U.S. Fish and Wildlife Service

Monitoring and Evaluation of the Entiat National Fish Hatchery Summer Chinook Salmon Program, 2017

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***On the cover**: Photograph taken in 2017. USFWS photograph.*

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Executive Summary- Entiat National Fish Hatchery (Entiat NFH) construction was completed August 1, 1941 as partial mitigation for the loss of anadromous fish production upstream of Grand Coulee Dam. Entiat NFH is located on the banks of the Entiat River in central Washington State and produces summer Chinook Salmon (*Oncorhynchus tshawytscha*) as a *segregated-harvest* program. The summer Chinook Salmon program at Entiat NFH began in 2009, with its first release in 2011. Summer Chinook Salmon broodstock originally came from Wells Fish Hatchery but since 2014 broodstock has been 100% Entiat NFH-origin returns. The goal of the program is to provide harvest opportunity of 1,600 adult summer Chinook Salmon with minimal impacts to natural-origin fish populations and their habitats. To achieve the harvest goal the hatchery targets a release of 400,000 yearling smolts at 17 (+/- 10%) fish/pound into the Entiat River. In 2017 Entiat NFH released 440,123 smolts. The harvest estimates for 2017 were 976 adult Entiat NFH-origin summer Chinook Salmon. The following report summarizes the rearing cycle of Brood Year 2015 and return year of 2017 as well as monitoring objectives that ensure the environmental/ecological goals were met.

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Introduction

The U. S. Fish and Wildlife Service (USFWS) owns and operates Entiat NFH located on the Entiat River 10.9 river kilometers upstream from the mouth. Operations began in 1942 as partial mitigation for the loss of anadromous fish production upstream of Grand Coulee Dam. From 1940 to 1974, Entiat NFH raised a variety of salmon and trout from multiple stocks however; the majority of effort was focused on spring and summer Chinook Salmon. Entiat NFH raised and reared solely spring Chinook Salmon from 1975–2007. The spring Chinook Salmon program was terminated in 2007 after concerns were raised regarding the benefits of the program compared to the impact of Entiat NFH spring Chinook Salmon production on natural-origin spring Chinook Salmon in the Entiat River. In response to this risk analysis in 2007 Entiat NFH halted the release of spring Chinook Salmon and initiated a new summer Chinook Salmon program in 2009.

Annual operations and accomplishments at Entiat NFH are described in this report and are organized by two life stages: juvenile and adult. The juvenile component includes the rearing cycle of the fish spawned in 2013 and released in 2015, including outmigration survival and travel times. The adult component focuses on the returning adults to the hatchery, harvest of returning adults, spawning and the subsequent egg production. The intent of this report is to summarize Entiat NFH operations and compare them to performance goals set for the program. Evaluating the development of this new program is important to measure its success and to help guide future decisions.

Legal Authorities

Entiat NFH was constructed and operates under the authority of Section 2 of the Rivers and Harbors Act of August 30, 1935 (49 Stat. 1028) as partial mitigation for the construction of Grand Coulee Dam. The hatchery is currently funded by the U.S. Bureau of Reclamation (BOR) and operated by the USFWS. The *U.S. v. Oregon* decision of 1969, through subsequent management agreements, sets production goals for the facility.

Endangered Species Act - Entiat NFH operates within the requirements of the Endangered Species Act of 1973. Though the Upper Columbia River summer Chinook Salmon stock currently produced is not listed, Biological Opinions (BiOp) are issued for ESA-listed upper Columbia River spring Chinook Salmon and steelhead (*Oncorhynchus mykiss*) by the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries), and for Bull Trout (*Salvelinus confluentus*) by the USFWS. Permits are issued for any incidental "take" of listed species through impacts from Entiat NFH operations and/or production. Additionally, these permits can and do specify terms and conditions related to specific

monitoring tasks that seek to evaluate the potential impacts to listed species through Entiat NFH operations and/or production.

Hatchery and Genetics Management Plan - A Hatchery and Genetics Management Plan (HGMP) is a Biological Assessment provided by the Entiat NFH and the MCFWCO to describe the effects of the Entiat NFH on ESA-listed species and their critical habitat. The HGMP is the tool the action agencies use in initiating ESA consultation and contributes to the development of the BiOps and subsequent permits issued by NOAA Fisheries. The HGMP describes the proposed action and sets broad performance standards that relate to the legal requirements and environmental impacts of the Entiat NFH.

Program

Entiat NFH is a mitigation hatchery established by the Grand Coulee Fish Maintenance Project (1937) to compensate for anadromous fish losses above Grand Coulee Dam. Entiat NFH operates a segregated (intended to be separate from natural-origin Chinook Salmon, not used for supplementation, or conservation) harvest program that currently produces summer Chinook Salmon for commercial, sport, and tribal harvest and attempts to minimize adverse impacts to the environment. The USFWS operates the facility with funds provided by the BOR. Summer Chinook Salmon from this program are not intended to spawn naturally, supplement, or support any summer Chinook Salmon populations. The release target of 400,000 adipose-clipped summer Chinook Salmon was established after discussion with the relevant co-managers and is a legally binding commitment described in the U.S. v. Oregon Columbia River Management Agreement.

Hatchery and Genetics Management Plan

A Hatchery and Genetics Management Plan (HGMP) for Entiat NFH was finalized and submitted to NOAA in compliance with its ESA 4(d) rule (USFWS 2009). Outlined in the HGMP are biologically-based artificial propagation strategies that describe all components of the hatchery's program, performance standards, strategies for minimizing program effects on ESA-listed species, monitoring, evaluation, and research plans to ensure that all legal and environmental obligations are meet by the program. The HGMPs program performance standards were used (section 1.9, 1.10) to develop measurable performance goals. The Entiat NFH annual report reflects the hatchery's abilities to meet the performance standards through the performance goals for 2015 and will be used to adapt propagation strategies through facility management in subsequent years.

Location

The Entiat NFH is located west of Entiat, WA on the Entiat River 10.9 river kilometers (rkm) upstream from the confluence of the Entiat and Columbia rivers (Figure 1). Fish migrating to and from Entiat NFH to the Pacific Ocean travel 790 rkm and pass through eight hydroelectric dams on the Columbia River.

