Juvenile Salmonid Monitoring in the Middle Fork John Day River Basin

2021 Annual Report

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SECTION 1: MIDDLE FORK JOHN DAY RIVER

MFJDR Project description

In 2002 the Confederated Tribes of Warm Springs (CTWS) acquired the Forrest Conservation Area, which included an 842-acre parcel of land on the MFJDR encompassing 6.4 river km. The parcel of land on the MFJDR is known as the Middle Fork Forrest Conservation Area (MFFCA). Since their acquisition, CTWS has implemented several habitat improvement projects on the MFFCA targeted at improving salmonid spawning and rearing habitat in the MFJD. Most recently CTWS secured funding to implement phase two of a habitat restoration project that began in 2017, located on the MFJDR between Caribou Creek and Vincent Creek, as well as begin a new habitat restoration project located on the MFJDR between Vincent Creek and Vinegar Creek. Treatment between Caribou Creek and Vincent Creek will include the addition of approximately 30 large woody debris structures, 5 mid channel bar creations, 200 m of high-flow side channel excavation and 5 railroad grade breaches. Treatment between Vincent Creek and Vinegar Creek will include the removal of approximately 1 km of railroad grade, which currently prevents the MJFD from connecting to its floodplain. Additionally, the channel will be rerouted onto the historic floodplain with the intent to create a network of multiple channels at low flow to maximize floodplain connectivity during spring run-off. The proposed implementation objectives include reducing stream temperatures through increased stream surface shading, reconnecting floodplain habitat and increasing instream habitat connectivity with the primary biological objective of increasing salmonid rearing capacity.

MFJDR project effectiveness monitoring

Project effectiveness monitoring for the MFJDR habitat improvement projects is a collaborative effort between the CTWS and ODFW. We are using a modified Before-After-Control-Impact (BACI) sampling design to monitor the effectiveness of the habitat improvement projects. Specifically, we will use the BACI sampling design to detect and document changes in 1) habitat complexity and diversity 2) juvenile *O. mykiss* and *O. tshawytscha* density, survival, and movement and 3) juvenile *O. mykiss* and *O. tshawytscha* habitat associations.

Control/treatment site selection

The habitat improvement reach located between Caribou and Vincent Creek is the first treatment reach (C2V), the habitat improvement reach located between Vincent and Davis Creek (V2V) is the second treatment reach, three sections of the MFJDR (Ruby to Granite Boulder-R2G, Davis to Bridge – V2B and upstream of Bridge – B2E) are the “control” reaches (Fig. 1.1). The control reaches fall along a gradient of true control to reference reaches (i.e., least improved to most improved). Upstream of Bridge Creek is the least improved and Granite Boulder to Ruby is the most improved reach.

Habitat monitoring

In 2019 we selected 10 sampling locations; hereafter referred to as habitat monitoring sites (Fig. 1.1). Three habitat monitoring sites were located in treatment 1 (C2V), three habitat monitoring sites were in treatment 2 (V2V) and four habitat monitoring sites were in the control reaches. In 2021 we added one additional habitat monitoring site in V2B. The three sites in V2V, and the three sites in C2V are historic CHaMP sites with fish and habitat monitoring beginning as early as 2011. Incorporating historic CHaMP sites into our monitoring plan will allow us to draw on historic habitat and fish data for our pre-treatment data analysis. For all 2019 and 2021 habitat surveys we followed methods outlined in the 2019 MFJDR Habitat Monitoring Protocol (Appendix 1.A).

In 2020 and 2021 we followed the channel unit classification and measurement methods outlined in the 2019 MFJDR Habitat Monitoring Protocol (Appendix 1.A) to conduct a habitat census, classifying every channel unit located in each control and treatment reach. In 2020, once the census was completed, we conducted a channel unit survey at 1/3 of each unit type (i.e. riffle, scour pool, and fast non-turbulent) located in each control and treatment reach.

