U.S. Fish and Wildlife Service

Leavenworth National Fish Hatchery Annual Report, 2016

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On the cover*: Adult spring Chinook Salmon sampling at the Leavenworth National Fish Hatchery. USFWS.*

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Disclaimers

LEAVENWORTH NATIONAL FISH HATCHERY ANNUAL REPORT, 2016.

Executive Summary- Leavenworth National Fish Hatchery (LNFH) was constructed as partial mitigation for anadromous fish loses associated with the construction of Grand Coulee Dam. The hatchery is located on Icicle Creek in central Washington State and produces an unlisted stock of spring Chinook Salmon (*Oncorhynchus tshawytscha*) as a segregated-harvest program. In release year 2016, LNFH force-released 945,277 juvenile spring Chinook Salmon into Icicle Creek, which was 21% under the production goal of 1,200,000. At the time of release juveniles were 20 fish per pound (fpp), which was 15% under the performance goal of 17 fpp for this program. In return year 2016, it was estimated 5,224 spring Chinook Salmon returned to Icicle Creek, of which 3,241 were captured at LNFH adult holding ponds. An estimated 303 fish were harvested in the Icicle Creek sport fishery and an estimated 1,550 fish were harvested in the Icicle Creek Tribal Fishery and 26 fish remained in Icicle Creek. Of the 3,241 fish that were captured in the adult holding ponds, 1,527 were excessed to regional Native American tribes, 640 were transferred to Chief Joe Hatchery (CJH) and 1,074 were used as broodstock. Testing of the female broodstock showed 93% were in the “very low” and “low” risk levels for transmitting BKD from mother to progeny. After culling, LNFH began rearing brood year 2016 with 1,335,641 eyed eggs.

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Table of Contents

List of Tables

List of Figures

Introduction

Location

Leavenworth National Fish Hatchery (LNFH) is located adjacent to Icicle Creek near the town of Leavenworth in central Washington State (47°33'32.12" N, 120°40'29.12" W, Figure 1). Icicle Creek is a tributary to the Wenatchee River, which flows into the Columbia River at river kilometer (rkm) 754, in the city of Wenatchee, Washington. LNFH is approximately 800 rkm from the Pacific Ocean, and upstream of seven Columbia River hydroelectric dams.

LNFH uses 59 outdoor rectangular raceways and two outdoor rectangular adult holding ponds for current production. There are also 53 historic Foster-Lucas style ponds that are no longer used for production of spring Chinook Salmon (Figure 2, Table 1). Indoor facilities include: 540 Heath type incubation trays in 36 stacks and 122 starter tanks.

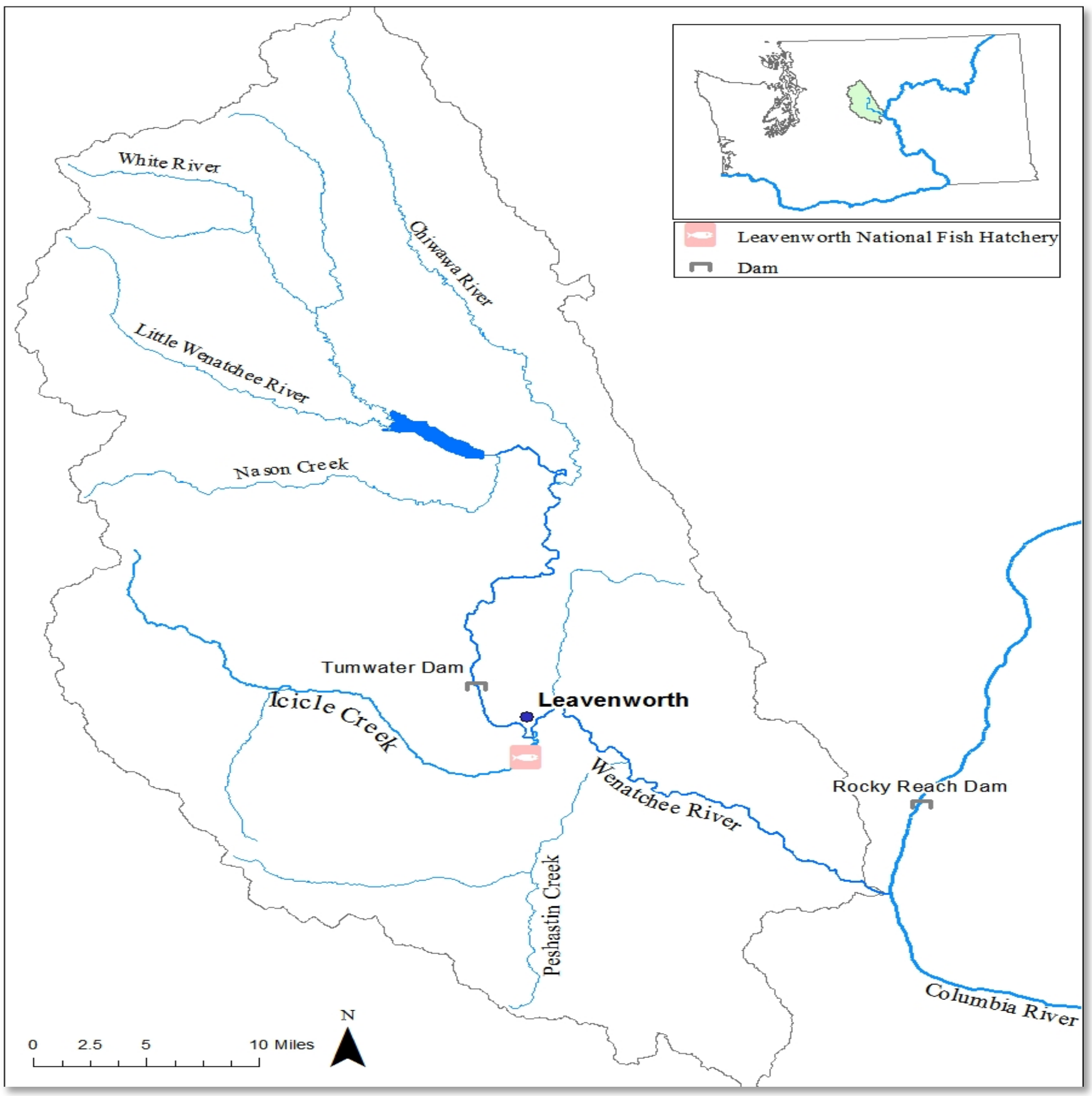

Figure 1. Map of the Wenatchee River watershed.

A. Well 5
B. Nursery Building
C. Small Foster-Lucas Ponds
D. Pollution Abatement Ponds
E. Adult Holding Ponds and Adult Return Ladder
F. Well 6
G. Large Foster-Lucas Ponds
H. 10x100 Raceways
I. 8x80 Raceways
J. Structure 5
K. Well 4
L. Sand Settling Basin
M. Well 1
N. Wells 2 and 7
O. Well 3
P. Hatchery Channel
Q. Structure 2
R. Spillway Pool and Barrier Dam

Figure 2. Primary structures of LNFH   * Surface water intake not pictured

Table 1. Outdoor facilities currently used for production at LNFH.

Description	N	Size (ft)	Covered?	Predation Risk?	Shape	Use

rearing pond	45	8x80	No	Yes	rectangular	juvenile rearing
rearing pond	14	10x100	Yes	No	rectangular	juvenile rearing
adult holding pond	2	15x150	No	Yes	rectangular	adult collection/juvenile rearing

Historic Operations
Since production began in 1940 LNFH has produced several trout and salmon species including, spring and summer/fall Chinook Salmon (*Oncorhynchus tshawytscha*), steelhead and Rainbow Trout (*O. mykiss*), and Sockeye Salmon (*O. nerka*).

From 1940-1943, spring Chinook were collected from upriver-bound stocks captured at Rock Island Dam. Some early imports of spring Chinook to LNFH from the lower Columbia River (1942) and McKenzie River, Oregon (1941) were part of homing studies, and probably few, if any, contributed to future production. Although spring Chinook have been produced annually (except brood years 1967 and 1968) at LNFH since 1940, Sockeye Salmon were the primary species produced 1940–1970. Beginning in the early 1970's, due to the limited benefits and significant disease risk, Sockeye were phased out and spring Chinook became the primary species produced at LNFH (USFWS 1986). Occasionally, eggs were imported from other Columbia River hatcheries, including Cowlitz Salmon Hatchery, Carson NFH and Little White Salmon NFH. Fish and/or eggs have not been imported to LNFH since 1985.

Current Operations
LNFH operates a segregated harvest supplementation program producing spring Chinook Salmon, and aids in the production of Coho Salmon (*O. kisutch*) for the Yakama Nation Mid-Columbia Coho Reintroduction Program, however only spring Chinook production will be discussed in this report.

The stock used by LNFH is not included in the ESA-listed Upper Columbia River spring Chinook Evolutionarily Significant Unit (ESU). Genetic analysis indicates that the current stock is more closely related to the lower Columbia River stocks than the natural population in the Wenatchee River (Ford et al. 2001). Spring Chinook produced at LNFH are commonly referred to as "Carson stock", referring to the Carson National Fish Hatchery, where the majority of imported eggs originated. However, considering the number of generations that this stock has been propagated at LNFH, it is increasingly being referred to as an "Icicle Creek" or "Leavenworth" stock.

The goal of the LNFH program is to provide harvest opportunities while minimizing impacts to natural populations and the habitats they occupy.

LNFH strives to achieve the following objectives;

1. Consistently contribute to harvest fisheries.
2. Protect indigenous fish populations by minimizing interactions through proper rearing, release, and adult collection management strategies.

3. Produce healthy, externally marked spring Chinook smolts for on-station release as per U.S. vs OR agreement.
4. Maintain stock integrity and genetic diversity of the hatchery and wild stocks through proper management of genetic resources.
5. Maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread, or amplification of fish pathogens.
6. Conduct environmental monitoring to ensure that hatchery operations comply with water quality standards and to assist in managing fish health.
7. Design and implement projects to improve quality of production at LNFH.
8. Effectively communicate with other salmon producers and managers in the Columbia River Basin.

Water Sources

LNFH has four water right certificates and two water right claims, allowing a maximum water withdrawal of 56.9 cubic feet per second (cfs) or 25,550 gallons per minute (gpm). Surface water rights allow up to 42 cfs (18,850 gpm) and groundwater withdrawals are authorized for 14.9 cfs (6,700gpm). The average combined water use is 41.22 cfs (18,500 gpm). Water use varies seasonally and is dependent on the number of fish on station.

Icicle Creek, a fifth-order stream draining high relief mountains, provides the majority of the water throughout the year for hatchery operations and serves as the release and collection point for cultured fish. During the low flow months (July- September) LNFH actively manages Upper Snow Lake to supplement and cool Icicle Creek upstream of LNFH's water intake. Water is released from Upper Snow Lake into Nada Lake via a tunnel and control valve with a targeted discharge of 50 cfs (22,442 gpm, Table 2). From Nada Lake water flows into Snow Creek and then into Icicle Creek (8.8rkm). The 50 cfs summer supplementation that enters Icicle Creek serves to ensure the availability of the 42 cfs surface water withdrawal that occurs downstream at the LNFH intake (7.1rkm).

Seven wells at LNFH provide pathogen-free water. Wells 5 and 6, withdraw water from a deep cool water aquifer on the north side of the LNFH property. The other five wells, extract water from a shallow aquifer on the south side of the property. The shallow aquifer has hydrologic continuity with Icicle Creek and is directly influenced by the saturation of the hatchery channel (Figure 2). All well pumps are equipped with variable frequency drives which allow operation at lower flow rates and maintain water levels in the aquifer. When water levels in the shallow aquifer are depleted, the wells start "competing" for water. Competition for water significantly constrains pumping capacity for multiple wells.

Table 2. Summary of water sources at LNFH.

Source	Depth (casing)	Annual Temp. ^{o}F	Average gpm	Min gpm	Max gpm	Storage Capacity ac-ft	Average Release Volume ac-ft
Icicle	Surface	42.3 - 53.9^{0}F	18,484*				

Snow/Nada	Surface	42.3 - 53.9^{0}F	22,442*			12,450	6,500
Well No. 1	80 (40-80')	42.3 - 53.9^{0}F	563	400	725		
Well No. 2A	203 (70-90')	47.0 - 49.4^{0}F	288	250	325		
Well No. 3A	120 (63-98')	44.0 - 49.8^{0}F	288	250	325		
Well No. 4A	333(64-94')	43.1 - 48.3^{0}F	425	350	500		
Well No. 5	300(250-300')	<52.0^{0}F	675	450	900		
Well No. 6	195(102-170')	50.5 - 52.5^{0}F	700	550	850		
Well No. 7	192(102-110')	43.3 - 46.7^{0}F	295	260	330		

*estimated

Hatchery Evaluation

The Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO) assists the LNFH spring Chinook program under its Hatchery Evaluation (HE) program. The HE program strives to use monitoring, evaluation, and targeted research to assist LNFH in effectively meeting both its mitigation goals and ESA responsibilities. Additionally, HE assists in guiding the hatchery in making decisions that balance the benefits of artificial production against risks to natural populations and their habitats.

The goals of the HE program can be characterized into three main areas of focus:

1. Evaluate hatchery operation and practices with respect to facilitating program optimization.
2. Research, assess and recommend methods to minimize impacts of hatchery production and operations on natural fish populations and their environment.
3. Facilitate coordination with the various managers involved in artificial production, evaluation and management of fisheries within the upper Columbia River basin.

Monitoring Objectives– Annual monitoring and coordination by the HE program assesses whether LNFH met mitigation objectives while working within acceptable levels of risk to natural-origin fish populations and their habitat. Monitoring and evaluation goals are broadly categorized as hatchery rearing metrics, post-release performance, and risk assessment to natural populations and habitat.

HE program objectives specific to LNFH include the following:

1. Forecast adult returns and track in-season fish abundance to effectively guide harvest and brood management.
2. Annually coordinate marking and tagging of production.
3. Monitor the effects of hatchery operations on natural populations.

4. Assess whether juveniles are reared and released in a manner that minimizes freshwater residence and early maturation while maximizing outmigration survival and homing fidelity.
5. Determine population characteristics of returning adults including: harvest contribution, straying, run timing, smolt-adult survival, genetics, and gender and age composition.

The following set of LNFH specific tasks are attempted annually to meet objectives:

1. Develop predictive models to forecast preseason adult return estimates for managers.
2. Adequately tag and use PIT tag interrogation to track the migration of Chinook and provide weekly in-season forecasts to managers.
3. Describe fishery contribution and stray rates using data from coded-wire tag recoveries, harvest estimates, spawning ground recoveries and hatchery returns.
4. Sample a statistically valid representation of the hatchery return to adequately describe population characteristics.
5. Operate PIT tag antennas in adult fish ladders at LNFH.
6. Monitor in hatchery rearing environment to meet survival, size and production targets.
7. Coordinate marking and tagging programs to assure that hatchery produced fish are identifiable for harvest management, escapement/fidelity goals and evaluation studies.
8. Monitor smolt outmigration metrics of survival and timing through the Columbia River corridor.
9. Monitor rates of precocial maturation in release groups.
10. Support Parental Based Tagging (PBT) genetic marking objectives (via DNA markers) as identified by the Columbia River Inter-Tribal Fish Commission (CRITFC).

