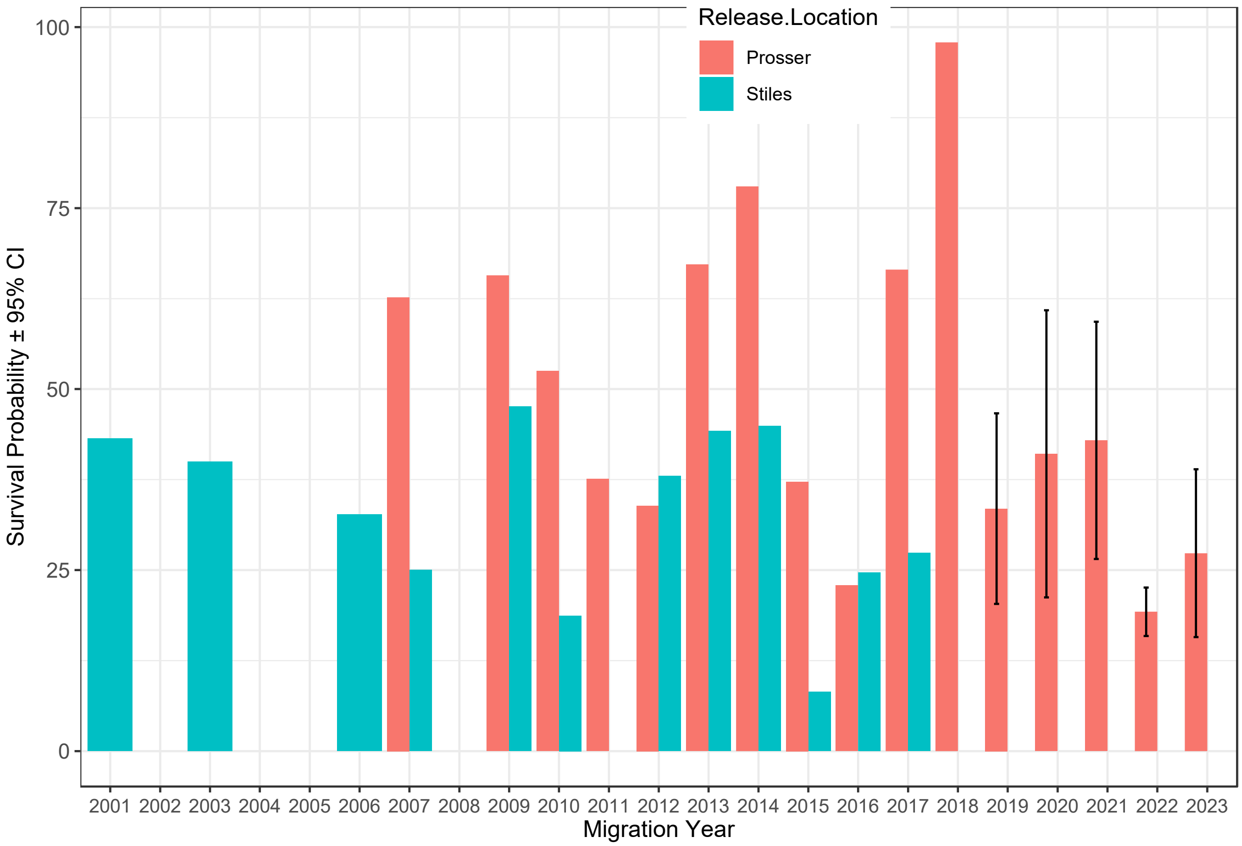
Similar to Prosser, the survival rate to McNary dam of Stiles releases also varied by year. There were no releases of Yakima stock from Stiles Pond after 2017 (Table 11), but as shown in Table 9, there were more years of releases from Stiles Pond than any other site besides Prosser Hatchery. Although the survival rates of Prosser and Stiles releases both varied by year, the Prosser release groups had higher survival rates to McNary Dam in most years than the Stiles groups, as might be expected from Stiles Pond's location about 120 km upstream from Prosser Hatchery. Only in 2012 and 2016 did Stiles releases survive better than Prosser releases (Figure 7).

Table. 11 Survival to McNary Dam for Yakima-origin released from Stiles Pond. No release from this site after 2017

Year	Number released	Release Date	Travel days (Mean ± SE)	Survival Probability (Mean ± SE)
2001	1240	5/17	22	43.2
2002				
2003	1249	5/7	14	40.0
2004				
2005				
2006	2490	4/3	38	32.7
2007	2449	4/5	41	25.0
2008				
2009	2515	4/15	36	47.6
2010	2501	4/12	36	18.7
2011				
2012	2526	4/16	32	38.0
2013	2504	4/15	30	44.2
2014	2505	4/16	25	44.9
2015	2520	3/23	51	08.2
2016	3768	4/7	35	24.7
2017	5007	4/17	31	27.4

Note: Results were adopted from Neeley (2018)

Figure 7. Bar plot showing Coho smolt survival to McNary Dam for the Yakima-origin Coho smolt released at Prosser Dam from 2007 through 2023 (red color) and from Stiles Pond (green color) from 2001 through 2022.



B.2 Parr releases

Among the release locations, the average survival rate from release to McNary was highest for the group released in Wilson Creek (21.37±30.39%). followed by Reecer Creek and Swauk Creek (Table 12).

Table 12. Survival probability (from the release location to McNary Dam) for Coho parr releases in 2018 through 2022 (outmigration years 2019 through 2023).

Release Location	2019		2020		2021		2022		2023	
	Mean (%)	SE (%)	Mean (%)	SE (%)	Mean %	SE	Mean %	SE	Mean %	SE
Ahtanum Creek	4.71	1.06								
Rattlesnake Creek	15.25	5.07								
Big Creek	0.4	0.15					5.1	1.96	1.25	0.1
Naches River	4.78	4.42								
Easton Reach	NA									
SF Cowiche Creek	0.4	0.28								
Reecer Creek	2.56	1.1					13.12	6.93	5.9	2.4
Swauk Creek	0.13	75.5*					9.89	4.46	3.34	1.2
Tieton River	9.16	8.6	0.93	0.71						
Coleman Creek	4.79	2.92					3.35	1.37	2.76	1.74
Little Naches	NA									
Wilson Creek	2.14	0.87					21.37	30.39	7.78	3.4
Yakima River ThorpBoatRamp	NA									
Turcker Cr (wild/natural)									1.57	0.16
Little Cr.									2.48	0.1
Tucker Crk(above barrier)					NA				NA	
Tucker Crk (below barrier)					0.02	0.02			0.02	0.02
NorthFork Teanaway Rv							2.28	0.56	0.934	1.5
Jack creek mobile accl. Site							1.96	0.97		
Badger creek							NA		6.48	2.28
Keechelus/Crystal springs							6.11	2.13		
Manastash Cr							4.89	2.46	0.934	1.7
Naches River										
Upper Taneum Cr							2.36	0.76		
Lower Taneum Cr							2.54	0.85		
Crystal Springs									0.62	0.3
CleElum River									0.31	0.02
First Cr									0.82	0.05
Williams Cr.									NA	NA
Mainstem Teanaway Rv.							0.58	0.26		
All (Pooled)	5.26		0.93				5.94	0.8	2.82	0.59

"NA" or "*" represents releases with too few downstream detections to estimate survival rate, while "*" flags excessive estimation error.

B.2.1. Annual comparison of survival rates for parr releases in Yakima Basin streams

Table 13 summarizes annual variations in survival rates of Coho parr released from several locations in the Yakima Basin. There was substantial variation among years within a site, and among the sites.

Table 13. Estimated survival from release to McNary Dam of Coho released as parr, by release location and migration year. For 2019, 2020 and 2021 results, average survival rate and its standard errors are also given (mean ± SE) where applicable. An asterisk indicates that the survival rate could not be computed because of too few downstream detections.

Released river/ tributary	Year	Released Pop^n (N)	Survival rate (%)	SE	Stock	Notes
Cowiche Creek	2008	3001	30.7		Yakima	
	2009	6			Wild Parr	
	2009	3001	23.3		Yakima	
	2010	3004	16.9		Yakima	South Fork
	2011	3021	19.6		Yakima	
	2011	28	81.2		Wild Parr	
	2011	3049	20.1		Yakima	
	2012					South Fork
	2013	3003	11.3		Yakima	
	2013	2495	27.5		Yakima	
	2014	3014	3.6		Yakima	
	2014	1249	25.4		Yakima	Cowiche Cr from Mobile Site
	2015	3017			Yakima	
	2015	1250	15.4		Yakima	Cowiche Cr from Mobile Site
	2016					
	2017					
	2018	3035	16.6		Yakima	
	2019	3013	0.40	0.28	Yakima	
	2020	No release				
	2021	No release				
	2022	No release				
Reecer Creek	2008	3001	37.41		Yakima	
	2009	2965	25.21		Yakima	
	2010	3015	23.24		Yakima	
	2011	3004	29.24		Yakima	
	2012	3026	30.52		Yakima	
	2013	3032	13.35		Yakima	
	2014	3031	7.46		Yakima	
	2015	3026	3.26		Yakima	
	2016				Yakima	
	2017				Yakima	
	2018	3069	29.96		Yakima	
	2019	3005	2.56	1.10	Yakima	
	2020	No release				

