THE CHIEF JOSEPH HATCHERY PROGRAM
SUMMER/FALL CHINOOK

2019 ANNUAL REPORT

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This report includes both hatchery production/operations and the corresponding monitoring activities completed through April of 2020. 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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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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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 2019 during the seventh year of operation for the Summer/Fall Chinook program. In July and August the CCT used a purse seine vessel to collect 1,223 summer/fall Chinook for broodstock for both the integrated and segregated programs (including Similkameen). Additionally, 10 summer/fall Chinook were collected at the Okanogan adult weir in August and 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 89.9% for hatchery-origin broodstock (HOB) and 95.8% for natural-origin broodstock (NOB). The survival standard (90%) was met by both the hatchery-origin and natural-origin brood. Total green egg take for the season was 2,530,220 (93% of full program). Egg survival from green egg to eyed egg averaged 82.9% for NOB and 87.2% for HOB, both under the survival standard (90%) for this life stage. Cumulative egg survival from green egg to eyed egg was 82.9% for NOB and 87.2% for HOB, which is under the survival standard (90%) for this life stage. After in-hatchery mortalities from pre-spawn holding through ponding there were 1,354,996 fish on hand at the end of April for the yearling releases in 2021 (93% of the yearling program) and 565,777 fish on hand for the sub-yearling releases in May 2020 (81% of full program).

2019 was the fifth year for Summer/Fall Chinook hatchery yearlings released from the CJH, Similkameen and Omak acclimation ponds. In April, 280,055 integrated yearling summer/fall Chinook were released from the Omak acclimation pond and 240,812 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 800,000 integrated yearlings. There were no integrated or segregated sub-yearlings from brood year (BY) 2018 released in May 2019. However, there were 399,299 yearling Chinook released directly from Chief Joseph Hatchery (80% of full program).

After release, the yearling programs from CJH and Omak Pond had similar survival when compared to previous years and other programs. Although CJH survival was about 7% below the -five-year mean, the travel time was considerably longer (11-12 days to Rocky Reach and McNary dams). In contrast, the travel time for fish released from Omak Pond was only 2-5 days slower than the five-year mean to Rocky Reach and McNary dams and the resulting survival was 0-4% higher than the five-year mean. The majority (>90%) of PIT tagged hatchery smolts released from Omak Pond migrated to the lower Okanogan River within three weeks of release. Although overall outmigration was slower than in previous years, 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 April 1 and continued through June 19, capturing 3,880 natural-origin Chinook and 290 hatchery-origin Chinook. After conducting 2 mark-recapture events, the efficiency of the trapping configuration was calculated to be approximately 0.65%. Because of the inability to collect sufficient data to confidently estimate juvenile outmigration, abundance estimates were not produced for the 2019 outmigration. 934 steelhead (*O. mykiss*) were also captured in the rotary screw trap including 32 natural-origin (adipose fin present and no CWT) and 902 hatchery-origin (adipose fin clipped and/or CWT present). Other species commonly caught in the rotary screw traps included Sockeye (*O. nerka*) (961), Yellow Perch (*P. flavescens*) (59), Northern Pikeminnow (*P. oregonensis*) (279), Bridgelip Sucker *(C. columbianus)* (38), and Mountain Whitefish (*Prosopium williamsoni*) (519).

Beach seining captured 26,757 juvenile Chinook and 26,439 (98%) were PIT tagged and released. Pre- and post-tag mortality was 2.8% and 2.5% respectively. In 2019, wild summer Chinook tagged at the mouth of the Okanogan had a minimum apparent survival of 36% (2% SE) to Rocky Reach Juvenile Bypass (RRJ) and 53% (16% SE) to McNary (MCN).

The lower Okanogan Adult Fish Weir was deployed on July 15th when discharge was 1,540 cfs. The thermal barrier was present in the lower Okanogan after installation until August 22nd 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 26% of fish passage occurred before the weir trap was operational in late August. In August pickets were up on the weir panels due to a high density of algae in the river. The algae created a dense blanket across the weir panels, and it became too difficult for field staff to maintain the weir without creating a head differential across the panels that was within the project's operating criteria.

Trapping occurred on 5 total days with the majority (87%) being caught from September 9-11. One hundred and fort-three adult Chinook were trapped in 2019. Ten natural-origin and two hatchery-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 2.3% 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. There were only 7 Chinook carcasses collected from July-September, however, this is likely an underestimate since weir panels were open for most of the season. 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 11.

Spawning ground surveys estimated 2,371 summer/fall Chinook redds and 467 carcasses were recovered (226 natural-origin and 241 hatchery-origin). Adult summer/fall Chinook spawning escapement in 2019 was estimated to be 5,453, with 2,604 natural-origin spawners and 2,849 hatchery origin spawners. In 2019, the effective pHOS (0.47) and the proportion of natural influence (PNI) (0.57) did not meet the program objectives (<0.3 pHOS, >0.67 PNI). The failure to meet PNI in 2019 was due to a conscious management decision to decrease the pNOB (0.63) 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 (0.29) and PNI (0.78) 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 2019. CCT removed 1,445 hatchery fish, including 41 jacks, during surplus events at the CJH ladder and trap, and tribal members removed another 1,314, including 51 jacks, at the Chief Joseph Dam tailrace fishery. The Harvest program's purse seine removed 101 hatchery fish, including 95 jacks. 15 natural-origin fish, including 1 jack, were released during surplus at the Chief Joseph Hatchery ladder. The purse seine released 182 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 143 fish in 2019, in which no hatchery fish were removed and 111 natural-origin fish, including 37 jacks, and 22 hatchery-origin fish were released back to the river. Within the WDFW state fishery, 1,931 hatchery Chinook, including 98 jacks, were harvested and 967 natural-origin Chinook, including 55 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).

Indeed, spawner distributions have changed during the CJH-era (2016-2019) compared to years prior. We find an increased proportion of redds in reaches O2 thru O6, and reduced proportions in reaches S1 and S2 for years 2016-2019 compared to years 2006-2015. Additionally, carcass recovery data show shifts in the composition of spawners, with increased pHOS in the lower basin (Reach O2) and reduced pHOS upstream. These changes in composition and distribution of spawners across the basin are likely the results of hatchery acclimation strategies, specifically with hatchery fish relating to their Omak Pond acclimation site in the lower basin and should help with the effectiveness of natural-origin spawners in the prime spawning habitat in the upper basin (Reach O6 and S1).

The CJH coded wire tag lab was in its fourth year of operation in 2019. 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 (53%) followed by Wells Hatchery (30%), Chelan Falls (8%), Dryden (4%), Okanogan integrated (4%), and three other programs made up the remaining 1%.

The majority (66%) of hatchery-origin spawners recovered on the spawning grounds in 2019 were from Similkameen (44%) and Okanogan (24%). Chief Joseph Hatchery segregated Chinook comprised 36% 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 2019, 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 (51%). Reach S1, the location of the Similkameen acclimation site in the Similkameen River accounted for almost half of the estimated spawning by Similkameen Pond fish (48%). 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 2014. The 2014 brood year had a stray of 0.9% to non-target basins and 1.0% to non-target hatcheries, which was similar to the long term and recent five-year average (1.0% for non-target basins and 0.2% to non-target hatcheries).

An Annual Program Review (APR) was held in April 2020 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 38,300 Upper Columbia summer/fall Chinook, the plan for 2020 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

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

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
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.

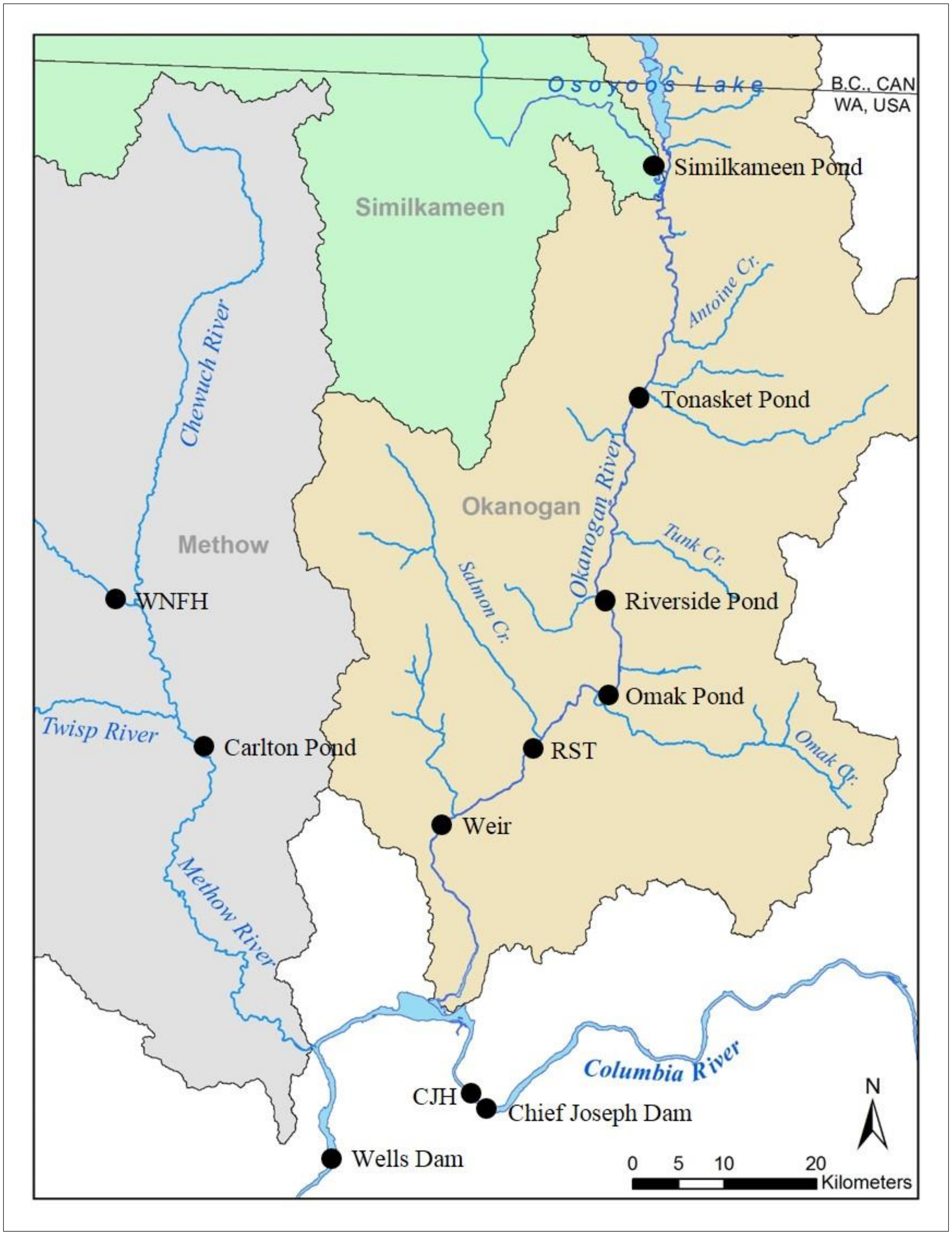

Figure 1. Map of the U.S. portion of the Okanogan River Basin, the Chief Joseph Hatchery (CJH), Winthrop National Fish Hatchery (WNFH), Okanogan adult weir (Weir), Rotary screw trap (RST), and Chinook Salmon acclimation sites. Horizontal coordinate information is referenced to the North American Datum 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 on the lowermost 27 km of the Okanogan River. Water level fluctuates frequently because of operational changes (power generation, storage) at Wells Dam.

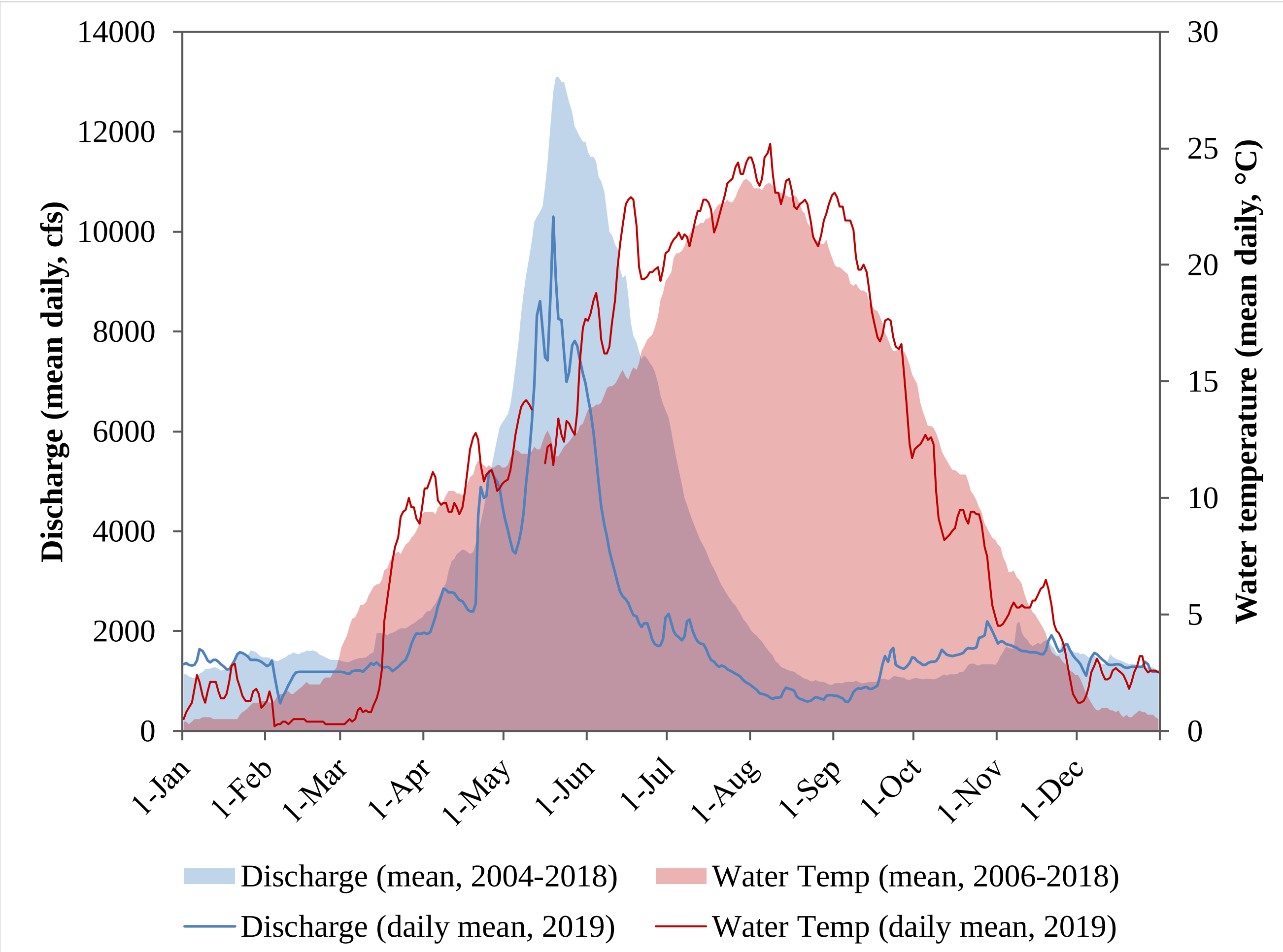

Figure 2. Okanogan River mean daily discharge (blue lines) and water temperature (red lines) at Malott, WA (USGS Stream Gage 12447200).

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.

[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 the Chief Joseph Hatchery Science Program office in Omak, WA. 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 April 1 to June 13, 2019. Trapping typically occurred continuously from Sundays at 2000 until Friday at 1300. 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.

The program did not capture enough subyearling wild juveniles from the screw traps in 2019; therefore, hatchery yearlings from the Omak Pond were used instead. Hatchery 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

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

Where $\hat{N}$ 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, $\hat{V}[\hat{N}]$, is calculated by the equation

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

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

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

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 14-16 in the Okanogan River side channel just upstream of Riverside and from May 28 to June 26 in the area near the confluence of the Okanogan and Columbia Rivers. Efforts at the confluence were 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). This area is known as Gebber's Landing. 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 based on results from stable isotope analysis conducted in 2018.

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 28 and 29, 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, tag reader, and antenna) needed for tagging. Water was pumped directly from the river using a ¼ horsepower pump. When tagging water temperatures were >17 °C, water was replaced in the trough with cooler water from the river. 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.

The 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 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 PITTAG4 (P4) software (Pacific States Marine Fisheries Commission). After completion of the tagging events, tag files were consolidated, uploaded to PTAGIS (www.ptagis.org).

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, expelled (shed) tags from live fish were recovered from the mesh floor via a powerful magnet. After that was completed, 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. Carcasses of summer Chinook were returned back to the river.

Lower Okanogan Adult Fish Pilot Weir

The Okanogan adult fish pilot weir (herein referred to as the 'weir') was in its eighth year of design modifications and testing in 2019. 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 2019 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 July 15th at a river flow of 1,540 cfs. and was completed with the underwater video system on July 19th. 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 (Figure 6). The trap was 3 m wide, 6 m long and 3 m high. 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 riverbanks, 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. Sandbags 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, 2019. Photo taken in late- August.

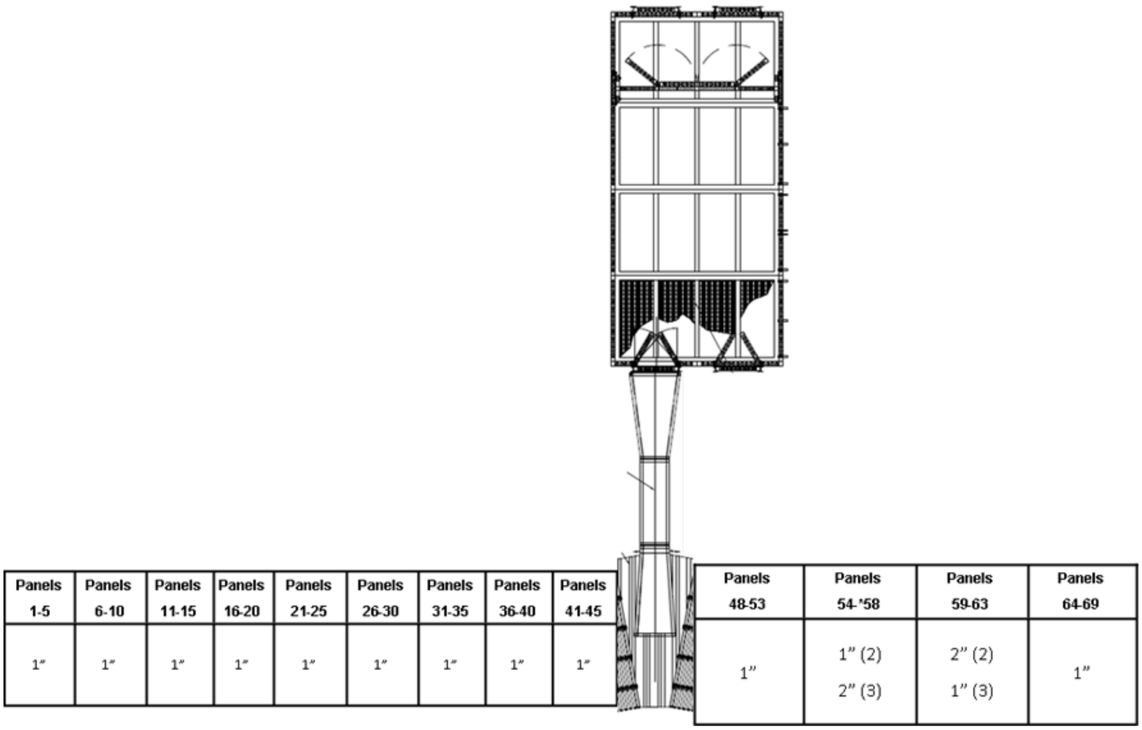

Figure 7. Conceptual diagram of picket (ABS pipe) spacing within each panel (or set of 5 panels) at the Lower Okanogan adult fish pilot weir. A 15 ft entrance chute was installed at the lower trap gate in 2019.

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) or afternoon (1200-1400), depending on when fish were migrating. 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 for the majority of the season, from July 22-August 25 and August 28- September 8. The last day of trapping was on September 11th. 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.

Nine natural-origin and two hatchery-origin Chinook were collected from the weir trap from August 26-27 and September 9-11, 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 2019 because by the time we were able to trap and collect brood for the program, only 10 adults were needed, which did not justify the program's need to setup the system.

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 (2.300 for 2019). The expansion factor = 1 + the number of males per female as randomly collected for broodstock at Wells Dam (1.300:1.000 in 2019). 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 2019 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 2019 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, although carcass efforts also occurred once a week during August and September on the Similkameen River as well. These surveys assessed potential prespawn mortality that occurred for those fish that held in the cooler waters of the Similkameen River before spawning began in October. 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)

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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.

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

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:

[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.

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

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:

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

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 March 2020 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.

[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).

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. A PIT tag group from the Similkameen Pond was released in 2019. 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 2019 to February 2020. 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

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

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

The rotary screw traps captured 4,170 Chinook juvenile out migrants, including 290 hatchery-origin and 3,880 natural-origin. The mean length of Chinook increased throughout the trapping season 873 natural-origin smolts were large enough (>60 mm) to PIT tag 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 Sockeye (Table 3). Thirty-two adipose fin present[6] steelhead and 902 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 1% juvenile trapping and handling mortality rate for steelhead. The encounter of 902 adipose clipped and 32 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).

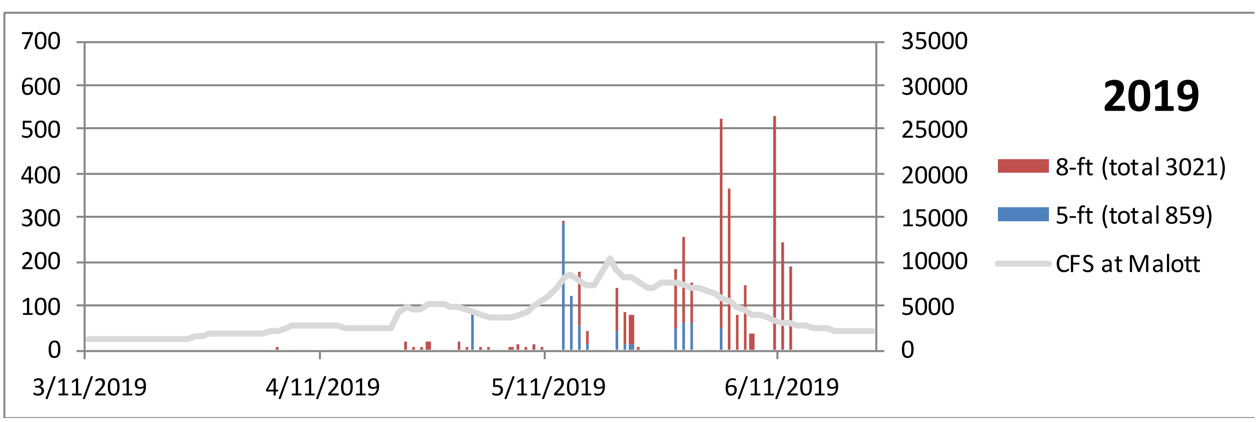


Figure 8. Daily natural-origin sub-yearling Chinook catch within an 8 foot and 5 foot the Okanogan River in 2019.

[6] Not all hatchery steelhead released in the Okanogan receive an adipose fin clip. In 2019, 183,353 steelhead were released into the Okanogan River with an adipose clip, and 18,197 unclipped steelhead were released.

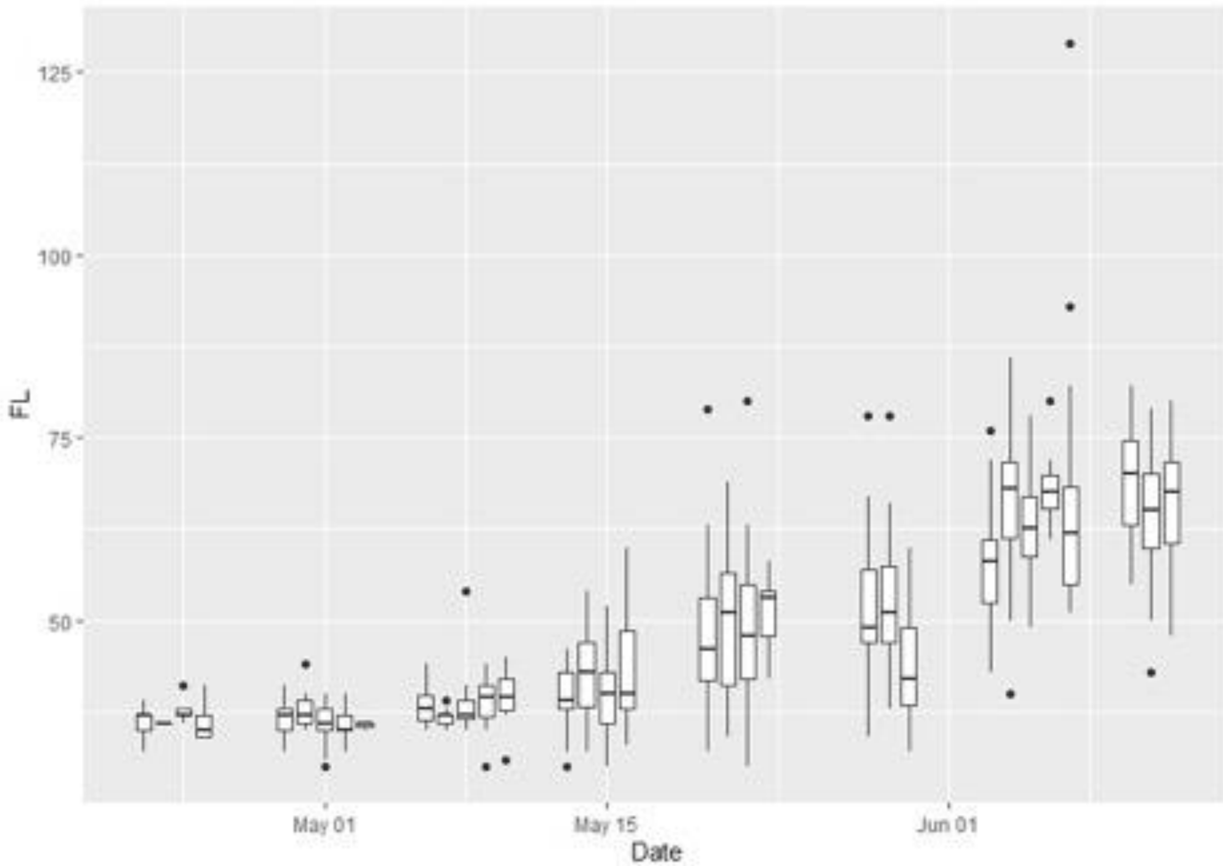


Figure 9. Natural-origin sub-yearling Chinook size distribution (n= 1,003) from the rotary screw traps on the Okanogan River in 2019. Boxes encompass the 25th to 75th percentiles of measured fish, points represent statistical outliers, and the mid-line in the box is the median fish length. FL = fork length in millimeters (mm).

Table 3. Number of juvenile fish trapped at the Okanogan River rotary screw traps in 2019.

Species	Total Trapped
Bluegill	14
Bridgelip Sucker	38
Common Carp	0
Longnose Dace	8
Northern Pikeminnow	279
Largemouth Bass	0
Sculpin (*Cottus* spp.)	4
Smallmouth Bass	16
Three Spine Stickleback	15
Peamouth	0
Redside shiner	0
Crappie (*Pomoxis* spp.)	0
Bullhead (*Ameiurus* spp.)	1
Yellow Perch	59
Yellow Bullhead	2
Channel Catfish	1
Unknown Dace	2
Non-salmonid total	439
Adipose Clipped steelhead	902
Adipose Present steelhead	32
Hatchery Chinook	290
Sockeye	961
Wild Chinook Subs	6635
Wild Chinook Yearling	0
Eastern Brook Trout	0
Mountain Whitefish	519
Salmonid total	10,217

Two 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 2019 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 2019 outmigration.

Table 4. Efficiency trials conducted on hatchery-origin Chinook yearlings at the Okanogan rotary screw traps in March and April 2019.

