THE CHIEF JOSEPH HATCHERY PROGRAM SUMMER/FALL CHINOOK

2020 ANNUAL REPORT

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This report covers work performed under contracts #73548, Rel 86 (M&E) and #73548, Rel 87 (O&M) for the performance period May 1, 2020 to April 30, 2021.

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This report includes both hatchery production/operations and the corresponding monitoring activities completed through April of 2021. 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 2020 during the eighth year of operation for the Summer/Fall Chinook program. In July and August the CCT used a purse seine vessel to collect 1,287 summer/fall Chinook for broodstock for both the integrated and segregated programs (including Similkameen). Additionally, 84 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 82.7% for hatchery-origin broodstock (HOB) and 80.0% for natural-origin broodstock (NOB). The survival standard (90%) was not met by both the hatchery-origin and natural-origin brood. Total green egg take for the season was 1,639,336 (60% of full program). Egg survival from green egg to eyed egg averaged 80.4% for NOB and 81.4% for HOB, both under the survival standard (90%) for this life stage. After in-hatchery mortalities from pre-spawn holding through ponding there were 1,156,450 fish on hand at the end of April for the yearling releases in 2022. (89% of the yearling program) and 177,115 fish on hand for the sub-yearling releases in May 2021 (25% of full program).

2020 was the sixth year for Summer/Fall Chinook hatchery yearlings released from the CJH, Similkameen and Omak acclimation ponds. In April, 298,988 integrated yearling summer/fall Chinook were released from the Omak acclimation pond and 409,348 were released by Washington Department of Fish & Wildlife (WDFW) from the Similkameen Pond; combined these programs were at 100% of the full program goal of 800,000 integrated yearlings. There were no integrated or segregated sub-yearlings from brood year (BY) 2019 released in May 2020. However, there were 568,625 yearling Chinook released directly from Chief Joseph Hatchery (100% of full program).

After release, the yearling programs from CJH and Omak Pond had lower survival when compared to previous years and other programs. Although survival was lower, the travel time was shorter, which was a confusing result that could not be explained. In contrast, subyearling survival was similar to or better than previous years. The majority (>95%) of PIT tagged hatchery smolts released from Omak Pond migrated to the lower Okanogan River within one month 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 five major activities; 1) beach seine (natural-origin smolt PIT tagging, smolt to adult return) 2) lower Okanogan adult fish pilot weir (adult escapement, proportion of hatchery-origin spawners [pHOS], broodstock) 3) spawning ground surveys (redd and carcass surveys)(viable salmonid population [VSP] parameters) 4) eDNA collection (VSP parameter—distribution/spatial structure) and 5) coded wire tag lab (extraction and reading). The rotary screw trap project was suspended in 2020 due to the program's inability to operate under CCT's COVID-19 safety guidelines.

Beach seining captured 20,340 juvenile Chinook and 18,700 (92%) were PIT tagged and released. Pre- and post-tag mortality was 1.0% and 7.0% respectively. In 2020, wild summer Chinook tagged at the mouth of the Okanogan had a minimum apparent survival of 43% (3% SE) to Rocky Reach Juvenile Bypass (RRJ) and 85% (34% SE) from RRJ to McNary (MCN).

The lower Okanogan Adult Fish Weir was deployed on August 17 when discharge was 1,900 cfs. The thermal barrier was present in the lower Okanogan after installation until August 25th when the mean Okanogan River temperature began dropping below 22.5 °C, allowing Chinook to migrate up the Okanogan. Trapping began on August 27 and continued until September 24 with the majority (66%) being caught from August 30-September 7. Eight hundred and seventy adult Chinook were trapped in 2020. Eighty-four natural-origin Chinook were transported to the hatchery and held as broodstock for the integrated program. Adult brood were transported from the weir trap to the hatchery brood truck by foot using a rubber boot. There were no immediate mortalities of these fish within the first week after transport to the hatchery. All other natural-origin fish were released upstream of the weir unharmed. One hundred and fifty-eight hatchery-origin were removed from the weir trap for adult management purposes. 6.6% 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 145 Chinook carcasses collected from August 28 to September 24. 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 24.

Spawning ground surveys estimated 4,127 summer/fall Chinook redds and 2,604 carcasses were recovered (1,908 natural-origin and 696 hatchery-origin). Adult summer/fall Chinook spawning escapement in 2020 was estimated to be 11,019, with 7,957 natural-origin spawners and 3,062 hatchery origin spawners. In 2020, the effective pHOS (0.24) and proportion of natural influence (PNI) (0.82) met the program objectives (<0.30 pHOS; >0.67 PNI). The five-year average for pHOS (0.25) and PNI (0.75) 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 2020. CCT removed 1,141 hatchery fish, including 88 jacks, during surplus events at the CJH ladder and trap, and tribal members removed another 1,658, including 49 jacks, at the Chief Joseph Dam tailrace fishery. The Harvest program's purse seine removed 170 hatchery fish, including 145 jacks. 62 natural-origin fish, including 3 jacks, were released during surplus at the Chief Joseph Hatchery ladder. The purse seine released 531 natural-origin fish, including 121 jacks during their efforts. The Okanogan temporary weir encountered 870 fish in 2020, in which 160 hatchery fish, including 6 jacks, were removed and 625 natural-origin fish, including 19 jacks, and 3 hatchery-origin fish were released back to the river. Within the WDFW state fishery above Wells Dam in the Columbia River, 1,088 hatchery Chinook (segregated and integrated fish), including 39 jacks, were harvested and 115 natural-origin Chinook, including 14 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 (2016-2020) 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 2016-2020 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 fifth year of operation in 2020. 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 (59%) followed by Wells Hatchery (18%), Chelan Falls (9%), Okanogan integrated (6%), and three other programs made up the remaining 8%.

The majority (66%) of hatchery-origin spawners recovered on the spawning grounds in 2020 were from Similkameen (48%) and Okanogan (27%). Chief Joseph Hatchery segregated Chinook comprised 19% of the HOS on the Okanogan spawning grounds. The level of segregated hatchery fish on the spawning grounds (5.4%) did not meet the program objective of <5% segregated pHOS and future management efforts should focus on reducing the stray rate of segregated hatchery fish to the Okanogan spawning grounds. Overall, the majority of fish acclimated at Similkameen Pond ended up spawning throughout the upper reaches of the Okanogan (reaches O5 & O6) (31%) and Similkameen Rivers (66%). Reach S1, the location of the Similkameen acclimation site in the Similkameen River accounted for just over half of the estimated spawning by Similkameen Pond fish (55%).

Fish released within the Okanogan Basin have consistently homed to their natal stream, and 2020 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, 90% in 2019, and 83% in 2020) 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.

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 2015. The 2015 brood year had a stray of 0.4% to non-target basins and 1.7% to non-target hatcheries, which was similar to the long term and recent five-year average (0.9% for non-target basins and 0.4% to non-target hatcheries).

An Annual Program Review (APR) was held in April 2021 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 an average pre-season forecast of 59,600 Upper Columbia summer/fall Chinook, the plan for 2021 is to operate the hatchery at full program levels of 2 million summer/fall Chinook with 100% pNOB. pNOB was set at 50% natural-origin broodstock for the integrated program and CCT will plan to harvest their allocation of 5,618 with the selective harvest program, including removals at the purse seine, the weir, and at the hatchery ladder.

INTRODUCTION

Salmon (*Oncorhynchus* spp.*)* and steelhead (*O. mykiss*) faced many anthropogenic challenges ever since European settlement of the Pacific Northwest. Harvest, hydropower development, and habitat alteration/disconnection have all had a role in reducing productivity or eliminating entire stocks of salmon and steelhead (MacDonald 1894; UCSRB 2007). These losses and reductions in salmon had a profound impact on Native American tribes, including the Confederated Tribes of the Colville Reservation. Hatcheries have been used as a replacement or to supplement the wild production of salmon and steelhead throughout the Pacific Northwest.

However, hatcheries and hatchery practices can pose a risk to wild populations (Busack and Currens 1995; Ford 2002; McClure et al. 2008). As more studies lead to a better understanding of hatchery effects and effectiveness, hatchery reform principles were developed (Mobrand et al. 2005; Paquet et al. 2011). The CJHP is one of the first of its kind to be structured using many of the recommendations emanating from Congress's Hatchery Reform Project, the Hatchery Science Review Group (HSRG) and multiple independent science reviews. Principally, the success of the program is not based on the ability to meet the same fixed smolt output or the same escapement goal each year. Instead, the program is managed for variable smolt production and natural escapement. Success is based on meeting targets for abundance and composition of natural escapement and hatchery broodstock (HSRG 2009). Chief Joseph Hatchery Program (CJHP) managers and scientists are accountable for accomplishments and/or failures, and therefore, have well-defined response alternatives that guide annual program decisions. For these reasons, the program is operated in a manner where hundreds of variables are monitored, and activities are routinely and transparently evaluated. Functionally, this means that directed research, monitoring, and evaluation (RM&E) are used to determine status and trends and population dynamics and are conducted to assess the program's progress in meeting specified biological targets, measure hatchery performance, and in reviewing the key assumptions used to define future actions for the entire CJHP.

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

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

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

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

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

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

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

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

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.

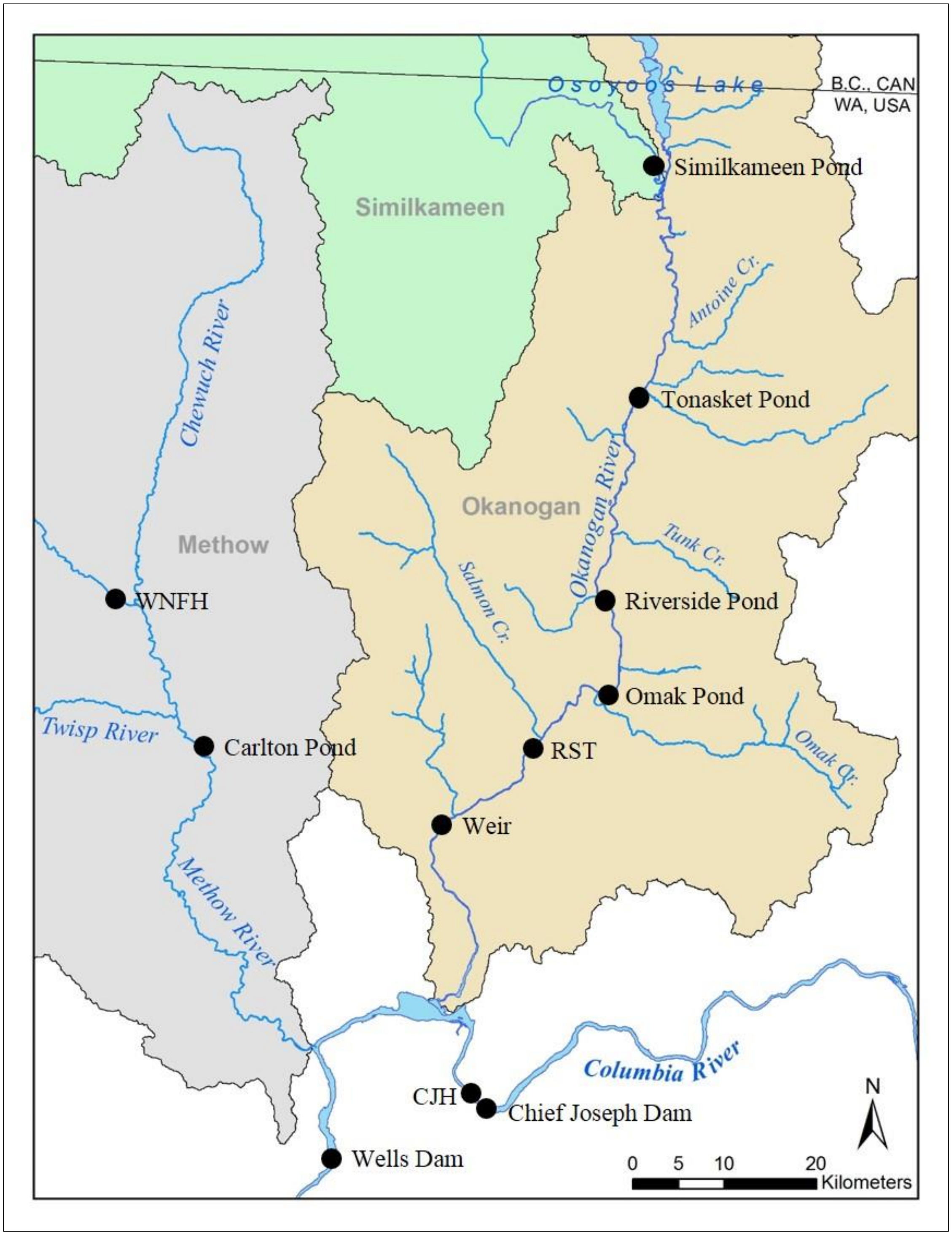

Figure 1. Map of the U.S. portion of the Okanogan River Basin, the Chief Joseph Hatchery (CJH), Winthrop National Fish Hatchery (WNFH), Okanogan adult weir (Weir), Rotary screw trap (RST), and Chinook Salmon acclimation sites. Horizontal coordinate information is referenced to the North American Datum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

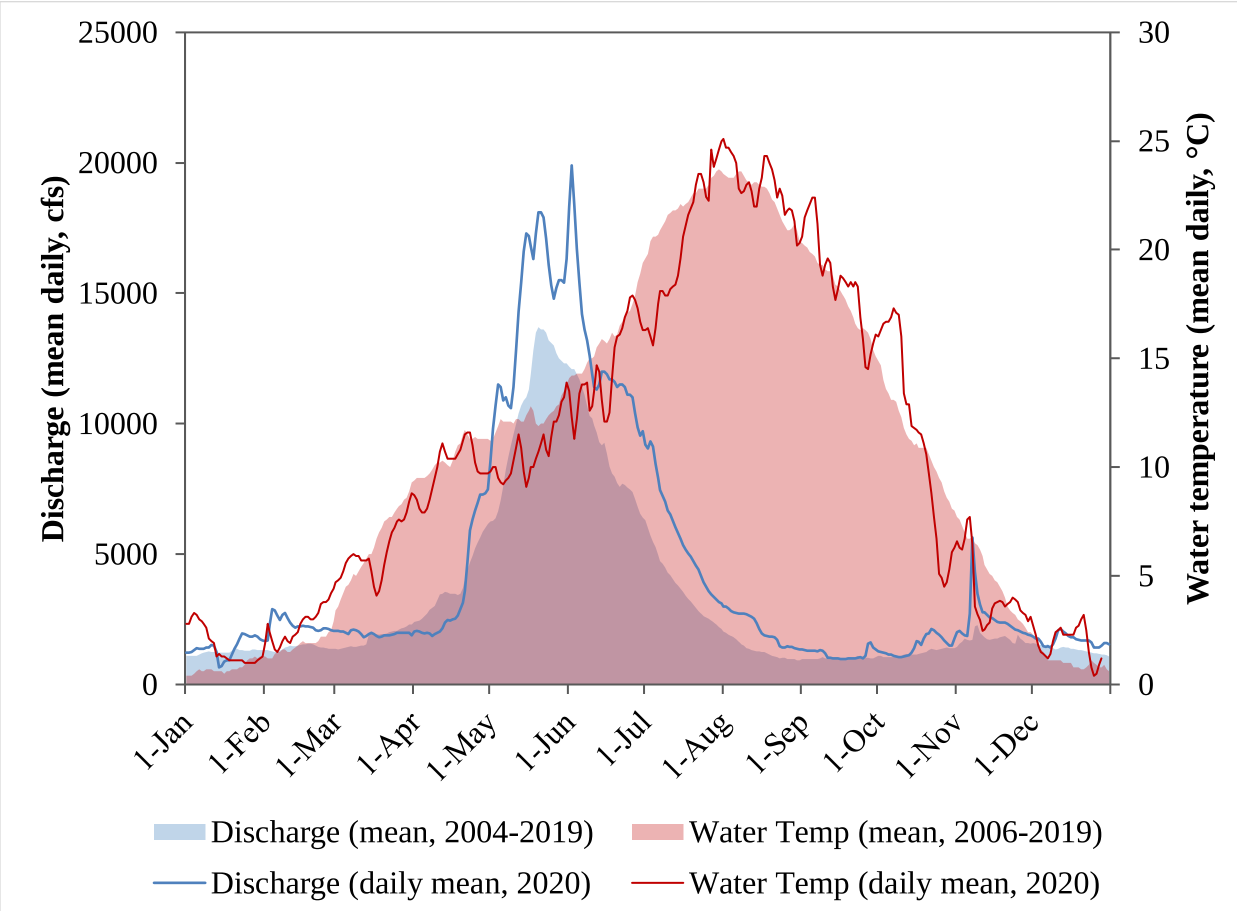

Figure 2. Okanogan River mean daily discharge (blue lines) and water temperature (red lines) at Malott, WA (USGS Stream Gage 12447200).

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 occurs at the rotary screw trap and the juvenile beach seine annually. 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 and (4) natural-origin Chinook encountered during juvenile electrofishing surveys.

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

CJH M&E staff were regrettably unable to operate the RST due to the program's inability to operate under the Colville Tribe's COVID-19 safety guidelines.

Juvenile Beach Seine and PIT Tagging

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

Beach seining took place from June 2- July 15 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 3). 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.

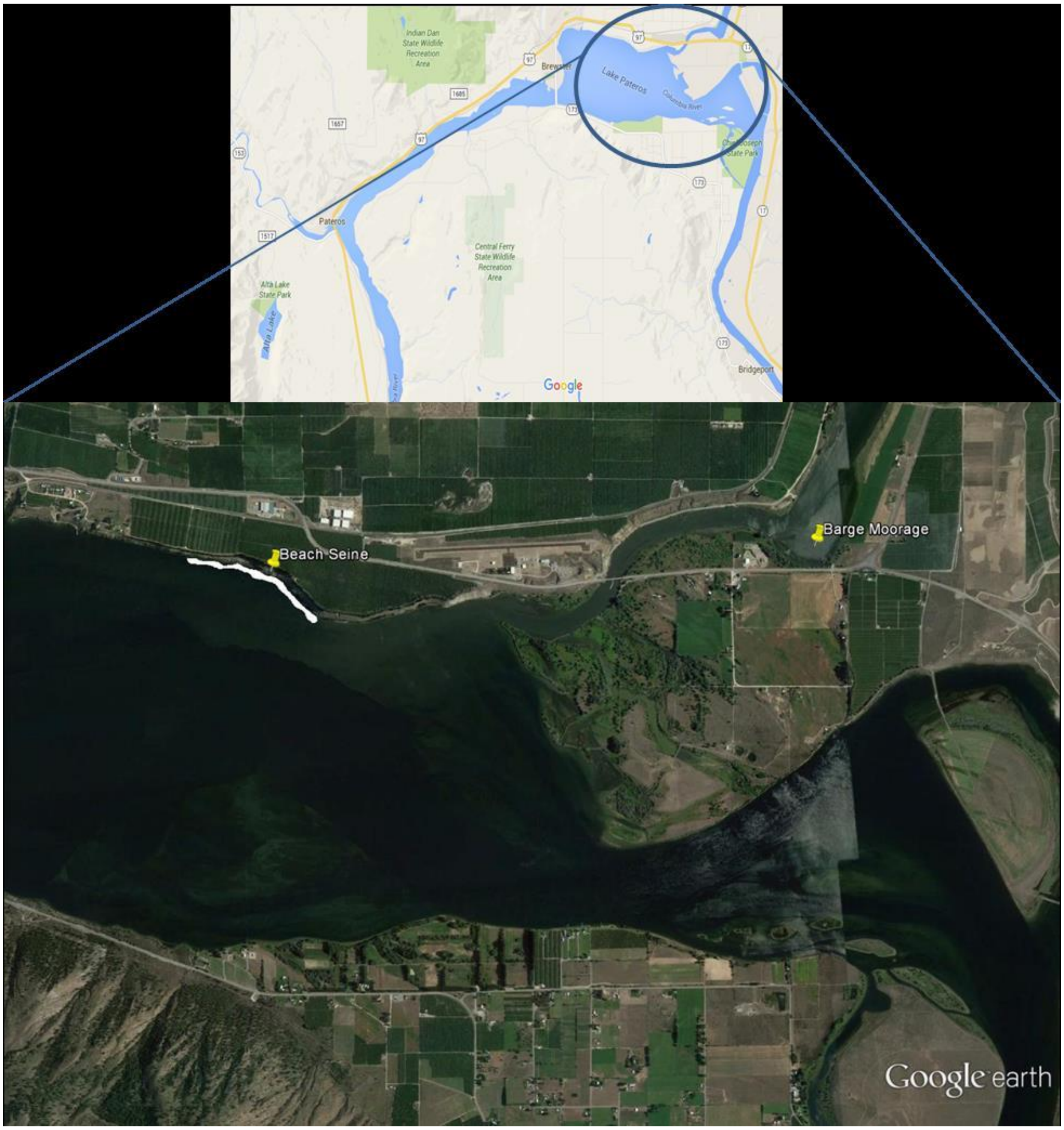

Figure 3. Seining location downstream (Gebber's Landing) of the confluence.

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 4). 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).

Figure 4. 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 or two taggers 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 ninth year of design modifications and testing in 2020. 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 2020 included:

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

The lower Okanogan fish weir was installed approximately 1.5 km downstream of Malott, WA (48°16'21.54 N; 119°43'31.98 W) in approximately the same location as previous years. Weir installation began on August 17th at a river flow of 1,900 cfs. and was completed with the underwater video system on August 21st. An aluminum trap was installed near the center of the channel at the downstream end of the deep pool in the thalweg of the channel. The trap was 3 m wide, 6 m long and 3 m high (Figure 1). A fifteen-foot aluminum accelerator chute was installed at the downstream trap gate. The wings of the weir stretched out from either side of the chute towards the river banks, angling downstream in a slight V configuration. The wings consisted of steel tripods with aluminum rails that supported the 3 m long Acrylonitrile butadiene styrene (ABS) pickets. Each panel was zip-tied to the adjacent panel for strength and stability. Gravel bags were placed between panels when needed to fill gaps that exceeded the target picket spacing. Picket spacing ranged from 2.5 to 5.1 cm (1 to 2 inch) in 1.2 cm. (half-inch) increments (Figure 2). 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 2). 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.

Figure 5. Lower Okanogan adult fish pilot weir, 2020. Photo taken in late- August.

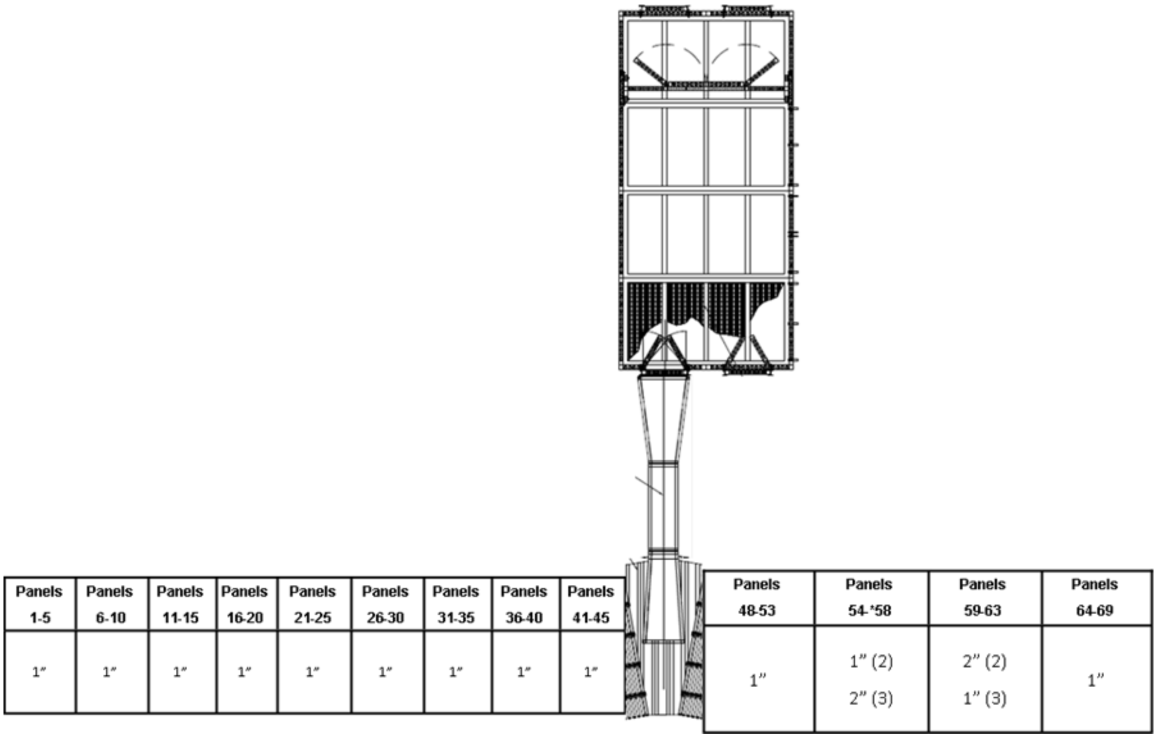

Figure 6. Conceptual diagram of picket (ABS pipe) spacing within each panel (or set of 5 panels) at the Lower Okanogan adult fish pilot weir. A 15 ft entrance chute was installed at the lower trap gate in 2020.

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 during mid-day (1100-1300), 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.

Trapping operations were conducted under allowable temperature (≤22.5° C) and head differential (<10 cm.) conditions for the season. Trapping operations began on August 27 and continued until September 24. When fish entered the trap during an active trapping session, the downstream fyke was closed and fish were identified and either released or collected for brood.

Eighty-four natural-origin Chinook were collected from the weir trap from August 31 –September 22 and 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 2020 staffing was limited to effectively operate the system during the season.

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 Jupiter Mesa rugged computer tablet (Jupiter Systems, Inc.). 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 Jupiter Mesa rugged computer tablet (Jupiter Systems, Inc.).

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 (2.670 for 2020). The expansion factor = 1 + the number of males per female as randomly collected for broodstock at Wells Dam (1670:1.000 in 2020). 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 2020 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 2020 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 Jupiter Mesa rugged computer tablet (Jupiter Systems, Inc.). Weekly carcass recovery totals were summed post-season to calculate annual carcass recovery totals per reach and per survey area.

Some key assumptions for carcass surveys included:

Assumption I – All carcasses had the same probability of being recovered on the spawning grounds (despite differences in sex, origin, size, or spawning location)

Assumption II – The diagnostic unit in which a carcass is recovered is the same as the reach in which the fish spawned

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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 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:

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

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

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

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

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

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

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

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

PNI was calculated as:

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

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

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

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

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

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

Origin of Hatchery Spawners

Snouts from adipose fin clipped fish were removed, individually labeled, frozen, and delivered to the Chief Joseph Hatchery coded wire tag lab for CWT extraction and reading. The Regional Mark Information System (RMIS; http://www.rmis.org/rmis) was queried in March 2021 to assess the rearing facility of hatchery-origin Chinook recovered on the Okanogan spawning grounds, the in-to-basin stray rate, and the out-of-basin stray rates. RMIS data queries are described in detail in the 2013 CJHP Annual Report (Baldwin *et al.* 2016).

Smolt-to-Smolt Survival and Travel Time

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

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

Migration timing from release to the lower Okanogan River was determined using a query of the PTAGIS database (https://www.ptagis.org/data/quick-reports/small-scale-site-detections) to determine the timing of PIT tag detections from releases of Summer Chinook at Omak Pond. No PIT tags were released from Similkameen Pond in 2020. 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 2020 to February 2021. 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

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

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

RESULTS

Rotary Screw Traps

There are no results for 2020 due to COVID safety guidelines.

Juvenile Beach Seine and Pit Tagging

In 2020, 20,340 natural-origin juvenile salmonids were collected over the course of 26 fishing days (Table 3.). Out of the juvenile summer/fall Chinook collected, 18,700 (92%) sub-yearling Chinook were PIT tagged and released (Figure 7). Pre- and post-tag mortality was 1.0% and 7% respectively. Twelve-hundred eighteen shed tags were recovered from the net pens prior to release, twelve-hundred twelve of which were from post-tag mortalities, and the other six 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 fluctuated and increased through time (Figure 8), peaking the week beginning July 06 at which point water temperatures began to rapidly rise above 14° C (Table 3). 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 43-125 mm, with an average of 69.9 mm (SD 10.2 mm) and a median of 70 mm (Figure 9). Bycatch included hatchery-origin juvenile Chinook, three-spine stickleback, mountain whitefish, smallmouth bass, and sculpin.

