The Chief Joseph Hatchery Program
Summer/Fall Chinook

2018 Annual Report

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This report includes both hatchery production/operations and the corresponding monitoring activities completed through April of 2019. It is structured to meet the RM&E technical report formatting requirements for BPA, and therefore the hatchery production portion is included in Appendix A.

Reports, program descriptions, annual review materials and background information, news and contact information can be found on our website at: https://www.cct-fnw.com/reports/.

All photos are credited to Confederated Tribes of the Colville Reservation Fish and Wildlife Department – Chief Joseph Hatchery Program unless otherwise noted.

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The list of people responsible for planning, designing, building, funding and implementing the Chief Joseph Hatchery (CJH) is too long to mention here. None of the authors of this report were involved in the initial efforts to convince the Federal government to fund this endeavor, but we are grateful for the efforts. As are the Colville Tribal fishermen and other fishermen from Alaska, British Columbia, the Washington Coast, and all through the Columbia River who will benefit from the fish production for many generations to come. We wish to acknowledge Randall Friedlander, CCT Fish & Wildlife Program Director, Kirk Truscott, CCT Anadromous Division Manager, the Colville Business Council and the Natural Resource Committee for their policy direction and program guidance. This hatchery program would not exist today if not for the vision and dedicated efforts of a variety of current and former employees of CCT and BPA, particularly the former CCT Fish and Wildlife Program Manager, Joe Peone and the former CCT Anadromous Division Manager, Jerry Marco. Additionally, expert contributions, counsel, and examples came from a variety of staff from management agencies (WDFW, USFWS), groups (Mid-C HCP hatchery committees), and contractors to the Colville Tribes. Some of the tables, formatting, and table header text were copied from the CPUD/GPUD 2013 annual report to provide continuity with reporting for other populations in the Upper Columbia River and past reporting in the Okanogan River.

We want to thank our skilled and dedicated CJHP staff who cared for the fish, collected the data, maintained the equipment and generally did whatever was necessary for the project to be successful. We appreciate their willingness to work long hours under adverse conditions to get the job done.

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Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government or the Confederated Tribes of the Colville Reservation

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EXECUTIVE SUMMARY

The Colville Confederated Tribes (CCT) Chief Joseph Hatchery (CJH) is the fourth hatchery obligated under the Grand Coulee Dam/Dry Falls project, originating in the 1940s. Leavenworth, Entiat, and Winthrop National Fish Hatcheries were built and operated as mitigation for salmon blockage at Grand Coulee Dam, but the fourth hatchery was not built, and the obligation was nearly forgotten. After the Colville Tribes successfully collaborated with the United States to resurrect the project, planning of the hatchery began in 2001 and construction was completed in 2013. The monitoring program began in 2012 and adult Chinook Salmon were brought on station for the first time in June 2013. Bonneville Power Administration (BPA) is the primary funding source for CJH, and the Mid-Columbia PUDs (Douglas, Grant and Chelan County) have entered into cost-share agreements with the tribes and BPA in order to meet some of their mitigation obligations.

The CJH production level was set at 100% in 2018 during the sixth year of operation for the Summer/Fall Chinook program. In July and August the CCT used a purse seine vessel to collect 1,159 summer/fall Chinook for broodstock for both the integrated and segregated programs (including Similkameen). Additionally, 19 summer/fall Chinook were collected at the Okanogan adult weir in September. The summer/fall Chinook program collected enough brood to meet full production level. The cumulative pre spawn holding survival, for all Summer/Fall brood collected, was 65.2% for hatchery-origin broodstock (HOB) and 77.1% for natural-origin broodstock (NOB). The survival standard (90%) was not met by both the hatchery-origin and natural-origin brood. Total green egg take for the season was 1,163,997 (58% of full program). Egg survival from green egg to eyed egg averaged 85.2% for NOB and 87.0% for HOB, both under the survival standard (90%) for this life stage. Cumulative egg survival from green egg to eyed egg was 88.5% for NOB and 78.9% for HOB, which is under the survival standard (90%) for this life stage. There was no integrated or segregated sub-yearling program for brood year 2018 due to low egg take. After in-hatchery mortalities from pre-spawn holding through ponding there were 475,411 fish on hand at the end of April for the yearling releases in 2020 (43% of the yearling program).

2018 was the fourth year for Summer/Fall Chinook sub-yearling hatchery releases from the CJH programs and the fourth year for yearlings released from Similkameen and Omak acclimation ponds that had been reared at the CJH central facility. In April, 280,055 integrated yearling summer/fall Chinook were released from the Omak acclimation pond and 240,725 were released by Washington Department of Fish & Wildlife (WDFW) from the Similkameen Pond; combined these programs were at 87% of the full program goal of 600,000 integrated yearlings. There were no integrated sub-yearlings from brood year (BY) 2017 released in May 2018. However, there were 399,299 yearling and 182,462 sub-yearling segregated Chinook were released directly from Chief Joseph Hatchery (80% and 46% of full program, respectively).

After release, the segregated yearling program from CJH had higher survival (83%) than previous years and other programs, whereas the integrated program had lower survival (54%) than previous years and other programs. The cause of this difference was undetermined. Segregated subyearling survival to RRJ was 65% and there was not a subyearling program at the Omak Pond in 2018. The segregated subyearling program had a similar survival (65%) to 2017, which was considerably higher than 2015 and 2016, but less than Wells Fish Hatchery subyearlings. The majority (>90%) of PIT tagged hatchery smolts released from Omak Pond migrated to the lower Okanogan River within two weeks of release. This assessment suggests that the program was successful at releasing actively migrating smolts.

The CJH monitoring project collected field data to determine Chinook population status, trend, and hatchery effectiveness centered on six major activities; 1) rotary screw traps (juvenile outmigration, natural-origin smolt PIT tagging) 2) beach seine (natural-origin smolt PIT tagging, smolt to adult return) 3) lower Okanogan adult fish pilot weir (adult escapement, proportion of hatchery-origin spawners [pHOS], broodstock) 4) spawning ground surveys (redd and carcass surveys)(viable salmonid population [VSP] parameters) 5) eDNA collection (VSP parameter—distribution/spatial structure) and 6) coded wire tag lab (extraction and reading).

Rotary screw trap operations began on March 12 and continued through June 21, capturing 3,251 natural-origin Chinook and 663 hatchery-origin Chinook. After conducting 3 mark-recapture events, the efficiency of the trapping configuration was calculated to be approximately 0.13%. Because of the inability to collect sufficient data to confidently estimate juvenile outmigration, abundance estimates were not produced for the 2018 outmigration. Twenty-five steelhead (*O. mykiss*) were also captured in the rotary screw trap including 7 natural-origin (adipose fin present and no CWT) and 18 hatchery-origin (adipose fin clipped and/or CWT present). Other species commonly caught in the rotary screw traps included Sockeye (*O. nerka*) (24), Yellow Perch (*P. flavescens*) (53), Bluegill (*L. macrochirus*) (11), common Carp *(C. carpio)* (39), and Mountain Whitefish (*Prosopium williamsoni*) (623).

Beach seining captured 25,069 juvenile Chinook and 23,668 (94%) were PIT tagged and released. Pre- and post-tag mortality was 1.0% and 2.8% respectively. In 2018, wild summer Chinook tagged at the mouth of the Okanogan had a minimum apparent survival of 44% (4% SE) to Rocky Reach Juvenile Bypass (RRJ) and 12% (3% SE) to McNary (MCN). The lower Okanogan Adult Fish Weir was deployed on August 6th when discharge was 1,230 cfs. The thermal barrier was present in the lower Okanogan after installation until August 10th when the mean Okanogan River temperature began dropping below 22.5 °C, allowing Chinook to migrate up the Okanogan. After reviewing the number of adult Chinook pit tagged at Bonneville and their detections at the Wells Adult Ladder and the Lower Okanogan Pit Array, we suspect that about 32% of fish passage occurred before the weir trap was operational on August 10. After trapping began, the majority of Chinook (77%) were trapped between August 15 and 29. Forty-eight adult Chinook were trapped in 2018. Nineteen natural-origin Chinook were transported to the hatchery and held as broodstock for the integrated program. Adult brood were transported from the weir trap to the hatchery brood truck by foot using a rubber boot. There were no immediate mortalities of these fish within the first week after transport to the hatchery. All other natural-origin fish were released upstream of the weir unharmed. All of the hatchery-origin fish encountered in the weir trap were released upstream. Only 0.09% of the Chinook spawning escapement was detected in the trap. All Chinook and Sockeye mortality encountered at the weir were categorized as impinged on the upstream side, indicating that they most likely died upstream and floated down onto the weir. The majority of the Chinook carcasses were encountered during the first two weeks of trapping. There was no immediate increase in mortality within that two-week period. The head differential, river velocity, and trap capacity were within the NOAA standard operating criteria. Water quality information, including dissolved oxygen, turbidity, and total dissolved solids were collected to assess potential impacts to increased fish mortality. Weir trapping operations ceased on September 21.

Spawning ground surveys estimated 2,112 summer/fall Chinook redds and 547 carcasses were recovered (374 natural-origin and 173 hatchery-origin). Adult summer/fall Chinook spawning escapement in 2018 was estimated to be 4,860, with 3,266 natural-origin spawners and 1,594 hatchery origin spawners. In 2018, the effective pHOS (0.28) met the program objective (<0.3) but the proportion of natural influence (PNI) (0.63) did not meet the objective of >0.67. The failure to meet PNI in 2018 was due to a conscious management decision to decrease the pNOB (0.48) in a year with relatively low natural-origin returns. This decision was made to allow more natural-origin fish to escape for spawning in the river, knowing that the 5-year average PNI would still remain above the long-term goal. The five-year average for pHOS (0.18) and PNI (0.82) met the long-term goal (<0.30 pHOS; >0.67 PNI). Selective harvest activities by CCT and WDFW contributed to the reduced pHOS and increased PNI in 2018. CCT removed more than 2,500, hatchery fish, including 309 jacks, during surplus events at the CJH ladder and trap, and tribal members removed another 753, including 32 jacks, at the Chief Joseph Dam tailrace fishery. The Harvest program's purse seine removed 148 hatchery fish, including 116 jacks. One hundred and sixty-five natural-origin fish, including 22 jacks, were released during surplus at the Chief Joseph Hatchery ladder, and 73 fish were released by tribal members at the tailrace fishery. The purse seine released 91 natural-origin jacks during their efforts. All natural-origin adults encountered with the purse seine were collected for broodstock for the program. The Okanogan temporary weir encountered less than 35 fish in 2018, in which only 2 hatchery fish were removed and 13 natural-origin fish, including 5 jacks, were released back to the river. Within the WDFW state fishery, 1018 hatchery Chinook, including 60 jacks, were harvested and 353 natural-origin Chinook, including 77 jacks were released back to the river.

The management strategy for the CJH integrated hatchery program in the Okanogan River appears to be having some of the intended effects on the spawning grounds. The intent of adding the Omak Acclimation Pond was to reduce spawning density and pHOS in the high density reaches of the upper Okanogan (O6) and lower Similkameen (S1) and to increase spawning in the under-utilized lower and middle reaches of the Okanogan (O2-O5). Data from 2017 and 2018 shows that there was a trend of increasing proportions of redds in reaches O3, O4 and O5 and corresponding decreases in proportions of redds in reaches O6 and S1. Additionally, carcass recovery data shows that there were more hatchery and natural-origin spawners in O3 and O5 in 2017-2018 compared to pre-CJH years and there were fewer hatchery-origin carcasses in S1. Finally, data from 2017-2018 showed reduced pHOS in the prime spawning habitat in the upper reaches (S1 and O6), which should help with the effectiveness of natural-origin spawners in those areas.

The CJH coded wire tag lab was in its third year of operation in 2018. Coded wire tags were extracted and read from Chinook snout recoveries from broodstock, ladder surplus, purse seine harvest, and creel and spawning ground surveys. The development of in-house CWT reading continues to be a huge success, providing age- and origin data within 2-3 months of the spawning ground surveys utilizing Colville tribal staff, rather than outsourcing to another lab. The majority of the summer Chinook adult returns to the CJH ladder were CJH Segregated (58%) followed by Wells Hatchery (16%), Chelan Falls (13%), Okanogan integrated (7%), Dryden (3%) and five other programs made up the remaining 3%.

The majority (67%) of hatchery-origin spawners recovered on the spawning grounds in 2018 were from Similkameen (43%) and Okanogan (25%). Chief Joseph Hatchery segregated Chinook comprised 27% of the HOS on the Okanogan spawning grounds. This level of segregated hatchery fish on the spawning grounds did not meet the program objective (<5%) and future management efforts should focus on reducing the stray rate of segregated hatchery fish to the Okanogan spawning grounds. However, removal of segregated hatchery fish in low abundance years, such as 2018, is a challenge because integrated hatchery fish are needed to meet escapement goals. Overall, the majority of fish acclimated at Similkameen Pond ended up spawning throughout the upper reaches of the Okanogan (reaches O5 & O6) and Similkameen Rivers (87%). Reach S1, the location of the Similkameen acclimation site in the Similkameen River accounted for just one-third of the estimated spawning by Similkameen Pond fish (34%). The most recent brood year that could be fully assessed (through age 5) for stray rate of Okanogan/Similkameen fish to spawning areas outside the Okanogan was 2013. The 2013 brood year had a stray of 2.4% to non-target basins and 0.3% to non-target hatcheries, which was similar to the long term and recent five-year average (1.0% for non-target basins and 0.3% to non-target hatcheries).

An Annual Program Review (APR) was held in March 2019 to share hatchery production and monitoring data, review the salmon forecast for the upcoming year, and develop action plans for the hatchery, selective harvest, and monitoring projects. Based on a lower-than-average pre-season forecast of 35,900 Upper Columbia summer/fall Chinook, the plan for 2019 is to still operate the hatchery at full program levels of 2 million summer/fall Chinook with a reduced pNOB. pNOB was set at 50% natural-origin broodstock for the integrated program and

CCT would not plan to harvest any of their allocation with the selective harvest program, including removals at the purse seine, the weir, and at the hatchery ladder.

INTRODUCTION

Salmon (*Oncorhynchus* spp.*)* and steelhead (*O. mykiss*) faced many anthropogenic challenges ever since European settlement of the Pacific Northwest. Harvest, hydropower development, and habitat alteration/disconnection have all had a role in reducing productivity or eliminating entire stocks of salmon and steelhead (MacDonald 1894; UCSRB 2007). These losses and reductions in salmon had a profound impact on Native American tribes, including the Confederated Tribes of the Colville Reservation. Hatcheries have been used as a replacement or to supplement the wild production of salmon and steelhead throughout the Pacific Northwest. However, hatcheries and hatchery practices can pose a risk to wild populations (Busack and Currens 1995; Ford 2002; McClure et al. 2008). As more studies lead to a better understanding of hatchery effects and effectiveness, hatchery reform principles were developed (Mobrand et al. 2005; Paquet et al. 2011). The CJHP is one of the first of its kind to be structured using many of the recommendations emanating from Congress's Hatchery Reform Project, the Hatchery Science Review Group (HSRG) and multiple independent science reviews. Principally, the success of the program is not based on the ability to meet the same fixed smolt output or the same escapement goal each year. Instead, the program is managed for variable smolt production and natural escapement. Success is based on meeting targets for abundance and composition of natural escapement and hatchery broodstock (HSRG 2009). Chief Joseph Hatchery Program (CJHP) managers and scientists are accountable for accomplishments and/or failures, and therefore, have well-defined response alternatives that guide annual program decisions. For these reasons, the program is operated in a manner where hundreds of variables are monitored, and activities are routinely and transparently evaluated. Functionally, this means that directed research, monitoring, and evaluation (RM&E) are used to determine status and trends and population dynamics, and are conducted to assess the program's progress in meeting specified biological targets, measure hatchery performance, and in reviewing the key assumptions used to define future actions for the entire CJHP.

The actions being implemented by the Colville Tribes, in coordination with regional management partners, represent an extraordinary effort to recover Okanogan and Columbia River natural-origin Chinook Salmon populations. In particular, the Tribes have embraced hatchery program elements that seek to find a balance between artificial and natural production and address the goals of increased harvest and conservation.

Two hatchery genetic management plans (HGMPs) were initially developed for the CJH during the Northwest Power and Conservation Council (NPCC) three-step planning process – one for summer/fall Chinook (CCT 2008a) and one for spring Chinook (CCT 2008b). Each of the two plans included an integrated and a segregated component. Integrated hatchery fish have a high proportion of natural origin parents, are released into the Okanogan River system and a proportion of these fish are expected to spawn in the natural environment. Segregated fish have primarily hatchery parents, are to be released from CJH directly into the Columbia River and adult returns are targeted exclusively for harvest.

In 2010 the CCT requested that the National Marine Fisheries Service (NMFS) designate a non-essential experimental population of spring Chinook in the Okanogan utilizing section 10(j) of the Endangered Species Act (ESA). In order to obtain a permit to transfer ESA listed fish from the Methow River to the Okanogan River, a new HGMP was developed (CCT 2013). Biological Opinions (BiOps) and permits have been issued by NMFS for the 2008 HGMPs, and CCT acquired a BiOp and permit for the 2013 spring Chinook in 2014. The program will be guided by all three HGMPs.

At full program the facility will rear up to 2 million summer/fall Chinook and 900,000 spring Chinook. Up to 1.1 million summer/fall Chinook will be released in the Okanogan and Similkameen Rivers as an integrated program and 900,000 will be released from CJH as a segregated program. Up to 700,000 segregated spring Chinook will be released from CJH and up to 200,000 Met Comp spring Chinook from the Winthrop National Fish Hatchery (WNFH) will be used to reintroduce spring Chinook to the Okanogan under section 10(j) of the ESA. In 2017, the summer/fall and spring Chinook program's production level was set at full production capacity.

The CJHP will increase harvest opportunity for all anglers throughout the Columbia River and Pacific Ocean. Additionally, the Colville Tribes and other salmon co-managers have worked with the mid-Columbia Public Utility Districts to meet some of their hydro-system mitigation through hatchery production (CPUD 2002a; CPUD 2002b; DPUD 2002).

In order to make full use of the best science available the program operates on the following general principles[1]:

1. Monitor, evaluate and adaptively manage hatchery and science programs
2. Manage hatchery broodstock to achieve proper genetic integration with, or segregation from natural populations
3. Promote local adaptation of natural and hatchery populations
4. Minimize adverse ecological interactions between hatchery- and natural-origin fish
5. Minimize effects of hatchery facilities on the ecosystem
6. Maximize survival of hatchery fish in integrated and segregated programs
7. Develop clear, specific, quantifiable harvest and conservation goals for natural and hatchery populations within an "All-H" (Hatcheries, Habitat, Harvest and Hydro) context
8. Institutionalize and apply a common analysis, planning, and implementation framework

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[1] Adapted from the Hatchery Reform Project, the Hatchery Science Review Group reports and independent science review.

9. Use the framework to sequence and or prioritize actions
10. Hire, train, and support staff in a manner consistent with successful implementation of the program
11. Conduct annual reviews to include peers, stakeholders, and regional managers, and
12. Develop and maintain database and information systems and a highly functional informational web-presence.

The CJHP annual RM&E activities were focused on six primary field activities to provide data for answering key management questions. These activities included:

1. Rotary screw traps (juvenile outmigration, natural-origin smolt PIT tagging)
2. Beach seine (natural-origin smolt PIT tagging)
3. Lower Okanogan adult fish pilot weir (adult escapement, pHOS, broodstock)
4. Spawning ground surveys (redd and carcass surveys)(VSP parameters)
5. eDNA collection (VSP parameter—distribution/spatial structure)
6. Coded wire tag lab (extraction, reading, reporting)

Additional data compilation activities occurred and were necessary in conjunction with our field efforts to answer the key management questions. These included:

1. Harvest (ocean, lower Columbia, terminal sport, and CCT)
2. Query RMIS for coded wire tag (CWT) recoveries to evaluate strays and stock composition
3. Query PTAGIS for PIT tag returns at mainstem dams and tributaries
4. EDT model estimates for abundance and productivity (from OBMEP)

In-hatchery monitoring/data collection was focused in five areas (see Appendix A):

1. Broodstock collection and bio-sampling
2. Life stage survival
3. Disease monitoring
4. Tagging, marking, and release
5. Ladder surplus / pHOS reduction

Study Area

The primary study area of the CJHP lies within the Okanogan River Subbasin and Columbia River near Chief Joseph Dam in north central Washington State (Figure 1). The Okanogan River measures approximately 185 km long and drains 2,316,019 ha, making it the third-largest subbasin to the Columbia River. Its headwaters are in Okanagan Lake in British Columbia, from which it flows south through a series of four lakes before crossing into

Washington State at Lake Osoyoos. Seventy-six percent of the area lies in Canada. Approximately 14 km south of the border, the Okanogan is joined by its largest tributary, the Similkameen River. The Similkameen River watershed is 510 km long and drains roughly 756,096 ha. The Similkameen contributes approximately 75% of the flow to the Okanogan River. The majority of the Similkameen is located in Canada. However, part of its length within Washington State composes an important study area for CJHP. From Enloe Dam (Similkameen rkm 14) to its confluence with the Okanogan, the Similkameen River contains important Chinook pre-spawn holding and spawning grounds. Downstream of the Similkameen confluence, the Okanogan River continues to flow south for 119 km until its confluence with the Columbia River at Columbia River km 853, between Chief Joseph and Wells dams, near the town of Brewster, Washington.

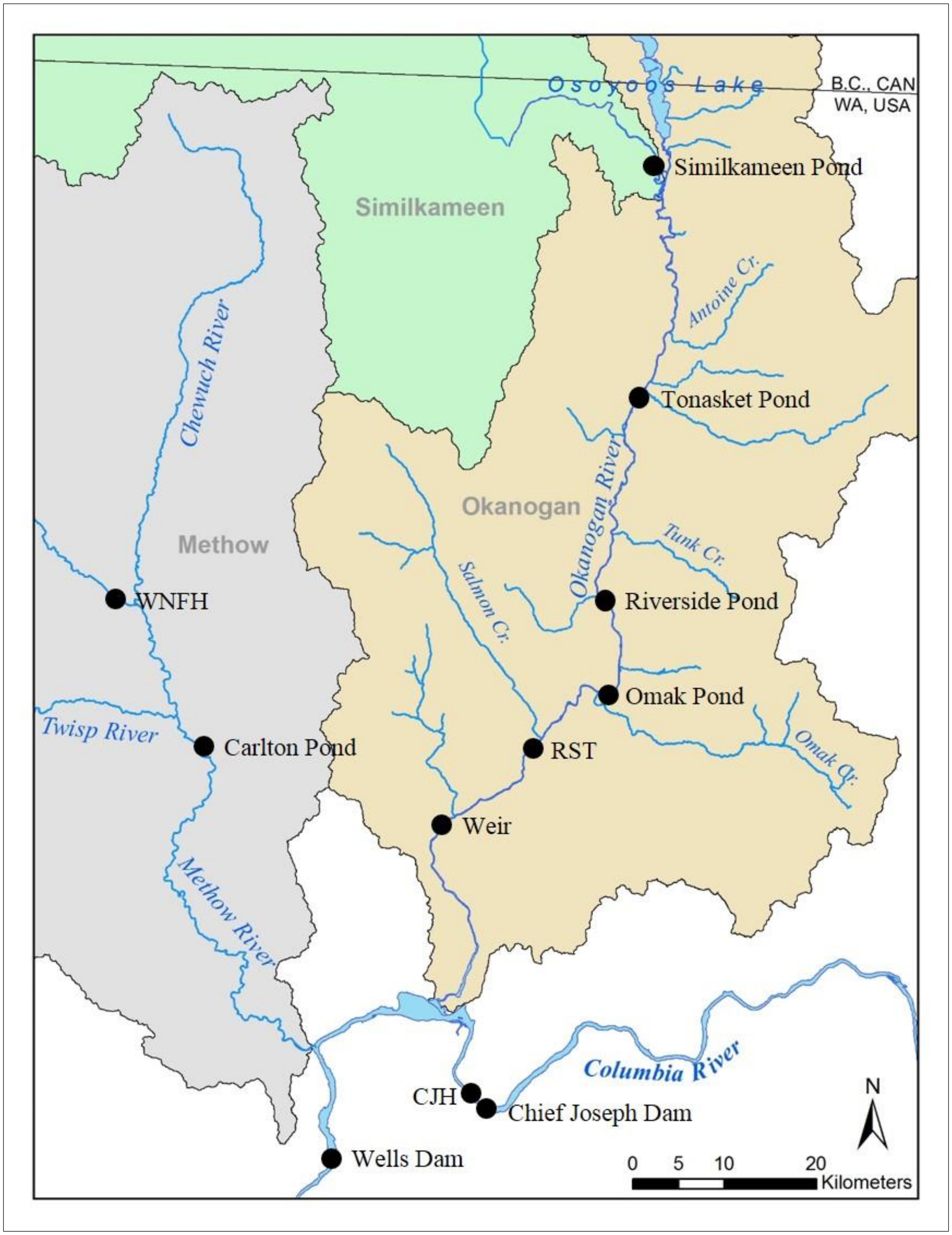

Figure 1. Map of the U.S. portion of the Okanogan River Basin, the Chief Joseph Hatchery (CJH), Winthrop National Fish Hatchery (WNFH), Okanogan adult weir (Weir), Rotary screw trap (RST), and Chinook Salmon acclimation sites. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD

Similar to many western rivers, the hydrology of the Okanogan River watershed is characterized by high spring runoff and low flows occurring from late summer through winter. Peak flows coincide with spring rains and melting snowpack (Figure 2). Low flows coincide with minimal summer precipitation, compounded by the reduction of mountain snowpack. Irrigation diversions in the lower valley also contribute to low summer flows. As an example, at the town of Malott, Washington (rkm 27), Okanogan River discharge can fluctuate annually from less than 1,000 cfs to over 30,000 cfs (USGS 2005).

The Okanogan Subbasin experiences a semi-arid climate, with hot, dry summers and cold winters. Water temperature can exceed 25° C in the summer, and the Okanogan River surface usually freezes during the winter months. Precipitation in the watershed ranges from more than 102 cm in the western mountain region to approximately 20 cm at the confluence of the Okanogan and Columbia Rivers (NOAA 1994). About 50% to 75% of annual precipitation falls as snow during the winter months.

For most of its length, the Okanogan River is a broad, shallow, low gradient channel with relatively homogenous habitat. There are few pools and limited large woody debris. Fine sediment levels and substrate embeddedness are high and large woody debris is rare (Miller et al. 2013). Towns, roads, agricultural fields and residential areas are adjacent to the river through most of the U.S. reaches.

Near its mouth, the Okanogan River is affected by the Wells Dam on the Columbia River, which creates a lentic influence to the lowermost 27 km of the Okanogan River. Water level fluctuates frequently because of operational changes (power generation, storage) at Wells Dam.

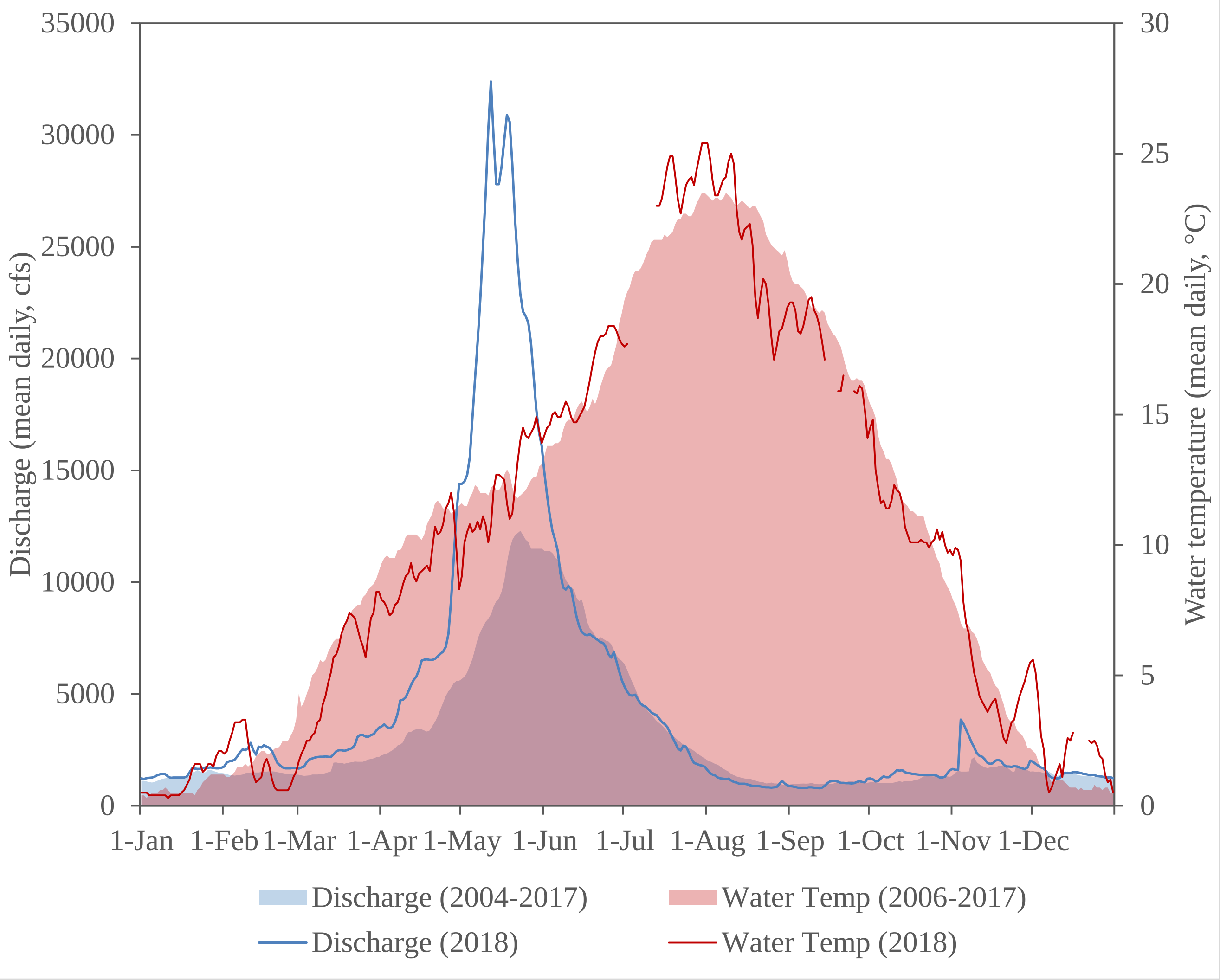

Figure 2. Okanogan River mean daily discharge (blue lines) and water temperature (red lines) at Malott, WA (USGS Stream Gage 12447200).

METHODS

Tag and Mark Plan

HATCHERY SUMMER/FALL CHINOOK. —All summer/fall hatchery-origin Chinook were marked with an adipose fin clip to ensure differentiation from natural-origin fish in the field and in fisheries. Additionally, all summer/fall Chinook raised for the integrated program have been/will be tagged with a CWT (with distinct codes differentiated by release location), which is inserted into the snout of fish while in residence at the hatchery. A batch of 200,000 summer/fall Chinook in the segregated program will receive a CWT, so the presence or absence of a CWT in adipose-clipped fish is a partial diagnostic as to which program an ad-clipped, hatchery-origin fish belongs (Table 1). This will allow for selective efforts in broodstock collection, purse seining, and hatchery trapping activities to be program specific by determining the presence or absence of a CWT in the field. It was decided that losing some resolution on field differentiation of the segregated and integrated populations was a good tradeoff in order to get the harvest information back from the batch of 200,000 CWT in the segregated program.

Under this strategy, a returning adult from the CJH with an adipose fin clip and CWT would be considered part of the integrated program and either collected for broodstock in the segregated program, allowed to escape to the spawning grounds (if pHOS is within acceptable levels), or removed from the population (for harvest or pHOS management). If a fish has an adipose fin clip but no CWT, then it is assumed from the segregated program (or a stray from another hatchery program) and removed for harvest or pHOS management. In this way, CWTs assist with in-season management of hatchery-origin stocks in the field. The 200,000 segregated fish with a CWT represent about 15% of the combined segregated (900,000) and integrated (1.1 million) hatchery fish with a CWT. If smolt to adult survival and adult holding/migration behaviors are identical, this would mean that 15% of the subsequent generation of segregated fish would have a segregated parent and would not be consistent with the 'stepping stone' approach. However, segregated fish should spend less time holding at the mouth of the Okanogan and therefore have a lower probability of being collected as broodstock in the purse seine. CWT monitoring from broodstock collections during the first several years of returns will provide insight to this tradeoff.

Coded wire tags are recovered from salmon carcasses during Chief Joseph Hatchery ladder surplus, CCT creel surveys, CCT purse seine, Okanogan weir trapping, and spawning ground surveys in the Okanogan Basin. All recovered CWTs are sent to the Chief Joseph Hatchery coded wire tag lab for extraction, reading, and data upload to the Regional Mark Processing Center operated by the Pacific States Marine Fisheries Commission (PSMFC)[2]. These data are used to develop estimates of total recruitment, rate of return to point of release (homing), contribution to fisheries, survival rates, mark rate, and other parameters, helping inform future management and production decisions within the CJHP.

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[2] website: http://www.psmfc.org/Regional_Mark_Processing_Center_RMPC

Table 1. General mark and tag plan for Chief Joseph Hatchery summer/fall Chinook.

Mark Group	Target max smolt released	Life-stage released	% CWT	Adipose Fin-Clip	PIT tag
Okanogan Integrated	1,100,000				
Similkameen	400,000	Yearling	100%	100%	
Omak Pond	400,000	Yearling	100%	100%	5,000
	300,000	Sub-yearling	100%	100%	5,000
Chief Joseph Segregated	500,000	Yearling	20%	100%	5,000
	400,000	Sub-yearling	25%	100%	5,000
Natural-Origin	RST and Confluence Seine	N/A	0%	0%	≤ 25,000

[1] The original plan was to use Riverside Pond for approximately 1/3 of the summer Chinook yearling production, however, to date it has been only been used to acclimate the 10(j) spring Chinook because Tonasket Pond has not been rehabilitated for acclimation of spring Chinook.

In addition to the adipose fin-clip and CWT, a subset of hatchery-origin fish will be PIT-tagged to further assist with fish monitoring efforts in subsequent years. Table 1 represents the general plan at full production.

NATURAL-ORIGIN FISH TAGGING. —The RM&E plan called for up to 25,000 PIT tags in juvenile natural-origin summer/fall Chinook parr/smolts. PIT tagging of natural-origin summer/fall Chinook occurred at the rotary screw trap and the juvenile beach seine in 2016. Please see those sections for details.

Genetic Sampling/Archiving

The CJHP collects and archives genetic samples for future analysis of allele frequency and genotyping of naturally spawned and hatchery Chinook populations. Genetic samples (fin clips) from outmigrant juvenile Chinook were collected during rotary screw trap operations. Samples were preserved in 200-proof molecular grade ethanol and are currently archived at USGS Forest and Rangeland Ecosystem Science Center (FRESC) Pacific Northwest Environmental DNA Laboratory in Boise, ID. Annual tissue collection targets are approximately n = 200 samples for: (1) natural-origin sub-yearling Chinook handled at the rotary screw trap/beach seine; (2) natural-origin yearling (>130 mm) Chinook handled at the rotary screw trap/beach seine and (3) natural- and hatchery-origin (100 each) Chinook encountered during carcass surveys on the spawning grounds.

The CJHP has also supported requests from Columbia River Inter-tribal Fish Commission (CRITFC) to provide genetic samples (caudal punches) from CJH summer-Chinook broodstock to aid in the development of a Columbia River Parentage Based Tagging (PBT) program. Samples were preserved on pre-labeled Whatman (GE Healthcare, Pittsburg, PA, USA) cellulose chromatography paper and shipped to CRITFC Lab in Hagerman, ID, USA. Genetic samples will continue to be collected from all hatchery broodstock at CJH.

Rotary Screw Traps

One 2.4 m and one 1.5 m rotary screw trap (RSTs) were deployed from the Highway 20 bridge near the City of Okanogan (rkm 40) (Figure 3). The RSTs were deployed from March 12 to June 21, 2018. Trapping typically occurred continuously from Mondays at 0600 until Saturday at 0600. Trapping operations were suspended on May 7-31 due to high river discharge. To continue trapping operations in varying river conditions, traps were operated in one of three trapping configurations: 2.4 m only, 1.5 m only, and both traps operational.

Figure 3. 2.4-m (left) and 1.5-m (right) traps fishing in the Okanogan River. The boat is used by technicians to access the 2.4-m trap. Photo by CCT.

During operation, the trap locations were adjusted in the river to achieve between 5-10 revolutions per minute. The traps were checked every two hours unless a substantial increase in flow (≥ 500 cfs in a 24-hour period) or debris load occurred, in which case they were checked and cleaned more frequently. All fish were enumerated, identified to species, and life stage, origin (adipose fin present or absent), and disposition (whether the fish was alive or dead), and a subsample of natural-origin Chinook was measured. The fork lengths of the first 10 unmarked Chinook of each 100 encountered in the live well were measured to the nearest mm and released during each trap check. Steelhead smolts were not measured in order to minimize handling and stress of ESA-listed species. Unmarked (adipose fin present) Chinook captured in the RST that were ≥ 65 mm total length received a 12 mm full duplex PIT tag, provided water temperatures were below 17°C. A tissue sample (fin clip) was collected from any yearling unmarked Chinook for future genetic analyses.

EFFICIENCY ESTIMATES. — An estimate of the daily number of juvenile out migrants passing the trap location requires an estimate of the proportion of fish caught by the traps. This was accomplished using mark-recapture methodologies developed by Rayton and Wagner (2006), maintaining continuity with the techniques employed at this RST operation in previous years. This mark-recapture procedure (hereafter referred to as an efficiency trial) was conducted using both natural-origin sub yearling Chinook and hatchery-origin yearling Chinook. Only fish with a fork length of at least 45 mm were used in efficiency trials.

After collection from both the 2.4 m and 1.5 m rotary screw traps, fish were marked in 5 gal buckets with Bismarck Brown dye at a concentration of 0.06 g/gal, held for 10-15 minutes with aeration and transported in buckets via a truck for release. Fish were released at night (typically between 0000 and 0330) approximately 1.6 river km upstream by the Oak Street Bridge. Fish were distributed evenly on both sides of the river to allow for equal distribution across the channel. The probability of capture was assumed to be the same for hatchery-origin fish as it was for natural-origin fish.

Because of variable flow and debris conditions, at any given moment, one of several trapping configurations could have been employed, in which either one, both, or neither of the 2.4 and 1.5 m screw traps could be operating. In order to derive an ultimate out migrant estimate, efficiency estimates for all of these configurations were calculated.

Trap efficiency was calculated by the equation

$$E_{ti} = \sum R_{ti} / \sum M_i$$

where E_{ti} is the trap efficiency for trapping configuration t in sampling period i, $\sum Rti$ is the sum of marked fish that are recaptured in trap configuration t during sampling period i, and $\sum M_i$ is the sum of marked fish released during the sampling period i.

Trap efficiencies were recorded for each individual trap as it operated, and for both traps operating in unison. Trap efficiencies for each individual trap were further refined by including results for each individual trap while both traps were in operation. For example, if 100 marked fish were released, and 1 was recaptured in each trap, each individual trap displays an efficiency of 1%, and the efficiency of both traps operating simultaneously is 2%. This relies on the assumption that the efficiency of each trap is unaffected by whether the other is operating or not.

RST ANALYSIS. — Hourly catch was expanded to an hourly outmigration estimate based on measured trap efficiency by using the Lincoln-Peterson mark-recapture model with a Chapman modifier, which can improve estimates when recapture rates are low (Seber 1982). This model relies on the following assumptions:

1.) All marked fish passed the screw trap or were recaptured during time period *i*
2.) The probability of capturing a marked or unmarked fish is equal
3.) All marked fish recaptured were correctly identified as a marked fish
4.) Marks were not lost or overlooked between time of release and recapture

Total juvenile Chinook emigration was calculated for each trap configuration using a pooled Peterson estimator with a Chapman modification, such that

$$\widehat{N} = \left[\frac{(M_p + 1)(C_p + 1)}{(R_p + 1)}\right] - 1$$

Where $\widehat{N}$ is total emigration estimate, $M_p$is the total number of marked individuals during the trapping season, C_p is the total number of fish caught during the trapping season, and

R_p is the total number of recaptured fish during the trapping season.

An approximately unbiased estimate of the variance of the population, $\widehat{V}[\widehat{N}]$, is calculated by the equation

$$\widehat{V}[\widehat{N}] = \frac{(M_p + 1)(C_p + 1)(M_p - R_p)(M_p - R_p)}{(R_p + 1)^2(R_p + 2)}$$

The precision of the population estimates was assessed by including 95% confidence intervals calculated by the equation

$$\widehat{N} \pm 1.96\sqrt{\widehat{V}[\widehat{N}]}$$

Estimates and confidence intervals were calculated for all trapping configurations and then summed to generate an overall estimate for the trapping season. During periods when neither trap was operating, an estimate was calculated based on the average catch of an equal time period immediately prior and following the inoperable period. For example, if no traps were operable on April 30, catch for that day would be estimated to be the average of total catch on April 29 and May 1.

Trapping efficiency and outmigration estimation was also examined using a smolt abundance estimator provided by WDFW and developed for its efforts in the Wenatchee River that incorporates stream flow and weights efficiency trials according to the number of released fish (Murdoch et al. 2012; Ryding 2000).

Juvenile Beach Seine/PIT tag effort

Portions of the following text describing the methods were taken directly from a draft DPUD report (DPUD 2014).

Beach seining took place from May 30 to July 3 in the area near the confluence of the Okanogan and Columbia Rivers. Efforts focused on beaches along the North bank of the Columbia River, downstream of the mouth of the Okanogan (48° 6'12. 46"N, 119°44'35. 48"W) (Figure 4). In 2018, Gebber's Landing and Washburn Island were the only areas used for collection. This location provided reasonable catch rates, limited bycatch, and provided suitable substrates (limited debris loads/underwater snags) for efficient sampling. Juvenile Chinook from this location were likely primarily fish originating from the Okanogan River; however, it is possible that offspring from mainstem Columbia River spawning could also be included, especially at the Washburn Island site.

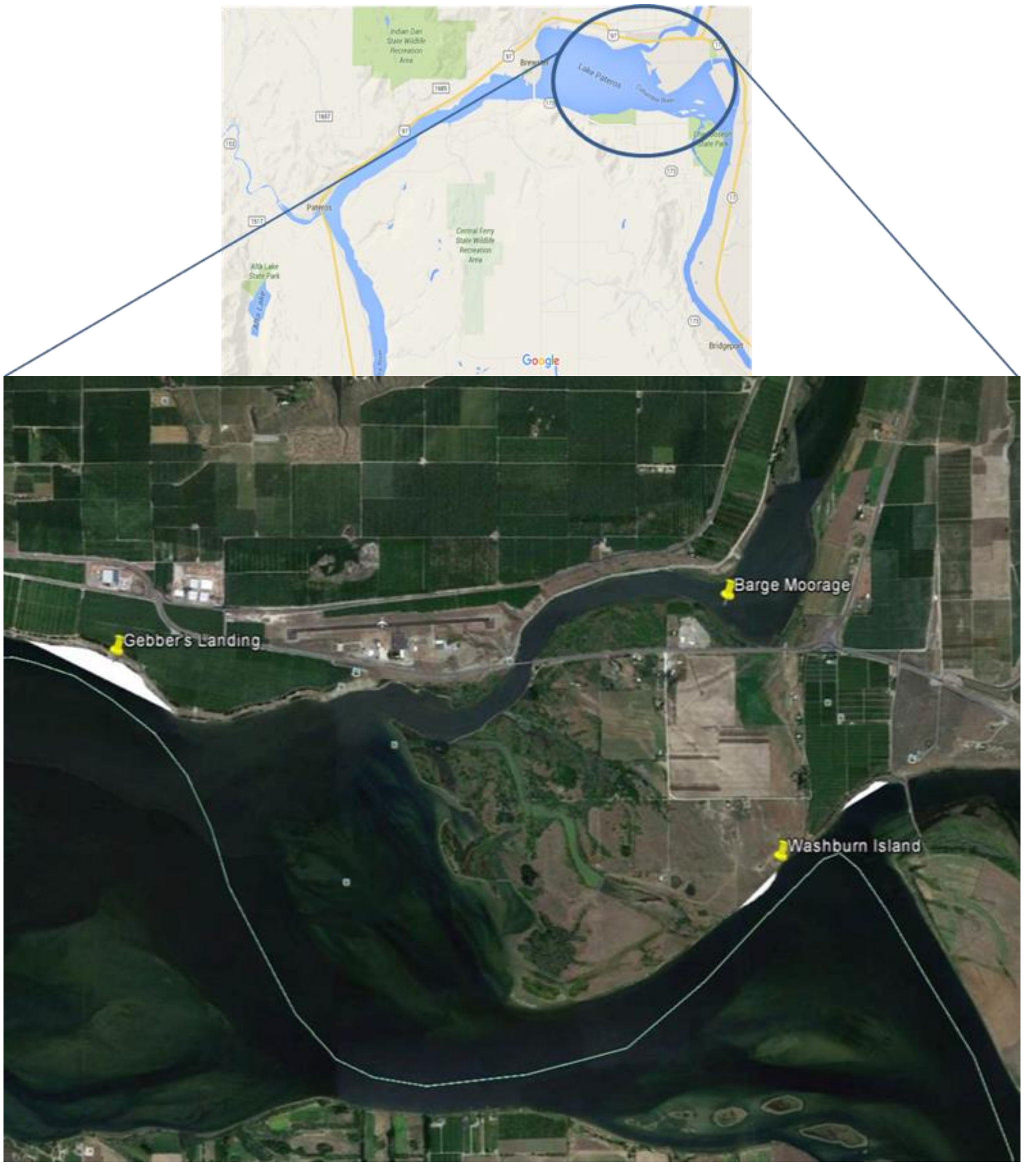

Figure 4. Seining locations downstream (Gebber's Landing) and upstream (Washburn Island) of the confluence.

A single beach seine (30.49 m × 3.05 m with a 28.32 m^3 'bag'; Christensen Net Works, Everson, WA) was used to capture fish. Netting was Delta woven 6.4 mm mesh with "fish-green" treatment. Weights (3-5 kg) were attached to each end of the seine to help keep it open during retrieval.

To capture fish, one end of the seine was tied off to an anchor point onshore, while the other was towed out by boat until the seine was stretched perpendicular to shore. The boat would then pull the seine upstream and return to shore, causing the seine to form a semi-circle intersected by the shoreline (Figure 5). The seine bridle was handed from the boat to a shore crew that would retrieve the seine. Juvenile Chinook were transferred to a 10-gallon tub filled with river water and transferred to a nearby floating net pen. Handling/holding time in the tub was generally <15 minutes. Floating net pens were approximately 5 m^3 and consisted of a PVC pipe frame covered with black 19.1-mm and 3.2-mm mesh. The mesh allowed for adequate water exchange, retained juvenile Chinook and prevented the entrance of predators. Noticeable bycatch, most commonly three-spine stickleback (*Gasterosteus aculeatus*) were released from the seine without enumeration. Any bycatch inadvertently transferred to the floating net pen were later sorted and released during tagging (untagged). On May 30 and June 1, fish captured in the beach seine were immediately tagged on the river shore and released after recovery from anesthesia.

Figure 5. Juvenile beach seine being retrieved by CCT staff near the confluence of the Okanogan and Columbia Rivers.

In most circumstances, juvenile Chinook were held 24 hours prior to tagging to assess capture/handling effects. Occasionally, due to staff availability or other complicating circumstances, fish were held for two days or released shortly after recovery from anesthesia. Chinook ≥ 65mm were tagged with a full duplex 12 mm PIT tag, and Chinook between 65 and 50mm were tagged with a full duplex 9mm PIT tag. After tagging, fish were returned to a floating net pen for 24 hours post-tagging to assess tag loss and tag application/handling mortality rates. Fish were then released to the Columbia River (Wells Pool) several hundred meters downstream of their capture location.

TAGGING PROCEDURES. —Tagging was conducted by CCT staff with support from USGS using a mobile tagging station (Biomark, Co., Boise, ID, USA). The tagging station consisted of an approximately 1 m^2 aluminum work surface with a trough for holding fish during the tagging process as well as all the necessary electronics (computer, scale, tag reader, and antenna) needed for tagging. Water was pumped directly from the river using a ¼ horsepower pump and radiator system to keep water temperatures ambient with river temperatures. When tagging water temperatures were >17 °C, ice was added to the anesthetic solution to decrease the temperature. A solution of 4.0 g Tricaine methanesulfonate (MS-222) per 1 L of water was used to anesthetize fish prior to tagging. The applied concentration of MS-222 would sedate fish to the desired level of stage-2 anesthesia in approximately 3 to 4 minutes. All fish were tagged within 10 minutes of the initial exposure. Recovery time was approximately 1 to 2 minutes.

Each tagging location had two net pens: one containing the fish to be tagged, and an empty pen for holding fish post-tagging. Fish to be tagged were collected from the respective net pens using a dip net and placed into an 18.9 L bucket of water. Up to 40 fish at a time were then transferred from the bucket using a smaller dip net and placed into the trough containing the anesthetic solution.

Fish were tagged with 12.5 mm 134.2 kHz ISO PIT tags using pre-loaded, 12-gauge hypodermic needles (BIO12.BPLT) fitted onto injection devices (MK-25). 12.5 mm PIT tags were used to maximize detection at downstream locations, particularly the Rocky Reach Juvenile Bypass and the Bonneville Dam Corner Collector, although 9 mm PIT tags were used in fish. Detection efficiencies at both of the former sites would dramatically suffer when using the smaller PIT tags available. The tagging crew consisted of one fish sorter, one tagger and one data collector. The data collector interrogated the tag in each tagged fish, recorded its fork length with an electronic wand on a digitizer board, and noted any anomalies. Tagged fish were transferred to the recovery/holding pen via a PVC pipe with flowing water.

Data collected during tagging were stored using PITTAG3 (P3) software (Pacific States Marine Fisheries Commission). After completion of the tagging events, tag files were consolidated, uploaded to PTAGIS (www.ptagis.org), and shared with Douglas PUD.

FISH RELEASES. —Tagged fish were released the morning after they had been tagged. Prior to release, the net pen was opened and all observed mortalities and moribund fish were removed. Once the mortalities were removed the net pen was tilted to allow the fish to volitionally exit. PIT tags were recovered from dead/moribund fish, the associated tag codes were marked as “Mortalities” in the tag files and the tag codes were deleted. Expelled tags were recovered from the mesh floor via a powerful magnet.

Carcasses of summer Chinook were collected and stored, frozen, with capture location and date of capture recorded. Otoliths from these carcasses were later extracted according to the protocol set forth in Glick and Shields (1993), and preserved for analysis in a pilot study to attempt to identify stream of origin for tagged Chinook (See Appendix E).

Lower Okanogan Adult Fish Pilot Weir

The Okanogan adult fish pilot weir (herein referred to as the 'weir') was in its seventh year of design modifications and testing in 2018. Continued operation and improvements to the weir are a central part of CCT's strategy for the successful implementation of the CJHP summer/fall Chinook Salmon (*Oncorhynchus tshawytscha*) programs. Pilot weir test results are essential for updating key assumptions, operations and design of the weir.

Objectives for the pilot weir in 2018 included:

1. Install the weir in early July and operate until late September under allowable flow conditions (<3,000 cfs) and temperature (<22.5 °C);
2. Document environmental effects of the weir through collection of physical and chemical data in the vicinity of the weir;
3. Test weir trapping operations and the Whooshh™ fish transport system including live Chinook capture, handling and release;
4. Direct observations and fish counts for estimating species composition, abundance, health, and timing to inform management decisions and future program operations;
5. Collect NOR and/or HOR brood stock at the weir and transport safely to the CJH;
6. Test the weir configuration, including the location of the trap box, to meet the program's biological and brood-take goals
7. Test fish entrainment through the trap entrance chute and into the trap box

The lower Okanogan fish weir was installed approximately 1.5 km downstream of Malott, WA (48°16'21.54 N; 119°43'31.98 W) in approximately the same location as previous years. Weir installation began on August 6th at a river flow of 1,230 cfs and was completed with the underwater video system on August 10th. An aluminum trap was installed near the center of the channel at the downstream end of the deep pool in the thalweg of the channel. The trap was 3 m wide, 6 m long and 3 m high (Figure 6). A fifteen foot aluminum accelerator chute was installed at the downstream trap gate. The wings of the weir stretched out from either side of the chute towards the river banks, angling downstream in a slight V configuration. The wings consisted of steel tripods with aluminum rails that supported the 3 m long Acrylonitrile butadiene styrene (ABS) pickets. Each panel was zip-tied to the adjacent panel for strength and stability. Sand bags were placed between panels when needed to fill gaps that exceeded the target picket spacing. Picket spacing ranged from 2.5 to 5.1 cm (1 to 2 inch) in 1.2 cm (half-inch) increments (Figure 7). Pickets were manually forced into the river substrate upon deployment and then as needed to prevent fish passage under the weir.

The river-right wing consisted entirely of 2.5 cm picket spacing (Figure 7). A 3 m gap between the last panel and the right shoreline remained to allow for portage of small vessels around the weir. This was a very shallow gravelly area and under most flow conditions it did not appear to be a viable path for adult salmon passage. However, a set up floating panels that were attached to the substrate extended from the last panel to the river-right shore to limit escapement via this route. The river left wing had variable picket spacing to accommodate non-Chinook fish passage through the pickets. The primary objective of the wider picket spacing was to allow Sockeye (*O. nerka*) to pass through the weir and reduce the number of Sockeye that would enter the trap. River left was selected for this spacing to better accommodate observation/data collection regarding successful passage of smaller fish through the panels. In past years CCT has observed jack and even adult Chinook passing through the 6.4 and 7.6 cm picket spacing panels. These picket spacing panels were replaced with 5.1 cm picket spacing panels during deployment to reduce the escapement of smaller hatchery Chinook but still allow Sockeye to pass through these panels.

Figure 6. Lower Okanogan adult fish pilot weir, 2018. Photo taken in mid- August after deployment.

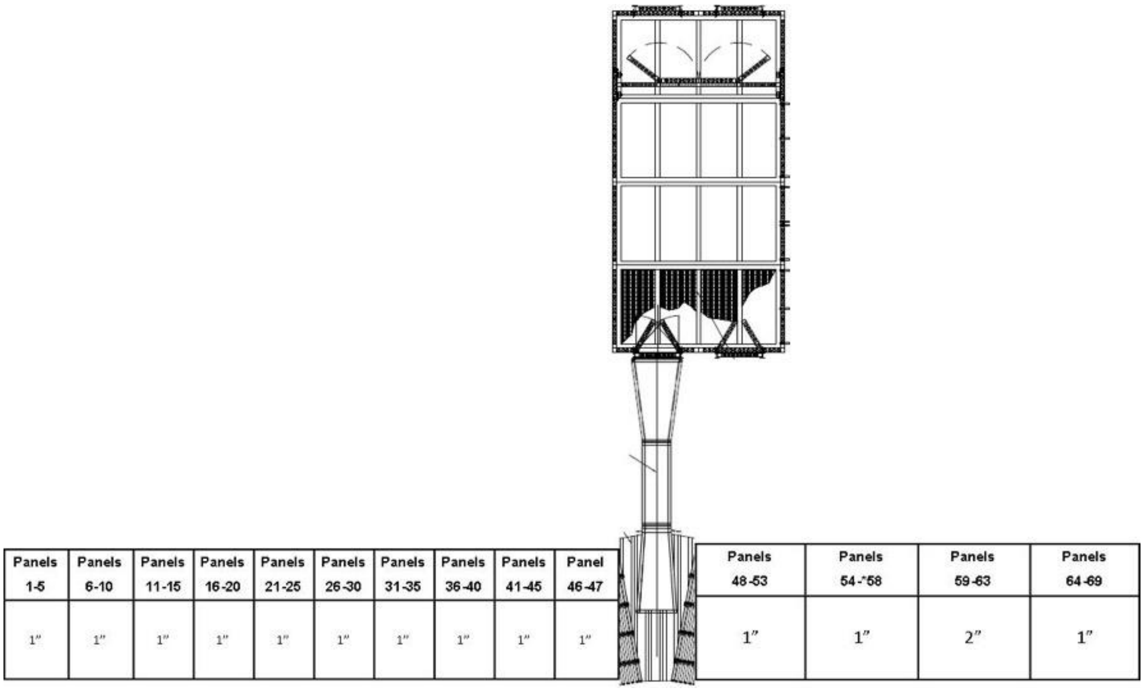

Figure 7. Conceptual diagram of picket (ABS pipe) spacing within each panel (or set of 5 panels) at the Lower Okanogan adult fish pilot weir. A 15 ft entrance chute was installed at the lower trap gate in 2018.

Physical and chemical data were collected in the vicinity of the weir including the water depth (ft) inside the trap, water velocity (ft/sec) upstream, downstream and in the weir trap, dissolved Oxygen (mg/L), total dissolved solids (TDS)(ppm), turbidity (NTU), temperature (°C), discharge (cfs) and head differential (cm). Temperature and discharge were taken from the online data for the USGS gauge at Malott (http://waterdata.usgs.gov/wa/nwis/uv?site_no=12447200). When river temperature exceeded 22.5° C, trapping operations ceased and weir pickets on panels adjacent to the trap on both sides were raised to allow for unrestricted fish passage.

