THE CHIEF JOSEPH HATCHERY PROGRAM 2017 ANNUAL REPORT

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This report includes both hatchery production/operations and the corresponding monitoring activities completed through April of 2018. 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/.

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

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EXECUTIVE SUMMARY

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

The CJH production level was set at 100% in 2017 during the fifth year of operation for the Spring and Summer/Fall Chinook programs. Early run forecast for returning Spring Chinook to Leavenworth was short of total program needs, so the program operated the ladder at CJH to collect returning adults from the BY 2013 production. 622 Spring Chinook broodstock were collected at the CJH ladder from May-July 2017. The segregated Spring Chinook program broodstock survival was 93.1% females, 93.7% males with a combined survival of 93.5%. The total green egg take for the segregated Spring Chinook program was 1,010,800 (92% of full program). Green egg to eyed egg survival was 42.7%. This survival was much lower than the standard (90%). With the lower than anticipated hatchery survival of eggs the segregated spring Chinook program was 48% of full program by April 30, 2018. The 10(j) spring Chinook reintroduction program received its full component of 206,138 eyed eggs from the Winthrop NFH in October.

In July and August the CCT used a purse seine vessel to collect 1,200 summer/fall Chinook for broodstock for both the integrated and segregated programs (including Similkameen). Additionally, 86 summer/fall Chinook were collected at the Okanogan adult weir in September. The summer/fall and spring Chinook programs collected enough brood to meet full production levels. The cumulative pre spawn holding survival, for all Summer/Fall brood collected, was 71.5% for hatchery-origin broodstock (HOB) and 54.6% 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 1,775,000 (65% of full program). Egg survival from green egg to eyed egg averaged 85.2% for NOB and 87.0% for HOB, both under the survival standard (90%) for this life stage. Cumulative egg survival from green egg to eyed egg was 86.1% for NOB and HOB, which is under the survival standard (90%) for this life stage. Ponding survival for the segregated subyearling program was 97.8%, which exceeded the survival standard (95%) for this life stage. There was no integrated sub-yearling program for brood year 2017 due to low egg take. After in-hatchery mortalities from pre-spawn holding through ponding there were 1,051,507 fish on hand at the end of April for the yearling releases in 2018 (81% of full program) and 182,558 fish on hand for the sub-yearling releases in May 2018 (26% of full program).

2017 was the fourth year for Summer/Fall Chinook sub-yearling hatchery releases from the CJH programs and the third year for yearlings released from Similkameen and Omak acclimation ponds that had been reared at the CJH central facility. In April, 301,246 integrated yearling summer/fall Chinook were released from the Omak acclimation pond (84% of full program) and 376,987 were released by Washington Department of Fish & Wildlife (WDFW) from the Similkameen Pond (100% of full program). Subsequently, sub-yearlings from brood year (BY) 2016 were transferred to Omak Pond for short term acclimation and 216,804 were released in May (72% of full program). Additionally 464,429 yearling and 185,821 sub-yearling segregated Chinook were released directly from Chief Joseph Hatchery (93% and 46% of full program, respectively). For Spring Chinook, 200,827 smolts (100% of full program) were released in the spring of 2018 and marked the third year of implementation of the non-essential experimental population under section 10(j) of the Endangered Species Act. Additionally, 555,636 segregated Spring Chinook smolts were released directly from Chief Joseph Hatchery (79% of full program).

Apparent survival of yearlings to RRJ (75-80%) was generally similar to or greater than previous years and other nearby programs in the UCR. One exception was the 10j Spring Chinook from Riverside Pond (52%). Apparent survival of yearlings to MCN was generally 50-60% regardless of species or release location with two note-able exceptions: 1) the 10j reintroduction Spring Chinook had lower survival to MCN (35%) and 2) the segregated Summer Chinook yearlings from CJH had much higher survival (82%) to MCN. The low survival of the 10j reintroduction Spring Chinook was likely related to an early escape from the acclimation pond that resulted from an ice problem at the facility. Apparent survival to RRJ for sub-yearling summer Chinook was 65-70% for fish released from CJH facilities, 48% for Wells Fish Hatchery releases and 46% for wild subyearlings captured in a beach seine near the mouth of the Okanogan. The majority (>95%) of PIT tagged hatchery smolts released from Omak Pond and Riverside Pond migrated to the lower Okanogan River within two weeks of release. This assessment suggests that the program was successful at releasing actively migrating smolts.

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

Rotary screw trap operations began on April 3 and continued through June 17, capturing 8,794 natural-origin Chinook and 2,140 hatchery-origin Chinook. After conducting 2 mark-recapture events, the efficiency of the trapping configuration was calculated to be approximately 0.02%. This translated to an overall juvenile natural-origin Chinook outmigration estimate of 1,209,216 with 95% confidence intervals of 8,734 to 4,576,536. 32 steelhead (*O. mykiss*) were also captured in the rotary screw trap including 18 natural-origin (adipose fin present and no CWT) and 14 hatchery-origin (adipose fin clipped and/or CWT present). Other species commonly caught in the rotary screw traps included sockeye (*O. nerka*) (39), yellow perch (*P. flavescens*) (113), bluegill (*L. macrochirus*) (29) and mountain whitefish (*Prosopium williamsoni*)(931).

25,580 juvenile Chinook salmonids were collected with the beach seine, and 21,280 (83%) were PIT tagged and released. Pre- and post-tag mortality was 2.4% and 3.7% respectively. In 2017, wild summer Chinook tagged at the mouth of the Okanogan had a minimum apparent survival to Rocky Reach Juvenile Bypass (RRJ) of 0.17. Apparent survival to McNary (MCN), John Day (JDA) and Bonneville (BON) Dams was 2.5%, 1.2% and 1.2% respectively

The lower Okanogan Adult Fish Weir was deployed on August 14th when discharge was 2,280 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. After reviewing the number of adult Chinook pit tagged at Bonneville and their detections at the Wells Adult Ladder and the Lower Okanogan Pit Array, we suspect that about 38% of fish passage occurred before the weir trap was operational on August 18. After trapping began, the majority of Chinook (75%) were trapped between August 22 and September 1. 447 adult Chinook were trapped in 2017. Eighty-four natural-origin and 9 hatchery-origin Chinook were transported to the hatchery and held as broodstock for the integrated and segregated program. Adult brood were transported from the weir trap to the hatchery brood truck with the Whooshh™ fish transport system. There were no immediate mortalities of these fish within the first week after transport to the hatchery. All other natural-origin fish were released upstream of the weir unharmed. All of the hatchery-origin fish encountered in the weir trap were removed for proportion of hatchery-origin spawner (pHOS) management. Only 0.57% of the Chinook spawning escapement was detected in the trap. All Chinook and sockeye mortality encountered at the weir were categorized as impinged on the upstream side, indicating that they most likely died upstream and floated down onto the weir. The majority of the Chinook carcasses were encountered during the first week of trapping, but none of the carcasses contained a floy tag, which suggests that the weir was not causing the mortality. 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 20.

Spawning ground surveys estimated 3,221 summer/fall Chinook redds and 1,201 carcasses were recovered (997 natural-origin and 204 hatchery-origin). Adult summer/fall Chinook spawning escapement in 2017 was estimated to be 6,568, with 5,283 natural-origin spawners. The values for pHOS (0.20) and proportion of natural influence (PNI) (0.86) in 2017 met the program objectives (<0.30 and >0.67, respectively). The five-year average for pHOS (0.22) and PNI (0.85) 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 2017, along with removals of more than 4,000 surplus hatchery fish at the CJH ladder and trap.

Spatial distribution of spring-Chinook in the Okanogan basin has been monitored using analysis of environmental DNA (eDNA) beginning in 2012. This data is used to assess status and trends in spatial structure and to track the progress of the reintroduction which began in 2015. Results revealed that the Okanogan basin likely saw a limited distribution of spring Chinook, even prior to the reintroduction effort. Following the initial reintroduction, several tributaries have produced consistent annual detections of Chinook eDNA, including Shingle Creek, Vaseux Creek, Salmon Creek and Omak Creek.

PIT tags were also used to evaluate Spring Chinook presence and distribution in the Okanogan. Of the 128 returning fish with a PIT tag to the Okanogan, eight (6%) had a final detection in the Methow, and 52 (40%) were detected in a U.S. tributary, none had a detection in a Canadian tributary to the Okanagan, and the remaining 68 (54%) were only detected at a mainstem site (OKL, OKC, or Zosel Dam). Again, the majority of detected adult spring Chinook were tagged as adults at Wells Dam, but returning PIT tags were also detected from fish released in the Methow and Okanogan river basins as juveniles.

The CJH coded wire tag lab was in its second year of operation in 2017. 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 majority of the summer Chinook adult returns to the CJH ladder were from Wells (38%), Chelan (29%) and Dryden (6%). The Similkameen represented 3% of the total estimated recoveries. The high proportion of fish from downstream Upper Columbia River programs is not surprising because 2017 was the first year of adult returns from the CJH segregated program. Spring Chinook were encountered during the summer Chinook ladder operations (generally early July to early August). All of the recoveries were from the Chief Joseph Hatchery segregated (80%) and integrated programs (20%).

The majority (99%) of hatchery-origin spawners recovered on the spawning grounds in 2017 were from Similkameen (70%) and Okanogan (30%). This was very similar to the average (95%) of recent years (2006-2016). Overall, the majority of fish acclimated at Similkameen Pond ended up spawning throughout the upper reaches of the Okanogan River (56%), especially in the upper most reach (O6). Reach S1, the location of the Similkameen acclimation site in the Similkameen River accounted for just half of the estimated spawning by Similkameen Pond fish

(44%). Less than 1% of the spawning escapements in the non-target basins of Wenatchee, Methow, Chelan or Entiat consisted of hatchery-origin Okanogan summer/fall Chinook in 2017. 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 2012. The 2012 brood year had a stray of 0.9%, which was similar to the long term and recent five year average (1.2%).

An Annual Program Review (APR) was held in March 2018 to share hatchery production and monitoring data, review the salmon forecast for the upcoming year, and develop action plans for the hatchery, selective harvest, and monitoring projects. Based on a strong pre-season forecast of 67,300 Upper Columbia summer/fall Chinook, the plan for 2018 is to operate the hatchery at full program levels of 2 million summer/fall Chinook and 900,000 spring Chinook. To maximize PNI, broodstock for the integrated program would be 100% natural-origin broodstock (NOB) and CCT would plan to harvest their full allocation with the selective harvest program removing as many adult hatchery Chinook as possible with 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

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

11. Conduct annual reviews to include peers, stakeholders, and regional managers, and
12. Develop and maintain database and information systems and a highly functional informational web-presence.

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

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

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

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

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

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

Study Area

The primary study area of the CJHP lies within the Okanogan River Subbasin and Columbia River near Chief Joseph Dam in north central Washington State (Figure 1). The Okanogan River measures approximately 185 km long and drains 2,316,019 ha, making it the third-largest subbasin to the Columbia River. Its headwaters are in Okanagan Lake in British Columbia, from which it flows south through a series of four lakes before crossing into Washington State at Lake Osoyoos. Seventy-six percent of the area lies in Canada. Approximately 14 km south of the border, the Okanogan is joined by its largest tributary, the Similkameen River. The Similkameen River watershed is 510 km long and drains roughly 756,096 ha. The Similkameen contributes approximately 75% of the flow to the Okanogan

River. The majority of the Similkameen is located in Canada. However, part of its length within Washington State composes an important study area for CJHP. From Enloe Dam (Similkameen rkm 14) to its confluence with the Okanogan, the Similkameen River contains important Chinook pre-spawn holding and spawning grounds. Downstream of the Similkameen confluence, the Okanogan River continues to flow south for 119 km until its confluence with the Columbia River at Columbia River km 853, between Chief Joseph and Wells dams, near the town of Brewster, Washington.

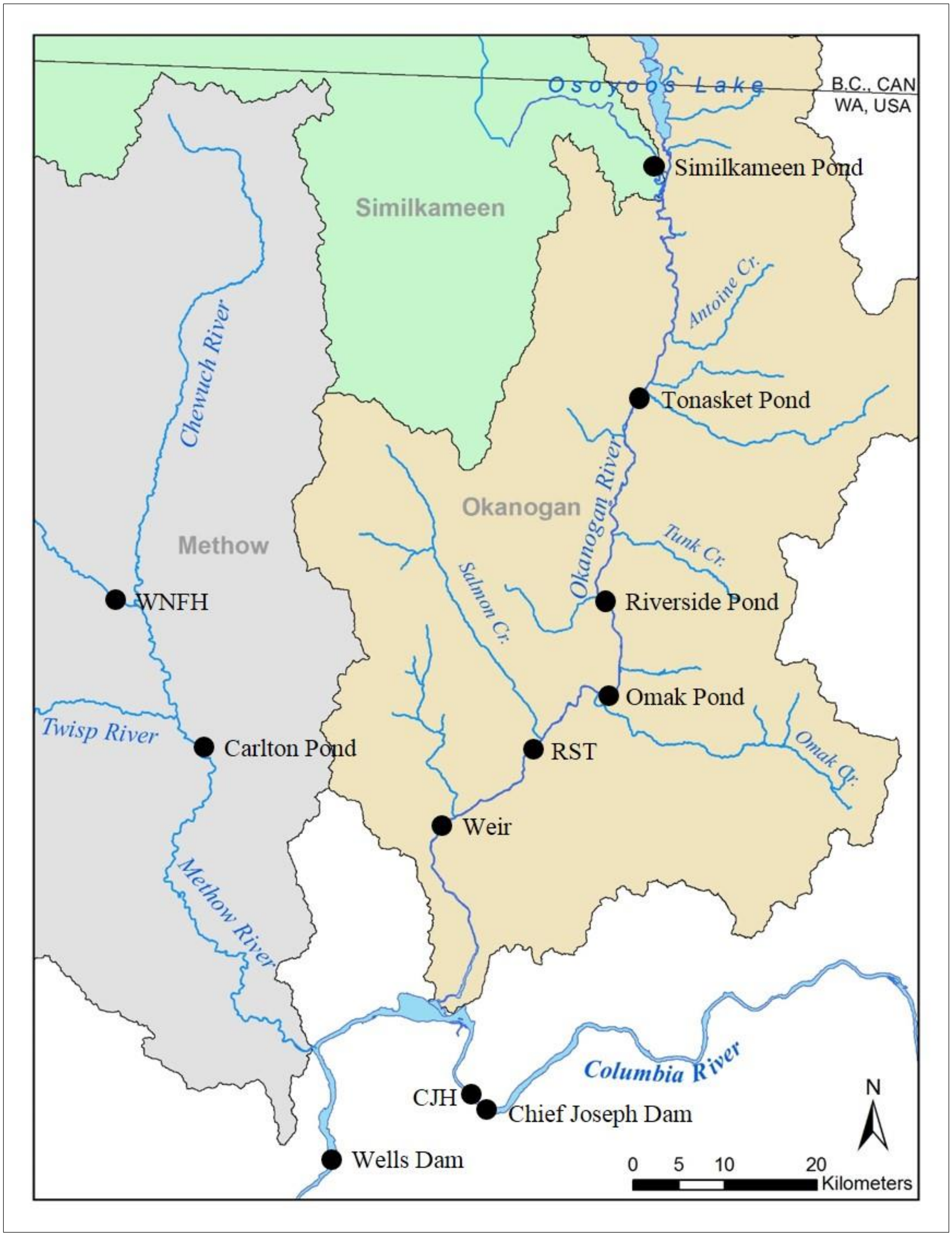


Figure 1. Map of the U.S. portion of the Okanogan River Basin, the Chief Joseph Hatchery (CJH), Winthrop National Fish Hatchery (WNFH), Okanogan adult weir (Weir), Rotary screw trap (RST), and Chinook Salmon acclimation sites. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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

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

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

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

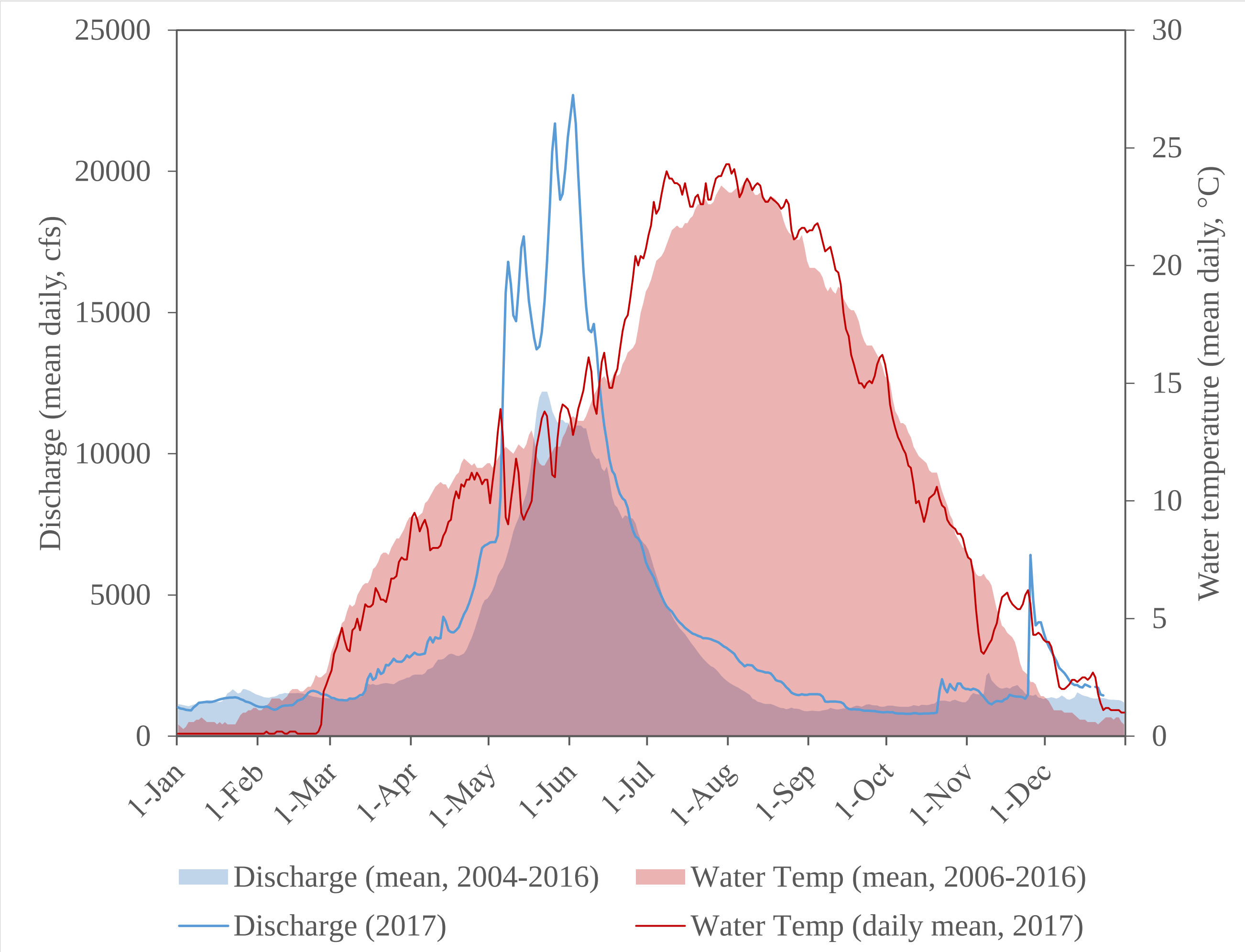


Figure 2. Okanogan River mean daily discharge (blue lines) and water temperature (red lines) at Malott, WA (USGS Stream Gage 12447200).

METHODS

Tag and Mark Plan

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

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

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

[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

1The 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.

HATCHERY SPRING CHINOOK. —The general tag and mark plan for spring Chinook can be seen in Table 2.

Table 2. General marking and tagging plan for Okanogan spring Chinook as part of the Chief Joseph Hatchery Program.

Mark Group	Smolt released	Life-stage released	% CWT (#)	Adipose Fin-Clip	PIT tag
Chief Joseph Segregated	700,000	Yearling	29% (200,000)	100%	5,000
Reintroduction (§10(j) fish from Winthrop)					
Tonasket or Riverside Pond	200,000	Yearling	100%		5,000
Natural-Origin	RST	Yearling	0%	0%	≤ 5,000

NATURAL-ORIGIN FISH TAGGING. —The RM&E plan called for up to 25,000 PIT tags in juvenile natural-origin summer/fall Chinook parr/smolts. PIT tagging of natural-origin summer/fall Chinook occurred at the rotary screw trap and the juvenile beach seine in 2017. Please see those sections for details.

Genetic Sampling/Archiving

The CJHP collects and archives genetic samples for future analysis of allele frequency and genotyping of naturally spawned and hatchery Chinook populations. Genetic samples (fin clips) from outmigrant juvenile Chinook were collected during rotary screw trap operations. Samples were preserved in 200-proof molecular grade ethanol and are currently archived at USGS Snake River Field Station, Boise, ID. No genetic analyses are currently being conducted. Annual tissue collection targets are at least 200 samples for: (1) natural-origin sub-yearling Chinook handled at the rotary screw trap/beach seine; (2) natural-origin yearling (>130 mm) Chinook handled at the rotary screw trap/beach seine and (3) natural- and hatchery-origin (100 each) Chinook encountered during carcass surveys on the spawning grounds.

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

Rotary Screw Traps

One 2.4 m and one 1.5 m rotary screw trap (RSTs) were deployed from the Highway 20 bridge near the City of Okanogan (rkm 40) (Figure 3). The RSTs were operated from April 3 to June 17, 2017. Trapping typically occurred continuously from Monday through Friday, and for 12 hours, from 2000-0800 Saturday and Sunday. Trapping operations were suspended on May 14, May 25- June 6, and June 11-12 due to high river discharge and debris load or staffing constraints. To continue trapping operations in varying river conditions, traps were operated in one of three trapping configurations: 2.4 m only, 1.5 m only, and both traps operational.

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

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

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

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

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

Trap efficiency was calculated by the equation

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

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

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

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

1.) All marked fish passed the screw trap or were recaptured during time period *i*

2.) The probability of capturing a marked or unmarked fish is equal

3.) All marked fish recaptured were correctly identified as a marked fish

4.) Marks were not lost or overlooked between time of release and recapture

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

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

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

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

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

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

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

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

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

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

Juvenile Beach Seine/PIT tag effort

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

Beach seining took place from May 12 to June 23 in the area near the confluence of the Okanogan and Columbia Rivers. Efforts focused on beaches along the North bank of the Columbia River, downstream of the mouth of the Okanogan (48° 6'12. 46"N, 119°44'35. 48"W) (Figure 4). In 2017, Gebber's Landing and Washburn Island were the only areas used for collection. This location provided reasonable catch rates, limited bycatch, and provided suitable substrates (limited debris loads/underwater snags) for efficient sampling. Juvenile Chinook from this location were likely primarily fish originating from the Okanogan River; however, it is possible that offspring from mainstem Columbia River spawning could also be included, especially at the Washburn Island site.

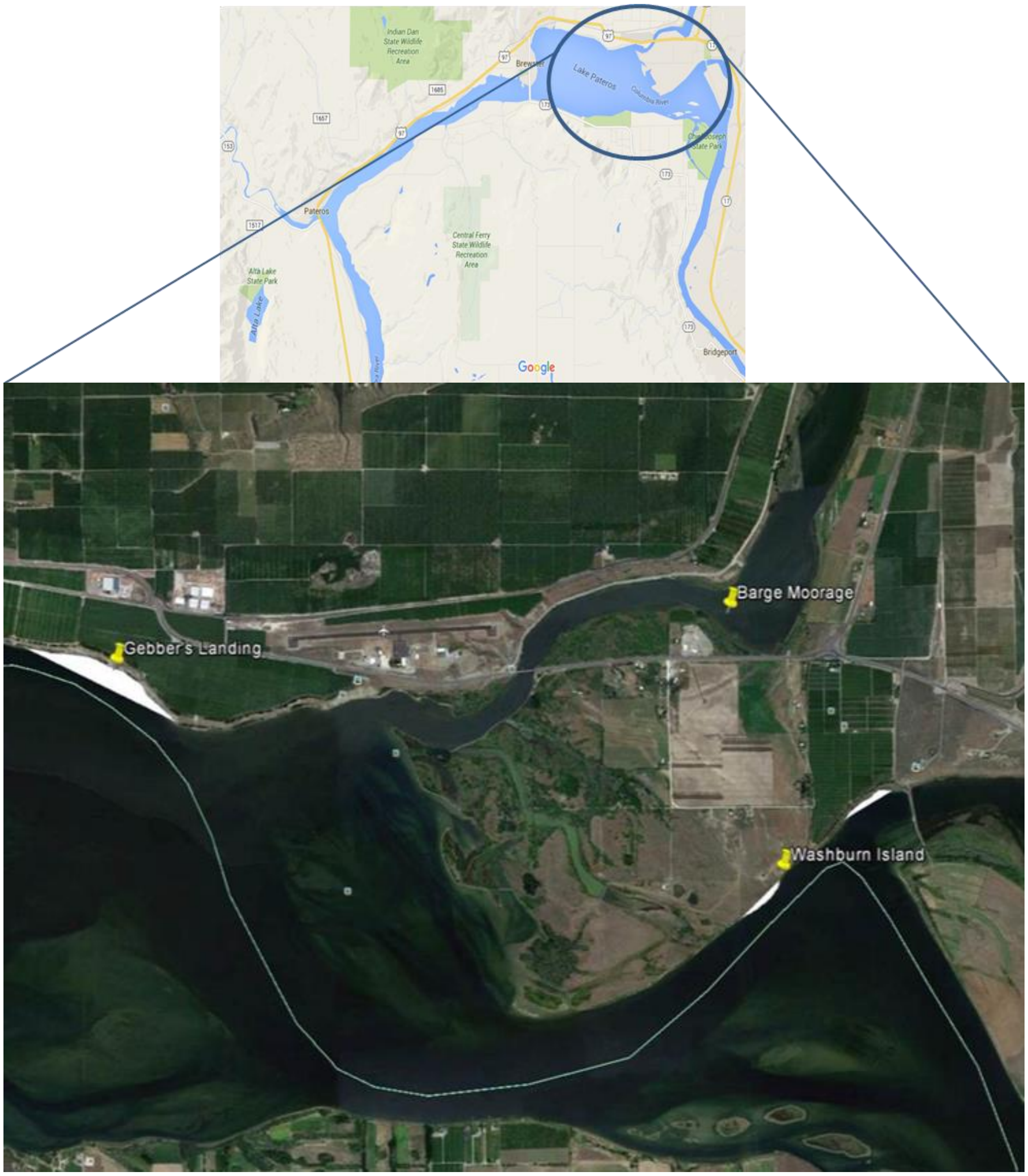


Figure 4. Seining locations downstream (Gebber's Landing) and upstream (Washburn Island) of the confluence.

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

To capture fish, one end of the seine was tied off to shore, 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 shore line (Figure 5). The seine bridle was handed from the boat to a shore crew that would retrieve the seine. Juvenile Chinook were transferred to a 10-gallon tub filled with river water and transferred to a nearby floating net pen. Handling/holding time in the tub was generally <15 minutes. Floating net pens were approximately 5 m^3 and consisted of a PVC pipe frame covered with black 19.1-mm and 3.2-mm mesh. The mesh allowed for adequate water exchange, retained juvenile Chinook and prevented the entrance of predators. Noticeable bycatch, most commonly three-spine stickleback (*Gasterosteus aculeatus*) were released from the seine without enumeration. Any bycatch inadvertently transferred to the floating net pen were later sorted and released during tagging (untagged). On May 12, 19, and 25, fish captured in the beach seine were immediately tagged on the river shore and released after recovery from anesthesia.

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

Juvenile Chinook were held 24 hours prior to tagging to assess capture/handling effects. Chinook ≥ 65mm were tagged with a full duplex 12 mm PIT tag, and Chinook between 65 and 50mm were tagged with a full duplex 9mm PIT tag. After tagging, fish were returned to a floating net pen for 24 hours post-tagging to assess tag loss and tag application/handling mortality rates. Fish were then released to the Columbia River (Wells Pool) several hundred meters downstream of their capture location.

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

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

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

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

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

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

Lower Okanogan Adult Fish Pilot Weir

The Okanogan adult fish pilot weir (herein referred to as the 'weir') was in its sixth year of design modifications and testing in 2017. 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 2017 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 broodstock 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

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 14th at a river flow of 2,280 cfs and was complete with the underwater video system on August 18th. 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). The wings of the weir stretched out from either side of the trap towards the river banks, angling downstream in a slight V configuration. The wings consisted of steel tripods with aluminum rails that supported the 3 m long Acrylonitrile butadiene styrene (ABS) pickets. Each panel was zip-tied to the adjacent panel for strength and stability. Sand bags were placed between panels when needed to fill gaps that exceeded the target picket spacing. Picket spacing ranged from 2.5 to 5.1 cm (1 to 2 inch) in 1.2 cm (half-inch) increments (Figure 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. In past years CCT has observed jack and even adult Chinook passing through the6.4 and 7.6 cm picket spacing panels. These picket spacing panels were replaced with 5.1 cm picket spacing panels during deployment to reduce the escapement of smaller hatchery Chinook. This decision was made after consultation with the Technical Oversight Group (TOG) because the majority of Sockeye had already escaped into Canada before the weir was deployed.

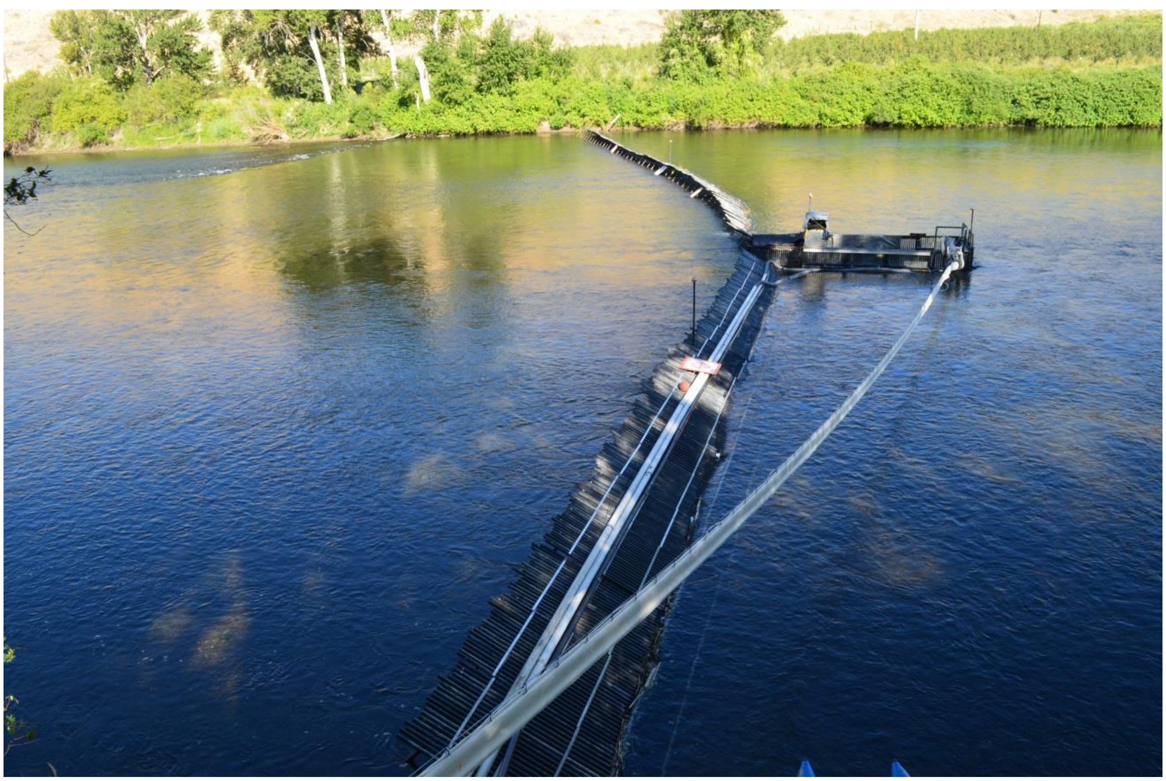


Figure 6. Lower Okanogan adult fish pilot weir, 2017. Photo taken in mid- August after deployment.

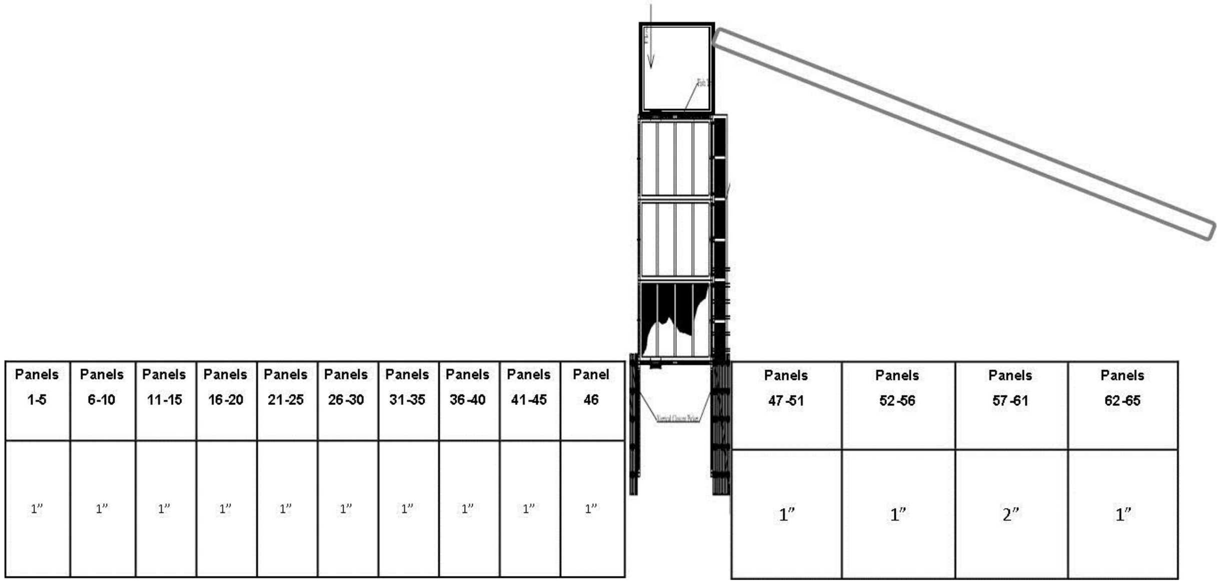


Figure 7. Conceptual diagram of picket (ABS pipe) spacing within each panel (or set of 5 panels) at the Lower Okanogan adult fish pilot weir in 2017.

On August 22nd a negative pressure transport tube, known as a Whooshh™ fish transport system, was installed to assist CCT with broodstock collection at the Okanogan weir. The 49 m tube was connected to an accelerator at the upstream side of the trap and at a mobile trailer fitted with a decelerator, tower, tube reel, blower housing, and accelerator entrance and exit mounts. A diesel generator provided remote power to run the pump that generated power for the pneumatic portions of the system.

Figure 8. Whooshh™ fish transport system installed at the Okanogan weir. Photo taken from the broodstock truck.

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

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

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

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

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

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

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

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

Trapping operations were conducted during daylight hours (0700-1500) during the first week, under allowable temperature conditions (≤22.5° C) from August 21-25. The trapping operations changed to 24 hours a day, 5 days a week, starting on August 26th. The last day of trapping was on September 20th. When fish entered the trap during an active trapping session, the downstream gate was closed and fish were identified and either released surplussed or collected for brood.

Eighty four natural origin and 9 hatchery origin Chinook were collected from the weir trap from September 5 to September 19, transported to a 2,500 gallon hatchery truck via the Whooshh™ fish transport system. The fish were then transported approximately 32 km to Chief Joseph Hatchery where they were held in the broodstock raceways until spawning in October.

Mark-recapture studies were performed at the weir trap to assess handling mortality at the weir as well as recovery bias of carcasses on the spawning grounds. All natural-origin Chinook that were trapped and destined for release upstream, were anesthetized with electronic anesthetic gloves, measured, and inserted with a floy tag. After the fish were tagged they were released over the crowder and into the upstream side of the trap where they recovered before they exited through the trap gates on their own volition.

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 3). Weekly surveys were timed to coincide with spawning in the basin, generally beginning the last week of September or the first week of October and ending approximately the second week of November. Redds were counted using a combination of fixed-wing aerial flight surveys and inflatable raft float surveys.

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

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

Table 3. Reach names and locations for the Okanogan and Similkameen for summer/fall Chinook Salmon spawning and carcass surveys.

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

All redds were classified as either a:

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

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

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

Escapement into Canada

Video systems operated by OBMEP and located in the fishways of Zosel Dam allow 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).

Passage over Zosel Dam can occur via the fishways or through the open dam gates. OBMEP assumes that any gate level > 1 foot is high enough for fish to pass upstream through the open gate rather than through the fish ladders and video arrays. In high water years, Chinook have the opportunity to pass through the gates rather than through the fishways. The estimates of Chinook escapement past Zosel Dam do not account for fish moving through the gates rather than the fishways. 2014 PIT detections of Chinook in the fishways indicated that smaller fish were able to fall back through the small openings in the Zosel Dam gates and then reascend through the fishways. An ascension/fallback/ ascension rate (AFA)was calculated and applied to the total Zosel estimate in 2014. Fallback/reascension is likely an underestimate of actual fallback since not all fallback re-ascend. Actual fallback is unknown. Due to uncertainties regarding estimations of AFA as well as the limitations of the video observation methods, Chinook passage is reported unadjusted for all subsequent years. AFA was calculated as the ratio of the number of unique PIT tagged fish (N_{PIT}) ascending the fishways, divided by the total number of their ascensions:

$$AFA = \frac{N_{PIT}}{\sum_{i-1}^{N_{PIT}} a_i}$$

where,

N_{PIT} = number of unique PIT-tagged fish ascending the ladder(s),

a_i = number of ascents made by the ith PIT-tagged fish (i= 1, …, = 1, …, N_{PIT}).

The video count (C) multiplied by the AFA provided an estimate of the total passage abundance (N):

$$N = C \cdot AFA$$

There were times when the video system was inactive for routine maintenance and cleaning. To estimate missed fish observations during this period, an average was taken of passage events during the hour before and after the inactive period. Spring Chinook were also removed from the total estimate based on run timing at Zosel.

Data and discussion presented herein are intended to begin the process of understanding what is known, what is not known, and what the possibilities are for obtaining a reliable estimate of summer/fall Chinook spawners in the Canadian portion of the Okanogan River.

CARCASS SURVEYS

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

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

The target sample size for carcass recovery efforts is 20% of the spawning population within each reach (Hillman et al. 2014). Carcass recovery efforts occurred simultaneously with redd float surveys. Recovered carcasses were transported within inflatable rafts downstream until a suitable site was found for processing. If a carcass was too degraded to sample for biological data, it was returned to the river, unsampled. 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]. Biological data collected from carcasses included sex, fork length (FL) and post-orbital hypural length (POH) to the nearest cm, and estimated egg retention for all females (0 to 5,000 max; visually estimated). All eggs that were not estimated to be within a carcass were assumed to have been successfully deposited. Any female carcass containing an estimated 5,000 eggs were considered a pre-spawn mortality. Forceps were used to remove five scale samples from all natural-origin Chinook. Scales were adhered to desiccant scale cards for preservation and identified by sample number and sample date. At the conclusion of spawning season, scales were sent to WDFW for post-hoc age analysis. Age analysis data were used to assess age-at-return (run-reconstruction), and combined with biological data to assess length-at-age. All Chinook were scanned for passive integrated transponder (PIT) tags and all PIT detections were recorded and later uploaded to PTAGIS. Carcasses were scanned with a T-wand (Northwest Marine Technology, Inc., Shaw Island, WA USA) for coded wire tags (CWT). If present, the snout portion was removed and individually bagged and labeled with species, origin, FL, river of recovery and date. After sampling each carcass, the caudal fin was removed before the carcass was returned to the river to avoid resampling on subsequent surveys. All data collected in the field were input directly into a YUMA rugged computer tablet (Trimble Navigation, Ltd.). Weekly carcass recovery totals were summed post-season to calculate annual carcass recovery totals per reach and per survey area.

Some key assumptions for carcass surveys included:

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

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

Assumption III – Sampled carcasses are representative of the overall spawning composition within each reach

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:

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

[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.

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:

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

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

[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.

was corrected for the proportion of redds in each reach to determine an adjusted Effective pHOS, such that:

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

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

PNI was calculated as:

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

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

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

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

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.

[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).

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 July 2017 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 and Spring Chinook at Riverside Pond. No PIT tags were released from Similkameen Pond in 2017. 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 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).

Spring Chinook Presence and Distribution

Smolt releases of CJH 10(j) spring-Chinook did not occur in the Okanogan until April 2015. However, occasional occurrence of spring-Chinook was detected in the Okanogan, likely due to straying of individuals from other populations. Pre-reintroduction monitoring for spring Chinook consisted of environmental DNA (eDNA) (see Laramie et al 2015 for details of the eDNA sampling) and PIT tag sampling and analysis at tributary and mainstem Okanogan sites to determine the baseline distribution, prior to the 10(j) reintroduction. In order to target spring-Chinook specifically, rather than summer/fall Chinook, eDNA samples were collected in tributary habitats, which are not typically utilized by summer/fall Chinook. Additionally, monitoring programs throughout the Columbia Basin are implanting PIT tags into both hatchery- and natural-origin spring Chinook as juveniles that might stray to the Okanogan as returning adults. The monitoring programs at Bonneville and Wells dams tagged returning adult spring Chinook, which greatly increased the probability of encountering spring Chinook with a PIT tag in the Okanogan. In 2017, the spatial distribution of spring Chinook was evaluated using a combination of eDNA and PIT tag data. We queried the PTAGIS database using an interrogation summary for all PIT detection sites in the Okanogan and Similkameen Rivers, including Canada. Once a list of tag codes was obtained, a complete tag history query was run to determine for all spring Chinook detected as returning adults in the Okanogan river basin to determine if any of the fish had a final detection outside the Okanogan. 2017 was the first year for adults (4 year olds) to return from the releases of PIT tagged juveniles as part of the CJH program.

Coded Wire Tag Lab Analysis

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

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

CWTs were expanded based on their mark and sample rate to estimate total catch contribution for a specific fishery. For each fishery, every CWT recovered was grouped according to the hatchery from which it originated, then divided by mark and sample rate to expand the number of fish caught. It was common to see many different tag codes from the same hatchery during a given brood year. These tags need to be summed together then multiplied by an adjustment factor to adjust for tags that are present, as well as lost and unreadable. This methodology is applied to all recovered CWTs in a given area, then summed together to represent the total number of fish harvested as well as their place of origin. The following equations are used to expand and adjust for CWT recoveries:

$$CWT_{Expansion} = \frac{Total\ Recovered}{Tag\ Rate} \cdot \left(\frac{1}{Sample\ Rate}\right) \cdot (XYZ)$$

where *Total Recovered* was the total number of recovered tags in the fishery, *Tag Rate* was the proportion of fish that are coded wire tagged in the tag group (expressed as a decimal percentage), *Sample Rate* was the proportion of the total catch that are sampled for CWTs, and *XYZ* was the total adjustment factor calculated from recoveries without a decoded tag.

Coded wire tag recoveries were also adjusted for tags not adhering to the normal recovery process. That process was: the snout arrives at the lab, the tag is extracted from the snout, the tag is readable, and the result matches the tag's release information. Recovery results fall into one of two general categories: with and without decoded tags. They were assigned one of the following CWT result codes after completing the snout recovery to tag reading procedure:

<u>Recoveries with a decoded tag:</u>

1 Code read from the wire tag matches a tag release and is consistent with release information.
9 The wire tag has no code (blank) or agency-only code.
7 Code read from the wire tag does not match a tag release, or it is not consistent with the release information.

<u>Recoveries without a decoded tag:</u>

4 Tag wire was present, but the code is unreadable.
3 Tag wire was present (dissected from the snout) but was lost prior to the reading process.
2 Tag was not present in snout.
8 Snout was determined in the field to be from a wire-tagged fish, but the snout was not processed in the Tag Recovery Lab.

Decoded recoveries were adjusted for CWT result code 8 (represented as *X* in the expansion formula), CWT result code 4 (represented as *Y* in the expansion formula), and CWT result code 3 (represented as *Z* in the expansion formula). The formulas for these adjustment factors were as follows and are applied to CWT result codes 1,7 and 9 recoveries:

(1) The adjustment factor due to the presence of CWT result code 8 tags is

$$X = \frac{\text{Tags}_1 + \text{Tags}_2 + \text{Tags}_3 + \text{Tags}_4 + \text{Tags}_7 + \mathbf{Tags_8} + \text{Tags}_9}{\text{Tags}_1 + \text{Tags}_2 + \text{Tags}_3 + \text{Tags}_4 + \text{Tags}_7 + \text{Tags}_9}$$

(2) The lost tag recoveries (code 3) are accounted for by the following formula:

$$Y = \frac{\text{Tags}_1 + \mathbf{Tags_3} + \text{Tags}_4 + \text{Tags}_7 + \text{Tags}_9}{\text{Tags}_1 + \text{Tags}_4 + \text{Tags}_7 + \text{Tags}_9}$$

(3) The unreadable tag recoveries (code 4) are accounted for by the following formula:

$$Z = \frac{Tags_1 + \mathbf{Tags_4} + Tags_7 + Tags_9}{Tags_1 + Tags_7 + Tags_9}$$

(4) Finally, any CWT result code 3, 4, or 8 recovery is assigned an expansion factor of zero, since its presence is accounted for in the decoded recoveries by the above adjustment equations. Decoded tags are not adjusted for CWT result code 2 "no tags".

RESULTS

Rotary Screw Traps

The rotary screw traps captured 10,934 Chinook juvenile out migrants, including 2,140 hatchery- and 8,794 natural-origin. Pulses of high catch rates coincided with the installation of the 5-ft trap, and periods of increasing streamflow in mid- and late-May (Figure 9). The mean length of Chinook increased throughout the trapping season, but the number of natural-origin smolts that were large enough (>60 mm) to PIT tag was small (n=553) (Figure 10). No natural-origin fish were captured that were likely yearling Chinook.

Following Chinook, the next most abundant species captured in the RST was mountain whitefish (Table 4). Notably, only 39 sockeye were detected, which is far lower than in some previous years. 18 adipose fin present[6] steelhead and 14 adipose fin absent (hatchery-origin) steelhead were removed from the trap and released immediately into the river. There were no juvenile steelhead mortalities at the trap resulting in a 0% juvenile trapping and handling mortality rate for steelhead. The encounter of 14 adipose clipped and 18 adipose present (assumed natural-origin) and mortality of zero (0) assumed natural-origin steelhead are within the take limits identified in the authorizing ESA Section 10(a)(1)(A) Permit for the rotary screw trap operation (Permit 16122).

[6] Not all hatchery steelhead released in the Okanogan receive an adipose fin clip. In 2017, 29,214 steelhead were released into the Similkameen River with an adipose clip, and 53 unclipped steelhead were released. In Omak Creek and the Okanogan River, 16,016 and 5,004 unclipped steelhead were released, respectively 39,926 adipose clipped and 72 unclipped steelhead were released into Salmon Creek in 2017.