Trap Date	River Flow @ USGS Malott	Total Chinook Marked and Released	Age Class / Origin	Total Chinook Recaptured	Trap Efficiency
4/2	1,980	1,916	1+ / Hatchery	22	1.15%
4/8	2,820	2,004	1+ / Hatchery	3	0.15%
Total		**3,920**		**25**	**0.65%**

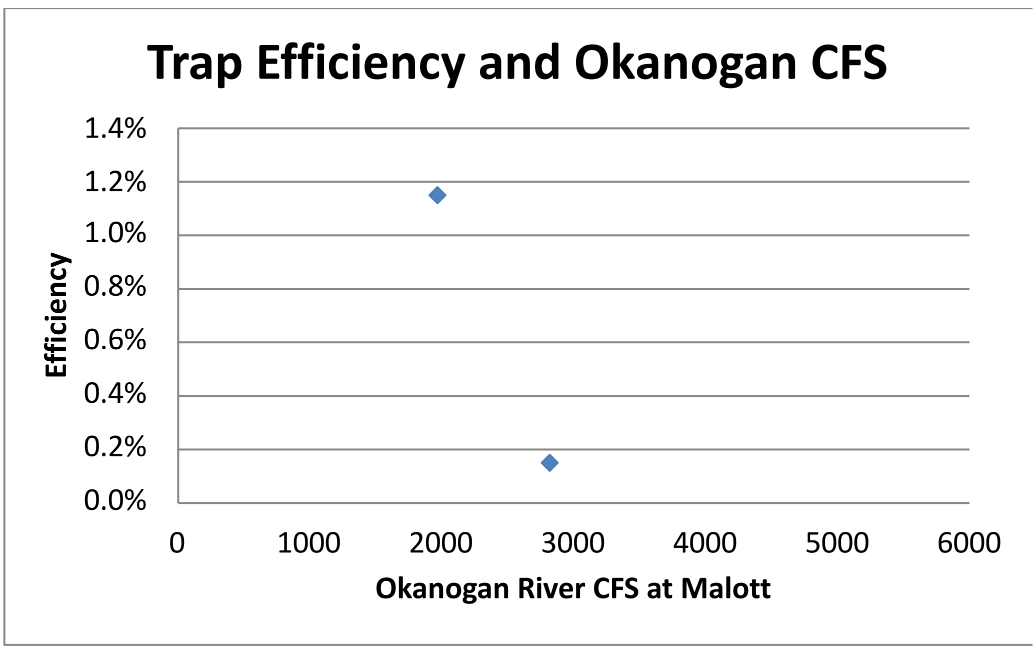


Figure 10. The efficiency trials conducted with hatchery-origin subyearlings are marked in blue.

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 2019 were conducted with hatchery-origin yearlings because of their availability for use and an inability to capture sufficient numbers of natural-origin subyearlings. Twenty-five hatchery-origin yearlings out of 3,920 released were recaptured (0.65% 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 trial results for 2.4m trap configurations. The 1.5m trap was not installed until 5/1/19 after efficiency trials were conducted; this is subject to flow conditions as well as yearling fish availability and their target release dates.

Trap	Stock	Mark-Released	Recaptured	Efficiency
2.4 m Trap	Hatchery Subyearling	N/A	N/A	N/A
	Hatchery Yearling	3,920	25	6.5%
1.5 m Trap	Hatchery Subyearling	N/A	N/A	N/A
	Hatchery Yearling	N/A	N/A	N/A

Table 6. Okanogan River Basin. Two efficiency trials were conducted with hatchery-origin yearling Chinook, and efficiency was low and variable. Juvenile abundance could not be reliably estimated in 2019.

Species	Population Estimate	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Hatchery-origin Chinook*	N/A	N/A	N/A
Natural-origin*** Chinook	N/A	N/A	N/A

* A total of 731,449 yearling hatchery-origin Chinook were released into the Okanogan River system upriver from the screw trap site in 2019. 210,582 were released from the Riverside acclimation pond from April 15-30; 240,812 were released from the Similkameen hatchery from April 15 – April 30; 280,055 were released from the Omak acclimation pond on April 15-30; and 8,229 hatchery-origin Chinook were released in Canada into the Okanagan River.

Juvenile Beach Seine and Pit Tagging

In 2019, 26,757 natural-origin juvenile salmonids were collected in over the course of 13 tagging days (Table 7.). Out of the juvenile summer/fall Chinook collected, 26,439 (98%) sub-yearling Chinook were PIT tagged and released (Figure 11). Pre- and post-tag mortality was 2.8% and 2.5% respectively. Twenty-six shed tags were recovered from the net pens prior to release, these tags 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), fish catch peaked June 8 through June 14 (Table 7). By late-June, Columbia River temperatures approached 14° C and catch began to decline. 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 43-113 mm, with an average of 67.8 mm (SD 9.6 mm) and a median of 68 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 in 2019. 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
5/28/2019	526	526	100%
6/5/2019	9,668	8,927	92%
6/11/2019	10,892	9,417	86%
6/18/2019	6,058	4,926	81%
6/24/2019	3,152	2,643	84%
Total	**30,296**	**26,439**	**87%**
Mean	**6,059**	**5,288**	

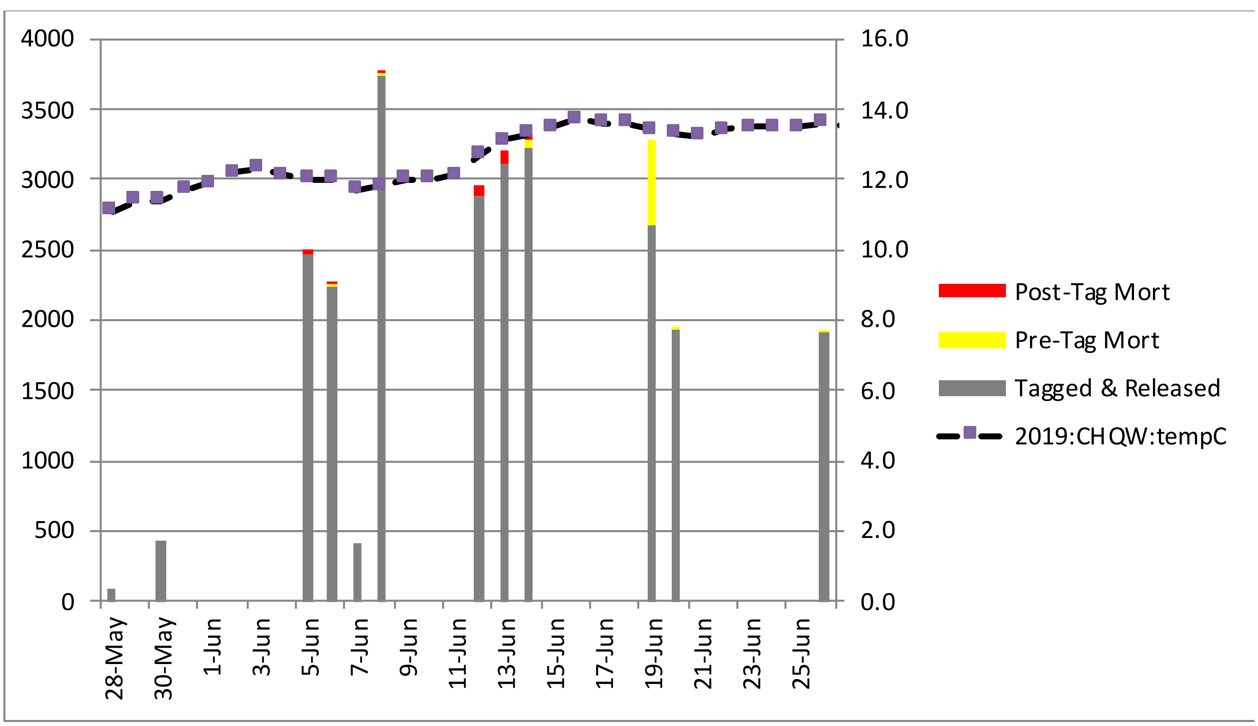


Figure 11. Total mortality and number of released natural-origin sub-yearling Chinook in 2019. Primary y-axis shows number of juvenile Chinook; secondary y-axis (right hand side) shows water temperature (degrees Celsius (C)).

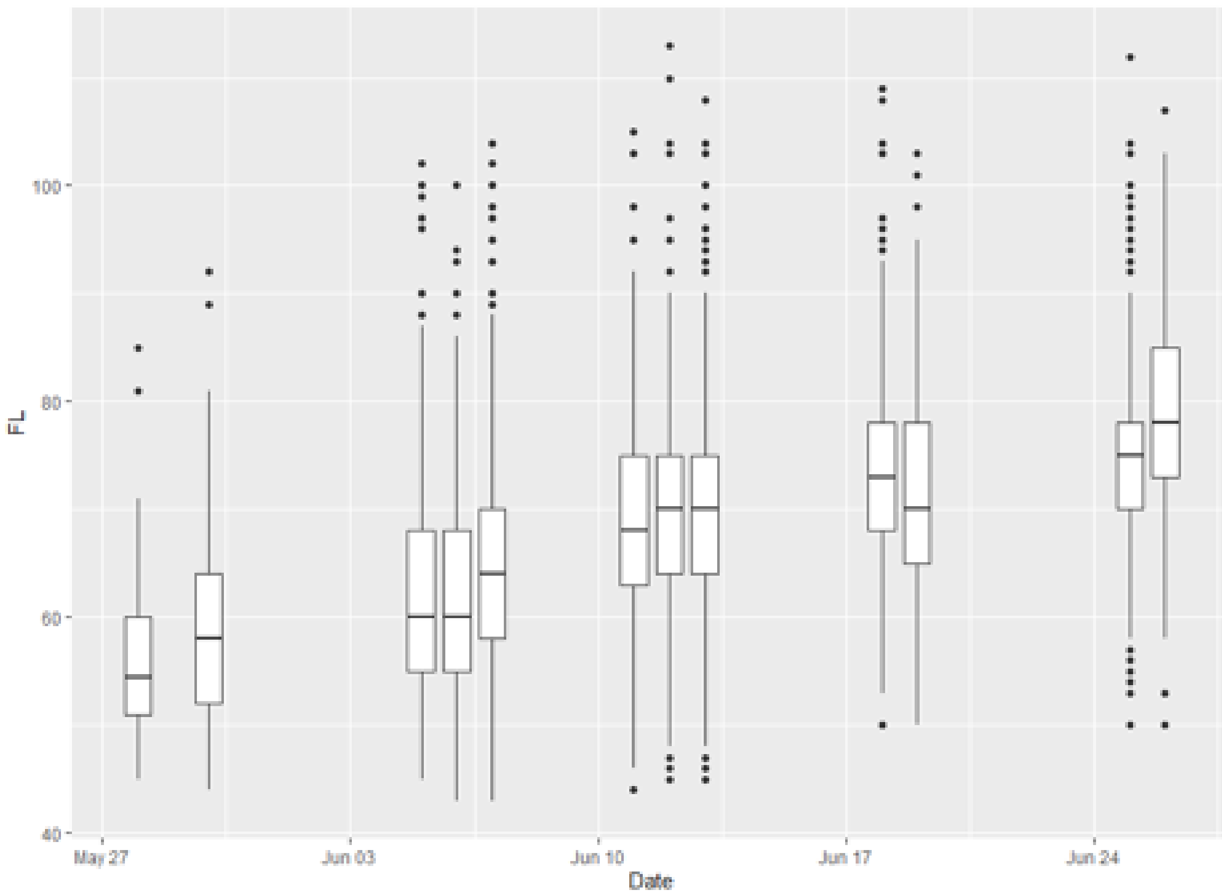


Figure 12. Size distribution of PIT tagged juvenile Chinook by release date from the beach seine effort in 2019. Boxes encompass the 25th to 75th percentiles of measured fish; the mid-line in the box is the median fish length. FL = fork length in millimeters (mm).

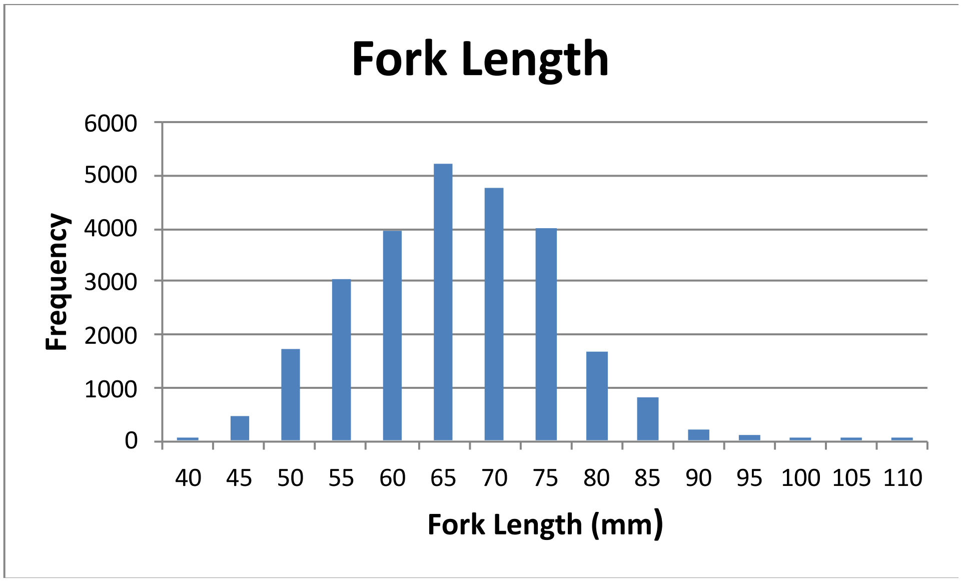
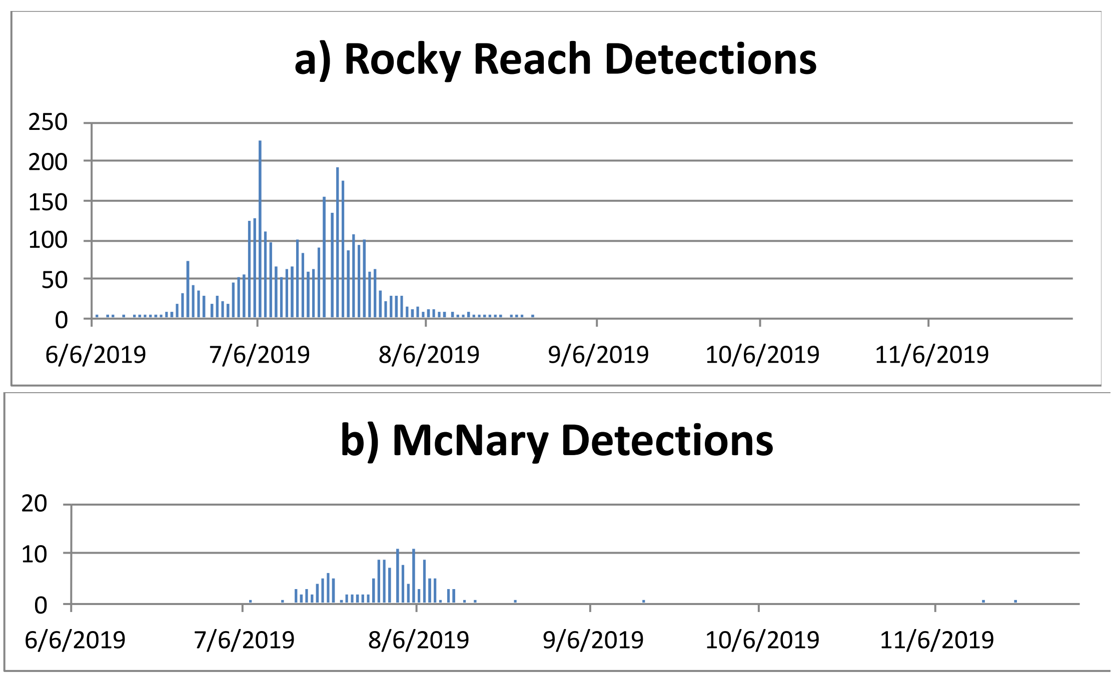


Figure 13. Size distribution of natural origin sub-yearling Chinook tagged during the beach seining effort in 2019.

The Rocky Reach juvenile bypass system detected 3,279 PIT tagged juvenile Chinook from the beach seining effort, which was 12.2% of total fish tagged and released. One hundred twenty-nine (0.6%), 280 (1.1%) and 11 (0.5%) 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 36% (SE 2.0%) to Rocky Reach and 53% (16.0% SE) to McNary.



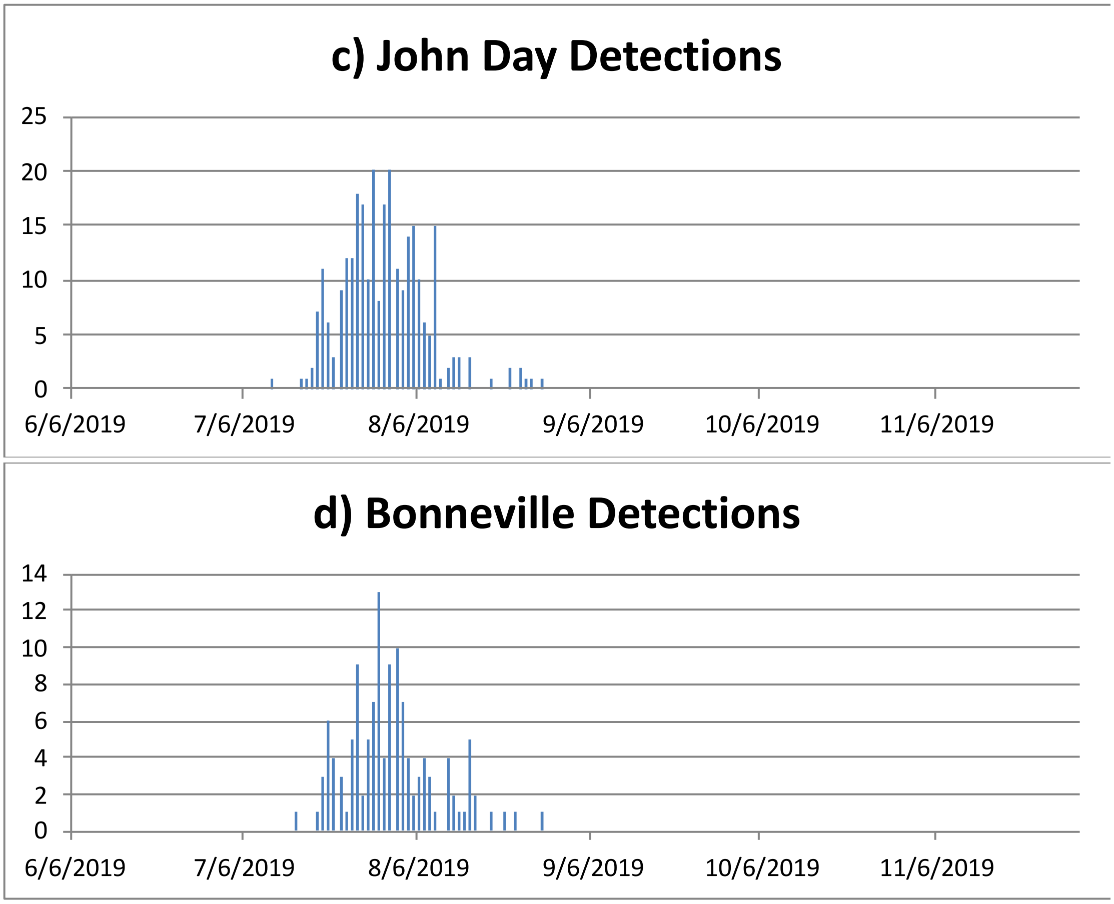


Figure 14. Daily distribution of detections of PIT-tagged sub-yearling Chinook at Rocky Reach, McNary, John Day, and Bonneville Dams in 2019. Note differences in scale on the y-axis. The y axes denote the numbers of PIT-tagged fish encountered daily at each of the mainstem project arrays.

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)	36.4(SE = 0.24; n=3,280)	2.6	50.5(SE = 1.42; n=128)	7.6	49.5 (SE = 0.99; n=280)	10.3	49.2(SE= 0.77; n=125)	12.6
Rocky Reach (762)			10.4(SE = 0.75; n=41)	28.1	14.8 (SE = 0.68; n=100)	28.0	16.4 (SE = 0.64; n=52	32.1
McNary (470)					3.2 (SE = 0.32; n=8)	38.4	4.9(SE=0.41; n=2)	48.0
John Day (347)							2.1(SE = 0.08; n=21)	53.3

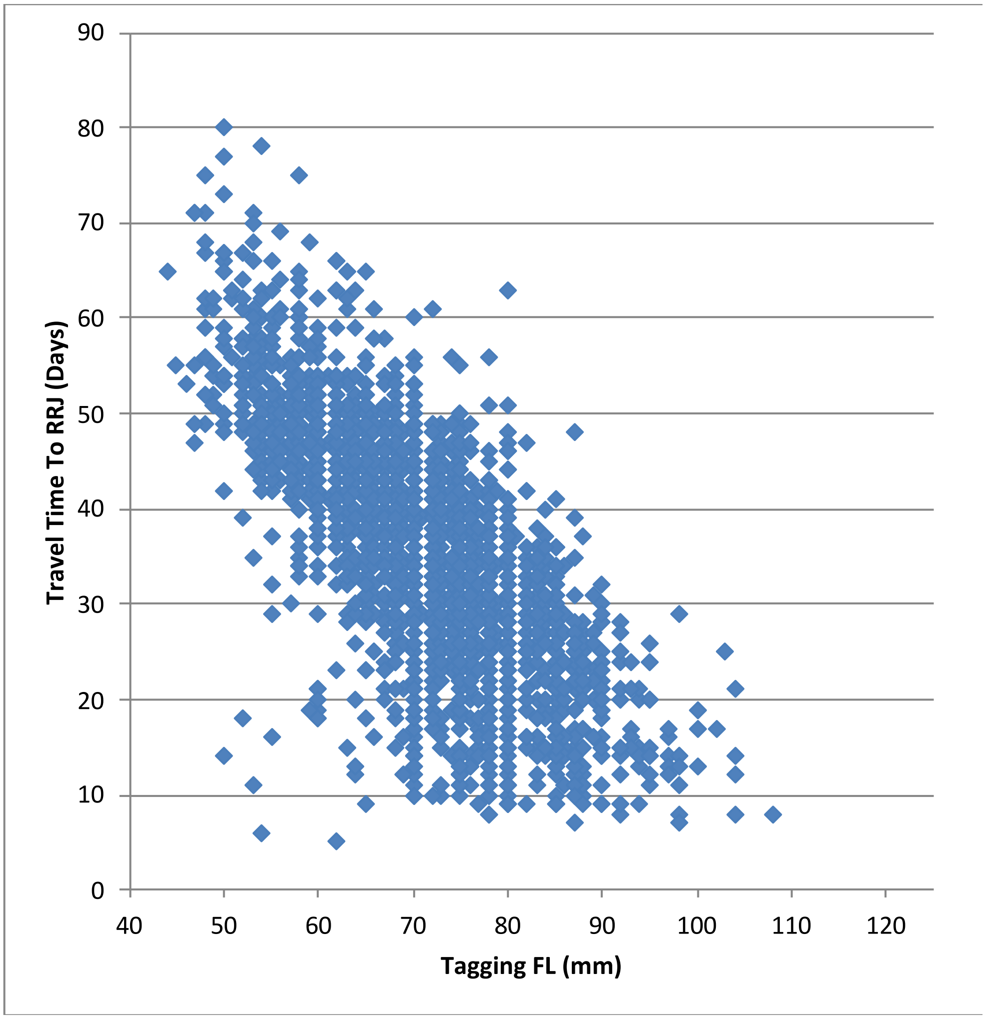


Figure 15. Fish size (fork length) and travel time of tagged Chinook to Rocky Reach Dam.

Lower Okanogan Adult Fish Pilot Weir

The Okanogan River (at Malott) discharge was below normal in 2019 and was below 1,000 cfs. for the majority of the trapping season. Staff were able to safely enter the river and begin installation on July 15th when discharge was 1,540 cfs. (Figure 16). Discharge continued to drop throughout the season and was at 1,000 cfs. by the time the weir was removed for the season.

Migration of sockeye and summer/fall 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 2019, 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 22. Daily mean temperature dropped below 22.5 °C on August 22nd and stayed below this mark until August 30th. Mean temperature dropped below the mark again on September 3rd and stayed below it for the rest of the season.

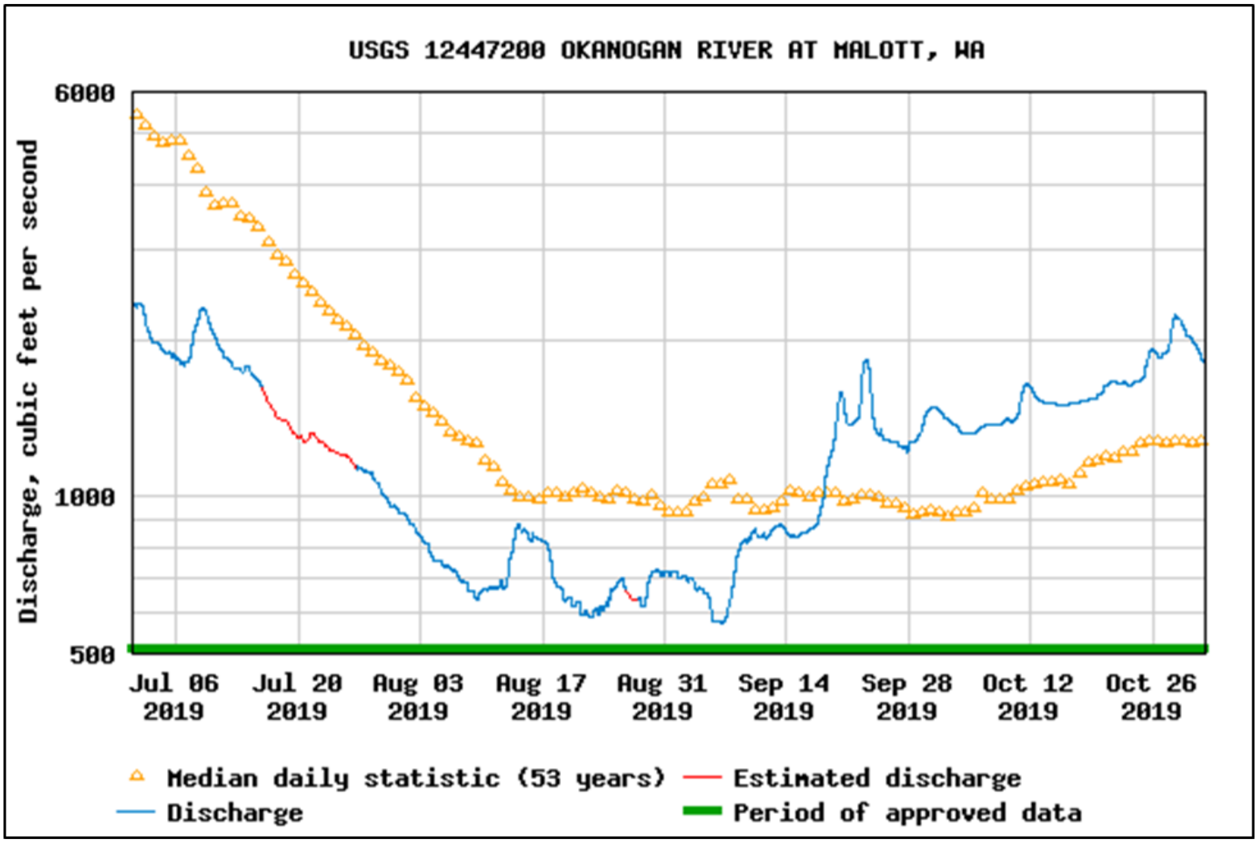


Figure 16. Discharge of the Okanogan River between July 1 and October 31, 2019. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

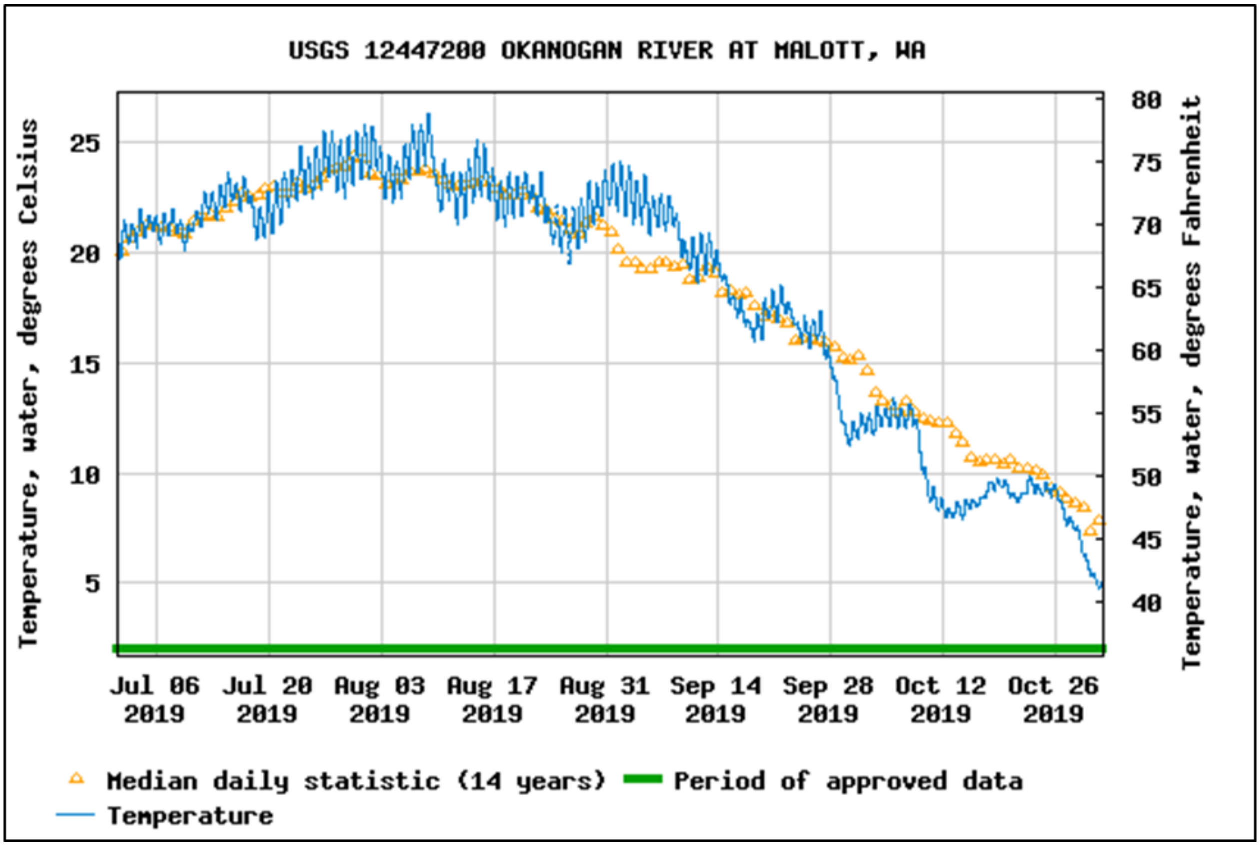


Figure 17. Temperature of the Okanogan River between July 1 and October 31, 2019. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

Dissolved Oxygen varied from 6.0 to 9.6 mg. /L; total dissolved solids varied from 130-158 ppm. and turbidity varied from 1.0 and 4.5 NTUs (Table 9). The head differential ranged from 2.0-3.0 cm across the weir panels. The maximum water velocity measured was 2.9 ft /sec (Table 10).