Five minute tower observations were conducted at least three times a day, in the morning (0600-0800), early afternoon (1200-1400) and evening (1700-1900) and an estimate of the number fish observed was recorded. Ten minute bank observations were conducted about 0.8 river km. downstream of the weir, around two pools, at least twice a day, in the morning and afternoon. An estimate of the number of fish observed below the weir was recorded. Algae and debris were cleared off of the weir at least once per day generally in the morning (0800-1000). Dead fish on the upstream side of the weir were enumerated, identified to species and the presence and extent of injuries were noted. The tail was cut off of each mortality before they were tossed downstream of the weir so that they would not be double counted during surveys.

Weir efficiency, a measure of the proportion of total spawning escapement encountered by the weir, was calculated by the equation;

$$X = \frac{W_T}{T}$$

where X was weir efficiency, W_T was the number of adult summer/fall Chinook encountered in the weir trap including released fish, and T was the total summer/fall Chinook spawning escapement for the Okanogan River Basin.

Weir effectiveness was a measure of the proportion of the adult hatchery Okanogan summer/fall Chinook run encountered in the weir trap, becoming available for removal from the population as a form of adult fish management. It was calculated by the equation;

$$Y = \frac{W_H}{W_H + HOS}$$

where Y is weir effectiveness, W_H is the number of adult hatchery origin fish encountered in the weir trap, and HOS is the total number of hatchery origin spawners.

Trapping operations were conducted 24 hours/day, 7 days/week, under allowable temperature conditions (≤22.5° C) for the season. Trapping operations were suspended from September 1-3. The last day of trapping was on September 21st. When fish entered the trap during an active trapping session, the downstream gate was closed and fish were identified and either released or collected for brood.

Nineteen natural-origin Chinook were collected from the weir trap from August 18 to September 18, transported to a 2,500 gallon hatchery truck via a rubber boot. The fish were then transported approximately 32 km to Chief Joseph Hatchery where they were held in the brood stock raceways until spawning in October. The Whoooshh™ fish transport system was not deployed in 2018 due to insufficient staff needed to operate the system effectively, including breakdown of the system during windy weather conditions.

In recent years, mark-recapture studies were performed at the weir trap to assess handling mortality at the weir as well as recovery bias of carcasses on the spawning grounds. All natural-origin Chinook that were trapped and destined for release upstream, were anesthetized with electronic anesthetic gloves, measured, and inserted with a floy tag. After the fish were tagged they were released over the crowder and into the upstream side of the trap where they recovered before they exited through the trap gates on their own volition. Unfortunately there were little to no carcasses recovered on the spawning grounds after the tagging effort, so the program decided not to conduct the study in 2018 until a larger number of fish were captured in the trap (i.e. higher weir efficiency).

Spawning Ground Surveys

The objectives for spawning surveys were to:

1. Estimate total spawning escapement based on the number of Chinook redds per reach
2. Estimate the proportion of natural spawners composed of hatchery-origin recruits (pHOS)
3. Estimate pre-spawn mortality and mean egg retention for wild- and hatchery-origin spawners
4. Determine the origin (rearing/release facility) of hatchery-origin spawners (HOS) in the Okanogan and estimate the spawner composition of out-of-population and out-of-ESU strays (immigration)
5. Estimate out-of-population stray rate for Okanogan hatchery Chinook and estimate genetic contribution to out-of-basin populations (emigration)
6. Determine age composition of returning adults through scale analysis
7. Monitor status and trends of demographic and phenotypic traits of wild- and hatchery-origin spawners (age-at-maturity, length-at-age, run timing, SAR)

REDD SURVEYS

A primary metric used to monitor the status and trends of salmonid populations is spawning escapement. Estimates of spawning escapement can be calculated based on redd counts and expanded by sex-ratios (Matthews and Waples 1991, Gallagher et al. 2007). This requires intensive visual survey efforts conducted throughout the spawning area and over the course of the entire spawning period. Visual redd surveys were conducted to estimate the number of redds per survey reach from the mouth of the Okanogan River to Zosel Dam (river km 124); the Similkameen River from its confluence with the Okanogan River upstream to Enloe Dam (river km 14); and in the mainstem Columbia River from the mouth of the Okanogan River upstream to Chief Joseph Dam (Table 2). Weekly surveys were timed to coincide with spawning in the basin, generally beginning the last week of September or the first week of October and ending approximately the second week of November. Redds were counted using a combination of fixed-wing aerial flight surveys and inflatable raft float surveys.

Aerial surveys occurred once weekly throughout the spawning season, each covering the entire survey area. Aerial surveys were flown at low elevation and at moderate speeds to accommodate visual identification of redds. From the aircraft, a trained observer recorded the number and GPS coordinates of all new redds as the plane passed overhead. All data were recorded directly into a YUMA rugged computer tablet (Trimble Navigation, Ltd.). Aerial surveys were primarily used to document redds in areas inaccessible to rafts, or in areas of low redd densities, such that they did not warrant weekly float surveys. All data points were visualized in ArcGIS (ESRI, Inc.), and quality controlled to ensure that redd counts were not duplicated during float surveys. Aerial surveys also served a secondary function of informing research crews where to focus weekly carcass recovery efforts (see below section on Carcass Surveys).

Float surveys occurred once daily, 5 days per week throughout the spawning season. Float surveys consisted of three 2-person teams using inflatable rafts to count redds while floating downstream. Each team was responsible for covering one-third of the river width, (1) left bank, (2) center, and (3) right bank. Each individual redd was counted and its position recorded directly into a YUMA rugged computer tablet (Trimble Navigation, Ltd.).

Table 2. Reach names and locations for the Okanogan and Similkameen for summer/fall Chinook Salmon spawning and carcass surveys.

Stream	Code	Reach Description	River km
Okanogan	O1	Mouth to Malott Bridge	0.0-27.0
	O2	Malott Bridge to Okanogan Bridge	27.0-41.8
	O3	Okanogan Bridge to Omak Bridge	41.8-49.1
	O4	Omak Bridge to Riverside Bridge	49.1-65.1
	O5	Riverside Bridge to Tonasket Bridge	65.1-90.9
	O6	Tonasket Bridge to Zosel Dam	90.9-124.0
Similkameen	S1	Mouth to Oroville Bridge	0.0-8.0
	S2	Oroville Bridge to Enloe Dam	8.0-14.0
Canada	C*x*	TBD	TBD

All redds were classified as either a:

1. *Test-redd* (disturbed gravel, indicative of digging by Chinook, but abandoned or without presence of Chinook; generally, this classification is reserved for early season redd counts, before substantial post-spawn mortalities have occurred as indicated by egg-voidance analysis of recovered carcasses). Test-redds do not contribute to annual redd counts.
2. *Redd* (disturbed gravel, characteristic of successful Chinook redd construction and/or with presence of Chinook).

Redds per reach were calculated for each week as the combined number of new redds counted during aerial- and float-surveys for a given week. Post-season analysis consisted of summing the combined aerial- and float-survey weekly redd totals to calculate annual redd totals per reach, and per total survey area. Estimated total spawning escapement was then calculated by multiplying the total redd count by the expansion factor for the current year (2.039 for 2017). The expansion factor = 1 + the number of males per female as randomly collected for broodstock at Wells Dam (1.039:1.000 in 2017). Assumptions include:

Assumption I –	Each redd was constructed by a single female Chinook, and each female Chinook constructed only one redd
Assumption II –	The male: female ratio on the spawning grounds was the same for wild- and hatchery-origin Chinook, and is equal to the male: female ratio as randomly collected for broodstock at Wells Dam
Assumption III -	Every redd was observable and correctly enumerated

Escapement into Canada

In previous years, video systems operated by OBMEP and located in the fishways of Zosel Dam allowed observation of salmonids passing over Zosel Dam and potentially into the British Columbia portion of the Okanagan River Basin. For detailed methods within a particular year please see the Okanogan Basin Monitoring and Evaluation Program (OBMEP) annual reports posted at (http://www.colvilletribes.com/obmep_publications.php). However, in 2018 no video monitoring occurred. Therefore, any information regarding Chinook passage at Zosel Dam and/or escapement into the Canadian portion of the Okanagan basin in 2018 is extremely limited and are based primarily on in-stream PIT array data and anecdotal observations.

CARCASS SURVEYS

Carcass surveys provide important biological samples for evaluation of hatchery- and natural-origin fish on the spawning grounds, including:

1) Spawner composition
    a. pHOS
    b. out of population hatchery strays (immigration)
    c. spatial distribution of natural- and hatchery origin spawners
2) Fish size
3) Sex-ratio
4) Age structure (CWT and scale analysis)
5) Pre-spawn mortality (i.e. egg retention)

The target sample size for carcass recovery efforts is 20% of the spawning population within each reach (Hillman et al. 2014). Carcass recovery efforts occurred simultaneously with redd float surveys. Recovered carcasses were transported within inflatable rafts downstream until a suitable site was found for processing. If a carcass was too degraded to sample for biological data, it was returned to the river without sampling. All adipose absent carcasses were assumed to be of hatchery-origin, and all carcasses displaying an intact adipose fin were assumed to be of natural-origin[3]. Origin was later verified by results from the WDFW scale lab analyses. Biological data collected from carcasses included sex, fork length (FL) and post-orbital hypural length (POH) to the nearest cm, and estimated egg retention for all females (0 to 5,000 max; visually estimated). All eggs that were not estimated to be within a carcass were assumed to have been successfully deposited. Any female carcass containing an estimated 5,000 eggs were considered a pre-spawn mortality. Forceps were used to remove five scale samples from all natural-origin Chinook. Scales were adhered to desiccant scale cards for preservation and identified by sample number and sample date. At the conclusion of spawning season, scales were sent to WDFW for post-hoc age analysis. Age analysis data were used to assess age-at-return (run-reconstruction), and combined with biological data to assess length-at-age. All Chinook were scanned for passive integrated transponder (PIT) tags and all PIT detections were recorded and later uploaded to PTAGIS. Carcasses were scanned with a T-wand (Northwest Marine Technology, Inc., Shaw Island, WA USA) for coded wire tags (CWT). If present, the snout portion was removed and individually bagged and labeled with species, origin, FL, river of recovery and date. After sampling each carcass, the caudal fin was removed before the carcass was returned to the river to avoid resampling on subsequent surveys. All data collected in the field were input directly into a YUMA rugged computer tablet (Trimble Navigation, Ltd.). Weekly carcass recovery totals were summed post-season to calculate annual carcass recovery totals per reach and per survey area.

Some key assumptions for carcass surveys included:

Assumption I –	All carcasses had the same probability of being recovered on the spawning grounds (despite differences in sex, origin, size or spawning location)
Assumption II –	The diagnostic unit in which a carcass is recovered is the same as the reach in which the fish spawned
Assumption III –	Sampled carcasses are representative of the overall spawning composition within each reach

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[3] There could have been some hatchery-origin fish with an intact adipose fin. Although all summer/fall Chinook hatchery programs in the Upper Columbia strive for a 100% adipose fin clip rate, a small percentage (~1%) may not receive the fin clip due to mechanical failure in the marking trailer. Additionally, not all fall Chinook programs, such as Priest Rapids Hatchery, clip the adipose fin of their releases.

pHOS and PNI

pHOS was first calculated using the straightforward method of calculation for the population-level pHOS by simply dividing the number of hatchery-origin spawners by the total spawners, such that:

$$pHOS = \frac{HOS_O}{HOS_O + NOS_O}$$

where HOS_O is the total recovered hatchery-origin carcasses and NOS_O is the total recovered natural-origin carcasses. This simple algorithm does not account for assumed deficiencies in hatchery fish effectiveness (*i.e.* relative reproductive success) nor does it account for spatial variation in pHOS and unequal sampling effort across reaches. For example, reach S1 tends to have a higher pHOS than other reaches because the Similkameen acclimation site is located in the reach. Likewise, the probability of recovering carcasses in low density spawning reaches is lower than in reaches with high density spawning. We have attempted to account for each of these factors.

Relative reproductive success has not been estimated for summer/fall Chinook in the Okanogan. One of the key assumptions in the In-Season Implementation Tool was that first-generation hatchery fish are less effective natural spawners than natural-origin fish. Currently, the hatchery fish effectiveness assumption for the Okanogan population is that first generation hatchery-origin spawners are 80% as effective as natural-origin fish as contributing genes to the next generation[4] This assumption is based on research conducted by Reisenbichler and McIntyre (1977) and Williamson et al. (2010). Therefore, the pHOS calculation was amended in 2013 to account for the reduction in hatchery spawner effectiveness, such that:

$$Effective\ pHOS = \frac{0.8\ HOS_O}{0.8\ HOS_O + NOS_O}$$

Further refinement of the pHOS calculation was needed to account for non-random sampling of carcasses and variable pHOS across reaches. This was done by weighting each reach's overall contribution to system-wide pHOS according to the overall proportion of summer/fall Chinook redds that occurred within that reach.

First, the proportion of redds that corresponded to each reach was calculated by the equation:

$$redd_{p,r} = \frac{redd_r}{redd_O}$$

---

[4] This 80% correction factor has also been suggested by the HSRG as a default value when no direct estimates are available (HSRG 2009). Also see HSRG 2014 for a discussion about the definition and calculation effective pHOS.

where, $redd_r$ is the number of documented redds that occur within reach r, $redd_O$ is the total number of redds documented in the U.S. portion in the Okanogan River Basin, and $redd_{p,r}$ is the proportion of total redds that were documented in reach r.

Next, Effective pHOS was calculated separately for each sampled reach, r, so that:

$$pHOS_r = \frac{0.8HOS_r}{0.8\ HOS_r + NOS_r}$$

where $pHOS_r$ is the Effective pHOS calculation for reach r, and HOS_r *and* NOS_r are the total recovered carcasses of hatchery- and natural-origin within that reach. Finally, Effective pHOS was corrected for the proportion of redds in each reach to determine an adjusted Effective pHOS, such that:

$$Effective\ pHOS = \sum_{i=1}^{n} pHOS_r(redd_{p,r})$$

where n is the total number of sampled reaches that compose the Okanogan River Basin. These calculations assumed that sampled carcasses were representative of the overall spawning composition within each reach; that no carcasses were washed downstream into another reach; that all carcasses had an equal probability of recovery; and that all fish within origin types had equal fecundity. While it is unlikely that all of these assumptions were correct, the modified calculation results in a better representation of the actual census pHOS.

PNI was calculated as:

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

where *pNOB* was the proportion of broodstock that were natural-origin Okanogan returns, and *Effective pHOS* was the reach weighted effective pHOS defined previously. To determine an Okanogan specific pNOB, we applied the results of a radio tracking study, which estimated that 90% of the natural-origin fish detected near the mouth of the Okanogan River in 2011 and 2012 ended up spawning in the Okanogan Basin (Mann and Snow 2013). Therefore, we assumed that 90% of the NOB collected in the purse seine (2010-2013) was of Okanogan origin.

In years prior to 2010 all of the broodstock for the Similkameen program were collected at Wells Dam. That program strived for 100% pNOB and did achieve >95% pNOB in 7 of the last 8 years (Hillman et al. 2014). However, the Wells Dam broodstock collection efforts composited natural-origin fish from the Okanogan and Methow populations as well as fish originating from downstream populations[5]. We made a correction for non-Okanogan NOB for all years when Wells Dam was used for brood collection using the formula:

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[5] A radio tracking study showed that fewer than 50% of the natural-origin fish tagged at Wells Dam ended up in the Okanogan in 2011 and 2012 (Mann and Snow 2013).

$$Adjusted\ Wells\ Dam\ pNOB = Wells\ Dam\ pNOB\ * (\frac{Okanogan\ NOS}{Okanogan\ NOS + Methow\ NOS})$$

where the *Adjusted Wells Dam pNOB* was estimated based on the proportion of natural-origin spawners (NOS) that were in the Okanogan compared to the Methow for that particular year. This correction was made for a portion of the broodstock in 2010 and 2011 and all of the broodstock previous to 2010. This correction did not account for stray NORs from downstream populations or NORs that would have remained in the Columbia River above Wells Dam. Although the radio tracking study provides an estimate of this for 2011 and 2012, there was uncertainty regarding the applicability of the radio tracking data for years prior.

Origin of Hatchery Spawners

Snouts from adipose fin clipped fish were removed, individually labeled, frozen, and delivered to the Chief Joseph Hatchery coded wire tag lab for CWT extraction and reading. The Regional Mark Information System (RMIS; http://www.rmis.org/rmis) was queried in February 2019 to assess the rearing facility of hatchery-origin Chinook recovered on the Okanogan spawning grounds, the in-to-basin stray rate, and the out-of-basin stray rates. RMIS data queries are described in detail in the 2013 CJHP Annual Report (Baldwin *et al.* 2016).

Smolt-to-Smolt Survival and Travel Time

Survival and travel time were assessed using the Data Acquisition in Real Time (DART) website analysis tools. DART calculates a survival estimate using a Cormack Jolly Seber mark recapture model, for full details on the analysis methods please see the DART website (http://www.cbr.washington.edu/dart/query/pit_sum_tagfiles). Each CJH release group with PIT tags were queried for survival from release to Rocky Reach Dam Juvenile bypass (RRJ) and McNary Dam Juvenile bypass (MCN). Although some recaptures were obtained further downstream than McNary Dam, survival through the entire hydropower system to Bonneville Dam could not be generated because there were not enough recaptures downstream to estimate the recapture probability. Survival estimates and travel time for nearby hatcheries and the wild summer Chinook captured in the RST and beach seine were also analyzed for comparison purposes.

Survival estimates are 'apparent survival' because they were not adjusted for residuals, tag failure, tag loss (shedding), or other factors which could result in fish not dying but not being detected at a downstream location. Due to these factors, actual survival would be higher than the apparent survival estimates provided in this report.

Migration timing from release to the lower Okanogan River was determined using a query of the PTAGIS database (https://www.ptagis.org/data/quick-reports/small-scale-site-detections) to determine the timing of PIT tag detections from releases of Summer Chinook at Omak Pond. No PIT tags were released from Similkameen Pond in 2016. The lower Okanogan

River PIT tag interrogation site (OKL) is located at rkm 25 and is within 2 km of the inundation effects of Wells Dam.

Smolt-to-adult Return

The smolt to adult return rate (SAR) was calculated using two different methods, PIT tags and coded-wire tags (CWT). For PIT tags, SAR was calculated for adult fish (age 4-6) from release, back to Bonneville and Wells dams using the formula:

$$SAR = \frac{\#\ PIT\ tags\ detected\ in\ adult\ ladders\ at\ dam\ x}{\#\ PIT\ tags\ released}$$

A correction was then applied to the SAR to account for adult fish harvested before reaching each dam. Standard harvest rates for each return year were applied based on harvest summaries for indicator stocks generated by the Technical Advisory Committee of US v Oregon.

The SAR for CWT was estimated as:

$$SAR = \frac{expanded\ CWT\ recoveries}{CWT\ released}$$

where expanded CWT recoveries included estimated expanded recoveries on the spawning grounds, at hatcheries and in fisheries. Two expansions were applied. First the number of recoveries was expanded to account for the proportion of the release group that wasn't tagged. For example, with a 99% CWT mark rate the recoveries would be increased by 1%. Second, the recoveries were expanded based on the proportion of the population that was sampled. For example, if carcass surveys recovered 20% of the estimated spawners then the number of CWT recoveries was expanded by 80%. The number of CWT fish released were simply the hatchery release data including all tag codes for CWT released fish (CWT + Ad Clip fish and CWT-only fish).

Coded Wire Tag Lab Analysis

Coded wire tags (CWT) from broodstock, ladder surplus, purse seine harvest, creel and spawning ground surveys were extracted, read, and reported in the Chief Joseph Hatchery Lab from December 2017 to February 2018. The snouts were then interrogated for the presence of a CWT by using a V-reader or T-wand. After positive detection, the snout was cut bilaterally into symmetrical portions keeping the half that indicated detection and discarding the other half into the snout bag from which it came. This process was then repeated until only a small piece of tissue containing the CWT remains. The final piece of tissue was then smeared on a cutting mat exposing the CWT, then placed on its corresponding snout card and finally on to a cafeteria tray (groups of ~25 tags) to be read under a microscope.

Extracted tags were removed from the tray one-by-one to be cleaned, recorded and read. The CWT was cleaned by wetting a lint free cloth and rolling the tag between a finger and cloth to remove all remaining tissue. The CWT was attached to a Northwest Marine Technologies (NMT) magnetic pencil and inserted into a jig to be read under a LCD microscope with the aid of an illuminator. Biological data was transcribed from the snout card to a final CWT datasheet. The CWT was attached to this datasheet with tape after the six digit code was read. Information from the datasheet was transferred to an excel workbook which contains all applicable CWT code combinations.

CWTs were expanded based on their tag loss and sample rate to estimate total catch contribution for a specific fishery. For each fishery, every CWT recovered and decoded was grouped according to their tag code with the total number of CWTs recovered from that release group, (e.g. tag code 200108 was recovered 10 times for a fishery/location (tag group 1). (see formula 1 below). Tag group 1 is then divided by the sum of all recovered/decoded CWTs for that specific fishery. This value was multiplied by the sum of all lost and scratched tags with tag group 1 being added to the end of the calculation. This provides an adjustment factor for lost and scratched tags for every unique tag code by hatchery of origin. Mark rates are typically high (~99%) for most Upper Columbia River release groups, however it is important to account for missing tags or tags that were shed during the fish's lifecycle. (see formula 2 below). Taking the adjustment factor for lost and scratched tags and multiplying it by the tag loss rate (tag loss rate can be found at www.RMPC.ORG) provides an adjustment for missing tags. These adjustments (lost/scratched/missing) can be summed together to provide total catch contribution for a fishery that was sampled at 100 percent. (see formula 3 below). When sampling occurred at less than 100 percent the adjustment total is divided by the sample rate to calculate the expanded number of fish for each release group.

(1) Adjustment for Lost/scratched tags:

$$CWT_{Adjustment=(Tag_{group\ 1}/\sum Total\ tags)*(\sum Lost+scratched\ Tags)+Tag_{group1}}$$

(2) Adjustment for tag loss:

$$CWT_{Adjustment=\{(Tag_{group\ 1}/\sum Total\ tags)*(\sum Lost+scratched\ Tags)+Tag_{group1}}\} * (Tag\ loss\ Rate)$$

(3) CWT expansion

$$\frac{CWT_{Adjustment=\{(Tag_{group\ 1}/\sum Total\ tags)*(\sum Lost+scratched\ Tags)+Tag_{group1}}\} * (Tag\ loss\ Rate)}{\text{Sample Rate}}$$

Finally, after accounting for the mark rate of each group, the remaining ad-clip, no-CWT fish were assigned to the CJH segregated group.

RESULTS

Rotary Screw Traps

Rotary screw trap activities were severely hindered in 2018 by an extreme flood event that caused trapping operations to be suspended for the majority of the month of May, when, presumably, the majority of juvenile outmigrants would have passed the trap. The rotary screw traps captured 3,914 Chinook juvenile out migrants, including 663 hatchery- and 3,251 natural-origin. Highest catches were recorded when Okanogan River flow began to increase, prior to removal of the screw traps because of the flood (Figure 8). The mean length of Chinook increased throughout the trapping season, but the number of natural-origin smolts that were large enough (>60 mm) to PIT tag was small, and only 272 fish were PIT tagged after capture at the screw trap (Figure 10). No natural-origin fish were captured that were likely yearling Chinook.

Following Chinook, the next most abundant species captured in the RST was mountain whitefish (Table 3). Notably, only 24 Sockeye were detected, which is far lower than in some previous years. Seven adipose fin present[6] steelhead and 18 adipose fin absent (hatchery-origin) steelhead were removed from the trap and released immediately into the river. There was one juvenile steelhead mortality at the trap resulting in a 4% juvenile trapping and handling mortality rate for steelhead. The encounter of 18 adipose clipped and 7 adipose present (assumed natural-origin) and mortality of zero (0) assumed natural-origin steelhead are within the take limits identified in the authorizing ESA Section 10(a)(1)(A) Permit for the rotary screw trap operation (Permit 16122).

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[6] Not all hatchery steelhead released in the Okanogan receive an adipose fin clip. In 2018, 67,649 steelhead were released into the Okanogan River with an adipose clip, and 326 unclipped steelhead were released.

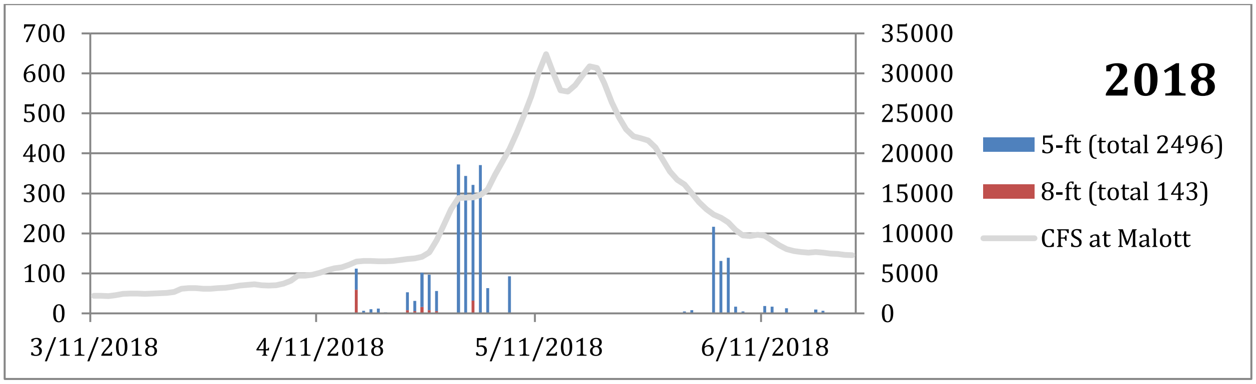


Figure 8. Daily natural-origin sub-yearling Chinook catch within an 8 foot and 5 foot the Okanogan River in 2018.

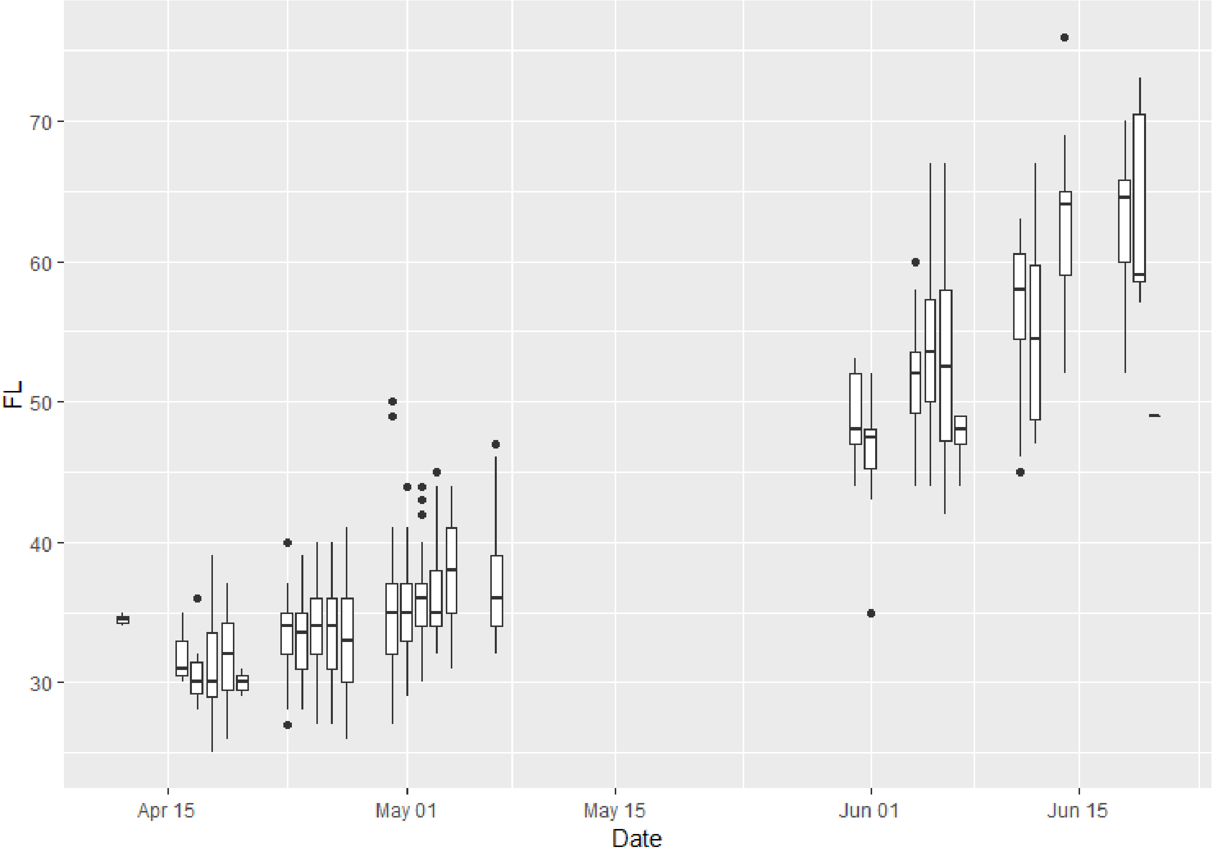


Figure 9. Natural-origin sub-yearling Chinook size distribution (n= 1,986) from the rotary screw traps on the Okanogan River in 2018. Boxes encompass the 25th to 75th percentiles of measured fish, points represent statistical outliers, and the mid-line in the box is the median fish length. FL = fork length in millimeters (mm).

Table 3. Number of juvenile fish trapped at the Okanogan River rotary screw traps in 2018.

Species	**Total Trapped**
Bluegill	11
Bridgelip Sucker	0
Common Carp	39
Longnose Dace	1
Northern Pikeminnow	6
Largemouth Bass	0
Sculpin (*Cottus* spp.)	2
Smallmouth Bass	0
Three Spine Stickleback	0
Peamouth	0
Redside shiner	0
Crappie (*Pomoxis* spp.)	0
Bullhead (*Ameiurus* spp.)	12
Yellow Perch	53
Non-salmonid total	124
Adipose Clipped steelhead	18
Adipose Present steelhead	7
Hatchery Chinook	663
Sockeye	24
Wild Chinook Subs	3,914
Wild Chinook Yearling	0
Eastern Brook Trout	0
Mountain Whitefish	623
Salmonid total	5,249

Three efficiency trials were conducted with juvenile Chinook (all with hatchery-origin yearlings) at varying cfs (Table 4.). Since RST efficiency and Okanogan River flow have not been correlated in the past and the number of efficiency trials conducted in 2018 was not large enough to show correlation during this year, the WDFW smolt abundance calculator was not employed. Because of the inability to collect sufficient data to confidently estimate juvenile outmigration, abundance estimates were not produced for the 2018 outmigration.

Table 4. Efficiency trials conducted on hatchery-origin Chinook sub-yearlings at the Okanogan rotary screw traps in March and April, 2018.

Trap Date	River Flow @ USGS Malott	Total Chinook Marked and Released	Age Class / Origin	Total Chinook Recaptured	Trap Efficiency
3/28	3,160	1,040	1+ / Hatchery	2	0.19%
4/2	3,640	1,000	1+ / Hatchery	1	0.10%
4/10	4,850	1,059	1+ / Hatchery	1	0.09%
Total		**3,099**		**4**	**0.13%**

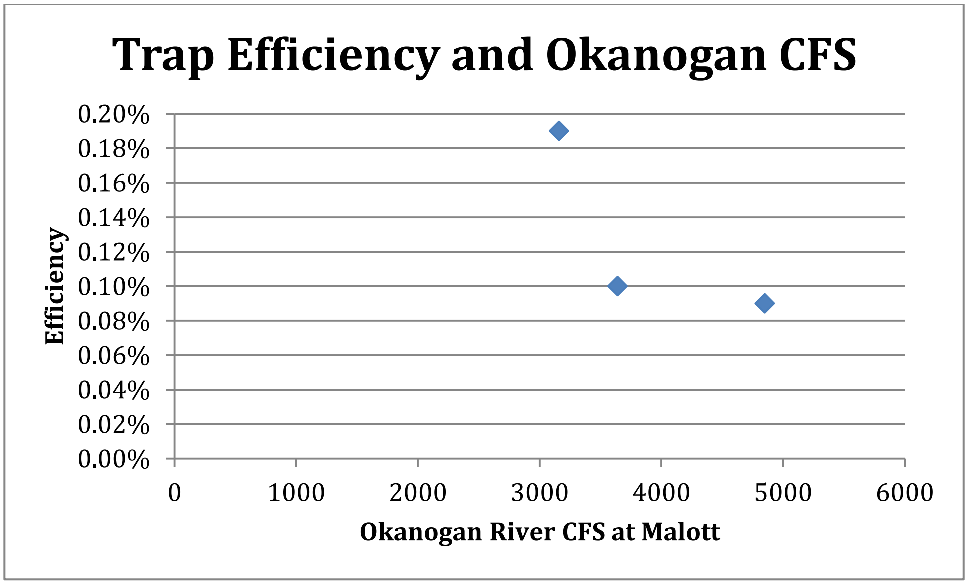


Figure 10. The efficiency trials conducted with hatchery-origin subyearlings are marked in blue.

It should be noted that the efficiency trials using hatchery yearlings from the Omak Pond (Table 4, Figure 10) as a release group is not an ideal proxy for natural-origin subyearling Chinook. In the past, such trials have been used to explore the possibility of using hatchery-origin yearlings as a surrogate for natural-origin subyearlings, but significant differences in capture efficiency ultimately led to the abandonment of this idea (see 2015 Annual Report). Nevertheless, all trials in 2018 were conducted with hatchery-origin yearlings because of their availability for use and an inability to capture sufficient numbers of natural-origin subyearlings. Only four hatchery-origin yearlings out of 3,099 released were recaptured (0.13% efficiency). The higher trapping efficiencies encountered in previous years for yearling Chinook indicates that the RST may be a useful tool in future years for estimation of yearling out-migrating Chinook. Yearling outmigrants are likely to increase in number once hatchery-origin spring Chinook released into the Okanogan river basin begin to return, and any of their potential progeny out migrate.

Since streamflow did not affect trapping efficiency, efficiency trials were pooled to calculate overall trap efficiency for both natural- and hatchery-origin fish (Table 5). Overall efficiency estimates for natural- and hatchery-origin fish were low as were total catches, leading to a relatively imprecise estimate of total emigration (Table 6).

Table 5. Pooled efficiency trail results for all trap configurations. Whenever fish were released, each trap was operational. Efficiency was calculated based on recaptures for each individual trap, as well as the combined efficiency of both traps.

Trap	Stock	Mark-Released	Recaptured	Efficiency
2.4 m Trap	Hatchery Subyearling	N/A	N/A	N/A
	Hatchery Yearling	3,099	4	0.13%
1.5 m Trap	Hatchery Subyearling	N/A	N/A	N/A
	Hatchery Yearling	3,099	0	0.00%

Table 6. Population estimates for hatchery- and natural-origin juvenile Chinook salmon in the Okanogan River Basin.

Species	Population Estimate	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Hatchery-origin Chinook*	507,461	663**	8,408,727
Natural-origin*** Chinook	N/A	N/A	N/A

* A total of 877,713 hatchery-origin Chinook were released into the Okanogan River system upriver from the screw trap site in 2018. 196,895 were released from the Riverside acclimation pond from April 16-19; 376,215 were released from the Similkameen hatchery from April 16 – April 30; 301,246 were released from the Omak acclimation pond on April 16-19; and 3,387 were released in Canada into the Okanagan River on June 6.

** The lower confidence interval is bounded by the number of hatchery-origin Chinook captured in the RST in 2018

*** Because of extreme flooding events in the Okanogan River, RST operations were curtailed such that an estimate of natural-origin Chinook outmigrants could not be produced.

Juvenile Beach Seine and Pit Tagging

In 2018, 25,069 natural-origin juvenile salmonids were collected in over the course of 17 tagging days (Table 7.). Out of the juvenile summer/fall Chinook collected, 23,668 (94%) sub-yearling Chinook were PIT tagged and released (Figure 11). Pre- and post-tag mortality was 1.0% and 2.8% respectively. Fifty-five shed tags were recovered from the net pens prior to release, fifty of which were from post-tag mortalities, and the other five were ejected from fish that were later released alive, but without a tag. All recovered tags were removed from the tagging file before upload to PTAGIS. Fish size increased through time (Figure 12), but after peaking in the week beginning on 18 June, the number of fish captured at Gebber's rapidly declined (Table 7). By late-June, Columbia River temperatures had risen to above 14° C. We suspect that sub-yearling Chinook may have migrated downstream, or to deeper, cooler water making it difficult to collect them via beach seine, as has presumably happened in past years. Fork length for tagged fish ranged from 48-110 mm, with an average of 70.4 mm (SD 8.9 mm) and a median of 70 mm (Figure 13). Bycatch included hatchery-origin juvenile Chinook, three-spine stickleback, mountain whitefish, smallmouth bass, and sculpin.

Table 7. Summary of juvenile Chinook beach seining effort at Gebber's Landing (Geb.) and Washburn Island in 2017. This table excludes Chinook salmon that were captured, PIT tagged, and then recaptured in the beach seine.

Week start	Gebber's Fish Collected	Gebber's Fish Tagged	Proportion Gebber's Fish Tagged	Washburn Fish Collected	Washburn Fish Tagged	Proportion Washburn Fish Tagged
5/27/2018	192	81	45%	130	81	62%
6/3/2018	1,199	1,145	95%	666	649	97%
6/10/2018	4,227	4,030	95%	2,423	2,332	96%
6/17/2018	11,979	11,831	99%	0	0	--
6/24/2018	3,869	3,852	99%	0	0	--
7/1/2018	384	348	91%	0	0	--
Total	**21,850**	**21,287**		**3,129**	**3,062**	
Mean	**3,640**	**3,548**		**537**	**510**	

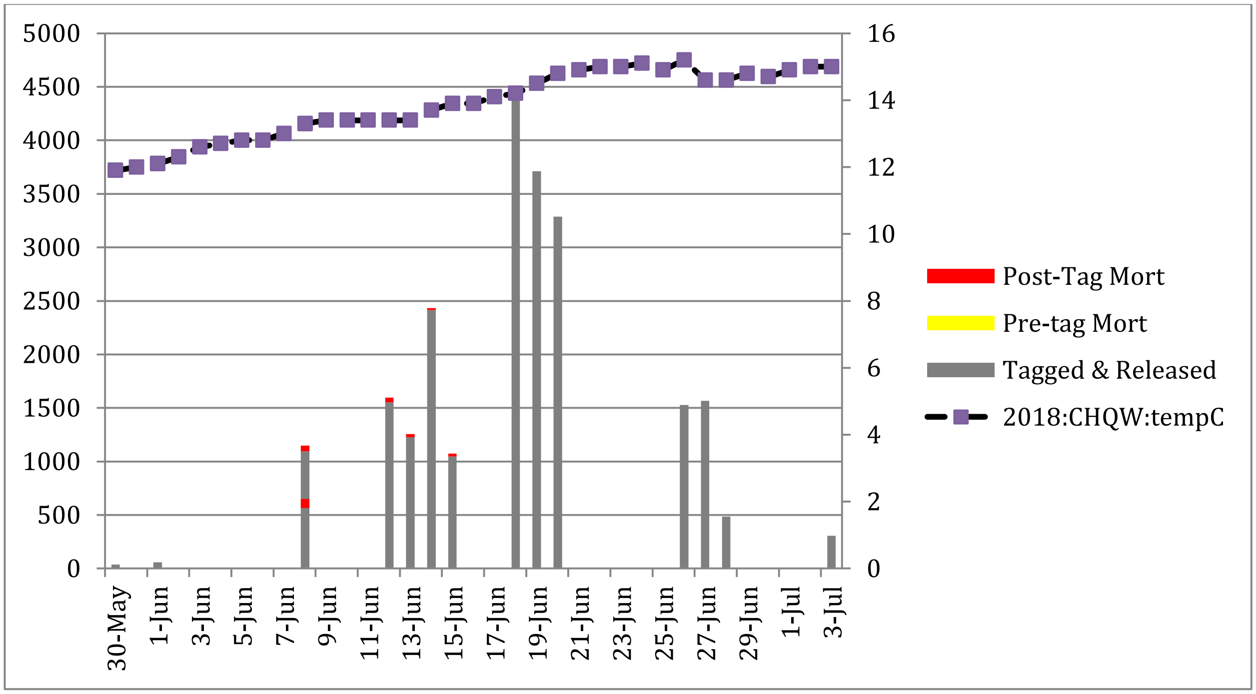


Figure 11. Total mortality and number of released natural-origin sub-yearling Chinook in 2018. Primary y-axis shows number of juvenile Chinook; secondary y-axis (right hand side) shows water temperature (degrees Celsius (C)).

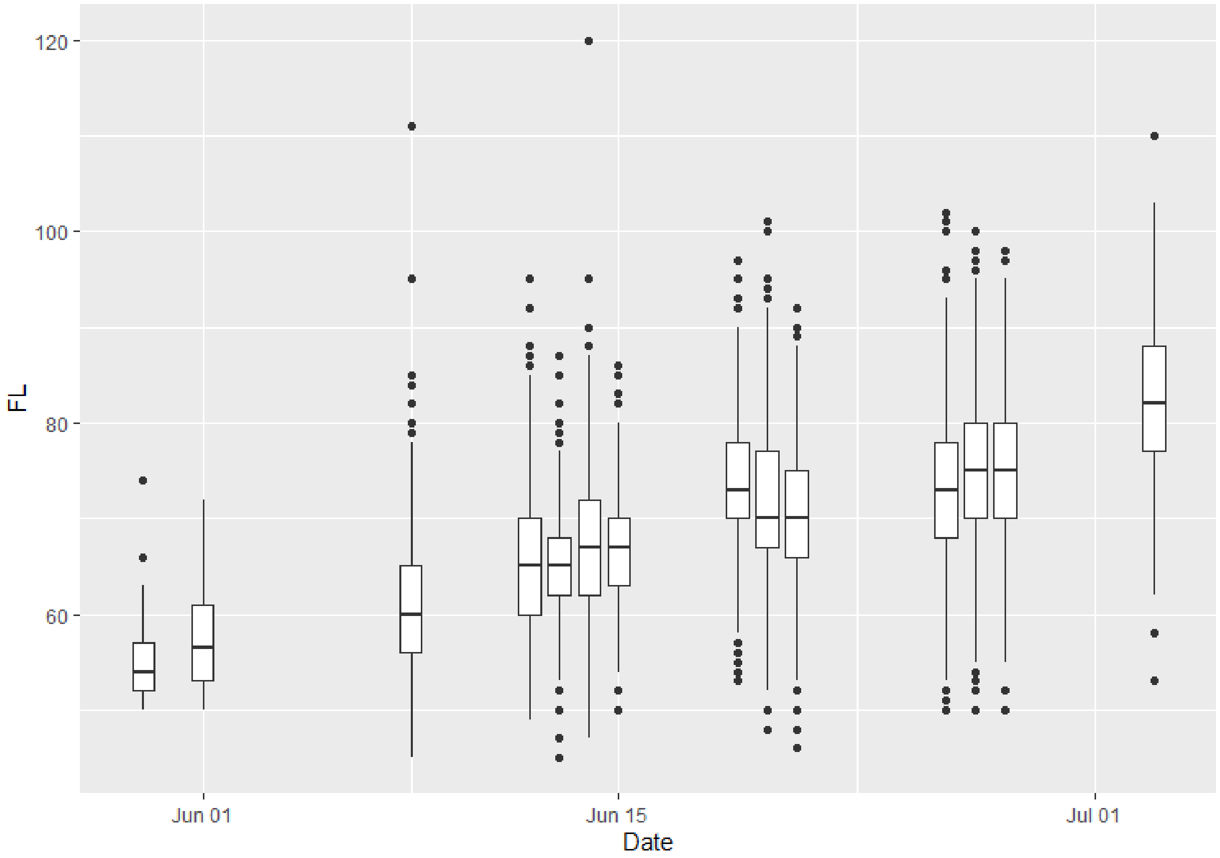


Figure 12. Size distribution of PIT tagged juvenile Chinook by release date from the beach seine effort in 2018. Boxes encompass the 25th to 75th percentiles of measured fish; the mid-line in the box is the median fish length. FL = fork length in millimeters (mm).

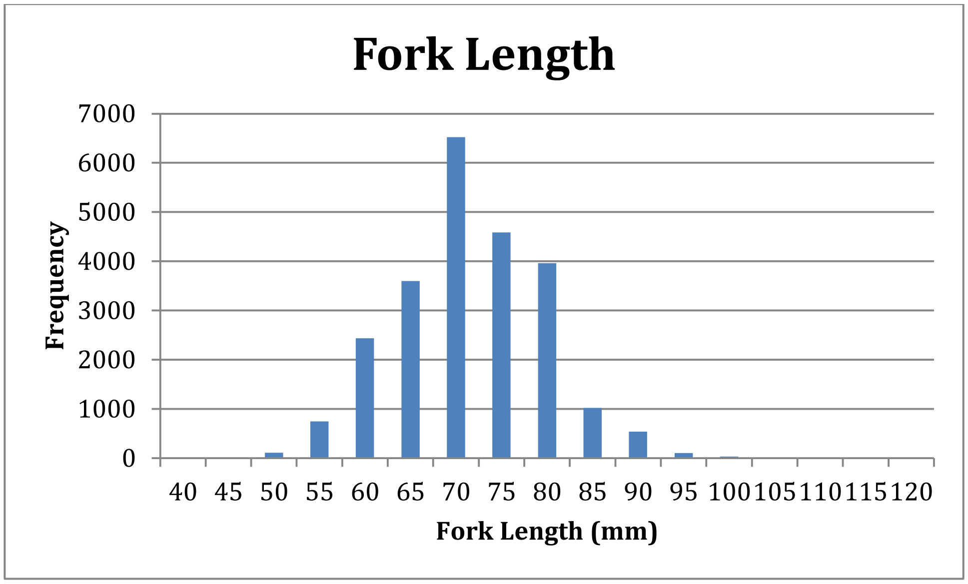
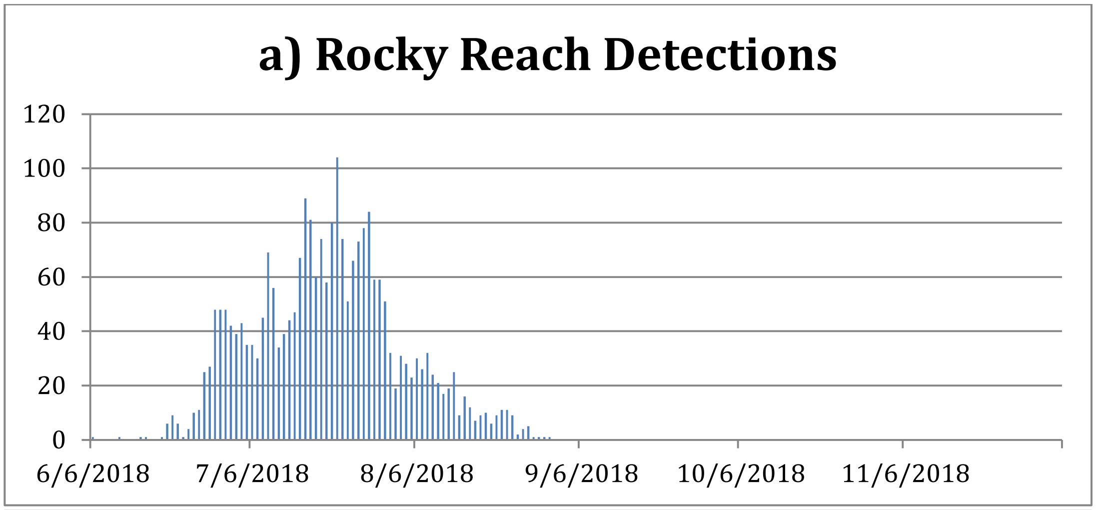
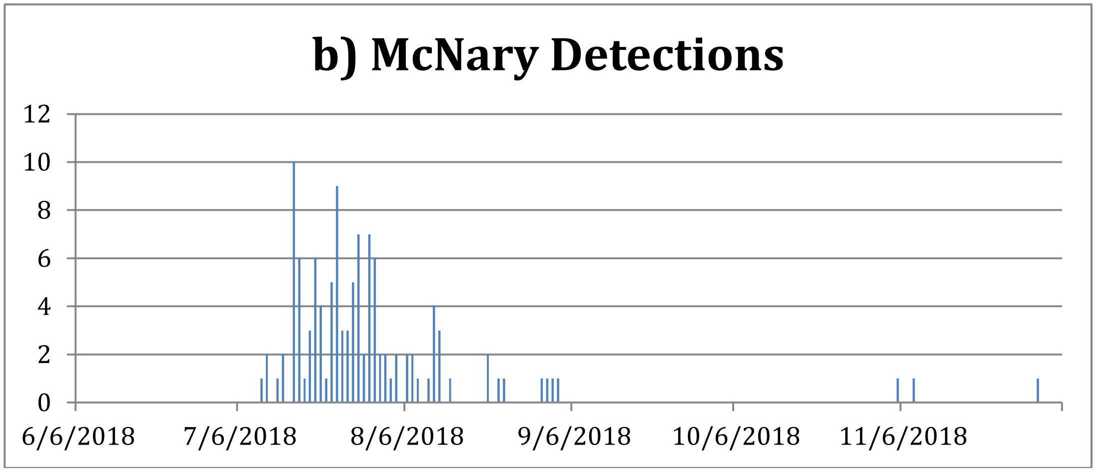


Figure 13. Size distribution of natural origin sub-yearling Chinook tagged during the beach seining effort in 2018

The Rocky Reach juvenile bypass system detected 2,465 PIT tagged juvenile Chinook from the beach seining effort, which was 10.5% of total fish tagged and released. One hundred seventeen (0.5%), 124 (0.5%) and 41 (0.2%) were detected at the McNary, John Day and Bonneville Dams respectively. Detections for sub-yearlings occurred primarily from late-June to early-August at all downriver dams (Figure 14). Utilizing the mark-recapture model from DART, the apparent survival rate was 44% (SE 4%) to Rocky Reach and 12% (3% SE) to McNary.


a) Rocky Reach Detections
120
100
80
60
40
20
0
6/6/2018
7/6/2018
8/6/2018
9/6/2018
10/6/2018
11/6/2018


b) McNary Detections
12
10
8
6
4
2
0
6/6/2018
7/6/2018
8/6/2018
9/6/2018
10/6/2018
11/6/2018

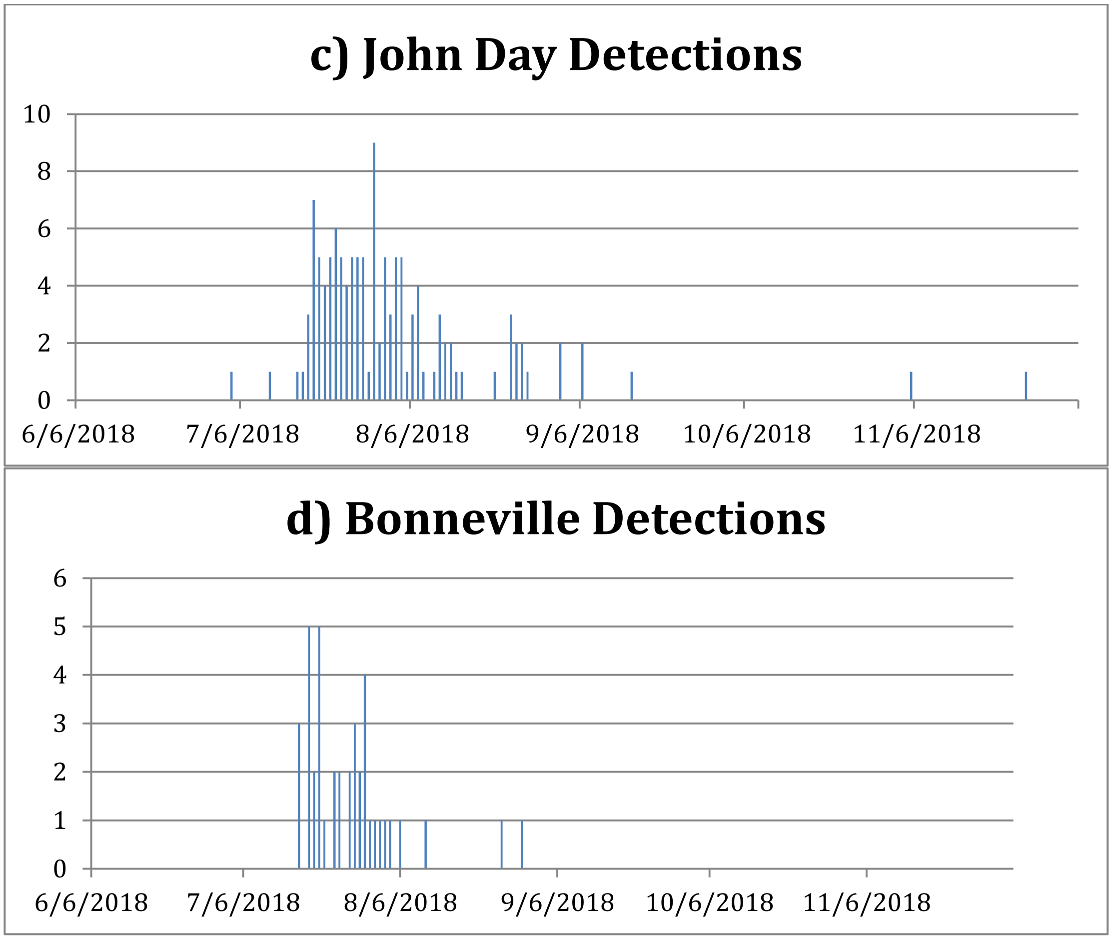


Figure 14. Daily distribution of detections of PIT-tagged sub-yearling Chinook at Rocky Reach, McNary, John Day, and Bonneville Dams in 2018. Note differences in scale on the y-axis. The y axes denote the numbers of PIT-tagged fish encountered daily at each of the mainstem project arrays.

Travel time from release to Rocky Reach Dam was the slowest compared to travel time from release to the other lower river dams – on average, fish moved downstream more quickly the further downstream they travelled (Table 8).Larger fish travelled faster to Rocky Reach Dam (Figure 15). This is similar to what was reported in 2011-2013 by Douglas County PUD and observed in previous years by CCT.

Table 8. Mean travel time (d) and rate (km/d) for PIT tagged sub-yearling Chinook released near Gebber's Landing and detected at Columbia River dam PIT arrays.

	Rocky Reach (762)		**McNary (470)**		**John Day (347)**		**Bonneville (235)**	
Location (River KM)	Travel Time (d)	Rate (km/d)	Travel Time (d)	Rate (km/d)	Travel Time (d)	Rate (km/d)	Travel Time (d)	Rate (km/d)
Release (856)	31.7 (Standard Deviation = 13.9; n=2,465)	3.0	44.9 (Standard Deviation = 20.8; n=117)	8.6	49.5 (Standard Deviation = 39.4; n=124)	10.3	54.6 (Standard Deviation= 60.9; n=41)	11.4
Rocky Reach (762)			14.5 (Standard Deviation = 14.9; n=70)	20.1	18.5 (Standard Deviation = 15.2; n=29)	18.8	52.1 (Standard Deviation = 87.1; n=15	28.0
McNary (470)					3.7 (Standard Deviation = 1.7; n=10)	33.2	4 (Standard Deviation=0 ; n=3)	58.8
John Day (347)							2.0 (Standard Deviation = 1.56; n=9)	56.0

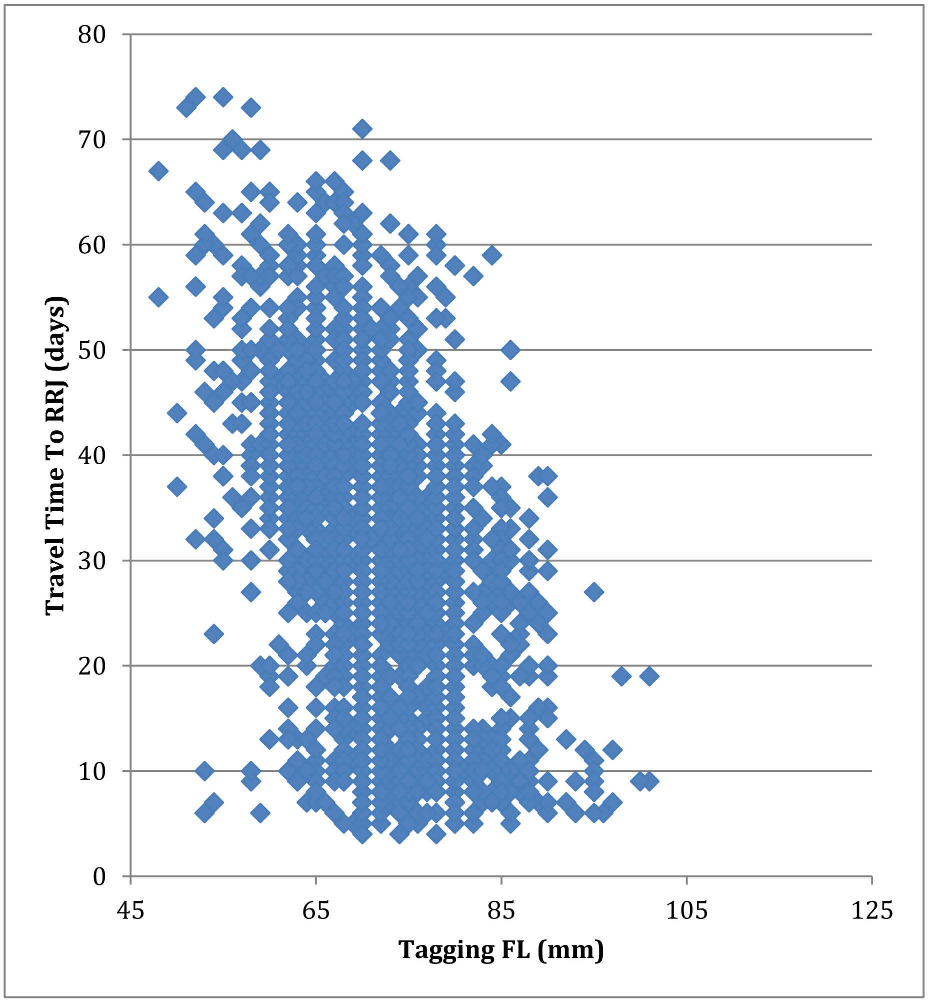


Figure 15. Fish size (fork length) and travel time of tagged Chinook to Rocky Reach Dam.