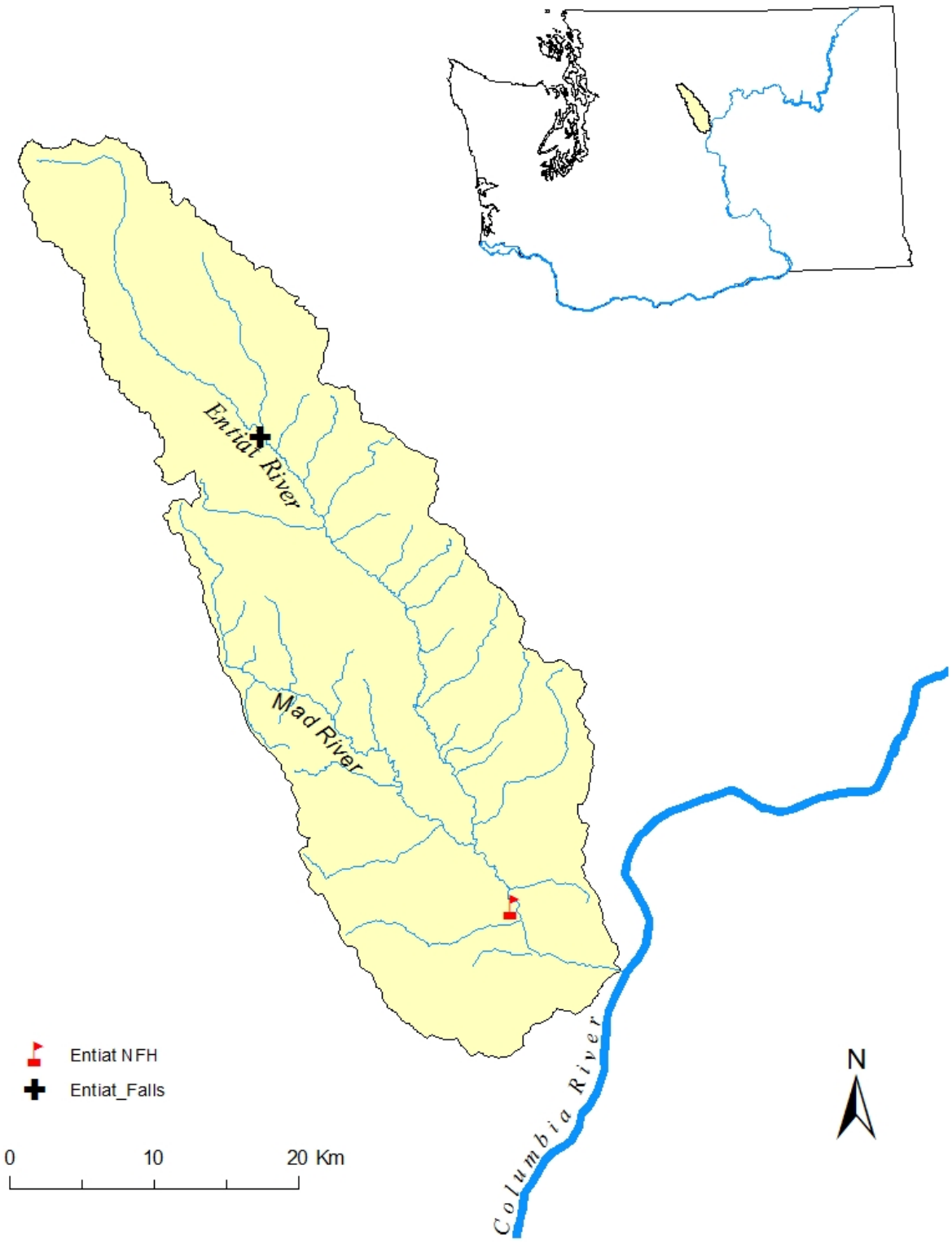

Figure 1. Map of the Entiat River sub-basin and facility location.

Facilities

The Entiat NFH is located on 37 acres adjacent to the Entiat River. The facilities include incubating, rearing and holding areas, a pollution abatement pond, water withdrawal area and a kids fishing pond (Figure 2). The nursery area is located in the main hatchery building and houses Marisource Heath tray stacked incubators operated with chilled spring/well water. The outdoor rearing area is composed of 30 raceways distributed equally in 3 groups (A, B, and C banks) each raceway is 8 ft wide and 80 ft long. Raceways are supplied with spring/well water during pre-smolt development and then spring/well/river water during acclimation (November 15 to April 15). The adult holding area is composed of two (16 ft x 120 ft) holding ponds that have river access via a fish ladder. All effluent from pond cleaning fish is pumped into the hatchery pollution abatement pond. The water withdraw area includes surface water (a river water intake), spring water and six groundwater wells with 35 cfs in total available water rights. The Entiat River provides water for hatchery operations, serves as the release point for fish raised at Entiat NFH and the collection point for fish returning to Entiat NFH.

Figure 2. Aerial photograph of the Entiat NFH.

Historic and Current Rearing Operations

Since 1942, Entiat NFH has released a variety of species from multiple stocks however both spring and summer Chinook Salmon (*Oncorhynchus tshawytscha*) have been the primary species reared to meet mitigation requirements. The hatchery began rearing spring Chinook Salmon that originated from mixed upriver stocks intercepted at Rock Island Dam in 1942 and 1944. No spring Chinook Salmon were reared from 1945 to 1974. In 1974, spring Chinook Salmon production resumed and egg sources included: Cowlitz River (1974), Carson NFH (1975–1982), Little White Salmon NFH (1976, 1978, 1979, 1981), Leavenworth NFH (1979–1981, 1994), and Winthrop NFH (1988). Returning adults that voluntarily entered the hatchery were the primary broodstock in 1980 and from 1982 to 2006. The spring Chinook Salmon rearing program was terminated in 2006 to reduce the impact of Entiat NFH-origin spring Chinook Salmon on ESA-listed natural-origin spring Chinook Salmon in the Entiat River. The last on-station release of spring Chinook Salmon to the Entiat River occurred in 2007 and the last adults returned in 2010.

In the fall of 2009, the hatchery began a new program propagating summer Chinook Salmon with broodstock captured at Wells Fish Hatchery. Wells Fish Hatchery (Wells stock) was selected as the broodstock because they are genetically part of the upper Columbia River summer Chinook Salmon stock (Kassler et al. 2011). Additionally, a genetic evaluation of the existing natural-origin stock in the Entiat River determined the population to not be genetically distinct from the Wells stock or the upper Columbia River summer Chinook ESU (Smith et al. 2011). Entiat NFH reared and released juvenile summer Chinook Salmon into the Entiat River from 1941–1964, and in 1976 (Mullan 1987). Summer Chinook Salmon egg sources have included: mixed upriver stocks intercepted at Rock Island Dam (1939–1943), Methow River (1944), Carson NFH (1944), Entiat River (1946–1965), Spring Creek NFH (1964), and Wells Hatchery (1974, 2009–2013). Adult summer Chinook Salmon returning to Entiat NFH have been the primary brood source since 2014.

Hatchery Program Goals

Salmon and steelhead artificial production programs in the Pacific Northwest are characterized as either conservation, safety-net or harvest augmentation programs. Conservation programs aim to recover or support depleted natural populations by integrating natural-origin adults into the hatchery environment to increase the survival rates and outmigration numbers. Safety-net programs primarily function as a conservation reserve that seeks to maintain some level of natural integration if needed during times of low abundance but can still support harvest in years of abundance. Harvest augmentation programs strive to minimize interactions with natural populations and aim to increase harvest opportunities.

