U.S. Fish and Wildlife Service

Entiat National Fish Hatchery Annual Report, 2015

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On the cover*: Aerial Photograph taken in 2006. USFWS photograph.*

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LEAVENWORTH NATIONAL FISH HATCHERY ANNUAL REPORT, 2015.

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In Review

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ENTIAT NATIONAL FISH HATCHERY ANNUAL REPORT, 2015.

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Executive Summary- The Entiat National Fish Hatchery (Entiat NFH) was constructed as partial mitigation for anadromous fish loses associated with the construction of Grand Coulee Dam. The hatchery 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 following report summarizes the rearing cycle of Brood Year 2013 and return year of 2015.

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Introduction

Location

The Entiat National Fish Hatchery (NFH) is located west of Entiat, WA on the Entiat River 10.8 river kilometers (rkm) upstream from the confluence of the Entiat River and the Columbia River (Figure 1). Fish migrating from Entiat NFH to the Pacific Ocean travel 790 rkm and pass through eight hydroelectric dams on the Columbia River.

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, a 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 that are operated with chilled spring/well water. The outdoor rearing area is composed of 30 raceways distributed equally in 3 groups (A, B, and C bank) 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 (December 1 to April 15). The holding area is composed of two (16 ft x 120 ft) adult holding ponds that have river access via a fish ladder. All effluent from fish culture practices 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 59,440 L/min. 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 collection point for the fish returning to Entiat NFH.