Table 9. Water quality data at or near the lower Okanogan weir in 2019. 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)
7/29	1.7	8.6	130	1.9
7/30	1.7	8.4	130	1.8
7/31	1.7	9.6	135	4.5
8/1	1.7	7.3	133	2.8
8/2	1.7	8.1	138	1.6
8/5	1.5	7.4	142	1.2
8/6	1.5	7.7	145	1.4
8/7	1.5	7.1	149	1.3
8/8	1.4	6.7	151	2.6
8/12	1.6	7.0	149	2.1
8/13	1.7	7.4	151	1.5
8/14	1.7	7.8	152	3.1
8/15	1.7	7.1	149	1.5
8/19	1.4	6.7	149	1.3
8/20	1.5	6.9	155	1.0
8/22	0.8	6.8	155	1.4
8/23	0.8	6.6	155	1.3
8/26	0.8	7.3	144	1.2
8/27	1.5	7.3	155	1.1
8/28	1.4	7.2	154	1.5
8/29	0.7	6.8	151	1.5
8/30	0.7	6.9	155	1.2
9/3	0.8	6.6	157	1.3
9/4	1.4	6.5	157	1.0
9/5	1.4	7.1	157	1.2
9/6	1.4	6.7	158	1.5
9/9	1.6	6.0	148	1.4
9/10	1.7	8.4	149	1.0
9/11	1.5	8.4	146	1.1
Min	0.7	6.0	130	1.0
Max	1.7	9.6	158	4.5

Table 10. 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 2019.

Date	River Left US	Center US	River Right US	River Left DS	Center DS	River Right DS	Trap Velocity
7/30	2.1	1.4	1.8	2.2	2.3	3.5	1.6
7/31	1.7	1.5	1.8	2.0	1.8	2.7	2.1
8/01	0.7	1.4	1.5	1.7	1.7	3.3	1.8
8/02	1.7	1.6	2.2	2.2	1.7	3.3	1.6
8/05	1.5	1.4	2.2	2.2	1.9	3.4	1.7
8/06	2.0	1.5	1.7	2.2	1.8	3.1	2.2
8/08	1.8	1.5	2.1	1.9	1.6	3.1	1.8
8/12	1.0	1.3	1.5	1.7	1.4	2.1	1.0
8/13	1.6	1.5	1.8	1.7	1.4	2.0	1.3
8/14	1.8	1.4	1.9	1.9	1.7	3.0	1.7
8/15	1.5	1.5	1.6	1.9	1.9	2.4	1.8
8/19	1.3	1.3	1.6	1.8	1.4	2.6	1.1
8/20	1.6	1.4	1.7	2.0	1.8	2.1	0.6
8/21	0.6	0.6	0.9	1.2	0.9	1.4	0.4
8/22	0.7	0.7	1.1	1.3	1.3	1.3	0.6
8/23	0.6	0.6	1.1	1.5	1.4	1.4	0.5
8/26	0.8	0.6	0.6	1.2	1.1	1.7	0.7
8/27	1.6	1.1	1.5	2.1	1.6	2.6	1.5
8/28	0.8	0.3	0.7	0.8	0.8	2.0	0.5
8/29	0.9	0.9	0.7	1.1	0.6	0.6	0.4
8/30	0.8	0.7	0.5	0.9	1.0	1.3	0.3
9/3	1.6	1.6	2.1	2.1	2.4	2.7	1.6
9/4	1.3	1.3	2.0	1.9	2.2	2.9	1.6
9/5	1.4	1.2	1.9	2.2	2.4	2.8	1.2
9/6	0.9	1.4	1.8	1.8	2.0	2.8	0.9
9/9	1.5	1.5	2.1	2.0	1.7	2.7	0.6
9/10	1.3	1.0	1.8	2.3	2.4	1.6	0.8
9/11	1.5	1.6	2.2	2.6	2.6	3.3	2.0
Min	0.6	0.3	0.5	0.8	0.6	0.6	0.3
Max	2.1	1.6	2.2	2.2	2.4	3.5	2.2

Eight dead fish were removed from the weir between August 1 and September 11. All of the mortalities were Chinook. All mortalities were impinged on the upstream side of weir indicating that they had most likely died upstream and floated down onto the weir.

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 quite a bit lower than previous season, especially during the month of August when the pickets were lifted. Estimates were highest during the last week of the weir season when mean daily river temperatures dropped below 22.5 °C and the majority of fish were trapped. 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 in September (Figure 18). Trapping operations were conducted on August 26-27 and September 9-11 when river temperature was ≤ 22.5 °C. The total fish trapped at the weir in 2019 was 159 with 90% of them being Chinook salmon (Figure 19). Ninety-three percent of the Chinook trapped were released back into the river (Figure 20). No steelhead were trapped in 2019.

Eight natural-origin and two hatchery-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. 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 or before they are mixed with the other brood at the hatchery.

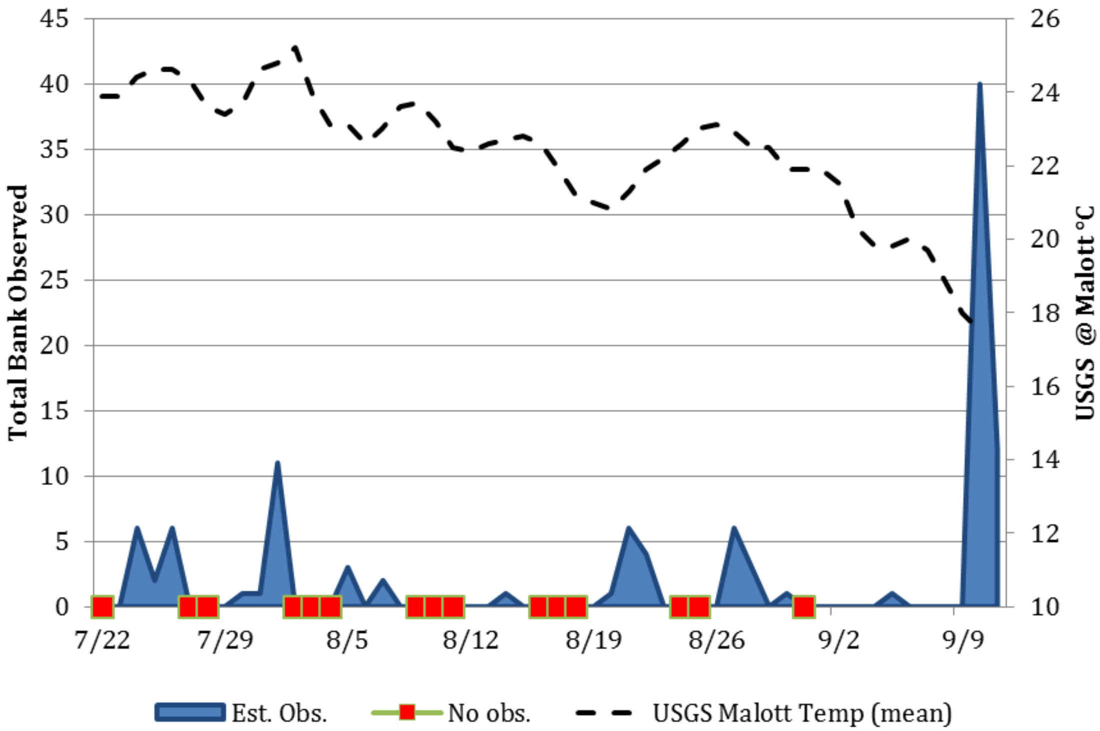


Figure 18. Estimate of Chinook observed from the bank at the lower pool, 0.8 km downstream of the weir. Primary y-axis indicates number of Chinook observed; secondary y-axis (right hand side) indicates the mean stream temperature in degrees Celsius (C).

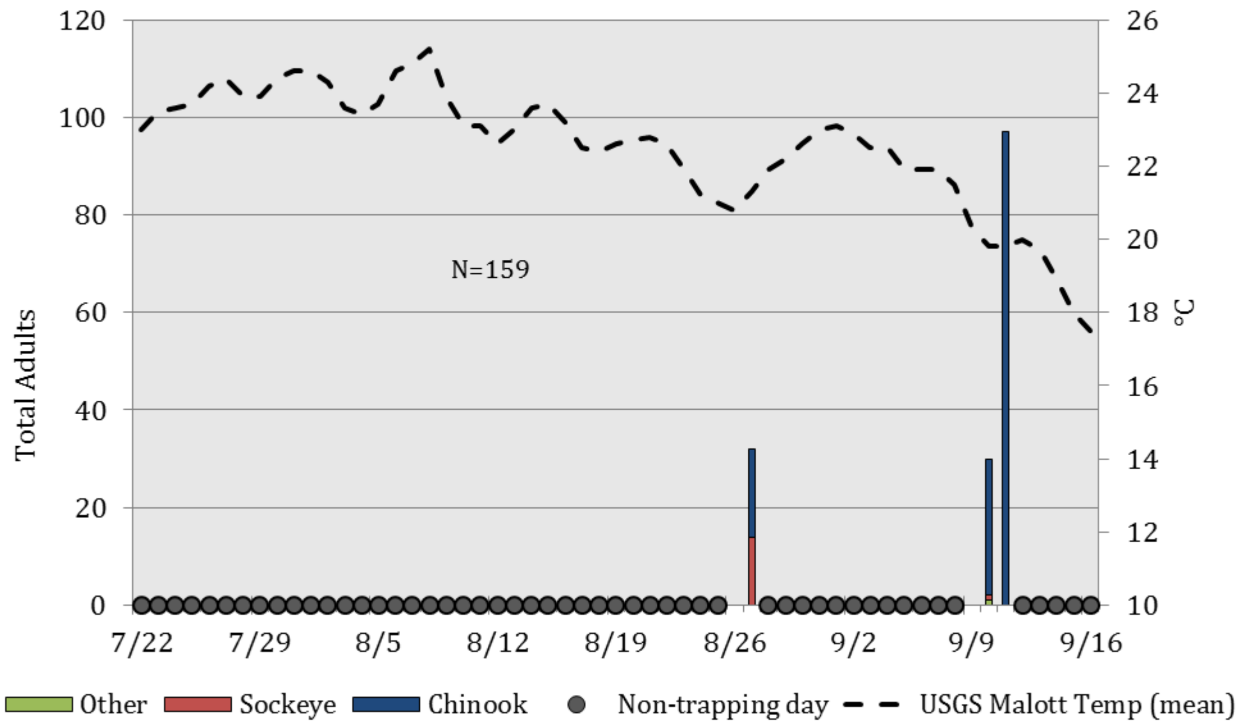


Figure 19. Total number of fish trapped at the Okanogan weir in 2019.

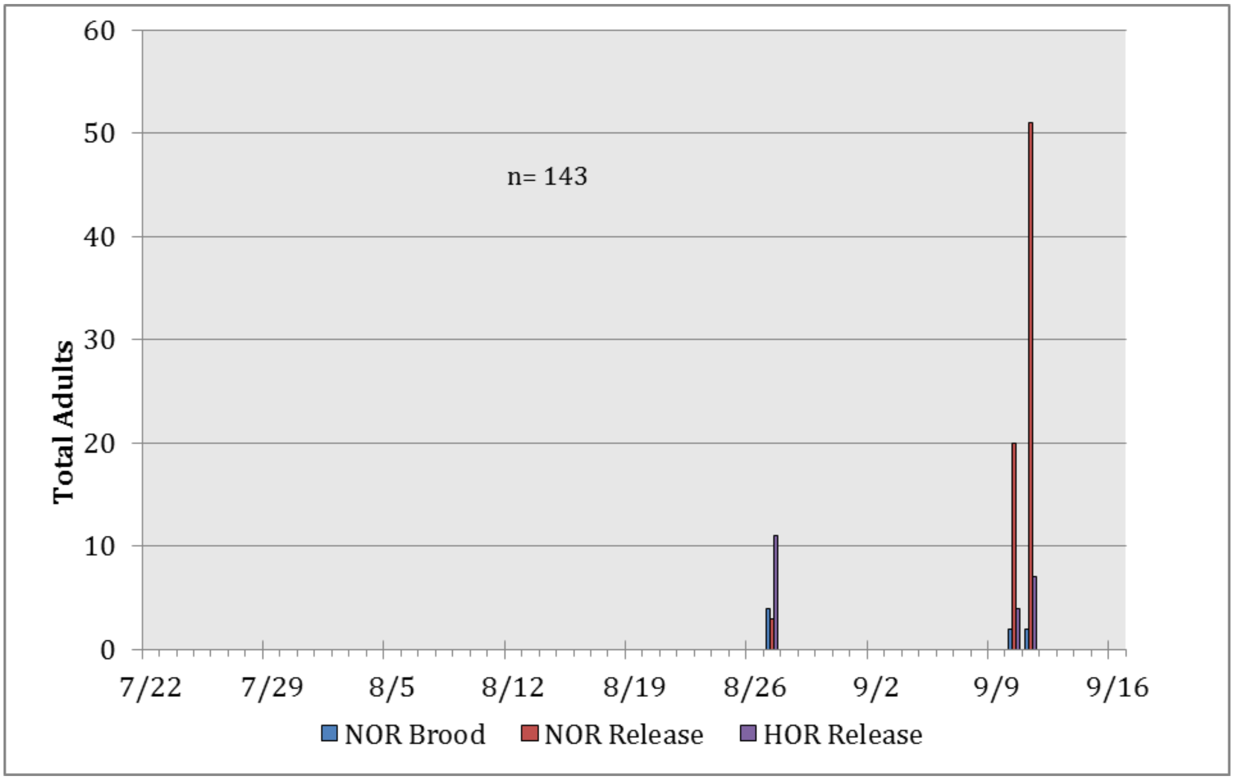


Figure 20. Final destination of Chinook adults captured in the weir trap during trapping operations in 2019.

In 2019, 0.017 (1.7%) of total spawning escapement was detected in the trap (i.e., weir efficiency) (Table 11). The potential weir effectiveness (if we had been removing all of the HOR encountered) was 0.001 (0.1%).

Table 11. The number of hatchery and natural origin Chinook Salmon encountered at the lower Okanogan weir in 2019. 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
2019	82	24	2,619	2.824	0.017	0.001
Average	387	75	6,609	1,785	0.037	0.033

[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 2019, 2,371 summer/fall Chinook redds were counted in the Okanogan and Similkameen rivers using a combination of ground and aerial surveys (Figure 22). The number of redds counted in 2019 was similar to the previous year (2018) – higher than the long-term average, but less than the more recent 5-year average (Table 12). Consistent with previous years, the majority of Chinook redds were located in reaches S1 (34%), O6 (30%), and O5 (21%; Table 15). These three reaches accounted for 85% 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) (Figure 22).

Estimated spawning escapement was 5,453 (2,371 redds × 2.3 fish per redd) (Table 14). Since 1989, the summer/fall Chinook spawning escapement within the U.S. portion of the Okanogan River Basin has averaged 5,848 and ranged from 473 to 13,857 (Table 14).

Summer/fall Chinook redds were counted during spawning ground surveys between September 29 - Nov 16 (Table 15). No spawning ground surveys were conducted after November 16.

Table 12. Total number of redds counted in the Okanogan River Basin, 1989-2019 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
2019	1,638	733	2,371
Average	1,262	1,015	2,216
5-yr Avg.	***2,298***	***1,153***	***3,451***

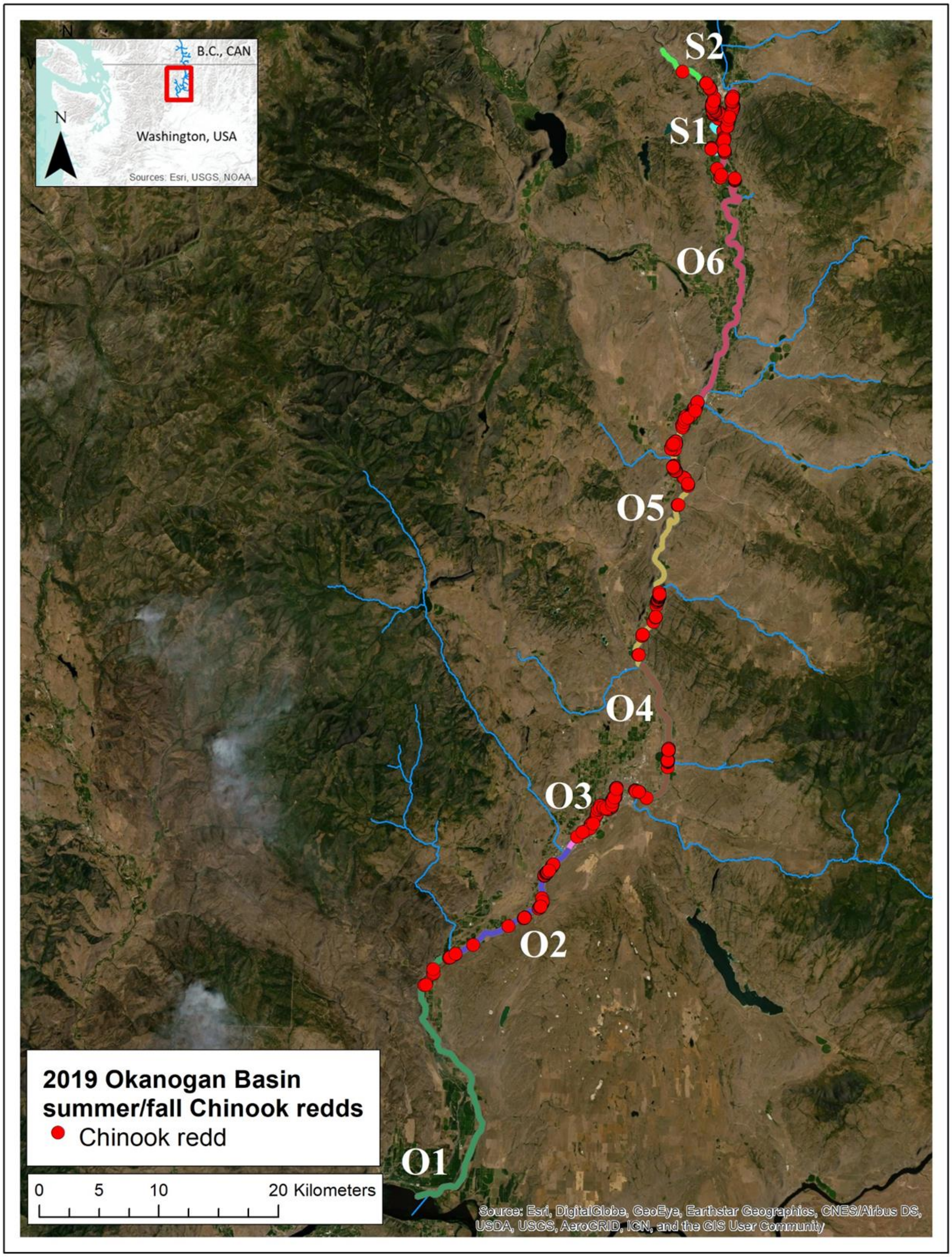


Figure 21. Distribution of summer/fall Chinook redds in 2019. Individual redds are identified by red circles. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Table 13. Annual and average abundance of summer/fall Chinook redds in each reach of the Okanogan (O1-O6) and Similkameen (S1-S2) Rivers from 2006-2019.

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
2019	12	154	275	92	600	505	694	39	2,371
Average	***9***	***58***	***152***	***97***	***650***	***966***	***1,069***	***169***	***3,170***

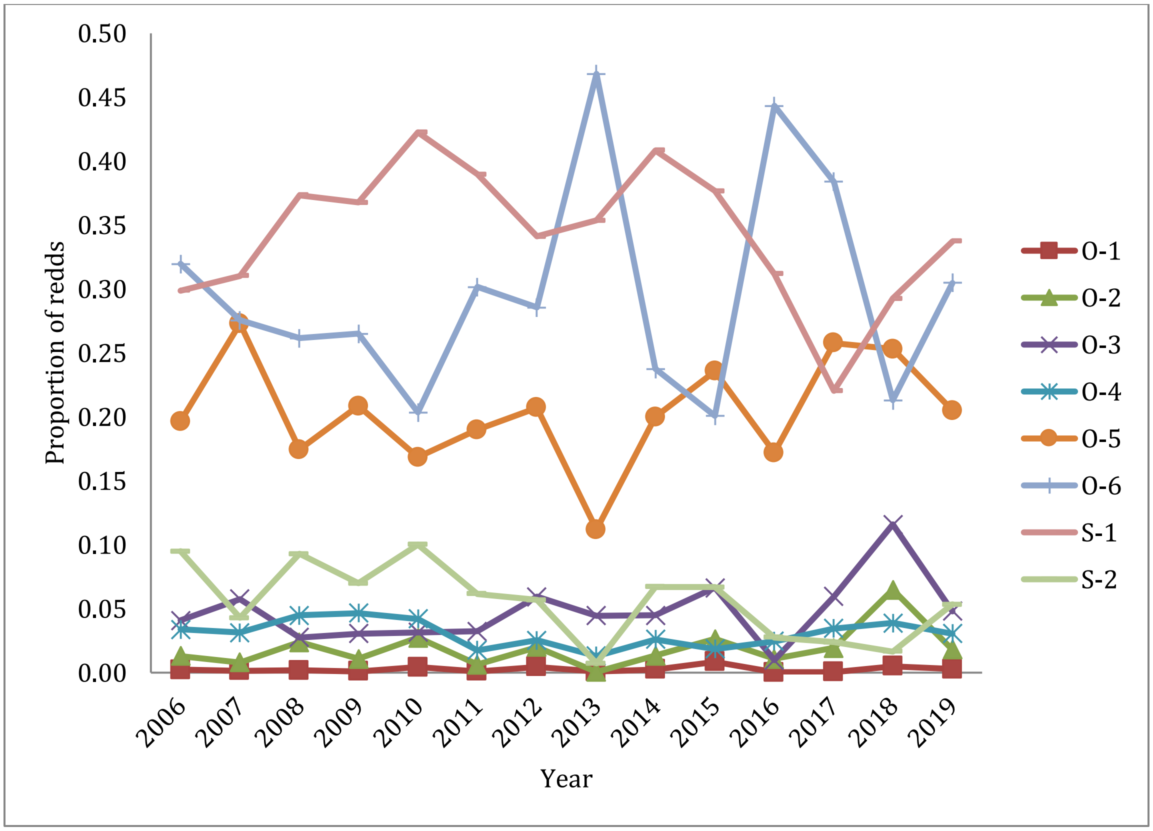


Figure 22. Proportion of redds in each reach of the Okanogan and Similkameen Rivers from 2006 to 2019.

Table 14. Spawning escapements for summer/fall Chinook in the Okanogan and Similkameen Rivers for return years 1989-2019.

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
2019	***2.300***	***3,767***	***1,686***	***5,453***
Average	***2.880***	***3,098***	***2,750***	***5,848***
5-Year Average	***2.370***	***5,395***	***2,856***	***8,251***

* 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 15. Number and timing of summer Chinook redd counts in reaches of the Okanogan and Similkameen Rivers in 2019.

Reach	River mile	Sept 29 - Oct 5	Oct 6 - 12	Oct 13 - 19	Oct 20 - 26	Oct 27 - Nov 2	Nov 3 - 9	Nov 10 - 16	Redd Count	Percent
Okanogan River										
O1	0.0-16.9	0	0	5	3	3	0	1	12	1%
O2	16.9-26.1	0	27	24	59	44	0	0	154	9%
O3	26.1-30.7	0	97	26	124	0	28	0	275	17%
O4	30.7-40.7	0	21	8	46	13	4	0	92	6%
O5	40.7-56.8	0	215	137	163	78	7	0	600	37%
O6	56.8-77.4	8	282	32	140	40	3	0	505	31%
Total		***8***	***642***	***232***	***535***	***178***	***42***	***1***	***1638***	100%
Similkameen River										
S1	0.0-1.8	2	123	167	252	74	76	0	694	95%
S2	1.8-5.7	0	21	2	16	0	0	0	39	5%
Total		***2***	***144***	***169***	***268***	***74***	***76***	***0***	***733***	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, insights into escapement into Canada had been based primarily 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 was 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 (Table 18). No video count data exists for Chinook in 2018 and 2019. 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).

Table 16. Chinook escapement to Canada as estimated by Zosel Dam counts and Okanogan Nation Alliance area-under-the-curve (AUC) methods.

Year	Zosel Dam Video Count	Zosel Dam % Hatchery	ONA AUC Spawner Estimate	ONA AUC % Hatchery
2006[a]	481	1%	34	3%
2007	455	40%	7	0%
2008	267	29%	14	23%
2009[a]	256	17%	6	0%
2010	359	29%	5	0%
2011[a]	1415	36%	21	21%
2012[a]	826	24%	11	10%
2013	2275	14%	40	13%
2014[b]	1188	10%	52	13%
2015	1206	7%	61	8%
2016	1823	13%	40	5%
2017	737	14%	55	6%
2018	No Data	No Data	10	20%
2019	No Data	No Data	15	18%
Average	***941***	***19%***	***39***	***10%***

[a]AUC spawner estimates is based on the number of carcasses sampled so this is the minimum estimate.
[b]2014 data were adjusted for fallback/re ascension, down camera time, and differentiation of spring Chinook from summer/fall Chinook.

More recently, 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). Using AUC estimation methods, the largest spawner estimate occurred in 2015 with 61 spawners (Table 16). In 2019, ONA estimated 15 Chinook on Canadian spawning grounds.

Carcass Surveys

In 2019, 467 carcasses were recovered on the spawning grounds, including 226 natural-origin and 241 hatchery-origin[7]. An additional 6 carcasses were recovered during pre-spawn surveys (3 ad-clipped, 3 ad-present). The spawning ground carcass recovery rate was 8.6% of the total spawning escapement. Similar to previous years, the majority of carcasses (*n* = 379; 81%) were collected from reaches O5, O6 and S1 (Figure 23, also see

[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.