The Leavenworth Complex currently has four separate production programs representing all three program types. Winthrop NFH operates a conservation summer steelhead program and a safety-net spring Chinook Salmon program. Leavenworth and Entiat NFH operate segregated

spring and summer Chinook Salmon harvest augmentation programs, respectively. Although each program has unique goals for brood source and the use of returning adults all programs have similar within hatchery and production objectives to efficiently produce migration ready smolts and maximize adult returns.

Entiat NFH currently operates a segregated summer Chinook Salmon harvest augmentation program. The goals of the program are to provide harvest opportunities while minimizing interactions with natural spawning populations.

Entiat NFH production and operations strive to achieve the following objectives:

1. Contribute substantially to harvest fisheries.
2. Maximize use of hatchery brood stock that return to ENFH and minimize transfers from other facilities or stocks.
3. Optimize hatchery ladder operations to trap returning hatchery-origin adults while minimizing trapping of natural-origin species.
4. Rear and release 400,000 migration ready yearling smolts in a manner that minimizes residualism and early maturation while maximizing outmigration survival and homing fidelity.

Hatchery Evaluation

The Hatchery Evaluation (HE) program at the Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO) monitors and evaluates the Leavenworth Complex of National Fish Hatcheries. The HE program uses monitoring, evaluation, and targeted research to assist the Leavenworth Hatchery Complex in effectively meeting both mitigation goals and ESA responsibilities. HE assists in guiding the Leavenworth Complex in making decisions that balance the benefits of artificial production against risks to natural populations and their habitats. The following three components characterize HE program goals:

1. Evaluate on-station hatchery operation and practices.
2. Research, assess and recommend methods to minimize impacts of hatchery production and operations on natural fish populations and their environment (Fraser and Hamstreet 2015, 2016.
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 Leavenworth Complex hatchery programs are meeting mitigation objectives while working within acceptable levels of risk to natural-origin fish populations and their habitat. Monitoring and evaluation goals vary depending on the program type (ie. conservation, safety-net, harvest) but are broadly categorized as hatchery rearing metrics, post-release performance, and risk assessment to natural populations and habitat.

HE program objectives specific to Entiat NFH include the following:

1. Forecast adult returns and track in-season fish abundance to guide fisheries and brood management.
2. Evaluate the effectiveness of Entiat NFH production to provide harvest opportunities.
3. Determine population characteristics of returning adults including: run timing, smolt-adult-survival.
4. Monitor the effects of hatchery operations on natural populations.
5. Assess whether juveniles are reared and released in a manner that minimizes freshwater residence and early maturation while maximizing outmigration survival and homing fidelity.

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

1. Develop predictive models to forecast preseason estimates for managers.
2. Use PIT tag detections to track the migration of Chinook and provide weekly in-season forecasts estimates to managers.
3. Describe fishery contribution using data from coded-wire tag recoveries, harvest estimates and hatchery returns.
4. Sample a statistically valid representation of the hatchery return to describe population characteristics.
5. Operate PIT tag antennas in adult fish ladders at Entiat NFH.
6. Monitor in hatchery rearing 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. Conduct spawning ground surveys in the Entiat River basin to assess the impacts of Entiat NFH production on natural-origin fish populations.
11. Support Parental Based Tagging (PBT) genetic marking objectives (via DNA markers) as identified by the Columbia River Inter-Tribal Fish Commission (CRITFC).

Data Sources - Data used in this report comes from direct collection by this agency, collection by other management agencies, and/or industry-specific databases. Most of the data used in this report were directly collected by either HE or hatchery staff. When data were not directly collected the source is cited. The three databases most often used for data collection in this report were:

1) *RMIS* - The 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 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 is available at www.rmpc.org.

2) *PTAGIS* - PIT Tag Information System (*PTAGIS*) is an online database also operated by the Pacific States Marine Fisheries Commission designed to store and manage Passive Integrated Transponder (PIT) tag data. Data including: capture location, capture date, size, species and run of fish are entered when fish are initially tagged. Subsequently, if/when a transceiver antenna ("interrogated") reads the PIT tag remotely, the tag code and location information are submitted. These data can be collected passively through non-lethal methods, and fixed interrogation stations can be set up at many locations throughout the watershed including main-stem rivers, tributaries, hatcheries and hydroelectric facilities. PTAGIS allows managers to track movement of the tagged fish. More information is available at www.ptagis.org.

3) *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 houses fish information including species, run, rear, release information and counts of fish passing hydroelectric facilities on the Columbia River and its tributaries. More information is available at www.cbr.washington.edu/dart/.

Performance Goals

The summer Chinook Salmon program at the Entiat NFH is evaluated and monitored by tracking performance goals throughout the year (Tables 1–3). Performance goals are derived from the FWS staff, legal authorities, HGMP's, and peer-reviewed literature and 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/broodstock, and brood year.

Release Year - Release year performance goals apply to the rearing of juveniles from egg eye-up through release of smolts (Table 1). Each release year cohort was reared at the hatchery for 1.5 years.

Table 1. Entiat NFH release year performance goals.

Timeframe	Metric	Performance Goal [1]
October	Green eggs collected [2]	600,000
	Green-eyed %	>90%
	Eyed-eggs	436,000 (109% of release target)
May	Fry Ponded	432,405 (98% of eyed)
May-Nov.	Summer Rearing (sub-yearlings)	420,098
July	Marking (sub-yearlings)	80-120 fpp w/ <10% CV, >98% Ad-clip /200k CWT
Nov.	Sub-Yearling Size	23.7 fpp (20k PIT)
Nov.-Mar.	Winter Rearing (Yearlings)	418,040
Apr.	Yearling Size	17 fpp
Entire rearing cycle	Density Index	<0.20
	Flow Index	<0.60
Apr.	Release Number	400,000
	Outmigration survival	>50%
	Travel to McNary Dam	<45 days

1) Performance goals have a range of +/- 10% of reported value.

2) Green egg collection is more than program needs due to poor condition of eggs from females in the later portion of the run.

Adult Return/Broodstock - The adult return/broodstock collection performance goals reflect the ability of the Entiat NFH to collect, hold, and spawn adult summer Chinook Salmon. Performance goals for the adult return/broodstock encompass the adult life stage from upstream migration through egg eye-up, and occur during one calendar year (Table 2).

Table 2. Entiat NFH adult return/broodstock objective and performance goals.

Timeframe	Objective	Performance Goal
February	Run Forecast	Accurately forecast the adult return for broodstock and harvest management.
May-June	Columbia River Run Timing	Track in-season run size and timing.
July	Adult Ladder Operation	Maximize hatchery-origin Chinook collection and minimize natural-origin fish collection.
May-July	Stray Rate of ENFH-origin fish in-basin & out-of-basin	<10% and 5%, respectively
May-September	Broodstock Use	>95%
October	Green Egg take	600,000

Brood Year - Brood year performance goals assess survival and harvest of a single release group or cohort of fish. Brood year performance goals cannot be accurately assessed until all of the adults have returned and all of the various marking programs have compiled their data. Reports on the brood year performance goals are often many years behind the actual brood year because of data processing and reporting delays. Brood year goals include maximizing harvest contribution and mitigating ecological/genetic risk. These goals are accomplished by maintaining high SAR rates, minimizing age-3 (i.e. Jack) returns, rearing migration ready smolts, minimizing juvenile early maturation, providing accurate and timely run forecasts to fishery managers, managing stray rates and excess hatchery-origin returns, and ensuring that hatchery operation have minimal effect on the natural environment.