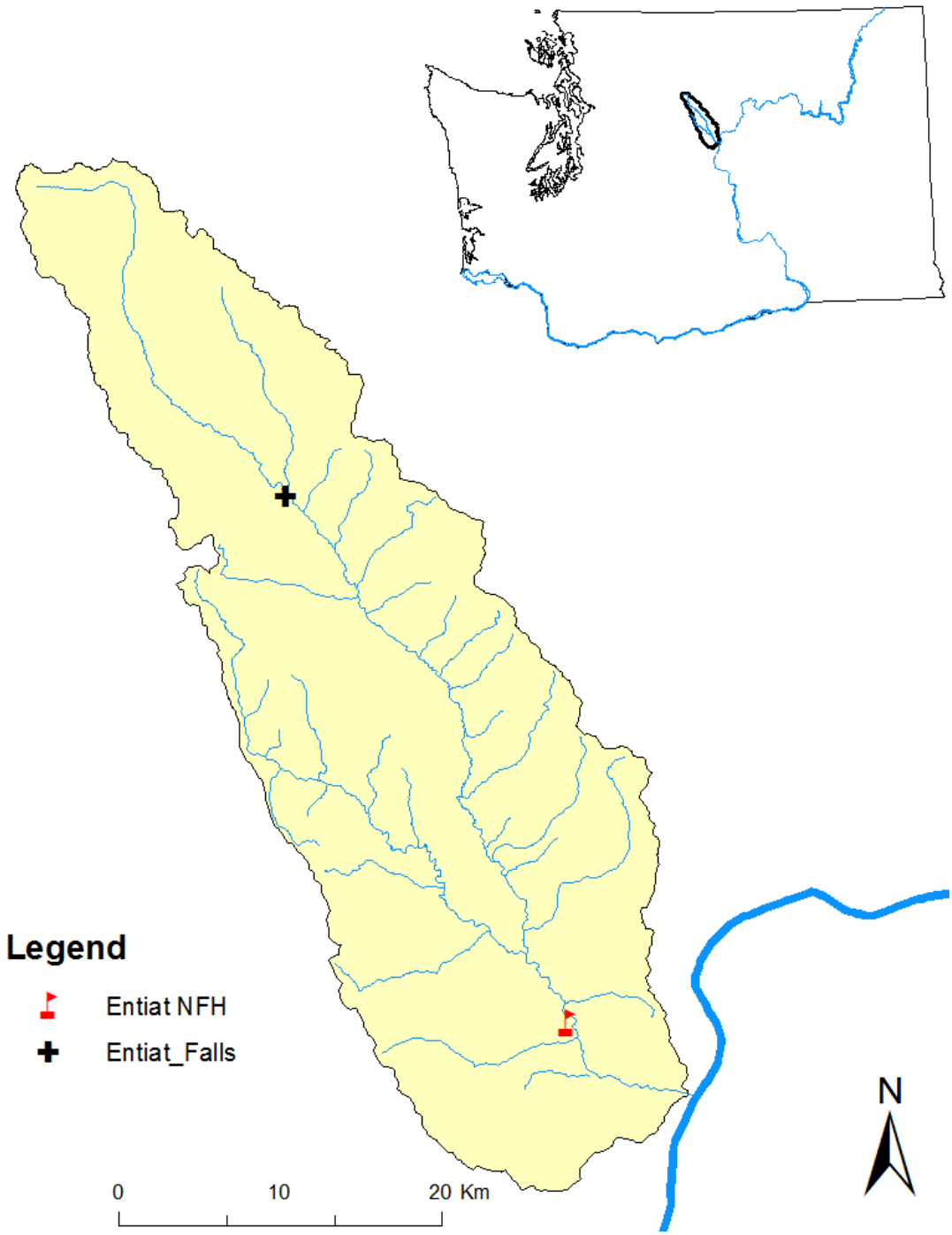

Figure 1. Map of the Entiat River watershed.

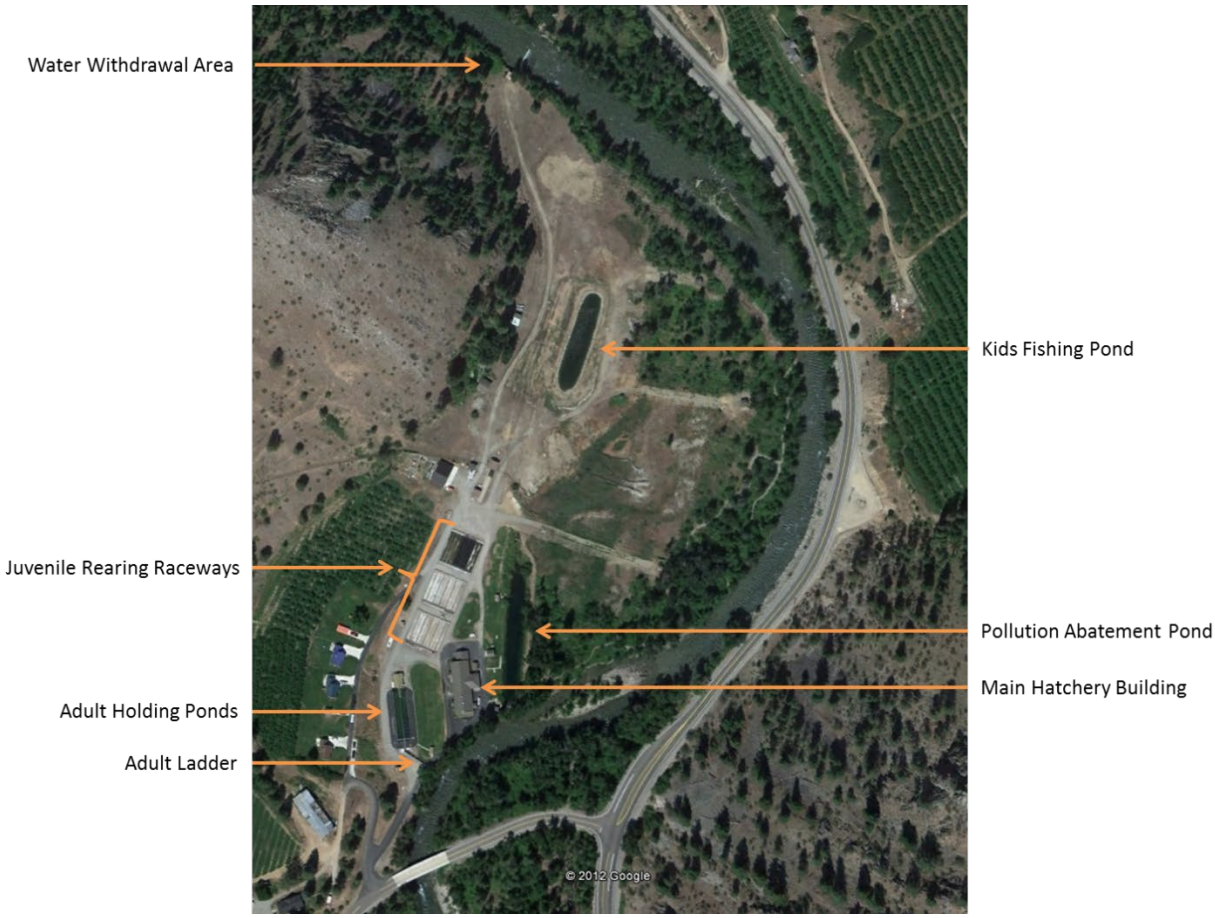

Figure 2. Aerial photograph of the Entiat NFH.