Lower Okanogan Adult Fish Pilot Weir

The Okanogan River (at Malott) discharge was above normal in 2018 and was below 2,000 cfs for the trapping season. Staff were able to safely enter the river and begin installation on August 6th when discharge was 1,230 cfs (Figure 16). Discharge continued to drop throughout the season and was 1,100 cfs by the time the weir was removed for the season.

Migration of Sockeye and summer Chinook is generally affected by a thermal barrier that is caused by warm water temperatures (≥~22 °C) in the lower Okanogan River. The thermal barrier is dynamic within and between years, but generally it sets up in mid-July and breaks down in late August. In some years, the Okanogan River will temporarily cool off due to a combination of interrelated weather factors including rainstorms, cool weather, cloud cover or wildfire smoke. This 'break' in the thermal barrier can allow a portion of the fish holding in the Columbia River to enter the Okanogan and migrate up to thermal refuge in the Similkameen River or Lake Osoyoos. In 2018, temperatures were similar to the median daily temperatures from the last 13 years (Figure 17).

Daily mean temperature was above 22.5 °C from July 1 to August 10. Daily mean temperature dropped below 22.5 °C on August 10th and stayed below this mark for the rest of the season.

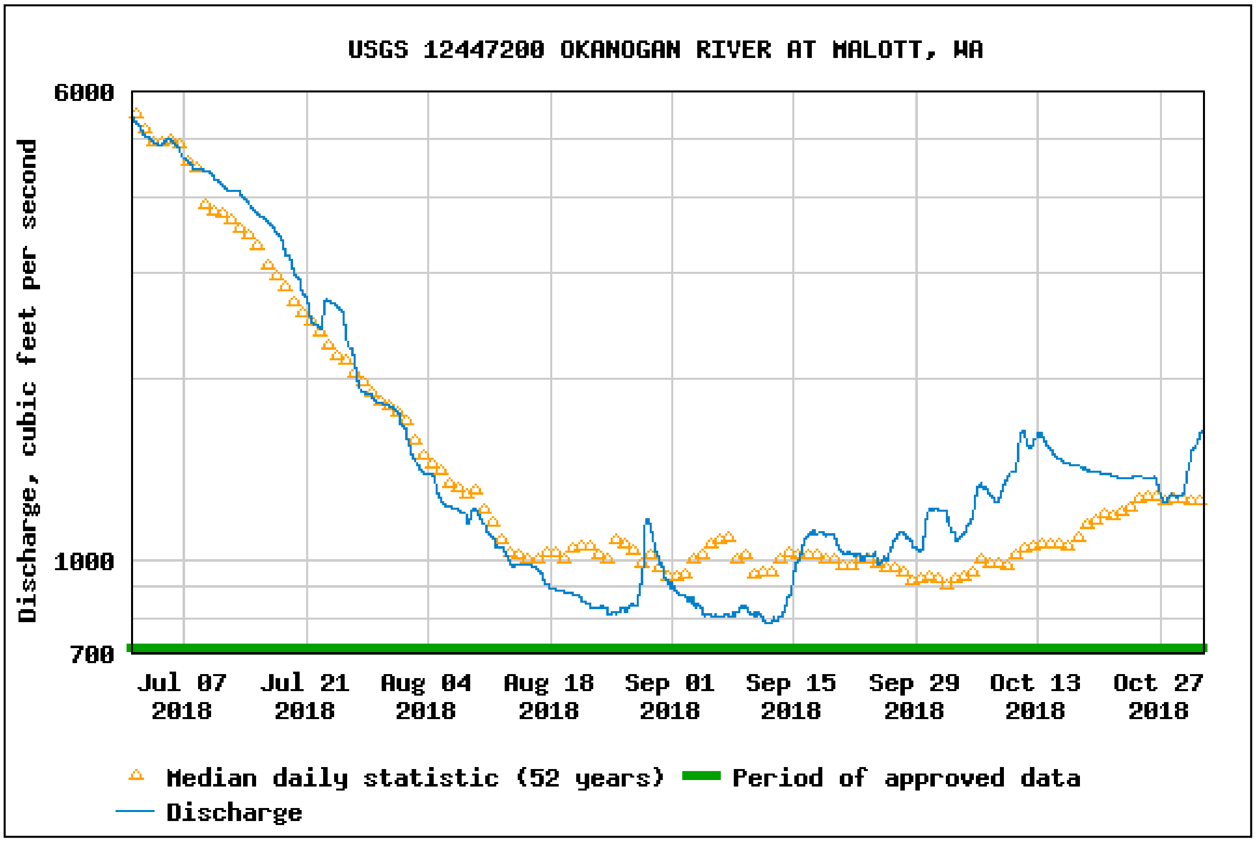


Figure 16. Discharge of the Okanogan River between July 1 and October 31, 2018. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

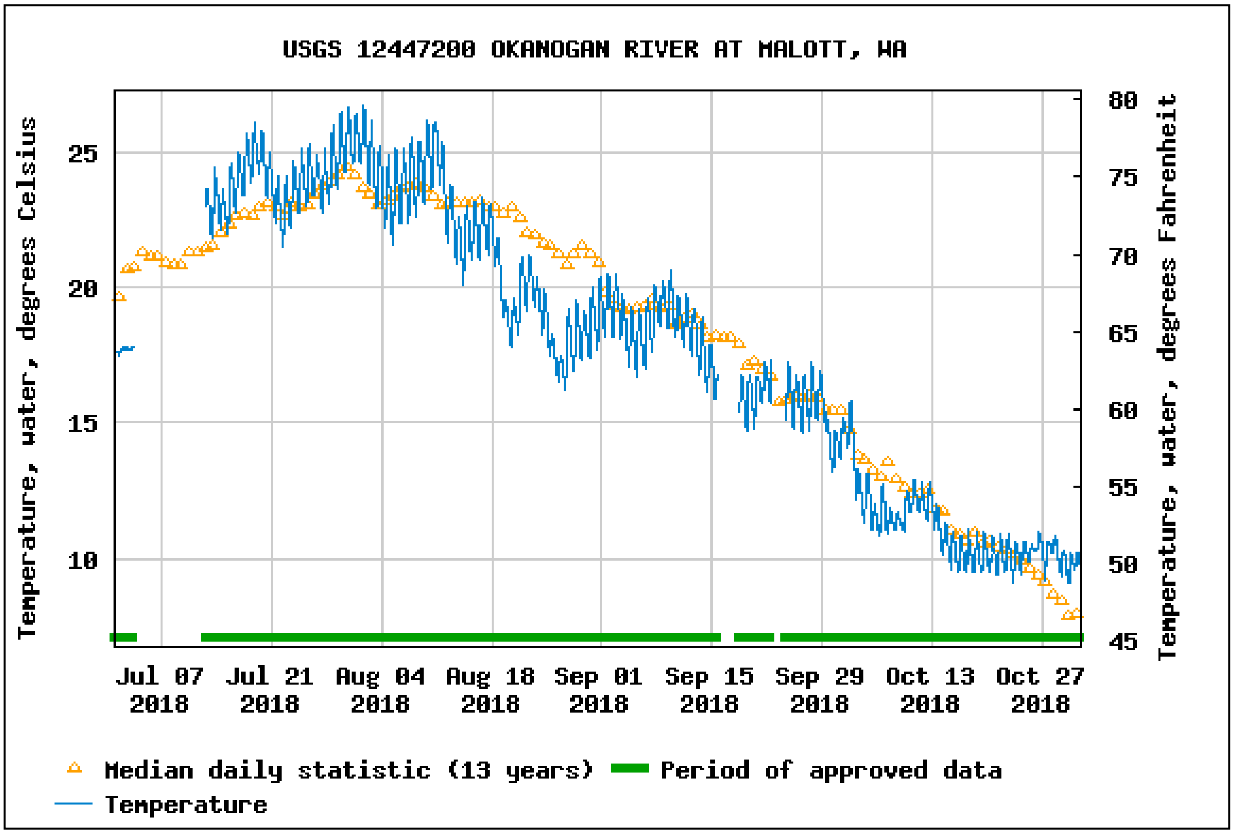


Figure 17. Temperature of the Okanogan River between July 1 and October 31, 2018. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

Dissolved Oxygen varied from 4.4 to 8.2 mg/L, total dissolved solids varied from 121-163 ppm and turbidity varied from 0.8 and 2.9 NTUs (Table 9). The head differential ranged from 0-2.5 cm across the weir panels (Table 10). The maximum water velocity measured was 2.9 ft /sec (Table 11).

Table 9. Water quality data at or near the lower Okanogan weir in 2018. Temperature and discharge were taken from the USGS gauge at Malott.

Date	Trap Depth (ft)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (ppm)	Turbidity (NTU)
8/13	2.9	7.9	155	1.1
8/14	2.9	7.0	153	1.1
8/15	2.9	7.5	157	1.5
8/16	2.9	no data	121	1.2
8/17	2.8	no data	159	1.1
8/20	2.8	no data	150	1.4
8/21	2.7	5.8	152	1.6
8/22	2.8	5.6	163	2.7
8/23	2.8	4.5	158	1.2
8/24	2.7	5.3	160	1.4
8/27	2.8	6.8	149	1.7
8/28	2.8	no data	154	1.4
8/29	3.0	7.5	152	1.4
8/30	3.0	6.2	147	1.2
8/31	2.9	6.4	147	1.4
9/4	2.9	5.4	150	1.5
9/5	2.9	6.5	150	1.3
9/6	2.8	6.0	153	2.0
9/7	2.8	7.5	155	1.9
9/10	2.8	4.4	157	0.9
9/11	2.8	5.1	155	0.8
9/12	2.8	4.7	156	1.1
9/13	2.8	8.2	156	0.9
9/14	2.9	7.8	152	0.9
9/17	3.0	6.5	133	2.2
9/18	3.1	7.9	133	1.0
9/19	3.0	6.3	134	2.0
9/20	3.0	6.2	135	2.6
9/21	3.0	6.8	132	2.9
Min	2.7	4.4	121	0.8
Max	3.1	8.2	163	2.9

Table 10. Head differential across the different picket spacings in 2018. If differential exceeded 10 cm, pickets were cleaned immediately. Measurements are in cm. Daily mean gage height is included in feet. Gage height is copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

Date	1.0" Picket Spacing (cm)	2.0" Picket Spacing (cm)	Gage Height (ft)
8/13	1.5	1.0	3.1
8/14	1.5	1.0	3.1
8/16	2.5	2.0	3.1
8/17	1.5	1.0	3.0
8/20	1.0	0.5	3.0
8/21	1.5	1.0	3.0
8/22	1.5	1.0	2.9
8/23	1.0	1.5	2.9
8/24	1.5	1.0	2.9
8/27	1.5	1.0	2.9
8/28	1.5	1.0	3.1
8/29	1.0	1.0	3.2
8/30	1.0	1.0	3.1
8/31	1.5	1.0	3.0
9/4	1.5	1.0	2.9
9/5	1.5	1.0	2.9
9/6	1.5	1.0	2.9
9/7	1.5	1.0	2.9
9/10	1.5	1.0	2.9
9/11	1.5	1.0	2.9
9/12	1.5	1.0	2.9
9/14	1.5	1.0	3.0
9/17	1.5	1.0	3.2
9/19	1.5	1.0	3.2
9/20	1.5	1.0	3.1
9/21	1.5	1.0	3.1
Min	1.0	0.5	2.9
Max	2.5	2.0	3.2

Table 11. Water velocity upstream (US) and downstream (DS) of the weir and in the trap. Velocity should not exceed 3.5 ft /sec Measurements are in ft /sec in 2018.

Date	River Left US	Center US	River Right US	River Left DS	Center DS	River Right DS	Trap Velocity
8/13	1.7	1.7	1.9	2.0	1.9	2.3	1.6
8/14	2.3	1.6	1.9	2.9	2.5	2.5	0.5
8/16	2.2	1.6	1.9	2.1	1.6	2.4	1.4
8/17	1.7	1.5	1.5	1.8	1.6	2.4	1.6
8/21	1.9	1.6	1.8	1.7	1.8	2.0	1.5
8/23	2.0	1.2	2.0	1.6	1.6	2.5	0.4
8/24	1.9	1.8	1.5	2.2	1.8	2.2	1.3
8/27	1.9	1.6	1.8	2.4	1.9	2.4	0.9
8/28	2.2	1.6	1.9	2.2	2.2	2.1	1.3
8/29	2.4	1.8	1.8	2.2	2.2	2.5	1.3
8/30	2.3	2.2	2.1	2.4	1.8	1.8	0.5
8/31	2.3	1.8	2.0	0.0	2.2	2.5	1.3
9/7	1.4	1.7	1.7	1.8	1.8	2.1	0.4
9/11	1.8	1.9	2.0	1.5	2.0	2.0	0.9
9/12	2.0	1.2	1.2	1.2	1.6	1.5	0.7
9/13	2.2	1.4	1.7	1.8	1.7	2.1	0.6
9/14	1.8	1.2	1.4	1.1	1.5	1.7	0.5
9/17	1.5	1.3	1.7	1.6	1.7	1.9	0.8
9/18	1.4	0.5	1.0	0.9	0.7	1.1	0.5
9/19	1.5	1.3	1.7	1.6	1.4	1.8	0.8
Min	1.4	0.5	1.0	0.0	0.7	1.1	0.4
Max	2.4	2.2	2.1	2.9	2.5	2.5	1.6

Forty-three dead fish were removed from the weir between August 12 and September 20 (Table 12). Sockeye were the most commonly encountered species (58%). There were no steelhead mortalities removed from the weir in 2018. There were very few Chinook carcasses, only 7 (6%), collected throughout the season. There was no noticeable increase in mortality after most Chinook were encountered in the trap (Figure 18). All mortalities were impinged on the upstream side of weir indicating that they had most likely died upstream and floated down onto the weir.

Table 12. Date and species of fish mortalities observed at the lower Okanogan fish weir in 2018. All fish mortalities were considered "wash downs" and collected on the upstream panels of the weir.

Date	Carp	Chinook	Mountain Whitefish	Northern Pike Minnow	Smallmouth Bass	Sockeye	Unknown Sucker
8/12	1			1	1	6	
8/14						1	
8/20		1				2	1
8/23				1		1	1
8/25		1					
8/27		1					1
8/28						4	
8/29				1		1	
8/30		1				2	
9/4	1					4	1
9/5		1				1	
9/7						3	
9/10						1	1
9/12		1					
9/14						2	
9/17						1	
9/18					1		
9/19					1	1	
9/20		1	1			1	1
Total	**2**	**7**	**1**	**3**	**3**	**31**	**6**

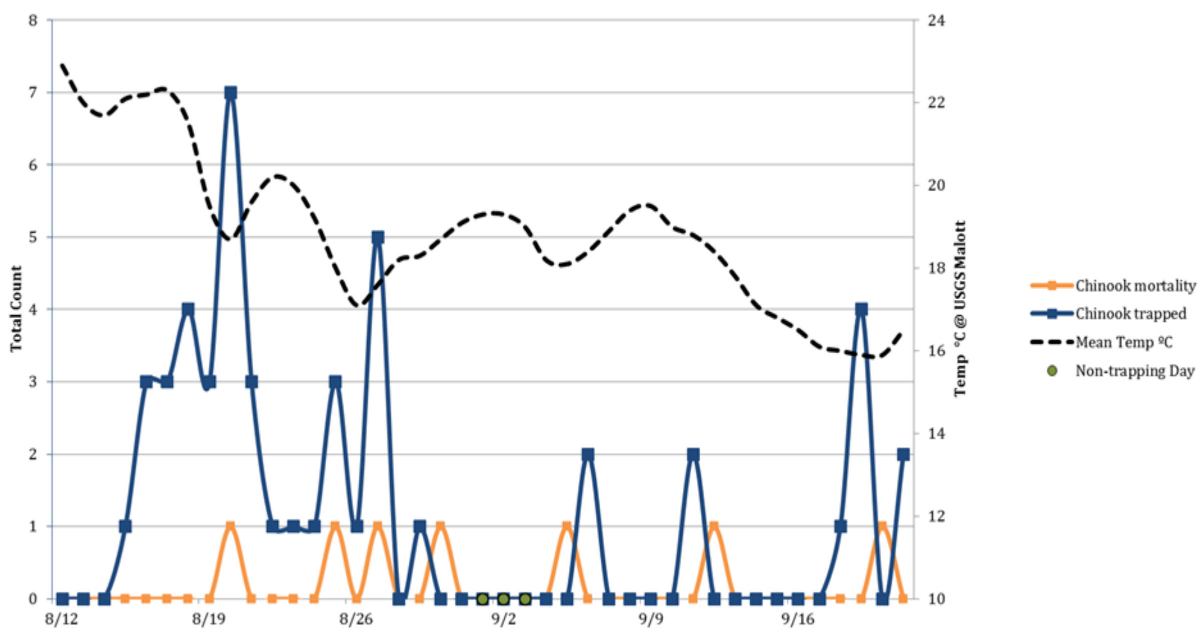


Figure 18. Total number of Chinook trapped and total number of Chinook carcasses collected off the weir panels.

Tower observations showed that most fish were equally distributed across the river, milling in the river right, left and center sections (looking downstream). Estimates were highest during the first two weeks of trapping in August when mean daily river temperatures dropped below 22.5 °C. Bank observations showed that the number fish observed holding in the lower pool, 0.8 km below the weir, increased about one week after the thermal barrier breakdown and then decreased until the first week in September. During the second week in September, the highest daily estimates of fish were observed throughout the week (Figure 19). Trapping operations were conducted on August 12th when river temperature was ≤ 22.5 °C. The total fish trapped at the weir was 205 with 23% of them being Chinook Salmon (Figure 20). Fifty-six percent of the Chinook trapped were released back into the river (Figure 21). Six steelhead were trapped between 9/7-9/21 and released in good condition within 30 minutes of observation. The TOG was notified when steelhead were trapped, including the total number, origin and condition after release. To reduce handling of fish, trap attendants opened the gate of the crowder and the upstream gate of the trap to allow for complete passage. Fish that were passed upstream were classified as having a vigorous condition, swimming away unharmed.

Nineteen natural-origin Chinook were transported to the hatchery and held in the brood stock ponds concurrently with the fish taken for brood stock from the purse seine and hatchery ladder. Adult Chinook were transported from the weir trap to the hatchery brood truck via a rubber boot. We were unable to assess the pre-spawn mortality of the weir brood because they were mixed with the rest of the integrated brood when they were transported to the hatchery. If we need to assess pre-spawn mortality in future years, we will need to mark these fish before they are transported to the hatchery.

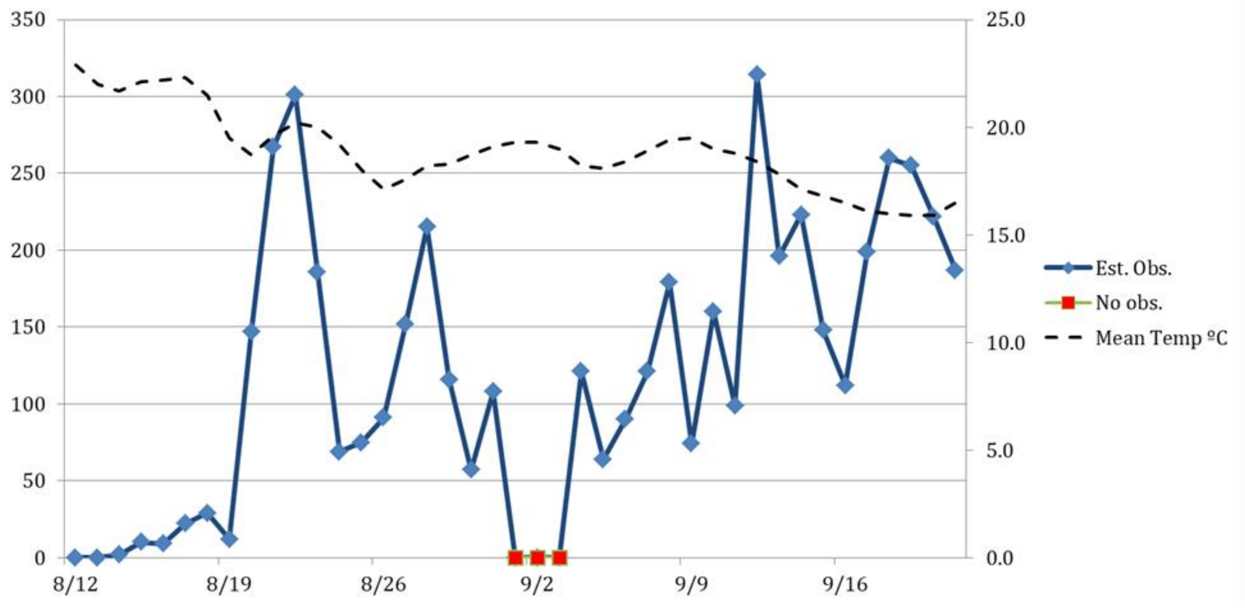


Figure 19. Estimate of Chinook observed from the bank at the lower pool, 0.8 km downstream of the weir. Primary y-axis indicates number of Chinook observed; secondary y-axis (right hand side) indicates the mean stream temperature in degrees Celsius (C).

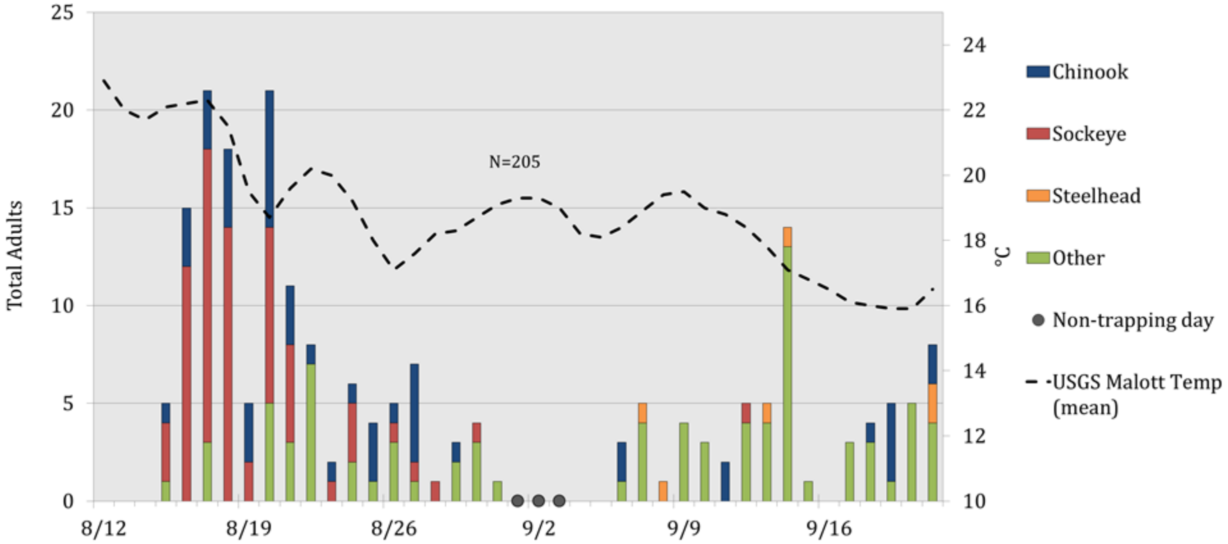


Figure 20. Total number of fish trapped at the Okanogan weir in 2018.

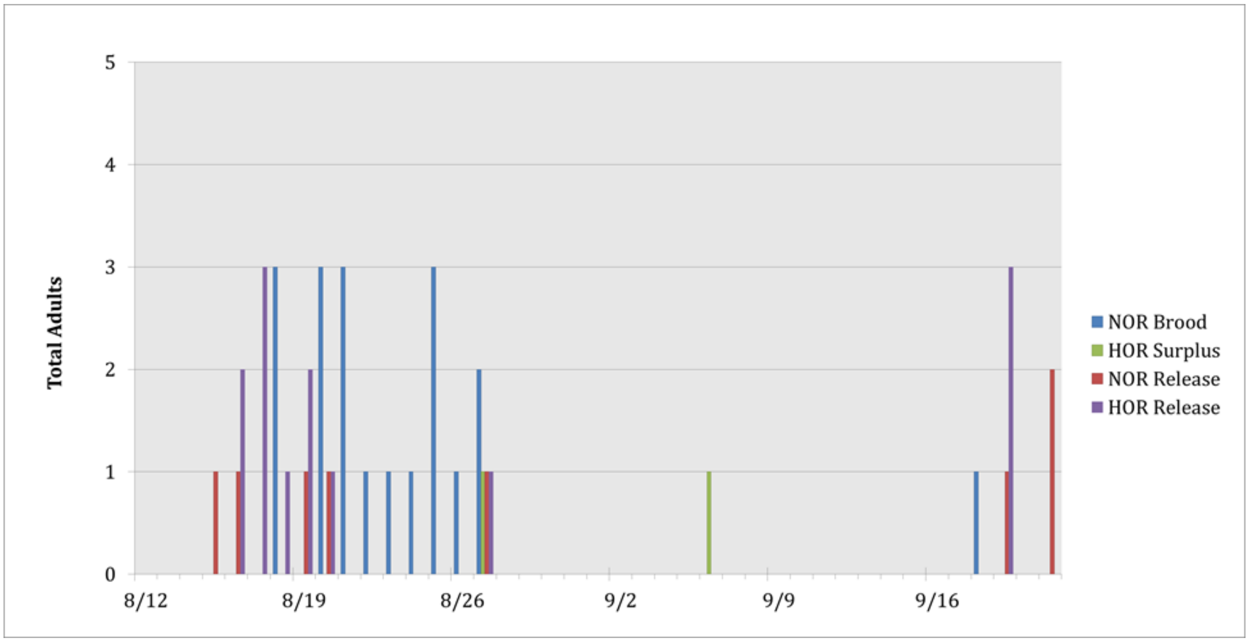


Figure 21. Final destination of Chinook adults captured in the weir trap during trapping operations in 2018.

In 2018, 0.009 (0.9%) of total spawning escapement was detected in the trap (i.e., weir efficiency) (Table 13). The potential weir effectiveness (if we had been removing all of the HOR encountered) was 0.001 (0.1%).

Table 13. The number of hatchery and natural origin Chinook Salmon encountered at the lower Okanogan weir in 2018. Weir efficiency and effectiveness were metrics for evaluating the potential for the weir to contribute to the CJHP population management goals in the future.

Survey Year	Chinook Adults Encountered in the Weir Trap		Chinook Spawning Escapement Estimates[c,d]		Weir Metrics	
	Natural Origin (NOR)	Hatchery Origin (HOR)	Natural Origin (NOS)	Hatchery Origin (HOS)	Weir Efficiency[a]	Weir Effectiveness[b]
2013	73	18	5,627	2,567	0.010	0.006
2014	2,006	318	10,402	1,762	0.147	0.138
2015	35	19	10,350	3,398	0.004	0.005
2016	135	34	8,661	1,944	0.014	0.016
2017	346	99	5,283	1,285	0.057	0.066
2018	32	16	3,322	1,538	0.009	0.001
Average	438	84	7,274	2,082	0.040	0.039

[a] Estimates for weir efficiency are adjusted for prespawn mortality and include Chinook adults that are harvested, released, and collected for brood.

[b] Estimates for weir effectiveness are adjusted for prespawn mortality and include Chinook adults that are harvested or removed for pHOS management.

[c] Estimates do not include Chinook Zosel Dam counts.

[d] NOS and HOS estimates determined by ‘reach-weighted’ pHOS calculations

Redd Surveys

In 2018, 2,112 summer/fall Chinook redds were counted in the Okanogan and Similkameen rivers using a combination of ground and aerial surveys. The number of redds counted in 2018 was lower than both the recent (5-year) and long term averages (Table 14). The majority of Chinook redds were located in reaches O5 (29.3%), O6 (24.0%), and S1 (23.7%). These three reaches accounted for 77.0% of the total Chinook spawning in the basin. The overall redd distribution across reaches was similar to previous years with the majority of spawning taking place in the upper Okanogan reaches (O5 and O6) and lower Similkameen (S1) (Table 15, Figure 23).

Estimated spawning escapement was 4,860 (2,112 redds × 2.301 fish per redd) (Table 16). Since 1989, the summer/fall Chinook spawning escapement within the U.S. portion of the Okanogan River Basin has averaged 5,861 and ranged from 473 to 13,857 (Table 16).

The majority of summer/fall Chinook redds were counted during spawning ground surveys between October 8 - Nov 4 (Table 17). No spawning ground surveys were conducted after November 4.

Table 14. Total number of redds counted in the Okanogan River Basin, 1989-2018 and the averages for the total time series and the most recent 5-year period.

Survey Year	**Number of summer Chinook redds**		
	Okanogan River	**Similkameen River**	**Total Count**
1989	151	370	521
1990	99	147	246
1991	64	91	155
1992	53	57	110
1993	162	288	450
1994	375*	777	1,152
1995	267*	616	883
1996	116	419	535
1997	158	486	644
1998	88	276	364
1999	369	1,275	1,644
2000	549	993	1,542
2001	1,108	1,540	2,648
2002	2,667	3,358	6,025
2003	1,035	378	1,413
2004	1,327	1,660	2,987
2005	1,611	1,423	3,034
2006	2,592	1,666	4,258
2007	1,301	707	2,008
2008	1,146	1,000	2,146
2009	1,672	1,298	2,970
2010	1,011	1,107	2,118
2011	1,714	1,409	3,123
2012	1,613	1,066	2,679
2013	2,267	1,280	3,547
2014	2,231	2,022	4,253
2015	2,379	1,897	4,276
2016	3,486	1,790	5,276
2017	2,434	787	3,221
2018	1,554	558	2,112
Average	1,248	1,025	2,211
5-yr Average	***2,417***	***1,411***	***3,828***

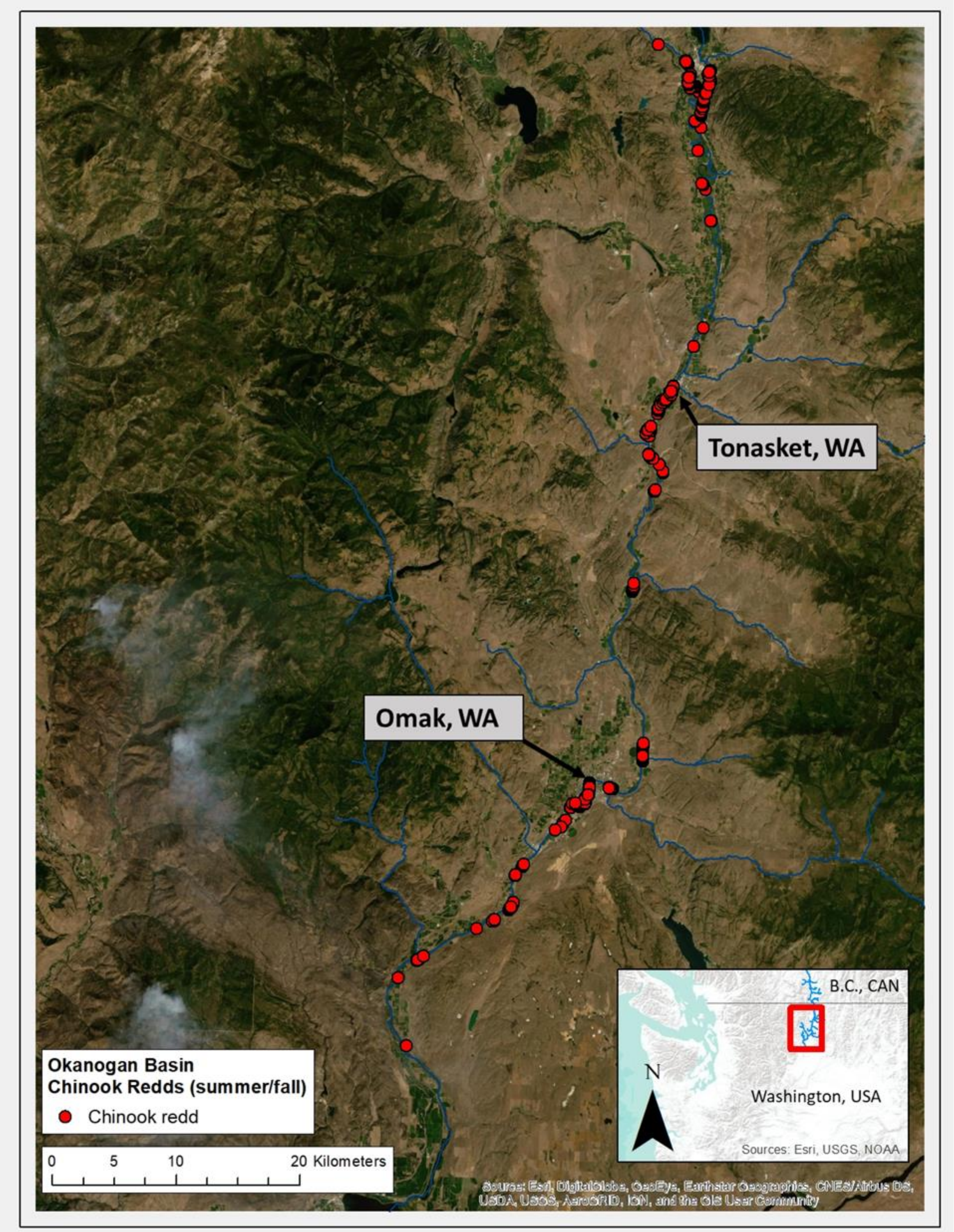


Figure 22. Distribution of summer/fall Chinook redds in 2018. Individual redds are identified by red circles. Horizontal coordinate information are referenced to the North American Datum of 1983 (NAD 83).

Table 15. Annual and average abundance of summer/fall Chinook redds in each reach of the Okanogan (O1-O6) and Similkameen (S1-S2) Rivers from 2006-2018.

Return Year	**Number of Summer Chinook Redds**								
	Okanogan						**Similkameen**		**Total**
	O1	**O-2**	**O-3**	**O-4**	**O-5**	**O-6**	**S-1**	**S-2**	
2006	10	56	175	145	840	1,366	1,388	278	4,258
2007	3	16	116	63	549	554	652	55	2,008
2008	4	51	60	96	374	561	801	199	2,146
2009	3	32	91	138	621	787	1,091	207	2,970
2010	9	58	67	89	357	431	895	212	2,118
2011	3	20	101	55	593	942	1,217	192	3,123
2012	12	54	159	68	555	765	914	152	2,679
2013	3	2	158	46	397	1,661	1,254	26	3,547
2014	11	57	191	111	851	1,010	1,737	285	4,253
2015	36	113	284	79	1,008	859	1,611	286	4,276
2016	2	57	52	130	907	2,338	1,645	145	5,276
2017	2	62	192	111	830	1,237	710	77	3,221
2018	11	74	211	133	618	507	501	57	2,112
Average	***8***	***50***	***143***	***97***	***654***	***1,001***	***1,109***	***167***	***3,230***

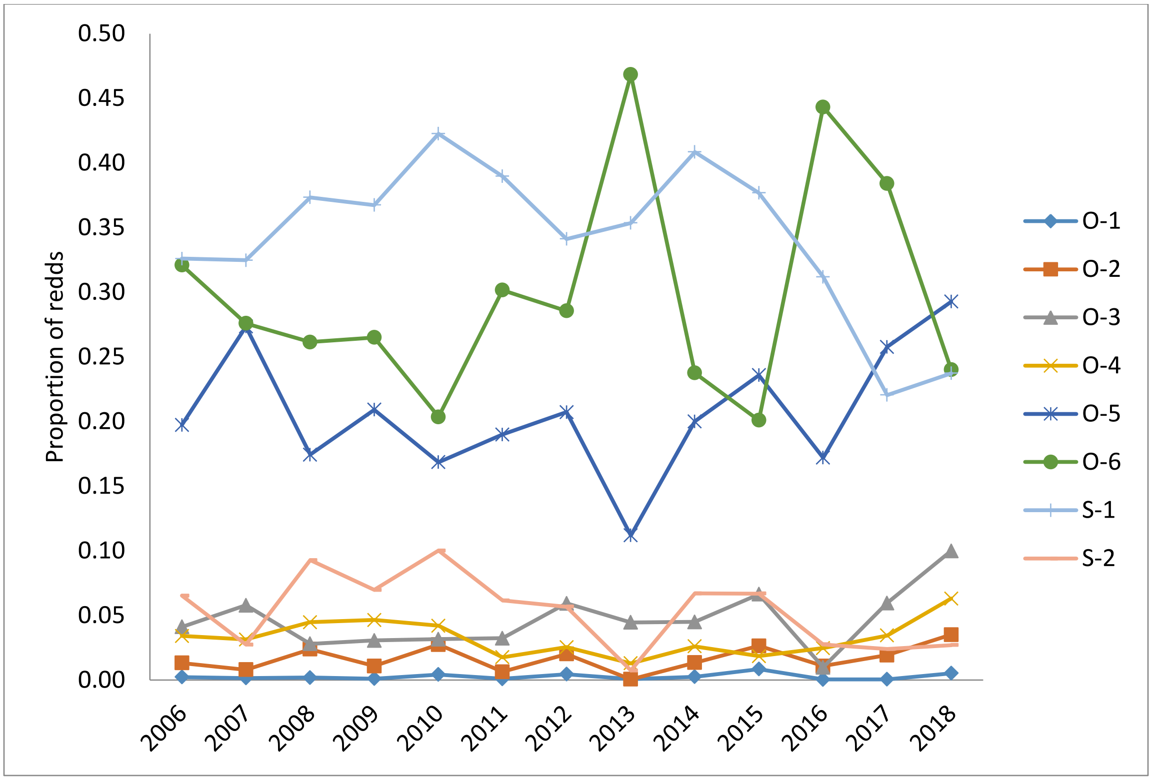


Figure 23. Proportion of redds in each reach of the Okanogan and Similkameen Rivers from 2006 to 2018.

Table 16. Spawning escapements for summer/fall Chinook in the Okanogan and Similkameen Rivers for return years 1989-2018.

Return Year	Fish/Redd Ratio	Spawning Escapement		
		Okanogan	Similkameen	Total
1989*	3.300	498	1,221	1,719
1990*	3.400	337	500	837
1991*	3.700	237	337	574
1992*	4.300	228	245	473
1993*	3.300	535	950	1,485
1994*	3.500	1,313	2,720	4,033
1995*	3.400	908	2,094	3,002
1996*	3.400	394	1,425	1,819
1997*	3.400	537	1,652	2,189
1998	3.000	264	828	1,092
1999	2.200	812	2,805	3,617
2000	2.400	1,318	2,383	3,701
2001	4.100	4,543	6,314	10,857
2002	2.300	6,134	7,723	13,857
2003	2.400	2,505	915	3,420
2004	2.300	2,986	3,735	6,721
2005	2.900	4,720	4,169	8,889
2006	2.020	5,236	3,365	8,601
2007	2.200	2,862	1,555	4,418
2008	3.250	3,725	3,250	6,975
2009	2.540	4,247	3,297	7,544
2010	2.810	2,841	3,111	5,952
2011	3.100	5,313	4,368	9,681
2012	3.070	4,952	3,273	8,225
2013	2.310	5,237	2,957	8,194
2014	2.860	6,381	5,783	12,164
2015	3.215	7,648	6,099	13,747
2016	2.010	7,007	3,598	10,605
2017	2.039	4,963	1,605	6,568
2018	2.301	3,576	1,284	4,860
Average	***2.901***	***3075***	***2785***	***5861***
5-Year Average	***2.485***	***5915***	***3674***	***9589***

* Spawning escapement was calculated using the "Modified Meekin Method" (i.e., 3.1 × jack multiplier).

Note: All values have been updated from previous reports to account for low sample rates (*i.e.*, carcass recoveries). For any reach with carcass recoveries <5%, the annual basin composition (*i.e.*, HOS:NOS) was used to determine the number of HOS and NOS.

Table 17. Number and timing of summer Chinook redd counts in reaches of the Okanogan and Similkameen Rivers in 2018.

Reach	River mile	Sept 17 - 23	Sep 24 - 30	Oct 1 - 7	Oct 8 - 14	Oct 15 - 21	Oct 22 - 28	Oct 29 - Nov 4	Redd Count	Percent
Okanogan River										
O1	0.0-16.9	0	0	0	1	5	0	5	11	1%
O2	16.9-26.1	0	0	2	25	15	0	32	74	5%
O3	26.1-30.7	0	0	8	33	29	113	28	211	14%
O4	30.7-40.7	0	0	1	35	48	14	35	133	9%
O5	40.7-56.8	0	0	33	210	107	173	95	618	40%
O6	56.8-77.4	0	0	15	183	93	112	104	507	33%
Total		***0***	***0***	***59***	***487***	***297***	***412***	***299***	1554	100%
Similkameen River										
S1	0.0-1.8	0	0	21	143	94	134	109	501	90%
S2	1.8-5.7	0	0	2	12	10	16	17	57	10%
Total		***0***	***0***	***23***	***155***	***104***	***150***	***126***	***558***	100%

Escapement into Canada

Methodological uncertainties have limited our confidence in Chinook escapement estimates into the Canadian portion of the Okanogan basin. Prior to 2018, estimates were been primarily based on video counts of fish ascending the passageway at Zosel Dam, with the important caveat being that due to the variations in dam operations, there is uncertainty regarding the proportion of fish that are passing within range of the video system, and thus, available for counting. Additionally, fish fallback and re-ascension is known to occur (as indicated by limited PIT tag data), though the frequency of occurrence is poorly understood. With these uncertainties in mind, we present Canadian escapement information for years prior to 2018. No video count data exists for Chinook in 2018. Average Chinook passage at Zosel Dam for years 2010 thru 2017 has been 1,315, with a minimum of 263 (2010) and a maximum of 2,276 (2013).

The Okanagan Nation Alliance (ONA) has provided information on escapement estimates in Canada based on live counts of summer Chinook adjusted by the residency estimate for the area under the curve (AUC) (R. Bussanich, pers. comm.) The AUC is the area covered during their routine Sockeye enumeration surveys, which are three designated sites, the Skaha (region above McIntyre Dam), 'index' (natural state), and channelized or vertical drop sections (VDS) on the Okanagan River. In 2018 they estimated 10 total fish in these areas. A small percentage of adipose fin-clipped fish were observed during surveys. The proportion of total spawners that was adipose-clipped was less than 25%.

Table 18. Count of run escapement of adult summer/fall Chinook at Zosel Dam using video monitoring in the fishways.

Chinook Passage at Zosel Dam		
Year	**Video Count**	**% Hatchery**
2006	481	1%
2007	455	40%
2008	267	29%
2009	256	17%
2010	359	29%
2011	1415	36%
2012	826	24%
2013	2275	14%
2014[a]	1188	10%
2015	1206	7%
2016	1823	13%
2017	737	14%
2018	No Data	No Data
Average	***941***	***19%***

[a] 2014 data were adjusted for fallback/re ascension, down camera time, and differentiation of spring Chinook from summer/fall Chinook.

Carcass Surveys

In 2018, 547 carcasses were recovered including 374 natural-origin and 173 hatchery-origin[7]. The overall carcass recovery rate was 11% of the total spawning escapement. Similar to previous years, the majority of carcasses (*n* = 455; 83%) were collected from reaches O5, O6 and S1 (Figure 24, also see Appendix C). Regarding the distribution of carcasses throughout the basin, the proportions of natural-origin carcasses

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[7] Origin assignments take into account all scale, ad-mark, coded wire tag and PIT tag information available at time of publication. Values may be updated in future annual reports depending on availability of data.

recovered in 2018 were lower in reaches S1 and S2, and higher in reaches O3 and O5, compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 24, panel A). The proportions of hatchery-origin carcasses recovered in 2018 were higher in reach O5 and much higher in reach O3, and lower in reaches S1 and S2 compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 24, panel B).

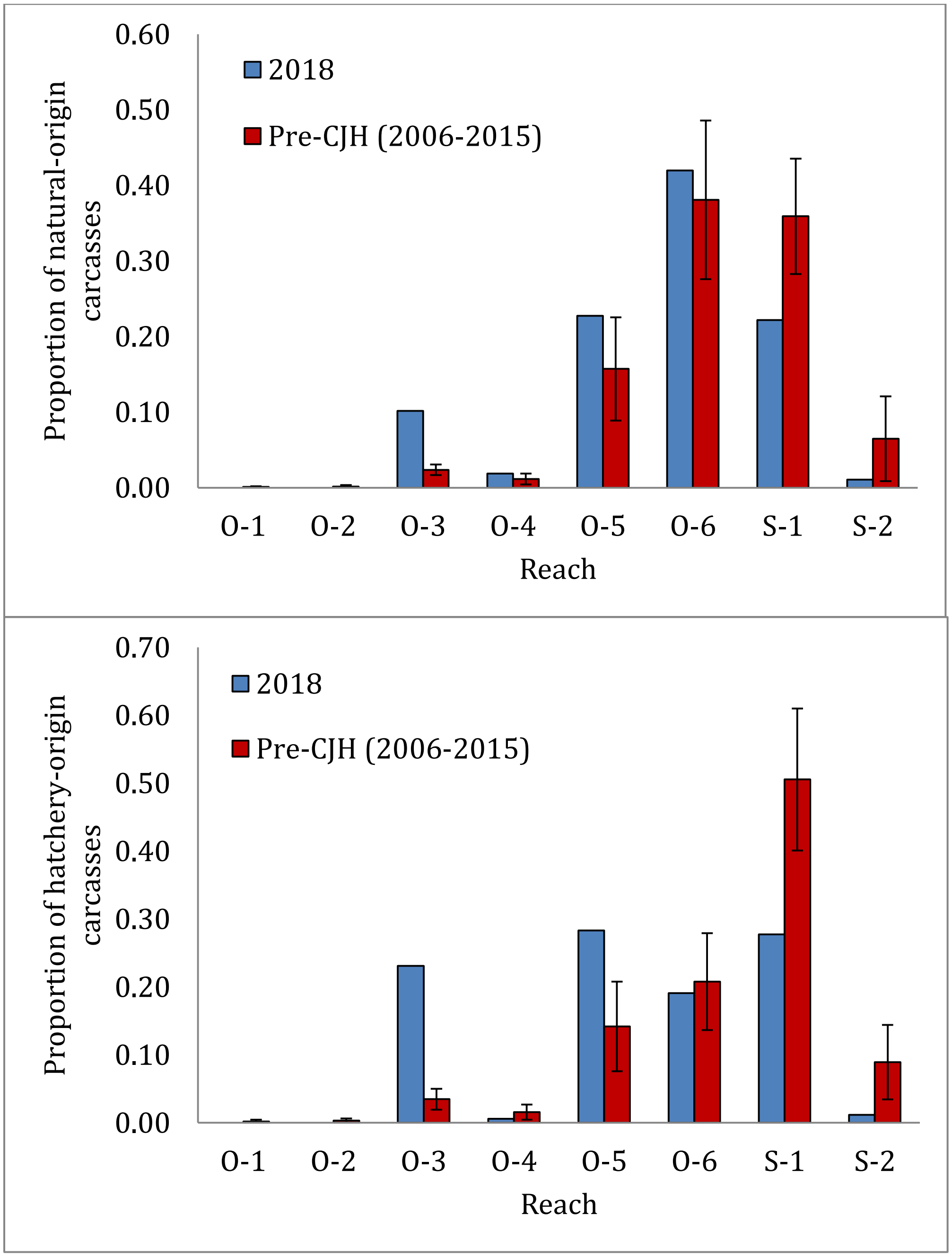

Figure 24. Distribution of natural-origin (panel A) and hatchery-origin (panel B) summer/fall Chinook carcasses recovered in the Okanogan (reaches O1-O6) and Similkameen (reaches S1-S2) Rivers in 2018 compared to the average of the 10 years

preceding Chief Joseph Hatchery (2006-2015). Error bars represent standard deviation (SD).

In the Okanogan basin, just 3 of the 547 sampled female carcasses were estimated to have retained all their eggs. Therefore, pre-spawn mortality, (for fish that survived to the spawn period) was estimated to be 0.00% for natural-origin females and 0.01% for hatchery-origin females (Table 19). Overall egg retention of all fish sampled (including fish that had expelled a portion of their eggs) was 1.02%.

Table 19. Egg retention and pre-spawn mortality of sampled summer/fall Chinook carcasses in the Okanogan Basin.

Year	Origin	Total carcasses sampled	Female carcasses sampled	Potential egg deposition	Eggs retained	[a]Egg retention rate	[b]Pre-spawn mortality rate
2013	Natural	613	326	1,630,000	6,152	0.40%	0.00%
	Hatchery	297	237	1,185,000	10,970	0.90%	0.00%
	Total	910	563	2,815,000	17,122	0.60%	0.00%
2014	Natural	2,123	1,136	5,680,000	373,708	6.60%	1.40%
	Hatchery	329	166	830,000	81,105	9.80%	1.80%
	Total	2,452	1,302	6,510,000	454,813	7.00%	1.50%
2015	Natural	2,554	981	4,905,000	609,869	12.40%	10.90%
	Hatchery	738	340	1,700,000	96,354	5.70%	5.00%
	Total	3,292	1,321	6,605,000	706,223	10.70%	9.40%
2016	Natural	2,171	1,370	6,850,000	300,046	4.38%	3.43%
	Hatchery	584	434	2,170,000	66,254	3.05%	2.76%
	Total	2,755	1,804	9,020,000	366,300	4.06%	3.27%
2017	Natural	997	592	2,960,000	17,345	0.59%	0.00%
	Hatcher	204	129	645,000	24,997	3.88%	3.10%
	Total	1,201	721	3,605,000	42,342	1.17%	0.55%
2018	Natural	374	251	1,255,000	3,075	0.25%	0.00%
	Hatchery	173	123	615,000	16,024	2.61%	3.25%
	Total	547	374	1,870,000	19,099	1.02%	1.07%

[a] Assuming fecundity of 5,000 eggs per female, egg retention rate is calculated as: (# eggs estimated remaining in sampled female carcasses) / (# female carcasses sampled * 5,000 eggs each)

[b] A pre-spawn mortality is determined when a female retains the assumed 5,000 eggs on the spawning grounds.

PHOS AND PNI

There was a decrease in the proportion of hatchery-origin spawners (pHOS) in reach O6 and S1 in 2018 compared to the 10 years preceding Chief Joseph Hatchery (Figure 25). Reaches O5 and O3 had pHOS similar to, or slightly above the years preceding CJH. However, no carcasses were recovered in reaches O1, O2, and very few in reaches O4 and

S1 (*n* < 5% of estimated spawners) therefore, no comparisons could be made as to the composition of spawners in these reaches. Combined, these four omitted reaches comprised only 13% of the spawning in the basin in 2018. Basin means (average pHOS) were used for these reaches in all subsequent analyses. Hatchery-origin spawners comprised 33% of the spawn escapement estimate in the U.S. portion of the Okanogan, which was the highest pHOS observed since 2012 (0.45) (Table 20). After corrections for hatchery fish effectiveness assumptions (0.80 relative reproductive success rate for hatchery-origin spawners) the effective pHOS for 2018 was 0.28, which was above the five-year average (0.18) (Table 21). Despite this single year increase, the five-year average is currently meeting the biological objective for pHOS (<0.3) (Figure 26).

The proportion of natural-origin broodstock (pNOB) in 2018 was 48% and the pNOB for Okanogan origin fish was 43% (Table 21). The resulting PNI for 2018 was 0.63, with a 5-year average PNI of 0.82. Despite this single year increase in PNI, the 5-year average is currently meeting the Biological Objective (>0.67) (Figure 27).

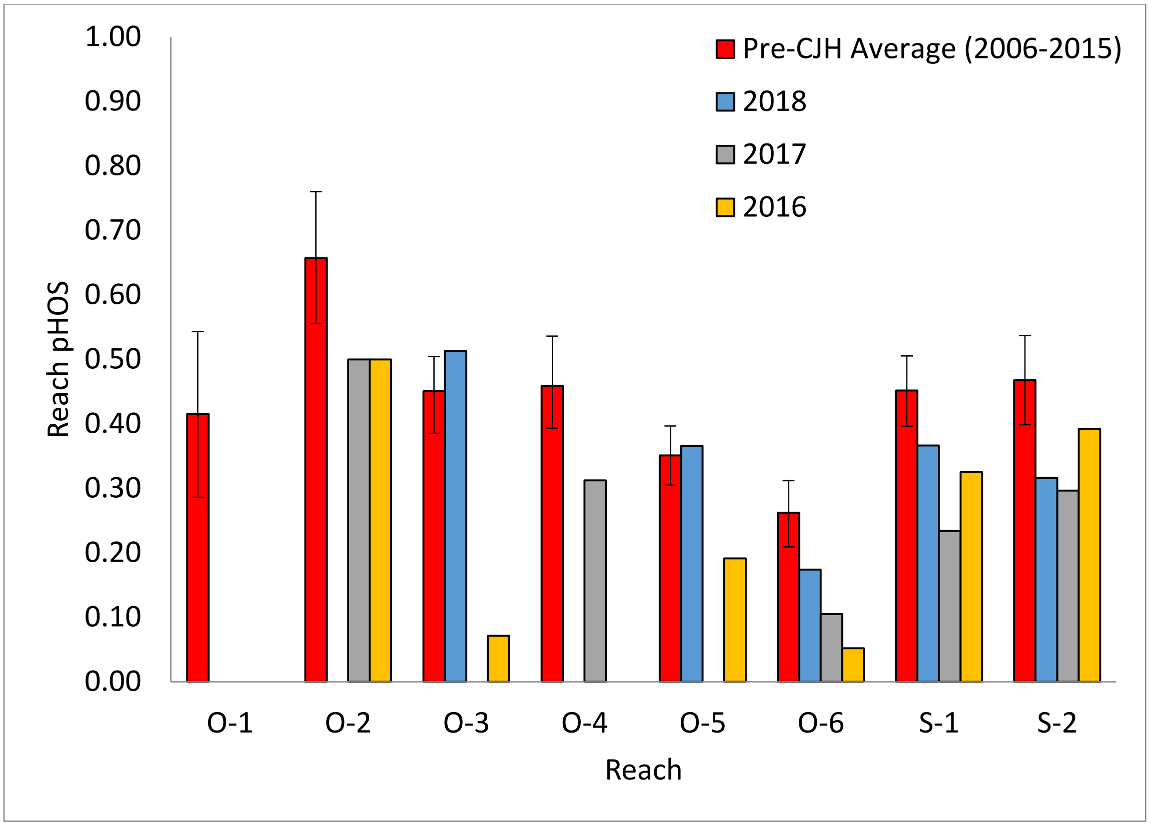

Figure 25. Okanogan (O1-O6) and Similkameen River (S1-S2) summer/fall Chinook pHOS (unadjusted for RSS) by reach for years since Chief Joseph Hatchery operation (2016, 2017, and 2018) and the average of the 10 years preceding Chief Joseph Hatchery (2006-2015). Reaches with<5% carcasses recoveries were omitted. Error bars represent standard error of the mean.

Table 20. Natural- (NOS) and hatchery- (HOS) origin spawner abundance and composition for the Okanogan River Basin, brood years 1989-2018.

Brood Year	Spawners			
	NOS	HOS	pHOS	Effective pHOS^
1989	1,719	0	0	0
1990	837	0	0	0
1991	574	0	0	0
1992	473	0	0	0
1993	915	570	0.38	0.33
1994	1,323	2,710	0.67	0.62
1995	979	2,023	0.67	0.62
1996	568	1,251	0.69	0.64
1997	862	1,327	0.61	0.55
1998	600	492	0.45	0.4
1999	1,274	2,343	0.65	0.6
2000	1,174	2,527	0.68	0.63
2001	4,306	6,551	0.6	0.55
2002	4,346	9,511	0.69	0.64
2003	1,933	1,487	0.43	0.38
2004	5,309	1,412	0.21	0.18
2005	6,441	2,448	0.28	0.23
2006	6,787	1,814	0.21	0.18
2007	2,730	1,688	0.38	0.33
2008	2,820	4,155	0.60	0.54
2009	4,100	3,443	0.46	0.40
2010	3,178	2,773	0.47	0.41
2011	4,618	5,063	0.52	0.47
2012	4,521	3,704	0.45	0.40
2013[a]	5,627	2,567	0.31	0.27
2014	10,407	1,756	0.14	0.12
2015	10,439	3,308	0.24	0.20
2016	8,700	1,905	0.18	0.15
2017	5,429	1,139	0.17	0.14
2018	3,266	1,594	0.33	0.28
Average	***3,542***	***2,319***	***0.38***	***0.34***
5-year Average	***7,648***	***1,940***	***0.21***	***0.18***

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[a] 2013 data have been updated to reflect age and origin data acquired from scale reading since the publication of the 2013 annual report.

^ Effective pHOS assumes 0.80 HOS effectiveness

Note: All values have been updated from previous reports to account for low sample rates (*i.e.*, carcass recoveries). For any reach with carcass recoveries <5%, the annual basin composition (*i.e.*, HOS:NOS) was used to determine the number of HOS and NOS.

