THE CHIEF JOSEPH HATCHERY PROGRAM SPRING CHINOOK

2021 ANNUAL REPORT

BPA Project Number 2003-023-00
CCT Project No. 312421 and 312221

This report covers work performed under contracts
#73548, Rel 113 (M&E) and #73548, Rel 114 (O&M)
for the performance period May 1, 2021 to April 30, 2022.

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Prepared for:
Bonneville Power Administration, and
Chelan, Douglas, & Grant County Public Utility Districts

February 2, 2024

This report was funded by the Bonneville Power Administration (BPA), the U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the authors, except for the U.S. Geological Survey author, and do not necessarily represent the views of BPA, other funding entities, or the Colville Confederated Tribes (CCT).

Cost shares for specific portions of this project were provided by the U.S. Geological Survey and the Washington State Recreation and Conservation Office. General cost shares were also provided by the Chelan, Douglas, and Grant County Public Utility Districts as part of their mitigation obligations under their respective hydroelectric project settlement agreements.

This report includes both hatchery production/operations and the corresponding monitoring activities completed through April of 2022. It is structured to meet the RM&E technical report formatting requirements for BPA, and therefore the hatchery production portion is included in Appendix A.

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

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

Suggested Citation: Pearl, A.M., Baldwin, C. M., Brudevold, K., Dietz, B., McDaniels, M.T. 2023. The Chief Joseph Hatchery Program Spring Chinook 2021 Annual Report. BPA Project No. 2003-023-00, 109 pages.

ACKNOWLEDGMENTS

The list of people responsible for planning, designing, building, funding, and implementing the Chief Joseph Hatchery (CJH) is too long to mention here. None of the authors of this report were involved in the initial efforts to convince the Federal government to fund this endeavor, but we are grateful for the efforts. As are the Colville Tribal fishermen and other fishermen from Alaska, British Columbia, the Washington Coast, and all through the Columbia River who will benefit from the fish production for many generations to come. We wish to acknowledge Joe Peone, Colville Confederated Tribes (CCT) Fish & Wildlife Program Director, Kirk Truscott, CCT Anadromous Division Manager, the Colville Business Council and the Fisheries Committee for their policy direction and program guidance. This hatchery program would not exist today if not for the vision and dedicated efforts of a variety of current and former employees of CCT and Bonneville Power Administration (BPA), particularly the former CCT Anadromous Division Manager, Jerry Marco. Additionally, expert contributions, counsel, and examples came from a variety of staff from management agencies (Washington Department of Fish & Wildlife, U.S. Fish & Wildlife Service), groups (Mid-Columbia Hatchery Conservation Planning Committee), and contractors to the CCT.

We want to thank our skilled and dedicated Chief Joseph Hatchery Program 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.

Administrative support for CCT was provided by Jeannette Finley, Fauna Ferguson, Roma Tynan, Cindy McCartney, Shelly Davis, Erica DeLeon, and others within the Tribal government. We greatly appreciate the administrative support of Maureen Kavanagh, the BPA contract officer technical representative for this project. These individuals provide collaboration on accounting and procurement and the considerable administrative transactions necessary to support a program of this scope.

We would also like to extend our appreciation to the many private landowners, Colville Tribal members, State and Federal agencies, the Okanagan Nation Alliance, and the Penticton and Osoyoos Indian Bands in Canada, who have provided land access and other forms of assistance enabling us to collect biological and other data within the Okanogan and Columbia basins.

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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 to mitigate 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 government 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 River Public Utility Districts (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 2021 during the ninth year of operation for the spring Chinook program. The program operated the ladder at CJH to collect returning adults from the BY 2016 and BY 2017 production. The spring Chinook programs did not collect enough brood to meet full production levels so additional brood were transferred from the Leavenworth National Fish Hatchery to meet the segregated program's goal. 251 spring Chinook broodstock were collected at the CJH ladder from May 17-June 27, 2021. 338 spring Chinook broodstock were transferred from the Leavenworth National Fish Hatchery to meet the quota. The segregated spring Chinook program broodstock survival was 94.1% for females, and 81.9% for males with a combined survival of 88.0% (see Appendix C for Glossary of Terms, Acronyms, and Abbreviations). The total green egg take for the segregated spring Chinook program was 1,085,733 (>100% of full program). Green egg to eyed egg survival was 89.6%. This survival was just below the standard (90%) and therefore, as of April 30, 2021, the segregated spring Chinook program was just below track to meet full program release targets. The Non-Essential Experimental Population (Endangered Species Act, Section 10(j)) spring Chinook reintroduction program (10(j), hereafter) received its full component of 245,000 eyed eggs from the Winthrop National Fish Hatchery (WNFH) in September and October 2021.

Releases of spring Chinook yearling smolts included 229,978 (115% of full program) 10(j) smolt released from the Riverside Acclimation Pond (Riverside, WA, USA) in December 2021 due to flooding of the Okanogan River and heavy sedimentation in the pond. Additionally, 814,631 segregated spring Chinook smolts were released directly from Chief Joseph Hatchery (116% of full program) in April 2022

Apparent survival of yearlings to PTAGIS Location Code 'RRJ' (Rocky Reach Dam juvenile bypass; Wenatchee, WA, USA) varied greatly between the programs. The segregated spring Chinook released from CJH had a survival (80%) to RRJ that was similar to other nearby programs and the 5-year average, whereas the 10(j) program, released from Riverside Pond survival (56%) was much lower. Travel time to RRJ was similar to the average for both programs, so it is unclear why the 10(j) program suffered so much lower survival unless the incubation chiller issue that is known to have affected BY2018 also had some effect on smolt quality from BY2017.

The CJH Monitoring & Evaluation Program collected field data to determine spring Chinook population status, trends, and hatchery effectiveness centered on five major activities; 1) rotary screw traps (juvenile outmigration, natural-origin smolt PIT tagging), 2) spawning ground surveys (redd and carcass surveys) (viable salmonid population [VSP] parameters), 3) environmental DNA (eDNA) analysis (VSP parameter—distribution/spatial structure), 4) electrofishing (natural-origin smolt PIT tagging, genetic sampling), and 5) coded wire-tag analysis (extraction and reading).

The rotary screw trap was operated for the primary purpose of collecting summer Chinook from the mainstem Okanogan River. Only one natural-origin fish was captured in 2021 that was likely a yearling Chinook. The program will continue to monitor the presence of yearling Chinook during screw trap operations.

Spatial distribution of spring Chinook in the Okanogan basin has been monitored using analysis of 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, particularly prior to the reintroduction effort. Following the initial reintroduction, several tributaries have produced consistent annual detections of Chinook eDNA, including Shingle Creek, Vaseux Creek, Loup Loup, Salmon Creek and Omak Creek. Similar to the fall 2020 and spring 2021 sampling events, detections were reduced in the fall of 2021 and spring of 2022. There was only 1 detection in Omak Creek and 1 detection in Antoine Creek in 2021/22. Chinook were detected in many of the tributaries in the fall of 2018 and again in the fall of 2019 (Table 3). Based on the lack of detection during the 2021 and 2022 sampling events, it would appear that natural juvenile production in the tributaries has been minimal the last two years.

PIT tags were also used to evaluate spring Chinook presence and distribution in the Okanogan from adults tagged at Priest Rapids Dam. Spring Chinook abundance in the Okanogan has increased more than 3-fold when comparing years prior to CJH returns (pre-2016) to years post CJH returns (post 2016). Of the 35 returning fish with a PIT tag to the Okanogan, 34 (97%) had a final detection at the lower Okanogan mainstem PIT array ('OKL'). There was 1 final detection in a Canadian tributary to the Okanagan at Shingle Creek. Escapement included 1,297 natural-origin and 1,432 hatchery-origin spring Chinook.

2021 marked the fourth year for spring Chinook redd and carcass surveys. Walked and floated visual surveys occurred between August 17 and September 21 on nine streams in the Okanogan River basin. There was one redd detected in 2021, and six live fish were detected between Loup Loup Creek, Omak Creek and the Similkameen River. A total of 11 carcasses were recovered during spring Chinook surveys between Loup Loup Creek, Salmon Creek, and the Similkameen River. Of these carcasses, three were ultimately determined to be spring Chinook. The others were classified as summer Chinook. All of these recovered carcasses were pre-spawn mortalities. Based on a 3.159 fish/redd ratio of fish passed over Wells Dam, the spawning escapement was only 3 total spawners for the season.

The CJH coded wire tag lab was in its sixth year of operation in 2021. Coded wire tags were extracted and read from Chinook snout recoveries from broodstock and spawning ground surveys. The majority of the segregated broodstock recoveries were from the Leavenworth National Fish Hatchery (61.5%), followed by the Chief Joseph Hatchery segregated (37.1%) and the rest were from the Winthrop National Fish Hatchery (1.4%).

The most recent brood year that could be fully assessed (through age 5) for stray rate of Okanogan 10(j) fish to spawning areas outside the Okanogan was 2016. There were 8 carcass recoveries in the target streams (Okanogan basin), this low sample size of carcasses likely biased the CWT-based stray/homing rate evaluation. The PIT tag run escapement estimate predicted that 1,432 hatchery spring Chinook returned to the Okanogan and half of them were likely from the 10(j) program. Likewise, sample size limitations hindered the assessment of straying and homing using PIT tags.

CJH segregated spring Chinook had a lower stray rate to non-target streams and hatcheries. For BY16, the CWT-based stray rate for non-target streams and hatcheries was 9.6% and 1.5% respectively. The homing rate to the Chief Joseph Hatchery was 88.9%. For return year 2021, there were no CJH segregated spring Chinook strays recovered in the Methow River and all other adjacent non-target streams. This assessment may have been biased towards lower than actual stray rates due to the lack of carcass recoveries in the Okanogan. Unfortunately, zero of the 10 returning segregated Spring Chinook with PIT tags were detected upstream of the Dalles Dam, so we could not assess homing fidelity to CJH with this small sample size and the existing mortality rate in the lower Columbia.

The Chief Joseph Dam Tailrace and mainstem Columbia River fishery did not open to tribal fishermen in 2021. The fishery was closed due to a low number of spring Chinook returns to the Columbia River. The pre-season run forecast was the lowest in the last two decades. An Annual Program Review (APR) was held in March 2022 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. The plan for 2022 is to operate the hatchery at full program level of 900,000 spring Chinook. To achieve full production, CJH operations would require the collection of 640 adult spring Chinook from the CJH ladder. The pre-season forecast for Upper Columbia spring Chinook salmon in 2022 is 21,700 which is slightly greater than the 10-year average. Given the low pre-season forecast we anticipate it will be a difficult year to collect broodstock and local fishery opportunities will be limited.   If LNFH has surplus brood, CJH staff will work with LNFH staff to supplement CJH brood collection with fish collected at LNFH.

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 the 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.

Integrated Program = The CJH integrated spring Chinook program consists of Met Comp eggs or Okanogan broodstock which are spawned at CJH and then reared at acclimation sites on the Okanogan River. Fish are released directly to the Okanogan River with the intention of adults returning to the Okanogan for natural spawning as part of an ESA-listed section 10(j) experimental population.

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.

Segregated Program = The CJH segregated spring Chinook program consists of CJH broodstock which are then spawned at CJH, and the offspring reared at acclimation ponds at the hatchery. These fish are released directly to the Columbia River with the intention of adults returning back to the hatchery ladder.

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 would produce adult offspring 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

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)

HPUE- Harvest Per Unit Effort

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

INTRODUCTION

Salmon (*Oncorhynchus* spp.*)* and steelhead (*O. mykiss*) face many anthropogenic challenges resulting from 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 have profoundly impacted Native American tribes, including the Confederated Tribes of the Colville Reservation. Hatcheries have been used as a replacement or to supplement the natural-origin production of salmon and steelhead throughout the Pacific Northwest. However, hatcheries and hatchery practices can pose biological and evolutionary risks 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 Chief Joseph Hatchery Program (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 (*i.e.,* natural-origin, or naturally spawning fish on the in-stream spawning grounds) and hatchery broodstock (*i.e.*, hatchery-origin adult returns collected for use in hatchery spawning programs) (HSRG 2009). 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 Confederated 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 (NEP) of spring Chinook in the Okanogan utilizing section 10(j) of the Endangered Species Act (ESA). 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 program in 2014. The program will be guided by all three HGMPs.

At full program the facility will rear up to 900,000 spring Chinook. Up to 700,000 segregated spring Chinook will be released from CJH and up to 200,000 Methow Composite stock (of Chewuch and Methow rivers origin; Met Comp, hereafter) 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 2018, a complete set of brood year spawners (age 3 to 5) returned to the Okanogan from the NEP

The CJHP will increase harvest opportunities for all anglers throughout the Columbia River and Pacific Ocean. The reintroduction of spring Chinook as a NEP into the Okanogan River is intended as a conservation and recovery activity, and direct harvest is neither authorized nor planned in the current phase of reintroduction. Incidental harvest of the NEP does occur throughout its range and this harvest is managed through ESA-take authorization for the various fisheries by NMFS.

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).

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

1. Monitor, evaluate and adaptively manage hatchery and science programs

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

2. Manage hatchery broodstock to achieve proper genetic integration with, or segregation from natural populations
3. Promote local adaptation of natural and hatchery populations
4. Minimize adverse ecological interactions between hatchery- and natural-origin fish
5. Minimize effects of hatchery facilities on the ecosystem
6. Maximize survival of hatchery fish in integrated and segregated programs
7. Develop clear, specific, quantifiable harvest and conservation goals for natural and hatchery populations within an "All-H" (Hatcheries, Habitat, Harvest and Hydro) context
8. Institutionalize and apply a common analysis, planning, and implementation framework
9. Use the framework to sequence and/or prioritize actions
10. Hire, train, and support staff in a manner consistent with successful implementation of the program
11. Conduct annual reviews to include peers, stakeholders, and regional managers, and
12. Develop and maintain database and information systems and a highly functional informational web-presence.

The CJHP annual RM&E activities were focused on four 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. Spawning ground surveys (redd and carcass surveys) (VSP parameters)
3. eDNA collection (VSP parameter—distribution/spatial structure)
4. Electrofishing (natural-origin smolt PIT tagging, genetic sampling)
5. 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, smolt-to-adult returns, and stock composition
3. Query PTAGIS for PIT tag returns at mainstem dams and tributaries and strays to out of basin

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 / reduction of the proportion of hatchery origin spawners (pHOS)

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 is 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 basin 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.

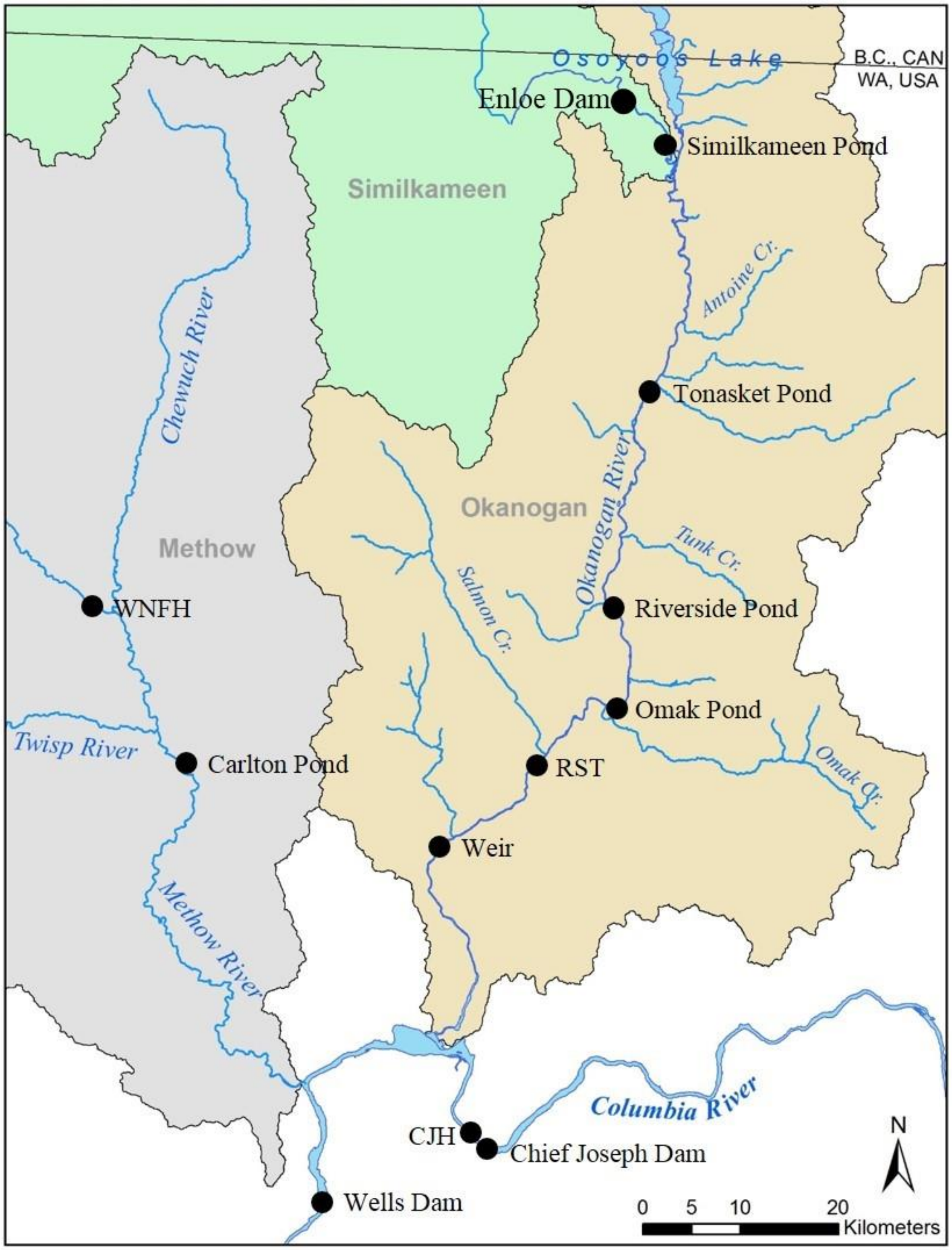


Figure 1. Map of the U.S. portion of the Okanogan River Basin, the Chief Joseph Hatchery (CJH), Winthrop National Fish Hatchery (WNFH), Okanogan adult weir (Weir), rotary screw trap (RST), and Chinook Salmon acclimation sites.