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 produces summer Chinook Salmon for commercial, sport and tribal harvest in a manner which minimizes adverse impacts to the environment. The U.S. Fish and Wildlife Service (USFWS) operates the facility with funds received from the U.S. Bureau of Reclamation (BOR). Summer Chinook Salmon from this program are not intended to spawn naturally, supplement, or support any summer Chinook Salmon populations. The production goal of 400,000 released Chinook Salmon was outlined by the U.S. v. Oregon decision of 1969 and through subsequent management agreements. Marking rates for summer Chinook Salmon released at Entiat NFH were outlined in the US/Canada Pacific Salmon Treaty of 1985.

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

hatcheries program, performance standards, strategies for minimizing program effects on ESA-listed species, and 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. This annual report reflects the Entiat NHH'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.

Historic and Current Rearing Operations

Entiat NFH has produced both spring and summer Chinook Salmon (*Oncorhynchus tshawytscha*) 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. In the fall of 2009, the hatchery began a new program propagating summer Chinook Salmon with broodstock captured at Wells Fish Hatchery that are genetically part of the upper Columbia River summer Chinook Salmon stock (Kassler et al. 2011).

Hatchery Evaluation

The Hatchery Evaluation (HE) program at the Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO) monitors and evaluates the Entiat NFH summer Chinook Salmon program. HE is directed by the Hatchery Evaluation Plan (HEP) a guideline composed of hatcheries governing documents that outlines objectives and tasks for evaluating hatchery programs. More specifically, the HEP states that HE staff must use *"monitoring, evaluation, and targeted research to assist the Entiat Hatchery Complex in effectively meeting both its mitigation goals and ESA responsibilities"*. HE is responsible for coordinating coded-wire tagging (CWT), PIT tagging, operating PIT tag antenna arrays on the fish ladder, adipose fin clipping, and biological sampling of the fish produced at the Entiat NFH. Biological sampling takes place at the hatchery during spawning events as well as in the Entiat River during spawning ground surveys to determine the hatchery impact on the natural-origin summer Chinook Salmon population (Fraser and Hamstreet 2015, 2016). All the tagging and marking of Entiat NFH summer Chinook Salmon is done by the Columbia River Fisheries Program Offices Hatchery Marking Team. Entiat NFH also works with the Olympia Fish Health Center that provides analysis and guidance on all fish health issues.

Date 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 are directly collected when data are not from direct collection the source is cited. The three databases most often used for data collection in this report are:

1) *RMPC* - The Regional Mark Processing Center (RMPC) is an online database operated by the Pacific States Marine Fisheries Commission and designed to house CWT data for the west coast of North America and the northern Pacific Ocean. In previous reports by this agency and others RMPC was referred to as RMIS. When a group of fish is tagged with a CWT, the tag code and number of fish tagged are submitted to RMPC 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 also submitted. RMPC allows managers to calculate survival and contribution metrics for the fisheries they are evaluating. More information can be found at www.rmpc.org.

2) *PTAGIS* - PIT Tag Information System (*PTAGIS*) is an online database 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 the PIT tag is read remotely by a transceiver antenna ("interrogated"), the tag code and location information are also submitted. These data can be collected non-lethally, 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 can be found 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 the fish information including: species, run, rear, release information and counts of fish passing hydroelectric facilities on the Columbia River and its tributaries. More information can be found at www.cbr.washington.edu/dart/.

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. BOR and operated by the USFWS. The *U.S. v. Oregon* decision of 1969, through subsequent management agreements, sets production goals for the facility.

Fish culture facilities, biological surveys, and experiments related to the conservation of fisheries resources were authorized in the Mitchell Act of 1938. The US/Canada Pacific Salmon Treaty of 1985 selected the Entiat NFH stock of spring Chinook Salmon as an indicator stock for the mid-Columbia River contribution to the mixed-stock US and Canadian ocean fisheries. To reduce the impact of Entiat NFH-origin spring Chinook Salmon on ESA-listed natural-origin spring Chinook Salmon in the Entiat River the Entiat NFH terminated their spring Chinook Salmon program in 2007 and in 2009 began raising summer Chinook Salmon.

Endangered Species Act - Entiat NFH operates within the requirements of the Endangered Species Act of 1973. Though the stock 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 (*Salvilinus confluentus*) by the USFWS. Permits are issued for any incidental "take" of listed species through impacts from 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. HGMP contributes to the development of the BiOps and the subsequent permits that are issued by NOAA Fisheries. The HGMP sets broad performance standards that relate to the legal requirements and environmental impacts of the Entiat NFH.

