U.S. Fish & Wildlife Service

Juvenile Salmonid Out-migration Monitoring on the Entiat River, 2015

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On the cover*: The rotary-screw trap deployed within the lower Entiat River.*

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JUVENILE SALMONID OUT-MIGRATION MONITORING ON THE ENTIAT RIVER, 2015.

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Disclaimers

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Abstract — During 2015, the Mid-Columbia Fish and Wildlife Conservation Office operated one rotary-screw trap on the Entiat River as part of the Integrated Status and Effectiveness Monitoring Program's Entiat River Intensively Monitored Watershed study. Trap operations were conducted 7 days a week between February and November when flow and water temperature permitted. A total of 15,870 fish were captured at the rotary-screw trap and 9,699 salmonids were implanted with Passive Integrated Transponder tags. Natural origin juvenile spring Chinook and summer steelhead made up for 22.4% and 17.0% of the total catch respectively.

Point estimates of emigrant abundance (95% C.I.) for yearling and sub-yearling spring Chinook were 5,083 (± 927) and 16,063 (± 2,336), respectively. Summer steelhead emigrant abundance was estimated at 25,031 (± 2,647). Summer Chinook emigrant abundance was estimated at 101,377 (± 21,416). Mean fork length (±SD) of spring Chinook was 97.7 (±8.7) mm and 87.8 (±10.9) mm, for yearling and sub-yearling species respectively. Mean fork length (±SD) of summer steelhead was 141.3 (±39.7) mm. Mean fork length (±SD) of summer Chinook was 62.0 (±13.7) mm. Spring Chinook smolt-to-adult return calculated for the 2009 brood year was estimated at 0.16% for sub-yearling, 1.34% for yearling out-migrants, and 0.34% for both juvenile life-histories combined.

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Introduction

This report provides results for juvenile salmonid monitoring efforts conducted by the Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO) in the Entiat River basin in central Washington during 2015. This work was conducted as part of the Integrated Status and Effectiveness Monitoring Program's (ISEMP) Entiat River Intensively Monitored Watershed (IMW) study. The intent of this report is to disseminate pertinent information and findings to interested parties while providing detailed documentation of procedures and methodologies. The goal of this project is to assess the status of ESA listed spring Chinook and steelhead within the Entiat River basin. This research and monitoring project provides estimates of juvenile abundance, productivity, survival and out-migration timing while additionally documenting various life-history strategies.

Background

The MCFWCO began operating a rotary-screw trap at the mouth of the Entiat River in 1997 (rkm 0.5). Early rotary-screw trap operations were opportunistic and focused on capturing wild, naturally produced (hereafter, wild) juvenile spring Chinook annually from mid-April through May for the purpose of comparing the genetic structure of wild and Entiat National Fish Hatchery (ENFH) produced spring Chinook.

In 2003, additional funding was secured through the United States Fish and Wildlife Service (USFWS) Fisheries Operational Needs System (FONS) for the purpose of documenting and comparing wild and ENFH produced juvenile spring Chinook size, migration timing, productivity, travel, and survival through the Columbia River hydro-system. Although early operations of a rotary-screw trap at the mouth of the Entiat River (rkm 0.5) proved effective for the collection of tissue samples, the location was deemed inadequate for out-migration and productivity monitoring as it was heavily influenced by the Rocky Reach forebay and a new location was chosen just below the ENFH (rkm 11.0) where the trap was operated between March and November annually.

In 2007, additional funding became available through ISEMP (BPA project #2003-0017). This additional funding allowed the MCFWCO to expand the smolt monitoring program to include juvenile summer steelhead (hereafter, steelhead) and install a second rotary-screw trap in the lower Entiat River above the influence of the Rocky Reach forebay (rkm 2.0). Additionally, a large habitat restoration project was planned in the lower Entiat River and a second trap below the planned restoration was desired to help evaluate the effectiveness of these actions. Both traps were operated through 2009 for the purpose of estimating juvenile abundance and productivity. Beginning in 2010, the uppermost trap (rkm 11.0) began intermittent operation for the sole purpose of increasing the precision and accuracy of annual out-migrant production estimates generated at the lowermost trap site (rkm 2.0) (Figure 1).

The 2008 Federal Columbia River Power System Biological Opinion identified the Entiat River basin as an Intensively Monitored Watershed (IMW; RPA 57.1) and in 2010 a formal IMW study was implemented by ISEMP and MCFWCO. IMWs represent a watershed-scale coordinated restoration effort coupled with an associated effectiveness monitoring program (Bilby et al. 2004, PNAMP 2005) that is implemented in an experimental fashion to maximize the ability to detect fish responses to changes in their habitat (Bilby et al. 2005; Roni et al. 2005; Reeve et al. 2006). Current rotary-screw trap operations within the Entiat River are intended to provide population level monitoring under the Entiat IMW study design.

Study Area

The Entiat River watershed originates from 11 glaciers and snowfields in the Cascade Mountains and flows southeast approximately 69 km to join the Columbia River at river kilometer (rkm) 778 (CCD 2004, Mullan et al. 1992). The Entiat watershed is bordered by the Entiat Mountains to the southwest and the Chelan Mountains to the northeast and drains approximately 1,085 km^2. The topography is steep with unstable erodible soils and vegetation types varying from semi-arid shrub steppe near the confluence with the Columbia River to temperate forests and alpine meadows in the headwaters.

Past glacial activity has shaped the Entiat River valley by creating a U-shaped valley upstream of terminal moraine at rkm 26.1 and V shaped valley downstream (Mullan et al. 1992). The present upstream limit to anadromy is at Entiat Falls (rkm 54.4)

The Entiat River watershed supports eight salmonid species including spring and summer Chinook salmon *Oncorhynchus tshawytscha*, steelhead and resident rainbow trout *O. mykiss gairdneri,* sockeye salmon *O. nerka*, westslope cutthroat trout *O. clarki lewisi*, coho salmon *O. kisutch*, mountain whitefish *Prosopium williamsoni*, bull trout *Salvelinus confluentus,* and introduced eastern brook trout *S. fontinalis*. Other fish species include, chiselmouth *Acrocheilus alutaceus*, northern pikeminnow *Ptychocheilus oregonensis*, largescale sucker *Catostomus macrocheilus*, bridgelip sucker *C. columbianus*, speckled dace *Rhinichthys osculus*, longnose dace *R. cataractae*, redside shiner *Richardsonius balteatus*, sculpin *Cottus spp*., three-spined stickleback *Gasterosteus aculeatus* and Pacific lamprey *Entosphenus tridentatus*. (Mullan et al 1992, CCCD 2004,).