Data used for evaluation came from direct collection, collection by other management agencies, and/or industry-specific databases. Most of the data used in this report are directly collected by HE and hatchery staff. Other commonly used data sources include:

RMIS- Regional Mark Information System (RMIS) is an online database operated by the Pacific States Marine Fisheries Commission and designed to house Coded Wire Tag (CWT) data for the west coast of North America and the northern Pacific Ocean. When a group of fish is tagged with a CWT, the tag code and number of fish tagged are submitted to RMIS by the tagging entity. Subsequently, if/when a fish is lethally sampled, either for scientific or commercial purposes, the tag code and location information is submitted. RMIS allows managers to calculate survival and contribution metrics for the fisheries they are evaluating. More information can be found at www.rmpc.org.

PTAGIS- PIT Tag Information System (*PTAGIS*) is an online database operated by the Pacific States Marine Fisheries Commission, and designed to house Passive Integrated Transponder (PIT) tag data. When a group of fish is tagged with a PIT tag, the tag codes and number of fish tagged are submitted to PTAGIS by the tagging entity. Subsequently, if/when the PIT tag is read remotely by a transceiver antenna ("interrogated"), the tag code and location information is also submitted. These data can be collected non-lethally, and fixed interrogation stations can be set up at any location with constant electricity, such as hatcheries and hydroelectric facilities. PTAGIS allows managers to track movement of the tagged fish. More information can be found at www.ptagis.org.

DART- Columbia River Data Access in Real Time (DART) is an online database operated by the Columbia Basin Research Department of the School of Aquatic and Fishery Sciences at the University of Washington.

DART uses data from RMIS and PTAGIS to provide summaries of juvenile fish survival and counts fish passing hydroelectric facilities on the Columbia River and its tributaries. More information can be found at www.cbr.washington.edu/dart/.

At LNFH, CWT's, adipose fin clipping, and PIT tags are administered by the Columbia River Fish and Wildlife Conservation Offices' hatchery marking team. This team marks and tags for a majority of the National Fish Hatcheries in the Columbia River basin, as well as other hatchery facilities in the region.

Legal Authorities

Construction of LNFH was authorized by the Grand Coulee Fish Maintenance Project April 3, 1937, and reauthorized by the Mitchell Act (52 Stat. 345) May 11, 1938. The Mitchel Act authorized the construction of LNFH fish culture facilities, biological surveys and experiments related to fish conservation. The hatchery is funded by the U.S. Bureau of Reclamation and operated by the U.S. Fish and Wildlife Service (USFWS). Production, marking and tagging goals for the facility are determined through the management framework established as an outcome of the *U.S. v Oregon* decision and are described in the 2008-2017 *U.S. v Oregon* Management Agreement.

Endangered Species Act - LNFH operates within the requirements of the Endangered Species Act (ESA) of 1973. Though the stock produced at LNFH is not ESA-listed, Biological Opinions (BiOp) are issued for ESA listed Upper Columbia River spring Chinook, steelhead, and Bull Trout (*Salvelinus confluentus*), all of which may reside in Icicle Creek. Permits are issued for any incidental "take" of listed species through impacts from LNFH operations and/or production. The term "take" is defined by the ESA as: to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect any threatened or endangered species. The Terms and Conditions outlined by each BiOp are located in Appendix A.

Hatchery and Genetic Management Plan - The Hatchery and Genetic Management Plan (HGMP) is a Biological Assessment provided by LNFH and MCFWCO to describe the effects of LNFH operations and production upon ESA listed species. The HGMP sets broad performance standards that are used by the National Marine Fisheries Service for the purpose of evaluating hatchery programs under the ESA.

Performance Goals

To accurately monitor and evaluate the spring Chinook Salmon program at LNFH, specific performance goals are tracked throughout the year (Table 3). Performance goals are derived from the legal authorities, HGMP's, Olympia Fish Health Center recommendations, peer-reviewed literature, and the Hatchery Evaluation Team. They are intended to give a point of comparison between cohorts and amongst similar hatchery programs. Performance goals are divided into three broad categories: Release Year, Adult Return, and Brood Year.

Release Year - Release year performance goals apply to the rearing of juveniles from egg eye-up through smolt release (Table 3). A release year cohort is on-station for 1.5 years.

Adult Return - The adult return/broodstock collection performance goals reflect the ability of LNFH to collect, hold, and spawn adults. These goals cover the adult life stage from upstream migration through egg eye-up, and occur during one calendar year (Table 3).

Brood Year- Brood Year Performance Goals apply to adult fish, assessing survival and contribution to harvest (Table 3). Assessment of Brood Year Performance Goals cannot be accurately completed until all of the adults have returned and all of the various marking programs have compiled their data. Because of these delays, reporting on the Brood Year Performance Goals is 7 years behind the actual Brood Year.

Table 3. LNFH production practices goals by life stage in 2016

Life Stage	Attribute	Current Practices and Goals
Adults	***collection***	Hatchery ladder
	ladder operation	Pulsed
	brood target	1000 for LNFH, additional 640 for Chief Joseph Hatchery
	prophylaxis	One antibiotic injection to brood females. Formalin treat ADHP
	Stock	Hatchery returns
	spawning	male:female = 1:1 (back up male)
	health monitoring	BKD 100% females, virology/bacteriology
	adult monitoring	Sex/age/length/Tag ID
	adult holding temperature	< 58^{o} F (14.4^{o}C)
	adult pre-spawn survival	88%
Eggs	***green egg target***	1,740,000 eggs
	prophylaxis	Disinfect, water harden, formalin treat
	incubation units	Heath trays
	water source	Well
	water quality monitoring	temperature, flow rates, and gases if suspect
	culling	15% by ELISA rank unless high number of moderate risk
	post culling egg total	>85% / 1,480,000 eggs
	shocking	Eggs pooled by rank / take and inventoried, 3500 eggs/tray

Table 3 continued. LNFH production practices goals by life stage in 2016

Fry	***rearing unit***	Starter tanks
	water source	Well, river water as emergency backup
	water quality monitoring	temperature and flow rates, dissolved gases when needed
	feed type	Bio Oregon Starter Feeds
	feeding frequency	6-8 times/day
	feed amount (%BW/Day)	1.0-2.0% BW/Day
	cleaning frequency	Daily
	monitoring	Weekly fish/pound counts, Monthly biometrics
Sub-yearlings	***rearing units***	8X80 raceways, 10x100's (covered) after CWT tagging
	water source	Well/river

	water quality monitoring	Temperature, dissolved gases when needed, & flow rates
	feed	Bio Oregon Feeds; Vita, Bio Pro 2, Bio Clarks Fry
	feeding frequency	4-6 times/day
	feed amount	1.0-2.0% BW/Day
	feed application	Hand
	cleaning frequency	1-3/week
	marking	17% CWT, 100% Adclip, inventory, 20K PIT's
	monitoring	Monthly fish health & biometrics, CWT & PIT retentions
Yearlings	***rearing units***	8X80's, 10X100's (covered), adult holding ponds
	water source	River/well/1 pass re-use in adult holding ponds when used for rearing
	water quality monitoring	Temp., dissolved gases when needed, & flow rates
	feed	BioVita
	feeding frequency	Variable: Daily to 3x/week
	feed amount (%BW/Day)	1.0-2.0% BW/Day
	feed application	Hand
	cleaning frequency	Brushed 1-2 times/ week
	monitoring	Monthly fish health & biometrics
	rearing parameters	Temp $<68^0$F $d0_2$ <80% saturation & 5ppm Turnover rate$\leq$ hour Density index $\leq$ 0.20 Flow index $\leq$ 0.60
	condition factor	1
	size	17 fish per pound
	early male maturation	< 20%
	release type	forced pumped
	release time	3rd week of April
	release goal	1,200,000
Survival Targets	***green egg to eyed egg survival***	$\geq$90% / 1,330,000 eggs
	eyed egg to fry survival	$\geq$95% / 1,260,000 fry
	green egg to smolt survival	81%
	fry to smolt survival	$\geq$95%
	outmigration survival	>50%
	smolt to adult survival	>0.40%
	hatchery return rate	>2.0

Release Year 2016

Environmental Conditions

In 2015, the Pacific Northwest was impacted by below average snowfall, early snowmelt and warmer than average air temperatures resulting the lowest snowpack in 67 years (data provided by Natural Resource Conservation Science). Icicle Creek flows were drastically reduced during early spring through late summer, resulting in the lowest flows since 2005 (the worst year on record). A peak flow of 1,560 cfs occurred on January 6th, 2015 and was substantially lower than the average annual peak flow of 2,070 cfs that typically occurs in early June (Figure 3). To exacerbate conditions, the eastern slopes of the cascades experienced two heat waves in June. Air temperature reached 103^{o}F on June 8th and 108^{o}F (44^{o}C) on June 28th in Wenatchee, WA. The average maximum air temperature for June is 90.5°F (OWSC, 2015). The recurring heat waves caused Icicle Creek temperatures to exceed 64°F (18°C) for eight consecutive days, reaching a maximum temperature on June 29th of 70°F (21°C). The near lethal temperatures in Icicle Creek prompted hatchery staff to release water a month early from the Snow Lakes reservoir. The cool water supplementation from Snow Creek helped reduce Icicle Creek temperatures by an average of 2.2°C (Fraser, 2015). By August, water levels in the shallow aquifer were dangerously low and approaching the groundwater well shut off level. In an effort to increase water levels in the shallow aquifer, LNFH staff initiated an emergency pump-back of effluent water into the hatchery canal. By using a temporary bladder dam, effluent water sufficiently filled the hatchery canal and provided enough head pressure to infiltrate the shallow aquifer successfully increasing the water level in the shallow aquifer. The ratio of pump back effluent to well discharge was estimated at 20:1 but sufficient to sustain the shallow aquifer and continue to provide well water production that would have otherwise have been lost.

A rain on snow event occurred in mid-November causing flows in Icicle Creek to increase from 300 cfs to 11,000 cfs in 24 hours (Figure 3). The high flows caused mud and debris to infiltrate the raceways, covering the bottoms with a thick layer of silt.

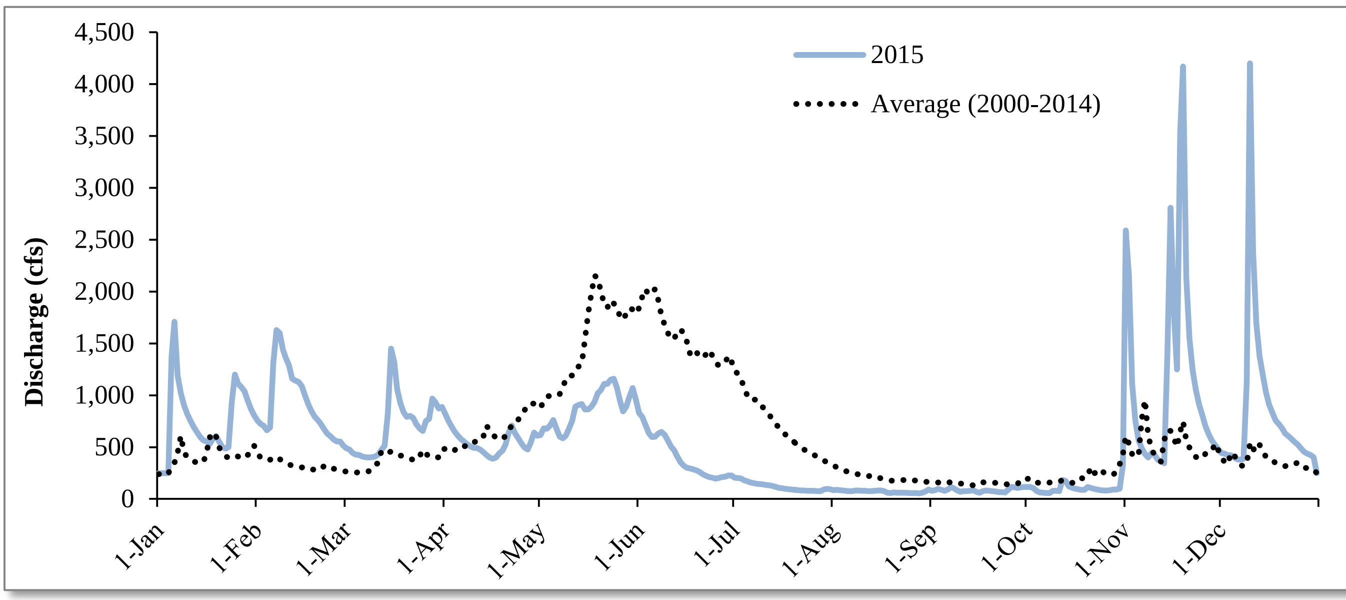

Figure 3. Mean daily flow (ft^3/s) of Icicle Creek, WA (U.S. Geological Survey gauge #12458000) for a 15 year period (2000–2014) and the primary rearing year 2015.

Juvenile Rearing

Spring Chinook Salmon smolts released in 2016 were derived from 2,391,794 eggs collected from adults that returned to LNFH in 2014. This was 138% above the green egg goal of 1,740,000. After culling, the green egg to eyed egg survival from the 2014 broodstock collection was 98% exceeding the performance goal of >90%. Juvenile rearing of this cohort began in December 2014, when 1,250,940 fry were placed into 123 starter tanks. This was 104% of the release number and within 1% of the fry ponding performance goal of 1,260,000. The highest mortality (55%) occurred when 1,084,156 eggs were culled due to Enzyme-Linked Immunosorbent Assay (ELISA) results. The ELISA tests are used to detect the prevalence of Bacterial Kidney Disease (BKD) from females used in propagation. ELISA's aid in determining the degree of risk for vertical transmission of BKD from mother to progeny (Tables 4, 15, and 16).

The abnormally high ELISA results in the 2014 broodstock were most likely attributed to multiple stress inducing events while being held in the adult holding ponds. Broodstock adults were exposed to a low dissolved oxygen event in early July causing a pre-spawn mortality event. Starting in mid-July, LNFH was the incident command post for the Chiwaukum Creek Complex Fires. By the end of the month, there were over 1,100 firefighters occupying the facility. Possible impacts to the adults included staging of mess hall and camp adjacent to the adult ponds. Fish were likely exposed to bright lights and vibrations from generators running 24 hours a day for approximately six weeks. As a consequence of high ELISA results throughout the broodstock, it was necessary to retain eggs that were of moderate risk of developing BKD to meet production goals.

Throughout the rearing cycle, the density of fish per rearing vessel, and the flow of water through the rearing vessel were monitored. Reduced densities and increased flow were desired as a disease risk reduction strategy; however this had to be balanced against rearing space and water availability. For the release year 2016 rearing cycle, the mean monthly Density Index (DI) and Flow Index (FI) was 0.11 and 0.42, respectively which met the performance goals (DI <0.2 &FI<0.6) for these categories (Table 4).

Piper et al. (1982) suggest calculating a Density Index (DI) as:

$$\frac{\text{Total weight of fish in pond (lbs.)}}{\text{(Mean length of fish (in.) x volume of vessel (cubic feet))}}$$

Likewise, a Flow Index (FI) is calculated as:

$$\frac{\text{Total weight of fish in pond (lbs.)}}{\text{(Mean length of fish (in.) x flow (gallons per minute))}}$$

In February 2015, the fry were moved from the nursery into 30 of the 8x80 raceways, each receiving approximately 26,000 fish. The raceways receive a mixture of well and river water, and approximately 50% of the fish receive second-pass reuse water due to limited water supply.