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 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). A release year cohort is the progeny of adult return/broodstock collection, and is reared at the hatchery for 1.5 years.

Table 1. Entiat NFH Release Year Performance Goals and Hatchery Evaluation Plan (HEP) tasks.

Life Stage	Timeframe	Performance Category	End Stage Performance Goal	HEP Task
Fry	May	Fry Ponded	432,405	1.2
Sub-yearling	May-Nov.	Summer Rearing	420,098	1.2
Sub-yearling	Nov.	Sub-Yearling Size	23.70 fpp	1.2
Yearling	Nov.-Mar.	Winter Rearing	418,040	1.2
Yearling	Apr.	Yearling Size	15-20	1.2
Yearling	Entire rearing cycle	Density Index	<0.20	1.2
Yearling	Entire rearing cycle	Flow Index	<0.60	1.2
Smolt	Apr.	Release Number	400,000	3.1-3.2

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 Performance Goals and Hatchery Evaluation Plan (HEP) tasks.

Life Stage	Timeframe	Performance Category	End Stage Performance Goal	HEP Task
Adult	February	Run Forecast	Accurately forecast the adult return to maximize harvest opportunity.	4.1
Adult	January-June	Columbia River Run Timing	Commensurate with run at-large	4.1
Adult	July	Adult Ladder Operation	Collect all available Entiat NFH-origin adults. Minimize straying.	5.1
Adult	May-July	Stray Rate	<2%	9.1-9.2
Adult	May-September	Broodstock Utilization	>95%	5.2
Adult	October	Green Egg take	620,000 (130% of release target)	1.2
Eggs	October	Eyed Eggs	437,566 (104% of release target)	1.2

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. Entiat NFH Brood Year Performance Goals and Hatchery Evaluation Plan (HEP) tasks.

Life Stage	Timeframe	Performance Category	End Stage Performance Goal	HEP Task
Adult	7 years post Brood Year	Smolt to Adult Return (SAR)	Maximize	5.3
Adult	7 years post Brood Year	Return Composition	Minimize 3YO component	4.1
Adult	7 years post Brood Year	Harvest Contribution	Maximize Harvest	4.1

Environmental Conditions

In 2015, central Washington experienced a warm, dry spring followed by a hot, dry summer. Mountain snowpacks were lower than average in 2015 and diminished rapidly due to warm temperatures resulting in low flows and warm water temperatures in the Entiat River (Figure 3).