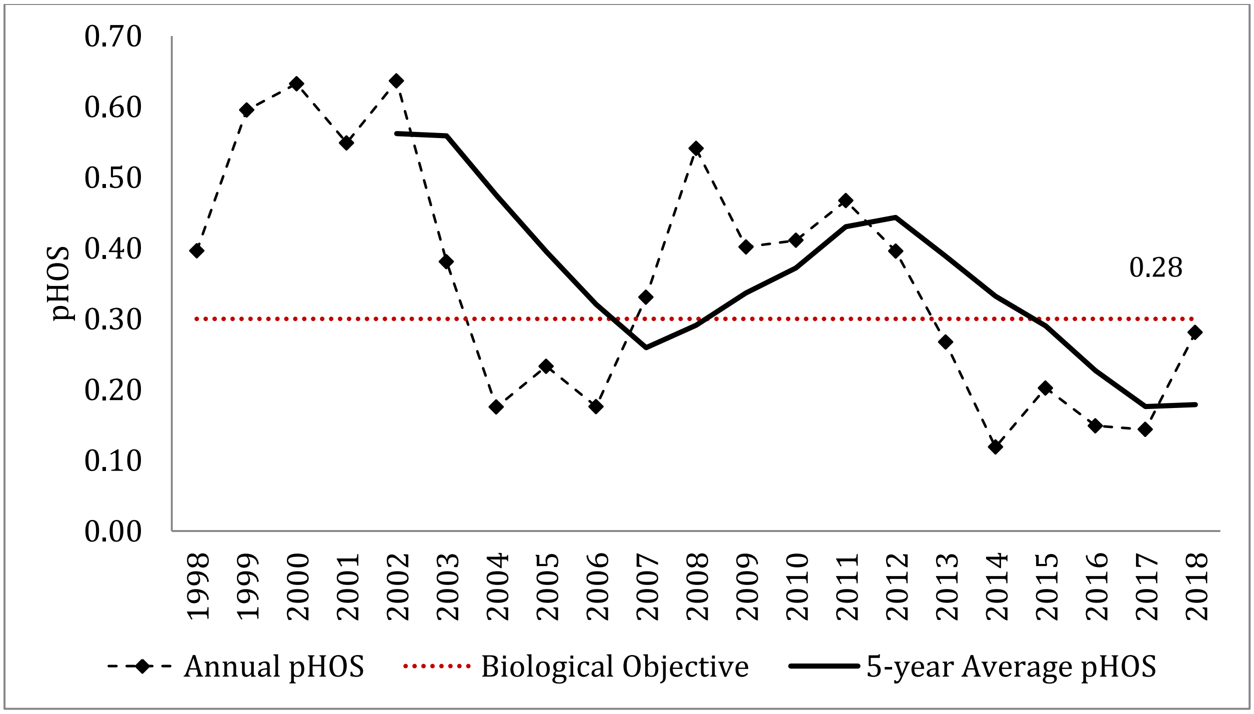


Figure 26. Annual and 5-year average proportion of hatchery-origin spawners (pHOS) in the Okanogan and Similkameen River (combined) from 1998-2018. pHOS values represent the effective pHOS.

Table 21. Okanogan River summer Chinook spawn escapement and broodstock composition, and calculated pHOS and PNI for Brood Years 1989-2018.

Brood Year	Spawners			Broodstock					PNI	Okan. PNI
	NOS	HOS	Effective pHOS	NOB	Okan NOB	HOB	pNOB	Okan pNOB		
1989	1,719	0	0.00	1,297		312	0.81		1.00	
1990	837	0	0.00	828		206	0.80		1.00	
1991	574	0	0.00	924		314	0.75		1.00	
1992	473	0	0.00	297		406	0.42		1.00	
1993	915	570	0.33	681		388	0.64		0.66	
1994	1,323	2,710	0.62	341		244	0.58		0.48	
1995	979	2,023	0.62	173		240	0.42		0.40	
1996	568	1,251	0.64	287		155	0.65		0.50	
1997	862	1,327	0.55	197		265	0.43		0.44	
1998	600	492	0.40	153	77	211	0.42	0.21	0.51	0.35
1999	1,274	2,343	0.60	224	112	289	0.44	0.22	0.42	0.27
2000	1,174	2,527	0.63	164	82	337	0.33	0.16	0.34	0.21
2001	4,306	6,551	0.55	12	46	345	0.03	0.13	0.06	0.19
2002	4,346	9,511	0.64	247	124	241	0.51	0.25	0.44	0.29
2003	1,933	1,487	0.38	381	191	101	0.79	0.40	0.67	0.51
2004	5,309	1,412	0.18	506	253	16	0.97	0.48	0.85	0.73
2005	6,441	2,448	0.23	391	196	9	0.98	0.49	0.81	0.68
2006	6,787	1,814	0.18	500	250	10	0.98	0.49	0.85	0.73
2007	2,730	1,688	0.33	456	228	17	0.96	0.48	0.75	0.60
2008	2,820	4,155	0.54	359	202	86	0.81	0.45	0.60	0.46
2009	4,100	3,443	0.40	503	254	4	0.99	0.50	0.71	0.55
2010	3,178	2,773	0.41	484	242	8	0.98	0.49	0.70	0.54
2011	4,618	5,063	0.47	467	332	26	0.95	0.67	0.67	0.59
2012	4,521	3,704	0.40	107	96	0	1.00	0.90	0.72	0.69
2013	5,627	2,567	0.27	353	318	0	1.00	0.90	0.79	0.77
2014	10,407	1,756	0.12	499	449	5	0.99	0.89	0.89	0.88
2015	10,439	3,308	0.20	421	379	9	0.98	0.88	0.83	0.81
2016	8,700	1,905	0.15	584	526	0	1.00	0.90	0.87	0.86
2017	5,429	1,139	0.14	350	315	17	0.95	0.86	0.87	0.86
2018	3,266	1,594	0.28	193	174	212	0.48	0.43	0.63	0.60
Average	***3,551***	***2,344***	***0.34***	***420***	***234***	***147***	***0.74***	***0.54***	***0.68***	***0.58***
5-Year Average	***8,120***	***2,135***	***0.18***	***441***	***397***	***6***	***0.98***	***0.89***	***0.85***	***0.84***

pHOS values are effective from 1989-2006 and Effective, Reach-weighted pHOS from 2006-2018

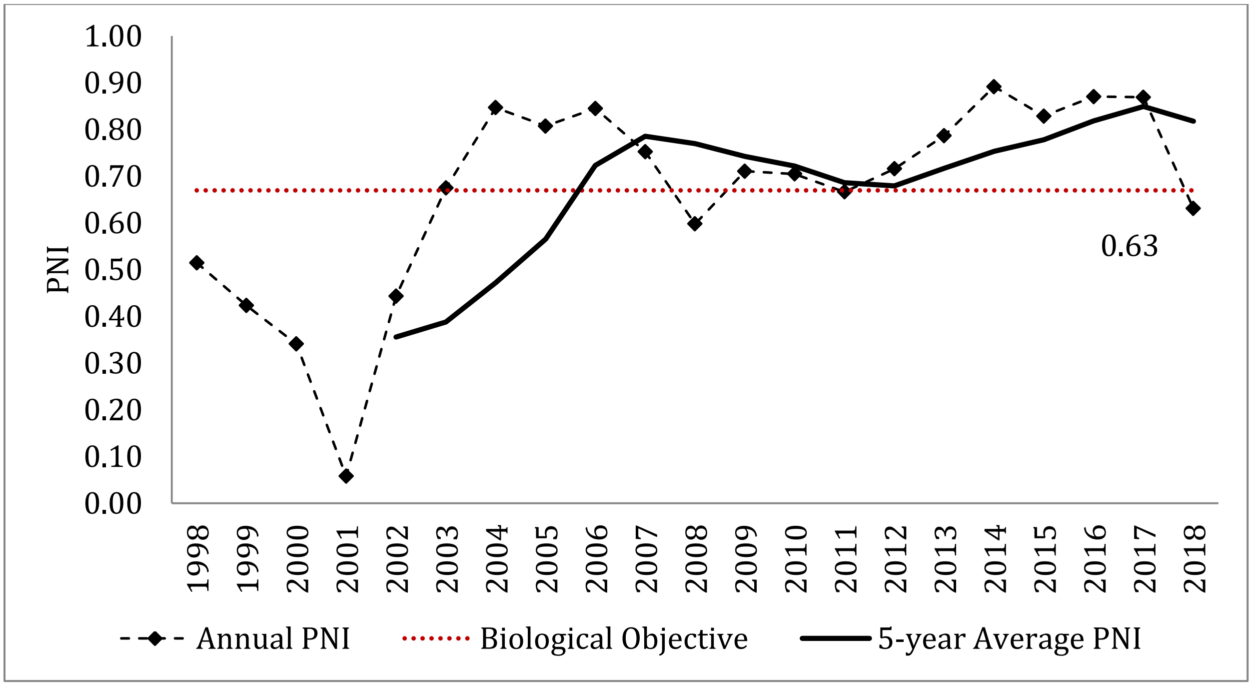


Figure 27. Annual and 5-year average proportionate natural influence (PNI) in the Okanogan and Similkameen Rivers (combined) from 1998 to 2018.

AGE STRUCTURE

Attempts were made to age all carcasses recovered on the spawning grounds, either by microscopy of scale annuli for natural-origin fish or by extracting and reading coded wire tag information for hatchery-origin fish. Historically, most natural-origin summer Chinook migrate as sub-yearlings, while the majority of hatchery-origin releases in the Okanogan river basin have been released as yearlings. To account for this difference, the number of winters a fish spent in the marine environment – salt age – is the format of reported data.

In 2018, the natural-origin female spawner age structures closely mirrored the 10-year average and was dominated by 3-year old (salt age) fish, (Figure 28). Male natural-origin spawners were comprised predominantly by 3-year old fish (salt age) but with more 2-year old returns as compared to females. This was similar to the average distribution. Hatchery-origin female age structure was similar to the 10-year average. Hatchery-origin males were dominated by 2-year old fish, which is consistent with the average, though there were no 1- year old (salt age) fish recovered on the spawning grounds (Figure 28).

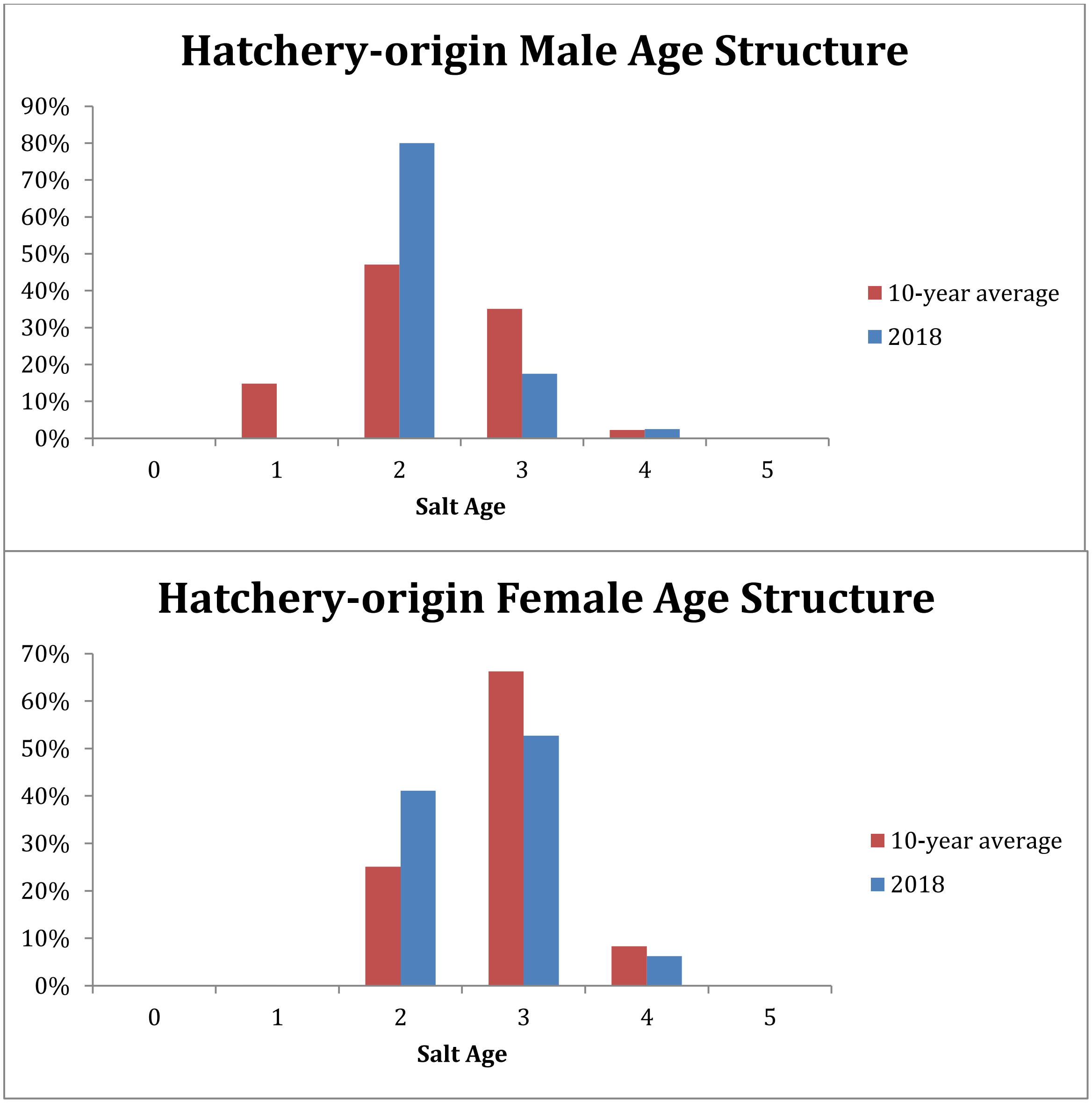


Figure 28. The salt ages of carcasses collected on the spawning grounds of the Okanogan and Similkameen Rivers in 2018 and 10-year averages (2009-2018).

HATCHERY-ORIGIN STRAY RATES

Strays to the Okanogan—The majority (67%) of hatchery-origin spawners recovered on the spawning grounds in 2018 were from Similkameen (43%) and Okanogan acclimated (25%) releases (Table 22). Chief Joseph Hatchery segregated Chinook comprised 27% of the HOS on the Okanogan spawning grounds. Strays into basin consisted of individuals from Carlton, Chelan, and Mainstem Columbia hatchery releases. Stray hatchery fish from outside the Okanogan comprised 10.2% of the total (HOS+NOS) Okanogan spawner composition (i.e., stray pHOS) (Table 23). This was far above the recent

(2006-2018) average of 2.4% and also above the biological target of < 5%. Note that this includes those fish released from the Chief Joseph Hatchery segregated program.

Strays outside the Okanogan— With the caveat that data is likely to continue to be updated in future reports as more data becomes available through the RMIS database, the most recent brood year that could be fully assessed (through age 5) for stray rate of Okanogan fish to spawning areas outside the Okanogan was 2013. The 2013 brood year had a stray rate of 2.7%, which was above the long term (1989-2013; 1.2%) and recent five-year (2009-2013; 1.36%) averages (Table 24). RMIS queries revealed an estimate of 43 Okanogan hatchery-origin Chinook recovered on spawning grounds in non-target spawning areas in 2018 (Table 24). Okanogan basin hatchery program strays comprise ≤2.3% to other basin population's spawner composition in 2018 (Table 25). 5-year averages were all well below 1%.

Table 22. Estimated number (and percent of annual total) of hatchery-origin spawners from different release basins recovered on the Okanogan/Similkameen spawning grounds, based on CWT recoveries and expansions, for return years 2006-2018.

Return Year		Release Site									
		Summer Chinook Run							Spring and Fall Chinook Run		
	Homing Fish			Straying Fish							
	Okanogan River Basin			Within ESU Stray					Out of ESU Stray		
	Okanogan River[a]	Similkameen River[b]	Methow River[c]	Wenatchee River[d]	Entiat River[e]	Chelan River[f]	Chief Joseph Hatchery (Seg.)	Mainstem Columbia River[g]	Mainstem Columbia River[h]	Snake River[i]	Other[j]
2006	0 (0%)	709 (87%)	12 (2%)	12 (2%)	0 (0%)	0 (0%)		81 (10%)	0 (0%)	0 (0%)	0 (0%)
2007	0 (0%)	1121 (95%)	17 (1%)	5 (0%)	0 (0%)	0 (0%)		42 (4%)	0 (0%)	0 (0%)	0 (0%)
2008	0 (0%)	3224 (95%)	11 (0%)	24 (1%)	0 (0%)	4 (0%)		133 (4%)	3 (0%)	0 (0%)	0 (0%)
2009	0 (0%)	2733 (95%)	14 (0%)	14 (0%)	0 (0%)	9 (0%)		99 (3%)	0 (0%)	5 (0%)	4 (0%)
2010	4 (0%)	2165 (89%)	44 (2%)	35 (1%)	0 (0%)	110 (5%)		75 (3%)	0 (0%)	4 (0%)	0 (0%)
2011	219 (5%)	4196 (93%)	44 (1%)	5 (0%)	0 (0%)	34 (1%)		22 (0%)	0 (0%)	6 (0%)	0 (0%)
2012	379 (13%)	2397 (83%)	29 (1%)	23 (1%)	0 (0%)	17 (1%)		52 (2%)	0 (0%)	0 (0%)	0 (0%)
2013	254 (14%)	1437 (81%)	10 (1%)	54 (3%)	0 (0%)	0 (0%)		10 (1%)	0 (0%)	0 (0%)	0 (0%)
2014	55 (5%)	1023 (90%)	16 (1%)	0 (0%)	6 (1%)	12 (1%)		29 (3%)	0 (0%)	0 (0%)	0 (0%)

2015	38 (1%)	2562 (91%)	70 (3%)	17 (1%)	19 (1%)	33(1%)		33 (1%)	4 (0%)	4 (0%)	21 (1%)
2016	81(4%)	1963 (91%)	42 (2%)	7 (0%)	3 (0%)	31 (1%)		14 (1%)	0 (0%)	0 (0%)	17(1%)
2017	153 (18%)	693 (81%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	TBD	9 (1%)	0 (0%)	4 (1%)	0 (0%)
2018	357 (24%)	628 (43%)	27 (2%)	0 (0%)	0 (0%)	6 (0%)	396 (27%)	28 (2%)	0 (0%)	0 (0%)	36 (2%)
Avg.	***113 (6%)***	***1912(86%)***	***26 (1%)***	***15 (1%)***	***2 (0%)***	***20 (1%)***	***198 (13%)***	***48 (3%)***	***1 (0%)***	***2 (0%)***	***6 (0%)***

[a] Includes releases from Bonaparte Pond. Three spring Chinook recovered in 2008 from an Omak Creek release were excluded from analysis.

[b] Includes releases from Similkameen Pond

[c] Includes releases from Carlton Acclimation Pond

[d] Includes releases from Dryden Pond and Eastbank Hatchery

[e] Includes releases from Entiat NFH

[f] Includes releases from Chelan PUD Hatchery, Chelan River NFH, and Chelan Hatchery

[g] Includes releases of summer Chinook from Wells Hatchery, Turtle Rock Hatchery, and Grant County PUD Hatchery

[h] Includes releases of fall Chinook from Hanford Reach

[i] Includes Releases from NPT Hatchery

[j] Includes releases from Marion Yakama Tribal, Cle Elum Hatchery, and Prosser Hatchery

Table 23. Percent of the total Okanogan spawning escapement comprised of various hatchery release groups, based on CWT recoveries and expansions for return years 2006-2018.

Return Year		Release Site										HOS Stray Contribution to Total Spawning Escapement	pHOS
		Summer Chinook Run						Fall Chinook Run					
	Okanogan River Basin		Within ESU Stray					Out of ESU Stray					
	Okanogan River[a]	Similkameen River[b]	Methow River[c]	Wenatchee River[d]	Entiat River[e]	Chelan River[f]	Chief Joseph Hatchery (Seg.)	Mainstem Columbia River[g]	Mainstem Columbia River[h]	Snake River[i]	Other[j]		
2006	0.0%	15.6%	0.3%	0.3%	0.0%	0.0%		1.8%	0.0%	0.0%	0.0%	2.3%	0.21
2007	0.0%	30.0%	0.5%	0.1%	0.0%	0.0%		1.1%	0.0%	0.0%	0.0%	1.7%	0.37
2008	0.0%	51.5%	0.2%	0.4%	0.0%	0.1%		2.1%	0.1%	0.0%	0.0%	2.8%	0.60
2009	0.0%	38.4%	0.2%	0.2%	0.0%	0.1%		1.4%	0.0%	0.1%	0.1%	2.0%	0.46
2010	0.6%	40.7%	0.8%	0.7%	0.0%	2.1%		1.4%	0.0%	0.1%	0.0%	4.5%	0.47
2011	2.5%	48.3%	0.5%	0.1%	0.0%	0.4%		0.3%	0.0%	0.1%	0.0%	1.3%	0.52
2012	5.3%	34.0%	0.4%	0.3%	0.0%	0.2%		0.7%	0.0%	0.0%	0.0%	1.7%	0.45
2013	3.4%	19.5%	0.1%	0.7%	0.0%	0.0%		0.1%	0.0%	0.0%	0.0%	1.3%	0.31
2014	0.7%	13.0%	0.2%	0.0%	0.0%	0.2%		0.4%	0.0%	0.0%	0.0%	0.7%	0.14
2015	0.3%	22.7%	0.6%	0.2%	0.2%	0.3%		0.3%	0.0%	0.0%	0.2%	1.7%	0.25
2016	0.3%	17.4%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.6%	0.18
2017	3.5%	15.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.3%	0.20
2018	7.3%	12.9%	0.6%	0.0%	0.0%	0.1%	8.2%	0.6%	0.0%	0.0%	0.7%	10.2%	0.27
Avg.	1.8%	27.7%	0.4%	0.2%	0.0%	0.3%	2.7%	0.8%	0.0%	0.0%	0.1%	2.4%	0.30

[a] Includes releases from Bonaparte Pond. Three spring Chinook recovered in 2008 from an Omak Creek release were excluded from analysis.

[b] Includes releases from Similkameen Pond

[c] Includes releases from Carlton Acclimation Pond

[d] Includes releases from Dryden Pond and Eastbank Hatchery

[e] Includes releases from Entiat NFH

[f] Includes releases from Chelan PUD Hatchery, Chelan River NFH, and Chelan Hatchery

[g] Includes releases of summer Chinook from Wells Hatchery, Turtle Rock Hatchery, and Grant County PUD Hatchery

[h] Includes releases of fall Chinook from Hanford Reach

[i] Includes Releases from NPT Hatchery

[j] Includes releases from Marion Yakama Tribal, Cle Elum Hatchery, and Prosser Hatchery

Table 24. Number and percent (%) of hatchery-origin Okanogan summer/fall Chinook that were recovered at target spawning areas or were captured at en route hatcheries (Wells and Chief Joseph Hatchery), and number and percent that strayed to non-target spawning areas and non-target hatcheries, brood years 1989-2013. As fish continue to return through time and the RMIS database is continually updated, reported data from recent brood years may change.

Brood Year	**Homing**				**Straying**			
	Target Stream		**En Route Hatchery**		**Non-target Streams**		**Non-target Hatchery**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
1989	3,132	69.7%	1,328	29.6%	2	0.0%	31	0.7%
1990	729	71.4%	291	28.5%	0	0.0%	1	0.1%
1991	1,125	71.3%	453	28.7%	0	0.0%	0	0.0%
1992	1,264	68.5%	572	31.0%	8	0.4%	1	0.1%
1993	54	62.1%	32	36.8%	0	0.0%	1	1.1%
1994	924	80.8%	203	17.7%	16	1.4%	1	0.1%
1995	1,883	85.4%	271	12.3%	52	2.4%	0	0.0%
1996	27	100.0%	0	0.0%	0	0.0%	0	0.0%
1997	11,659	97.1%	309	2.6%	35	0.3%	2	0.0%
1998	2,784	95.4%	102	3.5%	31	1.1%	2	0.1%
1999	828	96.7%	18	2.1%	10	1.2%	0	0.0%
2000	2,091	93.8%	29	1.3%	94	4.2%	15	0.7%
2001	105	98.1%	2	1.9%	0	0.0%	0	0.0%
2002	702	96.2%	17	2.3%	11	1.5%	0	0.0%
2003	1,580	96.2%	47	2.9%	16	1.0%	0	0.0%
2004	4,947	94.4%	206	3.9%	85	1.6%	2	0.0%
2005	606	93.2%	22	3.4%	22	3.4%	0	0.0%
2006	5,210	97.6%	60	1.1%	68	1.3%	0	0.0%
2007	1,330	97.9%	19	1.4%	10	0.7%	0	0.0%
2008	3,673	96.5%	111	2.9%	19	0.5%	4	0.1%
2009	1,149	80.8%	256	18.0%	14	1.0%	2	0.1%
2010	1,058	61.4%	646	37.5%	9	0.5%	10	0.6%
2011	4,449	79.9%	873	18.9%	10	0.6%	25	0.5%
2012	478	72.8%	174	26.5%	4	0.6%	1	0.2%
2013	484	26.7%	1282	70.7%	43	2.4%	5	0.3%
Total	52,271	83.4%	7,323	15.4%	559	1.0%	103	0.2%

Table 25. Number and percent (%) of spawning escapements that consisted of hatchery-origin Okanogan summer/fall Chinook within non-target basins, return years 1994-2017.

Return Year	**Wenatchee**		**Methow**		**Chelan**		**Entiat**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
1994	0	0.00%	0	0.00%	-	-	-	-
1995	0	0.00%	0	0.00%	-	-	-	-
1996	0	0.00%	0	0.00%	-	-	-	-
1997	0	0.00%	0	0.00%	-	-	-	-
1998	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1999	0	0.00%	0	0.00%	0	0.00%	0	0.00%
2000	0	0.00%	6	0.50%	30	6.40%	0	0.00%
2001	12	0.10%	0	0.00%	10	1.00%	0	0.00%
2002	0	0.00%	3	0.10%	4	0.70%	5	1.00%
2003	0	0.00%	8	0.20%	22	5.30%	14	2.00%
2004	0	0.00%	0	0.00%	5	1.20%	0	0.00%
2005	5	0.10%	27	1.10%	36	6.90%	7	1.90%
2006	0	0.00%	5	0.20%	4	1.00%	7	1.80%
2007	0	0.00%	3	0.20%	4	2.10%	0	0.00%
2008	0	0.00%	9	0.50%	46	9.30%	4	1.90%
2009	15	0.20%	3	0.20%	11	1.80%	18	9.90%
2010	5	0.06%	0	0.00%	32	2.48%	0	0.00%
2011	0	0.00%	0	0.00%	49	4.79%	0	0.00%
2012	7	0.09%	5	0.22%	17	0.36%	0	0.00%
2013	0	0.00%	0	0.00%	0	0.00%	0	0.00%
2014	0	0.00%	0	0.00%	0	0.00%	0	0.00%
2015	0	0.10%	0	0.00%	4	0.37%	0	0.00%
2016	0	0.00%	4	0.20%	4	0.35%	0	0.00%
2017	0	0.00%	0	0.00%	11	1.17%	0	0.00%
2018	0	0.00%	4	0.34%	4	0.53%	0	0.00%
Total	***44***	***0.03%***	***77***	***0.15%***	***293***	***2.18%***	***55***	***0.88%***
5-year Total	***0***	***0.02%***	***8***	***0.11%***	***23***	***0.48%***	***0***	***0.00%***

Homing Fidelity

The 154 coded-wire tags recovered during spawning grounds surveys in fall of 2018 expanded to 366 and 628 spawners originated from Omak Pond and Similkameen Pond acclimation sites, respectively. The majority (92%) of the spawners originating from the Omak Pond acclimation site spawned in the Okanogan River (Table 26). Those fish tended to spawn in habitat upstream of the Omak Pond site, with the majority (59%) in reach O5.   No Omak pond or Similkameen pond CWT's were recovered below reach O3 (Figure 29). Twenty eight of the 366 fish (8%) that were acclimated at Omak Pond were recovered in the Similkameen River. Most fish acclimated at Similkameen Pond spawned in the Okanogan River (60%), especially in reach O5 (Figure 29). However, some of the CWT recoveries in reach O5 could have been fish that spawned upstream in S1 and swam or drifted downstream after spawning. Reach S1, the location of the Similkameen acclimation site in the Similkameen River, accounted for under half of the estimated spawning by Similkameen Pond fish (34%) (Table 26).

Table 26. Spawning distribution by river, for fish acclimated at Omak Pond and Similkameen Pond acclimation sites.

	Acclimation site (origin)	
Spawning location	**Omak Pond**	**Similkameen Pond**
Okanogan River	92%	60%
Similkameen River	8%	40%

[

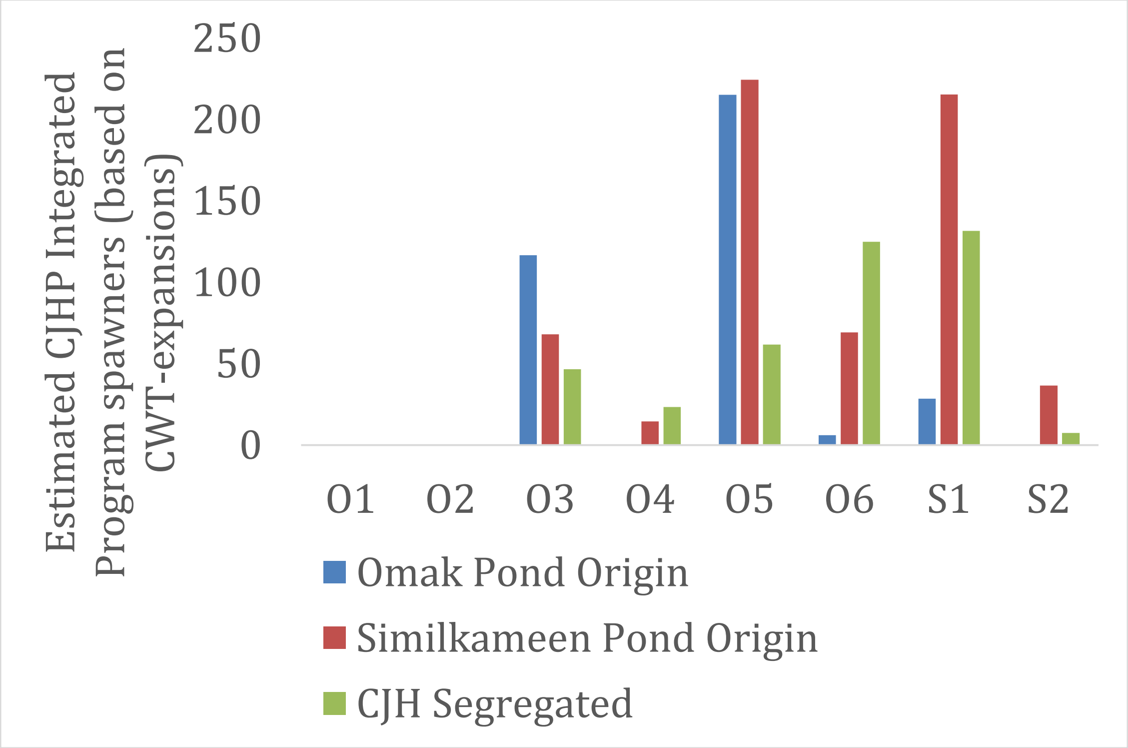


Figure 29. 2018 spatial distribution of CJHP integrated program Chinook spawners originally reared at the Similkameen Pond and Omak Pond acclimation sites and CJHP segregated program strays to Okanogan spawning grounds.

Smolt Survival and Travel Time

Apparent survival of yearlings to RRJ in 2018 was 83% (SE 5%) for the segregated program released from CJH and 54% (SE 4%) for integrated fish released from Omak Pond (Table 27). Apparent survival of yearlings to MCN was 60% (SE 6%) for the segregated program released from CJH and 42% (SE 6%) for the integrated fish released from Omak Pond (Table 27). The segregated yearling program from CJH had higher survival than previous years and other programs, whereas the integrated program had lower survival than previous years and other programs (Figure 30).

Segregated subyearling survival to RRJ was 65% (SE 6%) and 53% (SE 9%) to MCN (Table 27). There was not a subyearling program at the Omak Pond in 2018. The segregated subyearling program had a similar survival to 2017, which was considerably higher than 2015 and 2016, but less than Wells Fish Hatchery subyearlings (Figure 31). Wild subyearlings had a survival to RRJ of 44% (SE 4%) and 12% (SE 3%) to MCN (Table 28). Statistical tests were not conducted to evaluate if the CJH releases were significantly different than nearby hatcheries or previous years. The guidance from the Annual Program

Review was to wait until a multi-year assessment could be conducted with 5 or more years of data to more accurately evaluate patterns between years and programs.

Releases of yearling Summer Chinook smolts began on April 16, 2018. Of the 5,326 PIT tagged fish released from Omak Pond (rkm 52), only 24 were detected at the Lower Okanogan PIT detection array. Fifty percent passed OKL within five days and 90% passed within 14 days. The travel time of summer Chinook released from CJH facilities to RRJ in 2018 varied from 22 days (6.8 km/day) for yearlings released from Omak Pond to 12.9 days (9 km/day) for yearlings released from CJH (Table 29). Subyearling hatchery Summer Chinook traveled at similar speeds as the yearlings; however, direct comparisons of migration speed may not be applicable because not all fish are released at the same time and location and therefore do not experience the same water conditions (e.g., temperature, velocity). Wild subyearlings traveled at much slower speeds to RRJ than hatchery subyearlings, possibly due to differences in size, timing and behavioral differences such as continued feeding and rearing during the early portion of their migration. The majority of yearling Summer Chinook from CJH and Omak Pond arrived at RRJ from late April to mid-May, with 90% passage dates of May 13 and May 26, respectively (Figure 31). The programs appeared to be successfully releasing actively migrating smolts and the migration speed increased substantially in reaches downstream of Rocky Reach Dam for all release groups (Table 29).

Table 27. Apparent survival estimates for PIT tagged Summer Chinook Salmon released in 2018 from Chief Joseph Hatchery (CJH), Omak Pond and other nearby hatcheries.

Summer Chinook Release Group	# PIT tags		Reach	Survival	Survival Standard Error (SE)	Capture Prob.	Capture Prob. (SE)
	Released	Recap.					
Yearlings released at CJH	4921	1175	Release to RRJ	0.83	0.04	0.29	0.02
		388	Release to MCN	0.60	0.06	0.13	0.02
Yearlings released at Omak Pond	5326	611	Release to RRJ	0.54	0.04	0.21	0.02
		265	Release to MCN	0.42	0.06	0.12	0.02
Yearlings released at Carlton Pond	4424	814	Release to RRJ	0.76	0.04	0.24	0.02
		310	Release to MCN	0.59	0.07	0.12	0.01
Yearlings released at Dryden Pond	20677						
		1696	Release to MCN	0.71	0.04	0.12	0.01
Subyearlings released at CJH	5027	584	Release to RRJ	0.65	0.06	0.18	0.02
		192	Release to MCN	0.53	0.09	0.12	0.02
Subyearlings released at Omak	No program in 2018						
Wells Fish Hatchery Subyearlings	5989	887	Release to RRJ	0.79	0.07	0.19	0.02
		189	Release to MCN	0.53	0.11	0.06	0.01
Wild subyearlings from Col. R. and Okanogan R.	23882	2609	Release to RRJ	0.44	0.04	0.24	0.02
		161	Release to MCN	0.12	0.03	0.06	0.02

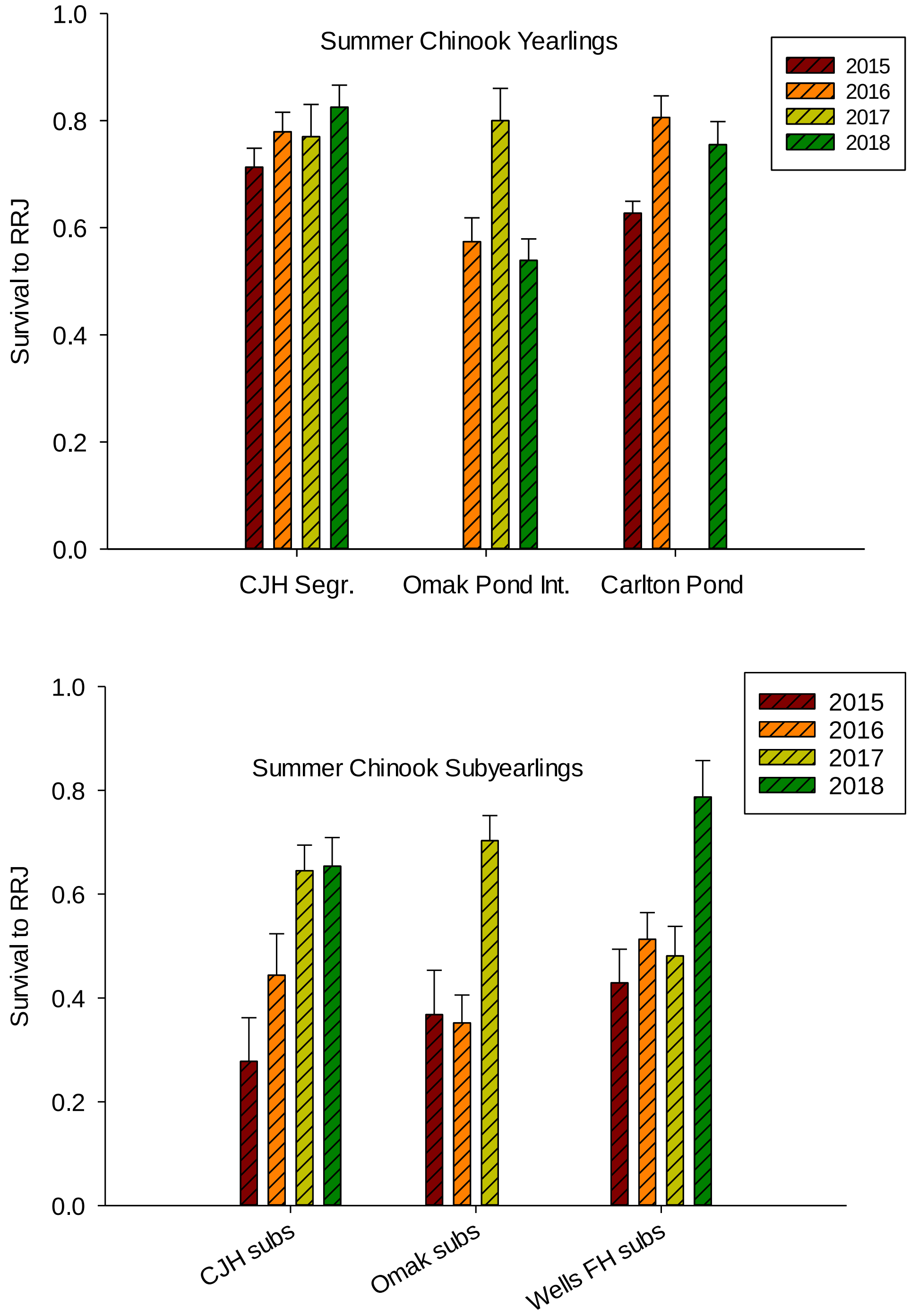


Figure 30. PIT tag survival estimates for juvenile Summer Chinook from release to Rocky Reach juvenile bypass (RRJ) from 2015 to 2018.

Table 28. PIT tag survival estimates for juvenile wild Summer Chinook Salmon captured in a beach seine in Wells Pool, primarily near the mouth of the Okanogan River. For 2015-2018 included additional fish tagged in the Okanogan River at the rotary screw trap and in a side-channel at Conservancy Island.

Wild Summer Chinook Release Group	# PIT tags Released	Recap.	Reach Release to:	Survival	Survival Standard Error (SE)	Capture Prob.	Capture Prob. (SE)
2011	13,221	1,200	RRJ	0.45	0.02	0.20	0.01
		920	MCN	0.30	0.02	0.23	0.02
2012	15,311	912	RRJ	0.54	0.04	0.11	0.01
		795	MCN	0.40	0.03	0.13	0.01
2013	17,760	1,988	RRJ	0.44	0.02	0.26	0.01
		747	MCN	0.39	0.04	0.11	0.01
2014	8,226	845	RRJ	0.35	0.03	0.29	0.02
		240	MCN	0.19	0.04	0.16	0.03
2015	7,787	569	RRJ	0.25	0.05	0.288	0.0628
		19	MCN	NE	NE	NE	NE
2016	14,674	1,411	RRJ	0.24	0.03	0.40	0.04
		81	MCN	NE	NE	NE	NE
2017	23,016	3,694	RRJ	0.46	0.02	0.35	0.02
		528	MCN	0.18	0.02	0.13	0.02
2018	23,882	2,609	RRJ	0.44	0.04	0.24	0.02
		161	MCN	0.12	0.03	0.06	0.02

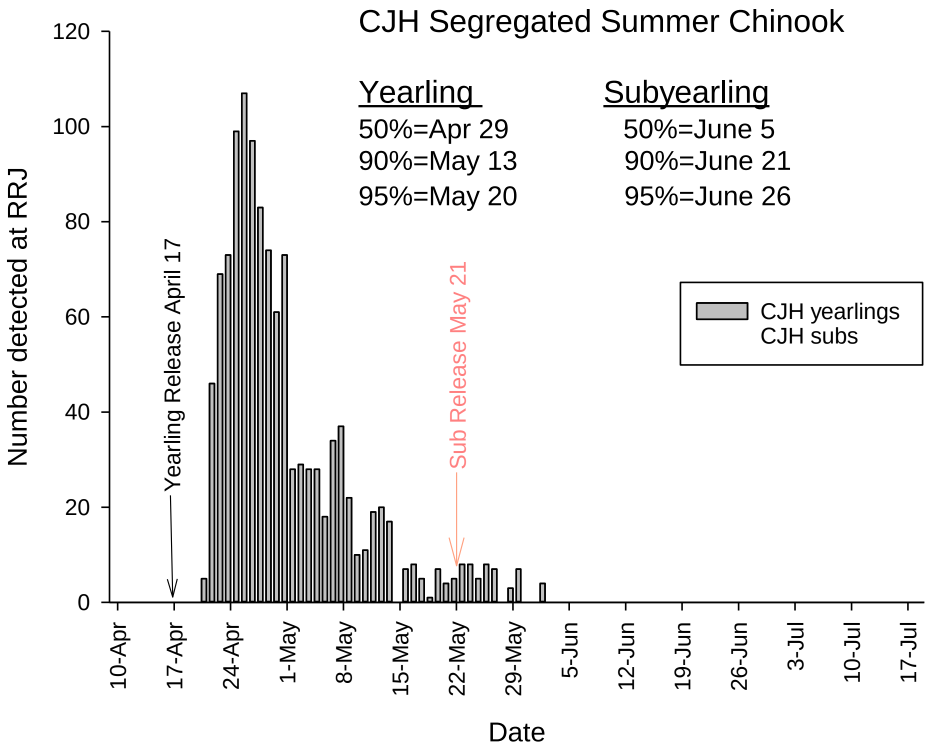
NE = No Estimate due to small sample size and low recapture probability

Table 29. Travel time and migration speed for Summer Chinook release groups in 2018

Release Group	First Day of Release 2018	Last Day of Release 2018	Forced or Volitional	Release to RRJ		RRJ to MCN	MCN to BON
				Mean Travel Time (d)	Travel Rate (km/day)	Travel Rate (km/day)	Travel Rate (km/day)
CJH Summer subs	21-May	22-May	Volitional	15.4	7.6	19.2	54.5
Omak Pond subs	NA	NA	NA	NA	NA	NA	NA
Wells FH subs	1-Jun	1-Jun	Forced	9.6	7.1	16.5	56.8
Wild subs	30-May	3-Jul	NA	31.1	3.1	17.7	a
CJH Summer yearlings	17-Apr	18-Apr	Volitional	12.9	9.0	24.2	60.4
Omak Pond yearlings	16-Apr	19-Apr	Volitional	22.0	6.8	27.5	48.7
Carlton yearlings	24-Apr	25-Apr	Forced	11.3	11.1	23.7	30.4
Dryden yearling	17-Apr	30-May	Volitional	NA	NA	13.0[b]	58.8

[a] sample size too small (<10) to calculate an estimate

[b] Release to McNary, not Rocky Reach to McNary



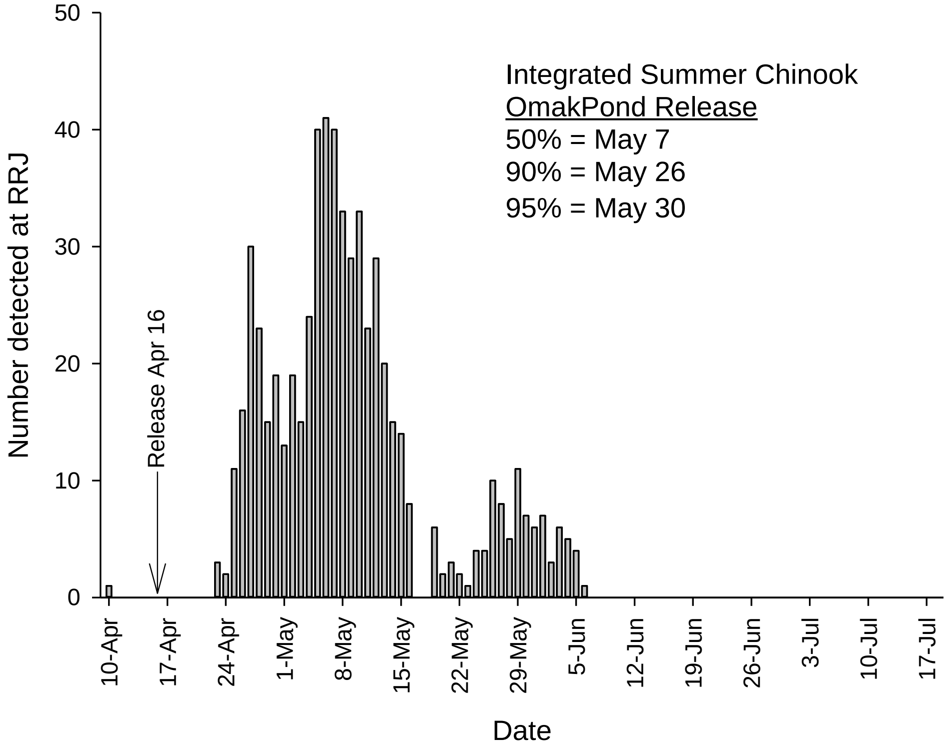


Figure 31. Arrival timing at Rocky Reach Juvenile bypass (RRJ) of PIT tagged Summer Chinook released from the Chief Joseph Hatchery and Omak Pond in 2018.

Smolt-to-Adult Return (SAR)

SAR was estimated using two methods, PIT tags and coded-wire tags.

PIT based estimate of SAR—The most recent brood year that could be fully assessed with PIT tags (through age 5) for SAR was 2014. For CJH segregated Summer Chinook from brood year 2014 (outmigration year 2016), 64 adult fish (age 4&5) returned to Bonneville Dam with a PIT tag, resulting in SAR estimates of 1.29% before harvest and 1.65% with harvested fish added back in (Table 30). For brood year 2014, the SAR back to Wells Dam was 0.85% before harvest and 1.34% with harvested fish added back in (Table 30).

For the brood year 2014 integrated yearling program released from Omak Pond, 28 adult fish (age 4-5) returned to Bonneville Dam with a PIT tag, resulting in SAR estimates of 0.67% before harvest and 0.86% with harvested fish added back in (Table 30). For brood year 2014, the SAR back to Wells Dam was 0.43% before harvest and 0.68% with harvested fish added back in (Table 30).

The subyearling program showed considerably worse SARs, with no adult PIT tagged fish returning from the segregated program thus far, resulting in an SAR estimate of 0%. For the brood year 2014 integrated sub yearling program at Omak Pond, three age 4 fish returned in 2018 resulting in a raw SAR of 0.06% and a harvest corrected SAR of 0.09% (Table 31).

Table 30. Estimate of the smolt to adult return rate (SAR) for yearling Summer Chinook from Chief Joseph Hatchery and Omak Pond. Adult return data were available through 2019, therefore the most recent brood year that could be assessed through age 5 was 2014.

CJH Segregated Yearling Summer Chinook		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	5017	17	16	28	24	0	1.0%	1.6%
2014	4951	1	7	35	29	NA	1.3%	1.8%
2015	5024	27	3	18	NA	NA		
2016	4921	3	NA	NA	NA	NA		
		PIT Tag Detections at Wells Dam						
2013	5017	5	12	16	15	0	0.6%	1.7%
2014	4951	0	4	20	22	NA	0.8%	2.0%
2015	5024	5	2	13	NA	NA		
2016	4921	2	NA	NA	NA	NA		

Integrated Yearling Summer Chinook from Omak Pond		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	1204	0	0	0	0	0	0.00%	0.00%
2014	4193	28	4	19	9	NA	0.67%	0.93%
2015	4830	4	8	22	NA	NA		
2016	5326	0	NA	NA	NA	NA		
		PIT Tag Detections at Wells Dam						
2013	1204	0	0	0	0	0	0.00%	0.00%
2014	4193	3	3	12	6	NA	0.43%	1.04%
2015	4830	2	6	17	NA	NA		
2016	5326	0	NA	NA	NA	NA		

Table 31. Estimate of the smolt to adult return rate (SAR) for subyearling Summer Chinook from Chief Joseph Hatchery and Omak Pond. Adult return data were available through 2019, therefore the most recent brood year that could be assessed through age 5 was 2014.

CJH Segregated Subyearling Summer Chinook		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	NA	NA	NA	NA	NA	NA		
2014	4967	0	0	0	0	NA	0.00%	0.00%
2015	4983	0	0	0	NA	NA		
2016	5029	0	0	NA	NA	NA		
		PIT Tag Detections at Wells Dam						
2013	NA	NA	NA	NA	NA	NA		
2014	4967	0	0	0	0	NA	0.00%	0.00%
2015	4983	0	0	0	NA	NA		
2016	5029	0	0	NA	NA	NA		

Integrated Subyearling Summer Chinook from Omak Pond		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	NA	NA	NA	NA	NA	NA		
2014	4941	0	2	3	0	NA	0.06%	0.09%
2015	4979	0	0	0	NA	NA		
2016	4571	1	1	NA	NA	NA		
		PIT Tag Detections at Wells Dam						
2013	NA	NA	NA	NA	NA	NA		
2014	4941	0	0	2	0	NA	0.04%	0.10%
2015	4979	0	0	0	NA	NA		
2016	4571	1	1	NA	NA	NA		

CWT-based estimate of SAR—Based on expanded CWTs, the 2011 brood year had a SAR of 3.1%, which was above the long-term and 5-year averages. However, this number may change as more adult captures from BY 2011 are uploaded to the RMIS database, and this table changes in the coming years to reflect those data (Table 32).

Table 32. Smolt-to-adult return rate (SARs) for Okanogan/Similkameen summer/fall Chinook, brood years 1989-2011.

Brood Year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
1989	202,125	4,293	2.1%
1990	367,207	972	0.3%
1991	360,380	975	0.3%
1992	537,190	2,282	0.4%
1993	379,139	117	0.0%
1994	212,818	1,526	0.7%
1995	574,197	2,842	0.5%
1996	487,776	32	0.0%
1997	572,531	18,570	3.2%
1998	287,948	7,742	2.7%
1999	610,868	2,782	0.5%
2000	528,639	6,765	1.3%
2001	26,315	424	1.6%
2002	245,997	1,979	0.8%
2003	574,908	3,503	0.6%
2004	676,222	12,960	1.9%
2005	273,512	1,662	0.6%
2006	597,276	13,605	2.3%
2007	610,379	4,943	0.8%
2008	516,533	14,894	2.9%
2009	522,295	7,119	1.4%
2010	610,927	10,666	1.7%
2011	625,234	18,757	3.0%
2012	113,305	2,567	2.3%
Total	***10,670,978***	***138,899***	***1.3%***
5-year Total	***2,388,294***	***54,003***	***2.3%***

[a] Includes all tag codes and CWT released fish (CWT + Ad Clip fish and CWT-only fish).

[b] Includes estimated recoveries (spawning grounds, hatcheries, all harvest - including the ocean and Columbia river basin, etc.) and observed recoveries if estimated recoveries were unavailable.

DISCUSSION

Rotary Screw Traps (RST)

In past years, primarily attributable to low capture efficiency, the data produced by the RST has proved insufficient to provide for estimation of juvenile production in the previous brood year. 2018 was no exception; the extreme flood event resulted in suspension of screw trapping activities for longer than typically occurs.

The pooled trap efficiency of approximately 0.13% is lower than in previous years (Rayton and Arterburn 2008, Johnson and Rayton 2007;https://static1.squarespace.com/static/56f45574d51cd42551248613/t/57c06a21e58c62290279a3d7/1472227873603/2006_Screw_Trap_Report_Final.pdf; https://static1.squarespace.com/static/56f45574d51cd42551248613/t/57c06a12e58c62290279a376/1472227860447/2007RstReportFinal.pdf), and remains insufficient to precisely estimate juvenile production for the basin. Additionally, the 95% confidence interval for hatchery-origin population was far too broad to provide information useful in making informed decisions. This indicates that, due to the difficulties in accurately estimating trap efficiency and juvenile production, the results of screw trapping activities in 2018 are to provide an accurate estimate of juvenile production.

NOAA Fisheries suggested a goal for precision of juvenile outmigration monitoring was to achieve a coefficient of variation (CV) of 15% or less (Crawford and Rumsey 2009). It is not clear that this level of precision is attainable in any large river system using conventional sampling methods such as a rotary screw trap (see Scofield and Griffith, 2014). Still, improving trap efficiency and narrowing juvenile emigration estimates remains the goal of CJHP such that informed management decisions can be made. Environmental factors such as river discharge, configuration, and trap size influenced the efficiencies of these trials. In order to mitigate these confounding variables, we will continue to attempt to conduct more frequent efficiency trials with large release groups (n ≥ 1000).

Again, no relationship between Okanogan River flow and trapping efficiency was observed, and the flow regression model used by other agencies in other river systems (Murdoch et al. 2012) was not applied to estimate outmigration. The CJHP will continue to assess methods to improve capture techniques to increase the precision of juvenile production estimates.

Historically differing efficiency rates for trials involving yearling and sub-yearling fish indicate that using hatchery releases of yearling fish as a surrogate to measure natural production would be inappropriate. However, in future years when wild spring Chinook yearlings are present and out-migrating in measurable quantities, this possibility could be reexamined. This should be especially relevant once integrated, §10(j) spring Chinook, first released from the Riverside Acclimation pond in April 2015, begin to return and spawn.

Finally, Pacific lamprey (*Entosphenus tridentatus*) were captured in the RST in both 2006 and 2007 but were not observed from 2008 to 2018. The status of this fish, an important cultural and ecological resource in the Okanogan River Basin is not examined in this report, but its disappearance from the RST is noteworthy.

Juvenile Beach Seine

The CJHP took over the beach seining effort in 2014, adopting methods used by Douglas County PUD and Biomark in 2011-2013. Given the low catch rate of taggable summer/fall Chinook from the RST, beach seining appeared to be a more reliable opportunity to capture large numbers of taggable summer/fall Chinook juveniles. Again in 2018, PIT tags deployed at the beach seine far outnumbered tags deployed at the RST.

Mortality related to capture, handling and tagging was similar to what it has been in previous years. Maintaining water temperatures below 18 °C, reducing MS-222 concentrations in the anaesthetizing solution, and further limiting handling time during tagging and capture likely contributed to this low pre- and post-tagging mortality. The hope for future years is to continue to reduce overall mortality associated with our PIT tagging efforts.

Fish size increased through the tagging period, but the number of fish captured and CPUE began to decrease in mid-June similar to 2016 and 2017, but earlier than what had been observed previous to that. Interestingly, dates of detection at downstream PIT arrays occurred later in the calendar year in 2018 than in the previous two years.

Capture locations in 2018 expanded to areas upstream of the confluence of the Okanogan and Columbia Rivers, to include a location adjacent to Washburn Island. We do not have absolute certainty regarding natal stream for any of the juvenile Chinook fitted with a PIT tag, but assume the vast majority, especially of fish captured at the Gebber’s location, are of Okanogan origin. However, juvenile summer Chinook in the Wells Pool originate from the Methow and Columbia Rivers as well. Therefore, future analyses of returning adults must recognize that some fish may not be destined for the Okanogan. Particularly, results from the stable isotope analysis indicate that some fish collected from the Washburn location may be of Columbia River origin (Appendix E).

Lower Okanogan Adult Fish Pilot Weir

Discharge conditions on the Okanogan River in 2018 were a little lower than those in 2017, allowing installation and operation of the weir in early August, which was a week earlier than 2017. Temperatures on the Okanogan River were fairly normal, compared to the 13 year median. Because temperatures stayed below 22.5 °C once trapping began on August 12th, trapping operations were not suspended because of this reason. Tower and bank fish observations were generally higher after the thermal barrier broke on August 12. In August, fish observations 0.8 km below the weir, at the lower pool, were similar than observations at the weir. This was not the case for September, when bank observations were much higher than the tower observations below the weir. When river temperature was lower and gauge height was less than 4 feet, Chinook were more likely to mill in deeper pools, but in previous years tower observations were much higher in September. Continued monitoring of Chinook passage through the weir with respect to temperatures should continue in order to better refine weir operations and future expectations for weir effectiveness. The number of Chinook handled at the weir (n = 48) was less than in 2017 (n= 447). Configuration of the weir was different in 2018 compared to 2017. The trap was installed further downstream, about 20 m, on the edge of the thalweg, and below the deep pool. Also a fish entrance chute was added to the trap gate to test whether it would increase entrainment to the trap box. We will evaluate the water conditions as it relates to discharge and stage height to decide if the trap should be moved to an alternate location for higher weir efficiency.