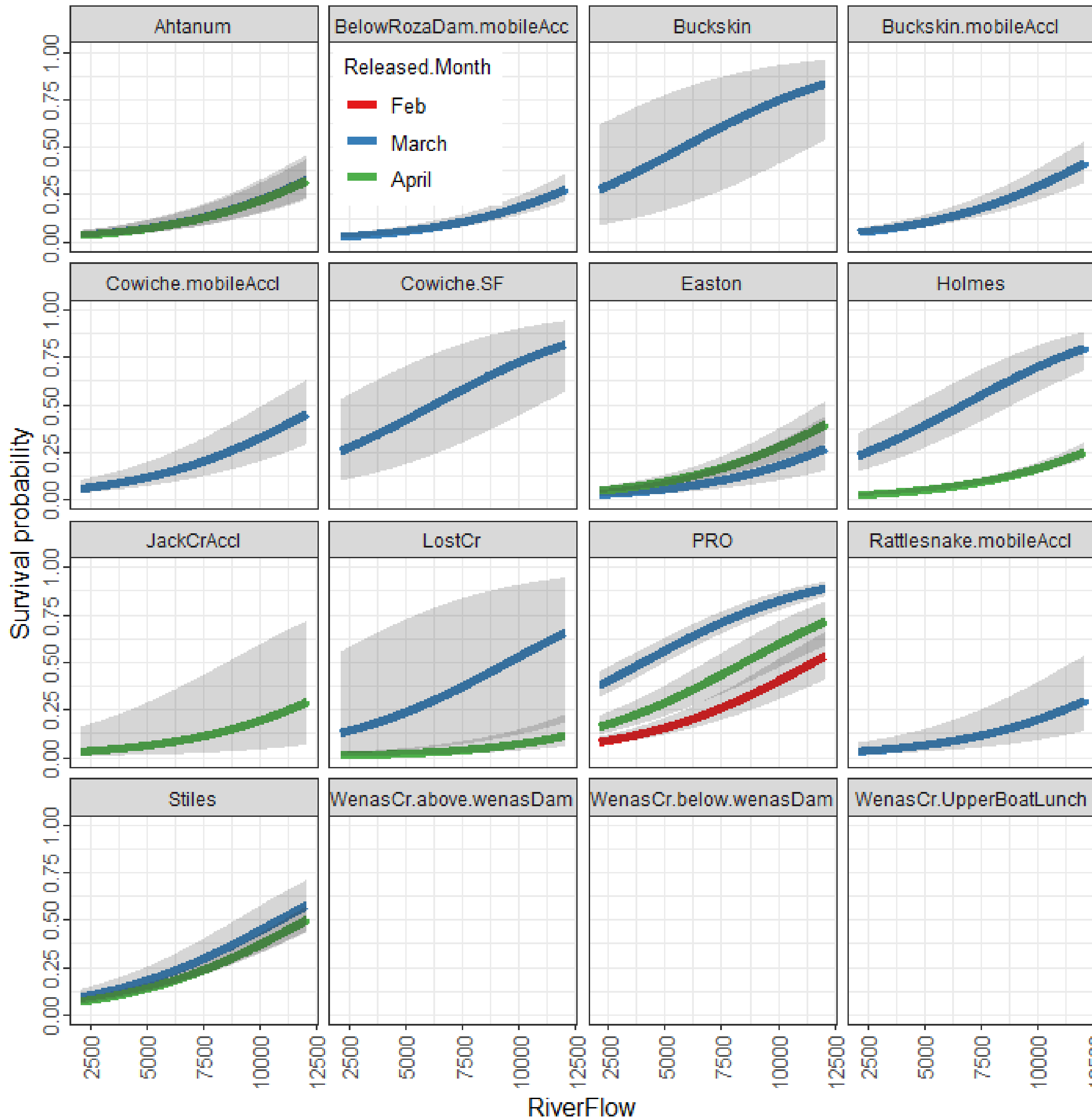
	2021	No release				
	2022	4088	13.13	6.93	Yakima	
	2023	4027	5.9	2.4	Yakima	
Little Naches	2009	3000	16.6		Yakima	
	2010	3072	18.3		Yakima	
	2011	3022	9.6		Yakima	
	2012	3014	20.3		Yakima	
	2013	3019	7.6		Yakima	
	2014	3012	6.6		Yakima	
	2015	3026	0		Yakima	
	2015	3004	0		Yakima	
	2015	6030	0		Yakima	
	2016	3008	2.6		Yakima	
	2017				Yakima	
	2018	3042	12.3		Yakima	
	2019	3006	*		Yakima	
	2020	No release				
	2021	No release				
Wilson Creek	2008	3000	11.4		Yakima	
	2009	3007	15.5		Yakima	
	2010	3050	12.1		Yakima	
	2011	3008	13.8		Yakima	
	2012	3020	11.2		Yakima	
	2013	1518	4.9		Yakima	Above Buried Section
	2013	1502	10.2		Yakima	Below Buried Section
	2014	3024			Yakima	
	2015	3027	8.2		Yakima	
	2016	3011	7.1		Yakima	
	2017		11.6		Yakima	
	2018	3019	48.5		Yakima	
	2019	6082	2.14	0.87	Yakima	
	2020	No release				
	2021	No release				
	2022	4074	21.38	20.4	Yakima	
	2023		7.78	3.4	Yakima	
Swauk Creek	2018	3024	2.85		Yakima	
	2019	3041	0.13	75.5	Yakima	
	2020	No release				
	2021	No release				
	2022	3031		9.89	Yakima	
	2023			3.34	Yakima	
Tieton River	2019	3010	9.16	8.6	Yakima	
	2020	No release				
	2021	1289	0.93	0.71	Yakima	

2022	No release
2023	No release

C. Effect of river flow and release month on smolt survival rate

One of our monitoring objectives was to evaluate the effects of river flow on juvenile Coho outmigration survival rate, and to determine whether the effect differed as a function of smolt release month (February, March and April). A CJS model was used to evaluate the effect of river flows on outmigration survival rate for each release month (February, March and April). Among several candidate models considered, the model with river flow and release month was the most parsimonious; the best competing model was φ (~Dam:Year:month + RF) p(~Dam:Year:month + RF). Based on the best CJS models that included river flow and release months as covariates (the model with the lowest QAICs), we observed a positive correlation between flow and survival rate (survival increased as flow increased) for all three months. The highest survival rates over the range of flows were found for the March release groups, followed by April releases, and lastly February releases (Figure 9). However, the sample size for February releases was small (4% of total releases) compared to March releases (45%) and April releases (51%). Since Prosser was the only location with releases in each month, we could not compare the effect of release month for all release groups across all locations. Survival rates among years at the Prosser location (Figure 9) were highest for the March release groups.

Figure 9. The relationship between survival probability from release location to McNary Dam and the river flow at Prosser Dam for the smolt release groups each month. The relationship was developed using 7 years of PIT-tag data (2015-2022).



3.7 Smolt-to-Adult Returns (McNary juvenile to Bonneville adult)

Coho salmon return to the spawning area after a period of 0-2 years after outmigration. We estimated the smolt-to-adult return (SAR) for both the outmigration years 2020 and 2021, but the data for 2021 may not be complete at this time, and we may need to wait for another year for a full accounting of returns from outmigration year 2021. The results from previous years (2004-2020) showed that SAR estimates varied depending on the year and life stage at release (parr and smolt), as depicted in Table 16. On average, the SAR was slightly higher for the group released as parr (5.83±0.39%) compared to the SAR of the group released as smolts (5.48±0.1%). (see table 16 and figure 10). However, for the migration year 2021, the SAR was highest for the smolt group (6.87% ± 1.04%), while it was zero for the Parr group. This zero-return rate for the parr group could be attributed to the low number of available PIT tags (only 1,989) for that particular migration year. Due to the smaller sample size and the additional sources of mortality experienced by the parr group, it appears that so few tagged juveniles survived to ocean entry that none of them returned to Bonneville Dam.

When comparing just the in-basin brood fish released as parr and smolts in upriver tributaries targeted for natural spawning, SARs for the parr releases were 7.89% while SARs for the smolt releases were 5.14%, based on the migration years spanning from 2008 through 2019. Likewise, within the Naches River basin, SAR for the parr releases stood at 5.05%, while SARs for the smolt releases were recorded at 5.15%.

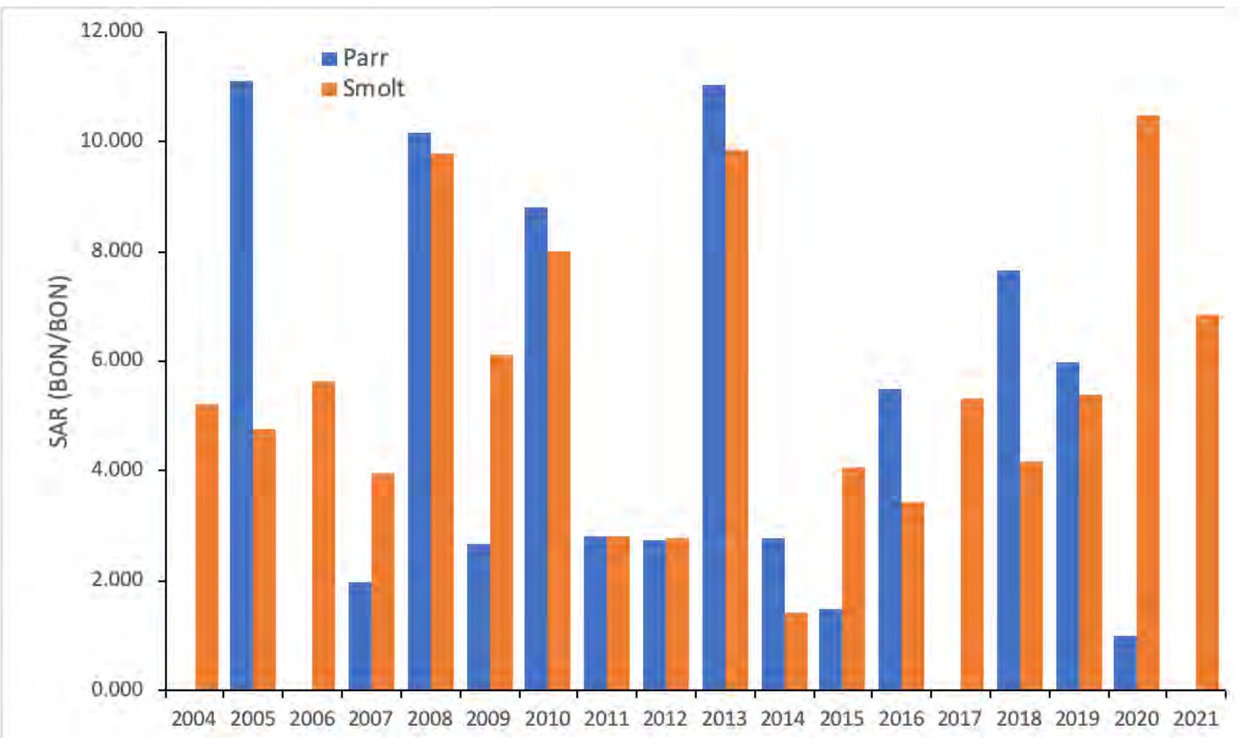
The variation in SARs among years can be associated with various factors, including smolt size, release and ocean entry timing, and ocean conditions. These factors can influence the survival and return rates of Coho salmon, leading to fluctuations in SAR estimates from year to year.

Table 16. Smolt-adult returns (SAR, based on juvenile detection at McNary Dam and adult detection at Bonneville Dam) for each release over migration years 2004-2021. The values with yellow color indicate the value is subject to revision if 2 or more year-ocean adults may return later. “N” represents the number of fish with PIT tags released; “SE” is the standard error.

Migration year	Parr			Smolt		
	N	SAR	SE	N	SAR	SE
2004	NA			12412	5.22	2.06
2005	9576	11.11	11.59	31246	4.76	1.32
2006	8091	0.00	0.00	21260	5.63	0.89
2007	11129	1.98	1.41	30681	3.97	0.72
2008	20507	10.17	1.93	33668	9.77	0.87
2009	29988	2.69	0.75	33146	6.13	0.69
2010	27325	8.82	1.14	22845	8.01	0.82
2011	27229	2.80	1.38	25286	2.82	0.92

2012	33657	2.74	0.71	26705	2.78	0.59
2013	31973	11.05	1.63	21023	9.86	0.89
2014	28782	2.78	0.95	19970	1.43	0.40
2015	28611	1.49	1.50	17544	4.07	0.90
2016	25815	5.48	1.49	25069	3.44	0.60
2017	NA			14469	5.31	1.16
2018	21244	7.65	1.47	19696	4.16	0.88
2019	41275	5.99	1.87	20305	5.38	1.16
2020	2538	1.00	0.76	13865	10.48	0.93
2021	1989		NA	9939	6.87	1.04
Average		5.83	0.39		5.48	0.10

Figure 10. Annual Smolt Adult returns (SAR) percentage Bonneville - Bonneville for groups released as "Parr" and "Smolt" for each migration year.