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 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 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.

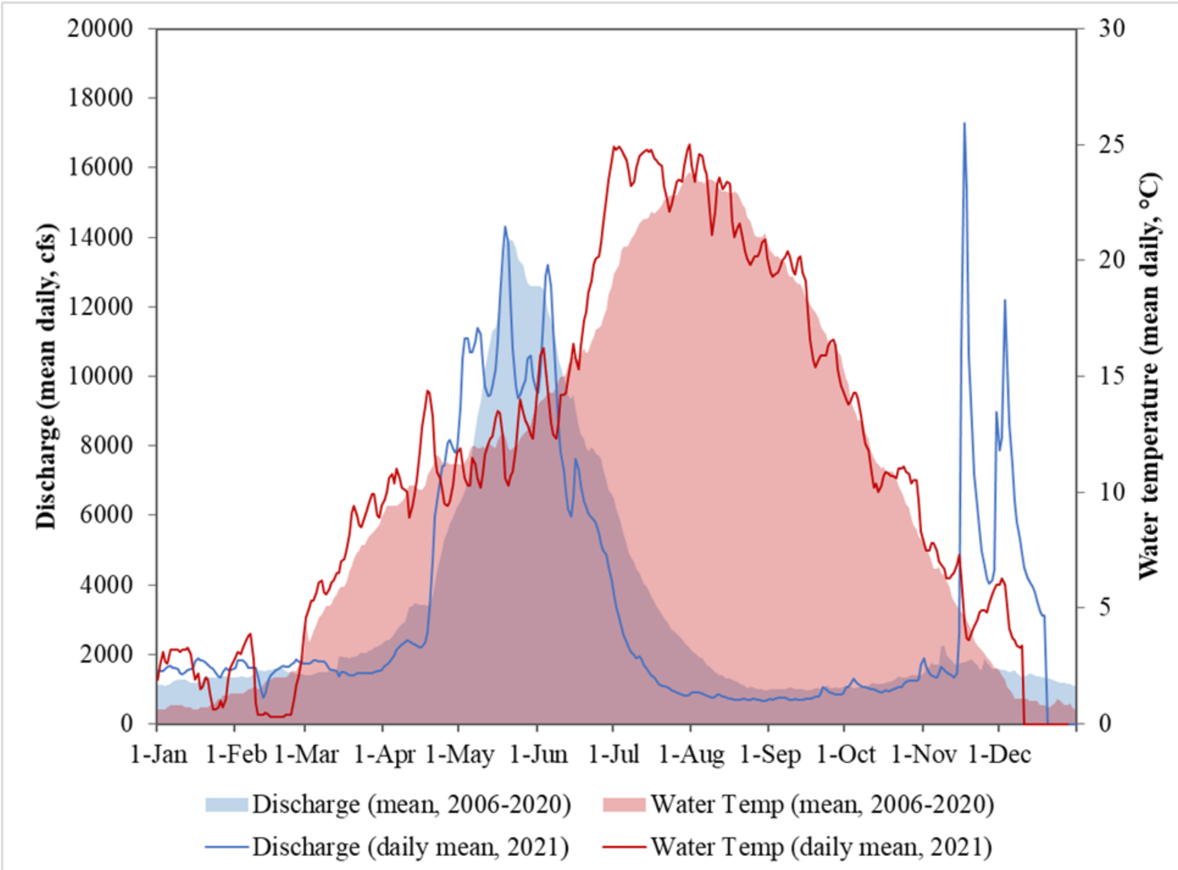


Figure 2. Okanogan River mean daily discharge (blue lines) and water temperature (red lines) at Malott, WA (USGS Stream Gage 12447200).

METHODS

Tag and Mark Plan

HATCHERY SPRING CHINOOK. —Table 1 describes the general tag and mark plan for spring Chinook.

Table 1. General marking and tagging plan for Okanogan spring Chinook as part of the Chief Joseph Hatchery Program.

Mark Group	Smolts 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)					
Riverside Pond	200,000	Yearling	100%		5,000
Natural-Origin	RST	Yearling	0%	0%	≤ 5,000

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 juvenile electrofishing surveys in the Okanogan tributaries. Samples were preserved in 200-proof molecular grade ethanol and sent to the Columbia River Inter-tribal Fish Commission (CRITFC) lab. Genetic analyses include 1) parentage assignment using single nucleotide polymorphisms (SNPs); 2) run/strain assignment (e.g., summer-run, spring-run); 3) Genetic stock identification to existing reporting groups; 4) Full Siblingship analysis/assignments were conducted in winter 2021. Annual tissue collection targets are at least 100 samples for natural-origin sub-yearlings.

The CJHP has also supported requests from the Columbia River Inter-tribal Fish Commission (CRITFC) to provide genetic samples (caudal punches) from CJH 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 Trap

One 2.4 m and one 1.5 m rotary screw trap (RSTs) were deployed from the Highway 20 bridge near the city of Okanogan (rkm 40) (Figure 3). The RSTs were deployed from April 12 to June 17, 2021. Trapping typically occurred continuously from Mondays at 2000 until Friday at 1300. To continue trapping operations in varying river conditions, traps were operated in one of three trapping configurations: 2.4 m only, 1.5 m only, and both traps operational.

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

During operation, the trap locations were adjusted in the river to achieve between 5-10 revolutions per minute. The traps were checked every two hours unless a substantial increase in flow (≥ 500 cfs in a 24-hour period) or debris load occurred, in which case they were checked and cleaned more frequently. All fish were enumerated, identified to species, and life stage, origin (adipose fin present or absent), and disposition (whether the fish was alive or dead), and a subsample of natural-origin Chinook were 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 due to their ESA-listed status. Unmarked (adipose fin present) Chinook captured in the RST that were ≥ 65 mm total length received a 12 mm full duplex PIT tag and fish that were between 50-65 mm total length received a 9 mm full duplex PIT tag, provided water temperatures were below 17°C. A tissue sample (fin clip) was collected from any yearling unmarked Chinook for future genetic analyses.

Spring-Chinook Presence and Distribution

Environmental DNA

CJHP collaborates with USGS to conduct Environmental DNA (eDNA) sampling and analysis 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 to assess the pre-management action spatial distribution of spring-Chinook, allowing CJHP to assess the status and progress of the reintroduction efforts. Analysis of eDNA data revealed that while spring-Chinook were listed as extirpated within the Okanogan ESU, 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 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). Several tributaries have produced consistent annual detections of Chinook eDNA, including Salmon Creek and Omak Creek, as well as Shingle Creek and Vaseux Creek to a lesser degree. In 2018 we included a March sampling event (n = 20 sites) in addition to the consistent fall sampling event (17 sites). This additional sampling event in late winter was intended to target juvenile Chinook production in tributary habitats to assess the distribution of successful spawning. In 2021, 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

Spring Chinook Run Escapement

2021 was the fourth year with a full complement of returning brood years (ages 3-5). Monitoring for distribution and abundance of spring Chinook consists of eDNA and PIT tag sampling and analysis at tributary and mainstem Okanogan sites, supplemented with redd surveys initiated in 2018. 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. Additionally, monitoring programs at Bonneville and Priest Rapids dams tagged returning adult spring Chinook, which greatly increased the probability of encountering spring Chinook with a PIT tag in the Okanogan. In 2021, the spatial distribution of spring Chinook was evaluated using a combination of eDNA and PIT tag data.

Spring Chinook salmon run escapement estimates to the Okanogan River basin and its tributaries were based on a WDFW-provided estimate of total spring Chinook salmon with a final location upstream of Priest Rapids Dam, the tag rate of returning adult spring Chinook salmon with a PIT tag implanted at Priest Rapids Dam by WDFW, and the final PIT array detection site of those fish.

Tagging rate was calculated by the equation:

$$\text{Tag Rate} = \frac{WDFW\ Sample}{Total\ Fish\ Above\ Priest\ Rapids}$$

where the WDFW Sample is the number of fish released by WDFW as part of their PIT tagging efforts, including fish captured as part of the study that already carried a PIT tag, and the Total Fish Above Priest Rapids is the number of total adult spring Chinook Salmon WDFW estimated to have an ultimate fate above Priest Rapids Dam.

Run escapement was then calculated at each PIT tag detection site within the Okanogan River basin. Run escapement estimates were calculated by the equation:

$$\text{Run Escapement} = \frac{Final\ Detections}{Tag\ Rate} \div Detection\ Efficiency$$

where Final Detections is the number of PIT tags from the WDFW sample with a final detection at a given site and the detection efficiency was calculated with the equation:

$$Detection\ efficiency = 1 - \left(\frac{Tr}{OKL}\right) * 100$$

Where**:**

Tr = Number of unique PIT detections at all tributary (and Canadian) arrays upstream of OKL, which were not detected at OKL

OKL = Total number of unique PIT detections at OKL (lower Okanogan array; Malott, WA, USA)

Determining detection efficiency is an important aspect of PIT tag expansions for run escapement and other evaluations such as stray rate. Detection efficiency could only be calculated for the lower most detection site (OKL) by using detections at upstream sites to determine the probability that a fish would be detected when entering the Okanogan. Detection efficiency could not be calculated for the tributaries so we assumed 100% detection efficiency. This assumption was acceptable because detection efficiency tends to be very high in smaller streams with less water depth over the array.

To calculate tributary run escapement for a tributary with multiple detection sites, (e.g., SA0 and SA1 within Salmon Creek) the total run escapement estimate for each detection site was summed. Since the Similkameen River does not have a PIT array, recovered spring Chinook carcasses from weekly float surveys in August and September were used to estimate run escapement in the Similkameen River. We used the total number of collected carcasses in the Similkameen River for the run escapement estimate.

Spawning Ground Surveys

The objectives[2] for spawning surveys were to:

1. Estimate the run escapement of hatchery- and natural-origin spring Chinook to the Okanogan basin and the spatial structure of the returning spawners.
2. Estimate total spawning escapement based on the number of Chinook redds per tributary
3. Estimate the proportion of natural spawners composed of hatchery-origin recruits (pHOS)
4. Estimate pre-spawn mortality and mean egg retention for natural- and hatchery-origin spawners

[2] Note: Sufficient carcass recovery (i.e., adequate sample rate) is necessary to make statistically valid estimates and is not likely to be feasible when adult spawning densities are extremely sparse (e.g., during the initial years of this reintroduction effort). For example, stray rate estimates can be extremely skewed by single or few carcass recoveries and should be interpreted accordingly.

5. Determine the source (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)
6. Estimate out-of-population stray rate for Okanogan hatchery Chinook and estimate genetic contribution to out-of-basin populations (emigration)
7. Determine age composition of returning adults through scale analysis
8. Monitor status and trends of demographic and phenotypic traits of natural-origin- and hatchery-origin spawners (age-at-maturity, length-at-age, run timing, smolt-to-adult return ratio, or SAR)

Redd Surveys

Spring Chinook spawning ground surveys involved walking in and along accessible stretches of tributary streams to the Okanogan River (Table 2), passing through areas surrounded by private land only if landowner permission had been granted. Streams in which PIT arrays had detected returning spring Chinook or which contained higher amounts of suitable spawning habitat were chosen for multiple surveys occurring on a weekly or semi-weekly basis, whereas streams without PIT detections were typically surveyed only once. Redd and carcass surveys were also conducted concurrent with summer Chinook pre-spawn mortality surveys on the Similkameen River by floating the river in single-seat pontoon rafts.

Redds were characterized by large disturbances in gravel substrate comprised of a tail spill pillow and a pit into which a trained observer determined that eggs had been deposited. Once detected, a point was plotted using a handheld GPS unit, and the redd location was marked with flagging tape. In addition to the location, the date of first and any subsequent detections of a redd was noted, as was the presence of Chinook salmon.

Table 2. Tributaries to the Okanogan River that were surveyed for spring Chinook salmon redds and carcasses.

Stream	Description	Reach Length (rkm)
Antoine Creek	Antoine Creek/Okanogan River Confluence to below Rylie's Canyon	1.6
Aeneas Creek	Aeneas Creek/Okanogan River Confluence to the barrier	0.4
Bonaparte Creek	Bonaparte Creek/Okanogan River Confluence to Bonaparte Falls	1.6
Johnson Creek	Johnson Creek/Okanogan River Confluence to 7 Lakes Rd.	1.0
Loup Loup Creek	Loup Loup Creek/Okanogan River Confluence to Loup Loup Creek diversion	2.3
Omak Creek	Omak Creek/Okanogan River Confluence to below Dutch Anderson Rd.	24.0
Salmon Creek	Salmon Creek/Okanogan River Confluence to Conconully Dam	31.0
Tunk Creek	Tunk Creek/Okanogan River Confluence to the falls	1.2
Similkameen	Mouth to Enloe Dam	14.6

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).

Assumptions include:

Assumption I –	Each redd was constructed by a single female Chinook, and each female Chinook constructed only one redd (Murdoch et al 2009)
Assumption II -	Every redd was observable and correctly enumerated

Carcass Surveys

During the course of spawning grounds surveys, any detected Chinook salmon carcasses were collected and sampled. Sex, fork length (FL), postorbital-hypural length (POH) to the nearest cm., adipose presence/absence, egg retention, date, and location of carcass recovery were recorded. 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 the 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 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 was removed from the carcass, individually bagged, and labeled with species, origin, FL, river of recovery and date. The coded wire tag was extracted from the snout at the Chief Joseph Hatchery lab after the season was complete.

Anecdotally, observations of live Chinook during spawning ground surveys were also recorded, but not on the Similkameen River, which is occupied by many summer/fall Chinook as well during the survey period. For carcasses that were recovered in the Similkameen River, where spring and summer Chinook overlap in time and space, a carcass was determined to be a spring Chinook only if either a coded wire tag or implanted PIT tag designated it as a spring run fish. All natural-origin carcasses recovered in the Similkameen River were treated as summer Chinook. This was determined to be the most likely outcome, given the robust natural-origin summer Chinook population in the Okanogan River basin, and the dearth of natural-origin spring Chinook.

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

Spawner Escapement

Spawner escapement was calculated for each tributary by multiplying the number of redds detected within a stream by the fish-per-redd ratio, which was calculated by the ratio of male to female fish that are observed passing over Wells Dam. This number was then divided by the percent of stream miles accessible to anadromy and capable of supporting spring Chinook redd construction and reproduction within a tributary that were surveyed. Total Okanogan spring Chinook spawner escapement was calculated by the total sum of spawner escapement for all Okanogan River tributaries within the U.S. portion of the basin.

Tributaries were determined to be occupied if and only if at least one redd was detected within that stream during spawning grounds surveys. Although other methods may be used for monitoring tributary habitat use (*e.g.*, eDNA surveys, PIT tag monitoring, electrofishing), spawner occupancy was determined only by the detection of, or failure to detect, a redd within a tributary during a spawning grounds survey.

pHOS and PNI

The CJH spring Chinook programs do not have objectives for origin composition of broodstock or natural spawners. The CJH program is a segregated harvest program, and therefore uses only hatchery origin returns to the ladder, or segregated broodstock or eggs from other facilities such as Leavenworth National Fish Hatchery (LNFH), Carson National Fish Hatchery and Little White Salmon National Fish Hatchery. The Okanogan spring Chinook reintroduction program, or 10(j), receives eggs from WNFH, which uses hatchery-origin broodstock from the Methow River. This program is still in the reintroduction phase, and therefore does not have objectives for pHOS or the proportion of natural influence (PNI). However, documenting the return of 10(j) hatchery fish and natural-origin spawners is important to monitoring the success of the program. Future management changes from a reintroduction program to a supplementation program with local-brood collection will depend on the documentation of natural-origin returns.

Hatchery-Origin Stray Rates

Chief Joseph Hatchery was the only homing location for the segregated spring Chinook, although Wells Hatchery was determined to be an "*en-route* hatchery". For the 10(j) program, any location within the Okanogan River basin was classified as a homing location, and all others were considered to be stray locations.

