# Integrated Status and Effectiveness Monitoring Program-Entiat River
# Intensively Monitored Watershed Study, 2014.

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## Abstract

During 2014, the Mid-Columbia Fishery Resource Office operated a rotary screw trap, conducted two mark-recapture studies in the mainstem Entiat River, conducted three mark-recapture studies in off-channel habitats, operated and maintained six stream-width Passive Integrated Transponder (PIT) tag interrogation sites and conducted steelhead redd surveys on the Entiat River as part of the Integrated Status and Effectiveness Monitoring Program's Entiat River Intensively Monitored Watershed study. Screw trap operations were conducted between March and November resulting in 28,668 fish being caught. Of these, 17,620 juvenile salmonids were PIT tagged. The Entiat River mark-recapture study collected 7,479 juvenile fishes at 20 locations along the main stem Entiat and Mad Rivers and PIT tagged 5,074 salmonids. The off-channel habitat study resulted in the capture of 2,619 juvenile fish of which 1,387 salmonids were PIT tagged. Six PIT tag interrogation sites and 13 remote antennas were operated within the Entiat River throughout the entire year. Due to river conditions, antennas were operational for 70-100% of the year. Steelhead redd surveys were conducted from February 17 to May 12, 2014 in the lower 45 km of the Entiat River. A total of 126 redds were observed. The first redd was observed on March 24, though peak spawning occurred in late April. High water prevented surveys after May 12.

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# Introduction

The Integrated Status and Effectiveness Monitoring Program (ISEMP – BPA project #2003-0017) was created as a cost effective means of developing protocols and new technologies, novel indicators, sample designs, analytical, data management and communication tools and skills, and restoration experiments. ISEMP activities support the development of region-wide Research, Monitoring and Evaluation (RME) programs to assess the status of anadromous salmonid populations, their tributary habitat and restoration and management actions.

The intent of the ISEMP project is to design monitoring programs that can efficiently collect information to address multiple management objectives over a broad range of scales. As well as status and trends monitoring, ISEMP is evaluating the benefits of habitat restoration actions to fish populations across the Columbia River Basin by implementing Intensively Monitored Watershed (IMW) studies. IMWs have been established in three pilot subbasins: Entiat River, WA; Bridge Creek, John Day River, OR; and Lemhi River, ID.

An IMW is a watershed-scale coordinated restoration effort with an associated effectiveness monitoring program (Bilby et al. 2004, PNAMP 2005) 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). In addition, intensive monitoring is used to identify mechanisms by which habitat manipulations impact fish, so that these strategies can be extrapolated to other systems (Carpenter et al. 1995). An IMW is a powerful approach to answer cause-and-effect questions at the scale relevant to management (i.e., at the watershed or population scale). IMWs are designed to address key questions in a disciplined scientific manner, reduce the complications associated with effectiveness monitoring, increase the comprehensiveness of monitoring and increase efficiencies through shared responsibilities.

The restoration of the Entiat River subbasin under an IMW study design offers an opportunity to quantitatively evaluate the effectiveness of habitat restoration actions with regard to improving salmonid productivity in the Entiat River subbasin. This subbasin meets the prerequisites for an IMW, such as the feasibility of obtaining quantitative estimates of smolt production, the record of smolt monitoring, fish species present, and influence of hatchery-produced fish. In addition, the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) identifies the Entiat River subbasin as an IMW (RPA 57.1) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) calls for effectiveness monitoring coupled with adaptive management to assess the effects of habitat actions and recover these listed species in the Entiat River subbasin.

The work presented in this report is a component of the overall ISEMP, and while it stands alone as an important contribution to the management of anadromous salmonids and their habitat, it also plays a key role within ISEMP. Each component of work within ISEMP is reported both individually and in annual summary reports that present the overall project components in their programmatic context and shows how the data and tools can be applied to the development of regionally consistent, efficient and effective RME.

*Juvenile outmigration study*
The primary goals of this study are to provide long-term monitoring information and to detect changes due to habitat restoration actions on the juvenile life history characteristics and productivity of spring Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss gairdneri* in the Entiat River basin. The study uses rotary screw traps to capture juveniles in order to quantify abundance, measure physical characteristics, and tag individuals to assess migration timing and survival throughout the Entiat River and Columbia basin. These data are incorporated into a regional database that is utilized by area resource managers to compare attributes both within and between populations located in the Upper Columbia River basin. The ultimate goal of this study is to guide scientifically sound decisions regarding the future management of these species.

*Entiat River IMW study*
The primary goal of the Entiat IMW study is to identify and quantify the effects of habitat restoration upon response variables for ESA listed spring Chinook salmon and steelhead in the Entiat River basin. The measured response variables are productivity (emigrant per redd), emigrant age structure, egg-to-parr survival, parr-to-emigrant survival, annual and seasonal growth of parr, and alterations in site specific fish density or observed movement of tagged individuals. The study uses mark-recapture methodologies to quantify and assess each response variable. The Entiat River IMW study is structured upon previous studies in the subbasin conducted by the U.S. Fish and Wildlife Service's Mid-Columbia River Fishery Resource Office (MCRFRO) which included snorkel surveys and remote fish capture and tagging at the watershed scale.

*Off-Channel Habitat study*
The goal of the Entiat River off-channel habitat study is to provide quantitative evaluations of the effects of existing and proposed off-channel habitats for fish populations. Evaluations include seasonal assessments of species composition, abundance, site use patterns, species age composition, growth, and survival. The study utilizes mark-recapture methodologies and Passive Integrated Transponder (PIT) tag antenna monitoring to quantify the evaluations. Study findings are made available to the habitat restoration community in order to increase current knowledge and better design future off-channel habitat projects within the Entiat watershed.

*PIT Tag Interrogation Site monitoring*
The goal of PIT tag interrogation site monitoring is to increase the amount of quantifiable data on PIT tagged adult and juvenile fish species within the Entiat subbasin. This is facilitated through remote detections, or resightings of PIT tagged fish at six independent interrogation sites within the Entiat subbasin. Interrogation site monitoring at these sites compliments a multitude of other projects occurring within the Upper Columbia basin. Resighting data from these sites are made available to resource managers through a regional database. Interrogation data collected within the Entiat subbasin bolster estimates of juvenile survival and abundance while providing opportunities to verify key assumptions associated with mark-recapture methodologies.

*Steelhead redd surveys*
Steelhead redd surveys serve to track the annual spawning success of adults returning to the Entiat River. These surveys map the distribution of steelhead redds and allow evaluation of

historic spawning areas and habitat restoration actions. Additionally, redd count metrics aid to calculate annual estimates of juvenile productivity.

## 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 (CCCD 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 a terminal moraine at rkm 26.1 and a V shaped valley downstream (Mullan et al. 1992). The present upstream limit to anadromy is at Entiat Falls (rkm 54.4) (Figure 1).

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).

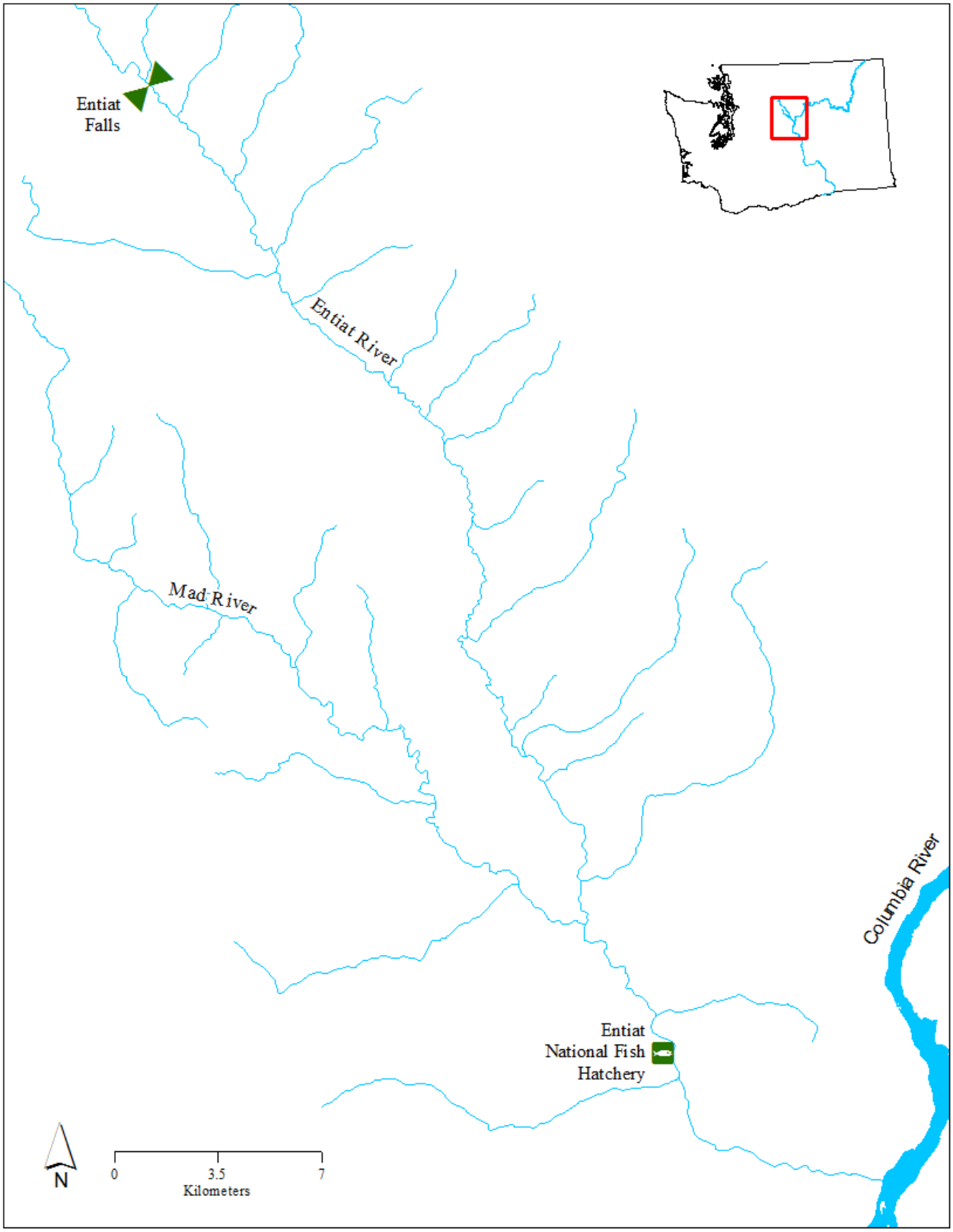


Figure 1. Map of the Entiat River from its mouth to Entiat Falls at river kilometer 54.

# Rotary Screw Trap

## Methods

*Rotary screw trap location*

MCRFRO has been operating a rotary screw trap in the Entiat River at rkm 11 near the Entiat National Fish Hatchery (ENFH) since 2003. Juvenile fish have been captured at other sites within the Entiat subbasin for PIT tagging since 2005. In addition to these legacy collection sites, MCRFRO added another rotary screw trap at rkm 2 during the 2007 field season (Figure 2).

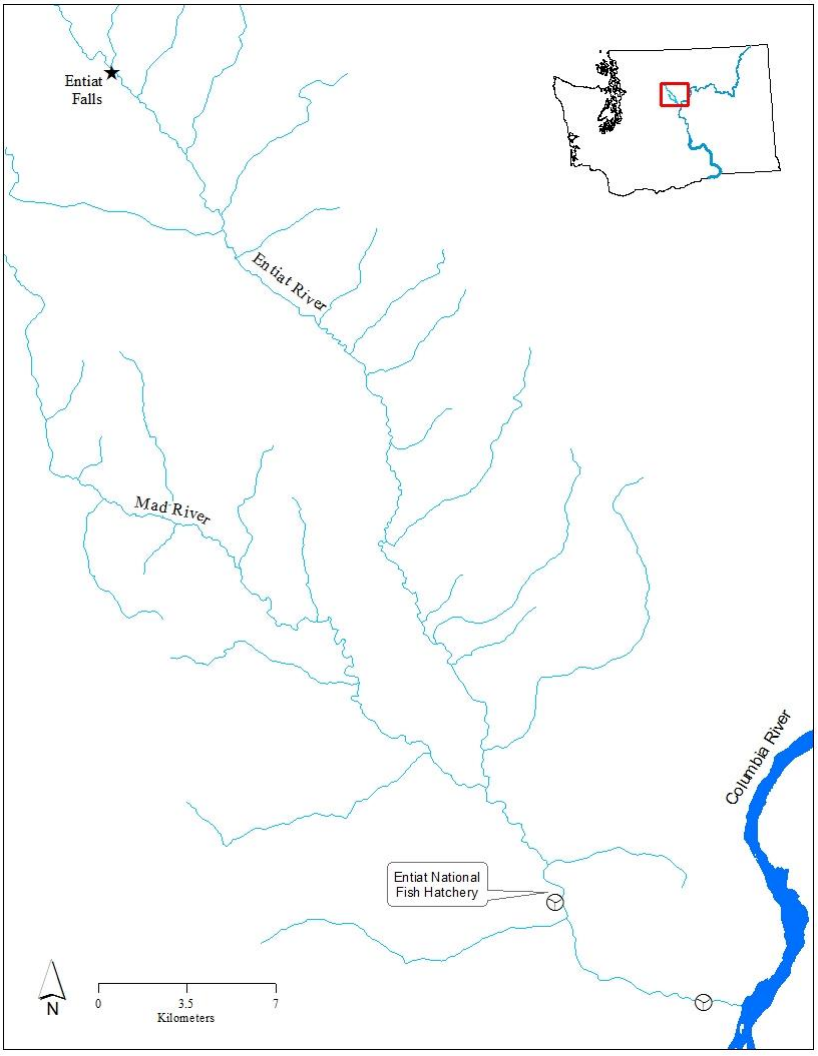


Figure 2. Map of the rotary screw trap location in the Entiat River, 2014.

*Rotary screw trap operation*

Two modified 5 ft. diameter rotary screw traps (EG Solutions Inc.) were used to capture downstream migrating salmonids. Traps were retrofitted with longer pontoons (8' vs. 6') to increase floatation and safety during higher flow. Traps were further modified to include a high pressure spray system to minimize algal accumulation upon the screen of the cone. Assembled

traps were lowered into the river via a boom truck, attached to one quarter inch aircraft cable, and anchored upstream to the bases of large cottonwood trees. A cross-river cable at the trap site suspended the anchor cable above the stream from the anchor point to the trap. A system of winches and pulleys were used to maintain the traps in fixed positions as flows changed throughout the trapping season.

The lower trap was operated seven days a week from March through November with allowances for some events. If possible, the trap was operated 24 hours a day; however, during spring high flows and periods of increased debris loads it was operated from sunset to sunrise. The daily status of the trap was recorded each morning. The collection period was considered complete if the trap operated during the full sunset to sunrise period. Operation of the trap was considered incomplete if the trap did not operate during the entire sunrise to sunset period. Common causes for an incomplete status include debris stopping or sinking the trap, unsafe operating conditions such as large increases in discharge, and/or mechanical failure of the trap itself due to debris. The upper trap was operated intermittently to increase fish numbers for lower trap efficiency trials.

*Fish handling*

Fish were handled in accordance with required permits. At least once a day, juvenile fish were removed from the trap live box and transferred to a permanent fish handling/tagging station at the Entiat National Fish Hatchery (ENFH) for PIT tagging and biological sampling. Five gallon buckets equipped with aerators were used to transport the fish the 8 km from the trap to the tagging facility.