Marking and tagging was conducted using an AutoFish System® (Northwest Marine Technology, Inc, http://www.nmt.us/products/afs/afs.shtml). The automatic tagging trailers annually provide a census of the rearing group and provide the first inventory update since the eyed stage. Fish were 100% adipose clipped and CWT's were implanted into 200,632 fish in mid-May (Appendix B). The success of marking is maximized if the fish meet a critical size target (75-190 fish per pound, fpp) with limited covariance in size (<6.0% CV). At the time of marking and tagging the fish were 119 fpp with a CV of 5.0% which met tagging size criteria. This size helped achieve a post mark CWT retention rate of >99.8% (target >98%) based on a sample of 1,039 fish 30 days post-tagging. To reduce densities, the fish were split into 30-8x80 and 14-10x100 raceways after tagging.

The second highest mortality incident (15%) occurred in July when multiple raceways were culled due to epizootic levels of the parasite *Ichthyophthirius multifiliis* (Ich) and a secondary bacterial infection of columnaris, despite aggressive formalin treatment. Ich is a common parasite at LNFH and is naturally occurring in Icicle Creek. The infestation was likely caused by the presence of numerous adult spring Chinook above the LNFH water intake combined with unfavorable conditions in Icicle Creek.

In August, 255,000 of the healthiest fish were transferred off station to Chief Joseph Hatchery (CJH). CJH produces spring Chinook approximately 90 miles to the north-east of LNFH at the base of Chief Joseph Dam on the Columbia River. The transported fish were placed into one lined earthen pond at CJH. By transferring fish off station, water was redistributed to the remaining fish at LNFH as another method for combating Ich. The transferred fish were reared at CJH until October 6th, when they were returned to LNFH.

As part of the Fish Passage Centers' smolt monitoring program, PIT tags were implanted into 19,957 fish in late October (Table 5). PIT tag data are used to assess post-release metrics including: outmigration survival rates, outmigration travel times, in season abundance estimates for returning adults and adult migration timing. At the time of PIT tagging, the fish were 25 fpp, which was 12% smaller than the performance goal of 22 fpp for the end of October. Opportunistic shed tag recoveries and mortalities were removed from the dataset during rearing, however total tag loss due to sheds and predation is difficult to ascertain.

Due to limited rearing space at LNFH, fish from 15 of the 8x80 raceways were moved into two adult holding ponds to complete their rearing in January of 2016. In the days following the transfer of fish to the adult holding ponds, LNFH was notified by Washington Department of Fish and Wildlife (WDFW) smolt trapping crews that numerous adipose clipped fish were recovered in the trap. LNFH staff identified unsecure dam boards in the adult holding ponds as the route of escape. The exact number of fish released was difficult to determine. The number of fish accidentally released was reported as 48,900. However, using PIT tag expansions the number was estimated to be 72,600.

Table 4. Juvenile rearing performance for release year 2016.

Month	Life Stage	Production Inventory	Fish per Pound	% Mort	Total Survival %	Temp (°F) Ave [a]	Water Source[b]			Flow GPM[c]	Flow Index (lbs./in* GPM)[d]	Density Index (lbs./in*ft^3)[d]
							% Well	% River	% Reuse			
August	Egg	1,607,020	NA	NA	NA	46.8	100	0	0	135	NA	NA
September	Egg	2,391,794	NA	NA	NA	48.2	100	0	0	195	NA	NA
October	Egg (cull)	1,307,638	NA	54.7	NA	48.5	100	0	0	155	NA	NA
November	Sac Fry	1,258,312	NA	3.9	96.1	48.4	100	0	0	155	NA	NA
December	Fry	1,250,940	945	0.6	95.5	48.3	100	0	0	2,440	0.35	0.08
January	Fry	1,248,027	387	0.2	95.3	47.9	100	0	0	3,294	0.48	0.14

February	Fry	1,246,869	250	0.1	95.2	46.9	90	10	0	4,535	0.46	0.06
March	Fingerling	1,246,403	176	0.1	95.1	45.4	90	10	50	4,535	0.58	0.07
April	Fingerling	1,246,247	120	0.1	95.1	45.0	40	60	50	6,750	0.51	0.09
May	Fingerling	1,244,160	100	0.2	95.0	48.5	40	60	0	13,960	0.28	0.06
June	Fingerling	1,243,550	56	0.1	94.9	58.0	0	100	0	17,860	0.32	0.08
July	Fingerling	1,077,314	44	15.4	79.5	59.9	0	100	0	13,600	0.42	0.11
August[g]	Fingerling	822,121	41	0.6	78.9	56.9	0	100	0	15,750	0.29	0.10
September	Fingerling	820,248	30	0.2	78.6	52.7	0	100	0	15,750	0.36	0.13
October[h]	Fingerling	1,062,013	25	0.3	78.4	49.4	0	100	0	18,350	0.46	0.15
November	Yearling	1,059,795	24	0.2	78.2	38.8	0	100	0	18,350	0.46	0.15
December	Yearling	1,057,306	25	0.2	77.9	34.9	0	100	0	18,350	0.46	0.15
January	Yearling	960,875	25	0.2	77.7	34.5	0	100	0	18,600	0.41	0.13
February	Yearling	957,430	22	0.4	77.4	37.1	0	100	28	18,600	0.44	0.14
March	Yearling	950,978	21	0.7	76.7	39.6	0	100	28	18,600	0.45	0.14
April	Smolt	945,277	18	0.6	76.1	42.0	0	100	28	18,600	0.46	0.14

Unless otherwise indicated, all values are for end of the month totals or values obtained for the last ten days of the month and not daily averages for the month.
[a]N is corrected by automated counting at time of marking.
[b]Includes monthly picking. Does not include predation.
[c]Temperature data is electronically measured every two hours and averaged for the month.
[d]Data indicates approximate water source usage. Actual usage depends on a variety of factors including disease and maintaining water (through well water inclusion) temperatures to minimize the formation of slush ice in winter and not to exceed 68^0 during summer months.
[e]Estimated GPM used by brood including re-use.
[f]Calculated from values taken at the end of each month.
[g] Juvenile fish transferred to CJH
[h] Juvenile fish transferred to LNFH

Release

During the daylight hours of April 21st, 945,277 yearling spring Chinook smolts were force-released via a Heathro Fish Pump into Icicle Creek (Table 5). This was 79% of the targeted release number of 1,200,000. Upon release fish were 18.5 fish per pound, the mean fork length was 139mm with a CV of 10.6%.

Table 5. LNFH release dates, release numbers and tagging information for 2003–2016.

Release Year	Date Released	Total Released	# CWT	% CWT	% Adipose Clip	# PIT
2016[a]	Apr. 21	945,277	200,632	16	100	19,957
2015	Apr. 15	1,139,567	196,151	17	100	14,994
2014	Apr. 23	1,239,025	198,913	16	99	13,380
2013	Apr. 24	1,289,293	207,443	16	100	14,951
2012	Apr. 19	1,186,622	218,977	19	98	14,901
2011	Apr. 20	1,189,442	216,791	18	100	14,875

2010	Apr. 26	1,284,653	217,492	17	100	14,948
2009	Apr. 28	1,685,038	196,529	12	100	14,931
2008	Apr. 28	1,539,668	389,100	26	100	15,968
2007	Apr. 18	1,177,568	547,049	46	100	14,969
2006	Apr. 17	1,005,505	470,174	47	100	14,700
2005	Apr. 15	1,476,046	782,602	53	100	14,825
2004	Apr. 19	1,422,100	822,022	58	100	216,698
2003	Apr. 21	1,288,893	771,756	60	100	240,558

[a] accidental released occurred in January, 2016

Smolt Outmigration

Survival and travel time data are provided by the Fish Passage Center and PTAGIS using PIT tagged fish as representatives of the population. Survival and travel time of out-migrating smolts produced at LNFH is customarily measured at McNary Dam, as it is the first in-stream structure encountered with dedicated juvenile monitoring facilities. McNary Dam is located at rkm 470, roughly half way downstream from LNFH to the Pacific Ocean. Multiple juvenile monitoring facilities downstream of McNary Dam enable mark-recapture methodologies to derive survival estimates at McNary Dam.

In 2016 LNFH smolts arrived and passed McNary Dam in multiple peaks throughout early to mid-May on the descending limb of the hydrograph (Figure 4). For the 2016 smolt release, the average travel time to McNary Dam was 17.4 days (Table 6). This was the fastest travel time in 13 years of record (2003-2015) and is 9 days faster than the average of 26 days. The survival of this cohort to McNary Dam was estimated at 52% which meets the performance goal of >50% but is lower than the long term average of 57%. The 2016 LNFH survival is lower compared to the spring Chinook programs at Winthrop NFH on the Methow River and Chiwawa Rearing Ponds in the upper Wenatchee River. This lowered survival may be due to the challenging rearing conditions experienced at LNFH in 2015; however, the comparative survivals between these three facilities have been highly variable over the years suggesting a comparable hatchery effect (Figure 5). Outmigration metrics for the 2016 release year were likely influenced by the accidental early release of fish in January. Although 380 PIT tag codes were detected prior to the release date and subsequently removed from the smolt migration metrics, it is probable that several PIT tags went undetected until after release.

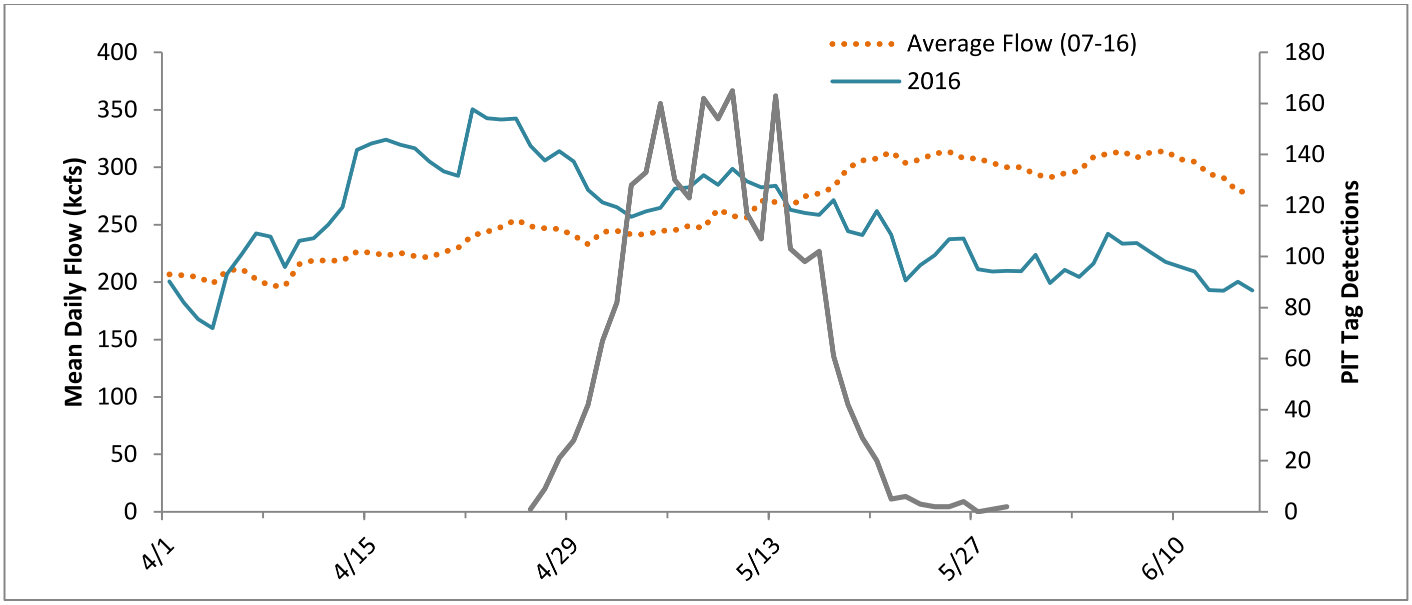

Figure 4. Daily passage of LNFH PIT tagged spring Chinook Salmon smolts compared to spill at McNary Dam in 2016.

Table 6. LNFH-origin spring Chinook Salmon smolt out-migration metrics, 2003–2016.

Release Year	Release Day	McNary Dam Mean Travel Time (Days)	Survival to McNary Dam	Confidence Limits (95%)	
2016[a]	Apr. 21	17.4	0.52	0.48	0.56
2015	Apr. 15	24.7	0.57	0.54	0.60
2014	Apr. 23	21.5	0.57	0.52	0.62
2013	Apr. 24	24.8	0.67	0.54	0.81
2012	Apr. 19	28.7	0.59	0.55	0.63
2011	Apr. 20	27.5	0.43	0.39	0.47
2010	Apr. 26	25.3	0.66	0.60	0.72
2009	Apr. 28	25.7	0.48	0.44	0.52
2008	Apr. 28	21.1	0.58	0.53	0.62
2007	Apr. 18	30.8	0.59	0.57	0.62
2006	Apr. 17	22.9	0.56	0.53	0.59
2005	Apr. 15	31.8	0.53	0.50	0.55
2004	Apr. 19	25.3	0.48	0.47	0.49
2003	Apr. 21	28.2	0.66	0.66	0.67
Mean (03–15)		**26.0**	**0.57**	**0.53**	**0.61**
St. Dev. (03–15)		**3.2**	**0.07**	**0.07**	**0.09**

[a] 380 PIT tags removed from Travel Time and Survival estimates

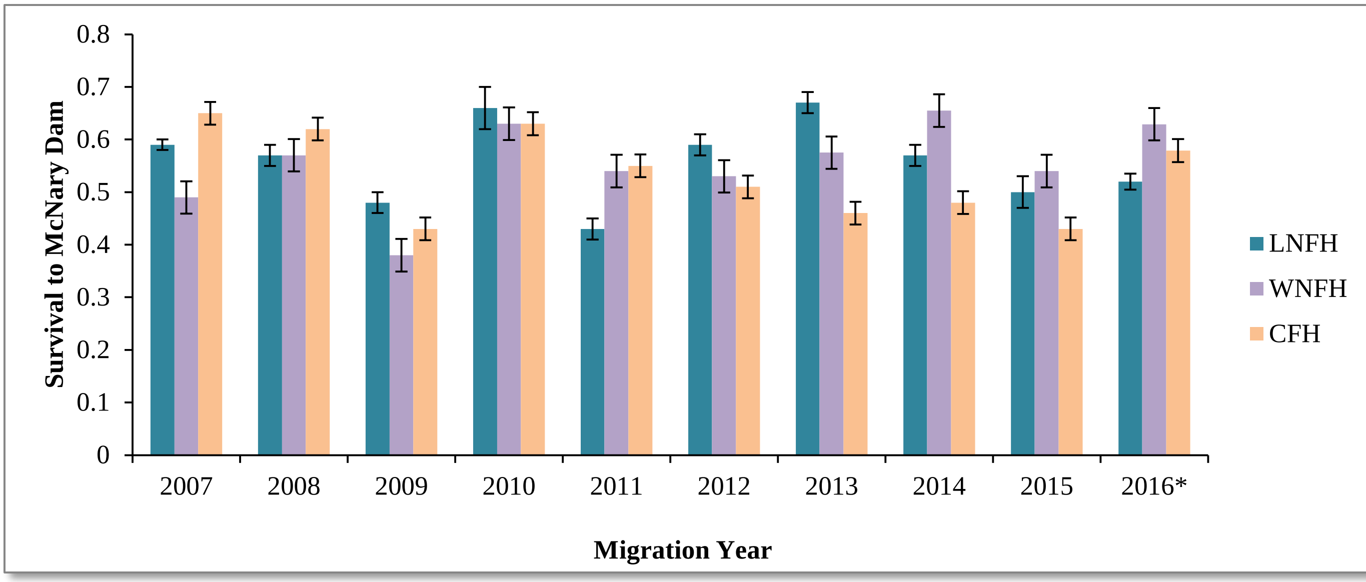

Figure 5. Upper Columbia River spring Chinook Salmon smolt survival (standard deviation) comparing LNFH with Winthrop National Fish Hatchery (WNFH) and Chiwawa Rearing Ponds (CRP), 2007–2016. *380 PIT tags removed from LNFH survival estimates based on accidental early release.