The percentage of strays was calculated by the formula:

$$\%\,Stray\ = \left\{\frac{NT}{NT+T}\right\}*100$$

Where:

NT = number of final detections at a non-target hatchery or tributary

T = number of final detections at a target hatchery or tributary

Assessment of Brood Year Strays Using CWT

To calculate stray rates, an "All Recoveries" query was submitted to the RMIS database for all the tag codes associated with a given release group. Fishery Codes were restricted to 50 (Hatchery) and 54 (Spawning Grounds), such that fish harvested in other fisheries prior to reaching a final destination were excluded from the analysis. The total sum of RMIS-provided "Estimated Number" field for each "Recovery Location Name" was used to determine the total number of fish returning to either home or stray locations.

Assessment of Return Year Strays Using PIT tags

Given the small sample size of CWT recovered within the Okanogan basin, it is useful to consider other information regarding the performance of the hatchery fish to meet their intended objectives. PIT tags offer an additional opportunity to evaluate straying and homing as supplemental information to the CWT assessment. To evaluate the return year stray rate using PIT tags, the PTAGIS database was queried for all segregated spring Chinook released from Chief Joseph Hatchery and 10(j) spring Chinook released from Riverside Pond for detections at the Bonneville Dam fishways in 2021. PTAGIS was then queried for the complete tag history of each group to determine each fish's final detection location. Fish with a final detection at an en route dam fishway were excluded from the stray rate calculation.

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 the Rocky Reach Dam Juvenile bypass (RRJ) and McNary Dam Juvenile bypass (MCN); see Figure 4. 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 were compared to nearby hatcheries with yearling spring Chinook releases.

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 (OKL), RRJ, MCN and Bonneville Dam were determined using queries of the PIT Tag Information System (PTAGIS) database (https://www.ptagis.org) and DART (http://www.cbr.washington.edu/dart). The OKL PIT tag interrogation site is located at rkm 25 and is within 2 km of the inundation effects of Wells Dam.

Figure 4. Overview of Okanogan Chinook migration corridor and points of interest throughout region.

Smolt-to-Adult Return

To calculate SAR using PIT tags, the following equation was employed:

$$\text{SAR} = \frac{PIT\ Tags\ Released}{PIT\ Tags\ Detected\ as\ Adults}$$

Where:

PIT tags Detected as Adults = the number of those PIT tags that were detected in following years at mainstem hydro projects, instream PIT arrays, or were detected as recaptured adult spring Chinook

PIT tags Released = the number of fish within a release group fitted with a PIT tag

To calculate SAR using coded wire tags, the following equation was used:

$$\text{SAR} = \frac{CWTs\ Released}{CWTs\ Detected\ as\ Adults}$$

Where:

CWT Released = the number of fish within a release group fitted with a CWT

CWT Detected as Adults = the number of those CWTs that were recovered in following years on the spawning grounds, hatcheries, and harvest

Coded Wire Tag Analysis

Coded wire tags 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 2021 to February 2022. Snouts were interrogated for the presence of a CWT by using a T-wand (Northwest Marine Technology, Inc.; nmt.us). After positive detection, the snout was cut bilaterally into symmetrical portions keeping the half that indicated detection and discarding the other half. This process was then repeated until only a small piece of tissue containing the CWT remained. 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, read and recorded. 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 magnetic pencil (Northwest Marine Technology, Inc.) and inserted into a jig to be read under an 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 contained all applicable CWT code combinations.

CWT count data were expanded to account for tag loss and sample rate to estimate total catch contribution to a specific fishery. For each fishery, every decoded CWT was grouped according to their recovery code with the total number of CWT recovered from each release group. Mark rates are typically high (~99%) for most Upper Columbia River release groups. However, several mark groups of CJH spring and summer Chinook were tagged with coded wire at a rate of 20-25%. Therefore, adult returns without a CWT or an adipose fin were presumed to be from the CJH segregated program. We assigned these fish as CJH segregated “no wire” fish. To adjust for the number of “no tag” recoveries, the sum of “no tags” are subtracted from the sum of adjustment for missing tags. This value is then added to all expanded numbers to calculate total catch contribution.

$$CWTadjustment =$$

$$\frac{\left[\left(\frac{CWTrecovered}{Total\ tags}\right) * (Lost\ and\ scratched\ tags) + CWTrecovered\right] * Tag\ loss\ rate + cwt\ recovered}{Sample\ rate}$$

Where:

CWT recovered = Number of tags recovered for single unique tag code within a fishery or recovery location

Total tags = Number of tags recovered for a single fishery or recovery location

Lost & scratched tags = Sum of CWTs which were either lost or scratched (unreadable) in the CJHP coded wire tag Laboratory during processing

Tag loss rate = Rate of CWT loss as estimated by www.rmpc.org for single unique tag code

Sample rate = Rate of sampling for a single fishery or recovery location

RESULTS

Rotary Screw Traps

The rotary screw trap was operated for the primary purpose of collecting summer Chinook from the mainstem Okanogan River (see Pearl et al 2023 for methods and results from the 2021 operation season). Only one natural-origin fish was captured in 2021 that was likely a yearling Chinook.

Spring-Chinook Presence and Distribution

Several tributaries have produced consistent annual detections of Chinook eDNA going back to 2012, including Salmon Creek and Omak Creek. Results of eDNA surveys also show that Chinook have been present in Shingle and Vaseux creeks in most years. Similar to 2018, we expanded our eDNA surveys in 2019 to include two temporal sampling events, one in March to target juvenile production in tributaries and another in September to target spawning adults. Our goal with this expanded sampling strategy was to help determine which tributaries were providing habitat for successful spring-Chinook spawning, as evidenced by positive detections in March – when no adult spring Chinook would be present in the basin We only had one detection in Omak Creek in the fall 2021 sampling event and 1 detection in Antoine Creek in the spring 2022 sampling event. Chinook were detected in many of the tributaries in the fall of 2018 and again in the fall of 2019 (Table 3). Based on the lower number of detections during the fall 2021 and spring 2022 sampling events, if would appear that natural juvenile production in the tributaries is minimal, as detection rates for Chinook using eDNA have been determined to be quite high (0.98), especially during low flow periods (Laramie *et al* 2015).

Table 3. eDNA results for sampling conducted in Okanogan basin tributaries from 2012-2021.

Site	Jun 2012	Aug 2012	Oct 2013	Sep 2014	2015	Sep 2016	Sep 2017	Mar 2018	Sep 2018	Mar 2019	Sep 2019	Sep 2020	Mar 2021	Sep 2021	Mar 2022
US Tributaries															
Aeneas Creek (1)			-	-		-	+	-	-	-	-	+	-	-	-
Antoine Creek (2)			-	+		+	-	-	+	-	+	-	-	-	+
Bonaparte Creek (3)	-	+		-		-	+	-	+	-	-	-	-	-	-
Johnson Creek (5)								-	+	-	-	-	-	-	-
Loup Loup Creek (6)			-	+		+	+	-	+	+	+		-	-	-
Ninemile Creek (7)	-	-		-		+		-		-	-	-	-	-	-
Omak Creek (near mouth) (17)	+	+		+		+	+	-	+	-	+	-	-	-	-
Omak Creek (above falls) (16)	-	-				+	+	-	+	-	-	-	-	-	-
Omak Creek (Haily Creek Washout) (37)														+	
Omak Creek (Mission bridge) (18)											-	-	-	-	-
Salmon Creek (RKM 0.6) (19)											-	-	-	-	-
Salmon Creek (RKM 2.9) (20)											-	-	-	-	-
Salmon Creek (RKM 7.1) (21)	+	+		+		+	+	-	+	+	+	-	-	-	-
Salmon Creek (RKM 17.3) (22)											+	-	-	-	-
Salmon Creek (RKM 21.9) (23)											-	-	-	-	-
Salmon Creek (RKM 25.5) (24)											-	-	-	-	-
Siwash Creek (30)			+					-		-		-	-		
Tonasket Creek (31)			+			-		-		-		-	-		-
Tunk Creek (32)			-			+	+	-	+	-	+	-	-	-	-
Wanacut Creek (34)			-			-	+	-		-		-	-		-
Canada Tributaries															
Inkaneep Creek (4)	-	+		-		-	-	-			-				
Shatford Creek (27)								-			+		-		
Shingle Creek (Lower) (26)	-	+		+		-	+	-			-				
Shingle Creek (Upper) (25)								-			+				
Shuttleworth Creek (28)	-	-		-		-		-			-				
Vaseux Creek (33)	-	+		+		+	+	-			-		-		

Spring Chinook Run Escapement

In 2021, the Fish Passage Center reported that 18,888 spring Chinook above Priest Rapids Dam(Figure 5). This estimate does not include those fish that travelled above Priest Rapids Dam only to eventually reverse course and return downstream. 2021 was the fourth year with 4- and 5-year-old returns from the Chief Joseph Hatchery Program. Total run escapement to the Okanogan Basin was 2,729 spring Chinook, with 24 of those being in a tributary and 2,705 with a final detection in the mainstem Okanogan (which includes the Similkameen River) (Figure 5, Table 4). These increases occurred despite decreasing or relatively consistent escapement of total spring Chinook to Wells Dam (Figure 5). Escapement included 1,297 natural-origin and 1,432 hatchery-origin spring Chinook (Table 4). Shingle Creek was the only tributary utilized by returning fish with a PIT tag (Table 4).

The detection efficiency of the OKL PIT array was estimated to be 94%, based on 35 adult spring Chinook PIT detections in the Okanogan basin with 2 that were not detected at OKL but were detected at an array upstream of OKL.

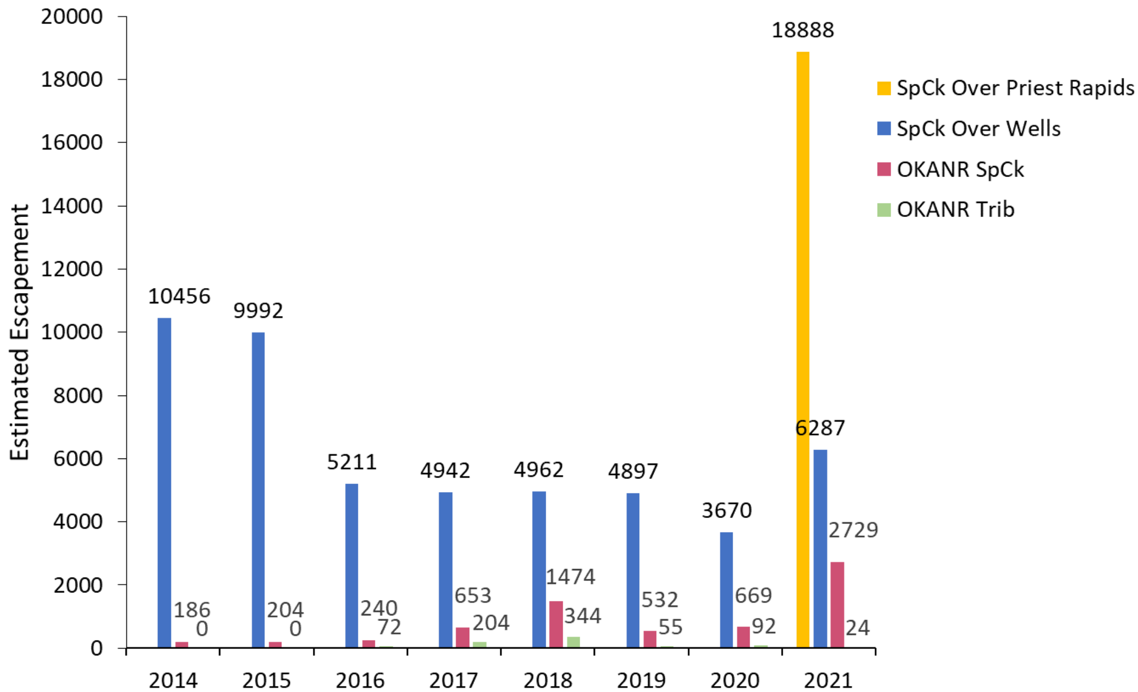


Figure 5. Annual Spring Chinook (SpCk) run escapement above Wells Dam, estimate provided by WDFW. OKANR SpCk is the estimated spring Chinook salmon run escapement estimate to the Okanogan River basin (includes Okanogan River, Similkameen River and tributaries to the Okanogan River). OKANR Trib is the total run escapement estimate for spring Chinook to Okanogan River tributary streams.

Table 4. 2021 Run escapement estimates for specific Okanogan River locations and tributary streams. Note that there is not a PIT array within the Similkameen River, whose estimate was generated through total carcass recoveries.

Stream	2021 Run Escapement Estimate	
	Hatchery	Natural-origin
Okanogan and Similkameen Mainstem[3]	1,432	1,273
Loup Loup Creek	0	0
Salmon Creek	0	0
Omak Creek	0	0
Johnson Creek	0	0
Bonaparte Creek	0	0
Antoine Creek	0	0
Zosel Dam	0	0
Okanagan Mainstem[4]	0	0
Vaseux Creek	0	0
Skaha Dam	0	0
Shingle Creek	0	24
Penticton Channel	0	0
Total	1,432	1,297

Redd Surveys

In 2021, walking surveys occurred from 17 August until 21 September. Each surveyed stream reach was walked either one or up to three times during the survey period. Float surveys in the Similkameen River occurred weekly from August 18 through September 15. Surveyed streams and barriers to anadromy are shown in (Figure 6). A live fish was detected on 18 August in Loup Loup creek and a redd was later detected downstream on 14 September near the Malott city park (48.28795° N, -119.7087° W). Results from the 2021 spring Chinook spawning ground surveys are presented below in Table 5.

[3] Okanogan and Similkameen Mainstem captures spring Chinook with a final detection at the OKL PIT array, near Malott, WA.
[4] Okanagan Mainstem captures spring Chinook with a final detection at the OKC PIT array, near Oliver, BC, Canada

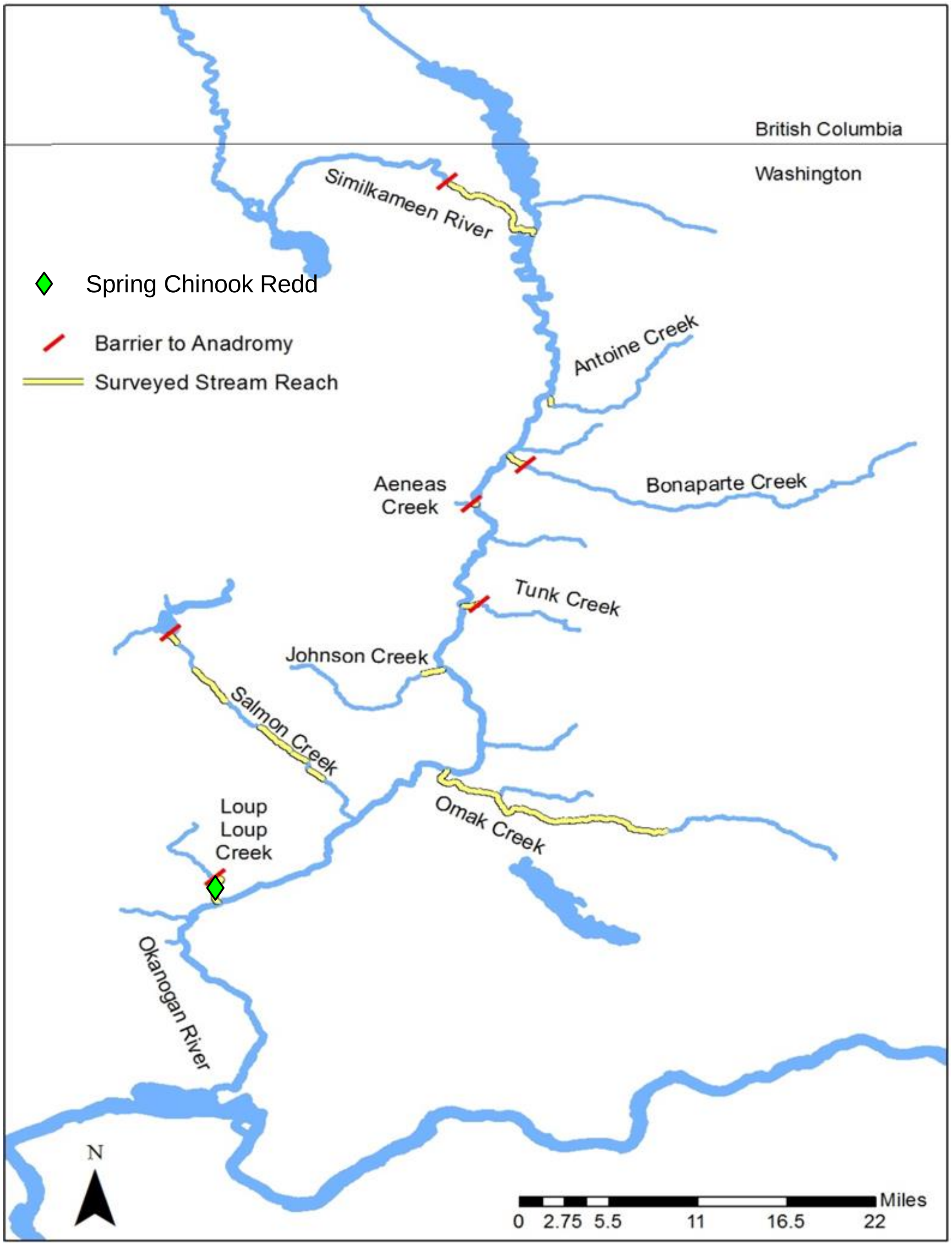


Figure 6. Map of the Okanogan River basin spring Chinook redd survey area. One spring Chinook redd was detected in 2021.