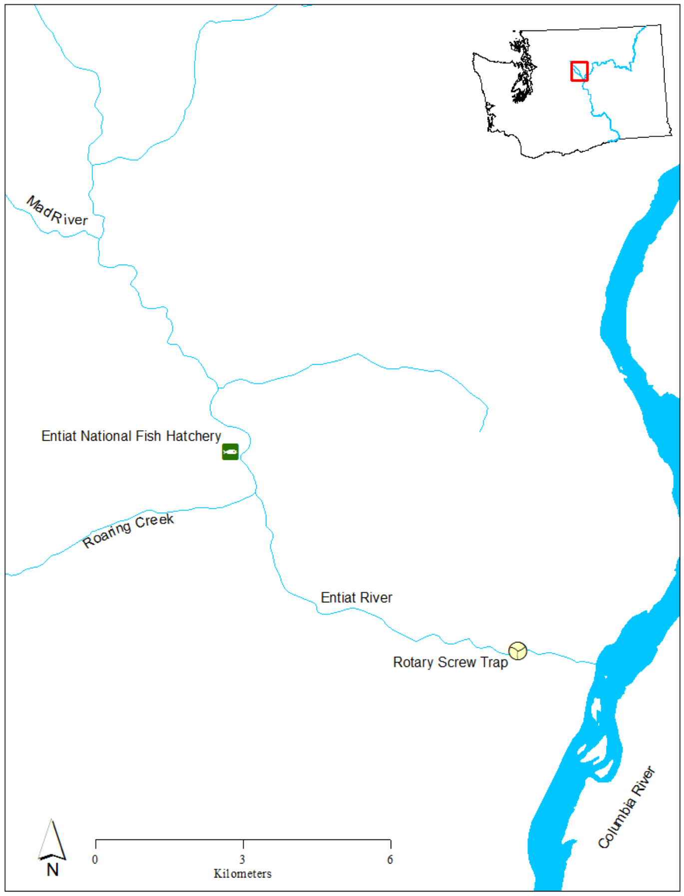

Figure 1. Map of the Entiat River basin and rotary-screw trap location.

Methods

Rotary-screw trap operation

A single 5 ft. diameter rotary-screw trap (EG Solutions Inc., Bend, Oregon) was used to capture downstream migrating salmonids. The trap was retrofitted with pontoons from an 8 foot style screw trap to facilitate better floatation and safety in higher flow regimes. Additionally, the trap was outfitted with a spray bar to pressure wash away accumulated periphyton that clogs the cone screen. Trap operations followed operational permit guidelines. A system of winches and pulleys were utilized throughout the season to maintain the trap in a fixed position. The trap was operated between sunset and sunrise seven days a week from February through November with allowances for some events. During extreme discharge events the trap was removed from the river until such time that river conditions warranted reinitiating operations.

Fish handling

Fish handling procedures were conducted in accordance with WDFW Scientific Collection Permit #14-252 and #15-293 (annual permits - start date July 15, 2014, expires July 15, 2015 and start date July 15, 2015, expires July 15, 2016); NOAA Permit 19-15-NWFSC100 (dated February 1, 2015, expires December 31, 2015); and USFWS sub permit No. MCRFO-14 (dated April 15, 2013, expires December 31, 2016) under Regional Blanket Permit TE-702631.

Juvenile fish were removed at a minimum of once a day from the trap live-box and transported within 5 gallon buckets equipped with aerators to a permanent fish handling/tagging station located at the ENFH. Fish collected for biological sampling were anesthetized in a water bath with a measured amount of tricaine (MS-222) and buffered with sodium bicarbonate. Small groups of fish were anesthetized at any one time to reduce the chance of incidental mortality from anesthetic overdose. All fish were identified to species with the exception of sculpin, dace, and suckers. All salmonids were ascribed a life history stage as either fry (<60 mm), parr (>60 mm and distinctive parr marks), transitional (>60 mm silver sheen, faint parr marks) or smolt (>60 mm silver sheen with absent parr marks with possible black tipped caudal). For all other species, a daily minimum of 30 fish per species and life stage were measured to the nearest mm of fork length and weighed to the nearest tenth of a gram. All Chinook, steelhead, coho, sockeye, bull trout, and cutthroat trout were measured to the nearest millimeter of fork length and weighed to the nearest tenth of a gram. Fulton-type condition factor was calculated for all Chinook and steelhead as described by Anderson and Gutreuter (1983) using the following calculation:

$$K = \frac{W}{L^3}$$

where K is the Fulton-type condition factor, W is the individual fish weight and L is the individual fish length.

After handling, all species were allowed to fully recover prior to release. Non-tagged individuals were released approximately 400 meters downstream from the trap after a minimum of one hour recovery time.

Marking of fish was performed using Passive Integrated Transponder (PIT) tags. PIT tagging of juvenile fish followed the procedures and file submission requirements outlined by Pacific State Marine Fisheries Commission PIT Tag Information System (PTAGIS). Fish were tagged using a disinfected hollow needle to insert the PIT tag into the abdominal cavity. Individuals measuring between 50 and 60 mm in fork length were tagged with a 9 mm PIT tag (ISO tag model TX148511B operating at 134.2 kHz and weighing 0.065 g) and individuals greater than 60 mm were tagged with a 12.5 mm PIT tag (ISO tag model TX1411SST operating at 134.2 kHz and weighing 0.102 g). In 2015, Fish Passage Center provided limited PIT tags for spring Chinook and steelhead as a part of the Comparative Survival Study. Tags for the remaining Chinook and steelhead were supplied by ISEMP, while Chelan County Public Utility District provided tags for bull trout, and MCFWCO supplied PIT tags for cutthroat trout and coho. Any injuries or abnormalities were noted and juveniles were not PIT tagged if determined to have had a recent or substantial injury that could be aggravated by tagging. PIT tagged juveniles were generally held

24 hours to monitor survival and tag retention. A maximum of 72 hours hold time was instituted on all tagged fish.

Data entry

All fish data were entered into the P3 program from PTAGIS (http://www.ptagis.org/). P3 is a data entry application used to collect and submit information about marked or recovered PIT tagged fish in the Columbia River basin. MCFWCO used this program to enter all fish information whether or not the fish was marked with a PIT tag. P3 serves as a Microsoft Access™ overlay which allows communication with peripheral devices. MCFWCO peripheral devices included a Destron Fearing FS2001-ISO transceiver/antenna for reading PIT tags, a GTCO Calcomp DrawSlate VI digitizing board and a GSE 350 electronic balance for automating data entry into a laptop computer. Data files generated from P3 were parsed into a custom Microsoft Access™ database constructed by MCFWCO staff for the purpose of preparing data for analytical use and various reports. The original P3 file was left intact and subsequently uploaded to PTAGIS where it is available to researchers throughout the Columbia River basin.

Genetic and scale sampling

Throughout the sampling period, a subset of captured bull trout, cutthroat trout, Chinook, and steelhead juveniles were sampled for genetic and age analysis as suggested within the Upper Columbia Monitoring Strategy (Hillman 2006). Genetic material was collected by taking a small clip of tissue from either the ventral fin (cutthroat trout & Chinook) or caudal fin (bull trout). Tissue samples were sent to the Region 1 USFWS genetics lab for archiving and analysis. Scales samples were transferred to ISEMP prior to age analysis.