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). All Chinook salmon, steelhead, coho salmon, sockeye salmon, 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. 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.

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 (0.065 g) and individuals greater than 60 mm were tagged with a 12.5 mm PIT tag (0.102 g).

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

*Data entry*

Data from all fish, whether tagged or not, were entered into the P3© program from PTAGIS. P3 is a data entry application used to collect and submit information about marked or recaptured PIT tagged fish in the Columbia River Basin. The P3 file was 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 salmon, 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 (steelhead, cutthroat trout & Chinook salmon) or caudal fin (bull trout). Tissue samples were sent to the Region 1 USFWS genetics lab for archiving and analysis. Scales were collected from steelhead and were cataloged and stored on site for future analysis.

*Screw trap efficiency*

A portion of the collected Chinook salmon 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 (<72 hrs.) prior to release. These fish were then transported to the release site using 5 gallon buckets with aerators to minimize stress. Juvenile fish used for efficiency trials were released after twilight upstream of the trap at rkm 2.3 (Keystone Ranch private bridge). Monitoring of the efficiency trials was limited to the three days following each release in order to minimize potential affects related to river flow. Recaptured fish were re-measured, released, and not included in subsequent efficiency testing.

*Water temperature and flow*

Hourly water temperature data was collected at the 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

*Trap operation period*

Rotary screw trap operations began on Febuary 28, 2014. The trap was operated on a seven day per week schedule through November 13, 2014. Of the 258 trapping days available within the season, the trap operated 142 (53.38%) complete days, 11 (4.89%) incomplete days, and was not operated for 111 days (41.73%).

*Rotary screw trap target species capture summary*

In 2014 a total of 28,668 fish were captured by the rotary screw trap (Table 1). Total juvenile fish capture consisted of 6,365 spring Chinook salmon (22.2%), 12,831 summer Chinook salmon (44.76%), 3,221 steelhead trout (11.24%), 21 coho salmon (0.07%), 348 sockeye salmon (1.23%), 60 bull trout (0.21%), 40 cutthroat trout (0.14%), 3,101 lamprey (10.95%), and 2,638 non-target species (9.2%). A total of 17,620 wild salmonids were implanted with PIT tags. Total daily captures for yearling spring Chinook salmon, sub-yearling spring Chinook salmon, summer Chinook salmon, and steelhead are presented in Figures 3 through 6. Detailed capture summaries including adult species and total mortality are included in Appendix 1.

Table 1**.** Number of fish captured and PIT tagged at Entiat River rotary screw trap, 2014.

| **Species and Life Stage** | **Total Number of fish caught** | **Total PIT tagged** |
|---|---|---|
| Sub-yearling spring Chinook salmon | 3,591 | 3,482 |
| Yearling spring Chinook salmon | 2,774 | 2,625 |
| Summer Chinook salmon | 12,831 | 8,395 |
| Coho salmon | 21 | 15 |
| Steelhead | 3,221 | 2,995 |
| Sockeye salmon | 348 | 12 |
| Bull trout | 60 | 50 |
| Cutthroat Trout | 40 | 38 |
| Lamprey sp. | 3,101 | 0 |
| Non-target species | 2,638 | 8 |
| **Grand total** | **28,668** | **17,620** |

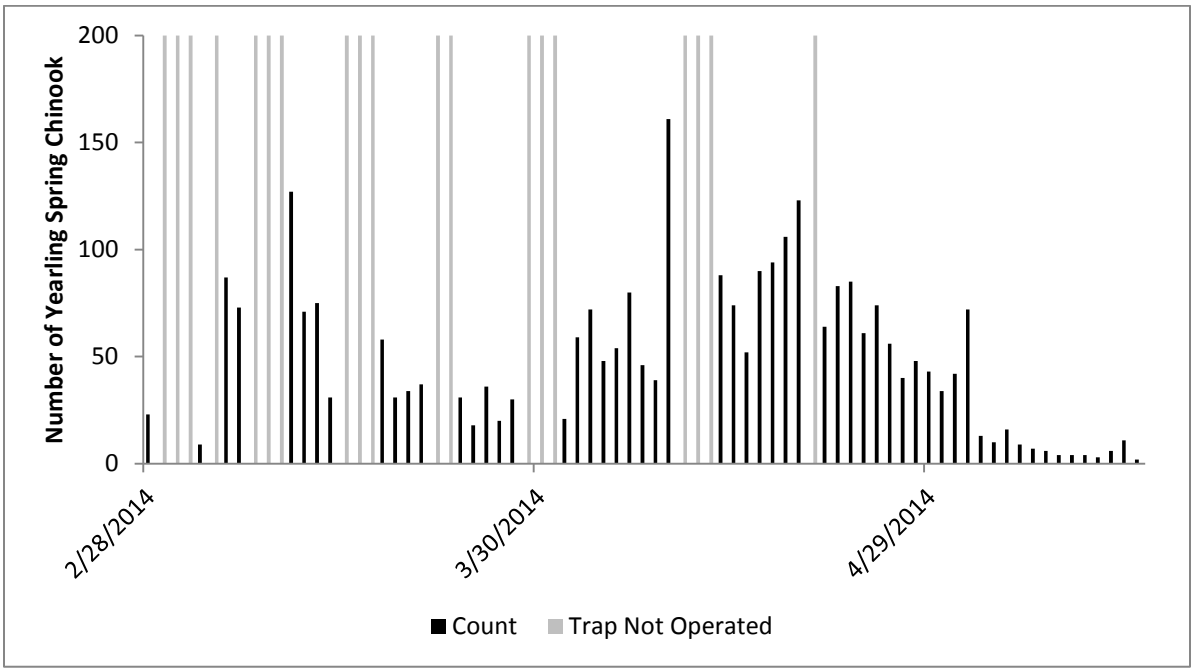


Figure 3. Total daily captures of yearling spring Chinook salmon at the Entiat River rotary screw trap, 2014.

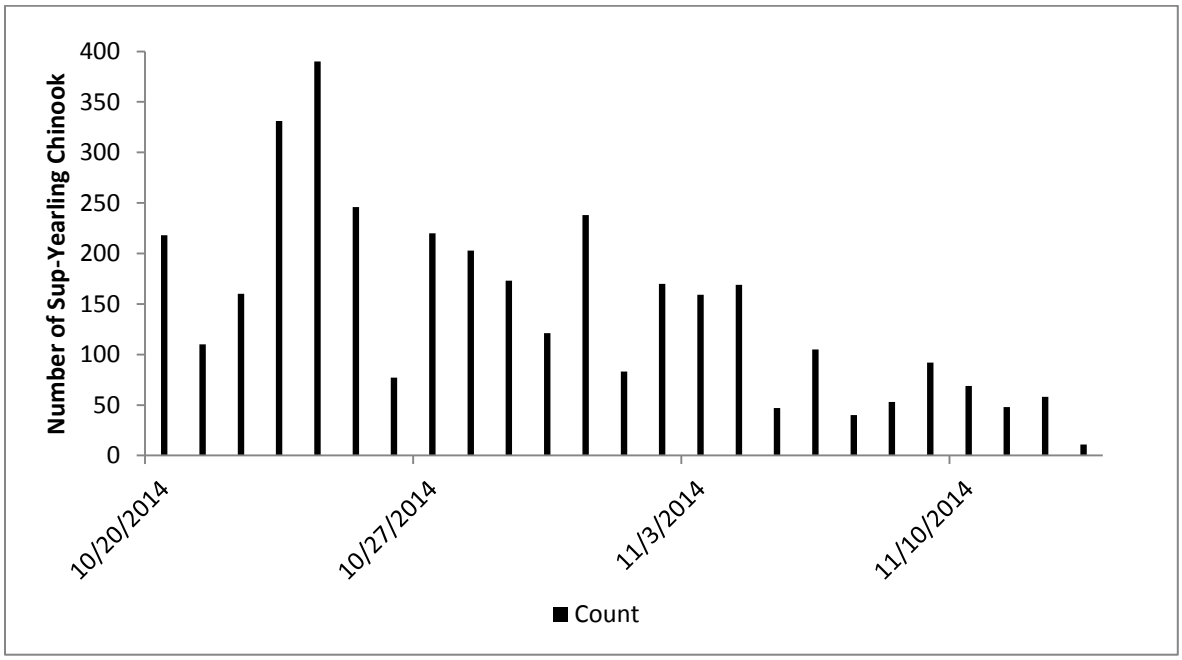


Figure 4. Total daily captures of sub-yearling spring Chinook salmon at the Entiat River rotary screw trap, 2014.

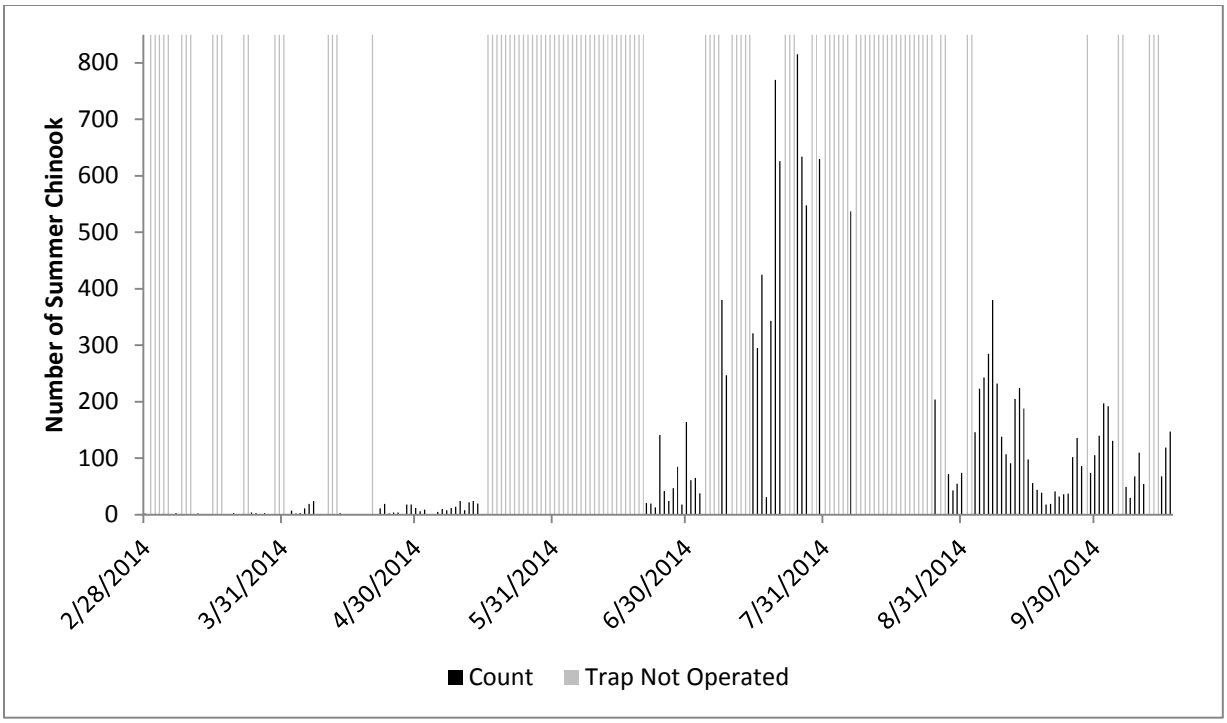


Figure 5. Total daily captures of summer Chinook salmon at the Entiat River rotary screw trap, 2014.

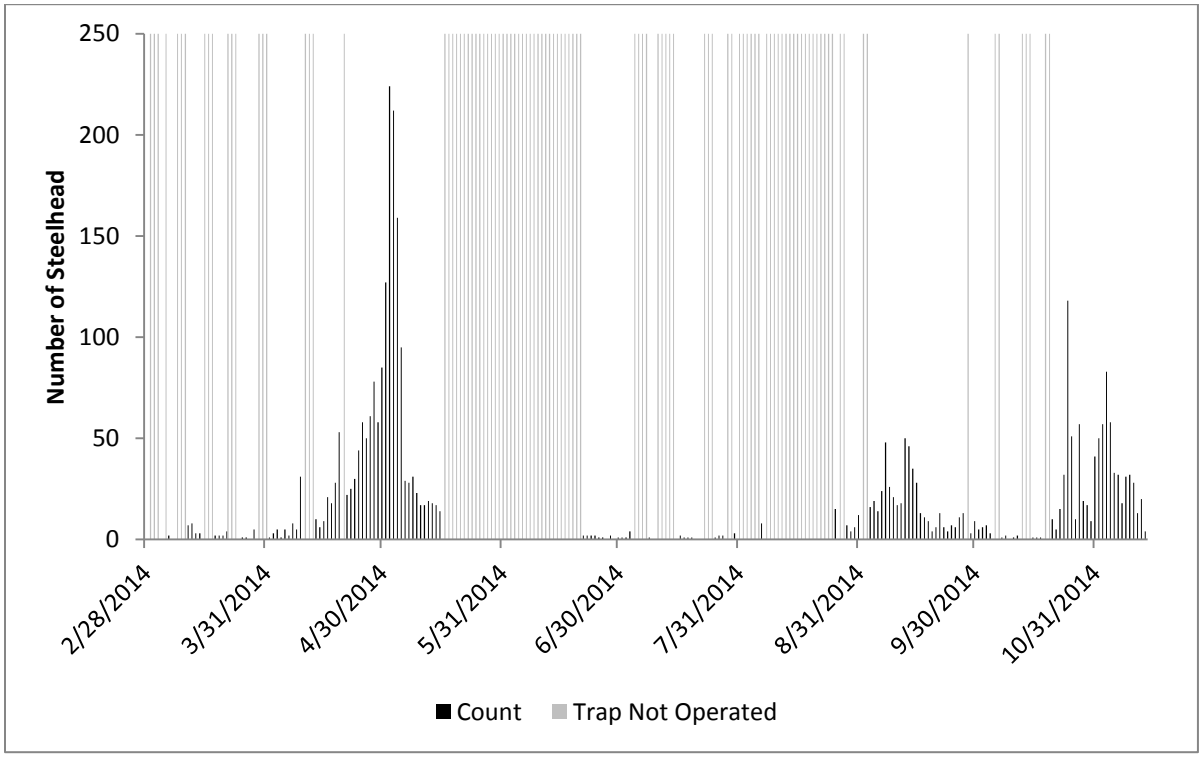


Figure 6. Total daily captures of steelhead at the Entiat River rotary screw trap, 2014.

Mean fork length (±SD) of spring Chinook was 97.13 (±8.69) mm and 82.63 (±9.28) mm, for yearling and sub-yearling species respectively (Table 2). Summer Chinook had a mean fork length of 65.40 (±12.64) mm and steelhead 152.26 (±35.69) mm (Table 3).

Table 2. Mean fork lengths (mm), weights (g), and body condition factor (K) for spring Chinook salmon captured at the Entiat River rotary screw trap, 2014.

| | Yearling spring Chinook | | | Sub-yearling spring Chinook | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **N** | **Mean** | **SD** | **N** |
| **Fork Length** | 97.13 | 8.69 | 2,622 | 82.63 | 9.28 | 3,511 |
| **Weight** | 9.29 | 2.67 | 2,617 | 5.90 | 2.11 | 3,504 |
| **K** | .98 | .89 | 2,616 | 1.00 | .08 | 3,502 |

Table 3. Mean fork lengths (mm), weights (g), and body condition factor (K) for summer Chinook salmon and steelhead captured at the Entiat River rotary screw trap, 2014.

| | Summer Chinook | | | Steelhead | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **N** | **Mean** | **SD** | **N** |
| **Fork Length** | 65.40 | 12.64 | 9,264 | 152.26 | 35.69 | 3,078 |
| **Weight** | 3.21 | 2.14 | 9,194 | 38.16 | 20.40 | 3,073 |
| **K** | 1.01 | 0.12 | 9,191 | .95 | 0.08 | 3,071 |

*Trap efficiencies*

Five viable efficiency trials using PIT tags were conducted for yearling spring Chinook salmon, 7 trials for sub-yearling spring Chinook salmon, 6 trials for summer Chinook salmon and 11trials for steelhead. 2 dye-mark trials were conducted for summer Chinook salmon measuring less than 50mm FL. PIT tag trials for yearling spring Chinook salmon efficiency averaged 21.7% (Table 4), sub-yearling spring Chinook 25.6% (Table 5), summer Chinook 28.0% (Table 6) and steelhead 15.4% (Table 7). The summer Chinook dye mark efficiency was 11.3% (Table 8).