Environmental Conditions

In 2017, Central Washington experienced a wet spring with average air temperatures followed by a normal summer. Mountain snow packs were 113% of average in 2017 (USDA Washington Water Supply Outlook April 2017 – Central Columbia) and diminished rapidly due to a wet spring resulting in above average spring flows. An above average flow peak of 4,650 ft^3/sec occurred on May 31 (Figure 3).

Over the 18 month rearing cycle Entiat NFH uses both ground and surface water to rear each brood however water sources differ seasonally. To minimize exposure to potential pathogens from anadromous adults in the river during the summer ground water is used. During the winter surface water is used to modulate growth and improve homing fidelity. Ground water is applied from the egg to sub-yearling life stages with final smolt rearing on a combination of surface (~80%) and groundwater (~20%) from November to spring release in mid-April.

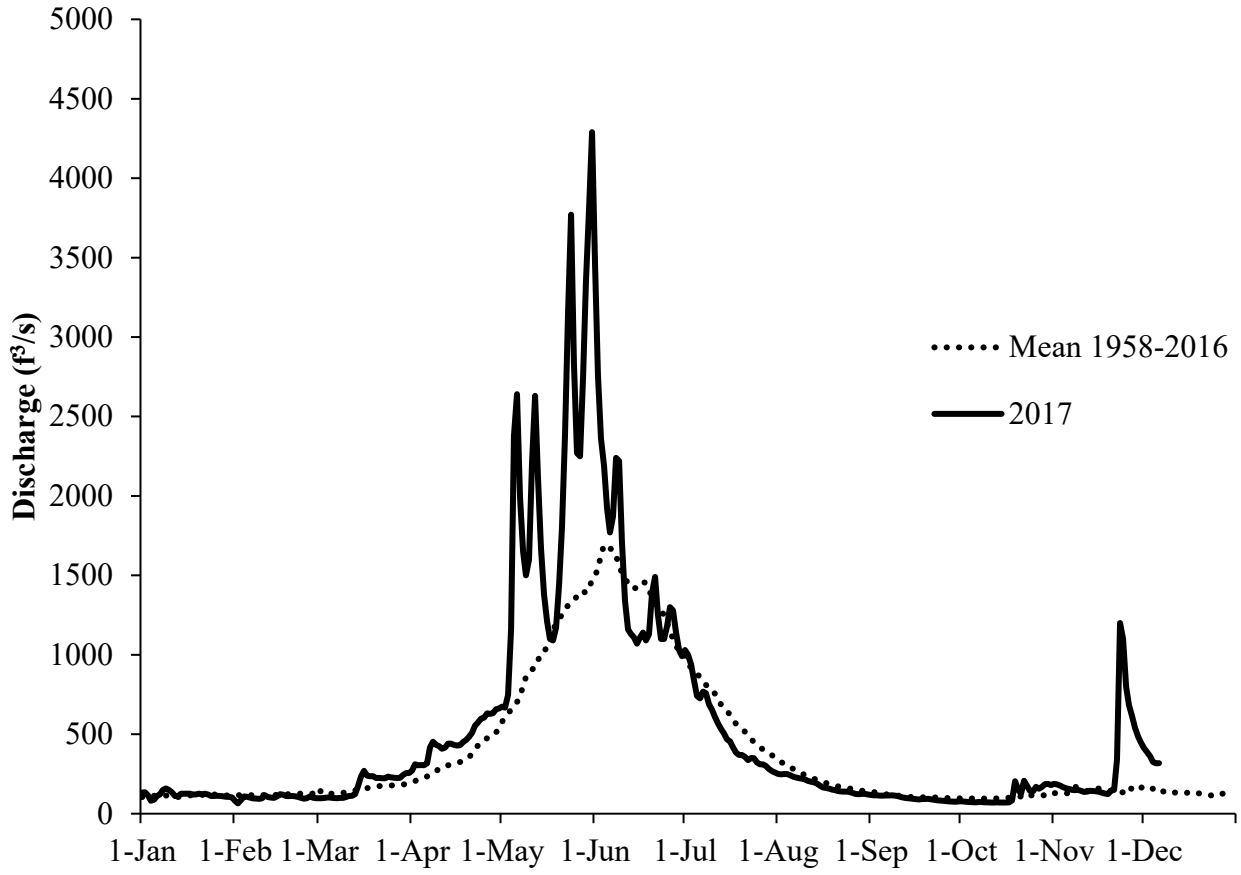

Figure 3. Mean daily flow (ft^3/s) of the Entiat River, WA (U.S. Geological Survey gauge #12452990) for the period of record (1958-2016) and study year 2017.

Release Year 2017

Juvenile Rearing

Yearling juvenile summer Chinook Salmon smolts released in 2017 came from eggs taken in brood year 2015. Broodstock in 2015 consisted of 150 pairs and all were of ENFH origin. The green egg take was estimated at 595,000 and nearly equal to the performance goal of 600,000 green eggs. One female had high ELISA values, that egg tray was culled. Five other trays of poor quality eggs were also culled. A total of 484,513 green eggs were harvested, which yielded 458,212 eyed-eggs for production at an eye-up of 95% which met the >90% survival goal for this life stage. Culling reduced egg numbers to 445,080 eggs. Juvenile rearing of this cohort began on April 29, 2015, when 431,031 fry were ponded into six of the raceways in A bank at approximately 72,000 fish per raceway and 882 FPP (Table 3). The number of fry ponded was 108% (target = 105%) of the smolt release target of 400,000, allowing for expected mortality rates. Feeding began on May 2. Fish were 100% adipose clipped and CWT's were implanted into 224,102 fish July 19–27. Fish were marked and tagged using an AutoFish System® (Northwest Marine Technology, Inc. http://www.nmt.us/products/afs/afs.shtml) that provides a complete census of the rearing group and is an important metric for determining the accuracy of monthly inventories since a complete census was conducted at the eyed stage. Additionally, the success of marking is maximized if the fish meet a critical size target (80-120 fpp target) with limited covariance in size (<10% CV). At the time of marking and tagging the fish were 105 fpp with a CV of 5.7% indicating that both metrics met size criteria. We estimated a post-mark CWT retention rate estimated at 99.4% (target >98%) and an ad-clip rate of 99.1% based on a sample of 507 fish 36 days post-tagging. Fish were accurately enumerated while being marked and distributed across 18 raceways. In November the fish were redistributed across 30 raceways after surface water was incorporated into the raceways.