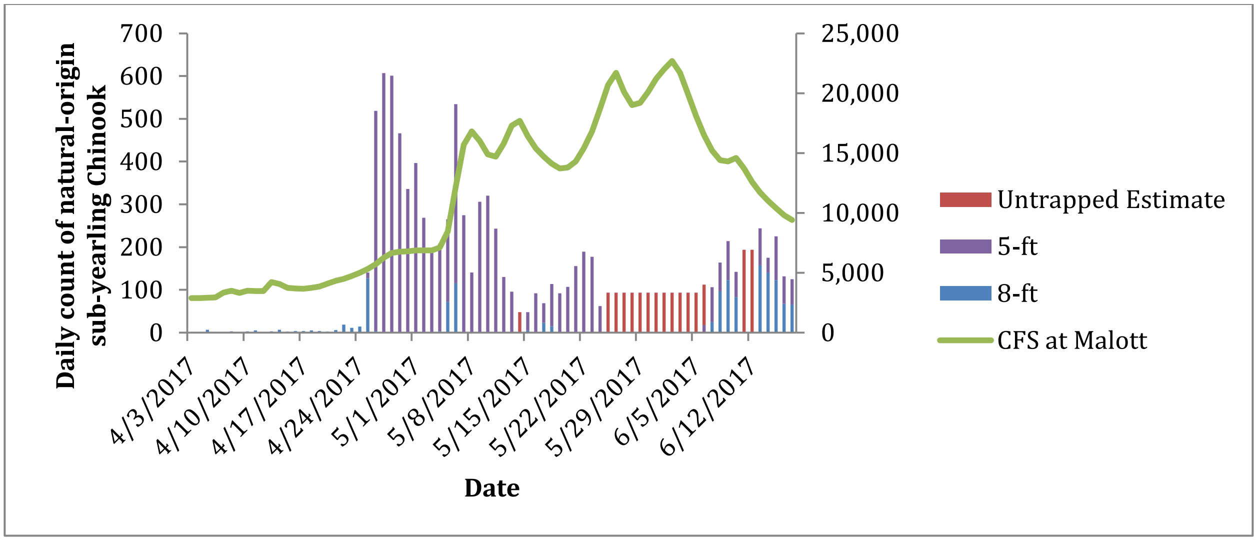


Figure 9. Daily natural-origin sub-yearling Chinook catch in the CJHP rotary screw trapping operation in the Okanogan River in 2017. Traps consisted of two rotary screw traps; one 5 foot diameter (5-ft) and one 8 foot diameter (8-ft).

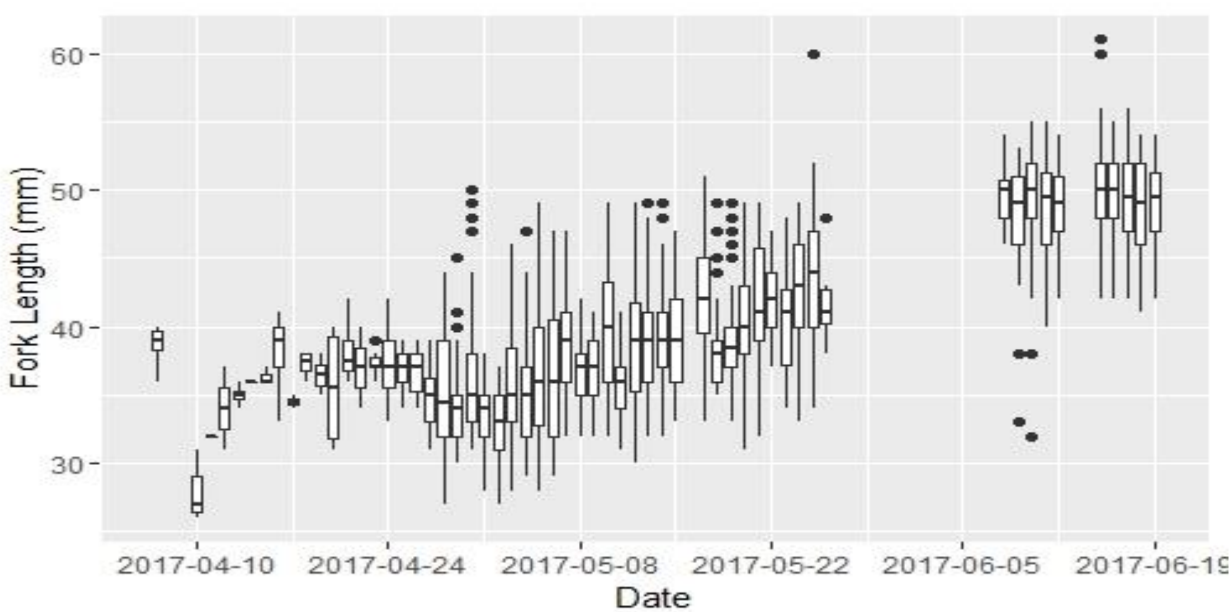


Figure 10. Natural-origin sub-yearling Chinook size distribution (n= 1,986) from the rotary screw traps on the Okanogan River in 2017. Boxes encompass the 25th to 75th percentiles of measured fish, the mid-line in the box is the median fish length.

Table 4. Number of juvenile fish trapped at the Okanogan River rotary screw traps in 2017.

Species	Total Trapped
Bluegill	19
Bridgelip Sucker	9
Common Carp	462
Longnose Dace	4
Mountain Whitefish	931
Northern Pikeminnow	9
Largemouth Bass	1
Sculpin (*Cottus* spp.)	3
Smallmouth Bass	2
Three Spine Stickleback	18
Peamouth	1
Redside shiner	7
Crappie (*Pomoxis* spp.)	1
Bullhead (*Ameiurus* spp.)	29
Yellow Perch	113
Non-salmonid	816
Adipose Clipped Steelhead	14
Adipose Present Steelhead	18
Hatchery Chinook	2,140
Sockeye	39
Wild Chinook Subs	8,794
Wild Chinook Yearling	0
Eastern Brook Trout	2
Salmonid	13,402

Two efficiency trials were conducted with juvenile Chinook (one with hatchery-origin yearlings and one with hatchery-origin subyearlings) at 3,350 and 15,200 cfs (Table 5.). Since RST efficiency and Okanogan River flow have not been correlated in the past and the number of efficiency trials conducted in 2017 was not large enough to show correlation during this year, the WDFW smolt abundance calculator was not employed, and pooled estimates were used.

Table 5. Efficiency trials conducted on natural-origin Chinook sub-yearlings at the Okanogan rotary screw traps in April and May, 2017.

Trap Date	River Flow @ USGS Malott	Total Chinook Marked and Released	Age Class / Origin	Total Chinook Recaptured	Trap Efficiency
4/11	3,350	1,124	1+ / Hatchery	38	0.034
5/16	15,200	1,024	0+ / Wild	6	0.006
Total		**2,148**		**44**	**0.020**

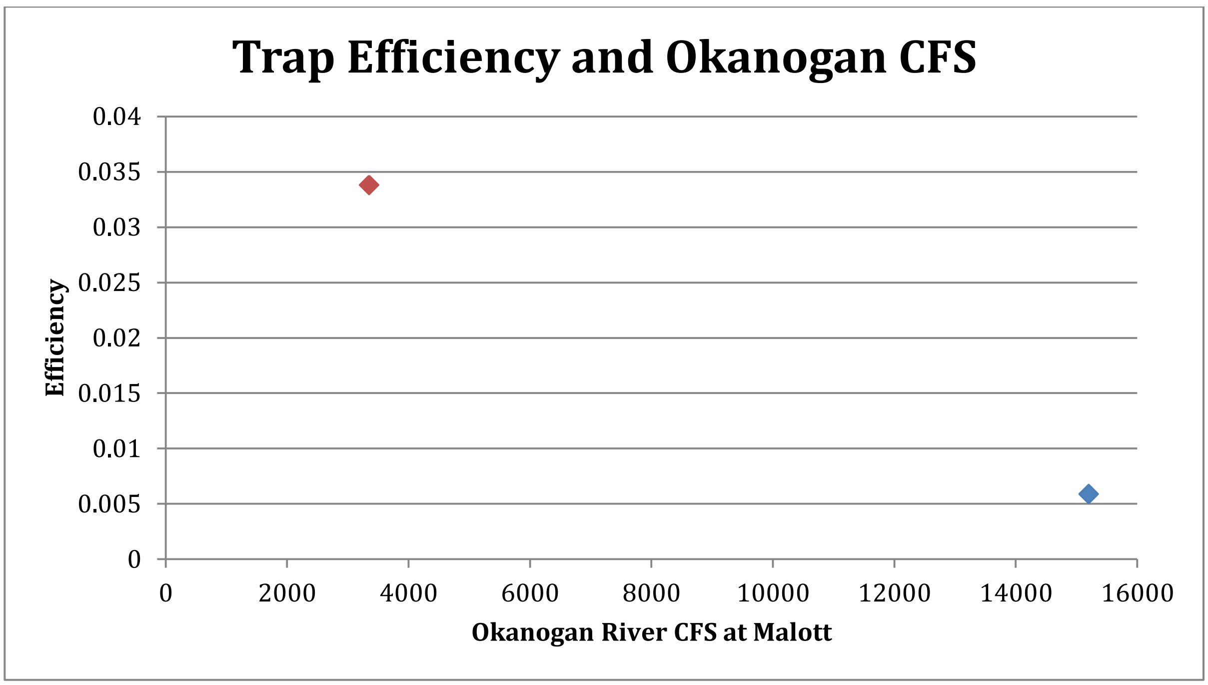


Figure 11. The efficiency trial conducted with hatchery-origin subyearlings is marked in blue, the trial conducted with hatchery-origin yearlings is marked in red.

It should be noted that the efficiency trial conducted on April 11 using a hatchery yearlings from the Omak Pond (Table 5) as a release group is not a good proxy for natural-origin subyearling Chinook. In the past, such trials have been used to explore the possibility of using hatchery-origin yearlings as a surrogate for natural-origin subyearlings, but significant differences in capture efficiency ultimately led to the abandonment of this idea (see 2015 Annual Report). Nevertheless, a trial with hatchery-origin yearlings was conducted in 2017. Thirty-eight hatchery-origin yearlings out of 1,124 released were recaptured (.34% efficiency).

The higher trapping efficiencies encountered in 2017 and previous years for yearling Chinook indicates that the RST may be a useful tool in future years for estimation of yearling out-migrating Chinook. Yearling outmigrants are likely to increase in number once hatchery-origin spring Chinook released into the Okanogan river basin begin to return, and any of their potential progeny out-migrate.

Since streamflow did not affect trapping efficiency, efficiency trials were pooled to calculate overall trap efficiency for both natural- and hatchery-origin fish (Table 6). Overall efficiency estimates for natural- and hatchery-origin fish were low as were total catches, leading to a relatively imprecise estimate of total emigration (Table 7).

Table 6. Pooled efficiency trail results for all trap configurations. Whenever fish were released, each trap was operational. Efficiency was calculated based on recaptures for each individual trap, as well as the combined efficiency of both traps.

		Mark-Released	**Recaptured**	**Efficiency**
2.4 m Trap	Hatchery Subyearling	1,024	2	3.38%
	Hatchery Yearling	1,124	38	0.072%
1.5 m Trap	Hatchery Subyearling	1,024	4	0.39%
	Hatchery Yearling	N/A	N/A	N/A
Combined Traps	Hatchery Subyearling	1,024	6	0.59%
	Hatchery Yearling	N/A	N/A	N/A

Table 7. Population estimates for hatchery- and natural-origin juvenile Chinook salmon in the Okanogan River Basin.

Species	**Population Estimate**	**Lower 95% Confidence Interval**	**Upper 95% Confidence Interval**
Hatchery-origin Chinook*	108,572	2,140**	249,531
Natural-origin Chinook	1,209,216	8,734**	4,576,536

* A total of 762,465 hatchery-origin Chinook were released into the Okanogan River system upriver from the screw trap site in 2017. 201,821 were released from the Riverside acclimation pond from April 13-17; 131,114 were released from the Similkameen hatchery from April 12 – April 15; 212,726 were released from the Omak acclimation pond on April 13-19; and 216,804 were released from Omak Pond on May 22.

** The number of fish captured in the RST during the 2017 trapping season was used as a floor for the 95% confidence interval

Juvenile Beach Seine and Pit Tagging

In 2017, 25,850 natural-origin juvenile salmonids were collected in over the course of 19 tagging days (Table 8.). Out of the juvenile summer/fall Chinook collected, 21,280 (82%) sub-yearling Chinook were PIT tagged and released (Figure 12). Pre- and post-tag mortality was 2.4% and 3.7% respectively. Eighty-six shed tags were recovered from the net pens prior to release. Seventy-seven of the sheds were from post-tag mortalities, the other nine were ejected from fish that were later released alive, but without a tag. All recovered tags were removed from the tagging file before upload to PTAGIS. Fish size increased through time (Figure 13), but after peaking in the week beginning on 18 June, the number of fish available for capture at Gebber's rapidly and dramatically declined (Table 8). By late-June, Columbia River temperatures had risen to above 14° C. We suspect that sub-yearling Chinook may have migrated downstream, or to deeper, cooler water making it difficult to collect them via beach seine, as has presumably happened in past years. Fork length for tagged fish ranged from 48-110 mm, with an average of 70.4 mm (Standard Deviation 8.9 mm) and a median of 70 mm (Figure 14). Bycatch included hatchery-origin juvenile Chinook, three-spine stickleback, mountain whitefish, smallmouth bass, and sculpin species.

Table 8. Summary of juvenile Chinook beach seining effort at Gebber's Landing (Geb.) and Washburn Island in 2017.

Week start	Gebber's Fish Collected	Gebber's Fish Tagged	Proportion Gebber's Fish Tagged	Washburn Fish Collected	Washburn Fish Tagged	Proportion Washburn Fish Tagged
5/7/2017	6	6	100%	1	1	100%
5/14/2017	0	0	--	0	0	--
5/21/2017	34	34	100%	10	10	100%
5/28/2017	170	160	94%	0	0	--
6/4/2017	4713	3263	69%	0	0	--
6/11/2017	6497	5662	87%	0	0	--
6/18/2017	10498	9570	91%	0	0	--
6/25/2017	721	704	98%	3191	2823	88%
Total	**22,639**	**19,399**		**3202**	**37**	
Mean	**2829.875**	**2,425**		**400**	**4**	

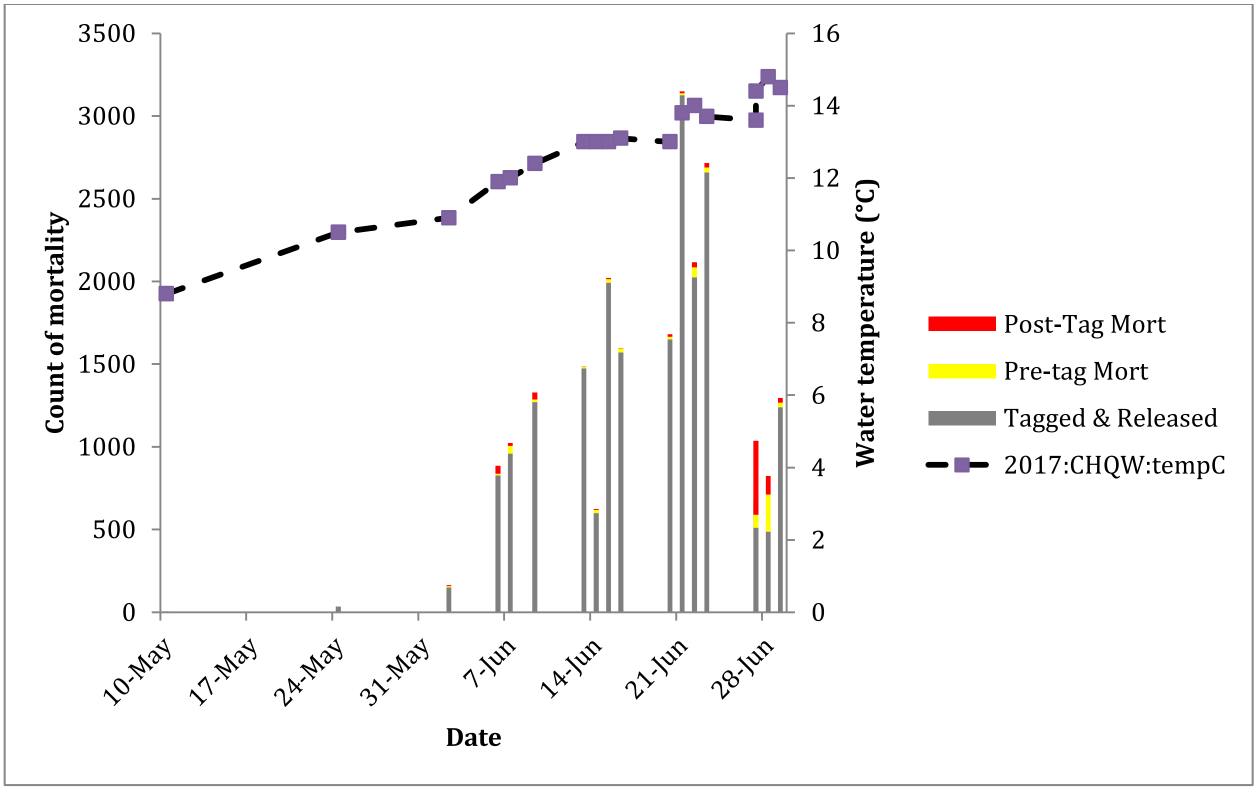


Figure 12. Total mortality and number of released natural-origin sub-yearling Chinook in 2017.

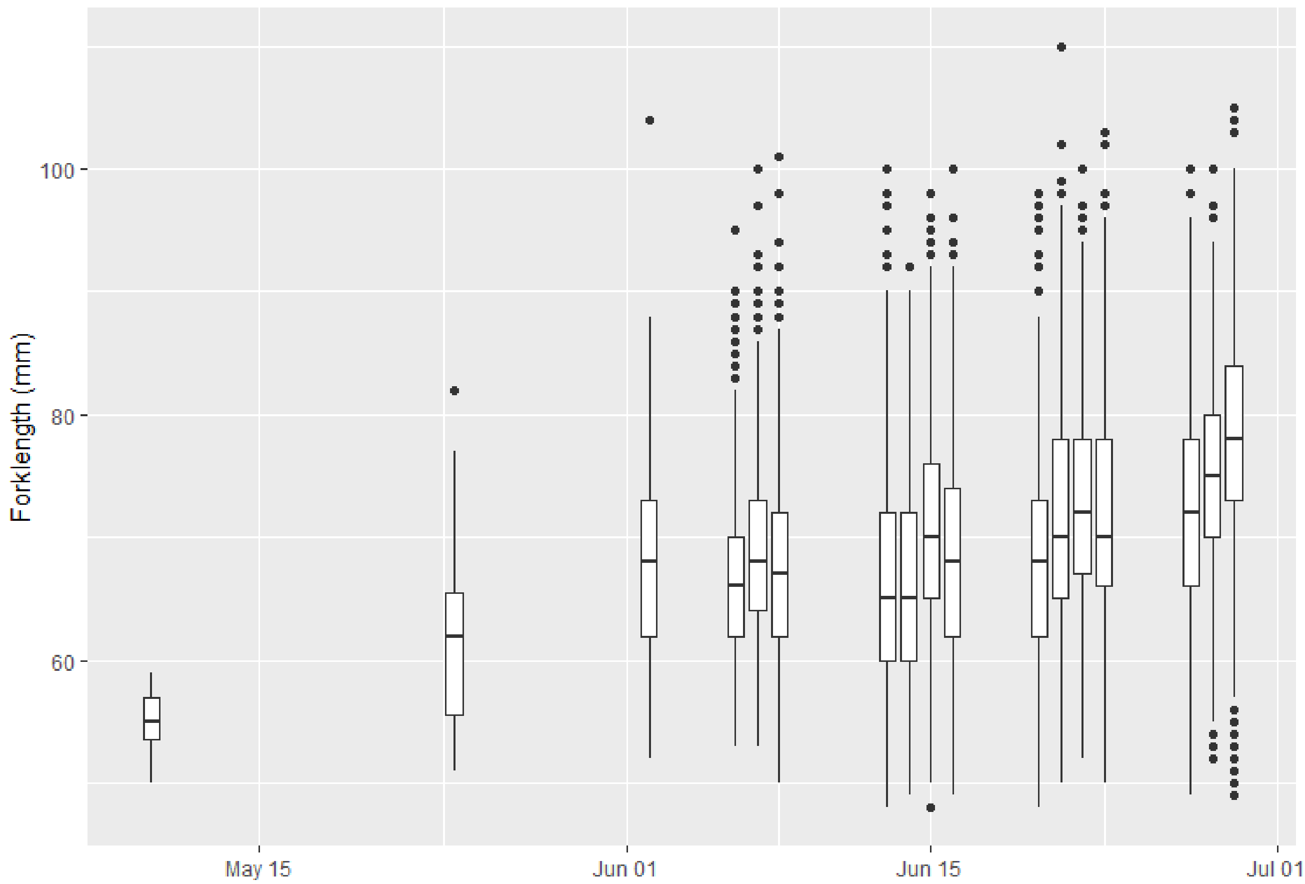


Figure 13. Size distribution of PIT tagged juvenile Chinook by release date from the beach seine effort in 2017. Boxes encompass the 25th to 75th percentiles of measured fish, the mid-line in the box is the median fish length.

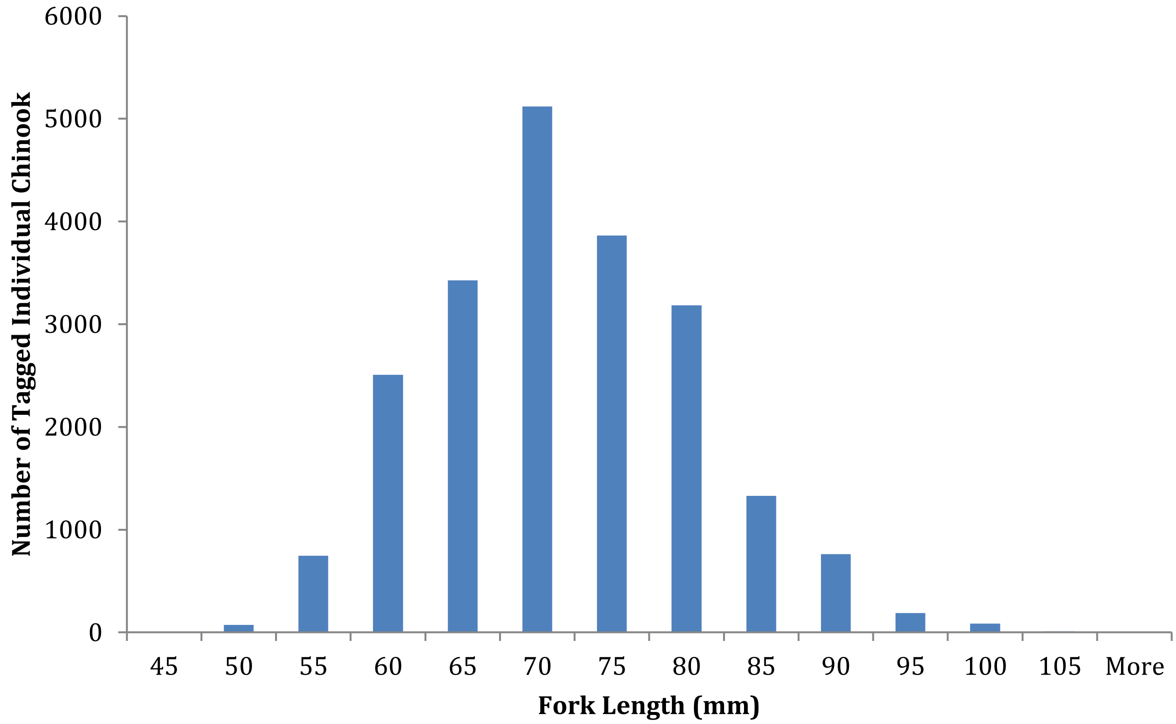
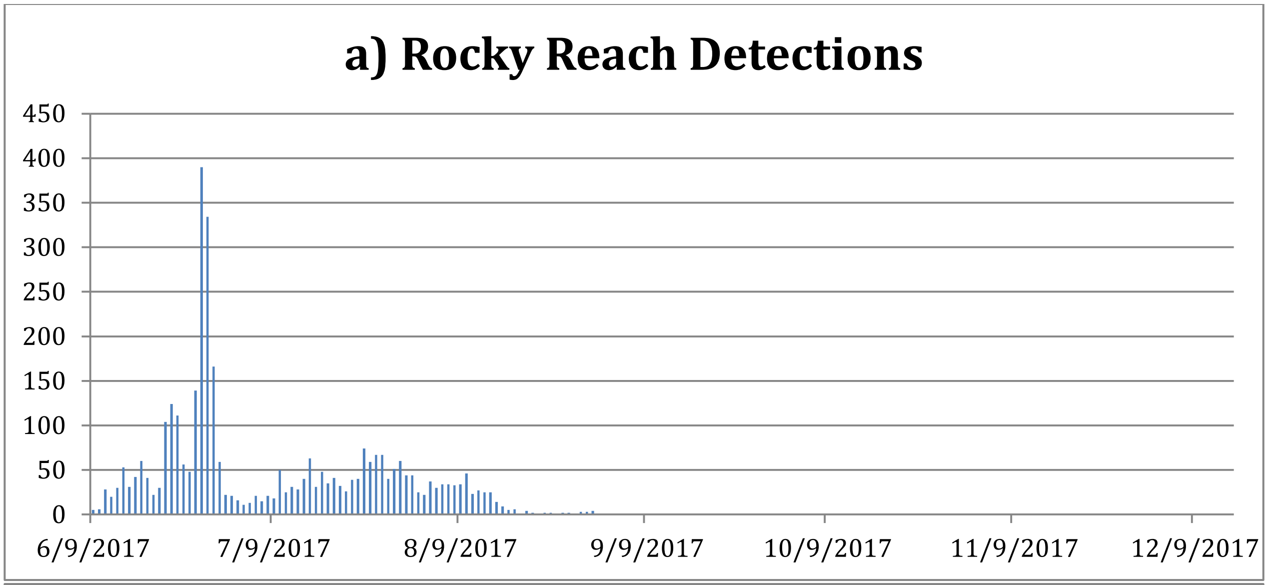
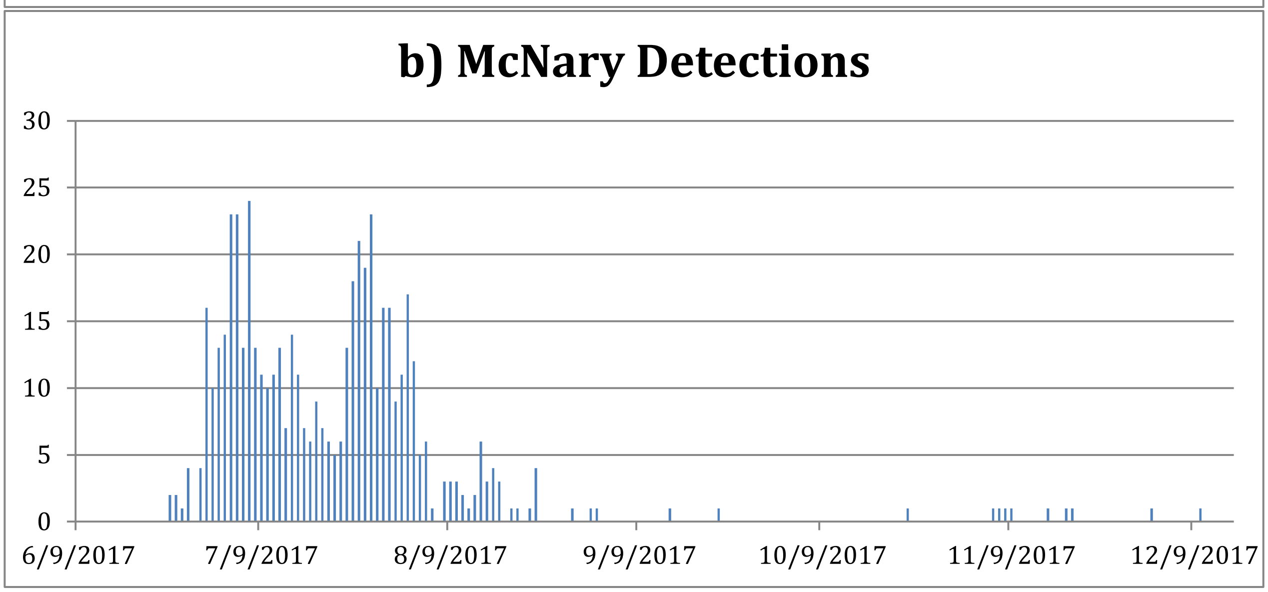


Figure 14. Size distribution of natural origin sub-yearling Chinook tagged during the beach seining effort in 2017

3,547 PIT tagged juvenile Chinook were detected at the Rocky Reach juvenile bypass system, which was 16.7% of total fish tagged and released. 534 (2.51%), 262 (1.23%) and 248 (1.17%) were detected at the McNary, John Day and Bonneville Dams respectively. Detections for sub-yearlings occurred primarily from late-June to early-July at all downriver dams (Figure 15).


a) Rocky Reach Detections
450
400
350
300
250
200
150
100
50
0
6/9/2017
7/9/2017
8/9/2017
9/9/2017
10/9/2017
11/9/2017
12/9/2017


b) McNary Detections
30
25
20
15
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9/9/2017
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11/9/2017
12/9/2017

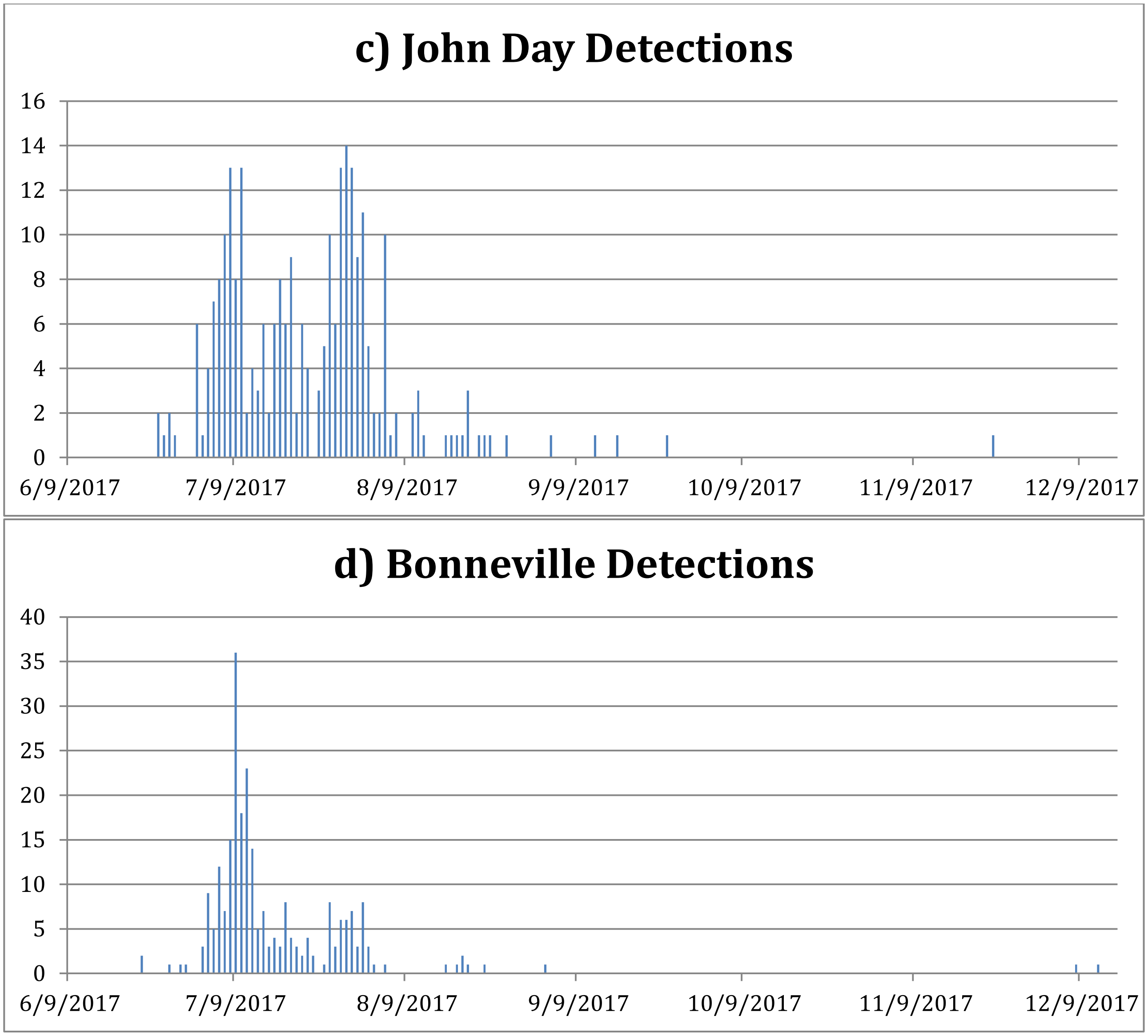


Figure 15. Daily distribution of detections of PIT-tagged sub-yearling Chinook at Rocky Reach, McNary, John Day, and Bonneville Dams in 2017. Note differences in scale on the y-axis. The y axes denote the numbers of PIT-tagged fish encountered daily at each of the mainstem project arrays.

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 began to move downstream more quickly the further downstream they travelled(Table 9). Larger fish travelled faster to Rocky Reach Dam (Figure 16). This is similar to what was reported in 2011-2013 by Douglas County PUD and observed in previous years by CCT.

Table 9. 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)	19.1 (Standard Deviation = 16.33; n=3494)	4.9	33.3 (Standard Deviation = 20.1; n=503)	11.6	35.2 (Standard Deviation = 14.9; n=259)	14.5	29.9 (Standard Deviation= 16.74; n=248)	20.1
Rocky Reach (762)			17.8 (Standard Deviation = 10.7; n=181)	16.4	22.0 (Standard Deviation = 11.5; n=92)	18.8	18.8 (Standard Deviation = 6.62; n=89	28.0
McNary (470)					3.2 (Standard Deviation = 1.5; n=30)	37.9	4.5 (Standard Deviation=0.84; n=19)	52.5
John Day (347)							1.6 (Standard Deviation = 0.58; n=25)	71.8

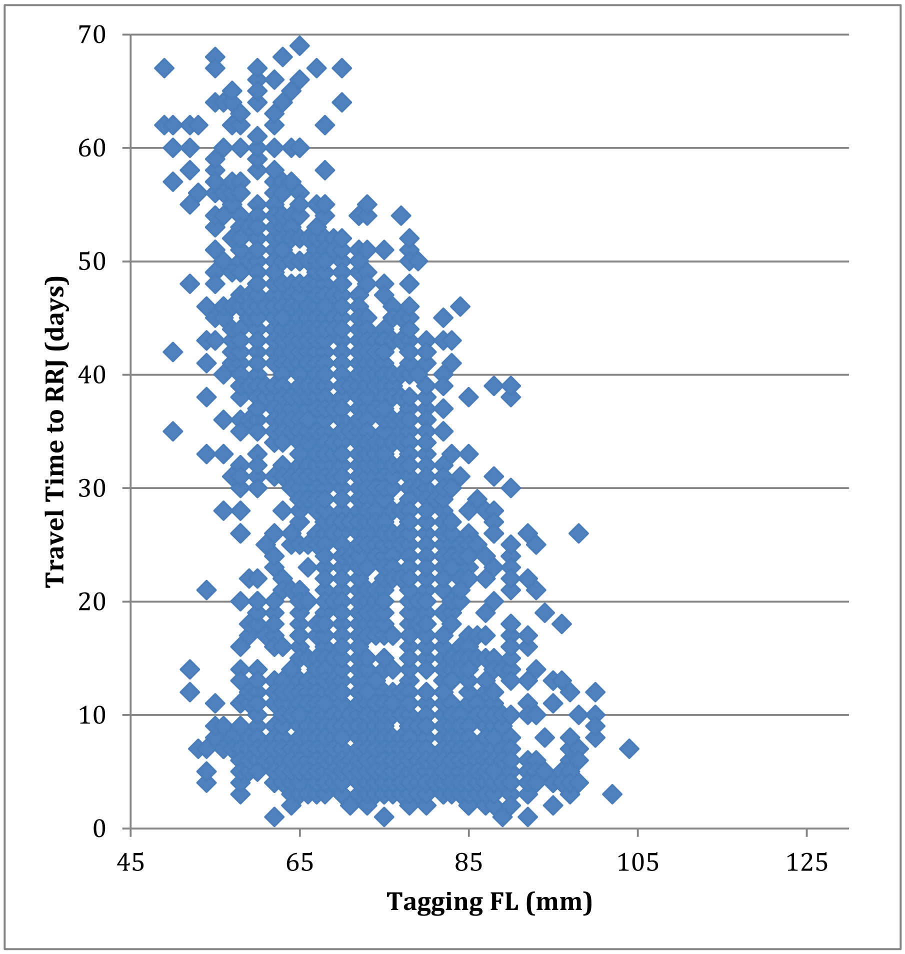


Figure 16. Fish size (fork length) and travel time of tagged Chinook to Rocky Reach Dam.

Lower Okanogan Adult Fish Pilot Weir

The Okanogan River (at Malott) discharge was above normal in 2017 and was below 2,000 cfs for the trapping season. Staff were able to safely enter the river and begin installation on August 14th when discharge was 2,280 cfs (Figure 17). Discharge continued to drop throughout the season and was at 860 cfs by the time the weir was removed for the season.

Migration of Sockeye and summer Chinook is generally affected by a thermal barrier that is caused by warm water temperatures (≥~22 °C) in the lower Okanogan River. The thermal barrier is dynamic within and between years, but generally it sets up in mid-July and breaks down in late August. In some years, the Okanogan River will temporarily cool off due to a combination of interrelated weather factors including rainstorms, cool weather, cloud cover or wildfire smoke. This 'break' in the thermal barrier can allow a portion of the fish holding in the Columbia River to enter the Okanogan and migrate up to thermal refuge in the Similkameen River or Lake Osoyoos. In 2017, temperatures were similar to, though occasionally higher than the median daily temperatures from the last 10 years (Figure 18). Daily mean temperature was above 22.5 °C from July 1 to August 25. Daily mean temperature dropped below 22.5 °C on August 25th and stayed below this mark for the rest of the season.

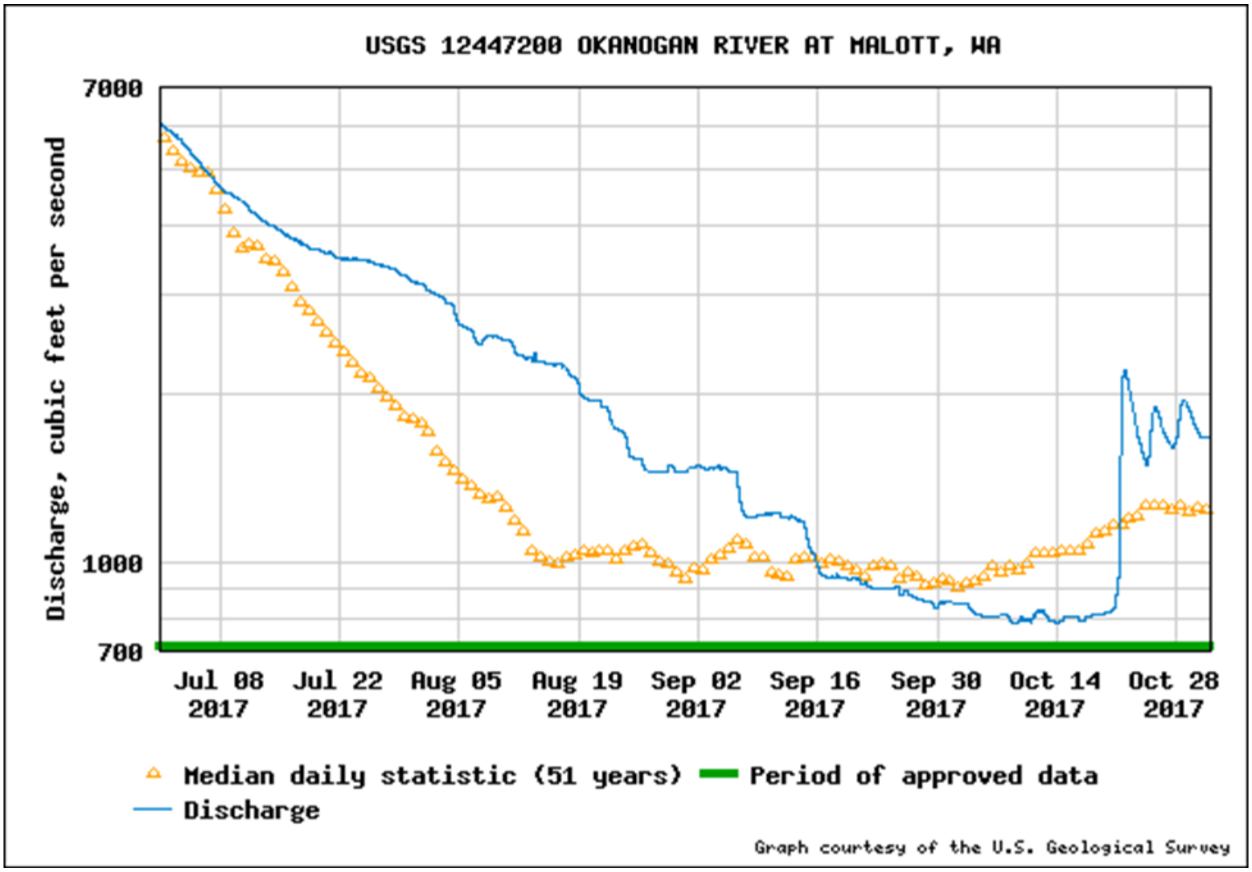


Figure 17. Discharge of the Okanogan River between July 1 and October 31, 2017. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

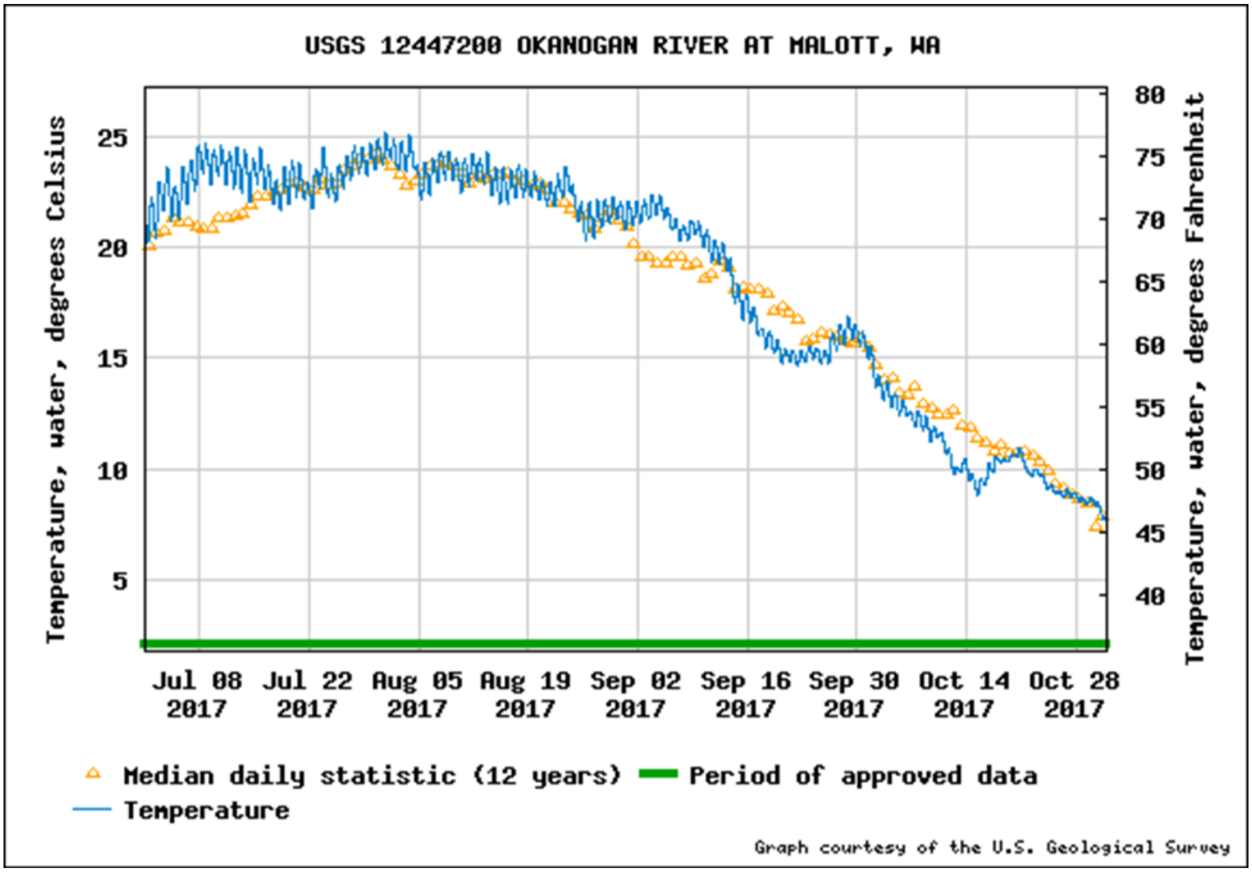


Figure 18. Temperature of the Okanogan River between July 1 and October 31, 2017. This figure was copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

Dissolved Oxygen varied from 5.2 to 8.2 mg/L, total dissolved solids varied from 134-148 ppm and turbidity varied from 1.2 and 2.5 NTUs (Table 10). The head differential ranged from 0-10 cm across the weir panels (Table 11). The maximum water velocity measured was 3.3 ft./sec. (Table 12).

Table 10. Water quality data at or near the lower Okanogan weir in 2017. Temperature and discharge were taken from the USGS gauge at Malott.

Date	Trap Depth (ft.)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (ppm)	Turbidity (NTU)
8/23	2.3	7.5	144	2.0
8/24	2.2	7.9	148	1.5
8/25	2.2	7.8	142	1.8
8/28	2.2	7.7	148	1.8
8/29	2.1	7.4	147	1.8
8/30	2.2	7.0	146	1.5
8/31	2.3	6.3	143	1.9
9/1	2.3	5.8	141	1.7
9/5	2.3	5.6	146	1.5
9/6	2.3	5.5	145	2.2
9/7	2.1	5.9	144	1.6
9/8	2.1	7.1	147	2.5
9/11	2.0	6.5	143	1.6
9/12	2.0	8.1	144	1.5
9/13	2.0	7.3	142	1.5
9/14	2.0	8.2	137	2.5
9/15	2.0	8.1	135	1.3
9/18	2.0	7.9	138	1.7
9/19	1.8	5.2	135	2.2
9/20	1.8	5.6	134	1.7
9/21	1.8	7.3	135	1.2
Min	1.8	5.2	134	1.2
Max	2.3	8.2	148	2.5

Table 11. Head differential across the different picket spacings. If differential exceeded 10 cm, pickets were cleaned immediately. Measurements are in cm. Daily mean gage height is included in feet. Gage height is copied directly from the USGS website (http://nwis.waterdata.usgs.gov/wa).