Table 4. Estimated capture efficiency of PIT tagged yearling spring Chinook salmon at the Entiat River rotary screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2014.

| **Trial Date** | **Flow ($m^3/s$)** | **Release Size (n)** | **Efficiency** |
|---|---|---|---|
| 03/12/2014 | 8.32 | 124 | 27.42% |
| 04/04/2014 | 6.66 | 142 | 29.58% |
| 04/16/2014 | 14.57 | 198 | 21.72% |
| 04/26/2014 | 16.20 | 130 | 13.08% |
| 05/01/2014 | 15.95 | 72 | 16.67 |

Table 5. Estimated capture efficiency of PIT tagged sub-yearling spring Chinook salmon at the Entiat River rotary screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2014.

| Trial Date | Flow ($m^3/s$) | Release Size (n) | Efficiency |
|---|---|---|---|
| 10/21/2014 | 5.32 | 213 | 37.56% |
| 10/22/2014 | 4.40 | 104 | 38.46% |
| 10/24/2014 | 5.38 | 319 | 26.02% |
| 10/25/2014 | 5.97 | 381 | 35.17% |
| 11/ 2/2014 | 15.68 | 310 | 11.94% |
| 11/ 4/2014 | 13.01 | 313 | 18.53% |
| 11/12/2014 | 15.97 | 204 | 11.27% |

Table 6. Estimated capture efficiency of PIT tagged summer Chinook salmon at the Entiat River rotary screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2014.

| Trial Date | Flow ($m^3/s$) | Release Size (n) | Efficiency |
|---|---|---|---|
| 07/16/14 | 15.01 | 162 | 9.26% |
| 07/19/14 | 12.86 | 448 | 18.08% |
| 08/29/14 | 4.39 | 34 | 35.29% |
| 09/03/14 | 4.12 | 137 | 37.23% |
| 09/15/14 | 3.15 | 275 | 26.18% |
| 09/25/14 | 4.49 | 128 | 42.19% |

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, 2014.

| Trial Date | Flow ($m^3/s$) | Release Size (n) | Efficiency |
|---|---|---|---|
| 04/19/14 | 15.26 | 64 | 17.19% |
| 04/26/14 | 16.20 | 90 | 14.44% |
| 05/01/14 | 15.95 | 134 | 13.43% |
| 05/02/14 | 19.24 | 114 | 11.40% |
| 05/03/14 | 27.85 | 217 | 7.37% |
| 05/04/14 | 34.09 | 202 | 7.92% |
| 05/06/14 | 32.42 | 238 | 12.18% |
| 09/13/14 | 3.34 | 80 | 12.50% |
| 10/25/14 | 5.97 | 113 | 24.78% |
| 10/31/14 | 9.82 | 41 | 24.39% |
| 11/04/14 | 13.01 | 137 | 24.09% |

Table 8. Estimated capture efficiency of dye marked summer Chinook salmon at the Entiat River rotary screw trap with average (sunset to sunrise) flow from the USGS Keystone gaging station, 2014.

| *Trial Date* | *Flow ($m^3/s$)* | *Release Size (n)* | *Efficiency* |
|---|---|---|---|
| 07/17/14 | 15.01 | 399 | 8.02% |
| 07/20/14 | 12.86 | 331 | 14.50% |

*Discharge*

Water temperature measurements averaged 10.6 ˚C throughout the study period (Figure 7). Water temperatures peaked at 20.91 ˚C on August 5th, and were lowest on October 30th when temperatures averaged 2˚C. Flow peaked in the spring on May 12th at 78.34 $m^3/s$. High water levels declined quickly, allowing rotary screw trap operations to resume on May 23rd.

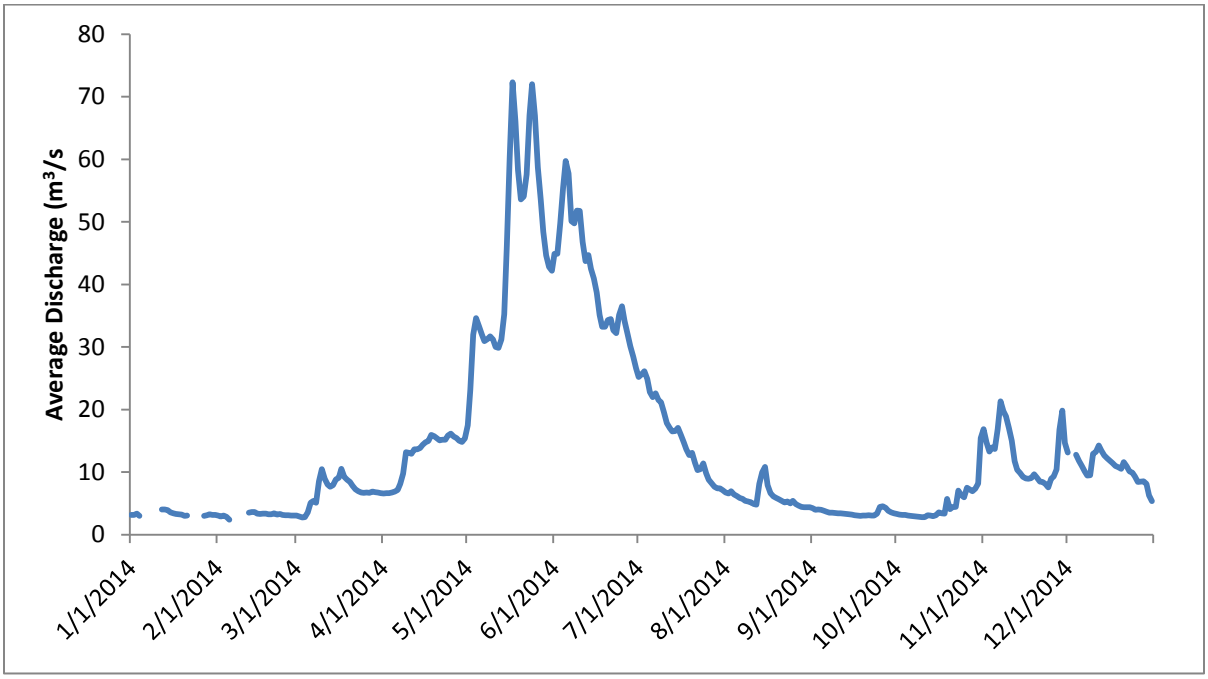


Figure 7. Average daily discharge ($m^3/s$) of the Entiat River at the location of the rotary screw trap, 2014.

# 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 periods due to trap failure. These periods require more staff to maintain the traps 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. The majority of non-operational days were due to snow melt resulting in a high spring flow. To a lesser extent, the staffing requirements of mark-recapture sampling resulted in a reduction of rotary screw trap operation during the associated field sampling periods.

*Summer vs. spring Chinook salmon*

Both spring and summer Chinook salmon spawn in the Entiat basin. Early in the season, distinct morphological differences between summer sub-yearlings and spring Chinook salmon yearlings make identification easy. Spring Chinook salmon yearlings are much larger in size (75-100 mm) than newly emergent summer Chinook fry (32-45 mm). Identification is more difficult during summer and early fall as both spring and summer Chinook sub-yearlings are similar sizes. Currently there is no definitive method to apportion these two runs of sub-yearlings. To determine if the difference in migration timing could be used to assign the proper run, total catch was monitored and plotted by day. When catch decreased and a relative nadir was reached in late October, all Chinook salmon captured onward were assigned a run based on any detectable break in fork length distributions. Undoubtedly, the run classification of some Chinook salmon is improperly assigned using this method. Utilizing data from Entiat River PIT tag interrogation sites and the emigration timing of PIT tagged Chinook salmon, it is clear that delineation of the two runs of sub-yearling Chinook salmon used in previous years was inadequate.

The MCRFRO 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 Genetics Lab. This preliminary analysis indicated a lack of precision in run assignment. MCRFRO has secured funding to update the genetic baseline for Entiat River summer Chinook, which is expected to increase run assignment precision and will rerun all samples following. In addition to better differentiating between spring and summer Chinook emigrants, this analysis will also document the level of hybridization between species should it exist. Findings from this analysis are expected in 2015 and will be disseminated through a separate report.

# Mark-Recapture Sampling

## Methods

*Sample periods and site selection*
Fish sampling within the IMW study has been designed around a framework of a rotating panel of sites within defined geomorphic reaches of the Entiat River. Fish sampling occurs twice annually in the winter and summer. Winter fish sampling generally begins in late February or early March as river surface ice recedes allowing crews access to river margins. Summer fish sampling begins in late July or early August as river discharge falls below the established maximum sampling threshold of 300$ft^3$/s.

Winter period sample sites remained unaltered from the summer 2013 selection. A total of 20 sites were sampled using mark-recapture or single pass methods during the winter period. Eight sites were identified as mark-recapture sites and 12 were sampled as single pass sites. New sites selected for the summer sampling period included multiple fixed location sites within each reach while remaining sites were selected at random from a rotating panel. Sites were further designated within each reach to be sampled with mark-recapture or single pass methods. Sample site selection was altered between the winter and summer sampling periods of 2014. A total of 20 sites were sampled using mark-recapture or single pass methods during the summer period. These 20 sites sampled in the summer period will be sampled again in the winter of 2015 and new rotating sites will be drawn for the following summer period of 2015. Sample site locations for winter and summer sample periods in 2014 are presented in Figures 8 and 9 respectively.

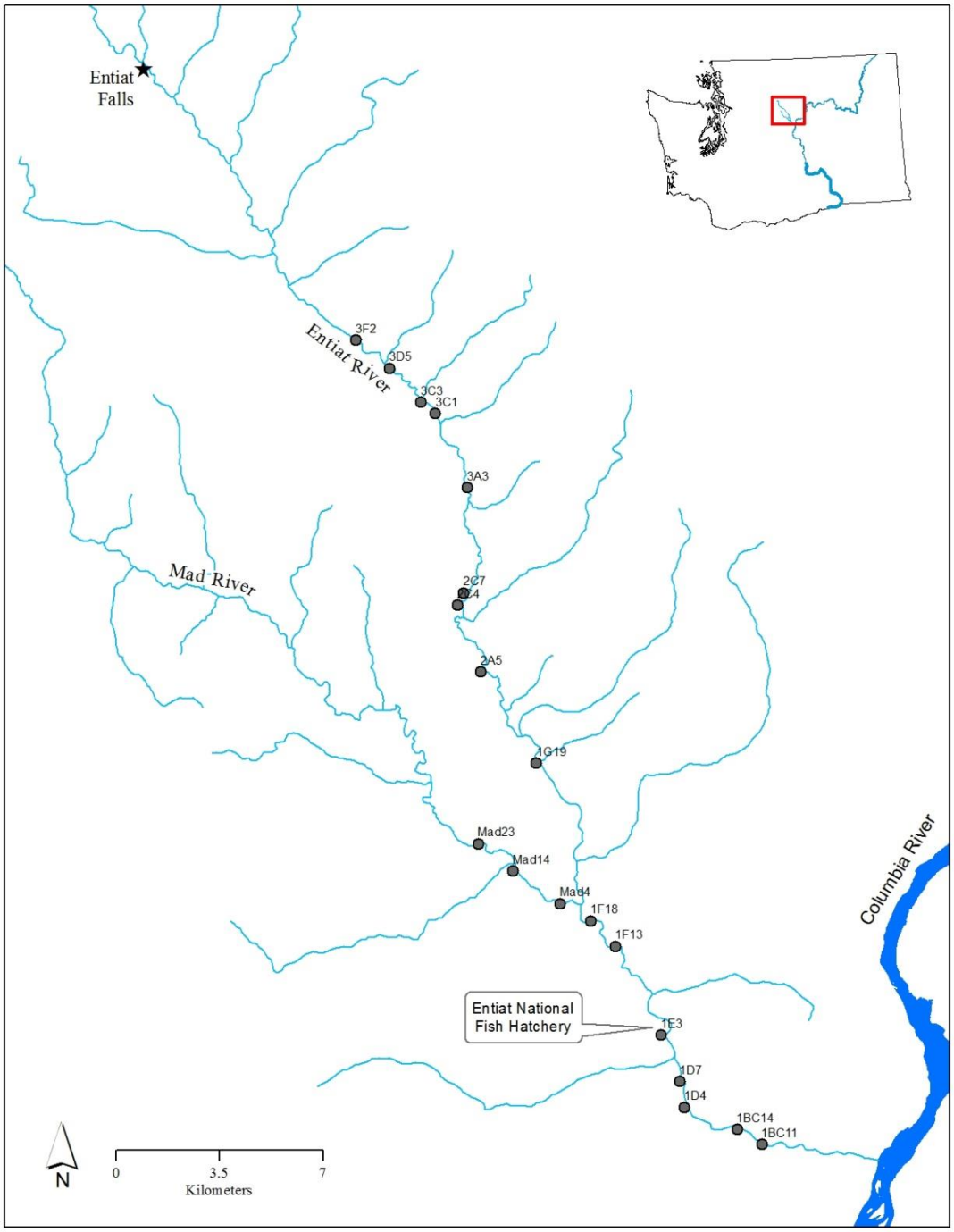


Figure 8. Map of the mark-recapture sites sampled during the winter period in the Entiat River, 2014.