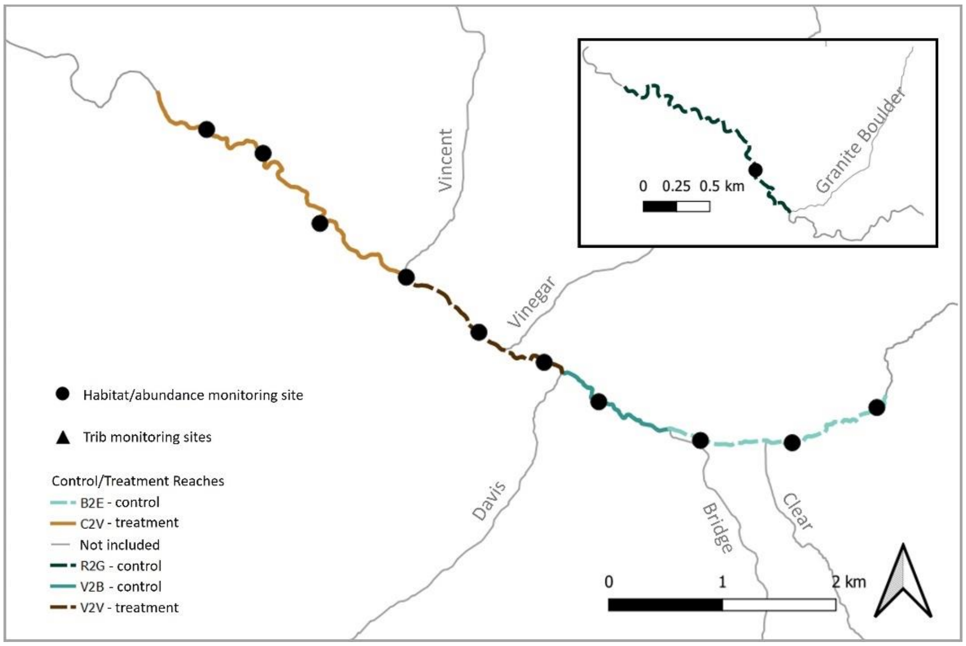

Figure 1.1. Location of control and treatment reaches, and 2021 mainstem habitat/abundance monitoring sites in the Middle Fork John Day River.

Juvenile salmonid abundance monitoring

In 2019 we selected five salmonid abundance monitoring sites, one in each control and treatment reach. Each 2019 abundance monitoring site was located near the center of the control/treatment reach and was 250 or 500 meters long (see Bare et al. 2020 for site selection descriptions). In 2020 we increased the number of abundance monitoring sites from five to ten and shifted the location of the abundance monitoring sites to match our 2019 habitat monitoring locations. In 2021 we increased the number of abundance monitoring sites from ten to eleven to incorporate the additional 2021 habitat monitoring location (Fig. 1.1; Table S1.1). The increase and relocation of abundance monitoring sites had two benefits 1) we were able to increase the number and spatial coverage of passive integrated transponder (PIT) tagged salmonids and 2) we were able to combine habitat information collected during habit surveys with the 2020 and 2021 fish abundance surveys to quantify fish/reach scale habitat associations.

To monitor juvenile salmonid density, we conducted either, single pass, or mark/recapture snorkel-herding at the abundance monitoring sites from 2019-2021. Sample timing varied by year due to crew availability, sampling conditions (i.e., flow and water temperature), outmigration timing, and landowner access. In 2019 we sampled the five abundance monitoring sites in July, August, and October. In 2020 we sampled five of the ten sites in June July and August, four sites in July and August, one site in June and August and one site in July. In 2021 we sampled the 11 abundance monitoring sites in June and August. In 2019 and 2020 we PIT tagged *O. mykiss* ≥ 70 mm and *O. tshawytscha* ≥ 65 mm and in

2021 we PIT tagged *O. mykiss* ≥ 65mm and *O. tshawytscha* ≥ 55 mm. Additionally, we recorded the fork length and weight of all salmonids.

Density – We corrected our raw catches of juvenile *O. tshawytscha* and *O. mykiss* from tagging reaches using the mean capture efficiency observed during mark/recapture sampling (Eq. 1, 2). We then estimated fish density (Eq. 3) for each tagging site.

Estimation of abundance based on mean capture efficiency:

$$CE = \frac{1}{n} \times \sum_i^n \frac{R_i}{M_i}, \quad (1)$$

$$N = \frac{C_1}{CE} \quad (2)$$

where,

i = mark-recapture event

C_1 = total number of fish caught during first pass

CE = mean capture efficiency

N = population estimate

R = number of recaptures in the second pass.