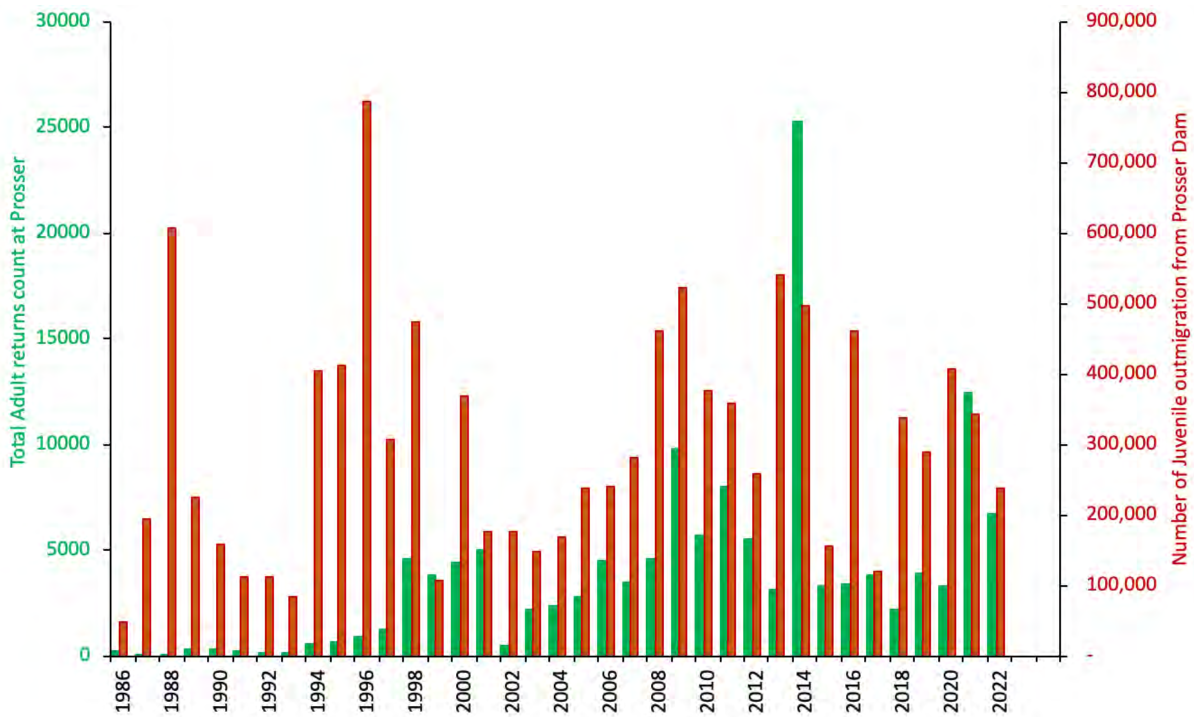
3.8 Adult returns

The figure 11 illustrates the number of juvenile outmigrants from Prosser and the adult returns to the Yakima River basin. From 1997 onwards, the average adult Coho escapement into the

Yakima Basin has been approximately 4,500 Coho per year. However, the highest recorded return of adults, combining both hatchery releases and natural production, exceeded 25,000 fish in 2014 (Figure 11). In 2022, the estimated total adult escapement was approximately 6,708.

The ratio between the number of juvenile outmigrants from Prosser and the adult returns into the Yakima Basin is approximately 1.2%. This indicates that, out of every 1,000 juveniles that migrate out from Prosser, around 12 adults successfully return back to the Yakima Basin.

Figure 11: Total juvenile outmigration from Prosser and the estimated adult escapement from 1986 through 2022.



3.9 Age- distribution at return

From outmigration years 2004 through 2022 a total of 4475 returning Coho with PIT tags that were released as smolt and 1521 returning Coho that were released as parr in the Yakima Basin were detected at Bonneville Dam (see Table 17). Among the tagged adults released as smolts, ~90% of the returning coho were age 3 (ocean age 1) while 10% of the returns were age 2 (ocean age 0), and less than 1% were age 4 (ocean age greater than 1). For the group released as Parr, the age distribution for the group released as parr was similar to the group released as smolts.

Approximately 93% of the returning Coho were age 3, 7% were age 2, and less than 1% were age greater than 3.

Table 17. Total number of PIT-tagged Coho detected at return to Bonneville Dam by ocean age (years) for the group of fish released as a life stage "smolt" (A) and the group of fish released as "Parr" (B). Values shaded yellow are subject to change based on any 2-ocean returns.

A. Smolts

Brd Year	Rel. Year	Migr. Year	Number of adult returns					
			Ocean Age <1	Ocean Age1	Ocean >Age 1	Ocean Age <1	Ocean Age1	Ocean >Age 1
2002	2004	2004	1	47	0	2.08	97.92	0.00
2003	2005	2005	12	167	0	6.70	93.30	0.00
2004	2006	2006	21	195	3	9.59	89.04	1.37
2005	2007	2007	5	188	0	2.59	97.41	0.00
2006	2008	2008	133	427	1	23.71	76.11	0.18
2007	2009	2009	17	260	0	6.14	93.86	0.00
2008	2010	2010	16	306	3	4.92	94.15	0.92
2009	2011	2011	3	136	2	2.13	96.45	1.42
2010	2012	2012	8	104	0	7.14	92.86	0.00
2011	2013	2013	19	546	0	3.36	96.64	0.00
2012	2014	2014	13	88	1	12.75	86.27	0.98
2013	2015	2015	13	64	0	16.88	83.12	0.00
2014	2016	2016	9	121	2	6.82	91.67	1.52
2015	2017	2017	16	131	0	10.88	89.12	0.00
2016	2018	2018	39	99	1	28.06	71.22	0.72
2017	2019	2019	8	192	0	4.00	96.00	0.00
2018	2020	2020	158	730	0	17.79	82.21	0.00
2019	2021	2021	24	146	0	14.12	85.88	0.00
2020	2022	2022	Not available yet					
Sum/Average			515	3947	13	9.98	89.62	0.39

B. Parr

			Number of adult returns					

Brd Year	Rel. Year	Migr. Year	Ocean Age <1	Ocean Age1	Ocean >Age 1	Ocean Age <1	Ocean Age1	Ocean >Age 1
2002	2004	2004	0	0	0			
2003	2005	2005	0	3	0	0.00	100.00	0.00
2004	2006	2006	0	6	0	0.00	100.00	0.00
2005	2007	2007	1	20	0	4.76	95.24	0.00
2006	2008	2008	30	242	0	11.03	88.97	0.00
2007	2009	2009	4	73	0	5.19	94.81	0.00
2008	2010	2010	10	246	0	3.91	96.09	0.00
2009	2011	2011	9	163	0	5.23	94.77	0.00
2010	2012	2012	15	73	0	17.05	82.95	0.00
2011	2013	2013	13	197	0	6.19	93.81	0.00
2012	2014	2014	2	30	0	6.25	93.75	0.00
2013	2015	2015	0	7	0	0.00	100.00	0.00
2014	2016	2016	2	52	0	3.70	96.30	0.00
2015	2017	2017	0	0	0			
2016	2018	2018	60	154	1	27.91	71.63	0.47
2017	2019	2019	8	98	0	7.55	92.45	0.00
2018	2020	2020	0	2	0	0.00	100.00	0.00
2019	2021	2021	0	0	0			
2020	2022	2022	Not available yet					
Sum/Average			154	1366	1	6.58	93.38	0.03

4. Acknowledgment

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APPENDIX E: Juvenile Outmigration Survival of Yakima Basin Summer Chinook Smolts to Prosser and McNary Dams, 2009-2023

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Executive Summary

Summer-run Chinook salmon in the Yakima River basin were once widespread but became locally extinct by the 1970s. Since 2009, the Yakama Nation has been actively engaged in a reintroduction program. This initiative involves transporting summer Chinook eggs from Upper Columbia Basin hatcheries to the Yakama Nation's Marion Drain Hatchery, where fertilization, incubation, and rearing occur. Sub-yearling presmolts are subsequently transferred from the hatchery to permanent and mobile acclimation sites upstream for eventual release as smolts into historical spawning and rearing areas within the Yakima Basin. This program employs diverse release strategies, including variations in release locations, life stages (yearling and sub-yearling), and experimentation with different release dates. These efforts aim to maximize the chances of establishing stable and robust natural-origin summer Chinook populations within the Yakima River basin and enhance population resilience to potential environmental changes.

In 2023, a total of 1,121,352 summer Chinook (sub-yearling and yearling) were released at five locations within the Yakima Basin. Among the PIT-tagged populations, altogether 56, 565 fish with PIT tags were released from five locations (Buckskin, Roza bypass, Wapato tailrace and Prosser). At the Prosser, two distinct groups existed: one reared in traditional raceways and another reared in circular raceways; as well as yearling. Both circular and tradional groups were released simultaneously from Prosser Dam on May 11th and 12th, 2023, totaling 5,580 fish from traditional raceways and 5,575 fish from circular raceways. This evaluation represents an ongoing annual monitoring effort, initiated in 2009, also aimed at assessing whether employing different rearing tanks results in improved post-release fish performance. Should alternative techniques prove more effective than the currently employed raceways, this study may guide decisions regarding potential shifts in fish rearing practices.

For data collected from 2009 to 2018, a logistic regression model (Neeley 2012) was used to estimate survival probability. However, since 2019, survival probability from release locations to downstream dams, along with detection rates at Prosser and McNary Dams, has been estimated using the Cormack-Jolly-Seber (CJS) mark-recapture model. Additionally, other statistical analyses have explored travel time and the impact of river flow. These analyses aim to answer various research questions, including the juvenile detection and survival rate from release sites to

McNary Dam of each group released at different locations. The general observations/results are given below:

- The survival rates of juvenile summer Chinook from release location to McNary Dam varied among years. In 2023, the average survival rate to McNary Dam for summer Chinook was 7.61% ± 2.76. Among the release groups, the highest survival rate was observed in the Roza group, but it had a large standard error (SE), indicating less precision, followed by the group released from Prosser, which was reared in circular raceways and had the second-highest survival rate (21.81% ± 7.6). The yearling group released at Prosser had a survival rate of 45.51% ± 4.4, while the lowest rate was found in the Wapatox group released as subyearling (2.14% ± 2.5, see Table 8).
- Analysis also reveals the importance of release month and fish size on survival rates. For instance, for fish with a length of 50mm released in April, the survival rate to Prosser Dam exceeded 50%, whereas the same-sized fish released in June had a survival rate of approximately 10%. However, for larger fish, release timing seemed to have no significant effect on survival rates.
- Avian predation on Yakima Basin summer Chinook is evident, with PIT tag recoveries providing insights. For instance, in 2017, out of 17,539 PIT-tagged summer chinook released, 403 fish were detected at McNary Dam, while 660 fish were retrieved on Badger Island. In 2023, among the 56,565 PIT tags released, 1051 summer Chinook PIT tags were detected at McNary Dam, while 5,46 PIT tags were recovered on Badger Island. It's essential to acknowledge that PIT tags found on islands represent only a fraction of tagged fish preyed upon by avian predators due to factors such as tag excretion in other areas on the way going to bird colonies, undetected tags on islands, tag displacement, damage, or loss during flooding. This recurring pattern of increased fish recapture in bird colonies highlights a significant predation impact, emphasizing the need for action to address the predation issue in the Yakima River basin.
- Smolt-Adult-Return (SAR) is a crucial metric indicating the percentage of smolts that survive and return to spawn. It provides insight into the sustainability of adult returns over time. SAR estimates from 2009 to 2018 (migration year) varied by year, with the highest SAR observed for fish released in 2011 (10.24% ± 1.14%) and 2012 (4.24% ± 0.09%). In contrast, the drought year of 2015 saw a SAR of zero, while other years had approximately 1% SAR from

Bonneville to Bonneville. The variation in SARs is influenced by factors such as smolt size, release and ocean entry timing, and ocean conditions.