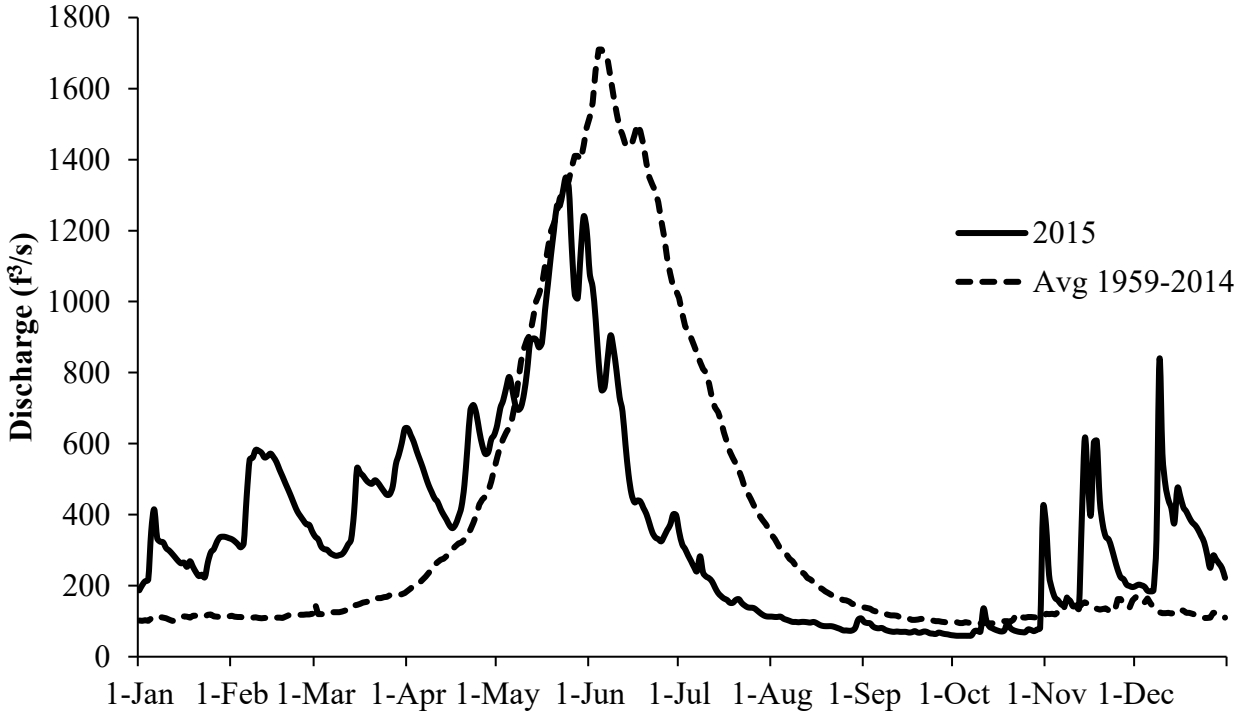

Figure 3. Mean daily flow (f^3/s) of the Entiat River, WA (U.S. Geological Survey gauge #12452990) for the period of record (1959-2014) and study year 2015.

Release Year 2015

The ongoing negotiations within *US vs. Oregon* Management Agreement set the Entiat NFH summer Chinook Salmon smolt release number performance goal for release year 2015 at 400,000.

Juvenile Rearing

Summer Chinook Salmon smolts released in release year 2015 came from eggs taken in brood year 2013. The broodstock consisted of 246 pairs, of the pairs 20 were returns from previous releases of Entiat NFH summer Chinook Salmon. 2013 was the first year that returns were used as broodstock for this program. Juvenile rearing of this cohort began on May 1, 2014, when 432,405 fry were ponded into six of the raceways in A bank at approximately 72,000 fish per raceway and 1,088 FPP (Table 4??). The number of fry ponded was 108% of the Performance Goal of 400,000. Fry were ponded three weeks earlier in 2014 than 2013 to allow feeding over a longer period of time at a more optimal growth rather than constantly maximizing feeding and growth to meet production goals. Feeding began on May 9. Fish were 100% adipose clipped and CWTs were implanted into 200,000 fish the week of July 21–27. During marking, inventory was taken and the exact numbers of fish per raceway were determined. The fish were split equally into all 30 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 are desired to reduce the risk of disease but densities and flow are often limited by rearing space and water availability. Piper et al. (1982) suggested 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:

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

For the Release Year 2015 rearing cycle, the mean monthly DI was 0.08. The DI Performance Goal of <0.20.

For the Release Year 2015 rearing cycle, the mean monthly FI was 0.44 and ranged from (0.24–0.70). Entiat NFH has a very clean water source but it lacks volume for August–October while on ground water. Once the Entiat River receives some fall rain and the last of the carcasses upstream of the intake are flushed out Entiat NFH switches to river water and the FIs improve.

In October of 2014, the USFWS marking crew PIT-tagged 9,963 fish at Entiat NFH as part of the Fish Passage Centers' smolt monitoring program (Table 4). 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. From this point until release every dead fish was scanned for a PIT tag, all recovered tags were removed from the database.

Table 4. Monthly biological and environmental data for the 2013 Brood Year reared at Entiat National Fish Hatchery and released into Entiat River on April 13, 2015.

Month-Year	N	Life Stage	Size (FPP)	Growth (in)	Mort (%)	Temp (ºF)	Ground water/ Surface water (%)
Oct-13	304	Adult				41	100/0
Oct-13 -Jan-14	620,000	Egg			29.84	40	100/0
Feb-Apr -14	435,000	Alevin	1088		0.60	40	100/0
May-14	432,405	Fry	442	0.493	0.26	48	100/0
Jun-14	431,288	Fry	442	0.618	0.06	48	100/0
Jul-14	421,429	Sub-yearling	98.46	0.614	0.08	49	100/0
Aug-14	421,156	Sub-yearling	54.14	0.476	0.06	50	100/0
Sep-14	420,572	Sub-yearling	34.02	0.574	0.14	50	100/0
Oct-14	420,301	Sub-yearling	25.26	0.246	0.06	50	100/0
Nov-14	420,098	Sub-yearling	23.70	0.134	0.05	36-50	15/85
Dec-14	419,351	Sub-yearling	n/a*	0	0.18	37	15/85
Jan-15	418,572	Sub-yearling	25.60	0	0.19	37	15/85
Feb-15	418,185	Sub-yearling	22.75	0.171	0.19	40	15/85
Mar-15	418,040	Yearling	16.41	0.607	0.03	43	15/85
Apr-15	417,995	Yearling	15.11	0.145	0.03	43	