M = number of fish caught, marked and released in first pass

Site-level fish density:

$$D_i = \frac{N_i}{d_i} \quad (3)$$

where

D_i = fish density (fish/linear m) at site i

N_i = estimated abundance based on mean capture (or snorkeler) efficiency at site i

d_i = linear stream length (m) sampled at site i

Juvenile salmonid movement monitoring

In addition to PIT tagging salmonids at abundance monitoring locations we PIT tagged salmonids at an additional three tributary sites (VCU, VCL, and DC1) in 2018, six tributary sites (VCU, VCL, DC1, Summit01, Summit03, Summit05) in 2019, three tributary (VCU, VCL, and DC1) and five mainstem sites (V2B_A, V2B_B, V2B_C, V2V_A, V2V_B) in 2020, and three tributary sites in 2021 (VCU, VCL, DC1) (Table 1.1). From 2020-2021 we monitored PIT tagged salmonid locations along a longitudinal spatial continuum throughout the control and treatment reaches using both passive (i.e., stationary PIT tag antennas) and active (i.e., mobile PIT tag antenna surveys) tracking techniques.

We operated six mainstem (MFJDR at Beaver, MFJDR at Granite Boulder, MFJDR at Caribou, MFJDR at Vincent, MFJDR at Davis, MFJDR at Bridge) and three (Bridge, Vinegar, Davis, and Granite Boulder) tributary stationary antennas (Fig 1.2). Due to technical difficulties and solar exposure, successful antenna operation varied by year and antenna, see Fig. S1.1 for a record of when each antenna was operational. From 2020-2021 we also conducted mobile PIT tag antenna surveys throughout the full extent of treatment and control reaches. In 2020 we conducted surveys in July, September and October and in 2021 we conducted surveys in July, August and September.

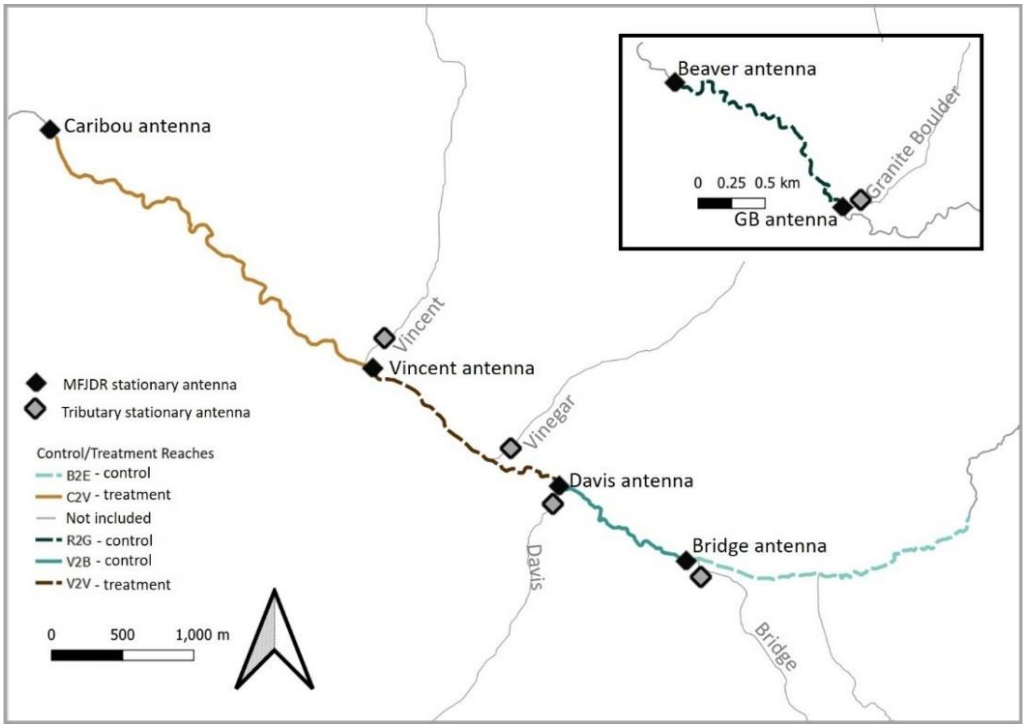

Figure 1.2. Location of stationary PIT tag antenna arrays in the Upper Middle Fork John Day River basin operated during the 2020 field season.

O. tshawytscha survival analysis

We fit a state-space Cormack Jolly-Seber model using Bayesian methods implemented with Markov chain Monte Carlo (MCMC) methods using program Winbugs (Lunn et al. 2000) invoked through program R (R Core Team 2020) to estimate over-summer parr, and parr-to-smolt survival (i.e., survival to the Galena array). The model incorporated capture data from juveniles PIT-tagged during juvenile monitoring surveys, detections recorded during mobile PIT tag antenna surveys, stationary antenna detections recorded at the Beaver, and Galena, John Day River and Columbia River dam locations as well as detection recorded during estuary trawl surveys.