Appendix C). Regarding the distribution of carcasses throughout the basin, the proportions of natural-origin carcasses recovered in 2019 were significantly lower in reach S1, and higher in reach O3, compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 23, panel A). The proportions of hatchery-origin carcasses recovered in 2019 were significantly higher in reaches O3 and O6, and lower in reaches S1 and S2 compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 23, panel B).

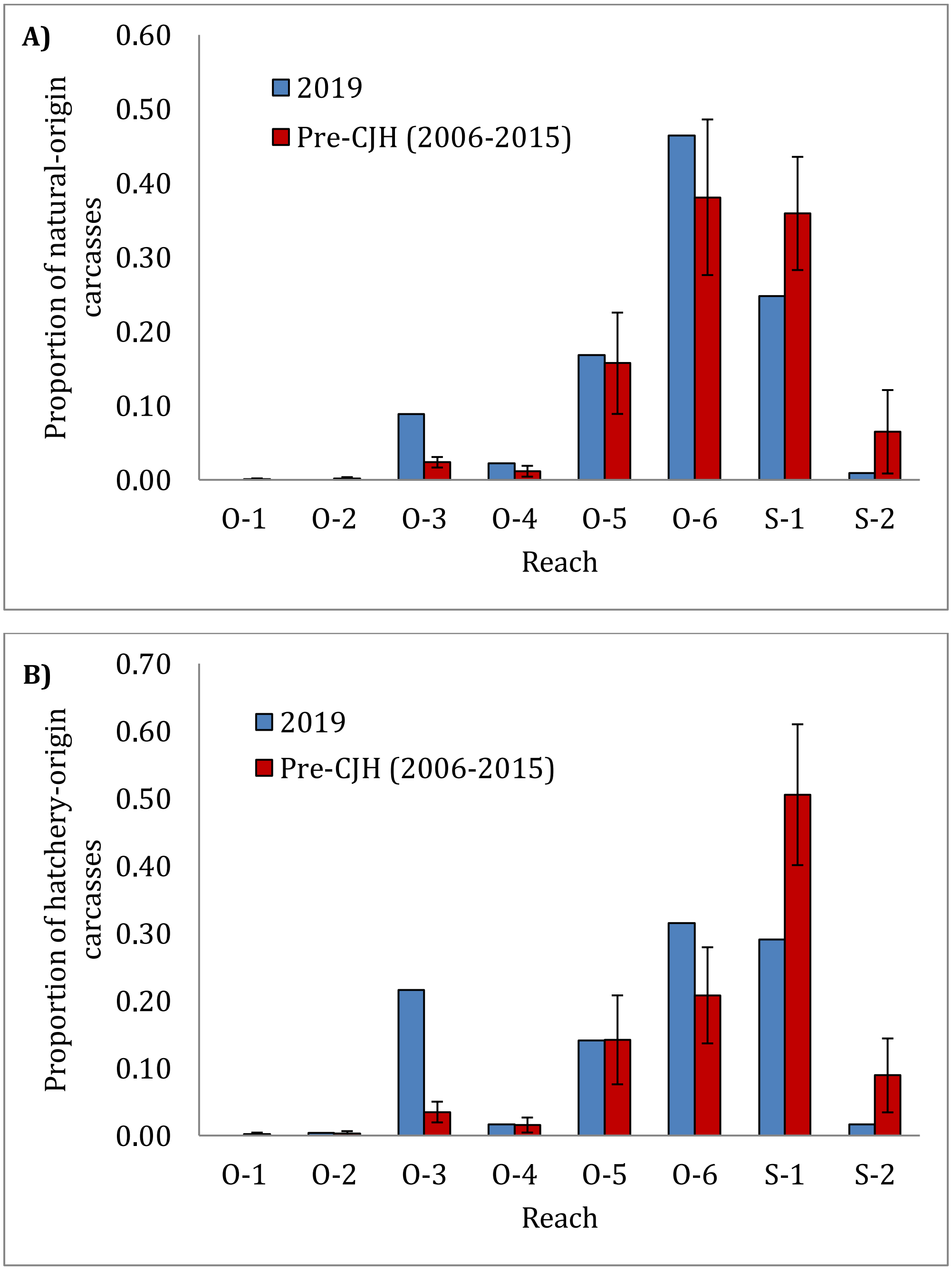


Figure 23. Distribution of (A) natural-origin and (B) hatchery-origin summer/fall Chinook carcasses recovered in the Okanogan (reaches O1-O6) and Similkameen (reaches S1-S2) Rivers in 2019 compared to the average of the 10 years preceding Chief Joseph Hatchery (2006-2015). Error bars represent standard deviation (SD).

In the Okanogan basin, just 6 of the 283 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 0.82% for natural-origin females and 2.48% for hatchery-origin females (Table 17). Overall egg retention of all fish sampled (including fish that had expelled a portion of their eggs) was 1.97%.

Table 17. 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%
2019	Natural	229	122	610,000	5,680	0.93%	0.82%
	Hatchery	244	161	805,000	22,149	2.75%	2.48%
	Total	473	283	1,415,000	27,829	1.97%	1.77%

[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 an increase in the proportion of hatchery-origin spawners (pHOS) across all reaches in 2019 compared to the 10 years preceding Chief Joseph Hatchery (Figure 24). However, few carcasses were recovered in reaches O1, O2, and O4(n < 5%) of estimated spawners) therefore, no comparisons could be made as to the composition of spawners in these reaches. Combined, these three omitted reaches comprised only 10.9% of the spawning in the basin in 2019. Basin means (average pHOS) were used for these reaches in all subsequent analyses. Hatchery-origin spawners comprised 52% of the spawn escapement estimate in the U.S. portion of the Okanogan, which was the highest pHOS observed since 2011 (also 0.52) (Table 18). After corrections for hatchery fish effectiveness assumptions (0.80 relative reproductive success rate for hatchery-origin spawners) the effective pHOS for 2019 was 0.47, which was well above the five-year average (0.29) (Table 19). Despite this single year increase, the five-year average is currently meeting the biological objective for pHOS (<0.3) (Figure 25).

The proportion of natural-origin broodstock (pNOB) in 2019 was 0.63 and the pNOB for Okanogan origin fish was 0.56 (Table 19). The resulting PNI for 2019 was 0.57, with a 5-year average PNI of 0.78. Despite the undesirable decrease in PNI over the last two years (2018 and 2019), the 5-year average is still meeting the Biological Objective (>0.67) (Figure 26).

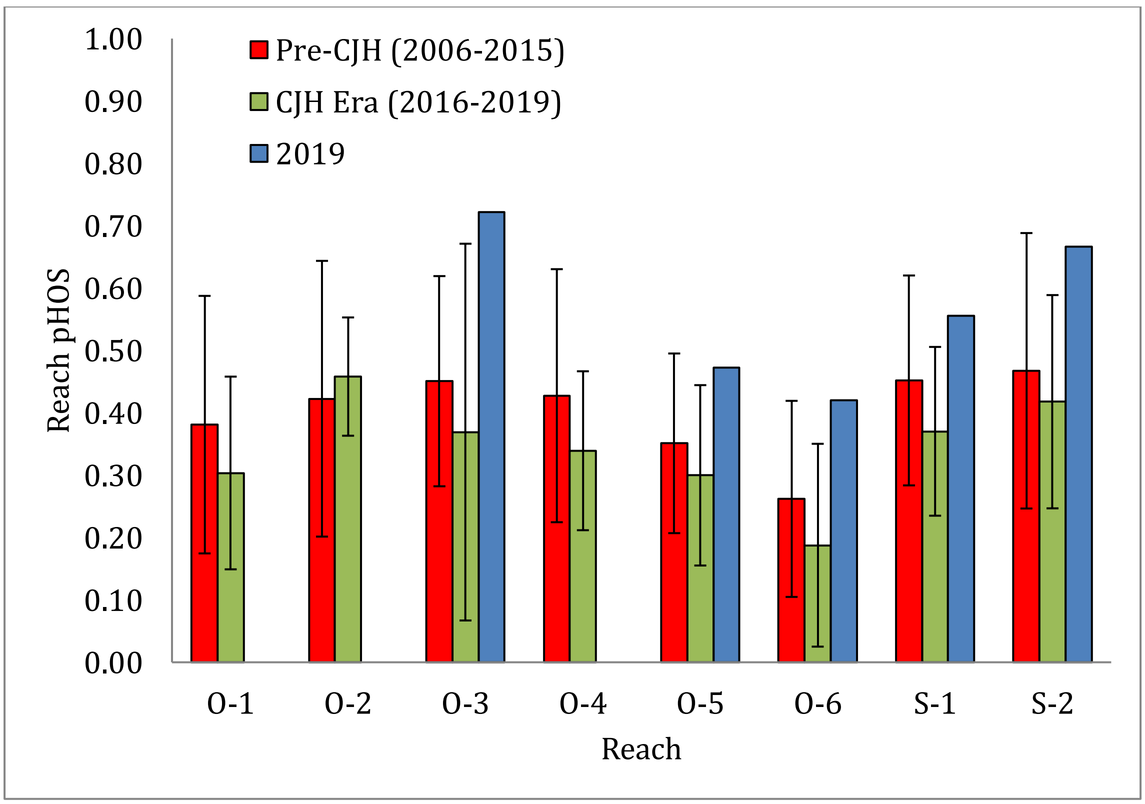


Figure 24. Okanogan (O1-O6) and Similkameen (S1-S2) river summer/fall Chinook pHOS (unadjusted for RSS) by reach. Red bars represent the average of the 10 years preceding Chief Joseph Hatchery (2006-2015), green bars represent the average of the years since Chief Joseph Hatchery operation (2016-2019), and blue bars represent the current year (2019). Reaches with <5% carcasses recoveries were omitted. Error bars represent standard deviation.

Table 18. Natural- (NOS) and hatchery- (HOS) origin spawner abundance and composition for the Okanogan River Basin, brood years 1989-2019.

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
2019	2,604	2,849	0.52	0.47
Average	3,512	2,336	0.39	0.35
5-year Average	6,088	2,159	0.29	0.25

[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.

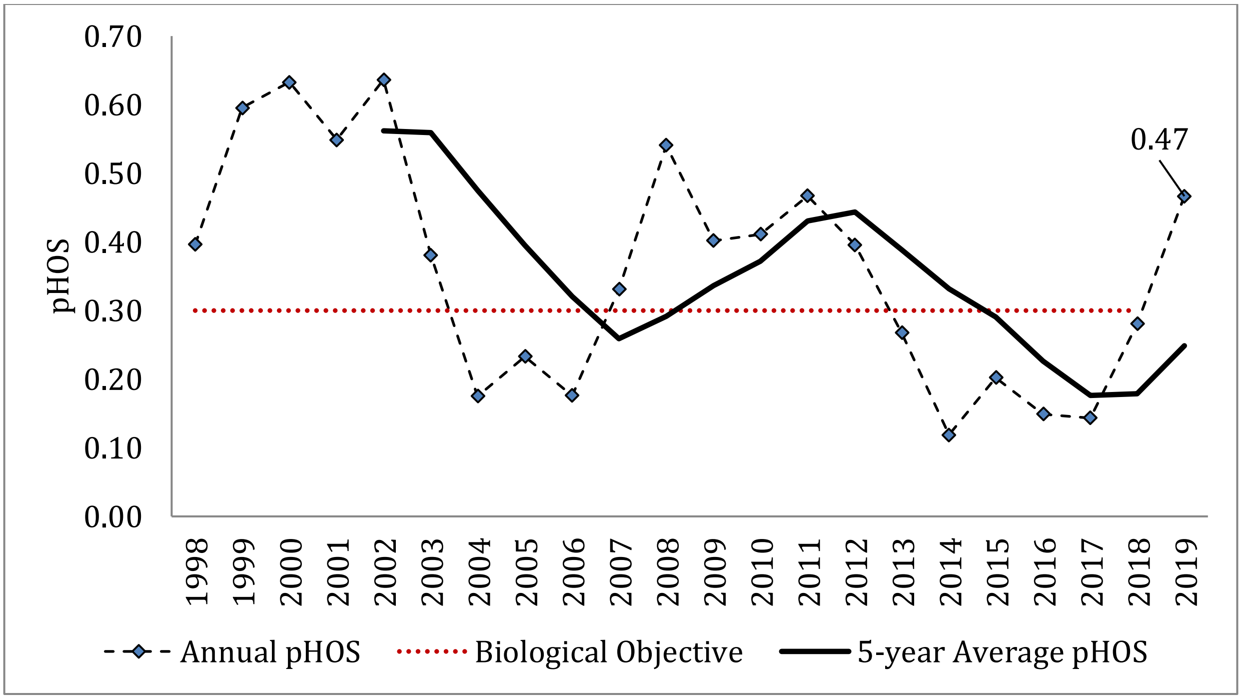


Figure 25. Annual and 5-year average proportion of hatchery-origin spawners (pHOS) in the Okanogan and Similkameen River (combined) from 1998-2019. pHOS values represent the effective pHOS (adjusted for RRS).

Table 19. Okanogan basin summer/fall Chinook spawn escapement, broodstock composition, pHOS, and PNI for Brood Years 1989-2019.

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	0.74
2007	2,730	1,688	0.33	456	228	17	0.96	0.48	0.74	0.59
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	0.71	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
2019	2,604	2,849	0.47	376	338	224	0.63	0.56	0.57	0.55
Average	3,512	2,336	0.35	411	236	152	0.73	0.53	0.68	0.58
5-Year Average	6,088	2,159	0.25	385	346	92	0.81	0.73	0.75	0.74

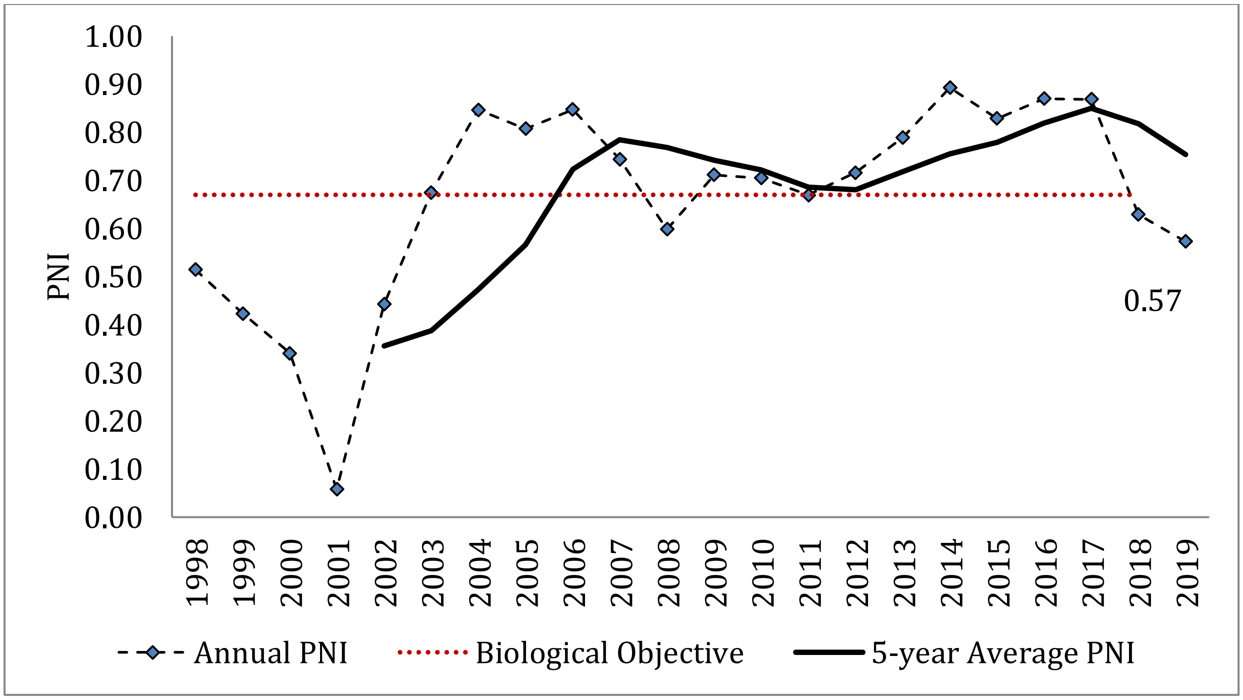
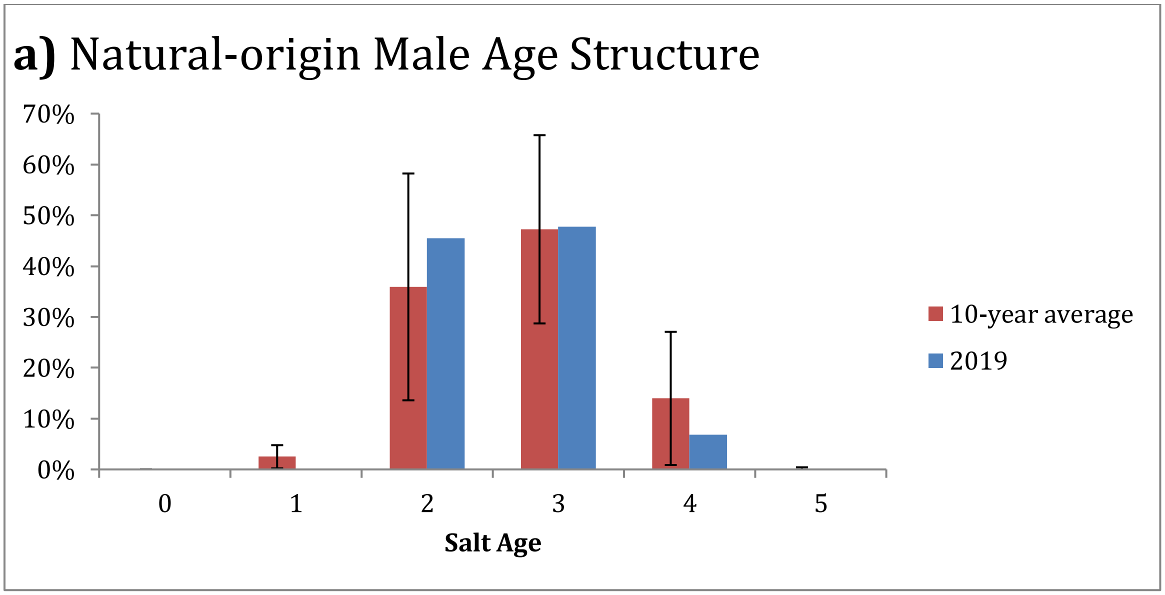


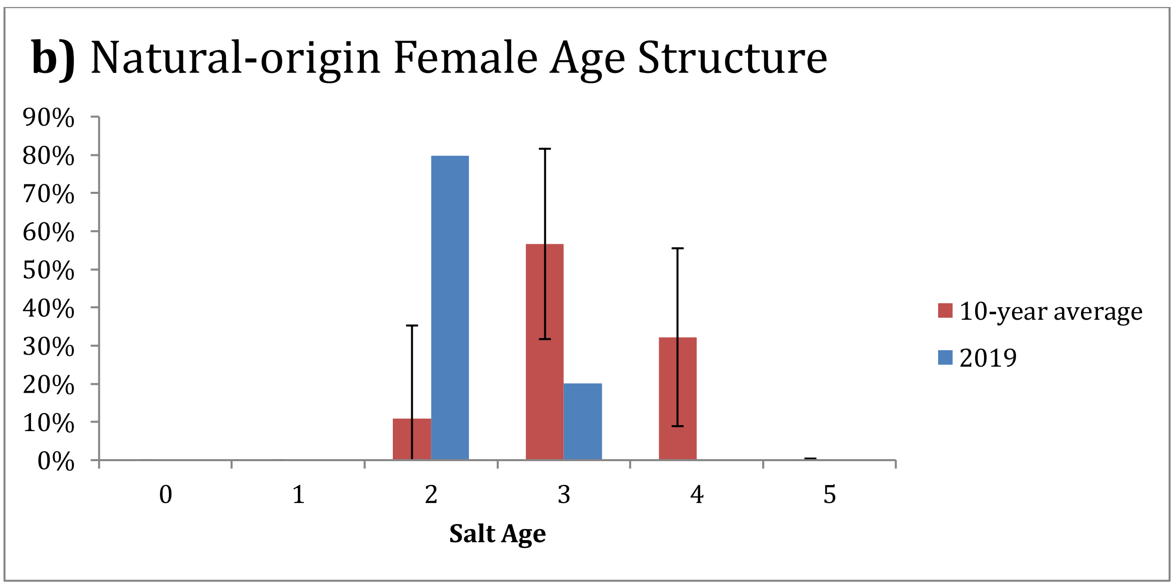
Figure 26. Annual and 5-year average proportionate natural influence (PNI) in the Okanogan basin from 1998 to 2019.

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 outmigrate 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 2019, male natural-origin spawners were comprised predominantly 2- and 3-year salt age fish, which is similar to previous years (Figure 28-a). Natural-origin female spawner age structures were skewed towards 2-year salt age fish compared to previous years (Figure 27-b). With 108 natural-origin female Chinook collected on the spawning grounds in 2019, none were determined to be 4-year salt age. Hatchery-origin males were comprised by 1- and 2-year salt age fish. No 3-year hatchery-origin males were recovered. Hatchery-origin females were comprised of 2- and 3-year fish, with no 4-year fish recovered.


a) Natural-origin Male Age Structure
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Salt Age
10-year average
2019


b) Natural-origin Female Age Structure
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Salt Age
10-year average
2019

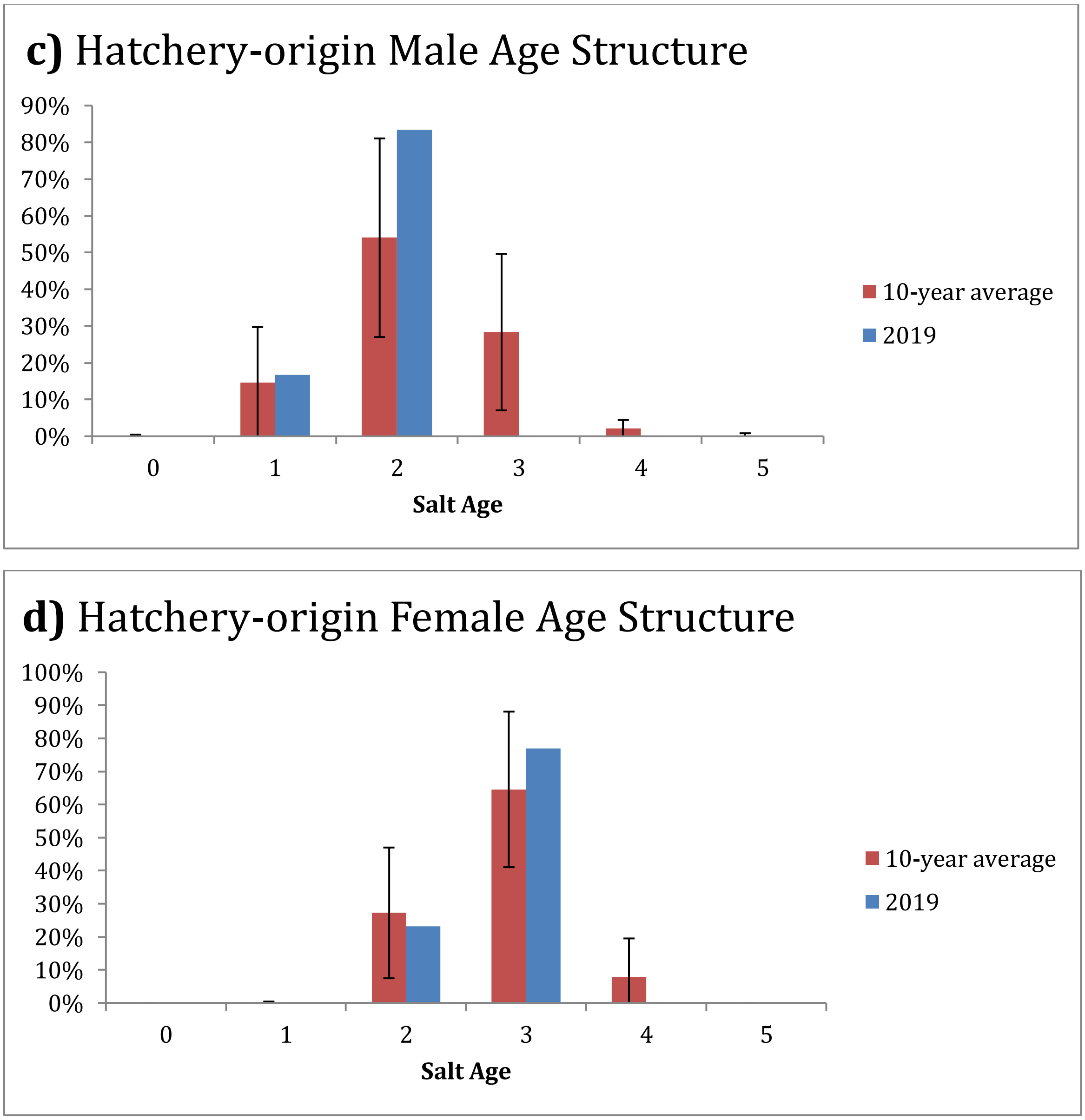


Figure 27. The salt ages of carcasses collected on the spawning grounds of the Okanogan and Similkameen rivers in 2019 along with 10-year averages (2010-2019) for a) Natural-origin males; b) Natural-origin females; c) Hatchery-origin males; and d) Hatchery-origin females.

HATCHERY-ORIGIN STRAY RATES

Strays to the Okanogan—The majority (68%) of hatchery-origin spawners recovered on the spawning grounds in 2019 were from Similkameen (44%) and Okanogan acclimated (24%) releases (Table 20). Chief Joseph Hatchery segregated Chinook comprised 34% of the HOS on the Okanogan spawning grounds. Strays into basin consisted of individuals from Methow River, Entiat River, Chelan River, mainstem Columbia River, and Snake River releases. Stray hatchery fish from outside the Okanogan basin comprised 21.4% of the total (HOS+NOS) Okanogan spawner composition (i.e., stray pHOS) (Table 21). This was far above the recent (2006-2019) average of 4.01% 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 are 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 2014. The 2014 brood year had a stray rate of 1.9% (includes straying to out of basin spawning grounds and hatcheries), which was slightly above the long term (1989-2014; 1.3%) and recent five-year (2009-2013; 1.5%) averages (Table 22). RMIS queries revealed an estimate of 16 Okanogan hatchery-origin Chinook recovered on spawning grounds in non-target spawning areas in 2019 (Table 22). Okanogan basin hatchery program strays comprised 1.35% to Chelan spawner composition in 2019 (Table 23). 5-year averages to Wenatchee, Methow, Chelan, and Entiat basins are all below 1%.

Table 20. 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 2006-2019.

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	249 (20%)	590 (46%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	428 (33%)	9 (1%)	0 (0%)	3(0%)	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%)
2019	403 (24%)	1250 (44%)	68 (2%)	0 (0%)	9 (0%)	37 (1%)	1021 (36%)	25 (1%)	0 (0%)	7 (0%)	0 (0%)
Avg.	140 (8%)	1857 (68%)	29 (1%)	14 (1%)	3 (0%)	20 (1%)	615 (32%)	46 (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, Irrigon, and Prosser Hatchery

Table 21. Percent of the total Okanogan spawning escapement comprised of various hatchery release groups, based on CWT recoveries and expansions for return years 2006-2019.