Date	1.0" Picket Spacing (cm)	1.5" Picket Spacing (cm)	2.0" Picket Spacing (cm)	Gage Height (ft.).
8/25	10.2	0.0	5.1	3.7
8/28	10.2	0.0	5.1	3.6
8/29	10.2	0.0	5.1	3.6
8/30	10.2	0.0	5.1	3.6
9/1	10.2	0.0	5.1	3.6
9/5	7.6	0.0	0.0	3.6
9/6	10.2	0.0	0.0	3.5
9/7	7.6	0.0	2.5	3.4
9/8	10.2	0.0	2.5	3.4
9/11	10.2	0.0	2.5	3.4
9/13	5.1	0.0	2.5	3.3
9/15	7.6	0.0	2.5	3.2
9/18	5.1	0.0	2.5	3.1
9/21	7.6	0.0	2.5	3.1
Min	5.1	0.0	0.0	3.1
Max	10.2	0.0	5.1	3.7

Table 12. 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	Center US	River Right US	River Left DS	Center DS	River Right DS	Trap Velocity
8/23	1.9	0.7	1.1	2.5	1.5	2.7	0.2
8/24	2.6	1.4	1.9	2.6	1.8	3.3	1.7
8/25	1.8	1.3	1.7	2.2	2.7	1.5	1.6
8/28	2.5	1.5	1.8	2.4	1.9	2.1	1.7
8/29	2.4	1.3	1.9	1.9	2.7	3.0	2.0
8/30	2.5	1.3	2.1	1.8	2.3	2.8	1.9
8/31	2.5	1.1	2.2	2.3	1.7	2.2	1.2
9/1	2.5	0.3	2.1	2.2	2.0	2.8	1.4
9/5	2.4	1.3	1.6	1.8	1.6	3.3	1.6
9/6	2.4	1.4	1.4	2.4	1.4	3.2	1.8
9/7	2.6	1.3	1.7	2.0	1.7	2.7	1.3
9/8	2.5	1.1	1.9	2.3	1.8	2.5	1.5
9/11	2.3	1.3	2.8	2.2	2.1	2.5	1.7
9/12	2.4	1.1	1.6	2.5	1.5	2.2	1.9
9/13	2.3	1.3	2.2	2.0	1.9	2.8	1.9
9/14	2.5	1.2	1.9	2.1	1.7	2.6	1.8
9/15	2.4	1.2	1.9	1.4	2.3	2.1	1.9
9/18	2.2	1.0	1.5	1.4	1.9	2.0	1.6
9/19	1.9	1.2	1.5	1.7	1.9	2.3	1.9
9/20	1.9	1.6	1.7	1.7	1.5	1.9	1.4
9/21	1.9	1.2	1.9	2.0	2.1	1.8	1.8
Min	1.8	0.3	1.1	1.4	1.4	1.5	0.2
Max	2.6	1.6	2.8	2.6	2.7	3.3	2.0

Ninety one dead fish were removed from the weir between August 23 and September 20 (Table 13). Chinook Salmon were the most commonly encountered species (74%). There were no Steelhead mortalities removed from the weir in 2017. All mortalities were impinged on the upstream side of weir indicating that they had most likely died upstream and floated down onto the weir. The majority of the Chinook carcasses were observed a week before the majority of Chinook were encountered in the trap (Figure 19). There were also no observations of fish caught between pickets in a head upstream direction, which would have indicated that a fish got stuck and died while trying to push through the pickets.

Table 13. Date and species of fish mortalities observed at the lower Okanogan fish weir in 2017. All fish mortalities were considered "wash downs" and collected on the upstream panels of the weir.

Date	Carp	Chinook	Mountain Whitefish	Smallmouth Bass	Sockeye	Unknown Sucker
8/23		2				
8/24		1			1	
8/25	3	4			1	
8/26	1	2				
8/27	1	1			1	
8/28	2	2			1	
8/29		3			2	
8/30	1				2	3
8/31		4			2	
9/1				1	4	
9/2						
9/3						
9/4						
9/5		9			2	
9/6	3					
9/7	2	2				
9/8	5					
9/9						
9/10						
9/11		1			2	
9/12					1	
9/13	2					1
9/14	2				1	1
9/15	1					1
9/16						
9/17						
9/18					1	
9/19	1				3	2
9/20						3
Total	**24**	**31**	**0**	**1**	**24**	**11**

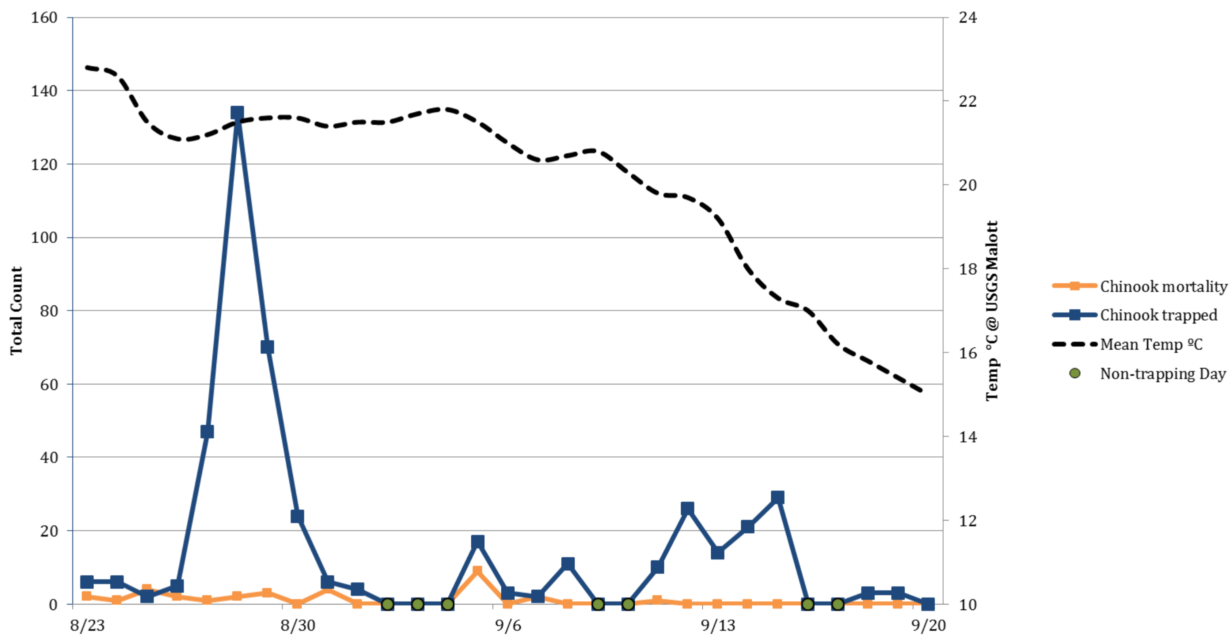


Figure 19 . Total number of Chinook trapped and total number of Chinook carcasses collected off the weir panels. The majority of the Chinook carcasses occurred a week before most Chinook were encountered in the trap.

Tower observations showed that most fish were equally distributed across the river, milling in the river right, left and center sections (looking downstream). Estimates were highest during the last week 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 two days after the thermal barrier breakdown and then decreased until the second week in September. During that time the highest daily estimates of fish were observed throughout the week (Figure 6). Trapping operations were conducted on August 21st when river temperature was ≤ 22.5 °C. The total fish trapped at the weir in 2017 was 492 with 91% of them being Chinook Salmon (Figure 7). Seventy percent of the Chinook trapped were released back into the river (Figure 8). Two steelhead were trapped between 9/10-9/20 and released in good condition within 30 minutes of observation. The TOG was notified when steelhead were trapped, including the total number, origin and condition after release. To reduce handling of fish, trap attendants opened the gate of the crowder and the upstream gate of the trap to allow for complete passage. Fish that were passed upstream were classified as having a vigorous condition, swimming away unharmed.

Prior to collecting broodstock we conducted several tests using hatchery origin fish brought to the weir via the hatchery truck. Eight adults and two jacks were manually carried to the weir in a boot (inner-tube) which took approximately 90 seconds each. These fish were sent back to the hatchery truck via the Whooshh™ transport tube in approximately eight seconds. This process was repeated three times over a several hour period. There were no immediate mortalities, although two fish were dead upon arrival at the hatchery that evening (nearly 10 hours after their initial capture in the hatchery ladder). This test was considered a success and the mortalities were not a concern because the fish had been handled much more extensively than the natural origin brood would be.

Sixteen natural origin Chinook were transported to the hatchery and held in the broodstock ponds concurrently with the fish taken for broodstock from the purse seine, hatchery ladder, and beach seine. Adult Chinook were transported from the weir trap to the hatchery brood truck via the Whooshh™ fish transport system. No immediate mortalities were observed related to the Whooshh™ transport system or during transport to the hatchery. There were zero mortalities of the Whooshh™ transported fish by September 15th (1-6 days). On September 15th, 70 natural-origin brood fish collected via a beach seine on the Similkameen River were added to the raceway with the weir collected fish so we could not evaluate longer term pre-spawn mortality separately. The mortality of the combined group was through the entire pre-spawn holding period was 26.7%. The overall pre-spawn mortality of all summer Chinook broodstock was 13.4%; however the majority of these fish were collected earlier and handled differently, making direct comparisons problematic.

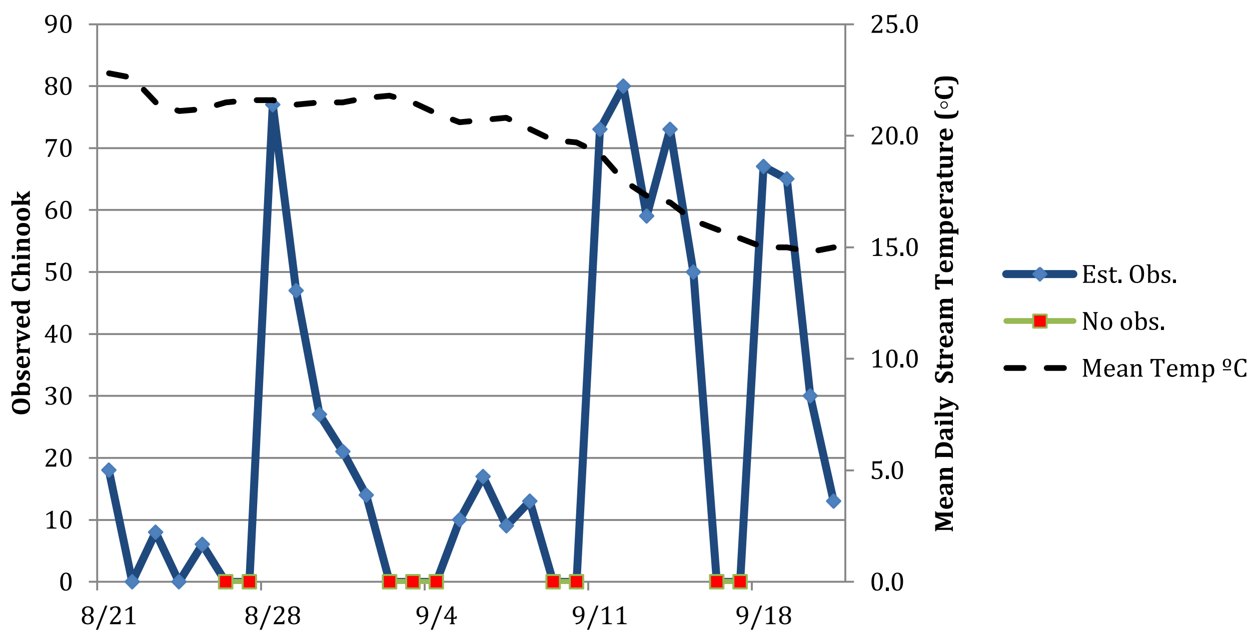


Figure 20. Estimate of Chinook observed from the bank at the lower pool, 0.8 km downstream of the weir.

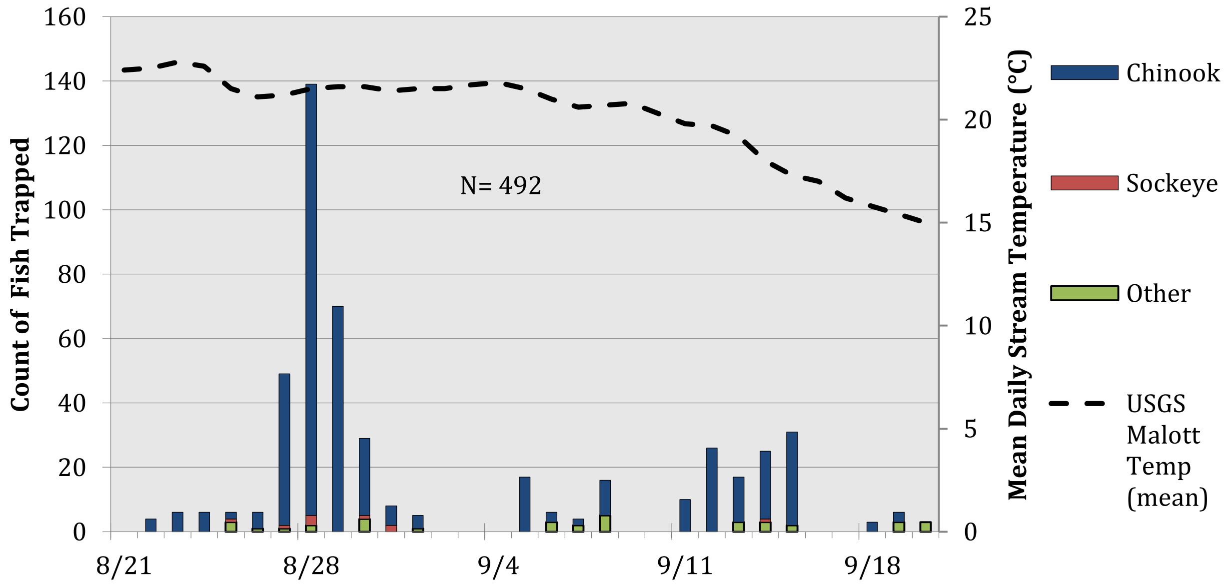


Figure 21. Total number of fish trapped at the Okanogan weir in 2017.

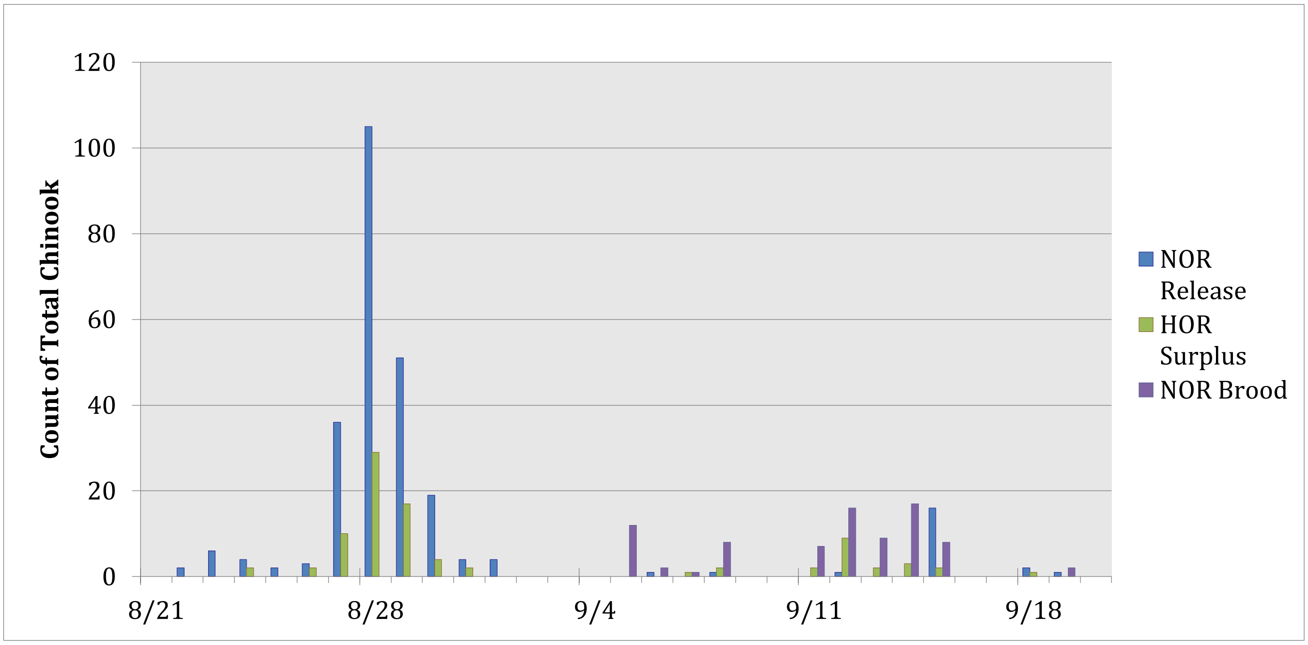


Figure 22. Final destination of Chinook adults captured in the weir trap during trapping operations in 2017.

In 2017, 0.057 (5.7%) of total spawning escapement was detected in the trap (i.e., weir efficiency) (Table 14). The potential weir effectiveness (if we had been removing all of the HOR encountered) was 0.066 (6.6%).

Table 14. The number of hatchery and natural origin Chinook Salmon encountered at the lower Okanogan weir in 2017. Weir efficiency and effectiveness were metrics for evaluating the potential for the weir to contribute to the CJHP population management goals in the future.

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

[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 2017, 3,221 summer/fall Chinook redds were counted in the Okanogan and Similkameen rivers using a combination of ground and aerial surveys (Table 15,). The number of redds counted in 2017 was higher than the long-term average but less than the more recent 5-year average (Table 15). The majority of Chinook redds were located in reaches O6 (38.4%), O5 (25.8%), and S1 (22.0%). These three reaches accounted for 86.2% of the total Chinook spawning in the basin. The overall redd distribution across reaches was similar to previous years with the majority of spawning taking place in the upper Okanogan reaches (O5 and O6) and lower Similkameen (S1) (Table 16, Figure 24).

Estimated spawning escapement was 5,896 (3,221 redds × 2.039 fish per redd) (Table 17). During the survey period 1989 through 2017, the summer/fall Chinook spawning escapement within the U.S. portion of the Okanogan River Basin has averaged 5,896 and ranged from 473 to 13,857 (Table 17).

The majority of summer/fall Chinook redds were counted during spawning ground surveys between October 9 - Nov 12 (Table 18). No spawning ground surveys were conducted after November 12.

Table 15. Total number of redds counted in the Okanogan River Basin, 1989-2017 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
Average	1,237	1,041	2,215
5-yr Average	***2,559***	***1,555***	***4,115***

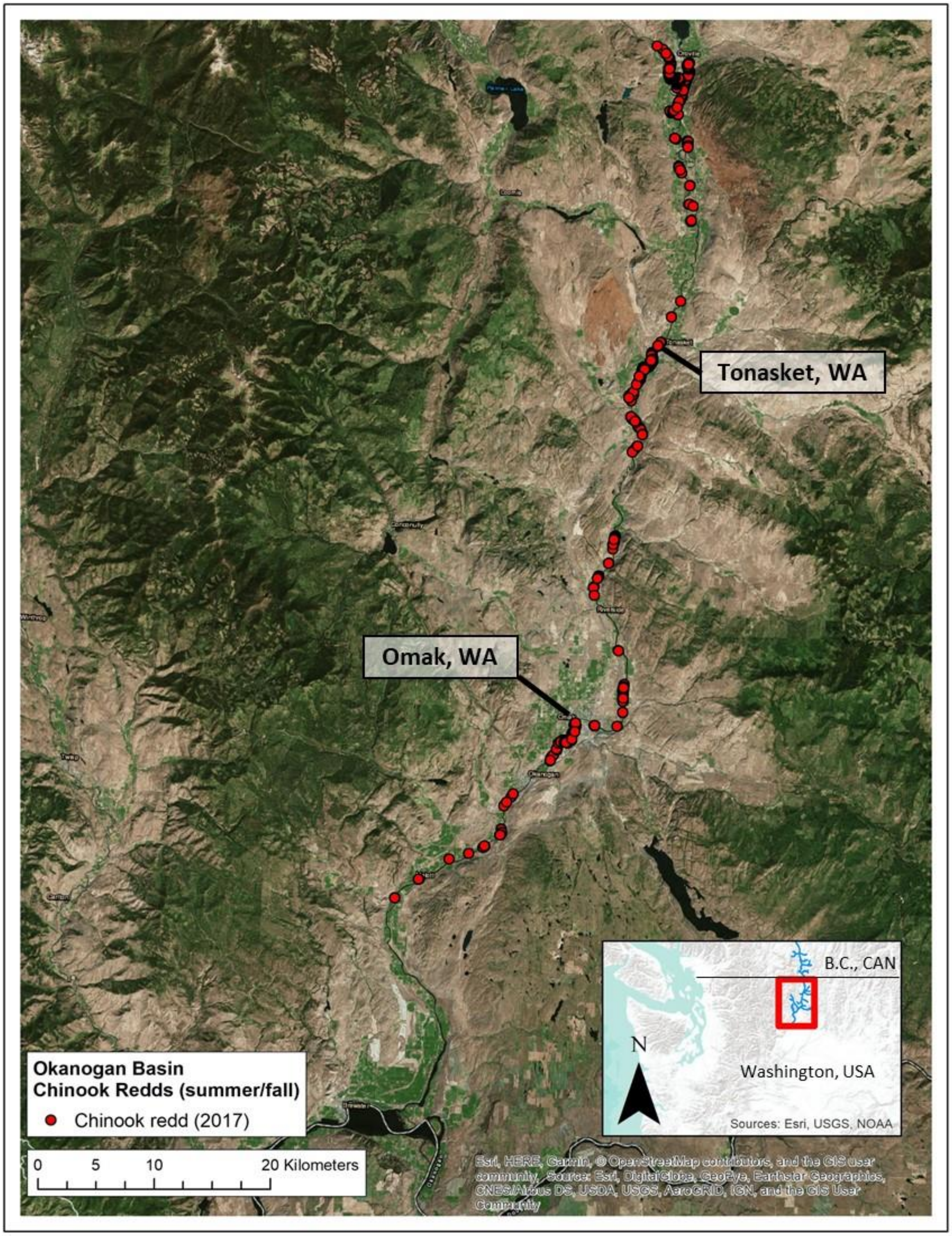


Figure 23. Distribution of summer/fall Chinook redds in 2017. Individual redds are identified by red circles. Horizontal coordinate information are referenced to the North American Datum of 1983 (NAD 83).

Table 16. Annual and average abundance of summer/fall Chinook redds in each reach of the Okanogan (O1-O6) and Similkameen (S1-S2) Rivers from 2006-2017.

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	1366	1277	405	4274
2007	3	16	116	63	549	554	624	86	2011
2008	4	51	59	96	374	561	801	199	2145
2009	3	32	91	138	619	787	1091	207	2968
2010	9	58	67	89	357	431	895	212	2118
2011	3	20	101	55	593	942	1217	192	3123
2012	12	54	159	68	555	765	914	152	2679
2013	3	2	158	46	397	1661	1254	26	3547
2014	11	57	191	111	851	1010	1737	285	4253
2015	36	113	284	79	1008	859	1611	286	4276
2016	2	57	52	130	907	2338	1645	145	5276
2017	2	62	192	111	830	1237	710	77	3221
Average	***8***	***48***	***137***	***94***	***657***	***1043***	***1148***	***189***	***3324***

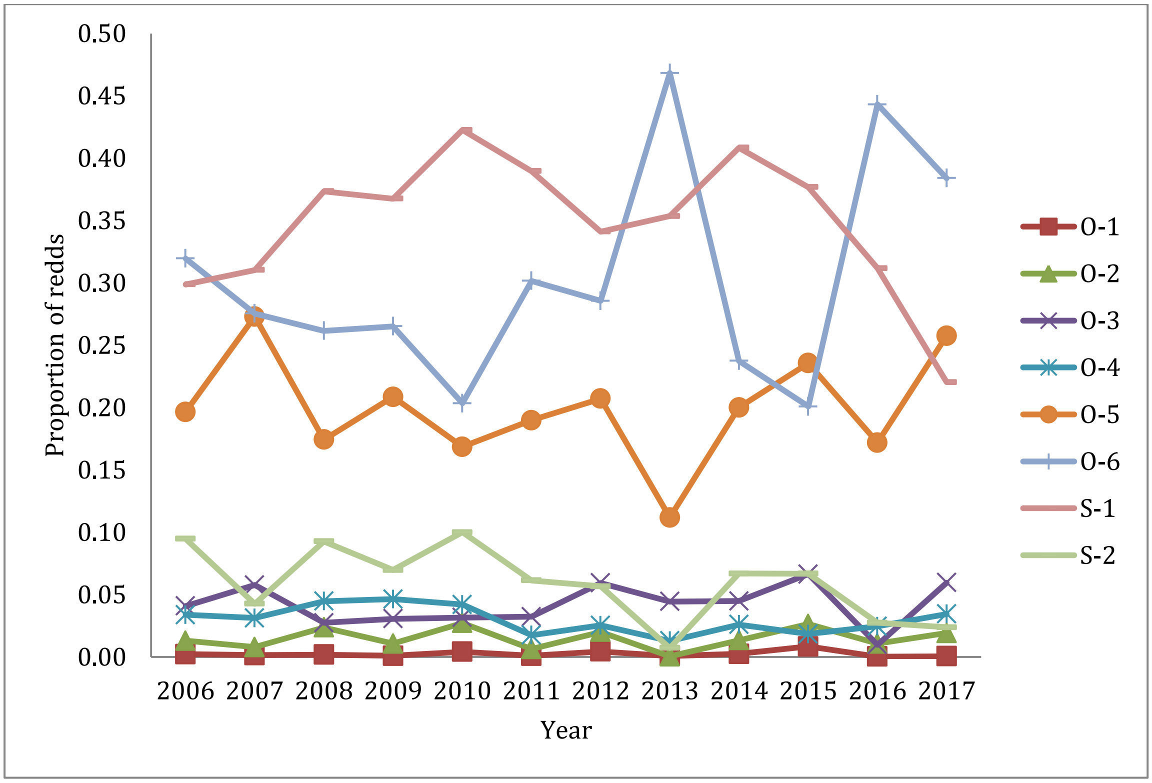


Figure 24. Proportion of redds in each reach of the Okanogan and Similkameen Rivers from 2006 to 2017.

Table 17. Spawning escapements for summer/fall Chinook in the Okanogan and Similkameen Rivers for return years 1989-2017.

Return Year	Fish/Redd Ratio	Spawning Escapement		
		Okanogan	Similkameen	Total
1989*	3.3	498	1,221	1,719
1990*	3.4	337	500	837
1991*	3.7	237	337	574
1992*	4.3	228	245	473
1993*	3.3	535	950	1,485
1994*	3.5	1,313	2,720	4,033
1995*	3.4	908	2,094	3,002
1996*	3.4	394	1,425	1,819
1997*	3.4	537	1,652	2,189
1998	3	264	828	1,092
1999	2.2	812	2,805	3,617
2000	2.4	1,318	2,383	3,701
2001	4.1	4,543	6,314	10,857
2002	2.3	6,134	7,723	13,857
2003	2.4	2,505	915	3,420
2004	2.3	2,986	3,735	6,721
2005	2.9	4,720	4,169	8,889
2006	2	5,236	3,365	8,601
2007	2.2	2,862	1,555	4,417
2008	3.3	3,725	3,250	6,975
2009	2.5	4,247	3,297	7,544
2010	2.8	2,841	3,111	5,952
2011	3.1	5,313	4,368	9,681
2012	3.1	4,952	3,273	8,225
2013	2.3	5,237	2,957	8,194
2014	2.9	6,381	5,783	12,164
2015	3.2	7,660	6,108	13,769
2016	2.01	7,007	3,598	10,605
2017	2.039	4,963	1,605	6,568
Average	***2.92***	***3058***	***2837***	***5896***
5-Year Average	***2.49***	***6250***	***4010***	***10260***

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

Table 18. Number and timing of summer Chinook redd counts in reaches of the Okanogan and Similkameen Rivers in 2017.

Reach	River mile	Sep 25-Oct 1	Oct 2-8	Oct 9-15	Oct 16-22	Oct 23-29	Oct 30-Nov5	Nov 6-12	Redd Count	Percent
	Okanogan River									
O1	0.0-16.9	0	0	0	2	0	0	0	2	0%
O2	16.9-26.1	0	0	21	35	2	4	0	62	3%
O3	26.1-30.7	0	0	130	53	6	3	0	192	8%
O4	30.7-40.7	0	7	65	37	1	1	0	111	5%
O5	40.7-56.8	0	36	454	284	55	1	0	830	34%
O6	56.8-77.4	0	114	600	159	338	26	0	1237	51%
Total		***0***	***157***	***1270***	***570***	***402***	***35***	***0***	***2434***	100%
	Similkameen River									
S1	0.0-1.8	0	123	340	142	94	11	0	710	90%
S2	1.8-5.7	0	5	47	20	3	2	0	77	10%
Total		***0***	***128***	***387***	***162***	***97***	***13***	***0***	***787***	100%

Escapement into Canada

Methodological uncertainties have limited our confidence in Chinook escapement estimates into the Canadian portion of the Okanogan basin. To date, estimates have been primarily based on video counts of fish ascending the passageway at Zosel Dam. However, due to the variations in dam operations, we are uncertain of the proportion of fish that are passing by 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 the following Canadian escapement information. In 2017 there were 737 summer/fall Chinook counted in the fishways of Zosel Dam (Table 19). This was the lowest annual count of Chinook migrating past Zosel Dam since 2010. 14% of the Chinook observed at Zosel Dam had a clipped adipose fin (*i.e.*, hatchery-origin).

The Okanagan Nation Alliance (ONA) has provided information on escapement estimates in Canada based on live counts of summer Chinook adjusted by the residency estimate for the area under the curve (AUC) (R. Bussanich, pers. comm.) The AUC is the area covered during their routine sockeye enumeration surveys, which are three designated sites, the Skaha (region above McIntyre Dam), 'index' (natural state), and channelized or vertical drop sections (VDS) on the Okanagan River. In 2017 they estimated 55 total fish in these areas. A small percentage of adipose fin-clipped fish (7%) were observed during surveys out of a total 32 collected. These adipose fin-clipped fish are not included in the escapement estimates.

Table 19. Count of run escapement of adult summer/fall Chinook at Zosel Dam using video monitoring in the fishways.

Chinook Passage at Zosel Dam		
Year	**Video Count**	**% Hatchery**
2006	481	1%
2007	455	40%
2008	267	29%
2009	256	17%
2010	359	29%
2011	1415	36%
2012	826	24%
2013	2275	14%
2014[a]	1188	10%
2015	1206	7%
2016	1823	13%
2017	737	14%
Average	***941***	***19%***

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

Carcass Surveys

In 2017, 1,201 carcasses were recovered including 997 natural-origin and 204 hatchery-origin[7]. The overall carcass recovery rate was 18% of the total spawning escapement. Genetic samples (tissue punches) were collected from a portion of the summer/fall Chinook carcasses in 2017 and are archived at the USGS Snake River Field Station Genetics Lab in Boise, ID. Similar to previous years, the majority of carcasses (*n* = 1,081; 90%) were collected from reaches O6 and S1 (Figure 25, also see Appendix C). Regarding the distribution of carcasses throughout the basin, the proportion of natural-origin carcasses recovered in 2017 was lower in reaches O3 and O5, and higher in reach O6, compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 25, panel A). The proportion of hatchery-origin carcasses recovered in 2017 was lower in reach O5 and higher in reaches O2 and O6 compared to the average of the 10 years preceding Chief Joseph Hatchery (Figure 25, panel B).

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

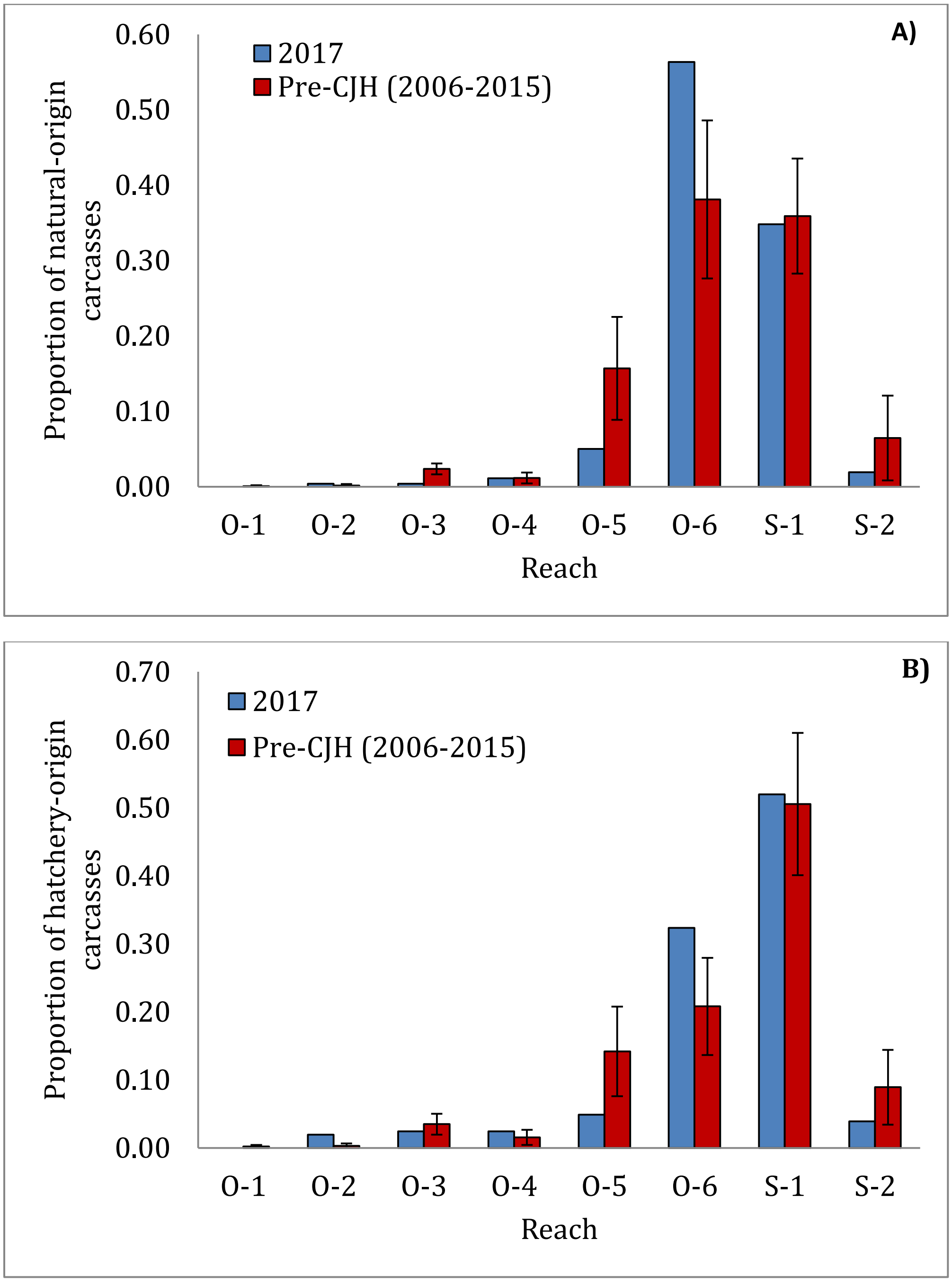


Figure 25. Distribution of natural-origin (panel A) and hatchery-origin (panel B) summer/fall Chinook carcasses recovered in the Okanogan (reaches O1-O6) and Similkameen (reaches S1-S2) Rivers in 2017 compared to average of the 10 years preceding Chief Joseph Hatchery (2006-2015).

In the Okanogan basin, just 4 of the 721 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% for natural-origin females and 0.6% for hatchery-origin females (Table 20). Overall egg retention of all fish sampled (including fish that had expelled a portion of their eggs) was 1.2%.

Table 20. 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-origin	613	326	1,630,000	6,152	0.40%	0.00%
	Hatchery-origin	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-origin	2123	1136	5,680,000	373,708	6.60%	1.40%
	Hatchery-origin	329	166	830,000	81,105	9.80%	1.80%
	Total	2452	1302	6,510,000	454,813	7.00%	1.50%
2015	Natural-origin	2554	981	4,905,000	609,869	12.40%	10.90%
	Hatchery-origin	738	340	1,700,000	96,354	5.70%	5.00%
	Total	3292	1321	6,605,000	706,223	10.70%	9.40%
2016	Natural-origin	2171	1370	6,850,000	300,046	4.38%	3.43%
	Hatchery-origin	584	434	2,170,000	66,254	3.05%	2.76%
	Total	2755	1804	9,020,000	366300	4.06%	3.27%
2017	Natural-origin	997	592	2,960,000	17,345	0.59%	0.00%
	Hatchery-origin	204	129	645,000	24,997	3.88%	3.10%
	Total	1201	721	3,605,000	42342	1.17%	0.55%

[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 significant decrease in the proportion of hatchery-origin spawners (pHOS) across all reaches in the Okanogan and Similkameen rivers in 2017 compared to the 10 years preceding Chief Joseph Hatchery (Figure 26). However, no carcasses were recovered in reaches O1, O2 and O3, therefore no comparisons could be made as to the composition of spawners in these reaches. Combined, these three lower reaches comprised only 8% of the spawning in the basin in 2017. Basin means (average pHOS) were used for these reaches in all subsequent analyses. Hatchery-origin spawners comprised 20% of the spawn escapement estimate in the U.S. portion of the Okanogan, which was the third lowest pHOS observed since 1992 (Table 21). After corrections for hatchery fish effectiveness assumptions (0.80 relative reproductive success rate for hatchery-origin spawners) the effective pHOS for 2017 was 0.16, which was below the five-year average (0.18) (Table 22). The five-year average is currently meeting the biological objective for pHOS (<0.3) and continues to trend toward the program objective of reduced pHOS (Figure 27).

The proportion of natural-origin broodstock (pNOB) in 2017 was 95% and the pNOB for Okanogan origin fish was 86% (Table 22). The resulting PNI for 2017 was 0.86, with a 5-year average PNI of 0.89, both meeting the Biological Objective (>0.67) (Figure 28).

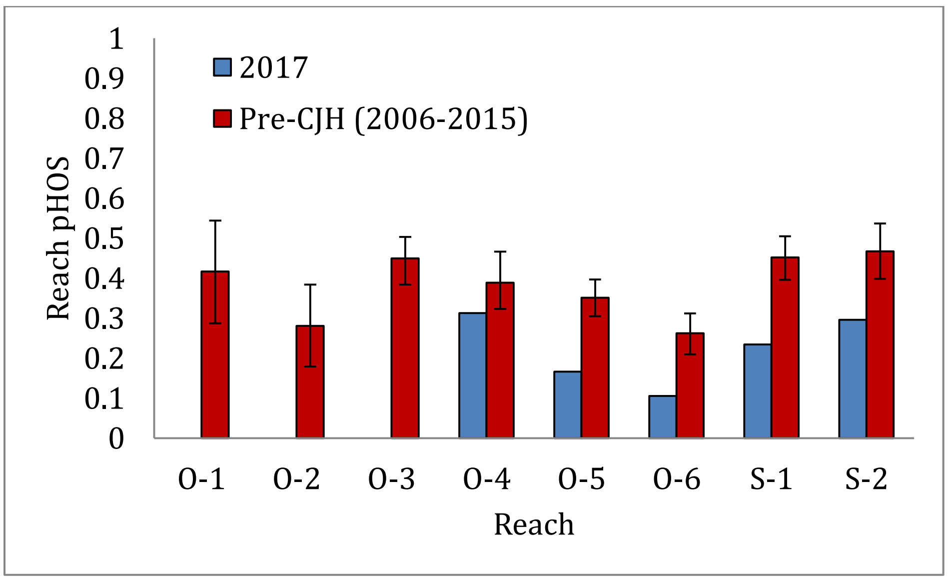


Figure 26. Okanogan (O1-O6) and Similkameen River (S1-S2) summer/fall Chinook unadjusted pHOS by reach for 2017 and the average of the 10 years preceding Chief Joseph Hatchery (2006-2015). Reaches with fewer than 10 carcasses recovered were not shown. Error bars represent standard error of the mean.

Table 21. Natural- (NOS) and hatchery- (HOS) origin spawner abundance and composition for the Okanogan River Basin, brood years 1989-2017.

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	0.40
1999	1,274	2,343	0.65	0.60
2000	1,174	2,527	0.68	0.63
2001	4,306	6,551	0.60	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*	5,507	3,094	0.21	0.18
2007*	2,983	1,434	0.37	0.32
2008*	2,998	3,977	0.60	0.54
2009*	4,204	3,340	0.46	0.40
2010*	3,189	2,763	0.47	0.41
2011*	4,642	5,039	0.52	0.47
2012*	4,840	3,385	0.45	0.40
2013*,a	5,520	2,674	0.31	0.27
2014*	10,402	1,762	0.14	0.12
2015*	10,350	3,398	0.25	0.21
2016*	8,661	1,944	0.18	0.15
2017	5,283	1,285	0.20	0.16
Average	***3,525***	***2,371***	***0.39***	***0.35***
5-year Average	***8,043***	***2,213***	***0.22***	***0.18***

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

* Indicates that pHOS has been reach-weighted by # of redds per reach.

^ Effective pHOS assumes 0.80 HOS effectiveness

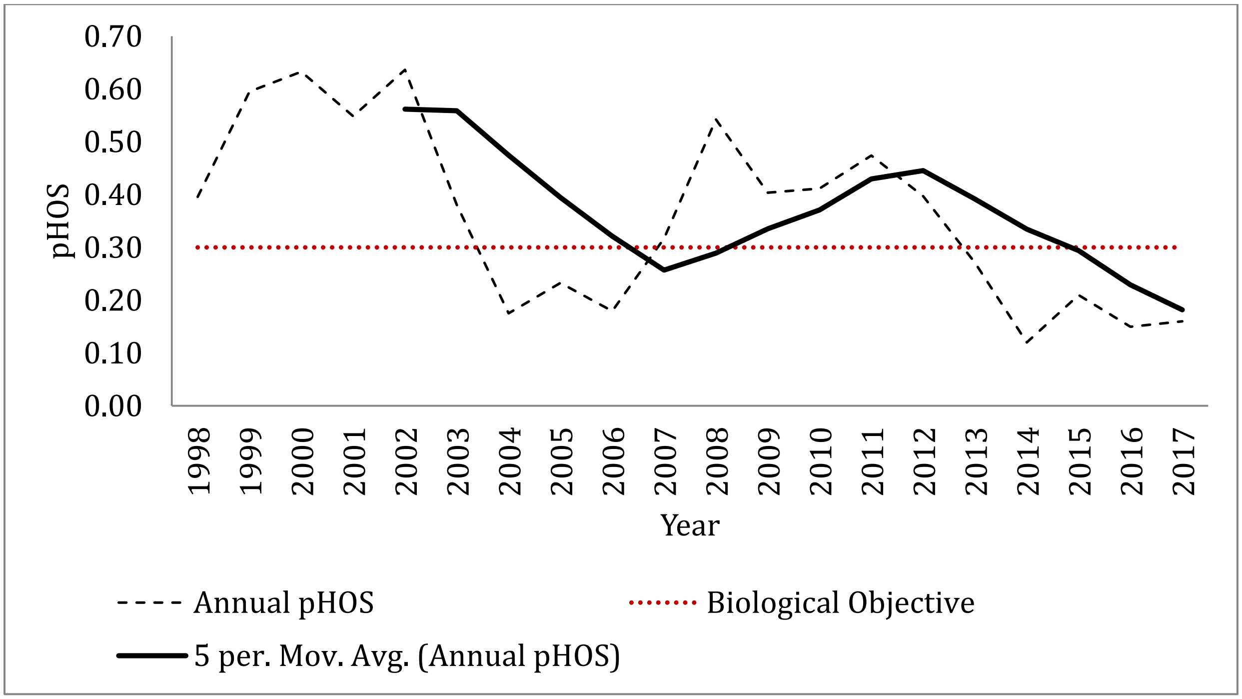


Figure 27. Annual and 5-year average proportion of hatchery-origin spawners (pHOS) in the Okanogan and Similkameen River (combined) from 1998-2017. pHOS values represent the effective pHOS.

Table 22. Okanogan River summer Chinook spawn escapement and broodstock composition, and calculated pHOS and PNI for Brood Years 1989-2017.