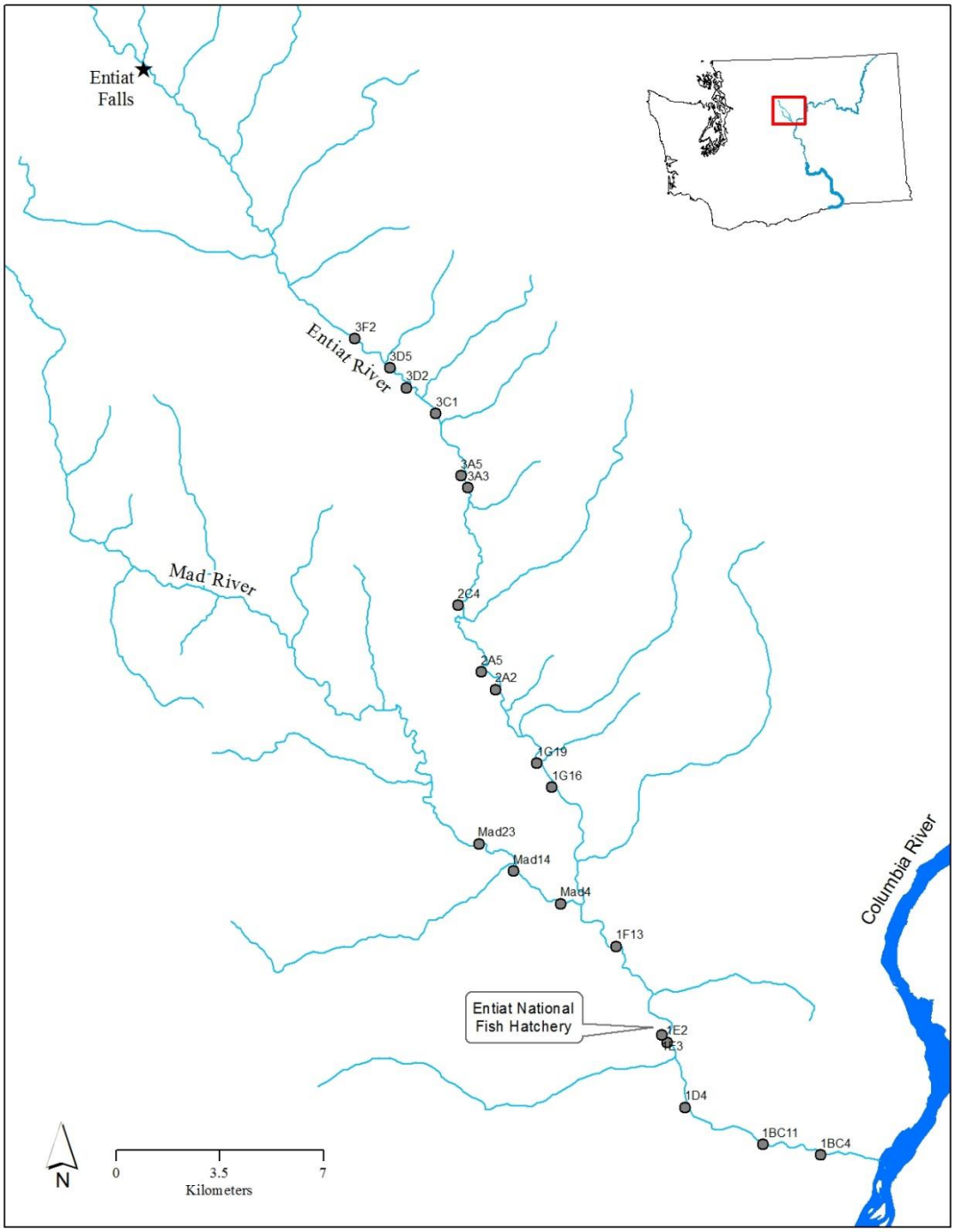


Figure 9. Map of the mark-recapture sites sampled during the summer period in the Entiat River, 2014.

*Fish collection overview*

Fish collection activities utilize one to three capture crews. Each crew consisting of a minimum of six personnel, sampled sites independently of one another. Prior to sampling, all sites were visually surveyed to determine a primary sampling method as applicable by sampling period limitations. All sampling was conducted with crews beginning at the lower site boundary and methodically working upstream until the site was completely sampled. In some cases, a site or specific habitat was sampled a second time using an alternative method if it was deemed more suitable to the specific conditions.

*Winter period fish collection*

Mark-recapture methods were utilized for fish sampling at all sites during the winter sampling period. Sampling occurred following dusk to maximize fish capture numbers as fish exhibit a nocturnal behavior specific to the water temperatures encountered during this period. Fish were captured using snorkel-herding and hand netting as other methods are precluded from use during night hours. All sites were sampled over a two day period. Fish were collected, marked and released in close proximity to their initial capture location during the first night of collection. Fish were allowed to recover for approximately 18 hours prior to the beginning of the recapture effort on the second night of sampling.

*Summer period fish collection*

Sites were sampled over a one or two day period depending upon their selection status as mark-recapture or single pass (Table 9 and 10). During the summer period daytime effort provided adequate captures but in order to avoid high afternoon water temperatures, all sampling began no later than 7:00 am and usually was complete by 2:00 pm. A primary sampling method of either backpack electrofishing or snorkel-seining was chosen based upon site specific conditions such as water depth, river discharge, expected age and species composition, and the overall complexity of habitat types present. Electrofishing was conducted with a Smith-Root LR-24 backpack electrofisher. Electrofishing operation followed the guidelines of the manufacturer and the National Marine Fisheries Service (NOAA 2000).

Table 9. The location and sampling type of winter mark recapture sites in the Entiat River, 2014.

| Site | River Kilometer | Sampling Type |
|---|---|---|
| 1BC11 | 4.2 | Mark-Recapture |
| 1BC14 | 5.2 | Single Pass |
| 1D4 | 7.4 | Mark-Recapture |
| 1D7 | 8.4 | Single Pass |
| 1E3 | 9.9 | Single Pass |
| 1F13 | 14.7 | Single Pass |
| 1F18 | 16.3 | Single Pass |
| 1G19 | 23.4 | Mark-Recapture |
| 2A5 | 28.1 | Mark-Recapture |
| 2C4 | 31.6 | Mark-Recapture |
| 2C7 | 32.5 | Single Pass |
| 3A3 | 36.7 | Single Pass |
| 3C1 | 40.2 | Mark-Recapture |
| 3C3 | 40.9 | Single Pass |
| 3D4 | 42.4 | Single Pass |
| 3D5 | 42.7 | Mark-Recapture |
| 3F2 | 44.6 | Single Pass |
| Mad4 | 0.7 | Mark-Recapture |
| Mad14 | 2.9 | Single Pass |
| Mad23 | 4.8 | Single Pass |

Table 10. The location and sampling type of summer mark recapture sites in the Entiat River, 2014.

| Site | River Kilometer | Sampling Type |
|---|---|---|
| 1BC4 | 1.9 | Single Pass |
| 1BC11 | 4.2 | Single Pass |
| 1D4 | 7.4 | Single Pass |
| 1E2 | 9.9 | Single Pass |
| 1E3 | 10.3 | Single Pass |
| 1F13 | 14.7 | Single Pass |
| 1G16 | 22.5 | Single Pass |
| 1G19 | 23.4 | Single Pass |
| 2A2 | 27.1 | Single Pass |
| 2A5 | 28.1 | Single Pass |
| 2C4 | 31.6 | Mark Recapture |
| 3A3 | 36.7 | Mark Recapture |
| 3A5 | 37.4 | Single Pass |
| 3C1 | 40.2 | Single Pass |
| 3D2 | 41.8 | Single Pass |
| 3D5 | 42.7 | Single Pass |
| 3F2 | 44.6 | Mark Recapture |
| M04 | 0.7 | Single Pass |
| M14 | 2.9 | Single Pass |
| M23 | 4.8 | Single Pass |

*Fish handling*

Fish were transported within 5 gallon aerated buckets from the point of capture to 25 gallon plastic live boxes located on the river margins throughout the site. Water temperatures and fish condition were closely monitored during transportation and holding. All individuals that exhibited signs of injury or excessive stress were scanned for a pre-existing PIT tag and released. Fish were periodically transported from live boxes to a stationary fish handling and tagging station.

Collected species were anesthetized in a water bath with a measured amount of tricaine (MS-222) buffered with sodium bicarbonate. Small groups of fish were anesthetized at any one time during daily handling to reduce the chance of incidental mortality from anesthetic overdose. Fish were identified to species with the exception of sculpin, dace and suckers. Chinook salmon run designation was classified as unknown when captured during the summer period due to the inability to distinguish between spring and summer run characteristics. All salmonids were ascribed to a life history stage as either fry (<60 mm), parr (>60mm and distinctive parr marks), transitional (>60 mm silver sheen, faint parr marks, and deciduous scales) or smolt (>60 mm silver sheen, absent parr marks, deciduous scales, and with possible black tipped caudal fins).

All Chinook salmon, steelhead, coho salmon, sockeye salmon, 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 previously. Non-target species were either measured or counted and released within the site dependent upon time restrictions. All individuals were allowed full recovery prior to release. Non-marked individuals were released within the site in close proximity to their point of capture.

Any injuries or abnormalities were noted and juveniles were not PIT tagged if determined it had a recent or substantial injury that could be aggravated by tagging. Marked juveniles were held until fully recovered prior to being released in close proximity to their capture origin.

*Genetic and scale sampling*
Throughout the summer sampling period genetic samples were taken from a subset of PIT tagged Chinook salmon. Tissue was obtained from a small portion of the ventral fin, preserved in alcohol and sent to the Region 1 USFWS genetics lab for storage. Scale samples were taken from a subset of juvenile steelhead and archived for future age analysis.

## Results

*Winter fish capture summary*
Fish sampling began on March 5, 2014 when river surface ice had receded allowing safe access to sample sites. All sampling activities were completed on March 18. Average daily flow ($ft^3/s$) during the sampling period is summarized in Figure 10.

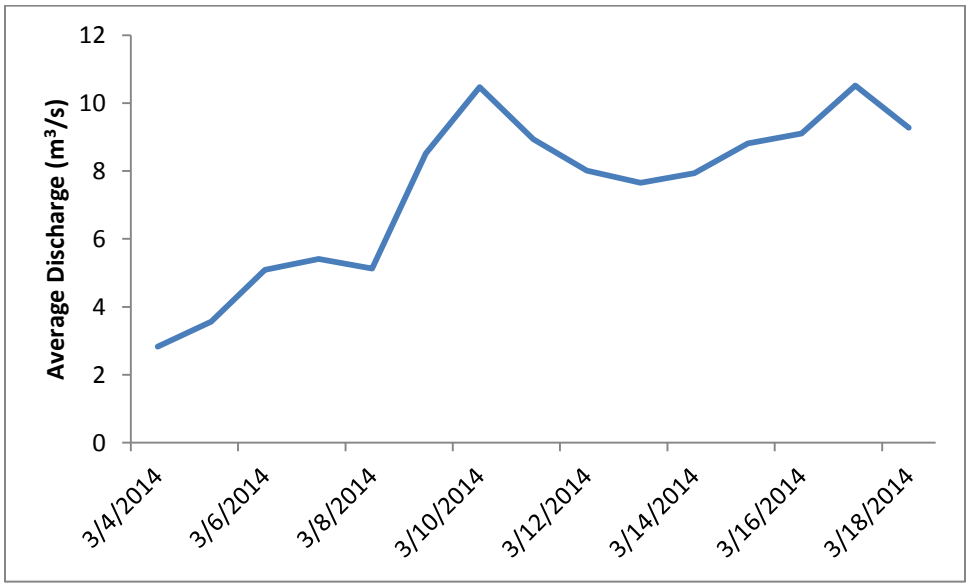


Figure 10. Entiat River average daily flow ($m^3/s$) (USGS gaging station 12452990) during winter period mark-recapture sampling, 2014.

A total of 3,061 fish were captured at 20 sites throughout the Entiat and Mad rivers during the 2014 winter sampling period (Table 11). Species composition included 1,003 wild spring Chinook salmon (32.77%), 2,054 wild steelhead (67.1%), and 4 bull trout (0.13%). Of the salmonids caught, a total of 3,061 wild salmonids (89.28%) were implanted with PIT tags. Mean fork length (SD) of juvenile spring Chinook and steelhead was 89.02 (±8.42) mm and 108.42 (±36.31) mm, respectively (Table 12). During the 2014 winter sample period, capture related mortality was attributed to a total of 2 Chinook salmon.

Table 11**.** Number of fish captured, PIT tagged, and associated mortality from the winter mark-recapture sample period, 2014.

| **Species** | **Total number of Fish Captured** | **Total PIT Tagged** | **Mortality** |
|---|---|---|---|
| Spring Chinook salmon | 1,003 | 942 | 2 |
| Steelhead | 2,054 | 1,787 | 0 |
| Bull trout | 4 | 4 | 0 |
| **Grand total** | **3,061** | **2,733** | **2** |

Table 12**.** Mean fork lengths (mm), weights (g), and body condition factor (K) for spring Chinook salmon and steelhead captured in the winter mark-recapture sample period, 2014.

| | **Spring Chinook** | | | **Steelhead** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **N** | **Mean** | **SD** | **N** |
| **Fork Length** | 89.02 | 8.42 | 1,003 | 108.42 | 36.31 | 2,054 |
| **Weight** | 7.47 | 2.31 | 1,001 | 16.97 | 17.5 | 2,053 |
| **K** | 1.03 | 0.08 | 1,001 | 1.0 | 0.07 | 2,053 |

*Summer fish capture summary*

Fish sampling began on August 11, 2014 when flows within the Entiat River reached 300 $ft^3/s$. Daily average flow ($m^3/s$) during the sampling period is summarized in Figure 11. Initial sampling efforts focused on the uppermost Entiat River sites in an attempt to complete sampling before the peak of spring Chinook spawning activity. All sampling activities were completed on September 16, 2014.

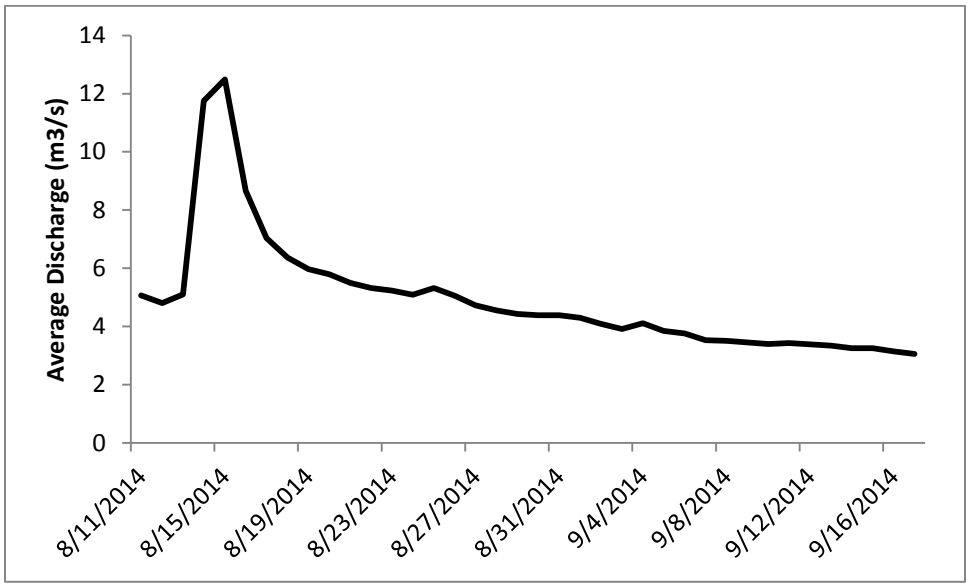


Figure 11. Entiat River average daily flow ($m^3/s$) (USGS gaging station 12452990) during summer period mark-recapture sampling, 2014.

A total of 4,418 fish were captured at 20 sites throughout the Entiat and Mad rivers during the 2014 summer sampling period (Table 13). Species composition included 1,605 wild Chinook salmon (36.33%), 1,497 wild steelhead (32.57%), 1 wild Coho salmon (0.02%), 9 bull trout (0.2%), 8 cutthroat trout (0.1.8%), and 1,356 non-target species (30.69%). Of the captured wild salmonids, a total of 2,341 (76.45%) were implanted with PIT tags. Mean fork length (SD) of Chinook salmon and steelhead was 66.95 (±12.59) mm and 103.38 (±51.75) mm respectively (Table 14). During the 2014 summer sample period, capture related mortality was attributed to a total of 29 Chinook salmon, 11 steelhead, and 2 non-target species. PIT tagging related mortality was observed in 5 Chinook salmon and 1 steelhead throughout the sampling period.