Screw trap efficiency

A portion of captured Chinook and steelhead were used to estimate trap capture efficiency. Fish from several collection events were pooled and held for up-to 72 hours before release upstream of the rotary-screw trap. All fish used for efficiency trials were either PIT tagged (>50 mm FL) or dye marked (<50 mm FL) with Bismarck Brown Y dye. All marked fish were placed in a live-box for holding prior to release. These fish were then transported to release sites using 5 gallon buckets with aerators to minimize stress. Juvenile fish used for efficiency trials were released after sunset upstream of the trap at rkm 2.3 to assure mixing and random distribution. Recaptures attributed to efficiency trials were limited to three days following each release in order to minimize potential changes in trap efficiency related to fluctuations in river flow. Recaptured fish were re-measured, released, and not included in subsequent efficiency testing.

Spring and summer run Chinook differentiation

Differentiation between spring and summer run sub-yearling Chinook was determined through analysis of emigration timing. Total annual catch was monitored and plotted by day. When catch decreased and a relative nadir was reached in the late summer, all Chinook captured onward were assigned a classification of spring run while preceding captures were classified as summer run.

Calculating juvenile production

Estimates of wild juvenile production from the Entiat River basin were derived for yearling spring Chinook, sub-yearling spring Chinook, summer Chinook, and steelhead. Production estimates were calculated using two steps. First, daily trap efficiency was determined based on regression analysis of the relationship between trap efficiency (dependent variable) and flow (independent variable). The resulting regression formula was then used to estimate daily trap efficiency and juvenile production.

Trap efficiency was calculated using the following formula:

$$\text{Trap efficiency, } E_i = \frac{R_i + 1}{M_i}$$

where E_i is the trap efficiency during time period i; M_i is the number of marked fish released during time period i; and R_i is the number of marked fish recaptured during time period i.

The number of fish captured was expanded by the estimated daily trap efficiency to estimate the daily number of fish migrating past the trap using the following formula derived from Bailey (1951):

$$\text{Estimated daily emigration} = \widehat{N}_i = \frac{C_i}{\hat{e}_i}$$

where N_i is the estimated number of fish passing the trap during time period i; C_i is the number of unmarked fish captured during time period i; and e_i is the estimated trap efficiency for time period i based on the regression equation. On days in which the trap was not operated (trap pulled) or only partially operated (incomplete), daily fish capture (N_i) was estimated through averaging known daily capture values from two days before and following the pulled or incomplete trapping day.

The variance for the total daily number of fish emigrating past the trap was calculated using the following formulas:

$$\text{Variance of daily emigration estimate} = \text{var}\left[\widehat{N}_i\right] = \widehat{N}_i^{\,2}\, \frac{\text{MSE}\left(1 + \frac{1}{n} + \frac{\left(X_i - \overline{X}\right)^2}{(n-1)s_x^2}\right)}{\hat{e}_i^2}$$

where the MSE is the mean squared error of the regression, X_i is the flow for time period i and n is the sample size.

The total emigration estimate and confidence interval was calculated using the following formulas:

$$\text{Total emigration estimate} = \sum \hat{N}_i$$

$$95\% \text{ confidence interval} = 1.96 \times \sqrt{\sum \mathrm{var}}\left[\hat{N}_i\right]$$

Egg deposition was calculated based on the number of redds counted in the Entiat River basin multiplied by an estimated fecundity. Spring Chinook fecundity estimates were calculated through regression analysis of the relationship between female fecundity and fork length using Leavenworth National Fish Hatchery (LNFH) spring Chinook brood stock collected between 2002 and 2008 ($n = 350$, $r^2 = 0.45$, $P = <0.01$). The resulting equation was applied to an average fork length of wild female spring Chinook carcasses recovered during Entiat River spawning ground surveys. Fecundity estimates for steelhead were generated from brood collection data within the Wenatchee River basin.

Smolt-to-adult return

Smolt-to-adult return (SAR) estimates were generated from releases of PIT tagged wild spring Chinook at Entiat River rotary-screw trap locations. SAR estimation was performed for both sub-yearling and yearling groups of out-migrants and for the individual brood years the combination of the groups represent. For example, SAR would be calculated for groups of sub-yearling emigrants encountered in 2014 and yearling emigrants from 2015 as well as the combination of these two groups which account for all emigrants associated with the 2013 brood year.

Following the annual return of adult spring Chinook to the Entiat River, PTAGIS queries were run to determine the total number of PIT tagged Entiat River origin adult spring Chinook. To account for the potential of Entiat origin adults to stray into other basins, only adults that were detected above Rocky Reach Dam were attributed to counts of total adult returns. Totals of PIT tagged juveniles by brood year were acquired from PTAGIS queries for the sub-yearling, yearling, and combined life-history groups. SAR was then calculated by dividing the number of returning adults by the number of PIT tagged juvenile spring Chinook from the corresponding brood year for each group.

Water temperature and flow

Hourly water temperature data was collected at the lower trapping site using HOBO U22 Water Temp Pro (version 2) data loggers (Onset Computer Corporation, Bourne, Massachusetts). Flow was monitored by USGS station number 12452990, located at rkm 2.3.

Results

Rotary-screw trap operation summary

Rotary-screw trap operation began on February 26, 2015. The trap was operated on a seven day per week schedule. The smolt trap was installed on February 25, 2015 and removed for the end of the trapping season on November 24, 2015. River and site conditions prevented installing the trap earlier in February. During the 273 trapping days available the trap was not operated 90 days (33%) of which 46 days (51%) were due to daily water temperatures exceeding the permitted maximum of 18.0° C, 25 days (28%) were due to high river discharge/debris, 13 days (14%) were due to mechanical failure/repairs, and 4 days (7%) were to avoid excessive capture and increased mortality and stress associated with hatchery summer Chinook released from the ENFH. Detailed daily operational summaries are included as Appendix Table 1.

Rotary-screw trap target species capture summary

In 2015, a total of 15,870 fish were captured by the rotary-screw trap (Table 1). Total wild juvenile fish capture consisted of 3,554 spring Chinook (22.3%), 6,585 summer Chinook (41.5%), 2,704 steelhead (17.0%), 21 coho (0.5%), 243 sockeye (1.5%), 25 bull trout (0.2%), 12 cutthroat trout (0.1%), 1,262 pacific lamprey (8.1%) and 1,403 non-target species (8.8%). A total of 9,699 wild salmonids were implanted with PIT tags. Total daily captures for yearling spring Chinook, sub-yearling spring Chinook, summer Chinook, and steelhead are presented in figures 2 through 5. Detailed capture summaries including adult species and total mortality are included in Appendix Table 2.

Table 1. Number of fish captured and PIT tagged at the Entiat River rotary-screw trap, 2015.