None of the water quality parameters monitored were at a level that would cause concern regarding an environmental effect of the weir on water quality. The number (53) of dead fish at the weir was lower in 2018 than 2017 and much lower than years prior (2014-2016). Chinook mortality was consistent throughout the season without a drastic increase after trapping began, indicating that trap operation and handling were not the immediate cause of mortality. The behavioral observations and lack of fish impinged between pickets (head upstream) were good indicators that this weir configuration and picket spacing were not a major cause of direct mortality. In an attempt to assess immediate indirect mortality, we marked and released adult natural-origin Chinook at the weir trap in 2016 and 2017. Because of the concern for over handling fish in a year with fewer returns and a lack of carcass recoveries on the spawning grounds, we did not conduct a mark-recapture study in 2018. We do not anticipate additional studies in the near future.

There were more observations of Sockeye at the weir during daylight and nighttime hours in 2018 than there were in 2017. Sixty-nine were trapped in 2018. It is likely that more Sockeye moved through the weir panels at night when observations did not occur. There were no observations of jack or small adult Chinook escaping through the 2” weir panels that were intended to allow Sockeye passage. We recommend using the 2 inch weir panels again next year to increase the efficiency of Chinook trapping without causing too many Sockeye to also use the trap. In 2018, there were very few (<5) Sockeye observations during daylight hours, but in past years we did have observations of Sockeye passing through the 2.0” picket spacing. We will continue to document passage of Sockeye and Chinook through all picket spacings.

There was no way to know exactly how many fish escaped past the weir before it was installed or how many fish swam through, around or jumped over the sealing aprons after it was installed. The potential weir effectiveness measure of 0.1% was very low because, after reviewing PIT detection at the Okanogan Instream Lower array, we suspect that about 30-35% of the fish had migrated past the weir before deployment in August. There was not a thermal barrier breakdown that occurred before the weir was fully functional; so it’s unlikely that the majority of fish passed the weir before it was installed. Fortunately, this did not hinder fish management objectives in 2018 because pHOS was already low and only 33% of the Chinook trapped were hatchery origin. In the future, with larger returns of hatchery fish due to CJH releases we anticipate a much higher pHOS at the weir resulting in higher weir effectiveness. Continuing these evaluations in future years will be critical to determining the long-term viability of the weir as a fish management tool for summer Chinook.

The brood stock collection protocol at the weir was to get 15% (n = 84) of the integrated program) from later arriving Chinook (after the thermal barrier breaks). The weir did not meet its brood stock goal, collecting only 19 fish. Despite the shortfall, the late-arriving fish represent a potentially important life-history characteristic, and the hatchery program is better off having included some run-timing diversity.

In 2018 CCT F&W staff were able to safely and successfully deploy, operate, and monitor the weir and add to the multi-year evaluation of the weir as a fish management tool for the CJH program. Although the program experienced lower than expected adult summer Chinook returns, the weir was successful at collecting some brood stock for the hatchery’s integrated program. The weir’s importance to the Okanogan summer/fall Chinook population will increase in the coming years with larger hatchery returns resulting from the increased production at CJH. Experiencing a broad range of environmental conditions spanning the extremely high summer flows of 2012 to the very low and warm flows in 2015 is important for understanding the range of challenges and resulting weir effectiveness that can be expected through time.

Redd Surveys

Summer Chinook spawning consisted of 2,112 redds in 2018, which was below both the 5-year and long-term averages, 3,828 and 2,211, respectively. Redd counts were below average in the upper Okanogan reaches (O5, and O6) and the Similkameen River (S1 and S2), but redd counts actually increased compared to the average in the lower Okanogan River (reaches O1, O2, O3, and O4) (Table 15).

The redd count in reach O6 was the lowest count since 2010 and spawning in reach S1 was the lowest on record, which dates back to 2006. These two adjacent reaches, along with reach O5 (which also saw substantially fewer redds) still provide the primary spawning habitat for summer Chinook in the Okanogan/Similkameen basin, comprising 77.0% of the total spawning in 2018. One objective of the CJHP is to increase the spatial distribution of spawning into the lower reaches of the Okanogan, where historically, a low proportion of the spawning activity has occurred. The 2018 redd counts showed an increase in the proportion of redds in all the lower Okanogan reaches (O1 thru O5), but especially reaches O2, O3, and O4. Although the changes are modest, they represent progress towards a goal that will likely take a long time to fully achieve. CJHP Chinook reared at the Omak pond acclimation site may be contributing to increased spawning in lower reaches through natal homing. Continued monitoring of redd and carcass distribution will be critical to evaluate this metric.

Chinook spawning in the Okanogan generally begins as water temperatures drop below 15°C. Spawn timing was slightly delaying, with the intensive spawning beginning the second week of October, despite water temperatures already dropping below 15°C by October 1. A substantial number of redds were constructed at the end of October and into early November (Table 19), when in previous years, minimal redd construction was taking place. Although aerial surveys contribute a relatively small portion of the observed redds compared to ground or float surveys, they remain an important tool for documenting spawning, or lack of, in areas not accessible by ground crews.

The fish per redd expansion was based on the sex ratio of fish passing Wells Dam. This method has been used since at least 1998 (Hillman et al. 2014) and is still being applied to both the Methow and Okanogan populations. However, there is uncertainty that the combined sex ratio of hatchery and wild summer Chinook at Wells Dam is representative of the Okanogan population because it includes Methow returns, mainstem released hatchery fish, as well as downstream hatchery and wild fish. If the Okanogan has a different ratio of precocial males (jacks) than that of the Wells count, then the Okanogan abundance estimate would be biased. We suggest exploring other approaches to estimating the number of fish per redd in the Okanogan and Similkameen Rivers.

ESCAPEMENT INTO CANADA

Escapement of summer/fall Chinook into Canada had been largely overlooked until recent years, aided by video counts of Chinook passing over Zosel Dam. Spawning escapement to Canada was still difficult to assess, as the video counts represent run escapement and the relationship between run escapement and spawn escapement is not clear. In 2018, video monitoring at Zosel Dam was discontinued, so we are now further limited in our ability to assess Chinook spawning escapement into Canada. In recent years, a substantial number of Chinook have been counted passing Zosel Dam, ranging from a low of 737 to a high of 2275 between 2013 and 2017 (Table 20), so there is the potential for Canada-bound Chinook to have a significant contribution to the trans boundary Okanogan population. No formal Chinook spawning grounds surveys are currently being conducted in Canada, but surveys for Sockeye (*O. nerka*) occur annually. Biologists in Canada have observed small numbers (i.e., substantially fewer than the Zosel Dam video counts) of Chinook spawners building redds in the Canadian portion of the Okanogan River (R. Bussanich, ONA, pers. comm., 2014). There is a clear need for increased collaboration between agencies to better monitor and manage this trans boundary population.

Research & monitoring needs may include:

1. Organization of protocols and methods for formal Chinook spawning grounds surveys in Canada
2. Increased PIT array systems to better assess PIT-tagged fish passage into Canada

Carcass Surveys

Monitoring efforts resulted in an 11% carcass recovery rate, which was below the target carcass recovery rate of 20%. However, it is unclear if 20% is necessary to obtain reliable bio-data or what resolution is lost with lower sampling rates. Zhou (2002) reported fish length as a significant factor in carcass recovery probability, with larger fish recovered at a higher rate than smaller fish. This is especially important as it relates to precocious males, or jacks, which are expected to occur with higher frequencies in hatchery-origin Chinook. Failing to assess and correct for biases and population discrepancies could lead to potential underestimation of hatchery-origin Chinook survival (resulting in inflated hatchery production) or over-estimation of wild-origin Chinook survival (masking potentially negative effects of the hatchery program) (Murdoch et al. 2010). We are considering methods (*e.g.* mark-recapture) to assess and quantify potential size bias in our carcass recovery efforts.

Surveys in late-September revealed few carcasses attributable to pre-spawn mortality (PSM) and October surveys found few PSM as well, resulting in an estimated PSM of just 3 fish or 1.1%. Given the thermally challenging conditions encountered by Chinook in the Okanogan River, it is likely that the majority of PSM occurs earlier in the season while water temperatures are higher and are a greater risk to fish attempting to travel to or hold near the spawning grounds. If this were true, the current design of our redd/carcass surveys would provide an underrepresentation of actual PSM. Therefore, egg retention and pre-spawn mortality results should be interpreted cautiously. The carcasses of fish that died prior to the onset of spawning and before sampling began may have been carried downstream of recovery floats, consumed by scavengers, or covered with sediment, making them unavailable for sampling or harder to detect and collect. This could result in an underestimation of pre-spawn mortality. The protocol assumes that each female may contain up to 5,000 eggs and were only considered pre-spawn mortality if they retained > 4500 eggs. A static fecundity assumption may not be the best approach because younger and smaller females will likely have fewer eggs. We expanded the assessment to include an evaluation of fish that retained greater than 1,000 eggs as an attempt to capture some of the variability in fecundity and situations where fish died before depositing a biologically important portion of their eggs. However, even when considering any female with that retained ≥1000 eggs, the estimated PSM was still just 1.3%. We are not sure that 1,000 eggs are biologically important, but clearly there should be some amount of egg retention that matters besides 100%. We suggest continued review and modification of the egg retention estimation methods/protocol in the future.

PHOS AND PNI

The biological target for CJHP is to maintain a 5-year average pHOS <0.3. 2015 was the first year since the CJHP began monitoring the population that the 5-year average (0.30) met this objective. 2018 pHOS (0.28) further reduced the 5-year average to 0.18. The program failed to meet the biological target for PNI (>0.67) in 2018. However, the 5-year mean PNI (0.82) did meet the objective. In the future, we suggest that continued aggressive removal of hatchery fish through selective fisheries and adult management at the weir and hatchery ladder given the uncertainty regarding the adequacy of the objectives to meet long-term population conservation goals. Exceeding the targets whenever possible also provides a buffer for years when goals may not be achieved due to low run size or challenging environmental conditions.

ORIGIN OF HATCHERY SPAWNERS

Hatchery-origin fish recovered on the spawning grounds in the Okanogan Basin were predominantly (67%) from Okanogan Basin (Okanogan and Similkameen Integrated) releases. Segregated fish made up 27% of the spawners, which was higher than the target of 20%; whereas stray hatchery-origin fish from outside the Okanogan made up 4% of the total estimated spawners, which was less than the goal of 5%. Okanogan Basin hatchery-origin fish strayed to other areas at a low rate (2.4% to non-target basins and 0.30% to non-target hatcheries) and were a small percentage of the spawner composition in other

Upper Columbia tributaries. Fish released within the Okanogan River basin have consistently homed to their natal stream, and 2018 was not an exception. One of the goals of the CJHP is to redistribute Chinook spawners to the middle and lower portion of the Okanogan River instead of inundating the Similkameen River with more spawners. Juvenile releases from the Omak Pond acclimation site are primarily spawning in the lower (O3 reach) and middle (O5 reach) of the Okanogan River.

SMOLT SURVIVAL AND TRAVEL TIME

The survival results for each release group provide a useful index of annual survival for comparison between release groups and, in the future, between years. Statistical tests were not conducted to determine if observed differences were statistically valid because we believe this should be done with a multi-year data set and the few total years for which we currently have results. Targets for post release survival have not been established, but it was encouraging to see that the 2018 estimates of CJH programs were similar to or greater than nearby programs, with the exception of the CJH segregated survival to McNary. In the future, with more years of smolt migration data, the program should develop a statistical framework for evaluating smolt-to-smolt survival and establish targets that could be used to help adaptively manage the release strategies, if it is determined that survival or travel time are not adequate to meet program goals. Similar to previous years, the hatchery fish migrated out of the system relatively quickly in 2018, with no detections of migrants in the Okanogan after May 3. This assessment suggests that the program was successful at releasing actively migrating smolts. This analysis did not attempt to account for detection probability at OKL, which was likely less than usual in 2018 due to the extremely high flows. It is likely that the detection rate was different throughout the time period when smolts were detected. However, detection rates at large river arrays generally increase with decreased flow, so late arriving fish would have a better chance of being detected at OKL than fish out-migrating during high flows from April to June. Therefore, it is not likely that a meaningful number of late migrating smolts or residual hatchery fish would have crossed OKL when compared to what was detected during peak migration. Although the OKL PIT detection site is 25 km from the confluence with the Columbia River, it is very close (~2km) to the inundated zone of Wells Pool. Therefore we can assume that smolts crossing OKL do represent fish leaving the Okanogan River system, or at least they are entering a more reservoir-like environment where interspecific competition for food and space is likely to be less than in the river. Unfortunately it is not possible to evaluate juvenile outmigration (or movement within the Columbia River) in the winter months because juvenile bypass facilities do not operate year round.

SMOLT-TO-ADULT RETURN

The 2014 is the earliest brood year that a PIT-based estimate of SAR could be calculated, because subyearlings were not PIT tagged for brood year 2013. The number of returning adults from the PIT tagged subyearlings was so low that the accuracy of the estimate has considerable uncertainty. However, the fact that zero fish returned from the segregated subyearling program and only three adults returned from the integrated program suggests that PIT tags may not be a good tool for evaluating the SAR of subyearling Summer Chinook. PIT tagging resources may be better utilized increasing the sample size of yearling release groups. In 2019, the program will have five years of data to assess smolt survival differences and two to three years of adult returns. This will provide insight on two options for the program: 1.) continue PIT tagging the subyearlings or 2.) rear fewer integrated subyearlings and, if possible, convert some of the integrated subyearlings to yearlings.

SAR for the most recent full brood returns (2011) was significantly above the 5-year and long-term averages. It is likely that the SAR estimate is biased low because some recovery efforts were not expanded within RMIS, and also because some fish likely have yet to return. We had no way to obtain information necessary to do these expansions or to even speculate as the magnitude of the potential error introduced because of it. In the future, we suggest also using PIT tags as an independent, additional estimate of SAR.

ADAPTIVE MANAGEMENT AND LESSONS LEARNED

The Annual Program Review (APR)

Each year the CJHP hosts a workshop to review and present findings from the previous year and plan for the upcoming fish production and science monitoring cycle. The APR was convened in March 2019 with the purpose of reviewing data collection efforts and results from 2018 and developing the hatchery implementation and monitoring plan for 2019 (Figure 32). This effort is focused on using adaptive management to guide the program. After a series of presentations highlighting the data collection activities and results, the group (CJHP staff and invited guests from Federal, State, PUD, and other organizations) used the In-Season Implementation Tool (ISIT) during the "Analysis" step (Figure 33). The group reviewed the ISIT input parameters for key assumptions, status and trends and decision rules to be sure that the best available information was included in the model. ISIT then used the pre-season Upper Columbia summer/fall Chinook Salmon forecast to provide an estimate of how the program could be implemented with respect to broodstock collection, harvest, weir and hatchery ladder operations to achieve biological targets for 2019. APR materials with more details than what is provided within this report can be found at https://www.cct-fnw.com/annual-program-review/.

Key Management Questions

Answering key management questions is an essential function of the CJHP and is central to the analysis and reporting steps in both the APR and this annual report. Management questions inform the development of the RM&E activities, the CJHPs Key Management Questions (KMQs) are:

1. What is the current status and recent historical trend of the naturally-spawning population in terms of Viable Salmonid Population (VSP) parameters?[8]
2. What is the current status and recent historical trends for hatchery returns and harvest?
3. Is the hatchery program meeting target in-hatchery performance standards?
4. Are the hatchery post-release targets met for survival, catch contribution and straying?
5. Are targets for total catch contribution and selectivity for HORs met?
6. Are there negative effects of the hatchery on the natural population?
7. Are assumptions about natural production potential valid?

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[8] From McElhany, 2000 (NOAA), a viable salmonid population is an independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame. The four VSP parameters are abundance, productivity, spatial structure and diversity.

8. How should the program be operated in the coming year?

Annual Planning Workflow

Hatchery Operations
Broodstock, incubation, rearing, acclimation, RM&E components

Hatchery Science
Data Collection, Analysis& Management, Science Design, Methods, Protocols

Adult and Juvenile Population Monitoring
Weir, Traps, Spawning, Escapement, Survival

Inseason Management Modeling/Updates
Population Analysis, Research & Development

Physical Habitat RM&E and Restoration
OBMEP and OSHIP

Adult Management/Selective Harvest
Data/Harvest/Population Management

Hatchery RME
Survival, Condition
Growth
Program Effectiveness
ISIST/AHA Attributes, Ops

Biological Data
POPULATION DYNAMICS
Abundance, Survival, Genetics
ISIT/AHA Attributes

Physical Data
HABITAT/ECOSYSTEM
Productivity and Capacity
ISIT/AHA Attributes, Restoration

Harvest/Hydro
All Fisheries
Passage
ISIT/AHA Attributes

Science and OPs
Data Collection
Data Analysis
Data Management

Annual Program Review (APR)
ISIT/AHA/APPT
Etc.

Decision Policy
Key Assumptions
Decision Rules
Uncertainty
Budget/Organization

Annual Chief Joseph Hatchery Program Plan
Production & Science Plans
Anadromous Division Supporting Activities (APPT)

Figure 32. The Chief Joseph Hatchery's annual planning process and work flow.

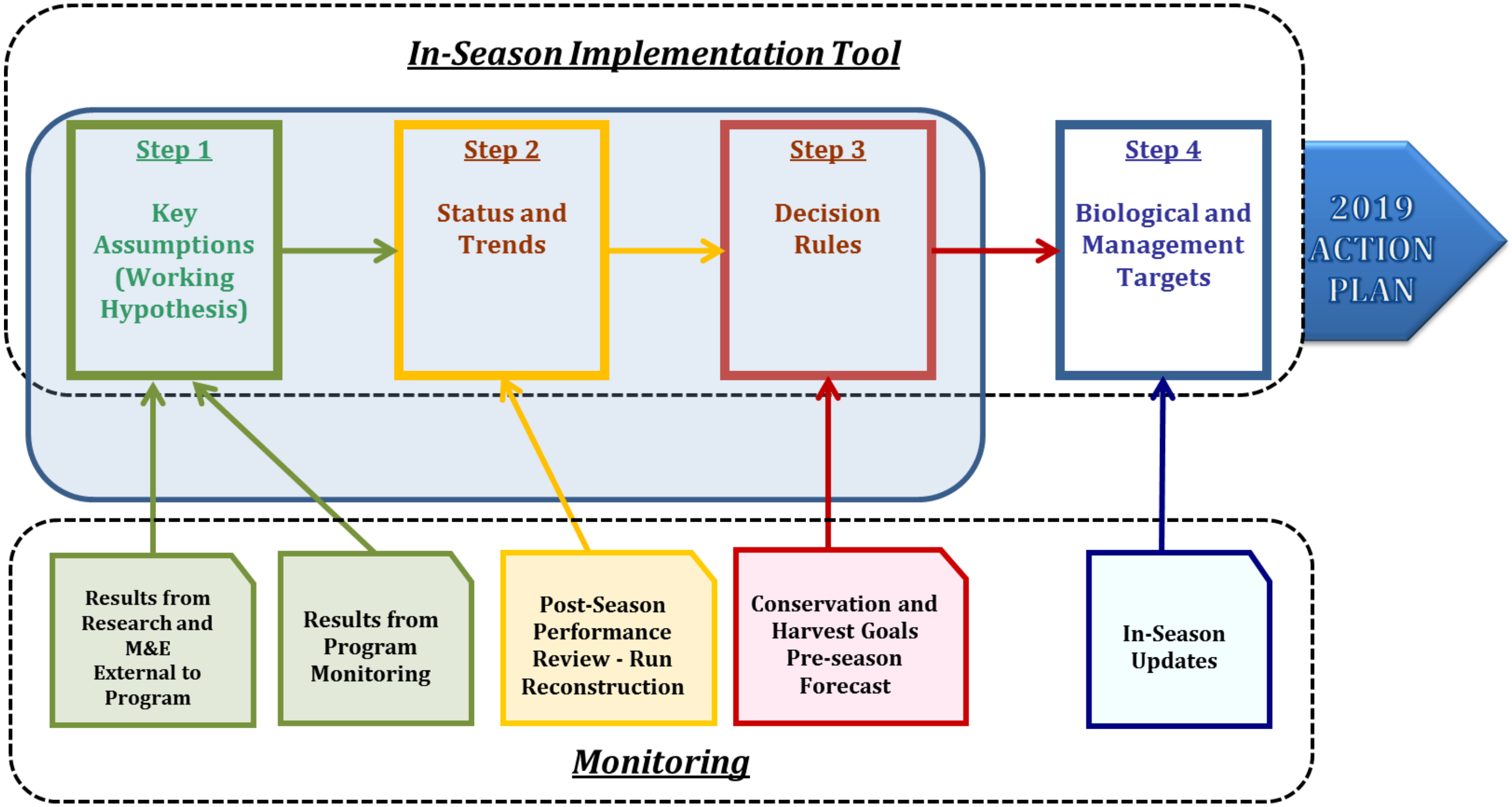
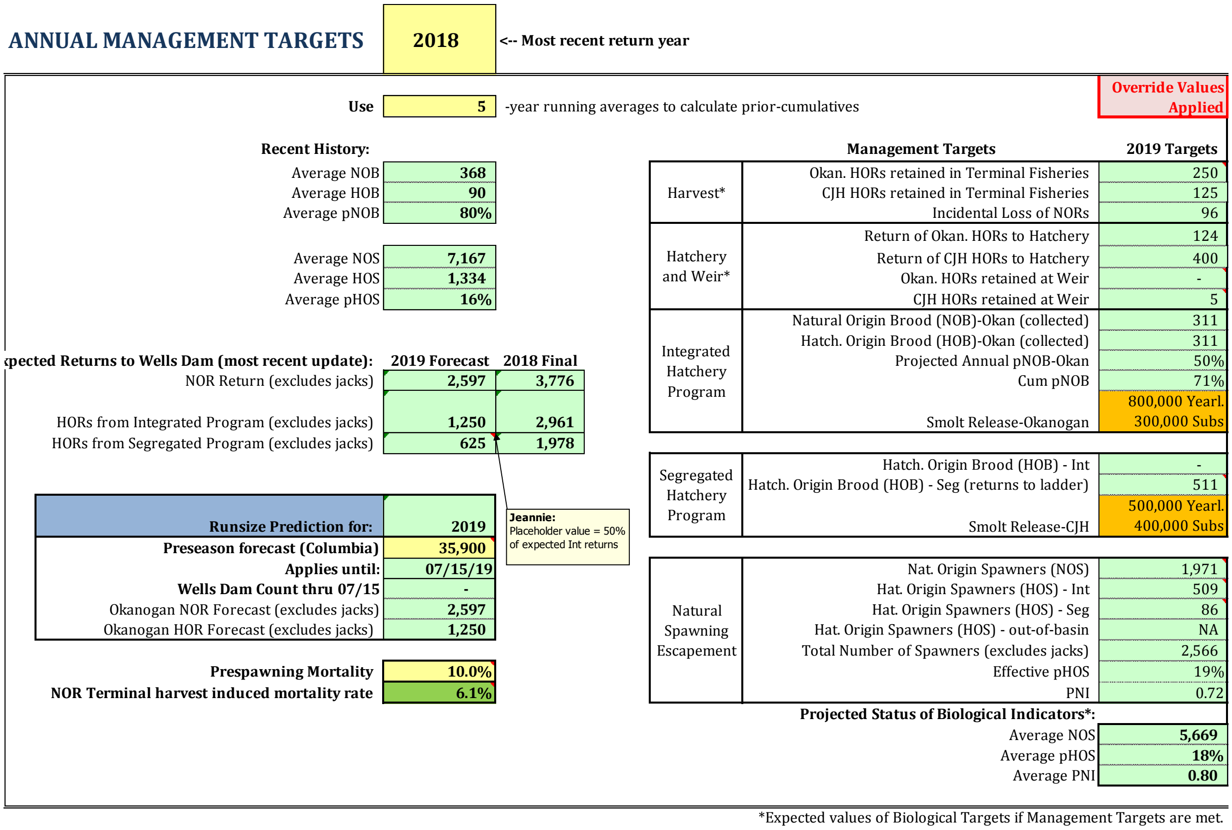


Figure 33. The Chief Joseph Hatchery's analytical workflow.

2019 Run Size Forecast and Biological Targets

Run-size forecasts and updates are an early indicator for the biological targets for the coming season, through the Decision Rules outlined in the ISIT. The preseason forecast is based on brood year escapement and juvenile survival indicators and is generated through the Technical Advisory Committee (TAC) to the *U.S. v. Oregon* fish management agreement. As the season nears, this information is supplemented with return data from downstream dam counts. The pre-season forecast for Upper Columbia summer Chinook Salmon was 35,900. The pre-season forecast, and subsequent run updates from early dam counts, were used to predict the NOR and HOR run size for the Okanogan population. Hatchery broodstock and selective harvest targets are determined based on these estimates and the objectives for pHOS (<0.30) and PNI (>0.67). A regression analysis conducted within ISIT in preparation for the APR predicted that the pre-season forecast of 35,900 upper Columbia would yield 2,597 NORs and 1,250 HORs (Figure 34). The harvest and broodstock collection goals were established from this prediction. With a NOR run size just less than 3,000 the broodstock collection recommendation for the integrated program was full production (622 NOB) with 50% pNOB (Figure 34). Likewise, the segregated program should achieve full production with 511 HOB. The model predicted that 375 HORs would be captured in the terminal (above Wells Dam) fisheries and that 5 HORs could be removed at the weir. These efforts could result in 1,971 NOS and 595 HOS for a pHOS of 19% and a PNI of 0.72. Under this modeling scenario the biological targets would be met in 2019. As run size updates become available (through TAC) the ISIT outputs will be double checked until the final in-season check point on July 15, 2019. At that time the run size at Wells Dam will be input into ISIT and the final plan for broodstock and harvest will be updated. If the July 15 update includes more hatchery and natural fish than predicted, then harvest and removal of surplus fish at the weir and the hatchery ladder will be implemented by CCT and WDFW (through their mark-selective sport fishery). If the July 15 update includes less hatchery and natural fish than predicted, then CCT and WDFW will manage the harvest and removal of surplus fish in a way that will allow enough natural and hatchery-origin fish to escape to the Okanogan basin spawning grounds (NOS ≥ 5,250, total escapement ≥ 7,500) and also meet the pHOS objective of < .30.



ANNUAL MANAGEMENT TARGETS **2018** **<-- Most recent return year**

Use 5 -year running averages to calculate prior-cumulatives

Override Values Applied

Recent History:	
Average NOB	**368**
Average HOB	**90**
Average pNOB	**80%**
Average NOS	**7,167**
Average HOS	**1,334**
Average pHOS	**16%**

xpected Returns to Wells Dam (most recent update):	**2019 Forecast**	**2018 Final**
NOR Return (excludes jacks)	**2,597**	**3,776**
HORs from Integrated Program (excludes jacks)	**1,250**	**2,961**
HORs from Segregated Program (excludes jacks)	**625**	**1,978**

Jeannie: Placeholder value = 50% of expected Int returns

Runsize Prediction for:	**2019**
Preseason forecast (Columbia)	**35,900**
Applies until:	**07/15/19**
Wells Dam Count thru 07/15	**-**
Okanogan NOR Forecast (excludes jacks)	**2,597**
Okanogan HOR Forecast (excludes jacks)	**1,250**

Prespawning Mortality	**10.0%**
NOR Terminal harvest induced mortality rate	**6.1%**

	Management Targets	**2019 Targets**
Harvest*	Okan. HORs retained in Terminal Fisheries	250
	CJH HORs retained in Terminal Fisheries	125
	Incidental Loss of NORs	96
Hatchery and Weir*	Return of Okan. HORs to Hatchery	124
	Return of CJH HORs to Hatchery	400
	Okan. HORs retained at Weir	-
	CJH HORs retained at Weir	5
Integrated Hatchery Program	Natural Origin Brood (NOB)-Okan (collected)	311
	Hatch. Origin Brood (HOB)-Okan (collected)	311
	Projected Annual pNOB-Okan	50%
	Cum pNOB	71%
	Smolt Release-Okanogan	800,000 Yearl. 300,000 Subs
Segregated Hatchery Program	Hatch. Origin Brood (HOB) - Int	-
	Hatch. Origin Brood (HOB) - Seg (returns to ladder)	511
	Smolt Release-CJH	500,000 Yearl. 400,000 Subs
Natural Spawning Escapement	Nat. Origin Spawners (NOS)	1,971
	Hat. Origin Spawners (HOS) - Int	509
	Hat. Origin Spawners (HOS) - Seg	86
	Hat. Origin Spawners (HOS) - out-of-basin	NA
	Total Number of Spawners (excludes jacks)	2,566
	Effective pHOS	19%
	PNI	0.72

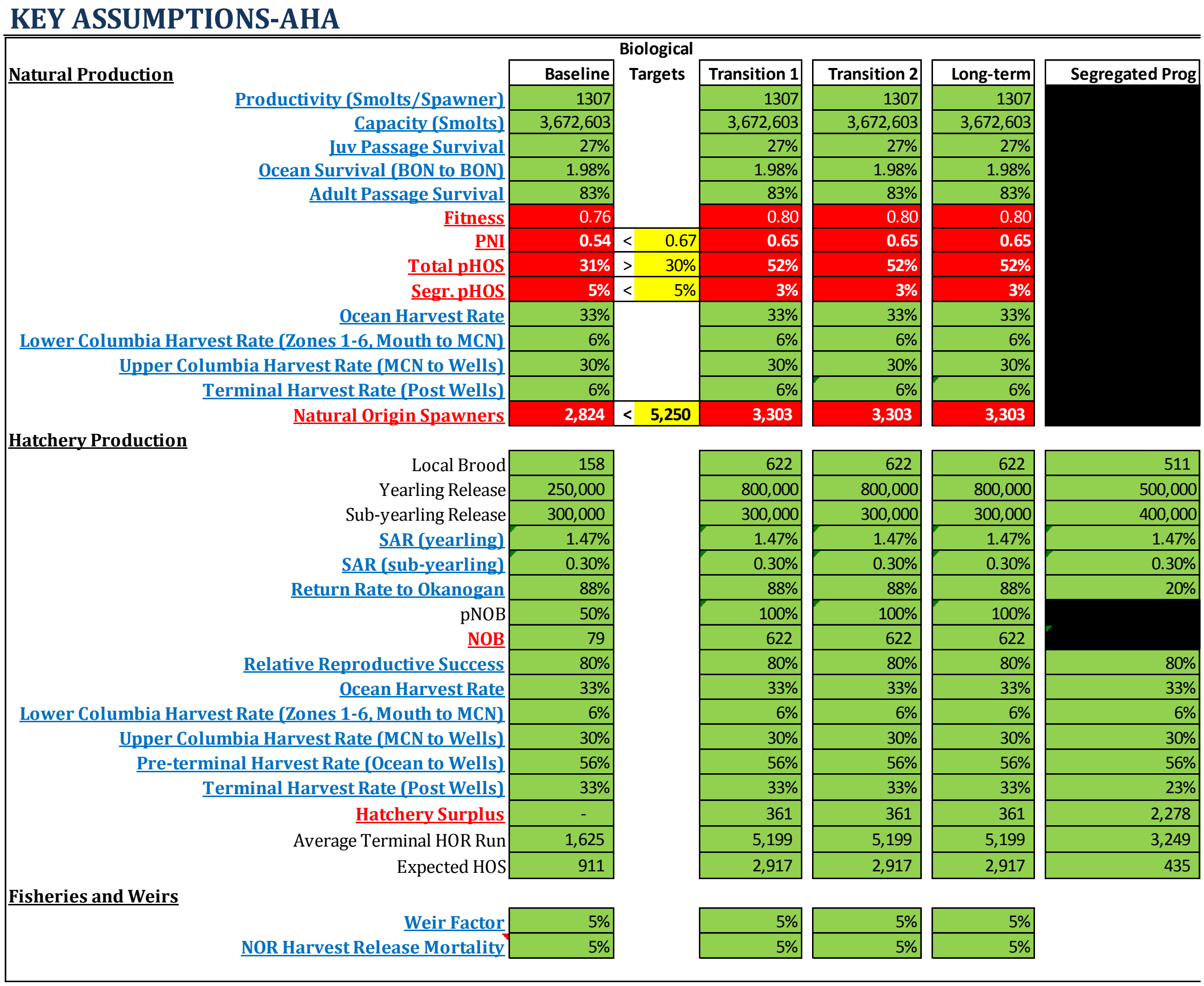
Projected Status of Biological Indicators*:	
Average NOS	**5,669**
Average pHOS	**18%**
Average PNI	**0.80**

*Expected values of Biological Targets if Management Targets are met.

Figure 34. The in-season updates management worksheet used to set biological targets for the upcoming year (2019) in the In-Season Implementation Tool.

2019 Key Assumptions

The CJHP reviews the key assumptions (working hypothesis) each year at the APR workshop. These assumptions directly affect the decision rules used to guide in-season management decisions. The program documents the changes and uses this information for future review and analysis (Figure 35).



KEY ASSUMPTIONS-AHA

Natural Production	Baseline	Biological Targets		Transition 1	Transition 2	Long-term	Segregated Prog
Productivity (Smolts/Spawner)	1307			1307	1307	1307	
Capacity (Smolts)	3,672,603			3,672,603	3,672,603	3,672,603	
Juv Passage Survival	27%			27%	27%	27%	
Ocean Survival (BON to BON)	1.98%			1.98%	1.98%	1.98%	
Adult Passage Survival	83%			83%	83%	83%	
Fitness	0.76			0.80	0.80	0.80	
PNI	0.54	<	0.67	0.65	0.65	0.65	
Total pHOS	31%	>	30%	52%	52%	52%	
Segr. pHOS	5%	<	5%	3%	3%	3%	
Ocean Harvest Rate	33%			33%	33%	33%	
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	6%			6%	6%	6%	
Upper Columbia Harvest Rate (MCN to Wells)	30%			30%	30%	30%	
Terminal Harvest Rate (Post Wells)	6%			6%	6%	6%	
Natural Origin Spawners	2,824	<	5,250	3,303	3,303	3,303	
Hatchery Production							
Local Brood	158			622	622	622	511
Yearling Release	250,000			800,000	800,000	800,000	500,000
Sub-yearling Release	300,000			300,000	300,000	300,000	400,000
SAR (yearling)	1.47%			1.47%	1.47%	1.47%	1.47%
SAR (sub-yearling)	0.30%			0.30%	0.30%	0.30%	0.30%
Return Rate to Okanogan	88%			88%	88%	88%	20%
pNOB	50%			100%	100%	100%	
NOB	79			622	622	622	
Relative Reproductive Success	80%			80%	80%	80%	80%
Ocean Harvest Rate	33%			33%	33%	33%	33%
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	6%			6%	6%	6%	6%
Upper Columbia Harvest Rate (MCN to Wells)	30%			30%	30%	30%	30%
Pre-terminal Harvest Rate (Ocean to Wells)	56%			56%	56%	56%	56%
Terminal Harvest Rate (Post Wells)	33%			33%	33%	33%	23%
Hatchery Surplus	-			361	361	361	2,278
Average Terminal HOR Run	1,625			5,199	5,199	5,199	3,249
Expected HOS	911			2,917	2,917	2,917	435
Fisheries and Weirs							
Weir Factor	5%			5%	5%	5%	
NOR Harvest Release Mortality	5%			5%	5%	5%	

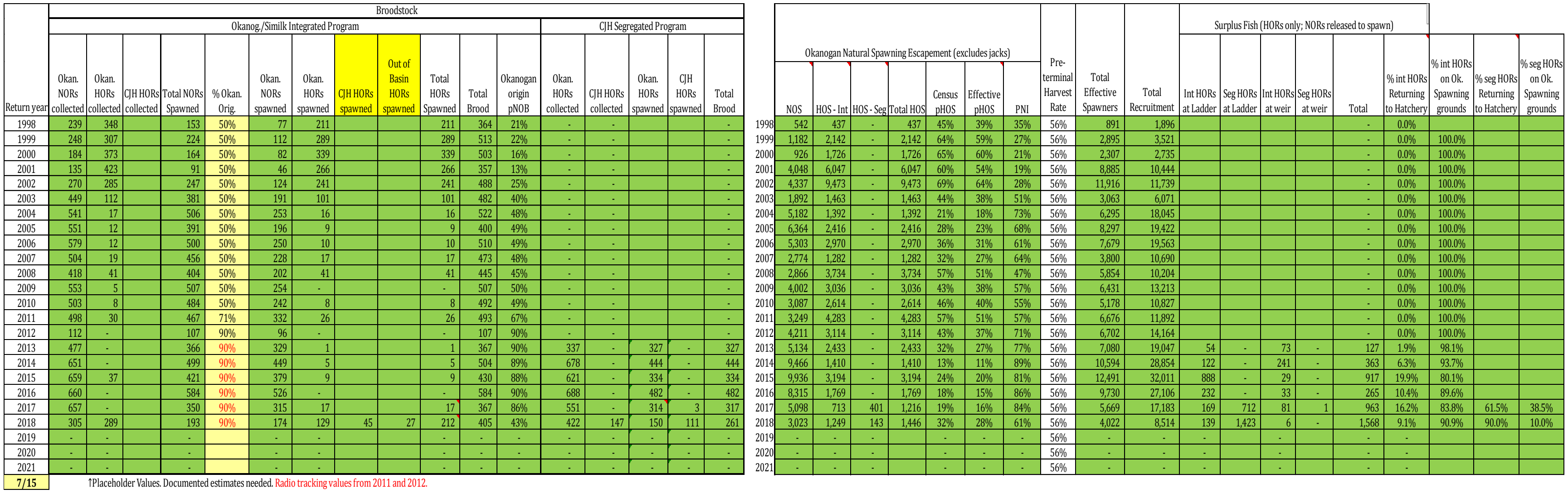
Figure 35. The key assumptions worksheet used in the 2019 In-Season Implementation Tool for the CJHP planning at the Annual Program Review

2019 Status and Trends

The recent performance of the population is a primary driver for determining how the hatchery program should be operated in the future. This was accomplished by updating and reviewing the status and trend information within five categories: (1) natural production, (2) hatchery production, (3) harvest, (4) migration, and (5) habitat (Figure 36).

Return year		FPC Reported Dam Count at Wells thru 07/15 (excludes jacks)	% of final count	PUD Counts at Wells Dam		Estimated Return of Okanogan Origin Fish to Wells Dam		
				NOR All Origins (excludes jacks)	HOR All Origins (excludes jacks)	**Okan. NORs**	Okan. HORs	CJH HORs
1998	3	**1,060**	0.25	970	5,519	841	833	-
1999	4	**999**	0.11	2,708	4,580	1,562	2,686	-
2000	5	**2,266**	0.26	2,726	7,398	1,213	2,291	-
2001	6	**9,766**	0.24	10,266	19,195	4,632	7,141	-
2002	7	**23,221**	0.34	24,138	42,035	5,207	11,801	-
2003	8	**20,564**	0.40	9,194	7,373	2,693	2,948	-
2004	9	**14,762**	0.40	23,227	13,989	8,004	2,599	-
2005	10	**14,449**	0.42	18,911	15,164	8,615	3,404	-
2006	11	**12,563**	0.43	20,262	8,730	8,677	4,114	-
2007	12	**5,532**	0.37	7,088	7,789	4,742	2,901	-
2008	13	**8,838**	0.35	11,244	13,779	4,526	6,369	-
2009	14	**13,753**	0.46	15,184	14,187	5,861	5,678	-
2010	15	**12,264**	0.41	5,671	7,167	4,802	5,394	-
2011	16	**3,912**	0.12	12,139	19,164	5,275	6,431	-
2012	17	**10,082**	0.24	14,424	27,716	6,283	7,172	-
2013	18	**25,571**	0.38	34,965	30,179	8,448	6,116	-
2014	19	**26,010**	0.39	36,060	21,015	12,798	4,517	-
2015	20	**25,153**	0.38	46,030	31,625	14,199	8,272	-
2016	21	**21,479**	0.32	28,467	21,542	12,023	5,163	3
2017	22	**15,124**	0.23	15,729	18,479	7,622	2,338	1,276
2018	23	**11,886**	0.18	6,533	18,347	3,776	2,961	1,978
2019	24	**-**	0.00	-	-	-	-	-
2020	25	**-**	0.00	-	-	-	-	-
2021		**-**	0.00	-	-	-	-	-
7/15		**2019**	**dam count at Wells was**			**-**	**adults**	

Terminal Harvest Above Wells														
Tribal Harvest						Recreational Harvest						Terminal Harvest Rates		
Total Tribal Harvest	Total NORs	Total HORs	Okan. NORs	Okan. HORs	CJH HORs	**Total Rec. Harvest**	Total NORs	Total HORs	Okan. NORs	Okan HORs	CJH HORs	NOR	Int HOR	Seg HOR
-	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
-	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
-	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
-	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
1,753	653	1100	118	990	-	**-**	-	-	-	-	-	2%	8%	-
2,130	785	1345	141	1,211	-	**-**	-	-	-	-	-	5%	41%	-
242	0	242	-	218	-	**2,803**	1,895	908	1,706	817	-	21%	40%	-
784	392	392	71	353	-	**1,419**	1,025	394	923	355	-	12%	21%	-
1,389	563	826	101	743	-	**2,119**	1,809	310	1,628	54	-	20%	19%	-
1,078	467	611	84	550	-	**1,803**	887	916	798	726	-	19%	44%	-
2,299	588	1711	106	1,540	-	**1,665**	698	967	628	561	-	16%	33%	-
2,598	363	2235	65	2,012	-	**1,062**	648	414	583	244	-	11%	40%	-
2,912	354	2558	64	2,174	-	**1,019**	612	407	551	204	-	13%	44%	-
1,097	449	648	81	577	-	**1,017**	200	817	180	556	-	5%	18%	-
3,184	656	2528	118	2,250	-	**2,470**	829	1,641	746	1,264	-	14%	49%	-
3,176	832	2344	150	1,781	-	**2,107**	179	1,928	161	848	-	4%	43%	-
2,963	1508	1455	271	1,164	-	**1,383**	321	1,062	289	627	-	4%	40%	-
9,729	6257	3472	1,126	2,639	-	**1,660**	289	1,371	260	425	-	10%	37%	-
3,141	1889	1252	340	989	3	**1,784**	237	1,547	213	1,021	-	5%	39%	100%
1,397	746	651	134	104	117	**1,568**	591	977	532	537	-	9%	27%	9%
1,238	484	754	87	128	249	**993**	28	965	25	589	-	3%	24%	13%
-	0	0	-	-	-	**-**	-	-	-	-	-	-	-	-
-	0	0	-	-	-	**-**	-	-	-	-	-	-	-	-
-	0	0	-	-	-	**-**	-	-	-	-	-	-	-	-



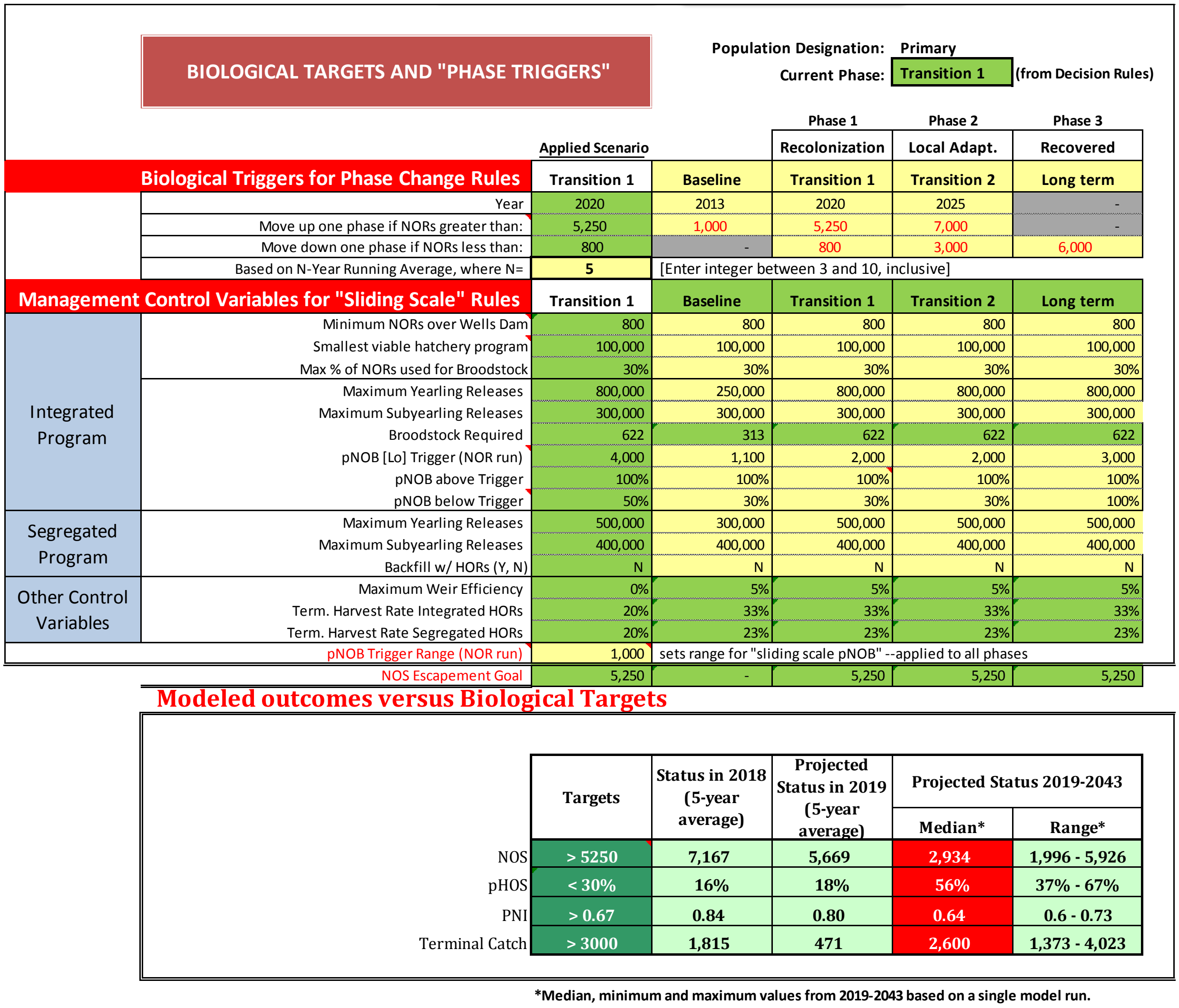
	Broodstock																
	Okanog./Similk Integrated Program												CJH Segregated Program				
Return year	Okan. NORs collected	Okan. HORs collected	CJH HORs collected	Total NORs Spawned	% Okan. Orig.	Okan. NORs spawned	Okan. HORs spawned	CJH HORs spawned	Out of Basin HORs spawned	Total HORs Spawned	Total Brood	Okanogan origin pNOB	Okan. HORs collected	CJH HORs collected	Okan. HORs spawned	CJH HORs spawned	Total Brood
1998	239	348		153	50%	77	211			211	364	21%	-	-			-
1999	248	307		224	50%	112	289			289	513	22%	-	-			-
2000	184	373		164	50%	82	339			339	503	16%	-	-			-
2001	135	423		91	50%	46	266			266	357	13%	-	-			-
2002	270	285		247	50%	124	241			241	488	25%	-	-			-
2003	449	112		381	50%	191	101			101	482	40%	-	-			-
2004	541	17		506	50%	253	16			16	522	48%	-	-			-
2005	551	12		391	50%	196	9			9	400	49%	-	-			-
2006	579	12		500	50%	250	10			10	510	49%	-	-			-
2007	504	19		456	50%	228	17			17	473	48%	-	-			-
2008	418	41		404	50%	202	41			41	445	45%	-	-			-
2009	553	5		507	50%	254	-			-	507	50%	-	-			-
2010	503	8		484	50%	242	8			8	492	49%	-	-			-
2011	498	30		467	71%	332	26			26	493	67%	-	-			-
2012	112	-		107	90%	96	-			-	107	90%	-	-			-
2013	477	-		366	90%	329	1			1	367	90%	337	-	327	-	327
2014	651	-		499	90%	449	5			5	504	89%	678	-	444	-	444
2015	659	37		421	90%	379	9			9	430	88%	621	-	334	-	334
2016	660	-		584	90%	526	-			-	584	90%	688	-	482	-	482
2017	657	-		350	90%	315	17			17	367	86%	551	-	314	3	317
2018	305	289		193	90%	174	129	45	27	212	405	43%	422	147	150	111	261
2019	-	-		-		-	-			-	-	-	-	-	-	-	-
2020	-	-		-		-	-			-	-	-	-	-	-	-	-
2021	-	-		-		-	-			-	-	-	-	-	-	-	-
7/15	↑Placeholder Values. Documented estimates needed. Radio tracking values from 2011 and 2012.																

	Okanogan Natural Spawning Escapement (excludes jacks)										Surplus Fish (HORs only; NORs released to spawn)								
	NOS	HOS - Int	HOS - Seg	Total HOS	Census pHOS	Effective pHOS	PNI	Pre-terminal Harvest Rate	Total Effective Spawners	Total Recruitment	Int HORs at Ladder	Seg HORs at Ladder	Int HORs at weir	Seg HORs at weir	Total	% int HORs Returning to Hatchery	% int HORs on Ok. Spawning grounds	% seg HORs Returning to Hatchery	% seg HORs on Ok. Spawning grounds
1998	542	437	-	437	45%	39%	35%	56%	891	1,896					-	0.0%			
1999	1,182	2,142	-	2,142	64%	59%	27%	56%	2,895	3,521					-	0.0%	100.0%		
2000	926	1,726	-	1,726	65%	60%	21%	56%	2,307	2,735					-	0.0%	100.0%		
2001	4,048	6,047	-	6,047	60%	54%	19%	56%	8,885	10,444					-	0.0%	100.0%		
2002	4,337	9,473	-	9,473	69%	64%	28%	56%	11,916	11,739					-	0.0%	100.0%		
2003	1,892	1,463	-	1,463	44%	38%	51%	56%	3,063	6,071					-	0.0%	100.0%		
2004	5,182	1,392	-	1,392	21%	18%	73%	56%	6,295	18,045					-	0.0%	100.0%		
2005	6,364	2,416	-	2,416	28%	23%	68%	56%	8,297	19,422					-	0.0%	100.0%		
2006	5,303	2,970	-	2,970	36%	31%	61%	56%	7,679	19,563					-	0.0%	100.0%		
2007	2,774	1,282	-	1,282	32%	27%	64%	56%	3,800	10,690					-	0.0%	100.0%		
2008	2,866	3,734	-	3,734	57%	51%	47%	56%	5,854	10,204					-	0.0%	100.0%		
2009	4,002	3,036	-	3,036	43%	38%	57%	56%	6,431	13,213					-	0.0%	100.0%		
2010	3,087	2,614	-	2,614	46%	40%	55%	56%	5,178	10,827					-	0.0%	100.0%		
2011	3,249	4,283	-	4,283	57%	51%	57%	56%	6,676	11,892					-	0.0%	100.0%		
2012	4,211	3,114	-	3,114	43%	37%	71%	56%	6,702	14,164					-	0.0%	100.0%		
2013	5,134	2,433	-	2,433	32%	27%	77%	56%	7,080	19,047	54	-	73	-	127	1.9%	98.1%		
2014	9,466	1,410	-	1,410	13%	11%	89%	56%	10,594	28,854	122	-	241	-	363	6.3%	93.7%		
2015	9,936	3,194	-	3,194	24%	20%	81%	56%	12,491	32,011	888	-	29	-	917	19.9%	80.1%		
2016	8,315	1,769	-	1,769	18%	15%	86%	56%	9,730	27,106	232	-	33	-	265	10.4%	89.6%		
2017	5,098	713	401	1,216	19%	16%	84%	56%	5,669	17,183	169	712	81	1	963	16.2%	83.8%	61.5%	38.5%
2018	3,023	1,249	143	1,446	32%	28%	61%	56%	4,022	8,514	139	1,423	6	-	1,568	9.1%	90.9%	90.0%	10.0%
2019	-	-	-		-	-	-	56%	-	-	-		-		-	-			
2020	-	-	-		-	-	-	56%	-	-	-		-		-	-			
2021	-	-	-		-	-	-	56%	-	-	-		-		-	-			

Figure 36. The status and trends worksheet in the In-Season Implementation Tool for CJHP planning at the Annual Program Review.

2018 Decision Rules

The decision rules determine the targeted size of the hatchery program and the management of natural escapement abundance and composition. The purpose of the Decision Rules is to assure that the CJHP manages the hatchery, terminal fisheries and weir to meet the guidelines for abundance, spawner composition, and distribution of the natural spawning escapement (Figure 37).



BIOLOGICAL TARGETS AND "PHASE TRIGGERS"

Population Designation: **Primary**
Current Phase: **Transition 1** **(from Decision Rules)**

		Applied Scenario		Phase 1 Recolonization	Phase 2 Local Adapt.	Phase 3 Recovered
Biological Triggers for Phase Change Rules		**Transition 1**	**Baseline**	**Transition 1**	**Transition 2**	**Long term**
	Year	2020	2013	2020	2025	-
	Move up one phase if NORs greater than:	5,250	1,000	5,250	7,000	-
	Move down one phase if NORs less than:	800	-	800	3,000	6,000
	Based on N-Year Running Average, where N=	**5**	[Enter integer between 3 and 10, inclusive]			
Management Control Variables for "Sliding Scale" Rules		**Transition 1**	**Baseline**	**Transition 1**	**Transition 2**	**Long term**
Integrated Program	Minimum NORs over Wells Dam	800	800	800	800	800
	Smallest viable hatchery program	100,000	100,000	100,000	100,000	100,000
	Max % of NORs used for Broodstock	30%	30%	30%	30%	30%
	Maximum Yearling Releases	800,000	250,000	800,000	800,000	800,000
	Maximum Subyearling Releases	300,000	300,000	300,000	300,000	300,000
	Broodstock Required	622	313	622	622	622
	pNOB [Lo] Trigger (NOR run)	4,000	1,100	2,000	2,000	3,000
	pNOB above Trigger	100%	100%	100%	100%	100%
	pNOB below Trigger	50%	30%	30%	30%	100%
Segregated Program	Maximum Yearling Releases	500,000	300,000	500,000	500,000	500,000
	Maximum Subyearling Releases	400,000	400,000	400,000	400,000	400,000
	Backfill w/ HORs (Y, N)	N	N	N	N	N
Other Control Variables	Maximum Weir Efficiency	0%	5%	5%	5%	5%
	Term. Harvest Rate Integrated HORs	20%	33%	33%	33%	33%
	Term. Harvest Rate Segregated HORs	20%	23%	23%	23%	23%
	pNOB Trigger Range (NOR run)	1,000	sets range for "sliding scale pNOB" --applied to all phases			
	NOS Escapement Goal	5,250	-	5,250	5,250	5,250

Modeled outcomes versus Biological Targets

	Targets	Status in 2018 (5-year average)	Projected Status in 2019 (5-year average)	Projected Status 2019-2043	
				Median*	Range*
NOS	> 5250	7,167	5,669	2,934	1,996 - 5,926
pHOS	< 30%	16%	18%	56%	37% - 67%
PNI	> 0.67	0.84	0.80	0.64	0.6 - 0.73
Terminal Catch	> 3000	1,815	471	2,600	1,373 - 4,023

*Median, minimum and maximum values from 2019-2043 based on a single model run.

Figure 37. Screen shot of the decision rules in the In-Season Implementation Tool for CJHP planning at the Annual Program Review.

Data Gaps and Research Needs

In a partnership with USGS, WDFW and the ONA, the CJHP is working to identify data gaps and applied research needs within the Okanogan Basin that would better inform hatchery management, increase available data for resource management decision making, and benefit overall salmonid recovery in the greater Columbia River basin. If funded in the future, the tasks identified could directly inform CJHP and other natural resource managers and aid in the decision making process. Some of the data gaps and applied research needs that have been identified include:

1. Refined estimates (extent, fate, timing and location) of summer/fall Chinook using the mainstem Columbia River above Wells Dam for spawning (i.e. straying), rather than returning to their natal Okanogan River using radio or acoustic telemetry.
2. Extent, fate, timing and location of spawning Chinook in the Canadian portion of the Okanogan Basin.
3. Development and testing of a panel of microsatellites and/or single nucleotide polymorphisms (SNPs) for genotyping genetic stocks of Chinook salmon in the Okanogan Basin and upper-Columbia River, upstream of Wells dam, to identify and differentiate Okanogan summer- vs. fall- vs. spring-Chinook, as well as hatchery × hatchery, hatchery × wild, and wild × wild crosses of these various life-history types.
4. Utilization of advancements in thermal imaging/LiDAR or other remote sensing technologies combined with in-stream temperature loggers and ArcGIS/R Statistical Program (STARS & FLoWs toolsets & SSN package) to map current thermal refugia in the Okanogan basin and model potential changes resulting from climate change scenarios.
5. Development and/or adaptation of existing methods for better estimation of fine sediment loads per reach length in the Okanogan River to quantify effects on Chinook salmon spawning redds and productivity.
6. Design for testing fish tagging rate assumptions. PIT, radio and genetic tagging emphasis.
7. Post-release mortality for various capture techniques including the purse seine, hatchery ladder, sport fishing, the weir, etc.

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APPENDIX A: SUMMER CHINOOK

Hatchery operations and production

The CJH's central facility is a 15 acre facility located immediately below Chief Joseph Dam along the right bank of the Columbia River at rkm 872 near Bridgeport, WA. There is one summer Chinook CJH acclimation facility on the Okanogan River, Omak (rkm 51) acclimation pond. There is an additional acclimation facility on the Similkameen River (rkm 6.4) that is part of the CJH program but is operated by WDFW and funded by the CPUD.

Construction of the hatchery was completed in 2013 and broodstock were brought on station for the first time. The goal of the CJHP is to contribute to the increased abundance, productivity, temporal-spatial diversity, re-colonization of Chinook in the Okanogan Basin, and provide increased harvest for all fishers.