Table 13. Number of fish captured, PIT tagged, and associated mortality from the summer mark-recapture sample period, 2014.

| Species | Total number of Fish Captured | Total PIT Tagged | Mortality |
|---|---|---|---|
| Chinook salmon | 1,605 | 1,497 | 29 |
| Steelhead | 1,439 | 847 | 11 |
| Coho salmon | 1 | 1 | 0 |
| Bull trout | 9 | 6 | 0 |
| Cutthroat trout | 8 | 8 | 0 |
| Non-target species | 1,356 | 0 | 2 |
| **Grand total** | **4,418** | **2,341** | **42** |

Table 14**.** Mean fork lengths (mm), weights (g), and body condition factor (K) for Chinook salmon (unknown run) and steelhead captured in the summer mark-recapture sample period, 2014.

| | Chinook (unknown run) | | | Steelhead | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **N** | **Mean** | **SD** | **N** |
| **Fork Length** | 66.95 | 12.59 | 1,601 | 103.38 | 51.75 | 1,309 |
| **Weight** | 3.78 | 4.30 | 1,596 | 21.51 | 28.01 | 1,298 |
| **K** | 1.11 | 0.1 | 1,596 | 1.07 | 0.11 | 1,296 |

## Discussion

*Fish sampling*

Warmer winter temperatures and lower snow accumulations minimized shelf ice buildup and allowed all sites to be sampled during the winter sampling period. A higher mortality level was again experienced in the summer sampling period as compared to winter. Our experience indicates a higher mortality rate is associated with electrofishing than other methods. This difference is most likely due to low conductivity which diminishes the size of the electrical field and requires higher voltage settings to stun and capture fish. The resulting mortality was observed predominantly when smaller juveniles were encountered (< 60mm fork-length). To reduce mortality, snorkel-seining will be used prior to electrofishing at sites where either method is possible. Mortality rates were maintained below maximum permit levels throughout each sampling period. Summer sampling was prolonged due to active fires in the upper Entiat and Mad River watersheds and two mudslides originating from the Pope Creek drainage. These mudslides caused excessive turbidity and hazardous water conditions for several days during the sampling period.

*Summer vs. spring Chinook salmon*

The problem of accurately assigning a run designation to Chinook salmon encountered during sampling was managed using similar criteria as was applied in the Entiat River rotary screw trap study. Based on time of year, size and life history, juvenile Chinook sampled during the winter period were categorized as “wild spring Chinook”. Juvenile Chinook salmon encountered in the summer and fall sampling periods were classified as ‘wild Chinook (unknown run)’.

# Off-Channel Habitat Study

## Methods

*Sample site selection*

Sample sites considered for the off-channel habitat study were limited to habitats distinctly separate from the main river channel where 1) flow was perennial, 2) the site was accessible year round, and 3) physical site conditions supported the PIT tag antenna monitoring requirements of the study. A total of 5 off-channel sites were sampled in 2014 (Figure 12).

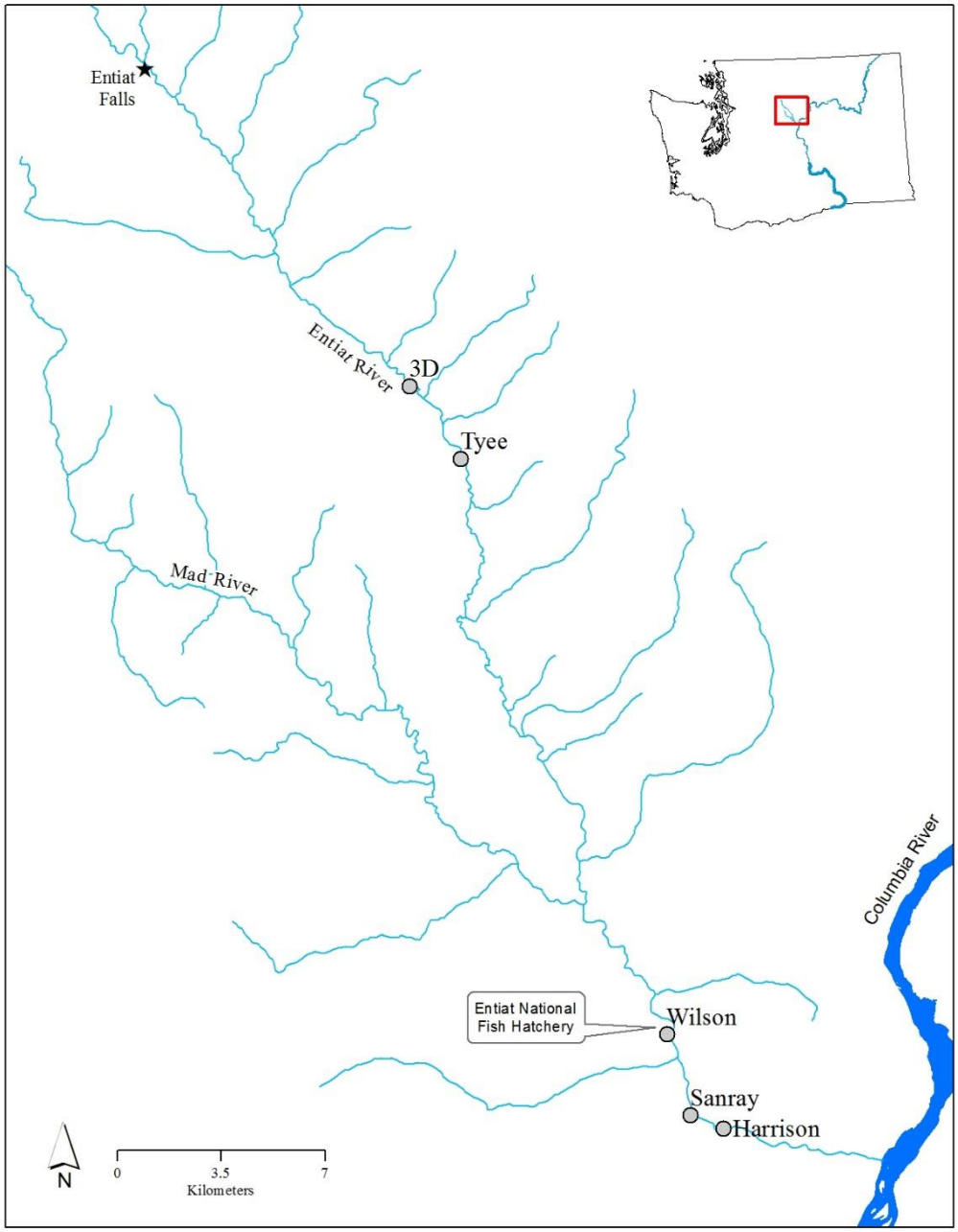


Figure 12. Map of the Entiat River watershed defining locations of the five off-channel study sites, 2014.

*Site Descriptions*
The Harrison side-channel (HAR) is located at rkm 6.0. In 2008 it was reconnected to the main-channel by partial removal of a levee. It is a 515 m long channel that has both a high flow and low flow connection to the main channel. The low flow branch consists mainly of beaver dams and sand. The high flow branch and lower channel below the confluence are comprised of low gradient large cobble riffle habitat and pools.

The SanRay side-channel (SAN), located at rkm 7.0, consists of a 117 m long naturally occurring perennial side-channel that reconnects to the main river. A now defunct irrigation canal historically entered the channel near its upstream end. The side-channel is composed primarily of riffle-run habitat with few pools and complex wood structure.

The Wilson side-channel (WLS), at rkm 11.0 near the ENFH, consists of a 286 m long reconnecting perennial side-channel. Habitat within the side-channel is complex and has changed considerably since its construction in 2006. The lower portion of the site is comprised of downed trees and a series of beaver dams and pools, whereas the upper portion is a cobble riffle with thick riparian cover.

The Tyee side-channel (TYE) is located at approximately rkm 38.0. The site was completed as part of the 2012 round of habitat implementation under the Entiat IMW. An existing beaver pond was deepened and enhanced with large wood in what is now the lower portion of the side-channel. Flow is maintained within the side-channel through connections made above and below the beaver pond. Upstream connections utilize a main, low flow channel as well as a reconnected high flow channel. The side-channel is 304 m in length and is largely a glide habitat with substrates including silt, sand, gravel, and cobble.

The 3D site is located at rkm 42.7. The site was completed as part of the 2012 round of habitat implementation under the Entiat IMW. The side-channel utilizes the lower portion of Brennegan Creek as it connects to the Entiat River. An additional channel was constructed making an upstream connection between the creek and the Entiat River and large wood was added to both sections. The total length of the side-channel is 402 m in length. The reconstruction of an existing beaver dam at the base of Brennegan Creek has resulted in added depth and reduced velocity within the lower portion of the side-channel.

*Sampling periods*
Sites are sampled three times annually; winter sampling occurred between March 20 and April 14, summer sampling occurred between July 22 and August 7, and fall sampling occurred from October 1 and October 15.

*Fish Collection*
Fish sampling methods included backpack electrofishing, seining and hand-netting. Since fish capture during daytime hours provided sufficient numbers of fish for marking and recapture, a night sampling period was not necessary. Fish sampling was conducted at each site over two consecutive days. Block nets were utilized at the top and bottom of each site and maintained for the duration of the mark-recapture period. One capture crew consisting of six personnel sampled each site. Sampling was conducted in an upstream direction with crews methodically working until the site was completely sampled. Electrofishing was conducted with a Smith-Root model

LR-24 backpack electrofishing unit. Electrofishing operations followed the guidelines of the manufacturer and the National Marine Fisheries Service (NOAA 2000). Fish handling and marking methods followed those outlined in the Entiat River mark-recapture study.

*PIT tag antenna monitoring*
A single channel spanning antenna was used at the inlet (upstream) and outlet (downstream) of each off-channel study site. An additional antenna was also located near the midway point of some channels depending on their characteristics (i.e. high and low flow channels) and structure. PIT tag antennas were operated continuously throughout the study period with exception to periods of equipment failure. Interrogation files were downloaded weekly or as necessary based on river conditions or expected periods of high fish movement. Records of operational status were taken during each site visit. Routine maintenance was conducted and included battery changing, replacement of anchor straps, and debris removal.

*Water temperature monitoring*
Water temperature was monitored at the top and bottom of each site throughout the study period. Hourly data was recorded using Onset temperature loggers. Loggers were downloaded at two week intervals.

*Habitat monitoring*
In 2014, physical habitat measurements were recorded by staff from Terraqua Inc. as part of the Columbia Habitat Monitoring Program (CHaMP). Habitat metrics are collected once annually from each site usually following the summer sampling period in August and can be found on the CHaMP website (www.CHaMPMonitoring.org).

## Results

*Fish capture summary*
A total of 2,619 fish were captured at five off-channel sites in 2014 (Tables 15, 16, 17). Total capture species composition included: 1,521 wild Chinook salmon (58.08%), 611 wild steelhead (23.33%), 8 wild coho salmon (0.31%), 4 wild sockeye salmon (0.15%), 3 bull trout (0.11%), 10 Pacific lamprey (0.38%), and 462 non-target species (17.64%). A total of 1,387 wild salmonids (53%) were implanted with PIT tags.

Table 15. Total number of fish captured in the Harrison (HAR), Sanray (SAN), Wilson (WLS), Tyee (TYE) and 3D side-channels during fall sampling in the Entiat River, 2014.

| | Site | | | | |
|---|---|---|---|---|---|
| Species | HAR | SAN | WLS | TYE | 3D |
| Spring Chinook salmon | 2 | 0 | 27 | 40 | 2 |
| Steelhead | 37 | 74 | 25 | 79 | 8 |
| Coho salmon | 7 | 0 | 1 | 0 | 0 |
| Sockeye salmon (unk. run) | 0 | 0 | 1 | 0 | 0 |
| Lamprey sp. | 0 | 0 | 0 | 0 | 0 |
| Non-target | 0 | 0 | 0 | 0 | 2 |

Table 16. Total number of fish captured in the Harrison (HAR), Sanray (SAN), Wilson (WLS), Tyee (TYE) and 3D side-channels during fall sampling in the Entiat River, 2014.

| | Site | | | | |
|---|---|---|---|---|---|
| Species | HAR | SAN | WLS | TYE | 3D |
| Chinook salmon (unk. run) | 628 | 55 | 231 | 224 | 198 |
| Steelhead | 30 | 44 | 20 | 69 | 4 |
| Bull trout | 0 | 0 | 0 | 1 | 0 |
| Sockeye salmon (unk. run) | 1 | 0 | 0 | 0 | 2 |
| Lamprey sp. | 2 | 0 | 2 | 2 | 0 |
| Non-target | 238 | 7 | 153 | 32 | 3 |

Table 17. Total number of fish captured in the Harrison (HAR), Sanray (SAN), Wilson (WLS), Tyee (TYE) and 3D side-channels during fall sampling in the Entiat River, 2014.

| | Site | | | | |
|---|---|---|---|---|---|
| Species | HAR | SAN | WLS | TYE | 3D |
| Chinook salmon (unk. run) | 8 | 11 | 40 | 52 | 2 |
| Steelhead | 9 | 90 | 22 | 98 | 2 |
| Bull trout | 0 | 0 | 0 | 2 | 0 |
| Lamprey sp. | 0 | 4 | 0 | 0 | 0 |
| Non-target | 0 | 0 | 0 | 3 | 0 |

Overall mean fork length for Chinook for winter, summer, and fall were 82.60, 58.93, and 70.9, respectively. The mean fork length for steelhead during the same time periods were 91.7, 79.63, and 74.58, respectively (Figure 13). Overall mean K factor of Chinook for winter, summer, and fall were 1.01, 1.08, and 1.05, respectively. Steelhead mean K factors were very similar to those of Chinook for each sampling period with values of 1.04, 1.12, and 1.09, respectively (Figure 14).

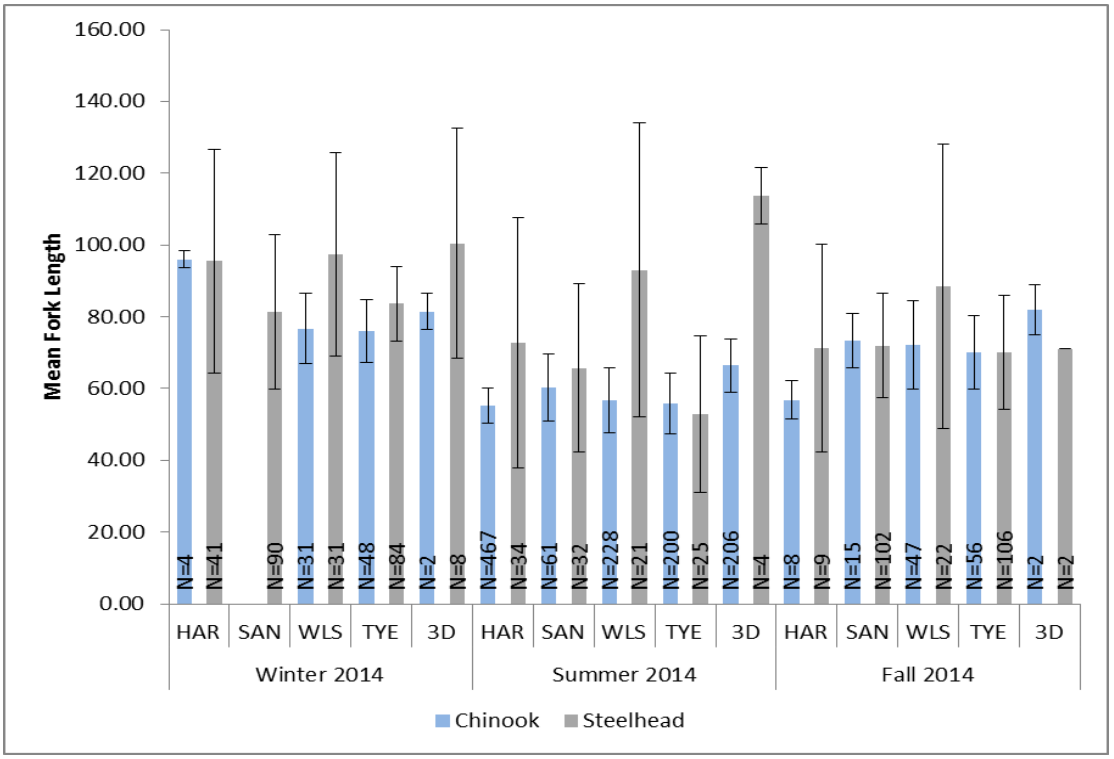


Figure 13. Mean fork lengths for Chinook salmon and steelhead in off-channel sites in the Entiat River, 2014.