Early Maturation

Spring Chinook Salmon most commonly mature in the ocean (after outmigration) at age 3 or older. Early maturation of spring Chinook is defined as the complete development of primary sexual characteristics (gonads) and/or the expression of reproductive behavior before age 3. Commonly referred to as “precocial parr” or “minijacks” these fish are typically male. In a hatchery, these fish may initiate maturation prior to release and remain near the point of release, or they may start to migrate toward the ocean, then reverse course and travel upstream and attempt to spawn (Mullan et al. 1992, Beckman and Larsen 2005).

The proportion of minijacks produced in a cohort represents hatchery effort that results in non-harvestable fish. They may also pose a risk of straying and spawning with natural origin populations. Because minijacks are too small to be trapped effectively in the LNFH adult holding ponds they are often difficult to quantify or remove from the river system.

Research has shown that early male maturation may be induced through hatchery practices, particularly the promotion of rapid growth and high adiposity (Clark and Blackburn 1994; Silverstein et al. 1998; Beckman et al. 1999, 2000; Shearer and Swanson 2000; Larsen et al. 2004). LNFH attempts to minimize the occurrence of early maturation through dietary regulation and the minimal use of warm, growth-promoting well water in the winter.

Beckman and Larsen (2005) suggested estimating the occurrence of minijacks post-release by monitoring the upstream migration of PIT tagged juveniles (via PIT detections at dams) during the year of release. Within the 2016 release year cohort there were two PIT tagged fish that were detected at dams and displayed upstream migration through dams (Table 7). Using this method, the rate of early maturation for LNFH-origin fish is <1% for release years 2003–2016, and it should be noted that this method of determining early maturation is plagued by very low sample sizes, and does not account for non-migrating minijacks.

To accurately address NMFS BiOp Term and Condition 3d (Appendix A), the HE program implemented pre-release male early-maturation sampling using a Gonadosomatic Index (GSI) as described by Larsen, 2004. GSI is the proportion of gonad weight to the total weight of the fish and was calculated for all males held for the study. Juveniles were sampled 30 days post-release to allow more time for gonad development and easier separation of maturation levels. Of the 244 males that were sampled, 21(8.6%) were showing signs of precocity and this only occurred in larger juveniles (>130mm of fork length; Figure 6).

Table 7. Rate of early maturation (minijacks) of LNFH-origin fish by release year, 2003–2016

Release Year	Release Number	# PIT	PIT Ratio Non-Tag/Tag	Observed Minijacks	Expanded Minijacks[a]	Minijack Rate (%)
2016	945,277	19,957	53	2	106	0.01
2015	1,139,567	14,994	76	4	306	0.03
2014	1,239,025	13,380	93	13	1206	0.10
2013	1,289,293	14,951	87	13	1127	0.09
2012	1,186,622	14,901	80	9	718	0.06
2011	1,189,400	14,875	83	9	751	0.06
2010	1,284,653	14,948	86	41	3533	0.28
2009	1,685,038	14,931	113	21	2370	0.14
2008	1,539,668	15,968	96	36	3471	0.23
2007	1,177,568	14,969	79	15	1180	0.10
2006	1,005,505	14,700	68	2	137	0.01
2005	1,476,046	14,825	100	1	100	0.01
2004	1,422,100	216,698	7	22	144	0.01
2003	1,288,893	240,558	5	65	348	0.03

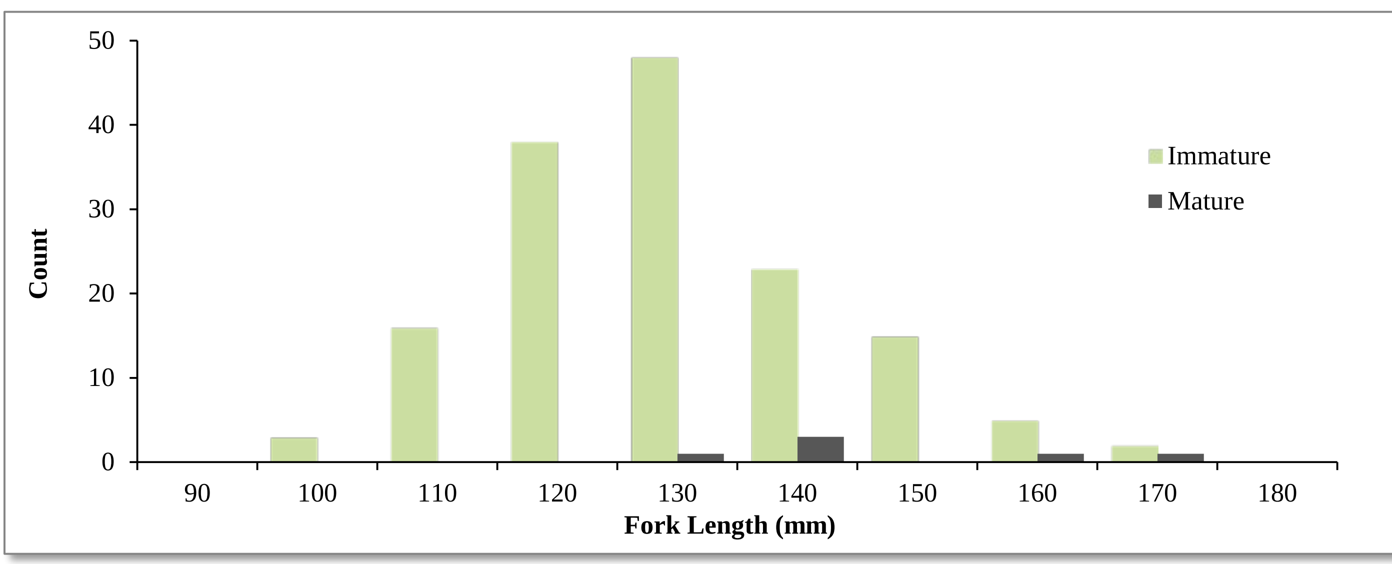

Figure 6. Precocity in sampled males by fork length, binned to the tenth mm, at LNFH, 30 days post-release.

Adult Return 2016

Run Timing

Returning LNFH-origin spring Chinook were first detected at the Bonneville Dam PIT tag antenna arrays on April 2nd with the 50% passage date occurring on April 30th.The returning adults rapidly passed upstream of Bonneville Dam reaching the 90% passage date on May 15th, a month earlier than the 13 year mean (Table 8). The detection efficiency of the PIT tag antenna arrays at Bonneville Dam are reported to be greater than 90% (Burke et al 2006). The 100% passage estimate over Bonneville Dam was July 10th. Adults took an average of 15 days to travel from Bonneville Dam to Rock Island Dam in 2016, which was 3 days faster than the recent five year average of 17 days (Figure 7). The average travel time of LNFH-origin adults from Rock Island Dam to the Lower Icicle Creek instream PIT tag antenna array was 12 days in 2016. This was slightly faster than the average (18 days) for the previous four years.

In 2016, an estimated 5,224 spring Chinook returned to Icicle Creek. In-basin estimates were generated from WDFW creel surveys, tribal harvest estimates, spawning ground surveys, and LNFH adult holding pond counts. The 2016 adult return was 86% of the average return for the previous 12 years (Table 9).

Table 8. Passage dates for LNFH-origin spring Chinook Salmon at Bonneville Dam, 2003–2016.

	Passage Dates								
Year	**First Passage Date**	**5% Passage Date**	**10% Passage Date**	**25% Passage Date**	**50% Passage Date**	**75% Passage Date**	**90% Passage Date**	**95% Passage Date**	**Last Passage Date**
2016	2-Apr	16-Apr	21-Apr	27-Apr	30-Apr	7-May	15-May	24-May	10-Jul
2015	9-Apr	12-Apr	16-Apr	20-Apr	28-Apr	9-May	25-May	27-Jun	27-Aug
2014	7-Apr	18-Apr	20-Apr	25-Apr	30-Apr	7-May	25-Jun	10-Jul	8-Aug
2013	5-Mar	23-Apr	25-Apr	29-Apr	6-May	24-Jun	7-Jul	18-Jul	4-Aug
2012	7-Apr	20-Apr	23-Apr	2-May	8-May	14-May	4-Jul	6-Jul	17-Jul
2011	20-Apr	26-Apr	28-Apr	3-May	9-May	18-May	6-Jul	15-Jul	27-Jul
2010	29-Mar	13-Apr	15-Apr	21-Apr	28-Apr	6-May	3-Jul	11-Jul	19-Jul
2009	22-Apr	24-Apr	26-Apr	2-May	8-May	16-May	28-Jun	9-Jul	17-Jul
2008	2-Mar	15-Apr	19-Apr	27-Apr	11-May	5-Jul	14-Jul	17-Jul	1-Aug
2007	12-Apr	13-Apr	15-Apr	19-Apr	26-Apr	9-May	21-Jun	29-Jun	19-Jul
2006	21-Feb	26-Apr	30-Apr	4-May	8-May	11-May	15-May	20-May	2-Jul
2005	11-Apr	20-Apr	22-Apr	25-Apr	28-Apr	4-May	11-May	16-May	19-Jul
2004	24-Mar	13-Apr	15-Apr	18-Apr	22-Apr	30-Apr	6-May	12-May	15-Jul
2003	2-Mar	18-Mar	28-Mar	10-Apr	7-May	27-Jun	11-Jul	16-Jul	13-Aug
Min	21-Feb	18-Mar	28-Mar	10-Apr	22-Apr	30-Apr	6-May	12-May	2-Jul
Max	22-Apr	26-Apr	30-Apr	4-May	11-May	5-Jul	14-Jul	18-Jul	27-Aug
Mean (03-15)	28-Mar	16-Apr	19-Apr	25-Apr	2-May	20-May	15-Jun	24-Jun	25-Jul

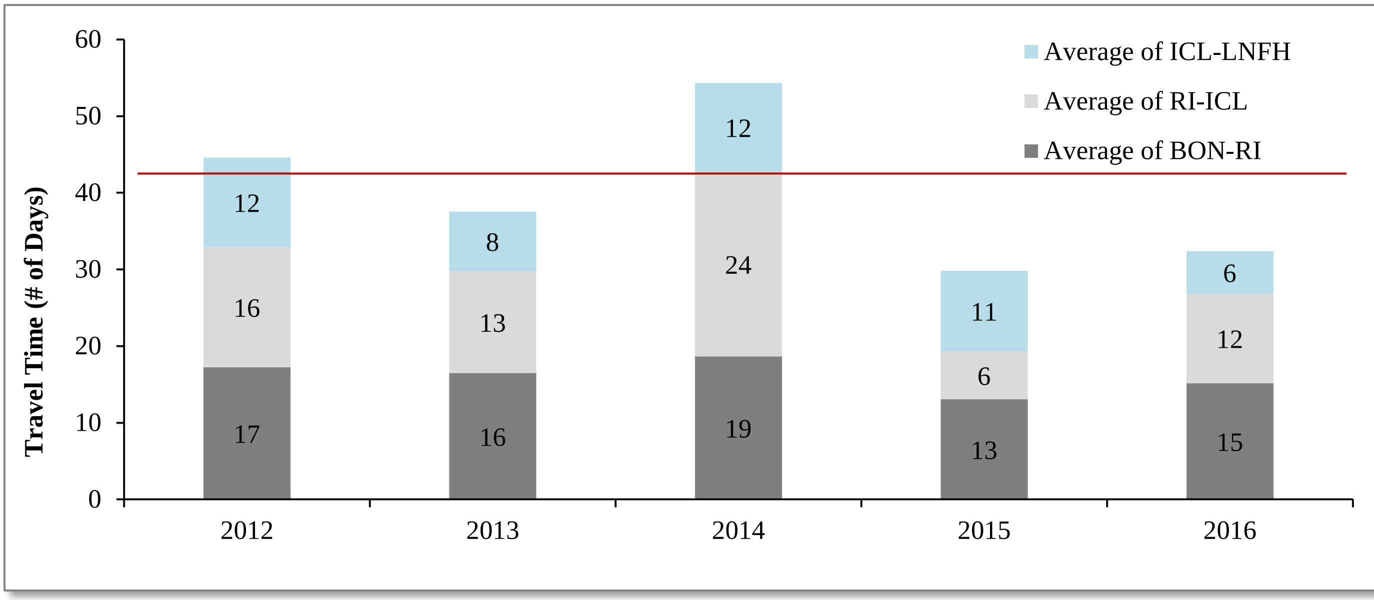

Figure 7. Travel time of adult LNFH-origin spring Chinook Salmon returns from Bonneville to Rock Island Dam (BON -RI), Rock Island Dam to the Lower Icicle array (RI-ICL) and the Lower Icicle Array to LNFH (ICL-LNFH). The average number of days is given for each reach in the data bars, with red line indicating mean travel time between BON to LNFH from 2004–2015.

Fish Ladder Operation

The fish ladder at LNFH was opened on May 6th. Throughout the 2016 return the fish ladder was opened and closed intermittently to capture portions of the run, minimize strays, and to maximize catch opportunity by sport and tribal harvest fisheries (Figure 9). During this time, 3,241 spring Chinook adults ascended the fish ladder and entered the adult holding pond (Table 10). This is 80% of the 13 year average of 4,059 fish. The fish ladder was closed for the season on July 12th.