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%	8.2%	0.1%	0.1%	0.0%	0.0%		0.9%	0.0%	0.0%	0.0%	1.2%	0.18
2007	0.0%	25.4%	0.4%	0.1%	0.0%	0.0%		1.0%	0.0%	0.0%	0.0%	1.4%	0.33
2008	0.0%	46.2%	0.2%	0.3%	0.0%	0.1%		1.9%	0.0%	0.0%	0.0%	2.5%	0.54
2009	0.0%	36.2%	0.2%	0.2%	0.0%	0.1%		1.3%	0.0%	0.1%	0.1%	1.9%	0.40
2010	0.1%	36.4%	0.7%	0.6%	0.0%	1.8%		1.3%	0.0%	0.1%	0.0%	4.5%	0.41
2011	2.3%	43.3%	0.5%	0.1%	0.0%	0.4%		0.2%	0.0%	0.1%	0.0%	1.1%	0.47
2012	4.6%	29.1%	0.4%	0.3%	0.0%	0.2%		0.6%	0.0%	0.0%	0.0%	1.5%	0.40
2013	3.1%	17.5%	0.1%	0.7%	0.0%	0.0%		0.1%	0.0%	0.0%	0.0%	0.9%	0.27
2014	0.5%	8.4%	0.1%	0.0%	0.0%	0.1%		0.2%	0.0%	0.0%	0.0%	0.5%	0.12
2015	0.3%	18.6%	0.5%	0.1%	0.1%	0.2%		0.2%	0.0%	0.0%	0.2%	1.5%	0.20
2016	0.1%	18.5%	0.4%	0.1%	0.0%	0.3%		0.1%	0.0%	0.0%	0.2%	1.1%	0.15
2017	3.8%	9.0%	0.0%	0.0%	0.0%	0.0%	6.5%	0.1%	0.0%	0.0%	0.0%	6.7%	0.14
2018	7.3%	12.9%	0.6%	0.0%	0.0%	0.1%	8.1%	0.6%	0.0%	0.0%	0.7%	10.1%	0.28
2019	4.9%	15.1%	0.8%	0.0%	0.1%	0.4%	12.3%	0.3%	0.0%	0.1%	0.0%	14.1%	0.47
Avg.	1.93%	23.20%	0.36%	0.19%	0.01%	0.26%	8.97%	0.63%	0.00%	0.03%	0.09%	3.50%	0.31

[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, Irrigon, and Prosser Hatchery

Table 22. 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 1989-2014. 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	1,699	92.7%	96	5.3%	37	2.0%	0	0.0%
2006	5,162	97.6%	60	1.1%	67	1.3%	0	0.0%
2007	1,384	97.7%	23	1.6%	9	0.7%	0	0.0%
2008	3,577	96.8%	95	2.6%	20	0.6%	4	0.1%
2009	1,102	79.9%	260	18.9%	14	1.1%	2	0.2%
2010	927	43.4%	648	54.1%	9	0.4%	10	2.1%
2011	3,028	76.7%	881	22.3%	16	0.4%	26	0.7%
2012	478	72.8%	174	26.5%	4	0.6%	1	0.2%
2013	1,111	62.0%	666	37.1%	7	0.4%	9	0.5%
2014	566	71.9%	201	25.7%	8	1.0%	11	1.4%
Total	52,868	83.4%	6,984	15.4%	551	0.9%	119	0.3%

Table 23. Number of estimated spawners and percent (%) of spawning escapements comprised of hatchery-origin Okanogan summer/fall Chinook within non-target basins, return years 1994-2019.

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%
2019	0	0.00%	0	0.00%	16	1.35%	0	0.00%
Total	***44***	***0.03%***	***77***	***0.14%***	***309***	***2.14%***	***55***	***0.84%***
5-year Total	***0***	***0.02%***	***8***	***0.11%***	***39***	***0.75%***	***0***	***0.00%***

Homing Fidelity

The 141 coded-wire tags recovered during spawning grounds surveys in fall of 2019 expanded to 403 and 1,250 spawners originated from Omak Pond and Similkameen Pond acclimation sites, respectively. The majority (90%) of the spawners originating from the Omak Pond acclimation site spawned in the Okanogan River (Table 24). Those fish tended to spawn in habitat upstream of the Omak Pond site, with the majority (46%) in reach O5. No Omak Pond or Similkameen pond CWT's were recovered below reach O3 (Figure 28). Forty-one of the 403 fish (10%) that were acclimated at Omak Pond were recovered in the Similkameen River (reach S1). Most fish acclimated at Similkameen Pond spawned in the Similkameen River (51%). Of the Similkameen-origin fish that spawned in the Okanogan River, most used reaches O5 and O6 (40% combined; Figure 28). 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 almost half of the estimated spawning by Similkameen Pond fish (48%) (Table 24).

Table 24. Spawning distribution by river, for fish acclimated at Omak Pond and Similkameen Pond acclimation sites for 2018 and 2019.

2018	Acclimation site (origin)	
Spawning location	Omak Pond	Similkameen Pond
Okanogan River	92%	60%
Similkameen River	8%	40%

2019	Acclimation site (origin)	
Spawning location	Omak Pond	Similkameen Pond
Okanogan River	90%	49%
Similkameen River	10%	51%

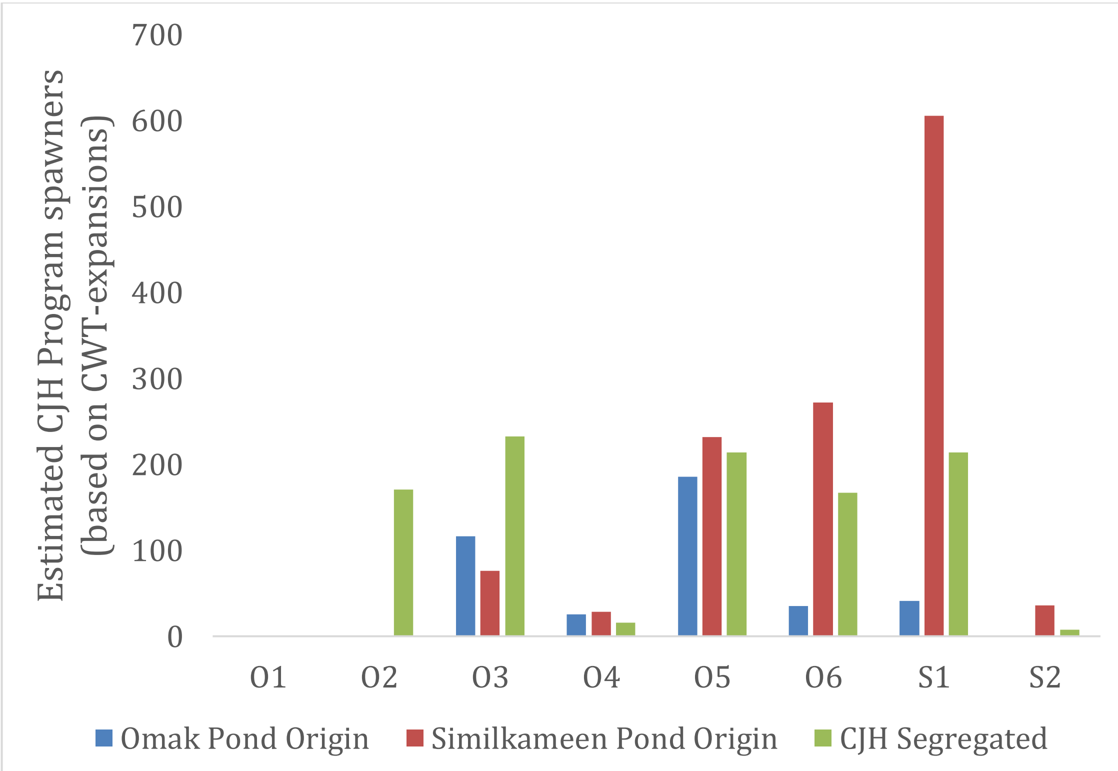


Figure 28. 2019 spatial distribution of CJHP integrated program summer/fall Chinook spawners originally reared at the Similkameen Pond and Omak Pond acclimation sites and CJHP segregated program strays to Okanogan spawning grounds.

Smolt Survival and Travel Time

Apparent survival of yearlings to RRJ in 2019 was 67% (SE 4%) for the segregated program released from CJH, 69% (SE 3%) for integrated fish released from Omak Pond and 63% (SE 3%) for Similkameen (Table 25). Apparent survival of yearlings to MCN was 45% (SE 10%) for the segregated program released from CJH, 50% (SE 8%) for the integrated fish released from Omak Pond and 53% (SE 10%) for Similkameen (Table 25). The segregated yearling program from CJH had lower survival than the five-year mean, whereas the integrated program at Omak Pond had higher survival than the five year mean to RRJ and the same as the five year mean to MCN (Table 26).

There was not a subyearling program at the CJH or Omak Pond in 2019. Wild subyearlings had a survival to RRJ of 36% (SE 2%) and 18% (SE 5%) to MCN (**Error! Reference source not found.**). The survival of wild summer Chinook from release to RRJ and MCN was very similar to the five-year mean (Table 26).

Table 25. Apparent survival estimates for PIT tagged summer/fall Chinook released in 2019 from Chief Joseph Hatchery (CJH), Omak Pond and other nearby hatcheries.

Summer Chinook Release Group	# PIT tags Released	Recap.	Reach	Survival	Survival Standard Error (SE)	Capture Prob.	Capture Prob. (SE)
Yearlings released at CJH	4945	1379	Release to RRJ	0.67	0.04	0.42	0.02
		111	Release to MCN	0.45	0.10	0.05	0.01
Yearlings released at Omak Pond	4987	1368	Release to RRJ	0.69	0.03	0.40	0.02
		170	Release to MCN	0.50	0.08	0.07	0.01
Yearlings released at Similkameen Pond	4945	1153	Release to RRJ	0.63	0.03	0.37	0.02
		139	Release to MCN	0.53	0.10	0.05	0.01
Yearlings released at Carlton Pond	5034	1674	Release to RRJ	0.79	0.04	0.42	0.02
		114	Release to MCN	0.56	0.11	0.04	0.01
Yearlings released at Dryden Pond	20723						
		688	Release to MCN	0.62	0.06	0.05	0.01
Yearlings Released at Wells Hatchery	3860	1155	Release to RRJ	0.86	0.04	0.35	0.02
		159	Release to MCN	0.65	0.10	0.06	0.01

Summer Chinook Release Group	# PIT tags Released	Recap.	Reach	Survival	Survival Standard Error (SE)	Capture Prob.	Capture Prob. (SE)
Subyearlings released at CJH	0	0	Release to RRJ		No program in 2019		
		0	Release to MCN				
Subyearlings released at Omak	0	0	Release to RRJ		No program in 2019		
		0	Release to MCN				
Wells Fish Hatchery Subyearlings	5998	2403	Release to RRJ	0.59	0.03	0.69	0.04
		22	Release to MCN	0.29	0.20	0.01	0.01
Wild Subyearlings from Columbia River Beach Seine	25717	3278	Release to RRJ	0.36	0.02	0.36	0.02
		128	Release to MCN	0.19	0.06	0.01	0.01
Wild subyearlings from Col. R. and Okanogan R.	26990	3423	Release to RRJ	0.36	0.02	0.36	0.02
		136	Release to MCN	0.18	0.05	0.03	0.01

Table 26. PIT tag survival estimates for juvenile summer/fall Chinook from release to Rocky Reach and McNary dams from 2015 to 2019.

Summer Chinook Yearling Release Group																
	Survival to Rocky Reach Dam								Survival to McNary Dam							
Release Year	CJH segr.		Omak Pond		Similk.		Carlton Pond		CJH segr.		Omak Pond		Similk.		Carlton Pond	
	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr
2015	0.71	0.04	NA	NA	NA	NA	0.63	0.02	0.68	0.14	NA	NA	NA	NA	0.55	0.10
2016	0.78	0.04	0.57	0.04	NA	NA	0.81	0.04	0.53	0.04	0.44	0.05	NA	NA	0.63	0.06
2017	0.77	0.06	0.80	0.06	NA	NA	NA	NA	0.82	0.14	0.63	0.10	NA	NA	NA	NA
2018	0.83	0.04	0.54	0.04	NA	NA	0.76	0.04	0.60	0.06	0.42	0.06	NA	NA	0.59	0.07
2019	0.67	0.04	0.69	0.03	0.63	0.03	0.79	0.04	0.45	0.10	0.50	0.08	0.53	0.10	0.56	0.11
Average	**0.75**		**0.65**		**0.63**		**0.75**		**0.62**		**0.50**		**0.53**		**0.58**	

Summer Chinook Sub-Yearling Release Group																
	Survival to Rocky Reach Dam								Survival to McNary Dam							
Release Year	CJH segr.		Omak Pond		Wells Hatchery		Wild		CJH segr.		Omak Pond		Wells Hatchery		Wild	
	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr
2015	0.28	0.08	0.37	0.09	0.43	0.06	0.26	0.06	0.20	0.20	0.23	0.15	0.77	0.76	NA	NA
2016	0.44	0.08	0.35	0.05	0.51	0.05	0.24	0.03	0.14	0.05	0.14	0.06	0.25	0.05	NA	NA
2017	0.65	0.05	0.70	0.05	0.48	0.06	0.46	0.02	0.34	0.06	0.48	0.07	0.22	0.05	0.18	0.02
2018	0.65	0.06	NA	NA	0.79	0.07	0.44	0.04	0.53	0.09	NA	NA	0.53	0.11	0.12	0.03
2019	NA	NA	NA	NA	0.59	0.03	0.36	0.02	NA	NA	NA	NA	0.29	0.20	0.18	0.05
Average	**0.51**		**0.47**		**0.56**		**0.35**		**0.30**		**0.28**		**0.41**		**0.16**	

Releases of yearling Summer Chinook smolts began on April 15, 2019. Of the 4,987 PIT tagged fish released from Omak Pond (rkm 52), only 44 were detected at the Lower Okanogan PIT detection array. Fifty percent passed OKL within eight days and 90% passed within 21 days. Only four fish released from Similkameen Pond were detected at OKL, therefore the sample size was too small to calculate passage timing. The mean travel time of summer Chinook released from CJH facilities to RRJ in 2019 varied from 23 days (6.4 km/day) for yearlings released from Omak Pond to 32 days (3.6 km/day) for yearlings released from CJH (Table 27). Travel times to RRJ, MCN and BON were noticeably longer for all programs in 2019 compared to the five-year means (Table 28, Table 29). The majority of yearling Summer Chinook from CJH and Omak Pond arrived at RRJ from early May to mid-June, with 90% passage dates of June 15 and May 30, respectively (Figure 29). 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 27).

Table 27. Travel time (days), migration speed (km/day) and the number of days to 90% passage for summer/fall Chinook release groups in 2019.

			Release to RRJ			Release to MCN	Release to MCN	RRJ to MCN	Release to BON	Release to BON	MCN to BON
Release Group	Release timing	Release Strategy	Mean Travel Time (d)	90% Passage (d)	Travel Rate (km/day)	Mean Travel Time (d)	90% Passage (d)	Travel Rate (km/day)	Mean Travel Time (d)	90% Passage (d)	Travel Rate (km/day)
CJH Summer subs	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Omak Pond subs	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wells FH subs	23-May	Forced	31	34	2.2	39	44	37	45	53	a
Wild subs	May 14-June 27	NA	36	51	2.6	50	62	28	49	62	a
CJH Summer yearlings	15-Apr	Volitional	32	61	3.6	43	69	18	58	75	48
Omak Pond yearlings	15-Apr	Volitional	23	44	6.4	36	62	22	47	68	53
Similkameen yearlings	17-Apr	Volitional	33	54	6.8	41	62	27	49	69	53
Carlton yearlings	23-Apr	Forced	23	44	5.4	36	59	19	45	64	58
Dryden yearling	22-Apr	Volitional	NA	NA	NA	23	32	14b	30	47	37

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

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

Table 28. Travel time (days) and the number of days to 90% passage for subyearling summer/fall Chinook release groups from 2015 to 2019.

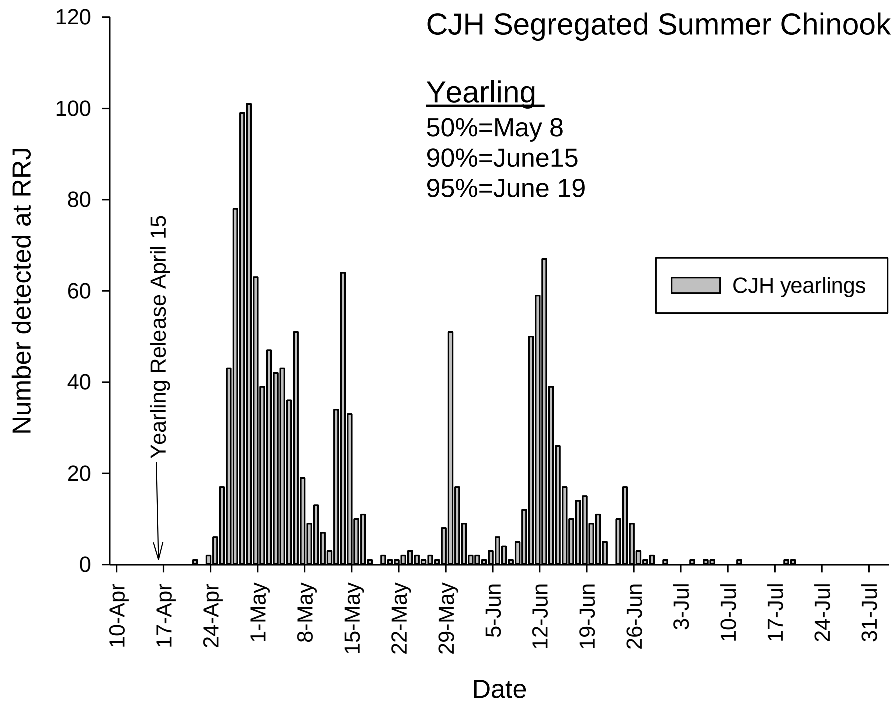
		Rocky Reach Dam		McNary Dam		Bonneville Dam	
Release Group	Year	Mean Travel Time (d)	90% Passage (d)	Mean Travel Time (d)	90% Passage (d)	Mean Travel Time (d)	90% Passage (d)
CJH Segregated Summer Subyearling	2015	35	54	48	63	55	65
	2016	18	31	27	38	31	44
	2017	21	32	32	43	36	46
	2018	15	32	27	46	30	43
	2019	NA	NA	NA	NA	NA	NA
	Average	**22**	**37**	**33**	**48**	**38**	**50**
Omak Pond Integrated Summer Subyearlings	2015	27	44	40	52	45	57
	2016	13	27	21	37	24	34
	2017	14	22	24	33	28	37
	2018	NA	NA	NA	NA	NA	NA
	2019	NA	NA	NA	NA	NA	NA
	Average	**18**	**31**	**28**	**41**	**32**	**43**
Wild Subyearlings[1]	2015	22	35	42	44	a	a
	2016	28	55	35	59	36	69
	2017	20	66	34	65	30	61
	2018	31	56	44	71	45	53
	2019	36	51	50	62	49	62
	Average	**25**	**53**	**39**	**60**	**37**	**61**

[1] Number of days to 90% passage was based on the mid-point of the release dates, which can vary by several weeks year to year

a) Sample size too small (<20) for a reliable estimate

Table 29. Travel time (days) and the number of days to 90% passage for yearling summer Chinook release groups from 2015 to 2019.

		Rocky Reach Dam			McNary Dam			Bonneville Dam	
Release Group	Year	Mean Travel Time (d)	90% Passage (d)		Mean Travel Time (d)	90% Passage (d)		Mean Travel Time (d)	90% Passage (d)
CJH Segregated Yearlings	2015	30	41		41	55		42	53
	2016	15	26		25	36		28	42
	2017	15	26		24	37		26	38
	2018	13	27		24	36		29	50
	2019	32	61		43	69		58	75
	Average	**18**	**30**		**29**	**41**		**31**	**46**
Omak Pond Integrated Yearlings	2015	NA	NA		NA	NA		NA	NA
	2016	16	30		25	36		27	39
	2017	22	37		30	44		32	44
	2018	22	42		31	47		39	58
	2019	23	44		36	62		47	68
	Average	**20**	**36**		**29**	**42**		**33**	**47**



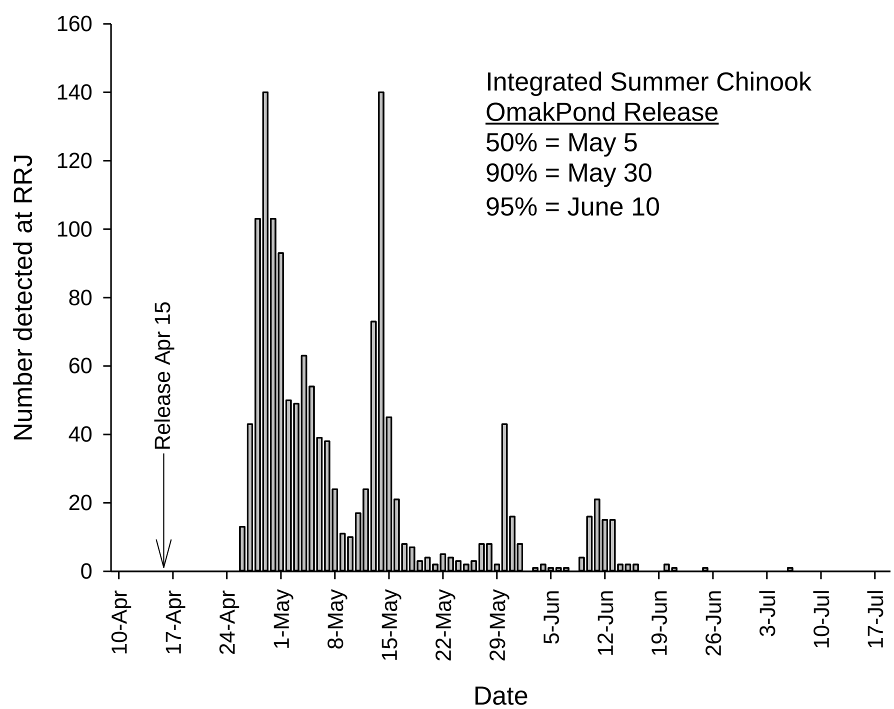


Figure 29. Arrival timing at Rocky Reach Juvenile bypass (RRJ) of PIT tagged Summer Chinook released from the Chief Joseph Hatchery and Omak Pond in 2019.

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 1.3% before harvest and 1.7% with harvested fish added back in (Table 30). For brood year 2014, the SAR back to Wells Dam was 0.8% before harvest and 2.0% 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 0.7% before harvest and 0.9% with harvested fish added back in (Table 30). For brood year 2014, the SAR back to Wells Dam was 0.4% before harvest and 0.7% 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/Fall 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/Fall 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/Fall 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/Fall 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 2012 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 1989-2012.

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	***10,513,721***	***141,977***	***1.4%***
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

The pooled trap efficiency of approximately <1% is much 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 2019 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 ($n \geq 1000$).

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 2019. 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 late June, which is later than what had been observed previous to that. Interestingly, dates of detection at downstream PIT arrays occurred about the same as they had in 2016 and 2017.

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. Results from the stable isotope analysis conducted in 2018 indicated that most fish collected from the Gebber's location are of Okanogan River origin (See 2018 Annual Report, Appendix E).

Lower Okanogan Adult Fish Pilot Weir

Discharge conditions on the Okanogan River in 2019 were quite a bit lower than those in previous years, allowing installation and operation of the weir in mid- July, which was a month earlier than 2018. Temperatures on the Okanogan River were fairly normal, compared to the 13-year median. They were not a factor for trapping operations once they began on August 26th. Tower observations were relatively low for the majority of the season outside of the last week in July and second week of September, the final week of operation. Bank fish observations were pretty steady throughout July and August and increased after the water temperature stayed below 22.5 °C in early September. In September, fish observations 0.8 km. below the weir, at the lower pool, were similar than observations at the weir. However, this was not the case for August, when bank observations were much higher than the tower observations below the weir. When river temperature was lower and gage 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. It's reasonable that there were more fish milling in the lower pool than there were milling around the weir in August. In August pickets were up on the weir panels due to a high density of algae in the river. The algae was creating a dense blanket across the weir panels and became too difficult for crew to maintain the weir without creating a head differential across the panels that was within the project's operating criteria. 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 = 143) was more than in 2018 (n= 48). Configuration of the weir was similar to that in 2018 with the trap installed downstream, on the edge of the thalweg, and below the deep pool. The fish entrance chute was added to the trap gate again to test whether it would increase entrainment to the trap box. We evaluated the water conditions as it relates to discharge and stage height and think that we should continue to install the trap at the same location as 2019 to continue testing it with the chute.

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. However, there are other water quality parameters that were not measured (i.e., pH, phosphorous, or nitrogen) that may have provided some insight to the algae issue. The number (8) of dead fish at the weir was the lowest it has ever been, and that can be a result from a lower potential to collect carcass washdowns in 2019. If the weir pickets were down more there likely would have been more prespawn mortalities collected. There were no fish impinged between pickets (head upstream) in 2019. 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 2019. We do not anticipate additional studies in the near future.

There were fifteen sockeye trapped in 2019. It is likely that more sockeye moved through the weir panels when pickets were up. When pickets were down and the trap was operating, there were no observations of jack or small adult Chinook escaping through the 2" weir panels that were intended to allow sockeye passage. We will continue to use 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.

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. The thermal barrier did not set up until late July, which was shortly after the weir was fully functional so it's likely that more fish passed the weir before it was installed. The barrier broke down in late August. Fortunately, this did not affect fish management objectives in 2019 because with a lower adult return, CCT decided to only collect broodstock at the weir and release all others, regardless of origin, back to the river to escape to the spawning grounds. 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/fall Chinook.

The brood stock collection protocol at the weir was to get 15% (n = 84) of the integrated program). By the time the weir trap was operational the protocol changed to collect up to 10 natural-origin and/or hatchery-origin adults. The weir met its brood stock goal, collecting 8 natural-origin and 2 hatchery-origin fish in late August and mid-September, after the post thermal barrier breakdown period.

In 2019 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 a limited trapping season and lower than expected adult summer/fall 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 should 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 or high algal densities in 2019 is important for understanding the range of challenges and resulting weir effectiveness that can be expected through time.

Redd Surveys

Summer/fall Chinook spawning consisted of 2,371 redds in 2019, which was above the long-term average (2,216 for 1989-2019) but below the more recent 5-year average of 3,451. Redd counts were below average across most reaches in the Okanogan and Similkameen rivers (O1, O4, O5, O6, S1, and S2) but actually increased compared to the average in the lower Okanogan River (reaches O2, O3) (Table 15).

The redd count in reach O6 – which most years, supports the largest proportion of natural-origin spawners – was the second lowest count on record, which dates back to 2006. Likewise, reach S1 in the Similkameen River – which generally supports the highest proportion of hatchery-origin spawners has its third lowest redd count going back to 2006.These two adjacent reaches, along with reach O5 (which also saw a slight reduction in the number of redd) still provide the primary spawning habitat for summer/fall Chinook in the Okanogan/Similkameen basin, comprising 76% of the total spawning in 2019. One objective of the CJHP is to increase the spatial distribution of spawning into the lower reaches of the Okanogan. Historically, a low proportion of the spawning activity has occurred in these reaches (O1 – O4), likely due to lower quality spawning habitat (increased fine substrate, reduced gradient, increased pool habitat). The 2019 redd counts showed an increase in the proportion of redds in reaches O1, O2, and O3 – continuing the trend from 2017 and 2018. 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 (located around the break between reach O3 and O4) 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. Conditions in 2019 were characterized by reduced discharge and increased stream temperatures going into the spawning period (Figure 2). However, despite these challenging holding conditions for Chinook, conditions improved (discharge increased and stream temperatures cooled to below average) at approximately the beginning of the spawning period (October). The greatest single week count of redds occurred between October 6 to October 12. Spawning lower in the Okanogan Basin (reaches O1, O2, and O3) appears to have peaked slightly later, with peak counts occurring the week of October 20-26. Few redds were recorded in November, as most spawning was complete by then (Table 19). 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.

As in previous years, the fish per redd expansion is 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 Chinook populations. However, there is uncertainty that the combined sex ratio of hatchery- and natural-origin summer/fall Chinook at Wells Dam is representative of the Okanogan population because it also includes Methow returns, mainstem released hatchery-origin Chinook, as well as roaming downstream hatchery- and natural-origin Chinook. If the Okanogan has a different ratio of precocial males (jacks) than that of the Wells count, then the Okanogan abundance estimate could be biased. We suggest exploring other approaches to estimating the number of fish per redd in the Okanogan and Similkameen Rivers. Until then, the annual spawning escapement will continue to be calculated using the sex ratio of fish at Wells Dam.

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 has still been 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 summer/fall Chinook 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. Researchers and managers for CCT and ONA have begun to discuss research and monitoring needs as well as potential strategies for accomplishing monitoring goals.

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

Spawning ground monitoring efforts resulted in an 8.6% carcass recovery rate, which was well below the target carcass recovery rate of 20%. However, it is unclear if 20% is necessary to obtain reliable biological-data or what the implications of reduced sampling rates may be. 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.