Production Objectives

Full program production totals 2 million summer/fall Chinook. The summer/fall Chinook program incorporates both an integrated program (1.1 million smolts) supported by Okanogan River natural-origin broodstock and a segregated program (900,000 smolts) supported by hatchery-origin adults returning from the integrated program.

In 2018, the summer/fall Chinook program production level did not meet full production as planned, due to higher than expected pre-spawn mortality on both the integrated and segregated summer/fall brood as well as poor incubation conditions due to a failing chiller.

Summer/Fall Chinook Salmon

BY 2017 SUMMER/FALL CHINOOK SALMON REARING AND RELEASE

Due to high pre-spawn mortality and reduced eyed egg survival, there was no integrated sub-yearling program for brood year 2017.

The BY-2017 segregated summer Chinook sub-yearlings were ponded on Feb 2nd. A total of 198,572 fry were ponded in starter troughs for four weeks prior to being moved outside. They were clipped and tagged beginning April 2nd. Approximately 5,000 PIT tags were added to each group and after subtracting shed tags and mortality, a total of 5,027 PIT tags were released (82 PIT tags were detected at release).

Table A 1. Chief Joseph Hatchery brood year 2017 segregated sub-yearling summer/fall Chinook rearing summary, May 2018.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	2/28/2018	194,403	2,773	167	406	98.53%
	3/31/2018	194,004	399	889	148	98.31%
	4/30/2018	182,558*	999	1,254	64	97.78%
	5/22/2018	182,462	96	792	49	97.73%
	Cumulative:	**182,558**	**4,267**	**3,102**	**49**	**97.73%**

**Shortage at marking - 10,447*

Volitional release began on 5/21/18 with all being forced out on 5/22/18.

The yearling summer/fall Chinook rearing proceeded on schedule, with both the integrated and segregated groups being marked in July and August. Marking was completed, for both the integrated and the segregated programs, on September 21, 2018. The segregated summer Chinook were 100% ad-clipped, with a 100k CWT group tagged. The integrated summer Chinook were 100% AD/CWT. As shown in Table A 2 and Table A 3, ponding and rearing mortality for both programs were about normal, although the integrated stock was short of book numbers at marking while the segregated program was over. The segregated fish were marked into rearing Pond B, while the integrated fish were marked into the lower raceways, and reared until transfer to the acclimation ponds in late October. The segregated group was released on April 18th. Approximately 5,000 PIT tags were added to each group in October 2018. After subtracting shed tags and mortality, a total of 4,945 PIT tags were released from the segregated group (811 were detected at release).

Table A 2. Chief Joseph Hatchery brood year 2017 segregated summer/fall yearling rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	5/31/2018	278,685	6,315	77	638	97.78%
	6/30/2018	377,752	2,863	589	357	97.77%
	7/31/2018	374,984	2,768	1,354	123	97.10%
	8/31/2018	399,870*	360	273	113	97.01%
	9/30/2018	399,786	84	1,056	71	96.99%
	10/31/2018	399,686	100	2,200	46	96.97%
	11/30/2018	399,469	217	2,948	38	96.92%
	12/31/2018	399,428	41	4,268	25	96.91%
	1/31/2019	399,403	25	2,372	35	96.90%
	2/28/2019	399,383	20	1,144	30	96.90%
	3/31/2019	399,311	72	2,367	30	96.88%
	4/18/2019	399,299	12	440	30	96.88%
	Subtotal:	399,299	12,877	19,088	30	96.88%

**Population adjusted after marking*

*Shortage after marking - 13,217

The integrated summer/fall Chinook were shipped to the Omak Acclimation Pond and the Similkameen Acclimation Pond between October 26th and October 30th. Reporting for the Similkameen Pond will reside with WDFW through release.

Omak Acclimation Pond

On October 26, 2018 Chief Joseph Hatchery staff transferred 281,943 Integrated BY 17 summer Chinook from Chief Joseph Hatchery to the Omak Acclimation Pond. At the time of transfer, the fish were approximately 27 fpp, and were programmed to be reared over winter, with a target size at release of 10 fpp. An additional 245,550 BY 17 Summer Chinook were transferred to WDFW's Similkameen Pond, as part of the cost share agreement. These fish were forced released April 18, 2019. Approximately 5,000 PIT tags were added to the group in October 2018. Due to a mix up during transfer, PIT tagged fish were sent to the Similkameen Pond in error. Because of this error approximately 5,000 PIT tags were added to the Omak Pond fish in April 2019. After subtracting shed tags and mortality, a total of 4,987 PIT tags were released from this integrated group (4,907 were detected at release). Table A 3 illustrates feed fed, feeding rate, and mortality to date for the integrated summer/fall Chinook transferred to the Omak Acclimation pond.

Table A 3. Omak Acclimation Pond BY 17 integrated yearling summer/fall Chinook rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
NOR	10/31/2018	281,943	45	660	27	99.99%
	11/30/2018	281,837	106	1,408	27	99.95%
	12/31/2018	281,740	97	-	25	99.92%
	1/31/2019	281,625	115	-	25	99.88%
	2/28/2019	281,424	201	-	25	99.81%
	3/31/2019	280,610	814	1,408	26	99.55%
	4/19/2019	280,055	555	1,584	20	99.36%
	Cumulative:	**280,055**	**1,933**	**5,060**	**20**	**99.36%**

Volitional release began on 4/16/19 with all being forced out on 4/19/19

Riverside Acclimation Pond

Riverside Acclimation Pond was not used to rear BY 2017 summer/fall Chinook, but was utilized to rear BY 17 10j Spring Chinook.

Similkameen Acclimation Pond

Similkameen Pond was used to rear yearling summer Chinook per the WDFW program funded by CPUD. Adult broodstock used to generate the juveniles for BY 2017 were collected via the CCT purse seine as part of the transition to the collaborative CJH program. On October 30, 2018, Chief Joseph Hatchery staff transferred 245,550 summer/fall Chinook to the Similkameen Pond, with the assistance of WDFW's Eastbank Hatchery staff. At the time of transfer, the fish were approximately 33 fpp, and were programmed for over winter acclimation, with a target size at release of 10 fpp. These fish began volitional release on April 15th, with an end release date of April 19, 2019. Cumulative survival, at the date of transfer, was 97.4%. Survival from transfer to release was 98.0%. Due to the transfer error mentioned above, PIT tagged fish were released from the Similkameen Pond; after subtracting mortality and shed tags, a total of 4,945 PIT tagged fish were released.

Cumulative egg to smolt survival

The target egg to smolt survival identified in the original summer/fall Chinook HGMP was 77.5% for sub-yearlings and 73.5% for yearlings (CCT 2008b). The cumulative egg to smolt survival, for the BY 2017 sub-yearlings, was 89.1%, which only includes the segregated program as there was not BY17 integrated sub-yearling program. The cumulative egg to smolt survival, for the BY 2017 yearlings, was 87.6%.

BY 2018 SUMMER/FALL CHINOOK SALMON

2018 Broodstock collection

Collection of summer/fall Chinook for BY 2018 occurred between July 2nd and August 17th via the CCT purse seine operation at the mouth of the Okanogan River. Both hatchery-origin and natural-origin brood were collected to supply the integrated and segregated production programs at CJH. As the seine was being pursed, 9-meter transport barges approached the seine vessel and tied off on the opposite side. The broodstock transport barges have two transport tanks, a 300 gallon for HORs and a 600 gallon for NORs. Brood fish were removed from the seine and placed headfirst in a rubber tube, or boot, containing some water and handed to the staff on the barges for placement in the holding tanks. A maximum of 14 HOR and 28 NOR brood could be loaded per barge. Once full, or at the commencement of the purse seine haul, the barges returned to the offload area at Mosquito Park approximately 2 km away. The brood was then removed from the tanks by hand, placed into a boot, then delivered to one of two 2,500 gallon tanker trucks and transported 16 km to the hatchery.

Water temperatures were of major concern during these operations and monitored to minimize trauma to the adult brood. Okanogan River temperatures during July ranged from 66° F (19° C) to 78° F (25.5° C). In order to limit the effects of the temperature changes we monitored the temperature of all transport vessels and strived to not expose brood to changes greater than 8° F. We accomplish this by utilizing both well water and surface water when filling the barges and transport tankers, and monitoring our raceway temperatures.

A weekly quota was developed to ensure that brood collections occurred across as much of the summer run timing as possible (Table A 4). If brood collection failed to meet the weekly quota it was adjusted the following week. The purse seine is only effective when there is a thermal barrier at the mouth of the Okanogan, therefore broodstock can only be collected there until late August or early September. Once at the hatchery, broodstock were offloaded 6 at a time into totes in order to inject with Draxxin and LA200 (liquamycin), with females receiving both while males only receiving LA200. Broodstock were then separated by program and sex and put into their designated raceways. The receiving water was approximately 57° F. The adult ponds had a flow rate of 500 gpm, and an exchange rate of 54 minutes, representing a Flow Index (FI) of 0.56 and a Density Index (DI) of 0.08 at max capacity. Upon arrival, adult ponds were put on well water. Due to low returns, the CJH ladder was also utilized to collect segregated broodstock.

All adult ponds were treated a minimum of five days per week with formalin to control fungus at a rate of 1:6000, for one exchange. Additionally, brood fish were treated twice per week with Chloramine-T at 12 ppm for one exchange to control Columnaris bacteria.

Table A 4. Chief Joseph Hatchery summer/fall Chinook weekly broodstock collection objectives and results for brood year 2018.

	Weekly Quota			Cumulative Collection	
Week	**Natural Origin***	**Hatchery Origin****	**Cumulative Proportion**	**Natural Origin**	**Hatchery Origin**
July 9 - July 15	44	44	0.08	44	44
July 16 - July 22	108	104	0.27	152	148
July 23 - July 29	108	104	0.45	260	252
July 30 - Aug 5	132	126	0.69	392	378
Aug 6 - Aug 12	132	126	0.92	524	504
Aug 13 - Aug 19	36	36	0.98	560	540
Aug 20 - Aug 26	12	12	1.00	572	552
***Sept 15 - Oct 15	84			656	

**Combined collection strategies in prioritized order: purse seine, tangle-net, Okanogan weir, beach seine, CJH ladder.*

***Combined collection strategies in prioritized order: purse seine, tangle-net, CJH ladder, Okanogan weir, beach seine.*

****NOR weir collection*

*Combined collection strategies in prioritized order: purse seine, tangle-net, Okanogan weir, beach seine, CJH ladder.
**Combined collection strategies in prioritized order: purse seine, tangle-net, CJH ladder, Okanogan weir, beach seine.
***NOR weir collection

A total of 559 HOB were collected including 286 females, 273 adult males and 0 jacks (Table A 10). A total of 600 NOB were collected including 329 females, 271 adult males, and 0 jacks (Table A 5). However, due to low wild returns, some hatchery brood were allocated to the integrated program, which included 136 males and 153 females. No steelhead or Bull trout were encountered during broodstock collection efforts.

Through the month of October 2018, there were 99 adult male and 95 adult female mortalities in the HOR brood, representing 67.3% and 66.8% cumulative pre-spawn survival to date, respectively. For the same time frame, 56 adult NOR Summer Chinook males died, and 83 females died, representing 79.3% and 74.8% cumulative pre-spawn survival, respectively. (Table A 5) Brood fish, particularly females, suffered higher than anticipated mortality due to Columnaris disease, which affected us particularly hard once the well water in which these fish are held reached >60°F.

The cumulative pre spawn holding survival, for all Summer/Fall brood collected, was 65.3% for HOB and 76.8% for NOB (Table A 5), with neither program meeting the survival standard (90%).

Table A 5. Chief Joseph Hatchery summer/fall Chinook Hatchery (HOB) and Natural (NOB) origin broodstock holding survival summary for brood year 2018. (M = adult males, J = jacks and F = adult females). The survival standard for this life stage was 90%.

		Beginning of Month			End of Month			Mortality			Monthly Survival (%)			Cumulative Survival (%)		
	Month	M	J	F	M	J	F	M	J	F	M	J	F	M	J	F
HOR	July	0	0	0	130	0	120	2	0	3	98.5%	NA	97.6%	98.5%	NA	97.6%
	August	130	0	120	270	0	281	1	0	2	99.6%	NA	99.3%	98.9%	NA	98.3%
	Sept	270	0	281	267	0	281	3	0	0	98.9%	NA	100.0%	98.5%	NA	99.3%
	Oct	267	0	281	0	0	0	93	0	90	65.2%	NA	68.0%	63.7%	NA	66.8%
	Total	**0**	**0**	**0**	**0**	**0**	**0**	**99**	**0**	**95**	**0.0%**	**NA**	**0.0%**	**63.7%**	**NA**	**66.8%**
NOR	July	0	0	0	159	0	171	0	0	0	100.0%	NA	100.0%	100.0%	NA	100.0%
	August	159	0	171	271	0	328	0	0	0	100.0%	NA	100.0%	100.0%	NA	100.0%
	Sept	271	0	328	270	0	325	1	0	4	99.6%	NA	98.8%	99.6%	NA	98.8%
	Oct	270	0	325	0	0	0	55	0	79	79.6%	NA	75.7%	79.3%	NA	74.8%
	Total	**0**	**0**	**0**	**0**	**0**	**0**	**56**	**0**	**83**	**0.0%**	**NA**	**0.0%**	**79.3%**	**NA**	**74.8%**

Hatchery staff began collection of NOR brood from the weir on August 19, 2018. Collections off the weir were slow and only 19 wild fish (2 males, 17 females) were caught and transferred to the hatchery for broodstock. Fish were transferred from the weir trap manually.

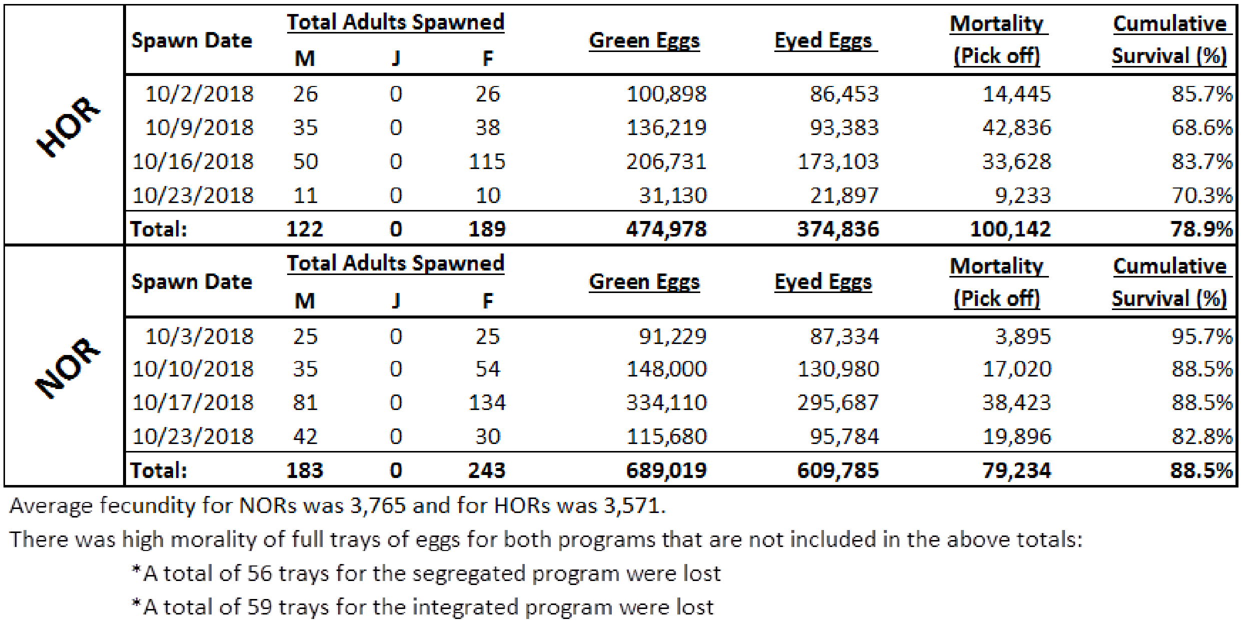
The fish were then transported approximately 32 km to Chief Joseph Hatchery where they were held in the broodstock raceways until the first spawn date the first week in October. We recognize that fish collected late may have arrived at any point in their run timing; however, the efforts to collect fish in late August into September at least offer the opportunity to include fish that arrive later in the run timing.

Spawning

Spawning of Summer Chinook began on October 2, 2018 with the segregated program, and continued through October 23, 2018. Beginning with the 2018 brood year, the segregated and integrated programs will be spawned on separate days. As with the Spring Chinook, the Summer Chinook program is also 100% ELISA sampled. For the 2018 brood, we experienced a much lower than normal disease profile, and as a result eggs from only 3 females were culled.

Total NOB spawned included 183 males, zero jacks, and 243 females. (Table A 6) Total HOR spawn included 122 males, zero jacks, and 189 females. Total eyed egg take for the season was 1,163,997. Egg survival from green egg to eyed egg for NOB averaged 88.5% (Table A 6). Egg survival for HOB averaged 78.9%. Survival was lower than the key assumption of (90%) for this life stage. Additionally, there were several trays of eyed eggs that were 100% lost due to the failed chiller which includes 56 trays of the segregated program and 59 trays of the integrated program.

Table A 6. Chief Joseph Hatchery brood year 2018 summer/fall Chinook spawning and incubation results.



	Spawn Date	Total Adults Spawned			Green Eggs	Eyed Eggs	Mortality (Pick off)	Cumulative Survival (%)
		M	J	F				
HOR	10/2/2018	26	0	26	100,898	86,453	14,445	85.7%
	10/9/2018	35	0	38	136,219	93,383	42,836	68.6%
	10/16/2018	50	0	115	206,731	173,103	33,628	83.7%
	10/23/2018	11	0	10	31,130	21,897	9,233	70.3%
	Total:	**122**	**0**	**189**	**474,978**	**374,836**	**100,142**	**78.9%**
	Spawn Date	Total Adults Spawned			Green Eggs	Eyed Eggs	Mortality (Pick off)	Cumulative Survival (%)
		M	J	F				
NOR	10/3/2018	25	0	25	91,229	87,334	3,895	95.7%
	10/10/2018	35	0	54	148,000	130,980	17,020	88.5%
	10/17/2018	81	0	134	334,110	295,687	38,423	88.5%
	10/23/2018	42	0	30	115,680	95,784	19,896	82.8%
	Total:	**183**	**0**	**243**	**689,019**	**609,785**	**79,234**	**88.5%**

Average fecundity for NORs was 3,765 and for HORs was 3,571.

There was high morality of full trays of eggs for both programs that are not included in the above totals:

*A total of 56 trays for the segregated program were lost

*A total of 59 trays for the integrated program were lost

*Mortality does not include 15,000 eggs culled for high ELISA values

Broodstock origin

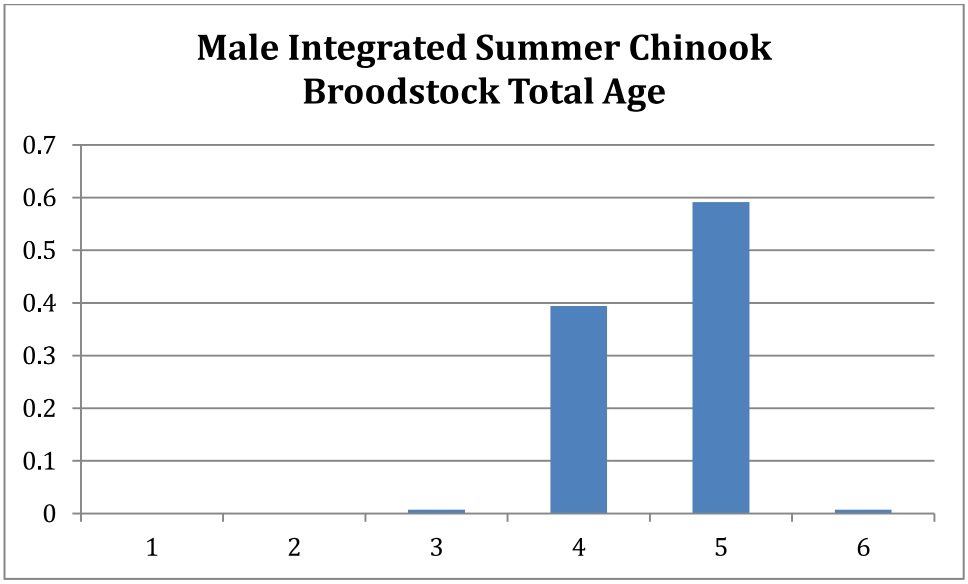
Broodstock were interrogated for coded-wire tags on four different spawning events during October: 10/2-3, 10/9-12, 10/16-17 and 10/23 When a wire was detected, the snout was collected for extraction and analysis that occurred in the laboratory at a later date. All of the brood stock collected for the summer Chinook segregated program came from an Upper Columbia River hatchery program. The CJH integrated program was the largest contributor to segregated brood with (n=329) 60.5% of adults coming from either the Similkameen or Omak Pond (Table A 7). Other Upper Columbia River Hatcheries contributed (n=57) 10.5%, most of which were from Wells Hatchery (5.9%) and Carlton A.P. (2.3%). A large portion of snouts (n=145) indicated detection during spawning events but a coded-wire tag was not found during extraction. Reasons for this include but are not limited to rapidly shaking a Northwest Marine Technologies (NMT) T-Wand when scanning for a cwt (false positive in the field), failure to detect a tag in the lab (false negative), metals in the soil that transfer to a fish during handling or hooks or other metal debris in the fish's head. The unknown component represents 26.6% of the 2018 segregated brood (Table A 7). A relatively large percentage of the segregated CJH does not receive a CWT (60-70%), and in 2018 5-year olds returned from the CJH segregated program. All summer Chinook programs upstream of Priest Rapids Dam are expected to have a 100% tag rate (except for CJH segregated).We would expect a portion of no CWT detection in the lab with the CJH segregated adult returns After adjusting for tag loss, the number of estimated non-CWT recoveries (n=145) can be assigned to the segregated CJH program. The overall composition of the segregated program (tagged and non-tagged) to the segregated brood was 28.9%.

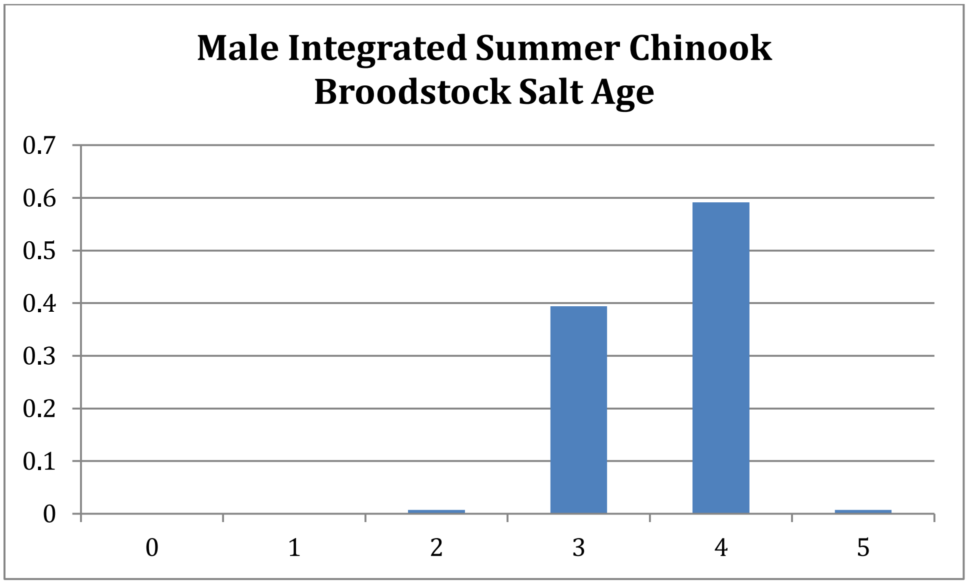
Table A 7. Composition of hatchery-origin brood, by program, collected for the CJH segregated program in 2018.

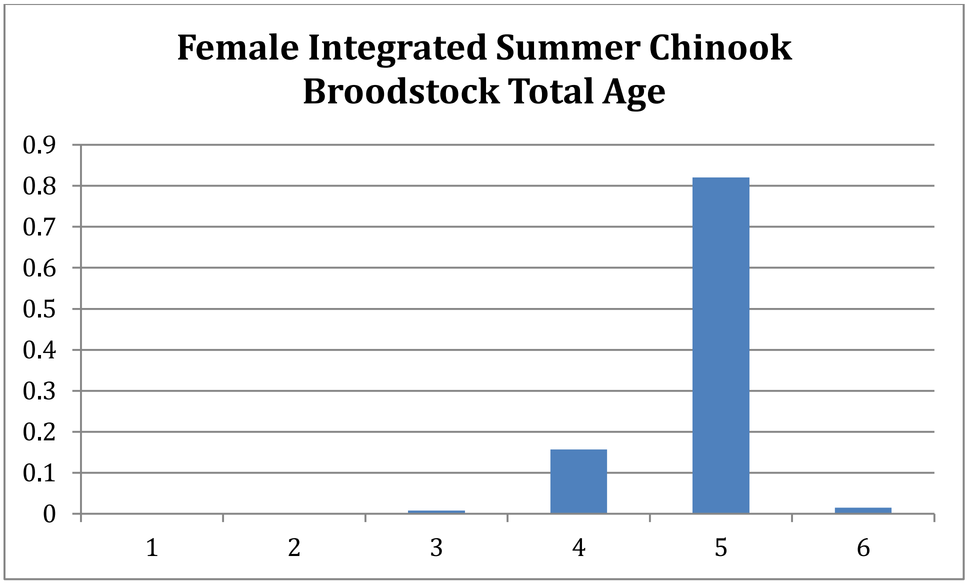
Category	Hatchery Program	Brood	% of brood	
Okanogan Integrated	Similkameen	147	27.0 %	61.0%
	Omak Pond	182	33.5 %	
CJH Segregated	Chief Joseph	13	2.3%	28.9%
	Chief Joseph (non-tagged)	145	26.6 %	
Other UCR summer/fall Chinook hatchery	Carlton	13	2.3%	10.1%
	Wells	32	5.9%	
	Chelan Falls	11	2.0%	
	Dryden Pond	1	<1.0%	
Total		544	100.0%	

Integrated Program Broodstock Age Structure

Scales are taken from summer Chinook integrated Program broodstock in order to capture the age of successfully spawned fish. In 2018, the integrated and segregated programs were comprised of mostly four and five-year old male and female fish (Figure A 1).







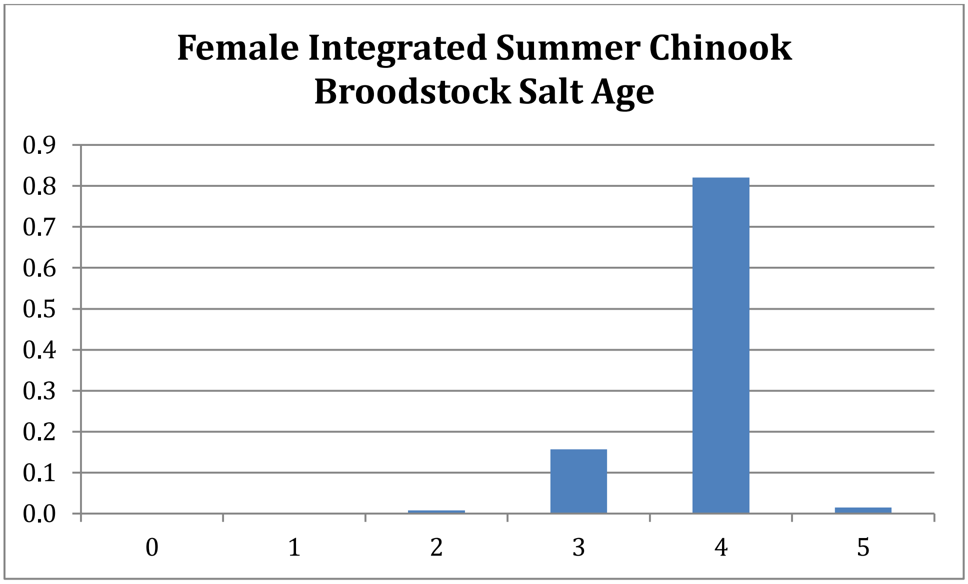
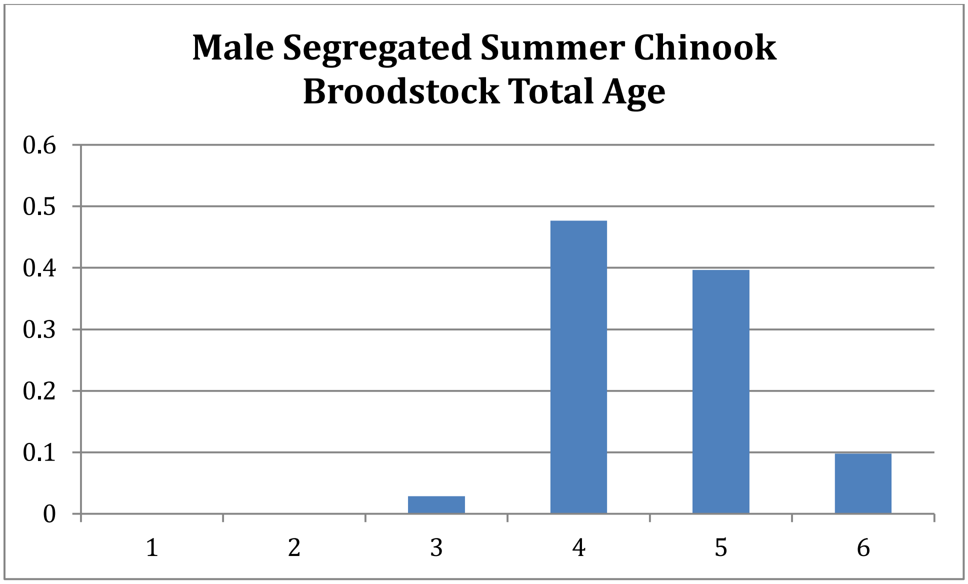
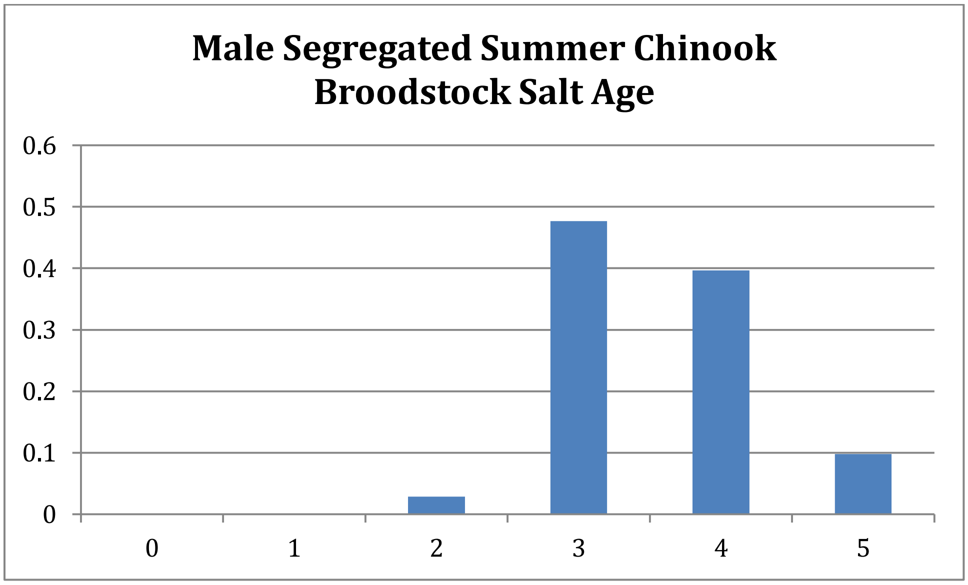


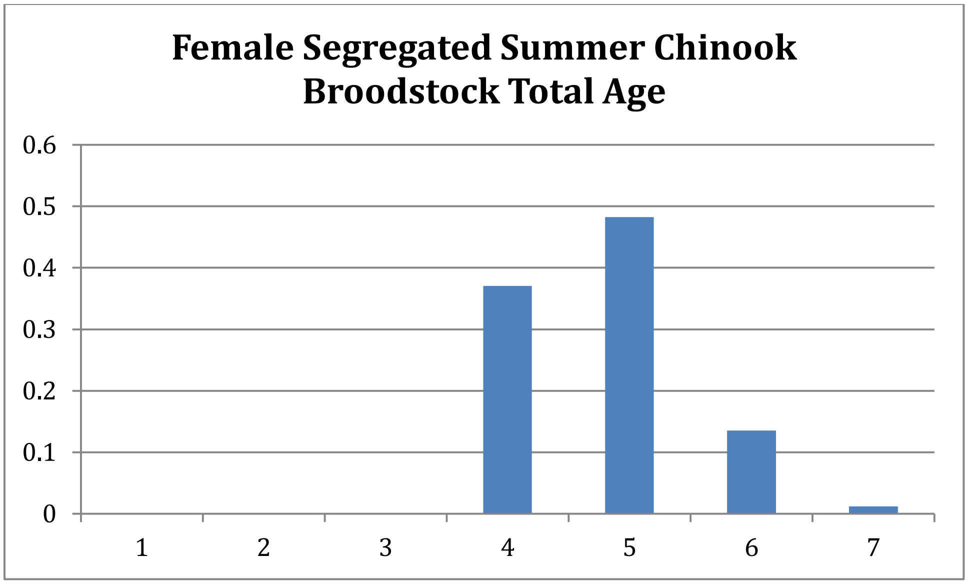
Figure A 1. The total and salt ages of the 2018 broodstock, males and females, collected for the Okanogan summer/fall Chinook integrated program.

Segregated Program Broodstock Age Structure

Coded wire tags are extracted from summer Chinook segregated program broodstock and later read in order to capture the age of successfully spawned fish (Figure A 2).







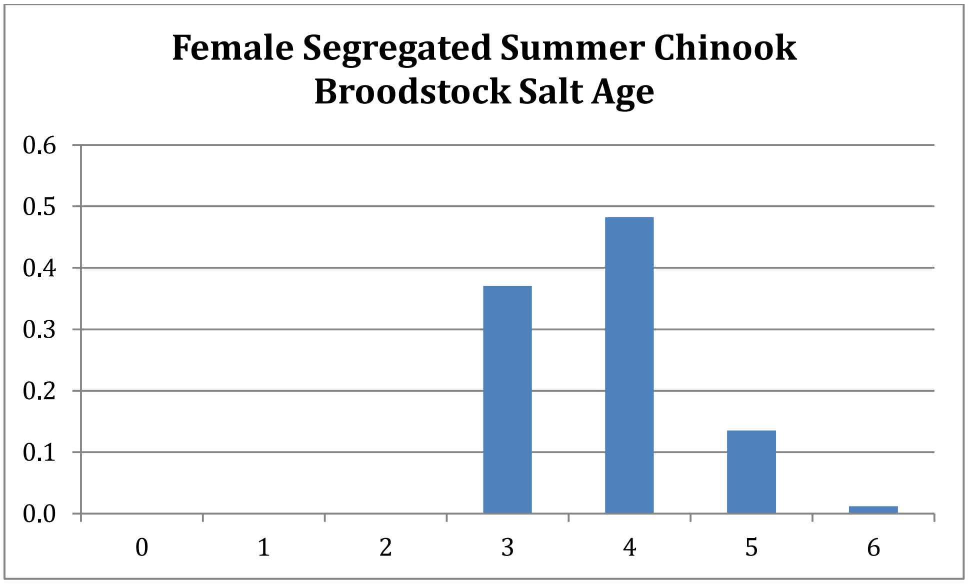


Figure A 2. The total and salt ages of the 2018 broodstock, males and females, collected for the Chief Joseph Hatchery segregated program.

Incubation

Eggs from each female summer/fall Chinook were placed in individual incubators (Heath Trays) and remained individually incubated until ELISA results were obtained. Once eye-up occurred, eggs from any moderate and high ELISA would be removed; 1 female was discarded from the 2018 integrated brood and none for the segregated brood. The cull rate for this production plan allows for a rate of 5% for segregated and 3% for integrated. After eye-up, egg mortality was removed and the eggs were inventoried and put back into their individual trays for hatching. Incubation water temperatures was initially manipulated to the level necessary to synchronize the hatching and ponding of the spawn takes throughout October and November 2018 and to achieve the size-at-release target for both yearling and sub-yearling summer Chinook programs. However, due to a failing chiller, chilled water was not an option for these eggs as in years past. And as mentioned above, there were several trays of eyed eggs that were 100% lost due to the failed chiller which includes 56 trays of the segregated program and 59 trays of the integrated program.

Rearing

Because of the low egg take and elevated egg loss during incubation, there were no brood year 2018 sub-yearlings for either the integrated or segregated programs.

The first group of segregated and integrated yearlings were brought out of incubation and transferred into early rearing troughs in December 2018 (Table A 8). During this time, the group was introduced to feed in the early rearing troughs and reared for a period of two weeks. After the initial rearing period inside, they were transferred outside to the standard raceways via the fry transfer line. No inventories were taken during transfers, to prevent excess handling stress.

Table A 8. Chief Joseph Hatchery brood year 2018 summer/fall Chinook yearling rearing summary.

	Month	Total on hand*	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	12/31/2018	305,839	-	20	1,172	100.00%
	1/31/2019	249,095	56,744	262	340	81.45%
	2/28/2019	247,042	2,053	288	234	80.78%
	3/31/2019	245,922	1,120	345	158	80.41%
	4/30/2019	244,753	1,169	312	123	80.03%
	Subtotal:	244,753	61,086	1,227	123	80.03%
NOR	12/31/2018	199,927	33,998	55	1,025	85.47%
	1/31/2019	138,509	61,418	453	325	59.21%
	2/28/2019	232,749	1,839	502	169	70.53%
	3/31/2019	231,716	1,033	633	111	70.22%
	4/30/2019	230,658	1,058	342	95	69.90%
	Subtotal:	230,658	99,346	1,985	95	69.90%
	Cumulative:	**475,411**	**160,432**	**3,212**	**NA**	**74.77%**

Chief Joseph Hatchery Ladder

The CJH ladder is operated with the primary purpose of adult management (reducing pHOS) but can also be utilized to collect brood for the segregated program in years of low abundance or if the purse seine is not effective due to environmental conditions. In 2018 the escapement and environmental conditions were such that brood was indeed collected from the CJH ladder. The CJH fish ladder began operation on June 20, 2018, with the first adult management activities occurring on July 25th. All hatchery Chinook and Sockeye were removed from the ladder and utilized for Tribal subsistence and ceremonial food purposes. All steelhead and NOR Chinook were returned to the river via a water to water transfer.

From June 20th thru August 30th, 2,535 hatchery-origin summer/fall Chinook and 3 Sockeye were removed at the CJH ladder and were utilized for tribal subsistence purposes (Table A 9). A total of 147 hatchery origin adults (76 males and 71 females) were taken from the ladder and used as broodstock. While there were 85 hatchery adults returned to river during the early stages of ladder operation in June. A total of 179 natural-origin Summer/Fall Chinook, 4 NOR steelhead and 10 HOR steelhead were trapped, handled and released back to the Columbia River (Tables A 10 and A 11). The encounter/handling and release of 4 NOR steelhead represents 36% of the allowable incidental take provided in the Biological Opinion (BiOp) for Chief Joseph Hatchery collection facilities (NMFS 2008). There were no observed immediate steelhead mortalities during the ladder operations in 2018.

Table A 9. Chief Joseph Hatchery adult summer/fall Chinook ladder operations from June to August 2018.

Month	# of Ladder Trap Checks	HOR Adults surplussed	HOR Jacks surplussed	NOR Adults RTS	NOR Jacks RTS	HOR Adults RTS	HOR Jacks RTS
June	6	0	0	4	0	85	0
July	1	192	11	6	0	0	0
Aug	10	2,034	298	147	22	0	0
Total	**17**	**2,226**	**309**	**157**	**22**	**85**	**0**

RTS= Return to stream

Table A 10. Chief Joseph Hatchery adult spring Chinook, Sockeye and steelhead ladder operations from June to August 2018.

Month	# of Ladder Trap Checks	HOR Spring Chinook Surplussed	HOR Spring Chinook Jacks Surplussed	NOR Spring Chinook RTS	NOR Spring Chinook Jacks RTS	Sockeye Surplussed	AD Present Steelhead RTS	AD Absent Steelhead RTS
June	6	0	0	77	23	0	0	0
July	1	0	0	6	2	0	0	1
Aug	10	7	2	27	2	3	4	9
Total	**17**	**7**	**2**	**110**	**27**	**3**	**4**	**10**

RTS= Return to stream

Table A 11. Chief Joseph Hatchery annual summer/fall Chinook, Sockeye, and steelhead collected during ladder operations.

Date	HOR Chinook surplused	HOR jacks (1) surplused	NOR Chinook RTS	NOR jack RTS	HOR Chinook Brood	Sockeye	AD Present Steelhead RTS	AD Absent Steelhead RTS	Coho RTS
Aug.-Nov. 2013	1,263	523	247	69	9	10	38	0	0
July-Nov. 2014	2,835	1,778	861	245	87	31	69	122	181[6]
July-Oct. 2015	6,773	1,651	1,671	369	217[4]	180	119[2]	401	2
June-Oct. 2016	5,359	995	465	91	196[5]	5	11[3]	45	0
June-Oct. 2017	3,818	492	401	62	0	33	0	10	0
June-Aug. 2018	2,226	309	157	22	147	3	4	10	0
Total	**22,274**	**5,748**	**3,802**	**858**	**656**	**262**	**241**	**588**	**183**

(1) Includes mini-jacks
(2) 24% AD Present steelhead were HORs
(3) 67% AD Present steelhead were HORs
(4) 147 adults (80 males, 67 females) taken for transfer to Eastbank Hatchery
(5) 98 males and 98 females taken in July and August,
(6) Surplussed fish
RTS= Return to stream

The ladder was closed and dewatered on August 31, 2018 for the season. The protocol was to sample 20% (one of five) of the adipose-clipped summer/fall Chinook for code-wire tags (CWT). Snouts with positive CWT detection were held frozen until December 2018 when CWT extraction and reading took place in the Chief Joseph Hatchery lab. Recovery data were expanded by the tag rate at the hatchery of origin and the sample rate at the ladder. Please refer to the Methods section for details on the expansion process for recovered tags. Beginning with jacks in 2016, snouts without a tag were assumed to be from the CJH segregated program.

Eight summer/fall Chinook hatchery programs were encountered at the CJH ladder in 2018, with the majority coming from the CJH segregated program (57.8%), Wells Hatchery (16.3%) and Chelan Falls (12.5%) (Table A 12). Approximately half of the recoveries were from ad-clipped, non-coded wire tagged (CWT) fish and are presumed to be from the CJH segregated program since this is the only one above Priest Rapids that releases ad-clipped, non-CWT fish.

Table A 12. Summary of summer/fall Chinook coded-wire tags encountered and expansions for the CJH ladder in 2018.

Category	**Hatchery Program**	**# Tags**	**Expanded Abundance**	**% of Ladder Surplus**
Okanogan Integrated	Omak Yearlings	13	86	4%
	Omak Subyearlings	2	13	<1%
	Similkameen	8	60	3%
CJH Segregated	Segregated yearlings	19	124	6%
	Segregated subyearlings	14	91	4%
	No CWT, presumed Segr	177	1086	48%
Other UCR summer/fall Chinook hatchery	Wells	56	368	16%
	Chelan	43	282	13%
	Carlton	6	39	2%
	Entiat	2	13	<1%
	Dryden	11	73	3%
Out of ESU hatchery	Klickitat	1	7	<1%
	Washougal	***1***	***7***	***<1%***
Total		***353***	***2249***	***100%***

Table A 13. Percent of CJH ladder surplus adult (age 4+) summer/fall Chinook each year estimated to be from various facilities based on CWT assessment. Similkameen includes some returns from Bonaparte Pond releases (2010 and 2011). Chelan includes returns from the Turtle Rock program (2010 and 2011). 2017 was the first year of adults (4 year olds) to CJH. 2018 was the first return year with a full complement of brood years in the return (through age 5).

	# Surplus Fish	**Facility/Program**									
		CJH Seg.[a]	**Omak**	**Similk[b]**	**Wells**	**Chelan[c]**	**Carlton**	**Entiat**	**Dryden[d]**	**Priest**	**Other**
2013	1,061	0%	0%	10%	22%	33%	8%	0%	26%	1%	1%
2014	2,008	0%	0%	10%	28%	26%	8%	2%	11%	0%	0%
2015	6,802	1%	0%	13%	34%	29%	6%	4%	12%	0%	0%
2016	5,788	5%	2%	3%	50%	26%	2%	2%	8%	0%	0%
2017	4,310	21%	7%	1%	35%	28%	2%	1%	5%	0%	<1%
2018	2,249	58%	4%	3%	16%	13%	2%	1%	3%	0%	<1%
Avg.	***3,703***	***14%***	***2%***	***7%***	***31%***	***26%***	***5%***	***2%***	***11%***	***0%***	***0%***

[a] Includes recoveries with 'no coded wire tags' in 2013-present: 2013 (47), 2014 (152), 2015 (71), 2016(45), 2017(76), 2018 (177); starting in 2017 recoveries with 'no coded wire tags' were classified as CJH segregated fish which was the first year of adults (4+) returned back to the CJH

[b] Includes Bonaparte pond releases, all years

[c] Includes releases from Chelan Falls (all years), PUD (2013), Net Pens (2013-2015) and Turtle Rock (all years)

[d] Includes releases by the Eastbank Hatchery into the Wenatchee R. (2013)

APPENDIX B

2019 Production Plan

Table B 1. Summer Chinook - Integrated Program

Chief Joseph Hatchery Production Plan

Brood Year:	2019	**Planting Goal:**	1,100,000
Species:	Summer Chinook	**Pounds:**	86,000
Stock:	Okanogan		
Origin:	Wild		
Program:	Integrated		
Egg Take Goal:	1,485,000	**Adult Goal:**	656

Estimated Release Data:

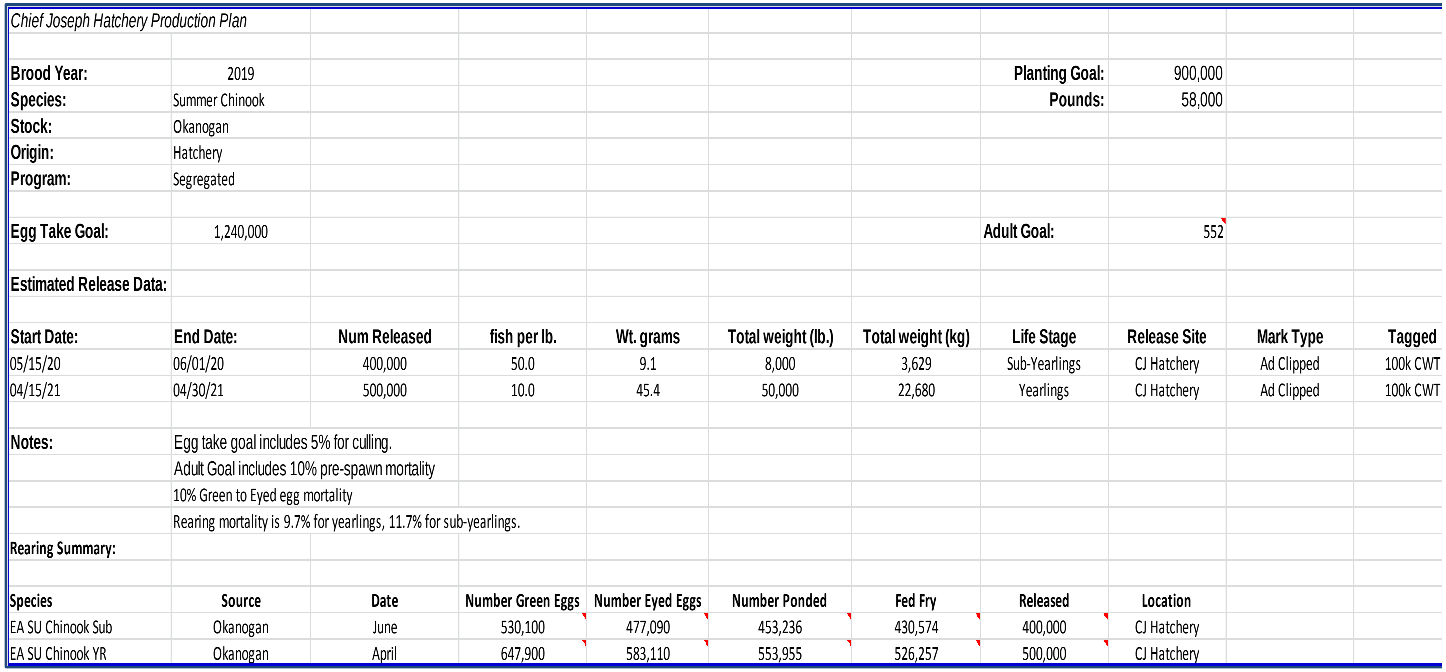
Start Date:	End Date:	Num Released	fish per lb.	Wt. grams	Total weight (lb.)	Total weight (kg)	Life Stage	Release Site	Mark Type	Tagged
05/15/20	06/01/20	300,000	50.0	9.1	6,000	2,722	Sub-Yearlings	Omak	Ad Clipped	100% CWT
04/15/21	04/30/21	400,000	10.0	45.4	40,000	18,144	Yearlings	Similkameen	Ad Clipped	100% CWT
04/15/21	04/30/21	400,000	10.0	45.4	40,000	18,144	Yearlings	Omak	Ad Clipped	100% CWT

Notes:
Egg take goal includes 3% for culling.
Adult Goal includes 10% pre-spawn mortality
10% Green to Eyed egg mortality
Rearing mortality 10.7% for all groups

Rearing Summary:

Species	Source	Date	Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
EA SU Chinook Sub	Okanogan	June	392,850	353,565	335,887	319,092	300,000	Omak
EA SU Chinook YR	Okanogan	April	523,800	471,420	447,849	425,457	400,000	Similkameen
EA SU Chinook YR	Okanogan	April	523,800	471,420	447,849	425,457	400,000	Omak

Table B 2. Summer Chinook – Segregated Program (CJH Site Release)



Chief Joseph Hatchery Production Plan										
Brood Year:	2019						**Planting Goal:**	900,000		
Species:	Summer Chinook						**Pounds:**	58,000		
Stock:	Okanogan									
Origin:	Hatchery									
Program:	Segregated									
Egg Take Goal:	1,240,000						**Adult Goal:**	552		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
05/15/20	06/01/20	400,000	50.0	9.1	8,000	3,629	Sub-Yearlings	CJ Hatchery	Ad Clipped	100k CWT
04/15/21	04/30/21	500,000	10.0	45.4	50,000	22,680	Yearlings	CJ Hatchery	Ad Clipped	100k CWT
Notes:	Egg take goal includes 5% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 9.7% for yearlings, 11.7% for sub-yearlings.									
Rearing Summary:										
Species	**Source**	**Date**	**Number Green Eggs**	**Number Eyed Eggs**	**Number Ponded**	**Fed Fry**	**Released**	**Location**		
EA SU Chinook Sub	Okanogan	June	530,100	477,090	453,236	430,574	400,000	CJ Hatchery		
EA SU Chinook YR	Okanogan	April	647,900	583,110	553,955	526,257	500,000	CJ Hatchery		

APPENDIX C

pHOS and Effective pHOS

Table C 1. Annual Chinook spawning grounds data for the Okanogan Basin from 2006 to 2018, including pHOS and effective pHOS values per reach

2018

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	11	2.301	25	0.0%	0	0	0	31.6%	68.4%	8	17	0.32
O2*	74	2.301	170	0.0%	0	0	0	31.6%	68.4%	54	116	0.32
O3	211	2.301	486	16.1%	78	40	38	51.3%	48.7%	249	237	0.51
O4*	133	2.301	306	2.6%	8	1	7	31.6%	68.4%	97	209	0.32
O5	618	2.301	1422	9.4%	134	49	85	36.6%	63.4%	520	902	0.37
O6	507	2.301	1167	16.3%	190	33	157	17.4%	82.6%	203	964	0.17
S1	501	2.301	1153	11.4%	131	48	83	36.6%	63.4%	422	730	0.37
S2*	57	2.301	131	4.6%	6	2	4	31.6%	68.4%	41	90	0.32
Totals	2112		4860	11.3%	547	173	374			1594	3266	0.33

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.33
effective pHOS	0.28

2017

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	2	2.039	4	0.0%	0	0	0	17.0%	83.0%	1	3	0.17
O2	62	2.039	126	6.3%	8	4	4	50.0%	50.0%	63	63	0.50
O3*	192	2.039	391	2.3%	9	5	4	17.0%	83.0%	66	325	0.17
O4	111	2.039	226	7.1%	16	5	11	31.3%	68.8%	71	156	0.31
O5*	830	2.039	1692	3.5%	60	10	50	17.0%	83.0%	287	1405	0.17
O6	1237	2.039	2522	24.9%	628	66	562	10.5%	89.5%	265	2257	0.11
S1	710	2.039	1448	31.3%	453	106	347	23.4%	76.6%	339	1109	0.23
S2	77	2.039	157	17.2%	27	8	19	29.6%	70.4%	47	110	0.30
Totals	3221		6568	18.3%	1201	204	997			1139	5429	0.17

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.17
effective pHOS	0.14

2016

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	2	2.01	4	0.0%	0	0	0	21.2%	78.8%	1	3	0.21
O2	57	2.01	115	10.5%	12	6	6	50.0%	50.0%	57	57	0.50
O3	52	2.01	105	13.4%	14	1	13	7.1%	92.9%	7	97	0.07
O4*	130	2.01	261	4.2%	11	4	7	21.2%	78.8%	55	206	0.21
O5	907	2.01	1823	12.6%	230	44	186	19.1%	80.9%	349	1474	0.19
O6	2338	2.01	4699	22.9%	1075	56	1019	5.2%	94.8%	245	4455	0.05
S1	1645	2.01	3306	36.7%	1214	395	819	32.5%	67.5%	1076	2231	0.33
S2	145	2.01	291	68.3%	199	78	121	39.2%	60.8%	114	177	0.39
Totals	5276		10605	26.0%	2755	584	2171			1905	8700	0.18

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.18
effective pHOS	0.15

2015

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	36	3.215	116	0.0%	0	0	0	22.4%	77.6%	26	90	0.22
O2*	113	3.215	363	2.8%	10	5	5	22.4%	77.6%	81	282	0.22
O3	284	3.215	913	6.7%	61	22	39	36.1%	63.9%	329	584	0.36
O4*	79	3.215	254	4.3%	11	2	9	22.4%	77.6%	57	197	0.22
O5	1008	3.215	3241	8.7%	283	74	209	26.1%	73.9%	847	2393	0.26
O6	859	3.215	2762	36.0%	994	63	931	6.3%	93.7%	175	2587	0.06
S1	1611	3.215	5179	32.9%	1702	516	1186	30.3%	69.7%	1570	3609	0.30
S2	286	3.215	919	25.2%	232	56	176	24.1%	75.9%	222	698	0.24
Totals	4276		13747	24.0%	3293	738	2555			3308	10439	0.24

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.24
effective pHOS	0.20

2014

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	11	2.86	31	3.2%	1	1	0	13.4%	86.6%	4	27	0.13
O2*	57	2.86	163	0.6%	1	0	1	13.4%	86.6%	22	141	0.13
O3	191	2.86	546	14.5%	79	19	60	24.1%	75.9%	131	415	0.24
O4	111	2.86	317	17.0%	54	7	47	13.0%	87.0%	41	276	0.13
O5	851	2.86	2434	11.3%	275	42	233	15.3%	84.7%	372	2062	0.15
O6	1010	2.86	2889	27.1%	783	67	716	8.6%	91.4%	247	2641	0.09
S1	1737	2.86	4968	15.5%	770	129	641	16.8%	83.2%	832	4136	0.17
S2	285	2.86	815	60.0%	489	64	425	13.1%	86.9%	107	708	0.13
Totals	4253		12164	20.2%	2452	329	2123			1756	10407	0.14

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.14
effective pHOS	0.12

2013

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1	3	2.31	7	0.0%	0	0	0	32.6%	67.4%	2	5	0.33
O2*	2	2.31	5	0.0%	0	0	0	32.6%	67.4%	2	3	0.33
O3	158	2.31	365	8.2%	30	8	22	26.7%	73.3%	97	268	0.27
O4	46	2.31	106	8.5%	9	2	7	22.2%	77.8%	24	83	0.22
O5	397	2.31	917	5.7%	52	15	37	28.8%	71.2%	265	653	0.29
O6	1661	2.31	3837	11.3%	432	80	352	18.5%	81.5%	711	3126	0.19
S1	1254	2.31	2897	13.1%	379	188	191	49.6%	50.4%	1437	1460	0.50
S2	26	2.31	60	13.3%	8	4	4	50.0%	50.0%	30	30	0.50
Totals	3547		8194	11.1%	910	297	613			2567	5627	0.31

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.31
effective pHOS	0.27

2012

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	12	3.07	37	2.7%	1	1	0	42.3%	57.7%	16	21	0.42
O2*	54	3.07	166	0.0%	0	0	0	42.3%	57.7%	70	96	0.42
O3	159	3.07	488	11.5%	56	38	18	67.9%	32.1%	331	157	0.68
O4	68	3.07	209	7.2%	15	6	9	40.0%	60.0%	84	125	0.40
O5	555	3.07	1704	15.0%	256	123	133	48.0%	52.0%	819	885	0.48
O6	765	3.07	2349	22.9%	537	110	427	20.5%	79.5%	481	1867	0.20
S1	914	3.07	2806	17.6%	494	288	206	58.3%	41.7%	1636	1170	0.58
S2	152	3.07	467	11.6%	54	31	23	57.4%	42.6%	268	199	0.57
Totals	2679		8225	17.2%	1413	597	816			3704	4521	0.45

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.45
effective pHOS	0.40

2011

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	3	3.1	9	0.0%	0	0	0	53.6%	46.4%	5	4	0.54
O2*	20	3.1	62	0.0%	0	0	0	53.6%	46.4%	33	29	0.54
O3	101	3.1	313	17.6%	55	34	21	61.8%	38.2%	194	120	0.62
O4	55	3.1	171	8.2%	14	10	4	71.4%	28.6%	122	49	0.71
O5	593	3.1	1838	19.6%	361	160	201	44.3%	55.7%	815	1024	0.44
O6	942	3.1	2920	16.4%	478	116	362	24.3%	75.7%	709	2212	0.24
S1	1217	3.1	3773	20.0%	753	537	216	71.3%	28.7%	2690	1082	0.71
S2	192	3.1	595	19.2%	114	95	19	83.3%	16.7%	496	99	0.83
Totals	3123		9681	18.3%	1775	952	823			5063	4618	0.52

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.52
effective pHOS	0.47

2010

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1	9	2.81	25	11.9%	3	2	1	66.7%	33.3%	17	8	0.67
O2	58	2.81	163	6.1%	10	5	5	50.0%	50.0%	81	81	0.50
O3	67	2.81	188	15.9%	30	11	19	36.7%	63.3%	69	119	0.37
O4	89	2.81	250	16.8%	42	24	18	57.1%	42.9%	143	107	0.57
O5	357	2.81	1003	24.0%	241	87	154	36.1%	63.9%	362	641	0.36
O6	431	2.81	1211	29.1%	352	172	180	48.9%	51.1%	592	619	0.49
S1	895	2.81	2515	24.9%	625	296	329	47.4%	52.6%	1191	1324	0.47
S2	212	2.81	596	24.8%	148	79	69	53.4%	46.6%	318	278	0.53
Totals	2118		5952	24.4%	1451	676	775			2773	3178	0.47

pHOS	0.47
effective pHOS	0.41

2009

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1	3	2.54	8	26.2%	2	0	2	0.0%	100.0%	0	8	0.00
O2	32	2.54	81	8.6%	7	4	3	57.1%	42.9%	46	35	0.57
O3	91	2.54	231	13.4%	31	18	13	58.1%	41.9%	134	97	0.58
O4	138	2.54	351	9.1%	32	18	14	56.3%	43.8%	197	153	0.56
O5	621	2.54	1577	22.1%	348	159	189	45.7%	54.3%	721	857	0.46
O6	787	2.54	1999	25.0%	500	153	347	30.6%	69.4%	612	1387	0.31
S1	1091	2.54	2771	25.4%	703	373	330	53.1%	46.9%	1470	1301	0.53
S2	207	2.54	526	28.5%	150	75	75	50.0%	50.0%	263	263	0.50
Totals	2970		7544	23.5%	1773	800	973			3443	4100	0.46

pHOS	0.46
effective pHOS	0.40

2008

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1	4	3.25	13	30.8%	4	2	2	50.0%	50.0%	7	7	0.50
O2	51	3.25	166	6.0%	10	9	1	90.0%	10.0%	149	17	0.90
O3	60	3.25	195	20.5%	40	26	14	65.0%	35.0%	127	68	0.65
O4	96	3.25	312	11.5%	36	25	11	69.4%	30.6%	217	95	0.69
O5	374	3.25	1216	20.4%	248	141	107	56.9%	43.1%	691	524	0.57
O6	561	3.25	1823	36.5%	665	341	324	51.3%	48.7%	935	888	0.51
S1	801	3.25	2603	33.0%	859	512	347	59.6%	40.4%	1552	1052	0.60
S2	199	3.25	647	24.3%	157	116	41	73.9%	26.1%	478	169	0.74
Totals	2146		6975	28.9%	2019	1172	847			4155	2820	0.60

pHOS	0.60
effective pHOS	0.54

2007

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1	3	2.2	7	30.3%	2	1	1	50.0%	50.0%	3	3	0.50
O2*	16	2.2	35	0.0%	0	0	0	38.1%	61.9%	13	22	0.38
O3	116	2.2	255	21.6%	55	25	30	45.5%	54.5%	116	139	0.45
O4*	63	2.2	139	0.7%	1	0	1	38.1%	61.9%	53	86	0.38
O5	549	2.2	1208	37.5%	453	169	284	37.3%	62.7%	451	757	0.37
O6	554	2.2	1219	42.6%	519	197	322	38.0%	62.0%	463	756	0.38
S1	652	2.2	1434	45.9%	658	253	405	38.4%	61.6%	552	883	0.38
S2	55	2.2	121	24.0%	29	9	20	31.0%	69.0%	38	83	0.31
Totals	2008		4418	38.9%	1717	654	1063			1688	2730	0.38

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.38
effective pHOS	0.33

2006

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1	10	2.02	20	19.8%	4	2	2	50.0%	50.0%	10	10	0.50
O2*	56	2.02	113	2.7%	3	1	2	23.0%	77.0%	26	87	0.23
O3	175	2.02	354	8.8%	31	9	22	29.0%	71.0%	103	251	0.29
O4	145	2.02	293	5.5%	16	6	10	37.5%	62.5%	110	183	0.38
O5	840	2.02	1697	7.1%	120	15	105	12.5%	87.5%	212	1485	0.13
O6	1366	2.02	2759	10.5%	291	44	247	15.1%	84.9%	417	2342	0.15
S1	1388	2.02	2804	18.1%	508	138	370	27.2%	72.8%	762	2042	0.27
S2	278	2.02	562	18.9%	106	33	73	31.1%	68.9%	175	387	0.31
Totals	4258		8601	12.5%	1079	248	831			1814	6787	0.21

*Indicates '%hatchery' and '%wild' values were estimated from basin carcass totals (only performed when carcasses recovered represented <5% of spawners for that reach)

pHOS	0.21
effective pHOS	0.18

Table C 2. Number of hatchery- and natural-origin (wild) summer Chinook carcasses collected in each reach of the Okanogan (O1-O6) and Similkameen rivers from 1993 to 2018.