Table 3. Summary of juvenile Chinook beach seining effort at Gebber's Landing in 2020. 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
6/4/2020	722	512	71%
6/10/2020	4,141	3123	75%
6/16/2020	4,577	3,371	73%
6/23/2020	6,866	6,303	91%
6/29/2020	6,114	5,215	85%
7/8/2020	2,270	1,524	67%
Total	**24,690**	**20,048**	
Mean	**4,115**	**3,341**	**77%**

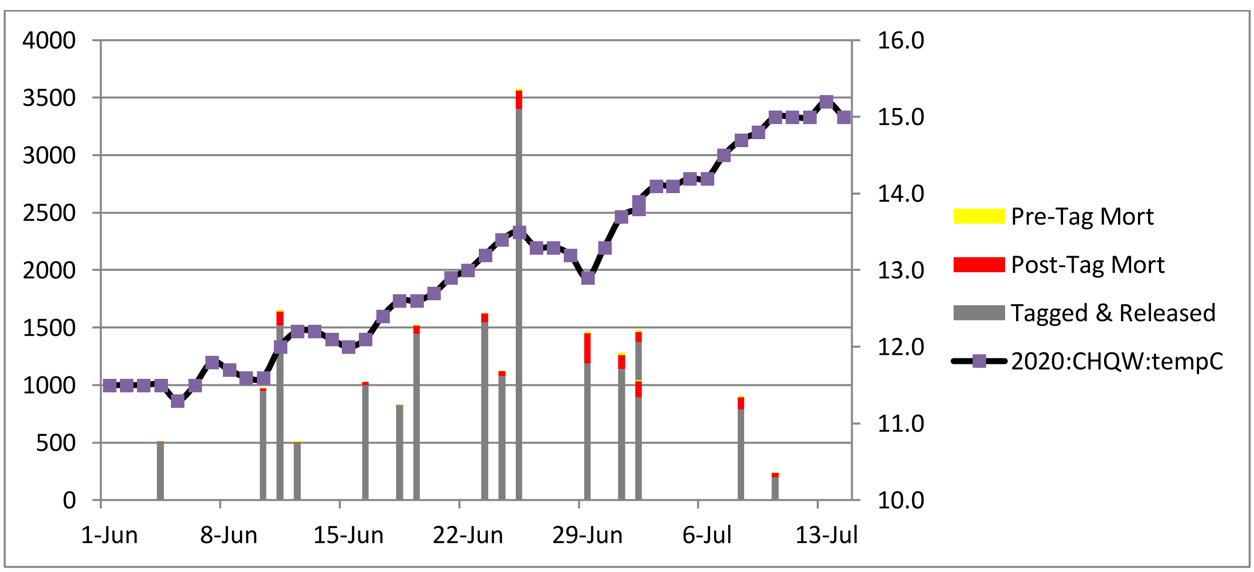


Figure 7. Total mortality and number of released natural-origin sub-yearling Chinook in 2019. Primary y-axis shows number of juvenile Chinook; secondary y-axis (right hand side) shows water temperature (degrees Celsius (C)).

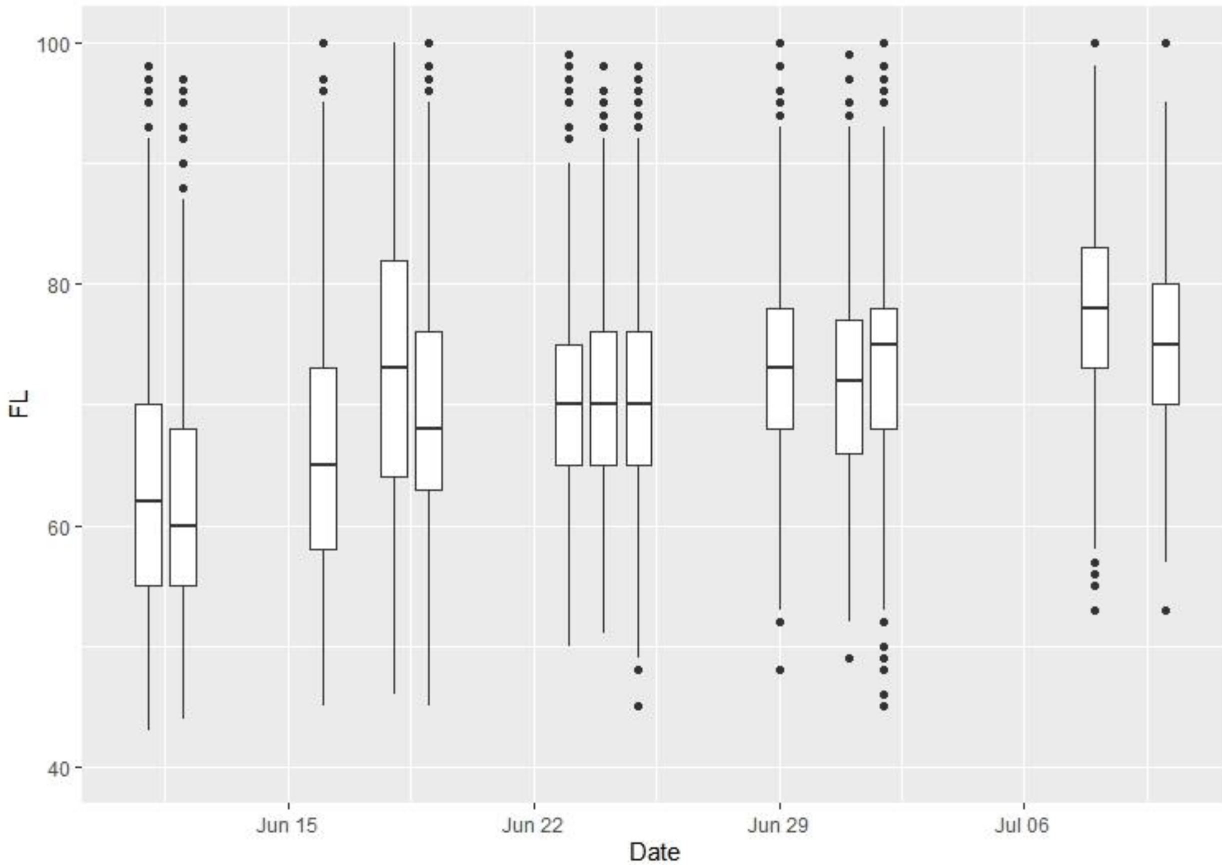


Figure 8. Size distribution of PIT tagged juvenile Chinook by release date from the beach seine effort in 2020. Boxes encompass the 25th to 75th percentiles of measured fish; the mid-line in the box is the median fish length. FL = fork length in millimeters (mm).

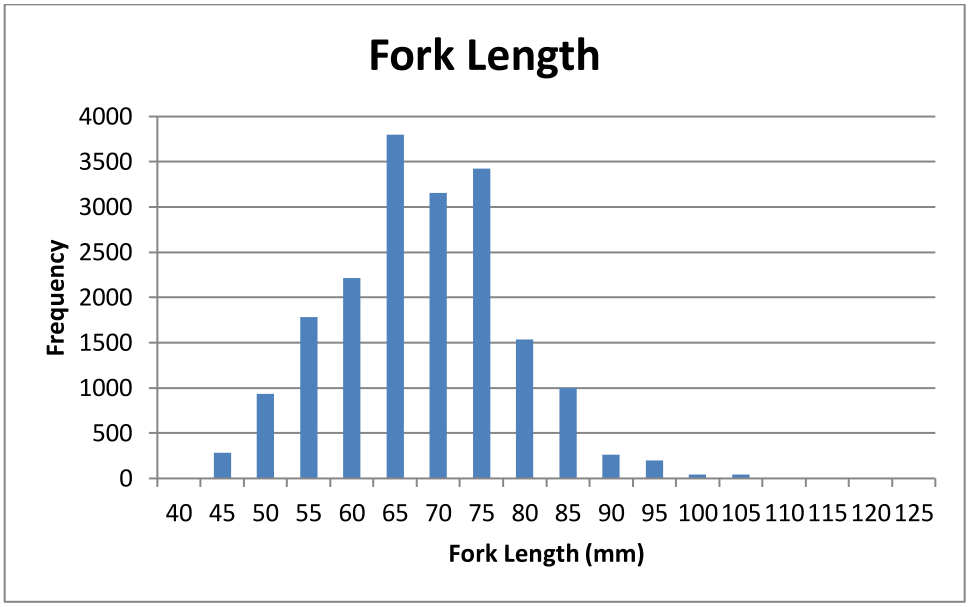
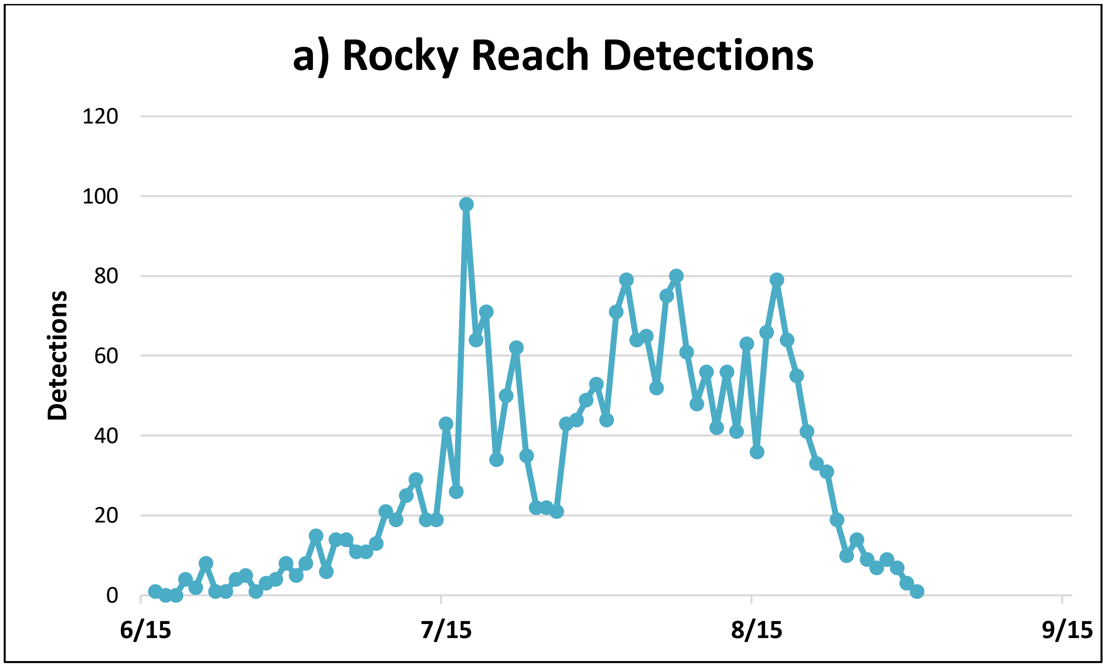
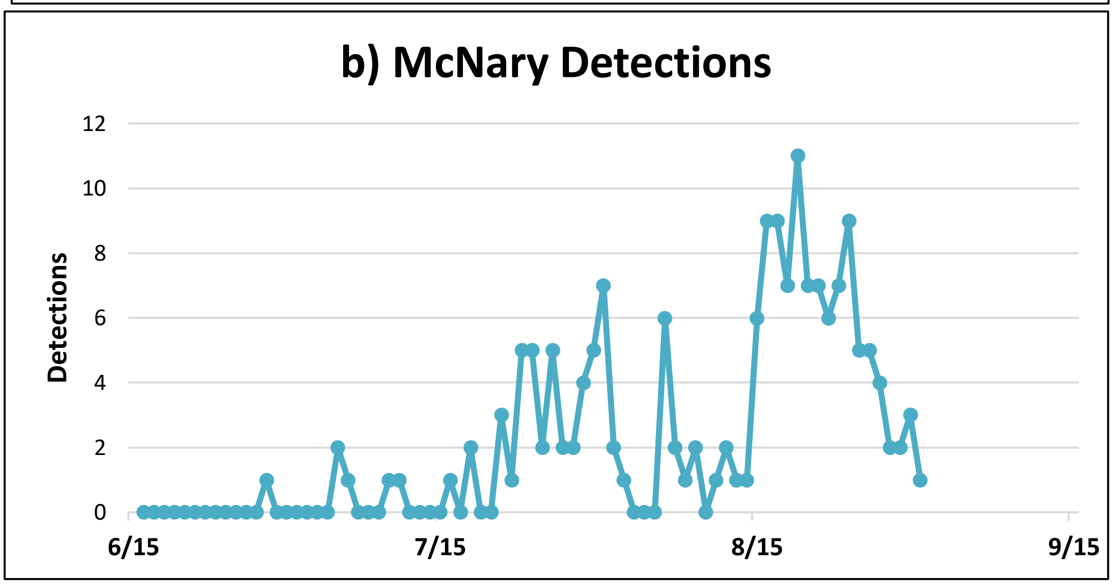


Figure 9. Size distribution of natural origin sub-yearling Chinook tagged during the beach seining effort in 2020.

The Rocky Reach juvenile bypass system detected 2,389 PIT tagged juvenile Chinook from the beach seining effort, which was 12.7% of total fish tagged and released. One hundred seventy-three (0.9%), 128 (0.6%) and 113 (0.6%) were detected at the McNary, John Day and Bonneville Dams respectively. Detections for sub-yearlings occurred primarily from mid-June to mid-August at all downriver dams (Figure 10). Utilizing the mark-recapture model from DART, the apparent survival rate was 43% (SE 3%) to Rocky Reach and 37% (34% SE) to McNary.



a) Rocky Reach Detections
Detections
120
100
80
60
40
20
0
6/15
7/15
8/15
9/15



b) McNary Detections
Detections
12
10
8
6
4
2
0
6/15
7/15
8/15
9/15

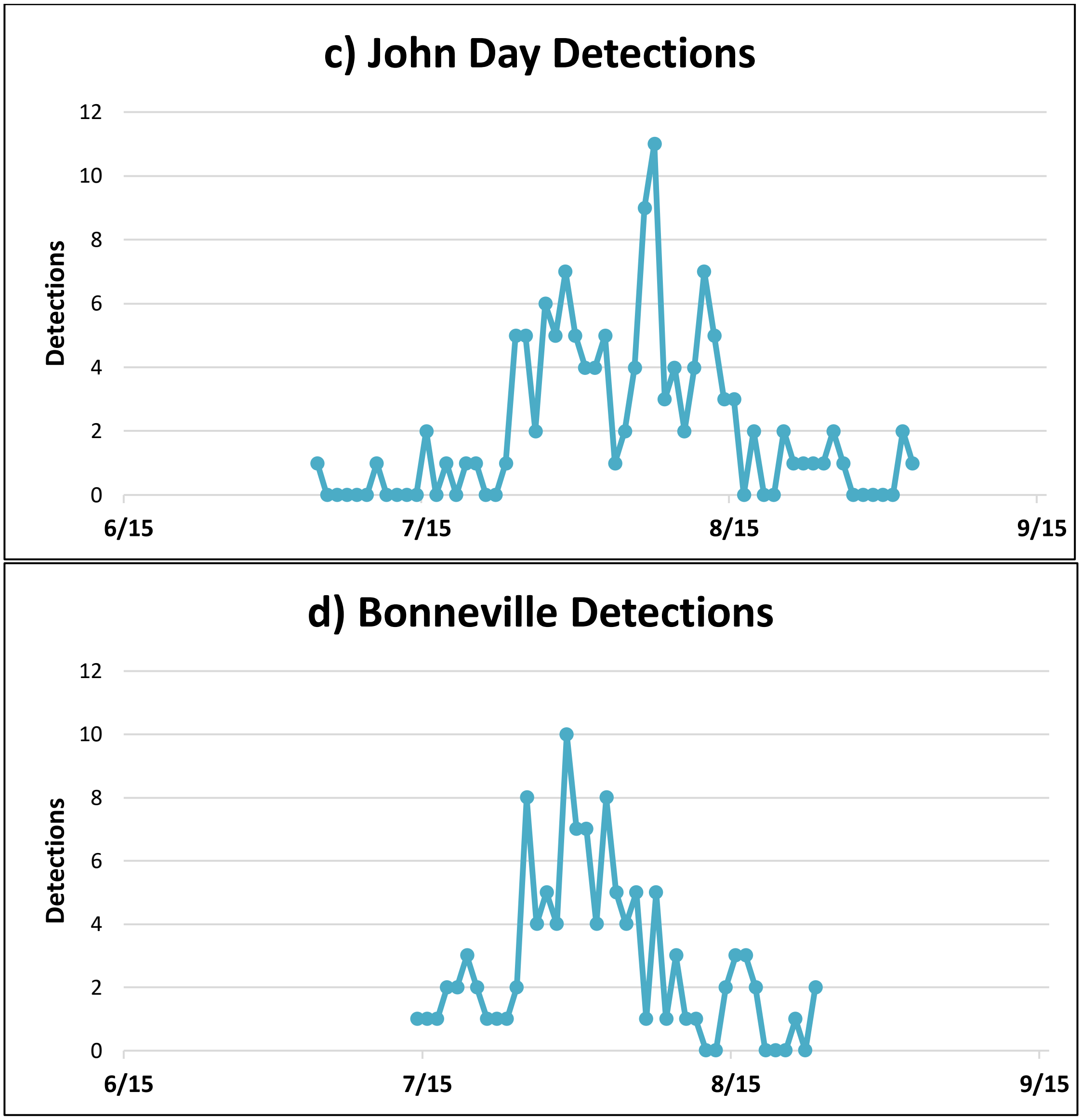
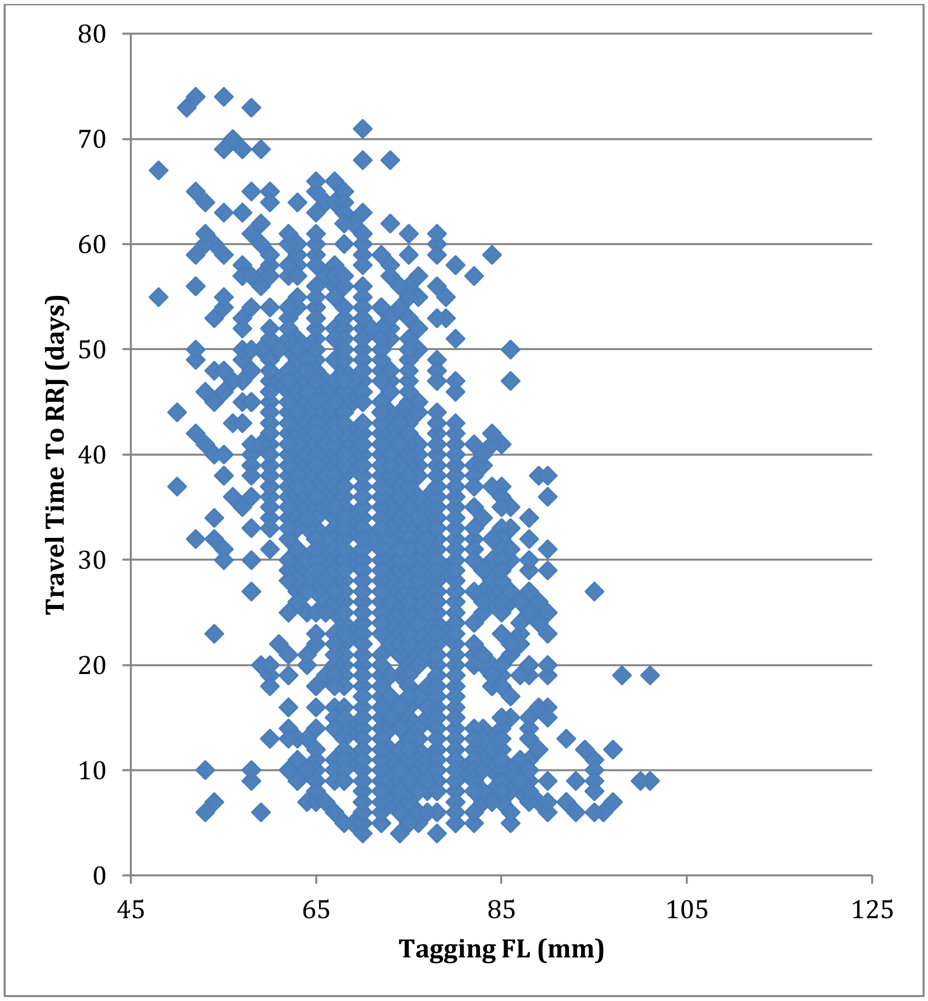


Figure 10. Daily distribution of detections of PIT-tagged sub-yearling Chinook at Rocky Reach, McNary, John Day, and Bonneville Dams in 2020. Note differences in scale on the y-axis. The y axes denote the numbers of PIT-tagged fish encountered daily at each of the mainstem project arrays.

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 4). Larger fish travelled faster to Rocky Reach Dam (Figure 11). This is similar to what was reported in 2011-2013 by Douglas County PUD and observed in previous years by CCT.

Table 4. 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)	36.3 (Standard Deviation = 14.7; n=2,386)	2.6	47.9 (Standard Deviation = 15.8; n=168)	8.1	42.9 (Standard Deviation = 10.6; n=128)	11.8	39.3 (Standard Deviation= 8.4; n=112)	15.8
Rocky Reach (762)			10.1 (Standard Deviation = 5.4; n=61)	28.9	14.2 (Standard Deviation = 6.5; n=41)	29.2	15.6 (Standard Deviation = 4.6; n=25	33.8
McNary (470)					3.5 (Standard Deviation = 1.0; n=4)	35.1	4.5 (Standard Deviation=0.3; n=2)	52.2
John Day (347)							2.1 (Standard Deviation = 0.5; n=13)	53.3



80
70
60
50
40
30
20
10
0
45
65
85
105
125
Travel Time To RRJ (days)
Tagging FL (mm)

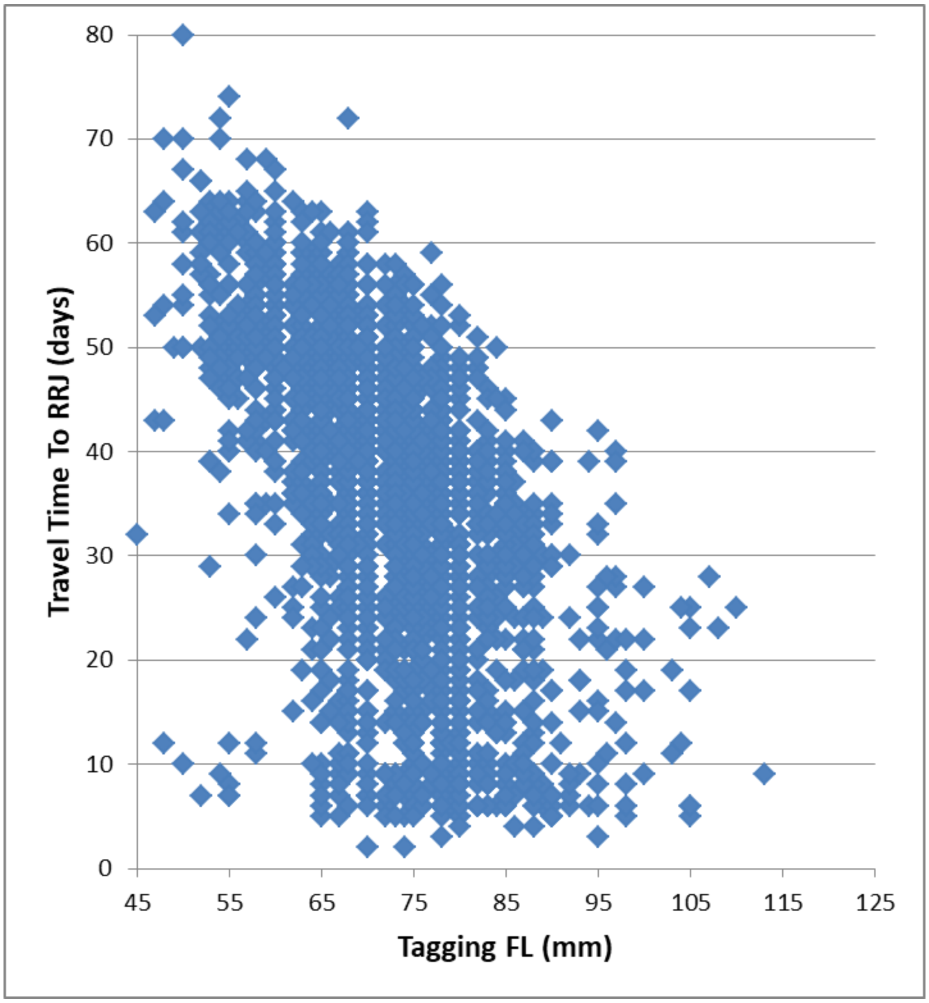


Figure 11. Fish size (fork length) and travel time of tagged Chinook to Rocky Reach Dam.

Lower Okanogan Adult Fish Pilot Weir

The Okanogan River (at Malott) discharge was above normal in 2020, which delayed deployment of the weir until August 17 when the river flow went below 2,000 cfs (Figure 3). Discharge continued to drop throughout the season and was approximately 1,000 cfs by the time the weir was removed for the season on September 24.

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 it generally 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 and/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 2020, temperatures were similar to the median daily temperatures from the last 13 years (Figure 4). Daily mean temperature was above 22.5 °C from July 21 to August 24. Daily mean temperature dropped below 22.5 °C on August 25th and stayed below this mark until the end of the season.