We focused our survival analysis on *O. tshawytscha* ≥ 65 mm tagged during July 2020. Using *O. tshawytscha* ≥ 65 mm tagged during July 2020 allowed us to incorporate detections from two mobile surveys and ensured outmigration for the cohort had been completed. We separated survival into four intervals. Intervals one and two corresponded with over-summer survival and included detections from the two mobile surveys that occurred on July 29, 2020, and October 3, 2020. Interval three corresponded to survival to the MFJDR array at Beaver Creek and interval four corresponded to survival to the MFJDR array at Galena, here-in referred to as parr-to-smolt survival. Detection efficiency and thus survival estimates incorporated detection data from the above mentioned as well as detections at the John Day Dam, Bonneville Dam and during Estuary trawls.

We estimated survival of all *O. tshawytscha* ≥ 65 mm tagged during July 2020 sampling as well as separated survival estimates by tagging reach. We were unable to estimate survival of *O. tshawytscha* tagged in R2G due to the small sample size of PIT tagged *O. tshawytscha* in R2G.

MFJDR 2021 sampling results and discussion

Juvenile salmonid movement monitoring

In 2020 we PIT tagged 2,408 *O. tshawytscha* and 427 *O. mykiss* during June, July, and August MFJDR snorkel herding surveys, and in 2021 we PIT tagged 978 *O. tshawytscha* and 347 *O. mykiss* during June, and August MFJDR snorkel herding surveys. In 2020 and 2021 we used both active (i.e., mobile PIT tag antenna surveys) and passive (stationary PIT tag antennas) techniques to track the movement of *O. mykiss* and *O. tshawytscha.* During mobile PIT tag antenna surveys, we detected 845 and 579 unique *O. tshawytscha*, and 174 and 219 unique *O. mykiss* in 2020 and 2021, respectively. The stationary antennas detected 1062 and 442 unique *O. tshawytscha,* and 106 and 129 unique *O. mykiss* in 2020 and 2021, respectively. Tracing salmonid movement patterns using both active and passive techniques enabled up to describe the seasonal movement patterns of *O. tshawytscha,* the outmigration timing of *O. tshawytscha* and *O. mykiss* and the tributary use of *O. tshawytscha* and *O. mykiss* tagged in the mainstem of the MFJDR.

Seasonal movement patterns – To investigate seasonal movement patterns we combined stationary antenna detection data with mobile detection data to quantify the percent of *O. tshawytscha* tagged in 2020 that were detected outside of their tagging reach through time (Fig. 1.3). We detected early season dispersal from each tagging reach from mid-June to early-July. The early season dispersal event was followed by little to no, over-summer dispersal, which was then followed by a second wave of dispersal (i.e., outmigration), beginning in October. Our seasonal movement results provide evidence that over-summer rearing capacity is best described by densities observed in each reach after early season dispersal and before outmigration, or from early August to early September.