Survey year	Origin	Survey reach								Total
		O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2	
1993[a]	Wild	0	0	3	0	13	4	48	1	69
	Hatchery	0	2	0	0	10	9	25	0	46
1994[b]	Wild	0	0	1	0	7	1	113	22	144
	Hatchery	0	4	3	0	20	4	205	38	274
1995	Wild	0	0	1	0	10	0	66	4	81
	Hatchery	0	0	1	0	20	0	173	11	205
1996	Wild	0	0	0	1	3	1	53	0	58
	Hatchery	0	0	0	1	2	1	173	0	177
1997	Wild	0	0	1	0	0	3	83	0	87
	Hatchery	0	0	1	0	9	0	142	1	153
1998	Wild	0	1	3	1	6	5	162	4	182
	Hatchery	0	0	5	0	1	2	178	0	186
1999	Wild	0	0	0	0	9	23	293	9	334
	Hatchery	0	0	3	2	14	30	473	39	561
2000	Wild	0	0	8	8	24	11	189	4	244
	Hatchery	0	2	12	7	23	5	538	37	624
2001	Wild	0	10	23	5	67	42	390	54	591
	Hatchery	0	16	52	5	60	70	751	51	1,005
2002	Wild	6	14	20	10	81	212	340	72	755
	Hatchery	4	18	63	25	123	360	925	187	1,705
2003[c]	Wild	0	0	13	0	12	152	231	124	532
	Hatchery	0	0	15	0	5	91	365	257	733
2004	Wild	0	2	19	19	108	225	1,125	260	1,758
	Hatchery	0	2	12	5	38	58	267	38	420
2005	Wild	0	5	51	21	256	364	531	176	1,404
	Hatchery	0	3	42	16	115	70	200	100	546
2006	Wild	2	2	22	10	105	247	370	73	831
	Hatchery	2	1	9	6	15	44	138	33	248
2007	Wild	1	0	30	1	284	322	405	20	1,063
	Hatchery	1	0	25	0	169	197	253	9	654
2008	Wild	2	1	14	11	107	324	347	41	847

	Hatchery	2	9	26	25	141	341	512	116	1,172
2009	Wild	2	3	13	14	189	347	330	75	973
	Hatchery	0	4	18	18	159	153	373	75	800
2010	Wild	1	5	19	18	154	180	329	69	775
	Hatchery	2	5	11	24	87	172	296	79	676
2011	Wild	0	0	21	4	201	362	216	19	823
	Hatchery	0	0	34	10	160	116	537	95	952
2012	Wild	0	0	18	9	133	427	206	23	816
	Hatchery	1	0	38	6	123	110	288	31	597
2013[d,e]	Wild	0	0	22	7	37	352	191	4	613
	Hatchery	0	0	8	2	15	80	188	4	297
2014	Wild	0	1	60	47	233	716	641	425	2123
	Hatchery	1	0	19	7	42	67	129	64	329
2015	Wild	0	5	39	9	209	931	1186	176	2555
	Hatchery	0	5	22	2	74	63	516	56	738
2016	Wild	0	6	13	7	186	1019	819	121	2171
	Hatchery	0	6	1	4	44	56	395	78	584
2017	Wild	0	4	4	11	50	562	347	19	997
	Hatchery	0	4	5	5	10	66	106	8	204
2018	Wild	0	0	38	7	85	157	83	4	374
	Hatchery	0	0	40	1	49	33	48	2	173
Average	***Wild***	***0.5***	***2.3***	***17.5***	***8.5***	***98.8***	***268.8***	***349.8***	***69.2***	***815.4***
	Hatchery	***0.5***	***3.1***	***17.9***	***6.6***	***58.8***	***84.5***	***315.2***	***54.2***	***540.7***

[a] 25 additional carcasses were sampled on the Similkameen and 46 on the Okanogan without any reach designation.

[b] One additional carcass was sampled on the Similkameen without any reach designation.

[c] 793 carcasses were sampled on the Similkameen before initiation of spawning (pre-spawn mortality) and an additional 40 carcasses were sampled on the Okanogan. The cause of the high mortality (*Ichthyophthirius multifilis* and *Flavobacterium columnarae*) was exacerbated by high river temperatures.

[d] In 2013, carcass recoveries were combined in reaches O-3 and O-4, and S-1 and S-2. Then re-apportioned based on redd counts within each reach.

e 2013 data have been updated to reflect age and origin data acquired from scale reading since the publication of the 2013 annual report

Age at Maturity

Table C 2. Salt age of recovered carcasses in the Okanogan and Similkameen Rivers.

Hatchery-Origin Male Salt Age Carcasses Recovered							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0	0	33	0	0	0	33
1994	0	5	23	92	0	0	120
1995	0	2	23	27	17	0	69
1996	0	3	17	24	5	0	49
1997	0	0	1	25	2	0	28
1998	0	9	64	12	9	0	94
1999	2	0	35	74	2	0	113
2000	7	65	6	104	8	0	190
2001	0	47	625	3	11	0	686
2002	0	10	267	419	0	1	697
2003	0	18	30	146	27	0	221
2004	0	2	100	67	18	0	187
2005	0	12	19	104	15	0	150
2006	0	7	15	11	27	0	60
2007	0	122	116	56	5	3	302
2008	0	18	460	137	3	0	618
2009	0	43	33	158	2	0	236
2010	4	20	293	29	7	0	353
2011	0	144	47	118	0	0	309
2012	1	31	168	63	7	0	270
2013	0	7	27	22	2	1	59
2014	0	55	58	39	0	0	152
2015	0	17	234	49	0	0	300
2016	0	6	15	74	4	0	99
2017	0	3	19	20	5	0	47
2018	0	0	32	7	1	0	40
Average	***1***	***25***	***106***	***72***	***7***	***0***	***211***

Hatchery-Origin Female
Salt Age Carcasses Recovered

Survey Year	0	1	2	3	4	5	Total
1993	0	0	10	1	0	0	11
1994	0	0	3	141	1	0	145
1995	0	0	9	44	82	0	135
1996	0	0	21	74	31	1	127
1997	0	0	2	107	16	0	125
1998	0	1	28	30	32	0	91
1999	1	0	31	393	13	2	440
2000	0	1	4	307	49	0	361
2001	0	1	256	19	42	0	318
2002	0	0	54	921	9	0	984
2003	0	1	9	368	54	0	432
2004	0	0	22	103	69	0	194
2005	0	0	11	303	64	2	380
2006	0	0	10	21	48	0	79
2007	0	0	53	178	22	4	257
2008	0	0	197	267	25	1	490
2009	0	0	9	516	22	0	547
2010	0	0	155	120	42	1	318
2011	0	1	22	602	6	0	631
2012	0	1	153	140	25	0	319
2013	1	0	34	188	7	0	230
2014	0	0	23	127	5	0	155
2015	0	1	138	102	5	0	246
2016	0	0	6	283	13	0	302
2017	0	1	19	38	37	0	95
2018	0	0	46	59	7	0	112
Average	***0***	***0***	***51***	***210***	***28***	***0***	***289***

Natural-Origin Male Salt Age Carcasses Recovered							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0	0	8	19	3	0	30
1994	0	3	13	22	10	0	48
1995	0	0	6	11	4	0	21
1996	0	1	7	4	1	0	13
1997	0	3	8	8	1	0	20
1998	0	3	32	27	5	0	67
1999	0	0	22	39	8	1	70
2000	0	6	24	27	12	0	69
2001	0	13	82	168	8	0	271
2002	0	15	85	232	52	1	385
2003	0	12	55	171	34	0	272
2004	0	19	226	166	303	3	717
2005	0	1	129	447	28	4	609
2006	0	1	14	189	116	0	320
2007	0	17	67	53	226	5	368
2008	0	8	258	263	13	2	544
2009	0	10	21	276	31	0	338
2010	0	3	90	123	50	0	266
2011	0	10	46	228	17	0	301
2012	1	14	160	112	58	0	345
2013	0	6	83	140	12	0	241
2014	0	43	135	633	76	0	887
2015	0	8	809	402	113	0	1332
2016	0	1	53	548	109	1	712
2017	0	0	15	176	159	3	353
2018	0	2	29	49	25	0	105
Average	***0***	***8***	***95***	***174***	***57***	***1***	***335***

Natural-Origin Female Salt Age Carcasses Recovered							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0	0	5	25	3	0	33
1994	0	0	2	36	29	0	67
1995	0	0	7	27	11	0	45
1996	0	0	3	18	2	0	23
1997	0	0	12	31	10	0	53
1998	0	0	21	51	12	0	84
1999	0	0	32	132	34	0	198
2000	0	0	9	106	32	0	147
2001	0	0	11	237	12	0	260
2002	0	0	18	199	90	0	307
2003	2	2	29	130	45	0	208
2004	0	0	37	233	539	2	811
2005	0	0	28	566	71	7	672
2006	0	0	2	250	256	2	510
2007	0	0	8	72	601	12	693
2008	0	0	12	269	19	3	303
2009	0	0	3	473	112	0	588
2010	0	0	20	195	226	1	442
2011	0	0	12	416	58	0	486
2012	0	0	15	195	196	0	406
2013	0	0	5	254	27	0	286
2014	0	3	24	809	189	0	1025
2015	0	0	66	342	426	1	835
2016	0	0	4	927	288	4	1223
2017	0	0	4	127	367	7	505
2018	0	0	10	102	63	0	175
Average	***0***	***0***	***15***	***239***	***143***	***2***	***399***

Table C 3. Salt age structure (percent of recovered carcasses) for sex-origin classes.

Hatchery-Origin Male Salt Age - Percent of carcasses recovered within origin/sex class							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	100%	0%	0%	0%	1
1994	0%	4%	19%	77%	0%	0%	1
1995	0%	3%	33%	39%	25%	0%	1
1996	0%	6%	35%	49%	10%	0%	1
1997	0%	0%	4%	89%	7%	0%	1
1998	0%	10%	68%	13%	10%	0%	1
1999	2%	0%	31%	65%	2%	0%	1
2000	4%	34%	3%	55%	4%	0%	1
2001	0%	7%	91%	0%	2%	0%	1
2002	0%	1%	38%	60%	0%	0%	1
2003	0%	8%	14%	66%	12%	0%	1
2004	0%	1%	53%	36%	10%	0%	1
2005	0%	8%	13%	69%	10%	0%	1
2006	0%	12%	25%	18%	45%	0%	1
2007	0%	40%	38%	19%	2%	1%	1
2008	0%	3%	74%	22%	0%	0%	1
2009	0%	18%	14%	67%	1%	0%	1
2010	1%	6%	83%	8%	2%	0%	1
2011	0%	47%	15%	38%	0%	0%	1
2012	0%	11%	62%	23%	3%	0%	1
2013	0%	12%	46%	37%	3%	2%	1
2014	0%	36%	38%	26%	0%	0%	1
2015	0%	6%	78%	16%	0%	0%	1
2016	0%	6%	15%	75%	4%	0%	1
2017	0%	6%	40%	43%	7%	0%	1
2018	0%	0%	80%	18%	3%	0%	1
Average	*0%*	*11%*	*43%*	*40%*	*6%*	*0%*	*100%*

Hatchery-Origin Female
Salt Age - Percent of carcasses recovered within origin/sex class

Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	91%	9%	0%	0%	1
1994	0%	0%	2%	97%	1%	0%	1
1995	0%	0%	7%	33%	61%	0%	1
1996	0%	0%	17%	58%	24%	1%	1
1997	0%	0%	2%	86%	13%	0%	1
1998	0%	1%	31%	33%	35%	0%	1
1999	0%	0%	7%	89%	3%	0%	1
2000	0%	0%	1%	85%	14%	0%	1
2001	0%	0%	81%	6%	13%	0%	1
2002	0%	0%	5%	94%	1%	0%	1
2003	0%	0%	2%	85%	13%	0%	1
2004	0%	0%	11%	53%	36%	0%	1
2005	0%	0%	3%	80%	17%	1%	1
2006	0%	0%	13%	27%	61%	0%	1
2007	0%	0%	21%	69%	9%	2%	1
2008	0%	0%	40%	54%	5%	0%	1
2009	0%	0%	2%	94%	4%	0%	1
2010	0%	0%	49%	38%	13%	0%	1
2011	0%	0%	3%	95%	1%	0%	1
2012	0%	0%	48%	44%	8%	0%	1
2013	0%	0%	15%	82%	3%	0%	1
2014	0%	0%	15%	82%	3%	0%	1
2015	0%	0%	56%	41%	2%	0%	1
2016	0%	0%	2%	94%	4%	0%	1
2017	0%	1%	20%	40%	39%	0%	1
2018	0%	0%	41%	53%	6%	0%	1
Average	*0%*	*0%*	*23%*	*62%*	*15%*	*0%*	*100%*

Natural-Origin Male
Salt Age - Percent of carcasses recovered within origin/sex class

Survey Year	0	1	2	3	4	5	Total
1993	0%	0%	27%	63%	10%	0%	1
1994	0%	6%	27%	46%	21%	0%	1
1995	0%	0%	29%	52%	19%	0%	1
1996	0%	8%	54%	31%	8%	0%	1
1997	0%	15%	40%	40%	5%	0%	1
1998	0%	4%	48%	40%	7%	0%	1
1999	0%	0%	31%	56%	11%	1%	1
2000	0%	9%	35%	39%	17%	0%	1
2001	0%	5%	30%	62%	3%	0%	1
2002	0%	4%	22%	60%	14%	0%	1
2003	0%	4%	20%	63%	13%	0%	1
2004	0%	3%	32%	23%	42%	0%	1
2005	0%	0%	21%	73%	5%	1%	1
2006	0%	0%	4%	59%	36%	0%	1
2007	0%	5%	18%	14%	61%	1%	1
2008	0%	1%	47%	48%	2%	0%	1
2009	0%	3%	6%	82%	9%	0%	1
2010	0%	1%	34%	46%	19%	0%	1
2011	0%	3%	15%	76%	6%	0%	1
2012	0%	4%	46%	32%	17%	0%	1
2013	0%	2%	34%	58%	5%	0%	1
2014	0%	5%	15%	71%	9%	0%	1
2015	0%	1%	61%	30%	8%	0%	1
2016	0%	7%	77%	15%	0%	0%	1
2017	0%	0%	4%	50%	45%	1%	1
2018	0%	2%	28%	47%	24%	0%	1
Average	*0%*	*4%*	*31%*	*49%*	*16%*	*0%*	*100%*

Natural-Origin Female Salt Age - Percent of carcasses recovered within origin/sex class							
Sample Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	15%	76%	9%	0%	1
1994	0%	0%	3%	54%	43%	0%	1
1995	0%	0%	16%	60%	24%	0%	1
1996	0%	0%	13%	78%	9%	0%	1
1997	0%	0%	23%	58%	19%	0%	1
1998	0%	0%	25%	61%	14%	0%	1
1999	0%	0%	16%	67%	17%	0%	1
2000	0%	0%	6%	72%	22%	0%	1
2001	0%	0%	4%	91%	5%	0%	1
2002	0%	0%	6%	65%	29%	0%	1
2003	1%	1%	14%	63%	22%	0%	1
2004	0%	0%	5%	29%	66%	0%	1
2005	0%	0%	4%	84%	11%	1%	1
2006	0%	0%	0%	49%	50%	0%	1
2007	0%	0%	1%	10%	87%	2%	1
2008	0%	0%	4%	89%	6%	1%	1
2009	0%	0%	1%	80%	19%	0%	1
2010	0%	0%	5%	44%	51%	0%	1
2011	0%	0%	2%	86%	12%	0%	1
2012	0%	0%	4%	48%	48%	0%	1
2013	0%	0%	2%	89%	9%	0%	1
2014	0%	0%	2%	79%	18%	0%	1
2015	0%	0%	8%	41%	51%	0%	1
2016	0%	0%	0%	76%	24%	0%	1
2017	0%	0%	1%	25%	73%	1%	1
2018	0%	0%	6%	58%	36%	0%	1
Average	*0%*	*0%*	*7%*	*63%*	*30%*	*0%*	*100%*

Contribution to Fisheries

Table C 4. Estimated number and percent of hatchery-origin Okanogan/Similkameen summer Chinook captured in different fisheries, brood years 1989-2011.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1989	2,360 (80)	553 (19)	0 (0)	53 (2)	2,966
1990	355 (89)	34 (8)	0 (0)	12 (3)	401
1991	220 (86)	37 (14)	0 (0)	0 (0)	257
1992	422 (91)	28 (6)	2 (0)	10 (2)	462
1993	24 (80)	6 (20)	0 (0)	0 (0)	30
1994	372 (92)	23 (6)	2 (0)	7 (2)	404
1995	643 (93)	9 (1)	12 (2)	25 (4)	689
1996	6 (100)	0 (0)	0 (0)	0 (0)	6
1997	6,483 (92)	136 (2)	36 (0)	424 (6)	7,079
1998	4,414 (89)	251 (5)	45 (1)	223 (5)	4,933
1999	1,359 (68)	224 (11)	31 (2)	384 (19)	1,998
2000	3,139 (69)	533 (12)	222 (5)	675 (15)	4,559
2001	184 (58)	81 (25)	31 (10)	23 (7)	319
2002	706 (56)	200 (16)	90 (7)	258 (21)	1,254
2003	711 (38)	568 (30)	130 (7)	466 (25)	1,875
2004	3,153 (39)	2,162 (26)	694 (8)	2,168 (27)	8,177
2005	470 (46)	306 (30)	79 (8)	167 (16)	1,022
2006	3,136 (37)	3,352 (40)	469 (6)	1,419 (17)	8,376
2007	1,549 (44)	992 (28)	67 (2)	905 (26)	3,513
2008	4,226 (38)	2,576 (39)	218 (2)	3,969 (36)	10,989
2009	2,005 (36)	2,155 (39)	207 (5)	1,138 (21)	5,505
2010	3,193 (38)	3,933 (46)	247 (4)	1,110 (13)	8,483
2011	5,801 (40)	5,812 (40)	456 (3)	2,598 (18)	14,667
2012	747 (51)	395 (27)	13 (1)	320 (22)	1,475
Average	***1,903 (51)***	***1,015 (27)***	***127 (3)***	***681 (18)***	***3,727***
Median	***1,053 (63)***	***279 (20)***	***41 (2)***	***289 (14)***	***1,937***

APPENDIX D

Glossary of Terms, Acronyms, and Abbreviations

The following is a list of key terms and variables used in the Chief Joseph Hatchery Program and in this Annual Report. This is not a complete list, but provides many of the main terms used in this report or that will likely be used in future CJHP Annual Report.

Accord/MOA = A ten-year agreement (2008 – 2018) between BPA and the CCT whereas BPA agreed to fund pre-determined fish and wildlife projects and CCT agreed not to sue the Action Agencies regarding the BiOp for the FCRPS.

CJHP Master Plan = A three-step development and review process required for all new hatcheries funded by BPA in the Columbia Basin.

eDNA = environmental DNA; dissolved or cell-bound DNA that persists in the environment.

Escapement Target = Number of fish of all origins targeted to pass upstream of the Okanogan Adult Fish weir

HOB = the number of hatchery-origin fish used as hatchery broodstock.

HOR = hatchery-origin recruit. The number of HORs equals the sum of HOS + HOB + hatchery-origin fish intercepted in fisheries.

HOR Terminal Run Size = Number of Chief Joseph Hatchery HORs returning to Wells Dam

HOS = the number of hatchery-origin fish spawning naturally.

Juvenile Abundance = annual abundance of out-migrant juveniles estimated by expanding data from juveniles captured at the rotary screw trap.

Met Comp = Methow composite Spring Chinook. These fish are part of the Winthrop NFH program and are intended to be used for the Okanogan reintroduction pending approval under section 10(j) of the ESA.

NOB = the number of natural-origin fish used as hatchery broodstock.

NOR = natural-origin recruit. The number of NOR's equals the sum of NOB, + NOS + natural-origin fish intercepted in fisheries.

NOR Terminal Run Size = Number of Okanogan (and Similkameen, combined) NOR's returning to Wells Dam.

NOS = the number of natural-origin fish spawning naturally.

pHOS = proportion of natural spawners composed of HORs. Equals HOS/ (NOS + HOS).

PNI = proportion of natural influence on a composite hatchery-/natural-origin population. Can also be thought of as the percentage of time the genes of a composite population spend in the natural environment. Equals 1 - pNOB/ (pNOB + pHOS).

pNOB = proportion of hatchery broodstock composed of NORs. Equals NOB/ (HOB + NOB).

SAR = smolt to adult return.

Recovery Plans = Federally-required plans under the Endangered Species Act that describe species status, recovery criteria and expected restoration actions.

Relative Reproductive Success = The probability that an HOR produce adult offspring and summer/fall expressed as a fraction of the same probability for a NOR

Spatial Distribution = Geographic spawning distribution of adult salmon.

Spawner Abundance = Total number of adult spawners each year**.**

Subbasin Plans = Plans developed in the early 2000s for the NPCC project funding process describing "limiting factors" used for development of regional recovery and protection strategies.

Total NOR Recruitment = Annual number of adult recruits (catch plus escapement)

AHA = All H Analyzer

APPT = Annual Program Planning Tool

APR = Annual Program Review

BiOp = Biological Opinion

BKD = Bacterial Kidney Disease

BPA = Bonneville Power Administration

CA = Coordinated Assessments

CBFWA = Columbia Basin Fish and Wildlife Authority

CCT = Confederated Tribes of the Colville Indian Reservation

cfs = Cubic feet per second

CJH = Chief Joseph Hatchery

CJHP = Chief Joseph Hatchery Program

Colville Tribes = Confederated Tribes of the Colville Reservation

CTFWP = Colville Tribes Fish &Wildlife Program

CRITFC = Columbia River Inter-Tribal Fish Commission

CWT = Coded Wire Tag

DI = Density Index

DPS = Distinct Population Segment

EDT = Ecosystem Diagnostic & Treatment

ELISA = Enzyme-Linked Immunosorbent Assay

ESA = Endangered Species Act

ESU = Evolutionarily Significant Unit

FCRPS = Federal Columbia River Power System

FI = Flow Index

FPP = Fish per pound

FWS = U.S. Fish and Wildlife Service

GIS = Geographic Information System

gpm = gallons per minute

GPS = Global Positioning System

HCP = Habitat Conservation Plan(s)

HGMP = Hatchery Genetic Management Plan(s)

HSRG = Hatchery Science Review Group

ISIT = In-season Implementation Tool

ISRP = Independent Scientific Review Panel

KMQ = Key Management Questions

LNFH = Leavenworth National Fish Hatchery

NEPA = National Environmental Policy Act

NMFS = National Marine Fisheries Service

NOAA = National Oceanic and Atmospheric Administration

NPCC = Northwest Power and Conservation Council

OBMEP = Okanogan Basin Monitoring and Evaluation Program

ODFW = Oregon Department of Fish and Wildlife

ONA = Okanagan Nation Alliance

PBT = Parental Based Tagging

PIT = Passive Integrated Transponder

PNAMP = Pacific Northwest Aquatic Monitoring Partnership

PSMFC = Pacific States Marine Fisheries Commission

PTAGIS = PIT Tag Information System

PUD = Public Utility District

RKM= River Kilometer

RM = River Mile

RMIS = Regional Mark Information System

RM&E = Research, Monitoring, and Evaluation

RST = Rotary Screw Trap

SNP = Single Nucleotide Polymorphism

TAC = Technical Advisory Committee

TRMP = Tribal Resources Management Plan

TU = Temperature Unit

UCSRB = Upper Columbia Salmon Recovery Board

USGS = U.S. Geological Survey

WDFW = Washington Department of Fish and Wildlife

WNFH = Winthrop National Fish Hatchery

APPENDIX E

Identification of Geochemical Signatures in Upper Columbia River Summer Chinook Salmon 2018

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December 31, 2018

Colville Confederated Tribes
Attn: Andrea Pearl, John Rohrback
Fish and Wildlife Department
PO Box 150
Nespelem, WA 99155

Dear John and Andrea:

Re: Identification of Geochemical Signatures in Upper Columbia River Summer Chinook Salmon – 2018

We have completed Phase 1 of the 2018 scope of work for analysis of the geochemical signatures in juvenile summer Chinook salmon from the Similkameen, Okanogan and Columbia Rivers. The objectives were to: (1) determine the inter-annual variation in geochemical markers present in these rivers, (2) determine if geochemical markers in resident fish such as sculpin, yellow perch and pike minnow from these rivers reflected those present in the water and salmon, and (3) conduct a more detailed analysis of the geochemical signatures in juvenile summer Chinook from the mixed stock area at Gebber's Landing. The purpose of objectives 1 and 2 was to assess whether the anomalous variation in several of the geochemical markers of juvenile Chinook in the Similkameen and Okanogan Rivers observed in 2017 may have resulted from mixing of fish between these systems or natural variation in water chemistry. Objective 3 was designed to capture any potential temporal variability in the spawning site contributions to fry abundance at Gebber's Landing.

We analyzed a total of *n*=8 water samples from the four sites for $^{87}Sr/^{86}Sr$, Sr/Ca, Ba/Ca and $\delta^{18}O$. In addition, we performed similar analyses on otoliths sent to us from pike minnow (*n*=15) and juvenile summer Chinook (*n*=10) collected in the Similkameen River. Otoliths were analyzed from yellow perch (*n*=18), sculpin (*n*=3), and juvenile summer Chinook (*n*=4) collected in the Okanogan River, as well as from juvenile summer Chinook collected in the Columbia River at Washburn Island (*n*=49) and Gebber's Landing (*n*=50). The methods of sample preparation and analysis were identical to those contained in our report for 2017.

Water Results

In summary, the results from 2018 confirm the earlier findings of the pilot study regarding the variation in water chemistry among the rivers. Inter-annual comparisons for each of the markers are shown in Figures 1a to 1e. There was generally high consistency for each of the markers within seasons between years, particularly for $^{87}Sr/^{86}Sr$, Sr/Ba and $\delta^{18}O$. The notable exceptions were higher and similar Sr/Ca ratios among the Similkameen, Gebber's and Washburn sites in the fall of 2018. The Ba/Ca ratio was also higher at each site in 2018 in both the spring and fall, although the river specific values in 2018 trended in opposite directions between the seasons.

More specifically, except for the Okanogan River, Ba/Ca decreased by approximately the same amount at each of the other sites between spring and fall in 2017. By contrast, in 2018 the relative Ba/Ca ratios in the spring for the non-Okanogan sites were Similkameen > Gebber's > Washburn, whereas in the fall the ratios were reversed; Similkameen < Gebber's < Washburn. In fact, Ba/Ca was higher in the fall at Washburn Island than in the spring, which is somewhat surprising because higher stream flows resulting from increased rainfall and snowmelt in the spring have been associated with higher not lower Ba/Ca in other river systems (Linley et al., 2016). If this temporal stability is persistent, it will aid future analyses of spawning site contributions to the juvenile Chinook salmon mixture at Gebber's Landing as well as adult returns

Table 1. Results of 2018 water analyses for all sites. Element / Ca ratios are expressed in mmol/mol, Sr/Ba is expressed in ppb/ppb, and $\delta^{18}O$ is reported in delta notation relative to Vienna Standard Mean Ocean Water (VSMOW).

Site	**Season**	$^{87}Sr/^{86}Sr$	**Sr/Ca**	**Ba/Ca**	**Sr/Ba**	$\delta^{18}O$
Okanogan	Spring	0.70679	8.19	0.47	17.33	-42.80
	Fall	0.70681	7.26	0.38	19.14	-41.54
Similkameen	Spring	0.70527	4.87	1.19	4.11	-46.84
	Fall	0.70526	4.82	0.53	9.05	-46.02
Gebber’s	Spring	0.71170	3.48	1.00	3.49	-46.30
	Fall	0.71502	4.97	0.75	6.59	-47.71
Washburn	Spring	0.71572	1.77	0.64	2.76	-46.75
	Fall	0.71527	4.95	0.77	6.47	-47.83

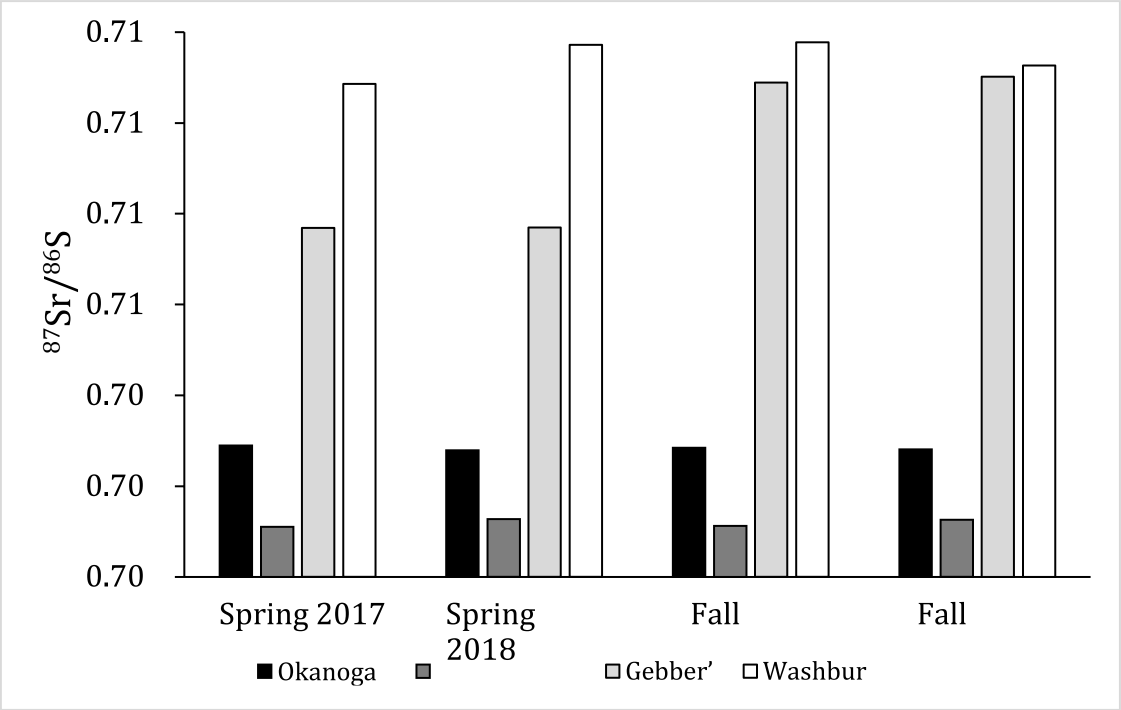

Figure 1a. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) among sites for 2017 and 2018.

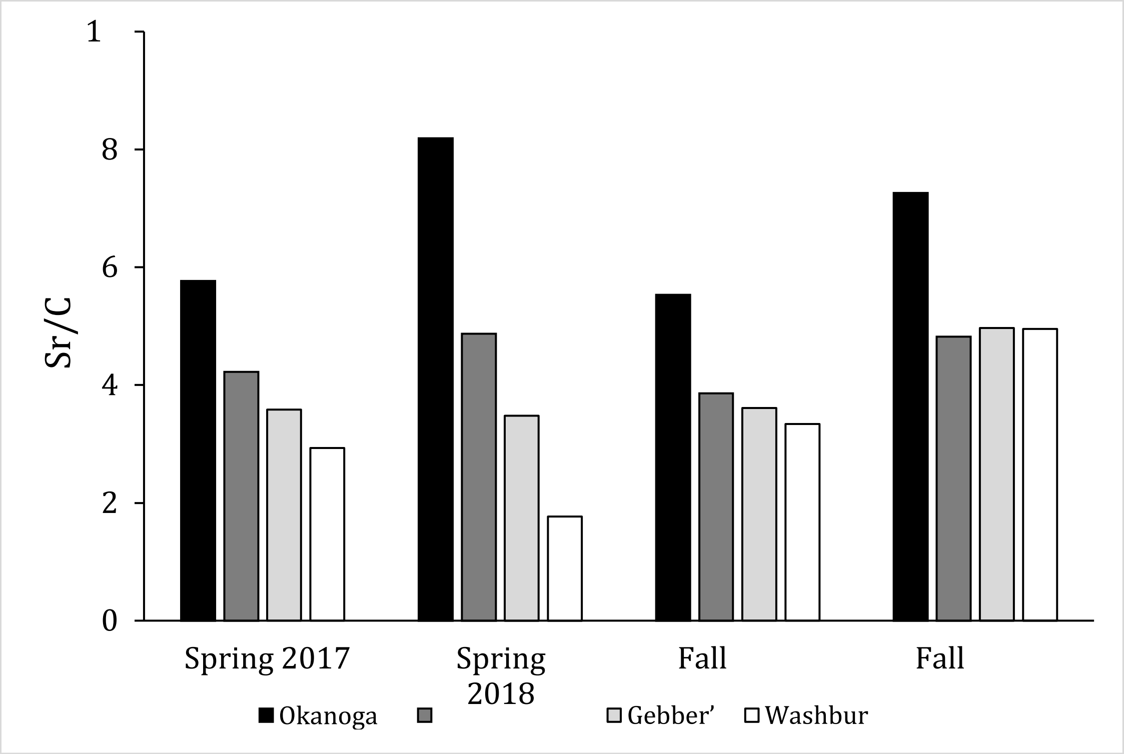

Figure 1b. Strontium/calcium ratios (mmol/mol) among sites for 2017 and 2018.

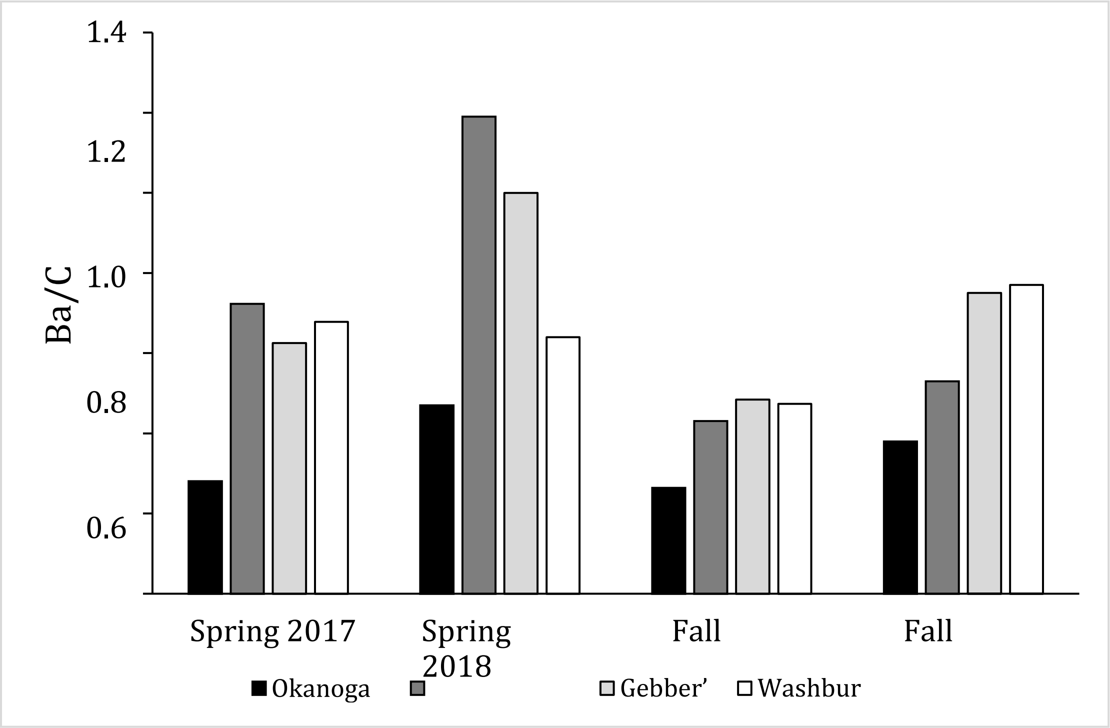

Figure 1c. Barium/calcium ratios (mmol/mol) among sites for 2017 and 2018.

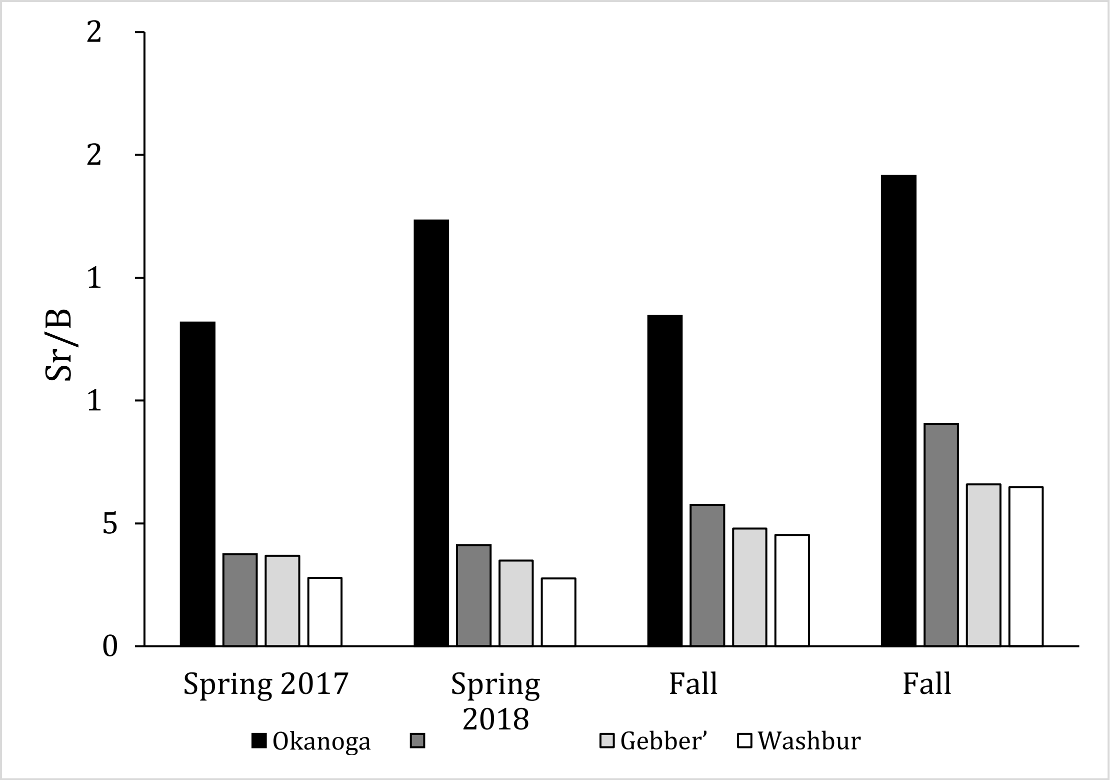

Figure 1d. Strontium/barium ratios (ppb/ppb) among sites for 2017 and 2018.

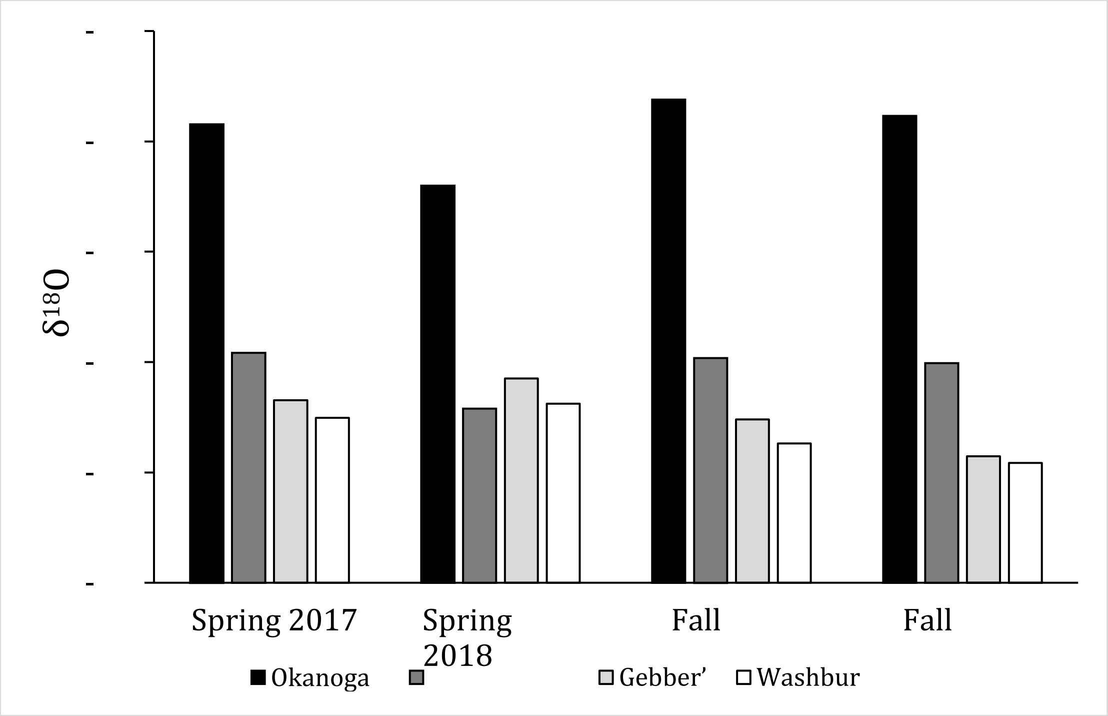

Figure 1e. Oxygen isotope ratios ($^{18}O/^{16}O$) among sites expressed in delta notation for 2017 and 2018.

Otolith Results

Analysis of variance revealed significant differences in otolith $^{87}Sr/^{86}Sr$, Sr/Ca, Ba/Ca and Sr/Ba among the sample sites (Table 2). The largest differences were in $^{87}Sr/^{86}Sr$ and Sr/Ca, although differences among sites were highly significant ($P < 0.001$) for each variable. The strontium isotopic ratio differed significantly among all sites, whereas Sr/Ca, Ba/Ca and Sr/Ba showed both differences as well as overlap among sites (Table 2). As we found last year, $^{87}Sr/^{86}Sr$ was notably higher in the Columbia River fish than in either the Okanogan or Similkameen fish. By contrast, the highest Sr/Ca ratio was found in the Okanogan River and varied widely among the three species (1.28 mmol/mol – 1.79 mmol/mol). The Ba/Ca ratio was highest in the Chinook samples from Washburn and Gebber's, and lowest in the pike minnow from the Similkameen.

Because of the anomalous variation we found for several markers in the Okanogan and Similkameen Rivers in 2017, and the possibility that this variation could reflect movement between sites by juvenile Chinook, we suggested that otolith samples also be collected from resident fish in 2018 to further examine this hypothesis. If such variation were present in resident fish it would presumably result from seasonal or inter-annual variation in water chemistry rather than movement between sites. Sample sizes for pike minnow (*n*=16) and Chinook salmon (*n*=10) in the Similkameen River (Table 2) in 2018 were large enough to make reasonable inter- specific comparisons. First, note that the standard deviations for

$^{87}Sr/^{86}Sr$ and Sr/Ba differ appreciably between the species and are statistically significant (variance ratio test $P \leq 0.047$), whereas Sr/Ca and Ba/Ca do not ($P \geq 0.151$). Moreover, a two-sample *t*-test indicated there were also significant differences in the samples means for each of the markers ($P \leq 0.027$). As a result, we conducted the discriminant analysis (DA) for assigning river origin using Chinook salmon and all resident fish combined, and all fish other than pike minnow.

Prior to analysis, the values (X) for each variable were standardized to remove magnitude bias by (X-μ)/σ, where μ and σ are the ratio mean and standard deviation for all samples, respectively.
We used quadratic discriminant analysis (QDA) to identify geochemical markers that produced the highest assignment accuracy because it does not require equality of the covariances among predictor variables. Prior probabilities were assumed to be equal and the relative contribution for each marker for assigning river origin was based on the *F*-to remove ratio in the QDA. Wilkes lambda was used as the multivariate analysis of variance statistic to test for equality of group means for the variables in the discriminant function. Stream assignment accuracy for the known samples was based on the jack-knifed procedure and cross validation of learning and test samples, whereas the posterior probabilities were used to assign river origin to the unknown samples collected at Gebber's Island.

Table 2. Results from ANOVA to test for differences in otolith $^{87}Sr/^{86}Sr$, Sr/Ca, Ba/Ca, Sr/Ba, and $\delta^{18}O$ among sample sites. $\delta^{18}O$ will be reported in an addendum.

Ratio	df	MSE	*F*	*P*
$^{87}Sr/^{86}Sr$	2,91	55.7	6284.9	< 0.001
Sr/Ca	2,92	27.2	60.3	< 0.001
Ba/Ca	2,92	5.1	9.8	< 0.001
Sr/Ba	2,92	30.9	53.6	< 0.001
$\delta^{18}O$				

Table 3. Mean (SD) isotopic and elemental results for natal rearing zone of otoliths. Element to calcium ratios are expressed in mmol/mol and Sr/Ba is expressed in ppb/ppb. Values without letters in common are significantly different from each other.

Site	**Species**	***N***	**$^{87}Sr/^{86}Sr$**	**Sr/Ca**	**Ba/Ca**	**Sr/Ba**
Okanogan	Yellow perch	18	0.70690 (0.00009)	1.28 (0.14)	0.017 (0.007)	64.7 (28.5)
	Sculpin	3	0.70688 (0.00023)	1.79 (0.10)	0.013 (0.002)	94.3 (12.0)
	Chinook	4	0.70701 (0.00010)	1.64 (0.17)	0.015 (0.009)	89.5 (47.2)
	River	25	0.70692 (0.00011)^{a}	1.40 (0.24)^{a}	0.016 (0.007)^{a}	72.2 (31.9)^{a}
Similkameen	Pike minnow	16	0.70532 (0.00040)	1.09 (0.21)	0.010 (0.003)	74.8 (23.7)
	Chinook	10	0.70580 (0.00018)	1.62 (0.23)	0.018 (0.005)	59.7 (12.2)
	River	28	0.70550 (0.00040)^{b}	1.25 (0.40)^{a}	0.013 (0.006)^{ab}	70.1 (21.7)^{a}
Gebber's	Chinook	51	0.70682 (0.00198)	1.33 (0.32)	0.020 (0.014)	52.2 (21.6)
Washburn	Chinook	49	0.71399 (0.00266)^{c}	0.82 (0.19)^{b}	0.020 (0.006)^{b}	29.0 (10.4)^{b}

For the combined samples, the QDA model showed that only $^{87}Sr/^{86}Sr$ and Sr/Ca ($P \leq 0.001$) contributed significantly to group membership, and $^{87}Sr/^{86}Sr$ contributed most to the discriminant function (*F*-to-enter = 3,563.2 and = 14.3, respectively for $^{87}Sr/^{86}Sr$ and Sr/Ca). There were also significant multi-variate differences among sites (Wilks lambda = 0.005, $P \leq 0.001$) Assignment accuracy based on the jackknifed classification (Table 4) ranged from 96% for the Similkameen to 100% for the Okanogan and Washburn sites, and totaled 99% overall. Using these same data and randomly classifying them into model learning (65%) and test (35%) samples resulted in a cross-validation accuracy of 98% and 100%, respectively (Table 5). For the model with all samples included, *n*=3 of the Gebber's Island fish were assigned to the Okanogan River, *n*=49 to the Similkameen and *n*=5 to Washburn Island. [We included *n*=5 samples from Washburn Island with $^{87}Sr/^{86}Sr < 0.707$ as unknowns in the Gebber's Island collection because they were clearly not of Washburn origin]. Excluding pike minnow from the Similkameen samples resulted in a jackknifed classification of 100% for each site (Table 6), and each of the markers had a significant effect on group membership (i.e., *F*-to-remove = 1042.5, 9.8, 6.6 and 3.3, respectively for $^{87}Sr/^{86}Sr$, Sr/Ca, Sr/Ba and Ba/Ca), and produced significant multi-variate differences among sample sites (Wilks lambda = 0.005, $P \leq 0.001$). Moreover, for this model, *n*=31 of the salmon collected at Gebber's Island were assigned to the Okanogan River, *n*=20 to the Similkameen and *n*=5 to Washburn.

Table 4. Jackknifed classification for group membership among sample sites for Chinook salmon and resident fish combined. Variables in the model include $^{87}Sr/^{86}Sr$ and Sr/Ca.

Site	Okanogan	Similkameen	Washburn	% Correct
Okanogan	25	0	0	100
Similkameen	1	25	0	96
Washburn	0	0	43	100
Total	26	25	43	99

Table 5. Cross-validation results for group membership among sites for learning (upper panel) and test (lower panel) samples of Chinook salmon and resident fish combined.

Site	Okanogan	Similkameen	Washburn	% Correct
Okanogan	19	0	0	100
Similkameen	1	18	0	95
Washburn	0	0	24	100
Total	20	18	24	98

Site	Okanogan	Similkameen	Washburn	% Correct
Okanogan	6	0	0	100
Similkameen	0	7	0	100
Washburn	0	0	19	100
Total	6	7	19	100

Table 6. Jackknifed classification for group membership among sample sites for all fish except pike minnow from the Similkameen River. Variables in the model include $^{87}Sr/^{86}Sr$, Sr/Ca, Ba/Ca and Sr/Ba.

Site	Okanogan	Similkameen	Washburn	% Correct
Okanogan	25	0	0	100
Similkameen	0	10	0	100
Washburn	0	0	43	100
Total	25	10	43	100

The distribution of fish from each of the sample sites are shown in figures 2 and 3. Figure 2 is a bi-variate plot of the data for $^{87}Sr/^{86}Sr$ and Sr/Ca. We used this plot rather than the canonical score plot for the QDA because it is easier to illustrate the relationship of these two variables in the model. Washburn Island salmon cluster well with $^{87}Sr/^{86}Sr$ alone, although some of the samples collected at Gebber's Landing also cluster with fish from the Washburn site. As noted above, the geochemical characteristics of the pike minnow from the Similkameen River differed significantly from summer Chinook salmon, and this is particularly evident by the graphical separation in Sr/Ca and to a lesser degree in $^{87}Sr/^{86}Sr$. By contrast, the resident fish and salmon in the Okanogan River show considerable overlap.

Most of the salmon collected at Gebber's Landing fall directly in between the Similkameen and Okanogan fish for otolith $^{87}Sr/^{86}Sr$, which is consistent with the QDA model excluding the pike minnow from the Similkameen River, whereby the Gebber's Island samples were more evenly assigned to the Okanogan and Similkameen Rivers. There are several factors that could influence the $^{87}Sr/^{86}Sr$ observed in the natal rearing zone of these salmon in either direction. [Recall that there is typically a 1:1 correlation between water and otolith

^{87}Sr/^{86}Sr]. First, the maternal contribution could elevate the otolith ^{87}Sr/^{86}Sr for juvenile salmon above the Similkameen and Okanogan water ^{87}Sr/^{86}Sr if much of the maturation occurred outside of their respective tributaries during their upstream migration. This is because the water ^{87}Sr/^{86}Sr of both the ocean (0.70918) and the Columbia River (>0.713) from Bonneville Dam to the Canadian border are well above the water ^{87}Sr/^{86}Sr for the Similkameen and Okanogan Rivers (< 0.707). Since the spatial extent of the maternal influence in the otolith is not precisely known for these fish, it is possible that some proportion of the salmon collected near spawning sites might retain this influence to the otolith edge. This could account for the otolith ^{87}Sr/^{86}Sr differing from the water ^{87}Sr/^{86}Sr for Similkameen juvenile salmon in 2017 (0.7073 ± 0.001 and ^{87}Sr/^{86}Sr of 0.70513 ± 0.00001, respectively), and may be due a difference in emergence and collection timing between 2017 and 2018 if this variation was also expressed by differences in fish size and the amount of yolk remaining. However, an attenuating effect on otolith ^{87}Sr/^{86}Sr from the maternal contribution could also be expressed directly in emergence timing is because it is linked to adult run timing. If early returning females arrive on the spawning grounds in a comparatively immature state, their egg ^{87}Sr/^{86}Sr is more likely to be closer to equilibrium with the natal stream ^{87}Sr/^{86}Sr than later run females that arrive in more mature condition. Since spawning time is the main determinant of emergence timing within and among populations, otolith core ^{87}Sr/^{86}Sr of early emergent fry should be presumably closer to the natal stream ^{87}Sr/^{86}Sr than in later emergent fry. Moreover, it also suggests there may be a difference in emergence timing between Similkameen and Okanogan Chinook salmon since the offset in otolith – water ^{87}Sr/^{86}Sr between the resident fish and Chinook is not observed in the Okanogan and was relatively consistent between years. Samples collected at the natal stream sites over the duration of the downstream migration would help determine if female run timing affects otolith ^{87}Sr/^{86}Sr in Similkameen and Okanogan River summer Chinook fry, and how this might potentially influence the assignment of spawning site origins for these fish.