Table 5. Total number of redds, live fish, and carcasses detected in the Okanogan River basin streams.

Stream	Number of surveys	Redds Detected	Live Fish Detected	Carcasses Detected
Loup Loup Creek	5	1	1	0
Salmon Creek	4	0	0	0
Omak Creek	5	0	2	0
Johnson Creek	N/A	N/A	0	0
Tunk Creek	1	0	0	0
Aeneas Creek	1	0	0	0
Bonaparte Creek	1	0	0	0
Antoine Creek	1	0	0	0
Similkameen River	5	2	2	8*

*Both summer and spring Chinook carcasses were detected in the Similkameen River and carcass assignment to a particular run could not be completed with 100% confidence. 8 carcasses were detected, of which 3 contained CWT tags characterizing them as spring Chinook.

Carcass Surveys

Coded wire tags were recovered from four carcasses during spawning grounds surveys. The other carcasses either did not contain a coded wire tag, or the snout was not recovered. Of the recovered tags, one belonged to a hatchery-origin summer Chinook pre-spawn mortality carcass that was recovered in the Similkameen River during spring Chinook spawning ground surveys. Table 6 provides data on the four coded wire tags recovered from spring Chinook.

Table 6. Coded wire tags recovered during 2021 Okanogan spring Chinook spawning grounds surveys

CWT	Brood Year	Total Age	Rearing Hatchery	Release Location	Recovery Location	Carcasses Recovered	§10(j) Release?
200144	2016	5	Similkameen Hatchery	Similkameen River	Similkameen River	1	N
201710	2017	4	Chief Joseph Hatchery	Riverside Pond	Similkameen River	1	Y
201710	2017	4	Chief Joseph Hatchery	Riverside Pond	Loup Loup Creek	1	Y
201710	2017	4	Chief Joseph Hatchery	Riverside Pond	Salmon Creek	1	Y

All recovered carcasses that were ultimately determined to be spring Chinook are included in Table 7. A total of 8 carcasses were recovered during spring Chinook spawning grounds surveys from the Similkameen River. Of these carcasses, 3 were ultimately determined to be spring Chinook based on coded wire tags. The others were classified as summer Chinook based on coded wire tag results. All of these recovered carcasses were pre-spawn mortalities.

Table 7. Spring Chinook carcasses recovered in 2021 Okanogan spring Chinook spawning ground surveys

Recovery Date	Fork Length (cm)	Recovery Location	Origin	Sex
7/19/2021	69	Salmon Creek	Hatchery	M
9/8/2021	64	Similkameen River	Hatchery	M
9/14/2021	68	Similkameen River	Hatchery	F

Spawning Escapement

One redd was detected in Loup Loup Creek within the Okanogan River basin in 2021. The ratio of male to female fish passed over Wells Dam was 3.159 fish per redd which expands to 3 total spawners for the season. A spring Chinook redd was detected in Loup Loup Creek on September 14, 2021, indicating the tributary was occupied by spawning spring Chinook (Table 8).

Table 8. Okanogan River basin tributary streams in which spring Chinook redds have been documented.

Site	2018	2019	2020	2021
Loup Loup Creek	-	-	-	+
Salmon Creek	-	-	-	-
Omak Creek	+	-	-	-
Johnson Creek	-	-	-	-
Tunk Creek	-	-	-	-
Aeneas Creek	-	-	-	-
Bonaparte Creek	-	-	-	-
Antoine Creek	-	-	-	-
Similkameen River	-	-	-	-

pHOS and PNI

pHOS could not be calculated because not enough redds or carcasses were observed to get a valid estimate. The PIT-based run escapement resulted in an estimate of 47.5% NORs (n = 1,297) in the Okanogan basin. PNI was not calculated because it is not a relevant metric for either program.

Hatchery-Origin Stray Rates

CWT Assessment of Brood Year and Return Year Stray Rates

Strays outside the Okanogan— The most recent brood year that could be fully assessed (through age 5) for stray rate of Okanogan 10(j) fish to spawning areas outside the Okanogan was 2016. However, there were zero carcass recoveries in the target stream (Okanogan), which makes calculating a CWT based stray rate impossible. We estimated that 3 fish from the 10(j) program returned to CJH, which comprised 8.4% of the recoveries for brood year 2016 (Table 9). Given our lack of ability to recover CWTs from carcasses in the Okanogan, the percentage of returns to CJH is not as relevant as the absolute number. Additionally, assuming that a high percentage of the PIT-based run escapement (1,432 hatchery returns) were from the 10(j) program, the stray rate back to CJH was probably more like 2-3%. The objective of this program is to return fish to the Okanogan River and technically, the fish that return to CJH are considered strays. However, these fish are raised at CJH from egg to fall parr, essentially acclimated to the Columbia River during this early life stage, so a relatively high return rate to that facility would not be unexpected.

For return year 2021, an estimated 18 Okanogan 10(j) fish strayed to the Methow River basin and contributed to 1.9% of the Methow total spawning escapement and 9 strayed to the Wenatchee which comprised 0.7% of that population's total spawning escapement (Table 10).

For the CJH segregated program BY15, the stray rate for non-target streams and hatcheries was 0% and 0%, respectively (Table 11). The homing rate to the Chief Joseph Hatchery was 100%.

For return year 2021, no CJH segregated fish strayed to the Wenatchee, Entiat or Methow basins (Table 12). All CJH segregated fish (estimated 430) fish were recovered at the CJH.

Table 9. Number and percent (%) of hatchery-origin Okanogan 10(j) spring Chinook that were recovered at target spawning areas, and number and percent that strayed to non-target spawning areas and non-target hatcheries, brood years 2014-2016. Values are derived from coded wire extractions and expansions. 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						En Route Fish	
	Target Stream		Non-target Streams		Non-target Hatchery		CJH Returns		Wells Hatchery	
	Number	%	Number	%	Number	%	Number	%	Number	%
2014	7	14.68%	49	68.8%	1	1.4%	10	13.7%	1	1.4%
2015	0	0.0%	8	70.4%	0	0.0%	2	20.5%	1	9.1%
2016	8	22.5%	23	63.4%	1	2.8%	3	4.8%	1	2.8%
Total	***15***	***12.4%***	***80***	***67.5%***	***2***	***1.4%***	***15***	***13.0%***	***3***	***4.4%***

Table 10. Number and percent (%) of total spawning escapements that consisted of hatchery-origin Okanogan 10j spring Chinook within other non-target basins, return years 2017-2021.

Return Year	Wenatchee		Methow		Entiat	
	Number	%	Number	%	Number	%
2017	0	0.0%	6	1.8%	0	0.0%
2018	0	0.0%	49	11.9%	0	0.0%
2019	0	0.0%	8	1.7%	0	0.0%
2020	0	0.0%	23	7.0%	0	0.0%
2021	9	0.7%	18	1.9%	0	0.0%
Total	***9***	***0.1%***	***104***	***4.9%***	***0***	***0.0%***

Table 11. Number and percent (%) of Chief Joseph Hatchery spring Chinook that were recovered at target spawning areas, and number and percent that strayed to non-target spawning areas and non-target hatcheries, brood years 2014-2016. Values are derived from coded wire extractions and expansions. 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				En Route Fish	
	Target Hatchery		Non-target Streams		Non-target Hatchery		Wells Hatchery	
	Number	%	Number	%	Number	%	Number	%
2014	135	93.6%	8	5.7%	1	0.7%	0	0.0%
2015	303	100.0%	0	0.0%	0	0.0%	0	0.0%
2016	183	88.9%	20	9.6%	3	1.5%	0	0.0%
Total	***621***	***94.2%***	***28***	***5.1%***	***1***	***1.1%***	***0***	***0.0%***

Table 12. Number and percent (%) of total spawning escapements that consisted of hatchery-origin Chief Joseph Hatchery spring Chinook within other non-target basins, return years 2017- 2021.

Return Year	Wenatchee		Methow		Entiat	
	Number	%	Number	%	Number	%
2017	0	0.0%	6	1.8%	0	0.0%
2018	0	0.0%	6	1.5%	1	6.3%
2019	0	0.0%	0	0.0%	0	0.0%
2020	0	0.0%	3	0.9%	0	0.0%
2021	0	0.0%	0	0.0%	0	0.0%
Total	***0***	***0.0%***	***15***	***0.8%***	***1***	***1.3%***

PIT Tag Assessment of Return Year Stray Rates

Ten PIT tags from the CJH segregated spring Chinook program were detected at Bonneville Dam as returning adults in 2021. All 10 of these fish had a final detection at an en-route dam ladder, therefore the sample size was too small to evaluate stray rate for return year 2020 with this method (Table 13).

Twenty-four PIT tags from the Okanogan 10(j) spring Chinook program were detected at Bonneville Dam as returning adults in 2021. Twelve of these fish had a final detection at an en-route dam ladder and were excluded from the analysis. All 12 of the remaining fish returned to the Okanogan and did not stray to a nearby tributary or return to CJH. It is unclear if 12 fish is a large enough sample size to conclude with confidence that the stray rate was actually zero.

Table 13. Summary of strays and homing for segregated spring Chinook released from Chief Joseph Hatchery for adult return year 2021. NA=Not applicable because sample size was too small for a valid stray rate calculation.

Destination/Last Detection	Number	Percent	Stray Rate
Homing	0	0%	
Stray	0	0%	NA
En route dam	10	100%	
Total	10		
Destination for strays			
Other hatchery	0	0%	
Other tributary	0	0%	

Table 14. Summary of strays and homing for Okanogan 10(j) spring Chinook released from Riverside Pond for adult return year 2021. Returns to the Okanogan basin were not adjusted for PIT detection array efficiency.

Destination/Last Detection	Number	Percent	Stray Rate
Homing	12	50%	
Stray	0	0%	0%
En route dam	12	50%	
Total	24		
Destination for strays			
Chief Joseph Hatchery	0	0%	
Other hatchery	0	0%	
Other tributary	0	0%	

Smolt-to-Smolt Survival and Travel Time

Apparent survival of spring Chinook yearlings in 2021 to RRJ was 80% for the segregated program released from CJH and 56% for the 10j reintroduction fish released from Riverside Pond (Table 15). For the CJH segregated fish, survival to RRJ in 2021 was 9% higher than the five-year average (71%) and 3% higher than a nearby program at WNFH (77%) (Table 16). For the Okanogan 10(j) fish, the 2021 survival was 10% lower than the five-year average (66%) and 21% lower than the nearby program at WNFH (77%) (Table 16).

Apparent survival of spring Chinook segregated yearlings from CJH to McNary Dam (MCN) was 140% with a standard error of 78%, which meant that the recapture probability was so low (1%) that the estimate was not valid. Survival to McNary Dam was estimated as 28% (7% SE) for the Okanogan 10(j) fish, which was 18% lower than average (Table 15, 16).

Table 15. Apparent survival estimates to McNary Dam (MCN) and Rocky Reach Dam (RRJ) for PIT tagged spring Chinook salmon smolts released from Chief Joseph hatchery (CJH), Riverside Acclimation Pond, Winthrop National Fish Hatchery (WNFH) and Leavenworth National Fish Hatchery (LNFH) in 2021.

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	4329	1506	Release to RRJ	0.80	0.04	0.43	0.03
		55	Release to MCN	1.40	0.78	0.01	0.01
Yearlings released at Riverside (10j)	4298	1050	Release to RRJ	0.56	0.04	0.44	0.03
		70	Release to MCN	0.28	0.07	0.06	0.02
Yearlings released at WNFH	19905	9025	Release to RRJ	0.77	0.01	0.59	0.01
		260	Release to MCN	0.63	0.10	0.02	0.00
Yearlings released at LNFH	19964						
		0	Release to MCN	0.51	0.06	0.05	0.01

Releases of spring Chinook smolts began on April 19, 2021. Of the 4,298 PIT tagged 10j fish released from Riverside Pond (rkm 64), only 6 were detected at the Lower Okanogan PIT detection array. Five of the six fish (83%) were detected at OKL within 2 days and the last fish was detected 18 days after release. This sample size was too small to calculate a reliable 90% passage date. The mean travel time of spring Chinook released from CJH facilities to RRJ in 2021 was 12 days (9.3 km/day) for the segregated spring Chinook released from CJH and 17 days (9.8.0 km/day) for the 10(j) reintroduction fish from Riverside Pond (Table 17). The 90% passage times for Rocky Reach Dam were 22 days for the CJH segregated program and 26 days for the 10(j) reintroduction program (Table 17). The majority of spring Chinook from CJH and Riverside Pond arrived at RRJ from late April to mid-May, with 90% passage dates of May 13 and May 16, respectively (Figure 7). The travel time in 2021 was 5 days less than the average from 2015 to 2020 for the segregated program but identical to the average for the Okanogan 10(j) program (Table 18). 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 16).

Table 16. Apparent survival estimates to McNary Dam (MCN) and Rocky Reach Dam (RRJ) for PIT tagged spring Chinook salmon smolts released from Chief Joseph hatchery (CJH), Riverside Pond (RivP), Winthrop National Fish Hatchery (WNFH) and Leavenworth National Fish Hatchery (LNFH) from 2015 to 2021.

	Spring Chinook Yearling Release Group													
	Survival to Rocky Reach Dam						Survival to McNary Dam							
Release	CJH segr.		RivP 10(j)		WNFH		CJH segr		RivP 10(j)		WNFH		LNFH	
Year	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr	Surv.	StdEr
2015	0.73	0.04	0.79	0.03	0.74	0.02	0.43	0.07	0.53	0.07	0.54	0.05	0.50	0.03
2016	0.74	0.03	0.81	0.03	0.75	0.02	0.48	0.03	0.63	0.04	0.58	0.02	0.49	0.02
2017	0.81	0.05	0.52	0.04	0.83	0.02	0.60	0.07	0.35	0.05	0.58	0.03	0.54	0.02
2018	0.71	0.05	0.70	0.05	0.76	0.02	0.44	0.07	0.60	0.10	0.59	0.05	0.66	0.04
2019	0.47	0.04	0.75	0.03	0.70	0.01	0.29	0.09	0.42	0.06	0.49	0.05	0.52	0.04
2020	0.70	0.04	0.50	0.04	0.75	0.01	0.33	0.06	0.42	0.13	0.56	0.06	0.61	0.05
2021	0.80	0.04	0.56	0.04	0.77	0.01	1.40*	0.78	0.28	0.07	0.63	0.10	0.51	0.06
Average	**0.71**		**0.66**		**0.76**		**0.43**		**0.46**		**0.57**		**0.55**	

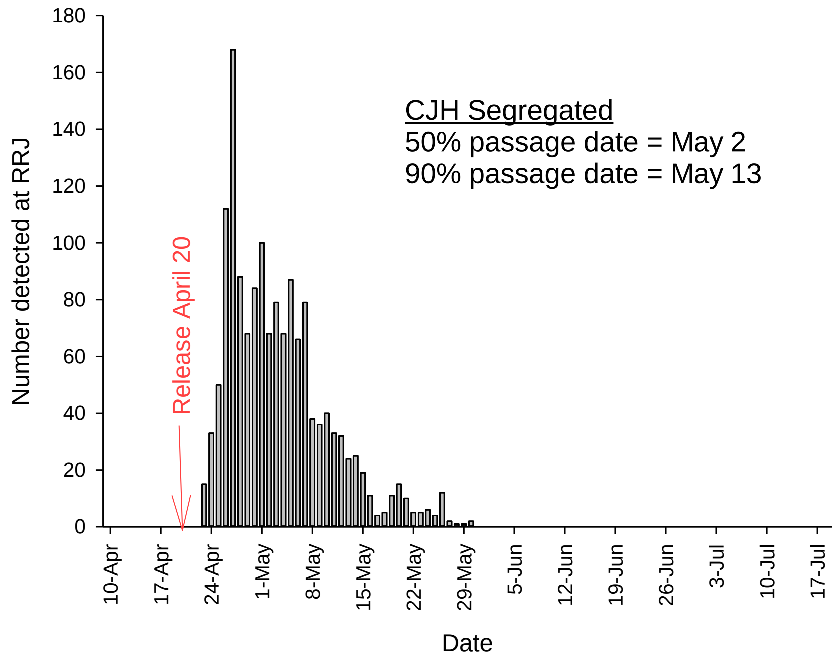
*Value not used in the average due to high standard error

Table 17. Travel time and migration speed for spring Chinook release groups in 2021.