*fish were not sampled due to ice over the raceways

Release

On April 13, 2015 Entiat NFH-staff force released 417,995 summer Chinook Salmon smolts into the Entiat River at 15.11fpp. The 2015 release year was 104.5% of the Performance Goal for Release Number and on the large end of the Performance Goal for fpp of 15-20. Just under half (47.6%) of the fish released were tagged with a CWT and all their adipose fins were clipped (Table 5). The 2015 release date was within the normal range for Entiat NFH summer Chinook Salmon release dates.

Table 5. Entiat National Fish Hatchery Release Year metrics, 2011–2015.

Release Date	Total Released	CWT Released	CWT (%)	Adipose Clip (%)	PIT tagged	PIT tag ratio non-tag/tag
4/13/2015	417,995	199,039	47.6	100	9,963	41.9
4/9/2014	386,569	173,731	44.9	100	9,897	39.1
4/16/2013	356,098	214,738	60.3	100	9,970	35.7
4/17/2012	174,661	173,930	99.6	100	9,944	17.6
4/15/2011	150,181	148,857	99.1	100	9,961	15.1

Smolt Outmigration

Survival and travel time of outmigrating smolts produced at the Entiat NFH was measured at McNary Dam, located at rkm 470. McNary Dam is roughly half the distance between Entiat NFH and the Pacific Ocean and the first in-stream structure with dedicated juvenile monitoring facilities. Additionally, McNary Dam is upstream of other juvenile monitoring facilities which allows HE Biologists to use mark-recapture methodologies to derive survival estimates.

In 2015, smolts released at Entiat NFH took an average of 38.5 days to reach McNary Dam and 47.9% were estimated to survive the journey (Table 6). The travel time was not substantially different from previous years however, the survival rate in 2015 was the lowest recorded for summer Chinook Salmon produced at Entiat NFH. Travel time and survival estimates are provided by the Fish Passage Center and are calculated using PIT tag detections at dams.

Table 6. Entiat National Fish Hatchery smolt out-migration metrics, 2011–2015.

Release Date	**PIT tags**	**Mean Travel Time to McNary Dam (Days)**	**PIT tags detected at McNary Dam**	**Survival to McNary Dam (%)**	**Confidence Limits (95%)**	
4/13/2015	9962	38.5	321	47.9	42.8	63.0
4/9/2014	9897	44.1	615	49.4	45.5	53.3
4/16/2013	9970	41.2	843	61.0	54.5	67.5
4/17/2012	9944	35.6	1024	54.0	49.7	58.3
4/15/2011	9961	34.0	772	61.4	56.9	65.9

Early Maturation

Summer Chinook Salmon most commonly mature in the ocean at age-3 or older however, some individuals mature earlier they are known as precocial parr or minijacks. 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 mature at age-2 or younger, and are almost always males. Minijacks are known to occur in natural-origin Chinook Salmon populations but their numbers are so low the trait is considered maladaptive. In contrast hatchery-origin Chinook Salmon exhibit higher rates of minijacks. 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). More than 50% of the minijacks from hatcheries on the upper Columbia River initiated their upstream spawning migration before reaching the ocean (Beckman and Larsen 2005).

Minijacks are of interest to the Entiat NFH because they represent hatchery effort that results in non-harvestable fish. Additionally, hatchery minijacks 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.

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 2015 there were 13 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, 11 were first detected moving upstream at Priest Rapids Dam and two were detected further upstream at Priest Rapids and Rocky Reach (Table 7). The rate of early maturation for Entiat NFH-origin fish is >1% for 2011–2015 (Table 8). Determining early maturation using this method is plagued by very low sample sizes, and does not account for non-migrating minijacks.

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 7. Suggested instances of early maturation of juveniles (minijacks) released from the Entiat NFH in 2015.

PIT Tag	Bonneville	Priest Rapids	Rocky Reach
3DA.1A19AF203F			7/4
3DD.00774AFAFB		7/16	
3DD.00774815FC	7/21		
3DD.00774A82DB	7/21		
3DD.00774A9E65	7/28		
3DD.007740EA9E	8/16		
3DD.0077571682	8/16		
3DA.1A19AF2A95	8/6		
3DD.007742D17E	8/17		
3DD.007744F5E2	8/25		
3DD.007746F3A0	8/26		
3DA.1A19AF3599	8/31		
3DD.007745FC8F	9/12		

Table 8. Rate of early maturation (minijacks) of Entiat NFH-origin fish by release year.