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	5,507	3,094	0.18	500	250	10	0.98	0.49	0.85	0.73
2007	2,983	1,434	0.32	456	228	17	0.96	0.48	0.75	0.60
2008	2,998	3,977	0.54	359	202	86	0.81	0.45	0.60	0.46
2009	4,204	3,340	0.40	503	254	4	0.99	0.50	0.71	0.55
2010	3,189	2,763	0.41	484	242	8	0.98	0.49	0.70	0.54
2011	4,642	5,039	0.47	467	332	26	0.95	0.67	0.67	0.59
2012	4,840	3,385	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	10,402	1,762	0.12	499	449	5	0.99	0.89	0.89	0.88
2015	10,350	3,398	0.21	421	379	9	0.98	0.88	0.82	0.81
2016	8,661	1,944	0.15	584	526	0	1.00	0.90	0.87	0.86
2017	5,283	1,285	0.16	350	315	17	0.95	0.86	0.86	0.84
Average	***3,528***	***2,367***	***0.34***	***420***	***234***	***147***	***0.74***	***0.54***	***0.68***	***0.58***
5-Year Average	***8,065***	***2,191***	***0.18***	***441***	***397***	***6***	***0.98***	***0.89***	***0.85***	***0.83***

pHOS values are effective from 1989-2006 and Effective, Reach-weighted pHOS from 2006-2017

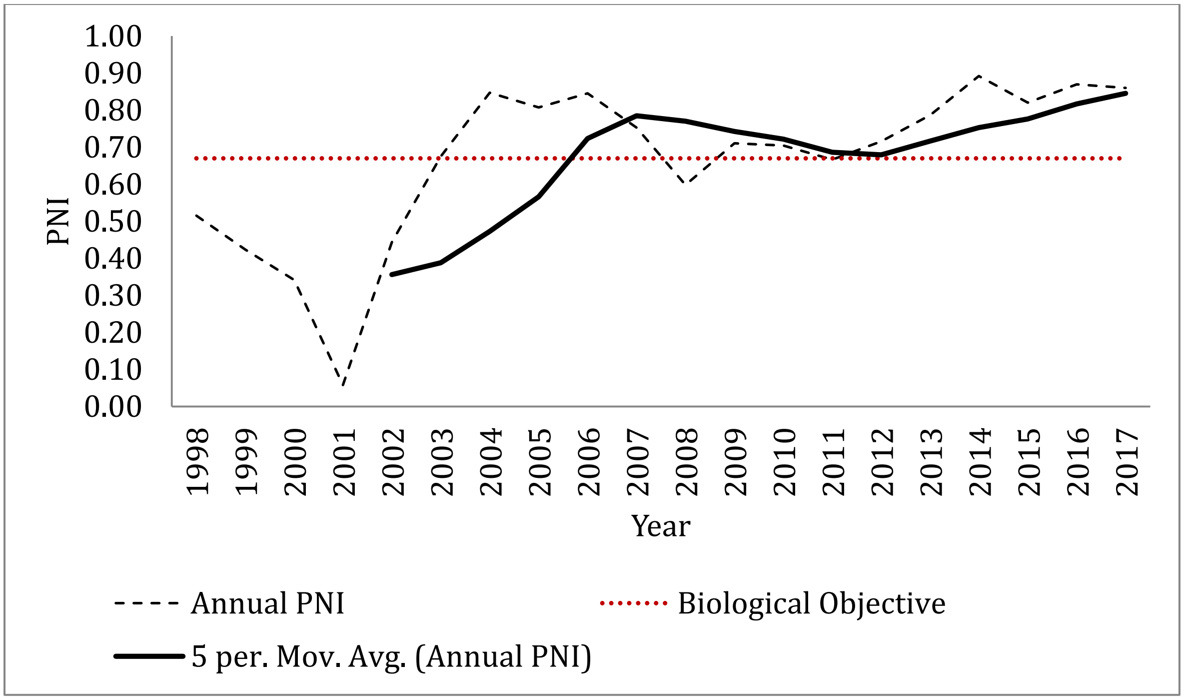
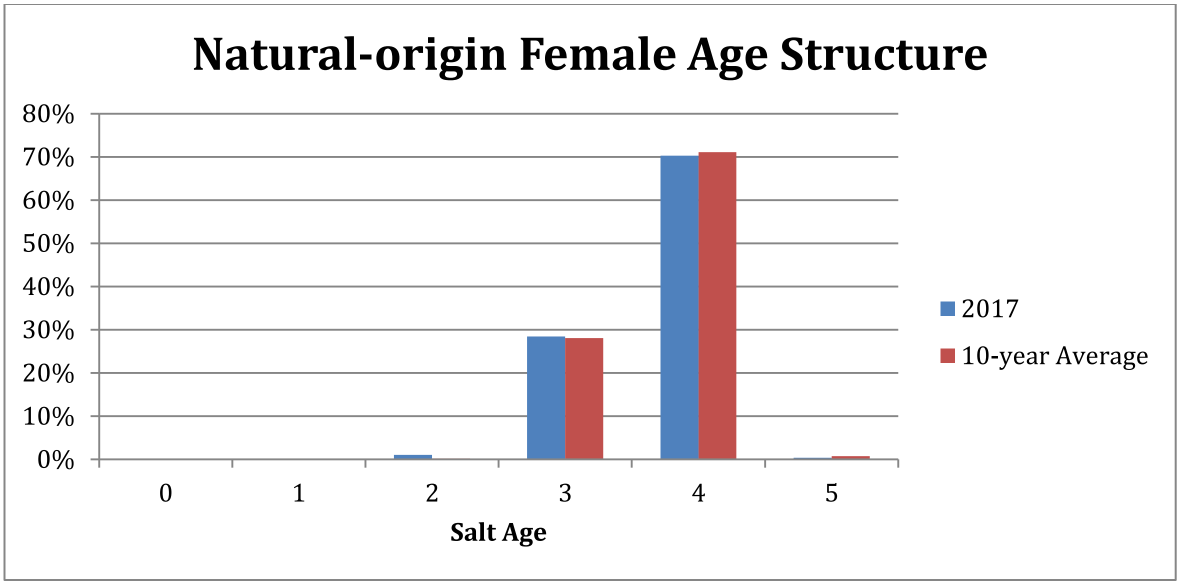


Figure 28. Annual and 5-year average proportionate natural influence (PNI) in the Okanogan and Similkameen Rivers (combined) from 1998 to 2017.

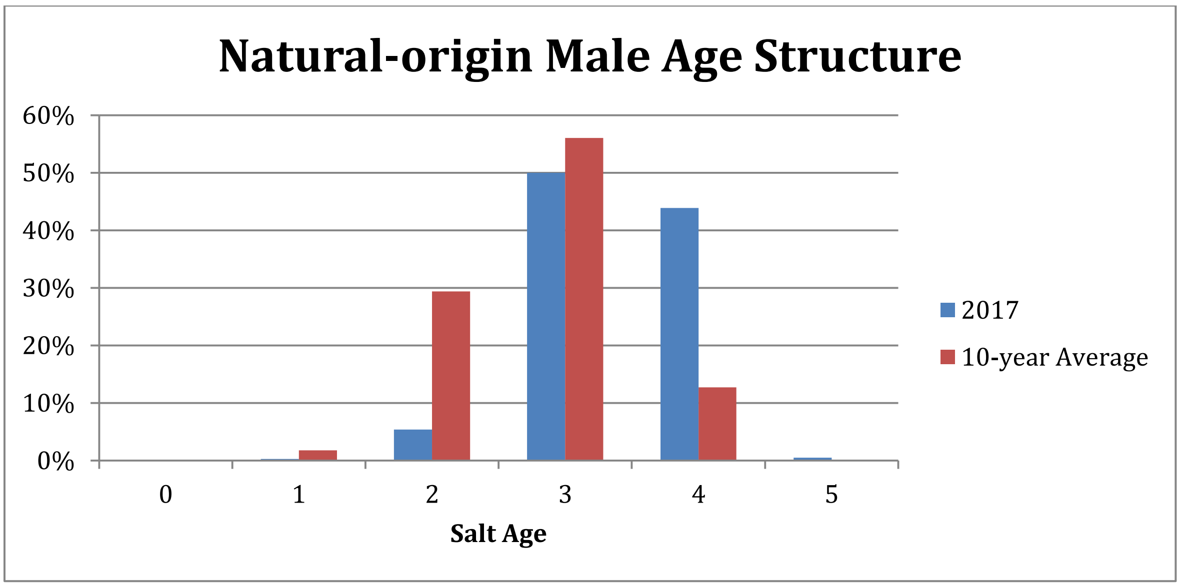
Age Structure

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

In 2017, the natural-origin female spawner age structure closely mirrored the 10-year average, while males were more apt to return as older than average, 4-salt fish. Both male and female hatchery-origin age structure appeared older in 2017 than the 10-year average.



Natural-origin Female Age Structure
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Salt Age
2017
10-year Average



Natural-origin Male Age Structure
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Salt Age
2017
10-year Average

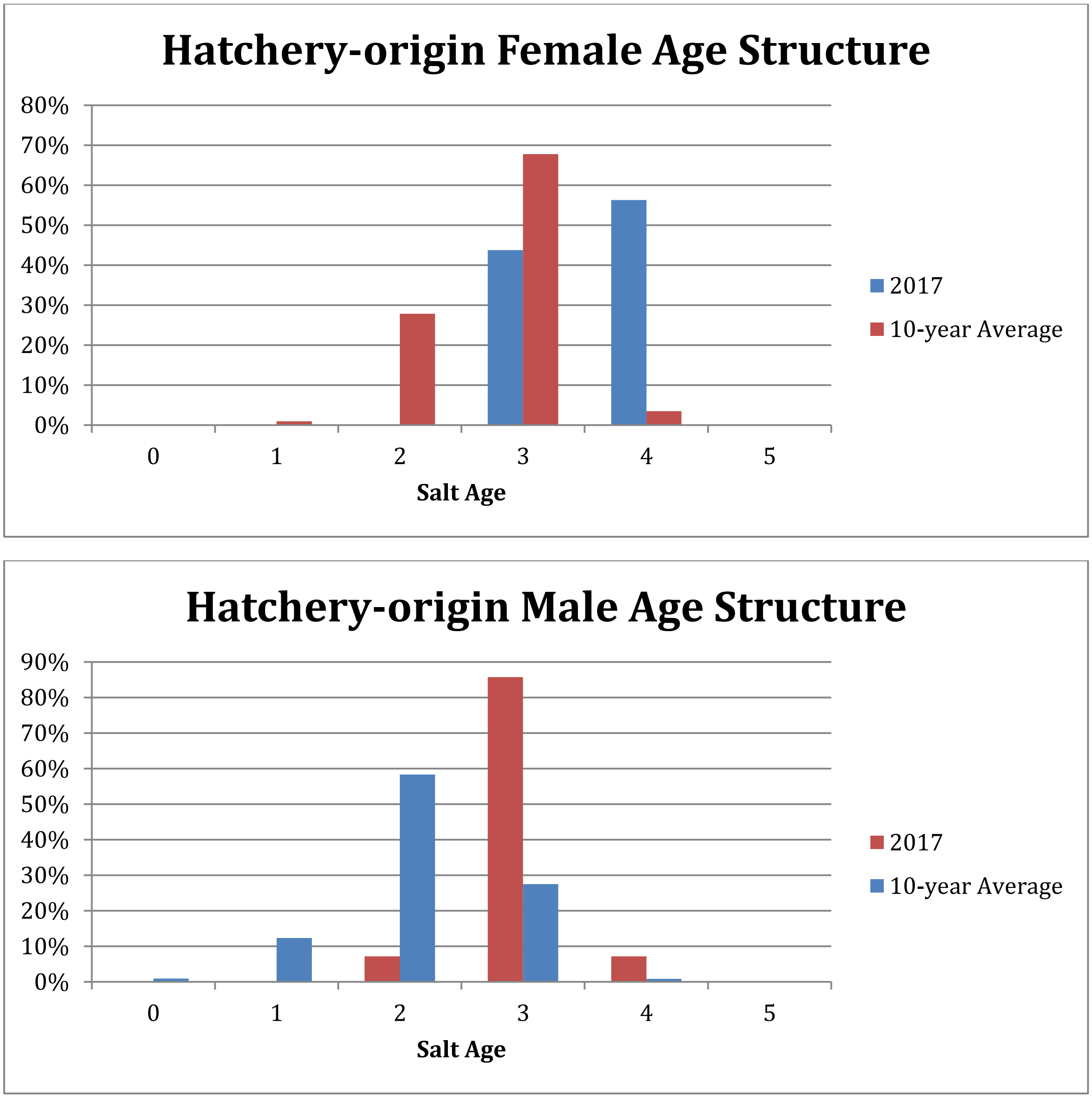


Figure 29. The salt ages of carcasses collected on the spawning grounds of the Okanogan and Similkameen Rivers in 2017 and 10-year averages (2008-2017).

HATCHERY-ORIGIN STRAY RATES

Strays within the Okanogan.—The majority (98%) of hatchery-origin spawners recovered on the spawning grounds in 2017 were from Similkameen River (80%) and Okanogan River (18%) releases (Table 23). This was very similar to the average (95%) of recent years (2006-2017). Strays into basin were from summer Chinook released from Wells Hatchery and fall Chinook from Lyons Ferry. One fish with a Coho cwt was recovered on the spawning grounds; since all recovered carcasses were Chinook, it is thought that this tag was misapplied, and so it is excluded from analysis. Stray hatchery fish from outside the Okanogan comprised 0.3% of total (hatchery plus natural-origin) Okanogan spawner composition (i.e., stray pHOS) (Table 24). This was less than the recent (2006-2017) average of 1.7% and well under the biological target of < 5%.

Strays outside the Okanogan.— With the caveat that data is likely to continue to be updated in future reports as more data becomes available through the RMIS database, the most recent brood year that could be fully assessed (through age 5) for stray rate of Okanogan fish to spawning areas outside the Okanogan was 2012. The 2012 brood year had a stray rate of 0.85%, which was similar to the long term and recent five year averages (Table 25). RMIS queries revealed an estimate of 4 Okanogan hatchery-origin from spawning ground recoveries in non-target spawning areas in 2017 (Table 25). Okanogan basin hatchery program strays comprise ≤1% to other basin population's spawner composition (in 2017 as well as long term average)(Table 26).

Table 23. 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 2006-2017.

<table>
<tr><th rowspan="5">Return Year</th><th colspan="11">Release Site</th></tr>
<tr><th colspan="8">Summer Chinook Run</th><th colspan="3">Spring and Fall Chinook Run</th></tr>
<tr><th colspan="2">Homing Fish</th><th colspan="9">Straying Fish</th></tr>
<tr><th colspan="2">Okanogan River Basin</th><th colspan="6">Within ESU Stray</th><th colspan="3">Out of ESU Stray</th></tr>
<tr><th>Okanogan River[a]</th><th>Similkameen River[b]</th><th>Methow River[c]</th><th>Wenatchee River[d]</th><th>Entiat River[e]</th><th>Chelan River[f]</th><th>Chief Joseph Hatchery (Seg.)</th><th>Mainstem Columbia River[g]</th><th>Mainstem Columbia River[h]</th><th>Snake River[i]</th><th>Other[j]</th></tr>
<tr><td>2006</td><td>0 (0%)</td><td>709 (87%)</td><td>12 (2%)</td><td>12 (2%)</td><td>0 (0%)</td><td>0 (0%)</td><td></td><td>81 (10%)</td><td>0 (0%)</td><td>0 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2007</td><td>0 (0%)</td><td>1121 (95%)</td><td>17 (1%)</td><td>5 (0%)</td><td>0 (0%)</td><td>0 (0%)</td><td></td><td>42 (4%)</td><td>0 (0%)</td><td>0 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2008</td><td>0 (0%)</td><td>3224 (95%)</td><td>11 (0%)</td><td>24 (1%)</td><td>0 (0%)</td><td>4 (0%)</td><td></td><td>133 (4%)</td><td>3 (0%)</td><td>0 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2009</td><td>0 (0%)</td><td>2733 (95%)</td><td>14 (0%)</td><td>14 (0%)</td><td>0 (0%)</td><td>9 (0%)</td><td></td><td>99 (3%)</td><td>0 (0%)</td><td>5 (0%)</td><td>4 (0%)</td></tr>
<tr><td>2010</td><td>4 (0%)</td><td>2165 (89%)</td><td>44 (2%)</td><td>35 (1%)</td><td>0 (0%)</td><td>110 (5%)</td><td></td><td>75 (3%)</td><td>0 (0%)</td><td>4 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2011</td><td>219 (5%)</td><td>4196 (93%)</td><td>44 (1%)</td><td>5 (0%)</td><td>0 (0%)</td><td>34 (1%)</td><td></td><td>22 (0%)</td><td>0 (0%)</td><td>6 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2012</td><td>379 (13%)</td><td>2397 (83%)</td><td>29 (1%)</td><td>23 (1%)</td><td>0 (0%)</td><td>17 (1%)</td><td></td><td>52 (2%)</td><td>0 (0%)</td><td>0 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2013</td><td>254 (14%)</td><td>1437 (81%)</td><td>10 (1%)</td><td>54 (3%)</td><td>0 (0%)</td><td>0 (0%)</td><td></td><td>10 (1%)</td><td>0 (0%)</td><td>0 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2014</td><td>55 (5%)</td><td>1023 (90%)</td><td>16 (1%)</td><td>0 (0%)</td><td>6 (1%)</td><td>12 (1%)</td><td></td><td>29 (3%)</td><td>0 (0%)</td><td>0 (0%)</td><td>0 (0%)</td></tr>
<tr><td>2015</td><td>38 (1%)</td><td>2562 (91%)</td><td>70 (3%)</td><td>17 (1%)</td><td>19 (1%)</td><td>33(1%)</td><td></td><td>33 (1%)</td><td>4 (0%)</td><td>4 (0%)</td><td>21 (1%)</td></tr>
<tr><td>2016</td><td>81(4%)</td><td>1963 (91%)</td><td>42 (2%)</td><td>7 (0%)</td><td>3 (0%)</td><td>31 (1%)</td><td></td><td>14 (1%)</td><td>0 (0%)</td><td>0 (0%)</td><td>17(1%)</td></tr>
</table>

2017	153 (18%)	693 (81%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	9 (1%)	0 (0%)	4 (1%)	0 (0%)
Avg.	***93 (5%)***	***1917 (90%)***	***22 (1%)***	***16 (1%)***	***2 (0%)***	***18 (1%)***	***0 (0%)***	***48 (3%)***	***2 (0%)***	**2 (0%)**	**4 (0%)**

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

[b] Includes releases from Similkameen Pond

[c] Includes releases from Carlton Acclimation Pond

[d] Includes releases from Dryden Pond and Eastbank Hatchery

[e] Includes releases from Entiat NFH

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

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

[h] Includes releases of fall Chinook from Hanford Reach

[i] Includes Releases from NPT Hatchery

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

Table 24. Estimated percent of spawner composition of hatchery-origin spawners from different release basins recovered on the Okanogan/Similkameen spawning grounds, based on CWT recoveries and expansions, for return years 2006-2017.

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]	Mainstem Columbia River[g]	Mainstem Columbia River[h]	Snake River[i]	Other[j]		
2006	0.0%	15.6%	0.3%	0.3%	0.0%	0.0%	1.8%	0.0%	0.0%	0.0%	2.3%	0.18
2007	0.0%	30.0%	0.5%	0.1%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	1.7%	0.32
2008	0.0%	51.5%	0.2%	0.4%	0.0%	0.1%	2.1%	0.1%	0.0%	0.0%	2.8%	0.54
2009	0.0%	38.4%	0.2%	0.2%	0.0%	0.1%	1.4%	0.0%	0.1%	0.1%	2.0%	0.4
2010	0.6%	40.7%	0.8%	0.7%	0.0%	2.1%	1.4%	0.0%	0.1%	0.0%	4.5%	0.41
2011	2.5%	48.3%	0.5%	0.1%	0.0%	0.4%	0.3%	0.0%	0.1%	0.0%	1.3%	0.47
2012	5.3%	34.0%	0.4%	0.3%	0.0%	0.2%	0.7%	0.0%	0.0%	0.0%	1.7%	0.4
2013	3.4%	19.5%	0.1%	0.7%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	1.3%	0.24
2014	0.7%	13.0%	0.2%	0.0%	0.0%	0.2%	0.4%	0.0%	0.0%	0.0%	0.7%	0.11
2015	0.3%	22.7%	0.6%	0.2%	0.2%	0.3%	0.3%	0.0%	0.0%	0.2%	1.7%	0.21
2016	0.3%	17.4%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.6%	0.19
2017	3.5%	15.8%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.3%	0.16
Avg.	1.4%	28.9%	0.3%	0.3%	0.0%	0.3%	0.8%	0.0%	0.0%	0.0%	1.7%	0.30

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

[b] Includes releases from Similkameen Pond

[c] Includes releases from Carlton Acclimation Pond

[d] Includes releases from Dryden Pond and Eastbank Hatchery

[e] Includes releases from Entiat NFH

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

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

[h] Includes releases of fall Chinook from Hanford Reach

[i] Includes Releases from NPT Hatchery

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

Table 25. 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 1989-2012. As fish continue to return through time and the RMIS database is continually updated, reported data from recent brood years may change.

Brood Year	Homing				Straying			
	Target Stream		En Route Hatchery		Non-target Streams		Non-target Hatchery	
	Number	%	Number	%	Number	%	Number	%
1989	3,132	69.7%	1,328	29.6%	2	0.0%	31	0.7%
1990	729	71.4%	291	28.5%	0	0.0%	1	0.1%
1991	1,125	71.3%	453	28.7%	0	0.0%	0	0.0%
1992	1,264	68.5%	572	31.0%	8	0.4%	1	0.1%
1993	54	62.1%	32	36.8%	0	0.0%	1	1.1%
1994	924	80.8%	203	17.7%	16	1.4%	1	0.1%
1995	1,883	85.4%	271	12.3%	52	2.4%	0	0.0%
1996	27	100.0%	0	0.0%	0	0.0%	0	0.0%
1997	11,659	97.1%	309	2.6%	35	0.3%	2	0.0%
1998	2,784	95.4%	102	3.5%	31	1.1%	2	0.1%
1999	828	96.7%	18	2.1%	10	1.2%	0	0.0%
2000	2,091	93.8%	29	1.3%	94	4.2%	15	0.7%
2001	105	98.1%	2	1.9%	0	0.0%	0	0.0%
2002	702	96.2%	17	2.3%	11	1.5%	0	0.0%
2003	1,580	96.2%	47	2.9%	16	1.0%	0	0.0%
2004	4,947	94.4%	206	3.9%	85	1.6%	2	0.0%
2005	606	93.2%	22	3.4%	22	3.4%	0	0.0%
2006	5,210	97.6%	60	1.1%	68	1.3%	0	0.0%
2007	1,330	97.9%	19	1.4%	10	0.7%	0	0.0%
2008	3,673	96.5%	111	2.9%	19	0.5%	4	0.1%
2009	1,149	80.8%	256	18.0%	14	1.0%	2	0.1%
2010	1,058	61.4%	646	37.5%	9	0.5%	10	0.6%
2011	4,449	79.9%	873	18.9%	10	0.6%	25	0.5%
2012	414	70.2%	171	29.0%	4	0.7%	1	0.2%
Total	**51,723**	**85.6%**	**6,038**	**13.2%**	**516**	**1.0%**	**98**	**0.2%**

Table 26. Number and percent (%) of spawning escapements that consisted of hatchery-origin Okanogan summer/fall Chinook within other non-target basins, return years 1994-2017.

Return Year	Wenatchee		Methow		Chelan		Entiat	
	Number	%	Number	%	Number	%	Number	%
1994	0	0.0%	0	0.0%	-	-	-	-
1995	0	0.0%	0	0.0%	-	-	-	-
1996	0	0.0%	0	0.0%	-	-	-	-
1997	0	0.0%	0	0.0%	-	-	-	-
1998	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1999	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2000	0	0.0%	6	0.5%	30	6.4%	0	0.0%
2001	12	0.1%	0	0.0%	10	1.0%	0	0.0%
2002	0	0.0%	3	0.1%	4	0.7%	5	1.0%
2003	0	0.0%	8	0.2%	22	5.3%	14	2.0%
2004	0	0.0%	0	0.0%	5	1.2%	0	0.0%
2005	5	0.1%	27	1.1%	36	6.9%	7	1.9%
2006	0	0.0%	5	0.2%	4	1.0%	7	1.8%
2007	0	0.0%	3	0.2%	4	2.1%	0	0.0%
2008	0	0.0%	9	0.5%	46	9.3%	4	1.3%
2009	15	0.2%	3	0.2%	11	1.8%	18	7.1%
2010	6	0.1%	0	0.0%	33	3.0%	0	0.0%
2011	0	0.0%	0	0.0%	46	3.6%	0	0.0%
2012	7	0.1%	5	0.2%	19	1.5%	0	0.0%
2013	0	0.0%	0	0.0%	0	0.0%	0	0.0%
2014	0	0.0%	3	0.2%	8	1.0%	0	0.0%
2015	4	0.1%	5	0.1%	4	0.3%	0	0.0%
2016	0	0.1%	4	0.2%	4	0.5%	0	0.0%
2017	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	***49***	***0.0%***	***81***	***0.2%***	***286***	***2.2%***	***55***	***0.9%***
5-year Total	***4***	***0.0%***	***12***	***0.1%***	***16***	***0.4%***	***-***	***0.0%***

Homing Fidelity

Based on 144 coded-wire tags recovered during spawning grounds surveys in fall of 2017, as estimated 244 and 557 spawners (expanded estimates) originated from Omak Pond and Similkameen Pond acclimation sites, respectively. Of those spawners, the majority (93%) of the fish originating from the Omak Pond acclimation site spawned in the Okanogan River (Table 27). Those fish tended to spawn in habitat upstream of the Omak Pond site, with the majority CWT's recovered in the reach O5. No Omak pond or Similkameen pond CWT's were recovered below reach O5 (Figure 30). Only 16 fish that were acclimated at Omak Pond were estimated to have spawned in the Similkameen River. Fish acclimated at the Similkameen Pond site did not exhibit the same homing fidelity as the Omak pond fish. Overall, the majority of fish acclimated at Similkameen Pond ended up spawning throughout the upper reaches of the Okanogan River (56%), especially in the upper most reach (O6) (Figure 30). Reach S1, the location of the Similkameen acclimation site in the Similkameen River did account for just under half of the estimated spawning by Similkameen Pond fish (44%) (Table 27).

Table 27. Spawning distribution by river, for fish acclimated at Omak Pond and Similkameen Pond acclimation sites.

	Acclimation site (origin)	
Spawning location	**Omak Pond**	**Similkameen Pond**
Okanogan River	93%	56%
Similkameen River	7%	44%

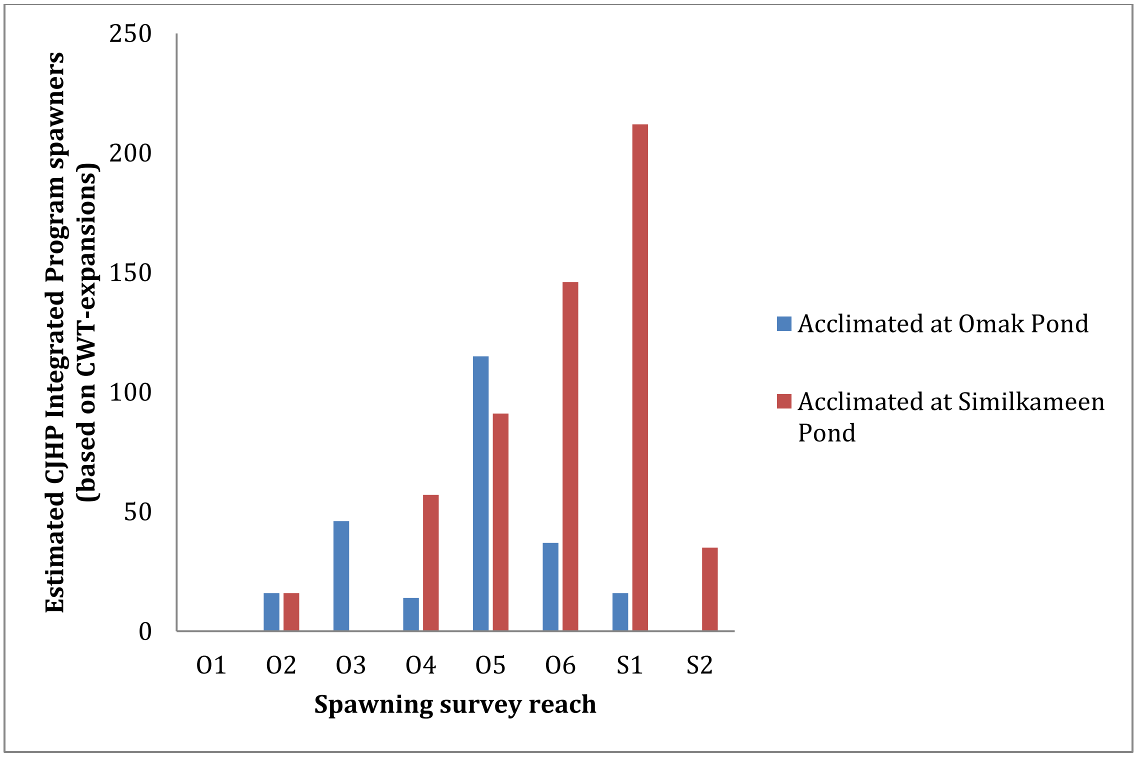


Figure 30. 2017 spatial distribution of CJHP integrated program Chinook spawners originally reared at the Similkameen Pond and Omak Pond acclimation sites.

Smolt-to-Smolt Survival and Travel Time

Apparent survival of yearlings to RRJ was generally between 75-80% with the exception of the 10j reintroduction spring Chinook from Riverside Pond that was 52% (Tables 28-29). Apparent survival of yearlings to MCN was generally 50-60% regardless of species or release location (Tables 28-29) with two note-able exceptions: 1) the 10j reintroduction Spring Chinook had lower survival to MCN (35%) and 2) the segregated Summer Chinook yearlings from CJH had much higher survival (82%) to MCN. The low survival of the 10j reintroduction fish was likely related to an early escape from the acclimation pond that resulted from an ice problem at the facility. PIT tag detections at the array in the lower Okanogan River indicated that the majority of tagged fish moved down the Okanogan River before the official release date on April 13th (Figure 30).

Apparent survival to RRJ for sub-yearling summer Chinook was 65-70% for fish released from CJH facilities, 48% for Wells Fish Hatchery releases and 46% for wild subyearlings captured in a beach seine near the mouth of the Okanogan (Table 29).

Statistical tests were not conducted to evaluate if the CJH releases were significantly different than nearby hatcheries or previous years. The guidance from the Annual Program Review was to wait until a multi-year assessment could be conducted with at least 4 or 5 years of data to more accurately evaluate patterns between years and programs.

Table 28. Apparent survival estimates for PIT tagged Spring Chinook Salmon smolts released from Chief Joseph hatchery (CJH), Winthrop National Fish Hatchery (WNFH) and Leavenworth National Fish Hatchery (LNFH) in 2017.

Spring Chinook Release Group	# PIT tags Released	# PIT tags Recap.	Reach	Survival	Survival Standard Error (SE)	Capture Prob.	Capture Prob. (SE)
Yearlings released at CJH	4815	781	Release to RRJ	0.81	0.05	0.20	0.01
		258	Release to MCN	0.60	0.07	0.09	0.01
Yearlings released at Riverside (10j)	5036	476	Release to RRJ	0.52	0.04	0.18	0.02
		177	Release to MCN	0.35	0.05	0.10	0.02
Yearlings released at WNFH	19918	4366	Release to RRJ	0.83	0.02	0.26	0.01
		1039	Release to MCN	0.58	0.03	0.09	0.01
Yearlings released at LNFH	19528	1632	Release to MCN	0.54	0.02	0.16	0.01

Table 29. Apparent survival estimates for PIT tagged Summer Chinook Salmon released in 2017 from Chief Joseph Hatchery (CJH) 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	5024	595	Release to RRJ	0.77	0.06	0.15	0.01
		232	Release to MCN	0.82	0.14	0.06	0.01
Yearlings released at Omak Pond	4830	658	Release to RRJ	0.80	0.06	0.17	0.01
		207	Release to MCN	0.63	0.10	0.07	0.01
Yearlings released at Carlton Pond	NA		Release to RRJ				
			Release to MCN				
Yearlings released at Dryden Pond	20604						
		645	Release to MCN	0.48	0.07	0.07	0.01
Subyearlings released at CJH	5029	849	Release to RRJ	0.65	0.05	0.26	0.02
		137	Release to MCN	0.34	0.06	0.07	0.01
Subyearlings released at Omak	4571	756	Release to RRJ	0.70	0.05	0.24	0.02
		231	Release to MCN	0.48	0.07	0.11	0.02
Wells Fish Hatchery Subyearlings	5960	535	Release to RRJ	0.48	0.06	0.19	0.02
		142	Release to MCN	0.22	0.05	0.11	0.02

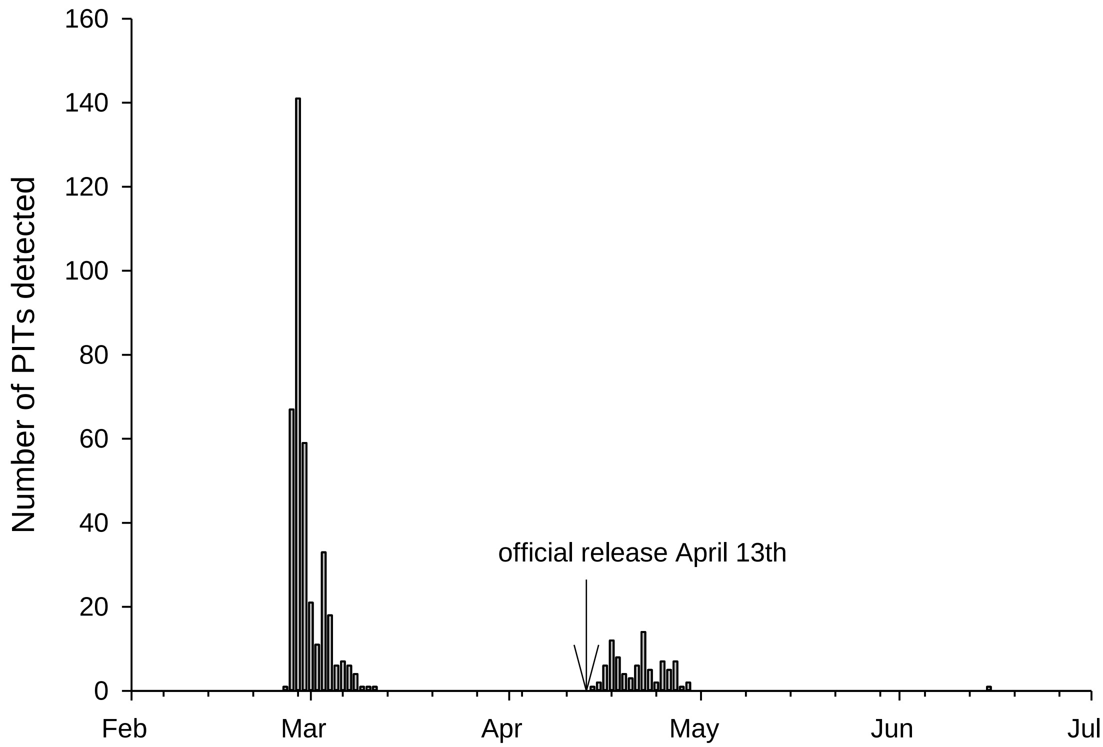


Figure 31. Number of hatchery Spring Chinook smolts from the 10j reintroduction program detected at the lower Okanogan PIT array in 2017. A buildup of ice on the exit screen resulted in overflow and fish escaping the pond before the official release on April 13, 2017.

Table 30. PIT tag survival estimates for juvenile wild Summer Chinook Salmon captured in a beach seine in Wells Pool, primarily near the mouth of the Okanogan River. 2015-2017a were only the fish captured in the beach seine and 2015-2017b were the beach seined fish pooled with those tagged in the Okanogan River at the rotary screw trap and in a side-channel at Conservancy Island.

Wild Summer Chinook Release Group	# PIT tags Released	# PIT tags Recap.	Reach Release to:	Survival	Survival Standard Error (SE)	Capture Prob.	Capture Prob. (SE)
2011	13,221	1,200	RRJ	0.45	0.02	0.20	0.01
		920	MCN	0.30	0.02	0.23	0.02
2012	15,311	912	RRJ	0.54	0.04	0.11	0.01
		795	MCN	0.40	0.03	0.13	0.01
2013	17,760	1,988	RRJ	0.44	0.02	0.26	0.01
		747	MCN	0.39	0.04	0.11	0.01
2014	8,226	845	RRJ	0.35	0.03	0.29	0.02
		240	MCN	0.19	0.04	0.16	0.03
2015a	5,823	519	RRJ	0.26	0.06	0.342	0.077
		13	MCN	NE	NE	NE	NE
2015b	7,787	569	RRJ	0.25	0.05	0.288	0.0628
		19	MCN	NE	NE	NE	NE
2016a	13,651	1,378	RRJ	0.25	0.03	0.40	0.04
		80	MCN	NE	NE	NE	NE
2016b	14,674	1,411	RRJ	0.24	0.03	0.40	0.04
		81	MCN	NE	NE	NE	NE
2017a	21,280	3,492	RRJ	0.46	0.02	0.36	0.02
		494	MCN	0.17	0.02	0.11	0.02
2017b	23,016	3,694	RRJ	0.46	0.02	0.35	0.02
		528	MCN	0.18	0.02	0.13	0.02

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

The travel time of fish released from CJH facilities to RRJ in 2017 varied from 21 days (5.6 km/day) for sub-yearlings released from the hatchery to 10 days (11.2 km/day) for the segregated Spring Chinook released from CJH (Table 31). As in 2015 and 2016, sub-yearling summer Chinook from the Omak Pond had one of the fastest migration speeds (11.1 km/day) of all release groups, outpacing all of the yearling summer Chinook groups (Table 31Table 31.). Direct comparisons of migration speed may not be applicable because not all fish are released at the same time and location and therefore do not experience the same water conditions (e.g., temperature, velocity). Most notably, the sub-yearlings were released approximately 1-1.5 months later than the yearlings when water velocities were higher in the Okanogan and Columbia rivers. Summer Chinook arrived at Rocky Reach over a 7-8 week period; late April to early June for yearlings and late May to late June for sub-yearlings (Figure 31). The majority of Spring Chinook from CJH and Riverside Pond arrived at RRJ from late April to mid-May (Figure 33). 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 31.).

Table 31. Travel time and migration speed for various Chinook release groups in 2017

Release Group	First Day of Release 2017	Last Day of Release 2017	Forced or Volitional	Release to RRJ		RRJ to MCN	MCN to BON
				Mean Travel Time (d)	Travel Rate (km/day)	Travel Rate (km/day)	Travel Rate (km/day)
CJH Summer subs	15-May	15-May	F	20.6	5.6	24.6	60.6
Omak Pond subs	22-May	22-May	F	13.5	11.1	28.0	57.5
Wells FH subs	24-May	15-Jun	V	23.0	3.0	23.5	a
Wild subs	8-May	25-Jun	NA	19.6	4.9	16.2	49.7
CJH Summer yearlings	17-Apr	18-Apr	V/F	15.2	7.6	27.9	63.0
Omak Pond yearlings	13-Apr	16-Apr	F	21.7	6.9	30.1	64.6
Carlton yearlings	18-Apr	19-Apr	F	10.1	12.4	16.8	57.9
Dryden yearling	17-Apr	26-Apr	V	NA	NA	13.4[b]	55.2
CJH Spring Chk	17-Apr	18-Apr	V/F	10.4	11.2	28.2	63.3
RivP Spr Chk (10j)	13-Apr	13-Apr	F	23.2	7.0	24.7	65.3
Winthrop Spring Chk	18-Apr	20-Apr	V/F	14.1	11.5	21.5	62.0
Leavenworth Spr Chk	18-Apr	18-Apr	F	NA	NA	14.0 [b]	50.2

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

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

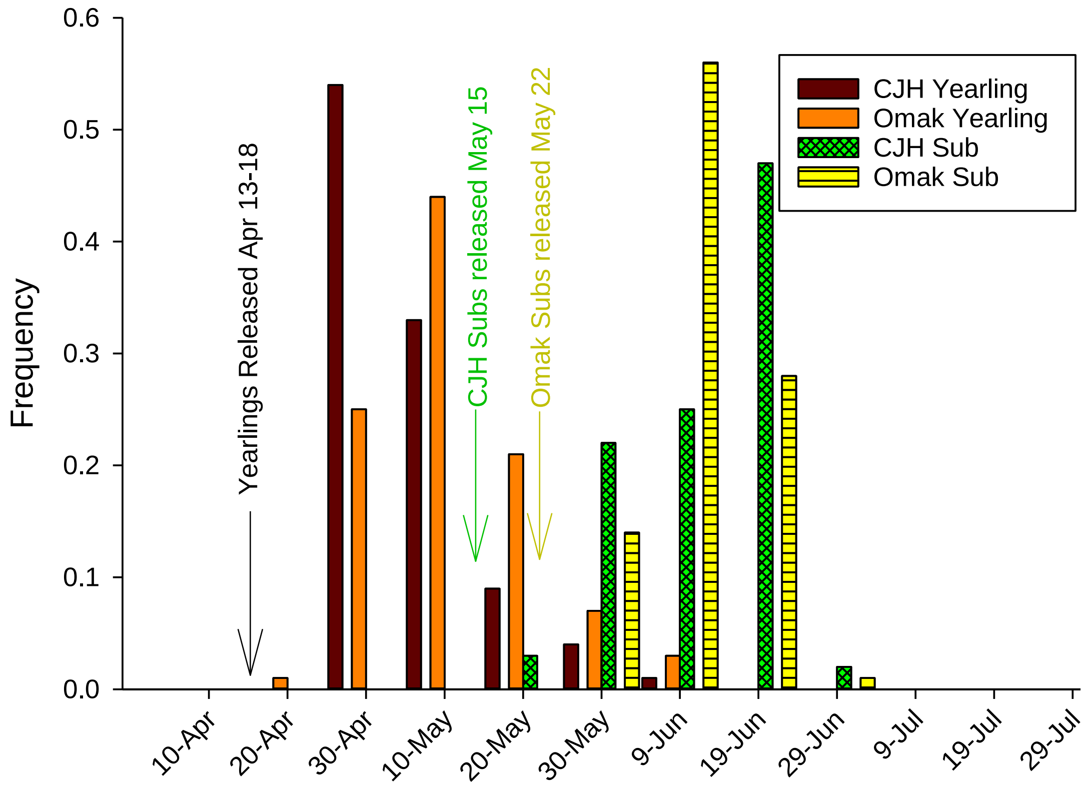


Figure 32. Arrival timing at Rocky Reach Juvenile bypass (RRJ) of PIT tagged Summer Chinook released from the Chief Joseph Hatchery and Omak Pond in 2017.

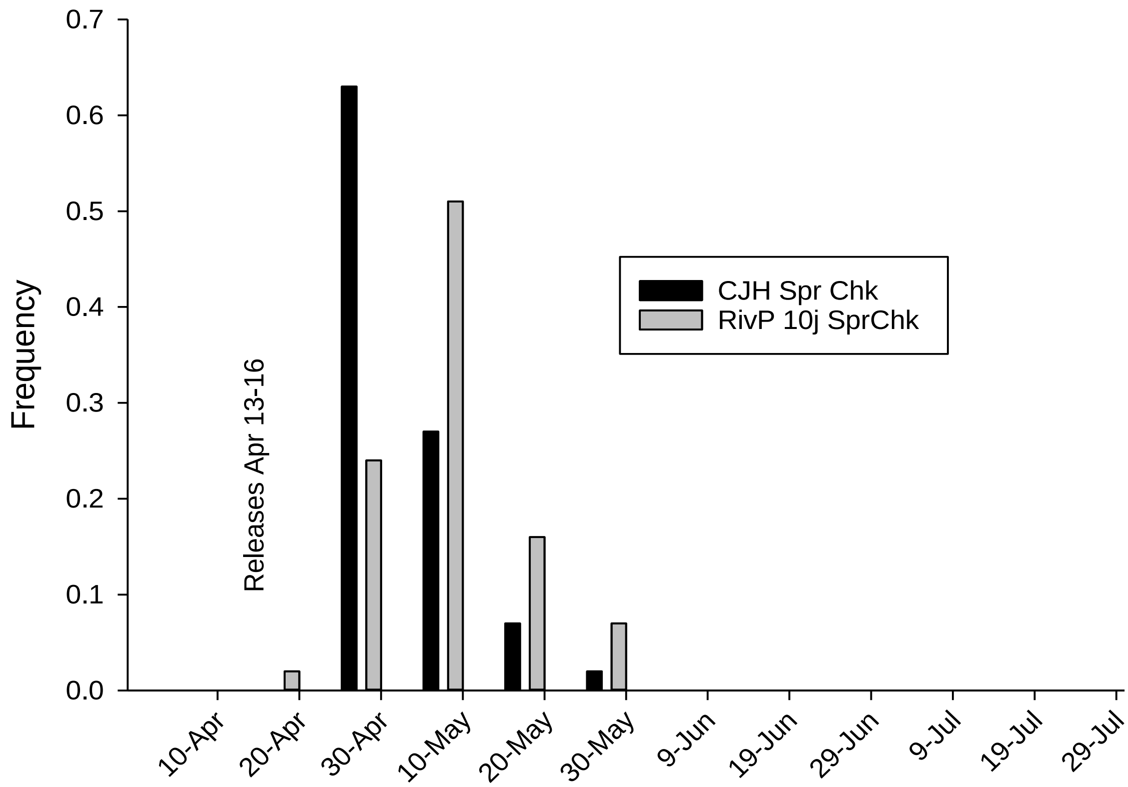


Figure 33. Arrival timing at Rocky Reach Juvenile bypass (RRJ) of PIT tagged Spring Chinook released from the Chief Joseph Hatchery (CJH) and Riverside Pond (RivP) in 2017.

Over 1,100 hatchery smolts with a PIT tag were detected at OKL between January 6 and June 15, 2017. Similar to 2016 results, Omak Pond sub-yearling Summer Chinook moved out the fastest, with 97% of the PIT detections within two days of release. The majority (68%) of yearling summer Chinook from Omak Pond were detected at OKL within 7 days of release, but it was approximately two weeks before 95% of the fish had passed. For yearling Spring Chinook released from Riverside Pond, there were two distinct detection periods due to an ice buildup on the screen (Figure 31) For the Spring Chinook yearlings released at the intended release date (April 13), 50% of them were detected at OKL within one week and 95% within 2 weeks. There was no evidence of residualization of hatchery Chinook in the Okanogan, although one yearling summer Chinook released in 2017 was detected in the adult ladders of multiple mainstem dams in September of 2017, suggesting it returned as a minijack.

Smolt-to-Adult Return (SAR)

The most recent brood year that could be fully assessed (through age 5) for SAR was 2011. Based on expanded CWTs, the 2011 brood year had a SAR of 3.1%, which was above the long-term and 5-year averages. However, this number may change as more adult captures from BY 2011 are uploaded to the RMIS database, and this table changes in the coming years to reflect those data (Table 32).

Table 32. Smolt-to-adult return rate (SARs) for Okanogan/Similkameen summer/fall Chinook, brood years 1989-2010.

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	1,528	0.7%
1995	574,197	2,851	0.5%
1996	487,776	31	0.0%
1997	572,531	18,600	3.2%
1998	287,948	7,687	2.7%
1999	610,868	2,776	0.5%
2000	528,639	6,762	1.3%
2001	26,315	424	1.6%
2002	245,997	1,975	0.8%
2003	574,908	3,489	0.6%
2004	676,222	12,896	1.9%
2005	273,512	1,660	0.6%
2006	597,276	13,626	2.3%
2007	610,379	4,758	0.8%
2008	604,064	14,932	2.5%
2009	673,372	8,547	2.2%
2010	650,137	8,504	1.3%
2011	627,978	19,214	3.1%
Total	***10,670,978***	***138,899***	***1.3%***
5-year Total	***3,165,930***	***55,955***	***2.0%***

[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.

Spring-Chinook Presence and Distribution

Environmental DNA

CJHP collaborates with USGS to conduct Environmental DNA (eDNA) sampling and as one approach to monitor status and trends in spring-Chinook spatial distribution throughout the Okanogan basin in response to the reintroduction of the experimental population. Monitoring began prior to the reintroduction in an attempt to assess the pre-management action spatial distribution of spring-Chinook, allowing CJHP to assess the status and progress of the 10(j)reintroduction efforts. While spring-Chinook were listed as extirpated within the Okanogan ESU, analysis of eDNA samples from tributaries (i.e. stream-type Chinook habitat) revealed that the basin likely does have a limited distribution of spring-Chinook. Additionally, PIT tag detections confirm the presence of occasional strays from out of basin (*see PIT Tag Detections Section below*).

As a proof of concept, sampling was initiated in 2012 with five mainstem Okanogan River sites and 11 Okanogan tributary sites as well as 32 sites throughout the Methow basin (See Laramie et al. 2015a and CJHP 2013 Annual Report). Sampling was conducted in June and August 2012 at all sites. In 2013, sampling was conducted only in the Okanogan basin, at eight additional tributary sites not visited during the proof of concept study. These sites were sampled in June and were located in tributary streams with potential for spring-Chinook recolonization. In 2014, all previously sampled sites in the Okanogan basin were re-visited and sampled (U.S. sites on 12-13 July, 2014, and Canada sites on 2 October 2014). All sampling was conducted following the methods and protocols described in Laramie et al 2015b, and available as PNAMP Method ID# 5476 (www.monitoringresources.org/Document/Method/Details/5476). See Appendix C for results from 2012 thru 2014 eDNA analyses. Several tributaries have produced consistent annual detection of Chinook eDNA, including Shingle Creek, Vaseux Creek, Salmon Creek and Omak Creek. No sampling was conducted in 2015. In 2017, 18 sites in both the U.S. and Canadian portions of the Okanogan Basin were re-sampled to monitor status and trends in spatial distribution during the early stages of the reintroduction effort (Table 33).