- The age composition of returning adult fish revealed that 64% were age 4 (3-year ocean age), 23% were age 3 (2-year ocean), 9% were age 5 (4-year ocean), and less than 1% were age 6 (5-year ocean age). Additionally, 4% of the juveniles detected at Bonneville returned as jacks (age-2, 1-year ocean).

1. Introduction

The summer Chinook (*Oncorhynchus tshawytscha*) is one of the three historical chinook runs in the Yakima River basin. Adults of the summer run first enter the Columbia River from the ocean in May, and the Yakima River as early as June, but the summer run to the Yakima is shaped by flow and temperature in the lower Yakima River, which is strongly influenced by irrigation withdrawals and return flow. Unfavorable conditions can delay entry of the latter part of the summer run from the Columbia River until near the fall spawning season. Juvenile summer Chinook typically leave the Yakima River from late spring to early summer of the year after spawning. Summer Chinook were once widely distributed in the Yakima and Naches rivers (Figure 1) but were extirpated from the Yakima basin by 1970. For decades, several programs such as habitat restoration and species reintroduction were implemented in the Yakima River. After decades of habitat and instream flow restoration, coupled with improved juvenile and adult passage at irrigation diversions and hydropower projects, reintroduced adult summer chinook are returning along with fall chinook to the Yakima basin. Annual abundance of summer/fall Chinook at Prosser Dam on the lower Yakima River has increased from an average of just over 1000 fish from 1983 through 1999 to over 3,600 fish on average during the period 2000-2023). We have successfully achieved some level of natural production and local adaptation, but both runs continue to depend on hatchery supplementation.

Based on 2009-2023 release data, an annual average of 359,660 summer Chinook juveniles were released in the Yakima basin (Table 1). Summer chinook eggs are brought either from the Entiat or Wells hatchery (Entiat and Wells stocks) to the Yakama Nation's Prosser Hatchery for fertilization, incubation and rearing through the fall and winter. The following spring, sub-yearlings are moved from the hatchery upstream to sites on the Yakima and Naches rivers adjacent to historical spawning areas where they are acclimated and released. Several release strategies have been utilized to maximize the likelihood of achieving stable and abundant returns of the species to the Yakima River and to enhance the stability and resiliency of the population against potential environmental changes. The strategies include releasing the juveniles from different locations (spatial variation) and on different dates (temporal variation). Whether one release strategy performs better than other strategies in terms of juvenile survival and smolt-to-adult return (SAR) are fundamental questions in determining whether species management and production goals are being reached. Each year a portion of each release group has been PIT-tagged as part of a long-term monitoring program to refine project objectives and strategies, applying what is learned from experimentation, monitoring, evaluation and literature reviews within an adaptive management framework. This evaluation is an update of ongoing annual monitoring that began with the first reintroductions in 2009. Furthermore, hatchery fish are typically raised in traditional rectangular raceways, which lack uniform water velocity across the raceways. However, recently, circular raceways have been introduced. Therefore, since 2023, we have initiated an experiment to evaluate the impact of fish rearing in two types of raceways (rectangular (traditional) and circular) on fish performance, especially after their release into the river.

Juvenile survival rates often vary by seasons and years. This variation can be associated with rearing history and environmental conditions. For example, Zabel and Achord (2004) found that juvenile survival rate of wild salmonids was related to fish size (fork length), with larger juveniles having higher downstream survival. Survival rate also increases as river flow increases. Although the Yakima River is highly controlled by storage reservoirs and irrigation and hydropower withdrawals, there is still a large variation in the flow pattern within and across years, which can affect the survival rate of juvenile salmon. Ocean-type summer and fall chinook, which naturally outmigrate from Columbia River tributaries in late spring and early summer, can be harmed by rising water temperature as they attempt to leave the Yakima Basin. Based on the effect of temperature, one can postulate that survival rate should be lower if the fish are released in later months, e.g. June, than fish released as early as April. However, individuals released earlier are likely to be smaller than fish released later and closer to natural outmigration timing. There may thus be an interaction between fish size and release timing on survival.

The primary objectives of this analysis are to determine the survival rate from release sites to Prosser Dam or McNary Dam of the groups released at different locations in the Yakima Basin; and understand how other factors (fish size and release date) affect juvenile survival rates using previous years' data (2009-2021). This information is critical for recovery of depressed Chinook stocks.

To achieve these objectives, we focused on the following research questions:

- What was the juvenile detection and survival rate from the release sites to Prosser Dam McNary Dam of each of the release groups during 2023?
- Does juvenile survival and travel time vary between sub-yearling and yearling release groups?
- What was the effect of release date and fish size at the time of tagging on survival rate and travel time?

- Do fish reared in circular raceways exhibit different post-release performance compared to those reared in traditional raceways?
- What was the Smolt-Adult return rate (SAR) for each year's combined release groups over the study period (2009-2023)?
- What was the age composition of the adult returns?

2. Methodology

2.1. Geographical distribution: historical and current

Spring, summer and fall runs of Chinook salmon are among the salmon species native to the Yakima River basin. Their historical spawning area encompassed the entire Yakima River and its larger tributaries (Figure 1A) but has been reduced by changes in habitat, passage and instream flow (Figure 1B), many of which have been remedied in recent years. A major objective of the summer-run Chinook reintroduction program, begun in 2009, is to re-establish spawning in the primary historical spawning areas for this run, which are the Yakima River upstream of Wapato Dam through the canyon reach above Roza Dam, and the Naches River from the Yakima River to its confluence with the Tieton River (Figure 1C). The uppermost acclimation and release sites designated in the reintroduction program were located to facilitate adult homing throughout this historical geographical distribution, while releases to the lower Yakima River were intended to maximize survival rates and improve opportunities to collect returning adults as we work to establish a localized brood source (Figure 1D). Figure 1D shows the release locations over the entire study period from 2009 through 2023.

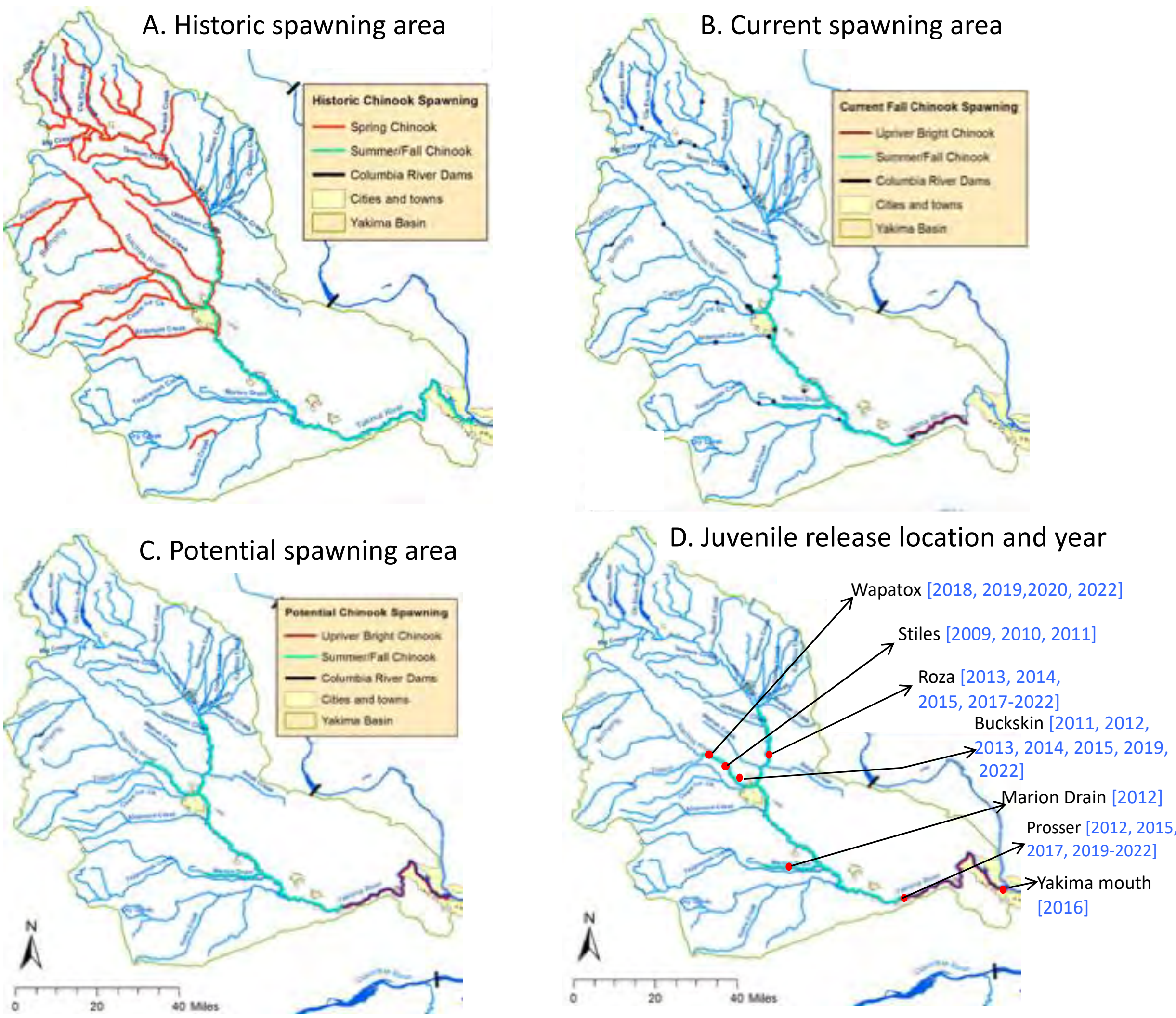

Figure 1. Historical (A), current (B) and potential (C) summer Chinook spawning areas; and the locations/tributaries/river segments (D) where summer Chinook juveniles were introduced from 2009 through 2022.

2.2. Brood stocks and fish data

Every year, eggs of summer Chinook have been brought to Yakima basin either from Wells Hatchery, Entiat Hatchery or Eastbank Hatchery. The adult fish were spawned at either Wells or Entiat; green eggs and milt were transferred to the YN Prosser Hatchery for fertilization, incubation and rearing. Yearlings released from Prosser Hatchery were reared in the Marion Drain hatchery, while the subyearlings were reared in Prosser hatchery. Fish were directly released from the hatchery or from acclimation facilities.

All PIT tag release and detection data are available in the PTAGIS database maintained by the Pacific States Marine Fisheries Commission. We queried PTAGIS (https://www.ptagis.org/) in April 2023 to retrieve available PIT-tag detection information for all summer Chinook juveniles released in the Yakima Basin from migration year 2009 through 2023. On average 36,333 juvenile summer Chinook were PIT-tagged per year from 2009 through 2023. In 2023, a total of 1,121,352 summer Chinook were released in the Yakima Basin. This release included 36,068 fish with PIT tags between May 11th, 2022 (as detailed in Table 1 and Table 2). More over, 5,575 fish from traditional raceways and 5,580 fish from circular raceways were released on April 26th and May 11, 2023, respectively.

Table 1. Total annual releases of summer Chinook and the numbers and percentages of PIT tags in each release.