Species and life stage	Total number of fish caught	Total PIT tagged
Yearling spring Chinook	508	454
Sub-Yearling spring Chinook	3,046	2,835
Summer Chinook	6,585	3,746
Coho	82	77
Steelhead	2,704	2,529
Sockeye	243	13
Bull trout	25	22
Cutthroat Trout	12	12
Lamprey sp.	1,262	0
Non-target species	1,403	2
Grand total	**15,870**	**9,690**

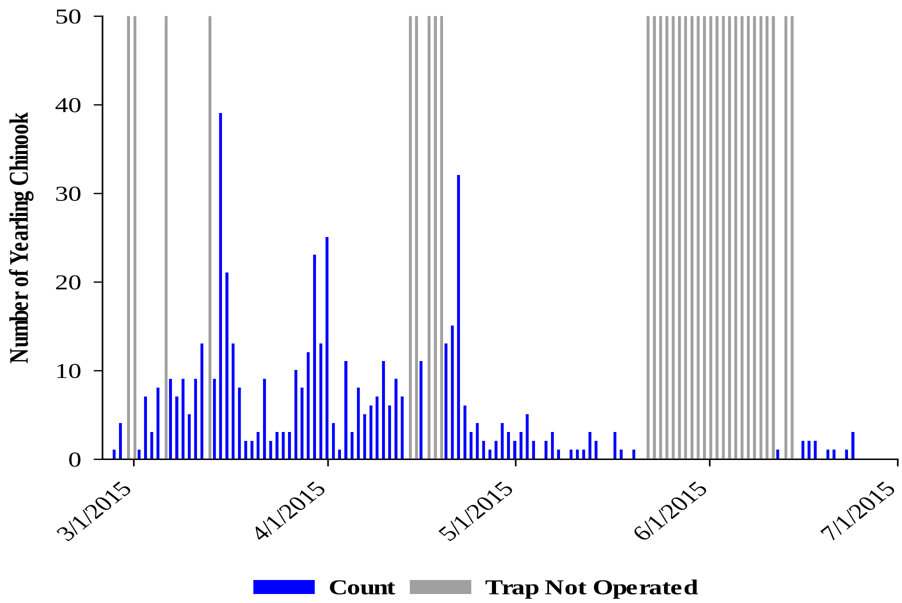

Figure 2. Total daily captures of yearling spring Chinook at the Entiat River rotary-screw trap, 2015.

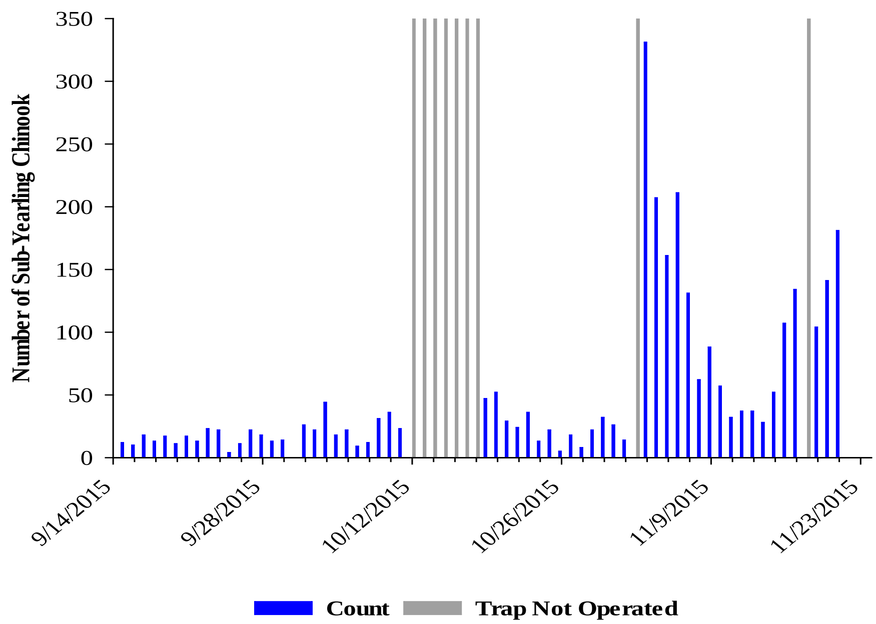

Figure 3. Total daily captures of sub-yearling spring Chinook at the Entiat River rotary-screw trap, 2015.

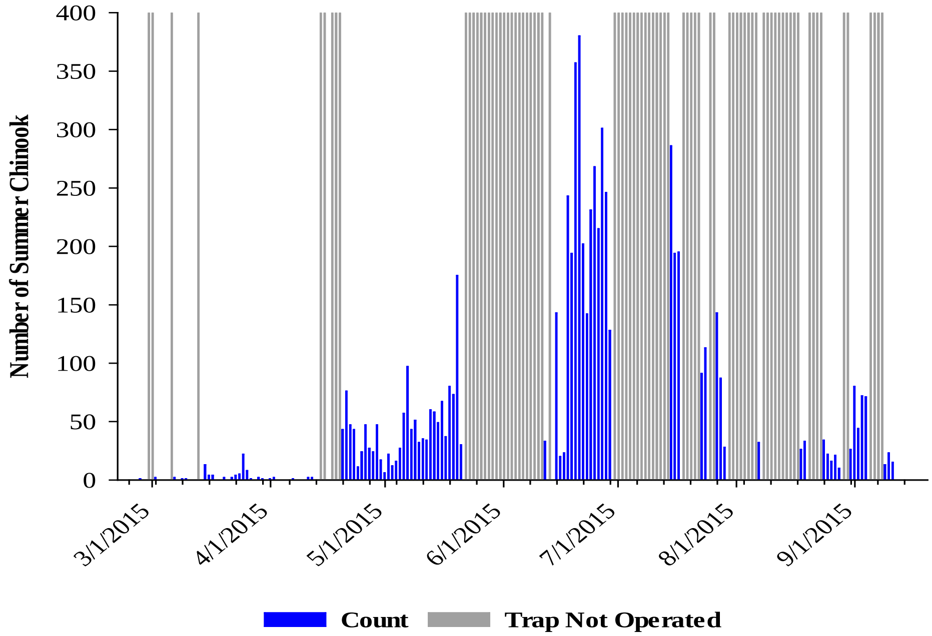

Figure 4. Total daily captures of summer Chinook at the Entiat River rotary-screw trap, 2015.