Table 33. eDNA results for sampling conducted in Okanogan basin tributaries from 2012-2017.

Site	2012	2013	2014	2015	2016	2017
Aeneas Creek		-	-		-	+
Antoine Creek		-	+		+	-
Bonaparte Creek	+		-		-	+
Inkaneep Creek	+		-		-	-
Johnson Creek						
Loup Loup Creek		-	+		+	+
Ninemile Creek	-		-		+	
North Fork Salmon Creek	-		-			-
Okanogan R. (above Salmon Cr.)	+		+			+
Okanogan R. (at Inkaneep Cr.)	+		+			+
Okanogan R. (at Shuttleworth Cr.)	-		+			
Okanogan R. (near Bonaparte Cr.)	+		+			
Okanogan R. (near mouth)	+		+			+
Okanogan R. (near Omak Cr.)						
Omak Creek (above falls)	-				+	+
Omak Creek (near mouth)	+		+		+	+
Salmon Creek	+		+		+	+
Shatford Creek						
Shingle Creek (Lower)	+		+		-	+
Shingle Creek (Upper)						
Shuttleworth Creek	-		-		-	
Similkameen River		+	+			+
Siwash Creek		+				
Tonasket Creek		+			-	
Tunk Creek		-			+	+
Vaseux Creek	+		+		+	+
Wanacut Creek		-			-	+
West Fork Salmon Creek	-		-			-

+	Chinook Presence
-	Chinook Not Detected

PIT Tag Detections

PTAGIS contained 129 unique records of returning spring-Chinook detected in the Okanogan basin in 2017 (Table 34). One tag was removed from analysis because it was implanted in a returning adult at Wells in 2010, and was most likely a tag that washed down over the Bonaparte Creek Array from an earlier return. Of the 128 remaining unique detections in the Okanogan and Similkameen, the majority (n=104; 81%) were hatchery fish that had been tagged at Wells Dam as an adult then detected in the Okanogan, primarily at the lower Okanogan array. Eight of the fish (6%) detected in the Okanogan had a last detection in the Methow basin at a later date.

A total of 83 adult spring Chinook were detected at the Lower Okanogan array between May 12 and August 25, 2017 with a median run timing of June 20. Two fish were detected at Zosel Dam on September 5 and 17. None of the fish tagged and classified as spring Chinook appeared to be mis-classified summer Chinook (there were 3 such fish in 2014). We did not evaluate fish tagged as summer Chinook or Chinook with undetermined race to assess if they might be spring Chinook.

Fourteen fish from the Riverside Pond release in 2015 (BY 2013) and 2016 (BY 2014) were detected in the Okanogan. These fish were detected at Salmon Creek, Johnson Creek, Omak Creek, Loup Loup Creek, and in Canada at OKC (Table 34).

There were 61 total unique PIT detections in the tributaries of the Okanogan in 2017. Of these unique tributary detections, Omak Creek had 11 detections (18%), Loup Loup Creek had 13 (21%) and Salmon Creek had 12 (21%), Johnson Creek had 11 (18%), and Bonaparte Creek had five (8%).

Of the fish that were tagged and released as juveniles, 21 of 35 (60%) were captured in the Methow River. The rest were from the 10(j) releases into the Okanogan (Table 34).

Table 34. Final PIT tag detections in the Okanogan for spring-Chinook in 2017. OKC/VDS3 is at vertical drop structure 3 in British Columbia upstream of Lake Osoyoos and OKL is the detection array in the lower Okanogan River near Malott, Washington.

Origin	Release Location	Final Detection Location(s)								
		Okan. then Methow	Okan then Other (besides Methow)	OKL	Salmon Ck.	Omak Ck.	Other U.S. Trib	Zosel Dam	OKC / VDS-3	B.C. Trib
Hatchery Spring Chinook	Methow/Winthrop Juvenile	1	1	2	1		1		1	
	Wells Dam Adult	6	1	47	11	16	18	2	3	
	Bon Dam Adult									
	CJH									
	RivP (10j)		1	7	1	2	2			1
	Other									
Natural Spring Chinook	Wells Dam Adult	1		1		1				
	Twisp R. Juv.									
	Entiat R. Juv.									
	Rock Isl. Dam Juv.									
	Methow R. Juv.									
	Okan R. Juv.									
Summer Chinook (mis-classified)	NA									
	NA									
	Total	8	3	57	13	19	21	2	4	1

DISCUSSION

Rotary Screw Traps (RST)

The pooled trap efficiency of approximately 0.2% is lower than in previous years (Rayton and Arterburn 2008, Johnson and Rayton 2007; https://static1.squarespace.com/static/56f45574d51cd42551248613/t/57c06a21e58c62290279a3d7/1472227873603/2006_Screw_Trap_Report_Final.pdf; https://static1.squarespace.com/static/56f45574d51cd42551248613/t/57c06a12e58c62290279a376/1472227860447/2007RstReportFinal.pdf),and remains insufficient to precisely estimate juvenile production for the basin. Additionally, the 95% confidence interval for hatchery-origin population did not capture the total known number of hatchery-origin fish released upstream of the RST. This indicates that, due to the difficulties in accurately estimating trap efficiency and juvenile production, the results of screw trapping activities in 2017 are unlikely to provide an accurate estimate of juvenile production.

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

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

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

Finally, Pacific lamprey (*Entosphenus tridentatus*) were captured in the RST in both 2006 and 2007, but were not observed from 2008 to 2017. The status of this fish, an important cultural and ecological resource in the Okanogan River Basin is not examined in this report, but its disappearance from the RST is notable.

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 2017, 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 was in 2016 (6.1%, compared to 5.3%). 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 decreased post tagging mortality. The hope for future years is to continue to reduce overall mortality associated with our PIT tagging efforts.

Fish size increased through the tagging period, but the number of fish captured and CPUE began to decrease in mid-June, earlier than in previous years, but similar to 2016. Similarly, dates of detection at downstream PIT arrays occurred earlier in 2017 than in previous years. This may be explained in part by the size of tagged fish, differences in flow regime, or other factors that can be examined in future years when a more robust, multiyear dataset has been developed.

Although capture locations in 2017 were limited to areas near the confluence of the Okanogan and Columbia Rivers, fish were captured in areas that could also be used by juveniles originating from Methow and Columbia River spawning areas. Therefore, future analyses of returning adults will need to take this into account by recognizing that some fish may not be destined for the Okanogan. Results from the stable isotope analysis indicate that some fish collected from the Washburn location may particularly be of Columbia River origin (Appendix E).

Lower Okanogan Adult Fish Pilot Weir

Discharge conditions on the Okanogan River in 2017 were higher than in 2016, delaying installation and operation of the weir until mid-August, which was a week later than 2016. Temperatures on the Okanogan River were fairly normal, compared to the 10 year median. Because temperatures stayed below 22.5 °C once trapping began on August 21st, trapping operations were not suspended because of this reason. Tower and bank fish observations were generally higher after the thermal barrier broke on August 25. During this time, fish observations 0.8 km below the weir, at the lower pool, were similar than observations at the weir. When river temperature was lower and gauge height was less than 4 feet, Chinook were more likely to mill in deeper pools. 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 = 447) was more than in 2016 (n= 169). Configuration of the weir was different in 2017 compared to 2016. The trap was installed further downstream on the edge of the thalweg, just below the deep pool. Water velocity was higher downstream of the trap gate in 2017 and this may have attracted more fish to the trap. We expect to keep the configuration the same in 2018 in regard to location of the trap box.

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 (91) of dead fish at the weir was higher in 2017 than 2016 but still lower than years prior (2014-2015). Mortality was highest after Labor Day weekend when trapping was suspended, indicating that trap operation and handling were not the immediate cause of mortality. The behavioral observations and lack of fish impinged between pickets (head upstream) were good indicators that this weir configuration and picket spacing were not a major cause of direct mortality. In an attempt to assess immediate indirect mortality, we marked and released 246 adult natural-origin Chinook at the weir trap. Six of them were collected as mortalities at the weir, which is less than 2.5% of all trapped, marked and released fish. None of them were collected as carcasses on the spawning grounds. We do not anticipate additional mark-recapture studies in the future.

There were few observations of Sockeye at the weir during daylight and nighttime hours and only nine were trapped in 2017. Most Sockeye passed the weir before trapping began on August 21. We did observe a few Sockeye (~20) pass through the weir trap during night hours (2000-0400) during the first couple weeks of trapping operations. It is likely that more Sockeye moved through the weir panels at night when observations did not occur. There were no observations of jack or small adult Chinook escaping through the 2" weir panels that were intended to allow Sockeye passage. We recommend using the 2 inch weir panels again next year to increase the efficiency of Chinook trapping without causing too many Sockeye to also use the trap. In 2017, there were no Sockeye observations during daylight hours, but in past years we did have observations of Sockeye passing through the 2.0" picket spacing. We will continue to document passage of Sockeye and Chinook through all picket spacings.

There was no way to know exactly how many fish escaped past the weir before it was installed or how many fish swam through, around or jumped over the wings after it was installed (jumping over the wings has never been observed). The potential weir effectiveness measure of 6.6% was low because, after reviewing PIT detection at the Okanogan Instream Lower array, we suspect that about 30-40% of the fish had migrated past the weir before deployment in August. There was not a thermal barrier breakdown that occurred before the weir was fully functional; so it's unlikely that the majority of fish passed the weir before it was installed. Fortunately, this did not hinder fish management objectives in 2017 because pHOS was already low and only 21% of the Chinook trapped were hatchery origin. In the future, with larger returns of hatchery fish due to CJH releases we anticipate a much higher pHOS at the weir resulting in higher weir effectiveness. Continuing these evaluations in future years will be critical to determining the long-term viability of the weir as a fish management tool for summer Chinook.

The broodstock collection protocol at the weir was to get 15% (n = 84) of the integrated program from the later arriving fish (in September, post thermal barrier). The weir met its broodstock goal, collecting 84 fish, 100% of the broodstock collection protocol, through the trap post thermal barrier breakdown period. The Whooshh™ transport tube worked well and initial mortality was low, indicating that further use and testing of this system should be continued in the future.

In 2017 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 weir was successful at collecting broodstock for the hatchery's integrated program and the Whooshh fish transport system was a beneficial tool for handling these fish safely for transport to the hatchery. The weir's importance to the Okanogan summer/fall Chinook population will increase in the coming years with larger hatchery returns resulting from the increased production at CJH. Experiencing a broad range of environmental conditions spanning the extremely high summer flows of 2012 to the very low and warm flows in 2015 is important for understanding the range of challenges and resulting weir effectiveness that can be expected through time.

Redd Surveys

Summer Chinook spawning activity in 2017 was slightly below average for the 2006-2017 period, with 3,221 redds (average = 3,324). Redd counts were above average in all Okanogan River reaches, with the exception of reach O-1. Redd counts in both Similkameen River reaches were well below average (Table 16).

The redd count in reach O-6 was the 4th highest on record, and spawning in reach S-1 dropped considerably. However, these two adjacent reaches, along with reach O-5continue to provide the primary spawning habitat for summer Chinook in the Okanogan/Similkameen basin, comprising 86.2% of the total spawning in 2017. One objective of the CJHP is to increase the spatial distribution of spawning into the lower reaches of the Okanogan, where historically, a low proportion of the spawning activity has occurred. 2017 redd counts showed an increase in spawning in the lower Okanogan reaches, especially reaches O-2 thru O-4-. It appears that, at least in these initial return years, CJHP Chinook reared at the Omak pond acclimation site may be contributing to increased spawning in lower reaches through natal homing. Continued monitoring of redd and carcass distribution will be critical to evaluation of this metric.

Spawn timing was similar to previous years, with the intensive spawning beginning the first week of October, coinciding with mean water temperatures dropping below 15°C. Few redds were constructed in November (Table 19) with no redd construction observed after November 5. This suggests that, if extant, a late-arriving fall-run population of Chinook is contributing minimally to the population at large. Although aerial surveys contribute a relatively small portion of the observed redds compared to ground or float surveys, they remain an important tool for documenting spawning, or lack of, in areas not accessible by ground crews.

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

ESCAPEMENT INTO CANADA

Escapement of summer/fall Chinook into Canada had been largely overlooked until recently, when the video counts of Chinook passing over Zosel Dam increased to a level where OBMEP staff brought the results to the attention of CJHP staff. Spawning escapement in Canada is still unknown, as the video counts represent run escapement and the relationship between run escapement and spawn escapement is not clear. However, a substantial number of Chinook have been counted passing Zosel Dam, 737 in 2017, down from 1823 in 2016(Table 20). No formal Chinook spawning grounds surveys are currently being conducted, 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). This discrepancy has at least three possible explanations that need to be further explored in the coming years.

1) Chinook can migrate downstream through Zosel Dam without being detected in the fishways video monitoring system.
2) Chinook are making it to spawning areas in the Canadian Okanogan and not being detected by Canadian spawning ground surveys. These surveys currently target sockeye, but the spawn timing and potential spawning areas are similar.
3) High pre-spawn mortality kills fish between passage at Zosel Dam and potential spawning grounds somewhere in Canada.

Some possible solutions to exploring these explanations include:

a) Evaluate PIT tag results for fish that might ascend through the fishways multiple times (this will not account for fish that fall back once and do not re-ascend).
b) Conduct surveys in the Canadian portions of the Okanagan River targeting Chinook spawning grounds (i.e. larger substrate) during peak spawning (mid-October).
c) Conduct carcass surveys above Zosel Dam, throughout Lake Osoyoos and the Canadian Okanogan looking for pre-spawn mortality.
d) Capture and radio tag fish in the Zosel fishways.

Until a definitive method is developed for estimating spawn escapement in Canada, The CJHP will continue to monitor and report run escapement via video monitoring. However, we will not add run escapement past Zosel Dam to spawn escapement in the U.S. because this could overestimate total spawners if explanation 1 or 3 (see list above) are true.

Carcass Surveys

1,201 carcasses were recovered out of an estimated 6,568 spawners, which was slightly below the target carcass recovery rate of 20%. Zhou (2002) reported fish length as a significant factor in carcass recovery probability, with larger fish recovered at a higher rate than smaller fish. This is especially important as it relates to precocious males, or jacks, which are expected to occur with higher frequencies in hatchery-origin Chinook. Failing to assess and correct for biases and population discrepancies could lead to potential underestimation of hatchery-origin Chinook survival (resulting in inflated hatchery production) or over-estimation of wild-origin Chinook survival (masking potentially negative effects of the hatchery program) (Murdoch et al. 2010). We are considering methods (e.g. mark-recapture) to assess and quantify potential size bias in our carcass recovery efforts.

Surveys in September revealed few carcasses attributable to pre-spawn mortality (PSM) and October surveys found few PSM as well (4 female fish, or 0.6%). It is likely that the majority of PSM occurs earlier in the season while water temperatures are higher and are a greater risk to fish attempting to travel to or hold near the spawning grounds. If this were true, the current design of our redd/carcass surveys would provide an underrepresentation of actual PSM. Therefore, egg retention and pre-spawn mortality results should be interpreted cautiously. The carcasses of fish that died prior to the onset of spawning and before sampling began may have been carried downstream of recovery floats, consumed by scavengers, or covered with sediment, making them unavailable for sampling or harder to detect and collect. This could result in an underestimation of pre-spawn mortality. The protocol assumes that each female may contain 5,000 eggs and were only considered pre-spawn mortality if they retained all 5,000 eggs. A static fecundity assumption may not be the best approach because younger and smaller females will likely have fewer eggs. Additionally, the current assumption used by the CJH during in-hatchery spawning activities for average fecundity is 4,600 eggs. We expanded the assessment to include an evaluation of fish that retained greater than 1,000 eggs as an attempt to capture some of the variability in fecundity and situations where fish died before depositing a biologically important portion of their eggs. However, even when considering any female with that retained ≥1000 eggs, the estimated PSM was still just 2%. We are not sure that 1,000 eggs are biologically important, but clearly there should be some amount of egg retention that matters besides 100%. We suggest continued review and modification of the egg retention estimation methods/protocol in the future.

pHOS and PNI

The biological target for CJHP is to maintain a 5- year average pHOS <0.3. 2015 was the first year since the CJHP began monitoring the population that the 5-year average (0.30) met this objective. 2017 pHOS (0.16) further reduced the 5-year average to 0.18. The program met the biological target for PNI (>0.67) for the sixth year in a row. The 5-year mean (0.85) met the objective, and PNI continues to improve. In the future, we suggest that continued aggressive removal of hatchery fish through selective fisheries and adult management at the weir and hatchery ladder given the uncertainty regarding the adequacy of the objectives to meet long-term population conservation goals. Exceeding the targets whenever possible also provides a buffer for years when goals may not be achieved due to low run size or challenging environmental conditions.

Origin of Hatchery Spawners

Hatchery-origin fish recovered on the spawning grounds in the Okanogan Basin were predominantly (98%) from the Okanogan Basin releases. Stray hatchery-origin fish from outside the Okanogan made up only 0.3% of total estimated spawners. Likewise, Okanogan Basin hatchery-origin fish strayed to other areas at a low rate (<1%) and were a small percentage of the spawner composition in other Upper Columbia tributaries. Stray rates and hatchery spawner composition were within the target levels for the program both within and outside the Okanogan Basin. Fish released within the Okanogan River basin have consistently homed to their natal stream, and 2017 was not an exception.

Smolt to Smolt Survival and Travel Time

The survival results for each release group provide a useful index of annual survival for comparison between release groups and, in the future, between years. Statistical tests were not conducted to determine if observed differences were statistically valid because we believe this should be done with a multi-year data set and the few total years for which we currently have results. Targets for post release survival have not been established, but it was encouraging to see that the 2017 estimates of CJH programs were similar to or greater than nearby programs, with the exception of the Riverside Pond icing problem that allowed early escape of Spring Chinook. 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 2017, with no detections of migrants in the Okanogan after June 15. 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.

In the winter of 2016, the Riverside Acclimation Pond froze over, and the pond gates had to be removed to prevent damage. Presumably, it was during this period when some §10(j) spring Chinook escaped. Although the exact date of escape from the pond is not known, a portion of the 10(j) release was detected at OKL from 6 January 2017 through 11 March 2017, with most being detected in a relatively narrow window between 26 February and 4 March. Examination of the SAR of the unintentional early release may provide insight regarding the importance of facility improvements to reduce the likelihood of re-occurrence. Assuming that the lower survival of juveniles translates to lower return of adults, management actions to prevent the icing problems at Riverside Pond should be considered.

This assessment suggests that the program was successful at releasing actively migrating smolts. This analysis did not attempt to account for detection probability at OKL. 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 outmigrating 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.

Smolt-to-adult Return

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

Spring-Chinook Presence and Distribution

Environmental DNA (eDNA) surveys have been an important tool for monitoring the early stages of the spring Chinook reintroduction effort. CJHP has developed an annual eDNA monitoring strategy that allows for basin-wide spatiotemporal distribution assessments. This data will be used for the purpose of developing an occupancy model to track seasonal changes in distribution. Initial eDNA monitoring efforts have confirmed a wide distribution of spring Chinook in the Okanogan River basin, including 11 tributaries in U.S. and Canada. This effort has been successful at identifying and prioritizing tributaries for future spawning ground surveys. Implementing eDNA sampling at a finer scale, within those tributaries that have indicated spring Chinook presence would help to locate spawning areas and/or reaches that would be most appropriate for more intensive survey efforts, such as visual redd surveys. Additionally, eDNA surveys conducted in winter or early spring could help to confirm successful spawning in a tributary, as a positive detection during this time of year would likely be the result of juvenile presence.

PIT tag have been another important tool for monitoring the progress of reintroduction efforts. Future analysis should include an estimate of run escapement to the Okanogan using fish PIT-tagged at Wells Dam as the mark group and those redetected in the Okanogan as the recapture group. Similar to previous years, a portion (6%) of the Spring Chinook detected in the Okanogan had a final destination in the Methow River basin, so it will be important to exclude those fish from escapement estimates.

Adaptive Management and Lessons Learned

The Annual Program Review (APR)

Each year the CJHP hosts a workshop to review and present findings from the previous year and plan for the upcoming fish production and science monitoring cycle. The APR was convened in March 2018 with the purpose of reviewing data collection efforts and results from 2017 and developing the hatchery implementation and monitoring plan for 2018 (Figure 34). 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 35). 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 2018. APR materials with more details than what is provided within this report can be found at https://www.cct-fnw.com/annual-program-review/.

Key Management Questions

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

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

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

Figure 34. The Chief Joseph Hatchery's annual planning process and work flow.

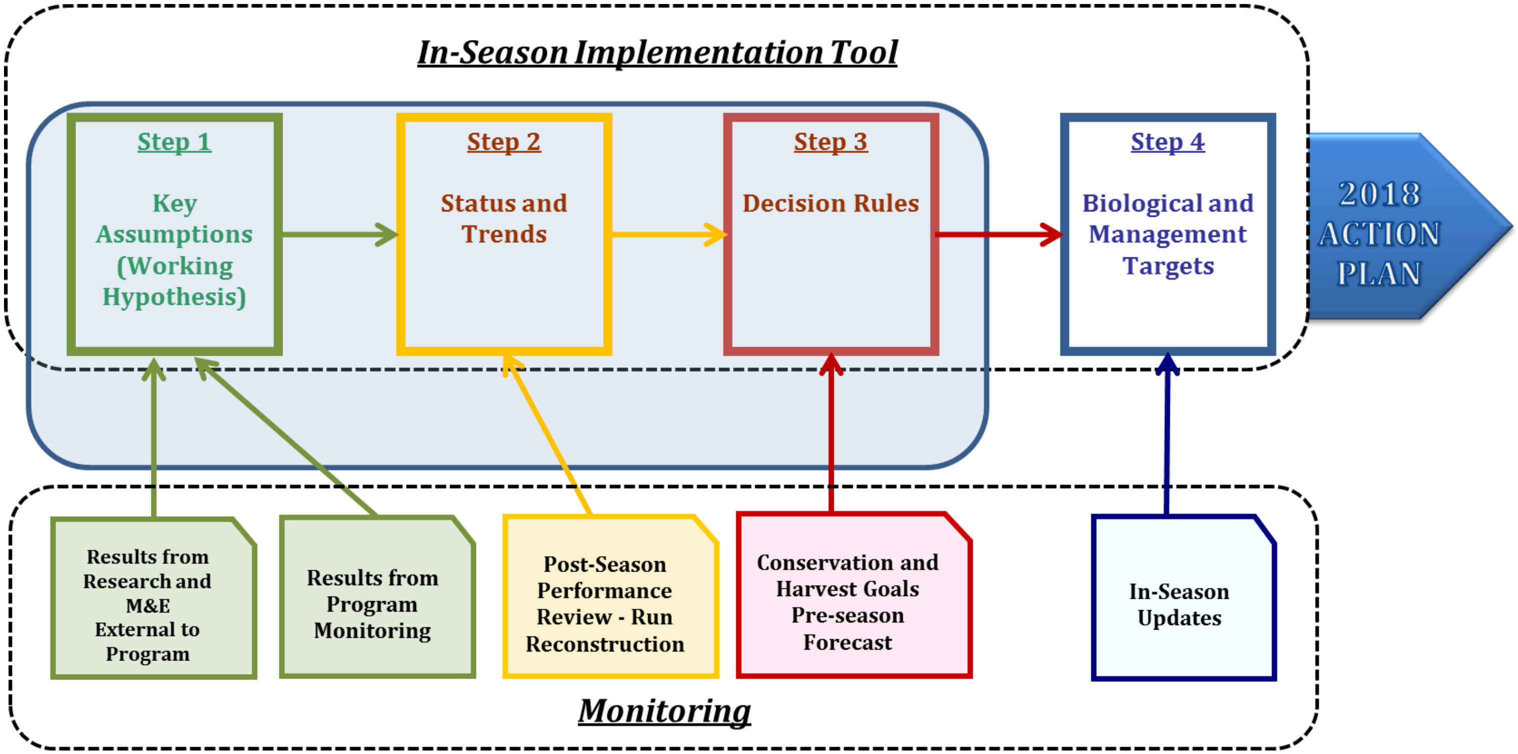


Figure 35. The Chief Joseph Hatchery's analytical work flow.

2018 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 67,300. The pre-season forecast, and subsequent run updates from early dam counts, were used to predict the NOR and HOR run size for the Okanogan population. Hatchery broodstock and selective harvest targets are determined based on these estimates and the objectives for pHOS (<0.30) and PNI (>0.67). A regression analysis conducted within ISIT in preparation for the APR predicted that the pre-season forecast of 67,300 upper Columbia would yield 4,561 NORs and 4,214 HORs (Figure 36). The harvest and broodstock collection goals were established from this prediction. With a NOR run size just a little less than 5,000 the broodstock collection recommendation for the integrated program was full production (616 NOB) with 100% pNOB (Figure 36). Likewise, the segregated program should achieve full production with 503 HOB. The model predicted that 1,306 HORs would be captured in the terminal (above Wells Dam) fisheries and that 49 HORs could be removed at the weir. These efforts could result in 3,261 NOS and 941 HOS for a pHOS of 19% and a PNI of 0.84. Under this modeling scenario the biological targets would be met in 2018. 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, 2018. 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 meeting the pHOS objective of < .30.

ANNUAL MANAGEMENT TARGETS

	2017	**<-- Most recent return year**
Use	**5**	-year running averages to calculate prior-cumulatives

Recent History:	
Average NOB	**400**
Average HOB	**51**
Average pNOB	**89%**
Average NOS	**7,721**
Average HOS	**1,502**
Average pHOS	**16%**
Average PNI	**0.84**

Expected Returns to Wells Dam (most recent update):	**2018 Forecast**	**2017 Final**
NOR Return (excludes jacks)	**4,561**	**6,646**
HORs from Integrated Program (excludes jacks)	**4,214**	**6,828**
HORs from Segregated Program (excludes jacks)	**-**	**-**

Runsize Prediction for:	**2018**
Preseason forecast (Columbia)	**67,300**
Applies until:	**07/15/18**
Wells Dam Count thru 07/15	**-**
Okanogan NOR Forecast (excludes jacks)	**4,561**
HOR Forecast (excludes jacks)	**4,214**

Prespawning Mortality	**10.0%**
NOR Terminal harvest induced mortality rate	**6.2%**

	Management Targets	**2018 Targets**
Harvest*	Okan. HORs retained in Fisheries	1,306
	Incidental Loss of NORs	322
	**Partial source of broodstock*	
Hatchery and Weir*	Return of HORs to Hatchery	1,814
	HORs retained at Weir	49
	**Partial source of broodstock*	
Integrated Hatchery Program	Natural Origin Brood (NOB)-Okan	616
	Hatch. Origin Brood (HOB)-Okan	-
	Projected Annual pNOB-Okan	100%
	Cum pNOB	91%
	Smolt Release-Okanogan	1,100,029
Segregated Hatchery Program	Hatch. Origin Brood (HOB) -CJH	503
	Smolt Release-CJH	900,000
Natural Spawning Escapement	Nat. Origin Spawners (NOS)	3,261
	Hat. Origin Spawners (HOS)	941
	Total Number of Spawners	4,202
	pHOS	19%
	PNI	0.84

Projected Status of Biological Indicators*:	
Average NOS	**7,346**
Average pHOS	**15%**
Average PNI	**0.86**

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

Figure 36. The in-season updates management worksheet used to set biological targets for the upcoming year (2018) in the In-Season Implementation Tool.

2018 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 37).

KEY ASSUMPTIONS-AHA

Natural Production	Baseline	Biological Targets	Transition 1	Transition 2	Long-term	Segregated Prog
Productivity (Smolts/Spawner)	1307		1307	1307	1307	
Capacity (Smolts)	3,672,603		3,672,603	3,672,603	3,672,603	
Juv Passage Survival	27%		27%	27%	27%	
Ocean Survival (BON to BON)	1.98%		1.98%	1.98%	1.98%	
Adult Passage Survival	83%		83%	83%	83%	
Fitness	0.94		0.90	0.92	0.92	
PNI	0.82	< 0.67	0.76	0.78	0.78	
Total pHOS	11%	> 30%	30%	26%	25%	
Segr. pHOS	2%	< 5%	1%	2%	2%	
Ocean Harvest Rate	35%		35%	35%	35%	
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	7%		7%	7%	7%	
Upper Columbia Harvest Rate (MCN to Wells)	28%		28%	28%	28%	
Terminal Harvest Rate (Post Wells)	6%		6%	6%	6%	
Natural Origin Spawners	4,063	< 5,250	3,485	3,848	3,827	
Hatchery Production						
Local Brood	140		616	421	421	337
Yearling Release	250,000		800,000	750,000	750,000	500,000
Sub-yearling Release	1		300,000	1	1	400,000
SAR (yearling)	1.63%		1.63%	1.63%	1.63%	1.63%
SAR (sub-yearling)	0.30%		0.30%	0.30%	0.30%	0.30%
Return Rate to Okanogan	38%		38%	38%	38%	20%
pNOB	50%		100%	100%	100%	
NOB	70		616	421	421	
Relative Reproductive Success	80%		80%	80%	80%	80%
Ocean Harvest Rate	35%		35%	35%	35%	35%
Lower Columbia Harvest Rate (Zones 1-6, Mouth to MCN)	7%		7%	7%	7%	7%
Upper Columbia Harvest Rate (MCN to Wells)	28%		28%	28%	28%	28%
Pre-terminal Harvest Rate (Ocean to Wells)	57%		57%	57%	57%	57%
Terminal Harvest Rate (Post Wells)	31%		31%	31%	31%	90%
Hatchery Surplus	799		2,649	2,284	2,284	362
Average Terminal HOR Run	1,761		5,635	5,283	5,283	3,522
Expected HOS	437		1,398	1,310	1,310	481
Fisheries and Weirs						
Weir Factor	5%		5%	5%	5%	
NOR Harvest Release Mortality	5%		5%	5%	5%	

Figure 37. The key assumptions worksheet used in the 2017 In-Season Implementation Tool for the CJHP planning at the Annual Program Review

2018 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 38).

				PUD Counts at Wells Dam		Okanogan Origin Fish to Wells Dam			Terminal Harvest Above Wells												Broodstock										
									Tribal Harvest					Recreational Harvest					Harvest Rates		Okanog./Similk Integrated Program						Okanogan Natural Spawning Escapement				
Return year		FPC Reported Dam Count at Wells thru 7/15 (excludes jacks)	% of final count	NOR All Origins (excludes jacks)	HOR All Origins (excludes jacks)	Okan. NORs	Okan. HORs		Total Tribal Harvest	Total NORs	Total HORs	Okan. NORs	Okan. HORs	Total Rec. Harvest	Total NORs	Total HORs	Okan. NORs	Okan HORs	NOR	HOR	Total NORs	Okan. NORs	Total HORs	Total Brood	Okanogan origin pNOB		NOS	HOS	Census pHOS	Effective pHOS	PNI
1998	3	1,060	0.25	970	5,519			0.00	-	0	0	-	-	-	-	-	-	-	-	-	153	77	211	364	21%	#	542	437	45%	39%	35%
1999	4	999	0.11	2,708	4,580	1,426	2,668		-	0	0	-	-	-	-	-	-	-	0%	0%	224	112	289	513	22%	#	1,182	2,142	64%	59%	27%
2000	5	2,266	0.26	2,726	7,398	1,111	2,257		-	0	0	-	-	-	-	-	-	-	0%	0%	164	82	339	503	16%	#	926	1,726	65%	60%	21%
2001	6	9,766	0.24	10,266	19,195	4,543	6,984		-	0	0	-	-	-	-	-	-	-	0%	0%	91	46	266	357	13%	#	4,048	6,047	60%	54%	19%
2002	7	23,221	0.34	24,138	42,035	5,060	11,757		1,753	653	1100	118	990	-	-	-	-	-	2%	8%	247	124	241	488	25%	#	4,337	9,473	69%	64%	28%
2003	8	20,564	0.40	9,194	7,373	2,434	2,937		2,130	785	1345	141	1,211	-	-	-	-	-	6%	41%	381	191	101	482	40%	#	1,892	1,463	44%	38%	51%
2004	9	14,762	0.40	23,227	13,989	7,716	2,598		242	0	242	-	218	2,803	1,895	908	1,706	817	22%	40%	506	253	16	522	48%	#	5,182	1,392	21%	18%	73%
2005	10	14,449	0.42	18,911	15,164	8,259	3,401	0.34	784	392	392	71	353	1,419	1,025	394	923	355	12%	21%	391	196	9	400	49%	#	6,364	2,416	28%	23%	68%
2006	11	12,563	0.43	20,262	8,730	8,348	4,113	0.43	1,389	563	826	101	743	2,119	1,809	310	1,628	54	21%	19%	500	250	10	510	49%	#	5,303	2,970	36%	31%	61%
2007	12	5,532	0.37	7,088	7,789	4,466	2,899	0.50	1,078	467	611	84	550	1,803	887	916	798	726	20%	44%	456	228	17	473	48%	#	2,774	1,282	32%	27%	64%
2008	13	8,838	0.35	11,244	13,779	4,311	6,368	0.43	2,299	588	1711	106	1,540	1,665	698	967	628	561	17%	33%	404	202	41	445	45%	#	2,866	3,734	57%	51%	47%
2009	14	13,753	0.46	15,184	14,187	5,561	5,673	0.38	2,598	363	2235	65	2,012	1,062	648	414	583	244	12%	40%	507	254	-	507	50%	#	4,002	3,036	43%	38%	57%
2010	15	12,264	0.41	5,671	7,167	4,541	5,394	0.77	2,912	354	2558	64	2,174	1,019	612	407	551	204	14%	44%	484	242	8	492	49%	#	3,087	2,614	46%	40%	55%
2011	16	3,912	0.12	12,139	19,164	5,116	6,419	0.37	1,097	449	648	81	577	1,017	200	817	180	556	5%	18%	467	332	26	493	67%	#	3,249	4,283	57%	51%	57%
2012	17	10,082	0.24	14,424	27,716	6,271	7,168	0.32	3,184	656	2528	118	2,250	2,470	829	1,641	746	1,264	14%	49%	107	96	-	107	90%	#	4,211	3,114	43%	37%	71%
2013	18	25,571	0.38	34,965	30,179	8,305	8,636	0.26	3,176	832	2344	150	2,110	2,107	179	1,928	161	1,735	4%	45%	366	329	1	367	90%	#	5,134	2,433	32%	27%	77%
2014	19	26,010	0.39	36,060	21,015	12,797	7,555	0.36	2,963	1508	1455	271	1,310	1,383	321	1,062	289	956	4%	30%	499	449	5	504	89%	#	9,648	1,249	11%	9%	90%
2015	20	25,153	0.38	46,030	31,625	13,567	14,332	0.36	9,729	6257	3472	1,126	3,125	1,660	289	1,371	260	1,234	10%	30%	421	379	9	430	88%	#	10,621	2,523	19%	16%	85%
2016	21	21,479	0.32	28,467	21,542	10,083	10,572	0.41	3,141	1889	1252	340	1,127	1,784	237	1,547	213	1,392	5%	24%	584	526	-	584	90%	#	8,103	1,968	20%	16%	85%
2017	22	15,124	0.23	-	-	-	-		-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#	-	-	-	-	-

Figure 38. The status and trends worksheet in the In-Season Implementation Tool for CJHP planning at the Annual Program Review.

2018 Decision Rules

The decision rules determine the targeted size of the hatchery program and the management of natural escapement abundance and composition. The purpose of the Decision Rules is to assure that the CJHP manages the hatchery, terminal fisheries and weir to meet the guidelines for abundance, spawner composition, and distribution of the natural spawning escapement (Figure 39).

BIOLOGICAL TARGETS AND "PHASE TRIGGERS"

Population Designation: Primary

Current Phase: Transition 1 (from Decision Rules)

		Applied Scenario		Phase 1 Recolonization	Phase 2 Local Adapt.	Phase 3 Recovered
Biological Triggers for Phase Change Rules		**Transition 1**	**Baseline**	**Transition 1**	**Transition 2**	**Long term**
	Year	2020	2013	2020	2025	-
	Move up one phase if NORs greater than:	5,250	1,000	5,250	7,000	-
	Move down one phase if NORs less than:	800	-	800	3,000	6,000
	Based on N-Year Running Average, where N=	5	[Enter integer between 3 and 10, inclusive]			
Management Control Variables for "Sliding Scale" Rules		**Transition 1**	**Baseline**	**Transition 1**	**Transition 2**	**Long term**
Integrated Program	Minimum NOR escapement	800	800	800	800	800
Integrated Program	Smallest viable hatchery program	100,000	100,000	100,000	100,000	100,000
Integrated Program	Max % of NORs used for Broodstock	30%	30%	30%	30%	30%
Integrated Program	Maximum Yearling Releases	800,000	250,000	800,000	750,000	750,000
Integrated Program	Maximum Subyearling Releases	300,000	1	300,000	1	1
Integrated Program	Broodstock Required	616	140	616	421	421
Integrated Program	pNOB [Lo] Trigger (NOR run)	2,000	1,100	2,000	2,000	3,000
Integrated Program	pNOB above Trigger	100%	50%	100%	100%	100%
Integrated Program	pNOB below Trigger	30%	30%	30%	30%	100%
Segregated Program	Maximum Yearling Releases	500,000	-	500,000	600,000	600,000
Segregated Program	Maximum Subyearling Releases	400,000		400,000		-
Segregated Program	Backfill w/ HORs (Y, N)	N	N	N	N	N
Other Control Variables	Maximum Weir Efficiency	5%	5%	5%	5%	5%
Other Control Variables	Term. Harvest Rate Integrated HORs	31%	31%	31%	31%	31%
Other Control Variables	Term. Harvest Rate Segregated HORs	90%	90%	90%	90%	90%
	pNOB Trigger Range (NOR run)	1,000	sets range for "sliding scale pNOB" --applied to all phases			
	NOS Escapement Goal	5,250	-	5,250	5,250	5,250

Modeled outcomes versus Biological Targets

	Targets	Status in 2017 (5-year average)	Projected Status in 2018 (5-year average)	Projected Status 2018-2042	
				Median*	Range*
NOS	> 5250	7,721	7,346	2,457	1,765 - 5,739
pHOS	< 30%	16%	15%	36%	16% - 45%
PNI	> 0.67	0.84	0.86	0.73	0.68 - 0.87
Terminal Catch	> 3000	1,306	1,627	4,094	806 - 6,568

*Median, minimum and maximum values from 2018-2042 based on a single model run.

Figure 39. 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.
8. Abundance of Priest Rapids Hatchery fish at the Okanogan weir and CJH ladder.
9. Use of otolith microchemistry to determine origin and rearing locations of sub-yearling Chinook captured at various beach seining locations.

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APPENDIX A

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 are two CJH acclimation facilities on the Okanogan River, Omak (rkm 51) and Riverside (rkm 64) acclimation ponds. 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 2.9 million Chinook Salmon, including 2 million summer/fall Chinook and 900,000 spring 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. The spring Chinook program includes a segregated program (700,000 smolts) supported by Leavenworth National Fish Hatchery (LNFH) broodstock and a re-introduction program (200,000 smolts) supported by WNFH broodstock (Met Comp stock) to reintroduce spring Chinook to the Okanogan under section 10(j) of the ESA.

In 2017, 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. The segregated spring Chinook program also did not meet full production goals due to higher than expected egg loss thought to be due to low fertilization rate and soft shell disease. The 10(j) spring Chinook reintroduction program was full program.

Spring Chinook Salmon

BY 2016 Leavenworth Spring Chinook Rearing and Release

Pre-spawn mortality was average and BKD prevalence was low, resulting in the program meeting its goal for egg take. However, green to eyed egg survival was only 51%, resulting in fewer ponded fry than anticipated. A total of 556,459 fish were ad-clipped, with a total of 204,573 also receiving a CWT. This group also received 5,000 PIT tags, with a total of 4,970 released (4,238 detected at release). During the month of April, reservoir water temperatures increased steadily, triggering a good smolt response. Feeding rates were increased for final grow out. A volitional release began on April 16th with the last of the fish being pushed out April 17th.

Cumulative egg to smolt survival

The cumulative egg to smolt survival for the 2016 brood Leavenworth-stock Spring Chinook was 90.2%, with the fry to smolt survival being 95.97% (Table A 1). This includes ponding loss, rearing loss, and subtracting the shortage realized at marking. This overall survival metric will be a critical assessment of the hatchery's performance each brood year. The target egg to smolt survival identified in the original spring Chinook HGMP was 77% (CCT 2008a).

Table A 1. Chief Joseph Hatchery BY 2016 Spring Chinook rearing summary, April 2018.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
5/31/2017	573,211	8,317	486	620	98.57%
6/30/2017	562,918	10,293	1,301	275	96.80%
7/31/2017	556,459*	3,450	2,208	100	96.19%
8/30/2017	556,273	186	1,497	80	96.15%
9/30/2017	556,141	132	2,369	60	96.13%
10/31/2017	555,956	185	2,860	53	96.10%
11/30/2017	555,571	385	3,432	42	96.03%
12/31/2017	555,363	208	3,432	32	96.00%
1/31/2018	555,278	85	1,892	31	95.98%
2/28/2018	555,250	28	1,056	31	95.98%
3/31/2018	555,224	26	3,026	31	95.97%
4/17/2018	555,188	36	3,784	25	95.97%
Cumulative:	**555,188**	**23,331**	**27,343**	**25**	**95.97%**

*Shortage at marking - 3,009
Volitional release began on 4/16/18 with all being forced out on 4/17/18

BY 2016 10J MET COMP SPRING CHINOOK REARING AND RELEASE

On October 3, 2016, CCT staff transported 206,138 MetComp Spring Chinook eyed eggs from the USFWS Winthrop National Fish Hatchery for rearing at CJH. On October 26, 2017 fish were transferred to the Riverside Acclimation Pond. Under Permit No. 18928, issued by the National Marine Fisheries Service, this group is designated as an (10j) experimental population, for the reintroduction of Spring Chinook into the Okanogan Basin.

Temperatures at both Omak and Riverside dropped dramatically during December, and both ponds iced over. Over the course of the spring, temperatures rose steadily, and the fish growth stayed on target for release. These fish were forced released on April 19, 2018. Table A 2 illustrates feed fed, feeding rate, and mortality to date. After subtracting mortality and shed tags, a total of 4,356 PIT tags were released (3,445 were detected at release.)

Table A 2. Riverside Acclimation Pond BY 2016 integrated spring Chinook rearing summary, April 2018.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
11/30/2017	202,791	2,340	1,629	30	98.86%
12/31/2017	202,148	668	0	30	98.53%
1/31/2018	201,521	602	44	36	98.24%
2/28/2018	201,282	239	44	36	98.12%
3/31/2018	201,157	125	1,144	28	98.06%
4/19/2018	200,827	330	1,364	22	97.90%
Cumulative:	200,827	4,304	4,225	22	97.90%

Volitional release began on 4/16/18 with all being forced out on 4/19/18

BY 2017 CJH/Leavenworth Spring Chinook

2017 Brood Collection

The segregated spring Chinook production goal for the 2017 brood is a release of 700,000 yearlings in April of 2019. The calculated number of brood needed to meet this production was 640 adults, based on a 50/50 ratio of males and females. This includes 10% pre-spawn mortality, up to 20% culling for Bacterial Kidney Disease (BKD) management, 10% egg loss, and rearing mortality of 15%. The mortality per life stage benchmarks were based on historical performance at LNFH. As with any new facility, baseline data collected during initial production years will be the basis for adjusting broodstock requirements in future years.

As early projections for returning Spring Chinook to Leavenworth looked to be short of total program needs, the decision was made to operate the ladder at CJH to collect returning adults from the BY 2013 production. The ladder was opened on May 29th, and on May 31st we collected 151 HORs for brood. The remainder of the brood was collected in June and July.

The broodstock were scanned for both CWT and PIT tags, and any CWT positive adults were segregated into a separate pond from the ad-clipped only adults. The adult pond had a flow rate of 475 gpm, and an exchange rate of 60 minutes, representing a Flow Index (FI) of 0.42 for both pond #5 and #6. Since collection, both adult ponds have been on 100% well water to maintain proper temperature profiles, and alleviate the risk of Columnaris. Both ponds #5 and #6 are being treated a minimum of 3 day/week with formalin to control fungus, at a concentration rate of 1:6000, for one exchange. Pre-spawn mortality was very low at 93.4% survival (Table A 3).

Table A 3. Chief Joseph Hatchery spring Chinook broodstock holding and survival summary for 2017. (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**
June	265	4	321	265	4	321	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	265	4	321	295	5	320	1	0	1	99.6%	100.0%	99.7%	99.7%	100.0%	99.7%
August	295	5	320	276	5	299	19	0	21	93.6%	100.0%	93.4%	93.6%	100.0%	93.5%
Total	**295**	**5**	**320**	**276**	**5**	**299**	**20**	**0**	**22**	**NA**	**NA**	**NA**	**93.7%**	**100.0%**	**93.1%**

Spawning

Spawning began on August 16th and concluded on August 30th. The spawn consisted of 266 females, 263 males and 3 jacks, with 12 non-viable (green) females killed resulting in an estimated green egg take of approximately 1,010,800.

Spawning occurred inside the spawning shed adjacent to the adult holding raceways, and gametes were then transported to the main facilities egg entry room for processing. Each individually numbered female was fertilized with a primary male initially, and then a backup male was added to ensure fertilization. Each female's eggs were then placed in the corresponding numbered trey. The eggs from 25 females were culled due to high or moderate ELISA results (culled eggs from ELISA results are not included in Table A 4.). This was approximately 9.4% of the females spawned and is less than what is planned for (up to 20%).

Incubation

Each female's eggs were initially incubated separately to facilitate culling based on ELISA results. Once eyed, egg mortality was removed and eggs were combined for hatching. All spring Chinook eggs were placed on varying degrees of chilled water. The water temperature was gradually dropped, on the first egg take, to 37° F degrees. This process was done over a several hour period four days after spawning. The second egg take was left on well water (60° F) until such time as the total numbers of temperature units (TUs) were earned to equal the first egg take, then the same procedure was used to lower water temperature to 37° F. This process provided the ability to control when, and how many, fish are brought out of the incubators and placed into early rearing.

Green egg to eyed egg survival was 42.7% (Table A 4). This survival was far lower than the key assumption (90%) due to low fertilization rate, soft shell disease and premature hatching.

Table A 4. Chief Joseph Hatchery spring Chinook spawning and egg survival summary for 2017 (M = adult males, J = jacks and F = adult females). The target survival standard for this life stage was 90%.

Spawn Date	Total Adults Spawned			Estimated Green Eggs	Eyed Eggs	Mortality* (Pick off)	Cumulative Survival (%)
	M	J	F				
8/16/2017	77	0	77	292,600	114,010	178,879	38.9%
8/23/2017	141	3	144	547,200	186,225	295,450	38.7%
8/30/2017	45	0	45	171,000	81,115	37,170	68.6%
Total:	**263**	**3**	**266**	**1,010,800**	**381,350**	**511,499**	**42.7%**

*Mortality does not include the 77,787 eggs culled for high ELISA values

Rearing

Due to the manipulation of TUs, all BY17 spring Chinook groups were ponded after April 30, 2018.