			Mean Travel Time (days)			90% Passage (days)			Travel Rate (km/day)		
Release Group	Release timing	Release Strategy	Release to RRJ	Release to MCN	Release to BON	RRJ	MCN	BON	Release to RRJ	RRJ to MCN	MCN to BON
CJH Spring Chk	20-Apr	Forced	12	20	24	22	29	31	9.3	28.5	a
RivP Spr Chk (10j)	19-Apr	Forced	17	24	29	26	32	35	9.8	31.7	55.0
Winthrop Spring Chk	19-Apr	Forced	17	27	30	30	38	39	9.7	27.6	51.5
LNFH Spr Chk	14,16 Apr	Forced	NA	32	36	NA	43	47	NA	10.2[b]	49.9

[a] sample size too small (<10) for a confident estimate

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



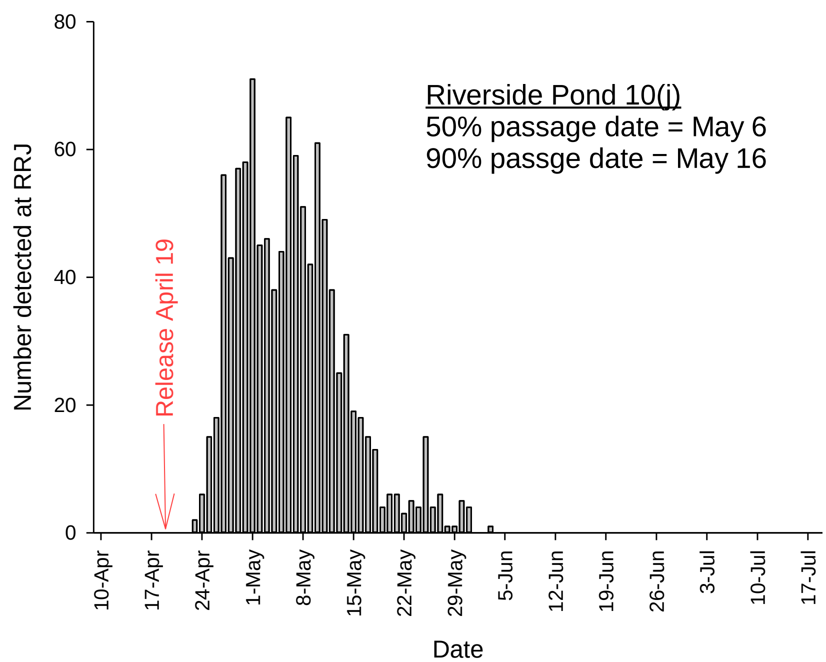


Figure 7. Arrival timing at Rocky Reach Juvenile bypass (RRJ) of PIT tagged spring Chinook released from the Chief Joseph Hatchery (CJH) and Riverside Pond in 2021.

Table 18. Mean travel time and 90% passage time (days) for spring Chinook released from Chief Joseph Hatchery and the Riverside Pond from 2015 to 2021.

Release Group	Year	Rocky Reach Dam Mean Travel Time (d)	Rocky Reach Dam 90% Passage (d)		McNary Dam Mean Travel Time (d)	McNary Dam 90% Passage (d)		Bonneville Dam Mean Travel Time (d)	Bonneville Dam 90% Passage (d)
CJH Spring Chinook Segregated	2015	31	43		41	54		42	53
	2016	14	27		23	34		26	37
	2017	10	24		18	29		21	35
	2018	14	25		25	35		32	46
	2019	28	45		39	51		54	64
	2020	11	20		23	30		24	31
	2021	12	22		20	29		24	31
	Average	**17**	**29**		**27**	**37**		**32**	**42**
Okanogan 10(j) Spring Chinook Riverside Pond	2015	15	23		27	33		32	39
	2016	12	23		21	30		24	35
	2017	23	34		33	43		35	46
	2018	17	27		25	33		30	39
	2019	20	28		30	36		35	46
	2020	15	23		24	32		25	30
	2021	17	26		24	32		29	35
	Average	**17**	**26**		**26**	**34**		**30**	**39**

Smolt-to-Adult Return (SAR)

The most recent brood year that could be fully assessed (through age 5) for SAR was 2016. We estimated the SAR using two methods, PIT tags and coded-wire tags.

PIT based estimate—SAR from release back to Bonneville and Wells Dam adult fish ladders were assessed, although sample sizes of returning adults were very small, leading to a high level of uncertainty in the results of the PIT-based estimate. CJH specific harvest rates were not available for the fisheries below Bonneville Dam (Zones 1-5); therefore, the average harvest rate on all spring Chinook below Bonneville Dam was used to estimate the harvest rate on CJH fish.

For CJH segregated spring Chinook from brood year 2016 (outmigration year 2018), 2 adult fish (age 4&5) returned to Bonneville Dam with a PIT tag, resulting in SAR estimates of 0.04% before harvest and 0.04% with harvested fish added back in). The SAR did not change with and without harvest because harvest below Bonneville Dam was only 2% in 2016 and there were zero 5-year-old returns in 2021.

For the 10j reintroduction program released from Riverside Pond, 19 adult fish (age 4-5) returned to Bonneville Dam with a PIT tag, resulting in SAR estimates of 0.44% before harvest and 0.44% with harvested fish added back in (Table 19). An important difference in the SAR estimates between the two groups was that, starting in brood year 2014, the 10j reintroduction fish were adipose present, and therefore were excluded from harvest in the non-treaty sport fishery. Therefore, harvest on this group was limited to incidental mortality from catch and release and the treaty fisheries between Bonneville and McNary.

Table 19. PIT-based SAR estimates for spring Chinook released from the Chief Joseph Hatchery (segregated) and Riverside Pond (10j reintroduction). Jacks were not included in the SAR calculation. The upriver spring Chinook harvest rates reported by the Technical Advisory Committee of US v. Oregon were used to adjust PIT return numbers and estimate total 'with harvest SAR'.

CJH Segregated Spring Chinook		PIT tag Detections at Bonneville Dam					Excluding Jacks	
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Without Harvest SAR	With Harvest SAR
2013	4970	1	3	8	0	0	0.16%	0.17%
2014	4967	0	0	12	2	0	0.28%	0.29%
2015	4815	5	1	11	0	0	0.23%	0.23%
2016	4970	1	1	2	0	NA	0.04%	0.04%
2017	4815	1	0	0	NA	NA	0.00%	0.00%
		PIT Tag Detections at Wells Dam						
2013	4970	0	3	5	0	0	0.10%	0.12%
2014	4967	0	0	8	2	0	0.20%	0.23%
2015	4815	1	1	8	0	0	0.17%	0.18%
2016	4970	0	1	1	0	NA	0.02%	0.02%
2017	4815	0	0	0	NA	NA	0.00%	0.00%

Riverside Pond 10j reintro. Spring Chinook		PIT tag Detections at Bonneville Dam						
Brood Year	Number of PIT tags	Age 2 Mini-Jack	Age 3	Age 4	Age 5	Age 6	Without Harvest	With Harvest SAR
2013	4902	0	9	26	0	0	0.53%	0.57%
2014	4959	6	6	23	1	0	0.48%	0.49%
2015	5036	3	5	9	0	0	0.18%	0.18%
2016	4356	0	3	15	4	NA	0.44%	0.44%
2017	5036	8	8	20	NA	NA	0.40%	0.40%
		PIT Tag Detections at Wells Dam						
2013	4902	1	8	18	0	0	0.37%	0.40%
2014	4959	0	6	18	1	0	0.38%	0.42%
2015	5036	0	5	4	0	0	0.08%	0.08%
2016	4356	0	3	12	3	NA	0.34%	0.34%
2017	5036	1	7	17	NA	NA	0.34%	0.36%

CWT-Based Estimate—Based on expanded CWT's, the 2015 brood year for the Okanogan 10j spring Chinook had a SAR of 0.01%. BY16 had an SAR of 0.02%, however, this number may change as more adult captures from BY16 are uploaded to the RMIS database, and this table changes in the coming years to reflect those data (Table 20). For the BY15 CJH spring Chinook the SAR was 0.17% (Table 21). BY16 had an SAR of 0.23%; however, this number may change as more adult captures from BY15 are uploaded to the RMIS database.

Table 20. Smolt-to-adult return rate (SARs) for Okanogan 10j spring Chinook, brood years 2013-2017.

Brood Year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
2013	195,145	310	0.16%
2014	191,112	97	0.05%
2015	190,712	21	0.01%
2016	193,597	43	0.02%
2017	201,298	148	0.07%
Total	***971,864***	***619***	***0.06%***

[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.

Table 21. Smolt-to-adult return rate (SARs) for Chief Joseph Hatchery spring Chinook, brood years 2013-2017.

Brood Year	Number of tagged smolts released[a]	Estimated adult captures[b]	SAR
2013	201,090	349	0.17%
2014	188,455	248	0.13%
2015	222,661	388	0.17%
2016	91,872	213	0.23%
2017	197,187	160	0.08%
Total	***901,265***	***1,358***	***0.16%***

[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 Harvest

The Chief Joseph Dam Tailrace and mainstem Columbia River fishery did not open to tribal fishermen in 2021. The fishery was closed due to a low number of spring Chinook returns to the Columbia River. The pre-season run forecast was the lowest in the last two decades. This fishery targets non-ESA listed, hatchery-origin, Carson stock spring Chinook returning to CJH as adults and jacks. Hook and line fishing, along with dip and hoop net are the only authorized gear types. This fishery is regulated to avoid significant take of ESA-listed spring Chinook and summer steelhead.

Table 22. Expanded tribal harvest of ad-clipped spring Chinook at the Chief Joseph Dam tailrace and Columbia River mainstem fisheries.

	Ad-Absent Harvest	Incidental Mortality	Effort Hours	Harvest Per Unit Effort (HPUE)
2017	79.3	0.5	908.8	0.087
2018	97.5	2.5	407.3	0.246
2019	104.5	2.7	523.0	0.205
2020	112.2	4.0	1,164	0.100
2021	0.0	0.0	0	0.000

DISCUSSION

Spring-Chinook Run Escapement

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 the 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 that time of year would likely be the result of juvenile presence.

PIT tags have been another important tool for monitoring the progress of reintroduction efforts. Since 2016, 5,000 spring Chinook have escaped above Wells Dam. 2021 was the fourth year with substantial returns from CJH releases. A much higher proportion of these returns entered the Okanogan basin. The majority of the run escapement (99%) occurred in the mainstem Okanogan and Similkameen rivers, followed by Shingle Creek (1%). The WDFW mark-recapture study at Priest Rapids Dam will continue to provide valuable information for returns from the reintroduction program to the Okanogan basin.

Spawning Escapement

Although PIT tag data show that there is a substantial presence of Spring Chinook throughout the Okanogan River basin, PIT detections at in-stream arrays do not imply spawning. 2021 Spring Chinook spawning grounds surveys occurred August through October; the tributaries were walked and floated with little evidence of spawning. It appears that although Spring Chinook are at least momentarily present within the Okanogan River basin, their presence does not readily translate to spawning activity. This may be due to poor spawning habitat conditions, including limited areas of suitable substrate, poor flow, and warm water temperatures.

Overall spring Chinook production was lower in 2021. To that point only 7 DNA fin clips were collected from juvenile natural-origin Chinook during electrofishing events; almost half the number of DNA fin clips collected in the fall of 2020. The seven spring Chinook were captured in the fall of 2021 from the following tributaries, Bonaparte, and Loup Loup creeks. Genetic analyses, including genetic stock identification (GSI), were conducted on the fin clips and results were conclusive for 1 out of the 7 samples. For the 1 sample, results identified it as the 2018 upper Columbia summer-run stock. Juvenile natural-origin spring Chinook estimates also indicate a declining population trend from 158 ± 0 in 2021 to 89 ± 36 in 2022 within Loup Loup and Salmon Creeks and about 92% being attributed to Loup Loup Creek (OBMEP. 2022). Fall 2021 eDNA sampling detected spring Chinook presence in Omak Creek at the Haley Creek washout (48.3577885° N, -119.3426421° W). There were no tributary detections for winter 2021 eDNA sampling sites. Despite spring Chinook spawning ground survey difficulties there was notable springer activity within Omak and Loup Loup creeks. A live adult spring Chinook was visually observed in Loup Loup Creek on August 18th and a redd was later detected downstream on September 14th. Two live adult spring Chinook were observed within Omak Creek below Omak Falls on June 28th.

It would be premature to form any sweeping conclusions, but a likely explanation may be that there is a small population of spawning spring Chinook in the Okanogan River basin, but the current spawning grounds survey effort is too constrained by staff availability to sufficiently detect redds or spawners. In future years, greater coverage of potential spawning areas, stronger returns of adult fish, or refined methodology could all potentially result in a more robust total spawn escapement estimate.

Hatchery-Origin Stray Rates

The homing and straying results for the 10(j) program should be interpreted cautiously. Recovery of spring Chinook carcasses in the natural environment is difficult, and constrained by environmental conditions, access to locations where carcasses may be present, and carcass recovery efforts. Due to the general lack of success in recovering spring Chinook carcasses in the Okanogan River basin (see Spawning Grounds); the homing and straying data based on CWT for the 10(j) program is biased. Therefore, the accuracy of straying and homing rates reported in the results are highly uncertain, but the observations of Okanogan (10(j) returns to the Methow basin are useful. Given that the origin of the brood for the Okanogan 10(j) program is from the Methow, it was not surprising that some returned there and the risk of these strays to the Methow population is minimal. Further evidence of the inaccuracy of the stray rate is provided by the run escapement estimate to the Okanogan River based on PIT tags. Based on the observed increase in spring Chinook run escapement to the Okanogan following the reintroduction of the 10(j) program, it is apparent that a high percentage of 10(j) spring Chinook are returning to the Okanogan. Both the CWT and PIT tag assessments indicated that Okanogan 10(j) fish also commonly return to the CJH. This result is understandable considering that these fish were reared from egg to fall parr at that facility. Although the fish that return to CJH would fail to meet the objective of the reintroduction program, they pose relatively little risk to other tributary populations. The return of Okanogan 10(j) fish to the CJH is likely an unavoidable consequence of the necessary rearing practices. Considering the positive trend in run escapement to the Okanogan, it is apparent that the program is successfully providing returning adults to the Okanogan and therefore some returns to CJH should not be cause for concern.

The CWT and PIT data (previous years) for the segregated program suggest a high fidelity for homing back to CJH. For the CWT assessment, this result may have been biased high in the Okanogan due to the low carcass recoveries, but the observation of a low stray rate to the other downstream tributaries is encouraging.

The PIT tag assessment of straying and homing had limited utility due to small sample size, but it did provide a useful supplement to the CWT assessment. For example, despite the lack of CWT recoveries in the Okanogan Basin the PIT data showed that 100% (n=12) of the known PIT tagged 10j fish that were detected upstream of Wells Dam were detected in the Okanogan. In future years with better ocean survival, we anticipate more confidence and utility of the PIT tag assessment of straying and homing.

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 larger multi-year dataset. Targets for post release survival and travel time have not been established. One troubling observation from 2021 was the lower than average survival of the 10(j) fish released from Riverside Pond. The travel time for this group was similar to or slightly less than average, so the mechanism causing the poor survival is not known. Normally we would expect travel time and survival to be positively correlated. With a longer time-series of data in the coming years we should be able to better understand the observed patterns. 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. This analysis may also be useful for adjusting pre-season forecasts based on higher or lower than normal outmigration survival. Similar to previous years, the hatchery fish appeared to migrate out of the system relatively quickly in 2021, but small sample sizes at OKL (n=6) prevented having much certainty with the assessment. 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 decreasing 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 that 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 could be calculated for four complete brood cycles, 2013-2017. The 2013-2015 brood years experienced bad ocean conditions, which is reflected in the low SAR values, but the 2016 and 2017 ocean conditions were slightly better. Although the program does not have a specific target for SAR, the PIT based estimates were only about 0.04% for the age-4 fish in the segregated program, which was definitely not enough fish to collect broodstock. The Okanogan reintroduction programs SARs were almost twice as high as the segregated program for BY14 and BY16, but lower for BY15. The reintroduction program did have higher smolt outmigration survival to RRJ and McNary for BY14 and BY16 but a lower smolt outmigration for BY15, which could explain some of the differences in SAR. Additionally, the 2014 and 2015 brood year fish were adipose present, which reduced a portion of the harvest mortality for returning adults due to a mark-selective sport fishery below Bonneville Dam. With additional years of data, future efforts should evaluate the mechanisms that may be contributing to lower survival of the segregated program to identify management actions that could help improve survival.

We also calculated a CWT-based estimate for BY13 through BY17 for the segregated program. The BY17 SAR for the segregated program was the lowest it has been since the program began in 2013. The average SAR for BY13-16 was 0.18% while the BY17 SAR was less than half that at 0.08%. We did not calculate an SAR for the Okanogan reintroduction program because there were zero carcass recoveries on the Okanogan spawning grounds in 2021 (despite a run escapement of around 2,700 fish). In order to calculate a valid CWT-based estimate the program needs to recover ~20% of the estimated run escapement. This did not happen, so PIT tag analysis will provide additional information on the distribution and returns of the Okanogan reintroduction program to the basin. We will continue to use PIT tags as an independent, additional estimate of SAR.

Adaptive Management and Lessons Learned

The Annual Program Review

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 Annual Program Review (APR) was convened in March 2022 with the purpose of reviewing data collection efforts and results from 2021 and developing the hatchery implementation and monitoring plan for 2022 (Figure 8). 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 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, and hatchery ladder operations to achieve biological targets for 2022. 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 trends of the naturally spawning population in terms of VSP parameters[5]
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 hatchery origin returns (HOR) met?
6. Are there negative effects of the hatchery on the natural population?
7. Are assumptions about natural production potentially valid?
8. How should the program be operated in the coming year?