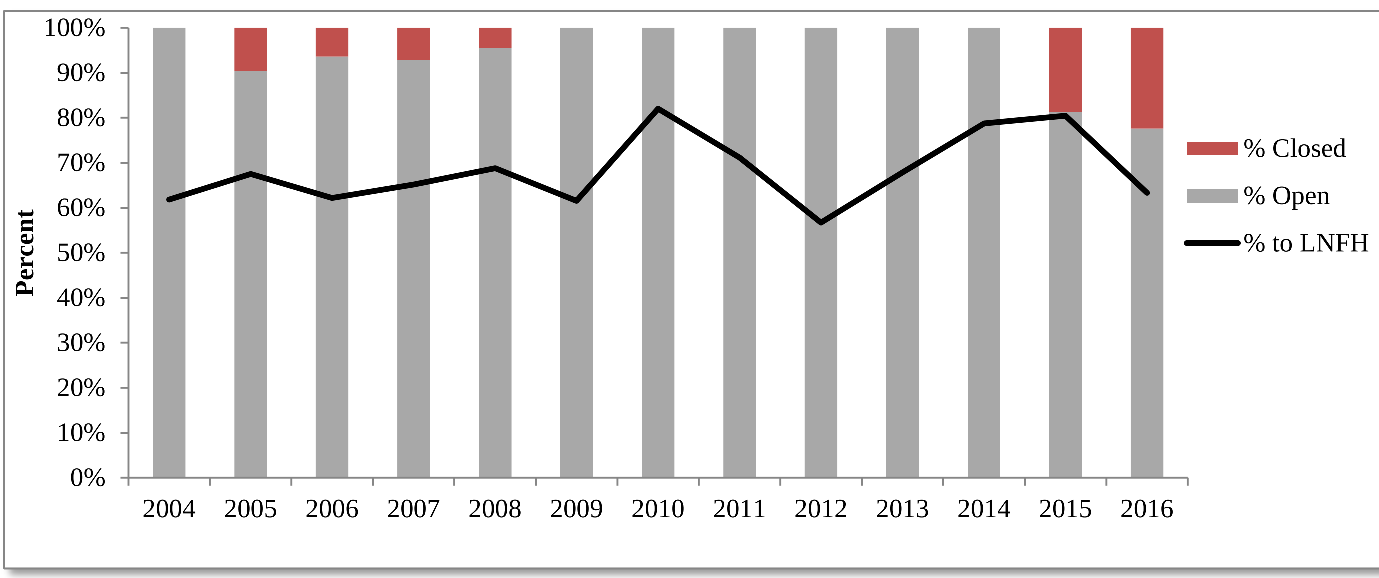

Figure 8. LNFH fish ladder operations and percent of the Icicle Creek returning spring Chinook Salmon trapped in LNFH adult holding pond.

Harvest

Spring Chinook Salmon were subject to 76 days of a mark selective (i.e. adipose clip) sport fishery in the Wenatchee River and Icicle Creek. Washington Department of Fish and Wildlife (WDFW) creel census of Icicle Creek estimated the sport fishery harvested 303 LNFH-origin spring Chinook in 2016 which is 60% of the 2004-2015 average of 505(Table 9, T. Maitland pers. comm.).

Table 9. Sport fishery harvest and creel estimates targeting Leavenworth NFH spring Chinook in Icicle Creek and/or Wenatchee River, 2004 – 2016.

Year	Season	# Anglers	Hours Fished	Fish Caught	Run Size	% Sport Harvest	CPUE	Hours/Fish
2016	May 16 - July 31	1,377	7,939	303	5,224	5.9%	0.0382	26.2
2015	May 20 - July 31	990	5,064	433	6,990	6.2%	0.0855	11.7
2014	May 23 - July 31	1,587	7,299	390	4,765	8.2%	0.0534	18.7
2013	May 18 - July 31	1,979	9,644	323	2,403	13.4%	0.0335	29.9
2012	May 19 - July 31	4,922	21,492	971	4,720	20.6%	0.0452	22.1
2011	May 21 - July 31	5,229	25,934	873	5,844	14.9%	0.0337	29.7
2010	May 13 - July 31	5,231	23,549	993	12,303	8.1%	0.0422	23.7
2009	May 22 - July 31	1,530	8,235	640	4,790	13.4%	0.0777	12.9
2008	May 28 - July 31	1,147	7,144	347	4,995	6.9%	0.0486	20.6
2007	May 22 - July 31	1,058	7,754	115	2,622	4.4%	0.0148	67.4
2006	May 26 - July 31	2,402	13,553	529	3,147	16.8%	0.0390	25.6
2005	May 28 - July 31	1,108	8,131	103	3,793	2.7%	0.0127	78.9
2004	May 16 - July 31	1,339	9,187	347	3,732	9.3%	0.0378	26.5
	Min	990	5,064	103	2,403	2.7%	0.0127	11.7
	Max	5,231	25,934	993	12,303	20.6%	0.0855	78.9
	Mean (04 – 15)	2,619	13,764	505	6,375	10.7%	0.0532	27.9

Additionally, Icicle Creek spring Chinook were subjected to a 78 day tribal harvest. Tribal harvest estimates were calculated using a linear regression of sport harvest to tribal harvest from 1999–2008. Using this methodology, it was estimated the tribal fishery harvested 1,550 fish from Icicle Creek in 2016 which is 61% above the 2004-2015 average of 964 (Table 10).

Table 10. Abundance and fate of LNFH-origin adult spring Chinook Salmon returning to Icicle Creek from 2003–2016.

Return Year	Total Run to Icicle Cr.	Returned to LNFH	Sport Harvest	Tribal [a]	Remaining in River
2016	5,224	3,241	303	1,550	130
2015	8,149	6,557	433	908	251
2014	6,005	4,729	390	818	422
2013	3,309	2,245	323	678	214
2012	7,074	4,013	971	2,036	318
2011	6,990	4,970	873	805	342
2010	13,862	11,366	993	1,314	248
2009	4,977	3,062	640	910	195
2008	4,692	3,229	347	833	283
2007	2,622	1,708	115	751	48
2006	3,147	1,957	529	588	73
2005	3,793	2,560	103	1,063	67
2004	3,732	2,307	347	863	214
Min	2,622	1,708	103	588	48
Max	13,862	11,307	993	2,036	422
Mean (04–15)	5,664	3,945	505	964	223

[a] Estimated tribal harvest, 2009-present

Tumwater Dam Stray Removal

Within the Wenatchee River basin, nearly all natural spawning of spring Chinook occurs in the upper basin, upstream of Tumwater Dam (Figure 1). While the structure is not used for power production, the WDFW use it as an interception point for spring Chinook attempting to enter the upper basin spawning grounds.

In 2009, LNFH partnered with WDFW to remove potential stray LNFH-origin and other non-target hatchery adults attempting to migrate above Tumwater Dam. Presumed LNFH-origin adults were identified for removal at Tumwater Dam if the fish was adipose clipped and did not have a CWT. Each year approximately 80% of LNFH-origin returning adults are adipose clipped without a CWT. In 2016, 39 presumably LNFH-origin, spring Chinook were removed at Tumwater Dam, euthanized and discarded. Due to treatment with MS-222 (anesthesia), the removed fish were not suitable for consumption.

Contribution of LNFH-origin spring Chinook to the upper Wenatchee River basin spawning population was evaluated using CWT recoveries expanded by the estimated recovery rate (number of carcass recovered/estimated spawning escapement) and by the percentage of marked fish representing each CWT release group. This methodology is conservative as the expanded recovery estimate does not take into account the removal of potential LNFH untagged adults at Tumwater Dam. In 2016, no LNFH-origin coded wire tags were identified on the spawning grounds in the upper Wenatchee River meeting NMFS BiOp Term and Condition 1a (Table 11, Appendix A).

Although adipose clipped, non-CWT fish removed at Tumwater Dam are presumed to be LNFH-origin, the fish could have originated from the upper Wenatchee River spring Chinook acclimation programs. For example, the CRP program had an average CWT shed rate of 1.6% for brood years 2011-2014. Further analysis of the proportion of these fish within the returning population is needed.

Table 11. Escapement abundance of spring Chinook Salmon to the upper Wenatchee River, sampling rates, and LNFH-origin fish data and expansions 2004–2016.

Return Year	Upper Wenatchee SCS Escapement[a]	Upper Wenatchee SCS Carcass Recoveries[a]	Percent Carcasses Sampled[b]	LNFH-origin CWT Recoveries[c]	LNFH-origin Estimated Recoveries[d]	LNFH-origin Expanded Recoveries[e,f]	Percent LNFH-origin in Upper Wenatchee SCS Escapement[g]
2016	879	337	38.3%	0	0	0	0.0%
2015	1,293	380	29.4%	*1*	4	20	1.5%
2014	1,389	430	31.0%	0	0	0	0.0%
2013	2,022	588	29.1%	0	0	0	0.0%
2012	2,436	792	32.5%	0	0	0	0.0%
2011	2,990	290	9.7%	0	0	0	0.0%
2010	1,761	382	21.7%	2	9	20	1.1%
2009	2,195	409	18.6%	2	11	17	0.8%
2008	2,141	765	35.7%	5	14	42	2.0%
2007	2,007	517	25.8%	0	0	0	0.0%
2006	940	484	51.5%	2	4	6	0.6%
2005	1,472	828	56.3%	2	4	4	0.3%
2004	1,607	407	25.3%	5	17	51	3.2%
Min	940	290	9.7%	0	0	0	0.0%
Max	2,990	828	56.3%	5	17	51	3.2%
Mean (04–15)	1,854	523	30.5%	2	5	13	0.8%

[a] From CCPUD M&E report (Hillman et al 2017)
[b] Upper Wenatchee SCS Carcass Recoveries/Upper Wenatchee SCS Escapement
[c] From RMIS
[d] LNFH-origin CWT Recoveries/Percent Carcasses Sampled
[e] LNFH-origin Estimated Recoveries/CWT rate (CWT rate not shown)
[f] This estimate should be considered a maximum impact as this does not include removal of adipose-clipped, non-CWT'd SCS removals at Tumwater Dam from 2009-2016.
[g] LNFH-origin Expanded Recoveries/ Upper Wenatchee SCS Escapement

Hatchery Returns

Of the 3,241 adults that returned to the LNFH holding pond 411 (13%) were randomly sampled to determine population characteristics. In addition to the random sample all fish were scanned for the presence of a PIT tag and CWT. Those with a positive detection of a tag were also sampled and used for population biometrics. If a CWT was detected, the snout was collected and age verified using tag information reported to RMIS. Age composition for LNFH-origin returns was based on 388 CWT recoveries. The age analysis resulted in 0.8% age-2 (n=2), 4% age-3 fish (n=16), 83.1% age-4 (n=322), and 12.1% (n=48) age-5 (Table 12). The age-4 component of this run was above average for the past 12 years, and the age-5 returns were below average. Age-3 females were not observed in 2016. The male-female ratio of returns was 0.8, with fewer males having returned than females (Table 13).

Fork lengths for returning adult male spring Chinook were within the standard deviation for all age classes with mean fork lengths of 52.5cm for age-3, 76.2cm for age-4 and 92.9cm for age-5. Age-4 females were within the standard deviation with a mean fork length of 72.6cm, while age-5 females returned slightly smaller than average with a mean fork length of 83.3cm (Table 14).

Of the 396 CWT's that were recovered, eight were out-of-basin hatchery spring Chinook (Table 15). All out-of-basin recoveries were of age-4 with the exception of an age-2 from the Methow Hatchery. All out-of-basin recoveries were surplused to regional tribes. The fate of all out-of-basin recoveries fell within the guidelines of the NMFS BiOp Terms and Conditions 1b (Appendix A).

Table 12. LNFH-origin spring Chinook Salmon age compositions by sex and return year, 2003–2016.

Return Year	% MALE AGE				% FEMALE AGE			% COMBINED AGE			
	2	3	4	5	3	4	5	2	3	4	5
2016	0.8	4.0	34.3	6.3	0.0	48.7	5.8	0.8	4.0	83.1	12.1
2015	0.1	9.0	35.8	2.1	0.1	50.0	2.9	0.1	9.1	85.8	5.0
2014	1.8	15.5	31.8	0.7	0.1	48.2	1.9	1.8	15.6	80.0	2.6
2013	3.8	18.2	19.0	9.4	0.2	35.9	13.5	3.8	18.4	54.9	22.9
2012	0.1	1.4	31.7	4.4	0.1	56.0	6.3	0.1	1.5	87.7	10.7
2011	0.9	34.8	14.3	11.6	0.1	23.2	15.1	0.9	34.9	37.5	26.7
2010	0.0	0.9	36.9	0.7	0.0	60.7	0.7	0.0	0.9	97.7	1.4
2009	0.0	24.3	25.2	5.6	0.1	37.9	6.9	0.0	24.4	63.2	12.4
2008	0.0	3.3	31.4	8.7	0.0	47.5	9.1	0.0	3.3	78.9	17.8
2007	0.0	19.9	16.2	12.4	0.2	40.8	10.5	0.0	20.1	57.1	22.9
2006	0.0	0.7	31.9	8.4	0.0	51.2	7.7	0.0	0.7	83.2	16.1
2005	0.0	2.5	34.8	2.7	0.0	57.1	3.0	0.0	2.5	91.9	5.6
2004	0.5	9.5	32.6	3.5	0.1	49.2	4.5	0.5	9.6	81.9	8.0
2003	0.5	3.1	8.2	37.7	0.0	9.0	41.5	0.5	3.1	17.2	79.2
Min	0.0	0.7	14.3	0.7	0.0	23.2	0.7	0.0	0.7	37.5	1.4
Max	3.8	34.8	36.9	37.7	0.2	60.7	41.5	3.8	34.9	97.7	79.2
Mean (03–15)	0.6	11	26.9	8.3	0.1	43.6	9.5	0.6	11.1	70.5	17.8

Table 13. Sex composition of sampled spring Chinook Salmon returning to LNFH, 2006–2016.

Return Year	% of Return Sampled	# Males	# Females	Male/Female Ratio
2016	12.7	174	214	0.8
2015	17.5	510	583	0.9
2014	23.7	498	536	0.9
2013	27.6	309	290	1.1
2012	35.2	471	779	0.6
2011	34.6	863	538	1.6
2010	11.8	409	733	0.6
2009	96.0	563	461	1.2
2008	97.9	1,380	1,779	0.8
2007	35.2	259	286	0.9
2006	31.6	227	334	0.7
Min	11.80	174	214	0.6
Max	97.89	1,380	1,779	1.6
Mean (06–15)	41.10	548.90	631.90	0.92

Table 14. LNFH spring Chinook Salmon mean fork length (cm) by age, sex, and return year, 2003–2016.

Return Year	Males			Females		
	age-3	age-4	age-5	age-3	age-4	age-5
2016	52.5	76.2	92.9		72.6	83.3

2015	52.4	75.9	90.0	72.0[a]	73.6	85.0
2014	50.6	79.2	88.7	56.0	74.0	83.6
2013	51.8	76.3	91.4	70.0	72.3	84.1
2012	50.5	75.3	93.3	61.0	71.9	84.9
2011	51.0	77.1	93.3	74.5[a]	74.0	86.7
2010	49.8	79.3	94.1		74.7	86.3
2009	53.1	79.2	93.2	62.0	75.4	87.4
2008	53.9	78.7	95.5		75.3	87.5
2007	52.8	79.6	93.6		75.1	85.9
2006	47.3	78.8	92.2		72.7	84.5
2005	52.9	78.7	92.8		74.7	84.3
2004	51.5	76.0	94.9		72.5	87.3
2003	52.8	78.0	97.0		75.9	89.5
Mean (03–15)	51.6	77.7	93.1	62.3	73.9	85.7
St. Dev. (03–15)	1.7	1.5	2.1	5.8	1.3	1.8

[a] *n=1*

Table 15. Fate of non-LNFH-origin fish that entered the LNFH adult holding pond in 2016.

CWT/Origin	# Observed	Age	% Tagged	Fate	Origin	Expanded #	Conservation Program
636577	1	4	97	Surplused	Chiwawa Rearing Pond	1	ESA
636485	1	4	98	Surplused	Chiwawa Rearing Pond	1	ESA
636757	1	2	98	Surplused	Methow Hatchery	1	ESA
100246	1	4	85	Surplused	Clearwater Hatchery	1	None
220134	1	4	100	Surplused	Nez Perce Tribal Hatchery	1	None
220130	1	4	100	Surplused	Nez Perce Tribal Hatchery	1	None
090719	2	4	99	Surplused	Umatilla Hatchery	2	None

Broodstock

Of 3,241 spring Chinook Salmon that returned to the hatchery, 640 were transferred to Chief Joseph Hatchery for broodstock, regional tribes received 1,527 surplus fish, 52 fish died while being held in the adult holding pond (DIP), 20 were green, bad, or spent, and 1,002 were spawned (Table 16).