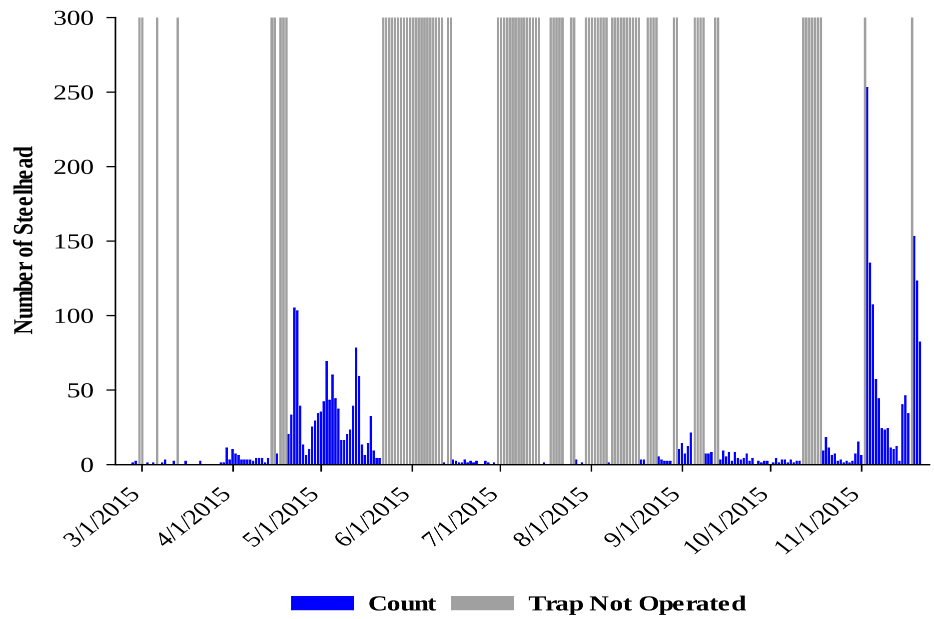

Figure 5. Total daily captures of steelhead at the Entiat River rotary-screw trap, 2015.

Mean fork length (±SD) of spring Chinook was 97.8 mm (±8.7) and 87.8 mm (±10.6), for yearling and sub-yearling species respectively (Table 2). Summer Chinook had a mean fork length of 62.0 mm (±13.7) and steelhead 141.3 mm (±39.7) (Table 3).

Table 2. Mean fork length (mm), weight (g), and body condition factor (K) for juvenile spring Chinook captured at the Entiat River rotary-screw trap, 2015.

	Yearling spring Chinook			**Sub-yearling spring Chinook**		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**
Fork Length	97.8	8.7	491	87.8	10.6	2,921
Weight	9.8	2.7	488	6.9	2.6	2,919
K	1.02	0.08	488	0.98	0.09	2,919

Table 3. Mean fork length (mm), weight (g), and body condition factor (K) for summer Chinook and steelhead captured at the Entiat River rotary-screw trap, 2015.

	Summer Chinook			**Steelhead**		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**
Fork Length	62.0	13.7	4809	141.3	39.7	2,672
Weight	3.0	1.8	4,748	32.9	21.6	2,664
K	1.05	0.14	4,748	0.96	0.09	2,664

Trap efficiencies

PIT tag trials for yearling spring Chinook efficiency averaged 11.0% (Table 4), sub-yearling spring Chinook 29.8% (Table 5), summer Chinook 12.4% (Table 6) and steelhead 11.4% (Table 7). The summer Chinook dye mark efficiency was 6.5% (Table 8).

Table 4. Estimated capture efficiency of PIT tagged yearling spring Chinook at the Entiat River rotary-screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2015.

Trial Date	**Flow (m^3/s)**	**Release Size (n)**	**Efficiency**
04/02/2015	21.9	58	10.3%
04/24/2015	24.1	60	11.7%

Table 5. Estimated capture efficiency of PIT tagged sub-yearling spring Chinook at the Entiat River rotary-screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2015.

Trial Date	**Flow (m^3/s)**	**Release Size (n)**	**Efficiency**
09/30/2015	2.2	52	15.4%
11/05/2015	4.9	203	33.5 %

Table 6. Estimated capture efficiency of PIT tagged summer Chinook at the Entiat River rotary-screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2015.

Trial Date	Flow (m^3/s)	Release Size (n)	Efficiency
06/18/15	14.0	79	5.1%
06/25/15	10.3	270	11.1%
09/02/15	3.1	79	24.1%

Table 7. Estimated capture efficiency of PIT tagged steelhead at the Entiat River rotary-screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2015.

Trial Date	Flow (m^3/s)	Release Size (n)	Efficiency
04/24/15	24.1	244	7.8%
05/07/15	25.6	135	3.0%
05/21/15	40.0	41	7.3%
09/02/15	3.1	13	23.0%
11/05/15	4.9	132	23.5%
11/17/15	11.6	84	16.2%

Table 8. Estimated capture efficiency of dye marked summer Chinook at the Entiat River rotary-screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2015.

Trial Date	Flow (m^3/s)	Release Size (n)	Efficiency
06/18/15	14.0	101	7.9%
06/25/15	10.3	98	7.1%

Spring and summer run Chinook differentiation

Yearling spring Chinook were captured from February 26th though June 24th, 2015 (Table 9). Late summer total catch was monitored and plotted by day and as sub-yearling summer Chinook catch decreased and a relative nadir was reached on September 14th and all Chinook captured onward were designated as sub-yearling spring Chinook (Table 9; Figure 6).

Table 9. Dates of inclusion for yearling and sub-yearling spring Chinook species used in 2015 Entiat River production estimates.

Capture Year	Brood Year	Life Stage	Start Inclusion	End Inclusion
2015	2013	Yearling	2/26/2015	6/24/2015
2015	2014	Sub-yearling	9/14/2015	11/21/2015

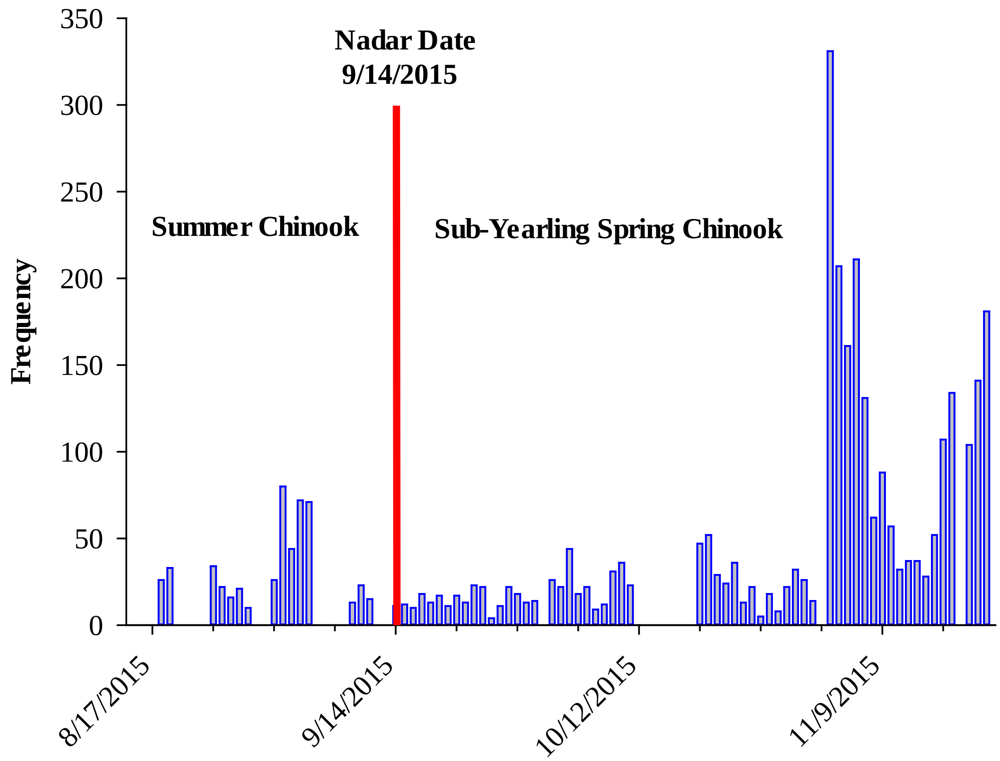

Figure 6. Catch frequency of sub-yearling Chinook used to assign run of summer Chinook and spring Chinook species used in 2015 Entiat River production estimates.