During the rearing cycle fish culturists monitor the density of fish per rearing vessel and the flow of water through the rearing vessel. Reduced densities and increased flow achieve desired growth rates and reduce the risk of disease but densities and flow are often limited by rearing space and water availability to achieve production targets. To assess the relationship of rearing volume and density Piper et al. (1982) suggested calculating a Density Index (DI) as:

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

Likewise, the relationship of density to flow uses a Flow Index (FI) calculated as:

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

2017 rearing cycle, the mean monthly DI was 0.08 (0.03–0.12). This met the DI performance goal of <0.20 and suggested that sufficient space was available to achieve production and size targets throughout the rearing cycle.

For the release year 2017 rearing cycle, the mean monthly FI was 0.43 (0.21–0.72). The FI performance goal (<0.60) was exceeded in the late summer and early-fall as juvenile growth exceeds available ground water supplies prior to switching to winter surface water resources. Entiat NFH has a very clean ground water source but lacks sufficient volume to meet FI goals year-round at production levels. Surface water (Entiat River water) was not used during early rearing at Entiat NFH because of disease risks from naturally spawning salmon upstream of the water intake. After natural spawning in the river is complete and fall flows have helped reduce potential pathogen loads, surface water was used for final rearing at Entiat NFH. The addition of river water to limited ground water resources during final rearing stage substantially improves the flow indices at Entiat NFH.

Table 3. Monthly biological and environmental data for the 2015 brood year reared at Entiat National Fish Hatchery and released into Entiat River on April 13, 2017.

Month-Year	N	Life Stage	Size FPP	Growth (inches)	Mort (%)	Temp (ºF)	% Water Source Ground/Surface
Oct-15	134	Adult				43	100/0
Oct-15-Jan-16	519,370*	Egg			8.14	40-43	100/0
Feb-Mar -16	480,276*	Alevin			3.16	40	100/0
Apr-16	465,564*	Fry	882	0	0.00	47	100/0
May-16	465,564*	Fry	266	0.742	0.12	48	100/0
Jun-16	465,006*	Fry	207	0.427	0.06	48	100/0
Jul-16	464,727	Sub-yearling	105	0.623	0.06	51	100/0
Aug-16	464,520	Sub-yearling	54	0.764	0.04	51	100/0
Sep-16	464,414	Sub-yearling	37	0.512	0.02	51	100/0
Oct-16	464,255	Sub-yearling	28	0.420	0.03	51	100/0
Nov-16	464,007	Sub-yearling	25	0.15	0.06	42	15/85
Dec-16	463,597	Sub-yearling	25	0.19	0.09	35	15/85
Jan-17	463,159	Sub-yearling	26	0.000	0.09	37	20/80
Feb-17	462,749	Sub-yearling	25	0.100	0.10	38	20/80
Mar-17	462,523	Yearling	18	0.460	0.05	41	20/80
Apr-17	462,116	Yearling	16.0	0.100	0.02	42	20/80

*These data were adjusted after the population census in July concluded that there were 34,000 more fish on station that previously estimated. Using mortality data we back-calculated and adjusted earlier numbers. Prior reports may have lower numbers for these metrics if they were not adjusted.

Release

On April 13, 2017 Entiat NFH staff force-released 462,116 summer Chinook Salmon smolts into the Entiat River at 16 fpp. The 2017 release number was 115.5% of the performance goal and 1.0 fpp larger than the performance goal range of 17 fpp. Just under half (48.5%) of the fish released were CWT-tagged and 100% were adipose-clipped (Table 4). Rain caused high flows in early-April that brought high loads of debris downstream that clogged screens at the surface water intake. Hatchery staff worked through the night to remove debris and keep water flowing to the fish. Fish were released into a turbid river with high flows.

In October of 2017, the USFWS marking crew PIT-tagged 20,058 fish at Entiat NFH as part of the HE's assessment plan. HE-staff use PIT tag data to assess post-release metrics including: outmigration survival rates, outmigration travel times, in season abundance estimates for returning adults and adult migration timing. Post-tagging and before the first cleaning of each raceway HE biologists used large magnets to scan and recover any PIT tags that had been shed by fish. All mortalities were scanned for PIT tags and if detected they were removed from the database.

Table 4. Entiat National Fish Hatchery release year metrics, 2011–2017.

Release Date	Total Released	CWT Released	CWT (%)	Adipose Clip (%)	PIT tagged	PIT tag ratios
4/13/2017	462,116	224,102	48.5	100	20,058	1 : 21.9
4/6/2016	421,783	201,246	47.8	100	19,919	1 : 21.1
4/13/2015	417,995	199,039	47.6	100	9,963	1 : 41.9
4/9/2014	386,569	173,731	44.9	100	9,897	1 : 39.1
4/16/2013	356,098	214,738	60.3	100	9,970	1 : 35.7
4/17/2012	174,661	173,930	99.6	100	9,944	1 : 17.6
4/15/2011	150,181	148,857	99.1	100	9,961	1 : 15.1

Smolt Outmigration

Initial smolt migration readiness was evaluated based on PIT tag interrogations at the juvenile bypass system at Rocky Reach Dam (RRJ) located 26 rkm (11 rkm Entiat River + 15 rkm Columbia River) downstream of ENFH at rkm 763. In 2017, it took smolts 27 days for 90% of the detected juveniles to pass the Rocky Reach Dam (Table 5). The 2017 outmigration year was the second quickest migration period recorded since monitoring began in 2011 however; passage timing has been highly variable and does not appear related to release date. For example, the earliest (2014) and latest (2012) release dates resulted in two of the fastest outmigration rates observed and are most likely the result of environmental variables such as flow and water temperature. Additionally, these crude results represent only the proportion of interrogated juveniles without any adjustments made to potential differences in seasonal or inter-annual detection efficiency or mortality after release that could significantly alter the observations described here.

Table 5. Entiat NFH summer Chinook Salmon juvenile migration cumulative passage dates and number of days from release to percent passage of out-migrating smolts detected at Rocky Reach Dam, 2011–2017.

Release	Passage Date				Days from release to passage			
Date	25%	50%	75%	90%	25%	50%	75%	90%
13-Apr 2017	14-Apr	15-Apr	19-Apr	11-May	1	2	6	27
6-Apr 2016	9-Apr	10-Apr	25-Apr	4-May	3	4	19	28
13-Apr 2015	21-Apr	28-Apr	8-May	20-May	8	8	25	37
9-Apr 2014	10-Apr	12-Apr	16-Apr	7-May	1	3	7	28
16-Apr 2013	29-Apr	13-May	27-May	30-May	13	30	41	44
17-Apr 2012	19-Apr	19-Apr	20-Apr	30-Apr	2	2	3	13
15-Apr 2011	19-Apr	1-May	15-May	19-May	4	16	30	34

Survival and travel time of smolt outmigration was also measured at McNary Dam, located at 319 rkm downstream from Entiat NFH at rkm 470. McNary Dam is roughly half the distance between Entiat NFH and the Pacific Ocean and has a dedicated juvenile monitoring and bypass interrogation facility. Additionally, McNary Dam is upstream of other juvenile monitoring facilities which allowed for use of Cormack-Jolly Seber mark-recapture methodologies to derive survival estimates. Travel time and survival estimates were provided by Columbia River DART (Data Access Real Time) program and calculated using PIT tag detections at dams.