Summer/Fall Chinook Salmon

BY 2016 Summer/Fall Chinook Salmon Rearing and Release

A total of 409,232 sub-yearling summer/fall Chinook were brought out of incubation from February 1, 2017 through February 15, 2017. Rearing proceeded on schedule, with the marking of both the integrated and segregated sub-yearlings in April 2017. In early May, a total of 217,909 integrated sub-yearlings were transferred to the Omak Acclimation Pond, at 75 fish per pound. This group was released on May 22, 2017, with a post transfer survival of 99.5%, and a cumulative survival from ponding of 94.0% (Table A 5). Approximately 5,000 PIT tags were added to each group and after subtracting shed tags and mortality, a total of 4,571 PIT tags were released (678 were detected at release).

A total of 185,844 segregated summer/fall sub-yearlings were marked and transferred into rearing Pond B, for final rearing and release. This group was released on May 16, 2017, at

50 fish per pound. Cumulative rearing survival was 98.0% (Table A 5). Approximately 5,000 PIT tags were added to each group and after subtracting shed tags and mortality, a total of 5,029 PIT tags were released (4,030 PIT tags were detected at release).

Table A 5. Chief Joseph Hatchery brood year 2016 sub-yearling summer/fall Chinook rearing summary, May 2017.

	On hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
Month	**Total**	**Total**	**Total**	**Total**	**Total**
HORs					
Mar. 31	183,751	507	714	120	98.1%
Apr. 30	185,844*	183	1,595	75	98.0%
May 16	185,821**	23	792	50	98.0%
sub-total	185,821	713	3,101	50	98.0%
NORs					
Mar. 31	225,481	550	896	120	94.9%
Apr. 30	217,909*	614	1,382	75	99.5%
May 22	216,804**	1,105	1,056	44	94.0%
sub-total	216,804	2,269	3,334	44	94.0%
Cumulative	402,625	2,982	6,435	47	96.0%

*Population adjusted after marking
**Released

The yearling summer/fall Chinook rearing proceeded on schedule, with both the integrated and segregated groups being marked in July and August. Marking was completed, for both the integrated and the segregated programs, on September 14, 2017. The segregated summer Chinook were 100% ad-clipped, with a 100k CWT group tagged. The integrated summer Chinook were 100% AD/CWT. As shown in Table A 6, ponding and rearing mortality for the segregated program has been lower than anticipated, although both stocks were short of book numbers, at marking. The segregated fish were marked into rearing Pond B, while the integrated fish were marked into the lower raceways, and reared until transfer to the acclimation ponds in late October. The segregated group was released on April 18th. Approximately 5,000 PIT tags were added to each group in October 2017. After subtracting shed tags and mortality, a total of 4,921 PIT tags were released from the segregated group (4,381 were detected at release).

Table A 6. Chief Joseph Hatchery brood year 2016 segregated summer/fall yearling rearing summary.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
6/30/2017	479,811	3,633	588	375	99.25%
7/31/2017	478,632	1,179	1,059	150	99.00%
8/31/2017	465,146*	269	1,232	90	98.95%
9/30/2017	465,080	66	2,122	50	98.94%
10/31/2017	465,000	80	2,332	46	98.92%
11/30/2017	464,693	307	3,300	30	98.86%
12/31/2017	464,693	245	3,564	28	98.80%
1/31/2018	464,425	23	2,288	26	98.80%
2/28/2018	464,394	31	1,973	25	98.79%
3/31/2018	464,365	29	6,360	25	98.79%
4/30/2018	464,329	36	3,872	25	98.78%
Subtotal:	**464,329**	**5,898**	**28,690**	**25**	**98.78%**

*Shortage after marking - 13,217

The integrated summer/fall Chinook were shipped to the Omak Acclimation Pond and the Similkameen Acclimation Pond between October 16th and October 24th. Reporting for the Similkameen Pond will reside with WDFW through release.

Omak Acclimation Pond

On October 24, 2017 Chief Joseph Hatchery staff transferred 303,138 Integrated BY 16 summer Chinook from Chief Joseph Hatchery to the Omak Acclimation Pond. At the time of transfer, the fish were approximately 30 fpp, and were programmed to be reared over winter, with a target size at release of 10 fpp. An additional 382,610 BY 16 Summer Chinook were transferred to WDFW's Similkameen Pond, as part of the cost share agreement. These fish were forced released April 19, 2018. Table A 7 illustrates feed fed, feeding rate, and mortality to date for the integrated summer/fall Chinook transferred to the Omak Acclimation pond. After subtracting mortality and shed tags, a total of 5,326 PIT tags were released (3,848 were detected at release).

Table A 7 Omak Acclimation Pond BY 16 integrated yearling summer/fall Chinook rearing summary.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
11/30/2017	303,138	581	1,629	30	99.81%
12/31/2017	302,921	217	0	20	99.74%
1/31/2018	302,567	354	44	28	99.62%
2/28/2018	302,174	393	88	28	99.49%
3/31/2018	301,839	335	1,760	25	99.38%
4/19/2018	301,246	593	2,156	20	99.19%
Cumulative:	**301,246**	**2,473**	**5,677**	**20**	**99.19%**

Volitional release began on 4/16/18 with all being forced out on 4/19/18

Riverside Acclimation Pond

Riverside Acclimation Pond was not used to rear BY 2016 summer/fall Chinook, but was utilized to rear BY 16 10j Spring Chinook, as noted above.

Similkameen Acclimation Pond

Similkameen Pond was used to rear yearling summer Chinook per the WDFW program funded by CPUD. Adult broodstock used to generate the juveniles for BY 2016 were collected via the CCT purse seine as part of the transition to the collaborative CJH program. On October 16, 2017, Chief Joseph Hatchery staff transferred 382,610 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 30 fpp, and were programmed for over winter acclimation, with a target size at release of 10 fpp. These fish began volitional release on April 16th, with an end release date of April 20, 2018. Cumulative survival, at the date of transfer, was 98.4%. Survival from transfer to release was 98.5%.

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 2016 sub-yearlings, was 66.9%. The cumulative egg to smolt survival, for the BY 2016 yearlings, was 88.3%.

2017 Broodstock collection

Collection of summer/fall Chinook for BY 2017 occurred between July 5th and August 27th via the CCT purse seine operation at the mouth of the Okanogan River. Both hatchery-origin and natural-origin brood were collected to supply the integrated and segregated production programs at CJH. As the seine was being pursed, 9-meter transport barges approached the seine vessel and tied off on the opposite side. The broodstock transport barges have two transport tanks, a 300 gallon for HORs and a 600 gallon for NORs. Brood fish were removed from the seine and placed headfirst in a rubber tube, or boot, containing some water and handed to the staff on the barges for placement in the holding tanks. A maximum of 14 HOR and 28 NOR brood could be loaded per barge. Once full, or at the commencement of the purse seine haul, the barges returned to the offload area at Mosquito Park approximately 2 km away. The brood was then removed from the tanks by hand, placed into a boot, then delivered to one of two 2,500 gallon tanker trucks and transported 16 km to the hatchery.

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

A weekly quota was developed to ensure that brood collections occurred across as much of the summer run timing as possible (Table A 8). If brood collection failed to meet the weekly quota it was adjusted the following week. The purse seine is only effective when there is a thermal barrier at the mouth of the Okanogan, therefore broodstock can only be collected there until late August or early September. Broodstock were offloaded, via water-to-water transfer, into adult ponds at CJH. The receiving water was approximately 57° F. The adult ponds had a flow rate of 425 gpm, and an exchange rate of 54 minutes, representing a Flow Index (FI) of 0.18 and a Density Index (DI) of 0.02. Upon arrival, adult ponds were put on well water. All adult ponds were treated a minimum of five days per week with formalin to control fungus at a rate of 1:6000, for one exchange. Additionally, brood fish were treated twice per week with Chloramine-T at 12 ppm for one exchange to control Columnaris bacteria. Based on the success of this treatment regime last year, it was decided to forego any adult injections of Draxxin and Vetrimycin – 200 (Oxytetracycline).

Table A 8. Chief Joseph Hatchery summer/fall Chinook weekly broodstock collection objectives and results for brood year 2017.

	Weekly Quota			Cumulative Collection	
Week	Natural Origin*	Hatchery Origin**	Cumulative Proportion	Natural Origin	Hatchery Origin
July 3 - July 9	22	22	0.04	22	22
July 10 - July 16	22	22	0.08	44	44
July 17 - July 23	108	104	0.27	152	148
July 24 - July 30	108	104	0.45	260	252
July 31 - Aug 6	132	126	0.69	392	378
Aug 7 - Aug 13	132	126	0.92	524	504
Aug 14 - Aug 20	36	36	0.98	560	540
August 21 - Aug 27	12	12	1.00	572	552
***Sept 15 - Oct 15	84			656	552

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

A total of 543 HOB were collected including 277 females, 266 adult males and 0 jacks (Table A 9). A total of 657 NOB was collected including 345 females, 312 adult males, and 0 jacks (Table A 9). No steelhead or Bull trout were encountered during broodstock collection efforts.

During the month of October 2017, there were 38 adult male and 99 adult female mortalities in the HOR brood, representing 85% and 63% cumulative pre-spawn survival to date. For the same month, 76 adult NOR Summer Chinook males died, and 171 females died, representing 70% and 41% cumulative pre-spawn survival. (Table A 9) Brood fish, particularly females, suffered higher than anticipated mortality due to Columnaris disease, which affected us particularly hard once the well water in which these fish are held reached >60°F.

The cumulative pre spawn holding survival, for all Summer/Fall brood collected, was 71.5% for HOB and 54.6% for NOB (Table A 9), with neither program meeting the survival standard (90%).

Table A 9. Chief Joseph Hatchery summer/fall Chinook Hatchery (HOB) and Natural (NOB) origin broodstock holding survival summary for brood year 2017. (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	Aug	266	0	277	265	0	273	1	0	4	99.6%	100%	98.6%	99.6%	100%	98.6%
	Sep	265	0	273	261	0	264	4	0	9	98.5%	100%	96.7%	98.1%	100%	95.3%
	Oct	261	0	264	223	0	165	38	0	99	85.4%	100%	62.5%	83.8%	100%	59.6%
	Total	**261**	**0**	**264**	**223**	**0**	**165**	**43**	**0**	**112**	**NA**	**NA**	**NA**	**83.8%**	**100%**	**59.6%**
NOR	Aug	269	0	304	265	0	296	4	0	8	98.5%	100%	97.4%	98.5%	100%	97.4%
	Sep	308	0	337	295	0	311	13	0	26	95.8%	100%	92.3%	94.6%	100%	90.1%
	Oct	295	0	311	219	0	140	76	0	171	74.2%	100%	45.0%	70.2%	100%	40.6%
	Total	**295**	**0**	**311**	**219**	**0**	**140**	**93**	**0**	**205**	**NA**	**NA**	**NA**	**70.2%**	**100%**	**40.6%**

After reaching target collections for brood via the purse seine, hatchery staff began collection of NOR brood from the weir. Collections off the weir went well and targets were reached without issue. Fish were transferred from the weir trap into the tanker truck using the Whooshh. No immediate or delayed mortalities caused by Whooshh handling-method were observed.

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 September at least offer the opportunity to include fish that arrive later in the run timing. These adults were 100% otolith sampled at spawning. The goal was to ensure that, prior to being included in the integrated production; there would be no unmarked Priest Rapids Hatchery fish in this group. Based on results from the WDFW Otolith Lab, there was one unmarked Priest Rapids Hatchery fish collected in September for the integrated program, but was not used in the integrated program.

Spawning

Spawning of Summer Chinook began on October 4, 2017, and continued through October 24, 2017. As with the Spring Chinook, the Summer Chinook program is also 100%

ELISA sampled. For the 2017 brood, we experienced a much lower than normal disease profile, and as a result eggs from only 3 females were culled.

Total NOB spawned included 167 males, zero jacks, and 162 females. (Table A 10) One of the 86 NOB taken from the weir and spawned had an otolith mark; identifying it as an ad-present Priest Rapids Hatchery adult. Total HOR spawn included 193 males, zero jacks, and 193 females. Total eyed egg take for the season was 1,245,910. Egg survival from green egg to eyed egg for NOB averaged 85.2% (Table A 10). Egg survival for HOB averaged 87.0%. Survival was lower than the key assumption of (90%) for this life stage.

Table A 10. Chief Joseph Hatchery brood year 2017 summer/fall Chinook spawning and incubation results.

	Spawn Date	Total Adults Spawned M	Total Adults Spawned J	Total Adults Spawned F	Estimated Green Eggs	Eyed Eggs	Mortality* (Pick off)	Cumulative Survival (%)
HOR	10/4/2017	61	0	61	305,000	204,725	34,601	85.5%
	10/11/2017	78	0	78	390,000	285,434	29,386	90.7%
	10/18/2017	43	0	43	215,000	127,612	15,238	89.3%
	10/24/2017	11	0	11	55,000	44,562	6,862	86.7%
	Total:	**193**	**0**	**193**	**965,000**	**662,333**	**86,087**	**87.0%**
	Spawn Date	**Total Adults Spawned M**	**Total Adults Spawned J**	**Total Adults Spawned F**	**Estimated Green Eggs**	**Eyed Eggs**	**Mortality (Pick off)**	**Cumulative Survival (%)**
NOR	10/4/2017	37	0	37	185,000	142,093	23,393	85.9%
	10/11/2017	83	0	78	390,000	279,485	47,895	85.4%
	10/18/2017	43	0	43	215,000	149,693	14,143	91.4%
	10/24/2017	4	0	4	20,000	12,306	732	94.4%
	Total:	**167**	**0**	**162**	**810,000**	**583,577**	**86,163**	**85.2%**

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

Broodstock origin

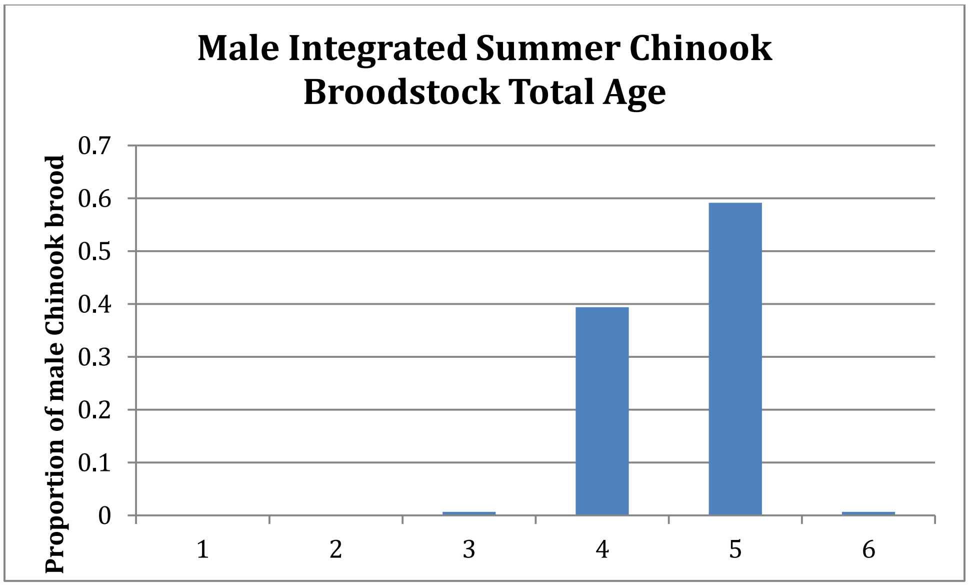
Broodstock were interrogated for coded-wire tags on four different spawning events during October: 10/4, 10/11, 10/18 and 10/24. When a wire was detected, the snout was collected for extraction and analysis that occurred in the laboratory at a later date. All of the brood stock collected for the summer Chinook segregated program came from an Upper Columbia River hatchery program. The CJH integrated program was the largest contributor to segregated brood with (n=336) 73.7% of adults coming from either the Similkameen or Omak Pond (Table A 11). Other Upper Columbia River Hatcheries contributed (n=64) 14.0%, most of which were from Wells (9.4%) and Chelan Falls (4.2%) hatcheries. A large portion of snouts (n=42) 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 9.2% of the 2017 segregated brood (Table A 11). A relatively large percentage of the segregated CJH does not receive a CWT (60-70%), and in 2017 4-year olds returned from the CJH segregated program. All summer Chinook programs upstream of Priest Rapids Dam are expected to have a 100% tag rate (except for CJH segregated).We would expect a portion of no CWT detection in the lab with the CJH segregated adult returns After adjusting for tag loss, the number of estimated non-CWT recoveries (n=36) can be assigned to the segregated CJH program. The overall composition of the segregated program (tagged and non-tagged) to the segregated brood was 9.7%.

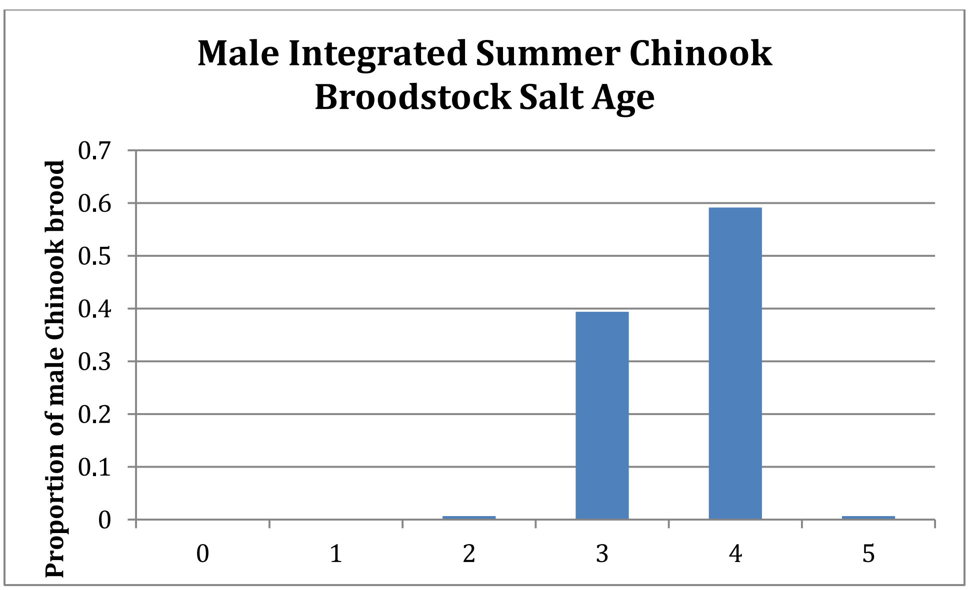
Table A 11. Composition of hatchery-origin brood, by program, collected for the CJH segregated program in 2017.

Category	Hatchery Program	# tags	% of brood	
Okanogan Integrated	Similkameen	188	41.2%	73.7%
	Omak Pond	148	32.5%	
CJH Segregated	Chief Joseph	8	1.8%	9.7%
	Chief Joseph (non-tagged)	36	7.9%	
Other UCR summer/fall Chinook hatchery	Carlton	1	0.2%	14.0%
	Wells	43	9.4%	
	Chelan Falls	19	4.2%	
	Entiat	1	0.2%	
Unknown	Lost/scratched Tags	6	1.3%	2.6%
	No tag in snout	6	1.3%	
Total		456	100.0%	

Integrated Program Broodstock Age Structure

Scales are taken from summer Chinook integrated Program broodstock in order to capture the age of successfully spawned fish. In 2017, the integrated and segregated programs were comprised of mostly four and five-year old male and female fish. (Figure A 1).





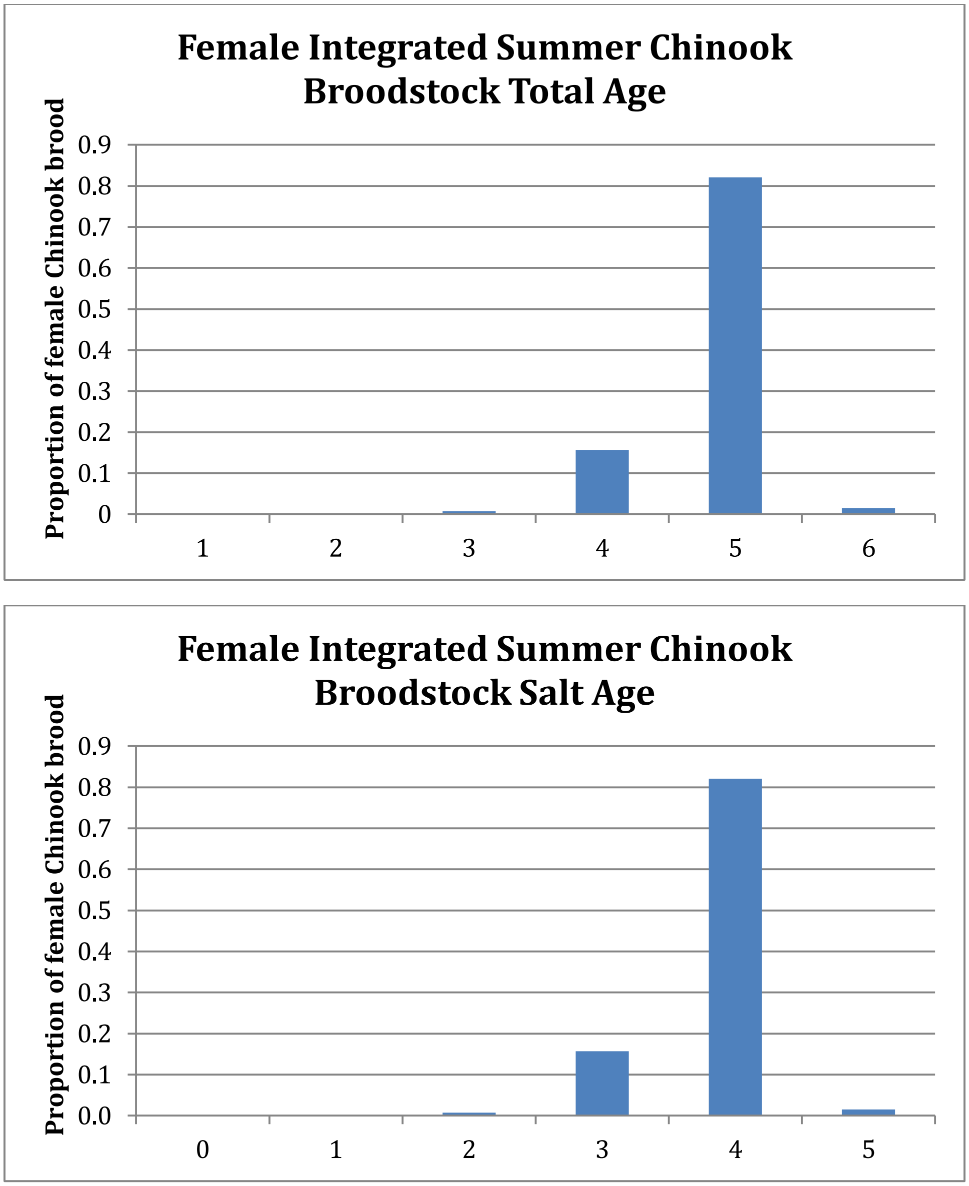
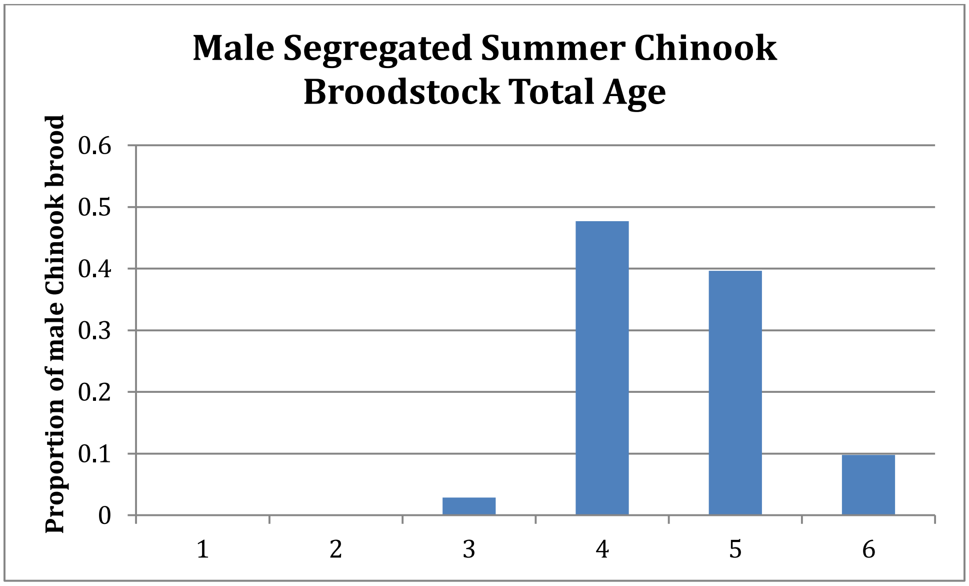
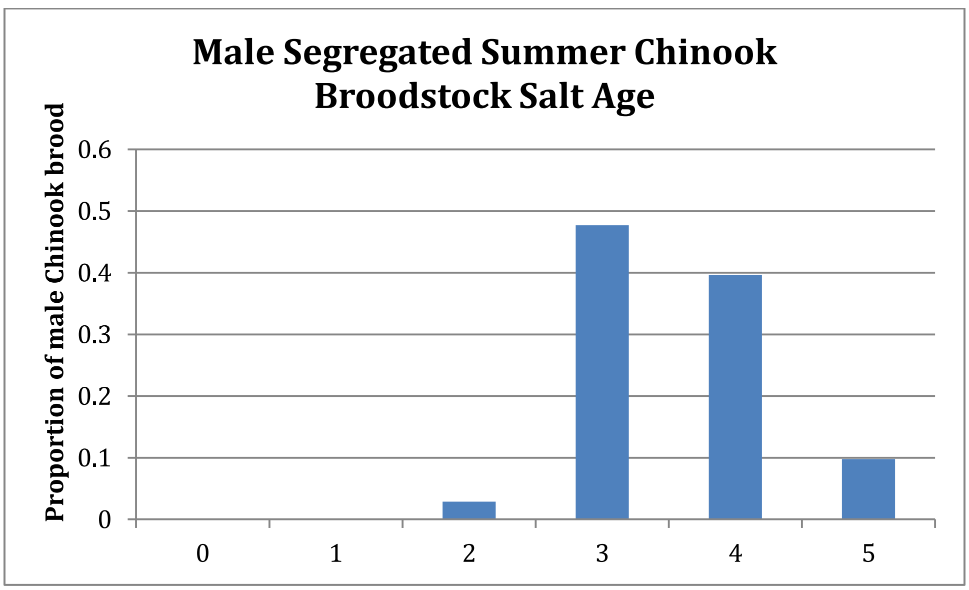


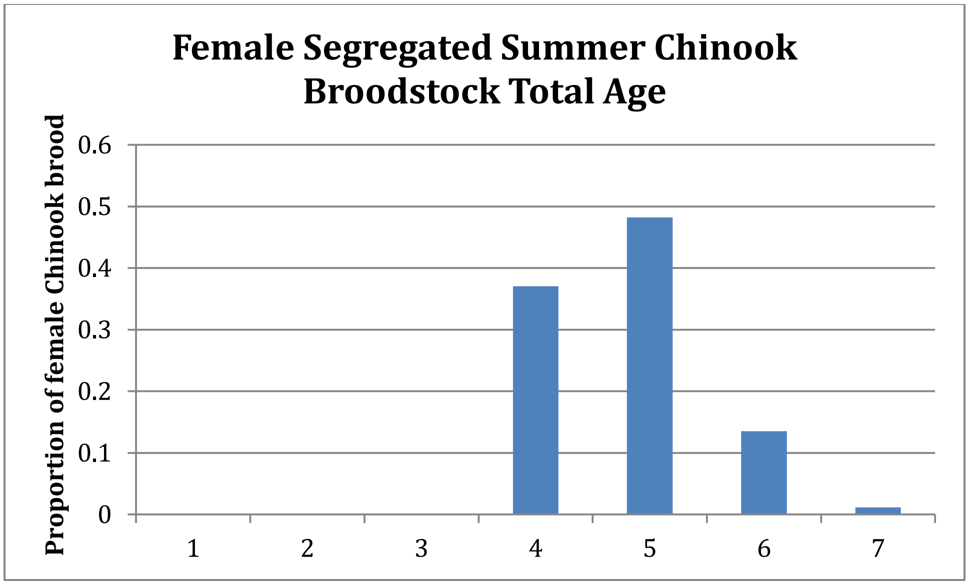
Figure A 1. The total and salt ages of the 2017 broodstock, males and females, collected for the Okanogan summer/fall Chinook integrated program.

Segregated Program Broodstock Age Structure

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







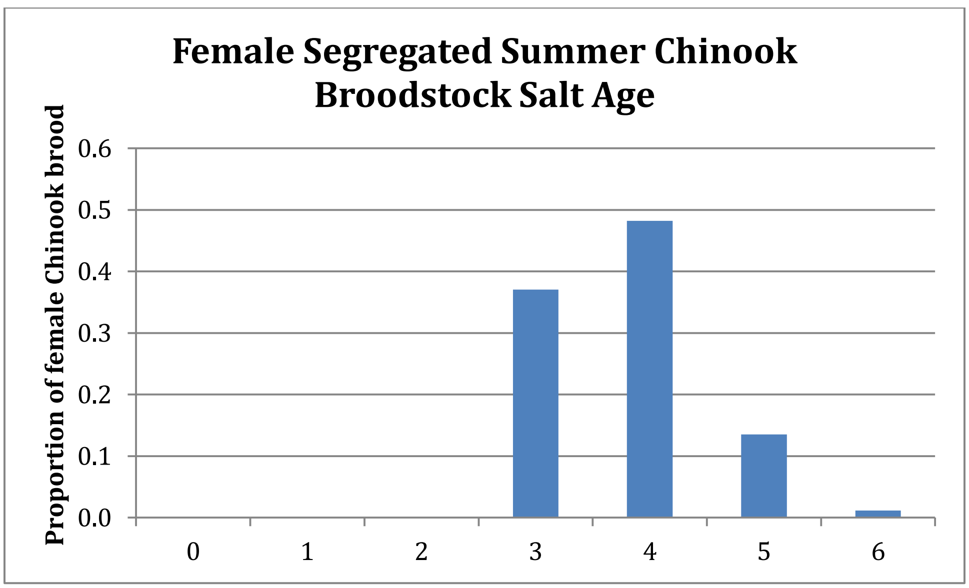


Figure A 2. The total and salt ages of the 2017 broodstock, males and females, collected for the Chief Joseph Hatchery segregated program.

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; 3 females were discarded from the 2017 brood. The cull rate for this production plan allows for a rate of 5% for segregated and 3% for integrated. After eye-up, egg mortality was removed and the eggs were inventoried and put into incubators at 5,000 eggs per tray for hatching. Incubation water temperatures were manipulated to the level necessary to synchronize the hatching and ponding of the spawn takes throughout October and November 2017 and to achieve the size-at-release target for both yearling and sub-yearling summer Chinook programs. Four days after spawning, the incubation water temperatures were gradually reduced on yearling egg-takes to a temperature of 37° F. Once each take achieved 100 TUs, incubation temperatures were manipulated to either advance or delay maturation. Variable incubation water temperatures were required to synchronize hatching dates associated with variable spawn dates throughout the spawn period within yearling and sub-yearling production groups and to achieve target hatching date associated with size-at-release targets, based on projected growth rates and release dates for the respective production groups.

Rearing

The segregated sub-yearlings (198,572) were brought out of incubation and transferred into early rearing troughs on February 2, 2018 (Table A 12). During the month of February, this 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. All sub-yearlings are released in the first spring of life, and after marking in April, they were released in May of 2018. Additionally, 5,000 fish received PIT tags. There was no integrated sub-yearling program for brood year 2017 due to low egg take.

Table A 12. Chief Joseph Hatchery brood year 2017 summer/fall Chinook sub-yearling rearing summary.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
2/28/2018	194,403	2,773	167	406	98.59%
3/31/2018	194,004	399	889	148	98.31%
4/30/2018	182,558*	999	1,254	64	97.77%
Cumulative:	**182,558**	**4,171**	**2,310**	**64**	**97.77%**

*Shortage at marking - 10,447

The first group of integrated yearlings was brought out of incubation and transferred into early rearing troughs after April 30, 2018.

Chief Joseph Hatchery Ladder

The CJH ladder is operated with the primary purpose of adult management (reducing pHOS) but can also be utilized to collect brood for the segregated program in years of low abundance or if the purse seine is not effective due to environmental conditions. In 2017 the escapement and environmental conditions were such that no brood was collected from the CJH ladder. The CJH fish ladder began operation on June 21, 2017, with the first adult management activities occurring on July 6th. All hatchery Chinook and Sockeye were removed from the ladder and utilized for Tribal subsistence and ceremonial food purposes. All steelhead and NOR Chinook were returned to the river via a water to water transfer.

From June 21st thru October 16th, 4,310 hatchery-origin summer/fall Chinook and 33 sockeye were removed at the CJH ladder and were utilized for tribal subsistence purposes (Table A 13). A total of 556 natural-origin Summer/Fall Chinook and 10 steelhead were trapped, handled and released back to the Columbia River (Tables A 14 and A 15).

The encounter/handling and release of 10 NOR steelhead represents 90% of the allowable incidental take provided in the Biological Opinion (BiOp) for Chief Joseph Hatchery collection facilities (NMFS 2008). There were no observed immediate steelhead mortalities during the ladder operations in 2017.

Table A 13. Chief Joseph Hatchery adult summer/fall Chinook ladder operations from June to October 2017.

Month	# of Ladder Trap Checks	HOR Males surplussed	HOR Females surplussed	HOR Jacks surplussed	NOR Males RTS	NOR Females RTS	NOR Jacks RTS
June	1	36	51	12	1	0	1
July	7	815	597	69	101	65	38
Aug	10	1231	812	314	147	69	19
Sept	2	126	70	68	12	6	4
Oct	1	46	34	29	0	0	0
Total	**21**	**2,254**	**1,564**	**492**	**261**	**140**	**62**

RTS= Return to stream

Table A 14. Chief Joseph Hatchery adult spring Chinook, sockeye and steelhead ladder operations from June to October 2017.

Month	# of Ladder Trap Checks	HOR Spring Chinook Surplussed	HOR Spring Chinook Jacks Surplussed	NOR Spring Chinook RTS	NOR Spring Chinook Jacks RTS	Sockeye Surplussed	AD Present Steelhead RTS	AD Absent Steelhead RTS
June	1	0	0	0	0	0	0	0
July	7	79	9	18	47	0	0	0
Aug	10	0	0	0	0	24	0	4
Sept	2	0	0	0	0	9	0	6
Oct	1	0	0	0	0	0	0	0
Total	**21**	**79**	**9**	**18**	**47**	**33**	**0**	**10**

RTS= Return to stream

Table A 15. Chief Joseph Hatchery annual summer/fall Chinook, sockeye, and steelhead collected during ladder operations.

Date	HOR Chinook surplussed	HOR jacks (1) surplussed	NOR Chinook RTS	NOR jack RTS	HOR Chinook Brood	Sockeye	AD Present Steelhead RTS	AD Absent Steelhead RTS	Coho RTS
Aug.- Nov. 2013	1,263	523	247	69	9	10	38	0	0
July-Nov. 2014	2,835	1,778	861	245	87	31	69	122	181[6]
July-Oct. 2015	6,773	1,651	1,671	369	217[4]	180	119[2]	401	2
June-Oct. 2016	5,359	995	465	91	196[5]	5	11[3]	45	0
June-Oct. 2017	3,818	492	401	62	0	33	0	10	0
Total	**20,048**	**5,439**	**3,645**	**836**	**509**	**259**	**237**	**578**	**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

Table A 16. Chief Joseph Hatchery spring Chinook collected during ladder operations in 2017.

Date	HOR Chinook surplussed	HOR Chinook Jacks surplussed	NOR Chinook RTS	NOR Chinook Jacks RTS	HOR Chinook RTS	HOR Chinook Jacks RTS	HOR Brood
May	0	0	0	0	1	0	151
June	0	0	6	13	247	136	441
July	79	9	12	34	0	0	32
August	37	2	5	6	0	0	0
Total	**116**	**11**	**23**	**53**	**248**	**136**	**624**

RTS= Return to stream

The ladder was closed and dewatered on October 16, 2017 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 2017 when CWT extraction and reading took place in the Chief Joseph Hatchery lab. Recovery data were expanded by the tag rate at the hatchery of origin and the sample rate at the ladder. Please refer to the Methods section for details on the expansion process for recovered tags. Beginning with jacks in 2016, snouts without a tag were assumed to be from the CJH segregated program.

Six summer/fall Chinook hatchery programs were encountered at the CJH ladder in 2017, all of which still came from upstream of Priest Rapids (Table A 17). Wells (33%) and Chelan (25%) hatcheries were the most common and Dryden (6%) and Similkameen (3%) still remained a small proportion of the composition (Table A 17). The Omak Pond (3%) program made up a small percentage of the overall ladder surplus while the CJH segregated program made up 26% of the composition. Half of these recoveries were from ad-clipped, non-coded wire tagged (CWT) fish and are presumed to be from the CJH segregated program since this is the only one above Priest Rapids that releases ad-clipped, non-CWT fish.

Table A 17. Summary of summer/fall Chinook coded-wire tags encountered and expansions for the CJH ladder in 2017.

Category	Hatchery Program	# Tags	Expanded Abundance	% of Ladder Surplus
Okanogan Integrated	Omak Yearlings	16	80	2%
	Omak Subyearlings	10	52	1%
	Similkameen	20	108	3%
CJH Segregated	Segregated yearlings	64	321	9%
	Segregated subyearlings	26	131	4%
	No CWT, presumed Segr	88	443	13%
Other UCR summer/fall Chinook hatchery	Wells	230	1155	33%
	Chelan	177	893	25%
	Carlton	19	96	3%
	Entiat	6	30	1%
	Dryden	38	195	6%
Out of ESU hatchery	Irrigon	1	5	0%
Total		***694***	***3,504***	***100%***

Table A 18. Percent of CJH ladder surplus 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 will be 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	25%	3%	3%	33%	25%	3%	1%	6%	0%	0%
Avg.	***3,994***	***6%***	***1%***	***8%***	***33%***	***28%***	***5%***	***2%***	***13%***	***0%***	***0%***

[a]Includes recoveries with 'no coded wire tags' in 2015-present

[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)

The spring Chinook CWT recovery data from the CJH ladder represents spring Chinook encountered during Chinook ladder operations (June 21-October 16). In 2017, the majority (75%) of spring Chinook encountered at the CJH ladder were from the CJH segregated program(Table A 31). Twenty-five percent of the Spring Chinook encountered at the ladder were from the Okanogan 10(j) program at Riverside Pond. There were no other hatcheries represented for recoveries in 2017.

Table A 19. Percent of CJH ladder surplus spring Chinook each year estimated to be from various facilities based on CWT assessment of spring Chinook. Estimated number of annual spring Chinook coded wire tag recoveries, by release hatchery, from Chief Joseph Hatchery ladder operations in June to October.

	# Surplus Fish	Facility/Program						
		Riverside Pond	CJH	Winthrop	Leavenworth	Chiwawa Pond	Methow Hatchery	Other[a]
2013	3	0%	0%	0%	0%	100%	0%	0%
2014	46	0%	0%	0%	91%	7%	2%	0%
2015	24	0%	0%	4%	75%	17%	0%	4%
2016	17	13%	43%	6%	13%	13%	6%	6%
2017	127	25%	75%	0%	0%	0%	0%	0%
Average	43	8%	24%	2%	36%	27%	2%	2%

[a] Releases from Out of ESU hatcheries include:, Parkdale and Nez Perce hatcheries

APPENDIX B

2018 Production Plan

Table B 1. Summer Chinook Early - Integrated Program (Similkameen Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2018						**Planting Goal:**	267,000		
Species:	Summer Chinook - Early						**Pounds:**	26,700		
Stock:	Okanogan									
Origin:	Wild									
Program:	Integrated									
Egg Take Goal:	360,000						**Adult Goal:**	158		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/20	04/30/20	267,000	10	45	26,700	12,015	yearlings	Similkameen	Ad Clipped	CWT
Notes:	Egg take goal includes 3% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 16.7%									
Rearing Summary:										

Species	Source	Date	Number Green Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
EA SU Chinook YR	Okanogan	April	349,200	314,280	298,566	283,638	267,000	Similkameen

Table B 2. Summer Chinook Late - Integrated Program (Omak Acclimation Pond Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2018
Species:	Summer Chinook - Late
Stock:	Okanogan
Origin:	Wild
Program:	Integrated
Egg Take Goal:	765,000
Planting Goal:	566,000
Pounds:	32,600
Adult Goal:	340

Estimated Release Data:

Start Date:	End Date:	Num Released	fish per lb.	Wt. grams	Total weight (lb.)	Total weight (kg)	Life Stage	Release Site	Mark Type	Tagged
04/15/20	04/30/20	266,000	10	45	26,600	11,970	yearlings	Omak	Ad Clipped	CWT
05/15/19	06/01/19	300,000	50	11	6,000	3,300	sub-yearling	Omak	Ad Clipped	CWT

Notes:
Egg take goal includes 3% for culling.
Adult Goal includes 10% pre-spawn mortality
10% Green to Eyed egg mortality
Rearing mortality is 15.7% for yearlings, 16.2% for subs.

Rearing Summary:

Species	Source	Date	Number Green Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
EA SU Chinook YR	Okanogan	April	348,764	313,887	298,193	283,283	266,000	Omak
EA SU Chinook Sub	Okanogan	June	393,287	353,958	336,260	319,447	300,000	Omak

Table B 3. Summer Chinook Late – Segregated Program (CJH Site Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2018						**Planting Goal:**	450,000		
Species:	Summer Chinook - Late						**Pounds:**	29,000		
Stock:	Okanogan									
Origin:	Hatchery									
Program:	Segregated									
Egg Take Goal:	620,000						**Adult Goal:**	276		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/20	04/30/20	250,000	10	45	25,000	11,250	yearlings	CJ hatchery	Ad Clipped	
05/15/19	06/01/19	200,000	50	11	4,000	2,200	sub-yearling	CJ hatchery	Ad Clipped	
Notes:	Egg take goal includes 5% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 14.4% for yearlings, 16.5% for subs.									

Rearing Summary:

Species	Source	Date	Number Green Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
EA SU Chinook YR	Okanogan	April	323,950	291,555	276,977	263,128	250,000	CJ Hatchery
EA SU Chinook Sub	Okanogan	June	265,050	238,545	226,618	215,287	200,000	CJ Hatchery

Table B 4. Summer Chinook Early – Integrated Program (Riverside Acclimation Pond Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2018						**Planting Goal:**	266,000		
Species:	Summer Chinook - Early						**Pounds:**	26,600		
Stock:	Okanogan									
Origin:	Wild									
Program:	Integrated									
Egg Take Goal:	360,000						**Adult Goal:**	158		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/20	04/30/20	266,000	10	45	26,600	11,970	yearlings	Riverside	Ad Clipped	CWT
Notes:	Egg take goal includes 3% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 16.7%									
Rearing Summary:										

Species	Source	Date	Number Green Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
EA SU Chinook YR	Okanogan	April	349,200	314,280	298,566	283,638	266,000	Riverside

Table B 5. Summer Chinook Early – Segregated Program (CJH Release Site)

Chief Joseph Hatchery Production Plan

Brood Year:	2018						**Planting Goal:**	450,000		
Species:	Summer Chinook - Early						**Pounds:**	29,000		
Stock:	Okanogan									
Origin:	Hatchery									
Program:	Segregated									
Egg Take Goal:	620,000						**Adult Goal:**	276		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/20	04/30/20	250,000	10	45	25,000	11,250	yearlings	CJ hatchery	Ad Clipped	
05/15/19	06/01/19	200,000	50	9	4,000	1,800	sub-yearling	CJ hatchery	Ad Clipped	
Notes:	Egg take goal includes 5% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 14.4% for yearlings, 16.5% for subs.									
Rearing Summary:										

Species	**Source**	**Date**	**Number Green Eggs**	**Number Eyed Eggs**	**Number Ponded**	**Fed fry**	**Released**	**Location**
EA SU Chinook YR	Okanogan	April	323,950	291,555	276,977	263,128	250,000	CJ Hatchery
EA SU Chinook Sub	Okanogan	June	265,050	238,545	226,618	215,287	200,000	CJ Hatchery

Table B 6. Spring Chinook - Leavenworth (CJH Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2018						**Planting Goal:**	700,000		
Species:	Spring Chinook						**Pounds:**	46,667		
Stock:	Leavenworth									
Origin:	Hatchery									
Egg Take Goal:	1,094,400						**Adult Goal:**	640		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/20	04/30/20	700,000	15	30	46,667	21,000	yearlings	CJ hatchery	Ad Clipped	
Notes:	Egg take goal includes 20% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 15.5%									
Rearing Summary:										

Species	Source	Date	Number Green Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
Spring Chinook	Leavenworth	April	875,520	787,968	748,570	711,141	700,000	CJ Hatchery

Table B 7. Spring Chinook - Met Comp (Riverside Acclimation Pond Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2018						**Planting Goal:**	200,000		
Species:	Spring Chinook						**Pounds:**	13,333		
Stock:	Met Comp									
Origin:	Hatchery/Wild									
Egg Take Goal:	326,800						**Adult Goal:**	190		
Estimated Release Data:										
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/20	04/30/20	200,000	15	30	13,333	6,000	yearlings	Tonasket Pond	Ad Clipped	CWT
Notes:	Egg take goal includes 20% for culling.									
	Adult Goal includes 10% pre-spawn mortality									
	10% Green to Eyed egg mortality									
	Rearing mortality is 15.8%									
Rearing Summary:										

Species	Source	Date	Number Green Eggs	Number Eyed Eggs	Number Ponded	Fed Fry	Released	Location
Spring Chinook	Met Comp	April	261,440	235,296	223,531	212,355	200,000	Tonasket

APPENDIX C

Reach Weighted Effective pHOS

Table C 1. pHOS information for adjustments based on hatchery fish effectiveness (relative reproductive success assumption) and the reach weighting based on the proportion of redds in each reach in the Okanogan River from 2006 to 2017.