Juvenile production

The point estimate of emigrant abundance (95% C.I.) for yearling and sub-yearling spring Chinook was 5,083 (± 927) and 16,063 (± 2,336), respectively; wild summer Chinook emigrant abundance was estimated at 110,377 (± 21,416); and wild summer steelhead emigrant abundance was estimated at 25,031 (± 2,647) (Table 10). Point estimates of abundance for prior years are presented in Appendix Table 3.

Table 10. Annual point estimates of abundance, 95% confidence intervals (C.I.), and coefficient of variation (C.V.) derived from Entiat River rotary-screw trap capture data, 2015.

Species	**Estimate**	**95% C.I. (+/-)**	**C.V.**
Spring Chinook Yearlings	5,083	927	0.09308
Spring Chinook Sub-Yearlings	16,063	2,336	0.07420
Summer Chinook	110,377	21,416	0.09899
Steelhead	25,031	2,647	0.05395

Abundance estimates for yearling spring Chinook in 2015 allowed for the completion of 2013 brood year productivity estimates. Total egg deposition for 2013 brood year spring Chinook was estimated at 423,225 eggs. Deposition was based on 99 redds counted within the Entiat River basin (Fraser and Hamstreet, 2015) multiplied by an estimated fecundity of 4,105 eggs. A total of 28,453 spring Chinook emigrants were estimated from the 2013 brood year. Egg-to-emigrant survival rate and emigrant-per-redd estimates were calculated at 6.72% and 287 fish, respectively for 2013 brood year for spring Chinook (Table 11).

Table 11. Estimated egg deposition (# of redds × estimated female fecundity), egg-to-emigrant survival rates, and emigrant per redd estimates for Entiat River wild spring Chinook juveniles, brood years 2002 to 2013.

Brood Year	**Number of Redds**	**Estimated Egg Deposition**	**Estimated Number**			**Egg-to-Emigrant Survival (%)**	**Emigrant per Redd**
			Sub-yearling	**Yearling**	**Total**		
2002	112	478,800	9,740	3,958	13,697	2.86% [a]	122 [a]
2003	108	461,700	9,123	5,349	14,472	3.13% [a]	134 [a]
2004	126	538,650	12,029	8,145	20,174	3.75% [a]	160 [a]
2005	148	632,700	13,386	9,090	22,477	3.55% [b]	152 [b]
2006	107	457,425	6,265	11,643	17,908	3.91%[c]	167[c]
2007	102	436,050	19,408	7,345	26,753	6.14%[c]	262[c]
2008	116	495,900	11,544	16,692	28,236	5.69%[c]	243[c]
2009	115	491,625	14,188	5,942	20,131	4.09%[c]	175[c]
2010	204	872,100	13,437	18,471	31,908	3.66%[c]	156[c]
2011	248	1,060,200	25,693	21,866	47,559	4.49%[c]	192[c]
2012	236	1,008,900	14,353	22,786	37,140	3.68%[c]	157[c]
2013	99	423,225	23,370	5,083	28,453	6.72%[c]	287[c]

[a] Derived from upper trap (rkm 11.0) estimates.
[b] Derived from upper trap (rkm 11.0) sub-yearling and lower trap (rkm 2.0) yearling estimates.
[c] Derived from lower trap (rkm 2.0) estimates.

Smolt-to-adult return

The 2015 adult spring Chinook return to the Entiat River completed the SAR estimates for the 2009 brood year. Sub-yearling spring Chinook SAR estimate was 0.16% and 1.34% for yearling spring Chinook. The combined spring Chinook SAR estimate was 0.34% for the 2009 brood year. SAR estimates for the sub-yearling and combined life-history groups of spring Chinook for the 2009 brood year were below the 9 year averages of 0.23% and 0.47%, respectively. However, the yearling spring Chinook group had a higher SAR then the 9 year average of 0.78%. The 2009 brood year showed similar trends as previous brood years, with a higher SAR for spring Chinook tagged as yearlings as compared to those tagged as sub-yearlings (Table 12).

Table 12. Estimated smolt-to-adult return (SAR) for sub-yearling, yearling and adult wild spring Chinook in the Entiat River for brood years 2001 to 2009.

Brood Year	Total Observations			SAR		
	Sub-yearling	**Yearling**	**Adult Returns**	**Sub-yearling**	**Yearling**	**Combined life-histories**
2001	n/a	2	2	0.000%	0.513%	0.513%
2002	0	5	5	0.000%	0.705%	0.394%
2003	1	5	6	0.040%	0.385%	0.157%
2004	3	5	8	0.129%	0.282%	0.195%
2005	3	1	4	0.150%	0.162%	0.153%
2006	17	100	117	0.564%	1.515%	1.217%
2007	23	25	48	0.412%	1.098%	0.611%
2008	21	42	63	0.341%	0.947%	0.595%
2009	6	9	15	0.165%	1.349%	0.349%

Water temperature and flow

Water temperature measurements at the rotary-screw trap averaged 9.2 ˚C from February 24th through November 24th (Figure 7). Water temperatures peaked at 25.2 ˚C on July 20th, and were lowest on November 21st when temperatures averaged 1.5˚C. Flow peak in the spring was on May 24th at 42.6 m^3/s. High water levels declined quickly, allowing rotary-screw trap operations to resume on June 15th.