Release Year	Release Number	# PIT	PIT Ratio Non-Tag/Tag	Observed Mini-jacks	Expanded Mini-jacks[1]	Mini-jack Rate (%)
2015	417,995	9962	41.9	13	544.7	0.13
2014	386,569	9897	39.1	8	312.8	0.08
2013	356,098	9970	35.7	21	749.7	0.21
2012	174,661	9944	17.6	32	563.2	0.32
2011	150,181	9961	15.1	70	1057	0.70

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

Adult Return/Broodstock 2015

Run Forecast

Unlike spring Chinook Salmon there is no pre-season estimates of summer Chinook Salmon returning to the mouth of the Columbia River. Forecasting returns with no return estimates did not allow for a run forecast in 2015 of summer Chinook Salmon. However, 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 return to the Columbia River were first detected by the PIT tag antenna arrays in the adult ladders at Bonneville Dam. Detection efficiency at Bonneville Dam adult fish ladders is greater than 90% (Burke et al 2006). Based on PIT tags from Entiat NFH-origin summer Chinook Salmon detected at Bonneville Dam expanded by the PIT tag ratios of each age class 6,517 Entiat NFH-origin summer Chinook Salmon were predicted to have passed Bonneville Dam in 2015. Using average survival rates from previous years from Bonneville Dam to Rocky Reach

Dam then from Rocky Reach Dam to Entiat NFH I predicted 4,451 and 2,867 Entiat NFH-origin summer Chinook Salmon, respectively.

The fish ladder at Entiat NFH opened on July 1 and closed on October 31 in 2015. In 2015, Entiat NFH experienced the largest return since the inception of the program, 1,507 summer Chinook Salmon returned to the facility (Table 9). However, this was less than was predicted during the in-season forecast. The large run prediction in 2015 precipitated an earlier opening of fishing in the Entiat River that increased fishing pressure and likely resulted in lower survival rates than the previous years that were used in the prediction from Rocky Reach Dam to Entiat NFH.

Table 9. Total abundance of fish by species and run that entered the Entiat NFH adult fish ladder for years 2011–2015.

Year	Chinook			Coho	Sockeye
	Summer	Spring	Fall		
2015	1507	1	0	6	3
2014	952	3	2	96	0
2013	856	3	3	3	0
2012	454	0	2	6	1
2011	251	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 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 production in 2009, the first release was 2011 and the first full production release was in 2013. The early returns from ENFH production (2011–2013) 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 (2013 and 2014) 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 2011–2015.

Year	First	Percent Passage							Last
		5%	10%	25%	50%	75%	90%	95%	
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 in 2015 was 2,019. The performance goal for harvest is 1,600. The emergency opening for this fishery on the Entiat River likely increased the harvest in 2015. If large returns continue the fishery will have a regular scheduled opening that will allow more days of fishing and will advertise to a larger group of sport fishermen.

Hatchery Returns - In 2015, of the 1507 summer Chinook Salmon that entered Entiat NFH 917 had a CWT. Of the 917 only 48 CWTs were from out-of-basin hatcheries and seven of those 48 were spring Chinook Salmon (Table 11). Additionally, 590 non-CWT adipose-clipped summer Chinook entered Entiat NFH and all were presumed to be Entiat NFH-origin based on CWT marking percentages.

Table 11. Chinook Salmon adults sampled at the Entiat NFH in 2015.

CWT	Observed	% Marked	Expanded	Age	Hatchery Origin	Run
636281	1	99	1	4	Chelan Falls	Summer
636283	1	99	1	4	Chelan Falls	Summer
635686	2	99	2	5	Chelan Falls	Summer
190367	1	100	1	3	Cle Elum	Spring
190333	1	100	1	4	Cle Elum	Spring
190335	1	100	1	4	Cle Elum	Spring
100237	1	99	1	4	Clearwater	Spring
636294	1	95	1	3	Dryden Ponds	Summer
636295	1	92	1	3	Dryden Ponds	Summer
636175	4	99	4	4	Dryden Ponds	Summer
636176	8	99	8	4	Dryden Ponds	Summer
636177	8	99	8	4	Dryden Ponds	Summer
636178	14	99	14	4	Dryden Ponds	Summer
635578	1	98	1	6	Dryden Ponds	Summer
055238	3	48	6	2	Entiat	Summer
054793	90	45	200	3	Entiat	Summer
055362	283	65	435	4	Entiat	Summer
055363	345	56	616	4	Entiat	Summer
051267	55	100	55	5	Entiat	Summer
053569	50	100	50	5	Entiat	Summer
055364	36	99	36	5	Entiat	Summer
053619	1	99	1	6	Entiat	Summer
055490	1	16	6	3	Leavenworth	Spring
220133	1	100	1	4	Nez Perce Tribe	Spring
090719	1	99	1	3	Umatilla	Spring
Tag Lost	6		- -	N/A	N/A	Summer