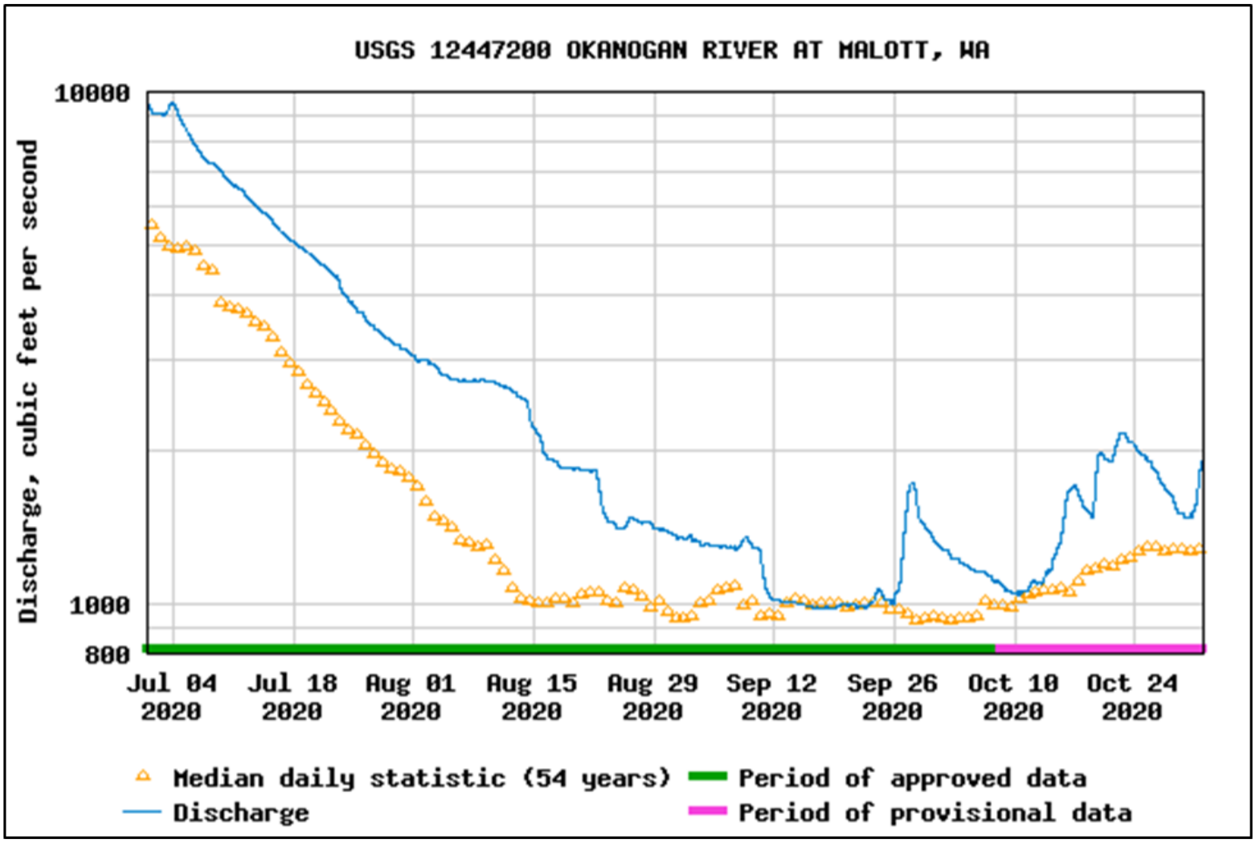


Figure 12. Discharge of the Okanogan River between July 1 and October 31, 2020. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

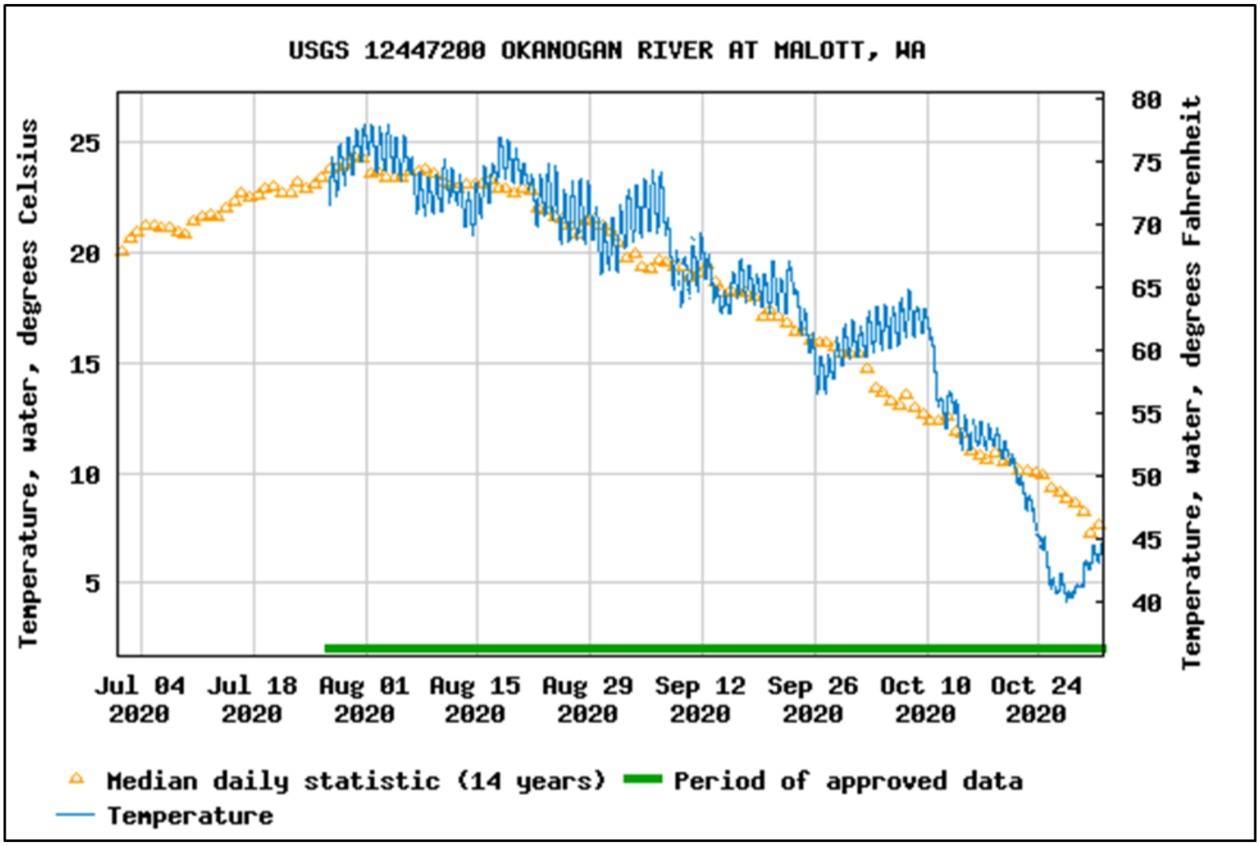


Figure 13. Temperature of the Okanogan River between July 1 and October 31, 2020. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

Dissolved Oxygen varied from 6.9 to 8.3 mg. /L, total dissolved solids varied from 129-180 ppm and turbidity varied from 0.7 and 2.1 NTUs (Table 1). The head differential was measured only when pickets were down and ranged from 1.0-4.0 cm. The maximum water velocity measured was 3.4 ft. /sec. (Table 2).

Table 5. Water quality data at or near the lower Okanogan weir in 2020. Temperature and discharge were taken from the USGS gage at Malott. Minimum depth allowed for trap depth is 6 inches and optimal dissolved oxygen levels for adult Chinook should not drop below 6 mg/L.

Date	Trap Depth (ft)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (ppm)	Turbidity (NTU)	Mean Temperature (◦C)	Mean Discharge (cfs)
8/24	1.7	7.80	180	1.2	23	1,430
8/25	1.7	7.80	134	1.4	22	1,470
8/26	1.7	7.85	132	2.1	22	1,470
8/27	1.7	7.74	133	1.3	22	1,450
8/28	1.7	8.01	135	2.0	22	1,440
9/2	1.6	7.89	139	1.3	22	1,330
9/3	1.6	7.00	133	1.5	22	1,300
9/4	1.6	6.93	136	1.1	22	1,300
9/5	1.6	7.05	139	1.1	22	1,290
9/9	1.5	7.98	133	0.8	19	1,290
9/10	1.5	8.23	132	0.8	19	1,190
9/11	1.4	7.36	134	1.6	20	1,030
9/14	1.3	7.98	129	0.7	18	1,010
9/15	1.5	7.46	134	1.2	18	997
9/17	1.4	8.30	138	0.8	19	982
9/18	1.4	7.65	136	0.8	19	984
9/21	1.4	7.41	131	0.8	18	993
9/22	1.4	7.75	135	0.8	19	989
9/23	1.4	7.25	137	1.1	18	1020
Min	1.3	6.9	129	0.7	18	982
Max	1.7	8.3	180	2.1	23	1,470

Table 6. 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.

Date	River Left US	US Center	River Right US	River Left DS	DS Center	River Right DS	Trap Velocity
8/24	1.8	1.9	2.7	2.6	2.3	3.4	1.0
8/25	1.8	1.9	2.7	2.5	2.3	2.7	1.3
8/26	1.9	1.9	2.5	3.0	2.0	2.8	1.0
8/27	1.6	1.6	2.5	2.4	2.5	3.1	1.2
8/28	1.6	1.5	1.9	2.7	2.5	3.1	1.1
8/31	2.4	1.8	2.0	2.8	2.9	2.9	1.1
9/2	1.4	1.4	2.9	3.0	2.3	2.5	1.2
9/3	1.7	1.4	2.8	3.2	2.3	2.3	1.2
9/4	1.3	1.2	2.1	2.6	2.6	2.4	1.1
9/5	1.8	1.4	2.5	2.3	2.1	2.3	1.4
9/10	2.0	1.4	1.7	2.7	2.2	2.0	1.1
9/11	1.3	1.4	1.5	2.9	2.3	2.1	1.0
9/14	1.7	1.5	2.3	2.1	1.9	2.5	1.0
9/15	1.7	1.4	1.8	2.3	2.4	3.2	1.5
9/17	1.4	1.5	1.5	2.4	3.0	2.0	0.9
9/18	1.1	1.4	1.6	2.3	2.2	3.0	1.0
9/21	1.2	1.2	1.6	2.0	2.2	2.6	0.8
9/22	1.3	1.2	2.1	2.0	2.4	2.6	0.9
9/23	1.5	1.3	1.3	2.1	2.2	2.5	0.8
Min	1.3	1.2	1.5	2.1	1.9	2.0	0.9
Max	2.4	1.9	2.9	3.2	3.0	3.4	1.5

One hundred and forty-five dead fish were removed from the weir between August 28 and September 24. The majority of the mortalities (67) were sockeye and 23 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 about half the fish were milling in the center section of the river, just below the trap with the rest being equally split between the river right and river left sections (looking downstream). Estimates were highest during the last weekend of August when mean daily river temperatures dropped below 22.5 °C. Bank observations showed that the number fish observed holding in the lower pool, 0.8 km below the weir, increased about one week after the thermal barrier breakdown in late August (Figure 5). Trapping operations were conducted from August 27-September 24 when river temperature was ≤ 22.5 °C. The total fish trapped at the weir in 2020 was 931 with 93% of them being Chinook salmon (Figure 6). Seventy-two percent of the Chinook trapped were released back into the river (Figure 7). Twenty-seven steelhead were trapped in 2020.

Eighty-four natural-origin Chinook were transported to the hatchery and held in the brood stock ponds concurrently with the fish taken for brood stock from the purse seine. 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. Past efforts have not indicated a problem with survival of brood fish collected at the weir. 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.

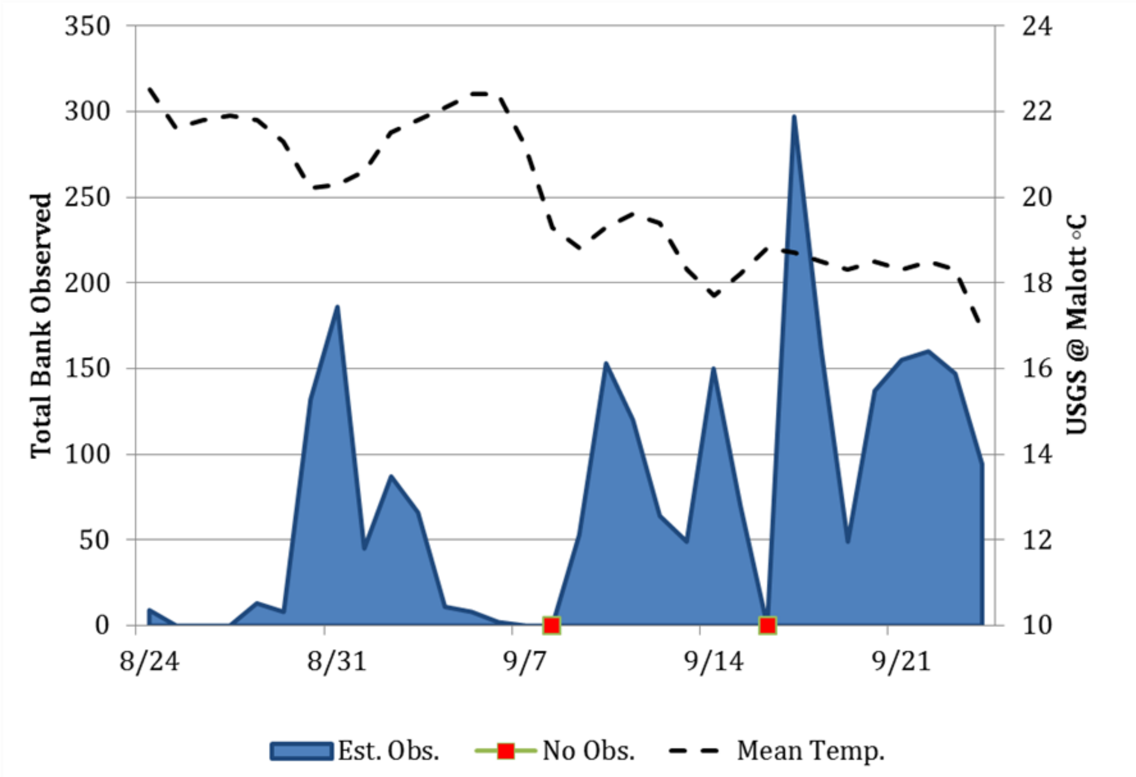


Figure 14. Estimate of Chinook observed from the bank at the lower pool, 0.8 km downstream of the weir. Primary y-axis indicates number of Chinook observed; secondary y-axis (right hand side) indicates the mean stream temperature in degrees Celsius (C).

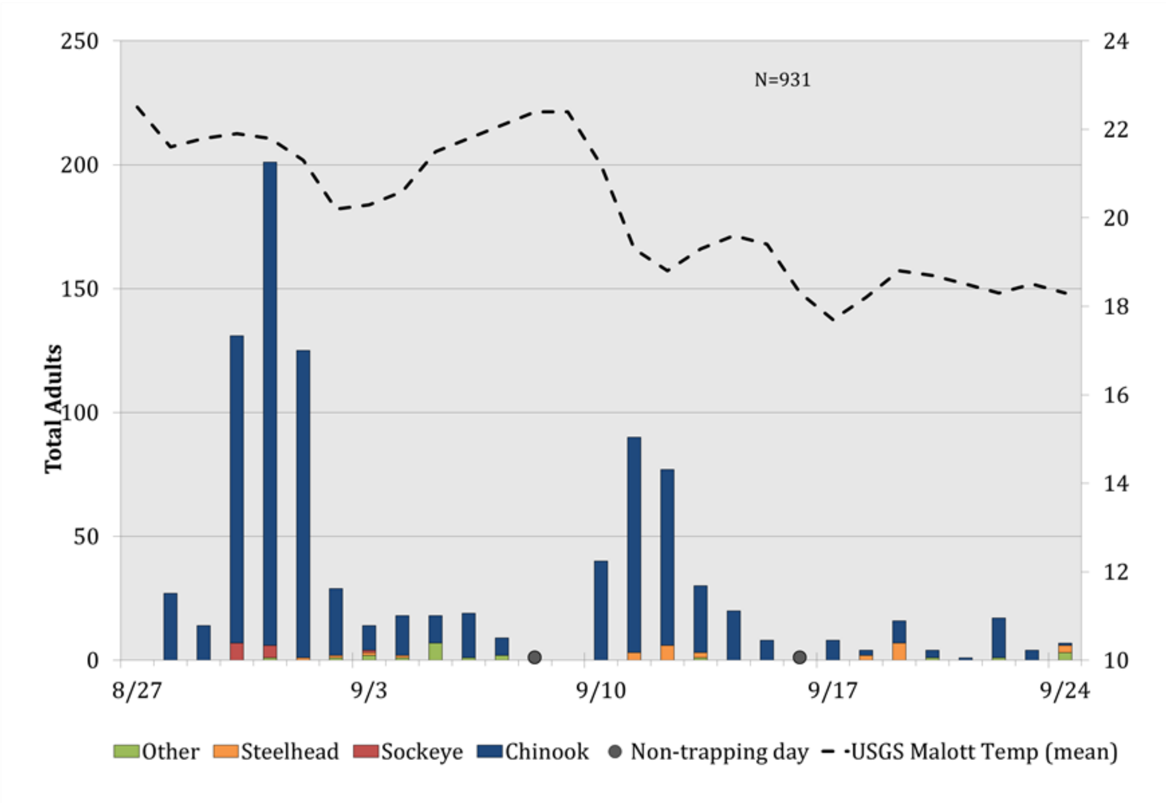


Figure 15. Total number of fish trapped at the Okanogan weir in 2020.

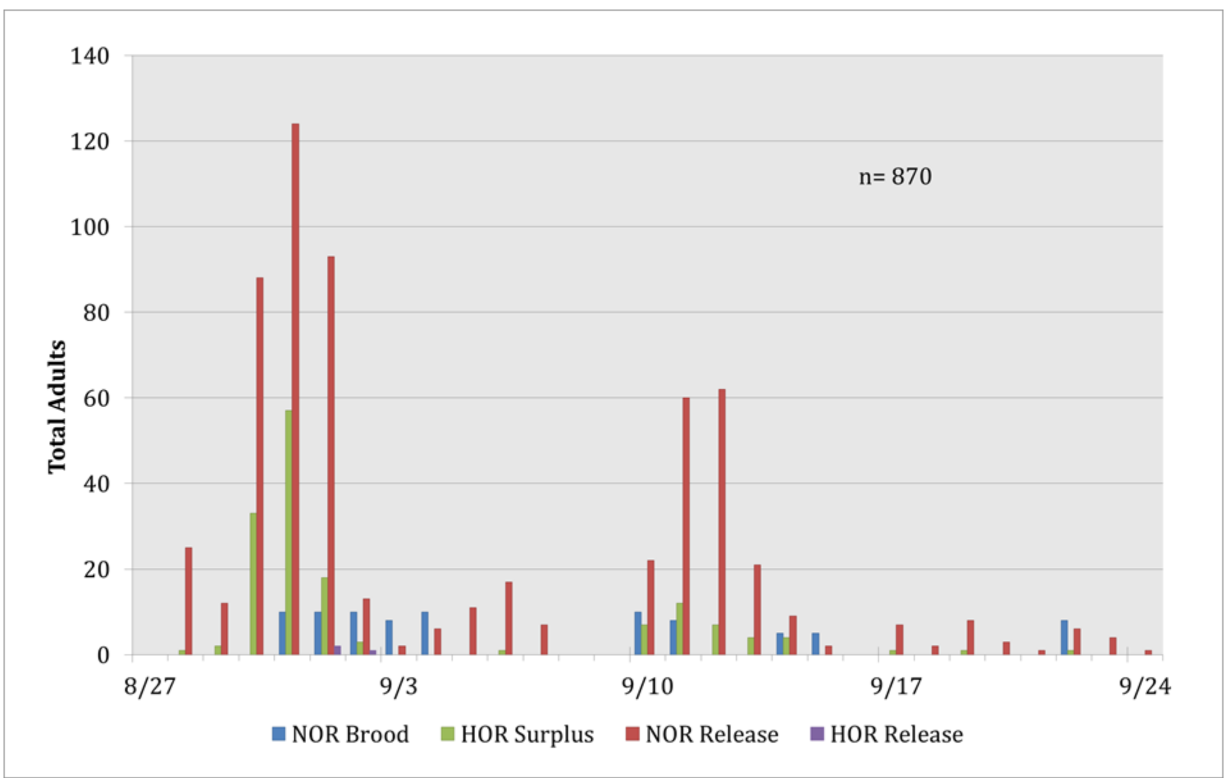


Figure 16. Final destination of Chinook adults captured in the weir trap during trapping operations in 2020.

In 2020, 0.065 (6.5%) of total spawning escapement was detected in the trap (i.e., weir efficiency) (Table 7). The potential weir effectiveness (if we had been removing all of the HOR encountered) was 0.043 (4.3%)**.**

Table 7. The number of hatchery and natural origin Chinook Salmon encountered at the lower Okanogan weir in 2020. 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	Number of Days Trapped	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	23	73	18	5,627	2,567	0.010	0.007
2014	34	2,006	318	10,407	1,756	0.147	0.140
2015	34	36	19	10,439	3,297	0.004	0.005
2016	30	135	34	8,700	1,905	0.014	0.016
2017	24	344	103	5,429	1,139	0.058	0.075
2018	38	32	16	3,266	1,594	0.009	0.009
2019	5	119	24	2,604	2,849	0.023	0.008
2020	27	709	161	7,957	3,062	0.066	0.045
Avg.	27	432	87	6,804	2,271	0.041	0.038

[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 2020, 4,127 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 2020 was higher than the previous year (2019) – higher than the long-term average and 5-year average (Table 8). Consistent with previous years, the majority of Chinook redds were located in reaches S1 (35%), O6 (30%), and O5 (17%; Table 15). These three reaches accounted for 82% 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 18).

Estimated spawning escapement was 11,019 (4,127 redds × 2.67 fish per redd) (Table 10). Since 1989, the summer/fall Chinook spawning escapement within the U.S. portion of the Okanogan River Basin has averaged 5,861 and ranged from 473 to 13,857 (Table 10).

Summer/fall Chinook redds were counted during spawning ground surveys between October 6- Nov 5 (Table 11).

Table 8. Total number of redds counted in the Okanogan River Basin, 1989-2020 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
2020	2,386	1,741	4,127
Average	***1,299***	***1,038***	***2,276***
5-yr Avg.	***2,300***	***1,122***	***3,421***

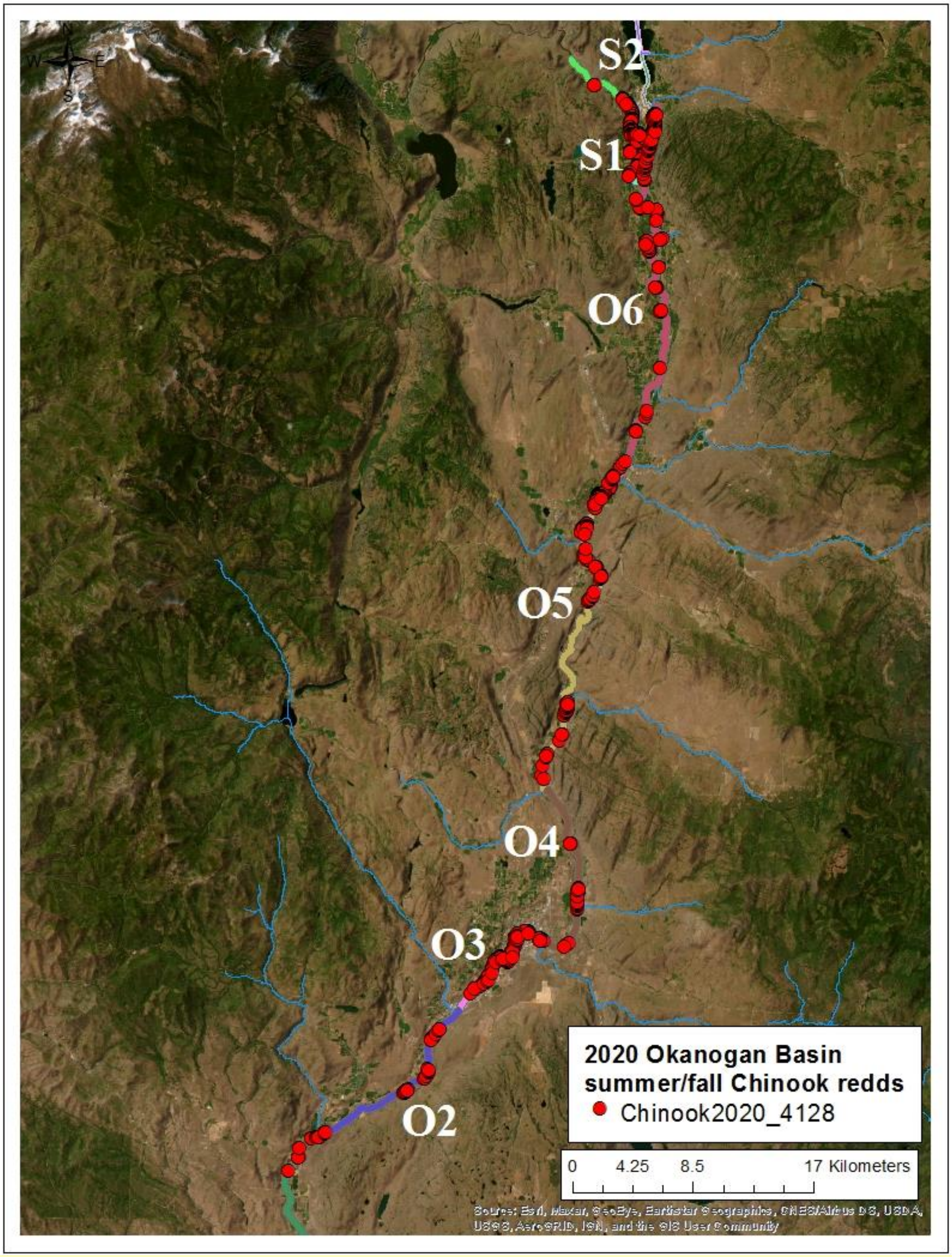


Figure 17. Distribution of summer/fall Chinook redds in 2020. Individual redds are identified by red circles. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Table 9. Annual and average abundance of summer/fall Chinook redds in each reach of the Okanogan (O1-O6) and Similkameen (S1-S2) Rivers from 2006-2020.

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
2020	25	51	270	103	683	1,254	1,445	296	4,127
Average	***10***	***57***	***160***	***97***	***652***	***985***	***1,104***	***167***	***3,232***

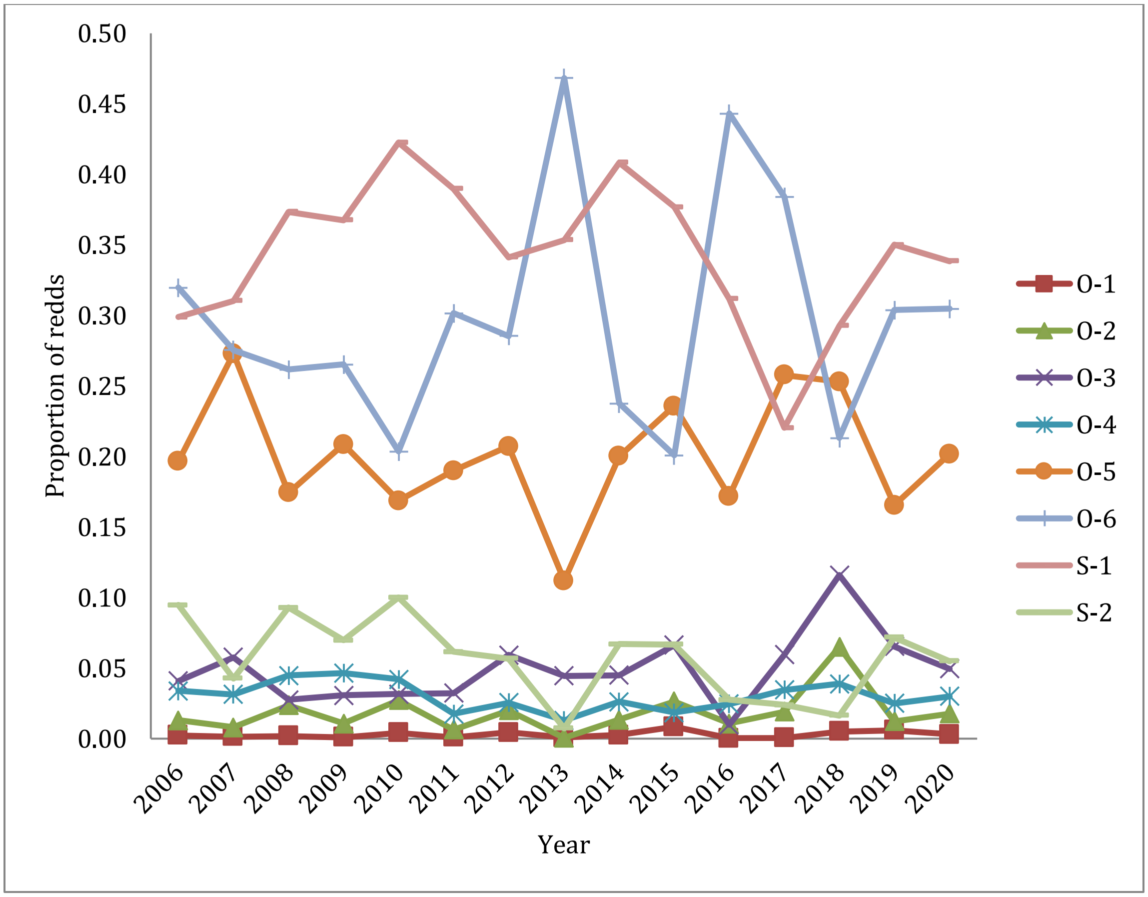


Figure 18. Proportion of redds in each reach of the Okanogan and Similkameen Rivers from 2006 to 2020.

Table 10. Spawning escapements for summer/fall Chinook in the Okanogan and Similkameen Rivers for return years 1989-2020.

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
2020	2.670	6,371	4,648	11,019
Average	***2.858***	***3248***	***2793***	***5861***
5-Year Avg.	***2.324***	***4690***	***2299***	***6989***

* 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 11. Number and timing of summer Chinook redd counts in reaches of the Okanogan and Similkameen Rivers in 2020.

Reach	River mile	Oct 5 - 11	Oct 12 - 18	Oct 19 - 25	Oct 26 - Nov 1	Nov 2 - 8	Redd Count	Percent
O1	0.0-16.9	0	5	18	2	0	25	1%
O2	16.9-26.1	5	17	22	7	0	51	2%
O3	26.1-30.7	24	107	134	5	0	270	11%
O4	30.7-40.7	7	63	25	8	0	103	4%
O5	40.7-56.8	497	76	103	7	0	683	29%
O6	56.8-77.4	651	522	67	14	0	1254	53%
Total		***1184***	***790***	***369***	***43***	***0***	***2386***	100%
Similkameen River								
S1	0.0-1.8	880	557	0	8	0	1445	83%
S2	1.8-5.7	142	152	0	2	0	296	17%
Total		***1022***	***709***	***0***	***10***	***0***	***1741***	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 from 2018-2020. 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 12. 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%
2020	No Data	No Data	79	7%
Average	***941***	***19%***	***30***	***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 more recently in 2020 with 79 spawners (Table 12).

Carcass Surveys

In 2020, 2,604 carcasses were recovered on the spawning grounds, including 1,908 natural-origin and 696 hatchery-origin[6]. An additional 4 carcasses were recovered during pre-spawn surveys (1 ad-clipped, 3 ad-present). The spawning ground carcass recovery rate was 23.6% of the total spawning escapement. Similar to previous years, the majority of carcasses (*n* = 2,229; 86%) were collected from reaches O5, O6 and S1 (Figure 19, also see

[6]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 2020 were similar in all reaches, compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 19, panel A). The proportions of hatchery-origin carcasses recovered in 2020 were significantly higher in reaches O1-O4 and lower in reaches O5, O6, S1 and S2 compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 19, panel B).