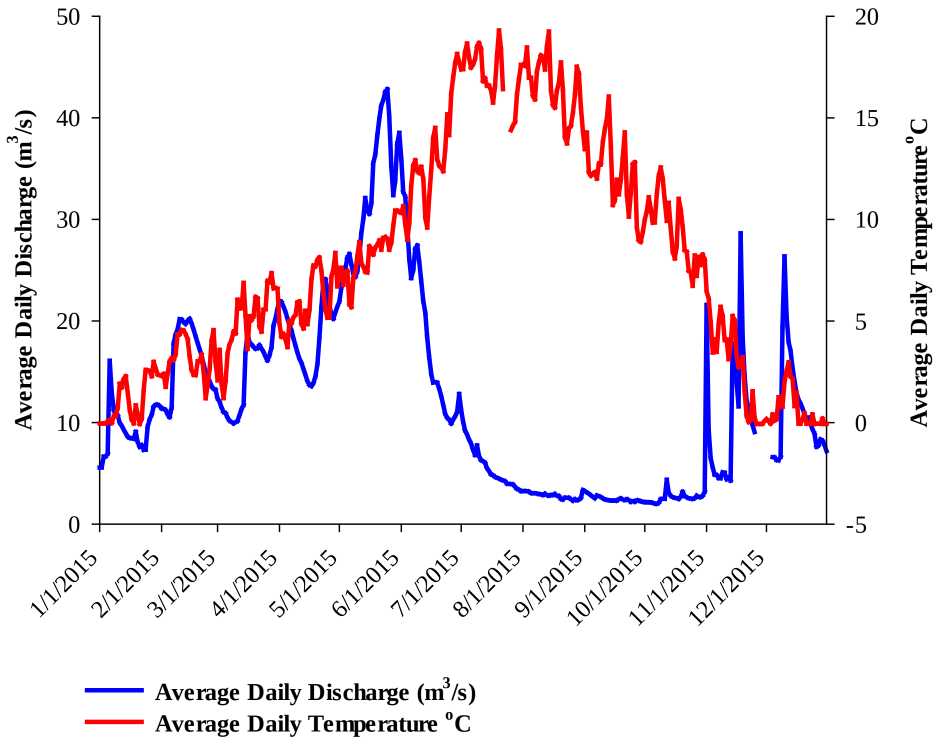

Figure 7. Average daily discharge (m^3/s) and average daily temperature (^oC) at the Entiat River rotary-screw trap, 2015.

Discussion

Rotary-screw trap operation

The day to day operation of rotary-screw traps can be time consuming and difficult. Seasonally high discharge and weather events often increase the amount of debris present within the river leading to higher frequencies of missed trapping days due to trap failure. These periods require more staff to safely maintain the trap in an operational condition. The high flows and debris can create a hazardous work environment for the crew, increase the trap related mortality of captured fish, and cause damage to equipment. To minimize these hazards, the trap was removed from operation when necessary. In 2015, rotary-screw trap operation was directly impacted by high summer water temperatures due to lower than average flow and increased air temperatures. When average daily water temperature exceeded 18^{o}C, the trap was not operated due to permitting restrictions. In 2015, this represented a substantial portion of time as compared to previous years.

Smolt-to-adult return

The return of adult spring Chinook in 2015 completed the 2009 brood year SAR estimates allowing for a total of 9 complete brood years to be represented; however, a change in SAR is noted when comparing estimates from brood years 2001-2005 and 2006-2009. This change in SAR coincides with a change in trap location from rkm 11.0 to 2.0 and an increase in PIT tagging effort resulting in a higher tagging rate of the emigrant population in more recent years. Despite this seemingly artificial increase in SAR estimates for the sub-yearling, yearling and combined group of spring Chinook, these results consistently indicate that sub-yearling emigrants have a lower contribution to the returning adult population than yearling emigrants.

Summer vs. spring run Chinook

Both spring and summer run Chinook spawn in the Entiat River basin. Early in the season, distinct morphological differences between summer run sub-yearling and spring run yearling Chinook make identification easy. Yearling spring Chinook are much larger in size (75-100 mm) than newly emergent summer Chinook fry (32-45 mm) but identification becomes more difficult during the summer and early fall as both spring and summer Chinook sub-yearlings are similar in size. Currently there is no definitive method to apportion these two runs of sub-yearlings. Undoubtedly, the run classification of some Chinook is improperly assigned using the relative catch nadir method. Utilizing data from Entiat River PIT tag interrogation sites and the emigration timing of PIT tagged Chinook , it is clear that delineation of the two runs of sub-yearling Chinook used in previous years was imperfect.

The MCFWCO is addressing this issue through a combination of PIT tag monitoring and genetic analysis. In 2013, preliminary genetic analysis was performed by the USFWS Abernathy Fish Technical Center Genetics Lab. This preliminary analysis indicated a lack of precision in the genetic based run assignment. MCFWCO has since updated the genetic baseline for Entiat River summer Chinook, which is expected to increase run assignment precision. Findings from this analysis are expected in 2016 and will be disseminated through a separate report.

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Appendix

Appendix Table 1. Summary of nonoperational days for the Entiat River rotary-screw trap, 2015.

Date	Trap Status	Comments
2/28/2015	NOT Operated	Trap pulled
3/1/2015	NOT Operated	Trap pulled
4/14/2015	NOT Operated	Trap pulled due to hatchery release
4/15/2015	NOT Operated	Trap pulled due to hatchery release
4/17/2015	NOT Operated	Trap pulled due to hatchery release
4/18/2015	NOT Operated	Trap pulled due to hatchery release
5/22/2015	NOT Operated	Trap pulled due to high flow
5/23/2015	NOT Operated	Trap pulled due to high flow
5/24/2015	NOT Operated	Trap pulled due to high flow
5/25/2015	NOT Operated	Trap pulled due to high flow
5/26/2015	NOT Operated	Trap pulled due to high flow
5/27/2015	NOT Operated	Trap pulled due to high flow
5/28/2015	NOT Operated	Trap pulled due to high flow
5/29/2015	NOT Operated	Trap pulled due to high flow
5/30/2015	NOT Operated	Trap pulled due to high flow
5/31/2015	NOT Operated	Trap pulled due to high flow
6/1/2015	NOT Operated	Trap pulled due to high flow
6/2/2015	NOT Operated	Trap pulled due to high flow
6/3/2015	NOT Operated	Trap pulled due to high flow
6/4/2015	NOT Operated	Trap pulled due to high flow
6/5/2015	NOT Operated	Trap pulled due to high flow
6/6/2015	NOT Operated	Trap pulled due to high flow
6/7/2015	NOT Operated	Trap pulled due to high flow
6/8/2015	NOT Operated	Trap pulled due to high flow
6/9/2015	NOT Operated	Trap pulled due to high flow
6/10/2015	NOT Operated	Trap pulled due to high flow
6/11/2015	NOT Operated	Trap pulled due to high flow
6/13/2015	NOT Operated	Trap pulled due to high flow
6/14/2015	NOT Operated	Trap pulled due to high flow
6/30/2015	NOT Operated	Trap pulled due to high water temperatures
7/1/2015	NOT Operated	Trap pulled due to high water temperatures
7/2/2015	NOT Operated	Trap pulled due to high water temperatures
7/3/2015	NOT Operated	Trap pulled due to high water temperatures
7/4/2015	NOT Operated	Trap pulled due to high water temperatures
7/5/2015	NOT Operated	Trap pulled due to high water temperatures
7/6/2015	NOT Operated	Trap pulled due to high water temperatures