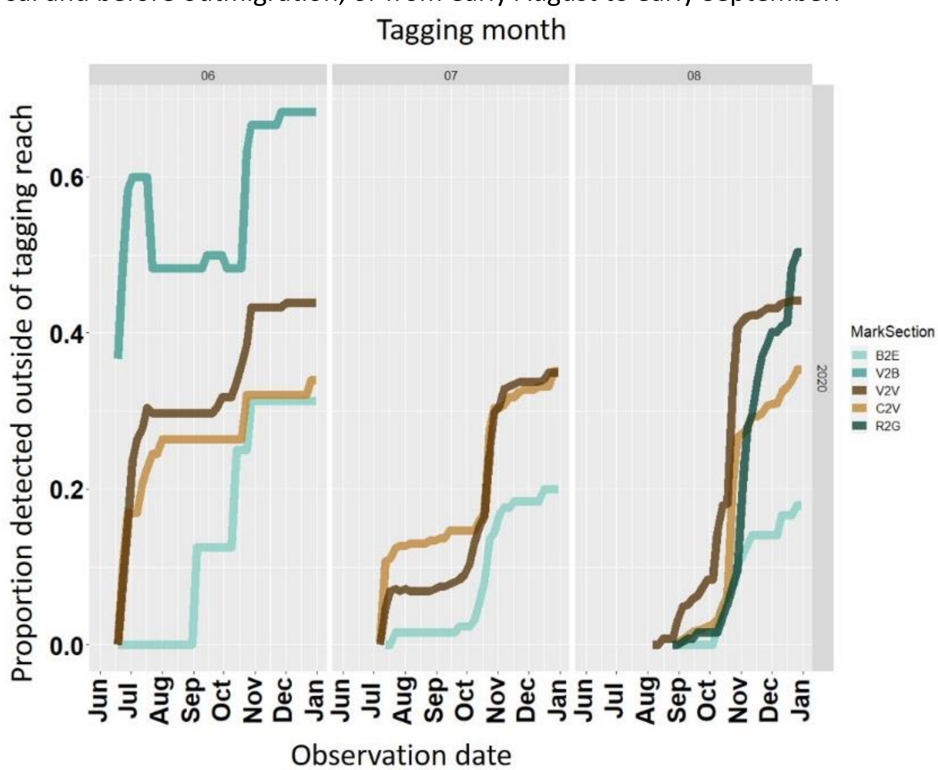

Figure. 1.3. Proportion of 2020 PIT tagged *O. tshawytscha* detected outside of their tagging reach, separated by tagging month, through time. Fish were detected outside of their tagging reach using both stationary and mobile antenna detections. Proportions are color coded by treatment.

Outmigration timing —

O. tshawytscha - The timing of PIT tag detections at the mainstem Beaver and Galena stationary antennas indicate outmigration of *O. tshawytscha* tagged in 2020 began in early September and largely ceased by the end of July with peak migration from October to April (Fig. 1.4-A). Detections at the Galena array closely tracked detections at the Beaver array indicating *O. tshawytscha* quickly migrate from the Beaver array to the Galena array. Notably, we did detect 10, *O. tshawytscha* tagged in 2020 out-migrating from Sept 7 – Sept 18, 2021.

O. mykiss - The timing of PIT tag detections at the mainstem Beaver and Galena stationary antenna arrays indicate outmigration of *O. mykiss* tagged in 2020 began in mid-September and largely ceased by the end of July (Fig. 1.4 – B). Unlike for *O. tshawytscha,* detection of *O. mykiss* at the Galena array did not track detections at the Beaver array. From September to April, we detected more *O. mykiss* on the Beaver array than the Galena array indicating some *O. mykiss* may over-winter downstream of Beaver and upstream Galena prior to out-migrating. Detections on the Galena array indicate peak *O. mykiss* outmigration occurred from late March to early June. Unfortunately, our Beaver array was not running from April 3 – May 26, 2020, and we therefore likely missed detecting peak out-migration at this array.