Spawning grounds surveys beginning in mid-August and lasting through November 16 revealed very few carcasses attributable to pre-spawn mortality, or PSM. Of the 283 female Chinook carcasses recovered, only 1.77% were determined to have expired pre-spawn. Also, few female carcasses had retained a significant portion of their eggs, with an egg retention rate of just 1.97%. In other words, it appears that if a significant pre-spawn mortality event takes place, it occurs prior to the spawning period in October, or even late September, as the carcasses we recover on the spawning grounds are nearly all void of eggs. Given the challenging thermal 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. One thing of note is that carcasses that are collected during spring Chinook spawning ground surveys in August and September are assessed via coded wire tag recovery to determine spring or summer run. During the 2019 surveys, 3 summer Chinook pre-spawn mortality carcasses were collected, one each in Loup Loup Creek, Aeneas Creek, and Bonaparte Creek. 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 that retained ≥1000 eggs, the estimated PSM remained unchanged. 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. 2019 pHOS (0.47) was above the biological target, however, the 5-year average remained within the parameter at 0.25. The program failed to meet the biological target for PNI (>0.67) in 2018 and again in 2019 (0.57). However, the 5-year mean PNI (0.75) remains above objective. The increased hatchery-origin contribution on the spawning grounds is a result of CJH segregated fish, which stray at an appreciable level to the Okanogan and Similkameen rivers. In the future, we suggest that continued aggressive removal of hatchery-origin 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 Chinook recovered on the spawning grounds in the Okanogan Basin were predominantly (68%) from Okanogan and Similkameen acclimated, CJH Integrated Program releases. CJH Segregated fish made up 36% of the hatchery-origin spawners, and 19% of the total spawning escapement. Stray hatchery-origin fish originating from outside the Okanogan made up 2.7% of the total estimated spawners, which was less than the goal of 5%, although if we include the CJH segregated spawners, the stray rate increases to 21.7%. Okanogan Basin hatchery-origin fish strayed to other areas at a low rate (0.9% to non-target basins and 1.0% to non-target hatcheries, based on RMIS queries of the 2014 BY) and were a small percentage of the spawner composition in other Upper Columbia tributaries in 2019 (less than 2% in any stray basin). Fish released within the Okanogan Basin have consistently homed to their natal stream, and 2019 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 already saturated Similkameen River with additional spawners. Juvenile Chinook releases from the Omak Pond acclimation site are primarily spawning in the Okanogan River (92% in 2018 and 90% in 2019) instead of the Similkameen River. Specifically, the Omak Pond-reared Chinook have spawned almost exclusively in the lower (O3 reach) and middle (O5 reach) sections 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 2019 estimates of CJH programs were similar to nearby programs and the five-year mean, despite large increases in travel time to Rocky Reach and McNary dams. 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 2019, with 90% passage at OKL within 21 days and only two detections after May 19. 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 and sample size was relatively small for the Omak Pond release (n=44) and extremely small for the Similkameen release (n=4). 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 future years the program will have more years of data to assess smolt to adult survival differences that can be used to 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 (2012) was similar to the 5-year and higher than the 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 April 2020 with the purpose of reviewing data collection efforts and results from 2019 and developing the hatchery implementation and monitoring plan for 2020 (Figure 30). 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 31). 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 2020. 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?
8. How should the program be operated in the coming year?

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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.

Figure 30. The Chief Joseph Hatchery's annual planning process and workflow.

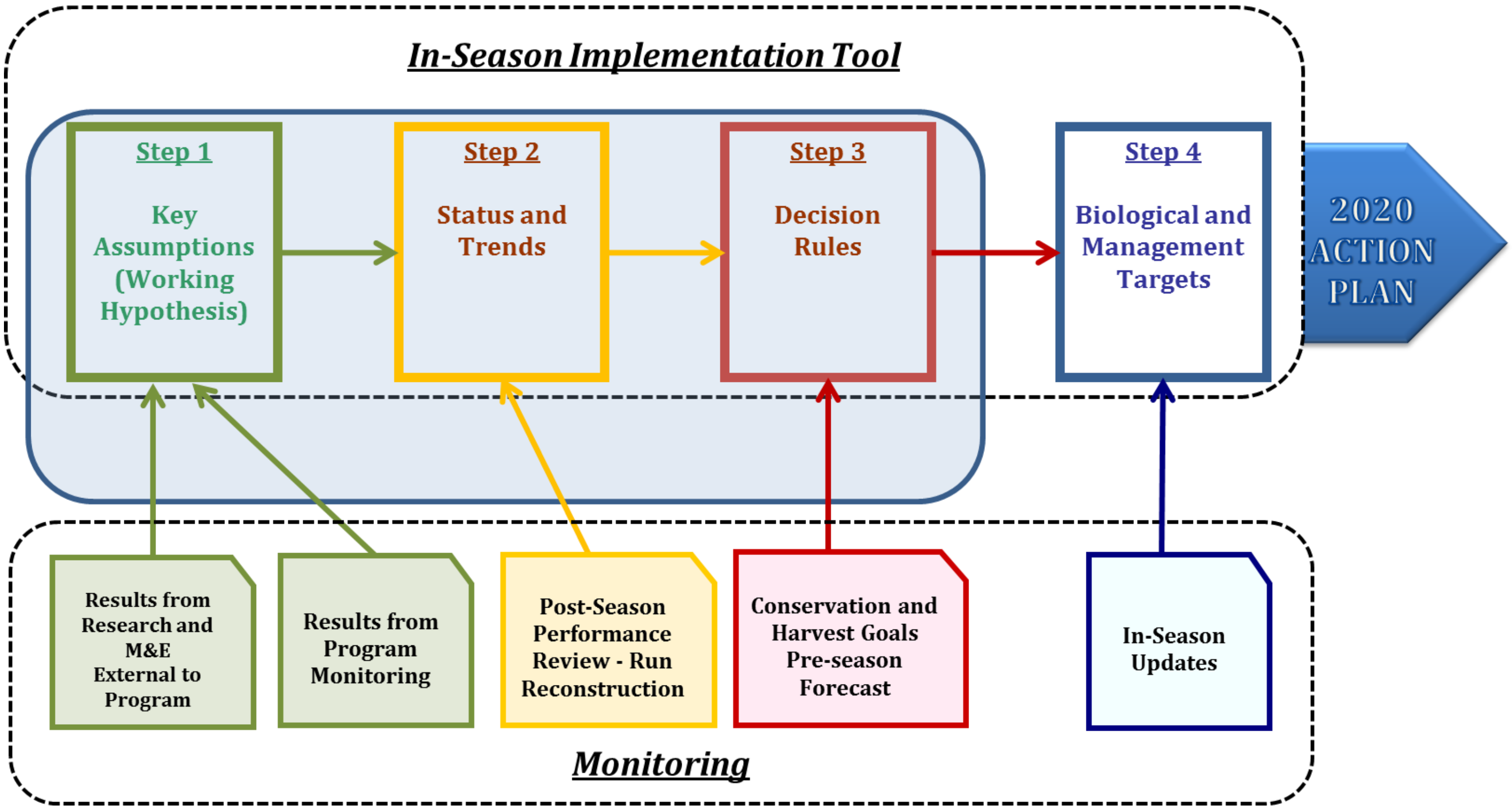

Figure 31. The Chief Joseph Hatchery's analytical workflow.

2020 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 38,300. 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 38,300 upper Columbia would yield 3,361 NORs and 5,146 HORs (Figure 32). The harvest and broodstock collection goals were established from this prediction. With a NOR run size just over 3,000 the broodstock collection recommendation for the integrated program was full production (439 NOB and 293 HOB) with 60% pNOB (Figure 32). Likewise, the segregated program should achieve full production with 581 HOB. The model predicted that 1,029 HORs would be captured in the terminal (above Wells Dam) fisheries and that no HORs could be removed at the weir. These efforts could result in 2,552 NOS and 1,689 HOS for a pHOS of 38% and a PNI of 0.61. Under this modeling scenario the biological targets will likely not be met in 2020. 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, 2020. 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 **2019** <-- Most recent return year

Use 5 -year running averages to calculate prior-cumulatives

Override Values Applied

Recent History:

Average NOB	346
Average HOB	131
Average pNOB	73%
Average NOS	5,761
Average HOS	1,637
Average pHOS	22%

xpected Returns to Wells Dam (most recent update):	2020 Forecast	2019 Final
NOR Return (excludes jacks)	3,361	3,230
HORs from Integrated Program (excludes jacks)	3,071	3,577
HORs from Segregated Program (excludes jacks)	2,075	2,380

Runsize Prediction for:	2020
Preseason forecast (Columbia)	38,300
Applies until:	07/15/20
Wells Dam Count thru 07/15	-
Okanogan NOR Forecast (excludes jacks)	3,361
Okanogan HOR Forecast (excludes jacks)	5,146

Prespawning Mortality	10.0%
NOR Terminal harvest induced mortality rate	5.2%

	Management Targets	2020 Targets
Harvest*	Okan. HORs retained in Terminal Fisheries	614
	CJH HORs retained in Terminal Fisheries	415
	Incidental Loss of NORs	87
Hatchery and Weir*	Return of Okan. HORs to Hatchery	287
	Return of CJH HORs to Hatchery	1,328
	Okan. HORs retained at Weir	-
	CJH HORs retained at Weir	-
Integrated Hatchery Program	Natural Origin Brood (NOB)-Okan (collected)	439
	Hatch. Origin Brood (HOB)-Okan (collected)	293
	Projected Annual pNOB-Okan	60%
	Cum pNOB	67%
	Smolt Release-Okanogan	800,000 Yearl. 300,000 Subs
Segregated Hatchery Program	Hatch. Origin Brood (HOB) - Int	-
	Hatch. Origin Brood (HOB) - Seg (purse seine and ladder)	581
	Smolt Release-CJH	500,000 Yearl. 400,000 Subs
Natural Spawning Escapement	Nat. Origin Spawners (NOS)	2,552
	Hat. Origin Spawners (HOS) - Int	1,689
	Hat. Origin Spawners (HOS) - Seg	299
	Hat. Origin Spawners (HOS) - out-of-basin	NA
	Total Number of Spawners (excludes jacks)	4,540
	Effective pHOS	38%
	PNI	0.61

Projected Status of Biological Indicators* (5-year averages):	
Average NOS	4,285
Average pHOS	25%
Average PNI	0.73

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

Figure 32. The in-season updates management worksheet used to set biological targets for the upcoming year (2020) in the In-Season Implementation Tool.

2020 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 33).

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	0.87			0.87	0.87	0.87	
PNI	0.72	<	0.67	0.72	0.72	0.72	
Total pHOS	100%	>	30%	100%	100%	100%	
Segr. pHOS	3%	<	5%	3%	3%	3%	
Ocean Harvest Rate	29%			29%	29%	29%	
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	2%			2%	2%	2%	
Upper Columbia Harvest Rate (MCN to Wells)	27%			27%	27%	27%	
Terminal Harvest Rate (Post Wells)	5%			5%	5%	5%	
Natural Origin Spawners	4,350	<	5,250	4,350	4,348	4,350	
Hatchery Production							
Local Brood	368			732	732	732	196
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	100%			100%	100%	100%	
NOB	740			740	740	740	
Relative Reproductive Success	80%			80%	80%	80%	80%
Ocean Harvest Rate	29%			29%	29%	29%	29%
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	4%			4%	4%	4%	4%
Upper Columbia Harvest Rate (MCN to Wells)	31%			31%	31%	31%	31%
Pre-terminal Harvest Rate (Ocean to Wells)	53%			53%	53%	53%	53%
Terminal Harvest Rate (Post Wells)	40%			40%	40%	40%	15%
Hatchery Surplus	141			141	158	141	2,462
Average Terminal HOR Run	1,733			5,545	5,545	5,545	3,466
Expected HOS	895			2,865	2,865	2,865	472
Fisheries and Weirs							
Weir Factor	2%			2%	2%	2%	
NOR Harvest Release Mortality	8%			8%	8%	8%	

Figure 33. The key assumptions worksheet used in the 2020 In-Season Implementation Tool for the CJHP planning at the Annual Program Review

2020 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 34).

Return year		FPC Reported Dam Count at Wells thru 07/15 (excludes jacks)	% of final count	PUD Counts at Wells Dam: NOR All Origins (excludes jacks)	PUD Counts at Wells Dam: HOR All Origins (excludes jacks)	Estimated Return of Okanogan Origin Fish to Wells Dam: **Okan. NORs**	Estimated Return of Okanogan Origin Fish to Wells Dam: Okan. HORs	Estimated Return of Okanogan Origin Fish to Wells Dam: CJH HORs	**%NOR**
1998	3	**1,060**	0.25	970	5,519	841	833.44	-	0.50
1999	4	**999**	0.11	2,708	4,580	1,562	2,686	-	0.37
2000	5	**2,266**	0.26	2,726	7,398	1,213	2,291	-	0.35
2001	6	**9,766**	0.24	10,266	19,195	4,632	7,141	-	0.39
2002	7	**23,221**	0.34	24,138	42,035	5,207	11,801	-	0.31
2003	8	**20,564**	0.40	9,194	7,373	2,693	2,948	-	0.48
2004	9	**14,762**	0.40	23,227	13,989	8,004	2,599	-	0.75
2005	10	**14,449**	0.42	18,911	15,164	8,615	3,404	-	0.72
2006	11	**12,563**	0.43	20,262	8,730	8,677	4,114	-	0.68
2007	12	**5,532**	0.37	7,088	7,789	4,742	2,901	-	0.62
2008	13	**8,838**	0.35	11,244	13,779	4,526	6,369	-	0.42
2009	14	**13,753**	0.46	15,184	14,187	5,861	5,678	-	0.51
2010	15	**12,264**	0.41	5,671	7,167	4,802	5,398	-	0.47
2011	16	**3,912**	0.12	12,139	19,164	5,275	6,161	-	0.46
2012	17	**10,082**	0.24	14,424	27,716	6,283	7,467	-	0.46
2013	18	**25,571**	0.38	34,965	30,179	8,448	5,981	-	0.59
2014	19	**26,010**	0.46	36,060	21,015	12,798	4,272	-	0.75
2015	20	**25,153**	0.32	46,030	31,625	14,199	8,340	-	0.63
2016	21	**21,479**	0.43	28,467	21,542	12,023	4,808	3	0.71
2017	22	**15,124**	0.44	15,729	18,479	7,622	2,280	1,334	0.68
2018	23	**11,886**	0.48	6,533	18,347	3,786	2,652	2,090	0.44
2019	24	**12,950**	0.47	8,499	18,800	3,230	3,577	2,380	0.35
2020	25	-	#DIV/0!	-	-	-	-	-	
2021		-	#DIV/0!	-	-	-	-	-	
7/15		**2020**	**dam count at Wells was**			**-**	**adults**		

Return year	Terminal Harvest Above Wells — Tribal Harvest: **Total Tribal Harvest**	Tribal: Total NORs	Tribal: Total HORs	Tribal: Okan. NORs	Tribal: Okan. HORs	Tribal: CJH HORs	Recreational Harvest: **Total Rec. Harvest**	Rec.: Total NORs	Rec.: Total HORs	Rec.: Okan. NORs	Rec.: Okan HORs	Rec.: CJH HORs	Terminal Harvest Rates: NOR	Terminal Harvest Rates: Int HOR	Terminal Harvest Rates: Seg HOR
1998	**-**	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
1999	**-**	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
2000	**-**	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
2001	**-**	0	0	-	-	-	**-**	-	-	-	-	-	0%	0%	-
2002	**1,753**	653	1100	118	990	-	**-**	-	-	-	-	-	2%	8%	-
2003	**2,130**	785	1345	141	1,211	-	**-**	-	-	-	-	-	5%	41%	-
2004	**242**	0	242	-	218	-	**2,803**	1,895	908	1,706	817	-	21%	40%	-
2005	**784**	392	392	71	353	-	**1,419**	1,025	394	923	355	-	12%	21%	-
2006	**1,389**	563	826	101	743	-	**2,119**	1,809	310	1,628	54	-	20%	19%	-
2007	**1,078**	467	611	84	550	-	**1,803**	887	916	798	726	-	19%	44%	-
2008	**2,299**	588	1711	106	1,540	-	**1,665**	698	967	628	561	-	16%	33%	-
2009	**2,598**	363	2235	65	2,012	-	**1,062**	648	414	583	244	-	11%	40%	-
2010	**2,912**	354	2558	64	2,174	-	**1,019**	612	407	551	208	-	13%	44%	-
2011	**1,097**	449	648	81	577	-	**1,017**	200	817	180	286	-	5%	14%	-
2012	**3,184**	656	2528	118	2,250	-	**2,470**	829	1,641	746	1,559	-	14%	51%	-
2013	**3,176**	832	2344	150	1,781	-	**2,107**	179	1,928	161	713	-	4%	42%	-
2014	**2,963**	1508	1455	271	1,164	-	**1,383**	321	1,062	289	382	-	4%	36%	-
2015	**9,729**	6257	3472	1,126	2,639	-	**1,660**	289	1,371	260	494	-	10%	38%	-
2016	**3,141**	1889	1252	340	989	3	**1,784**	237	1,547	213	665	-	5%	34%	100%
2017	**1,397**	746	651	134	104	117	**1,568**	591	977	532	479	59	9%	26%	13%
2018	**1,238**	484	754	87	128	249	**993**	28	965	25	280	68	3%	15%	15%
2019	**1,363**	129	1234	23	457	234	**1,924**	91	1,833	82	733	110	3%	33%	14%
2020	**-**	0	0	-	-	-	**-**	-	-	-	-	-	-	-	-
2021	**-**	0	0	-	-	-	**-**	-	-	-	-	-	-	-	-

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
	Broodstock																
	Okanog./Similk Integrated Program												CJH Segregated Program				
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	45	193	90%	174	212	45	27	212	405	43%	422	147	150	111	261
2019	419	250	73	376	90%	338	224	56	36	224	600	56%	391	174	297	132	429
2020	-	-		-		-	-			-	-	-	-	-	-	-	-
2021	-	-		-		-	-			-	-	-	-	-	-	-	-

Return year	NOS	HOS - Int	HOS - Seg	HOS-out of basin	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
	Okanogan Natural Spawning Escapement (excludes jacks)											Surplus Fish (HORs only; NORs released to spawn)				
1998	542	437	-		437	45%	39%	35%	53%	891	1,778					-
1999	1,182	2,142	-		2,142	64%	59%	27%	53%	2,895	3,301					-
2000	926	1,726	-		1,726	65%	60%	21%	53%	2,307	2,564					-
2001	4,048	6,047	-		6,047	60%	54%	19%	53%	8,885	9,791					-
2002	4,337	9,473	-		9,473	69%	64%	28%	53%	11,916	11,005					-
2003	1,892	1,463	-		1,463	44%	38%	51%	53%	3,063	5,692					-
2004	5,182	1,392	-		1,392	21%	18%	73%	53%	6,295	16,917					-
2005	6,364	2,416	-		2,416	28%	23%	68%	53%	8,297	18,209					-
2006	5,303	2,970	-		2,970	36%	31%	61%	53%	7,679	18,340					-
2007	2,774	1,282	-		1,282	32%	27%	64%	53%	3,800	10,022					-
2008	2,866	3,734	-		3,734	57%	51%	47%	53%	5,854	9,567					-
2009	4,002	3,036	-		3,036	43%	38%	57%	53%	6,431	12,388					-
2010	3,087	2,614	-		2,614	46%	40%	55%	53%	5,178	10,150					-
2011	3,249	4,283	-		4,283	57%	51%	57%	53%	6,676	11,149					-
2012	4,211	3,114	-		3,114	43%	37%	71%	53%	6,702	13,279					-
2013	5,134	2,433	-		2,433	32%	27%	77%	53%	7,080	17,857	54	-	73	-	127
2014	9,466	1,410	-		1,410	13%	11%	89%	53%	10,594	27,051	122	-	241	-	363
2015	9,936	3,194	-		3,194	24%	20%	81%	53%	12,491	30,011	888	-	29	-	917
2016	8,315	1,769	-		1,769	18%	15%	86%	53%	9,730	25,412	232	-	33	-	265
2017	5,098	713	401	101	1,216	19%	16%	84%	53%	5,990	16,109	169	712	81	1	963
2018	3,023	1,249	143	54	1,446	32%	28%	61%	53%	4,137	8,003	139	1,423	6	-	1,568
2019	2,436	1,521	939	147	2,607	52%	46%	55%	53%	4,404	6,828	50	745	6	-	801
2020	-	-	-			-	-	-	53%	-	-	-		-		-
2021	-	-	-			-	-	-	53%	-	-	-		-		-

† Placeholder Values. Documented estimates needed. Radio tracking values from 2011 and 2012.

Figure 34. The status and trends worksheet in the In-Season Implementation Tool for CJHP planning at the Annual Program Review.

2020 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 35).

BIOLOGICAL TARGETS AND "PHASE TRIGGERS"

Population Designation: Primary
Current Phase: Transition 2 (from Decision Rules)

		Applied Scenario		Phase 1	Phase 2	Phase 3
				Recolonization	Local Adapt.	Recovered
Biological Triggers for Phase Change Rules		Transition 2	Baseline	Transition 1	Transition 2	Long term
	Year	2025	2013	2020	2025	-
	Move up one phase if NORs greater than:	7,000	1,000	5,250	7,000	-
	Move down one phase if NORs less than:	3,000	-	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 2	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	702	353	702	702	702
	pNOB [Lo] Trigger (NOR run)	2,000	1,100	2,000	2,000	3,000
	pNOB above Trigger	100%	100%	100%	100%	100%
	pNOB below Trigger	100%	100%	100%	100%	100%
Segregated Program	Maximum Yearling Releases	500,000	500,000	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	3%	3%	3%	3%	3%
	Term. Harvest Rate Integrated HORs	36%	36%	36%	36%	36%
	Term. Harvest Rate Segregated HORs	24%	24%	24%	24%	24%
	pNOB Trigger Range (NOR run)	1,000	sets range for "sliding scale pNOB" --applies to all phases			
	NOS Escapement Goal	5,250	-	5,250	5,250	5,250

Modeled outcomes versus Biological Targets

	Targets	Status in 2020 (5-year average)	Projected Status in 2021 (5-year average)	Projected Status 2021-2045	
				Median*	Range*
NOS	> 5250	5,325	4,448	4,548	4,048 - 4,677
pHOS	< 30%	23%	26%	44%	29% - 45%
PNI	> 0.67	0.76	0.75	0.69	0.69 - 0.78
Terminal Catch of HORs (Int and Seg)	> 3000	2,535	2,197	3,602	801 - 3,602

*Median, minimum and maximum values from 2021-2045 based on a single model run.

Figure 35. 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/FALL 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/fall 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 2019, 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 2018 SUMMER/FALL CHINOOK SALMON REARING AND RELEASE

Due to high pre-spawn mortality and reduced eyed egg survival, there was no integrated or segregated sub-yearling program for brood year 2018.

The yearling summer/fall Chinook rearing started earlier than anticipated due to a failing chiller. Marking was completed, for both the integrated and the segregated programs, on September 3, 2019. The segregated summer/fall Chinook were 100% ad-clipped, with a 100k CWT group tagged. The integrated summer/fall Chinook were 100% AD/CWT. As shown in Table A 1 and Table A 2, ponding and rearing mortality for both programs were elevated as a result of the failing chiller 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 16th. Approximately 5,000 PIT tags were added to each group in October

2019. After subtracting shed tags and mortality, a total of 4,081 PIT tags were released from the segregated group (3,267 were detected at release).

Table A 1. Chief Joseph Hatchery brood year 2018 segregated summer/fall yearling rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	12/31/2018	258,944	-	20	1,172	100.00%
	1/31/2019	202,200	56,744	262	340	78.09%
	2/28/2019	200,147	2,053	288	234	77.29%
	3/31/2019	199,027	1,120	345	158	76.86%
	4/30/2019	197,858	1,169	312	123	76.41%
	5/31/2019	197,316	542	280	105	76.20%
	6/30/2019	196,273	1,043	1,451	58	75.80%
	7/31/2019	195,243	1,030	2,474	25	75.40%
	8/31/2019	195,036	207	2,182	19	75.32%
	9/30/2019	194,748	288	545	20	75.21%
	10/31/2019	193,752	996	1,687	19	74.82%
	11/30/2019	192,378	1,374	1,294	15	74.29%
	12/31/2019	191,820	558	2,175	14	74.08%
	1/31/2020	191,120	700	982	12	73.81%
	2/29/2020	190,671	449	739	12	73.63%
	3/31/2020	190,324	347	874	12	73.50%
	4/16/2020	189,855	469	109	11	73.32%
	Total SEG	**189,855**	**69,089**	**16,019**	**11**	**73.32%**

The integrated summer/fall Chinook were shipped to the Omak Acclimation Pond and the Similkameen Acclimation Pond between October 24th 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 133,940 Integrated BY 18 summer/fall Chinook from Chief Joseph Hatchery to the Omak Acclimation Pond. Approximately 5,000 PIT tags were added to the group in October 2019. At the time of transfer, the fish were approximately 16 fpp, and were programmed to be reared over winter, with a target size at release of 10 fpp. These fish were forced released April 30, 2020. After subtracting shed tags and mortality, a total of 4,532 PIT tags were released from this integrated group (3,780 were detected at release). Table A 2 illustrates feed fed, feeding rate, and mortality to date for the integrated summer/fall Chinook transferred to the Omak Acclimation Pond.

Table A 2. Omak Acclimation Pond BY 18 integrated yearling summer/fall Chinook rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
NOR	10/31/2019	133,940	-	-	16	100.00%
	11/30/2019	123,937	10,003	880	16	92.53%
	12/31/2019	123,096	841	-	16	91.90%
	1/31/2020	122,915	181	-	16	91.77%
	2/29/2020	122,607	308	352	14	91.54%
	3/31/2020	122,546	61	1,496	14	91.49%
	4/17/2020	122,147	399	1,188	10	91.20%
	Cumulative:	**122,147**	**11,793**	**3,916**	**10**	**91.20%**

Riverside Acclimation Pond

Riverside Acclimation Pond was not used to rear BY 2018 summer/fall Chinook but was utilized to rear BY 18 10j Spring Chinook.

Similkameen Acclimation Pond

Similkameen Pond was used to rear yearling summer/fall Chinook per the WDFW program funded by CPUD. Adult broodstock used to generate the juveniles for BY 2018 were collected via the CCT purse seine as part of the transition to the collaborative CJH program. On October 30, 2019, Chief Joseph Hatchery staff transferred 120,387 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 16 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 30, 2020. Cumulative survival, at the date of transfer, was 67.3%. Survival from transfer to release was 94.4%.

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 2018 yearlings, was 45.5% (52.8% for the segregated program and 38.2 for the integrated program. The reduced survival rate is due to the chiller issues. There were no BY18 sub-yearling releases for either program.

2019 Broodstock collection

Collection of summer/fall Chinook for BY 2018 occurred between July 8th and August 13th 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 67.5° F (19.7° C) to 78.4° F (25.8° 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/fall run timing as possible (Table A 3). If brood collection failed to meet the weekly quota it was adjusted the following week. However, due to low returns and to ensure overall broodstock goals were met, this quota was not followed and broodstock was collected as early as possible. 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.

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. Diquat was also used under an INAD once Columnaris was detected in broodstock, which was from mid-August through October.

Table A 3. Chief Joseph Hatchery summer/fall Chinook weekly broodstock collection objectives and results for brood year 2019.

Chief Joseph Hatchery BY 19 Summer Chinook Weekly Broodstock Collection Objectives

Week	Weekly Quota[1]		Cumulative Proportion	Cumulative Collection	
	Natural Origin[2]	Hatchery Origin[3]		Natural Origin	Hatchery Origin
July 1 - July 7	22	22	0.04	22	22
July 8 - July 14	22	22	0.08	44	44
July 15 - July 21	108	104	0.27	152	148
July 22 - July 28	108	104	0.46	260	252
July 29 - Aug 4	132	126	0.69	392	378
Aug 5 - Aug 11	132	126	0.92	524	504
Aug 13 - Aug 18	36	36	0.98	560	540
Aug 19 - Aug 25	12	12	1.00	572	552
*Sept 15 - Oct 15	84			656	

*NOR weir collection

[1]Weekly collection short-fall to be added to following week's collection

[2]Combined collection strategies in priority order: purse seine, tangle-net, Okanogan weir beach seine and CJH ladder

[3]Combined collection strategies in priority order: purse seine, tangle-net, CJH ladder, Okanogan weir and beach seine

A total of 553 HOB were collected including 302 females, 220 adult males and 31 jacks (Table A 4). However, it's believed some of these were mis-sexed as they entered the hatchery, so these numbers do not match exactly to the table. A total of 670 NOB were collected including 330 females, 284 adult males, and 56 jacks (Table A 4). Some of the fish initialed classified as jacks were actually adult males, this the difference from Table A 5. Due to low wild returns, some hatchery brood were allocated to the integrated program, which included 105 males, 127 females and 16 jacks. No steelhead or Bull trout were encountered during broodstock collection efforts.

Through the month of October 2019, there were 22 adult male and 31 adult female mortalities in the HOR brood, representing 91.3% and 89.0% cumulative pre-spawn survival to date, respectively. For the same time frame, 11 adult NOR summer/fall Chinook males died, and 15 females died, representing 95.5% and 95.4% cumulative pre-spawn survival, respectively. (Table A 4) 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 89.9% (including jack) for HOB and 95.8% (including jacks) for NOB (Table A 4), the NOR program exceeded the survival goal of 90% while the HOB was just shy of the goal.