[5] 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 8. The Chief Joseph Hatchery's annual planning process and workflow.

2022 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 In-season Implementation Tool (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 (https://wdfw.wa.gov/fishing/management/columbia-river/reports). As the season nears, this information is supplemented with return data from downstream dam counts. The pre-season forecast for Upper Columbia spring Chinook salmon was 21,700 which is slightly greater than the 10-year average. Unfortunately, due to the water chiller failure at CJH for brood year 2018, we did not anticipate very many adult CJH spring Chinook returns because the release numbers were substantially below target. Those smolts that were released experienced lower survival than other programs. The CJH spring Chinook programs lack a history of returns and therefore there is no predictive model for estimating program specific returns. Therefore, we adapted the LNFH return model to estimate returns for the CJH segregated program. This was accomplished by adjusting the predicted returns to LNFH to the release numbers of the CJH. We did not apply additional mortality to CJH smolts based on their different release location, but there would certainly be some differences that would affect the accuracy of our adapted forecast model. The LNFH used two models (DLM Pred and TAC) to forecast a return for LNFH of between 192 and 487 spring Chinook. For brood years 2016-2018 the releases at CJH averaged 25% of the LNFH releases. Multiplying the LNFH forecasts by 25% resulted in a prediction of CJH returns between 48-121 adults. The CJH has a broodstock collection target of 640 adults, therefore if the forecast is accurate the program would not be able to meet its goals and managers should anticipate a shortfall in the program. Fishing opportunities will be negligible and ladder operations should be maximized to meet broodstock needs. Managers should also consider taking additional spring Chinook brood during the summer Chinook time period (post July 1), when spring Chinook individuals can be positively identified.

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. Extent, fate, timing, and location of spawning Chinook in the Canadian portion of the Okanogan basin.
2. 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 × natural-origin, and natural-origin × natural-origin crosses of these various life-history types.
3. 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.
4. 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.
5. Design for testing fish tagging rate assumptions. PIT, radio and genetic tagging emphasis.
6. Post-release mortality for the hatchery ladder

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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 is one CJH acclimation facility on the Okanogan River, Riverside (rkm 64) acclimation pond.

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 900,000 spring Chinook. 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.

Spring Chinook Salmon

BY 2020 Leavenworth Spring Chinook Rearing and Release

Pre-spawn mortality was higher than the goal of 10% at 2.8%. With a low BKD prevalence and green to eyed survival was just below the target of 90% (87.2%), the program did meet its egg take goal. A total of 817,636 fish were ad-clipped with 221,603 also receiving a CWT. This group also received 4,998 PIT tags, with a total of 4,965 released (4,365 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 18, 2022, with the last of the fish being pushed out April 19, 2022.

Cumulative egg to smolt survival

The cumulative egg to smolt survival for the 2020 brood Leavenworth stock spring Chinook was 97.2%, with the fry to smolt survival being 95.38% (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 2020 spring Chinook rearing summary, April 2022.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
3/31/2021	823,871	30,227	487	618	96.46%
4/30/2021	819,514	4,357	1,518	244	95.95%
5/31/2021	817,923	1,591	3,173	115	95.76%
6/30/2021	817,337	586	3,398	74	95.70%
7/31/2021	816,833	504	7,744	58	95.64%
8/31/2021	816,521	312	6,160	35	95.60%
9/30/2021	816,118	403	11,132	26	95.55%
10/31/2021	815,861	257	5,984	26	95.52%
11/30/2021	815,290	571	7,700	19	95.46%
12/31/2021	815,043	247	9,504	14	95.43%
1/31/2022	814,956	87	572	12	95.42%
2/28/2022	814,756	200	440	12	95.39%
3/31/2022	814,674	82	1,628	12	95.38%
4/19/2022	814,631	43	396	12	95.38%
Cumulative:	**814,631**	**39,467**	**59,836**	**12**	**95.38%**

BY 2020 10J MET COMP SPRING CHINOOK REARING AND RELEASE

On October 20, 2020, CCT staff transported 243,666 Met Comp spring Chinook eyed eggs from the WNFH for rearing at CJH. This group was initially incubated on chilled well water until they were ponded on March 1, 2021. On November 8th and 9th of 2021, 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.

Shortly after moving these fish, flooding in the Okanogan River occurred, resulting in heavy sedimentation over a 3-week period compromising fish health. It was at the recommendation of the fish health specialist to release the fish immediately to give them a better chance of survival, thus all fish were released on Dec. 7, 2021.

Table A 2 illustrates feed fed, feeding rate, and mortality. All fish received a CWT only (no ad clip) and 4,987 also received a PIT tag. After subtracting mortality and shed tags, a total of 4,930 PIT tags were released. No fish were detected at release because the PIT interrogation system was not operating at the time of release.)

Table A 2. Riverside Acclimation Pond BY 2020 integrated spring Chinook rearing summary, December 2021.

Month	Total on hand*	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
11/30/2021	232,084	759	-	26	99.67%
12/7/2021	229,978	2,106	-	26	98.77%
Cumulative:	**229,978**	**2,865**	**-**	**26**	**98.77%**
All fish were released early due to health issues and were forced out on Dec. 7, 2021.					

BY 2020 CJH/LEAVENWORTH SPRING CHINOOK

2021 Brood Collection

The segregated spring Chinook production goal for the 2021 brood is a release of 700,000 yearlings in April of 2023. 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 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.

The ladder was opened on May 17th with all HOR used for brood. Collection ended on June 23rd. A majority of broodstock (149 males and 189 females) was obtained from Leavenworth National Fish Hatchery. Broodstock consisted of ad clipped fish only, which were scanned for PIT tags, sexed, and inoculated prior to separating them into raceways by sex. The adult pond had a flow rate of 500 gpm, and an exchange rate of 54 minutes, representing a Flow Index (FI) of 0.70 for both ponds #5 and #6 during peak population. 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 were 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 increased after the second spawn due to excessive handling during spawning activities. (Table A 3).

Table A 3. Chief Joseph Hatchery spring Chinook broodstock holding and survival summary for 2021. (M= adult males, J = jacks, and F = adult females). The survival standard for this life stage was 90%.

Month	Beginning of Month			End of Month			Mortality			Monthly Survival (%)			Cumulative Survival (%)		
	M	J	F	M	J	F	M	J	F	M	J	F	M	J	F
May	0	0	0	56	1	100	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
June	56	1	100	257	6	323	2	0	2	99.2%	100.0%	99.4%	99.2%	100.0%	99.4%
July	257	6	323	256	6	322	1	0	1	99.6%	100.0%	99.7%	98.8%	100.0%	99.1%
August	256	6	322	72	6	57	41	0	15	86.2%	100.0%	95.5%	83.0%	100.0%	94.4%
September	72	6	57	0	0	0	3	0	1	96.0%	100.0%	98.3%	81.9%	100.0%	94.1%
Total	**72**	**6**	**57**	**0**	**0**	**0**	**47**	**0**	**19**				**81.9%**	**100.0%**	**94.1%**

Spawning

Spawning began on August 11, 2021 and concluded on September 1, 2021. The spawn consisted of 305 females, 201 males and 6 jacks, with no non-viable (green) female killed resulting in an estimated green egg take of approximately 1,058,769. However, beginning with the 2021 brood, eggs that were left in the female after collecting ripe eggs were counted and put into a category of non-viable eggs. After taking into account those eggs, total adjusted egg take was 1,085,733. Non-viable eggs are counted to estimate more accurately a total overall fecundity.

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 tray. The eggs from 1 female were culled due to high ELISA results. This was approximately 0.3% of the females spawned and is less than what is planned for (up to 20%).

Broodstock origin

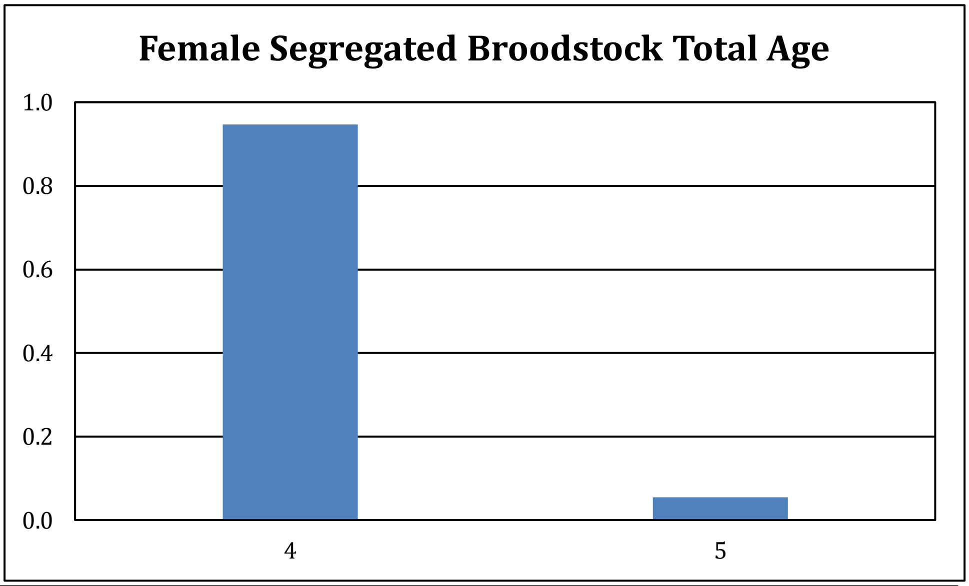
Broodstock were interrogated for coded-wire tags on four different spawning events (August 10, 17, 24, 29 and September 7). When a coded wire was detected, the snout was collected for extraction and later examined in the laboratory. Results indicate that 61.5%(n=315) of all brood stock collected for the spring Chinook program came from the Leavenwoth National Fish Hatchery (LNFH) and 30.9% (n=158) of brood stock came from the CJH segregated program (Table A 4). A portion of snouts (n=32) were examined in the lab and determined to not have a wire. These "no wire" snouts were assigned to the CJH segregated program.

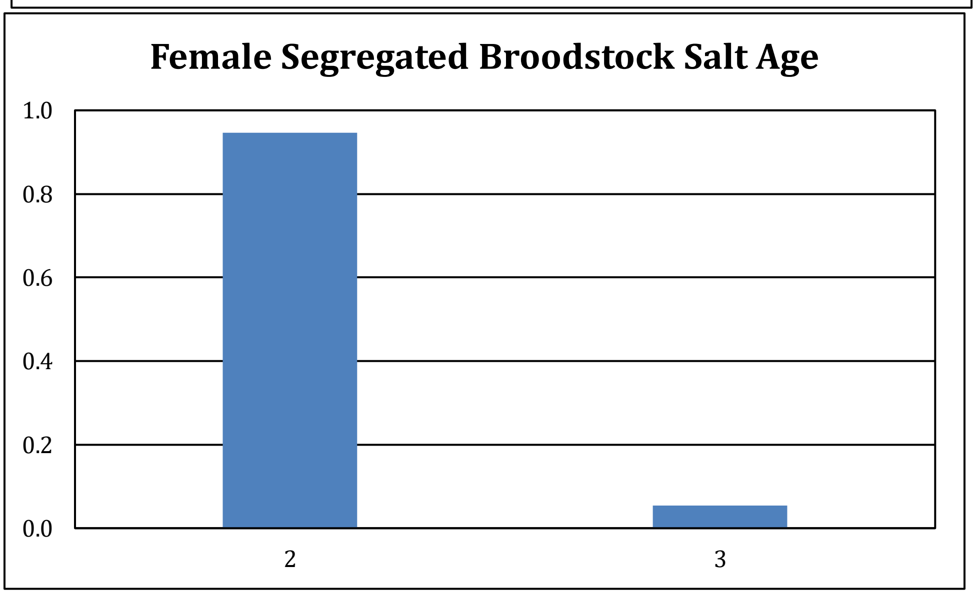
Table A 4. Composition of hatchery-origin brood, by program, collected for the CJH spring Chinook program in 2021.

Category	Hatchery Program	# tags	% of brood	
Okanogan Integrated	Riverside Pond	0		0%
CJH Segregated	Chief Joseph	190	31%	37%
	Chief Joseph (non-tagged)	32	6%	
Other UCR spring Chinook hatchery	Winthrop	7	1%	63%
	Leavenworth National Fish Hatchery	315	62%	
Total		512	100%	

Segregated Program Broodstock Age Structure

Coded wire tags are extracted from spring Chinook segregated program broodstock and later read to determine the age of successfully spawned fish (Figure A 1).





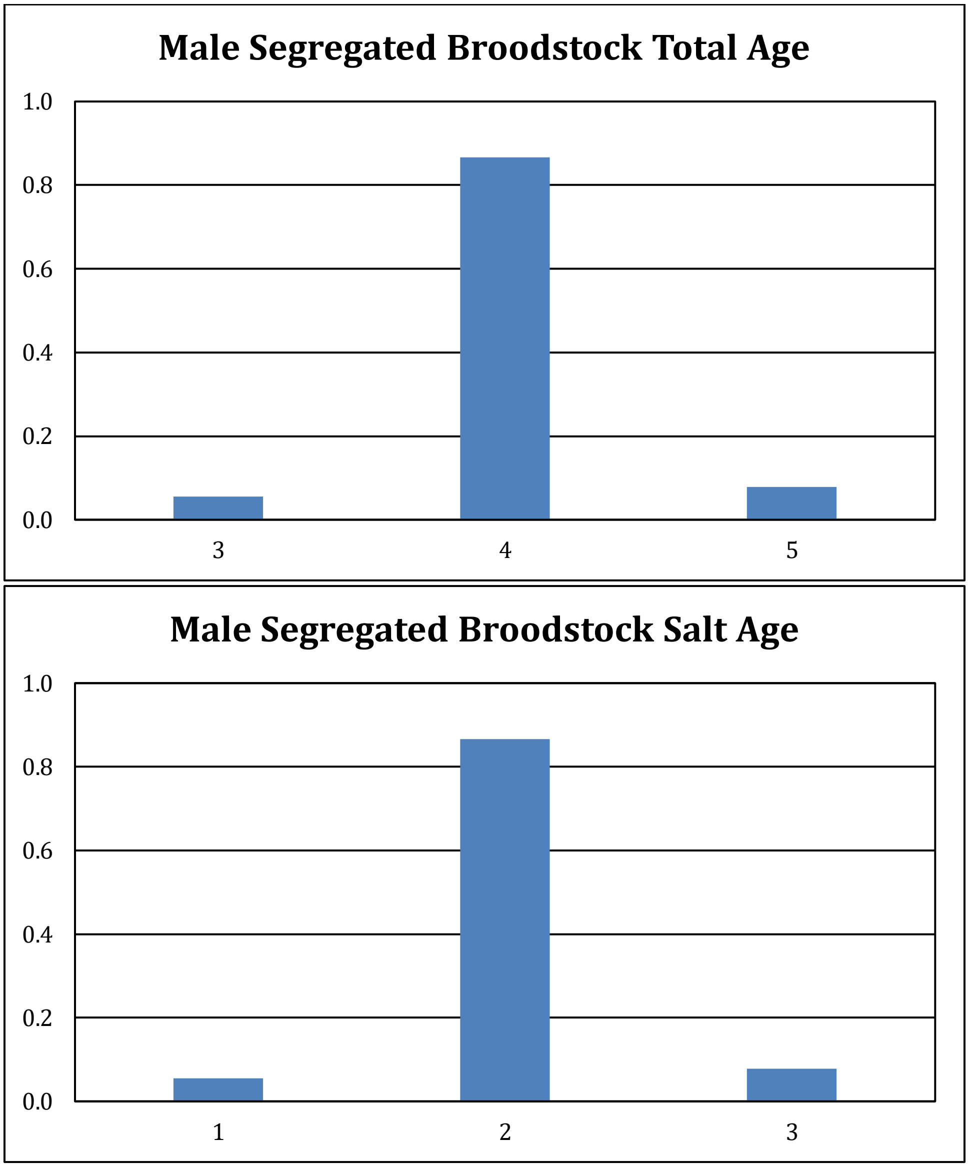


Figure A 1. The total and salt ages of the 2021 broodstock, males and females, collected for the Chief Joseph Hatchery segregated program.

Incubation

Each female's eggs were initially incubated separately to facilitate culling based on ELISA results. Once eyed, egg mortality was removed and remaining eyed eggs were enumerated and put back into their original trays. All spring Chinook eggs were initially placed on ground water.

The water temperature was gradually dropped on the first egg take to 40° F degrees. This process was done over a several hour period four days after spawning. The second egg take was left on well water (55° 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 40° 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 89.6% (Table A 5). This survival was above the key assumption of 90%.

Table A 5. Chief Joseph Hatchery spring Chinook spawning and egg survival summary for 2021 (M = adult males, J = jacks and F = adult females). The target survival standard for this life stage was 90%.