In 2017, smolts released at Entiat NFH took an average of 29.2 days to reach McNary Dam and we estimated that 65.2% survived the journey (Table 6). The travel time was not substantially different from previous years however; the survival rate in 2017 was tied with 2016 for the highest recorded for summer Chinook Salmon produced at Entiat NFH.

Table 6. Entiat National Fish Hatchery smolt out-migration metrics, 2011–2017.

Release Date	PIT tags	Mean (harmonic) Travel Time to McNary Dam in Days (95% CI)	PIT tags detected at McNary Dam	Survival to McNary Dam % (95% CI)
4/13/2017	20,058	29.2 (28.5–29.9)	1,121	65.2 (57.2-73.2)
4/6/2016	19,919	29.9 (29.6–30.2)	2,356	65.2 (58.4–67.8)
4/13/2015	9,962	35.8 (34.8–36.8)	321	47.9 (42.8–63.0)
4/9/2014	9,897	40.5 (39.5–41.5)	615	49.4 (45.5–53.3)
4/16/2013	9,970	37.3 (36.4–38.2)	843	61.0 (54.5–67.5)
4/17/2012	9,944	31.6 (30.8–32.4)	1,024	54.0 (49.7–58.3)
4/15/2011	9,961	29.3 (28.4–30.2)	772	61.4 (56.9–65.9)

Early Maturation

Summer Chinook Salmon most commonly mature in the ocean at age-3 and older; however, some individuals mature earlier they are primarily male and are known as precocial parr or minijacks (Beckman and Larsen 2005). Early maturation of Chinook Salmon is defined as the complete development of primary sexual characteristics (gonads) and/or the expression of reproductive behavior before age-3. Minijacks are known to occur in natural-origin Chinook Salmon populations but their numbers are so low the trait is considered maladaptive (Beckman and Larsen 2005). In contrast, hatchery-origin Chinook Salmon often exhibit higher minijack rates. In a hatchery, minijacks may mature prior to release and residualize at the point of release, or they may initiate out migration only to reverse course and migrate upstream and attempt to spawn (Mullen et al. 1992; Beckman and Larsen 2005).

Entiat NFH staff are interested in monitoring minijack rates because they represent hatchery effort that resulted in non-harvestable fish. Additionally, hatchery minijacks can stray and spawn with natural-origin populations which is often viewed as an example of maladaptive hatchery genes negatively impacting the natural populations of Chinook Salmon (Beckman and Larsen 2005). Furthermore, minijacks are too small to be trapped effectively at the Entiat NFH adult ladder so if they do return to the hatchery they could escape to the river having ecological and geneflow effects. However, minijacks are removed from the adult ponds every year and though they could return to the river they rarely do likely because of ripe females in the adult ponds.

Beckman and Larsen (2005) suggested estimating the occurrence of minijacks by monitoring PIT tagged juvenile upstream migration (via PIT detections at dams) during the year of their intended outmigration. They suggested that Chinook Salmon detected in the Columbia River after June 1 of the year they were released should be considered minijacks. In 2017 there were 97 PIT-tagged fish that were detected at dams after June 1 and/or displayed upstream migration through dams. Of the fish that showed upstream migration, 89 were first detected moving upstream at Bonneville Dam. The rate of early maturation for Entiat NFH-origin fish using this technique was <1% for 2011–2017 (Table 7).

Table 7. Rate of early maturation (minijacks) of Entiat NFH-origin fish using PIT tag detections of fish moving upstream the same year they were released after June 1 by release year.

Release Year	Release Number	# PIT	PIT Ratio Non-Tag/Tag	Observed Minijacks	Estimated Minijacks[1]	Minijack Rate (%)
2017	462,116	20,058	21.9	97	2,124	0.46
2016	421,783	19,919	21.1	173	3,650	0.87
2015	417,995	9,962	41.9	13	545	0.13
2014	386,569	9,897	39.1	8	313	0.08
2013	356,098	9,970	35.7	21	750	0.21
2012	174,661	9,944	17.6	32	563	0.32
2011	150,181	9,961	15.1	70	1,057	0.70

[1]"Expanded" refers to the number of minijacks x the PIT tag ratio.

Determining early maturation using PIT detections was plagued by very low sample sizes, and did not account for non-migrating minijacks that were not available for PIT tag interrogation. Evaluation of gonad maturation rates by lethally sampling a portion of the fish prior to release indicated that maturation rates were 15.1% (Table 8), much higher than those estimated by PIT tag data. It is important to note that the PIT tag method estimates % maturation for the entire population while the GSI sampling estimates only male maturation. For a direct comparison between the methods divide the GSI % maturation in half, assuming an equal sex ratio of the smolts released. We calculated a gonadosomatic index (GSI) for 325 and 319 Entiat NFH-origin male summer Chinook Salmon in 2016 and 2017, respectively. We weighed the fish to the nearest tenth of a gram then weighed the testes on a microbalance to the nearest milligram and applied the following formula: 100 x (testes weight/body weight) (Larsen et al. 2004; Larsen et al. 2013).

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). Entiat NFH attempts to minimize the occurrence of early maturation through dietary regulation and the minimal use of warm, growth-promoting well water in the winter.

Table 8. Maturation percentage of male summer Chinook Salmon at Entiat NFH determined by gonadosomatic index.

Release Year	% Mature	Sampled (n)
2017	15.1	325
2016	21.3	319

Adult Return/Broodstock 2017

Run Forecast

During this initial period of the Entiat NFH summer Chinook Salmon program HE staff are gathering data and developing predictive models to estimate run size before Chinook Salmon enter the Columbia River. In-season projections of the run size were made as returning fish were detected by PIT tag antenna arrays in the Columbia River.

Adult Return

Columbia River- Entiat NFH-origin summer Chinook Salmon that were PIT tagged as juveniles that returned as adults to the Columbia River were first detected by PIT-tag antenna arrays in the adult ladders at Bonneville Dam. Detection efficiency at Bonneville Dam and other main-stem adult fish ladders is greater than 90% (Burke et al 2006) and assumed as a nearly complete interrogation census of returning tagged adults. Based on PIT tags from Entiat NFH-origin summer Chinook Salmon detected at Bonneville Dam as expanded by the PIT tag ratios of each age class 2,890 Entiat NFH-origin summer Chinook Salmon were predicted to have passed Bonneville Dam in 2017. Using average reach survival rates from Bonneville Dam to Rocky Reach Dam then from Rocky Reach Dam to Entiat NFH it was predicted that 1,664 Entiat NFH-origin summer Chinook Salmon migrated above Rocky Reach Dam and 1,072 to Entiat NFH.

The 2017 return was larger than predicted during the in-season forecast (Table 9). The fish ladder at Entiat NFH was open continuously from July 1–October 31 in 2017. The opening and closing dates of the fish ladder are dictated in the operational permit for the facility.

Table 9. Total abundance of fish by species and run that entered the Entiat NFH adult fish ladder for years 2011–2017.