	Total Release		
Year	Total release (with & without PIT tags)	PIT tags	PIT tag Percentage (%)
2009	180,911	30,045	16.61
2010	200,747	29,997	14.94
2011	215,770	49,893	23.12
2012	197,103	29,996	15.22
2013	136,563	40,507	29.66
2014	254,881	30,278	11.88
2015	277,448	34,457	12.42
2016	37,000	37,000	100.00
2017	244,499	34,826	14.24
2018	74,000	30,131	40.72
2019	806,000	41,143	5.10
2020	1,307,843	12,814	0.94
2021	279,594	66,233	23.68
2022	822,875	41,609	5.06
2023	1,121,352	36,068*	3.21
Average	410,439	36,333	21%

* Only sub-yearlings are included in this figure. The total number of yearlings with PIT tags was 20,497, but they have not been included.

For each fish with a PIT tag we constructed a detection history: a record indicating all detection locations and whether the tagged fish was detected or not detected at each juvenile detection site, focusing on Prosser, McNary, John Day and Bonneville dams (PRO, MCJ, JDJ, B2J, BCC), and the Estuary Towed Experimental Array (TWX).

Table 2. Brood year, broodstock, and the number of PIT-tagged sub-yearling summer Chinook released by location and date (Early, Mid and Late) from outmigration years 2009 through 2023. Fish were released during April, May and June every year. Releases on or before May 10; May 11 through May 25; and after May 25 are represented as Early, Mid and Late release periods, respectively.

Brood Year	Broodstock	Migration Year	Release Location	Life stage	Early									Mid													Late						total
					April				May					May													May		June				
					4/10	4/24	4/29	4/30	5/6	5/7	5/8	5/9	5/10	5/11	5/12	5/13	5/14	5/15	5/16	5/17	5/18	5/19	5/20	5/23	5/24	5/25	5/29	5/31	6/1	6/12	6/2	6/5	total
2008	WELLS	2009	StilesPond																											30045			30045
2009	WELLS	2010	StilesPond														29997																29997
2010	WELLS	2011	NelsonSp				29893																										29893
2010	WENN	2011	StilesPond																20000														20000
2011	WELLS	2012	MarionDH																						9999								9999
2011	WELLS	2012	NelsonSp																		9998												9998
2011	WELLS	2012	Prosser														9999																9999
2012	WELLS	2013	NelsonSp															15063											10053				25116
2012	WELLS	2013	RozaDam																								15087						15087
2013	WELLS	2014	NelsonSp												10088																10109		20197
2013	WELLS	2014	RozaDam																													10081	10081
2014	WELLS	2015	NelsonSp													10332																	10332
2014	WELLS	2015	Prosser						4030																								4030
2014	WELLS	2015	RozaDam				10043												10052														20095
2015	WELLS	2016	RozaDam				37000																										37000
2016	WELLS	2017	NelsonSp																									17296					17296
2016	WELLS	2017	Prosser															2504															2504
2016	WELLS	2017	RozaDam																							15026							15026
2017	WELLS	2018	RozaDam															15082															15082
2017	WELLS	2018	Wapatox																				15049										15049
2018	WELLS/ENT	2019	NelsonSp																	10365													10365
2018	WELLS/ENT	2019	Prosser													10267																	10267
2018	WELLS/ENT	2019	RozaDam													10254																	10254
2018	WELLS/ENT	2019	Wapatox																			10266											10266
2019	WELLS	2020	Prosser		5011																												5011
2019	WELLS	2020	RozaDam												2813																		2813
2019	WELLS	2020	Wapatox								4996																						4996
2020	WELLS	2021	Prosser	Sub-yearling						15012																							15012
2020	WELLS	2021	Prosser	Yearling		20640																											20640
2020	WELLS	2021	Wapatox (Riv)	Sub-yearling				15815																									15815
2020	WELLS	2021	Wapatox(pipe)	Sub-yearling				14766																									14766
2021	EastbankCirs	2022	Prosser (cir.)	Sub-yearling								5240																					5240
2021	EastbankRw	2022	Prosser (race)	Sub-yearling								5210																					5210
2021	WELLS/ENT	2022	RozaDam	Sub-yearling																			13810										13810
2021	WELLS/ENT	2022	Nelson	Sub-yearling									3544																				3544
2021	WELLS/ENT	2022	Wapatox	Sub-yearling																				13805									13805
2022		2023	Prosser (cir.)	Sub-yearling										5575																			5575
2022		2023	Prosser (race)	Sub-yearling										5580																			5580
2022		2023	Buckskin	Sub-yearling										11133																			11133
2022		2023	Roza Tailrace	Sub-yearling										11152																			11152
2022		2023	Wapatox	Sub-yearling										2628																			2628

Note: "WELL" represents Wells Hatchery broodstock , "WENN" represents Wenatchee stock, "WELLS/ENT" represents Wells Hatchery or from Entiat hatchery Stock.

2.3. Statistical analyses

2.3.1. Survival and Detection Probability

Juvenile survival probabilities from release locations to Prosser and/or McNary were estimated for each release group from migration years 2009 through 2022. We also estimated the average survival rate for each migration year regardless of release site. For releases from 2009 through 2018 a logistic regression model (Neeley 2012) was used to estimate survival. Beginning in 2019 and in this report, survival probability from release locations to downstream detection at McNary Dam; and the detection rate at Prosser and McNary dams were estimated using the Cormack-Jolly-Seber (CJS) mark-recapture model (White and Burnham 1999; Lebreton et al. 1992; Williams et al. 2002, Conner et al. 2015), which has been commonly used within the

Federal Columbia River Power System (FCRPS) to estimate survival rates for juvenile salmon and steelhead (Tuomikoski et al. 2013). The model uses multiple detections of individually marked fish at several dams with PIT-tag detection capabilities (i.e. antenna arrays). One of the assumptions of the CJS model is that there is no immigration or emigration during capture and recapture intervals, which is valid for discrete tag groups migrating through the hydrosystem (which involves passage at several hydroelectric dams) because all fish in the tag group are moving in one direction and over a relatively short period (Conner et al. 2015). All of the assumptions of the CJS models are considered to be met.

To evaluate post-release performance among releases grouped by life stage (yearling vs. sub-yearling) or release location (Naches River vs bypass pipe at the Wapatox diversion) we compared juvenile survival rates and travel times. We also introduced fish size and release period as covariates in the CJS model to determine how release date (April, May or June) and fish size affected the survival rate from the release location to Prosser, and from Prosser to McNary. This CJS model was built within RMark (Laake 2019) in R, an extension of Program MARK (White and Burnham 1999).

2.3.2. Relationship between annual survival rate and river flow

Several environmental factors are known to influence downstream smolt survival, and river flow is among the most impactful (Raymond 1968; Connor et al. 2003; Tiffan et al. 2009). We therefore further evaluated whether there was a relationship between the annual survival rate and the average river flow for two summer months (May and June) measured below Prosser Dam. We chose only May and June because most of the juvenile summer Chinook were released from the end of April (29^{th}) to the first week of June (5^{th})) from 2009 through 2023, and they usually leave the Yakima River within 3 or 4 weeks after release. Given this timing, May and June flow can be the most influential factor for the outmigration of this run of Chinook. We downloaded river flow data for the Bureau of Reclamation gaging station (YRPW) located below Prosser Dam in the Yakima River, using the Hydromet site: https://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html, which was accessed in April 2024. A univariate linear relationship between the average survival rate of each migration year and the average river flow (May and June) of each year was built to determine whether the average annual survival rate was a function of river flow.

2.3.3. Relationship between survival rate, release month and fish size

We selected only the fraction of those tagged fish with fish length information for this analysis. Fish release dates were categorized by month. As mentioned under subheading 2.3.1, we used fish length and release month as covariates in the CJS model. Using this model, the average survival rates from release location to Prosser Dam, and from Prosser to McNary Dam were estimated for each release group with its release month and average fish length.

2.3.4. Travel time and migration rate

Travel time was estimated as the difference between either the date of release or the date of detection at Prosser Dam (site PRO), and the date of detection at McNary Dam (MCJ) or Bonneville Dam (B2J or BCC) for each group. Migration rate was calculated as length of the reach of interest (km) divided by travel time in days for the group.

2.4.5. Smolt-to-Adult-Returns (SAR)

SAR, or the percentage of smolts that survive and return as adults, is a metric that captures most of the cumulative impacts of the hydro-system and ocean conditions on anadromous fish, indicating how sustainable the returns of adults are over time. In our analysis the SAR was estimated as the percentage of smolts detected at Bonneville Dam returning as adults to Bonneville Dam using the following equation for each year and release group:

$$U_{at\ BON} / J_{at\ BON}$$

Where, $U_{at\ BON}$ is a total number of PIT tagged fish detected at Bonneville Dam both during outmigration as a juvenile and immigration as adults. $J_{at\ BON}$ is the total number of fish detected at Bonneville Dam as juveniles. Because summer Chinook can spend as many as 5 years in the ocean, we estimated SAR of the populations that out-migrated from 2009 through 2017.

The variance of SAR estimates for each category was computed by a non-parametric bootstrap re-sampling method (Efron and Tibshirani 1993; Manly 1997). For each sample data set (the total release group for each migration year), individual capture histories were resampled with replacement. One thousand bootstrap sample data sets were constructed and 1000 estimates of SAR were generated. Statistical bias was assessed as the difference between the mean of the bootstrap replicates and the point estimate derived from the original data (Efron and Tishirani, 1993). Due to the non-normal distribution of bootstrap SAR estimates, bias correction was used to construct 95% confidence intervals as suggested by Manly (1997).

2.4.6. Age composition of adult returns

Age composition of adult returns was estimated by subtracting the year of adult return detection at Bonneville Dam from the brood year (migration year – 1 for subyearling releases and migration year – 2 for yearling releases).

3.0. Results and discussion

3.1. Fish length

During the study period from 2009 through 2023, a total of 91,634 PIT tags fish had fish size information (Table 3). Based on the available data, the average size of the sub-yearlings (fork length) at the time of tagging was 71 mm, and the size of the fish released in different months was found to be different. Fish (subyearling) released in April were somewhat smaller (84.32 mm) than fish released in May (73.81mm), but the fish released in June averaged only 62.53mm. One would expect that fish released later would be bigger than the fish released earlier, but we found that fish released in June were smaller than the group released in May. Not getting the same result as we expected might be due to a number of reasons. One possible reason could be differences in incubation and rearing temperature among groups from different hatcheries with different water sources. Grouping by age and release location, the size of the yearling group averaged 140.55±0.4mm, whereas the average sub-yearling released from Prosser measured 79.60±0.20 mm.

When comparing the fish length between those reared in circular and traditional raceways in 2022, it's evident that the fish reared in circular raceways were larger (81mm) than those reared in traditional ones (76mm; see), but in 2023 there was no difference.