Brood Year		Number of Summer Chinook Carcasses								Total	Effective Reach Weighted pHOS[1]
		Okanogan						Similkameen			
		O-1	O-2	O-3	O-4	O-5	O-6	S-1	S-2		
2006	NOS	2	2	22	10	105	247	370	73	831	18.0%
	HOS	2	1	9	6	15	44	138	33	248	
	Effective pHOS[2]	44.4%	28.6%	24.7%	32.4%	10.3%	12.5%	23.0%	26.6%		
	% Redds	0.2%	1.3%	4.1%	3.4%	19.7%	32.0%	29.9%	9.5%	100%	
2007	NOS	1	0	30	1	284	322	405	20	1063	31.7%
	HOS	1	0	25	0	169	197	253	9	654	
	Effective pHOS[2]	44.4%	0.0%	40.0%	0.0%	32.3%	32.9%	33.3%	26.5%		
	% Redds	0.2%	0.8%	5.8%	3.1%	27.3%	27.6%	31.0%	4.3%	100%	
2008	NOS	2	1	14	11	107	324	347	41	847	54.3%
	HOS	2	9	26	25	141	341	512	116	1172	
	Effective pHOS[2]	44.4%	87.8%	59.8%	64.5%	51.3%	45.7%	54.1%	69.4%		
	% Redds	0.2%	2.4%	2.8%	4.5%	17.4%	26.2%	37.3%	9.3%	100%	
2009	NOS	2	3	13	14	189	347	330	75	973	40.4%

	HOS	0	4	18	18	159	153	373	75	800	
	Effective pHOS[2]	0.0%	51.6%	52.6%	50.7%	40.2%	26.1%	47.5%	44.4%		
	% Redds	0.1%	1.1%	3.1%	4.7%	20.9%	26.5%	36.8%	7.0%	100%	
2010	NOS	1	5	19	18	154	180	329	69	775	41.2%
	HOS	2	5	11	24	87	172	296	79	676	
	Effective pHOS[2]	61.5%	44.4%	31.7%	51.6%	31.1%	43.3%	41.9%	47.8%		
	% Redds	0.4%	2.7%	3.2%	4.2%	16.9%	20.3%	42.3%	10.0%	100%	
2011	NOS	0	0	21	4	201	362	216	19	823	47.4%
	HOS	0	0	34	10	160	116	537	95	952	
	Effective pHOS[2]	0.0%	0.0%	56.4%	66.7%	38.9%	20.4%	66.5%	80.0%		
	% Redds	0.1%	0.6%	3.2%	1.8%	19.0%	30.2%	39.0%	6.1%	100%	
2012	NOS	0	0	18	9	133	427	206	23	816	39.7%
	HOS	1	0	38	6	123	110	288	31	597	
	Effective pHOS[2]	100.0%	0.0%	62.8%	34.8%	42.5%	17.1%	52.8%	51.9%		
	% Redds	0.4%	2.0%	5.9%	2.5%	20.7%	28.6%	34.1%	5.7%	100%	
2013	NOS	0	0	22	7	37	352	191	4	613	27.1%
	HOS	0	0	8	2	15	80	188	4	297	
	Effective pHOS[2]	0.0%	0.0%	21.6%	21.6%	24.5%	15.4%	44.1%	44.1%		
	% Redds	0.1%	0.1%	4.5%	1.3%	11.2%	46.8%	35.4%	0.7%	100%	
2014	NOS	0	1	60	47	233	716	641	425	2123	12.0%
	HOS	1	0	19	7	42	67	129	64	329	

	Effective pHOS[2]	100.0%	0.0%	20.2%	10.6%	12.6%	7.0%	13.9%	10.8%		
	% Redds	0.3%	1.3%	4.5%	2.6%	20.0%	23.7%	40.8%	6.7%	100%	
2015	NOS	0	5	39	9	209	931	1186	176	2555	21.0%
	HOS	0	5	22	2	74	63	516	56	738	
	Effective pHOS[2]	20.8%	44.4%	31.1%	15.1%	22.1%	5.1%	25.8%	20.3%		
	% Redds	0.8%	2.6%	6.6%	1.8%	23.6%	20.1%	37.7%	6.7%	100%	
2016	NOS	0	6	13	7	186	1019	819	121	2171	15.5%
	HOS	0	6	1	4	44	56	395	78	584	
	Effective pHOS[2]	15.5%	44.4%	5.8%	31.4%	15.9%	4.2%	27.8%	34.0%		
	% Redds	0.0%	1.1%	1.0%	2.5%	17.2%	44.3%	31.2%	2.7%	100%	
2017	NOS	0	4	4	11	50	562	347	19	997	16.3%
	HOS	0	4	5	5	10	66	106	8	204	
	Effective pHOS[2]	14.1%	44.4%	50.0%	26.7%	13.8%	8.6%	19.6%	25.2%		
	% Redds	0.1%	1.9%	6.0%	3.4%	25.8%	38.4%	22.0%	2.4%	100%	
Average % Redds		***0.2%***	***1.5%***	***4.2%***	***3.0%***	***20.0%***	***30.4%***	***34.8%***	***5.9%***		
Average Effective pHOS		***37.1%***	***28.8%***	***38.1%***	***33.8%***	***28.0%***	***19.9%***	***37.5%***	***40.1%***		
Average Reach Weighted Effective pHOS =											***28.2%***

Table C 2. Number of hatchery- and natural-origin (wild) summer Chinook carcasses collected in each reach of the Okanogan (O1-O6) and Similkameen rivers from 1993 to 2017.

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

	Hatchery	2	1	9	6	15	44	138	33	248
2007	Wild	1	0	30	1	284	322	405	20	1,063
	Hatchery	1	0	25	0	169	197	253	9	654
2008	Wild	2	1	14	11	107	324	347	41	847
	Hatchery	2	9	26	25	141	341	512	116	1,172
2009	Wild	2	3	13	14	189	347	330	75	973
	Hatchery	0	4	18	18	159	153	373	75	800
2010	Wild	1	5	19	18	154	180	329	69	775
	Hatchery	2	5	11	24	87	172	296	79	676
2011	Wild	0	0	21	4	201	362	216	19	823
	Hatchery	0	0	34	10	160	116	537	95	952
2012	Wild	0	0	18	9	133	427	206	23	816
	Hatchery	1	0	38	6	123	110	288	31	597
2013[d,e]	Wild	0	0	22	7	37	352	191	4	613
	Hatchery	0	0	8	2	15	80	188	4	297
2014	Wild	0	1	60	47	233	716	641	425	2123
	Hatchery	1	0	19	7	42	67	129	64	329
2015	Wild	0	5	39	9	209	931	1186	176	2555
	Hatchery	0	5	22	2	74	63	516	56	738
2016	Wild	0	6	13	7	186	1019	819	121	2171
	Hatchery	0	6	1	4	44	56	395	78	584
2017	Wild	0	4	4	11	50	562	347	19	997
	Hatchery	0	4	5	5	10	66	106	8	204
Average	***Wild***	***1***	***2***	***17***	***9***	***99***	***273***	***360***	***72***	***833***
	Hatchery	***1***	***3***	***17***	***7***	***59***	***87***	***326***	***56***	***555***

[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 3. 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
Average	***1***	***26***	***109***	***75***	***7***	***0***	***218***

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
Average	***0***	***0***	***51***	***216***	***29***	***0***	***296***

Natural-Origin Male Salt Age Carcasses Recovered							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0	0	8	19	3	0	30
1994	0	3	13	22	10	0	48
1995	0	0	6	11	4	0	21
1996	0	1	7	4	1	0	13
1997	0	3	8	8	1	0	20
1998	0	3	32	27	5	0	67
1999	0	0	22	39	8	1	70
2000	0	6	24	27	12	0	69
2001	0	13	82	168	8	0	271
2002	0	15	85	232	52	1	385
2003	0	12	55	171	34	0	272
2004	0	19	226	166	303	3	717
2005	0	1	129	447	28	4	609
2006	0	1	14	189	116	0	320
2007	0	17	67	53	226	5	368
2008	0	8	258	263	13	2	544
2009	0	10	21	276	31	0	338
2010	0	3	90	123	50	0	266
2011	0	10	46	228	17	0	301
2012	1	14	160	112	58	0	345
2013	0	6	83	140	12	0	241
2014	0	43	135	633	76	0	887
2015	0	8	809	402	113	0	1332
2016	0	1	53	548	109	1	712
2017	0	0	15	176	159	3	353
Average	***0***	***8***	***98***	***179***	***58***	***1***	***344***

Natural-Origin Female Salt Age Carcasses Recovered							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0	0	5	25	3	0	33
1994	0	0	2	36	29	0	67
1995	0	0	7	27	11	0	45
1996	0	0	3	18	2	0	23
1997	0	0	12	31	10	0	53
1998	0	0	21	51	12	0	84
1999	0	0	32	132	34	0	198
2000	0	0	9	106	32	0	147
2001	0	0	11	237	12	0	260
2002	0	0	18	199	90	0	307
2003	2	2	29	130	45	0	208
2004	0	0	37	233	539	2	811
2005	0	0	28	566	71	7	672
2006	0	0	2	250	256	2	510
2007	0	0	8	72	601	12	693
2008	0	0	12	269	19	3	303
2009	0	0	3	473	112	0	588
2010	0	0	20	195	226	1	442
2011	0	0	12	416	58	0	486
2012	0	0	15	195	196	0	406
2013	0	0	5	254	27	0	286
2014	0	3	24	809	189	0	1025
2015	0	0	66	342	426	1	835
2016	0	0	4	927	288	4	1223
2017	0	0	4	127	367	7	505
Average	***0***	***0***	***16***	***245***	***146***	***2***	***408***

Table C 4. Salt age structure (percent of recovered carcasses) for sex-origin classes.

Hatchery-Origin Male Salt Age - Percent of carcasses recovered within origin/sex class							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	100%	0%	0%	0%	1
1994	0%	4%	19%	77%	0%	0%	1
1995	0%	3%	33%	39%	25%	0%	1
1996	0%	6%	35%	49%	10%	0%	1
1997	0%	0%	4%	89%	7%	0%	1
1998	0%	10%	68%	13%	10%	0%	1
1999	2%	0%	31%	65%	2%	0%	1
2000	4%	34%	3%	55%	4%	0%	1
2001	0%	7%	91%	0%	2%	0%	1
2002	0%	1%	38%	60%	0%	0%	1
2003	0%	8%	14%	66%	12%	0%	1
2004	0%	1%	53%	36%	10%	0%	1
2005	0%	8%	13%	69%	10%	0%	1
2006	0%	12%	25%	18%	45%	0%	1
2007	0%	40%	38%	19%	2%	1%	1
2008	0%	3%	74%	22%	0%	0%	1
2009	0%	18%	14%	67%	1%	0%	1
2010	1%	6%	83%	8%	2%	0%	1
2011	0%	47%	15%	38%	0%	0%	1
2012	0%	11%	62%	23%	3%	0%	1
2013	0%	12%	46%	37%	3%	2%	1
2014	0%	36%	38%	26%	0%	0%	1
2015	0%	6%	78%	16%	0%	0%	1
2016	0%	6%	15%	75%	4%	0%	1
2017	0%	6%	40%	43%	7%	0%	1
Average	***0%***	***11%***	***41%***	***40%***	***7%***	***0%***	***1***

Hatchery-Origin Female Salt Age - Percent of carcasses recovered within origin/sex class							
Survey Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
1993	0%	0%	91%	9%	0%	0%	1
1994	0%	0%	2%	97%	1%	0%	1
1995	0%	0%	7%	33%	61%	0%	1
1996	0%	0%	17%	58%	24%	1%	1
1997	0%	0%	2%	86%	13%	0%	1
1998	0%	1%	31%	33%	35%	0%	1
1999	0%	0%	7%	89%	3%	0%	1
2000	0%	0%	1%	85%	14%	0%	1
2001	0%	0%	81%	6%	13%	0%	1
2002	0%	0%	5%	94%	1%	0%	1
2003	0%	0%	2%	85%	13%	0%	1
2004	0%	0%	11%	53%	36%	0%	1
2005	0%	0%	3%	80%	17%	1%	1
2006	0%	0%	13%	27%	61%	0%	1
2007	0%	0%	21%	69%	9%	2%	1
2008	0%	0%	40%	54%	5%	0%	1
2009	0%	0%	2%	94%	4%	0%	1
2010	0%	0%	49%	38%	13%	0%	1
2011	0%	0%	3%	95%	1%	0%	1
2012	0%	0%	48%	44%	8%	0%	1
2013	0%	0%	15%	82%	3%	0%	1
2014	0%	0%	15%	82%	3%	0%	1
2015	0%	0%	56%	41%	2%	0%	1
2016	0%	0%	2%	94%	4%	0%	1
2017	0%	1%	20%	40%	39%	0%	1
Average	*0%*	*0%*	*22%*	*63%*	*15%*	*0%*	*1*

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

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

Contribution to Fisheries

Table C 5. Estimated number and percent of hatchery-origin Okanogan/Similkameen summer Chinook captured in different fisheries, brood years 1989-2011.

Brood year	Ocean fisheries	Columbia River Fisheries			Total
		Tribal	Commercial (Zones 1-5)	Recreational (sport)	
1989	2,360 (80)	553 (19)	0 (0)	53 (2)	2,966
1990	355 (89)	34 (8)	0 (0)	12 (3)	401
1991	220 (86)	37 (14)	0 (0)	0 (0)	257
1992	422 (91)	28 (6)	2 (0)	10 (2)	462
1993	24 (80)	6 (20)	0 (0)	0 (0)	30
1994	372 (92)	23 (6)	2 (0)	7 (2)	404
1995	643 (93)	9 (1)	12 (2)	25 (4)	689
1996	6 (100)	0 (0)	0 (0)	0 (0)	6
1997	6,483 (92)	136 (2)	36 (0)	424 (6)	7,079
1998	4,414 (89)	251 (5)	45 (1)	223 (5)	4,933
1999	1,359 (68)	224 (11)	31 (2)	384 (19)	1,998
2000	3,139 (69)	533 (12)	222 (5)	675 (15)	4,559
2001	184 (58)	81 (25)	31 (10)	23 (7)	319
2002	706 (56)	200 (16)	90 (7)	258 (21)	1,254
2003	711 (38)	568 (30)	130 (7)	466 (25)	1,875
2004	3,153 (39)	2,162 (26)	694 (8)	2,168 (27)	8,177
2005	470 (46)	306 (30)	79 (8)	167 (16)	1,022
2006	3,136 (37)	3,352 (40)	469 (6)	1,419 (17)	8,376
2007	1,549 (44)	992 (28)	67 (2)	905 (26)	3,513
2008	4,226 (38)	2,576 (39)	218 (2)	3,969 (36)	10,989
2009	2,005 (36)	2,155 (39)	207 (5)	1,138 (21)	5,505
2010	3,193 (38)	3,399 (46)	247 (4)	1,110 (13)	8,483
2011	5,801 (40)	5,812 (40)	456 (3)	2,598 (18)	14,667
Average	***1,953 (51)***	***1,042 (27)***	***132 (3)***	***697 (18)***	***3,825***
Median	***1,359 (68)***	***251 (19)***	***45 (2)***	***258 (13)***	***1,998***

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

Pilot Study Report: Identification of Geochemical Signatures in Upper Columbia River Summer Chinook Salmon

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April 30, 2018

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

Dear John and Andrea:

Re: Pilot Study Report – Identification of Geochemical Signatures in Upper Columbia River Summer Chinook Salmon

We have completed our pilot study of the geochemical signatures present in juvenile summer Chinook salmon from the Similkameen, Okanogan and Columbia Rivers. The objectives of the study were to determine: (1) if the isotopic and (or) elemental composition of water samples collected from these rivers varied sufficiently to produce geochemical signatures that could be used to distinguish among the sites, and 2) if these isotopic and (or) elemental markers are represented in the natal rearing zones of otoliths collected from juvenile Summer Chinook at these sites could be used to assign fish to a natal stream or site. The analyses showed material differences in water $^{87}Sr/^{86}Sr$, $\delta^{18}O$, Sr/Ca and Ba/Ca among the rivers, and these differences were similarly expressed in otoliths collected at these sites, supporting the potential use of geochemical signatures to distinguish the natal origins of summer Chinook in mixed stock areas. However, overlapping $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ratios from discrete groups of otoliths collected in the

Similkameen and Okanogan Rivers and Washburn Island also suggest possible movement by summer Chinook fry between these sites, however, larger sample sizes will be needed to confirm this hypothesis. The rational for the study, methods, results and interpretation of the data are discussed below.

Background

We had suggested that published information regarding water strontium isotope ratios ($^{87}Sr/^{86}Sr$) showed differences between the upper Columbia River and the Okanogan River (Miller et al. 2011; Linley et al. 2016), but evidence to distinguish among all of the summer Chinook spawning sites in the region was inconclusive (i.e. Similkameen River). To resolve this question we proposed a scope of work (SOW) that included analyses of water and otoliths for $^{87}Sr/^{86}Sr$, $\delta^{18}O$, Sr/Ca, Ba/Ca and Sr/Ba ratios. The basis of the SOW related, in part, to the geologic heterogeneity of the region (Figure 1), which can influence both $^{87}Sr/^{86}Sr$ as well as element/Ca ratios in watersheds and hence summer Chinook otoliths. More specifically, because water $^{87}Sr/^{86}Sr$ in the upper Columbia River is comparatively much higher (0.71546) than in the Okanogan River (0.70584), and there is typically a 1:1 correlation between water and otolith $^{87}Sr/^{86}Sr$, we thought this variation should be expressed in the otoliths of summer Chinook salmon from these rivers. Moreover, because the Similkameen River originates from the same geologic formation as the Methow River (i.e. Methow Graben), where summer Chinook have otolith $^{87}Sr/^{86}Sr$ that are 0.70432 (Barnett-Johnson et al. 2010), we proposed that otolith $^{87}Sr/^{86}Sr$ might also differ between Similkameen and Okanogan Rivers. This view was supported by the differences in rock type and age along an east-west gradient in which east side streams in the Okanogan basin drain largely from metamorphic and Cenozoic volcanic formations (10-60 ma), whereas the Similkameen watershed is dominated by volcanic and plutonic rocks of Mesozoic age (100-200 ma).

Secondly, in addition to the isotope and (or) elemental ratios of metals, we suggested there was the potential that oxygen isotope ratios ($^{18}O/^{16}O$), denoted as $\delta^{18}O$, might also provide a distinct marker to identify natal origins. The reason that otolith $\delta^{18}O$ may vary among these rivers is because it is typically in equilibrium with water $\delta^{18}O$ (Patterson et al. 1993) and fractionates inversely with water temperature. Thus, differences in water $\delta^{18}O$ and (or) water temperature among the spawning and early rearing sites for summer Chinook could lead to similar variation in otolith $\delta^{18}O$. Importantly, in contrast to metal isotopic and elemental ratios in otoliths, which are often correlated, $\delta^{18}O$ is usually orthogonal to these markers because the physical mechanisms that determine their ratios are unrelated (watershed lithology vs. stream temperature, evaporation), enhancing its utility for additional discrimination.

We also noted that ability to distinguish river-specific geochemical signatures in summer Chinook was partly dependent on the residence time within and movement among rivers by juvenile fish prior to downstream migration, as well as the amount of time that adult females spend on or within the vicinity of their natal stream. Juvenile salmon that migrate downstream at or soon after emergence may not acquire otolith geochemical signatures consistent with their natal origin, other than in the part of the otolith formed prior to this event, i.e. maternal zone, which reflects the geochemical contributions from the yolk and incubation water during embryonic development. Thus, spatial resolution of these zones within otoliths is critical to interpretation of the geochemical signatures.

Methods

Water samples collected by CCT in July and November from the Okanogan River, Similkameen River, and Washburn Island (upstream of Okanogan confluence) and Gebber's Landing (downstream of Okanogan confluence) sites on the Columbia River were analyzed for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotope ratios and for Sr, Ba and Ca concentrations. A total n=10 otoliths from juvenile summer Chinook salmon collected at Washburn Island, n=15 collected in the Okanogan and Similkameen Rivers, and n=20 from Gebber's Landing were analyzed for these same geochemical markers. Based on our initial results from these samples, we conducted additional analyses of $\delta^{18}O$ and [Sr, Ba, Ca] on otoliths of n=5 fish from the Okanogan and Similkameen Rivers, and n=3 fish from Gebber's Landing. The additional analyses were conducted to confirm anomalous findings from the initial samples and to obtain a better understanding of the spatial variation in geochemical signatures within otoliths.

Water samples analyzed for $^{87}Sr/^{86}Sr$ and element/Ca ratios were collected in acid washed (2% HNO_3) 120 mL perfluoroalkoxy (PFA) bottles following the procedures described in Linley et al. (2016). After shipment to PNNL, the samples were filtered through PFA (1-2 μm) membranes, dried over low heat, and treated with alternating treatments of ultra-high purity 15M nitric acid and 30% hydrogen peroxide to dissolve organic matter. Following re-suspension in 7 M nitric acid the samples were divided into equal aliquots for $^{87}Sr/^{86}Sr$ and element/Ca analysis. Samples analyzed for $^{87}Sr/^{86}Sr$ were subsequently loaded onto Sr Spec cation exchange columns, washed with 7 M nitric acid, and eluted with 0.05 M nitric acid to capture the available Sr. All sample preparation and column chemistry was performed in a class 1000 clean lab, under a class 100 laminar flow hood. Water samples for $\delta^{18}O$ were collected in 60 mL polypropylene bottles and stored at 4 °C until analysis.

Otoliths collected from juvenile summer Chinook were cleaned of residual endolymph and adhering tissue by sonicating in successive solutions of ultra-pure DI water, 2% hydrogen peroxide and DI water, then stored dry in Teflon tubes under a class-100 laminar hood until analysis. Otoliths were prepared for $^{87}Sr/^{86}Sr$, element/Ca and $\delta^{18}O$ analysis by embedding sulcus side up in epoxy resin and curing for 24 hours. Once cured, resin blocks were attached to glass slides with thermoplastic glue (Crystal Bond 509) and polished with successively finer grit paper to reveal the otolith core.

Water and otolith analyses for $\delta^{18}O$ were conducted using a Los Gatos Liquid Water Isotope Analyzer and a Thermo Scientific Delta V Plus isotope ratio mass spectrometer coupled to a Thermo Scientific Gas Bench II, respectively. Water samples were run in duplicate and bracketed by three standards (Los Gatos Research, $\delta^{18}O_{VSMOW}$ = -19.49, -16.24, -13.39‰) previously calibrated against Standard Light Antarctic Precipitation ($\delta^{18}O_{VSMOW}$ = -55.5‰) and Vienna Standard Mean Ocean Water 2 (VSMOW, $\delta^{18}O_{VSMOW}$ = 0‰). The analytical precision for the standards was $\geq$ 0.1‰.

The $^{87}Sr/^{86}Sr$ of water samples was analyzed by a Nu Instruments thermal ionization mass spectrometer (TIMS). A purified 200 ng aliquot of Sr was loaded onto a degassed Re filament with Ta_2O_5 and phosphoric acid activators. Parafilm was used to restrict the sample to the center of the ionizing surface. Instrument performance was monitored by repeat analysis of SRM 987 yielding a mean value of 0.71023 ± 3 (2σ; n = 10).

Otoliths collected from the Okanogan River, Similkameen River and Washburn Island site were analyzed by placing the whole otolith into a gas-tight 15 mL Exetainer® vial with a butyl septum. Vials were flushed for 15 minutes using ultra-high purity He at a flow rate of 100 mL/min, after which 0.2 mL of 100% phosphoric was added to the vial and allowed to incubate for 3 hours at 70 °C before analysis. For analysis, the otoliths samples were bracketed by using the NBS-10 standard ($CaCO_3$ in the form of limestone, $\delta^{18}O_{VPDB}$ = -2.20‰) to correct raw sample $\delta^{18}O$ values. Analytical precision was $\geq$ 0.1‰. Otoliths collected from salmon at Gebber's Landing were analyzed in an analogous manner except a micro-mill (Electro Scientific Industries, Inc.) was used to obtain sample material only from the otolith core. The samples were collected by milling a four point grid approximately 600 µm by 600 µm to an estimated depth of ~ 5 µm to ensure sufficient material was obtained for analysis. Supplemental samples from Gebber's were also micro-milled in three locations (edge, upper core and lower core) to determine the spatial heterogeneity of $\delta^{18}O$ within otoliths.

Isotope values are reported in δ notation relative to VSMOW or Vienna Pee Dee belemnite (VPDB) where R represents the ratio of $^{18}O/^{16}O$ in the sample or standard.

$$\delta = \left(\frac{Rsample - Rstandard}{Rstandard}\right) x\ 1000\ (‰)$$

All otolith and water values were reported by the instrumentation relative to VSMOW and converted to following equation from Coplen et al. (1983):

$$\delta^{18}O_{VSMOW} = 1.03091\ \delta^{18}O_{VPDB} + 30.91$$

Otoliths were analyzed for $^{87}Sr/^{86}Sr$ by laser ablation, inductively coupled plasma mass spectrometry (LA-ICP-MS) on a multi-collector ICP-MS Nu Plasma II (Nu Instruments) coupled to a NWR 213 nm Nd:YAg Laser (Electro Scientific Industries, Inc.). On-peak zeroes were measured and subtracted prior to every run to remove the ^{84}Kr signal interference with ^{84}Sr while ^{82}Kr and ^{83}Kr signal sizes were monitored. Instrument mass fractionation was corrected online for each measurement by correcting the measured $^{86}Sr/^{88}Sr$ to 0.1194 with a logarithmic correction. Marine coral standards were run every 10 samples to ensure that instrument tuning had not drifted, and that the $^{87}Sr/^{86}Sr$ value of modern seawater ($^{87}Sr/^{86}Sr$ = 0.70918) was obtained within two standard errors (mean $^{87}Sr/^{86}Sr$ = 0.70920, SE = 0.00001, n = 7). Washout times between measurements were approximately 1 minute, with the Faraday cup detector signals monitored to ensure a complete return to baseline values before subsequent runs.

Before data collection, a cleaning pass of the otolith with the laser was performed with a beam size of 100μm and power output 10% to reduce potential contamination. Otoliths were first ablated along a transect from the core to the dorsal edge, perpendicular to the sulcus (beam width 40 um, 80% power, 10 Hz, scan speed 3 μm/s) to identify the transition between the maternal (marine influenced) zone and the natal stream signature, which was approximately 300 um on average from the primordia. A second path was then ablated perpendicular to the transect line and parallel to the growth rings in the early rearing portion of the otolith to obtain the $^{87}Sr/^{86}Sr$ signal used for natal assignment (approx. 200 μm in length). Element/Ca ratios were obtained from these same otoliths in an analogous manner by LA-ICP-MS using the same laser coupled to a Thermo Fisher X-Series quadrupole ICP-MS. Element concentrations were converted to molar amounts and expressed relative to Ca as an internal standard in mmol/mol.

Data Analysis

Differences in otolith $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and element/Ca ratios among sites were tested using the Kruskal–Wallis rank tests because preliminary analysis indicated the data were not normally distributed and could not be transformed to meet this assumption. Pairwise comparisons for these markers were made using the Dwass-Steel-Chritchlow-Flinger test. The level of significance for all tests was $\alpha \leq 0.05$. A quadratic discriminant analysis (QDA) was used as a preliminary test to assign unknown samples from Gebber's Landing to one of the three known natal sites. The QDA was used for assignment because it is more robust to violations of inequality in the variance-covariance matrix among groups. A jackknife (leave-one-out) procedure was used to determine classification accuracy of the known samples. These samples were then used to train the QDA model for assignment of unknown fish collected at Gebber's Landing.

Results and Interpretation

Water $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and element/Ca ratios varied widely among sample sites, but were generally consistent within sites (Table 1). The lowest $^{87}Sr/^{86}Sr$ measurement was the spring sample from the Similkameen River, whereas the highest occurred in the fall at Washburn Island. By contrast, Sr/Ca (spring) and Ba/Ca (fall) in the Okanogan River were the highest and lowest, respectively, while the lowest Sr/Ca and highest Ba/Ca were measured at Washburn Island (fall) and the Similkameen River (spring). The Okanogan River also had the highest $\delta^{18}O$, while Washburn Island had the lowest. These differences, particularly in $^{87}Sr/^{86}Sr$, are partly related to the underlying geology of the river basins. The Okanogan and Similkameen, for example, flow from the Cascade Range, which is geologically young compared to many of the tributary systems and the mainstem of the upper Columbia River that drain from the older formations of the Rocky Mountains. Older geologic formations such as the Rocky Mountains tend to have higher $^{87}Sr/^{86}Sr$ because the abundance of the heavier isotope is partly due to the decay of rubidium (^{87}Rb). Moreover, the Sr/Ca ratio often varies inversely with $^{87}Sr/^{86}Sr$, and that pattern is evident for these rivers as well. The wide seasonal variation in Ba/Ca is likely a reflection of spring runoff and weathering of Ba rich rock, and that effect may be attenuated in the Okanogan River because of the upstream presence of Osoyoos Lake. Osoyoos Lake may also be the major reason why $\delta^{18}O$ in the Okanogan River is much higher than in the other rivers. The lighter isotope ^{16}O is preferentially removed by evaporation, thus ^{18}O becomes relatively enriched (i.e. $\delta^{18}O$ is less negative) in water bodies such as lakes with large surface areas and higher rates of evaporation.

There were significant differences among sample sites for otolith Sr/Ba (H = 7.51, df = 2, P = 0.023) and $\delta^{18}O$ (H = 20.79, df = 2, P < 0.001), but not for $^{87}Sr/^{86}Sr$, Sr/Ca and Ba/Ca ($H \leq$ 5.74, df = 2, $P \geq$ 0.06). The absence of a significant difference among samples site for $^{87}Sr/^{86}Sr$, Sr/Ca and Ba/Ca is partly due to the small sample size relative to the variability in these markers (Figures 2-4), but also due to the fact that several of the Washburn fish were most likely migrants from the Okanogan or Similkameen Rivers. This is best shown in Figure 2 where two distinct groups can be seen that cluster around otolith $^{87}Sr/^{86}Sr \approx 0.707$ and 0.715, and where the water $^{87}Sr/^{86}Sr$ at Washburn Island was ≈ 0.715. This is interesting because it suggests that fry from the Okanogan and (or) Similkameen are moving upriver after entering the Columbia River, perhaps into more favorable rearing habitat.

Of equal interest is that similar behavior may be occurring between the Okanogan and Similkameen Rivers (Figure 6). Water $\delta^{18}O$ for these sites averaged -41.47 ‰ and -45.88 ‰, respectively (Table 1), and salmon otolith $\delta^{18}O$ should be correlated with these values (Zeigler and Whitledge 2010). Yet within each site there appear to be two distinct groups of otolith $\delta^{18}O$ at ≈ 7-9 ‰ and 11-13 ‰ that reflect values from the corresponding site. The relationship between otolith $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ among these sites also supports this hypothesis (Figure 6). Otolith $^{87}Sr/^{86}Sr$ for Washburn fry clearly separate into groups at ≈ 0.707 and 0.715, whereas the corresponding otolith $\delta^{18}O$ for these groups average 13.4 ‰ and 14.3 ‰, respectively. The mean otolith $\delta^{18}O$ for Similkameen fry less than the site median of -12.55 ‰ is -12.94 ‰, which suggests that for the Washburn fry of presumptive Similkameen origin, their otolith $\delta^{18}O$ may be moving more rapidly into equilibrium with the Columbia River $\delta^{18}O$ than their otolith $^{87}Sr/^{86}Sr$. Laboratory studies have shown that otolith $^{87}Sr/^{86}Sr$ takes at least 20 days to reach equilibrium with water $^{87}Sr/^{86}Sr$ (Elsdon and Gillanders 2005), and it seems reasonable that time required for otolith $\delta^{18}O$ to reach equilibrium with water $\delta^{18}O$ could be much less given the abundance of oxygen in the otolith $CaCO_3$ structure. Moreover, it indicates that the fry sampled at Gebber's Landing were probably recent arrivals because the water $^{87}Sr/^{86}Sr$ for this site in the spring (0.71169) was closer to the Columbia River water $^{87}Sr/^{86}Sr$ (0.71486) than to the combined Okanogan – Similkameen water $^{87}Sr/^{86}Sr$ (0.70598).

All of the fry from the Gebber's Landing site had otolith $^{87}Sr/^{86}Sr \leq 0.70877$ and most fell within a range of 0.706 – 0.707 (Figure 8), indicating that none of these fish originated from Columbia River spawning. Otolith $\delta^{18}O$ for these fry fell mostly between -11.3 and -14.1, suggesting most may have come from the Similkameen River. Using a quadratic discriminant analysis model trained with samples from the known sites (Table 3) resulted in assignment of n=11 Gebber's fry to the Similkameen River, n=8 to the Okanogan and none to Washburn. The n=6 samples from Washburn Island with otolith $^{87}Sr/^{86}Sr \leq 0.70840$ were also included in this analysis, and n=4 of these were assigned to the Okanogan River and n=2 to the Similkameen River. The variables in the model and their order of contribution to assignment were $^{87}Sr/^{86}Sr$, Ba/Ca and $\delta^{18}O$. Separation between fry originating from the Okanogan and Similkameen Rivers was mostly improved by Ba/Ca since there is little overlap between these fry (Figures 4 and 8).

The assignment of the Gebber's and Washburn fry to either the Okanogan or Similkameen Rivers should be viewed with some caution, partly because of the bi-modal distribution of otolith $\delta^{18}O$ at these sites, but also because of the small sample sizes the data for the QDA are not multi-variate normal. Moreover, the Gebber's samples were micro-milled to sample material from as close to the otolith core as possible. We assumed these samples contained material that was accreted only during residence in the natal stream. However, due to the limitations on the spatial resolution of the drill bit and size of these otoliths (whole otolith diameter ≈ 930 µm, core diameter ≈ 600 µm), it is possible that we also obtained material laid down after entry into the Columbia River, which would have inflated the otolith $\delta^{18}O$ values of fry from the Okanogan River. This uncertainty is illustrated in Figure 11. The data are from three Gebber's Landing otoliths that were milled at a single point in the core (upper [circle] and lower [square]) and near the outer margin (triangle) to profile depth and surface variation in $\delta^{18}O$. Samples 1 and 2 clearly show a change in $\delta^{18}O$ between the upper and lower part of the core and the margin, whereas sample 3 is relatively homogenous throughout. These results demonstrate that: (1) sufficient material for $\delta^{18}O$ analysis can be obtained from a single point sample, improving the spatial resolution by ≈ 5-fold, and (2) movement between water bodies (i.e. Okanogan and Similkameen fry to Gebber's Landing) leads to a relatively rapid equilibrium between otolith and water $\delta^{18}O$ that can be detected through spatial profiling.

Conclusions and Recommendations

The results of this pilot study demonstrate clearly detectable differences in water $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and element/Ca ratios among the sample sites that are seasonally stable, particularly the isotopic signatures. This variation is also reflected in otolith chemistry that can be used to assign fry samples from mixed stock areas to their natal streams with reasonable accuracy. However, anomalous departures between water and otolith signatures such as those for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ suggest the potential of upstream movement of fry to neighboring sites prior to downstream movement to the mixing area at Gebber's Landing. This could confound assignment accuracy and precision. Clearly, this is the case for some of the fry collected at Washburn Island with otolith $^{87}Sr/^{86}Sr$ approximating the water $^{87}Sr/^{86}Sr$ from the Okanogan-Similkameen watershed, and possibly the bimodal otolith $\delta^{18}O$ variation in the Okanogan and Similkameen Rivers.

To address the question as to whether and to what degree of precision the contributions from the Okanogan, Similkameen and Columbia River spawning sites can be determined in the mixed stock fry aggregations at Gebber's Landing, we suggest the following:

1. Increase the total sample size and use time-weighted sampling protocol to collect otoliths at each site over the duration of the fry migration.
2. If possible, sample at locations closer to the known spawning grounds to reduce uncertainty about the potential movement of fry to neighboring natal sites.
3. Conduct a second year of water chemistry sampling to determine inter-annual variation.

In closing, on behalf of all of us who have worked on this project, I want to thank both of you for giving us the opportunity to help you address questions regarding the origins, habitat use and movement of summer Chinook in the upper Columbia River. We realize there are important management questions linked to this research and we look forward to discussing the objectives for the coming year.

Sincerely,

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List of Tables

Table 1. Water $^{87}Sr/^{86}Sr$, $\delta^{18}O_{VPDB}$ and element/Ca ratios for the Okanogan, Similkameen, Gebber's and Washburn sample sites. Element/Ca ratios are in mmol/mol.

Site	Season	$^{87}Sr/^{86}Sr$	Sr/Ca	Ba/Ca	Sr/Ba	$\delta^{18}O$
Okanogan	Spring	0.70689	5.77	0.28	13.17	-41.69
	Fall	0.70684	5.53	0.26	13.44	-41.24
Similkameen	Spring	0.70510	4.23	0.72	3.75	-45.83
	Fall	0.70512	3.86	0.43	5.75	-45.92
Gebbers	Spring	0.71169	3.59	0.63	3.68	-46.69
	Fall	0.71489	3.61	0.48	4.78	-47.04
Washburn	Spring	0.71486	2.93	0.68	2.78	-47.01
	Fall	0.71578	3.34	0.47	4.52	-47.47

Table 2. The mean (± standard deviation) for otolith geochemical markers in summer Chinook.

Site	*N*	$^{87}Sr/^{86}Sr$	*N*	Sr/Ca	Ba/Ca	Sr/Ba	$\delta^{18}O$
Okanogan	10	0.70681 (0.00047)	15	2.51 (0.42)	0.029 (0.016)	74.86 (30.42)	-10.17 (2.10)
Similkameen	10	0.70712 (0.00062)	15	2.33 (0.21)	0.055 (0.033)	41.79 (24.30)	-11.41 (1.90)
Gebbers	19	0.70681 (0.00064)	19	2.25 (0.45)	0.037 (0.022)	46.21 (20.23)	-12.54 (1.26)
Washburn	11	0.71039 (0.00389)	11	2.12 (0.44)	0.052 (0.043)	35.38 (19.90)	-13.83 (0.81)

Table 3. Jack-knifed classification matrix from quadradic discriminant analysis for otolith samples from known sites. Variables in the model are $^{87}Sr/^{86}Sr$, Ba/Ca and $\delta^{18}O$. *n*=5 samples from Washburn Island were excluded from the analysis because otolith $^{87}Sr/^{86}Sr$ approximated the Okanogan – Similkameen River $^{87}Sr/^{86}Sr$.

Site	Okanogan	Similkameen	Washburn	% Correct
Okanogan	8	2	0	80
Similkameen	2	7	0	78
Washburn	0	0	5	100
Total	10	9	5	83

List of Figures

Figure 1. The Okanogan and lower Similkameen watersheds showing coarse scale surface geology.

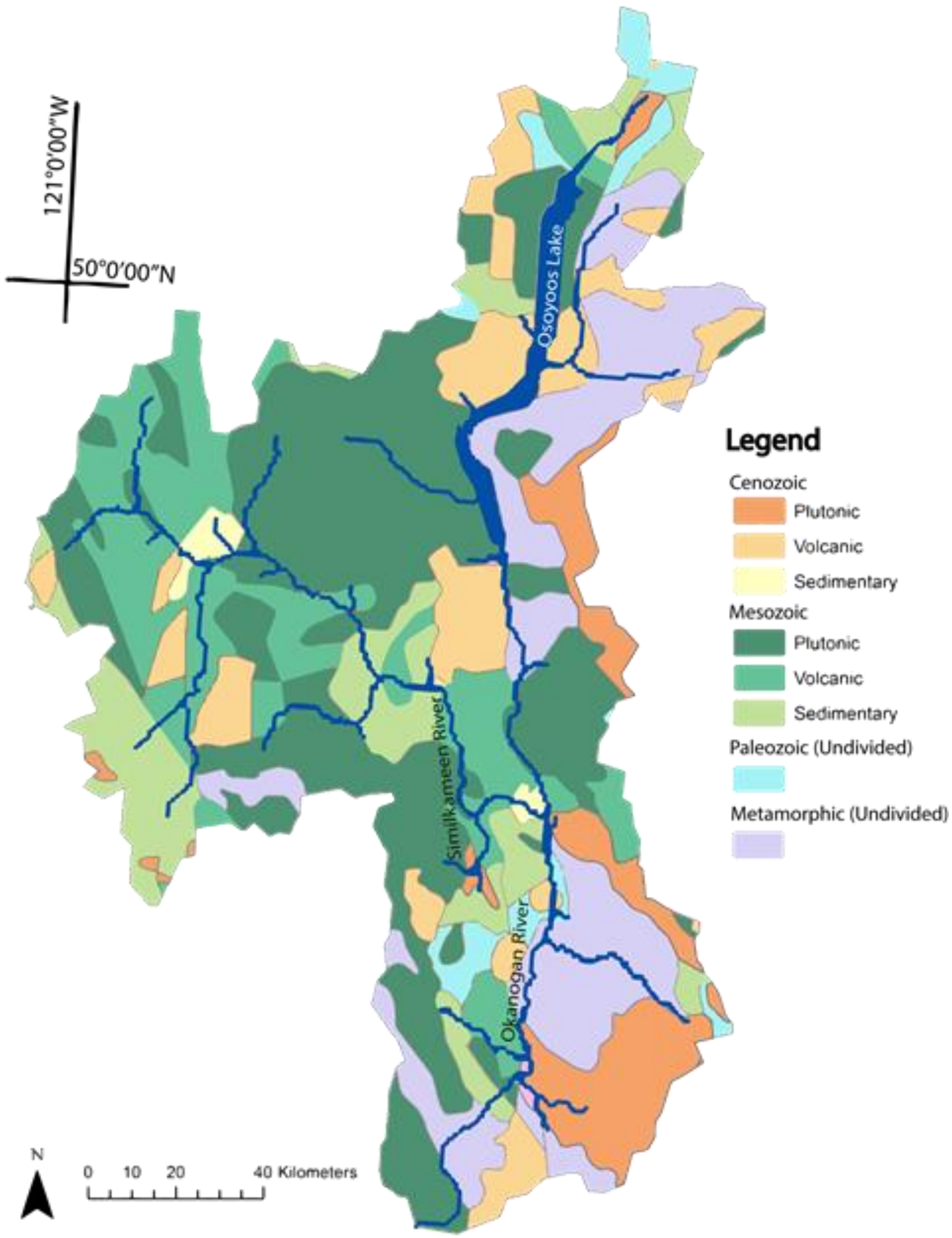


Figure 2. Scatterplot of water and otolith $^{87}Sr/^{86}Sr$ for the Okanogan, Similkameen and Washburn sample sites.

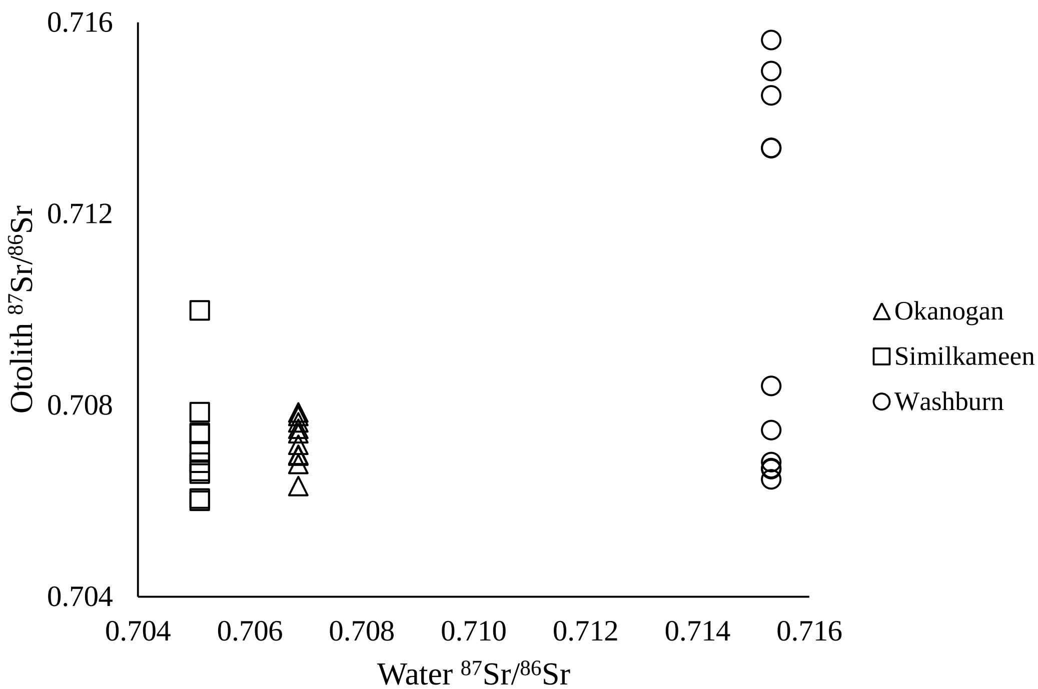


Figure 3. Scatterplot of water and otolith Sr/Ca for the Okanogan, Similkameen and Washburn sample sites. Values are in mmol/mol.

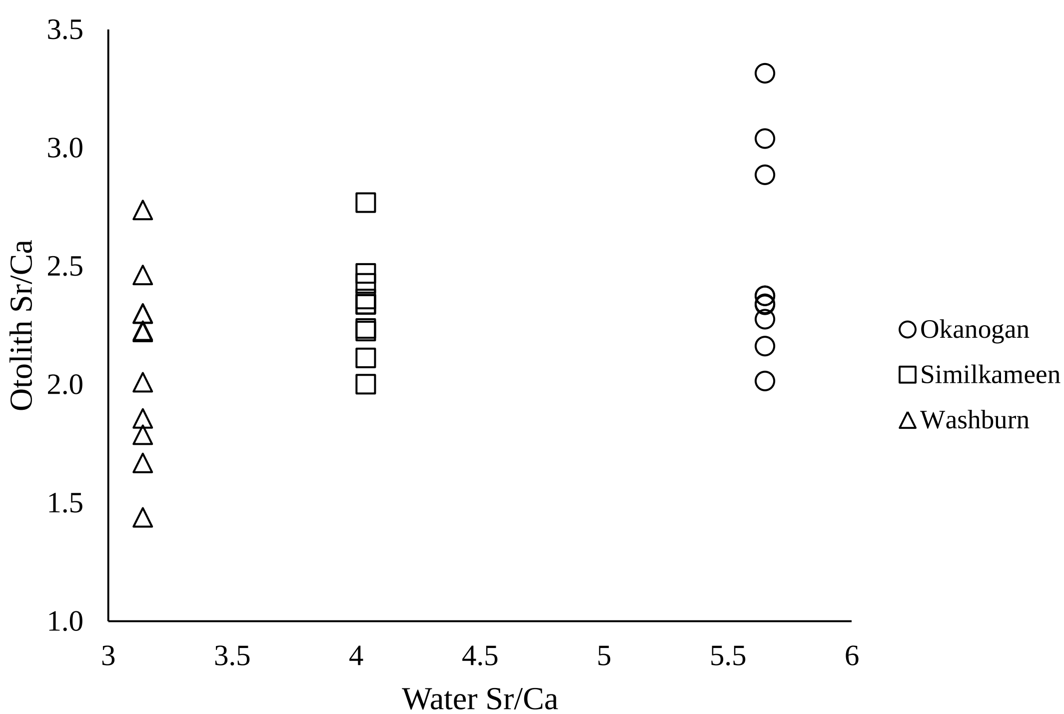


Figure 4. Scatterplot of water and otolith Ba/Ca for the Okanogan, Similkameen and Washburn sample sites. Values are in mmol/mol.