Year	Chinook			Coho	Sockeye	Bull Trout	Steelhead
	Summer	Spring	Fall				
2017	1,330	1	0	33	0	0	1
2016	2,111	2	0	2	0	0	0
2015	1,507	1	0	6	3	0	0
2014	952	3	2	96	0	1	0
2013	856	3	3	3	0	2	0
2012	454	0	2	6	1	0	0
2011	251	0	0	0	0	0	0

Run Timing - The timing of the run based on detections at Bonneville Dam has been earlier each year since the first run in 2011 (Table 10). Chinook Salmon exhibit an age-dependent temporal pattern in their returns with older fish returning earlier than younger fish (Beer 2007; Anderson and Beer 2009; Bracis and Anderson 2013). ENFH began summer Chinook Salmon production in 2009, the first release was 2011 and the first full production release was in 2013. The return years 2011–2013 from ENFH production were disproportionately composed of younger age-classes therefore the overall timing of the run was likely skewed towards later dates. Considering the temporal pattern of returns by age the more recent years (2014–2016) were favored in assessing the percentage of the run over Bonneville.

Table 10. PIT tag detection (First and Last) and the percent of the run passage of Entiat NFH-origin summer Chinook Salmon at Bonneville Dam 2011–2017 (Columbia River DART).

Year	First	Percent Passage							Last
		5%	10%	25%	50%	75%	90%	95%	
2017	25-May	9-June	16-Jun	24-Jun	18-Jul	1-Aug	8-Aug	17-Aug	8-Sep
2016	25-May	9-Jun	13-Jun	23-Jun	16-Jul	26-Jul	6-Aug	14-Aug	18-Sep
2015	25-May	9-Jun	12-Jun	22-Jun	30-Jun	14-Jul	25-Jul	9-Aug	12-Sep
2014	28-May	7-Jun	12-Jun	22-Jun	1-Jul	13-Jul	26-Jul	5-Aug	14-Aug
2013	6-Jun	16-Jun	19-Jun	1-Jul	17-Jul	3-Aug	7-Aug	12-Aug	31-Aug
2012	17-Jun	24-Jun	28-Jun	23-Jul	2-Aug	9-Aug	19-Aug	27-Aug	16-Sep
2011	19-Jul	23-Jul	27-Jul	2-Aug	11-Aug	17-Aug	22-Aug	28-Aug	13-Sep

Harvest - Total commercial and sport harvest for Entiat NFH-origin summer Chinook Salmon age-3 and older in 2017 was estimated at 976. The harvest performance goal of 1,600 fish available to harvest (NMFS 2013) was reached when considering the additional 1,330 fish that returned to ENFH and were available for harvest. Harvest data were based on recovered CWT tags collected by various entities and entered into RMIS then expanded to reflect CWT-tagging rates at Entiat NFH. Much of the CWT data used to describe harvest in this report was voluntarily reported and not all data may have been submitted or validated at the time of this publication. Due to delays in reporting these data are subject to change however, we do not expect small changes in data to alter the general trends discussed in this document. The biggest difference in harvest between 2017 and the two previous years was in the commercial harvests. However with larger returns to Entiat NFH and increased awareness of fishing opportunities we anticipate increased angling pressure and a larger river harvest in coming years.

Table 11. Annual estimate of age-3 and older Entiat NFH-origin summer Chinook Salmon harvested in ocean, estuary and freshwater environments by three harvest groups.

Year	Ocean			Estuary	Freshwater			Total
	Commercial	Sport	Tribal	Sport	Commercial	Sport	Tribal	
2017	503	140	16	0	19	269	29	976
2016	1,606	209	41	2	898	148	149	3,176
2015	1,620	85	12	1	2,056	451	33	4,258
2014	556	105	26	8	298	271	26	1,291
2013	72	18	0	6	48	48	10	202
2012	5	27	0	0	0	7	0	39

Hatchery Returns - In 2017, of the 1,330 summer Chinook Salmon that entered Entiat NFH 756 had a CWT. Of these, 60 CWTs were from out-of-basin hatcheries and two additional CWTs were found in spring Chinook Salmon (Table 12). All hatchery fish were retained and either surplused or used in brood stock operations as per our operation mandates (NMFS 2013). All stray, hatchery-origin summer Chinook Salmon captured in the adult pond at Entiat NFH in 2017 came from programs with 98–100% CWT rates. Considering that less than half of the Entiat NFH production was marked with a CWT all of the 576 non-CWT adipose-clipped summer Chinook entered Entiat NFH were presumed to be Entiat NFH-origin.

Entiat NFH-origin summer Chinook Salmon have an unusual return timing behavior when they migrate upstream into the hatchery ladder. Two pulses of fish return to Entiat NFH and they are separated by about 6 weeks. Roughly 75% of the return on any given year occurs mid-July through mid-August. Then there is a pause in the return and in late-September roughly 25% of the return migrates up the fish ladder into the facility. Entiat NFH-staff strive to donate as much of the early return as possible to the tribes after they have secured their broodstock. However, relying on the late return for broodstock is risky so management retains the majority of the broodstock needed for production from the early portion of the return. The late-run fish are not suitable for consumption so Entiat NFH-staff are able to harvest more eggs than necessary for production goals to buffer against the potential impacts of stack failures, poor eye-up and low fecundity while not negatively impacting fish use.

Table 12. Origin of hatchery-origin returns removed from the holding pond at Entiat NFH in 2017.

Hatchery Origin	Observed	% CWT Tagged	Expanded	Run
Chelan Falls	8	99	8	Summer
Chiwawa	1	98	1	Spring
Dryden Pond	50	99	50	Summer
ENFH	667	48[1]	1,270	Summer
Leavenworth NFH	1	23	4	Spring
Wells	2	99	2	Summer
Winthrop NFH	4	91[2]	- -	Coho
CWT Tag Lost	29		- -	- -

1) Composite tag rate weighted by return year abundance, CWT % varied 47–90 but most returns were from release years 2013-2017.
2) Composite tag rate weighted by rerelease location abundance, CWT % varied 71-97, all were from release year 2016.

The majority of summer Chinook Salmon that returned to Entiat NFH in 2017 were age-5 (Table 13). In 2017 age-5 returns were from release year 2014. A dominate age-5 class was not expected, it was likely the result of poor ocean conditions for returning age-4 fish that were released in 2015. Similarly, age-4 spring Chinook Salmon returns in 2017 were one of the lowest on record. If ocean conditions were the cause of the low age-4 returns we expect poor returns from age-5 fish in 2018.

Table 13. Age composition of Entiat NFH adult pond by year including: returns, strays and brood transfer from Wells Hatchery (2011–2013).