Table A 4. Chief Joseph Hatchery summer/fall Chinook Hatchery (HOB) and Natural (NOB) origin broodstock holding survival summary for brood year 2019. (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	226	28	262	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	August	226	28	262	252	31	281	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Sept	252	31	281	251	31	280	1	0	1	99.6%	100.0%	99.6%	99.6%	100.0%	99.6%
	Oct	251	31	280	0	0	0	21	4	30	91.6%	88.6%	89.3%	91.3%	87.1%	89.0%
	Total	**251**	**31**	**280**	**0**	**0**	**0**	**22**	**4**	**31**				**91.3%**	**87.1%**	**89.0%**
NOR	July	0	0	0	214	77	245	1	0	0	99.5%	100.0%	100.0%	99.5%	100.0%	100.0%
	August	214	77	245	244	93	321	1	0	0	99.6%	100.0%	100.0%	99.2%	100.0%	100.0%
	Sept	244	93	321	244	93	326	0	0	1	100.0%	100.0%	99.7%	99.2%	100.0%	99.7%
	Oct	244	93	326	0	0	0	9	2	14	96.3%	97.9%	95.7%	95.5%	97.8%	95.4%
	Total	**244**	**93**	**326**	**0**	**0**	**0**	**11**	**2**	**15**				**95.5%**	**97.8%**	**95.4%**

Hatchery staff began collection of NOR brood from the weir on August 27, 2019. Collections off the weir were slow and only 8 wild females and 2 hatchery 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/fall Chinook began on October 1, 2019, with the segregated program, and continued through October 29, 2019. Beginning with the 2018 brood year, the segregated and integrated programs will be spawned on separate days. As with the spring Chinook, the summer/fall Chinook program is also 100% ELISA sampled. For the 2019 brood, there were no eggs culled for either program in 2019.

Total NOB spawned included 273 males, 37 jacks, and 314 females. (Table A 5) Total HOR spawn included 198 males, 16 jacks, and 248 females. Total eyed egg take for the season was 1,988,520. Egg survival from green egg to eyed egg for NOB averaged 82.9% (Table A 5). Egg survival for HOB averaged 87.2%. Survival was lower than the key assumption of (90%) for this life stage.

Table A 5. Chief Joseph Hatchery brood year 2019 summer/fall Chinook spawning and incubation results.

	Spawn Date	Total Adults Spawned M	J	F	Est. Green Eggs On Hand	Eyed Eggs On Hand	Mortality (Pick off)	Cumulative Survival (%)
HOR	10/1/2019	20	1	1	87,560	75,467	2,207	97.2%
	10/8/2019	55	5	60	258,280	213,212	24,384	89.7%
	10/15/2019	78	8	126	547,580	460,130	60,593	88.4%
	10/22/2019	39	2	55	242,000	172,691	44,978	79.3%
	10/29/2019	6	0	6	26,400	11,190	4,898	69.6%
	Total:	**198**	**16**	**248**	**1,161,820**	**932,690**	**137,060**	**87.2%**
	Spawn Date	Total Adults Spawned M	J	F	Est. Green Eggs On Hand	Eyed Eggs On Hand	Mortality (Pick off)	Cumulative Survival (%)
NOR	10/2/2019	16	0	15	61,380	59,020	1,559	97.4%
	10/9/2019	38	1	36	158,400	129,925	9,139	93.4%
	10/16/2019	101	21	153	669,680	516,496	105,473	83.0%
	10/23/2019	56	2	58	253,440	198,245	46,993	80.8%
	10/29/2019	62	13	52	225,500	152,144	54,652	73.6%
	Total:	**273**	**37**	**314**	**1,368,400**	**1,055,830**	**217,816**	**82.9%**

Broodstock origin

Broodstock were interrogated for coded-wire tags by program throughout October and the first week of November. Beginning October 1st, segregated fish were spawned on Tuesday of each week, while integrated fish were spawned on Wednesdays. A total of twelve spawning events occurred in 2019. All ad-clipped chinook incorporated in the integrated and segregated programs were sampled at 100% for CWTs regardless of electronic detection via T-wand. Collected samples were then frozen until mid-December where CWTs are extracted and analyzed in the laboratory during winter months.

All broodstock collected for the summer/fall Chinook segregated program came from an Upper Columbia River hatchery program. The CJH integrated program was the largest contributor to segregated brood with (n=297) 58.8% of adults coming from either the Similkameen or Omak Pond (Table A 6). Other Upper Columbia River Hatcheries contributed (n=79) 15.4%, most of which were from Wells Hatchery (8.7%) and Carlton A.P. (3.1%). A large portion of snouts (n=106) 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 20.9% of the 2019 segregated brood (Table A 6). The mark rate for brood year 2013-2017 segregated releases vary between 99% and 24% ad-clipped + CWT however, overall mark rate between these brood years averages 68.5%. All summer/fall 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=106) can be assigned to the segregated CJH program. The overall composition of the segregated program (tagged and non-tagged) to the segregated brood was 25.8%.

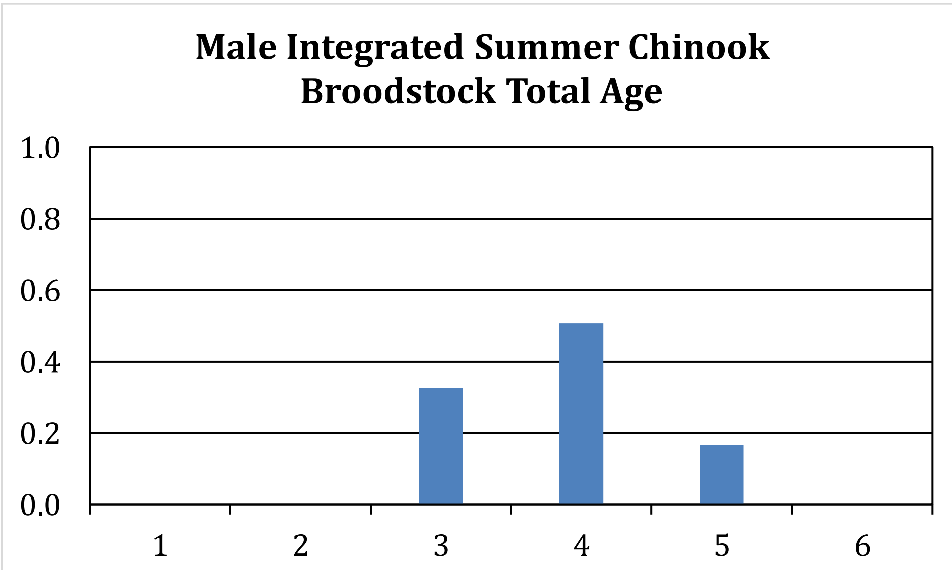
Table A 6. Composition of hatchery-origin brood, by program, collected for the CJH segregated program in 2019.

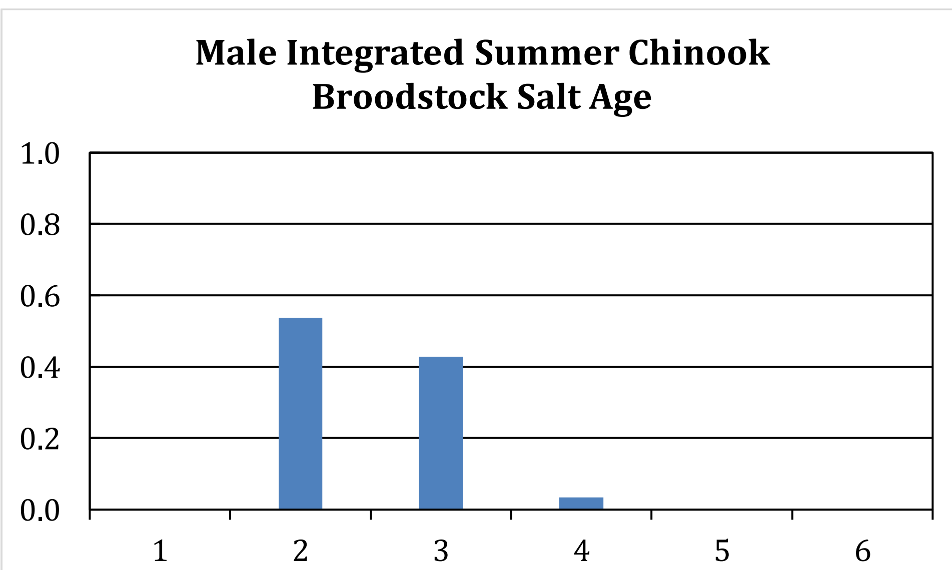
Category	Hatchery Program	Brood	% of brood	
Okanogan Integrated	Similkameen	186	36.8 %	58.8%
	Omak Pond	108	21.3 %	
	Natural Origin	3	<1.0%	
CJH Segregated	Chief Joseph	24	4.7%	25.8%
	Chief Joseph (non-tagged)	106	20.9 %	
Other UCR summer/fall Chinook hatchery	Wells	44	8.7%	15.4%
	Carlton A.P.	16	3.1%	
	Chelan Falls	10	1.9%	
	Entiat NFH	6	1.1%	
	Dryden Pond	3	<1%	
Total		506	100.0%	

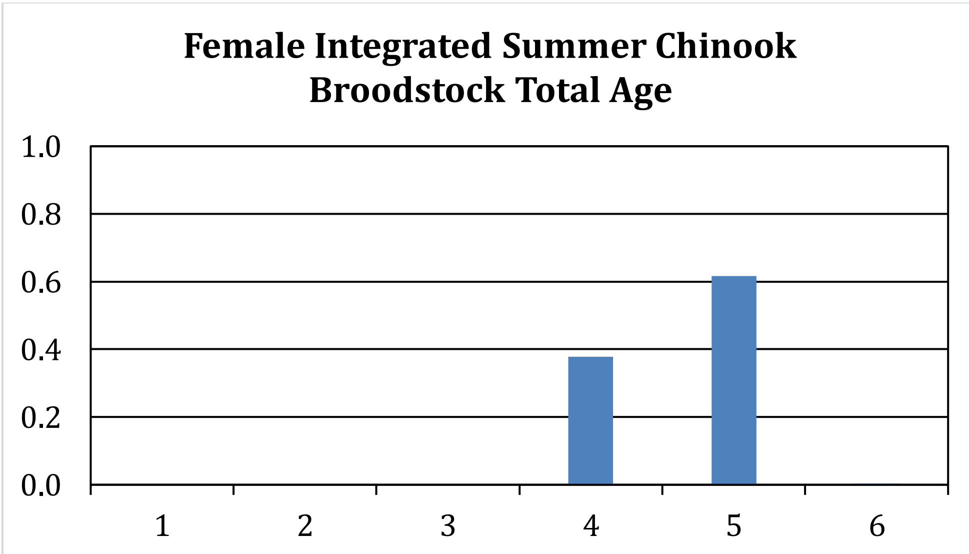
*Brood values are adjusted to account for segregated no tag fish and are rounded to the nearest whole number.

Integrated Program Broodstock Age Structure

Scales are taken from summer/fall Chinook integrated Program broodstock in order to capture the age of successfully spawned fish. In 2019, the integrated and segregated programs were comprised of mostly four and five-year old male and female fish (Figure A 1).







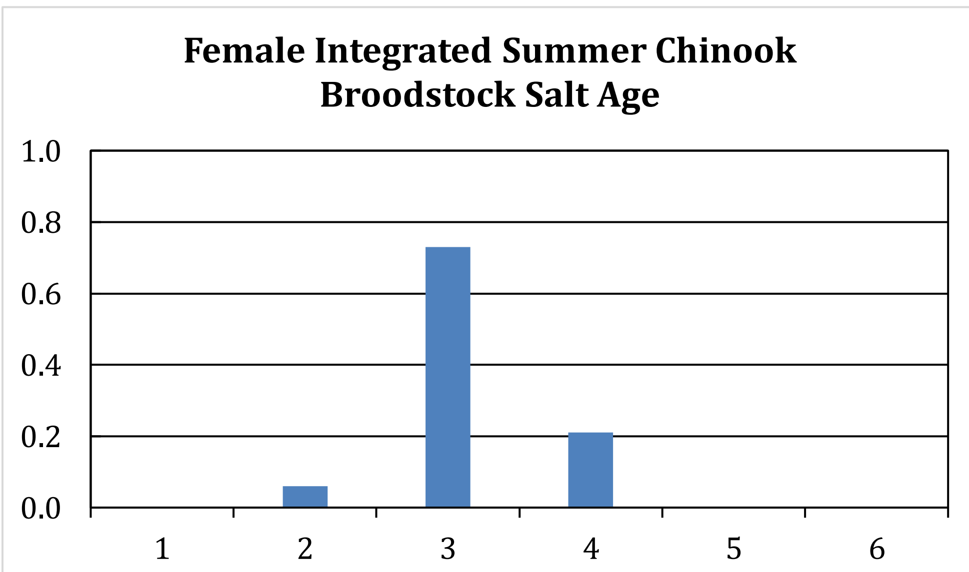
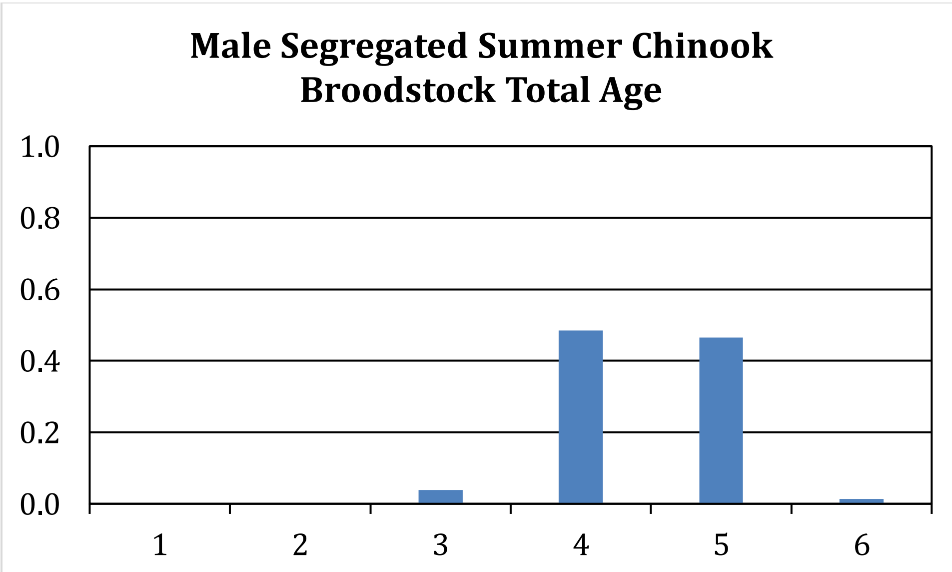
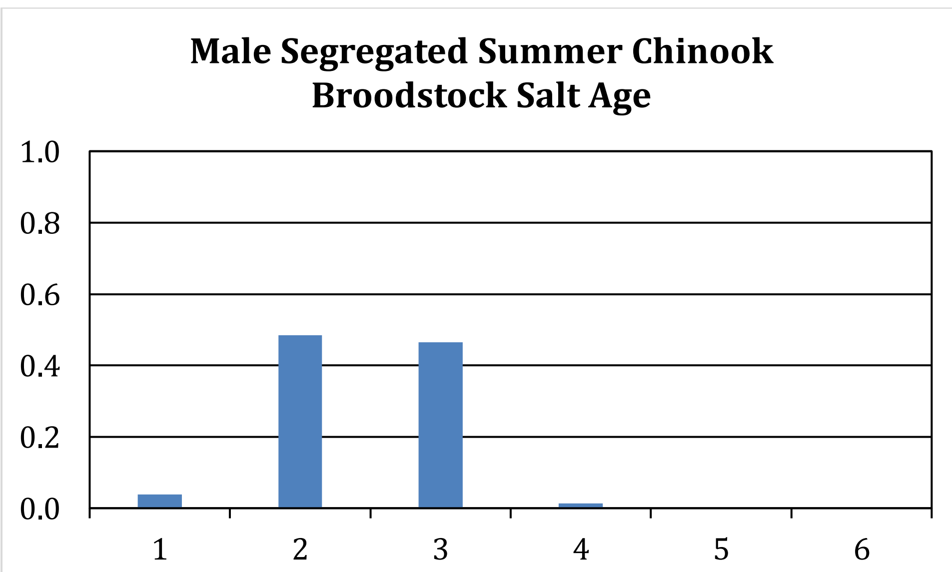


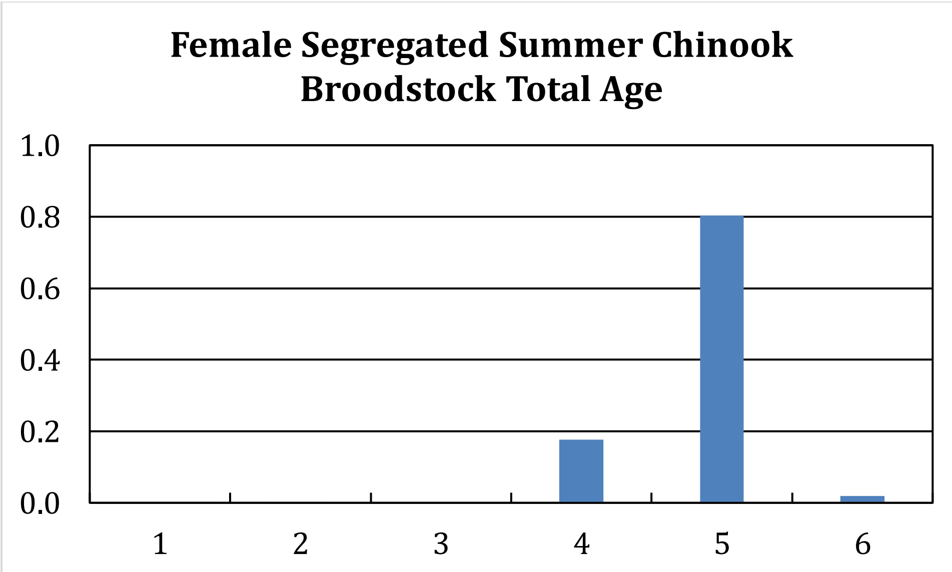
Figure A 1. The total and salt ages of the 2019 broodstock, males and females, collected for the Okanogan summer/fall Chinook integrated program.

Segregated Program Broodstock Age Structure

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







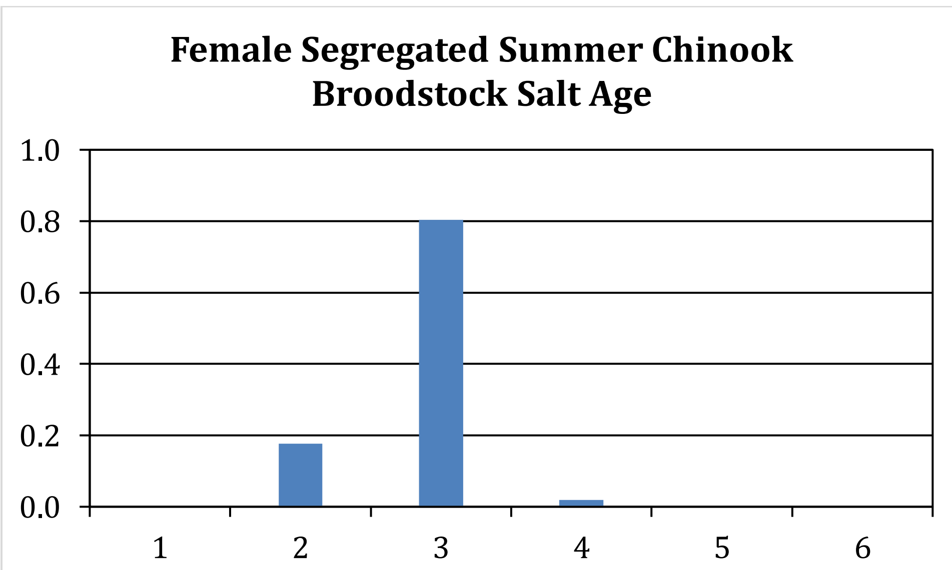


Figure A 2. The total and salt ages of the 2019 broodstock, males and females, collected for the Chief Joseph Hatchery segregated program.

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; No eggs were discarded from either program. 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 2019 and to achieve the size-at-release target for both yearling and sub-yearling summer/fall Chinook programs.

Rearing

The first group of brood year 2019 sub-yearlings were brought out of incubation and transferred into early rearing troughs in early February 2020 (Table A 7). 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.

The first group of integrated yearlings were brought out of incubation and transferred into early rearing troughs in late February 2020 while the first group of segregated yearlings were brought out in early March 2020 (Table A 7). 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 6. Chief Joseph Hatchery brood year 2019 summer/fall Chinook yearling rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	3/31/2020	597,689	2,584	142	888	99.57%
	4/30/2020	592,521	5,168	886	494	98.71%
	Subtotal:	592,521	7,752	1,028	494	98.71%
NOR	2/29/2020	147,101	8,190	24	1,035	94.73%
	3/31/2020	766,849	7,726	211	885	97.95%
	4/30/2020	762,475	4,374	1,584	455	97.38%
	Subtotal:	762,475	20,290	1,819	455	97.38%
	Cumulative:	**1,354,996**	**28,042**	**2,847**	**NA**	**97.96%**

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. The CJH fish ladder began operation on May 20, 2019, for spring chinook broodstock collection, with the first summer/fall chinook 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 May 20th thru August 28th, 1,445 hatchery-origin summer/fall Chinook were removed at the CJH ladder and were utilized for tribal subsistence purposes (Table A 8). There was 1 hatchery adult and 1 hatchery jack returned to river during the early stages of ladder operation in June. A total of 15 natural-origin summer/fall Chinook, 19 NOR steelhead and 65 HOR steelhead were trapped, handled, and released back to the Columbia River (Tables A 9 and A 10). The encounter/handling and release of 19 NOR steelhead represents 16% 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 2019.

Table A 7. Chief Joseph Hatchery adult summer/fall Chinook ladder operations from June to August 2019.

Month	# of Ladder Trap Checks	HOR Adults Surplussed	HOR Jacks Surplussed	NOR Adults RTS	NOR Jacks RTS	HOR Adults RTS	HOR Jacks RTS
June	1	0	0	1	0	1	1
July	1	534	29	6	1	0	0
Aug	2	870	12	7	0	0	0
Total	**4**	**1,404**	**41**	**14**	**1**	**1**	**1**

RTS = Return to stream

Table A 8. Chief Joseph Hatchery adult spring Chinook, Sockeye, and steelhead ladder operations from May to August 2019.

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
May	5	0	0	69	0	0	19	65
June	3	230	20	42	6	0	0	0
July	1	15	0	15	0	0	0	0
Aug	2	32	2	2	0	0	0	0
Total	**11**	**277**	**22**	**128**	**6**	**0**	**19**	**65**

RTS = Return to stream

Table A 9. Chief Joseph Hatchery annual summer/fall Chinook, Sockeye, and steelhead collected during ladder operations.

Date	HOR Chinook surplussed	HOR jacks (1) surplussed	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	2,174	180	1,192	401	2
June-Oct. 2016	5,359	995	465	91	1,965	5	113	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
June-Aug. 2019	1,404	41	14	1	0	0	19	65	0
Total	**23,678**	**5,789**	**3,816**	**859**	**4,382**	**262**	**1,435**	**653**	**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, 2019 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 2019 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.

Six summer/fall Chinook hatchery programs were encountered at the CJH ladder in 2019, with the majority coming from the CJH segregated program (54%), Wells Hatchery (30%) and Chelan Falls (8%) (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 10. Summary of summer/fall Chinook coded-wire tags encountered and expansions for the CJH ladder in 2019.

Category	Hatchery Program	# Tags	Expanded Abundance	% of Ladder Surplus
Okanogan Integrated	Omak Yearlings	2	11.2	<1
	Omak Subyearlings	0	0	0%
	Similkameen	6	38.4	3%
CJH Segregated	Segregated yearlings	24	134.1	10%
	Segregated subyearlings	1	5.5	<1%
	No CWT, presumed Segr	130	605.0	43%
Other UCR summer/fall Chinook hatchery	Wells	76	420.8	30%
	Chelan	19	105.2	8%
	Carlton	2	11.1	<1%
	Entiat	3	16.7	1%
	Dryden	10	56.0	4%
Out of ESU hatchery		0	0	0%
		0	***0***	***0%***
Total		***273***	***1404.0***	***100%***

Table A 11. 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%
2019	1,404	53%	<1%	3%	30%	8%	<1%	<1%	4%	0%	0%
Avg.	***3,375***	***20%***	***2%***	***6%***	***31%***	***23%***	***4%***	***2%***	***10%***	***<1%***	***<1%***

[a]Includes recoveries with 'no coded wire tags' in 2013-present: 2013 (47), 2014 (152), 2015 (71), 2016(45), 2017(76), 2018 (177), 2019 (130); 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

2020 Production Plan

Table B 1. Summer/Fall Chinook - Integrated Program

Chief Joseph Hatchery Production Plan

Brood Year:	2020						**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**
05/15/21	06/01/21	300,000	50.0	9.1	6,000	2,722	Sub-Yearlings	Omak	Ad Clipped	100% CWT
05/22/20	04/30/22	400,000	10.0	45.4	40,000	18,144	Yearlings	Similkameen	Ad Clipped	100% CWT
04/15/22	04/30/22	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	Number Green 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/Fall Chinook – Segregated Program (CJH Site Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2020						**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**
05/15/21	06/01/21	400,000	50.0	9.1	8,000	3,629	Sub-Yearlings	CJ Hatchery	Ad Clipped	100k CWT
04/15/22	04/30/22	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 2019, including pHOS and effective pHOS values per reach

2019

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	%hatchery	%wild	HOS	NOS	pHOS
O1*	12	2.3	28	0.0%	0	0	0	51.6%	48.4%	14	13	0.52
O2*	154	2.3	354	0.3%	1	1	0	51.6%	48.4%	183	171	0.52
O3	275	2.3	633	11.4%	72	52	20	72.2%	27.8%	457	176	0.72
O4*	92	2.3	212	4.3%	9	4	5	51.6%	48.4%	109	102	0.52
O5	600	2.3	1380	5.2%	72	34	38	47.2%	52.8%	652	728	0.47
O6	505	2.3	1162	15.6%	181	76	105	42.0%	58.0%	488	674	0.42
S1	694	2.3	1596	7.9%	126	70	56	55.6%	44.4%	887	709	0.56
S2	39	2.3	90	6.7%	6	4	2	66.7%	33.3%	60	30	0.67
Totals	2371		5453	8.6%	467	241	226			2849	2604	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

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/fall Chinook carcasses collected in each reach of the Okanogan (O1-O6) and Similkameen rivers from 1993 to 2019.

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	2,123
	Hatchery	1	0	19	7	42	67	129	64	329
2015	Wild	0	5	39	9	209	931	1186	176	2,555
	Hatchery	0	5	22	2	74	63	516	56	738
2016	Wild	0	6	13	7	186	1019	819	121	2,171
	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
2019	Wild	0	0	20	5	38	105	56	2	226
	Hatchery	0	1	52	4	34	76	70	4	241
Avg.	***Wild***	***1***	***2***	***18***	***8***	***96***	***264***	***309***	***59***	***756***
	Hatchery	***1***	***3***	***19***	***7***	***59***	***85***	***308***	***53***	***534***

[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
2019	0	3	21	18	1	0	43
Average	***1***	***24***	***103***	***70***	***7***	***0***	***203***

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
2019	0	0	3	10	0	0	13
Average	***0***	***0***	***49***	***202***	***27***	***0***	***279***

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
2019	0	0	40	42	6	0	88
Average	***0***	***7***	***93***	***169***	***55***	***1***	***326***

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
2019	0	0	0	87	22	0	109
Average	***0***	***0***	***15***	***234***	***139***	***1***	***389***

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
2019	0%	17%	83%	0%	0%	0%	1
Average	*0%*	*11%*	*44%*	*38%*	*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
2019	0%	0%	23%	77%	0%	0%	1
Average	*0%*	*0%*	*23%*	*63%*	*14%*	*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
2019	0%	0%	45%	48%	7%	0%	1
Average	*0%*	*3%*	*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
2019	0%	0%	0%	80%	20%	0%	1
Average	*0%*	*0%*	*7%*	*63%*	*29%*	*0%*	*100%*

Contribution to Fisheries

Table C 4. Estimated number and percent of hatchery-origin Okanogan/Similkameen summer/fall Chinook captured in different fisheries, brood years 1989-2013.