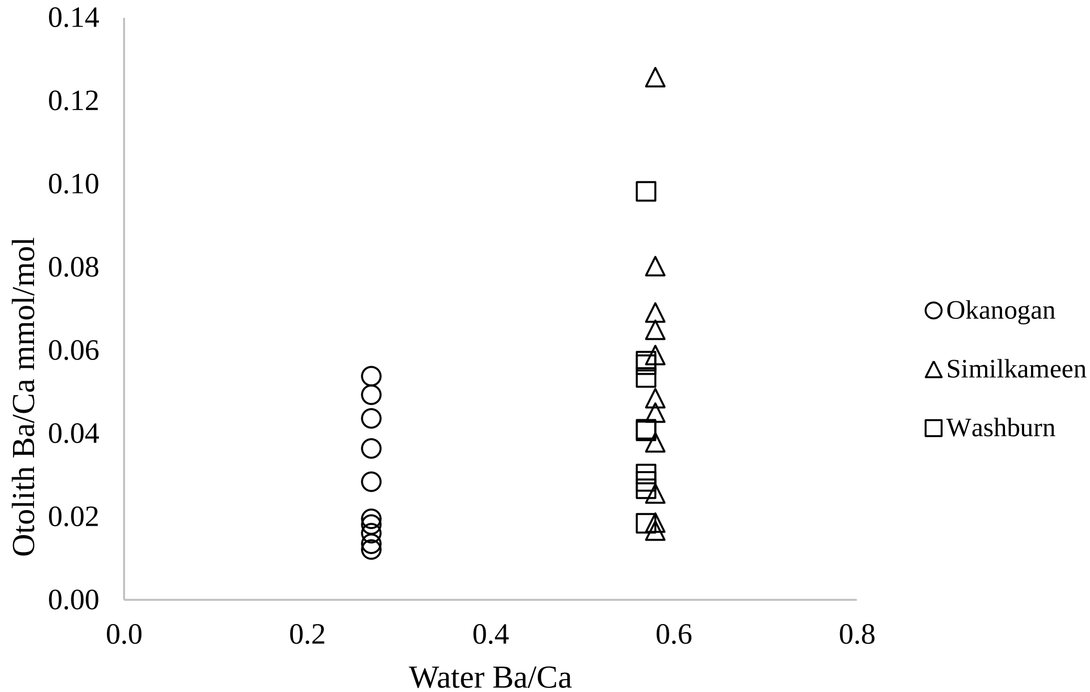


Figure 5. Scatterplot of water and otolith Sr/Ba for the Okanogan, Similkameen and Washburn sample sites.

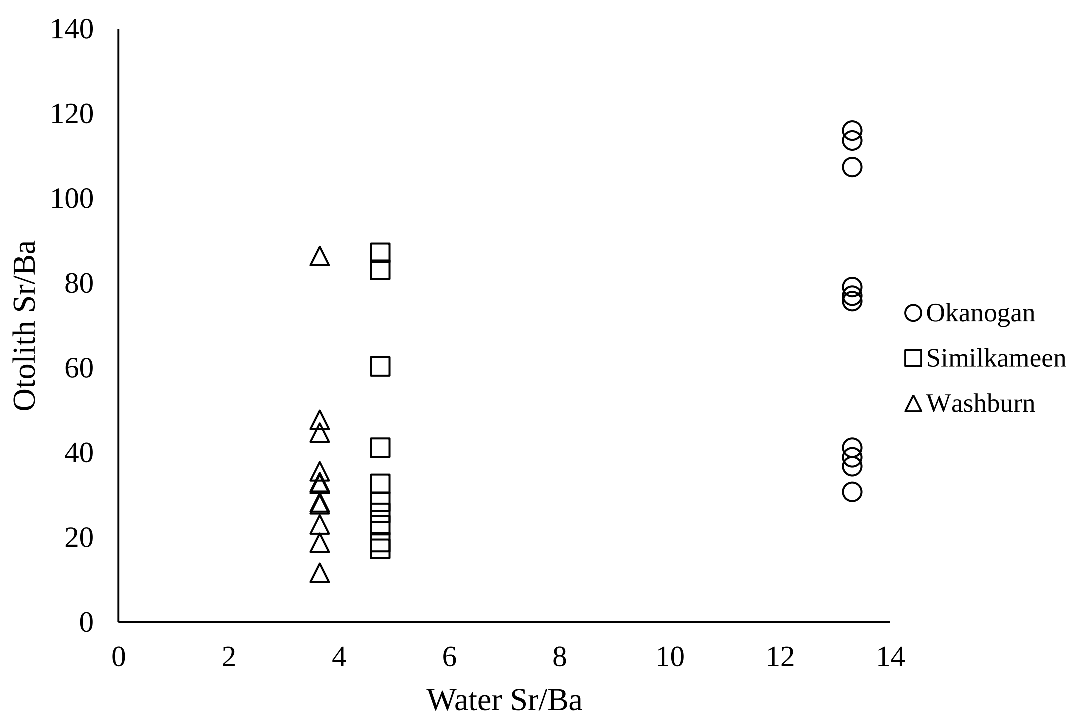


Figure 6. Scatterplot of water and otolith δ^{18}O for the Okanogan, Similkameen and Washburn sample sites.

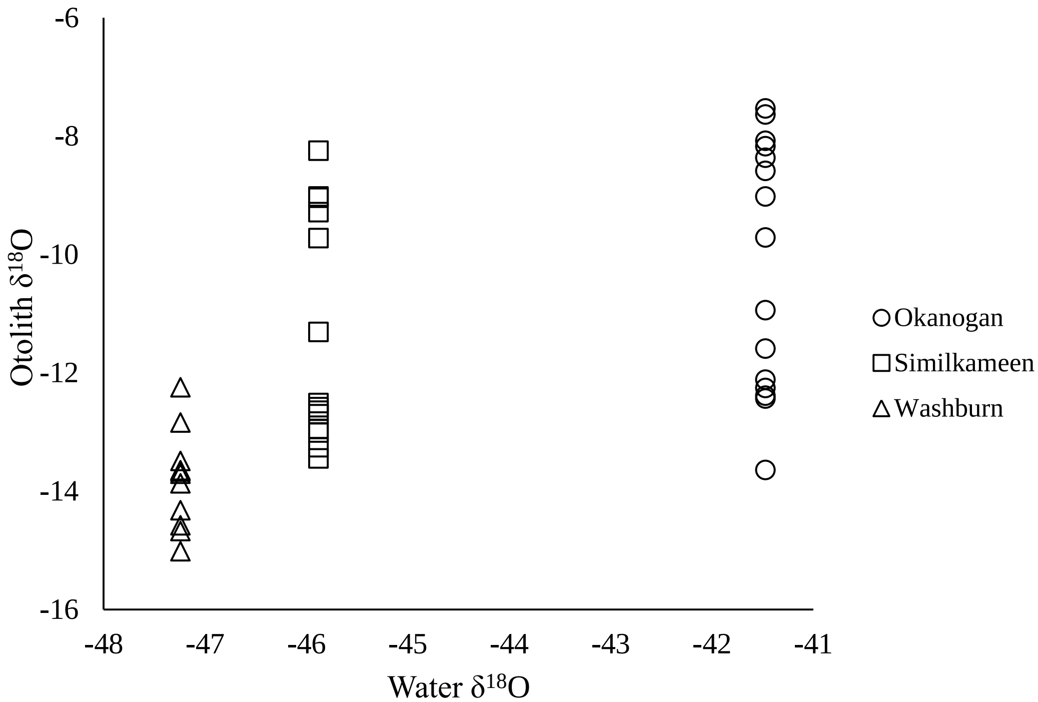


Figure 7. Correlation plot between otolith ^{87}Sr/^{86}Sr and δ^{18}O for the Okanogan, Similkameen and Washburn sample sites.

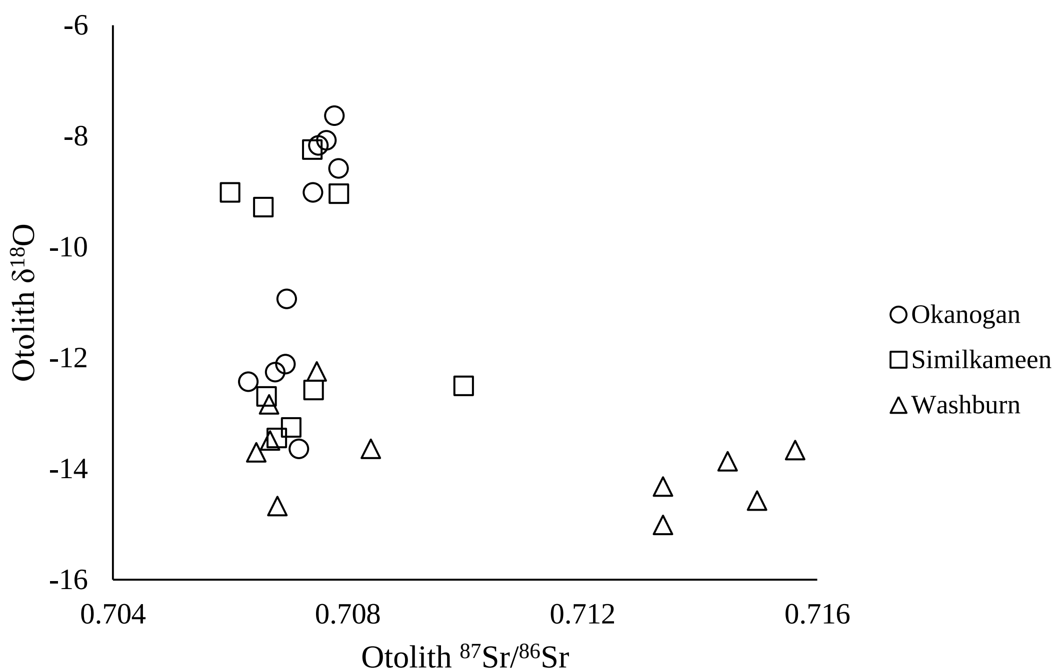


Figure 8. Correlation plot between otolith Sr/Ca and Ba/Ca for the Okanogan, Similkameen and Washburn sample sites. Values are in mmol/mol.

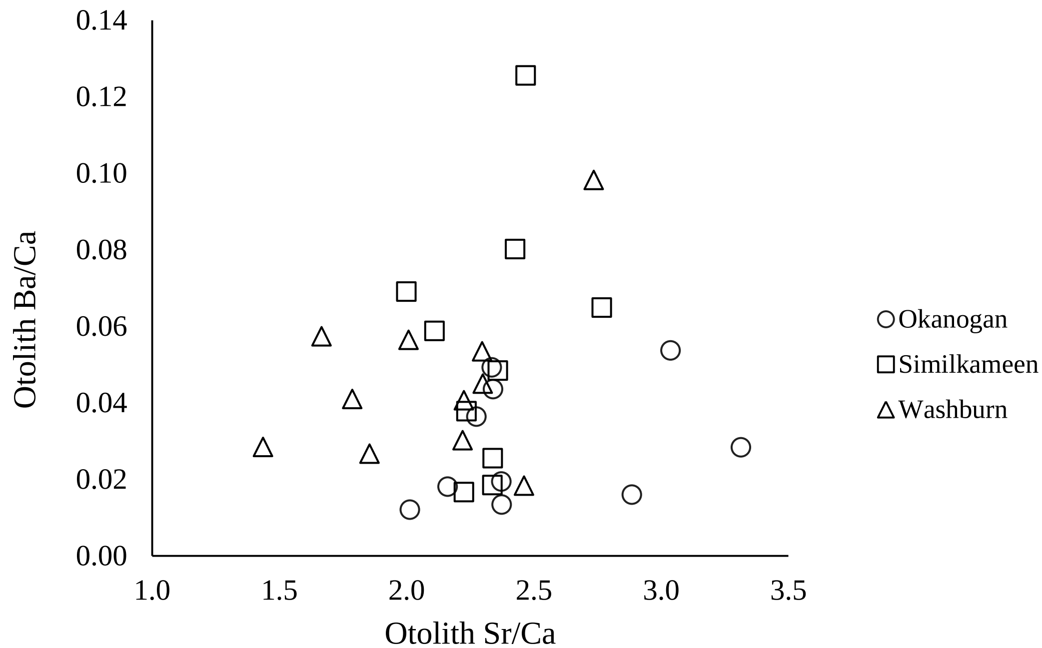


Figure 9. Correlation plot between otolith $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ for samples from Gebber's Landing.

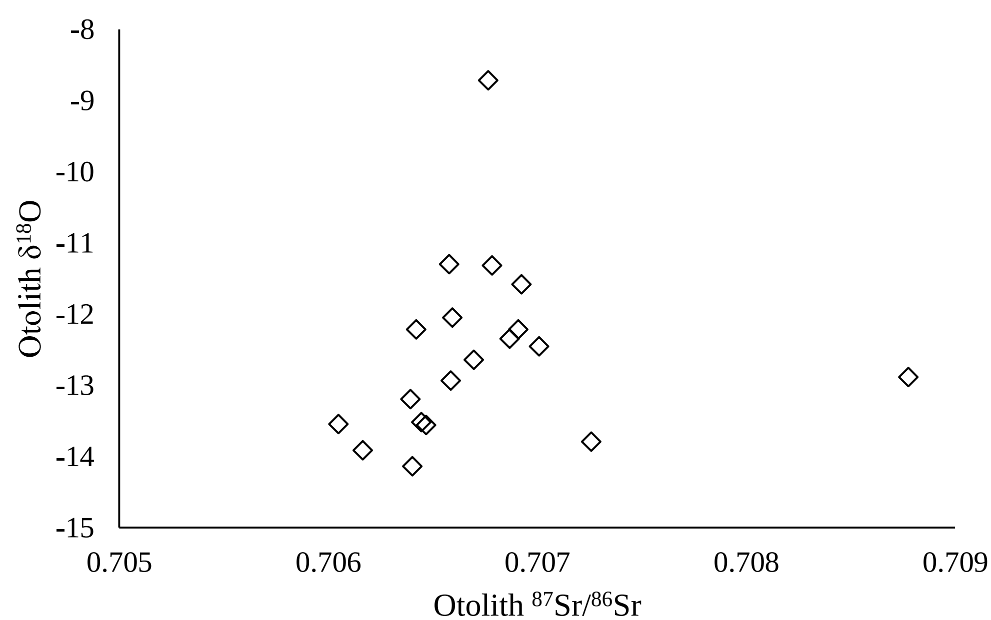


Figure 10. Correlation plot between otolith Sr/Ca and Ba/Ca for samples from Gebber's Landing. Values are in mmol/mol.

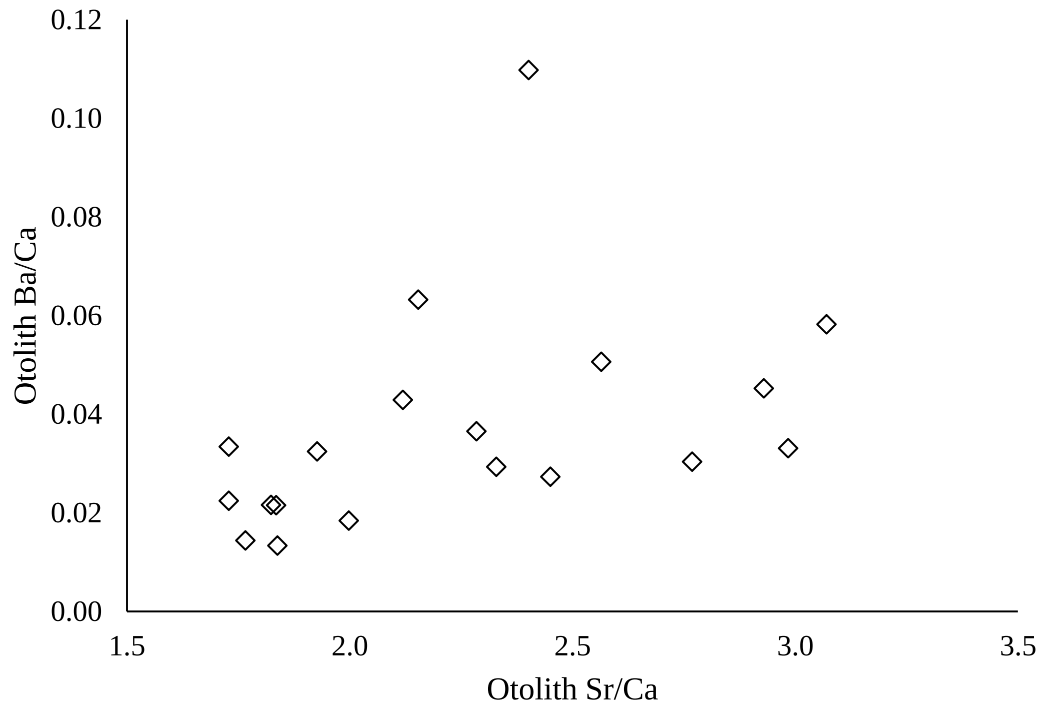
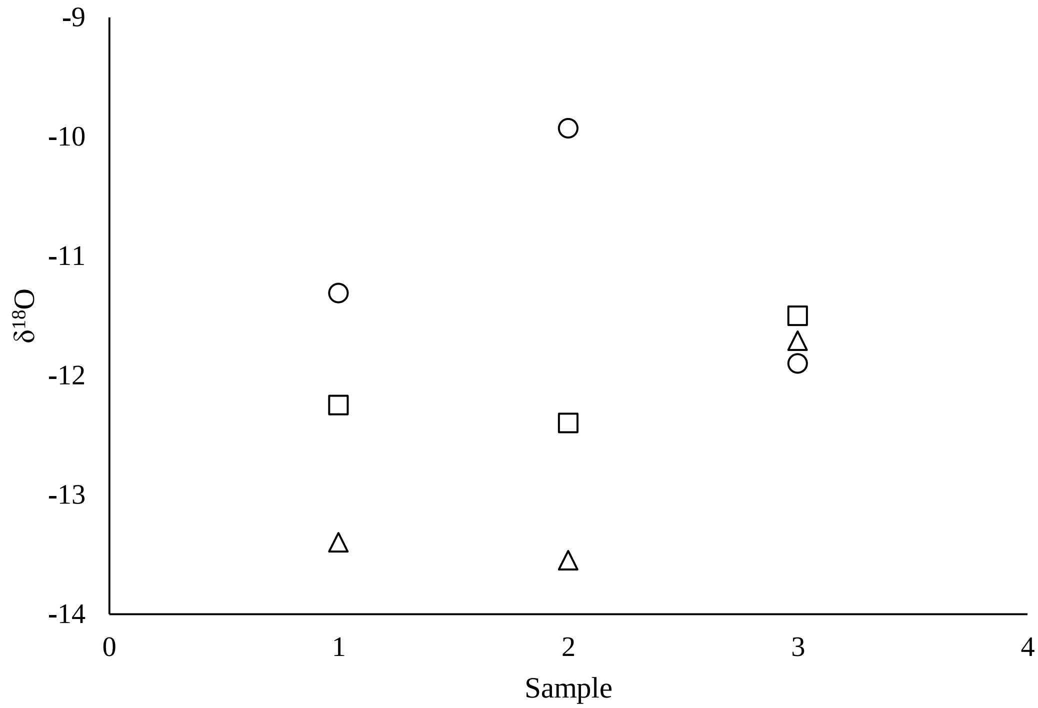


Figure 11. Scatterplot of three Gebber's Landing otoliths micro-milled for depth and surface variation in $\delta^{18}O$. Symbols are otolith core surface (circle), otolith core below surface (square) and otolith edge (triangle).



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APPENDIX F

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

Date: 2 May 2018

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

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

CC: Kirk Truscott

Subject: Minijack rates for 2018 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 April, 2018, and provide estimates for the rate of early maturation ("minijack rate") from each yearling group released in 2018 (brood year 2016).

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 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. The CJHP did not have the budget to implement the 11-KT method and therefore 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 2018 CJH release group for dissection and examination. The release groups are:

- Segregated spring Chinook; released from Chief Joseph Hatchery, hatchery-origin broodstock from Leavenworth National Fish Hatchery
- 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 broodstock from Winthrop National Fish Hatchery
- Integrated summer Chinook; released from the Omak Acclimation Pond, natural-origin broodstock primarily of Okanogan-origin stock
- Integrated summer Chinook; released from the Similkameen Acclimation Pond, natural-origin broodstock primarily of Okanogan-origin stock

Fish were euthanized with MS-222, and processed in accordance with the USFWS GSI sampling protocol (Pfannenstein 2016, see Appendix A). USFWS staff participated in the first day of sampling (April 9, 2018) with CCT to ensure consistency with the USFWS protocol. 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 low rates of early maturity (0.00%-4.52%, Table 1). However, a distinct separation in Log10 GSI between immature and mature fish was not apparent in any of the sampled groups. Because of this, a cutoff value and for classifying sampled fish as mature or immature, and therefore a minijack rate, could not be calculated by the model for any group except for segregated spring Chinook (Figure 1). Histograms that display the distribution of Log10 GSI for each sampled release group are presented in Figures 1-5.

Discussion and Recommendations

The data and analyses presented herein suggest there was not a problem with early maturation rate of brood year 2016 Chinook reared at the CJH and its acclimation facilities. The minijack rates for all CJH release groups in 2018 were low relative to many other Columbia River hatchery programs (Harstad et al. 2014). However, the inability to statistically determine a GSI cutoff value for the all but one program was disconcerting. Visual determination of maturity state is subjective and is likely only useful when the state of maturity has progressed to the point where observer error or bias can be overcome. Without statistical confirmation, the visual maturity classifications are unsubstantiated and the uncertainty associated with a purely visual determination of maturation status unresolved. Differentiation in Log10 GSI between immature and mature subpopulations can be increased by holding sample groups post-release and allowing more time for sexual maturation and gonadal development in mature fish prior to sampling. If practicable, CJH fish to be sampled for early maturation should be held for as long as possible to increase the likelihood of statistically determining a cutoff value between immature and mature Chinook. The USFWS holds their sample fish until mid-May (about 1 month post release) to better determine the GSI cutoff for early maturation. This extra holding period presents a couple of challenges for CCT. First, there are no facilities to hold 300 fish at the Omak and Similkameen acclimation ponds after the majority of fish are released and bringing those fish back to CJH would present a pathogen risk. Second, M&E staff may not be available in mid-to late May to implement the lab work. A recommendation for 2019 is to duplicate the lab effort on 300 fish held for 1 month longer at CJH and determine if the extra month makes a difference in the ability to detect a statistically significant cutoff. CJHP should also consider doing an 11-KT test on one group of fish each year to provide a control group and comparison to validate the visual and GSI approach.

Additionally, staff should receive further training in visual classification of immature and mature individuals. Within the Omak integrated summer Chinook sample group (n=132), no fish was visually classified as mature. However, two fish (1.51% of the sample) had a Log10 GSI of greater than -1.058 - more than three standard deviations away from the mean. This result could be due to a suite of reasons, including variation within the immature population or measurement error. However, it could also be explained by incorrect assignment of mature fish to the immature category. This potential error can be reduced with additional training as to visual classification of maturity stage.

Table 1. Mini-jack rate for each Chief Joseph Hatchery release group from brood year 2016.

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	155	150	5	3.23%	4.52%
Segregated Summer Yearlings	Chief Joseph Hatchery	163	156	7	4.29%	N/A
Integrated Spring Yearlings	Riverside Acclimation Pond	149	147	2	1.34%	N/A
Integrated Summer Yearlings	Omak Acclimation Pond	132	132	0	0.00%	N/A
Integrated Summer Yearlings	Similkameen Acclimation Pond	134	133	1	0.75%	N/A

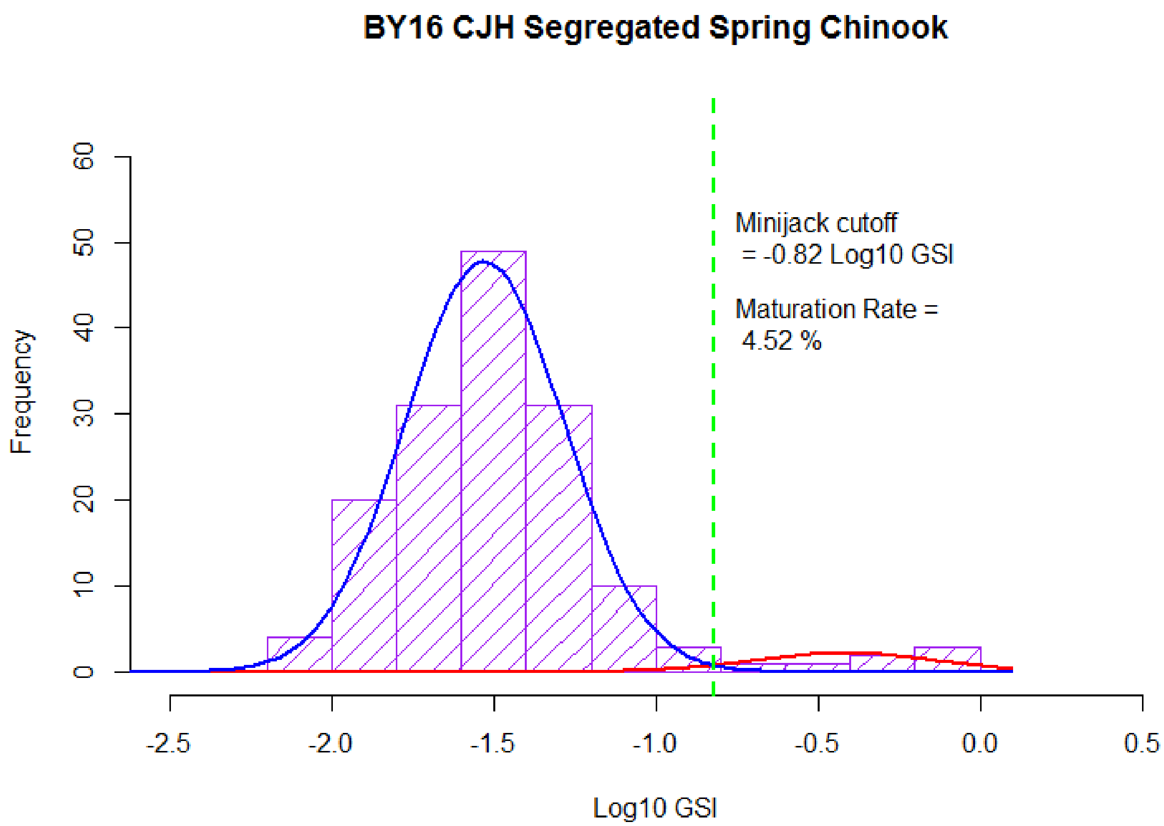

Figure 1. Distribution of Log10 GSI for the segregated spring Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

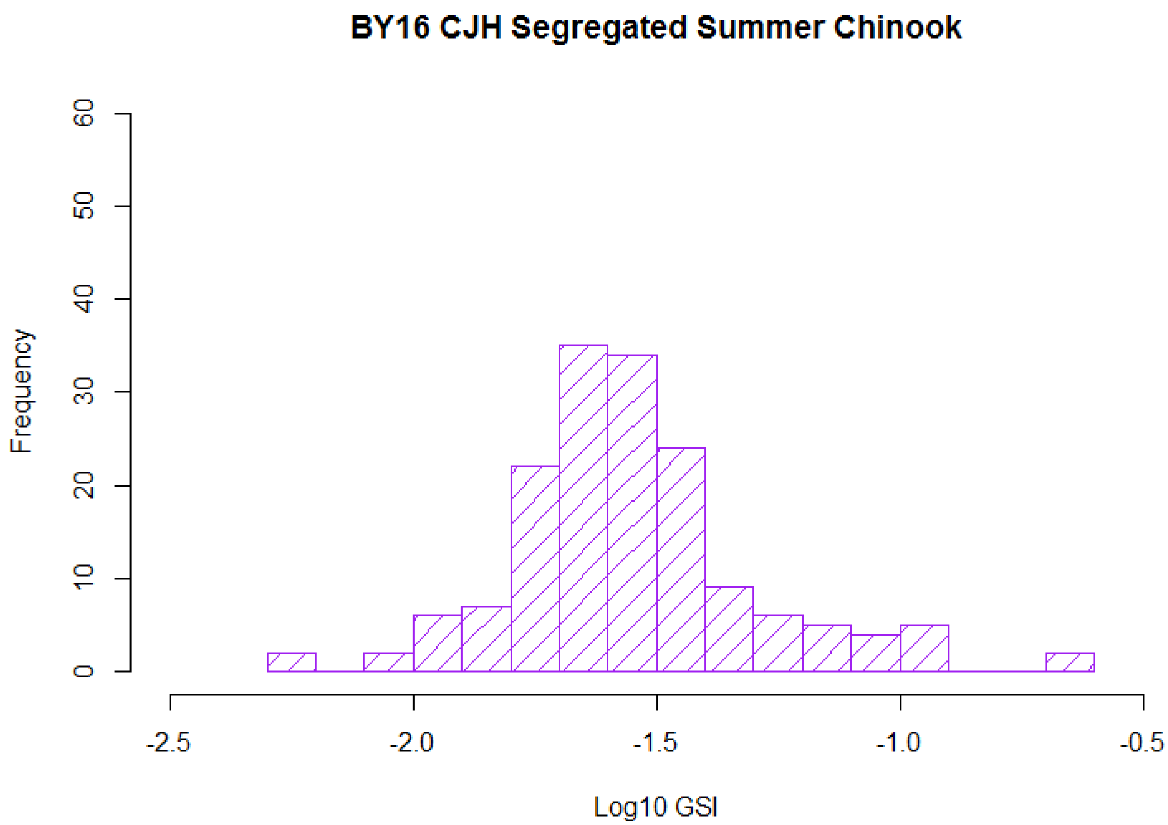

Figure 2. Distribution of Log10 GSI for the segregated summer Chinook released from the Chief Joseph Hatchery. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

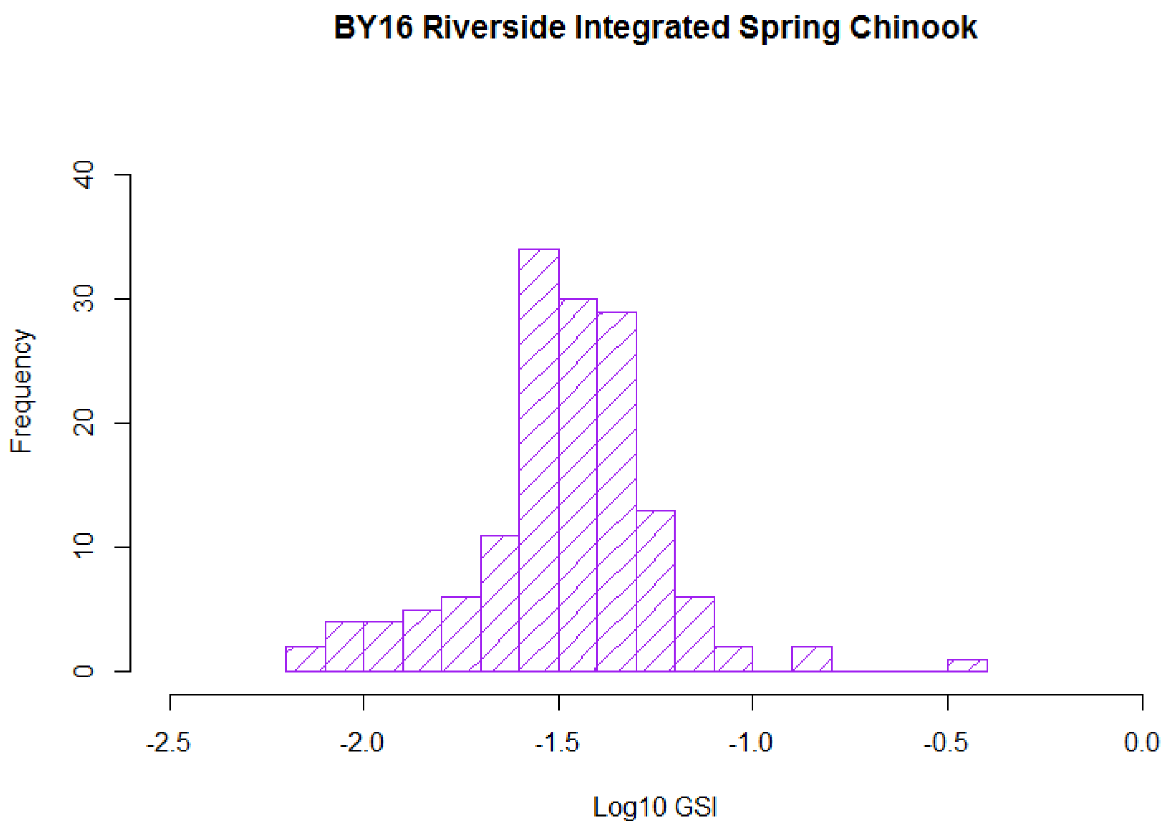

Figure 3. Distribution of Log10 GSI for the integrated spring Chinook released from the Riverside Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

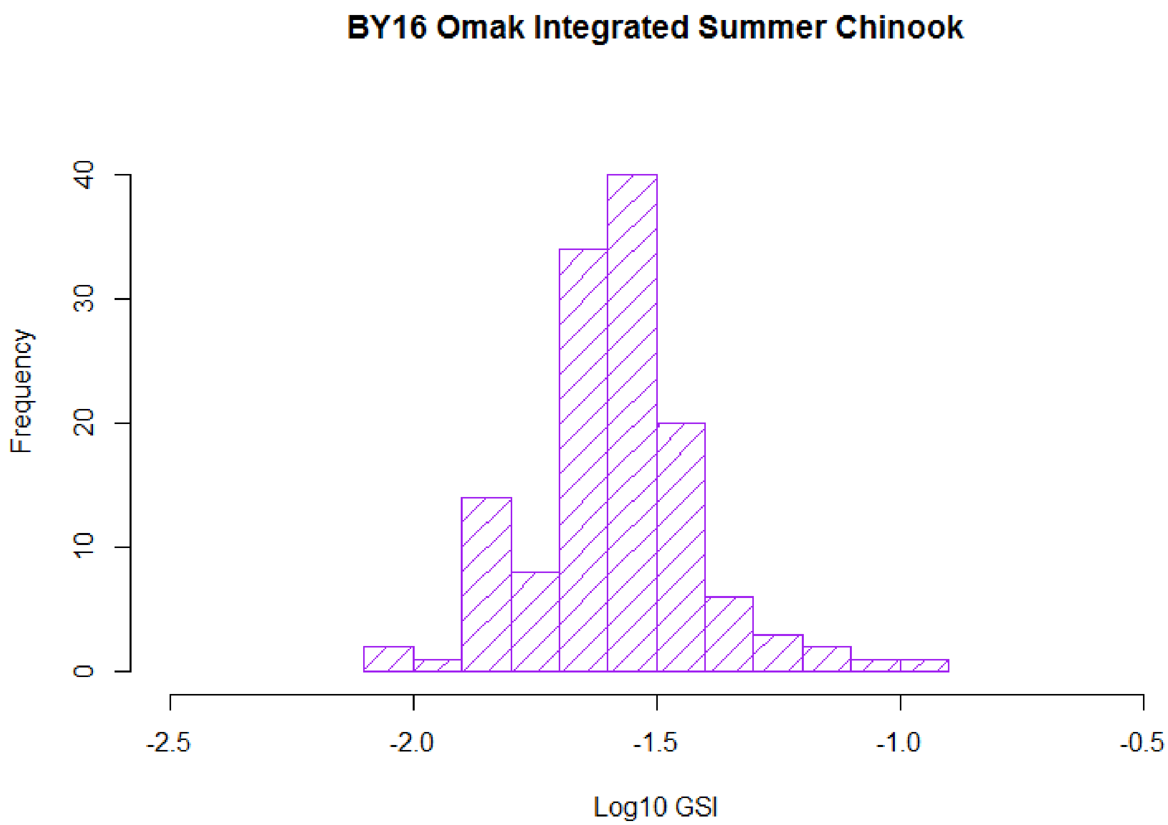

Figure 4. Distribution of Log10 GSI for the integrated summer Chinook released from the Omak Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

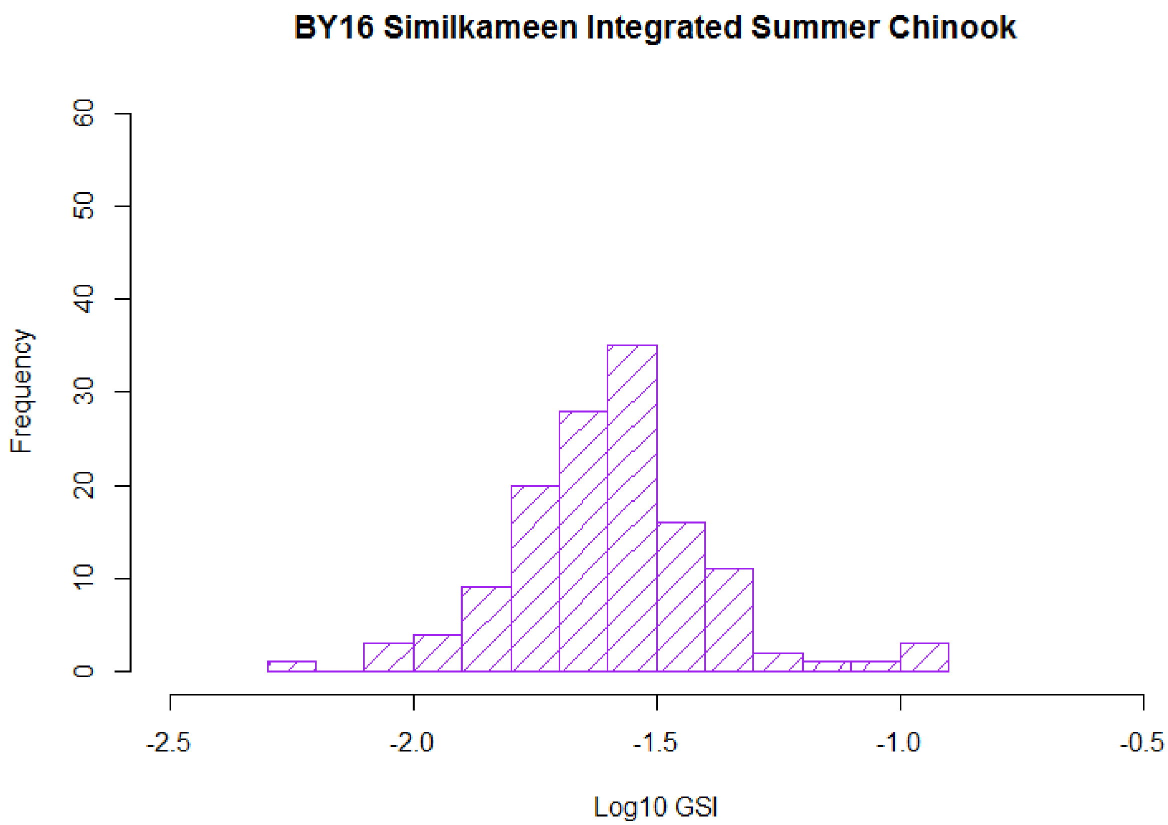

Figure 5. Distribution of Log10 GSI for the integrated summer Chinook released from the Similkameen Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

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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

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

Daily consumables:

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

General:

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

Length and weight station:

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

Dissecting station:

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

‘NAD Sampling How-To

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

PRE-RELEASE JUVENILE SAMPLING DATA SHEET Page____of____

Date: ___/___/20____ Samplers:____

Hatchery: __________________________ Species/Stock______________________________

Group:_______________________Bank:____________________Raceway(s)__________________

Other:____

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

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

PRE-RELEASE JUVENILE SAMPLING DATA SHEET Page____of____

Date: ___/___/20____

Hatchery: __________________________ Species/Stock______________________________

Group:_______________________Bank:____________________Raceway(s)__________________

Other:____

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

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

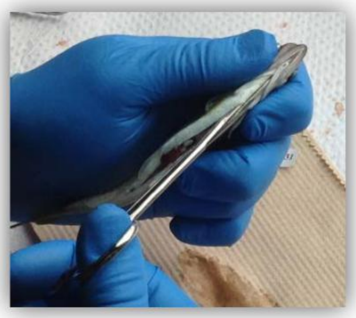
2. Collect fish from hatchery ponds. Random sample? Keep different ponds separate? CWT? Pit Tag?

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

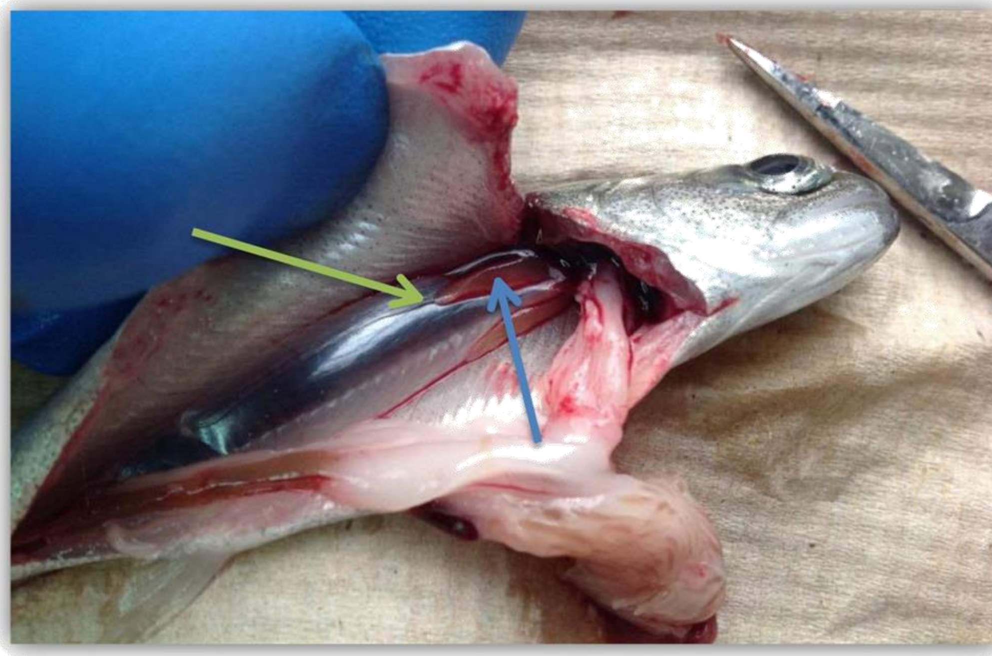
4. Smolt index: 1. Parr, dark marks (bottom fish), 2. Transitional, faded marks (middle fish), 3. Smolt, silver, no marks (top fish)

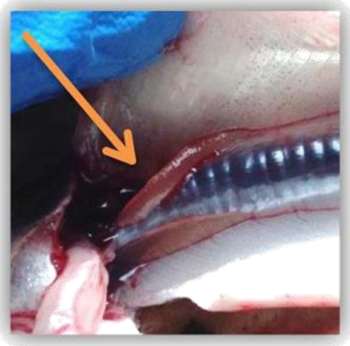
5. Set out 15-20 fish in a row on the sponges. Add number tags to fish. Assess smolt index while all fish are in the line. Obtain weights and lengths, place on paper towel to pass to the dissecting crew.

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



7. Female identification: 1. Ovary forms a point and then narrows to oviduct – thread like (green arrow) 2. Ovary is angular, has ridge (blue arrow), 3. Granulated (orange arrow), 4. Color (red arrow) is not a good indicator as it can vary from pink to white.



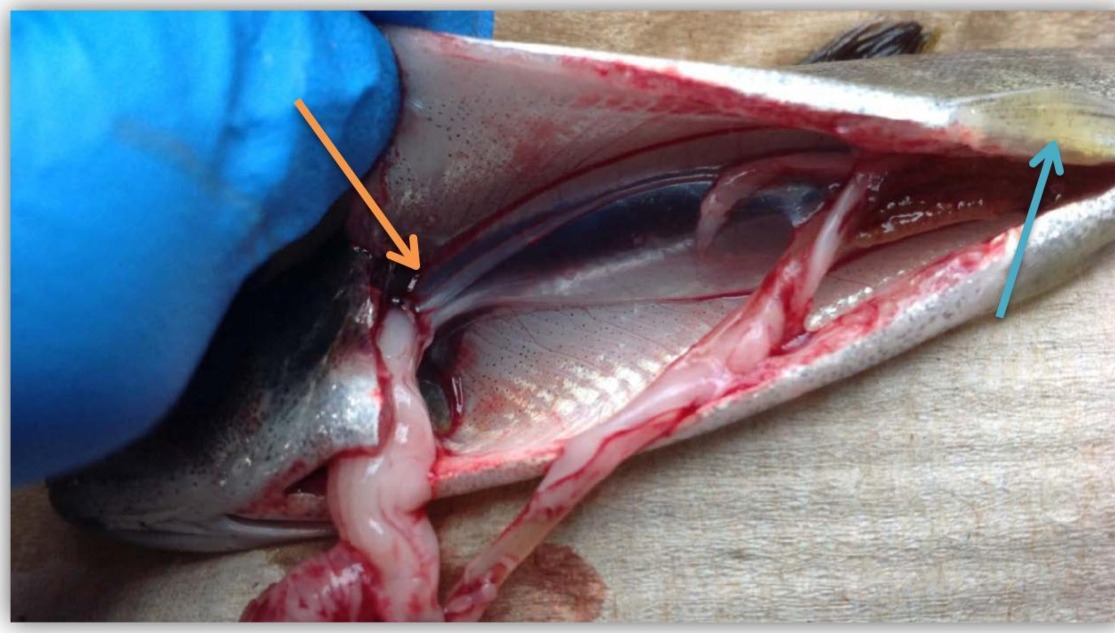


8. Immature male identification: Testes are thready throughout, smooth and round, no development or thickness (green arrows).

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

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

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

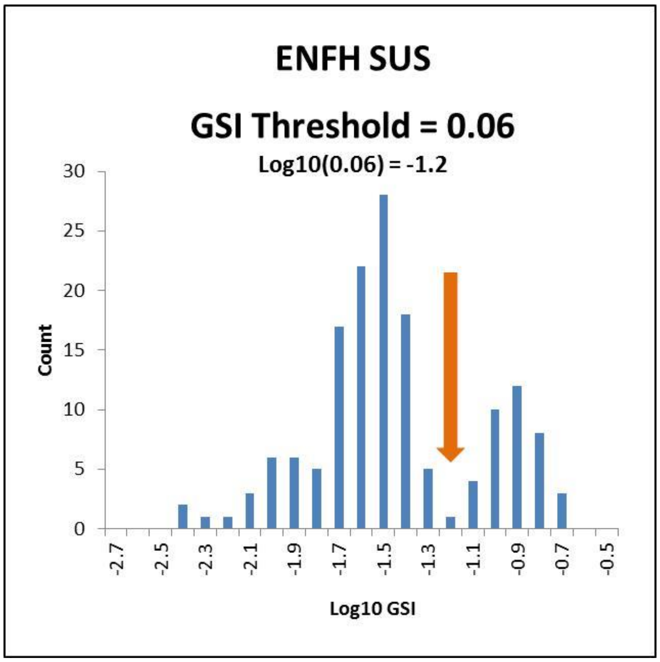


12. To use the scale: Close all doors, zero balance, open door, place 'nads in weight boat, close doors, wait for number to stabilize. 'Nads will evaporate and become lighter in a short period of time.

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

NAD Data Summary and Analysis Methods

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



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

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

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

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

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

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

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

References:

Larsen, D. A., B. R. Beckman, K. A. Cooper, D. Barrett, M. Johnston, P. Swanson, and W. W. Dickhoff. 2004. Assessment of high rates of precocious male maturation in a spring Chinook salmon supplementation hatchery program. Transactions of the American Fisheries Society 133:98–120.

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

Mixture model and maturity cutoff calculation

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

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

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

Copy and paste the code below the line into rStudio

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

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

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

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

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

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