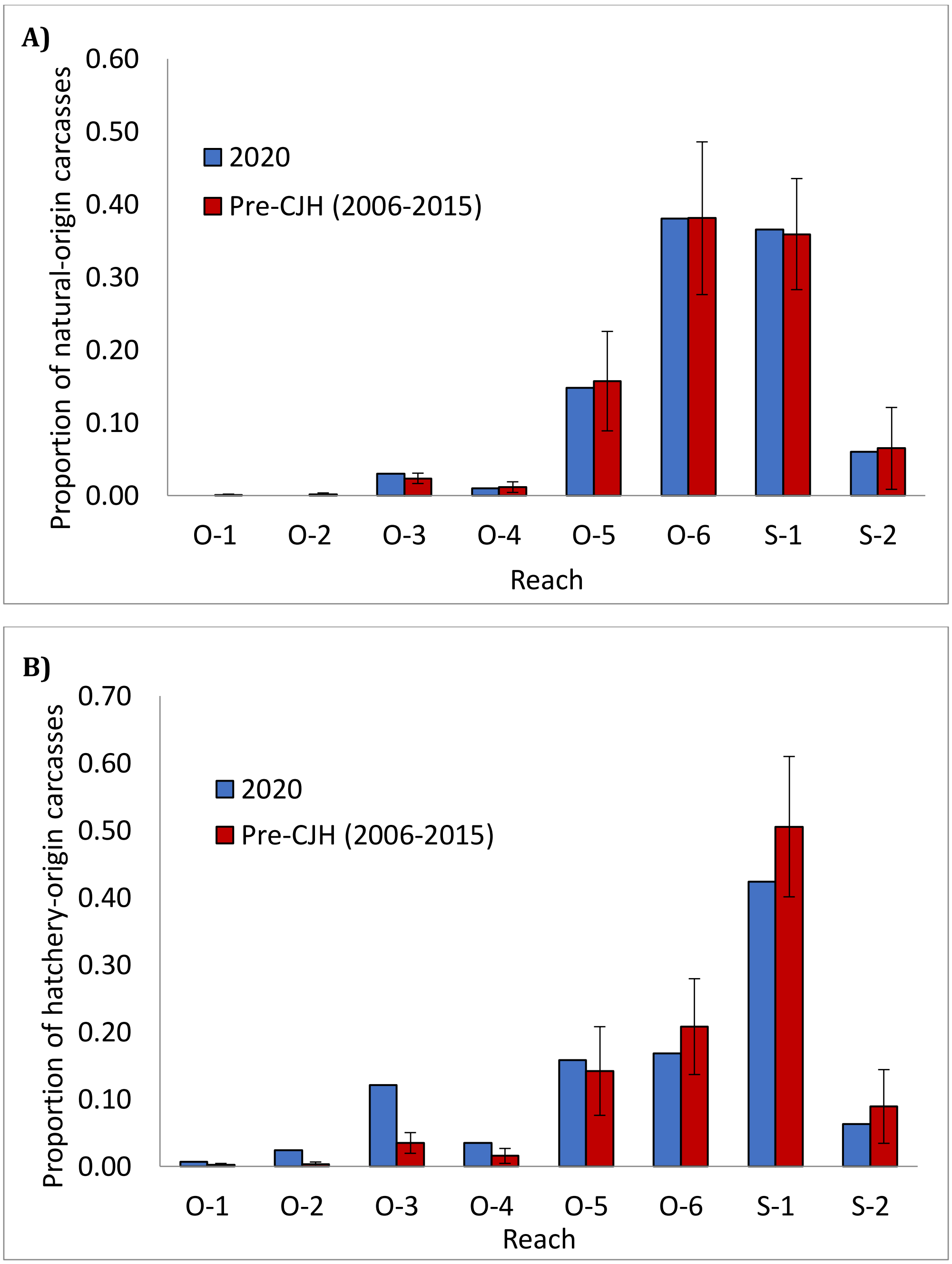


Figure 19. Distribution of (A) natural-origin and (B) hatchery-origin summer/fall Chinook carcasses recovered in the Okanogan (reaches O1-O6) and Similkameen (reaches S1-S2)

Rivers in 2020 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 16 of the 1,389 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 0.99% for natural-origin females and 1.60% for hatchery-origin females (Table 13). Overall egg retention of all fish sampled (including fish that had expelled a portion of their eggs) was 3.15%.

Table 13. 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%
2020	Natural	1,908	826	4,045,568	84,432	2.04%	0.99%
	Hatchery	696	252	1,260,000	53,552	4.25%	1.60%
	Total	2,604	1,078	5,305,568	137,984	3.15%	1.30%

[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 lower reaches (O1-O4) in 2020 compared to the 10 years preceding Chief Joseph Hatchery (Figure 20). Hatchery-origin spawners comprised 28% of the spawn escapement estimate in the U.S. portion of the Okanogan, which was almost half the pHOS observed in 2019 (.52). After corrections for hatchery fish effectiveness assumptions (0.80 relative reproductive success rate for hatchery-origin spawners) the effective pHOS for 2020 was 0.24, which was just below the five-year average (0.25) (Table 15). The five-year average is currently meeting the biological objective for pHOS (<0.3) (Figure 21).

The proportion of natural-origin broodstock (pNOB) in 2020 was 0.99 and the pNOB for Okanogan origin fish was 0.89 (Table 15). The resulting PNI for 2020 was 0.82, with a 5-year average PNI of 0.75. The 5-year average is still meeting the Biological Objective (>0.67) (Figure 22).

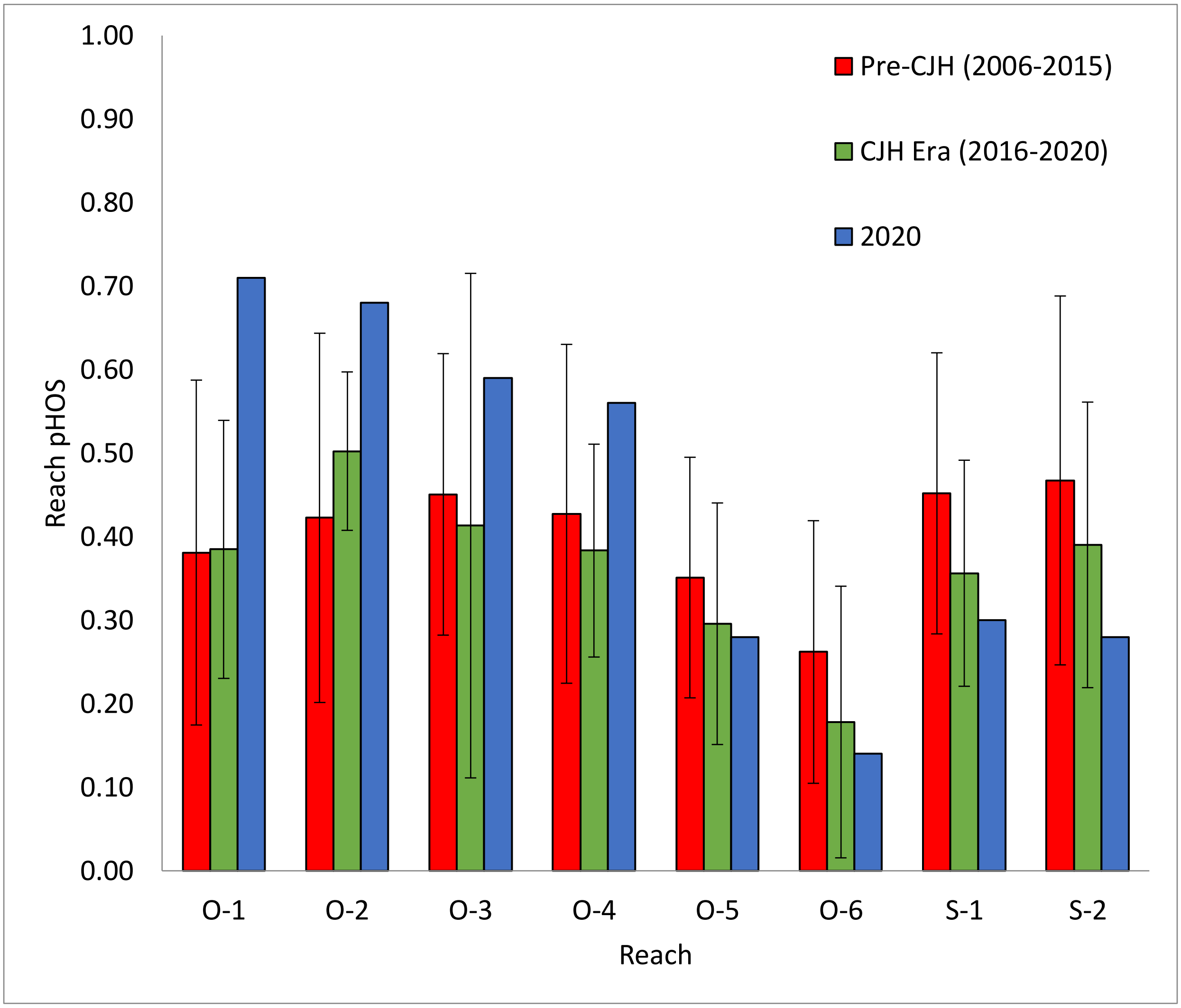


Figure 20. Okanogan (O1-O6) and Similkameen (S1-S2) river summer/fall Chinook pHOS (unadjusted for RSS) by reach. Red bars represent the average of the 10 years preceding Chief Joseph Hatchery (2006-2015), green bars represent the average of the years since Chief Joseph Hatchery operation (2016-2020), and blue bars represent the current year (2020). Reaches with <5% carcasses recoveries were omitted. Error bars represent standard deviation.

Table 14. Natural- (NOS) and hatchery- (HOS) origin spawner abundance and composition for the Okanogan River Basin, brood years 1989-2020.

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
2020	7,957	3,062	0.28	0.24
Average	***3,650***	***2,359***	***0.38***	***0.34***
5-year Average	***5,591***	***2,110***	***0.30***	***0.26***

[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.

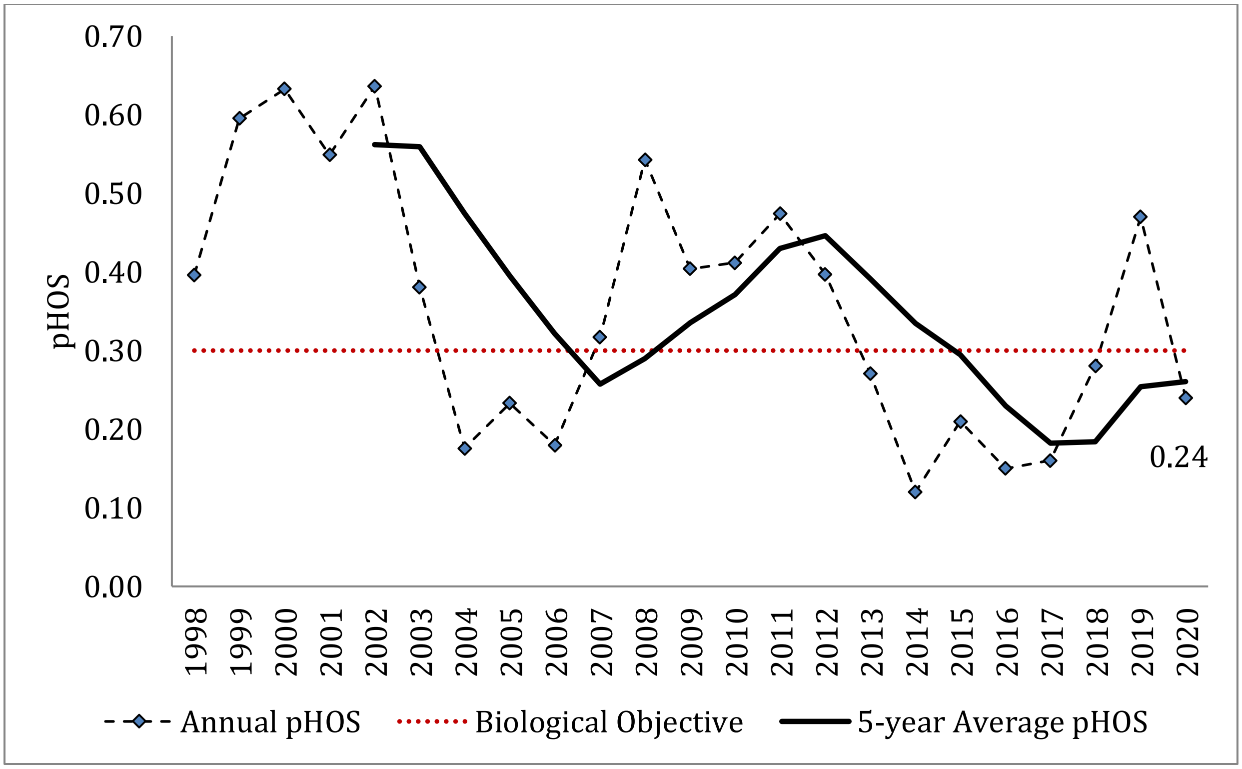


Figure 21. Annual and 5-year average proportion of hatchery-origin spawners (pHOS) in the Okanogan and Similkameen River (combined) from 1998-2020. pHOS values represent the effective pHOS (adjusted for RRS).

Table 15. Okanogan basin summer/fall Chinook spawn escapement, broodstock composition, pHOS, and PNI for Brood Years 1989-2020.

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
2020	7,957	3,062	0.22	530	477	5	0.99	0.89	0.82	0.80
Average	***3,650***	***2,359***	***0.34***	***415***	***246***	***146***	***0.74***	***0.55***	***0.68***	***0.59***
5-Year Average	***5,591***	***2,110***	***0.25***	***408***	***367***	***88***	***0.81***	***0.73***	***0.75***	***0.74***

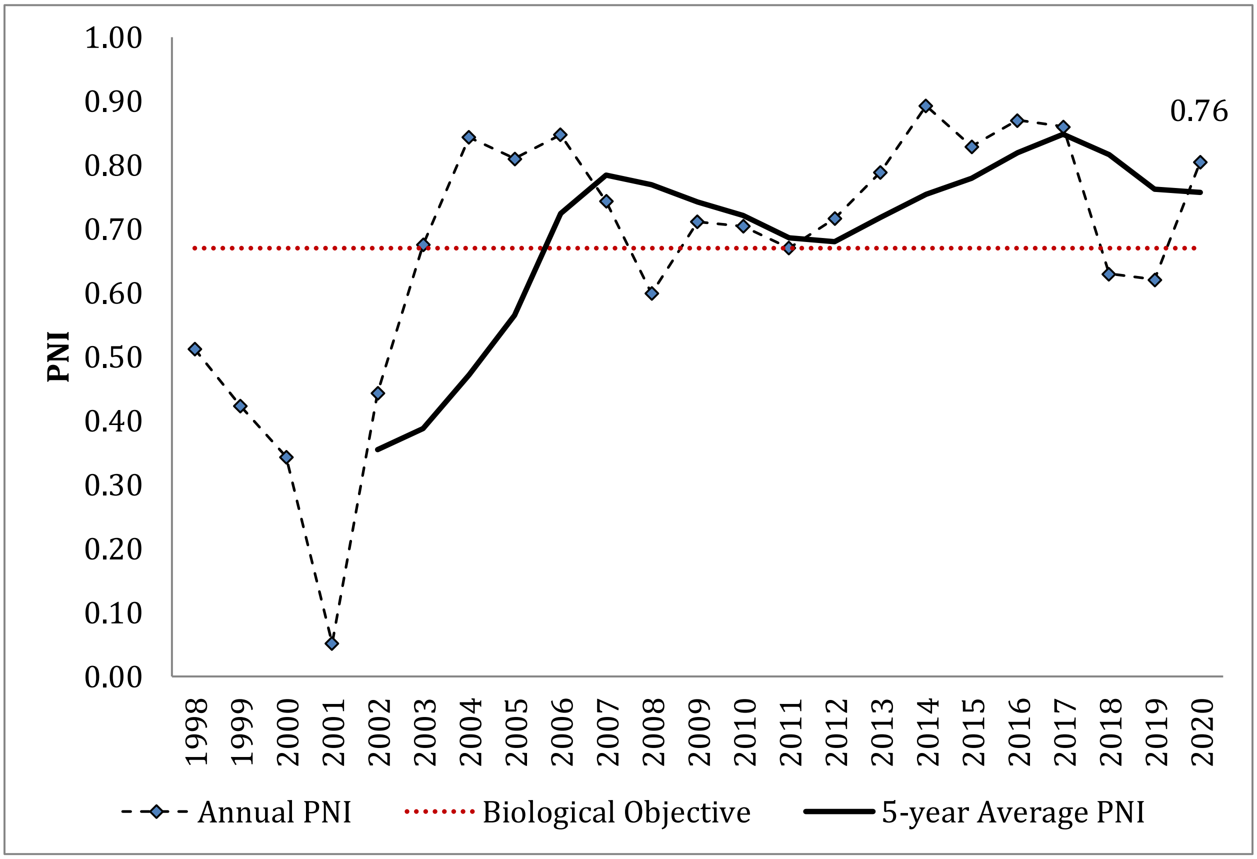


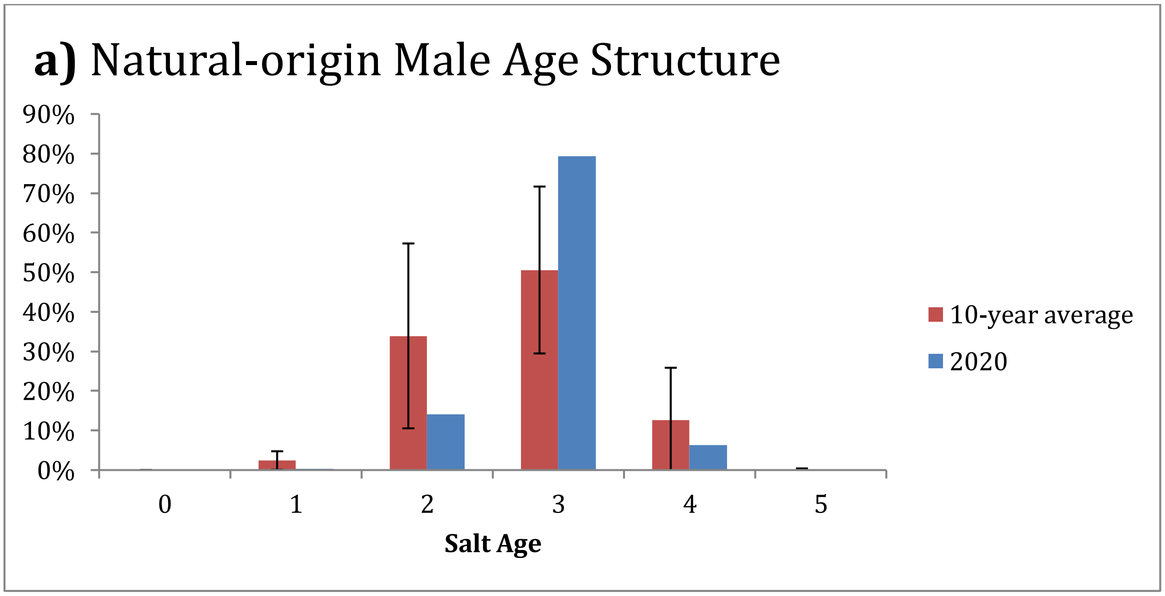
Figure 22. Annual and 5-year average proportionate natural influence (PNI) in the Okanogan basin from 1998 to 2020.

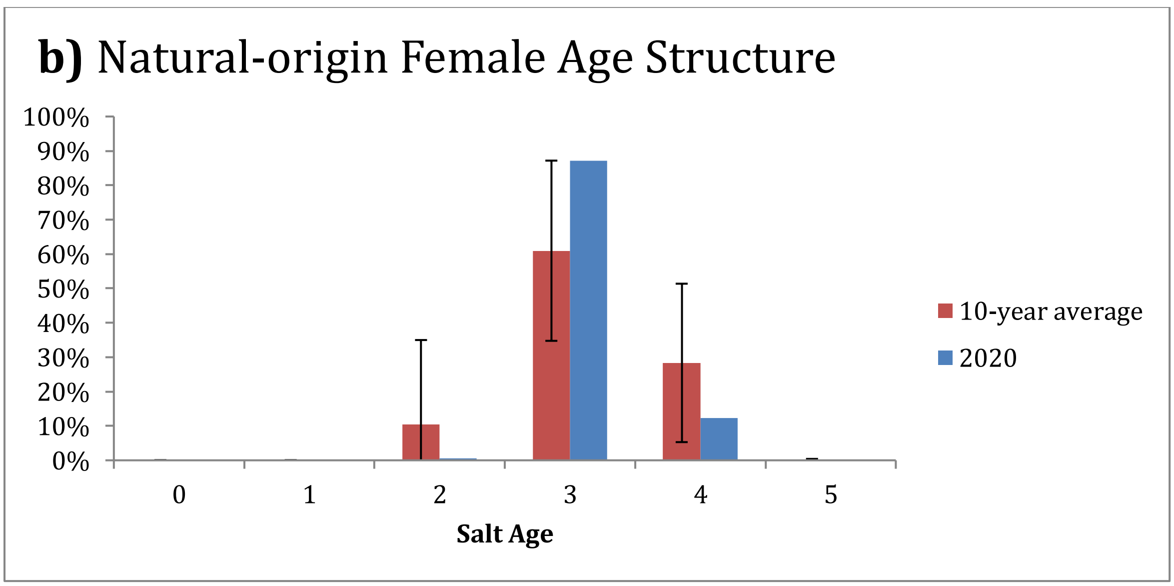
Age Structure

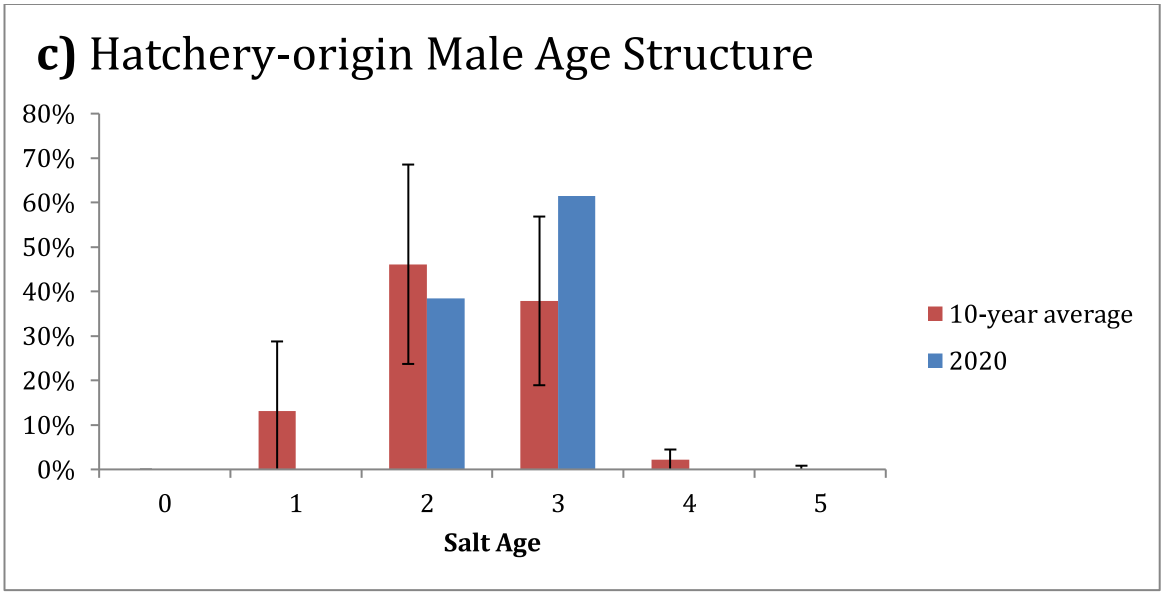
Attempts were made to age all carcasses recovered on the spawning grounds, either by microscopy of scale annuli for natural-origin fish or by extracting and reading coded wire tag information for hatchery-origin fish. Historically, most natural-origin summer Chinook out migrate as sub-yearlings, while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

In 2020, male natural-origin spawners were comprised predominantly 3-year salt age fish, which is different than previous years (Figure 28-a). Natural-origin female spawner age structures were skewed towards 3-year salt age fish similar to previous years (Figure 23-b). With 1,013 natural-origin female Chinook collected on the spawning grounds in 2020, 102 were determined to be 4-year salt age. Hatchery-origin males were comprised by 2- and 3-year salt age fish. No 4-year hatchery-origin males were recovered.

Hatchery-origin females were also comprised of 2- and 3-year fish, and no 4-year fish were recovered.







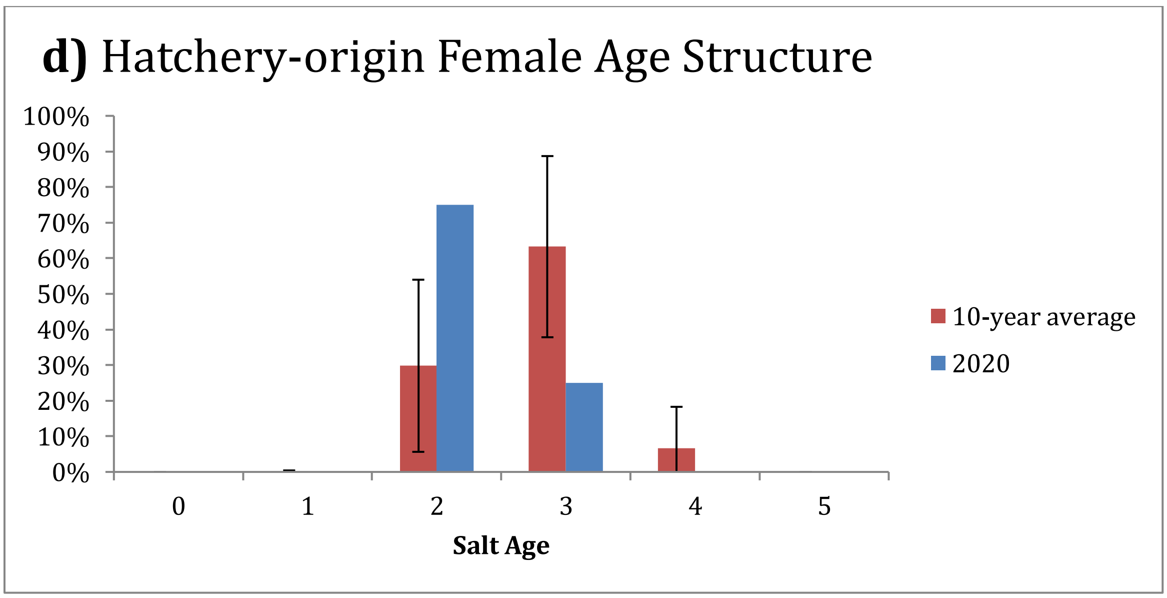


Figure 23. The salt ages of carcasses collected on the spawning grounds of the Okanogan and Similkameen rivers in 2020 along with 10-year averages (2011-2020) for a) Natural-origin males; b) Natural-origin females; c) Hatchery-origin males; and d) Hatchery-origin females.

Hatchery-Origin Stray Rates

Strays to the Okanogan— The majority (75%) of hatchery-origin spawners recovered on the spawning grounds in 2020 were from the integrated CJH program Similkameen (48%) and Okanogan acclimated (27%) releases (Table 16). The majority of strays from outside the Okanogan were from the Chief Joseph Hatchery segregated program (19%), whereas strays from other hatchery programs in the Methow River, Entiat River, Chelan River, and mainstem Columbia River releases comprised 6% (Table 20). The contribution of stray hatchery fish to total spawn escapement was 7% (i.e., stray pHOS) (Table 17). This was above the recent (2006-2020) average of 4.21% and also above the biological target of < 5%. Note that this includes those fish released from the Chief Joseph Hatchery segregated program which comprised 5.4% of the spawner composition.

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 2015. The 2015 brood year had a stray rate of 2.1% (includes straying to out of basin spawning grounds and hatcheries), which was slightly above the long term (1989-2015; 1.2%) and recent five-year (2011-2015; 1.5%) averages (Table 18). For return year 2020, RMIS queries revealed an estimate of 4 Okanogan hatchery-origin Chinook recovered on spawning grounds in non-target spawning areas in 2020 (Table 18). Okanogan basin hatchery program strays comprised 0.24% to Methow spawner composition in 2020 (Table 19). 5-year averages to Wenatchee, Methow, Chelan, and Entiat basins are all below 1%.

Table 16. 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 2006-2020.