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	771 (35)	827 (37)	13 (1)	619 (28)	2,230
2013	1,640 (684)	2,671 (820)	26 (10)	1,354 (209)	5,691
Average	***1,894 (89)***	***1,099 (50)***	***123 (3)***	***720 (21)***	***3,835***
Median	***1,359 (68)***	***306 (20)***	***36 (2)***	***384 (15)***	***2,230***

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

Technical Memorandum: Minijack Rates for 2019 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/fall 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/fall Chinook; released from the Omak Acclimation Pond, natural-origin broodstock primarily of Okanogan-origin stock
- Integrated summer/fall 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 summer/falls 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/fall 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/fall 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/Fall 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/Fall Yearlings	Omak Acclimation Pond	163	131	32	19.63%	29.63%
Integrated Summer/Fall Yearlings	Similkameen Acclimation Pond	134	114	20	14.25%	N/A

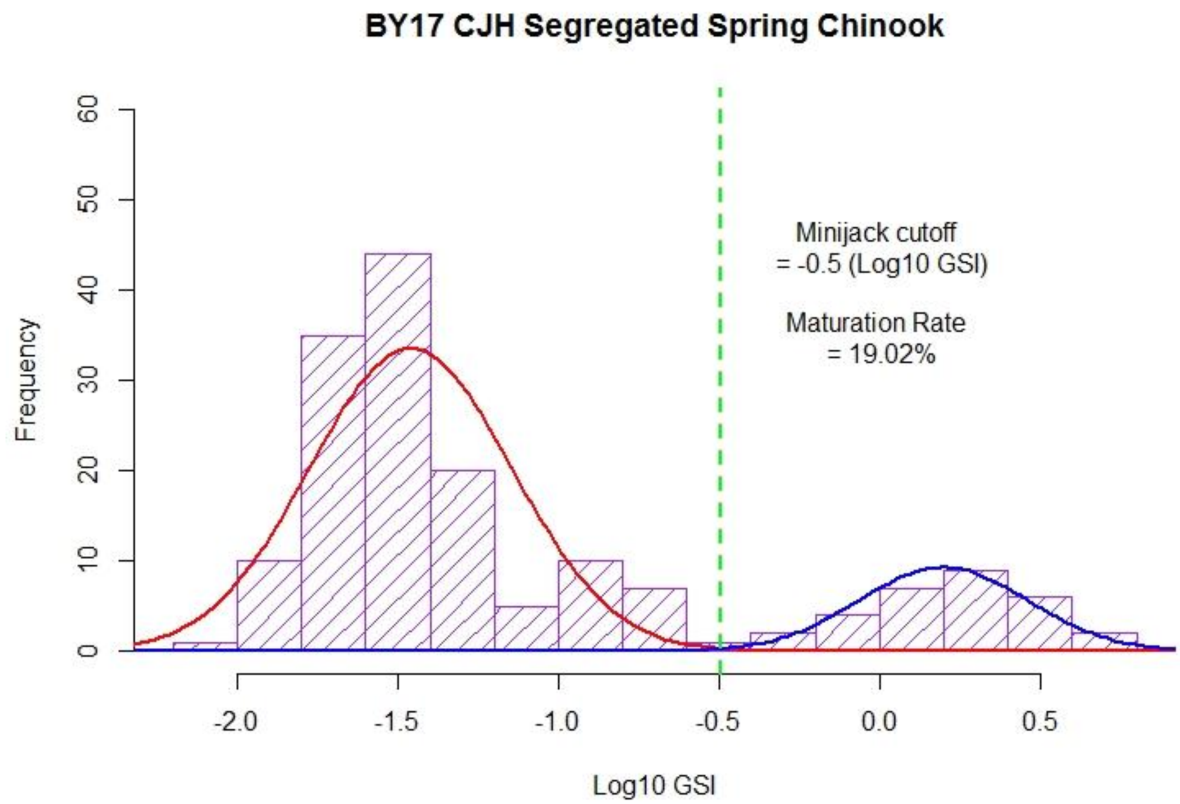


Figure 1. Distribution of Log10 GSI for the segregated spring Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

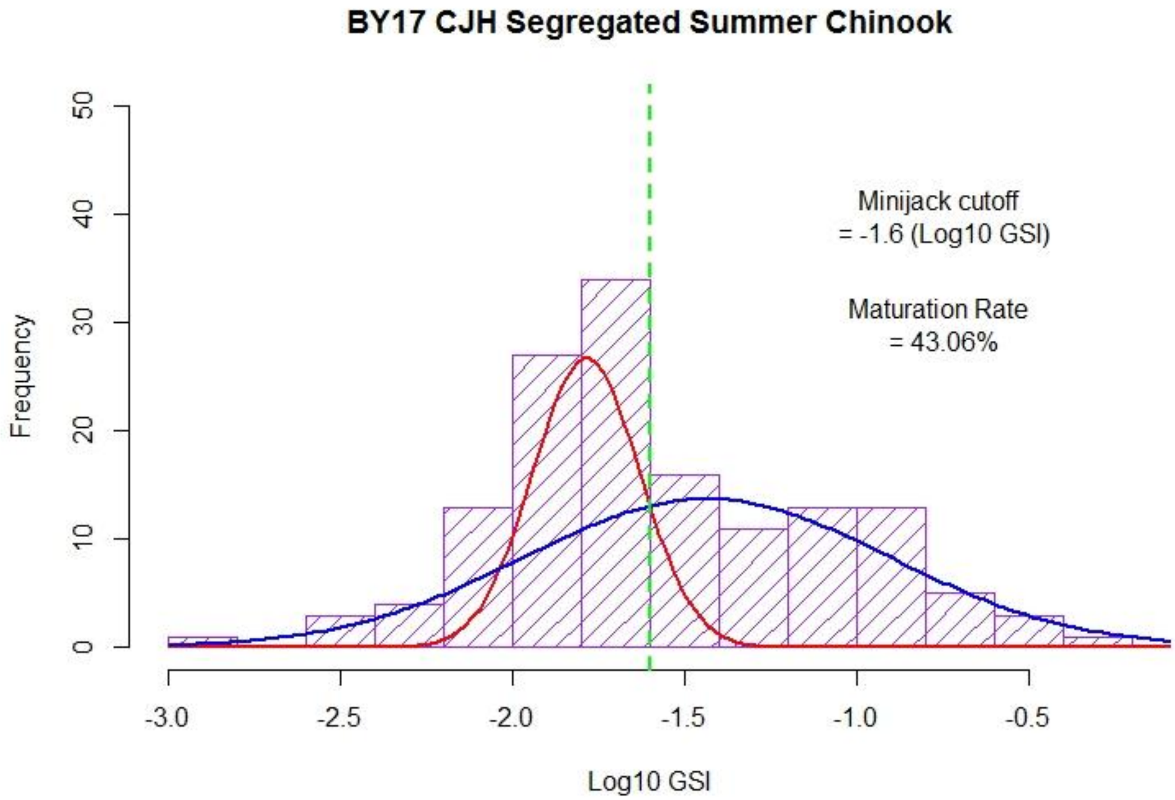


Figure 2. Distribution of Log10 GSI for the segregated summer/fall Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

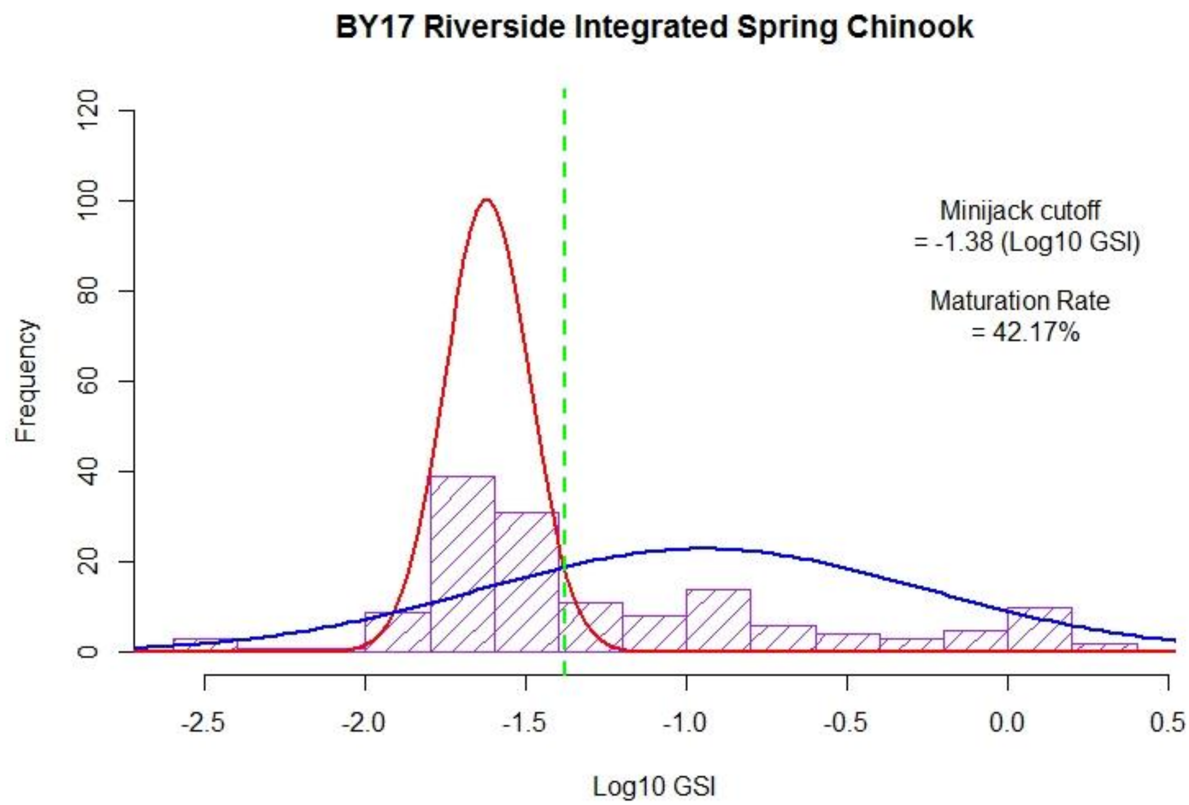


Figure 3. Distribution of Log10 GSI for the integrated spring Chinook released from the Riverside Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

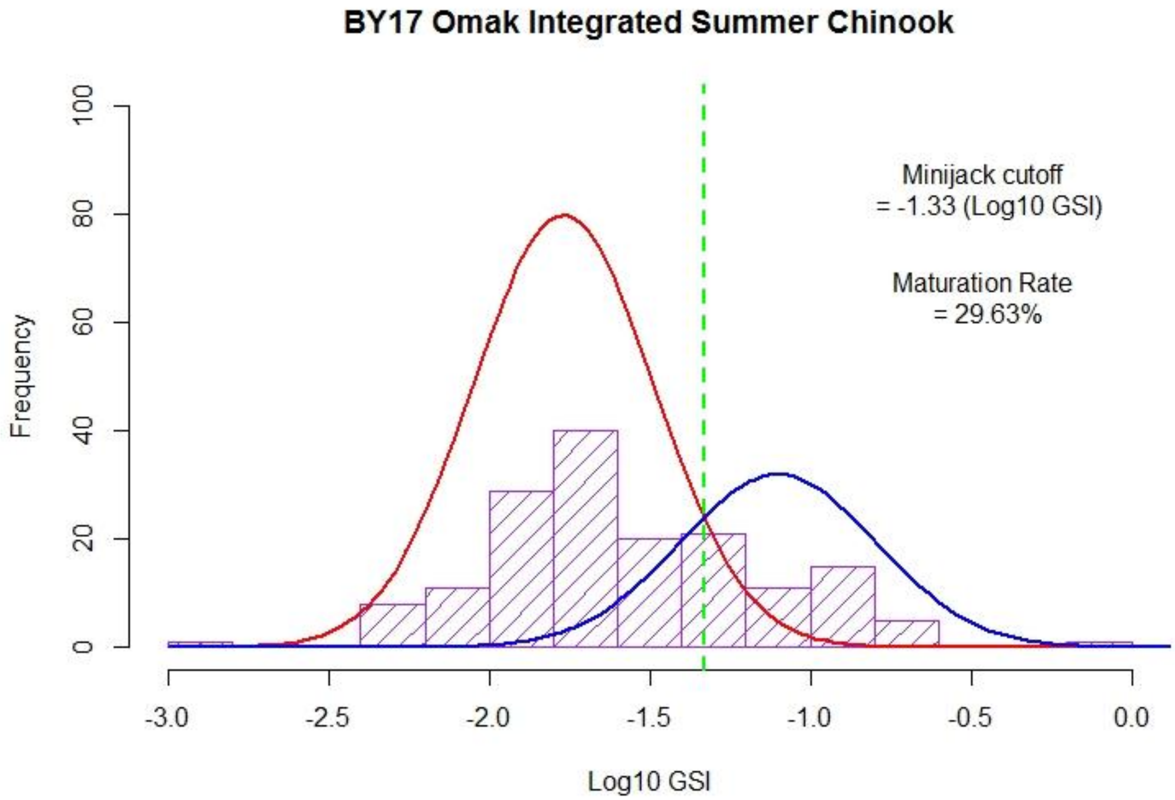


Figure 4. Distribution of Log10 GSI for the integrated summer/fall Chinook released from the Omak Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

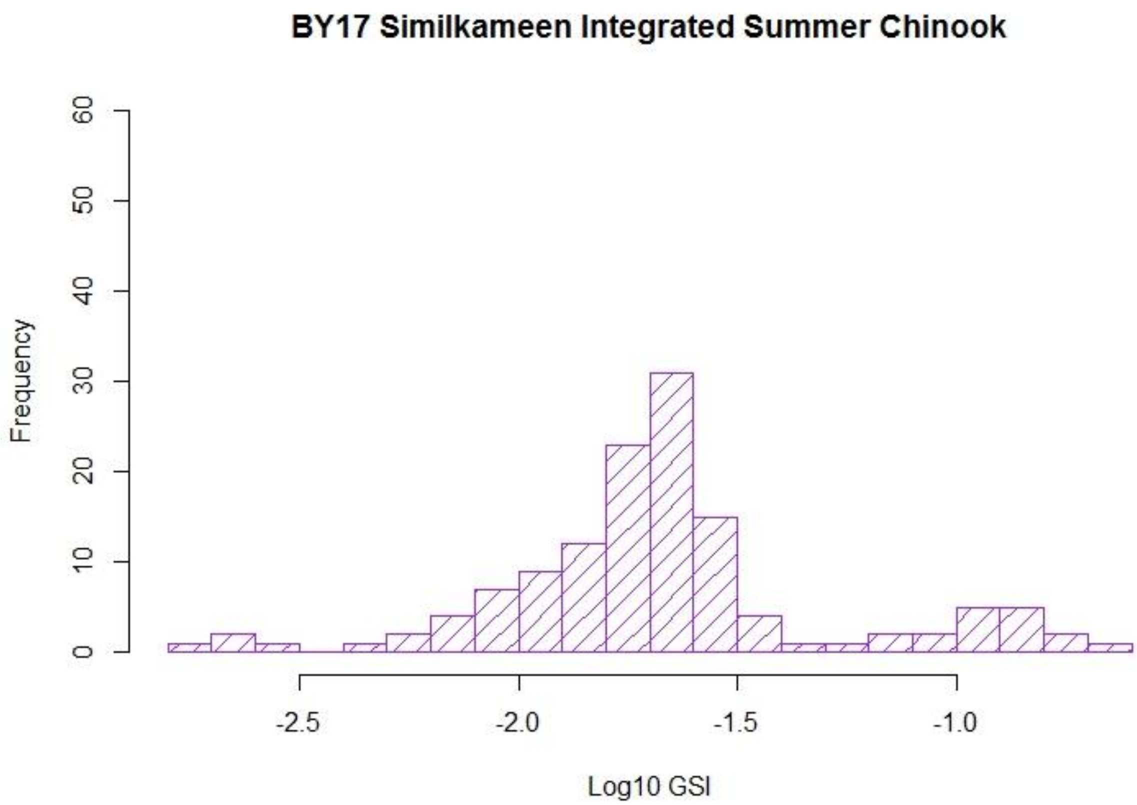


Figure 5. Distribution of Log10 GSI for the integrated summer/fall Chinook released from the Similkameen Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

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

Year		CJH Segregated Spring Chinook	CJH Segregated Summer/Fall Chinook	Riverside Integrated Spring Chinook	Omak Integrated Summer/Fall Chinook	Similkameen Integrated Summer/Fall 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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Shearer, K., P. Parkins, Gadberry, B., Beckman, B., Swanson, P. 2006. Effects of growth rate/body size and a low lipid diet on the incidence of early sexual maturation in juvenile male spring Chinook salmon (*Oncorhynchus tshawytscha*). Aquaculture 252:546-556.

‘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:

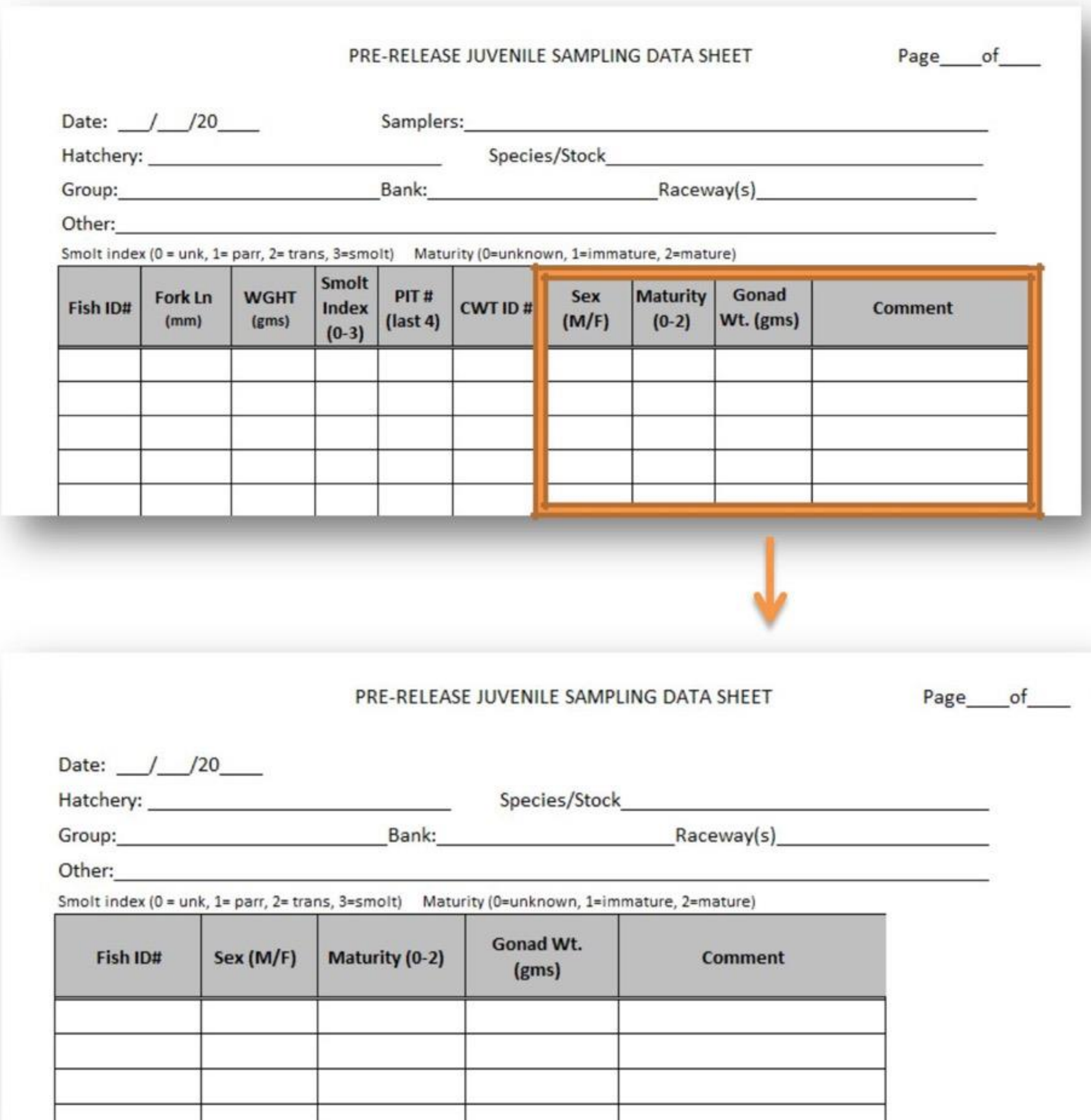
- Tricane Methanesulfonate (MS 222)
- [1] Tub for fish
- [1] Dip net
- [1] Pit scanner + [1] stand
- [4] large sponges + [1] cookie tray
- [1] Scale for weights + [1] smolt weight pan
- [1] Length board

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

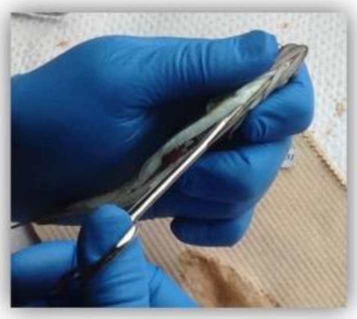
2. Collect fish from hatchery ponds. Random sample? Keep different ponds separate? CWT? Pit Tag?

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

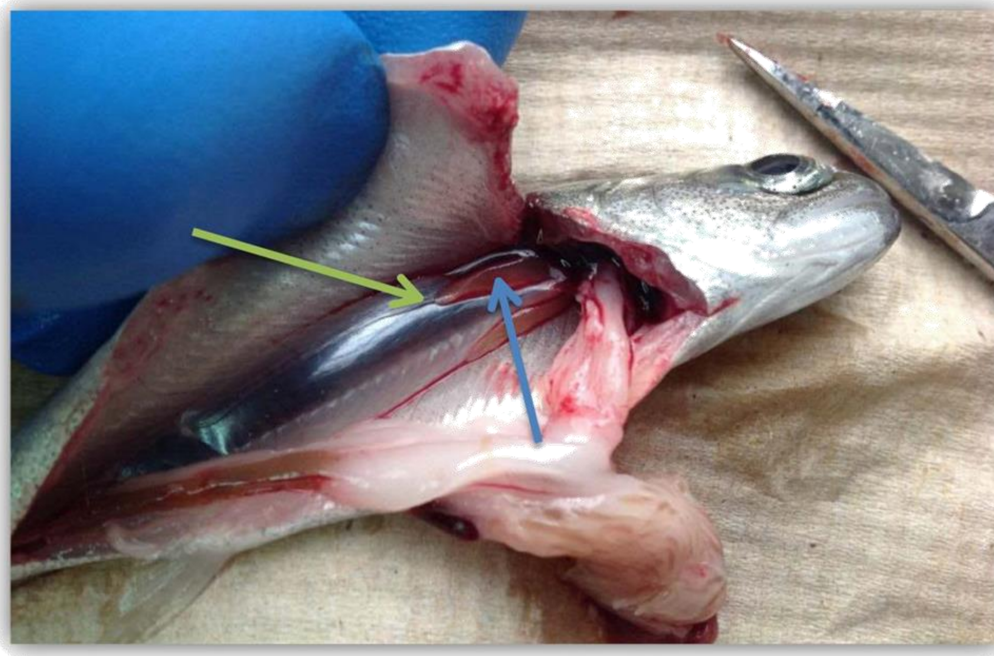
4. Smolt index: 1. Parr, dark marks (bottom fish), 2. Transitional, faded marks (middle fish), 3. Smolt, silver, no marks (top fish)

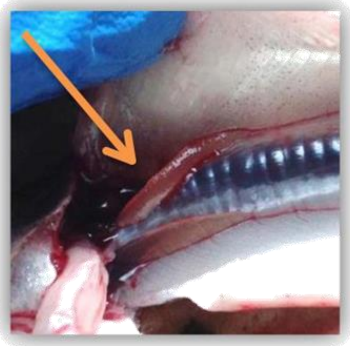
5. Set out 15-20 fish in a row on the sponges. Add number tags to fish. Assess smolt index while all fish are in the line. Obtain weights and lengths, place on paper towel to pass to the dissecting crew.

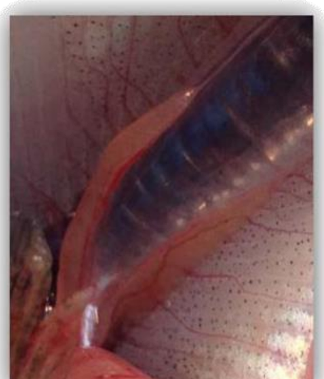
6. Fish dissection: Cut open belly from vent (shallow incision), cut behind gill, open fish and gently remove guts to expose air bladder. Both male and female gonads are located on the top/edge of the air bladder (orange arrow on mature male).



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.





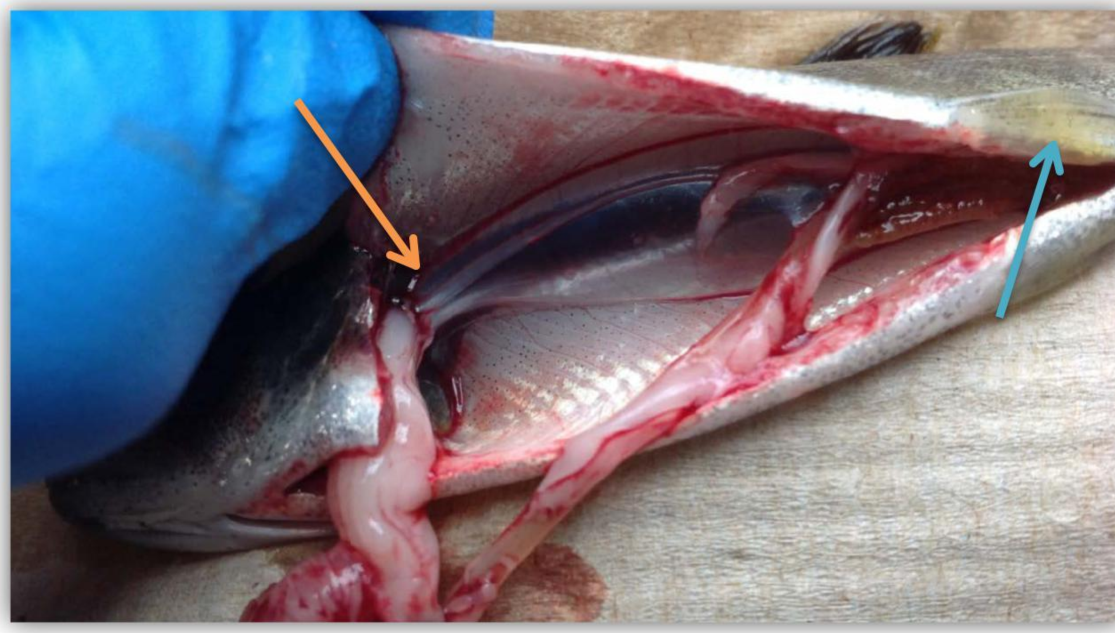


8. Immature male identification: Testes are thready throughout, smooth and round, no development or thickness (green arrows).

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.

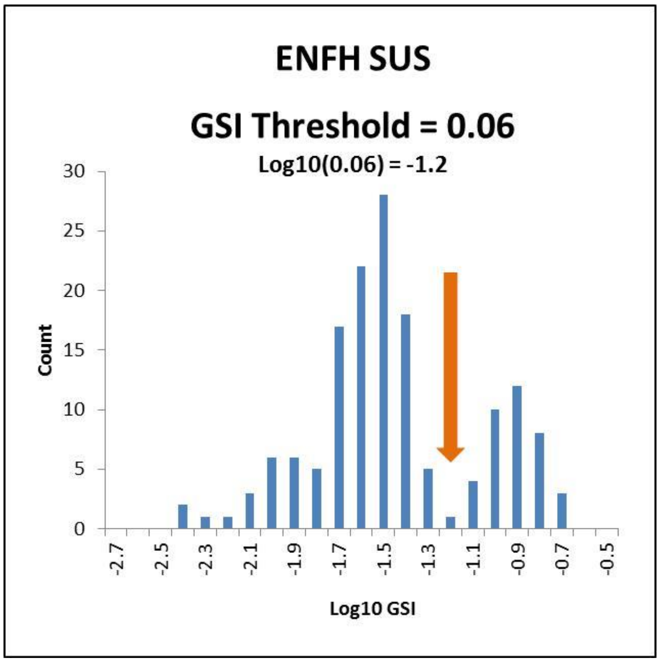


12. To use the scale: Close all doors, zero balance, open door, place 'nads in weight boat, close doors, wait for number to stabilize. 'Nads will evaporate and become lighter in a short period of time.

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)" ))
```