In late July, 500 females were given a single injection of Draxxin to reduce the transmission of BKD vertically from infected females to eggs. To minimize pre-spawn mortality of adults, daily formalin treatments were administered for one hour a day at 167 ppm to the adult holding ponds to control fungus and parasites.

In 2016, LNFH spawned 1,002 of the 1,145 fish held for broodstock resulting in 88% broodstock utilization, which met the utilization target (Table 3). Fish were determined to be "held for broodstock" if they remained in the adult holding ponds after the last excessing event. There were 510 females and 605 adult males available at the time of spawning. Of fish available for spawning ten females and ten males were not used because they were either green (not ready), spent (no milt remaining), or poor condition. The remaining males were not utilized for production. The targeted male:female spawning ratio is 1:1, with a backup male used in the event the primary male was infertile. The average fecundity between the two takes was 3,840 eggs (Table 18). The green egg take of 1,921,935 was 10% above the performance goal of 1,740,000 (Table 3).

Portions of the returning adults were tested for pathogens, including: Viral Hemorrhagic Septiciemia Virus (VHSV), Infectious Pancreatic Necrosis Virus (IPNV), and Infectious Hematopoietic Necrosis Virus (IHNV). Pathogen profiles for the broodstock used for production were supplied by Olympia Fish Health Center, USFWS. Sampling protocols included testing all females for the presence and relative abundance of *R. salmoninarum*. Additionally, bacteriology and virology testing were performed on kidney/spleen samples from 60 fish and virology testing was conducted on ovarian fluid from 60 females.

Table 16. Fate of spring Chinook Salmon that entered the adult holding ponds at LNFH, 2004–2016.

Return Year	Total Returns to LNFH	DIPS	Excessed	Spawned	Green/ Spent/ Bad	Transfers
2016	3,241	52	1,527	1,002	20	640
2015	6,565	124	4,838	955	8	640
2014	4,729	122	2,801	1,101	65	640
2013	2,082	227	666	767	0	422
2012	4,009	42	2,931	1,036	0	0
2011	4,970	112	3,932	926	0	0
2010	11,297	104	10,250	729	214	0
2009	3,053	109	2,178	714	52	0
2008	3,226	64	2,189	968	5	0
2007	1,708	41	712	955	0	0
2006	1,757	99	677	981	0	0
2005	2,491	8	1,807	676	0	0
2004	1,946	34	924	987	1	0
Min	1,708	8	666	676	0	0
Max	11,297	227	10,250	1,101	214	640
Mean (04–15)	3,929	87	2,726	907	28	

Virology and ELISA Results

For salmonids, the Olympia Fish Health Center categorizes BKD risk from ELISA optical density (OD) values into six levels, ranging from “No Detection” to “Very High” risk (Table 17). In 2016, over 93% of the females were in the “Very Low” and “Low” risk levels. At the time of spawning, the eggs from each female were held in separate trays. When the ELISA results were complete, “Moderate”, “High” and “Very High” risk groups were culled. On average approximately 18% of the tested spring Chinook females rank moderate or higher. However, the long term average was greatly increased due a high proportion of moderate risk detections from 2010-2014.

Table 17. Summary of BKD detection from female spring Chinook Salmon at LNFH, 2004–2016.

Year	No Detection (%)	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	N
2016	0.6	5.8	86.6	3.6	0.6	2.8	500
2015	0	11.6	81.9	3.4	1.5	1.7	476

2014	0	0	30.6	42.8	19.4	7.2	572
2013	0	0.2	60.3	35.5	2.7	1.2	408
2012	0	1	77.7	19.6	1	0.8	520
2011	0	2.2	74.7	19.2	1.7	2.2	463
2010	0	0.7	75.9	21.6	1	0.7	402
2009	0	31.8	64.7	2.1	0.3	1.1	380
2008	0	46.7	50.3	0.8	0.2	1.9	473
2007	0	26.2	69	1.9	0.8	2.1	523
2006	0	14.8	74.6	6.8	0.9	2.9	547
2005	0.3	77.7	17.2	1.2	1.2	2.4	337
2004	15.2	74.1	4.3	0.4	1.2	4.9	494
Min	0	0	4.3	0.4	0.2	0.7	337
Max	15.2	77.7	86.6	42.8	19.4	7.2	572
Mean (04-15)	1.3	23.9	56.8	12.9	2.7	2.4	466

Egg Survival

In 2016, 98.4% of the green eggs survived to eye-up, meeting the stage survival target of >90% (Table 18). The percentage does not include the 547,544 culled eggs, of which 133,770 eggs were culled as a result of ELISA testing. The 29% culling rate was 91% higher than the 15% performance goal for this category. In December, the emergent fry were placed in the indoor starter tanks to begin the rearing cycle.

Table 18. Eyed egg survival for LNFH spring Chinook Salmon for return years 2006–2016.

Return Year	Fecundity	Green Eggs	Bad Eggs	Culled[a]	Eyed Eggs Kept	% Eyed Survival
2016	3,840	1,921,935[b]	31,250	547,544	1,335,641	98.4
2015	4,104	1,953,690[b]	41,400	600,636	1,301,654	97.4
2014	3,960	2,391,794	39,988	1,084,156	1,307,638	100.0
2013	3,909	1,557,224	123,802	260,528	1,172,894	92.0
2012	3,656	1,857,748	58,748	504,000	1,295,000	96.8
2011	3,993	1,809,216	74,257	428,609	1,306,350	95.9
2010	4,109	1,651,881	46,416	385,597	1,219,868	97.2
2009	4,252	1,620,733	25,635	326,349	1,268,749	98.4
2008[c]	3,980	1,949,442	20,910	652,857	1,275,675	98.9
2007	3,546	2,125,339	36,755	377,454	1,711,130	98.3
2006	3,766	1,845,443	68,090	199,388	1,577,965	96.3
Min	3,546	1,557,224	20,910	199,388	1,172,894	92
Max	4,252	2,391,794	123,802	1,084,156	1,711,130	100
Mean (06–15)	3,928	1,867,647	53,600	481,957	1,343,692	97

[a] Includes ELISA culling
[b] Shipped 10,000 eggs to Pacific Northwest National Laboratory
[c] Beginning in return year 2008, the release number goal was reduced to 1,200,000.

Brood Year 2010

Analysis of Brood Year performance is delayed by several factors: It will take at least five years for a Brood Year cohort to return as adults. Additionally, it may take several more years for CWT recoveries to be reported. Given these delays, the Brood Year analysis herein uses Brood Year 2010 as the most recent cohort for which reasonably complete data is available. All Brood Year data is subject to change as more CWT recoveries are reported.

2010 Adult Return Recap

The 2010 Brood Year was produced from the largest adult return to LNFH in the recent history of the facility. The hatchery captured 11,307 adults in 2010. LNFH kept 402 females for production, yielding a green egg take of 1,651,881 and an average fecundity of 4,109 eggs per female. The green egg take was below the estimated 1,740,000 needed to meet the release goal of 1,200,000.

Many of the Adult Return/Broodstock metrics for the 2010 Brood Year fell in the "average" category. Broodstock Utilization, 50% spawn date, and size were all on par for this program. The 2010 adult return sex ratio was skewed towards females with a male to female ratio of 0.6/1. In addition to the skewed sex ratio, the 2010 Brood Year was the first year in a series of years to observe elevated ELISA results, with 92 (23%) of the spawned females ranking moderate or higher. With no other major mortality events, Brood Year 2010 ultimately released 1,186,622 smolts into Icicle Creek on April 19, 2012. The release number was slightly below the performance goal of 1.2M due to the culling of 385,597 eggs as a result of high ELISA results.

Brood Year 2010 Performance

Population Cohort- A Smolt-to-Adult Return (SAR) is the primary metric for evaluating hatchery program performance for a Brood Year. SAR is the number of adults that are produced from a single release of juveniles. The HE program calculates SAR by compiling LNFH-origin spring Chinook return data by age from a variety of data sources, including hatchery returns, harvest creels, and spawning ground surveys.

Spring Chinook from Brood Year 2010, returned as adults from 2013-2015 and had an SAR of 0.57% meeting the performance goal of >0.40% but slightly below the 15 year average of 0.60% (Figure 9). Annual variation in LNFH's SAR may be explained by LNFH specific factors such as on-site rearing metrics or off-site metrics common among hatchery programs in the region such as ocean or river conditions. To assess whether on-site of off-site metrics caused annual SAR variation we compared LNFH SARs to the Chiwawa Rearing Pond (CRP) in the upper Wenatchee River basin and WNFH in the Methow River Basin (Figure 10). Intra-hatchery variables could be any of the rearing parameters that occur on-site.

Similar to LNFH, annual variation in SARs occurred at CRP and WNFH from 2002–2010 suggesting that external hatchery conditions influenced all three programs similarly. For example, in 2005 the SARs were low for all three programs followed by large increases for all three programs in 2006 (Figure 10).

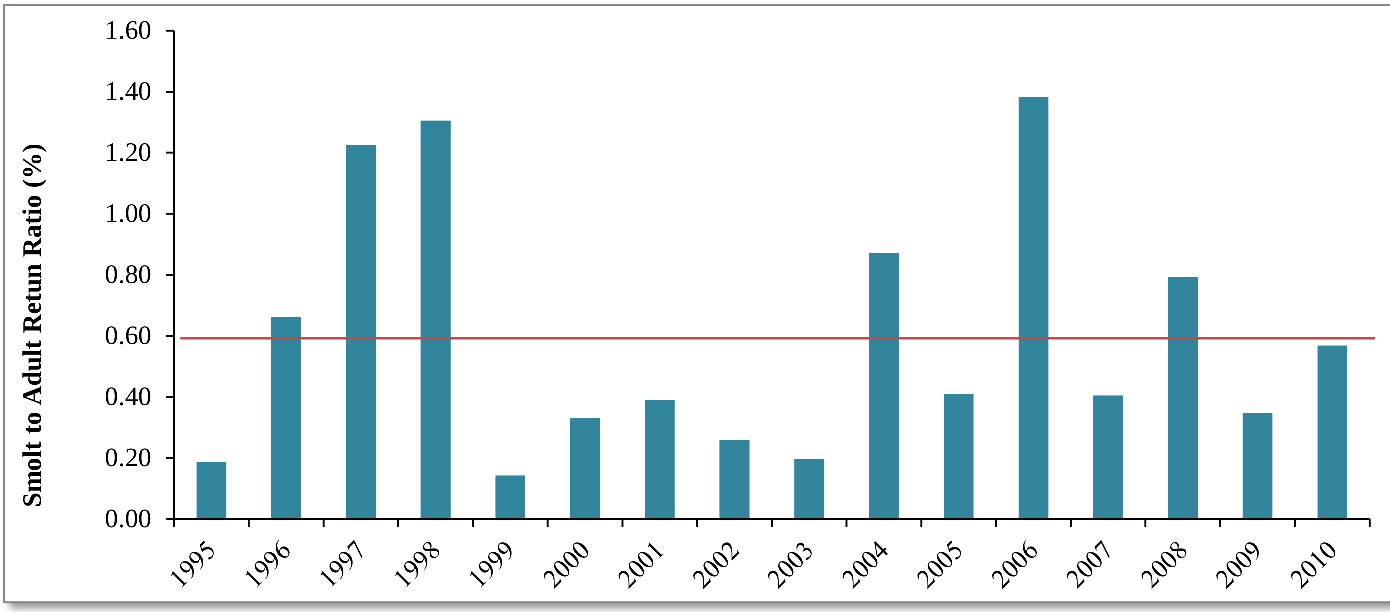

Figure 9. LNFH SAR's, 1995-2010, with red line indicating 1995–2009 mean.

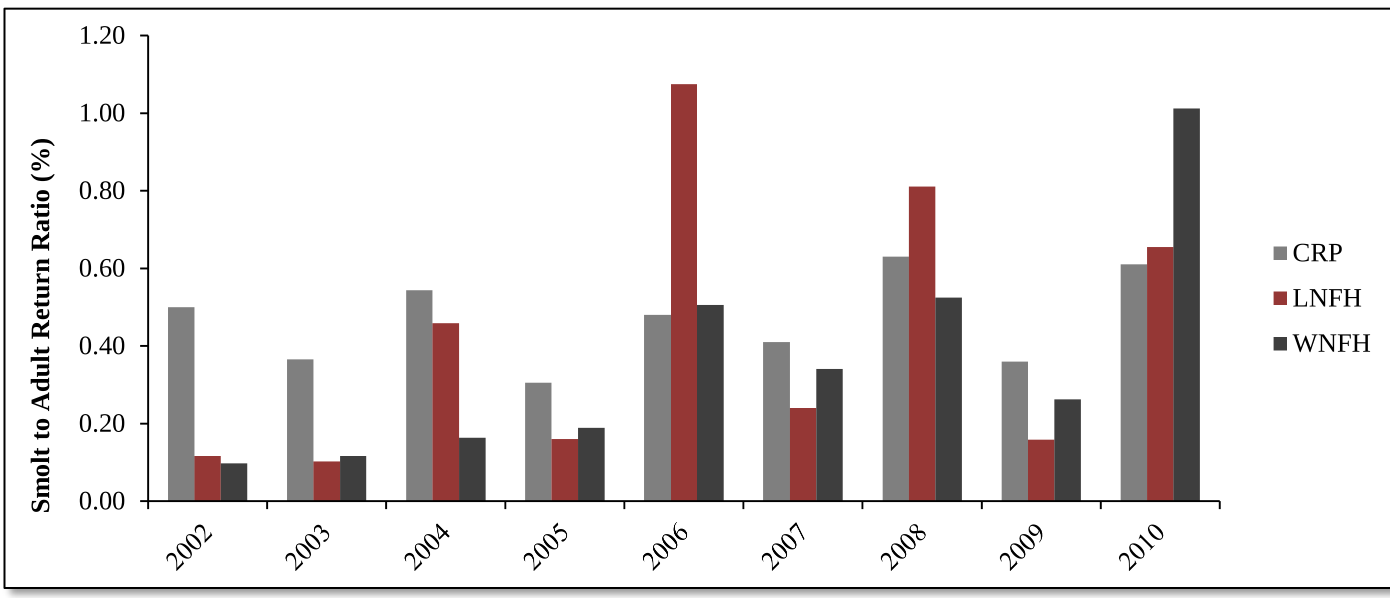

Figure 10. Smolt to Adult Return (SAR) for Chiwawa Rearing Pond (CRP), Leavenworth National Fish Hatchery (LNFH), and Winthrop National Fish Hatchery (WNFH) for brood years 2002–2010.

Brood year 2010 return age classes were 18% age-3 fish, 77% age-4 fish, and 5% age-5 fish (Figure 11). These data are derived from CWT's recovered at the LNFH, and assumes that the application of and/or presence of CWT's does not influence age of return, and that CWT's are recovered randomly. The gender composition for brood year 2010 was 53.9% females and 46.1% males (age-3+) (Figure 12).