Year	April			May			June			Pooled		
	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE
2009							30036	63.17	0.03	30036	63.17	0.03
2010				22711	74.62	0.055				22711	74.62	0.05
2011	1467	67.58	0.14	3619	91.33	0.388				5086	84.48	0.32
2012				3095	68.27	0.131				3095	68.27	0.13
2013				3000	68.51	0.121				3000	68.51	0.12
2014				1268	63.83	0.105	1845	61.89	0.11	3113	62.68	0.1
2015	702	66.75	1	3071	69.41	0.182				3773	68.92	0.27
2016				1106	75.65	0.649				1106	75.65	0.65
2017				918	66.2	0.728				918	66.2	0.73
2019				264	75.21	0.423				264	75.21	0.42
2020				4974	75.71	0.094				4974	75.71	0.09
2021 (Yearling)	1418	140.5	0.41							1418	140.5	0.41
2021(Sub-Yearling)	2952	75.16	0.4	1117	79.61	0.2				4069	77.38	0.1
2022 (SubY.circ)	504	80.7	0.3							504	80.7	0.3
2022 (Sub.Y.race)	512	75.25	0.31							512	75.25	0.31
2023 (yearling)*												
2023 (Sub.Y.circ)				508	77.39	0.18				508	77.39	0.18
2023 (Sub.Y.trad)				526	77.62	0.17				526	77.62	0.17
Mean		84.32			73.81			62.53			77.165	

Note: *represents the fish size was not measured in that year

Table 3. Average fish size (mm) at the time of tagging by releasing year and month (April, May, June). The number "n" represents the subset of fish with length data in the PIT Tag Information System (PTAGIS; http://www.ptagis.org).

3.2. Detection Probabilities at Prosser and McNary

The probability of detection of juvenile summer Chinook at McNary Dam varied among years (Table 4). Of the five groups released in 2023, only the group released at Roza Dam exhibited a lower detection rate (1.50% ± 0.08). However, the other four groups had relatively similar detection rates at McNary Dam (see Table 5). Specifically, when comparing the detection rates between the two groups reared in circular and traditional raceways (table 5 and 6), the circular-reared group had a rate of 4.67% ± 2.04, while the traditional raceways-reared group had a rate of 6.25% ± 2.28.

When examining the variability in the detection rate at McNary Dam across different years (Table 4), it becomes apparent that this variation may be attributed to the operational practices of surface-passage structures. The detection rate at Columbia River dams is contingent on the percentage of fish that access juvenile bypass systems where detectors are installed. In recent years, there has been a notable increase in the use of spill and the implementation of surface-passage structures (such as spillway weirs) as a primary management strategy to enhance the survival of juvenile fish navigating the dams within the Federal Columbia River Power System. This increased reliance on spillways results in a reduced proportion of fish entering juvenile bypass systems where PIT tags can be detected (Widener et al. 2018). Consequently, fluctuations in spill and flow can give rise to variable detection rates across different years or within a single migration season.

Table 4. Annual detection and survival probabilities for summer Chinook (in percent) at Prosser and McNary Dam with standard errors, (SE) during the period from 2010 through 2023. Enumeration of fish fate (detection events) is coded by detection (1) and no detection (0). For example, for the McNary Dam: the code “1.0.1” means not detected at McNary Dam but detected downstream of McNary Dam, “1.1.0” means detected at McNary Dam but not detected downstream, and “1.1.1” means detected at both McNary Dam and downstream. “N” is the total number of PIT-tagged summer chinook released.

Year	N	Prosser Dam					McNary Dam				
		Detection events			Detection Prob. %	Survival Prob%	Detection events			Detection Prob. %	Survival Prob%
		1.0.1	1.1.0	1.1.1			1.0.1	1.1.0	1.1.1		
2010	29747	667	4712	359	34.99 ± 1.4	48.72 ± 2.02	700	865	161	18.69 ± 1.3	18.4 ± 1.2
2011	49365	2392	1187	87	3.5 ± 0.3	73.54 ± 7.47	2295	2151	328	12.50 ± 0.65	40.16 ± 1.9
2012	26562	891	2242	126	25.12 ± 2.91	64.09 ± 5.20	1469	830	187	11.29 ± 0.7	30.2 ± 1.9
2013	30186	1210	8171	413	28.57 ± 0.3	100 ± 0.0	920	1360	288	23.9±1.2	22.9±1.1
2014	30524	278	5506	150	35.04 ± 2.3	52.87 ± 3.4	300	361	67	18.3±2	7.68 ± 0.8
2015	33829	17	662	0	1.95 ± 0.0	NA	27	15	2	6.88±4.7	0.72 ±0.46
2016	35546	2163					932	1933	230	19.8±1.16	30.74 ± 1.7
2017	17534	289	2098	96	24.93 ± 0.2	50.18 ± 4.36	604	308	77	11.3±1.21	19.4±1.88
2018	30130	126	1749	14	10.00 ± 2.5	58.51 ± 14.7	123	11	27	18±3.14	2.58±0.41
2019	41151	185	3161	40	17.77 ± 2.5	43.75 ± 6.24	334	199	26	7.22±1.36	7.57±1.35
2020	12820	66	1342	30	31.25 ± 4.7	35.94 ± 5.3	203	81	15	6.88±1.71	11.42±2.63
2021	66233	523	4229	62	43.80 ± 4.23	28.65± 2.76	88	848	14	4.17±0.68	21.14 ± 3.3
2022	31173	658	2962	198	43.82 ± 2.65	23.14± 1.44	85	451	33	27.97±4.13	12.71 ± 1.8
2023	24913	23	4108	8	21.42 ±1.09	77.10±39.44	85	1044	7	7.61±2.76	24.41±8.84

NA indicates model convergence issue due to no downstream detections

Table 5. Summary of yearling and sub-yearling summer chinook releases, detections, survival and travel time by release group to McNary Dam for 2021, 2022 and 2023. "Det.Prob%", and "Surv. Prob%" are the detection probability ±SE at McNary Dam, survival probability ± SE from the release location McNary Dam, respectively. "PRO", "MCJ", "JDJ" and "BON" are the number of PIT tags detected at Prosser, McNary, John Day and Bonneville dams, respectively. "N" is the total release number with PIT tags.

							No. of Fish detection at				Release Location to McNary Dam	
Mig. Year	Stock	Life Stage	Rearing	Release location	Release date	N	PRO	MCJ	JDJ	BON (B2J+BCC)	Det. Prob.%	Surv.Prob.%
2021	Wells	Yearling	Marin Drain	Prosser	7-May-2021	20649		329	254	593	3.87±0.79	41.09 ±8.11
2021	Wells	Subyearling	Prosser Hat	Prosser	24-Apr-2021	15012		119	176	121	2.47 ±1.41	31.97 ±8.80
2021	Wells	Subyearling	Prosser Hat	Wapatox (in River)	30-Apr-2021	15815	2050	86	88	83	7.22 ±2.84	7.52 ±2.86
2021	Wells	Subyearling	Prosser Hat	Wapatox (in Canal)	30-Apr-2021	14766	1787	51	104	65	6.15 ±2.98	5.61 ±2.98
2022	Eastbank	Subyearling	Prosser Cir. Race	Prosser	9-May-2022	5206		64	116	29	27.77 ±7.47	20.03 ±3.17
2022	Eastbank	Subyearling	Prosser Trad. Race	Prosser	9-May-2022	5240		53	58	38	26.19 ±6.78	14.16 ±2.04
2022	WELLS/ENT	Subyearling	Prosser	Roza Dam	20-May-2022	13808	1261	273	209	66	12.79± 2.63	25.75 ±5.38
2022	WELLS/ENT	Subyearling	Marion Drain	Nelson (Buckskin)	10-May-2022	3543	305	118	81	44	29.54 ±6.87	18.34 ±4.17
2022	WELLS/ENT	Subyearling	Prosser	Wapatox	23-May-2022	13822	1594	116	101	45	28.26 ±6.66	5.35 ±1.23
2023	Eastbank	Subyearling	Prosser	Prosser Cir. Race	11-May-23	5575		76	38	78	4.67± 2.04	21.81± 7.6
2023	Eastbank	Subyearling	Prosser	Prosser Trad. Race	12-May-23	5580		48	51	59	6.25± 2.28	18.4 ±7.57
2023	WELLS/ENT	Subyearling	Marion Drain	Buckskin	12-May-23	11133		96	79	158	6.19± 1.64	19.64± 5.30
2023	WELLS/ENT	Subyearling	Prosser	RozaTailrace	12-May-23	11152		82	59	147	1.50± 0.08	77.66 ±44.1
2023	WELLS/ENT	Subyearling	Prosser	WaptoTailrace	13-May-23	2628		3	0	3	3.33± 2.72	2.14± 2.5
2023	Eastbank	Yearling	Prosser	Prosser	24-Mar-23	20597		746	544	643	7.99± 0.81	45.51 ±4.4

Table 6. Detection rate at McNary Dam (MCJ) for yearling and sub-yearling summer Chinook released from 2010 to 2023.

Detection Probability at McNary Dam (MCJ)

Migration year	Stiles	Buckskin	Marion drain	Roza	Prosser	Yakima mouth	Wapatox	Pooled
2010	18.7 ± 1.3							18.7 ± 1.32
2011	10.9 ± 1	13.5 ± 0.9						12.5 ± 0.6
2012		9.5 ± 1.1	12.6 ± 1.3		12.4 ± 1.7			11.29 ± 0.7
2013		25.7 ± 1.6		21.5 ± 1.9	11.8 ± 7.8			23.89 ± 1.2
2014		18.7 ± 2.3		14.1 ± 4.3	33.3 ± 15.7	NA		18.25 ± 2
2015		0.9485±156		0.022±0.001	19.8 ± 1.2			6.88 ± 4.7
2016					12.5 ± 3.7			19.79 ± 1.16
2017								11.3 ± 1.21
2018				18 ± 3.3			18.2 ± 11.6	18 ± 3.14
2019		5.6 ± 5.4		5.9 ± 2.4	7.9 ± 1.7		0.939 ± 18570*	7.22 ± 1.36
2020		6.2 ± 2.7		6.7 ± 2.6	8.5 ± 4.1			6.88 ± 1.71
2021					0.61 ± 0.42 (yearling); 2.48 ± 1.14 (Subyearling);		6.15±2.98 (Pipe); 7.22±2.84 (River)	4.18 ± 0.68
2022		29.54±6.87		12.79±2.63	27.77 ±7.47 (Circu); 26.19± 6.78 (Tradi);		28.26 ±6.66	27.96 ± 4.13
2023		6.19±1.64		1.50 ± 0.08	4.67 ±2.04(Circu); 6.25± 2.28 (Tradi);		3.33 ±2.72	7.61±2.76

** Model convergence issue due to no downstream detections.*

Note: Some juveniles were detected at John Day Dam but not detected at BON. The number of detections attributed to Bonneville Dam includes fish that were detected either at John Day Dam (JDJ), Bonneville Dam (B2J or BCC), or by the Estuary Towed Experimental Array (TWX).

3.3. Juvenile Release-Prosser and McNary Survival Rate

3.3.1. Annual juvenile Survival rate

The annual survival rate of juvenile summer Chinook from release site to Prosser and McNary Dam varied among years (Figure 3; Tables 4 and 7). The highest average annual survival rate at McNary Dam was in 2011 (40.15±1.94%); and the lowest survival rate was in 2015 (0.73±0.47%) and the same trend was followed by the Prosser Dam (73.64±7.47 in 2011 and 1.95±0 in 2015). In terms of last year (2023) release groups, the average annual survival rate from all release locations to McNary was 24.41% ± 8.84%, marking a decrease compared to the preceding two years (2020-2023). When comparing the two groups (circular versus traditional raceways), the survival rate was higher for the group reared in circular raceways (21.8% ± 7.6) than for the group reared in traditional raceways (18.4% ± 7.6, see table 5 and 8).