Spawn Date	Total Adults Spawned			Eyed Eggs On Hand	Mortality* (Pick off)	Non-Viable Eggs**	Culled eggs	Adjusted Total Egg Take	Cumulative Survival (%)^
	M	J	F						
8/11/2021	10	0	15	48,728	9,237	2,773	-	60,738	84.1%
8/18/2021	20	0	40	121,726	22,247	2,886	-	146,859	84.5%
8/25/2021	113	0	195	615,288	49,343	18,960	6,154	689,745	92.6%
9/1/2021	58	6	55	157,228	28,820	2,343	-	188,391	84.5%
Total:	**201**	**6**	**305**	**942,970**	**109,647**	**26,962**	**6,154**	**1,085,733**	**89.6%**

Rearing

The BY 2021 spring Chinook were ponded on March 10th and March 24th with an initial population of 932,821 fry. Fish will be adipose fin-clipped in May, with some receiving both a clip and CWT. See Table A 6 for rearing details.

Table A 6. Chief Joseph Hatchery brood year 2021 spring Chinook rearing summary, May 2022.

Month	Total on hand	Mortality	Feed Fed	Fish per pound	Cumulative Survival (%)
3/31/2022	925,831	6,990	269	816	99.25%
4/30/2022	915,764	10,067	1,792	439	98.17%
Cumulative:	**915,764**	**17,057**	**2,061**	**439**	**98.17%**

Chief Joseph Hatchery Ladder

The CJH ladder was operated from May 17 to June 23 to collect brood for the segregated program. During this time frame when the weekly broodstock collection reached its goal, the ladder was closed immediately for the season. All steelhead and ad-present Chinook were returned to the river via a water-to-water transfer. A total of 251 hatchery origin adults (110 males and 135 females) and 6 jacks were taken from the ladder and used as broodstock. A total of 67 natural-origin spring Chinook, 288 ad present, hatchery-origin spring Chinook 54 ad present steelhead and 55 ad-absent steelhead were trapped, handled and released back to the Columbia River (Table A 7 and Table A 8). The encounter/handling and release of 54 ad present steelhead and 55 ad absent steelhead represents 15% of the allowable incidental for natural and hatchery origin steelhead 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 2021.

Table A 7. Chief Joseph Hatchery adult spring Chinook, Sockeye, and steelhead ladder operations from May to August 2021.

Month	# of Ladder Trap Checks	HOR Spring Chinook Surplussed	HOR Spring Chinook Jacks Surplussed	NOR Spring Chinook RTS	NOR Spring Chinook Jacks RTS	Sockeye Surplussed	AD Present Steelhead RTS	AD Absent Steelhead RTS
May	4	0	0	11	0	0	46	55
June	5	0	0	47	1	0	8	0
July	0	0	0	0	0	0	0	0
Aug	2	2	0	8	0	0	0	0
Total	**11**	**2**	**0**	**66**	**1**	**0**	**54**	**55**

RTS= Return to stream

Table A 8. Chief Joseph Hatchery spring Chinook collected during ladder operations in 2021.

Month	HOR Spring Chinook Surplussed	HOR Spring Chinook Jacks Surplussed	NOR Spring Chinook RTS	NOR Spring Chinook Jacks RTS	HOR Spring Chinook RTS	HOR Spring Chinook Jacks RTS	HOR Brood
May	0	0	11	0	9	0	157
June	0	0	47	1	261	10	94
July	0	0	0	0	0	0	0
Aug	2	0	8	0	36	2	0
Total	**2**	**0**	**66**	**1**	**306**	**12**	**251**

RTS= Return to stream

The ladder was closed and dewatered on August 31, 2021, for the season. There was spring Chinook ladder surplus operations in 2021 due to low number of adult returns. The annual spring Chinook CWT recovery data from the CJH surplus ladder operations is summarized in Table A 9.

Table A 9. 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 May to August.

	# 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%
2018	7	0%	100%	0%	0%	0%	0%	0%
2019	231	0%	95%	5%	0%	0%	0%	0%
2020	0	0%	0%	0%	0%	0%	0%	0%
2021	0	0%	0%	0%	0%	0%	0%	0%
Avg.	**51**	**4%**	**35%**	**2%**	**20%**	**15%**	**1%**	**1%**

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

Appendix B

2022 Production Plan

Table B 1. Spring Chinook – Met Comp (Riverside Pond Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2022						**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**
04/15/24	04/30/24	200,000	15.0	30.2	13,333	6,048	Yearlings	Riverside Pond	None	100% 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 10.5%									
Rearing Summary:										

Species	**Source**	**Date**	**Number Green Eggs**	**Number Eyed Eggs**	**Number Ponded**	**Fed Fry**	**Released**	**Location**
Spring Chinook	Winthrop NFH	April	261,440	235,296	223,531	212,355	200,000	Riverside

Table B 2. Spring Chinook - Leavenworth (CJH Release)

Chief Joseph Hatchery Production Plan

Brood Year:	2022						**Planting Goal:**	700,000		
Species:	Spring Chinook						**Pounds:**	46,667		
Stock:	CJ Hatchery									
Origin:	Hatchery									
Egg Take Goal:	1,094,400						**Adult Goal:**	640		
							Assumed Fecundity	*3,800*		
Estimated Release Data:							*Average Fecundity (BY16-BY21)*	*3,355*		
Start Date:	**End Date:**	**Num Released**	**fish per lb.**	**Wt. grams**	**Total weight (lb.)**	**Total weight (kg)**	**Life Stage**	**Release Site**	**Mark Type**	**Tagged**
04/15/24	04/20/24	700,000	15.0	30.2	46,667	21,168	Yearlings	CJ Hatchery	Ad Clipped	200k 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 6.5%									
Rearing Summary:										

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

APPENDIX C

Technical Memorandum: Minijack Rates for 2021 Chief Joseph Hatchery Integrated and Segregated Chinook Releases

Date: August 2, 2021

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

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

CC: Kirk Truscott

Subject: Minijack rates for 2021 Chief Joseph Hatchery Chinook release groups

Background

This technical memorandum will summarize the results of gonadal-somatic index (GSI) sampling conducted by the Chief Joseph Hatchery Program (CJHP) in May 2021, and provide estimates for the rate of early maturation ("minijack rate") from each yearling group released in 2021 (brood year 2019).

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

USFWS for the Leavenworth complex for a number of years with good success (Matt Cooper, personal communication). The CJHP staff believe the GSI evaluation presented herein meets the intent of the reporting requirement (#6) described in the NMFS determination letter.

Methods

Prior to release, approximately 300 fish were collected from each yearling 2021 Chief Joseph Hatchery (CJH) release group for dissection and examination. Similar to 2020, these fish were held at CJH after their cohorts had been released for approximately one month. This was to allow for additional maturation and facilitate distinction between mature and immature fish. The release groups are:

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

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

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

Results

Based on the visual assessment of maturity, CJH yearlings overall displayed moderate rates of early maturity (0.00%-3.08%, Table C 1). The mixture model was fit to all release groups and encompassed a smaller range of expected rates of early maturation (0.00% - 15.12%, Table C 1). There was no distinct separation in Log10 GSI between immature and mature fish in any of the release groups. Nevertheless, a cutoff value for classifying sampled fish as mature or immature, and therefore a minijack rate, could be modeled for all groups (Figures C 1-C 5). Histograms that display the distribution of Log10 GSI for each sampled release group are presented in Figures C 1-C 5. Annual rates of early maturation are recorded in Table C 2.

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

2019.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	130	126	4	3.08%	4.62%
Segregated Summer Yearlings	Chief Joseph Hatchery	153	152	1	0.65%	3.92%
Integrated Spring Yearlings	Riverside Acclimation Pond	145	143	2	1.38%	8.39%
Integrated Summer Yearlings	Omak Acclimation Pond	172	171	1	0.58%	15.12%
Integrated Summer Yearlings	Similkameen Acclimation Pond	151	151	0	0.00%	0.00%

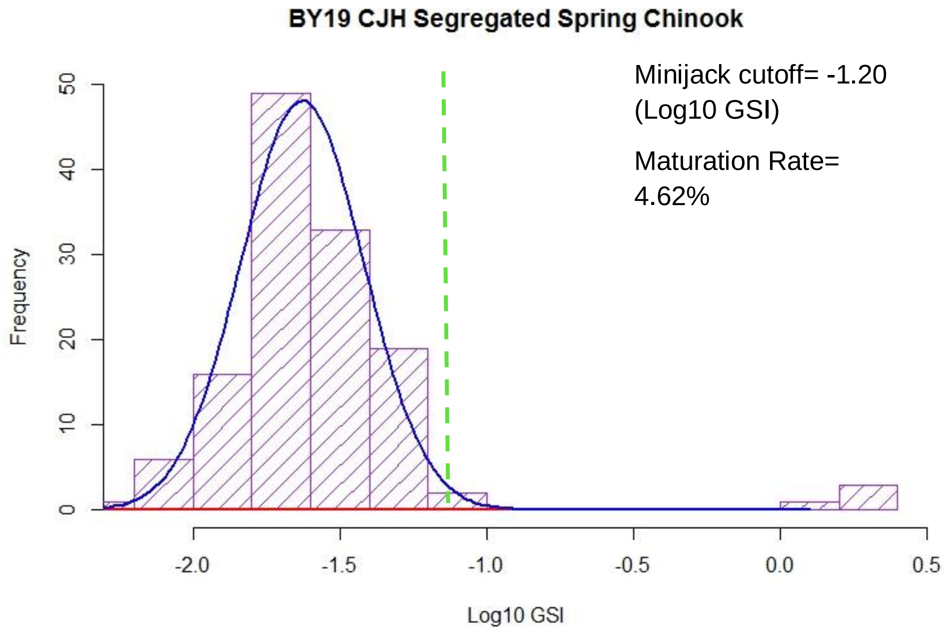


Figure C 1. Distribution of Log10 GSI for the segregated spring Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

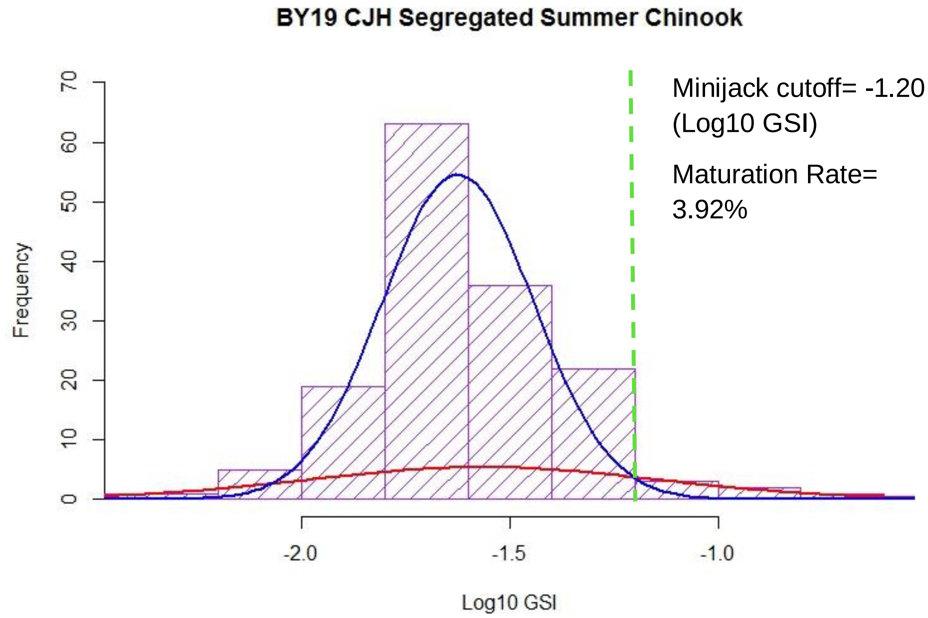


Figure C 2. Distribution of Log10 GSI for the segregated summer Chinook released from the Chief Joseph Hatchery. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

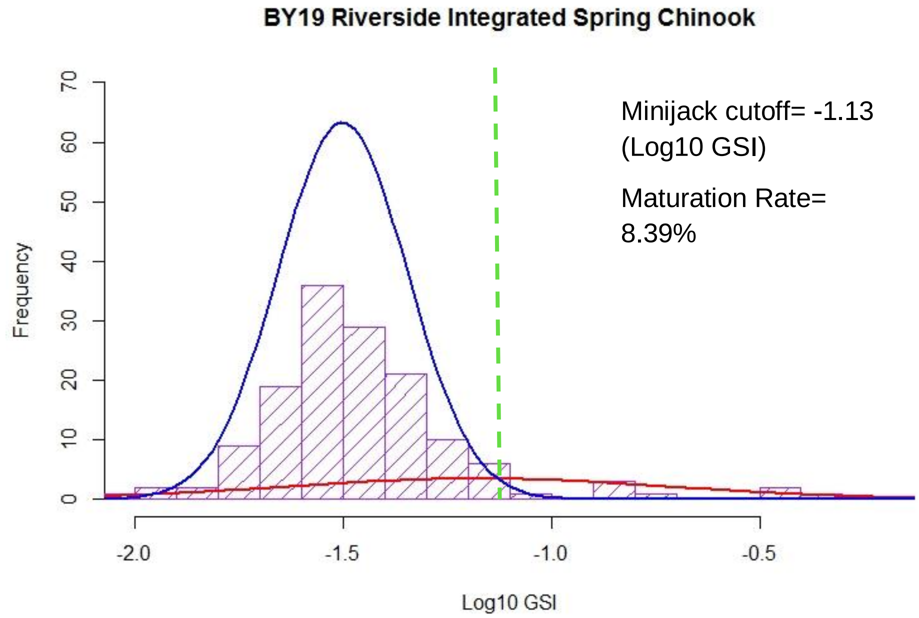


Figure C 3. Distribution of Log10 GSI for the integrated spring Chinook released from the Riverside Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

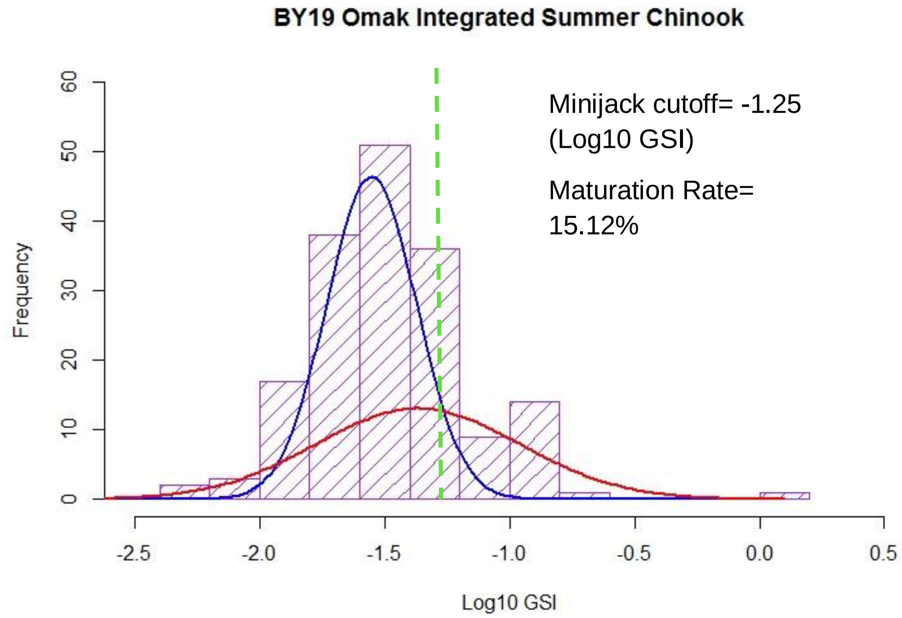


Figure C 4. Distribution of Log10 GSI for the integrated summer Chinook released from the Omak Acclimation Pond. The cutoff value is marked by the vertical green dashed line. It marks the point of differentiation between immature fish (appearing to the left of the cutoff line) and mature fish (appearing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

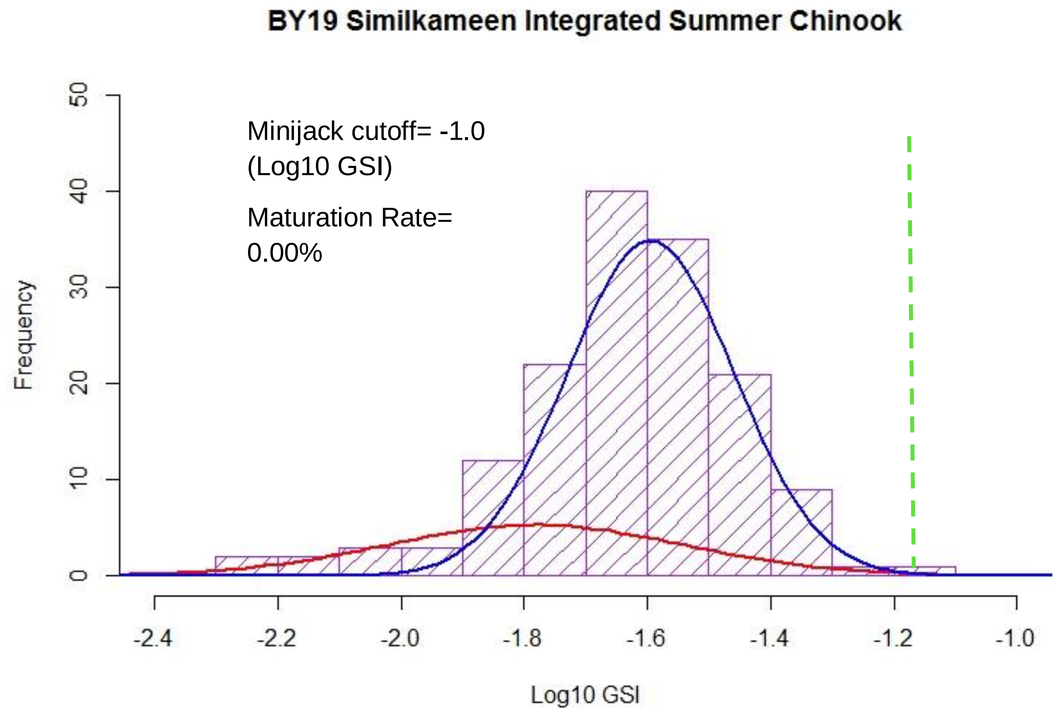


Figure C 5. Distribution of Log10 GSI for the integrated summer Chinook released from the Similkameen Acclimation Pond. Since a cutoff value differentiating immature and mature subpopulations was not determinable, subpopulations distribution functions and the cutoff value are not displayed.