Appendix 1. continued

Date	Trap Status	Comments
7/7/2015	NOT Operated	Trap pulled due to high water temperatures
7/8/2015	NOT Operated	Trap pulled due to high water temperatures
7/9/2015	NOT Operated	Trap pulled due to high water temperatures
7/10/2015	NOT Operated	Trap pulled due to high water temperatures
7/11/2015	NOT Operated	Trap pulled due to high water temperatures
7/12/2015	NOT Operated	Trap pulled due to high water temperatures
7/13/2015	NOT Operated	Trap pulled due to high water temperatures
7/14/2015	NOT Operated	Trap pulled due to high water temperatures
7/18/2015	NOT Operated	Trap pulled due to high water temperatures
7/19/2015	NOT Operated	Trap pulled due to high water temperatures
7/20/2015	NOT Operated	Trap pulled due to high water temperatures
7/21/2015	NOT Operated	Trap pulled due to high water temperatures
7/22/2015	NOT Operated	Trap pulled due to high water temperatures
7/25/2015	NOT Operated	Trap pulled due to high water temperatures
7/26/2015	NOT Operated	Trap pulled due to high water temperatures
7/30/2015	NOT Operated	Trap pulled due to high water temperatures
7/31/2015	NOT Operated	Trap pulled due to high water temperatures
8/1/2015	NOT Operated	Trap pulled due to high water temperatures
8/2/2015	NOT Operated	Trap pulled due to high water temperatures
8/3/2015	NOT Operated	Trap pulled due to high water temperatures
8/4/2015	NOT Operated	Trap pulled due to high water temperatures
8/5/2015	NOT Operated	Trap pulled due to high water temperatures
8/6/2015	NOT Operated	Trap pulled due to high water temperatures
8/8/2015	NOT Operated	Trap pulled due to high water temperatures
8/9/2015	NOT Operated	Trap pulled due to high water temperatures
8/10/2015	NOT Operated	Trap pulled due to high water temperatures
8/11/2015	NOT Operated	Trap pulled due to high water temperatures
8/12/2015	NOT Operated	Trap pulled due to high water temperatures
8/13/2015	NOT Operated	Trap pulled due to high water temperatures
8/14/2015	NOT Operated	Trap pulled due to high water temperatures
8/15/2015	NOT Operated	Trap pulled due to high water temperatures
8/16/2015	NOT Operated	Trap pulled due to high water temperatures
8/17/2015	NOT Operated	Trap pulled due to high water temperatures
8/20/2015	NOT Operated	Trap pulled due to high water temperatures
8/21/2015	NOT Operated	Trap pulled due to high water temperatures
8/22/2015	NOT Operated	Trap pulled due to high water temperatures
8/23/2015	NOT Operated	Trap pulled due to high water temperatures
8/29/2015	NOT Operated	Trap pulled due to high water temperatures
8/30/2015	NOT Operated	Trap pulled due to high water temperatures

Appendix 1. continued

Date	Trap Status	Comments
9/5/2015	NOT Operated	Trap pulled due to debris drum repairs
9/6/2015	NOT Operated	Trap pulled due to debris drum repairs
9/7/2015	NOT Operated	Trap pulled due to debris drum repairs
9/8/2015	NOT Operated	Trap pulled due to debris drum repairs
9/12/2015	NOT Operated	Trap pulled due to debris drum repairs
9/13/2015	NOT Operated	Trap pulled due to debris drum repairs
10/1/2015	Incomplete	Branch stopped cone
10/12/2015	NOT Operated	Trap pulled due to debris drum repairs
10/13/2015	NOT Operated	Trap pulled due to debris drum repairs
10/14/2015	NOT Operated	Trap pulled due to debris drum repairs
10/15/2015	NOT Operated	Trap pulled due to debris drum repairs
10/16/2015	NOT Operated	Trap pulled due to debris drum repairs
10/17/2015	NOT Operated	Trap pulled due to debris drum repairs
10/18/2015	NOT Operated	Trap pulled due to debris drum repairs
11/1/2015	Incomplete	Trap pulled due to leaf debris
11/2/2015	NOT Operated	Trap pulled due to high flow
11/14/2015	Incomplete	Trap pulled due to leaf debris
11/15/2015	Incomplete	Trap pulled due to leaf debris
11/18/2015	NOT Operated	Trap pulled due to high flow

Appendix Table 2. Summary of fish species captured in the Entiat River rotary-screw trap, 2015.

Species and Life Stage	**Total Capture**	**Capture Mortality**
Wild spring Chinook juvenile	3,554	42
Hatchery summer Chinook juvenile	2,561	0
Wild summer Chinook adult	1	0
Wild summer Chinook juvenile	6,582	44
Hatchery Chinook (unknown r/t) jack	0	0
Hatchery Chinook (unknown r/t) juvenile	0	0
Wild Chinook (unknown r/t) adult	2	0
Wild Chinook (unknown r/t) jack	0	0
Wild Chinook (unknown r/t) precocial	15	1
Wild Chinook (unknown r/t) juvenile	0	0
Wild coho juvenile	82	1
Wild steelhead adult	5	1
Wild steelhead juvenile	2,704	25
Bull trout adult	4	0
Bull trout juvenile	21	0
Wild cutthroat trout juvenile	12	0
Wild sockeye (unknown run) adult	1	0
Wild sockeye (unknown run) juvenile	243	2
Pacific lamprey ammocoete	1,184	3
Pacific lamprey macrophthalmia	78	0
Northern pikeminnow adult	2	0
Northern pikeminnow juvenile	93	1
Mountain whitefish adult	8	0
Mountain whitefish juvenile	271	8
Unknown sucker adult	8	1
Unknown sucker juvenile	228	2
Unknown dace	132	2
Chiselmouth	3	0
Unknown sculpin	129	12
Red side shiner	39	2
Three-spine stickleback	192	1

Appendix Table 3. Annual point estimates of abundance and 95% confidence intervals derived from Entiat River rotary-screw trap capture data, capture years 2010 to 2015.

Year	Species	Estimate	± 95% C.I.	C.V.
2010	Spring Chinook Yearlings	16,692	2,324	0.07105
	Spring Chinook Sub-Yearlings	14,188	2,061	0.07412
	Summer Chinook	98,620	31,958	0.16533
	Steelhead	25,945	2,822	0.05549
2011	Spring Chinook Yearlings	5,942	999	0.08575
	Spring Chinook Sub-Yearlings	13,437	1,700	0.06453
	Summer Chinook	391,078	102,877	0.13421
	Steelhead	17,437	1,939	0.05674
2012	Spring Chinook Yearlings	18,471	3,263	0.09013
	Spring Chinook Sub-Yearlings	25,693	6,298	0.12507
	Summer Chinook	190,180	77,599	0.20818
	Steelhead	21,669	2,787	0.06561
2013	Spring Chinook Yearlings	21,866	3,628	0.08465
	Spring Chinook Sub-Yearlings	14,353	1,902	0.06760
	Summer Chinook	620,357	168,064	0.13822
	Steelhead	22,991	2,699	0.05989
2014	Spring Chinook Yearlings	22,786	3,517	0.07875
	Spring Chinook Sub-Yearlings	23,370	5,003	0.10923
	Summer Chinook	0	0	0.00000
	Steelhead	30,689	4,539	0.07546
2015	Spring Chinook Yearlings	5,083	927	0.09308
	Spring Chinook Sub-Yearlings	16,063	2,336	0.07420
	Summer Chinook	110,377	21,416	0.09899
	Steelhead	25,031	2,647	0.05395