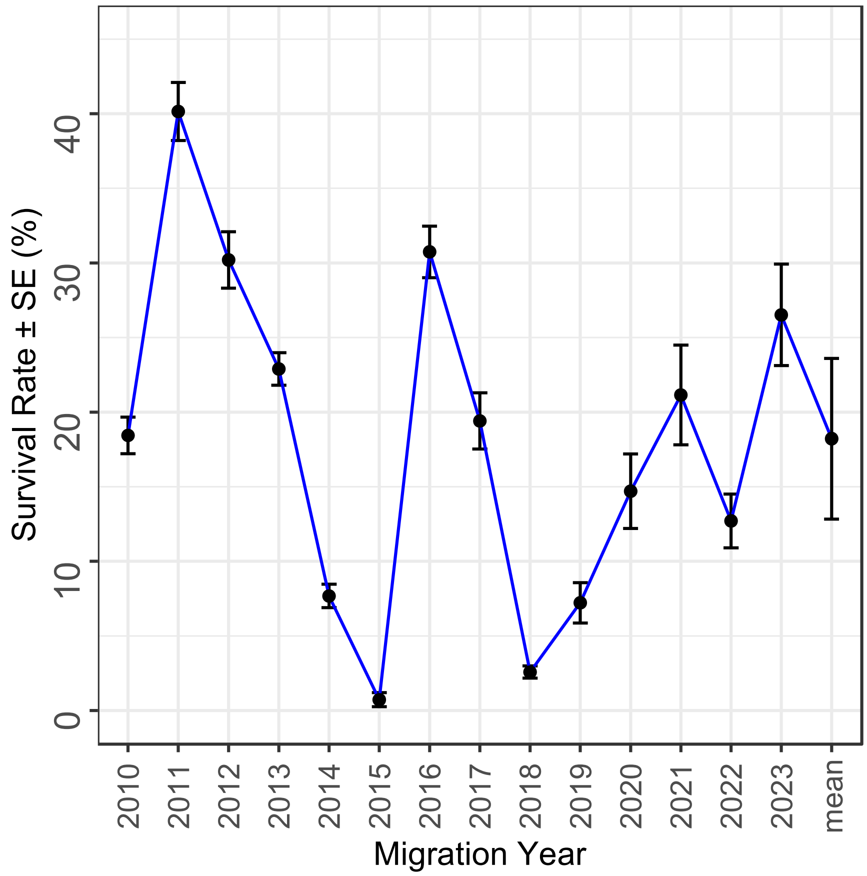

Figure 3. Average annual survival rate (release site to McNary Dam) for juvenile summer Chinook released from 2010 through 2023.

Table 7. Total release, survival rate from release locations to McNary Dam and its standard error (SE) and the average river flow in May and June of each year from 2010 through 2023.

Outmigration /Release Year	Released fish with PIT tags	Survival Rate (%)		Average River flow (cfs) (May & June)
		Average	SE	
2010	29747	18.44	1.22	2896
2011	49321	40.15	1.94	9305
2012	29821	30.20	1.89	7102
2013	30186	22.89	1.09	3842
2014	30524	7.68	0.79	3131
2015	33829	0.73	0.47	699

2016	35546	30.74	1.73	2559
2017	17534	19.41	1.88	5400
2018	30028	2.58	0.41	4064
2019	41071	7.22	1.35	1307
2020	12729	14.70	2.50	1795
2021	66233	21.15	3.34	2265
2022	41609	12.71	1.8	4311
2023	56665	24.41	8.84	3700

We further explored whether Yakima River flow below Prosser Dam had an effect on survival rate. We built the univariate relationship between the average river flow in May and June and the annual survival rate, and found that survival rate was strongly influenced by the May and June average river flow (R^2=0.47, p=0.01, see Figure 4). It indicates that survival rate was a function of river flow, however the river flow was able to explain only about 47% of the annual variation in survival rate. Other factors such as temperature or predation or interactions between temperature might also have affected the survival rate, but these variables were not included in the model. Further investigations, especially into how release period and fish size affected survival rate, are discussed in Section 3.3.4. (Effect of release period and fish size on survival).

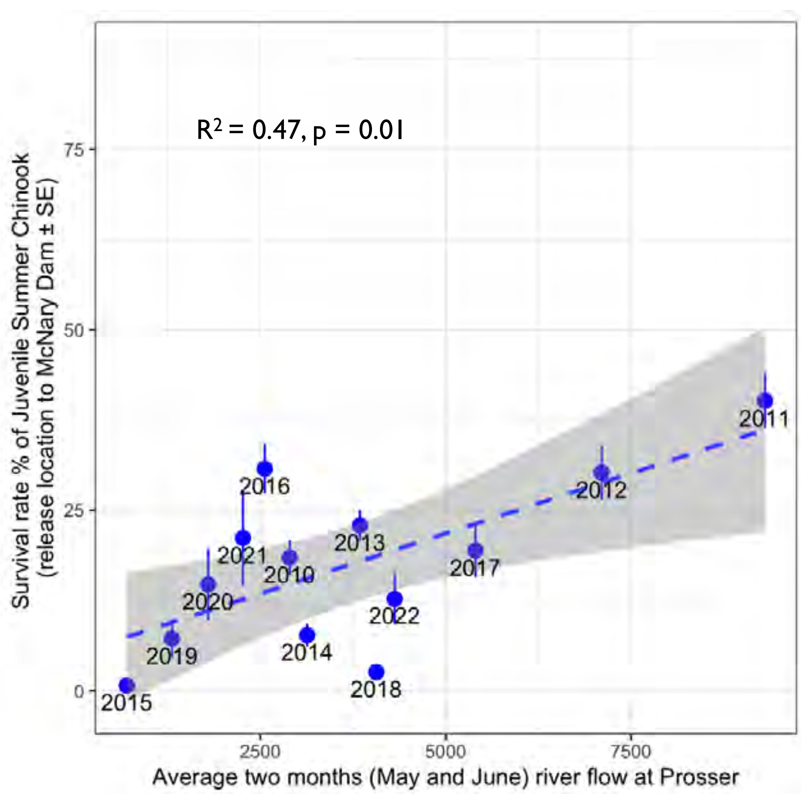

Figure 4. Relationship between average May-June river flow and the annual survival rate of juvenile summer Chinook from all release sites to McNary Dam for all years. Each point with error bar is the average survival rate and its 95% confidence interval (CI) for each year. The dotted line with the shaded area is the predicted linear trend (survival rate vs. river flow) and its 95% CI.

3.3.2. Survival rate among release locations

As mentioned above, the average annual survival rate from all release sites to McNary Dam varied by year. The survival rate also varied by release location (Table 8 and Figure 5). In 2023, In 2023, the average survival rate to McNary Dam for sub-yearling summer Chinook was 7.61% ± 2.76. Among the release groups, the highest survival rate was observed in the Roza group, but it had a large standard error (SE), indicating less precision, followed by the group released from Prosser, which was reared in circular raceways and had the second-highest survival rate (21.81% ± 7.6). The yearling group released at Prosser had a survival rate of 45.51% ± 4.4, while the lowest rate was found in the Wapatox group released as subyearling (2.14% ± 2.5, see Table 8).

Initially, it was expected that the group released from Prosser would have a higher survival rate than the other groups due to its shorter travel distance. However, the Roza group actually exhibited a higher survival rate. While it's challenging to pinpoint the exact reasons for this difference, factors such as release timing and brood stock might have played a role. Notably, the Roza group was released approximately 10 days later than the Prosser group, and the brood stock for the Roza group was Wells, whereas for the Prosser group, it was East bank. These factors could have influenced the outcomes.

Table 8. Survival rate (%) of summer Chinook from each release site to McNary Dam from 2009 through 2023 for the 7 release sites. The survival rate and its standard Error (SE) are given for the 2019 and 2021 estimates. Early, Mid and Late releases correspond to the period through May 10; May 11 through May 25; and the period after May 25 respectively.

	Stiles		Buckskin			Marion drain	Roza			Prosser		Yakima River Mouth	Wapatox
Year	Mid	Late	Early	Mid	Late	Mid	Early	Mid	Late	Early	Mid	Early	Mid
2009		1.5											
2010	19.7												
2011	39.7		43.7										
2012				37.2		35.8					20.8		
2013				29.8					20.9				
2014				18.3	3.2				4.8				
2015				0.01	0		0.07	0		2.6			
2016												31.2	
2017								19.4			19.6		
2018								4.9					0.3
2019				2.3 ±2.1				11.0±4.2			17.9 ±3.7		00
2020				13.6 ± 3.4				15.0±5.6			16.9±5.5		
2021										41.1±8.1[1]; 31.1±8.8[2]			7.52±2.8[3]; 5.6±2.9[4]
2022				18.3 ±4.2				25.7±5.4		20.0±3.2 (circ) 14.16±2.0 (trad)			5.3±1.2
2023				19.6 ±5.3				77.6±44.1		21.8±7.6 (circ) 18.4±7.6 (trad)			2.1±2.5

Note: the survival rate estimates from 2009 through 2018 are from a previous report (Neeley 2019, Appendix G).1 indicates Yearling released in Prosser, 2: indicates sub-yearling released in prosser.3 indicates released in diversion canal, and 4 indicates released fish in Naches river near Wapatox. “circ” and “trad” represent circular raceways and traditional raceways, respectively.

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3.3.4. Effect of release month and fish size on survival

The results showed that release months of smaller fish affected their survival to Prosser. For example, for fish measuring 50mm released in April, the survival rate to Prosser Dam exceeded 50%, whereas 50mm fish released in June had a survival rate of approximately 10% (Figure 6, first panel). However, for the largest fish, there seemed to be no effect of release timing on the survival rate.

From Prosser-to-McNary Dam (right panel of Figure 6), the relationship of fish size to survival rate was similar for April and May releases, but release in June depressed the Prosser-to-McNary survival rate over the entire range of fish sizes. Standard errors for the groups released in April and May were large, which might be due to small sample size. As mentioned in 3.1., the sample size was relatively low for the groups released in April (2,155) and June (1,844) compared to May releases (38,874).

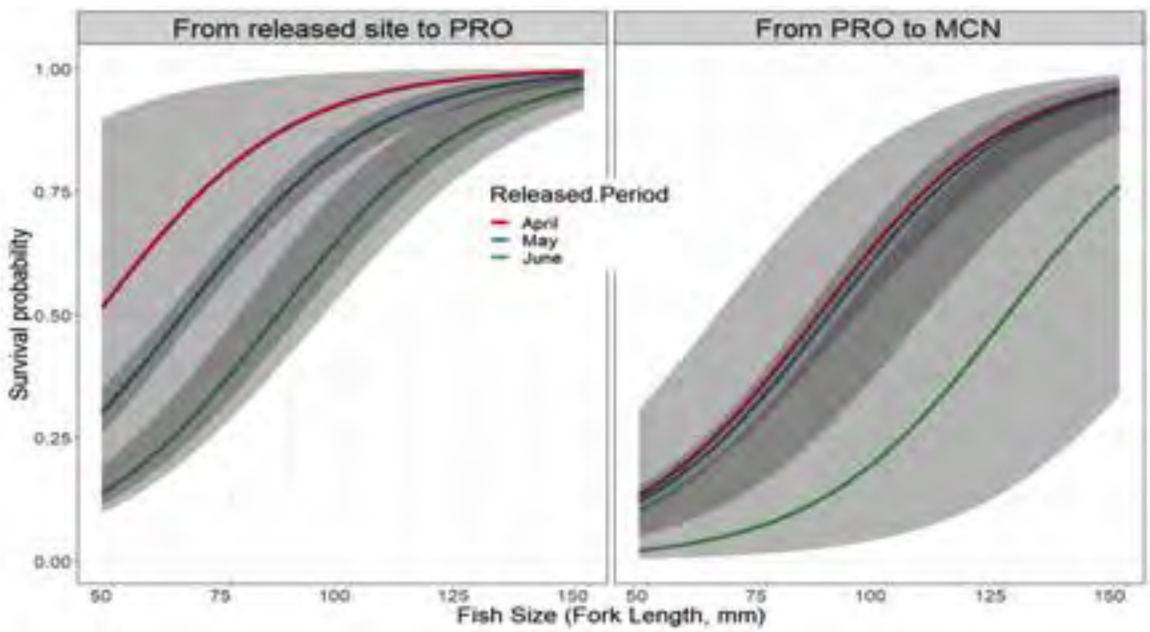

Figure 6. Effect of release period and fish size on the rate of survival from upstream release sites to Prosser Dam, and for all groups from Prosser Dam to McNary Dam. The shaded area is the standard Error (SE).