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%)
2020	813 (27%)	1,470 (48%)	65 (2%)	5 (0%)	17 (1%)	18 (1%)	589 (19%)	78 (3%)	0 (0%)	0 (0%)	0 (0%)
Avg.	1490 (10%)	1831 (78%)	31 (1%)	13 (1%)	4 (0%)	21 (1%)	609 (29%)	49 (3%)	0 (0%)	2 (0%)	5 (0%)

[a] Includes releases from Omak Pond and 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 and Goat Wall 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 Falls 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 17. Percent of the total Okanogan spawning escapement comprised of various hatchery release groups, based on CWT recoveries and expansions for return years 2006-2020.

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	0.00%	8.20%	0.10%	0.10%	0.00%	0.00%		0.90%	0.00%	0.00%	0.00%	1.10%	0.18
2007	0.00%	25.40%	0.40%	0.10%	0.00%	0.00%		1.00%	0.00%	0.00%	0.00%	1.50%	0.33
2008	0.00%	46.20%	0.20%	0.30%	0.00%	0.10%		1.90%	0.00%	0.00%	0.00%	2.50%	0.54
2009	0.00%	36.20%	0.20%	0.20%	0.00%	0.10%		1.30%	0.00%	0.10%	0.10%	2.00%	0.4
2010	0.10%	36.40%	0.70%	0.60%	0.00%	1.80%		1.30%	0.00%	0.10%	0.00%	4.50%	0.41
2011	2.30%	43.30%	0.50%	0.10%	0.00%	0.40%		0.20%	0.00%	0.10%	0.00%	1.30%	0.47
2012	4.60%	29.10%	0.40%	0.30%	0.00%	0.20%		0.60%	0.00%	0.00%	0.00%	1.50%	0.40
2013	3.10%	17.50%	0.10%	0.70%	0.00%	0.00%		0.10%	0.00%	0.00%	0.00%	0.90%	0.27
2014	0.50%	8.40%	0.10%	0.00%	0.00	0.10%		0.20%	0.00%	0.00	0.00	0.40%	0.12

					%					%	%		
2015	0.30%	18.60%	0.50%	0.10%	0.10 %	0.20%		0.20%	0.00%	0.00 %	0.20 %	1.30%	0.20
2016	0.10%	18.50%	0.40%	0.10%	0.00 %	0.30%		0.10%	0.00%	0.00 %	0.20 %	1.10%	0.15
2017	3.80%	9.00%	0.00%	0.00%	0.00 %	0.00%	6.50%	0.10%	0.00%	0.00 %	0.00 %	6.60%	0.14
2018	7.30%	12.90%	0.60%	0.00%	0.00 %	0.10%	8.10%	0.60%	0.00%	0.00 %	0.70 %	10.10%	0.28
2019	7.39%	22.92%	1.25%	0.00%	0.17 %	0.68%	18.72%	0.46%	0.00%	0.13 %	0.00 %	21.40%	0.47
2020	7.38%	13.34%	0.59%	0.05%	0.15 %	0.16%	5.35%	0.71%	0.00%	0.00 %	0.00 %	7.01%	0.24
Avg.	2.46%	23.06%	0.40%	0.18%	0.03 %	0.28%	9.67%	0.64%	0.00%	0.03 %	0.08 %	4.21%	0.31

[a] Includes releases from Omak Pond and 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 and Goat Wall 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 Falls 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 18. 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 1989-2015. 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%
2015	1,097	95.8%	24	2.1%	4	0.4%	19	1.7%
Total	53,965	83.9%	7,008	14.9%	555	0.9%	138	0.4%

Table 19. Number of estimated spawners and percent (%) of spawning escapements comprised of hatchery-origin Okanogan summer/fall Chinook within non-target basins, return years 1994-2020.

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	0.00%	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%	8	0.23%	0	0.00%
2020	0	0.00%	4	0.24%	0	0.00%	0	0.00%
Total	***44***	***0.02%***	***81***	***0.15%***	***301***	***2.00%***	***55***	***0.80%***
5-year Total	***0***	***0.00%***	***12***	***0.16%***	***27***	***0.46%***	***0***	***0.00%***

Homing Fidelity within the Okanogan Basin

The 469 coded-wire tags recovered during spawning grounds surveys in fall of 2020 expanded to 814 and 1,471 spawners originated from Omak Pond and Similkameen Pond acclimation sites, respectively. The majority (83%) of the spawners originating from the Omak Pond acclimation site spawned in the Okanogan River and 16% in the Similkameen River (Table 20). The Omak Pond fish tended to spawn in habitat downstream and upstream of the Omak Pond site, with the majority in reaches O3 (24%) and O5 (32%). Only Omak Pond CWT's were recovered below reach O3 (Figure 24). . Most fish acclimated at Similkameen Pond spawned in the Similkameen River (65%) (Table 20). Of the Similkameen-origin fish that spawned in the Okanogan River, most used reaches O5 and O6 (32% combined; Figure 24). 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.

Table 20. Spawning distribution by river, for fish acclimated at Omak Pond and Similkameen Pond acclimation sites for 2018-2020.

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%

2020	Acclimation site (origin)	
Spawning location	Omak Pond	Similkameen Pond
Okanogan River	83%	35%
Similkameen River	17%	65%

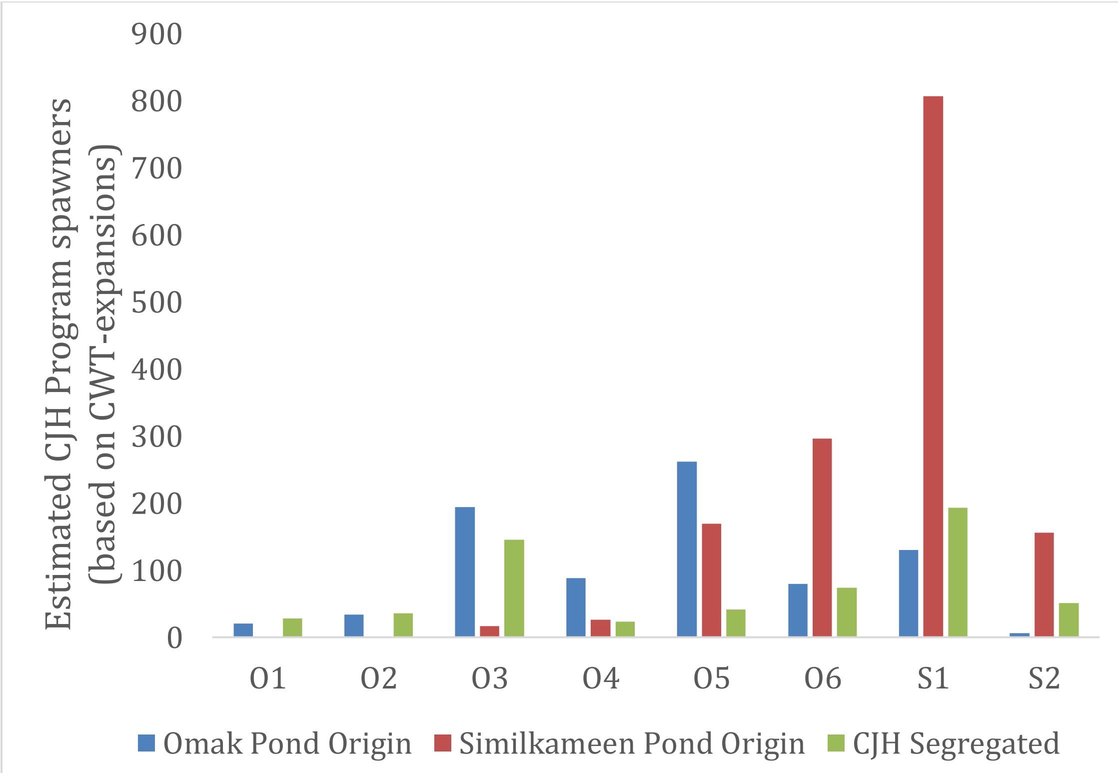


Figure 24. 2020 spatial distribution of CJHP integrated program summer/fall Chinook spawners originally reared at the Similkameen Pond and Omak Pond acclimation sites and CJHP segregated program strays to Okanogan spawning grounds.

Smolt Survival and Travel Time

Apparent survival of yearlings to RRJ in 2020 was 66% (SE 6%) for the segregated program released from CJH and 56% (SE 4%) for integrated fish released from Omak Pond (Table 25). PIT tagged fish were not released from Similkameen pond in 2020. Apparent survival of yearlings to MCN was 22% (SE 5%) for the segregated program released from CJH and 37% (SE 8%) for the integrated fish released from Omak Pond (Table 25). Both programs had lower survival than the recent average and Carlton Pond (Table 26).

Apparent survival of subyearlings to RRJ in 2020 was 49% (SE 8%) for the segregated program released from CJH and 45% (SE 5%) for integrated fish released from Omak Pond (Table 25). Apparent survival of subyearlings to MCN was 23% (SE 8%) for the segregated program released from CJH and 27% (SE 8%) for the integrated fish released from Omak Pond (Table 25). Both programs had very similar survival compared to their recent averages and lower survival than Wells Hatchery subyearlings (Table 26). The reduced survival compared to Wells Hatchery is to be expected considering the shorter migration distance; however Wells is the only other subyearling program in the area.

Table 21. Apparent survival estimates for PIT tagged summer/fall Chinook released in 2020 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	4081	923	Release to RRJ	0.66	0.06	0.34	0.03
		104	Release to MCN	0.22	0.05	0.11	0.03
Yearlings released at Omak Pond	4532	802	Release to RRJ	0.56	0.04	0.31	0.03
		129	Release to MCN	0.37	0.08	0.08	0.02
Yearlings released at Similkameen Pond	0	0	Release to RRJ	NA	NA	NA	NA
		0	Release to MCN	NA	NA	NA	NA
Yearlings released at Carlton Pond	5052	2054	Release to RRJ	0.82	0.03	0.50	0.02
		123	Release to MCN	0.60	0.14	0.04	0.01
Yearlings released at Dryden Pond	20725						
		577	Release to MCN	0.68	0.08	0.04	0.01
Yearlings Released at Wells Hatchery	4933	1409	Release to RRJ	0.82	0.05	0.35	0.02
		117	Release to MCN	0.64	0.15	0.04	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	4785	378	Release to RRJ	0.49	0.08	0.16	0.03
		38	Release to MCN	0.23	0.08	0.04	0.01
Subyearlings released at Omak	5085	449	Release to RRJ	0.45	0.05	0.20	0.02
		60	Release to MCN	0.27	0.08	0.04	0.01
Wells Fish Hatchery Subyearlings	4976	796	Release to RRJ	0.59	0.05	0.27	0.02
		58	Release to MCN	0.39	0.12	0.03	0.01
Wild subyearlings from Col. R.	17261	2386	Release to RRJ	0.43	0.03	0.32	0.02
		165	Release to MCN	0.37	0.15	0.03	0.01

Table 22. PIT tag survival estimates for juvenile summer/fall Chinook from release to Rocky Reach and McNary dams from 2015 to 2020.

Summer Chinook Yearling Release Group																
	Survival to Rocky Reach Dam								Survival to McNary Dam							
Release	CJH segr.		Omak Pond		Similk.		Carlton Pond		CJH segr.		Omak Pond		Similk.		Carlton Pond	
Year	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
2020	0.66	0.06	0.56	0.04	NA	NA	0.82	0.03	0.22	0.05	0.37	0.08	NA	NA	0.60	0.14
Average	**0.74**		**0.63**		**0.63**		**0.76**		**0.55**		**0.47**		**0.53**		**0.59**	

Summer Chinook Sub-Yearling Release Group																
	Survival to Rocky Reach Dam								Survival to McNary Dam							
Release	CJH segr.		Omak Pond		Wells Hatchery		Wild		CJH segr.		Omak Pond		Wells Hatchery		Wild	
Year	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
2020	0.49	0.08	0.45	0.05	0.59	0.05	0.43	0.03	0.23	0.08	0.27	0.08	0.39	0.12	0.37	0.15
Average	**0.50**		**0.47**		**0.56**		**0.36**		**0.29**		**0.28**		**0.41**		**0.21**	

Wild subyearlings had a survival to RRJ of 43% (SE 3%) and 37% (SE 15%) to MCN (Table 21). The survival of wild summer Chinook from release to RRJ and MCN was higher than the recent average but, at least for estimates to McNary the uncertainty was relatively high due to the large standard error (Table 22).

Releases of yearling Summer Chinook smolts began on April 15, 2020. Of the 4,532 PIT tagged yearling summer Chinook released from Omak Pond (rkm 52), only 26 were detected at the Lower Okanogan PIT detection array. Fifty percent passed OKL within 3 days and 90% passed within 28 days. Travel time data for subyearlings revealed that 50% had negative travel times (arriving at OKL before the release date), indicating that fish were released earlier than the reported release date or some other issues were present in the data set (as per reported on DART and PTAGIS). We had no way of figuring out the correct release date or travel time for those or what proportion of the release it affected, therefore travel times will not be reported subyearling summer Chinook in 2020. The mean travel time of yearling summer Chinook released from CJH facilities to RRJ in 2020 was very similar for CJH segregated yearlings (12 days; 10.1 km/day) and Omak Pond yearlings (13 days; 11.6 km/day) (Table 23). Although travel times and speeds could not be calculated for subyearlings due to the apparent early release of some portion of the programs, the 90% arrival dates at RRJ, MCN, and BON were 10-15 days longer than the 5 year average (Table 28). Travel times to RRJ, MCN and BON were 5-9 days shorter CJH and Omak yearling programs in 2020 compared to the five-year means (Table 29). The majority of yearling Summer Chinook from CJH and Omak Pond arrived at RRJ from late April to early May, with 90% passage dates of May 4 and May 6, respectively (Figure 25). 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 23).

Table 23. Travel time (days), migration speed (km/day) and the number of days to 90% passage for summer/fall Chinook release groups in 2020.

			Mean Travel Time (days)			90% Passage (days)			Travel Rate (km/day)		
Release Group	Release timing	Release Strategy	Release to RRJ	Release to MCN	Release to BON	RRJ	MCN	BON	Release to RRJ	RRJ to MCN	MCN to BON
CJH Summer subs	May 27	Volitional	c	c	c	56	61	62	c	a	a
Omak Pond subs	May 27	Forced	c	c	c	51	58	61	c	29.1	71.6
Wells FH subs	Apr 29-Jun 1	?	28	38	47	47	57	59	2.4	34.2	69.1
Wild subs	Jun 4-Jul 11	NA	49	a	a	54	64	51	2.0	a	a
CJH Summer yearlings	Apr 15	Volitional	12	23	25	17	32	30	10.1	28.0	a
Omak Pond yearlings	Apr 15	Volitional	13	24	25	19	29	30	11.6	31.2	61.4
Carlton yearlings	Apr 20	Forced	18	26	33	26	37	42	7.1	29.0	61.4
Dryden yearling	Apr 14	Volitional	NA	30	35	NA	42	46	NA	10.4 b	51.2

[a] sample size too small (<10) to calculate an estimate
[b] Release to McNary, not Rocky Reach to McNary
[c] Some negative travel time values were in the data, suggesting fish were released earlier than reported, or some escaped before the official release date

Table 24. Travel time (days) and the number of days to 90% passage for subyearling summer/fall Chinook release groups from 2015 to 2020.

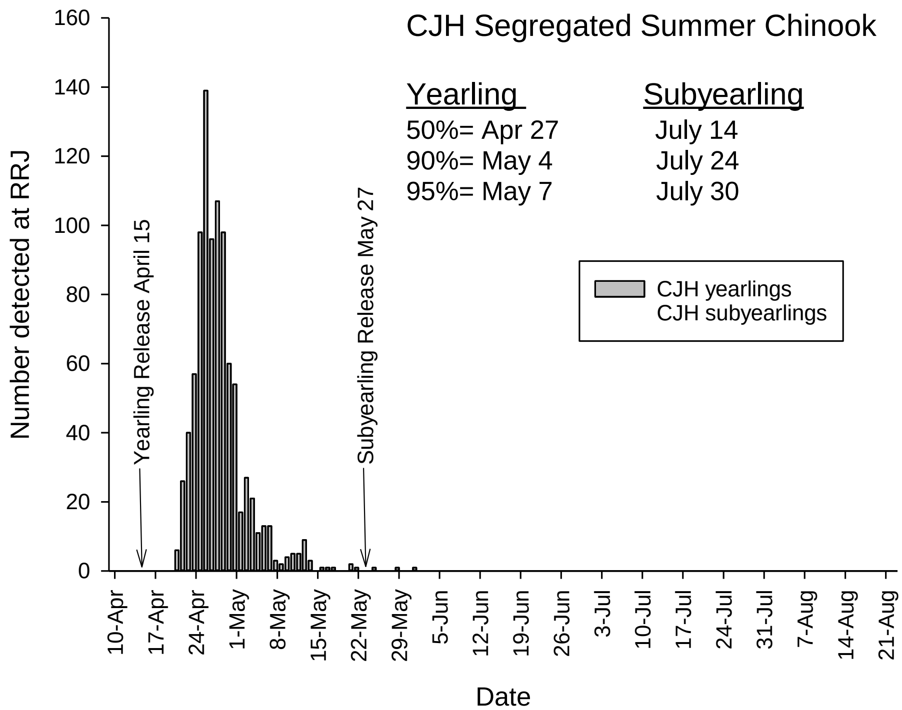
		Rocky Reach Dam		McNary Dam		Bonneville Dam	
Release Group	Year	Mean Travel Time (d)	90% Passage (d)	Mean Travel Time (d)	90% Passage (d)	Mean Travel Time (d)	90% Passage (d)
CJH Segregated Summer Subyearling	2015	35	54	48	63	55	65
	2016	18	31	27	38	31	44
	2017	21	32	32	43	36	46
	2018	15	32	27	46	30	43
	2019	NA	NA	NA	NA	NA	NA
	2020	c	56	c	61	c	62
	Average	**22**	**41**	**33**	**50**	**38**	**52**
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
	2020	c	51	c	58	c	61
	Average	**18**	**36**	**28**	**45**	**32**	**47**
Wild Subyearlings	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
	2020	49	54	a	64	a	51
	Average	**31**	**53**	**41**	**61**	**40**	**59**

a) Sample size too small (<10) for a reliable estimate

c) Some negative travel time values were in the data, suggesting fish were released earlier than reported, or some escaped before the official release date

Table 25. Travel time (days) and the number of days to 90% passage for yearling summer Chinook release groups from 2015 to 2020.

		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
	2020	12	17	23	32	25	30
	Average	**19**	**33**	**30**	**44**	**35**	**48**
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
	2020	13	19	24	29	25	30
	Average	**19**	**34**	**29**	**44**	**34**	**48**



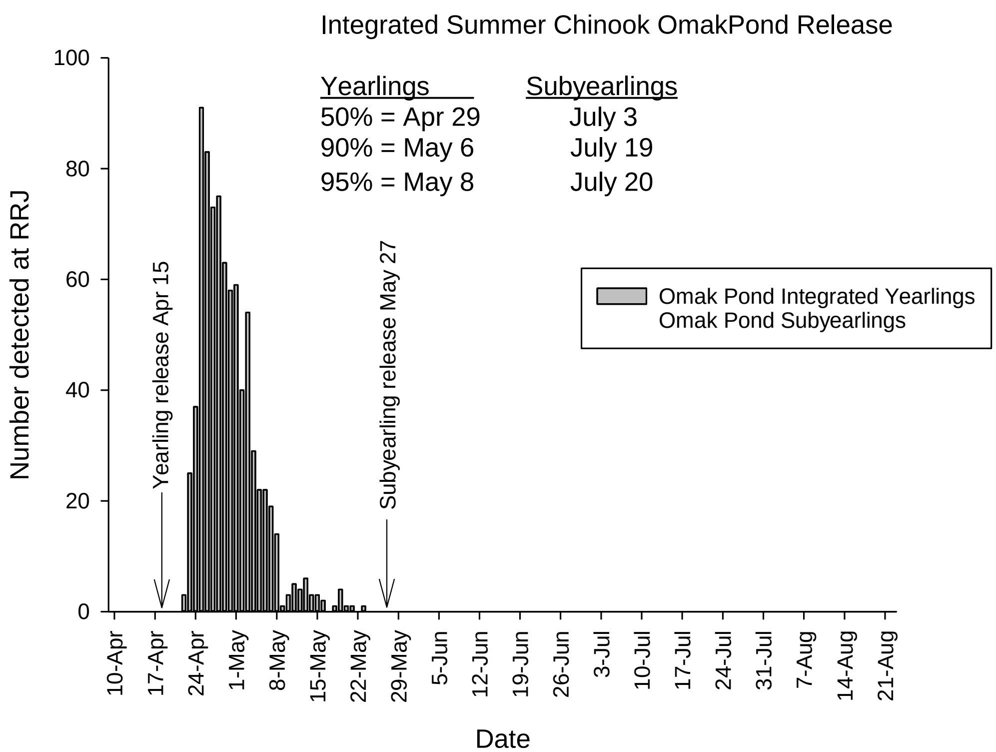


Figure 25. Arrival timing at Rocky Reach Juvenile bypass (RRJ) of PIT tagged Summer Chinook released from the Chief Joseph Hatchery and Omak Pond in 2020.

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 2015. For CJH segregated Summer Chinook from brood year 2015 (outmigration year 2017), 28 adult fish (age 4&5) returned to Bonneville Dam with a PIT tag, resulting in SAR estimates of 0.6% before harvest and 0.7% with harvested fish added back in (Table 26). For brood year 2015, the SAR back to Wells Dam was 0.4% before harvest and 0.7% with harvested fish added back in (Table 26).

For the brood year 2014 integrated yearling program released from Omak Pond, 56 adult fish (age 4-5) returned to Bonneville Dam with a PIT tag, resulting in SAR estimates of 1.2% before harvest and 1.6% with harvested fish added back in (Table 26). For brood year 2015, the SAR back to Wells Dam was 0.9% before harvest and 1.5% with harvested fish added back in (Table 26).

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 2015 integrated sub yearling program at Omak Pond, zero adult fish returned in 2020 resulting in an SAR of 0% (Table 27).

Table 26. 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 2020, therefore the most recent brood year that could be assessed through age 5 was 2015.

CJH Segregated Yearling Summer Chinook		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	5017	17	16	28	24	0	1.0%	1.4%
2014	4951	1	7	35	29	0	1.3%	1.7%
2015	5024	27	3	18	10	NA	0.6%	0.7%
2016	4921	4	2	40	NA	NA		
2017	4945	0	0	NA	NA	NA		
		PIT Tag Detections at Wells Dam						
2013	5017	5	12	16	15	0	0.6%	1.0%
2014	4951	0	4	20	22	0	0.8%	1.4%
2015	5024	5	2	13	7	NA	0.4%	0.7%
2016	4921	2	1	24	NA	NA		
2017	4945	0	0					

Integrated Yearling Summer Chinook from Omak Pond		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	1204	0	0	0	0	0		
2014	4193	28	4	19	9	0	0.7%	0.9%
2015	4830	4	8	22	34	NA	1.2%	1.6%
2016	5326	0	0	15	NA	NA		
2017	4987	2	1	NA	NA	NA		
	PIT Tag Detections at Wells Dam							
2013	1204	0	0	0	0	0		
2014	4193	3	3	12	6	0	0.4%	0.7%
2015	4830	1	5	17	26	NA	0.9%	1.5%
2016	5326	0	0	11	NA	NA		
2017	4987	2	0	NA	NA	NA		

Table 27. 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 2015.

CJH Segregated Subyearling Summer Chinook		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	NA	NA	NA	NA	NA	NA		
2014	4967	0	0	0	0	0	0.0%	0.0%
2015	4983	0	0	0	0	NA	0.0%	0.0%
2016	5029	0	0	7	NA	NA		
2017	5027	1	17	0	NA	NA		
	PIT Tag Detections at Wells Dam							
2013	NA	NA	NA	NA	NA	NA		
2014	4967	0	0	2	0	NA	0.0%	0.1%
2015	4983	0	0	0	0	NA	0.0%	0.0%
2016	5029	0	0	5	NA	NA		
2017	5027	0	0	0				

Integrated Subyearling Summer Chinook from Omak Pond		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Raw SAR	Harvest Corrected SAR
2013	NA	NA	NA	NA	NA	NA		
2014	4941	0	2	3	0	0	0.1%	0.1%
2015	4979	0	0	0	0	NA	0.0%	0.0%
2016	4571	1	1	3	NA	NA		
2017	0	NA	NA	NA	NA	NA		
	PIT Tag Detections at Wells Dam							
2013	NA	NA	NA	NA	NA	NA		
2014	4941	0	0	2	0	0	0.0%	0.1%
2015	4979	0	0	0	0	NA	0.0%	0.0%
2016	4571	1	1	2	NA	NA		
2017	0	NA	NA	NA	NA	NA		

CWT-based estimate of SAR—Based on expanded CWTs, the 2015 brood year had a SAR of 0.77%, which was below the long-term and 5-year averages. (Table 28).

Table 28. Smolt-to-adult return rate (SARs) for Okanogan/Similkameen summer/fall Chinook, brood years 1989-2015.

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	157,390	3,643	2.3%
2013	677,483	5,580	0.82%
2014	749,546	6,047	0.81%
2015	474,928	3,667	0.77%
Total	***12,459,763***	***158,347***	***1.27%***
5-year Total	***536,916***	***7,539***	***1.40%***

[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

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 early July, 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 2017 and 2019.

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 2020 were quite a bit higher than those in previous years, restricting installation of the weir until mid- August, which was a month later than 2019. Temperatures on the Okanogan River were fairly normal, compared to the 13 year median. Temperature was not a factor for trapping operations once it began on August 27th. Tower observations were relatively low for the majority of the season outside of the last week in August. Observations of fish from the bank of the downstream pool increased after the water temperature stayed below 20 °C in mid-September. In September, fish observations 0.8 km. below the weir, at the lower pool, were higher than observations at the weir. When river temperature was lower and gage height was less than 4 feet, Chinook were more likely to mill in deeper pools. In previous years tower observations were much higher in September, so it's reasonable that there were more fish milling in the lower pool than there were milling around the weir in September. Continued monitoring of Chinook passage through the weir with respect to temperatures should continue in order to better refine weir operations and future expectations for weir effectiveness.

The number of Chinook handled at the weir (n = 870) was more than the average (n=468). Configuration of the weir was similar to that in 2019 with the trap installed downstream, on the edge of the thalweg, and below the deep pool. The fish entrance chute was included with 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 2020 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. The number (23) of dead fish at the weir was similar to other years with similar run sizes. There were no fish impinged between pickets (head upstream) in 2020.

There were thirteen sockeye trapped in 2020. 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, but we did observe several sockeye pass through the panels during the day. 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 while the pickets were up or jumped over the sealing aprons after it was installed. The potential weir effectiveness measure of 4.3% was the third highest to date. Although the barrier broke down in late August, this did not affect fish management objectives in 2020. With a higher adult return, CCT was able to collect their full brood stock quota (84) at the weir and remove about 4% of the hatchery-origin returns. 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.

In 2020 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. The program experience a larger run than the previous two years which allowed the program to successfully collect brood stock for the hatchery's integrated program and remove a portion of the hatchery-origin returns to manage pHOS. The weir's importance to successful management of the Okanogan summer/fall Chinook population should continue 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 4,127 redds in 2020, which was above the long-term average (2,276 for 1989-2020) and above the more recent 5-year average of 3,421. Redd counts were below average in only one reach in the Okanogan River (O2) and above average in all other reaches in the Okanogan and Similkameen rivers (Table 15).

The redd count in reach O6 – which most years, supports the largest proportion of natural-origin spawners – was the fourth highest 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 had its fourth highest redd count going back to 2006. These two adjacent reaches, along with reach still provide the primary spawning habitat for summer/fall Chinook in the Okanogan/Similkameen basin, comprising 82% of the total spawning in 2020. 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 2020 redd counts showed an increase in the proportion of redds in reaches O1 and O4. Although the changes are modest, they represent progress towards a goal that will likely take a long time to fully achieve. CJHP Chinook reared at the Omak Pond acclimation site (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 2020 were characterized with average 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 5 to October 11. 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 19-25. 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 23.6% carcass recovery rate, which was well above 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).