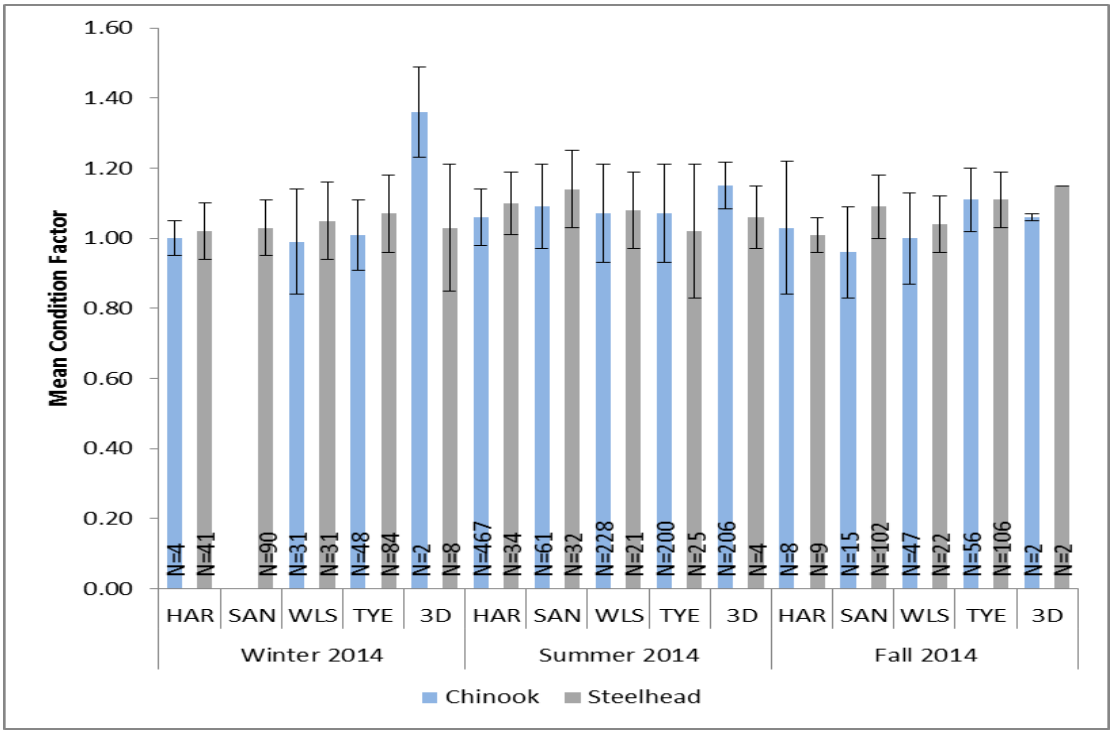


Figure 14. Mean condition factors for Chinook salmon and steelhead in off-channel sites in the Entiat River, 2014.

Mortality rates were tracked for all species throughout the study. Capture related mortality in 2014 accounted for a total of 58 fish (Table 18). This included 37 wild Chinook salmon, 19 wild summer steelhead, 1wild Coho, and 1 non-target species. Tagging-related mortality was limited to 1 wild Chinook.

Table 18. Capture and tagging related mortality for each sampling period of the off-channel study in the Entiat River, 2014.

| Species | Capture Mortality | | | Tagging Mortality | | |
|---|---|---|---|---|---|---|
| | Winter | Summer | Fall | Winter | Summer | Fall |
| Spring Chinook salmon | 2 | 0 | 0 | 0 | 0 | 0 |
| Chinook salmon (unk. run) | 0 | 24 | 11 | 0 | 1 | 0 |
| Coho salmon | 1 | 0 | 0 | 0 | 0 | 0 |
| Steelhead | 1 | 5 | 8 | 0 | 0 | 0 |
| Lamprey sp. | 0 | 0 | 0 | 0 | 0 | 0 |
| Non-target species | 0 | 1 | 0 | 0 | 0 | 0 |

## Discussion

*Fish sampling*

Two new sites were added to the sampling efforts in 2013. The 3D channel was successfully sampled during all three periods while the Tyee side-channel was added mid-season and sampled during the summer and fall periods. Two sites sampled in years past were not sampled in 2013. This was due to several factors. Sampling efforts within the Don Jean side-channel (rkm 30.6) yielded too few fish to support study objectives. Low fish densities within the site may in part be due to the available habitat and relatively persistent high water velocities typical of the site. We will periodically revisit the Don Jean side-channel to assess changes in fish abundance as additional habitat actions are implemented. We were unable to sample the PUD side-channel in 2013 due to a combination of ongoing maintenance activities conducted by Chelan County PUD and concerns raised by an irrigator utilizing the canal. Although data collected from the PUD side-channel is limited, we believe the channel may play a significant role in juvenile rearing and hope that current issues may be adequately addressed allowing for sampling to resume.

Off-channel fish capture methods primarily relied upon electrofishing. In our experience, electrofishing has resulted in higher numbers of capture related mortalities when compared to other methods. Low water depth and high turbidity inhibits the use of hand-netting and snorkel-seining as a capture method at most of the off-channel sites. These methods are preferable due to the lower occurrence of capture related mortality and will be utilized in the future as site conditions allow. Tagging mortalities, particularly during the summer sampling period, were higher than last year. This may be attributed in part to the warmer water temperatures experienced during the summer months. Delayed mortality and tag shed rates were not assessed during off-channel sampling as these rates have been well documented in past mark-recapture efforts.

*Summer vs. spring Chinook salmon*

The problem of accurately assigning a run designation to Chinook salmon encountered in the late summer months was managed using the same criteria as was applied in the Entiat River mark-recapture study. Juvenile Chinook salmon encountered in the summer and fall sampling periods were classified as 'wild Chinook (unknown run)'. This classification will continue during subsequent summer and fall periods as run classification of Chinook encountered during spring period is known.

# PIT Tag Interrogation Site Monitoring

## Methods

*Interrogation site locations*

MCRFRO operated six PIT tag interrogation sites within the Entiat watershed in 2013 (Figure 15). The lower Entiat River interrogation site (ENL) has been operational since 2007 and is located below the rotary screw trap at rkm 2. The interrogation site near the town of Ardenvoir (ENA) was installed in May of 2011 and is located at rkm 17.1. The middle Entiat River interrogation site (ENM) has been operational since 2008 and is located below the McKenzie diversion dam at rkm 26. The interrogation site near Stormy Creek (ENS) was installed in April of 2011 and is located at rkm 35.7. The Entiat River Forest Service boundary (ENF) site became operational in 2010 and is located at rkm 40.6. The Mad River (MAD) site has been operational since 2008 and is located on the Mad River at rkm 1.

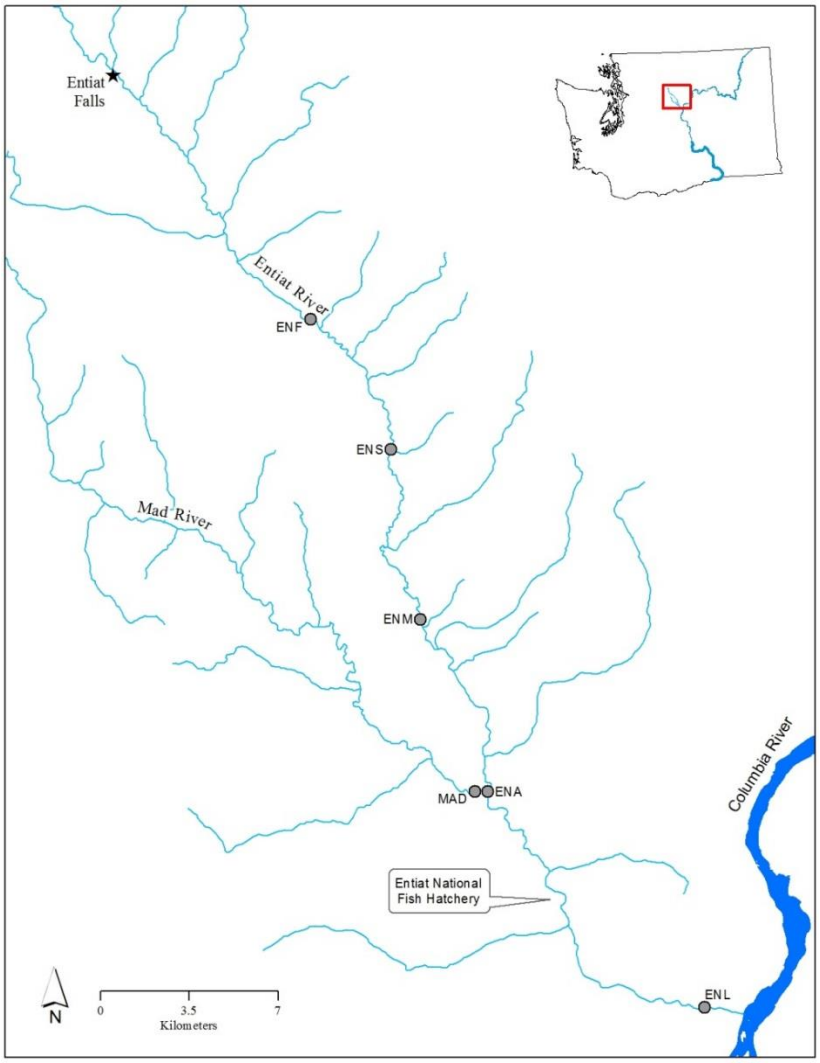


Figure 15. Map of the locations of PIT tag interrogation sites in the Entiat River, 2014.

*Interrogation site operation*
Interrogation sites were installed and operated following the protocols outlined in Nelle (2008). Six antennas spanned the width of the river at each site. Antenna size was dependent upon the width of the river and thus varied between individual sites. Antennas were configured within the river in rows to determine the direction of fish movement and increase site efficiency through redundancy. All main-stem Entiat River interrogation site antennas were configured as two rows of three while at the Mad River interrogation site three rows of two antennas were used.

Interrogation sites were operated continuously throughout the year with exception to brief periods of equipment failure. All sites were downloaded weekly or as necessary based on river conditions or expected periods of high fish movement. Site operational status and data files were uploaded to the PTAGIS website on a weekly basis.

*Interrogation site maintenance*
Routine maintenance was conducted by MCRFRO and included cable reconnection, replacement of anchor straps, debris removal, and antenna tuning.

# Steelhead Redd Surveys

## Methods

Surveys to count steelhead redds were conducted using methods described in Nelle and Moberg (2008). The main-stem Entiat River was surveyed from Fox Creek Campground (river kilometer (rkm) 45) to the Entiat information kiosk (rkm 1.1). The survey area was divided into four reaches based on river access points and distances that could be surveyed in a work day (Figure 16, Table 19). A two person crew each using a 10'cataraft conducted redd surveys while moving downstream. Surveyors walked areas that were inaccessible or unsafe to raft. Steelhead redd surveys began on February 20, 2014 and continued through May 14, 2014. All four reaches were surveyed on a weekly basis as long as the weather and stream conditions permitted.

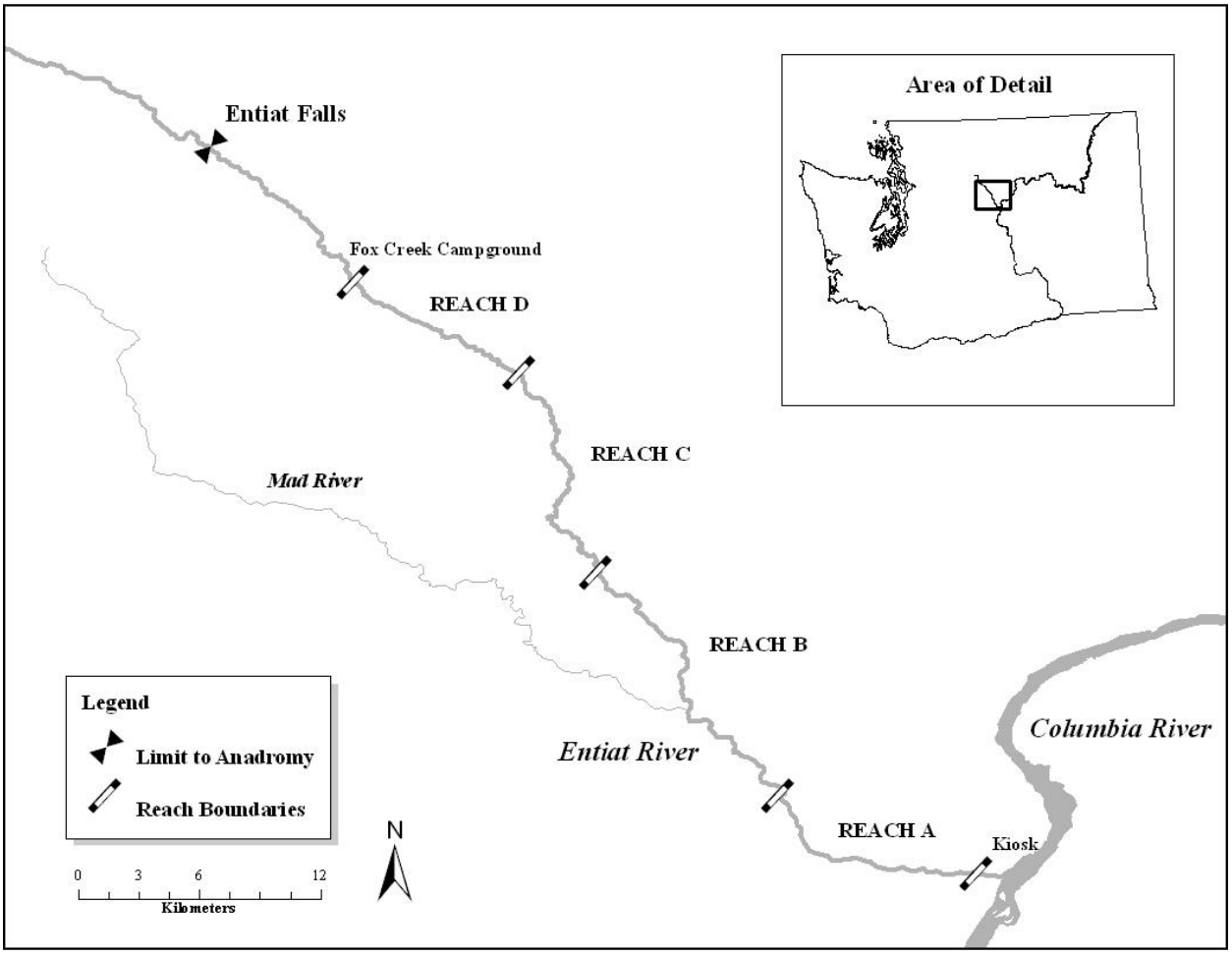


Figure 16**.** The four reaches of steelhead redd surveys on the Entiat River, 2014.