Return Year	Age					
	2	3	4	5	6	7
2017	5.6%	8.9%	14.9%	58.4%	12.2%	0.0%
2016	3.1%	3.5%	25.9%	64.9%	2.6%	0.0%
2015	0.3%	10.4%	73.3%	15.7%	0.2%	0.0%
2014	3.5%	26.2%	57.3%	12.9%	0.0%	0.0%
2013	22.0%	13.8%	44.4%	19.3%	0.4%	0.1%
2012	28.7%	11.5%	46.3%	12.2%	1.4%	0.0%
2011	0.0%	12.9%	27.2%	57.8%	2.2%	0.0%

In 2017, more males than females returned to Entiat NFH (Table 14). A skewed sex ratio was expected at this point because of the 14.5% of returning age-2 and age-3 fish which are predominately male.

Table 14. Sex composition of sampled adults at Entiat NFH 2010–2017 (includes brood transfer from Wells Hatchery 2010–2013).

Return Year	Male	Female	Ratio (M:F)
2017	404	327	1.2
2016	1,191	805	1.5
2015	827	566	1.5
2014	769	368	2.1
2013	642	428	1.5
2012	319	272	1.2
2011	124	232	0.5
2010	53	102	0.5

Broodstock - Only 23 of the 1,330 summer Chinook Salmon that returned to Entiat NFH in 2017 were either pond mortalities or unsuitable for use as brood stock resulting in a use efficiency rate of 98.3% which exceeds the performance goal of 95% (Table 15).

To minimize prespawn mortality (PSM) of adults, formalin treatments were added to the holding ponds to control fungus and parasites five days/week. Formalin was administered by adding the chemical to the water as it entered the holding pond, for one-hour at a concentration of 167 ppm.

The Olympia Fish Health Center provided health profiles for the broodstock used for production. Sampling protocols included testing all females for the presence and extent of BKD. Additionally, bacteriology (kidney/spleen) was conducted on a minimum of sixty males and virology (ovarian fluid) on a minimum of 150 females. Similar to 2015 and 2016 no erythromycin was injected in 2017 due to lack of BKD issues on-station and in previous years.

Table 15. Entiat NFH summer Chinook Salmon use data 2011–2017.

Year	Spawn	Surplus/Donated	DIP/Jump out	Green/Spent/Bad	Ad Present (returned to river)	Efficiency
2017	299	971	23	5	30	98%
2016	301	1,775	25	5	5	99%
2015	268	1,126	75*	34	4	93%
2014	310	618	8	16	0	98%
2013	306	543	2	5	0	99%
2012	245	198	1	10	0	98%
2011	230	7	10	4	0	94%
2010	100	3	15	2	0	86%

*50 fish came up the ladder mid-late October in poor condition

Spawning - In 2017, spawning occurred on October 3. The broodstock consisted of 299 adults and five that were in poor condition or green and were not used. Spawned fish included 149 adult males and 150 females for a sex ratio of 1:1. The green egg take was estimated at 600,000, which is the performance goal calculated with a fecundity of 4,000 total eggs/female.

The Enzyme-Linked Immunosorbent Assay (ELISA) was used to detect the prevalence of BKD from females used in propagation. ELISA aids in determining the degree of risk for vertical transmission of BKD from mother to progeny. In salmonids, the Olympia Fish Health Center divides risk into six levels, ranging from "No Detection" to "Very High" risk. In 2017, over 98% of the females were in the "Very Low" and "Low" risk levels (Table 16). At the time of spawning, the eggs from each female were held in separate trays. When the ELISA results were complete, "High" and "Very High" risk groups were normally culled and would only be kept in extreme cases. For example on a very low return year high ELISA results may be kept on station and if so they would be isolated as much as possible throughout the rearing cycle. If the hatchery has more eggs than necessary for production, eggs from the higher risk females may be culled.

Table 16. ELISA results for Entiat NFH spawned females by percentage and total females spawned (N) 2009–2017.

Year	None	Very Low	Low	Moderate	High	Very High	No Data	N
2017	0.0	81.3	17.3	0.0	0.7	0.7	0.0	150
2016	0.0	97.3	2.0	0.0	0.0	0.7	0.0	150
2015	0.0	72.7	26.7	0.0	0.0	0.7	0.0	150
2014	0.0	78.2	19.2	0.6	0.6	1.3	0.0	156
2013	0.0	62.7	35.3	0.7	0.0	0.7	0.7	153
2012	0.7	11.1	83.7	0.0	0.0	0.0	4.4	135
2011	3.5	85.2	11.3	0.0	0.0	0.0	0.0	115
2010	0.0	80.0	18.0	0.0	0.0	2.0	0.0	50
2009	2.3	95.5	2.3	0.0	0.0	0.0	0.0	44

In 2017, the total egg take was estimated at 586,295, which was slightly below the estimated 600,000. After culling of excess eggs harvested—due to the bimodal distribution of hatchery return timing discussed earlier—488,579 green eggs were kept for production (Table 17). Fecundity is difficult to estimate in a new program and we will continue to improve estimates and adjust our goals accordingly as more years of data become available. Two egg trays were removed due to a high ELISA and 23 trays were culled to select for the healthiest egg trays and reduce egg numbers. 89.8% of the green eggs survived to eye-up (Table 17). The performance goal of >90% stage survival was met in 2017. Since 2013 the eye-up % has met or exceeded the performance goal. Similarly, other summer Chinook hatcheries in the area also reported lower than average fecundity (84–88%) suggesting that ocean conditions may have retarded development of a higher percentage of eggs than normal.

Table 17. Egg data for summer Chinook Salmon spawned at Entiat NFH 2009–2017.

Year	Green Eggs	Good Eggs	Bad Eggs	Eye-up %	Green Eggs/Female
2017	488,579	438,617	49,962	89.8	3,909
2016	456,515	445,703	10,812	97.6	4,188
2015	484,513	458,212	26,301	94.6	3,876*
2014	509,028	492,397	16,631	96.7	4,072
2013	451,712	437,566	14,146	96.9	4,222
2012	442,183	412,794	29,389	93.4	3,685
2011	424,214	381,641	42,537	90.0	3,928
2010	198,585	183,791	14,794	93.0	4,053
2009	190,057	173,942	16,115	92.0	4,400

*Marking in July found the estimated number of fry to be 34,000 less than the actual number. After back-calculating from marking data estimated fecundity of the 134 spawned females at 3,876.

Brood Year

An analysis of a full brood year for a full production release from Entiat NFH was not possible at this time. The first release of summer Chinook Salmon program was in 2011 but it was half the production goal of 400,000. The program gradually increased production and the 2013 release was less than 50,000 fish short of full production but was not within the +/-10% of the 400,000 target. The 2014 release (brood year 2012) can be analyzed in a brood year report after 2018 return data is completed.

Brood years 2009–2011 have complete adult returns ages 3–6. Smolt-to-adult (SAR) rates for brood year 2009 were 0.5%, for brood year 2010 were 1.4%, and for brood year 2011 were 2.4%. For these calculations all adults harvested age 3–6 in ocean and freshwater were used. However, brood year 2009 and 2010 were only 150,181 and 174,661 respectively, each was less than half the full production goal. Although the SAR rate appears to be fairly high the sample sizes of the first two release groups were small and at this point no further investigation is warranted.

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