The majority of summer Chinook Salmon that returned to Entiat NFH in 2015 were age-4 (Table 12). However, in 2015 age-5 returns were from release year 2012 which was less than half the full production release goal. Return year 2016 will give us the first glimpse at how age composition returns from full production in ages 3–5.

Table 12. Age composition of Entiat NFH adult returns.

Year	Age					
	2	3	4	5	6	7
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 2015, the more males than females returned to Enthat NFH (Table 13). A skewed sex ratio is expected at this point because the majority of early returning fish (age-3) are males and as discussed above the age-5 returns are not from full production releases. Much like the sex composition the return year 2016 will be more informative for the long-term sex ratios because it will be composed of full production returns of ages 3–5 fish.

Table 13. Sex composition of sampled adults returning to Entiat NFH.

Year	Male	Female	Ratio (M:F)
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 75 of the 1,507 summer Chinook Salmon that returned to Entiat NFH in 2015 weren't used resulting in a broodstock utilization of 95.1% (Table 14). Low flows and high water temperatures likely accounted for the high number of DIP/Jump outs recorded in 2015.
To minimize prespawn mortality of adults, daily formalin treatments were added to the holding ponds to control fungus and parasites. 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.

Beginning in late July, all females are given a single injection of erythromycin prevent the vertical transmission of Bacterial Kidney Disease (BKD). Portions of the returning adults are tested for pathogens, including BKD, Infectious Pancreatic Necrosis Virus (IPNV), and Infectious Hematopoietic Necrosis Virus (IHNV). The Olympia Fish Health Center provides

health profiles for the broodstock utilized for production. Sampling protocols include testing all females for the presence and extent of BKD. Additionally, bacteriology (kidney/spleen) is conducted on a minimum of sixty males and virology (ovarian fluid) on a minimum of 150 females (Ray Brunson pers. comm.).

Table 14. Entiat NFH summer Chinook Salmon use data.

Year	Spawn	Surplus/Donated	DIP/Jump out	Green/Spent/Bad	Ad Present
2015	268	1126	75	34	4
2014	310	618	8	16	
2013	306	543	2	5	
2012	245	198	1	10	
2011	230	7	10	4	
2010	100	3	15	2	

Spawning - In 2015, spawning occurred on October 8. The broodstock consisted of 302 adults of which 34 pair were in poor condition or green and were not used. Of the spawned fish 130 were adult males, 4 were jacks and 134 were females for a sex ratio of 1:1. The green egg take of 1,620,733 was 8% above the Performance Goal of 1,500,000 due to a higher than projected fecundity of 4,288 eggs/female. The preseason estimated fecundity of 4,000 eggs/female would have met the green egg take Performance Goal at these broodstock collection numbers.
The Enzyme-Linked Immunosorbent Assay (ELISA) is used to detect the prevalence of Bacterial Kidney Disease (BKD) from females used in propagation. This assay 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 2009, over 96% of the females were in the "Very Low" and "Low" risk levels (Table 15). At the time of spawning, the eggs from each female are held in separate trays. When the ELISA results are complete, "High" and "Very High" risk groups are 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 15. ELISA results for Entiat NFH spawned females 2009–2015.

Year	None	Very Low	Low	Moderate	High	Very High	No Data	N
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 2015, 94.6% of the green eggs survived to eye-up (Table 16). This does not include the 326,349 eggs culled as a result of ELISA testing. This exceeds the Performance Goal of 96%

stage survival. In December, the emergent fry were placed in the indoor starter tanks to begin the rearing cycle.

Table 16. Egg data for summer Chinook Salmon spawned at Entiat NFH 2009–2015.

Year	Green Eggs	Good Eggs	Bad Eggs	Eye-up %	Eggs/Female
2015	484,513	458,212	26,301	94.6	3,615
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

Brood Year

An analysis of Brood Year for a full production release from Entiat NFH is 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. The 2013 release can be analyzed in a brood year report after 2016 when age 3–5 fish have returned from that release.

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