Table 19**.** Steelhead spawning ground reaches on the Entiat River in 2014.

| Reach | Start (Landmark) | End | Length (km) |
|---|---|---|---|
| D | rkm 45.0 (Fox Cr. Campground) | rkm 37.7 | 7.3 |
| C | rkm 37.7 (Brief Bridge) | rkm 25.9 | 11.8 |
| B | rkm 25.9 (McKenzie Diversion) | rkm 10.6 | 15.3 |
| A | rkm 10.6 (Entiat NFH) | rkm 1.1 | 9.5 |

Three separate methods were used to describe water clarity. First, we continued to use a Secchi disk method of calculating lateral water visibility that we first used in 2011. This technique uses a weighted Secchi disk attached to a cord 1.5m in length and a fifty meter measuring tape. The downstream surveyor rests the Secchi disk on the river bed at a depth of 0.5m with the face oriented parallel to the water surface. A second observer wades upstream unreeling the measuring tape until the disk's color patterns are no longer discernible. The distance is then recorded (Figure 17). The second method categorizes water clarity by visual estimation. Water clarity is recorded as 1 (very clear), 2 (somewhat turbid), or 3 (too turbid to see through) by the observers. A category 3 determination precludes the survey for the day. Finally, water samples were taken to measure stream turbidity by light scatter due to suspended particles. In the office samples were transferred into clear glass vials, placed in a Hach 2100P Portable Turbid meter, and measurements in nephelometric turbidity units (NTUs) were recorded. All three water visibility measurements were recorded at the start and end of each survey.

Weather conditions were recorded at the beginning of each survey. Changes in weather conditions taking place throughout the duration of the survey were recorded. Water temperatures were recorded at the beginning and end of each survey reach. Temperatures (°C) were taken with calibrated thermometers accurate to +/- 0.04 - 0.07°.

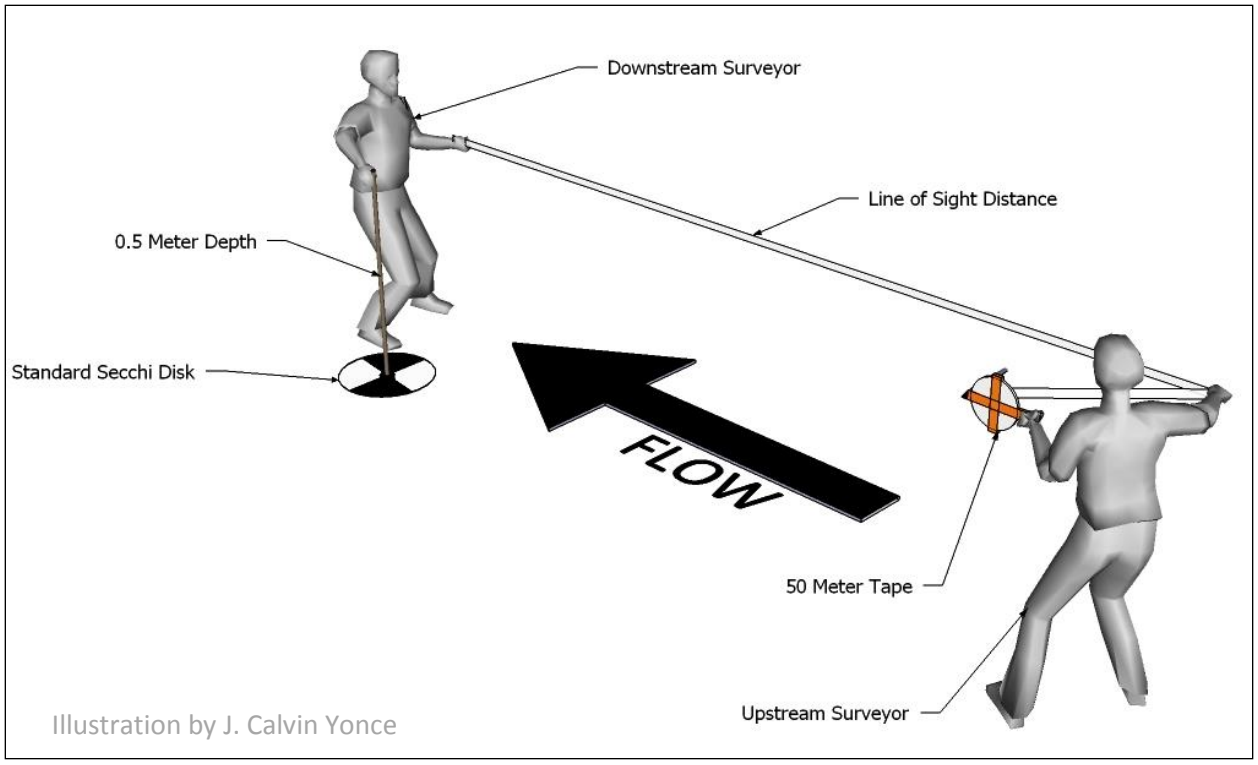


Figure 17**.** Lateral Secchi Disk visibility measurement.

## Results

During the survey season water temperatures ranged from 2.0°C to 9.0° C. Turbidity averaged 1.3 NTU, lateral Secchi disk visibility readings averaged 19.5 meters, water clarity averaged 1. Average turbidity was greatest in Reach A, and turbidity was generally lower farther upstream. There was minimal difference in lateral Secchi disk readings based on location alone (Table 20).

Table 20**.** Ranges and means of temperature, Secchi disk lateral visibility, turbidity, and water clarity of the Entiat River during steelhead redd surveys, 2014.

| | Ranges (mean) | | | |
|---|---|---|---|---|
| **Reach** | **Temp °C** | **Secchi Disk (m)** | **Turbidity (NTU)** | **Water Clarity** |
| A | 2.0 – 9.0 (6.0) | 6.8 – 29.6 (16.5) | 0.2 – 2.8 (1.5) | 1 – 2 (1) |
| B | 2.0 – 8.5 (5.5) | 9.2 – 25.0 (17.7) | 0.4 – 2.8 (1.3) | 1 – 2 (1) |
| C | 2.5 – 8.0 (4.9) | 10.5 – 34.1 (21.2) | 0.6 – 2.6 (1.4) | 1 - 2 (1) |
| D | 3.5 – 7.0 (4.8) | 15.0 – 35.6 (22.6) | 0.7 – 2.1 (1.0) | 1 - 2 (1) |
| All Reaches | 2.0 – 9.0 (5.3) | 6.8 – 35.6 (19.5) | 0.2 – 2.8 (1.3) | 1 – 2 (1) |

A total of 126 redds were counted during 2014 (Table 21). The first redd was observed on March 25 in Reach B when mean water temperature was 5.0 °C. Eighty-four percent (106/126) of

observed steelhead redds were constructed in April, with a peak of thirty-two new redds the week beginning Monday, April 28. The mean temperature during this peak spawning week was 6.2°C. Reach B had the greatest number of redds in any reach with 56 (44% of all observed redds) (Table 22). Redds were generally distributed throughout the river in areas with suitable habitat. High concentrations of redds were seen in areas with large areas of suitable gravel (Figures 18-21). Similar to previous years, the majority of new redds (97% in 2014) were observed during April and May (Figure 22).

Table 21**.** The numbers of new steelhead redds counted each week and cumulative totals in the survey reaches on the Entiat River, 2014.

| Number of steelhead redds | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Survey** | **Monday** | **A** | | **B** | | **C** | | **D** | | **All Reaches** | |
| **Week** | **Date** | **New** | **Total** | **New** | **Total** | **New** | **Total** | **New** | **Total** | **New** | **Total** |
| 1 | 02/17/14 | 0 | 0 | | | | | | | 0 | **0** |
| 2 | 03/10/14 | 0 | 0 | | | | | | | 0 | **0** |
| 3 | 03/17/14 | | | 0 | 0 | 0 | 0 | | | 0 | **0** |
| 4 | 03/24/14 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 3 | **3** |
| 5 | 03/31/14 | 1 | 1 | 5 | 7 | 5 | 6 | 0 | 0 | 11 | **14** |
| 6 | 04/07/14 | 7 | 8 | 4 | 11 | 3 | 9 | | 0 | 14 | **28** |
| 7 | 04/14/14 | 7 | 15 | 19 | 30 | 4 | 13 | 1 | 1 | 31 | **59** |
| 8 | 04/21/14 | 7 | 22 | 14 | 44 | 4 | 17 | 2 | 3 | 27 | **86** |
| 9 | 04/28/14 | 4 | 26 | 8 | 52 | 12 | 29 | 8 | 11 | 32 | **118** |
| 10 | 05/05/14 | 0 | 26 | 2 | 54 | 1 | 30 | | 11 | 3 | **121** |
| 11 | 05/12/14 | 1 | 27 | 2 | 56 | 0 | 30 | 2 | 13 | 5 | **126** |

Note: Blank cells indicate a survey was not conducted in that reach during the survey week.

Table 22**.** The total number of steelhead redds by reach on the Entiat River from 2006 to 2014.

| | Reach | | | | |
|---|---|---|---|---|---|
| **Year** | **A** | **B** | **C** | **D** | **Total** |
| 2006 | 38 | 26 | 34 | 13 | 111 |
| 2007 | 40 | 7 | 14 | 3 | 64 |
| 2008 | 93 | 84 | 31 | 14 | 222 |
| 2009 | 128 | 37 | 27 | 8 | 200 |
| 2010 | 87 | 33 | 52 | 17 | 189 |
| 2011 | 55 | 73 | 51 | 26 | 205 |
| 2012 | 29 | 20 | 28 | 0 | 77 |
| 2013 | 34 | 59 | 37 | 11 | 141 |
| 2014 | 27 | 56 | 30 | 13 | 126 |

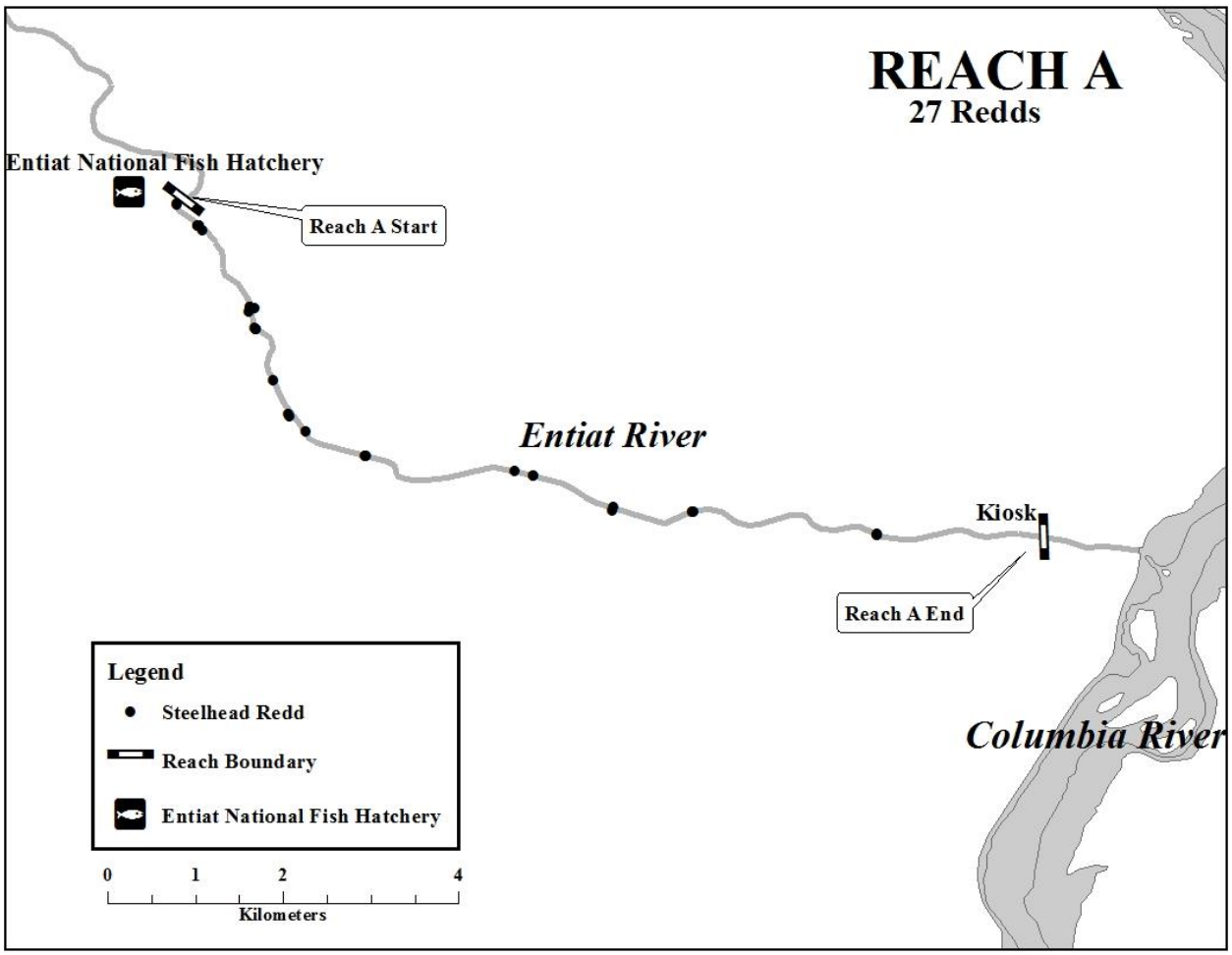


Figure 18**.** Location of steelhead redds in reach A during 2014.

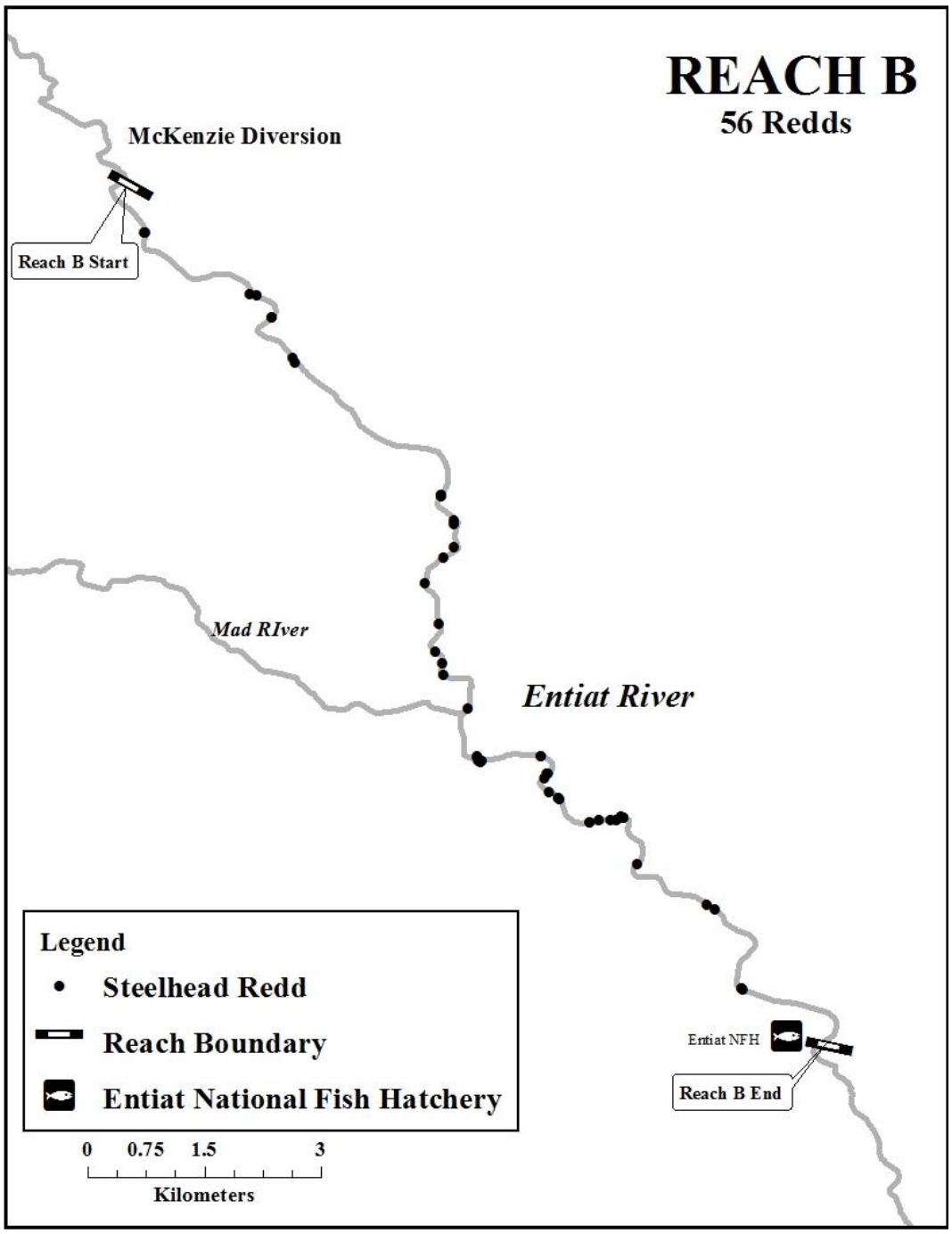


Figure 19**.** Location of steelhead redds in reach B during 2014.