3.4. Travel time and rate of migration

Summer Chinook generally exhibited immediate outmigration behavior after release, regardless of age and release date, but later outmigrants showed greater urgency. Comparing sub-yearling and yearling ages in 2021, yearlings took less time to reach McNary than sub-yearlings. The range of travel time for yearlings from Prosser to McNary Dam was from 1 to 30 days with the average of 4 days; whereas the range for sub-yearlings was from 5 to 47 days with a mean of 30 (Table 3). In 2022, all individuals were sub-yearlings but their travel times varied slightly among different groups, particularly between the group raised in circular raceways and those raised in traditional raceways.

The median travel time to reach McNary was only 39 days for the circular raceways group, whereas other release groups (releasing from Prosser which was reared in traditional raceways, as well as those released from Roza Dam, Buckskin, and Wapatox) took approximately 42 to 43 days (see table 5).

Among the release months (excluding yearling group), travel times from Prosser Dam to Bonneville Dam for the groups released in April were about 73.08±37.77 days, whereas the fish released in June took only 32.70± 9.89 days to reach Bonneville Dam (Table 9).

Table 9. Travel days ± SE and rate of travel (km/day ± SE) from Prosser to Bonneville Dam for the groups released in April, May and June from 2010 through 2020.

Release Month	Number of PIT Tags	Travel days	Rate of migration (km/day)
April	24,555	73.08±37.77	7.19±0.10
May	28,318	65.08±14.03	8.15±0.04
June	20,140	32.70± 9.89	16.64±0.03

The distance between Prosser Dam and Bonneville Dam is normally given as 381 rkm and the rate of travel over that distance was 7.19 km/day for the group released in April; but the rate more than doubled (16.64 km/day) for the group released in June. The slower rate of travel for earlier releases indicates that fish released earlier spent more time in-river in order to go through the series of physiological and morphological changes that allow for a transition to life in salt water. Before entering the ocean, anadromous species must change their osmoregulation process, undergoing physical adaptations of their gills and kidneys that build a tolerance to salt water. The study suggests that regardless when they were released, summer Chinook seemed to enter the ocean at nearly the same time, although outmigration survival rate was higher for the early release.

3.5 Recovered PIT tags on Bird Islands

Figure 7 displays 13 bird nesting colonies where PIT tag recoveries were undertaken to assess avian predation. The data consistently reveal a substantial incidence of avian predation on Yakima Basin summer Chinook, as detailed in Table 8. In 2023, among the 56,565 PIT tags released during that year, 1051 summer Chinook PIT tags were detected at McNary Dam, while a 5,46 PIT tags were recovered on Badger Island. Notably, the highest tag recovery on Badger Island in the last five years occurred in 2022, totaling 1,441 PIT tags.

It's crucial to recognize that PIT tags found on islands represent only a fraction of the tagged fish preyed upon by avian predators. This is because tags may be excreted in other locations, not all tags on the islands may have been detected, tags can be displaced from nesting areas due to factors such as high tides in the Columbia River estuary, storms, or high-water events, and they may also suffer damage or become lost during the nesting season. The consistent pattern of increased fish recapture in bird colonies strongly suggests a significant predation impact. Therefore, it is imperative that we take action to address the predation issue in the Yakima River basin.

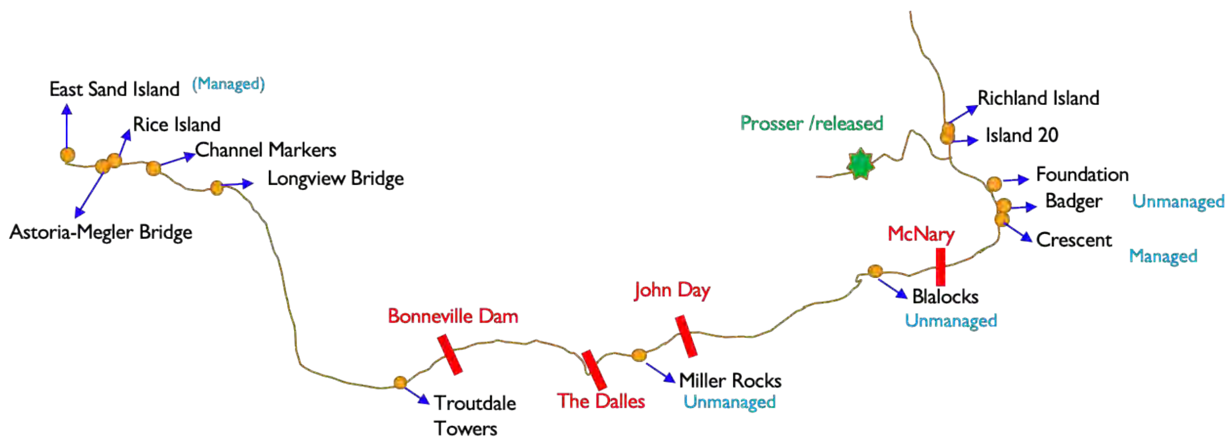

Figure 7. Schematic of mark–recapture–recovery sites of PIT-tagged Coho released in Yakima Basin for the migration year 2023.

Table10. The number of recaptured Summer Chinook Pit tags in bird nesting islands in the Columbia River basin for the last 6 years (2017-2023). Recovery locations include “RICHIS” = Richland Island, “FOUNDI”= Foundation Island, “BADGER”= Badger Island, “CRESIS”= Crescent Island, “CBLAIS”=Central Blalock Island, “MLRSIN”, = Miller Sands Island, “LMILS”= Little Miller Island, “ASMEBR”= Astonia-Megler-Bridge, “ESANIS”=East Sand Island, and “POTH”= Potholes Reservoir. “%” is the percent of the fish recaptured in Islands to the total release PIT tags summer chinook in the Yakima basin.

		Detect. at Dams			Recaptured in Islands (AVIAN predation)											
Year	N	MCJ	JDJ	BON	RICHIS	FOUNDI	BADGEI	CRESIS	CBLAIS	MLRSNI	LMILIS	ASMEBR	ESANIS	POTH	Total	%
2017	17539	403	361	423	6	8	670		43				4		731	4.17
2018	30130	143	103	169	10	2	608		11		2		5		638	2.12
2019	41151	233	187	186	36	35	1167		15	3	3		9		1268	3.08
2020	12814	169	219	169	1	7	177				1	0	4	0	190	1.48
2021	66233	585	622	862	51	96	981	1	13	4	30	19	23	1	1219	1.84
2022	48451	619	574	192	11	38	1441	19	6	1	29	2	29		1576	3.25
2023	56565	1051	771	1088	8	38	546	32	15			67	21		727	2.29

3.6. Smolt-to-Adult Returns

SAR which is the percentage of smolts that survive and return to spawn and captures most of the cumulative impacts of the hydro system and ocean condition on fish, telling us how sustainable the returns of adults are over time. The SAR estimate was based on the percentage of smolts detected at Bonneville Dam that returned as adults to Bonneville Dam. In general, the SAR varied by year during the study period. The highest SAR was for the fish released in 2011 (10.24±1.14%) and 2012 (4.24±0.09%), whereas it was zero for the group released in 2015 (see Table 10). The groups of fish released in other years averaged about 1% SAR from Bonneville juvenile to Bonneville adult. The variation in SAR among years can be associated with many factors such as smolt length, release timing, ocean conditions etc. Since SAR and juvenile survival both were high in 2011 and 2012 compared to other years, the higher SAR seems to be related to higher juvenile downstream survival.

Table 10. Smolt-adult returns (based on Juvenile and adult detection at Bonneville Dam) for each release over migration years 2010-2019. The value with yellow color indicates the value is subject to revision if 4-ocean adults may return in 2023 from the 2019 releases.

YEAR	Stiles	Buckskin	Marion drain	Roza	Prosser	Yakima mouth	Wapatox	Pooled
2010	1.25 ± 0.46							1.25 ± 0.46
2011	10.2 ± 2.06	10.22 ± 1.35						10.21 ± 1.14
2012		4.10 ± 1.4	3.29 ± 1.18		6.89 ± 2.71			4.24 ± 0.9
2013		2.08 ± 0.86		1.46 ± 0.81				1.80 ± 0.60
2014		0.69± 0.6		0				0.53 ± 0.52
2015		0		0	0			0
2016					1.07 ± 0.48			1.07 ± 0.48
2017				0.88 ± 0.49	1.97 ± 1.90			1.02 ± 0.53
2018				1.67 ± 1.20	2.01 ± 0.70		1.01 ± 0.91	1.5 ± 0.45
2019								1.6 ± 0.23
2020								
2021	Still adults are expected to return back, no SAR was calculated							
2022								
2023								

3.7. Age-at-return distribution

From the total of 1104 returning adult fish with PIT tags were detected at Bonneville Dam from 2009 through 2017, 64% were age 4 (3-year ocean age), 23% of the returns were age 3 (2- ocean), 9% were age 5 (4- ocean) and less than 1% were age of 6 (5-year ocean age). Four percent of the juveniles detected at Bonneville returned as jacks (age 2, 1-ocean; Table 11).

Table 11. Total number of PIT-tagged sub-yearling fish detected at return to Bonneville Dam by ocean age (years). Values shaded yellow are subject to change based on 4-ocean returns.

Migration Year	Number of returning adults						Percentage				
	Age1Y	Age2Y	Age3Y	Age4Y	Age5Y	Total	Age1Y	Age2Y	Age3Y	Age4Y	Age5Y
2010	7	21	79	19	0	126	5.56	16.67	62.70	15.08	0.00
2011	33	170	339	53	2	597	5.53	28.48	56.78	8.88	0.34
2012	0	19	106	32	0	157	0.00	12.10	67.52	20.38	0.00

2013	1	49	40	8	0	98	1.02	50.00	40.82	8.16	0.00
2014	1	2	14	1	0	18	5.56	11.11	77.78	5.56	0.00
2016	4	26	47	2	0	79	5.06	32.91	59.49	2.53	0.00
2017	2	3	24	0	0	29	6.90	10.34	82.76	0.00	0.00
2018	3	24	52	1	0	80	3.75	30	65	1.25	0
2019											
2020											
2021	Adults are expected to return back, no Age distribution was calculated										
2022											
2023											
Average							4.17	23.95	64.11	7.73	0.04

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