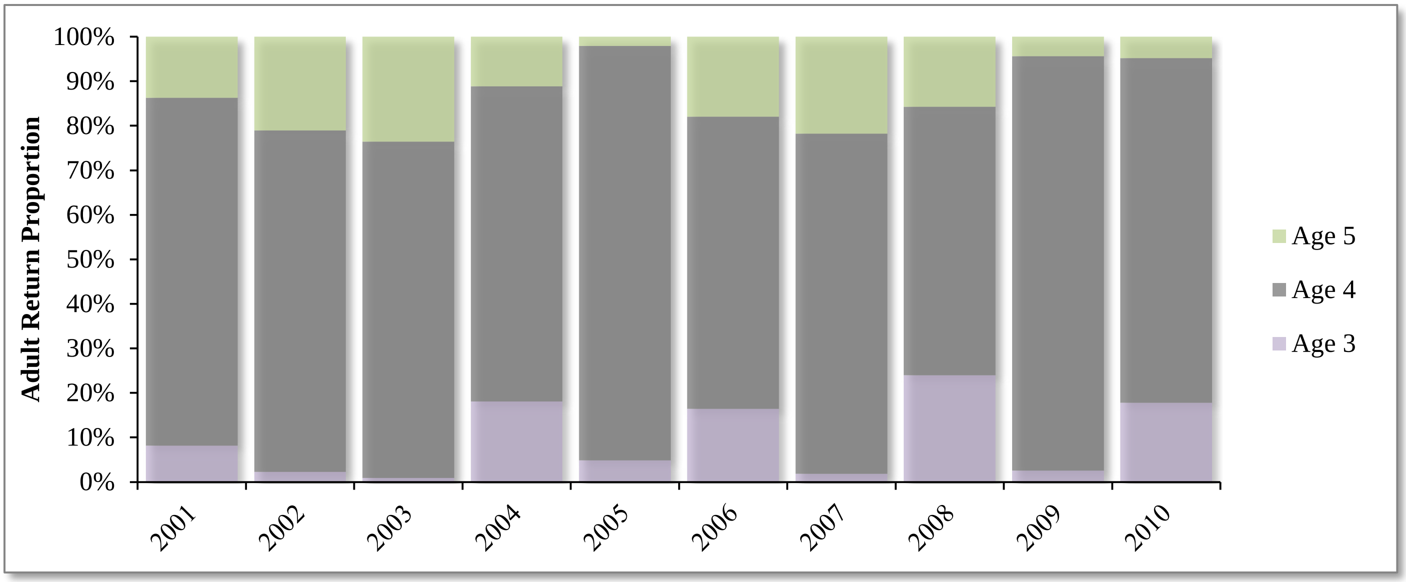

Figure 11. Leavenworth NFH spring Chinook proportion of ages produced, by brood year. Note: Percentages may not equal 100% due to rounding and outliers (i.e. age-2 and age-6)

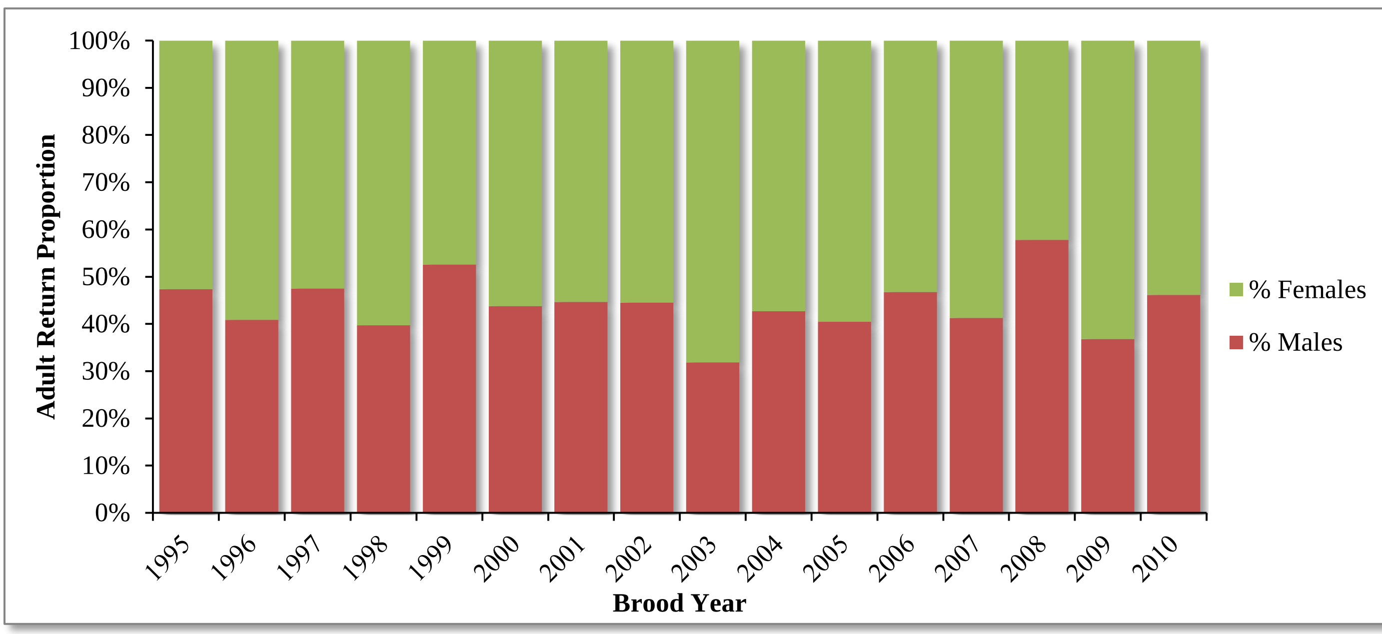

Figure 12. Leavenworth NFH spring Chinook sex composition produced by brood year.

Harvest Contribution- Brood year 2010 produced an estimated 6,744 returning adults. Of these 5,404 (80%) were either harvested or excessed for consumption, 1,070 (16%) were utilized for brood stock and 270 (4%) were found in "other" areas to include spawning ground recoveries. Locally, the sport fishery in the Wenatchee River and Icicle Creek accounted for 15% (1,044) of the return and tribal fishers in Icicle Creek harvested another 825 (12%) adults (Table 19). The largest portion of Brood Year 2010 returning adults contributed to a variety of Columbia Basin Tribes either through harvest or hatchery excessing efforts(51%). This is slightly higher than the average for brood years 2003-2009 (49%).

Table 19. LNFH-origin adult return and fate by brood year.

Brood Year	Total Return	Columbia River Harvest		Sport Fishery (Wenatchee Basin)		Sport Fishery (Icicle Creek)		Tribal Fishery (Icicle Creek)		Hachery Production		Excess Hatchery Returns		Other	
2003	2,840	453	15.9%		0.0%	132	4.6%	582	20.5%	725	25.5%	803	28.3%	145	5.1%
2004	8,438	3,115	36.9%		0.0%	376	4.5%	921	10.9%	1,044	12.4%	2,140	25.4%	842	10.0%
2005	4,282	647	15.1%		0.0%	465	10.9%	621	14.5%	493	11.5%	1,592	37.2%	464	10.8%
2006	20,562	4,219	20.5%		0.0%	1,031	5.0%	1,721	8.4%	1,134	5.5%	11,596	56.4%	862	4.2%
2007	4,932	568	11.5%		0.0%	1,012	20.5%	532	10.8%	465	9.4%	1,880	38.1%	476	9.6%
2008	10,725	1,943	18.1%		0.0%	704	6.6%	2,222	20.7%	1,407	13.1%	4,095	38.2%	353	3.3%
2009	2,841	108	3.8%	15	0.5%	566	19.9%	424	14.9%	465	16.4%	482	17.0%	780	27.5%
2010	6,744	930	13.8%	544	8.1%	500	7.4%	825	12.2%	1,070	15.9%	2,605	38.6%	270	4.0%
Mean	7,803	1,579	17.4%		0%	612	10%	1,003	14%	850	13%	3,227	34%	560	10%
St. Dev	6,346	1,570	10.1%		0%	330	7%	694	5%	362	6%	3,870	13%	274	8%

Discrete Rearing Cohort- LNFH rears juvenile spring Chinook in three different banks of raceways. A portion of the juveniles are reared in the 10x100's for their entire outdoor rearing cycle. Another portion of the juveniles are reared in the 8x80's for the entire outdoor rearing cycle. A third portion of the juveniles are reared in the 8x80's (8x80-AP) for the first half of the rearing cycle, then are transferred to two 15x150 adult holding ponds to complete the rearing cycle.

To evaluate whether any of the rearing cycles influenced survival of fish post-release we compared the SARs of rearing cycles across the years (Table 20; Figure 13). Each of these rearing banks has a portion of juveniles marked with CWT's. The year-to-year variation in SAR by rearing bank was large, resulting in no significant difference in SAR between rearing banks at the LNFH ($p=0.815$, one-way ANOVA on ranks) for brood years 2003-2010.

Table 20. LNFH-origin SAR by rearing bank for brood years 2003–2010.

	10x100			8x80-AP			8x80		
Brood Year	N	Estimated Adult Return	SAR(%)	N	Estimated Adult Return	SAR(%)	N	Estimated Adult Return	SAR(%)
2003	785,977	1,036	0.132	319,500	315	0.099	370,569	256	0.069
2004	383,383	2,054	0.536	413,054	1,976	0.478	209,068	1,523	0.728
2005	704,435	1,844	0.262	205,570	200	0.097	267,563	424	0.158
2006*									
2007*									

2008	663,120	7,078	1.067	309,054	2,184	0.707	312,479	2,196	0.703
2009	581,328	1,056	0.182	309,558	370	0.120	298,556	428	0.143
2010*									
Mean			0.436			0.300			0.360
St. Dev.			0.386			0.279			0.326

* Tagging design did not allow comparison between rearing units

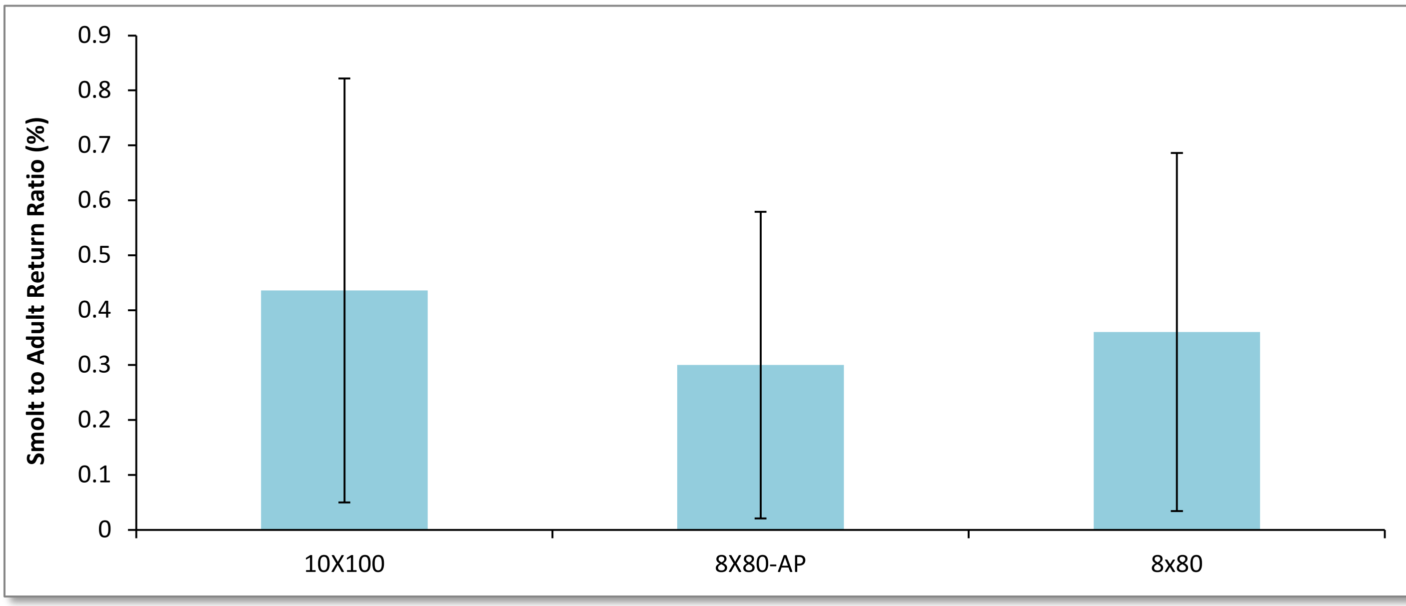

Figure 13. Mean LNFH spring Chinook smolt-adult return by rearing bank with error bars, 2003–2010.

Summary

- The 2014 brood year had a green egg to smolt survival of 76.1%, which fell short of the 81% production goal.
- The targeted density and flow indices of < 0.20 and < 0.60, respectively, were met.
- The 2016 LNFH release of 945,277 spring Chinook was 79% of the production goal of 1,200,000. The production number was low due to epizootic levels of “Ich” causing high mortalities throughout July.

- Fish were released at 20 fish per pound (fpp) which was below the goal of 17 fpp. The small size can be attributed to the infestation of "Ich" and the decreased feed during treatments.

- Juvenile survival to McNary dam was 52%, which was lower than other spring Chinook hatcheries in the upper Columbia River basin. However, an accidental early release of a portion of the brood in January could be confounding these results.

- In 2016 an estimated 5,224 spring Chinook returned to Icicle Creek. Of which 1,853 (36%) were harvested, 3,241 (63%) were trapped in the adult holding ponds and 26 (1%) remained in Icicle Creek.

- Age composition of spring Chinook returning to LNFH in 2016 was 4% age-3 fish (n=16), 83.1% age-4 (n=329), and 12.1% (n=48) age-5. Based on CWT recoveries no age-6 fish were detected.

- In 2016, 20 jacks, 481 males, and 500 females were spawned at LNFH. Females used for broodstock had average fecundity of 3,822.

- In 2016, LNFH had a green egg take of 1,914,435. This was 10% above the performance goal of 1,740,000.

- LNFH culled 547,544 eggs and began rearing brood year 2016 with 1,335,641 eyed-eggs.

- The 2010 Brood Year had a SAR of 0.57%, which fell slightly below the average of 0.60%.

- The covered 10'x100' rearing bank had the highest average SAR, though not statistically different when compared to the other available rearing banks.

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Appendix A: National Marine Fisheries Service Biological Opinion Term and Conditions for Leavenworth National Fish Hatchery

2.8.4. Terms and Conditions

The terms and conditions described below are non-discretionary, and the Action Agencies must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). The Action Agencies (USFWS and USBR) have a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this incidental take statement (50 CFR 402.14). If the following terms and conditions are not complied with, the protective coverage of section 7(o)(2) will lapse. The USFWS and USBR will:

1a. NMFS is using pHOS as a surrogate for gene flow. The LNFH will continue their marking strategy for the spring Chinook salmon hatchery program to help identity LNFH spring Chinook salmon, remove them at TWD, and validate that the surrogate for gene flow i.e., pHOS is no higher than the rates evaluated in this opinion (0.8% to 3.2%) annually for the Upper Wenatchee and Entiat Basins. Monitoring and escapement estimates shall be reported to NMFS SFD annually (see 3b). If the LNFH exceeds this limit, the Services will convene and discuss the reasons for pHOS exceedance (e.g., unusual circumstances), the effects on ESA-listed species, and potential remedies.