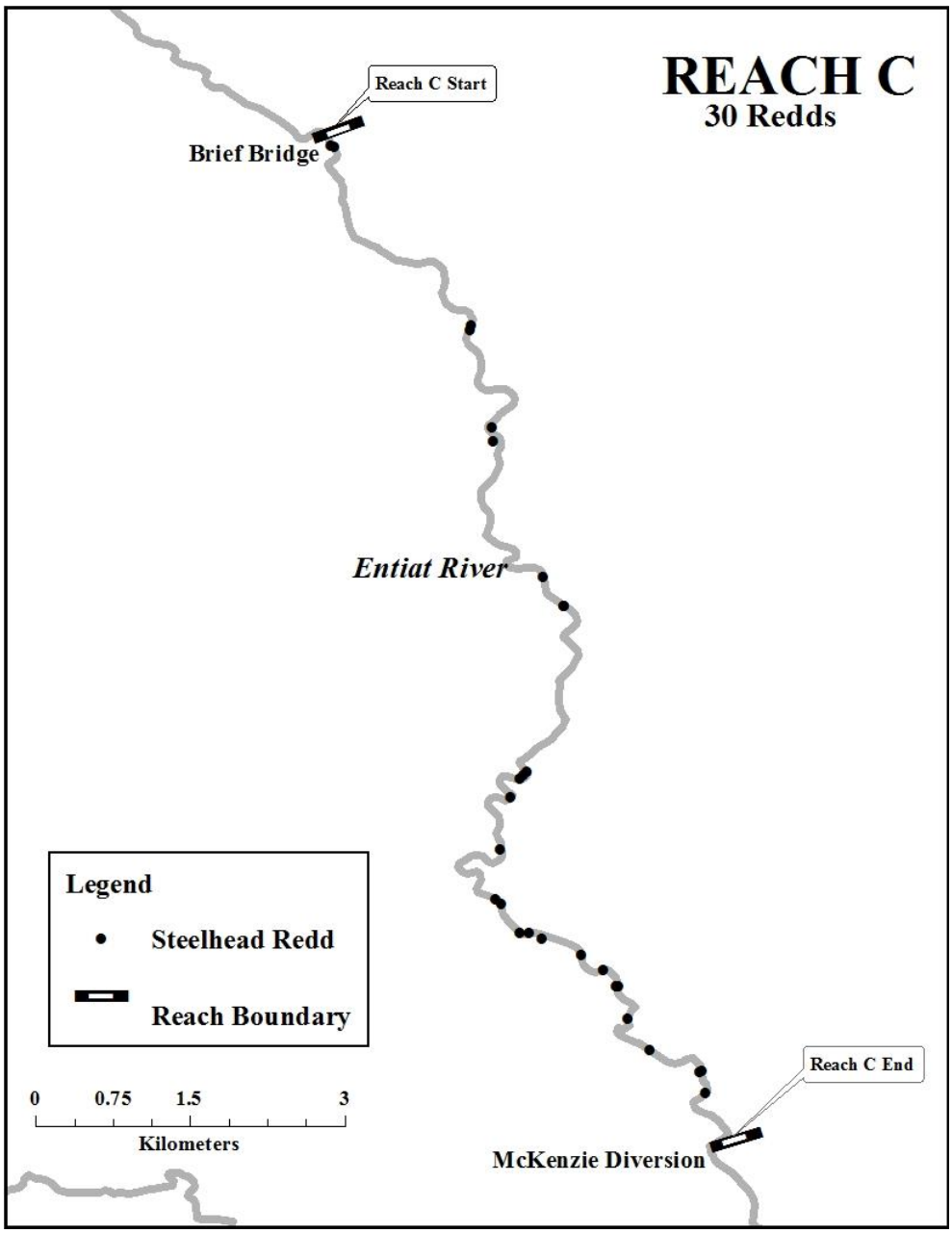


Figure 20**.** Location of steelhead redds in reach C during 2014.

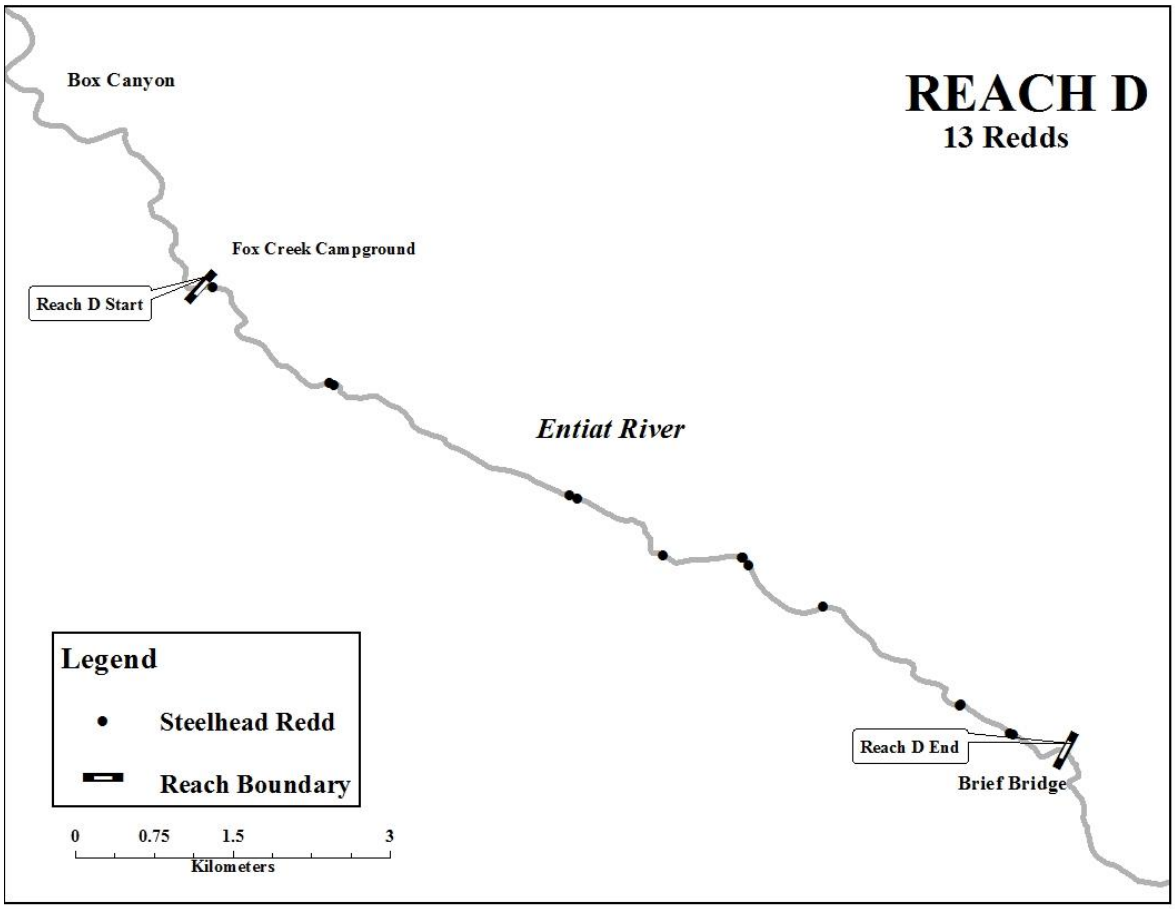


Figure 21. Location of steelhead redds in reach D during 2014.

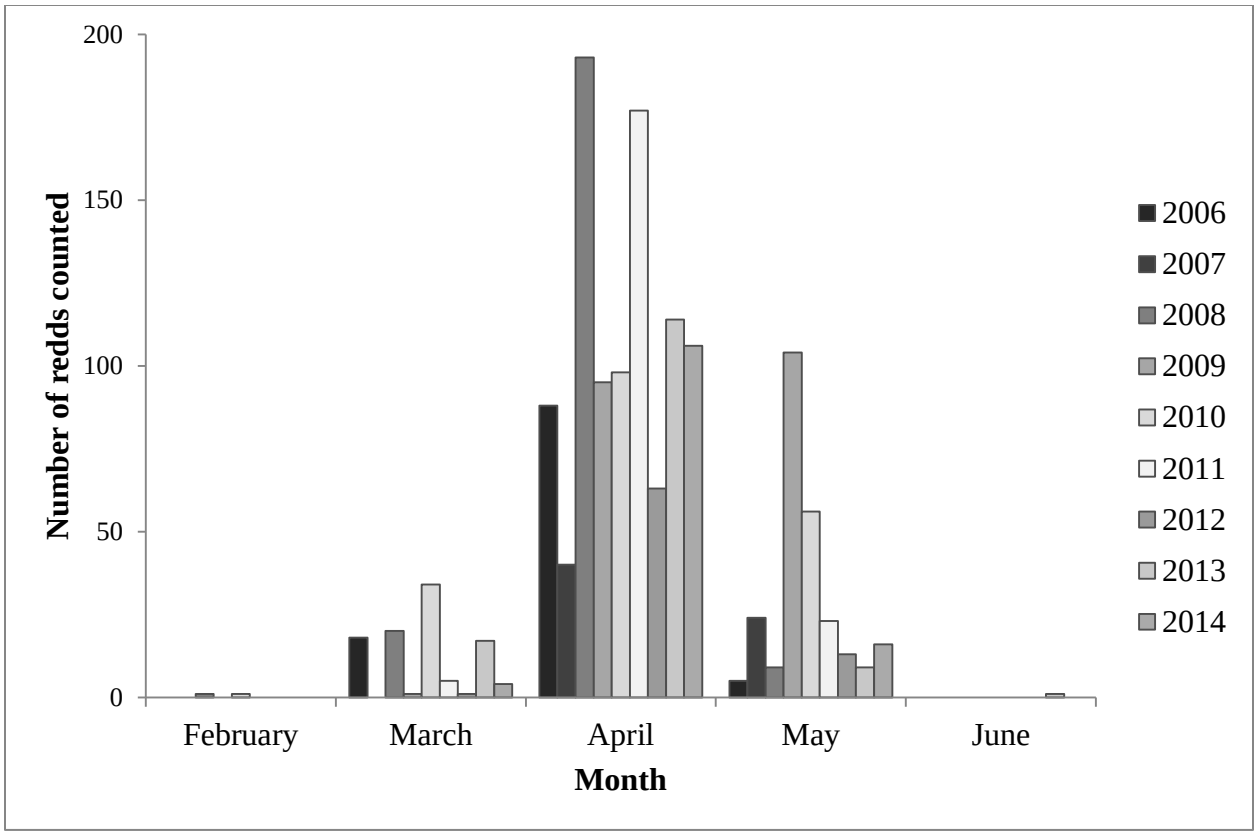


Figure 22**.** The numbers of steelhead redds observed by month in the Entiat River from 2006 to 2014.

## Discussion

Steelhead spawning ground surveys on the Entiat River were conducted within the required time frame. Surveys were initiated in mid-February to avoid missing the beginning of spawning activity. At least one survey during which no redds were seen was conducted in each reach. We were able to determine the onset of the spawning season with the first redd being seen in reach B on March 25$^{th}$ this year. The greatest number of new redds were seen in the week beginning Monday, April 28$^{th}$. River flows increased during the following week (beginning May 5$^{th}$). Conditions included greater turbidity and water depth making it more difficult for observers to see redds. Increased flow also causes evidence of redds to be erased more quickly. These factors likely decreased the total numbers of redds observed at that time as some redds may not have been seen. The peak of spawning activity was therefore not well defined. Discharge continued to increase to a point which would not allow for effective surveys, and the final survey was conducted on May 13$^{th}$. Spawning likely continued after the final survey, so timing of the cessation of spawning activity could not be determined.

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# Appendix

**Appendix 1.** Summary of fish species captured in the Entiat River rotary screw trap, 2014.

| Species and Life Stage | Total Capture | Capture Mortality |
|---|---|---|
| Wild spring Chinook salmon juvenile | 6,365 | 61 |
| Hatchery summer Chinook salmon juvenile | 151 | 0 |
| Wild summer Chinook salmon adult | 1 | 0 |
| Wild summer Chinook salmon juvenile | 12,830 | 336 |
| Hatchery Chinook salmon (unknown r/t) jack | 1 | 0 |
| Hatchery Chinook salmon (unknown r/t) juvenile | 2 | 0 |
| Wild Chinook salmon (unknown r/t) adult | 1 | 0 |
| Wild Chinook salmon (unknown r/t) jack | 1 | 0 |
| Wild Chinook salmon (unknown r/t) precocial | 40 | 0 |
| Wild Chinook salmon (unknown r/t) juvenile | 1 | 0 |
| Wild coho salmon juvenile | 21 | 2 |
| Wild summer steelhead adult | 3 | 0 |
| Wild steelhead juvenile | 3,218 | 20 |
| Bull trout adult | 2 | 0 |
| Bull trout juvenile | 58 | 0 |
| Wild cutthroat trout juvenile | 40 | 0 |
| Wild sockeye salmon (unknown run) adult | 1 | 0 |
| Wild sockeye salmon (unknown run) juvenile | 347 | 12 |
| Pacific lamprey ammocoete | 3,078 | 1 |
| Pacific lamprey macropthalmia | 23 | 0 |
| Northern pikeminnow adult | 2 | 0 |
| Northern pikeminnow juvenile | 115 | 1 |
| Mountain whitefish adult | 5 | 0 |
| Mountain whitefish juvenile | 1,071 | 29 |
| Unknown sucker adult | 14 | 0 |
| Unknown sucker juvenile | 195 | 1 |
| Unknown dace | 132 | 2 |
| Chiselmouth | 11 | 0 |
| Unknown sculpin | 91 | 10 |
| Red side shiner | 493 | 0 |
| Three-spine stickleback | 355 | 4 |