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

Year		CJH Segregated Spring Chinook	CJH Segregated Summer Chinook	Riverside Integrated Spring Chinook	Omak Integrated Summer Chinook	Similkameen Integrated Summer Chinook
2018	Visual Estimate	3.23%	4.29%	1.34%	0.00%	0.75%
	Modeled Estimate	4.52%	N/A	N/A	N/A	N/A
2019	Visual Estimate	31.29%	14.29%	37.41%	19.63%	14.25%
	Modeled Estimate	19.02%	43.06%	42.17%	29.63%	N/A
2020	Visual Estimate	11.11%	25.30%	23.74%	49.66%	20.14%
	Modeled Estimate	19.26%	65.06%	43.88%	54.36%	46.53%
2021	Visual Estimate	3.08%	0.65%	1.38%	0.58%	0.00%
	Modeled Estimate	4.62%	3.92%	8.39%	15.12%	0.00%

Discussion and Recommendations

The data and analyses presented herein suggest that the early maturation rates for brood year 2019 releases were much lower than that of brood year 2018 and 2017. The decrease in minijack rates occurred with all of the Chinook release groups and were comparable to other Columbia River hatchery programs (Harstad et al. 2014).

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

Visual determination of maturity state is subjective and is likely only useful when the state of maturity has progressed to the point where it becomes so clear that observer error or bias can be overcome. Similarly, the mixture model relies on an ability to differentiate between two distinct, normally distributed populations within a sample. Holding the fish for an additional month post-release allowed more time for gonadal development in the early maturing fish. Similar to the 2019 and 2020 releases, this allowed for mixture model convergence at a much higher rate than in 2018 and may have contributed to reducing Type II error in the visual determination. Although this implies that the minijack rates reported in 2019 may have been artificially low, such a determination cannot be confidently made without supportive PIT tag data. It is recommended that a holdover period similar to what was employed in 2019-2021 be maintained in future years.

Literature Cited

Hard, J. J., A. C. Wertheimer, W. R. Heard, and R. M. Martin. 1985. Early male maturity in two stocks of chinook salmon (*Oncorhynchus tshawytscha*) transplanted to an experimental hatchery in southeastern Alaska. Aquaculture 48:351-359.

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Medeiros, L. For Data Analysis: Determine cutoff for maturing vs. non-maturing fish. (R script).

Pfannenstein, K. 2016. ‘NAD sampling protocols. US Fish & Wildlife Service, Mid-Columbia River Fishery Resource Office.

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

‘NAD Sampling Protocols

Supplies List

Sampling How-To

Data Summary and Analysis Methods

Notes from 2016

By Katy Pfannenstein

Mid-Columbia River Fishery Resource Office

US Fish and Wildlife Service

Katy_Pfannenstein@fws.gov

<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:

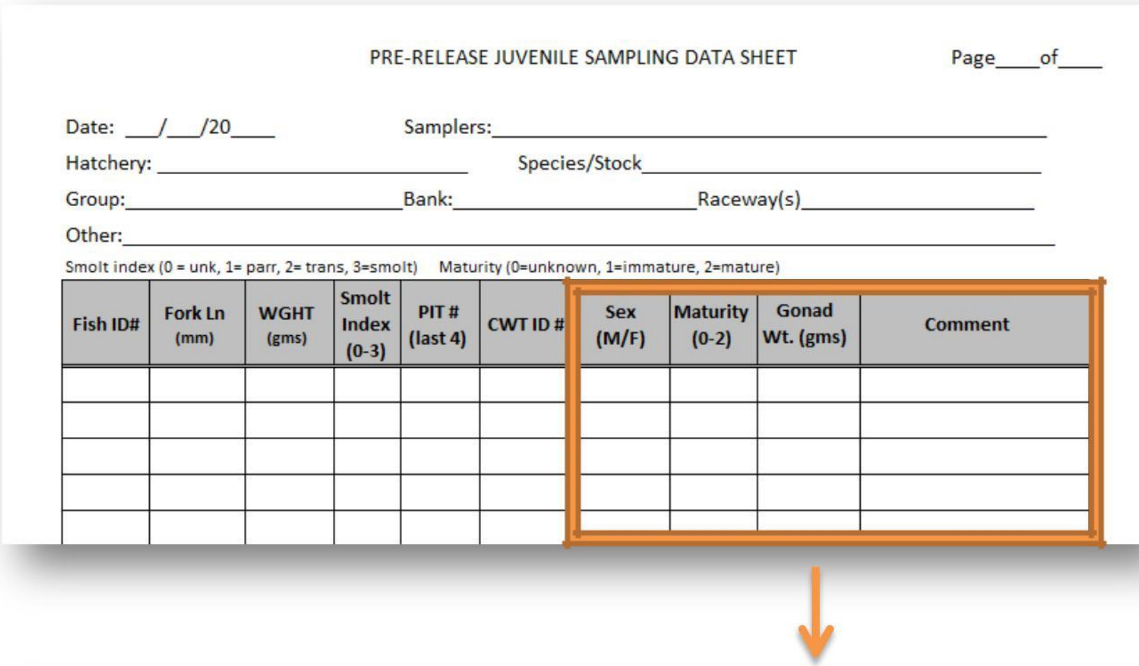
- Tricane Methanesulfonate (MS 222)
- [1] Tub for fish
- [1] Dip net
- [1] Pit scanner + [1] stand
- [4] large sponges + [1] cookie tray
- [1] Scale for weights + [1] smolt weight pan
- [1] Length board

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), and 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:______________________________

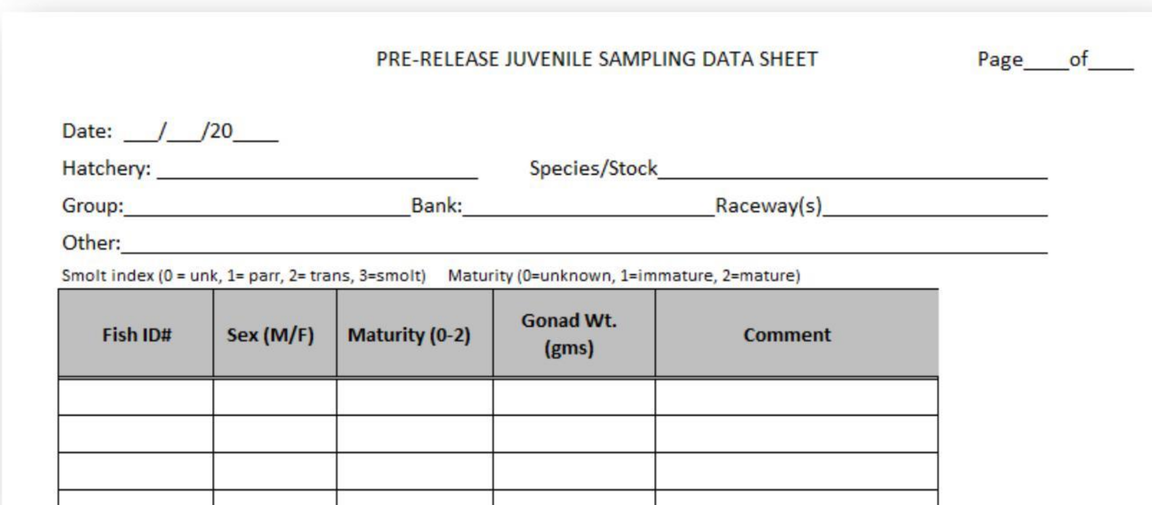
Hatchery: ______________________ Species/Stock______________________

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

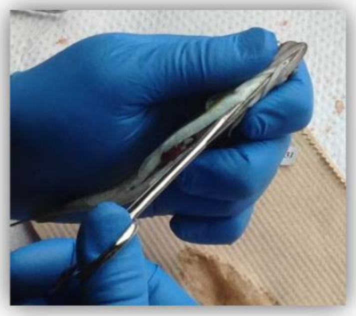
2. Collect fish from hatchery ponds. Random sample? Keep different ponds separate? CWT? Pit Tag?

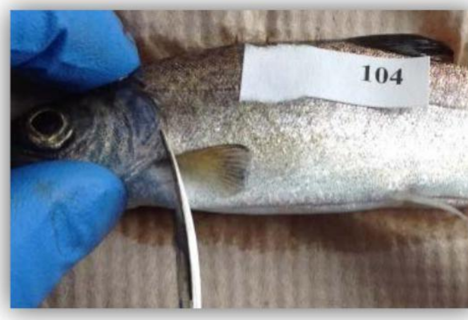
3. Set up stations. Note length/weight station is at standing height.

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

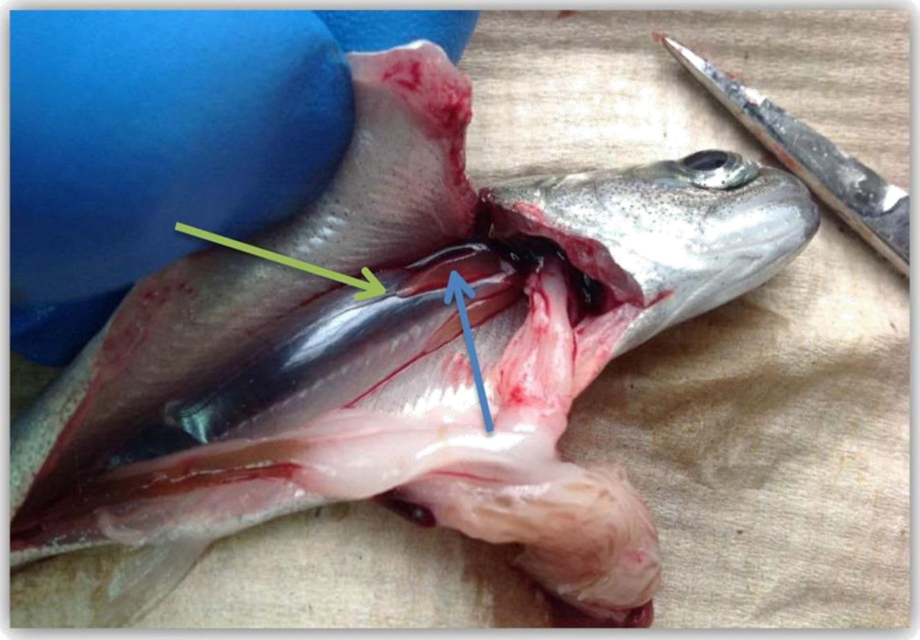
5. Set out 15-20 fish in a row on the sponges. Add number tags to fish. Assess smolt index while all fish are in the line. Obtain weights and lengths, place on paper towel to pass to the dissecting crew.

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).

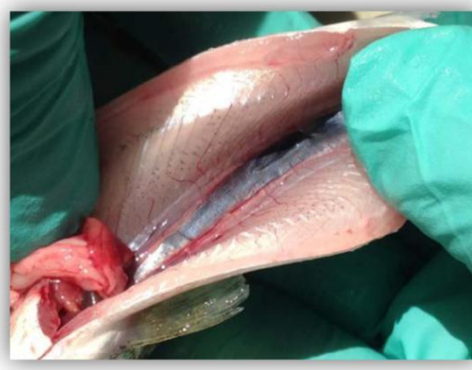




7. Female identification: 1. Ovary forms a point and then narrows to oviduct – thread like (green arrow) 2. Ovary is angular, has ridge (blue arrow), 3. Granulated (orange arrow), 4. Color (red arrow) is not a good indicator as it can vary from pink to white.



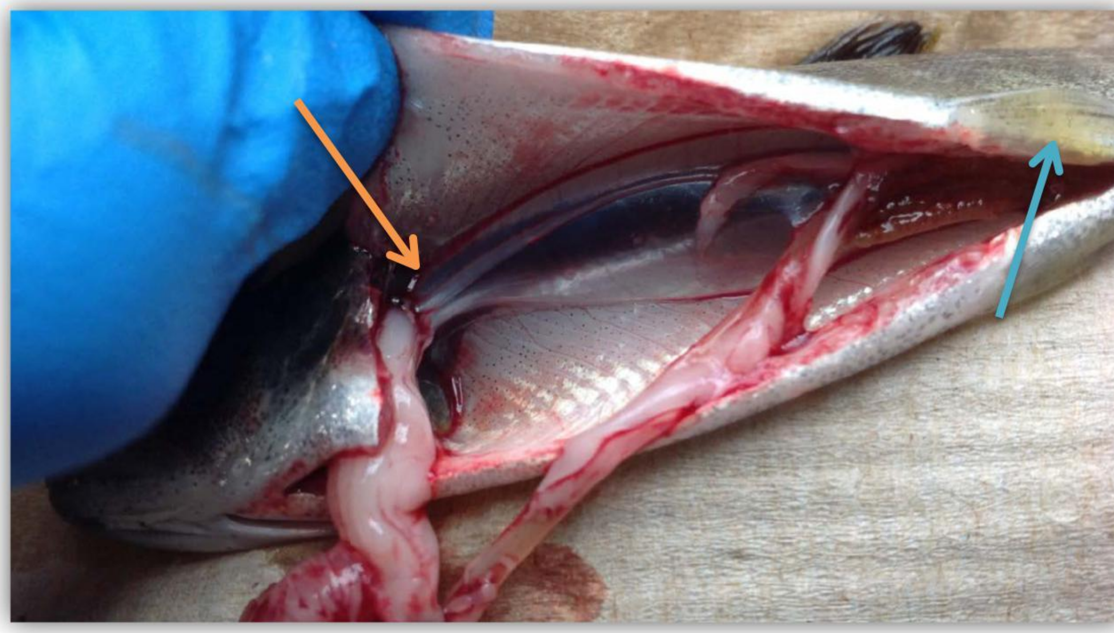
8. Immature male identification: Testes are thready throughout, smooth and round, no development or thickness (green arrows).



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.

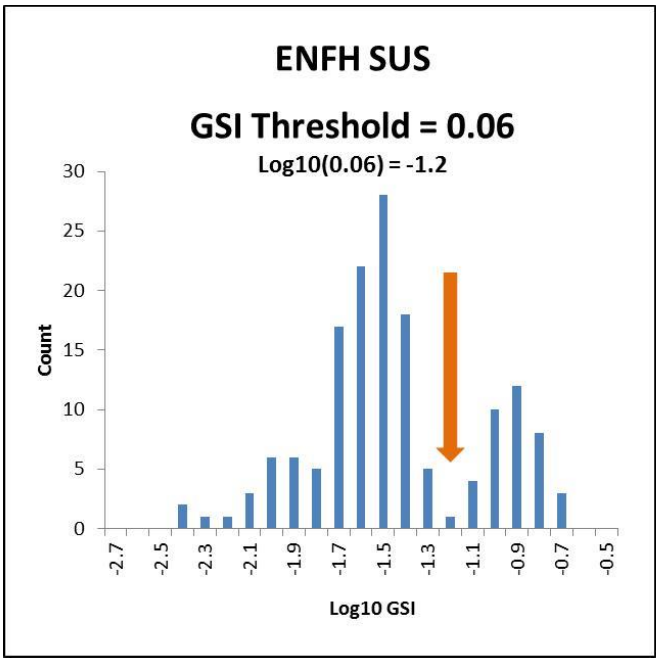


12. To use the scale: Close all doors, zero balance, open door, place 'nads in weight boat, close doors, wait for number to stabilize. 'Nads will evaporate and become lighter in a short period of time.

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, weight 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.

<u>NAD Sampling Notes (What worked? What didn't?)</u>

- 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.

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.

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Mixture model and maturity cutoff calculation

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

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

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

Copy and paste the code below the line into rStudio

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

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

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

```
    return(uniroot(f=f, lower=-2, upper=2)$root)  # Careful with division by zero if
changing lower and upper
}
cutoff <- c(find.cutoff(proba=0.5)) # Can change to have range around 50/50
probability, but this is the value we use to determine if a fish is maturing or not
# Define curves from normalmixEM for plotting on histogram
h <- hist(LC,ylim=c(0,140),breaks=20) # will produce basic histogram of data used
for stats it produces; may need to alter ylim to reflect frequency of tallest bin and
breaks
xfit <- seq(-0.7,1.4,length=200)
        #First number should minimum bin, second number should be maximum bin,
        length is number of plots pointed (higher number = smoother curve… to a
        point)
yfit1 <- model$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)" ))
```