Spawning grounds surveys beginning in mid-August and lasting through November 8 revealed very few carcasses attributable to pre-spawn mortality, or PSM. Of the 283 female Chinook carcasses recovered, only 1.30% 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 3.15%. 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 2020 surveys, 4 summer Chinook pre-spawn mortality carcasses were collected, in the Similkameen River. 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. 2020 pHOS (0.24) was below the biological target and the 5-year average. The program met the biological target for PNI (>0.67) in 2020 (0.82) after failing to meet it in 2018 and 2019. The 5-year mean PNI (0.75) remains above objective. There was a reduction in hatchery-origin spawners, including CJH segregated fish, on the spawning grounds in 2020. 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 (75%) from Okanogan and Similkameen acclimated, CJH Integrated Program releases. CJH Segregated fish made up 19% of the hatchery-origin spawners, and 5% of the total spawning escapement. In order to stay under the 5% segregated pHOS goal on the spawning grounds there will need to be more removals of segregated Chief Joseph Hatchery fish before they reach the Okanogan. More aggressive operations of the Chief Joseph Hatchery ladder could help the program obtain this goal. Stray hatchery-origin fish originating from outside the Okanogan made up 1.7% 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 7.0%. Okanogan Basin hatchery-origin fish strayed to other areas at a low rate (0.4% to non-target basins and 1.7% to non-target hatcheries, based on RMIS queries of the 2015 BY) and were a small percentage of the spawner composition in other Upper Columbia tributaries in 2020 (less than 2% in any stray basin). Fish released within the Okanogan Basin have consistently homed to their natal stream, and 2020 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, 90% in 2019, and 83% in 2020) 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. Targets for post release survival have not been established, but it was noteworthy that yearling survival from CJH and Omak Pond were 7-8% less than the recent average and 16-26% less than yearlings from Carlton Pond in 2020. This was a particularly surprising result considering that the travel times for CJH and Omak Pond were faster than normal. 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 2020, with 90% passage at OKL within 28 days and only one detection after May 15. The assessment of sub-yearling travel time was invalid because half of the detections at OKL and some of the detections at RRJ occurred before the reported release date (5/27/2020). It is unclear if this was due to an undocumented early release or some other cause. Regardless, we were still able to evaluate the outmigration timing of subyearlings from the Okanogan and note that the last detection of a subyearling at OKL was June 11, 2020. These assessments suggest 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=26). 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 2015 is the earliest brood year that a PIT-based estimate of SAR could be calculated. The data set for PIT-based estimates of SAR is too short to evaluate trends, but it was discouraging to see that the SAR for the segregated program dropped considerably for BY2015 compared to BY2013 and BY2014. Also discouraging was that there were zero returns of any PIT tagged subyearlings from BY2015. Clearly the poor ocean conditions in recent years have been affecting the program. It's unclear if CJH programs have been affected more or less than nearby programs. 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.

The CWT based SAR for the most recent full brood returns (2015) was less than the 5-year and long-term averages.

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 2021 with the purpose of reviewing data collection efforts and results from 2020 and developing the hatchery implementation and monitoring plan for 2021 (Figure 26). 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 27). 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 2021. 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?[7]
2. What is the current status and recent historical trends for hatchery returns and harvest?
3. Is the hatchery program meeting target in-hatchery performance standards?
4. Are the hatchery post-release targets met for survival, catch contribution and straying?
5. Are targets for total catch contribution and selectivity for HORs met?
6. Are there negative effects of the hatchery on the natural population?
7. Are assumptions about natural production potential valid?

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

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

Figure 26. The Chief Joseph Hatchery's annual planning process and workflow.

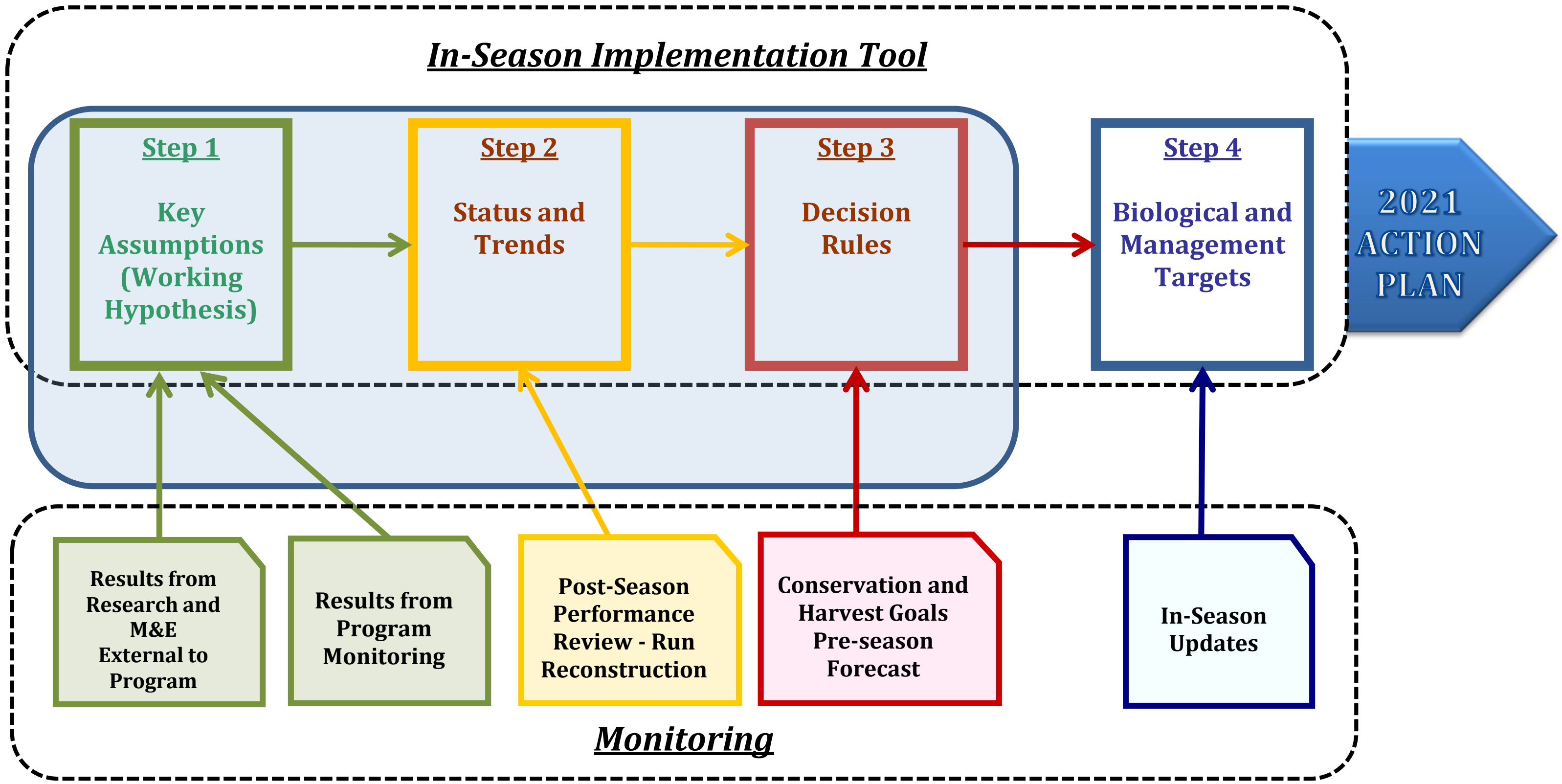

Figure 27. The Chief Joseph Hatchery's analytical workflow.

2021 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 59,600. 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 59,600 upper Columbia would yield 4,871 NORs and 4,674 HORs (Figure 28). The harvest and broodstock collection goals were established from this prediction. With a NOR run size just under 5,000 the broodstock collection recommendation for the integrated program was full production (791 NOB) with 100% pNOB (Figure 28). Likewise, the segregated program should achieve full production with 670 HOB. The model predicted that 1,465 HORs would be captured in the terminal (above Wells Dam) fisheries and that 66 HORs could be removed at the weir. These efforts could result in 3,511 NOS and 1,043 HOS for a pHOS of 19% and a PNI of 0.84. Under this modeling scenario the biological targets will likely be met in 2021. 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, 2021. 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

2020 <-- Most recent return year

Use **5** -year running averages to calculate prior-cumulatives

Recent History:

Average NOB	367
Average HOB	129
Average pNOB	74%
Average NOS	5,325
Average HOS	1,579
Average pHOS	23%

Expected Returns to Wells Dam (most recent update):	2021 Forecast	2020 Final
NOR Return (excludes jacks)	4,871	10,451
HORs from Integrated Program (excludes jacks)	2,844	7,623
HORs from Segregated Program (excludes jacks)	1,831	5,053

Runsize Prediction for:	2021
Preseason forecast (Columbia)	59,600
Applies until:	07/15/21
Wells Dam Count thru 07/15	25,965
Okanogan NOR Forecast (excludes jacks)	4,871
Okanogan HOR Forecast (excludes jacks)	4,674

Prespawning Mortality	10.0%
NOR Terminal harvest induced mortality rate	3.4%

	Management Targets	2021 Targets
Harvest*	Okan. HORs retained in Terminal Fisheries	1,021
	CJH HORs retained in Terminal Fisheries	444
	Incidental Loss of NORs	180
Hatchery and Weir*	Return of Okan. HORs to Hatchery	205
	Return of CJH HORs to Hatchery	1,110
	Okan. HORs retained at Weir	52
	CJH HORs retained at Weir	14
Integrated Hatchery Program	Natural Origin Brood (NOB)-Okan (collected)	791
	Hatch. Origin Brood (HOB)-Okan (collected)	-
	Projected Annual pNOB-Okan	100%
	Cum pNOB	78%
	Smolt Release-Okanogan	800,000 Yearl. 300,000 Subs
Segregated Hatchery Program	Hatch. Origin Brood (HOB) - Int	670
	Hatch. Origin Brood (HOB) - Seg (purse seine and ladder)	-
	Smolt Release-CJH	500,000 Yearl. 400,000 Subs
Natural Spawning Escapement	Nat. Origin Spawners (NOS)	3,511
	Hat. Origin Spawners (HOS) - Int	806
	Hat. Origin Spawners (HOS) - Seg	237
	Hat. Origin Spawners (HOS) - out-of-basin	NA
	Total Number of Spawners (excludes jacks)	4,554
	Effective pHOS	19%
	PNI	0.84

Projected Status of Biological Indicators* (5-year averages):

Average NOS	4,356
Average pHOS	25%
Average PNI	0.76

Figure 28. The in-season updates management worksheet used to set biological targets for the upcoming year (2020) in the In-Season Implementation Tool.

2021 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 29).

KEY ASSUMPTIONS

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	38%	> 30%	38%	38%	38%	
Segr. pHOS	2%	< 5%	2%	2%	2%	
Ocean Harvest Rate	24%		24%	24%	24%	
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	1%		1%	1%	1%	
Upper Columbia Harvest Rate (MCN to Wells)	22%		22%	22%	22%	
Terminal Harvest Rate (Post Wells)	3%		3%	3%	3%	
Natural Origin Spawners	5,747	< 5,250	5,747	5,747	5,747	
Hatchery Production						
Local Brood	398		791	791	791	275
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)	1.66%		1.66%	1.66%	1.66%	1.66%
SAR (sub-yearling)	0.30%		0.30%	0.30%	0.30%	0.30%
Return Rate to Okanogan	89%		89%	89%	89%	20%
pNOB	100%		100%	100%	100%	
NOB	709		709	709	709	
Relative Reproductive Success	80%		80%	80%	80%	80%
Ocean Harvest Rate	24%		24%	24%	24%	24%
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	3%		3%	3%	3%	3%
Upper Columbia Harvest Rate (MCN to Wells)	27%		27%	27%	27%	27%
Pre-terminal Harvest Rate (Ocean to Wells)	47%		47%	47%	47%	47%
Terminal Harvest Rate (Post Wells)	36%		36%	36%	36%	24%
Hatchery Surplus	362		362	362	362	2,721
Average Terminal HOR Run	2,211		7,075	7,075	7,075	4,422
Expected HOS	1,217		3,895	3,895	3,895	622
Fisheries and Weirs						
Weir Factor	3%		3%	3%	3%	
NOR Harvest Release Mortality	11%		11%	11%	11%	

Figure 29. The key assumptions worksheet used in the 2021 In-Season Implementation Tool for the CJHP planning at the Annual Program Review

2021 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 30).

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	10,047	2,749	-	0.79
2007	12	**5,532**	0.37	7,088	7,789	4,480	3,154	-	0.59
2008	13	**8,838**	0.35	11,244	13,779	4,337	6,554	-	0.40
2009	14	**13,753**	0.46	15,184	14,187	5,751	5,782	-	0.50
2010	15	**12,264**	0.41	5,671	7,167	4,791	5,409	-	0.47
2011	16	**3,912**	0.12	12,139	19,164	5,256	6,184	-	0.46
2012	17	**10,082**	0.24	14,424	27,716	5,974	7,793	-	0.43
2013	18	**25,571**	0.38	34,965	30,179	8,559	5,842	-	0.59
2014	19	**26,010**	0.46	36,060	21,015	12,803	4,251	-	0.75
2015	20	**25,153**	0.32	46,030	31,625	14,294	8,246	-	0.63
2016	21	**21,479**	0.43	28,467	21,542	12,065	4,766	3	0.72
2017	22	**15,124**	0.44	15,729	18,479	7,778	2,406	1,344	0.67
2018	23	**11,886**	0.48	6,533	18,347	3,730	2,398	2,212	0.45
2019	24	**12,950**	0.47	8,499	18,800	3,215	3,586	2,323	0.35
2020	25	**25,965**	0.46	22,243	36,309	9,271	3,500	1,763	0.64

Return year	Terminal Harvest Above Wells: Tribal Harvest: **Total Tribal Harvest**	Tribal Harvest: Total NORs	Tribal Harvest: Total HORs	Tribal Harvest: Okan. NORs	Tribal Harvest: Okan. HORs	Tribal Harvest: CJH HORs	Recreational Harvest: **Total Rec. Harvest**	Recreational Harvest: Total NORs	Recreational Harvest: Total HORs	Recreational Harvest: Okan. NORs	Recreational Harvest: Okan HORs	Recreational Harvest: 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	-	17%	29%	-
2007	**1,078**	467	611	84	550	-	**1,803**	887	916	798	726	-	20%	40%	-
2008	**2,299**	588	1711	106	1,540	-	**1,665**	698	967	628	561	-	17%	32%	-
2009	**2,598**	363	2235	65	2,012	-	**1,062**	648	414	583	244	-	11%	39%	-
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%	49%	-
2013	**3,176**	832	2344	150	1,781	-	**2,107**	179	1,928	161	713	-	4%	43%	-
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%	35%	
2017	**1,397**	746	651	134	143	91	**1,568**	591	977	532	479	59	9%	26%	11%
2018	**1,238**	484	754	87	128	204	**993**	28	965	25	280	68	3%	17%	12%
2019	**1,363**	129	1234	23	457	234	**1,924**	91	1,833	82	733	110	3%	33%	15%
2020	**1,731**	95	1636	17	360	327	**1,150**	101	1,049	91	-	-	1%	10%	19%

	Broodstock																	
	Okanog./Similk Integrated Program												CJH Segregated Program					
Return year	Okan. NORs collected	Okan. HORs collected	CJH HORs collected	Total NORs Spawned	% Okan. Orig.	Okan. NORs spawned	Okan. HORs spawned	CJH HORs spawned	Out of Basin HORs spawned	Total HORs Spawned	Total Brood	Okanogan origin pNOB	Okan. HORs collected	CJH HORs collected	Okan. HORs spawned	CJH HORs spawned	Out of Basin HORs Spawned	Total Brood
1998	239	348		153	50%	77	211			211	364	21%	-	-				-
1999	248	307		224	50%	112	289			289	513	22%	-	-				-
2000	184	373		164	50%	82	339			339	503	16%	-	-				-
2001	135	423		91	50%	46	266			266	357	13%	-	-				-
2002	270	285		247	50%	124	241			241	488	25%	-	-				-
2003	449	112		381	50%	191	101			101	482	40%	-	-				-
2004	541	17		506	50%	253	16			16	522	48%	-	-				-
2005	551	12		391	50%	196	9			9	400	49%	-	-				-
2006	579	12		500	50%	250	10			10	510	49%	-	-				-
2007	504	19		456	50%	228	17			17	473	48%	-	-				-
2008	418	41		404	50%	202	41			41	445	45%	-	-				-
2009	553	5		507	50%	254	-			-	507	50%	-	-				-
2010	503	8		484	50%	242	8			8	492	49%	-	-				-
2011	498	30		467	71%	332	26			26	493	67%	-	-				-
2012	112	-		107	90%	96	-			-	107	90%	-	-				-
2013	477	-		366	90%	329	1			1	367	90%	337	-	327	-	-	327
2014	651	-		499	90%	449	5			5	504	89%	678	-	444	-	-	444
2015	659	37		421	90%	379	9			9	430	88%	621	-	334	-	-	334
2016	660	-		584	90%	526	-			-	584	90%	688	-	482	-	-	482
2017	657	-		350	90%	315	17			17	367	86%	551	-	349	41	65	390
2018	305	243	46	193	90%	174	152	29	31	212	405	43%	422	147	185	127	30	312
2019	419	168	82	381	90%	343	114	56	35	205	586	59%	391	174	297	132	78	429
2020	676	-	-	530	90%	477	5	-	-	5	535	89%	541	71	391	51	58	442

	Okanogan Natural Spawning Escapement (excludes jacks)														Surplus Fish (HORs only; NORs released to spawn)				
	NOS	HOS - Int	HOS - Seg	HOS-out of basin	Total HOS	Census pHOS	Effective pHOS	Seg pHOS	Effective Seg 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
1998	542	437	-	-	437	45%	39%			35%	47%	891	1,577					-
1999	1,182	2,142	-	-	2,142	64%	59%			27%	47%	2,895	2,928					-
2000	926	1,726	-	-	1,726	65%	60%			21%	47%	2,307	2,275					-
2001	4,048	6,047	-	-	6,047	60%	54%			19%	47%	8,885	8,686					-
2002	4,337	9,473	-	-	9,473	69%	64%			28%	47%	11,916	9,763					-
2003	1,892	1,463	-	-	1,463	44%	38%			51%	47%	3,063	5,050					-
2004	5,182	1,392	-	-	1,392	21%	18%			73%	47%	6,295	15,008					-
2005	6,364	2,416	-	-	2,416	28%	23%			68%	47%	8,297	16,154					-
2006	6,536	1,741	-	-	1,741	21%	18%			74%	47%	7,929	18,839					-
2007	2,539	1,509	-	-	1,509	37%	32%			60%	47%	3,746	8,401					-
2008	2,696	3,902	-	-	3,902	59%	54%			46%	47%	5,817	8,133					-
2009	3,903	3,130	-	-	3,130	45%	39%			56%	47%	6,407	10,784					-
2010	3,076	2,623	-	-	2,623	46%	41%			55%	47%	5,175	8,983					-
2011	3,233	4,304	-	-	4,304	57%	52%			57%	47%	6,675	9,856					-
2012	3,933	3,408	-	-	3,408	46%	41%			69%	47%	6,659	11,202					-
2013	5,233	2,336	-	-	2,336	31%	26%			77%	47%	7,102	16,049	54	-	42	-	96
2014	9,470	1,405	-	-	1,405	13%	11%			89%	47%	10,594	24,008	122	-	225	-	347
2015	10,021	3,110	-	-	3,110	24%	20%			82%	47%	12,509	26,802	888	-	29	-	917
2016	8,352	1,734	-	-	1,734	17%	14%			86%	47%	9,739	22,623	232	-	31	-	263
2017	5,239	672	391	16	1,079	17%	14%	6%	5%	86%	47%	6,089	14,585	297	754	86	6	1,143
2018	2,972	1,044	402	52	1,498	34%	29%	9%	8%	60%	47%	4,129	6,994	159	1,301	6	-	1,466
2019	2,422	1,535	949	138	2,621	52%	46%	19%	17%	56%	47%	4,408	6,028	128	666	4	2	798
2020	7,639	2,193	570	176	2,939	28%	24%	5%	5%	79%	47%	9,849	17,385	12	729	151	3	892

Figure 30. The status and trends worksheet in the In-Season Implementation Tool for CJHP planning at the Annual Program Review.

2021 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 31).

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	791	398	791	791	791
	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	4,356	4,459	3,959 - 4,587
pHOS	< 30%	23%	25%	45%	29% - 45%
PNI	> 0.67	0.76	0.76	0.69	0.69 - 0.78
Terminal Catch of HORs (Int and Seg)	> 3000	2,535	1,464	3,602	801 - 3,602

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

Figure 31. 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 2020, 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 lower than anticipated fecundity.

Summer/Fall Chinook Salmon

BY 2019 Summer/Fall Chinook Salmon Rearing and Release

The yearling summer/fall Chinook rearing began February 19, 2020. Marking was completed, for both the integrated and the segregated programs, on July 28, 2020. 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 the segregated program was elevated between Dec. 2020 and Feb. 2021 due to irritated gills and some delayed dropout from earlier issues. 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 21st. Approximately 5,000 PIT tags were added to each group in October 2020. After subtracting shed tags and mortality, a total of 4,972 PIT tags were released from the segregated group (3,204 were detected at release).

Table A 1. Chief Joseph Hatchery brood year 2019 segregated summer/fall yearling rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	3/31/2020	601,237	2,584	142	888	99.57%
	4/30/2020	596,069	5,168	886	494	98.72%
	5/31/2020	595,117	952	1,723	139	98.56%
	6/30/2020	594,955	162	1,285	113	98.53%
	7/31/2020	594,690	265	2,014	87	98.49%
	8/31/2020	594,495	195	2,346	57	98.46%
	9/30/2020	620,624	450	3,191	41	98.45%
	10/31/2020	620,115	509	3,016	35	98.37%
	11/30/2020	619,486	629	3,476	25	98.27%
	12/31/2020	595,272	24,214	9,460	21	94.43%
	1/31/2021	584,080	11,084	8,032	21	92.67%
	2/28/2021	570,910	13,170	8,844	14	90.58%
	3/31/2021	568,911	1,999	8,448	14	90.26%
	4/21/2021	568,625	286	1,546	14	90.22%
	Tot SEG	**568,625**	**61,667**	**54,409**	**14**	**90.22%**

The integrated summer/fall Chinook were shipped to the Omak Acclimation Pond and the Similkameen Acclimation Pond between October 10th and October 29th. Reporting for the Similkameen Pond will reside with WDFW through release.

Omak Acclimation Pond

On October 29, 2020 Chief Joseph Hatchery staff transferred 308,729 Integrated BY 19 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 37 fpp, and were programmed to be reared over winter, with a target size at release of 10 fpp. These fish were forced released April 22, 2021. After subtracting shed tags and mortality, a total of 4,715 PIT tags were released from this integrated group (3,638 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 19 integrated yearling summer/fall Chinook rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
NOR	10/31/2020	308,550	179	-	32	99.94%
	11/30/2020	307,281	1,269	792	35	99.53%
	12/31/2020	306,796	485	-	35	99.37%
	1/31/2021	305,649	1,147	-	35	99.00%
	2/28/2021	303,173	2,476	110	35	98.20%
	3/31/2021	299,841	3,332	2,288	26	97.12%
	4/22/2021	298,988	853	2,838	23	96.84%
	Cumulative:	**298,988**	**9,741**	**6,028**	**23**	**96.84%**

Riverside Acclimation Pond

Riverside Acclimation Pond was not used to rear BY 2018 summer/fall Chinook but was utilized to rear BY 19 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 2019 were collected via the CCT purse seine as part of the transition to the collaborative CJH program. On October 12, 2020, Chief Joseph Hatchery staff transferred 417,184 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 37 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, 2021. Cumulative survival, at the date of transfer, was 96.55%. Survival from transfer to release was 96.84%.

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 2019 yearlings, was 84.5% (83.1% for the segregated program and 85.8% for the integrated program.

2020 Broodstock collection

Collection of summer/fall Chinook for BY 2020 occurred between July 2nd and August 17th via the CCT purse seine operation at the mouth of the Okanogan River. Both hatchery-origin and natural-origin brood were collected to supply the integrated and segregated production programs at CJH. As the seine was being pursed, 9-meter transport barges approached the seine vessel and tied off on the opposite side. The broodstock transport barges have two transport tanks, a 300 gallon for HORs and a 600 gallon for NORs. Brood fish were removed from the seine and placed headfirst in a rubber tube, or boot, containing some water and handed to the staff on the barges for placement in the holding tanks. A maximum of 14 HOR and 28 NOR brood could be loaded per barge. Once full, or at the commencement of the purse seine haul, the barges returned to the offload area at Mosquito Park approximately 2 km away. The brood was then removed from the tanks by hand, placed into a boot, then delivered to one of two 2,500 gallon tanker trucks and transported 16 km to the hatchery.

Water temperatures were of major concern during these operations and monitored to minimize trauma to the adult brood. Okanogan River temperatures during July ranged from 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 three 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 2020.

Chief Joseph Hatchery BY 20 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 6 - July 12	22	22	0.04	22	22
July 13 - July 19	22	22	0.08	44	44
July 20 - July 26	108	104	0.27	152	148
July 27 - Aug 2	108	104	0.46	260	252
Aug 3 - Aug 9	132	126	0.69	392	378
Aug 10 - Aug 16	132	126	0.92	524	504
Aug 17 - Aug 23	36	36	0.98	560	540
Aug 24 - Aug 30	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 611 HOB were collected including 270 females, 277 adult males and 64 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 676 NOB were collected including 324 females, 330 adult males, and 22 jacks (Table A 4). Some of the fish initialed classified as jacks were actually adult males, thus the difference from Table A 5.

Through the month of November 2020, there were 75 adult male and 32 female mortalities in the HOR brood, representing 72.2% and 88.4% cumulative pre-spawn survival to date, respectively. For the same time frame, 93 adult NOR summer/fall Chinook males died, and 43 females died, representing 71.3% and 87.0% cumulative pre-spawn survival, respectively. (Table A 4) Brood fish, particularly males, 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 81.2% (including jack) for HOB and 79.3% (including jacks) for NOB (Table A 4); neither program achieving program survival goal of 90%.

Table A 4. Chief Joseph Hatchery summer/fall Chinook Hatchery (HOB) and Natural (NOB) origin broodstock holding survival summary for brood year 2020. (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	270	64	175	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
HOR	August	270	64	175	268	64	277	2	0	0	99.3%	100.0%	100.0%	99.3%	100.0%	100.0%
HOR	Sept	268	64	277	268	64	277	0	0	0	100.0%	100.0%	100.0%	99.3%	100.0%	100.0%
HOR	Oct	268	64	277	12	7	9	68	8	32	74.6%	87.5%	88.4%	74.1%	87.5%	88.4%
HOR	Nov	12	7	9	0	0	0	5	0	0	58.3%	100.0%	100.0%	72.2%	87.5%	88.4%
HOR	**Total**	**270**	**64**	**277**	**12**	**7**	**9**	**75**	**8**	**32**				**72.2%**	**87.5%**	**88.4%**
NOR	July	0	0	0	249	22	220	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
NOR	August	249	22	220	271	22	290	1	0	3	99.6%	100.0%	99.0%	99.6%	100.0%	99.0%
NOR	Sept	271	22	290	322	22	327	1	0	0	99.7%	100.0%	100.0%	99.4%	100.0%	99.1%
NOR	Oct	322	22	327	63	14	62	75	2	30	76.7%	90.9%	90.8%	76.2%	90.9%	90.0%
NOR	Nov	63	14	62	0	0	0	16	2	10	74.6%	85.7%	83.9%	71.3%	81.8%	87.0%
NOR	**Total**	**324**	**22**	**330**	**0**	**0**	**0**	**93**	**4**	**43**				**71.3%**	**81.8%**	**87.0%**

Hatchery staff began collection of NOR brood from the weir on August 31, 2020 and concluded on September 22, 2020 with 43 wild males and 41 wild females 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 6, 2020 with the segregated program, and continued through November 4, 2020 for segregated program and November 10, 2020 for the integrated program. 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 2020 brood, there were no eggs culled for either program in 2020.

Total NOB spawned included 234 males, 10 jacks, and 281 females. (Table A 5) Total HOR spawn included 221 males, 25 jacks, and 245 females. Total eyed egg take for the season was 1,639,336. Egg survival from green egg to eyed egg for NOB averaged 80.4% (Table A 5). Egg survival for HOB averaged 81.4%. Survival was lower than the key assumption of (90%) for this life stage.

Table A 5. Chief Joseph Hatchery brood year 2020 summer/fall Chinook spawning and incubation results.