Alternatively, the water of the combined Similkameen and Okanogan River below their confluence could act to increase otolith ^{87}Sr/^{86}Sr for Similkameen River salmon, or cause it to decline in Okanogan River salmon, assuming that the water ^{87}Sr/^{86}Sr for the combined systems is intermediate to their respective tributary ^{87}Sr/^{86}Sr values, and that the migrating juvenile salmon spend sufficient time in this stretch of the river to reach ^{87}Sr/^{86}Sr equilibrium before entering the Columbia. Because of these confounding effects, we cannot distinguish Okanogan from Similkameen origin Chinook based on ^{87}Sr/^{86}Sr alone, hence the utility of the additional markers for Sr/Ca, Ba/Ca and Sr/Ba. Although otolith Sr/Ca was not significantly different (t = 1.24, P = 0.22) between the Similkameen River and the Okanogan River when all the samples are included, it contributed significantly to determining group membership in the two variable QDA model. However, as we noted, including the pike minnow samples in the QDA also resulted in 86% (49/57) of the juvenile salmon of unknown origin being assigned to the Similkameen River, which is unlikely unless adult escapement and egg to fry survival in the Similkameen River greatly exceed those in the Okanogan River. Water samples collected from the Okanogan River below the confluence with the Similkameen could potentially identify the individual river contributions to water $^{87}Sr/^{86}Sr$ in this mixing zone, and the extent to which this water source modifies otolith $^{87}Sr/^{86}Sr$. Moreover, given the consistent variation in water $\delta^{18}O$ within and between the Similkameen and Okanogan Rivers (Table 1, Figure 1e), we anticipate that otolith $\delta^{18}O$ will provide additional information for assigning Gebber's Island fry to their natal stream.

By comparison, excluding the pike minnow samples resulted in a QDA model that gave higher assignment of unknown origin fish to the Okanogan (55%) than to the Similkameen (35%). In addition to $^{87}Sr/^{86}Sr$ and Sr/Ca, this model also included Ba/Ca and Sr/Ba as significant predictors of group membership. The canonical scores plot of the multi-variate model is shown in Figure 3. The highest assignment weight for Factor 1 was provided by $^{87}Sr/^{86}Sr$, whereas Sr/Ba had the greatest influence for Factor 2. Much like the bi-variate model, the Gebber's Island samples fall between the Similkameen and Okanogan River fish along the Factor 1 axis, but the differences in stream assignment for these fish due to the inclusion of Sr/Ba in the model is also apparent from the differences in the group mean when the pike minnow are excluded from the analysis (Table 3). This is partly because the elemental ratios of Sr and Ba in the water differed considerably between the Okanogan and Similkameen Rivers, with the Okanogan being much higher in Sr/Ca and lower in Ba/Ca compared to the Similkameen (Table 1, Figures 1b-d). However, these values in the otoliths were also highly variable between species within rivers (Table 3). For example, the mean ± SD Sr/Ca for yellow perch and sculpin in the Okanogan River and pike minnow in the Similkameen River were 1.36 ± 0.23 and 1.09 ± 0.21 mmol/mol, respectively, whereas the Sr/Ca ratio for juvenile Chinook from the Okanogan and Similkameen were 1.65 (±0.17) and 1.62 (±0.23) mmol/mol, respectively.

We suggest the difference in Sr/Ca (and possibly Ba/Ca) between the resident fish and juvenile Chinook may relate to the attenuation of the maternal signature. Both the $^{87}Sr/^{86}Sr$ and elemental concentration data were collected just outside the core of the otolith, approximately 300 μm from the primordia of the otolith. To avoid including the maternal signature, we first conducted a laser ablation transect across the otolith to determine where the $^{87}Sr/^{86}Sr$ reached equilibrium with the water and the marine $^{87}Sr/^{86}Sr$ signature from the maternal contribution had completely attenuated, but we did not conduct a similar transect for Sr, Ba and Ca. For most of the juvenile salmon collected in the tributaries, the equilibrium location for $^{87}Sr/^{86}Sr$ was near the very edge of the otolith. However, Hegg et al. (2018) recently demonstrated that the maternal influence of $^{87}Sr/^{86}Sr$ and elemental concentrations do not necessarily attenuate at the same time or distance across the otoliths of juvenile Chinook, and it is possible that Sr and Ba measured in the otoliths of these juvenile Chinook was still influenced by maternal (marine) Sr. Strontium concentrations are 5-10 greater in seawater than in freshwater, whereas the reverse is true for Ba, which would be consistent with the higher molar ratios we found for Sr in the juvenile salmon compared to yellow perch and pike minnow, but would not account for the higher Sr/Ca observed in the Okanogan sculpin, nor the comparatively lower Ba/Ca for all resident fish.

In conclusion, the results to date show the potential for high assignment accuracy of Gebber's Island summer Chinook fry to their natal sites. Both the bivariate and multivariate QDA models produced either jackknifed or cross-validation accuracy of the known samples that approach 100%, and the assignment of the Gebber's Island samples to mainstem spawning versus the Okanogan – Similkameen tributaries appears equally valid. Although differences in element/Ca ratios between the juvenile salmon and resident fish confound assignment of unknown samples between the Okanogan and Similkameen rivers, the consistent differences in water $\delta^{18}O$ between these sites and the lack of a maternal $\delta^{18}O$ effect on otolith $\delta^{18}O$ should further resolve their relative contributions to the salmon fry population at Gebber's Island. We expect the otolith $\delta^{18}O$ analyses will be completed in January. Once they are complete, we will send you an amended Phase 1 report along with specific recommendations for implementing a full-scale population assessment of the summer Chinook fry at Gebber's Island in 2019. In the meantime, I will arrange a day and time either this week or next to discuss these results.

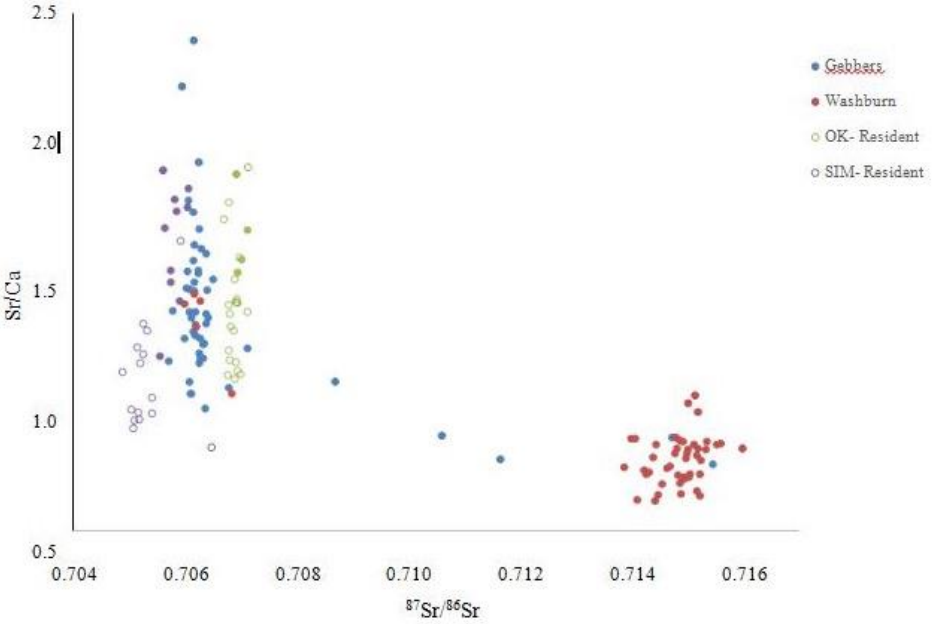

Figure 2. Otolith $^{87}Sr/^{86}Sr$ and Sr/Ca (mmol/mol) from the natal rearing zone of fish collected at all sites. Resident fish from the Okanogan (OK) include yellow perch and sculpin, all resident fish analyzed from the Similkameen (SIM) were northern pikeminnow.

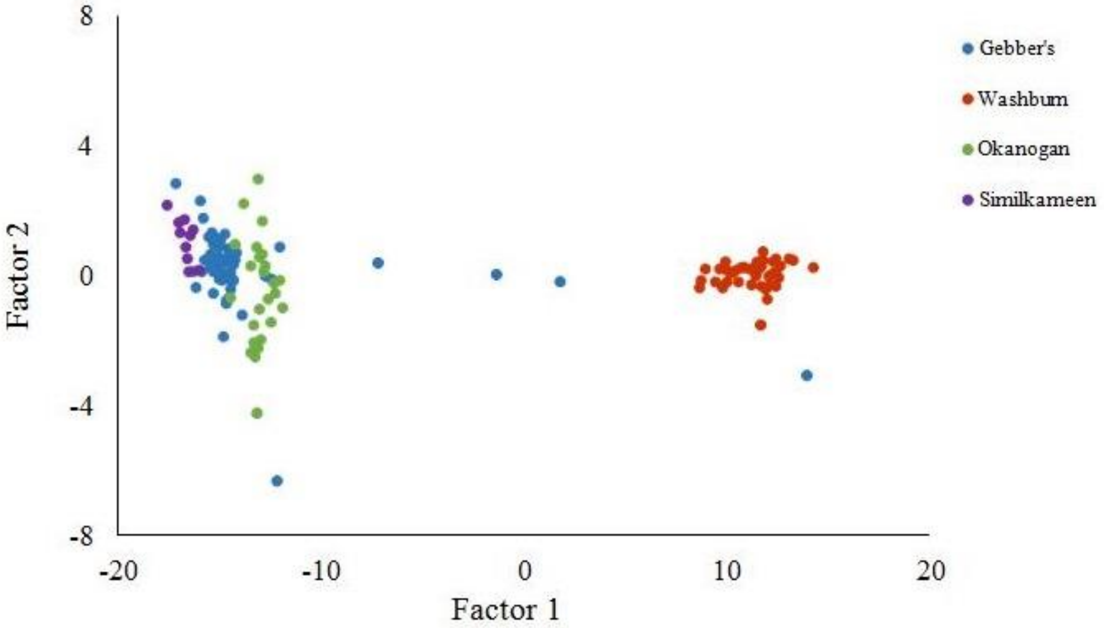

Figure 3. Canonical score plot for the multi-variate QDA model that included $^{87}Sr/^{86}Sr$, Sr/Ca, Ba/Ca and Sr/Ba as significant predictors of group membership.

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APPENDIX F

Technical Memorandum: Minijack Rates for 2018 Chief Joseph Hatchery Integrated and Segregated Chinook Releases

Date: 8 July 2019

From: John Rohrback; john.rohrback@colvilletribes.com (509) 634-1068

To: Andrea Pearl, Matthew McDaniel, Casey Baldwin, Anthony Cleveland, Jim Andrews

CC: Kirk Truscott

Subject: Minijack rates for 2019 Chief Joseph Hatchery Chinook release groups

Background

This technical memorandum will summarize the results of gonadal-somatic index (GSI) sampling conducted by the Chief Joseph Hatchery Program (CJHP) in May 2019, and provide estimates for the rate of early maturation ("minijack rate") from each yearling group released in 2019 (brood year 2017).

Early maturation of male hatchery-origin Chinook salmon is a concern throughout the Columbia river basin, with some hatchery releases exhibiting minijack rates of over 70% (Harstad et al. 2014). The production of high levels of minijacks is not consistent with the goals and objectives of the CJHP, which intends to produce adult fish for harvest and conservation. Additionally, the National Marine Fisheries Service (NMFS) requested that the Confederated Tribes of the Colville Indian Reservation (CCT) include an evaluation of early maturation on all yearling Chinook programs because early maturation is considered a 'take surrogate' for potential competitive interactions with natural-origin fish (NMFS 2017). The reporting requirements of NMFS were based on the methodology described in Harstad et al. (2014) that used a blood plasma test to evaluate the level of 11-ketotestosterone to estimate initiation of male maturation as mini-jacks. Absent funding to implement the 11-KT method, the CJHP elected to use a visual and GSI approach to evaluate early maturation. The GSI approach has been implemented by the USFWS for the Leavenworth complex for a number of years with good success (Matt Cooper, personal communication). The CJHP staff believe the GSI evaluation presented herein meets the intent of the reporting requirement (#6) described in the NMFS determination letter.

Methods

Prior to release, approximately 300 fish were collected from each yearling 2019 Chief Joseph Hatchery (CJH) release group for dissection and examination. In contrast to 2018, these fish were held at CJH after their cohorts had been released for approximately one month. This was to allow for additional maturation and facilitate distinction between mature and immature fish. The release groups are:

- Segregated spring Chinook; released from Chief Joseph Hatchery, hatchery-origin broodstock collected at the Chief Joseph Hatchery Ladder
- Segregated summer Chinook; released from Chief Joseph Hatchery, hatchery-origin broodstock collected from the Columbia River near the mouth of the Okanogan River
- Integrated spring Chinook; released from the Riverside Acclimation Pond, natural-origin MetComp broodstock from Winthrop National Fish Hatchery
- Integrated summer Chinook; released from the Omak Acclimation Pond, natural-origin broodstock primarily of Okanogan-origin stock
- Integrated summer Chinook; released from the Similkameen Acclimation Pond, natural-origin broodstock primarily of Okanogan-origin stock

Fish were euthanized with MS-222, and processed in accordance with the USFWS GSI sampling protocol (Pfannenstein 2016, see Appendix A). Males were classified as either mature or immature based on a visual inspection of the gonads, and the gonadal-somatic index (GSI) was also calculated for statistical estimation of minijack rates for each release group.

After data was collected, GSI values were analyzed using a mixture model (Medeiros, see Appendix B) in an attempt to identify immature and mature sub-populations and estimate the minijack rate within each sampled release group.

Results

Based on the visual assessment of maturity, CJH yearlings overall displayed moderate rates of early maturity (14.25%-37.41%, Table 1). The mixture model was fit to all release groups except Similkameen summers, and encompassed a similar range of expected rates of early maturation (19.02% - 43.06%, Table 1). A distinct separation in Log10 GSI between immature and mature fish was apparent only in the segregated spring Chinook release group. Such a break also seemed to occur in the Similkameen integrated summer Chinook release group, but it could not be captured by the mixture model. Nevertheless, a cutoff value for classifying sampled fish as mature or immature, and therefore a minijack rate, could be modeled for all groups except for integrated summer Chinook released into the Similkameen River (Figures 1-4). Histograms that display the distribution of Log10 GSI for each sampled release group are presented in Figures 1-5.

Annual rates of early maturation are recorded in Table 2.

Table 1. Mini-jack rate for each Chief Joseph Hatchery release group from brood year 2017.

Release Group	Release Location	Males Examined	Visually classified immature	Visually classified mature	Visual mini-jack Rate	Modeled mini-jack rate
Segregated Spring Yearlings	Chief Joseph Hatchery	163	112	51	31.29%	19.02%
Segregated Summer Yearlings	Chief Joseph Hatchery	147	126	21	14.29%	43.06%
Integrated Spring Yearlings	Riverside Acclimation Pond	147	92	55	37.41%	42.17%
Integrated Summer Yearlings	Omak Acclimation Pond	163	131	32	19.63%	29.63%
Integrated Summer Yearlings	Similkameen Acclimation Pond	134	114	20	14.25%	N/A

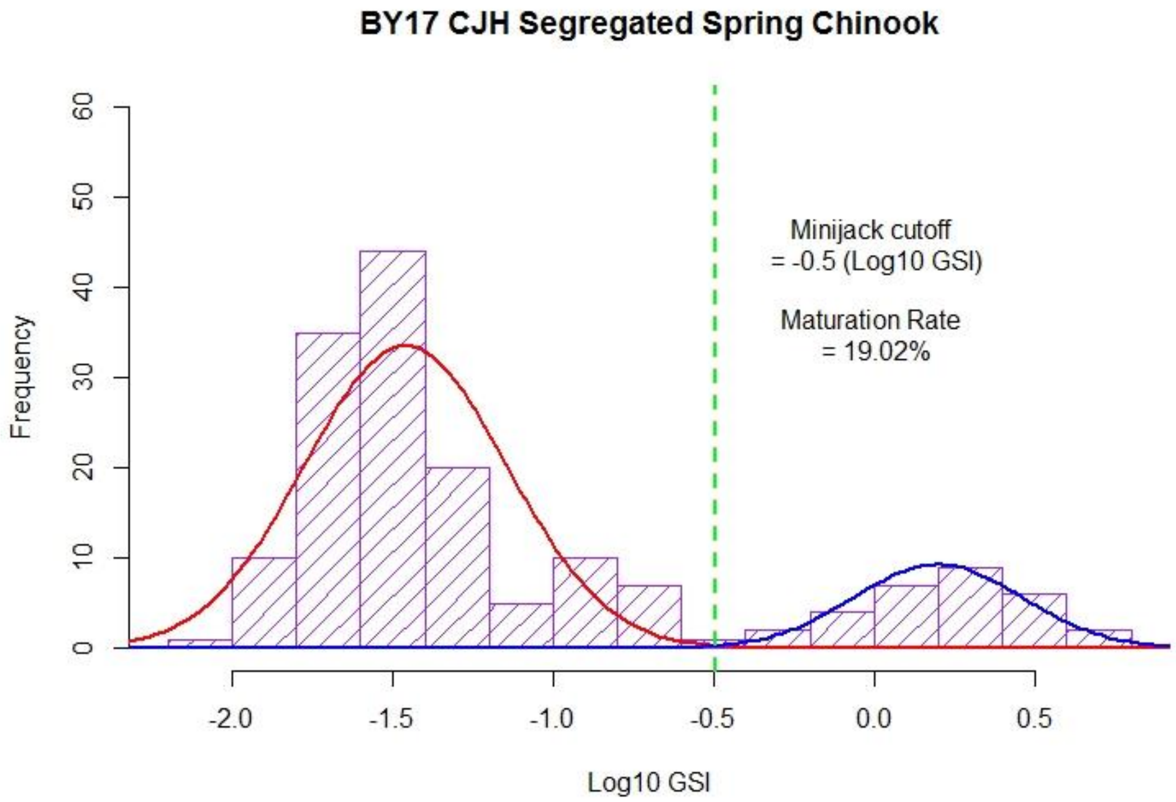

Figure 1. Distribution of Log10 GSI for the segregated spring Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing to the right of the line). The solid blue line shows the distribution function of immature fish, and the solid red line shows the distribution function of mature fish.

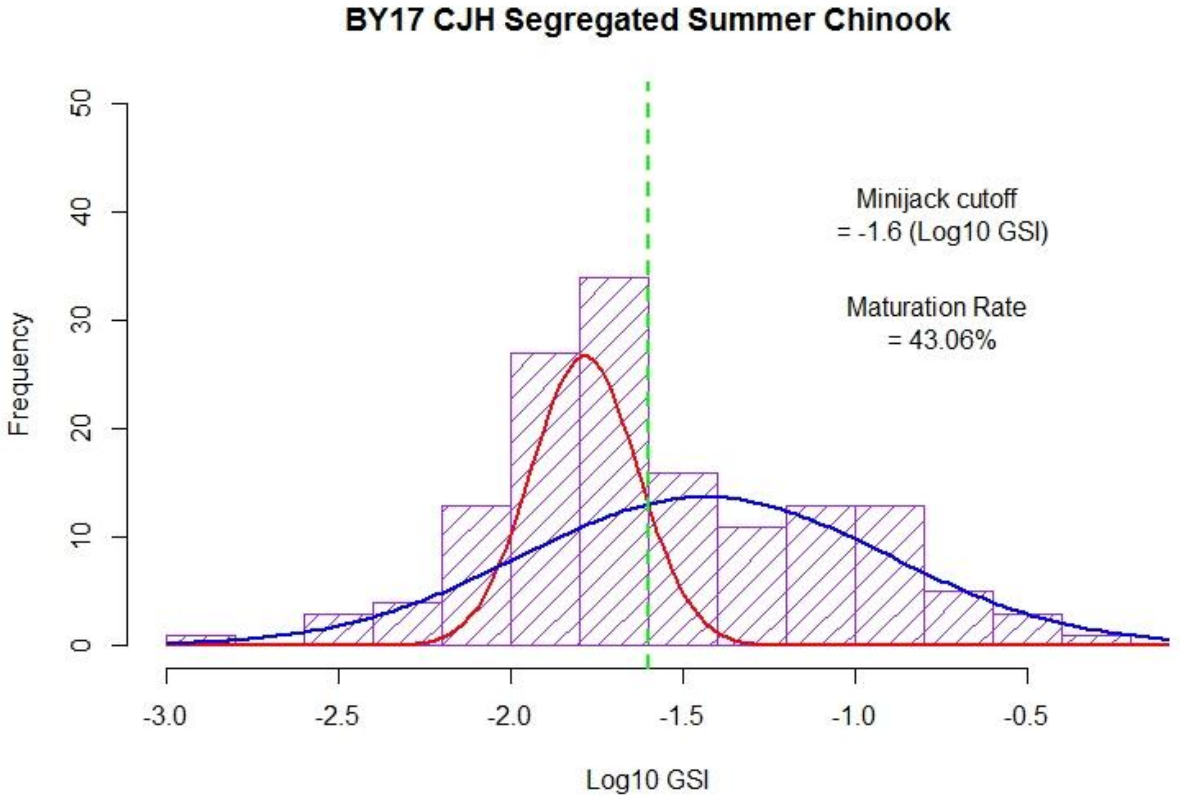

Figure 2. Distribution of Log10 GSI for the segregated summer Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing to the right of the line). The solid blue line shows the distribution function of immature fish, and the solid red line shows the distribution function of mature fish.

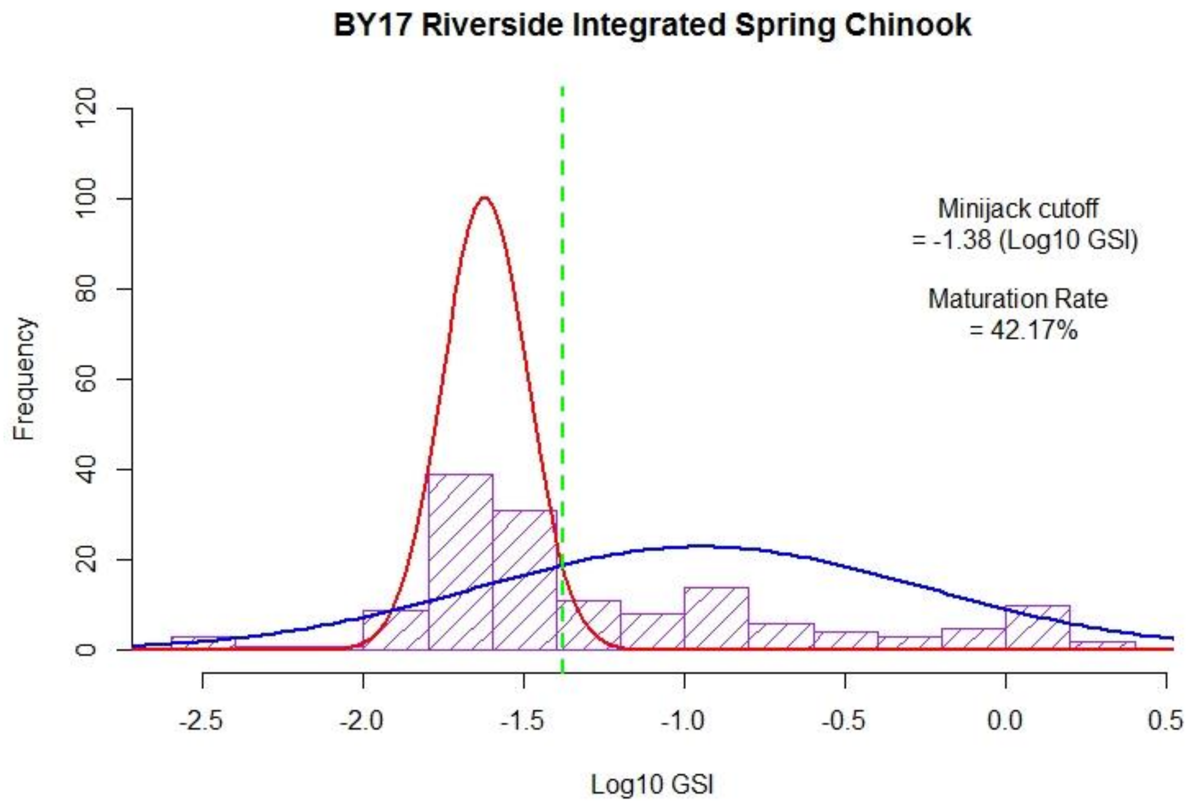

Figure 3. Distribution of Log10 GSI for the integrated spring Chinook released from the Riverside Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing to the right of the line). The solid blue line shows the distribution function of immature fish, and the solid red line shows the distribution function of mature fish.

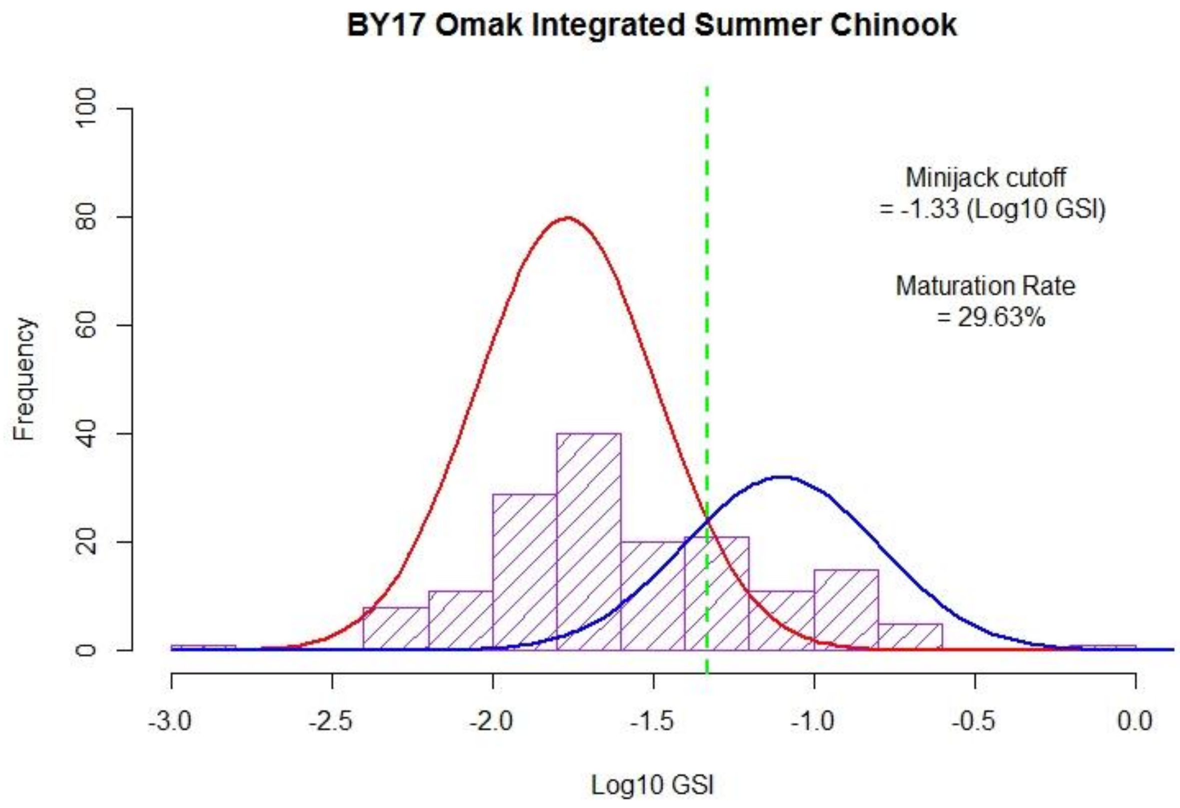

Figure 4. Distribution of Log10 GSI for the integrated summer Chinook released from the Omak Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing to the right of the line). The solid blue line shows the distribution function of immature fish, and the solid red line shows the distribution function of mature fish.

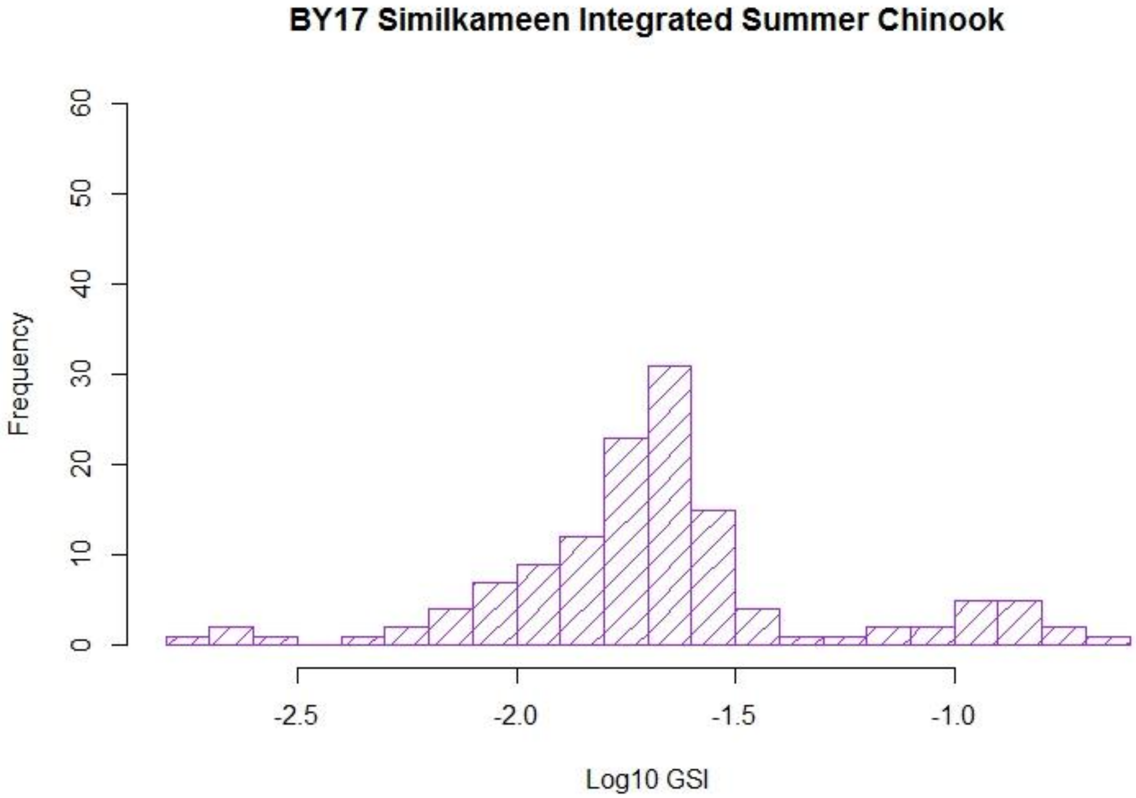

Figure 5. Distribution of Log10 GSI for the integrated summer Chinook released from the Similkameen Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

Table 2. Annual predicted minijack rate for all CJH release groups.

Year		CJH Segregated Spring Chinook	CJH Segregated Summer Chinook	Riverside Integrated Spring Chinook	Omak Integrated Summer Chinook	Similkameen Integrated Summer Chinook
2018	Visual Estimate	3.23%	4.29%	1.34%	0.00%	0.75%
	Modeled Estimate	4.52%	N/A	N/A	N/A	N/A
2019	Visual Estimate	31.29%	14.29%	37.41%	19.63%	14.25%
	Modeled Estimate	19.02%	43.06%	42.17%	29.63%	N/A

Discussion and Recommendations

The data and analyses presented herein suggest that the early maturation rate for brood year 2017 releases was much higher than that of brood year 2016 Chinook. Despite a year-over-year increase in minijack rates from CJH releases, the predicted rates minijack rates for all CJH release groups in 2019 were still comparable to other Columbia River hatchery programs (Harstad et al. 2014).

Although the range of rates of minijacking between release groups estimated by visual assessment and the mixture model were similar, there was not perfect agreement between the two methodologies. This predictive exercise should be paired with a retrospective analysis which uses PIT tag data to estimate actual rates of minijacking within each release group. Such an analysis could shed light on whether one method of estimating minijack rate is more accurate than the other. Or, if PIT analysis shows rates of early maturation that are strongly divergent from both of the GSI-based estimates, that could provide a basis for future implementation of 11-KT testing.

Visual determination of maturity state is subjective and is likely only useful when the state of maturity has progressed to the point where it becomes so clear that observer error or bias can be overcome. Similarly, the mixture model relies on an ability to differentiate between two distinct, normally distributed populations within a sample. Holding the fish for an additional month post-release allowed more time for gonadal development in the early maturing fish. This allowed for mixture model convergence at a much higher rate than in 2018, and may have contributed to reducing Type II error in the visual determination. Although this implies that the minijack rates reported in 2018 may have been artificially low, such a determination cannot be confidently made without supportive PIT tag data. It is recommended that a holdover period similar to what was employed in 2019 be maintained in future years.

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‘NAD Sampling Protocols

Supplies List

Sampling How-To

Data Summary and Analysis Methods

Notes from 2016

By Katy Pfannenstein

Mid-Columbia River Fishery Resource Office

US Fish and Wildlife Service

Katy_Pfannenstein@fws.gov

NAD Supplies List *[Bracketed numbers are **minimum** numbers needed for ONE CREW, 4-6 people, for 300 fish]*

Daily consumables:

- Data sheets: Length/weight sheet AND gonad weight sheet (Rite in the Rain) Paper number tabs (Rite in the Rain)
- Paper towels (brown single fold, ~100/pack)

General:

- [3] Clipboards
- [3] Mechanical pencils + lead
- [2] Tables
- [4] Chairs
- [4] Buckets to raise table (small white)
- [2] Power strips
- [2] Extension cords
- Garbage bags
- Absorbent lab paper to cover work surfaces (roll)
- Duct tape
- Large scissors and a sharpie
- Extra batteries (9 volt + AA)
- Buckets + aerators
- Counting clickers
- Camera/iPad

Length and weight station:

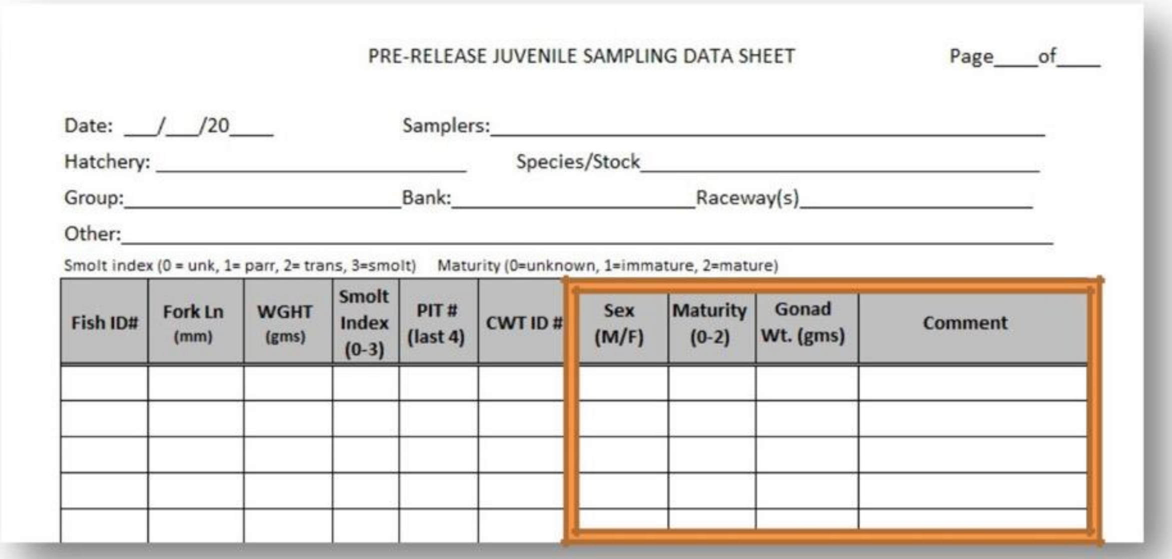
- Tricane Methanesulfonate (MS 222)
- [1] Tub for fish
- [1] Dip net
- [1] Pit scanner + [1] stand
- [4] large sponges + [1] cookie tray
- [1] Scale for weights + [1] smolt weight pan
- [1] Length board

Dissecting station:

- [1 or 2] Micro scale (minimum power 0.001 g) + power cords
- [4] Scissors + [4] tweezers
- [2] Buckets for garbage (5 gallon)
- S/M/L glove boxes
- Weigh boats for scales
- Portable lights

‘NAD Sampling How-To

1. Prepare TWO different data sheets: one with fish ID, fork length, weight, smolt index (0-3), pit #, and the other with fish ID, sex (M/F), maturation (0-2), gonad weight. Each fish will have an individual fish ID number, which will be matched up during data entry. Measure fish body weight to the nearest 0.1 g and gonad weight to 0.0001 g.

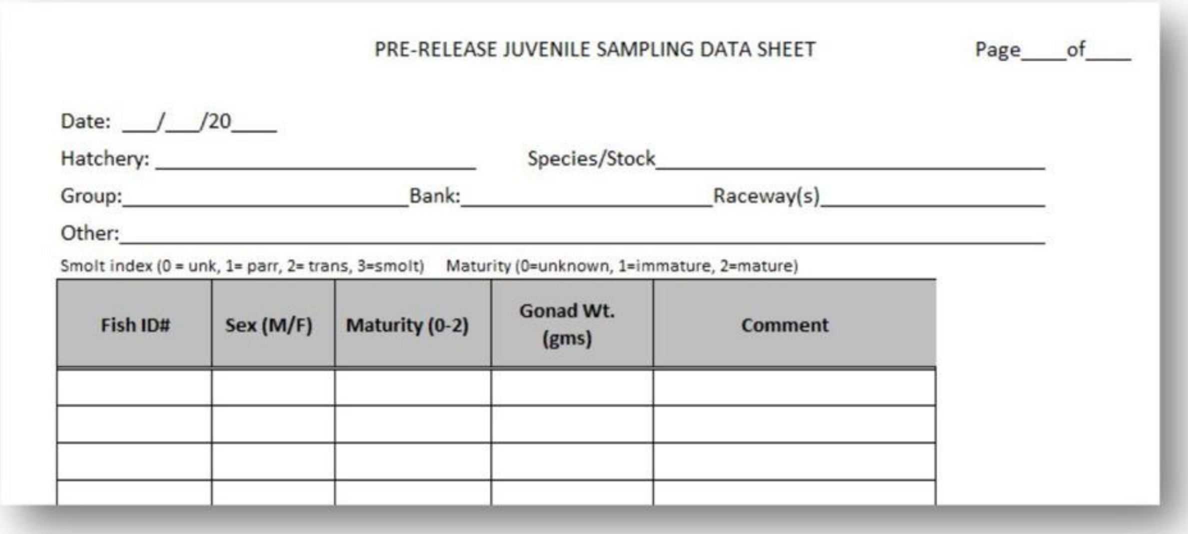


PRE-RELEASE JUVENILE SAMPLING DATA SHEET

Page____of____

Date: ___/___/20____ Samplers:______________________________
Hatchery: ______________________ Species/Stock______________________
Group:__________________Bank:_______________Raceway(s)_____________
Other:____
Smolt index (0 = unk, 1= parr, 2= trans, 3=smolt) Maturity (0=unknown, 1=immature, 2=mature)

Fish ID#	Fork Ln (mm)	WGHT (gms)	Smolt Index (0-3)	PIT # (last 4)	CWT ID #	Sex (M/F)	Maturity (0-2)	Gonad Wt. (gms)	Comment



PRE-RELEASE JUVENILE SAMPLING DATA SHEET

Page____of____

Date: ___/___/20____
Hatchery: ______________________ Species/Stock______________________
Group:__________________Bank:_______________Raceway(s)_____________
Other:____
Smolt index (0 = unk, 1= parr, 2= trans, 3=smolt) Maturity (0=unknown, 1=immature, 2=mature)

Fish ID#	Sex (M/F)	Maturity (0-2)	Gonad Wt. (gms)	Comment

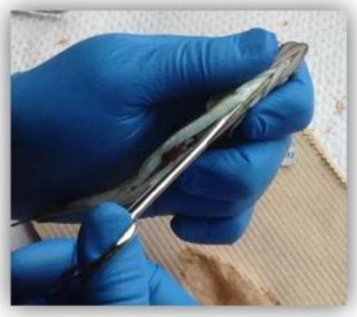
2. Collect fish from hatchery ponds. Random sample? Keep different ponds separate? CWT? Pit Tag?

3. Set up stations. Note length/weight station is at standing height.

4. Smolt index: 1. Parr, dark marks (bottom fish), 2. Transitional, faded marks (middle fish), 3. Smolt, silver, no marks (top fish)

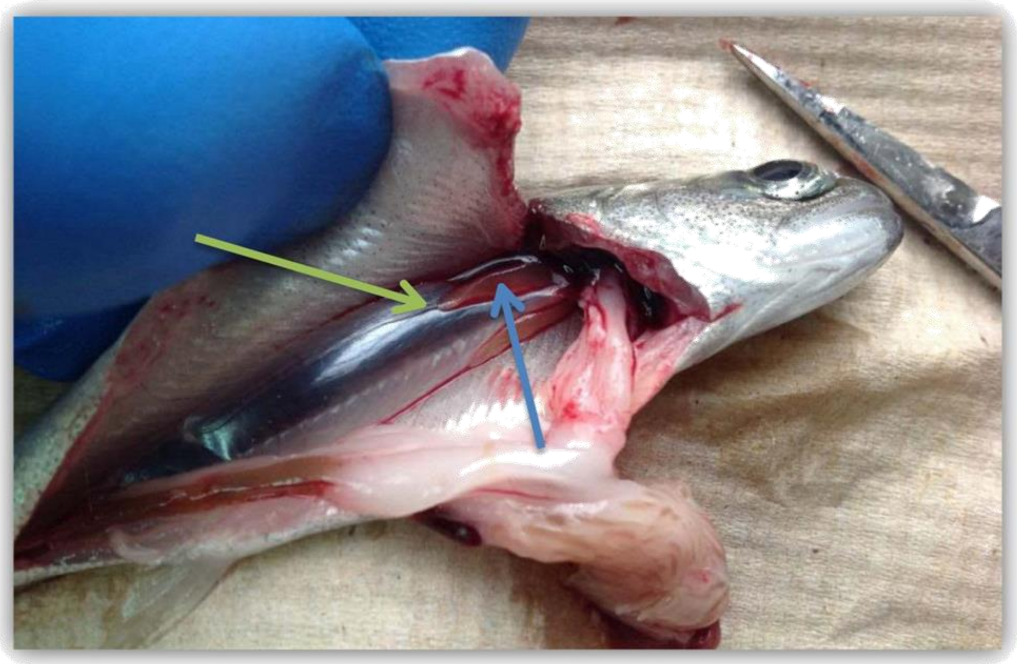
5. Set out 15-20 fish in a row on the sponges. Add number tags to fish. Assess smolt index while all fish are in the line. Obtain weights and lengths, place on paper towel to pass to the dissecting crew.

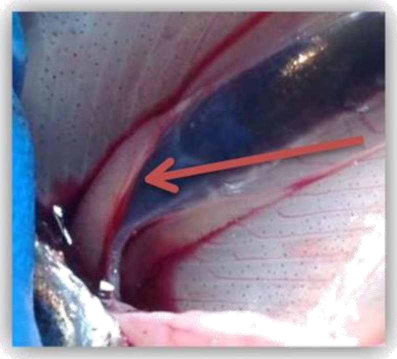
6. Fish dissection: Cut open belly from vent (shallow incision), cut behind gill, open fish and gently remove guts to expose air bladder. Both male and female gonads are located on the top/edge of the air bladder (orange arrow on mature male).



7. Female identification: 1. Ovary forms a point and then narrows to oviduct – thread like (green arrow) 2. Ovary is angular, has ridge (blue arrow), 3. Granulated

(orange arrow), 4. Color (red arrow) is not a good indicator as it can vary from pink to white.



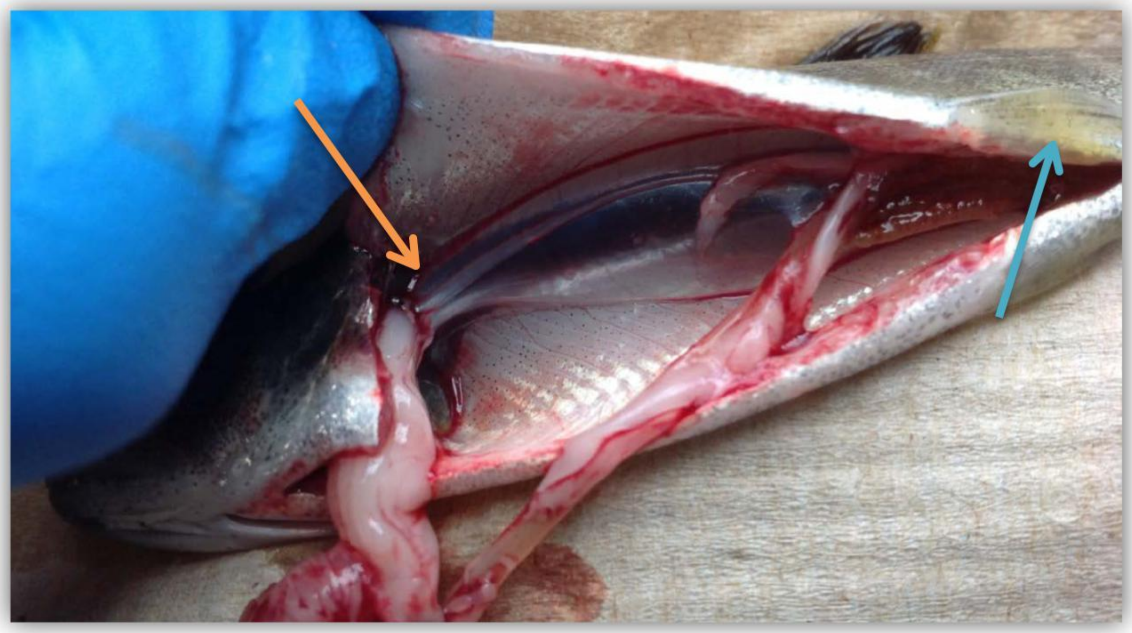


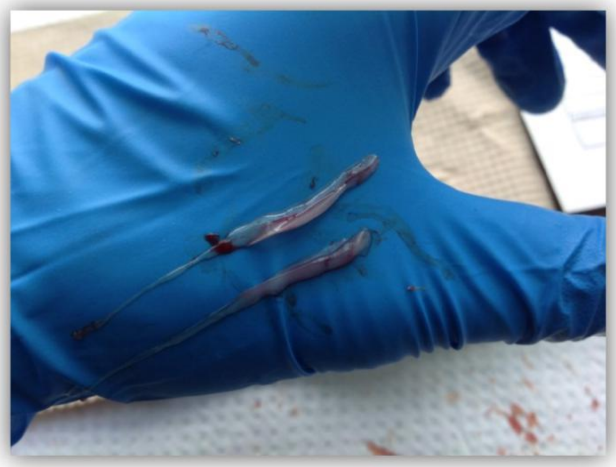
8. Immature male identification: Testes are thready throughout, smooth and round, no development or thickness (green arrows).

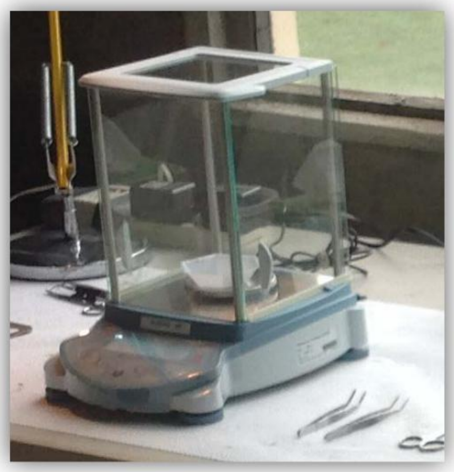
9. Mature male identification: Testes thicken, become white/translucent, smooth, tapers to tail.

10. Visually identify fish sex. If female, record fish number and sex on datasheet. If male, visually identify if immature or mature PRIOR to weighing gonads, record visual call and then remove and weigh gonads.

11. Removal of testes for weighing: Use a fine point tweezers, start as near to the anterior insertion as possible (orange arrow), gently lift the entirety of the 'nad off of air bladder down to the tail (blue arrow). Place on the back of your hand and remove second 'nad. Weigh both complete testes. If you were only able to remove one, double the weight on the datasheet, and note that only one was weighed.





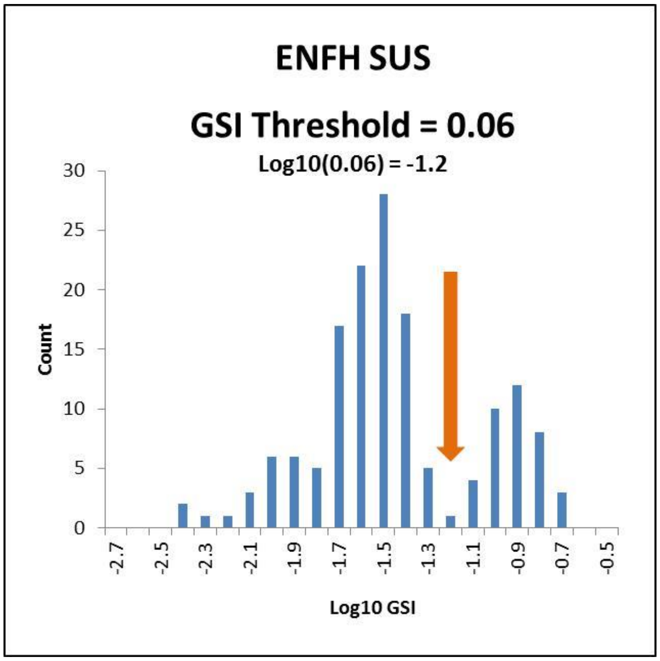


12. To use the scale: Close all doors, zero balance, open door, place ‘nads in weight boat, close doors, wait for number to stabilize. ‘Nads will evaporate and become lighter in a short period of time.

13. Enjoy all the ‘nad jokes you can handle and interagency mingling!

NAD Data Summary and Analysis Methods

- Enter data and QA/QC work, make sure to include specific banks/raceways.
- Calculate Gonadosomatic Index (GSI = gonad weight (g) / weight (g) *100).
- Calculate Condition Factor (K= (10^5) *weight/length^3).
- Calculate the Log10(GSI) and graph the frequencies in a histogram to visually see the bimodal pattern of the immature and mature males. Use this graph to determine the GSI threshold that separates immature and mature males.



- From the GSI threshold, calculate the counts, percentages, average length, weight, and condition factor for immature and mature males.
- In a summary table, for both males and females, include gender counts, percentages, and average length, weight and condition factors. For males, summarize visual counts for immature and mature fish and the percentage of mature fish. Summarize GSI counts and percent for immature and mature fish and list the average length, weigh and condition factor for each group. Make sure to note what GSI threshold was used.

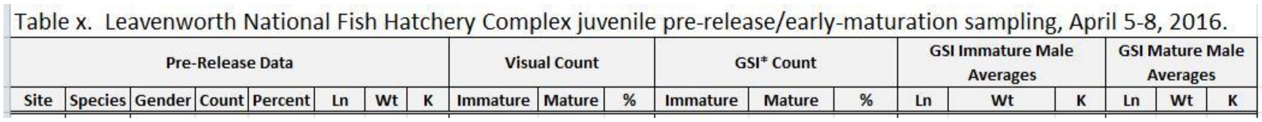


Table x. Leavenworth National Fish Hatchery Complex juvenile pre-release/early-maturation sampling, April 5-8, 2016.

Pre-Release Data								Visual Count			GSI* Count			GSI Immature Male Averages			GSI Mature Male Averages		
Site	Species	Gender	Count	Percent	Ln	Wt	K	Immature	Mature	%	Immature	Mature	%	Ln	Wt	K	Ln	Wt	K

- Perform additional statistics as desired (Were the raceways different? Feed differences? Circular tanks vs. raceways, differences between years, etc). Normality, chi-squared goodness of fit, t-test, Anova, etc.

NAD Sampling Notes (What worked? What didn't?)

- Print off more data sheets than you think you need. The two data sheet system works best; the dissectors can record their own data.
- Have two people per dissection scale- the more people that use the scale, the more awkward it gets.
- Weighing all male gonads vs. writing "T" for threads/trace? What is best for level of accuracy desired?
- Can we eyeball maturation, i.e. distinguish between 1 (immature) and 2 (mature)?
- Can maturation be determined by gonad weight or % GSI? OR is maturation highly variable and dependent on stock and/or sampling date?
- For data analysis, "T" weight gonads were given a gonad weight of 0.00001 g for a visual representation on the graphs.
- Steelhead that were expressing milt were assigned a maturity level of 3, and were counted, but not weighed. For data analysis, they were assigned a gonad weight of 1.0 g in order to calculate GSI and to be visually represented on the graphs.

Thank you to everyone who participated in the 2016 'NAD sampling: USFWS, WDFW, Chelan PUD, Douglas PUD and Grant PUD!

References:

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.

Harstad, D. L., D. A. Larsen, and B. R. Beckman. 2014. Variation in minijack rate among hatchery populations of Columbia River basin Chinook salmon. Transactions of the American Fisheries Society 143:768-778.

Mixture model and maturity cutoff calculation

For Data Analyses: Determine cutoff for maturing vs. non-maturing fish

From Dr. Lea Medeiros, University of Idaho Post-Doc
Example using C16 11-kT data from minijack study
Export list of Log(conc) or Conc (and convert to Log(conc) once imported into R studio)
Import C16 CSV using import button in rStudio

- Make sure that the separator is set to “Comma” if importing a CSV… sometimes wants to import as whitespace

Copy and paste the code below the line into rStudio

```
# Load the appropriate packages
library(mixtools)
library(diptest)
library(Hmisc)

# Define variables (columns in imported CSV)
LC=C16$Log
        # Only define variables for which you have columns
        # If value shows up as factor instead of num you have a non-numeric value in the
CSV

# Determine if distribution is bimodal
dip.test(LC) # returns dip statistic (D) and p-value, as well as what hypothesis (i.e., initial or
alternate) to accept. If alternate is accepted, proceed.
# Determine the variables for the normal curves in the bimodal distribution
model=normalmixEM(LC)
plot(model, whichplots = 2)
#Make sure things look right, but won’t actually use this graph as it plots on a density scale
and may cause confusion. However, this should look pretty spot on (final graph will just be
scaled up by a constant determined later on) so make sure that the point where the two
curves intersect is where you are expecting the cutoff to be
# Determine cutoff
index.lower <- which.min(model$mu)
find.cutoff <- function(proba=0.5, i=index.lower) {
  ## Cutoff such that Pr[drawn from bad component] == proba
  f <- function(x) {
    proba - (model$lambda[i]*dnorm(x, model$mu[i], model$sigma[i]) /
           (model$lambda[1]*dnorm(x, model$mu[1], model$sigma[1]) +
model$lambda[2]*dnorm(x, model$mu[2], model$sigma[2])))
    }
    return(uniroot(f=f, lower=-2, upper=2)$root)  # Careful with division by zero if
changing lower and upper
```

```
}
cutoff <- c(find.cutoff(proba=0.5)) # Can change to have range around 50/50 probability, but this is the value we use to determine if a fish is maturing or not

# Define curves from normalmixEM for plotting on histogram
h <- hist(LC,ylim=c(0,140),breaks=20) # will produce basic histogram of data used for stats it produces; may need to alter ylim to reflect frequency of tallest bin and breaks
xfit <- seq(-0.7,1.4,length=200)
        #First number should minimum bin, second number should be maximum bin, length is number of plots pointed (higher number = smoother curve… to a point)
yfit1 <- model$lambda[1]*dnorm(xfit,mean=model$mu[1],sd=model$sigma[1])
yfit2 <- model$lambda[2]*dnorm(xfit,mean=model$mu[2],sd=model$sigma[2])
yfit1 <- yfit1*diff(h$mids[1:2])*length(LC)
yfit2 <- yfit2*diff(h$mids[1:2])*length(LC)

# Plot pretty graph
v1 = seq(-0.65,1.35,length=11) # offset from minimum bin by 0.05 so that ticks are in middle of bins
v2 = c(0.2, 0.32, 0.50, 0.80, 1.26, 2.0, 3.2, 5.0, 7.9, 12.6, 20.0) # actual ng/mL values on log scale
hist(LC, breaks = 20, density = 10, col = "purple", xaxt="n", xlab = "Plasma [11-kt] (ng/mL)", ylim = c(0, 140), main = "Plasma [11-kT] in Yakima River Juvenile Males")
lines(xfit, yfit1, col="red", lwd=2)
lines(xfit, yfit2, col="blue", lwd=2)
axis(side = 1, at = v1, labels = v2)
abline(v=cutoff, col="green", lty=2, lwd=2)
text(0.05,135, paste("Minijack cutoff", "\n =", round(10^(cutoff), 2),"(ng/mL)" ))
```