1b. The disposition of all natural origin and hatchery origin spring Chinook salmon and steelhead that enter the LNFH fish collection ladder and water delivery system combined will be addressed as follows:

i. All ESA-listed natural origin spring Chinook salmon and steelhead (i.e., identified by adipose fin and verified with scale pattern as appropriate) shall be returned to Icicle Creek with no more than three mortalities for spring Chinook salmon and no more than five mortalities for steelhead annually.

ii. Up to 120 ESA-listed hatchery origin spring Chinook (i.e., identified by adipose- fin clip and coded wire tag; safety-net program) would be encountered shall be returned to Icicle Creek or transferred to the appropriate hatchery operator (e.g., WDFW) for use as broodstock; no more than 120 mortalities annually. hatchery origin

iii. 50 ESA-listed hatchery origin spring Chinook (i.e., identified by adipose fin and CWT; conservation program) shall be returned to Icicle Creek or transferred to the appropriate hatchery operator (e.g., WDFW) for use as broodstock; no more than 50 mortalities annually.

iv. Up to 1,000 naturally spawned spring Chinook salmon juveniles would be encounter with no more than 50 mortalities annually.

v. 20 adults and 550 juvenile ESA-listed steelhead shall be returned to Icicle Creek; no more than five mortalities. Icicle Creek also contains a resident rainbow trout population. Since juvenile steelhead are indistinguishable from juvenile rainbow trout during the first few years of their life, this take is likely to include fish from both life history strategies.

2a. Ensure that the gates at Structure 2 are open from March 1 through May 31 to allow for unimpeded steelhead adult migration with the following exception. If Structure 2 is closed during LNFH origin spring Chinook salmon broodstock collection (i.e. due to reaching 50 fish trigger), traps would be checked twice daily and ESA-listed spring Chinook salmon and steelhead would be released upstream or downstream of Structure 5 (depending on spawning status).

2b. From August 1 through September 30, provide up to 50 cfs of supplemental flow from the Snow/Nada Lake Basin Supplementation Water Supply Reservoirs, to ensure access to LNFH's surface water withdrawal and improve instream flow conditions to the extent possible during the irrigation season in cooperation with IPID as described in this opinion.

2c. Structure 2 will not be operated for aquifer recharge in August.

2d. In September, if the natural flow remaining after subtracting the amount of water diverted by the LNFH and all water users is less than 60 cfs, the LNFH will not route more water into the hatchery channel than the volume of its Snow/Nada Lake storage release (up to 50 cfs) minus the diversion at Structure 1 (up to 42 cfs).

2e. In March, Structure 2 will only be operated if adult steelhead have not been detected recently (within the last month) in Icicle Creek.

2f. The circumstances where the LNFH would need to deviate from 100 cfs in the Icicle Creek historical channel within the eight-year period are described and analyzed in Section 2.4.2.6.2, Table 26. Under these circumstances, the LNFH would operate Structure 2 for purposes of aquifer recharge in a manner intended to maintain instream flow goals of 40 cfs in October, 60 cfs in November - February, and 80 cfs in March in the Icicle Creek historical channel.

2g. Within eight years, have a water delivery system in place and operating that complies with NMFS current screening and fish passage criteria for anadromous fish passage facilities (NMFS 2011a). All holding areas and intake structures incidentally take listed species. Because water withdrawals at the LNFH facility do not currently meet or exceed NMFS current water intake screening criteria, to prevent injury or death of listed species:

Regularly surveying the sand settling basin and successfully capturing and releasing listed species as follows:

- v. On a weekly basis, during mid-April through October, survey the sand settling basin for the presence of listed species (particularly during the spring steelhead smolt migration and again during the first onset of cold weather during the fall). Monitoring may consist of visual observation (to determine if fish are present and capture and release is required) as long as the entire sand settling basin can be viewed. If any steelhead or spring Chinook salmon are present, they shall be promptly captured and released unharmed into Icicle Creek near the LNFH spillway pool (RM 2.8). If a steelhead is in pre-spawn condition, it shall be released upstream of Structure 1.
- vi. During mid-April through October, if after three weeks, no steelhead or spring Chinook salmon are encountered (other than during the spring steelhead smolt migration in fall as described above), survey the sand settling basin for the presence of listed species monthly. If any steelhead or spring Chinook salmon are present, they shall be promptly captured and released unharmed into Icicle Creek near the LNFH spillway pool (RM 2.8). If a steelhead is in pre-spawn condition, it shall be released upstream of Structure 1. If more than five steelhead are detected in the month, then the monitoring interval shall change back to weekly.
- vii. During the November through mid-April period, after the onset of cold weather, survey the sand settling basin and remove listed species once a month. If more than five steelhead are detected in this period, then the monitoring interval shall change back to weekly.
- viii. During short periods of time when surveying the sand settling basin is ineffective (e.g., high sediment loads) and/or removing fish from the basin is not possible (e.g., presence of ice covering basin pool), immediately survey basin and remove ESA-listed species as soon as possible and return to regular survey schedule as stated above.

Include results of the above actions and monitoring in annual reports submitted to NMFS (see 3b).

2h. The USFWS will monitor and report monthly average instream flows in Icicle Creek. Within 12 months, the USFWS will install real time instream flow monitoring stations with the intent of measuring flows upstream of the intake at RM 4.5 (Structure 1) and with the intent of measuring flows in the Icicle Creek historical channel between RM 3.8 and 2.8 (Structure 2) in order to monitor instream flows in Icicle Creek. Instream flow reporting can be combined with other hatchery reporting requirements and submitted to NMFS by March 1st, see 3b.

2i. Avoid disturbing natural origin spawning salmon and steelhead during hatchery maintenance activities of diversions and instream structures. Avoid disturbing salmon and steelhead redds.

3a. NMFS' SFD must be notified, in advance, of any change in hatchery program operation and implementation that would potentially result in increased take of ESA-listed species or a change in the manner of that taking.

3b. NMFS' SFD must be notified as soon as possible, if such an event is likely but no later than two days after any authorized level of take is exceeded. A written report shall be provided to SFD detailing why the authorized take level was exceeded or is likely to be exceeded.

NMFS prefers communication via phone and electronic submission of reporting documents. The current point of contact for document submission is Craig Busack (craig.busack@noaa.gov), but this may change during the life of the permits. All reports, as well as all other notifications required in the permits, can also be submitted to NMFS at:

Craig Busack
Anadromous Production and Inland Fisheries NMFS –Sustainable Fisheries Division
c/o National Marine Fisheries Service, West Coast Region 1201 NE Lloyd Blvd, Suite 1100
Portland, Oregon 97232
Phone: (503) 230-5412
Fax: (503) 872-2737

3c. Apply measures to ensure that before their release into Icicle Creek, LNFH origin spring Chinook salmon juveniles are ready to actively migrate to the ocean. To meet this condition, fish shall be released at a uniform size and demonstrate signs of smoltification that ensure that the fish will migrate seaward without delay.

iv. Variance from this release requirement is only approved in the event of an emergency, such as flooding, water loss to raceways, or vandalism, which necessitates early release to prevent catastrophic mortality.

x. Any emergency releases must be reported as soon as reasonably possible to SFD.

3d. Post-release survival of spring Chinook salmon smolts shall be monitored and evaluated to determine the speed of emigration and level of residualism.

3e. To the extent possible without imposing increased risk to ESA-listed species, enumerate and identify marks and tags on all anadromous species encountered at adult collection and water intake sites. This information shall be included in the broodstock protocol or LNFH monitoring report submitted to NMFS annually.

3f. If water temperature in the adult holding ponds or sand settling chamber exceeds 21°C (69.8°F), fish collection shall cease pending further consultation with NMFS to determine if continued collection poses substantial risk to ESA-listed species that may be incidentally encountered.

3g. Update and provide SFD, by March 1st of each year, the projected hatchery releases by age class and location for the upcoming year (see 3b).

3h. Provide annual report(s) that summarize numbers, pounds, dates, tag/mark information, locations of artificially propagated fish releases, and monitoring and evaluation activities that occur within the hatchery environment and adult return numbers to the UCR basin for each program. Ensure collection and reporting of the coefficient of variation around the average (target) release size for LNFH spring

Chinook salmon immediately prior to their liberation from the rearing ponds to serve as an indicator of population size uniformity and smoltification status. Reports must include any preliminary analyses of scientific research data, identification of any problems that arise during conduct of the authorized activities, a statement as to whether or not the activities had any unforeseen effects, and steps that have been and will be taken to coordinate the research or monitoring with that of other researchers. Unless otherwise noted in the specific terms and conditions, the reports shall be submitted by March 1st, of the year following release (i.e., brood year 2013, release year 2014, report due March 2015, see 3b) to NMFS.

3i. Provide plans in advance of any future projects and/or changes in collection locations for NMFS concurrence through the annual broodstock protocol memorandum.

3j. Adult return information shall include available annual estimates of pHOS for LNFH spring Chinook salmon in the Wenatchee and Entiat basins, including the number, location, and timing of recoveries. Adult return information and results from monitoring and evaluation activities outside the hatchery environment shall be included in the annual report or a separate report. If a separate report on monitoring and evaluation activities conducted outside the hatchery environment is prepared, it shall be submitted by March 1st, of the year following the monitoring and evaluation activities (i.e., surveys conducted on 2014, report due March 2015, see 3b).

Appendix B: U.S. Fish and Wildlife Service Biological Opinion Terms and Conditions for Leavenworth National Fish Hatchery

V. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, the LNFH must comply with the following terms and conditions (T&Cs), which implement the reasonable and prudent measures described above, and are designed to minimize impacts to bull trout. These terms and conditions are mandatory.

To implement RPM 1:

T&C 1. In years where the >50 Chinook salmon trigger is met (and structure 5 is closed during the BSC period, which will also require structure 2 to be closed to manage flows), structures 2 and 5 shall be re-opened by June 24. This action will minimize the period of impairment of upstream passage of migratory bull trout and provide for a total of 6 of 7 predicted weeks of passage opportunities for migratory bull trout.

To implement RPM 2:

T&C 2. The analysis in the Biological Opinion assumed up to 64 bull trout would be exposed to adverse effects as a result of aquifer recharge in August. To validate this assumption and ensure that the extent of effects of the Project is within the scope of what was analyzed, the LNFH shall conduct surveys as follows:

- Conduct 3 daytime snorkel surveys (as broadly spaced in time as possible) between rm 2.8-3.8 at least 2 weeks prior to the August aquifer recharge.
- If the mean number of bull trout observed is <64, then the effects are within those analyzed and August aquifer recharge may proceed.
- If the mean number of bull trout observed is >64, then the effects are not within those analyzed and reinitiation of consultation is required prior to the August aquifer recharge. Alternately, if the mean number of bull trout observed is >64, and aquifer recharge is delayed until September, then reinitiation of consultation is not required.

T&C 3. The analysis in the Biological Opinion assumed lethal effects to bull trout would not likely be caused by the August aquifer recharge. To validate this assumption and ensure that the effects of the Project are within the scope of what was analyzed, the LNFH shall conduct temperature monitoring as follows:

- Temperature monitoring shall be conducted at least two weeks prior to the August aquifer recharge, and should incorporate the techniques of Isaak and Horan (2011) and Dunham et al. (2005). Measure the 7-day average daily maximum (7-DADMax) temperature in the historical channel with structure 2 open. If the 7-DADMax is less than 19 °C, the temperature criterion for proceeding with aquifer recharge is met and August aquifer recharge may proceed.
- If the 7-DADMax is greater than 19 °C in the historical channel with structure 2 open, defer aquifer recharge for one week, and continue temperature monitoring. If the 7-DADMax remains above 19 °C after one week, reinitiate consultation. Alternately, if aquifer recharge is delayed until September, then reinitiation of consultation.
- Monitor water temperatures during August aquifer recharge, if it occurs. If the 7-DADMax is greater than 19 °C during August aquifer recharge, cease operations immediately and re-open structure 2.
- If on-going temperature monitoring efforts can achieve this same objective of determining water temperatures in the historical channel in August, then the additional temperature monitoring prescribed above need not occur.

To implement RPM 3:

T&C 4. Monitor, capture, and release all bull trout in the sand settling basin as follows (based on the expected likelihood of bull trout presence recorded in the LNFH 2006-2010 capture log):

- In July through October, weekly monitoring for bull trout presence in the sand settling basin shall occur. Monitoring may consist of visual observation (to determine if fish are present and capture and release is required) as long as the entire sand settling basin can be viewed. If any bull trout are detected, they shall be promptly captured and released.
- In January through June and November through December, the interval for monitoring, capturing, and releasing all bull trout shall be monthly. If any bull trout are detected in this period, then the interval shall be changed to weekly and reinitiation of consultation shall occur.
- Any bull trout captured in the sand settling basin shall be released downstream of rm 4.5.

T&C 5. Schedule the annual maintenance at the intake (ladder, water conveyance channel, and building sump) to avoid the upstream migration period of bull trout. The BA specifies that once or twice a year, maintenance could occur between November 1 and June 1 for 2-3 days.

To implement RPM 4:

T&C 6. During BSC, when water temperatures are <15 °C in the Chinook salmon holding ponds, the interval for monitoring, capturing, and releasing all bull trout shall be weekly. During BSC, when water temperatures are >15 °C in the Chinook salmon holding ponds, the interval of monitoring, capturing, and releasing all bull trout shall be twice weekly. This T&C is designed to minimize physiological stress and allow for the bull trout to return to normal behavior patterns (e.g., the ability to feed, breed, etc.), with consideration of environmental (e.g., temperature, water quality, overcrowding, etc.) stressors.

T&C 7. Between May and August, release all bull trout captured in the Chinook holding ponds above rm 5.7. Based on past records, very few bull trout ascend the hatchery ladder and enter the Chinook salmon holding ponds. If the affected individuals are of Icicle Creek local population origin, then this T&C facilitates their upstream migration. If these affected individuals are not of Icicle Creek local population origin, then they will likely either (1) not spawn and move downstream under their own volition, or (2) they may spawn in upper Icicle Creek (which would be consistent with the expected infrequent demographic and genetic contributions from bull trout from other local populations).

T&Cs common to all RPMs:

T&C 8. Continue the adaptive management group process, during the BSC period, to develop and implement strategies to minimize upstream passage impairment at structure 2 and 5 and other adverse effects to bull trout caused by the Project. These strategies shall be consistent with the conservation needs of the bull trout and the conservation role of critical habitat for the bull trout.

T&C 9. Keep written records of all adjustments to structures 2 and 5. Include key information such as staff gauge readings at structure 2, dates of operational changes and maintenance, estimated degree of opening at structure 2, and other data. These data may better inform our understanding of the relationship between operational changes and effects of the Project on bull trout.

T&C 10. Record all incidents of bull trout being observed, captured, handled, and released at LNFH facilities and structures. These data will enhance our understanding of bull trout distribution and abundance in the Project area and better inform the assessment of LNFH effects to bull trout.

Appendix C: Release Year 2015 Coded Wire Tag Codes.

Table B1. Release year 2016 coded wire tag codes

Tag Code	N tagged
055492	100,096
055493	100,536

U. S. Fish and Wildlife Service
Mid-Columbia Fish and Wildlife Conservation Office
7501 Icicle Road
Leavenworth, WA

August 2016