	Spawn Date	Total Adults Spawned			Eyed Eggs On Hand	Mortality (Pick off)	Culled eggs	Adjusted Total Egg Take	Cumulative Survival (%)
		M	J	F					
HOR	10/6/2020	21	0	21	74,615	2,321	-	76,936	97.0%
	10/13/2020	49	2	51	147,800	33,212	-	181,012	81.7%
	10/20/2020	83	12	94	305,617	58,052	-	363,669	84.0%
	10/27/2020	58	10	70	188,613	63,331	-	251,944	74.9%
	11/4/2020	10	1	9	16,588	10,456	-	27,044	61.3%
	Total:	**221**	**25**	**245**	**733,233**	**167,372**	**-**	**900,605**	**81.4%**
	Spawn Date	Total Adults Spawned			Eyed Eggs On Hand	Mortality (Pick off)	Culled eggs	Adjusted Total Egg Take	Cumulative Survival (%)
		M	J	F					
NOR	10/6/2020	10	0	10	39,419	5,063	-	44,482	88.6%
	10/14/2020	39	2	41	137,724	29,373	-	167,097	82.4%
	10/21/2020	79	4	83	267,300	62,459	-	329,759	81.1%
	10/28/2020	53	0	104	327,275	93,081	-	420,356	77.9%
	11/4/2020	41	1	38	118,530	27,129	-	145,659	81.4%
	11/10/2020	12	3	5	15,855	4,163	-	20,018	79.2%
	Total:	**234**	**10**	**281**	**906,103**	**221,268**	**-**	**1,107,353**	**80.4%**

Broodstock origin

Broodstock were interrogated for coded-wire tags by program throughout October and the first week of November. Beginning October 6th, segregated fish were spawned on Tuesday of each week, while integrated fish were spawned on Wednesdays. A total of eight spawning events occurred in 2020. 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=326) 67% of adults coming from either the Similkameen or Omak Pond (Table A 6). Other Upper Columbia River Hatcheries contributed (n=92) 19%, most of which were from DCPUD releases near Wells, (6.1%) , Chelan Falls, (5.7%) and Wells Hatchery (5%). A portion of snouts (n=52) 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 10.7% of the 2020 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=52) can be assigned to the segregated CJH program. The overall composition of the segregated program (tagged and non-tagged) to the segregated brood was 14%.

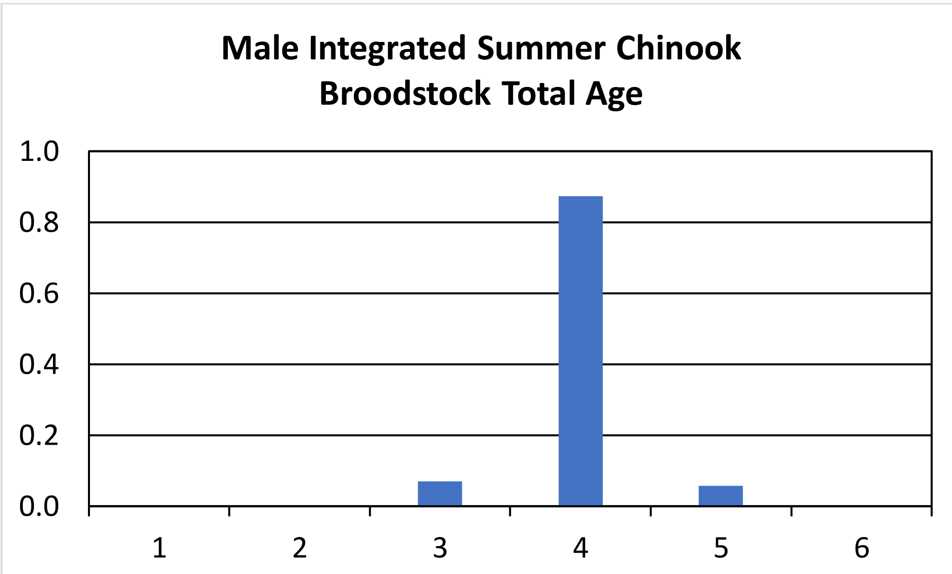
Table A 6. Composition of hatchery-origin brood, by program, collected for the CJH segregated program in 2020.

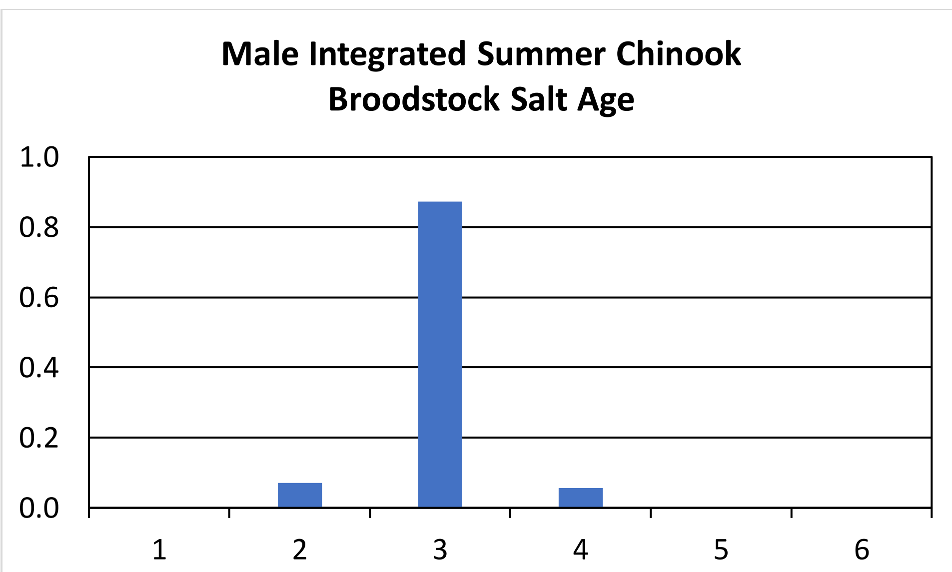
Category	Hatchery Program	Brood	% of Brood	
Okanogan Integrated	Similkameen	196	40.3 %	67%
	Omak Pond	130	26.7 %	
CJH Segregated	Chief Joseph	16	3.3%	14%
	Chief Joseph (non-tagged)	52	10.7 %	
Other UCR summer/fall Chinook hatchery	Chelan Falls	28	5.7%	19%
	DCPUD	30	6.1%	
	Entiat	5	1%	
	WDFW	4	<1%	
	Wells	25	5%	
Total		***486***	***100.0%***	

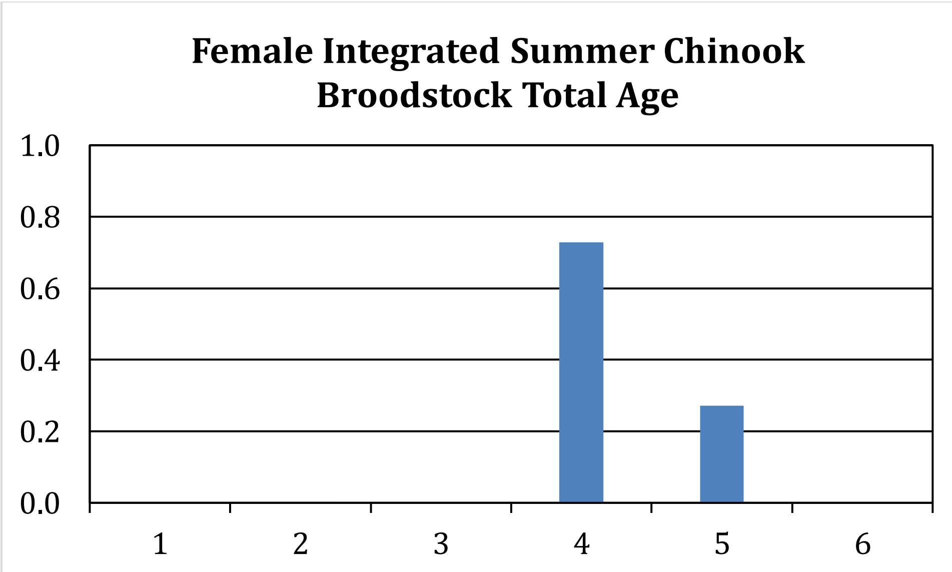
*Brood values are adjusted to account for segregated no tag fish and are rounded to the nearest whole number.

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 2020, the integrated and segregated programs were comprised of mostly four and five-year old male and female fish (Figure A 1).







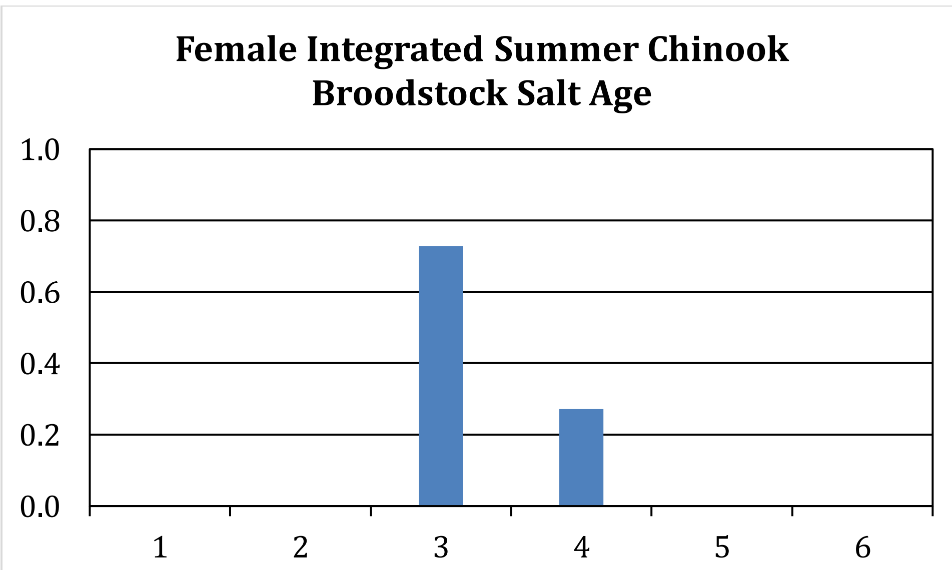
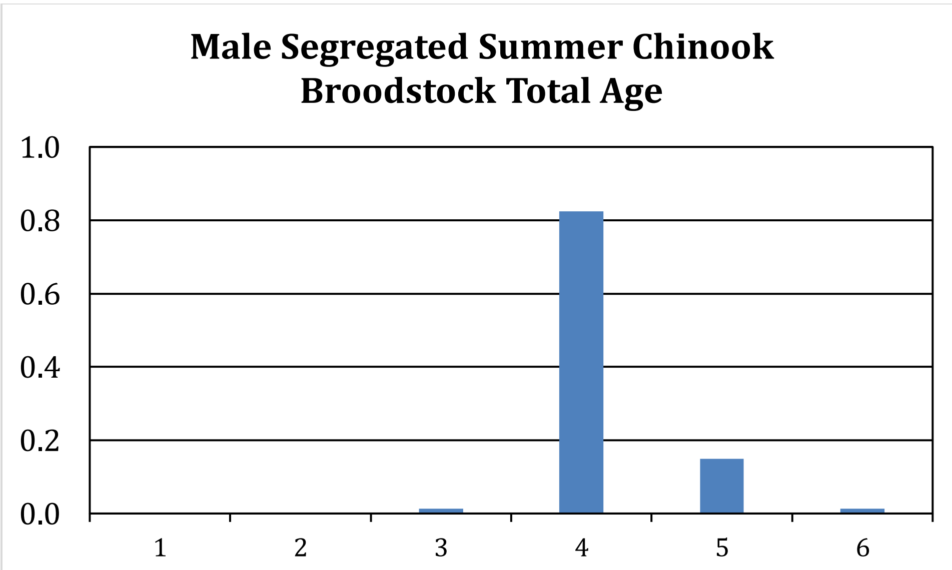
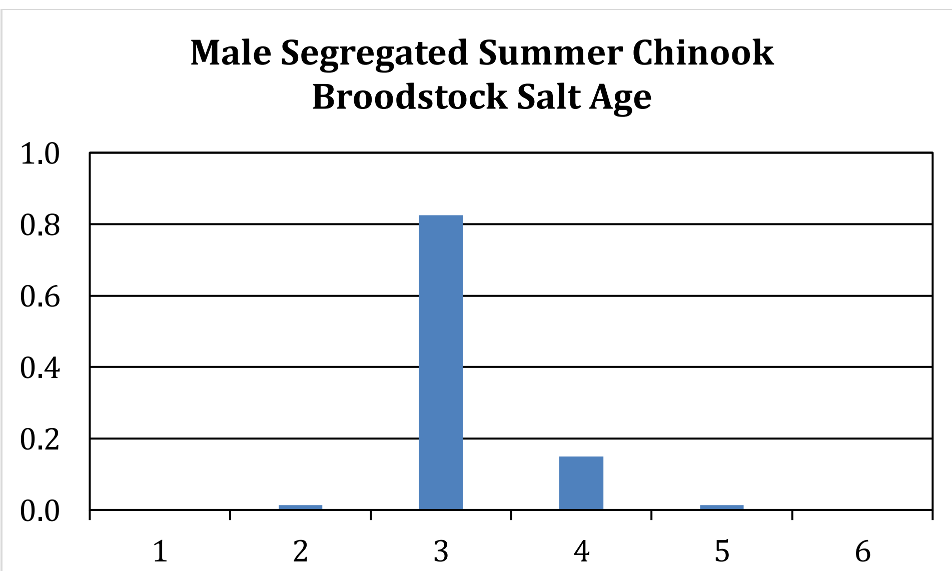


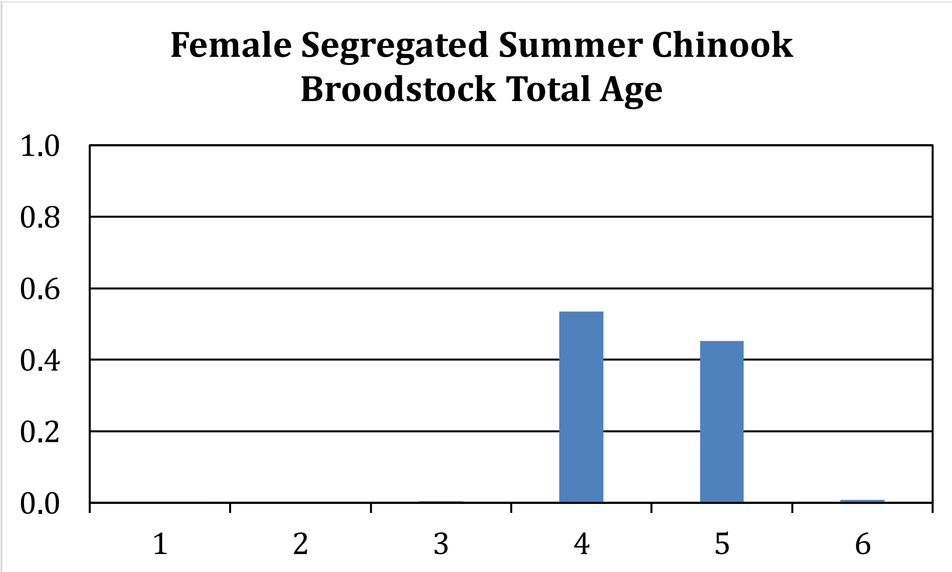
Figure A 1. The total and salt ages of the 2020 broodstock, males and females, collected for the Okanogan summer/fall Chinook integrated program.

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).







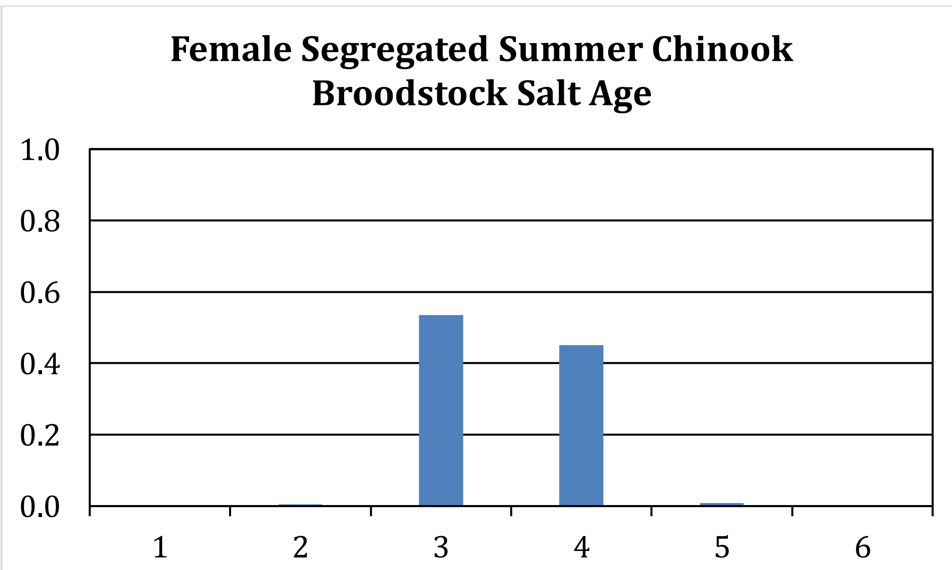


Figure A 2. The total and salt ages of the 2020 broodstock, males and females, collected for the Chief Joseph Hatchery segregated program.

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 were initially manipulated to the level necessary to synchronize the hatching and ponding of the spawn takes throughout October and November 2020 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 2020 sub-yearlings were brought out of incubation and transferred into early rearing troughs in early February 2021 (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 March 2021 while the first group of segregated yearlings was brought out in early April 2021 (Table A 8). During this time, the group was introduced to feed in the early rearing troughs and reared for a period of two weeks. After the initial rearing period inside, they were transferred outside to the standard raceways via the fry transfer line. No inventories were taken during transfers, to prevent excess handling stress.

Table A 6. Chief Joseph Hatchery brood year 2020 summer/fall Chinook sub-yearling rearing summary.

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	3/31/2021	180,061	3,396	188	448	98.1%
	4/30/2021	178,715	1,346	700	137	97.4%
	5/31/2021	178,366	349	594	97	97.2%
	Subtotal:	178,366	5,091	1,482	97	97.2%
NOR	2/28/2021	90,648	5,437	25	685	94.34%
	3/31/2021	88,731	1,917	148	219	92.35%
	4/30/2021	0**	90	203	140	92.25%
	Subtotal:	0**	7,444	376	140	92.25%
	Cumulative:	**-**	**12,535**	**1,858**	**NA**	**95.51%**

***88,641 fish were transferred to Omak on April 26, 2021*

	Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
NOR	4/30/2021	88,583	58	66	140	99.93%
	5/31/2021	88,474	109	726	47	99.94%
	Cumulative:	88,474	**167**	**792**	47	**99.94%**

**88,474 were released from the Omak Pond on May 27, 2021*

Table A 7. Chief Joseph Hatchery brood year 2020 summer/fall Chinook yearling rearing summary.

	Month	Total on hand*	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
HOR	4/30/2021	248,285	595	6	792	99.76%
	5/31/2021	480,970	5,594	262	462	98.73%
	Subtotal:	480,970	6,189	268	462	98.73%
NOR	3/31/2021	353,042	3,577	-	1,200	99.00%
	4/30/2021	677,323	5,719	534	410	98.65%
	5/31/2021	675,480	1,843	1,738	156	98.38%
	Subtotal:	675,480	11,139	2,272	156	98.38%
	Cumulative:	**675,480**	**17,328**	**2,540**	**NA**	**98.52%**

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 18, 2020, for spring chinook broodstock collection, with the first summer/fall chinook adult management activities occurring on August 11th. 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 August 11th thru August 18th, 1,053 hatchery-origin summer/fall Chinook were removed at the CJH ladder and were utilized for tribal subsistence purposes (Table A 8). A total of 62 natural-origin summer/fall Chinook (59 adults, 3 jacks), no NOR steelhead or HOR steelhead were trapped during summer/fall Chinook ladder operations (Tables A 9 and A 10).

Table A 8. Chief Joseph Hatchery adult summer/fall Chinook ladder operations from June to August 2020.

Month	# of Ladder Trap Checks	HOR Adults Surplussed	HOR Jacks Surplussed	NOR Adults RTS	NOR Jacks RTS	HOR Adults RTS	HOR Jacks RTS
June	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0
Aug	2	1,053	88	59	3	0	0
Total	**2**	**1,053**	**88**	**59**	**3**	**0**	**0**

RTS= Return to stream

Table A 9. Chief Joseph Hatchery adult spring Chinook, Sockeye, and steelhead ladder operations from May to August 2020.

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	4	0	0	5	0	0	2	32
June	7	0	0	52	4	0	3	3
July	1	0	0	0	0	0	0	0
Aug	2	0	0	13	2	0	0	0
Total	**10**	**0**	**0**	**65**	**6**	**0**	**3**	**3**

RTS= Return to stream

Table A 10. Chief Joseph Hatchery annual summer/fall Chinook, Sockeye, and steelhead collected during summer/fall Chinook 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
June-Aug. 2020	1,053	88	59	3	0	0	3	3	0
Total	**24,731**	**5,877**	**3,875**	**862**	**4,382**	**262**	**1,438**	**656**	**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 mid-September 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 2020 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.

Seven summer/fall Chinook hatchery programs were encountered at the CJH ladder in 2020, with the majority coming from the CJH segregated program (69%), Wells Hatchery (16%) and Douglas County PUD (7%) (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 program above Priest Rapids that releases ad-clipped, non-CWT fish.

Table A 11. Summary of summer/fall Chinook coded-wire tags encountered and expansions for the CJH ladder in 2020.

Category	Hatchery Program	# Tags	Expanded Abundance	% of Ladder Surplus
Okanogan Integrated	Omak Yearlings	0	0.0	0.0%
	Omak Subyearlings	0	0.0	0.0%
	Similkameen	3	11.7	1.1%
CJH Segregated	Segregated yearlings	61	232.1	22.0%
	Segregated subyearlings	3	11.4	1.1%
	No CWT, presumed Segr	132	485.7	46.1%
Other UCR summer/fall Chinook hatchery	Wells	44	167.5	15.9%
	Chelan	15	57.0	5.4%
	DCPUD	20	76.2	7.2%
	WDFW	3	11.4	1.1%
	Entiat NFH	0	0.0	0.0%
Total		***281***	***1053.0***	***100%***

Table A 12. 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%
2020	1,053	69%	0%	1%	21%	5%	2%	0%	1%	0%	0%
Avg.	***3,084***	***26%***	***2%***	***6%***	***30%***	***21%***	***4%***	***1%***	***9%***	**<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)
[e]Includes releases from DCPUD(5%) and WDFW(3%) 2020.

APPENDIX B

2021 Production Plan

Table B 1. Summer/Fall Chinook - Integrated Program

Chief Joseph Hatchery Production Plan

Brood Year:	2021						**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		
							Assumed Fecundity	*5,000*		
Estimated Release Data:							*Average Fecundity (BY15-BY20)*	*4,059*		
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
05/15/22	06/01/22	300,000	50.0	9.1	6,000	2,722	Sub-Yearlings	Omak	Ad Clipped	100% CWT
04/15/23	04/30/23	400,000	10.0	45.4	40,000	18,144	Yearlings	Similkameen	Ad Clipped	100% CWT
04/15/23	04/30/23	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:	2021						**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		
							Assumed Fecundity	*5,000*		
Estimated Release Data:							*Average Fecundity (BY15-BY20)*	*3,873*		
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
05/15/22	06/01/22	400,000	50.0	9.1	8,000	3,629	Sub-Yearlings	CJ Hatchery	Ad Clipped	100k CWT
04/15/23	04/30/23	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 2020, including pHOS and effective pHOS values per reach.

2020

reach	redds	fish per redd	spawners per reach	% sampled	total carcasses	hatchery carcasses	wild carcasses	% hatchery	% wild	HOS	NOS	pHOS
O1	25	2.67	67	10.5%	7	5	2	71.4%	28.6%	48	19	0.71
O2	51	2.67	136	18.4%	25	17	8	68.0%	32.0%	93	44	0.68
O3	270	2.67	721	19.7%	142	84	58	59.2%	40.8%	426	294	0.59
O4	103	2.67	275	15.6%	43	24	19	55.8%	44.2%	153	122	0.56
O5	683	2.67	1824	21.6%	393	110	283	28.0%	72.0%	510	1313	0.28
O6	1254	2.67	3348	25.2%	843	117	726	13.9%	86.1%	465	2883	0.14
S1	1445	2.67	3858	25.7%	993	295	698	29.7%	70.3%	1146	2712	0.30
S2	296	2.67	790	20.0%	158	44	114	27.8%	72.2%	220	570	0.28
Totals	4127		11019	23.6%	2604	696	1908			3062	7957	0.28

pHOS	0.28
effective pHOS	0.24

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	18.2%	77.6%	46	197	0.19
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			3297	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 2020.

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
2020	Wild	2	8	58	19	283	726	698	114	1,908
	Hatchery	5	17	84	24	110	117	295	44	696
Avg.	***Wild***	***1***	***2***	***19***	***9***	***103***	***279***	***352***	***68***	***833***
	Hatchery	***1***	***4***	***21***	***7***	***60***	***85***	***306***	***52***	***536***

[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
2020	0	0	5	8	0	0	13
Average	***1***	***23***	***100***	***68***	***6***	***0***	***198***

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
2020	0	0	9	3	0	0	12
Average	***0***	***0***	***48***	***195***	***26***	***0***	***270***

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	1,332
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
2020	0	2	92	518	41	0	653
Average	***0***	***7***	***93***	***182***	***54***	***1***	***337***

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	1,025
2015	0	0	66	342	426	1	835
2016	0	0	4	927	288	4	1,223
2017	0	0	4	127	367	7	505
2018	0	0	10	102	63	0	175
2019	0	0	0	87	22	0	109
2020	0	0	4	720	102	0	826
Average	***0***	***0***	***18***	***249***	***136***	***1***	***404***

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%	100%
1994	0%	4%	19%	77%	0%	0%	100%
1995	0%	3%	33%	39%	25%	0%	100%
1996	0%	6%	35%	49%	10%	0%	100%
1997	0%	0%	4%	89%	7%	0%	100%
1998	0%	10%	68%	13%	10%	0%	100%
1999	2%	0%	31%	65%	2%	0%	100%
2000	4%	34%	3%	55%	4%	0%	100%
2001	0%	7%	91%	0%	2%	0%	100%
2002	0%	1%	38%	60%	0%	0%	100%
2003	0%	8%	14%	66%	12%	0%	100%
2004	0%	1%	53%	36%	10%	0%	100%
2005	0%	8%	13%	69%	10%	0%	100%
2006	0%	12%	25%	18%	45%	0%	100%
2007	0%	40%	38%	19%	2%	1%	100%
2008	0%	3%	74%	22%	0%	0%	100%
2009	0%	18%	14%	67%	1%	0%	100%
2010	1%	6%	83%	8%	2%	0%	100%
2011	0%	47%	15%	38%	0%	0%	100%
2012	0%	11%	62%	23%	3%	0%	100%
2013	0%	12%	46%	37%	3%	2%	100%
2014	0%	36%	38%	26%	0%	0%	100%
2015	0%	6%	78%	16%	0%	0%	100%
2016	0%	6%	15%	75%	4%	0%	100%
2017	0%	6%	40%	43%	7%	0%	100%
2018	0%	0%	80%	18%	3%	0%	100%
2019	0%	7%	49%	42%	2%	0%	100%
2020	0%	0%	38%	62%	0%	0%	100%
Average	*0%*	*10%*	*43%*	*40%*	*6%*	*0%*	*100%*

Hatchery-Origin Female Salt Age - Percent of carcasses recovered within origin/sex class							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	91%	9%	0%	0%	100%
1994	0%	0%	2%	97%	1%	0%	100%
1995	0%	0%	7%	33%	61%	0%	100%
1996	0%	0%	17%	58%	24%	1%	100%
1997	0%	0%	2%	86%	13%	0%	100%
1998	0%	1%	31%	33%	35%	0%	100%
1999	0%	0%	7%	89%	3%	0%	100%
2000	0%	0%	1%	85%	14%	0%	100%
2001	0%	0%	81%	6%	13%	0%	100%
2002	0%	0%	5%	94%	1%	0%	100%
2003	0%	0%	2%	85%	13%	0%	100%
2004	0%	0%	11%	53%	36%	0%	100%
2005	0%	0%	3%	80%	17%	1%	100%
2006	0%	0%	13%	27%	61%	0%	100%
2007	0%	0%	21%	69%	9%	2%	100%
2008	0%	0%	40%	54%	5%	0%	100%
2009	0%	0%	2%	94%	4%	0%	100%
2010	0%	0%	49%	38%	13%	0%	100%
2011	0%	0%	3%	95%	1%	0%	100%
2012	0%	0%	48%	44%	8%	0%	100%
2013	0%	0%	15%	82%	3%	0%	100%
2014	0%	0%	15%	82%	3%	0%	100%
2015	0%	0%	56%	41%	2%	0%	100%
2016	0%	0%	2%	94%	4%	0%	100%
2017	0%	1%	20%	40%	39%	0%	100%
2018	0%	0%	41%	53%	6%	0%	100%
2019	0%	0%	23%	77%	0%	0%	100%
2020	0%	0%	75%	25%	0%	0%	100%
Average	*0%*	*0%*	*24%*	*62%*	*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%	100%
1994	0%	6%	27%	46%	21%	0%	100%
1995	0%	0%	29%	52%	19%	0%	100%
1996	0%	8%	54%	31%	8%	0%	100%
1997	0%	15%	40%	40%	5%	0%	100%
1998	0%	4%	48%	40%	7%	0%	100%
1999	0%	0%	31%	56%	11%	1%	100%
2000	0%	9%	35%	39%	17%	0%	100%
2001	0%	5%	30%	62%	3%	0%	100%
2002	0%	4%	22%	60%	14%	0%	100%
2003	0%	4%	20%	63%	13%	0%	100%
2004	0%	3%	32%	23%	42%	0%	100%
2005	0%	0%	21%	73%	5%	1%	100%
2006	0%	0%	4%	59%	36%	0%	100%
2007	0%	5%	18%	14%	61%	1%	100%
2008	0%	1%	47%	48%	2%	0%	100%
2009	0%	3%	6%	82%	9%	0%	100%
2010	0%	1%	34%	46%	19%	0%	100%
2011	0%	3%	15%	76%	6%	0%	100%
2012	0%	4%	46%	32%	17%	0%	100%
2013	0%	2%	34%	58%	5%	0%	100%
2014	0%	5%	15%	71%	9%	0%	100%
2015	0%	1%	61%	30%	8%	0%	100%
2016	0%	7%	77%	15%	0%	0%	100%
2017	0%	0%	4%	50%	45%	1%	100%
2018	0%	2%	28%	47%	24%	0%	100%
2019	0%	0%	45%	48%	7%	0%	100%
2020	0%	0%	14%	79%	6%	0%	100%
Average	*0%*	*3%*	*31%*	*50%*	*15%*	*0%*	*100%*

Natural-Origin Female Salt Age - Percent of carcasses recovered within origin/sex class							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	15%	76%	9%	0%	100%
1994	0%	0%	3%	54%	43%	0%	100%
1995	0%	0%	16%	60%	24%	0%	100%
1996	0%	0%	13%	78%	9%	0%	100%
1997	0%	0%	23%	58%	19%	0%	100%
1998	0%	0%	25%	61%	14%	0%	100%
1999	0%	0%	16%	67%	17%	0%	100%
2000	0%	0%	6%	72%	22%	0%	100%
2001	0%	0%	4%	91%	5%	0%	100%
2002	0%	0%	6%	65%	29%	0%	100%
2003	1%	1%	14%	63%	22%	0%	100%
2004	0%	0%	5%	29%	66%	0%	100%
2005	0%	0%	4%	84%	11%	1%	100%
2006	0%	0%	0%	49%	50%	0%	100%
2007	0%	0%	1%	10%	87%	2%	100%
2008	0%	0%	4%	89%	6%	1%	100%
2009	0%	0%	1%	80%	19%	0%	100%
2010	0%	0%	5%	44%	51%	0%	100%
2011	0%	0%	2%	86%	12%	0%	100%
2012	0%	0%	4%	48%	48%	0%	100%
2013	0%	0%	2%	89%	9%	0%	100%
2014	0%	0%	2%	79%	18%	0%	100%
2015	0%	0%	8%	41%	51%	0%	100%
2016	0%	0%	0%	76%	24%	0%	100%
2017	0%	0%	1%	25%	73%	1%	100%
2018	0%	0%	6%	58%	36%	0%	100%
2019	0%	0%	0%	80%	20%	0%	100%
2020	0%	0%	0%	87%	12%	0%	100%
Average	*0%*	*0%*	*10%*	*62%*	*89%*	*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
2014	738 (335)	1,602 (483)	9 (4)	1,015 (117)	3,364
Average	***1,849 (98)***	***1,118 (69)***	***119 (3)***	***732 (25)***	***3,817***
Median	***1,065 (69)***	***420 (23)***	***34 (2)***	***404 (16)***	***2,598***

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 2020 Chief Joseph Hatchery Integrated and Segregated Chinook Releases

Date: July 29, 2020

From: Andrea Pearl; andrea.pearl@colvilletribes.com (509) 634-1364

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

CC: Kirk Truscott

Subject: Minijack rates for 2020 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 2020, and provide estimates for the rate of early maturation ("minijack rate") from each yearling group released in 2020 (brood year 2018).

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 2020 Chief Joseph Hatchery (CJH) release group for dissection and examination. Similar to 2019, these fish were held at CJH after their cohorts had been released for approximately one month. This was to allow for additional maturation and facilitate distinction between mature and immature fish. The release groups are:

- Segregated spring Chinook; released from Chief Joseph Hatchery, hatchery-origin broodstock collected at the Chief Joseph Hatchery Ladder
- Segregated summer Chinook; released from Chief Joseph Hatchery, hatchery-origin broodstock collected from the Columbia River near the mouth of the Okanogan River
- Integrated spring Chinook; released from the Riverside Acclimation Pond, natural-origin MetComp broodstock from Winthrop National Fish Hatchery
- Integrated summer Chinook; released from the Omak Acclimation Pond, natural- and hatchery-origin broodstock primarily of Okanogan-origin stock
- Integrated summer Chinook; released from the Similkameen Acclimation Pond, natural- and hatchery-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 (11.11%-49.66%, Table 1). The mixture model was fit to all release groups and encompassed a larger range of expected rates of early maturation (19.26% - 65.06%, Table 1). There was no distinct separation in Log10 GSI between immature and mature fish in any of the release groups. Such a break almost occurred in the Omak integrated summer Chinook release group, but it wasn't completed separated. Nevertheless, a cutoff value for classifying sampled fish as mature or immature, and therefore a minijack rate, could be modeled for all groups (Figures 1-5). 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 2018.

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	135	120	15	11.11%	19.26%
Segregated Summer Yearlings	Chief Joseph Hatchery	166	124	42	25.30%	65.06%
Integrated Spring Yearlings	Riverside Acclimation Pond	139	106	33	23.74%	43.88%
Integrated Summer Yearlings	Omak Acclimation Pond	149	75	74	49.66%	54.36%
Integrated Summer Yearlings	Similkameen Acclimation Pond	144	115	29	20.14%	46.53%

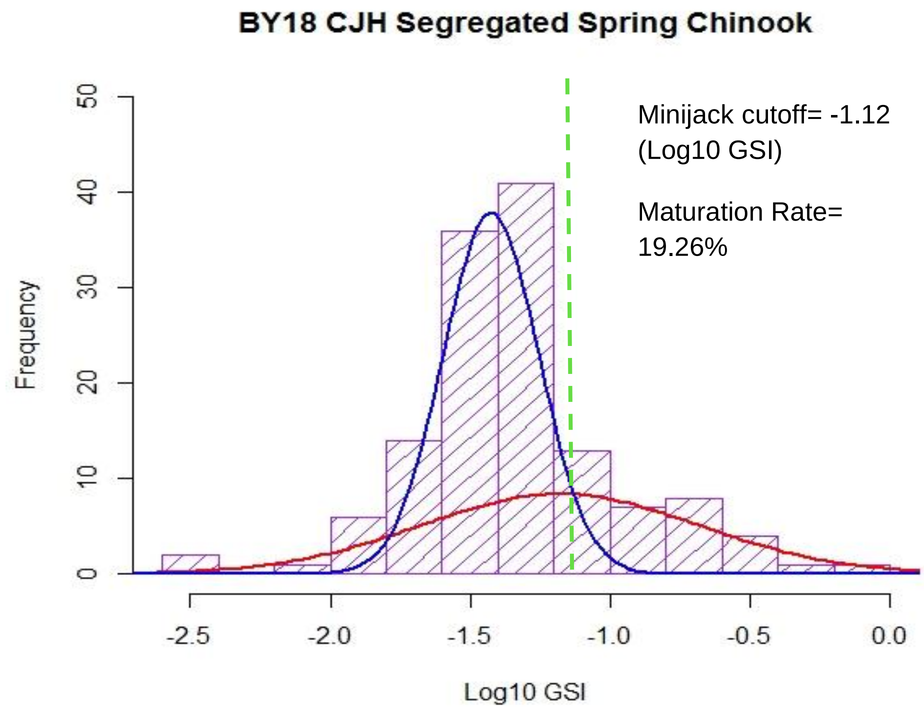


Figure 1. Distribution of Log10 GSI for the segregated spring Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

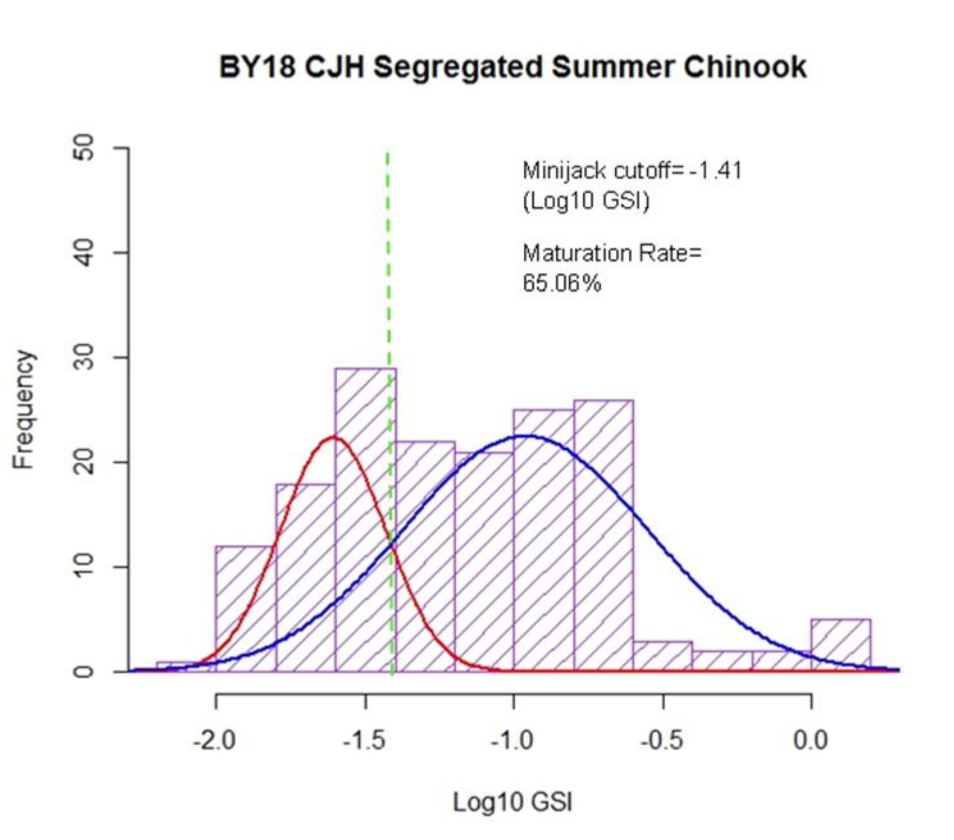


Figure 2. Distribution of Log10 GSI for the segregated summer/fall Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

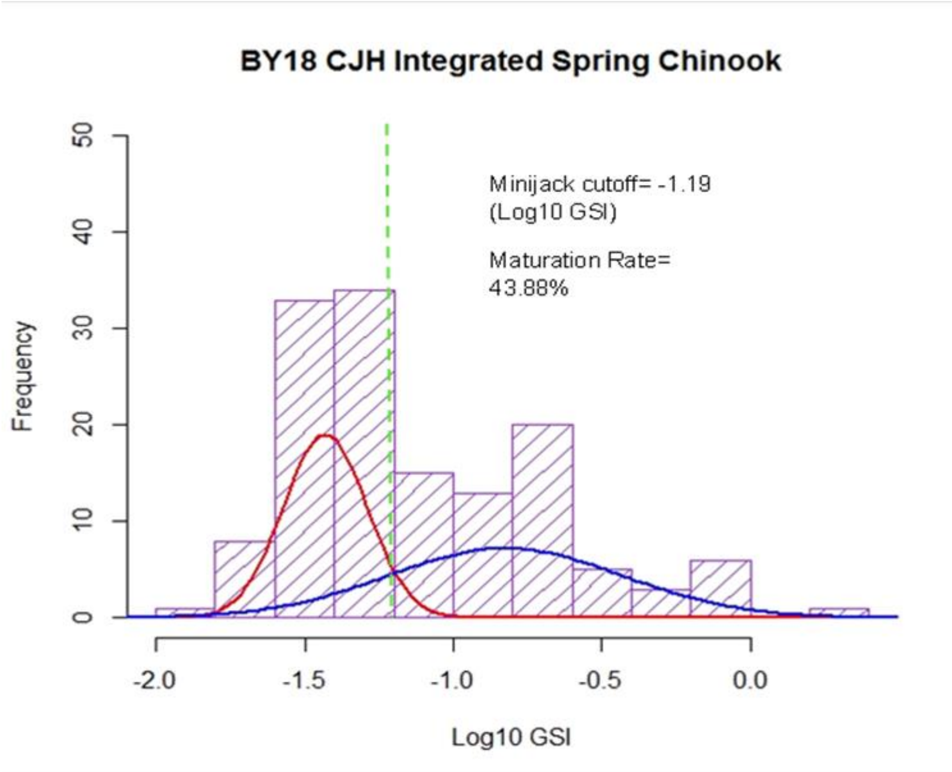


Figure 3. Distribution of Log10 GSI for the integrated spring Chinook released from the Riverside Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

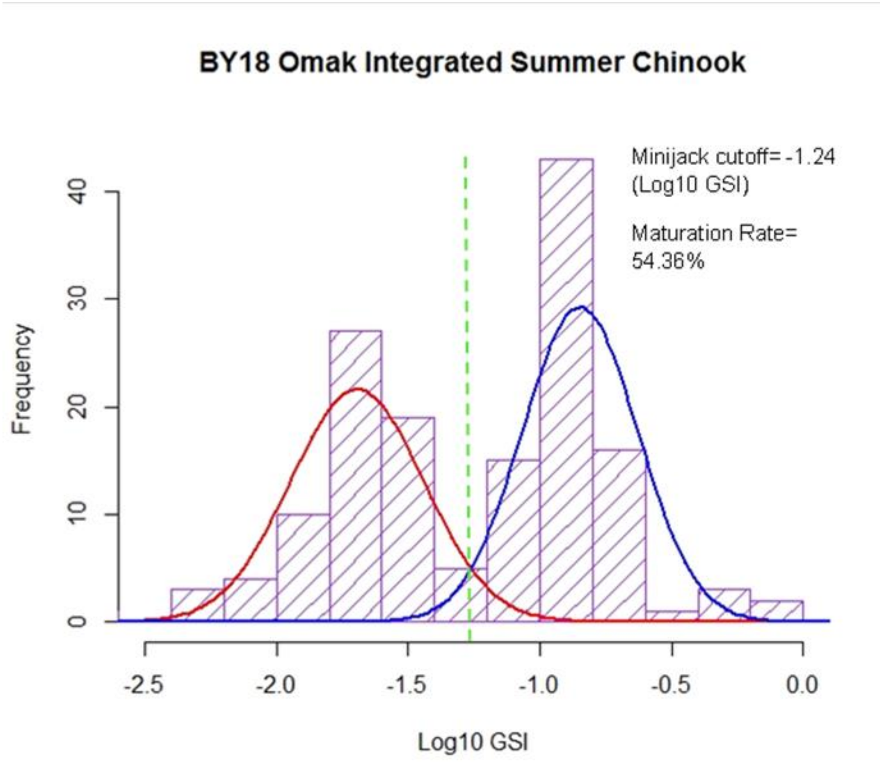


Figure 4. Distribution of Log10 GSI for the integrated summer/fall Chinook released from the Omak Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

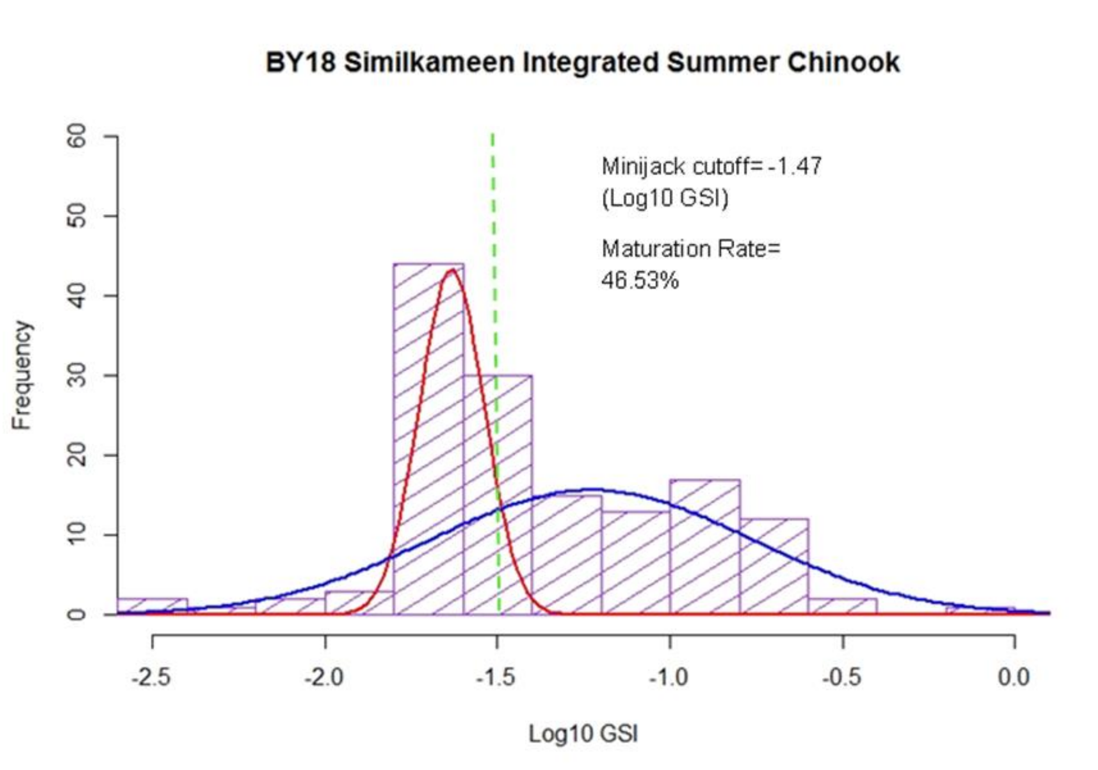


Figure 5. Distribution of Log10 GSI for the integrated summer/fall Chinook released from the Similkameen Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

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

Year		CJH Segregated Spring Chinook	CJH Segregated Summer Chinook	Riverside Integrated Spring Chinook	Omak Integrated Summer Chinook	Similkameen Integrated Summer Chinook
2018	Visual Estimate	3.23%	4.29%	1.34%	0.00%	0.75%
	Modeled Estimate	4.52%	N/A	N/A	N/A	N/A
2019	Visual Estimate	31.29%	14.29%	37.41%	19.63%	14.25%
	Modeled Estimate	19.02%	43.06%	42.17%	29.63%	N/A
2020	Visual Estimate	11.11%	25.30%	23.74%	49.66%	20.14%
	Modeled Estimate	19.26%	65.06%	43.88%	54.36%	46.53%

Discussion and Recommendations

The data and analyses presented herein suggest that the early maturation rates for brood year 2018 releases were much higher than that of brood year 2016 and 2017 Chinook for some of the release groups. The increase in minijack rates occurred with all of the summer Chinook release groups with almost a two-fold increase in the integrated group and a one and half increase in the segregated group. A potential cause for this increase in minijack rates could be due to the failure of the chiller during the incubation stage in November and December of 2018. These release groups were not incubated under chilled water during the eye up stage and were therefore ponded earlier than expected due to premature hatching. The spring Chinook release groups had similar minijack rates to those in 2019 and 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 for some groups, 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. Similar to the 2019 releases, 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 2019 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 and 2020 be maintained in future years.

Literature Cited

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‘NAD Sampling Protocols

Supplies List

Sampling How-To

Data Summary and Analysis Methods

Notes from 2016

By Katy Pfannenstein

Mid-Columbia River Fishery Resource Office

US Fish and Wildlife Service

Katy_Pfannenstein@fws.gov

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

Daily consumables:

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

General:

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

Length and weight station:

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

Dissecting station:

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

'NAD Sampling How-To

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

PRE-RELEASE JUVENILE SAMPLING DATA SHEET　　Page____of____

Date: ___/___/20____　　Samplers:________________________

Hatchery: ____________________　　Species/Stock____________________

Group:________________Bank:________________Raceway(s)________________

Other:____

Smolt index (0 = unk, 1= parr, 2= trans, 3=smolt)　Maturity (0=unknown, 1=immature, 2=mature)

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

PRE-RELEASE JUVENILE SAMPLING DATA SHEET　　Page____of____

Date: ___/___/20____

Hatchery: ____________________　　Species/Stock____________________

Group:________________Bank:________________Raceway(s)________________

Other:____

Smolt index (0 = unk, 1= parr, 2= trans, 3=smolt)　Maturity (0=unknown, 1=immature, 2=mature)

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

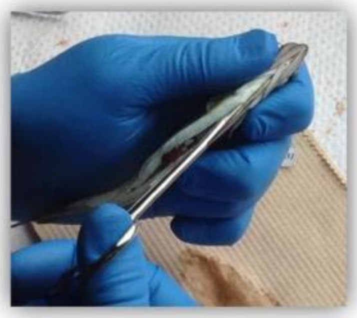
2. Collect fish from hatchery ponds. Random sample? Keep different ponds separate? CWT? Pit Tag?

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

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

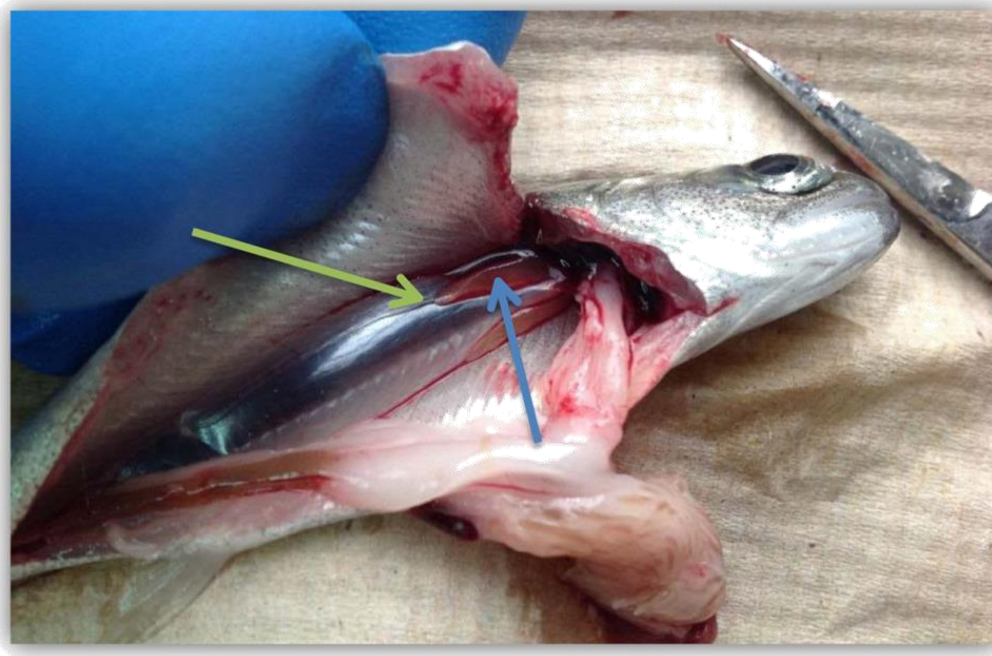
5. Set out 15-20 fish in a row on the sponges. Add number tags to fish. Assess smolt index while all fish are in the line. Obtain weights and lengths, place on paper towel to pass to the dissecting crew.

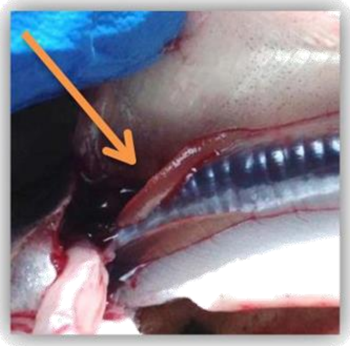
6. Fish dissection: Cut open belly from vent (shallow incision), cut behind gill, open fish and gently remove guts to expose air bladder. Both male and female gonads are located on the top/edge of the air bladder (orange arrow on mature male).

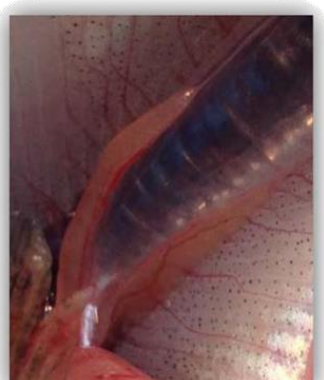


7. Female identification: 1. Ovary forms a point and then narrows to oviduct – thread like (green arrow) 2. Ovary is angular, has ridge (blue arrow), 3. Granulated

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





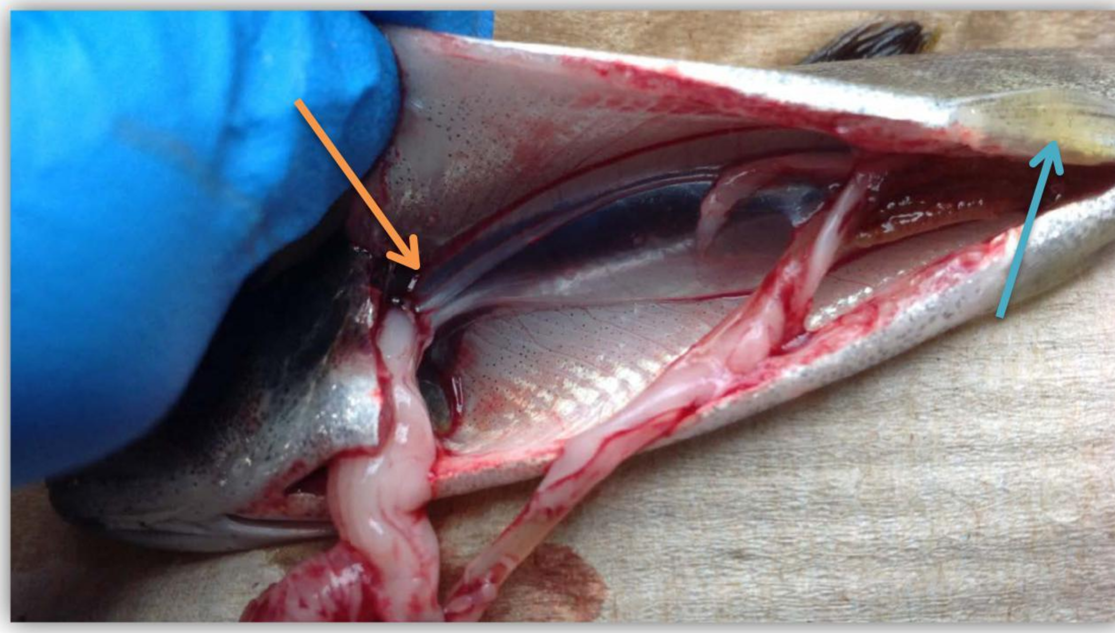


8. Immature male identification: Testes are thready throughout, smooth and round, no development or thickness (green arrows).

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

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

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

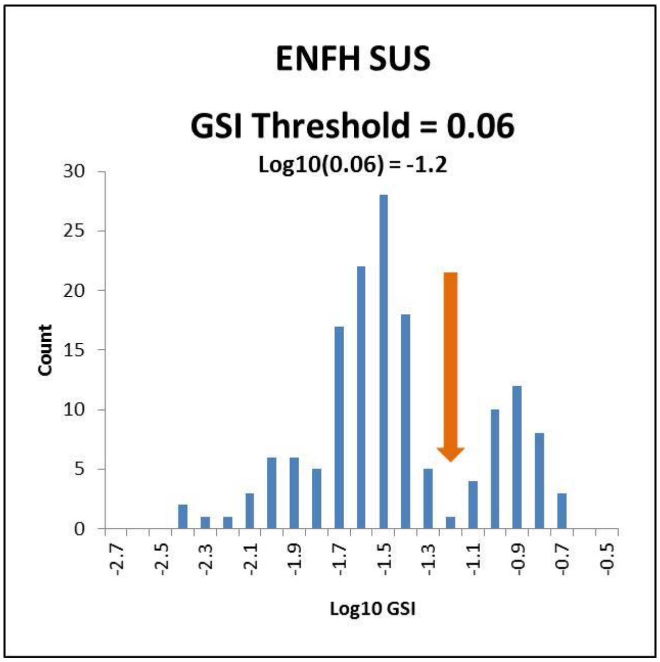


12. To use the scale: Close all doors, zero balance, open door, place ‘nads in weight boat, close doors, wait for number to stabilize. ‘Nads will evaporate and become lighter in a short period of time.

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

NAD Data Summary and Analysis Methods

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



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

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

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

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

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

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

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

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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
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}
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)" ))
```