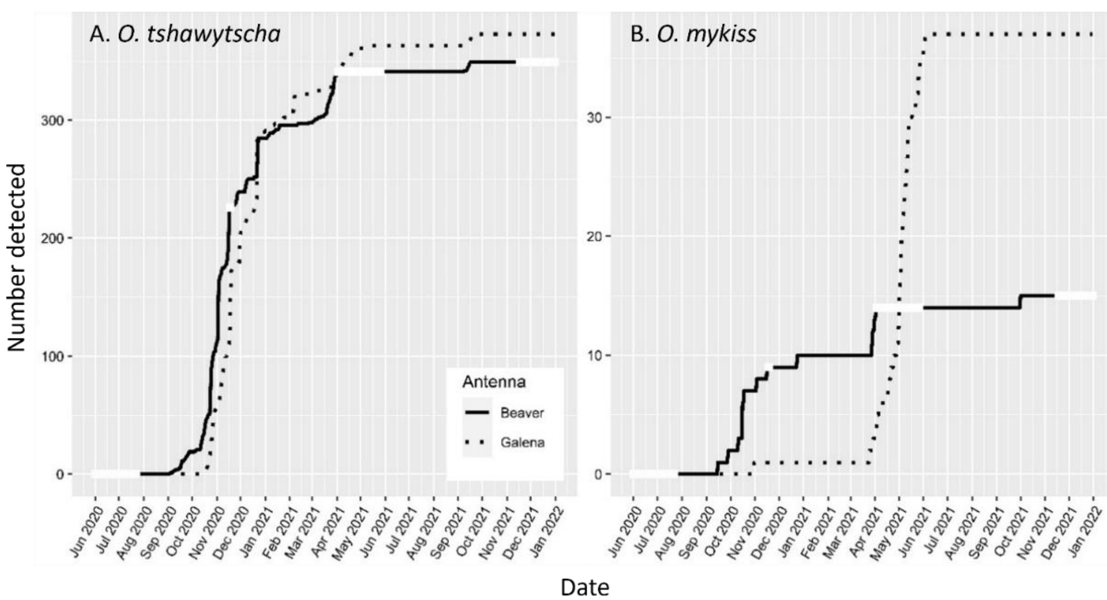

Figure. 1.4. Number of 2020 PIT tagged *O. tshawytscha* (A) and *O. mykiss* (B) detected at the mainstem Beaver (solid line) and Galena (dotted line) stationary antennas through time. The white sections on the count of mainstem Beaver antenna detections indicate periods of time when the antenna was off. Because the mainstem Beaver antenna was off from April to June we did not detect peak *O. mykiss* outmigration on this antenna.

Tributary use —In total we detected 10.2 and 12.7% of *O. tshawytscha* tagged in the MJFDR at tributary stationary antennas in 2020 and 2021, respectively. We detected 6.6 and 5.8% of *O. mykiss* tagged in the MFJDR at tributary stationary antennas in 2020 and 2021, respectively. Dispersal of PIT tagged *O. tshawytscha* into tributaries varied by year and across tagging sites (Fig. 1.5). A visual inspection of Fig. 1.5. indicated fish tagged downstream of confluences were more likely to enter tributary habitat than those tagged upstream of the tributary confluence.

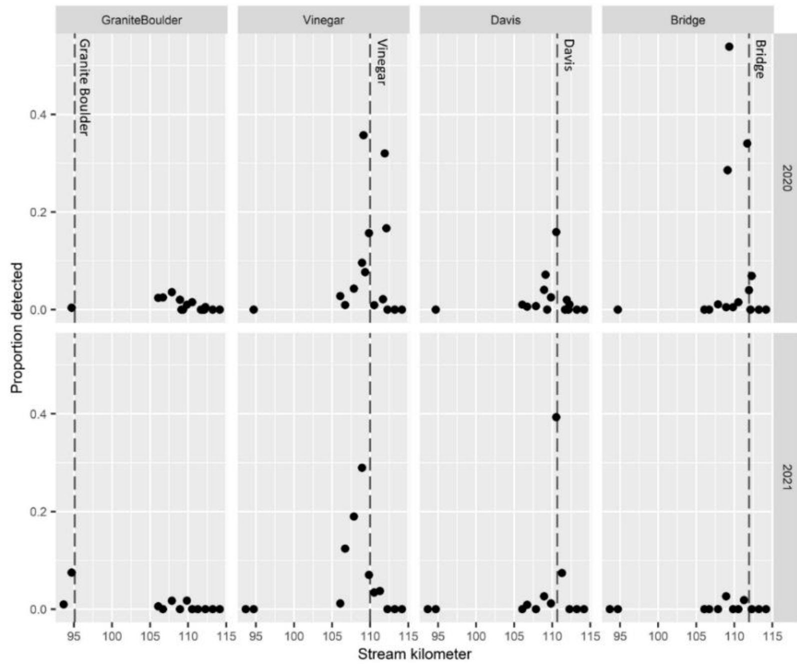

Figure. 1.5. Proportion of PIT tagged *O. tshawytscha* from each Middle Fork John Day River tagging location detected in Granite Boulder, Vinegar, Davis, and Bridge Creeks (plotted left to right) in 2020 (top row) and 2021 (bottom row). Tagging locations are plotted by river kilometer. The location of each tributary confluence is indicated by the dotted black line.

Using fish tagged in 2020 and 2021 we used a logistic regression to examine the relationship between the distance *O. tshawytscha* were tagged from the confluences of Vinegar and Davis creeks and the probability they entered Vinegar and Davis creeks. We found the probably of *O. tshawytscha* entering both Vinegar and Davis creeks was inversely related to the distance from the confluence that *O. tshawytscha* were tagged, as distance increased probability of entry decreased. Furthermore, we found the probability of entry was different between fish that were tagged upstream and those that were tagged downstream of each respective confluence (Fig. 1.6). *O. tshawytscha* tagged 2 kilometers downstream of the Vinegar Creek confluence had a 0.07 higher probability of entering Vinegar Creek than those tagged 2 kilometers upstream. *O. tshawytscha* tagged 2 kilometers downstream of the Davis Creek confluence also had greater probability (+0.03) of entering Davis Creek than those tagged 2 kilometers upstream.

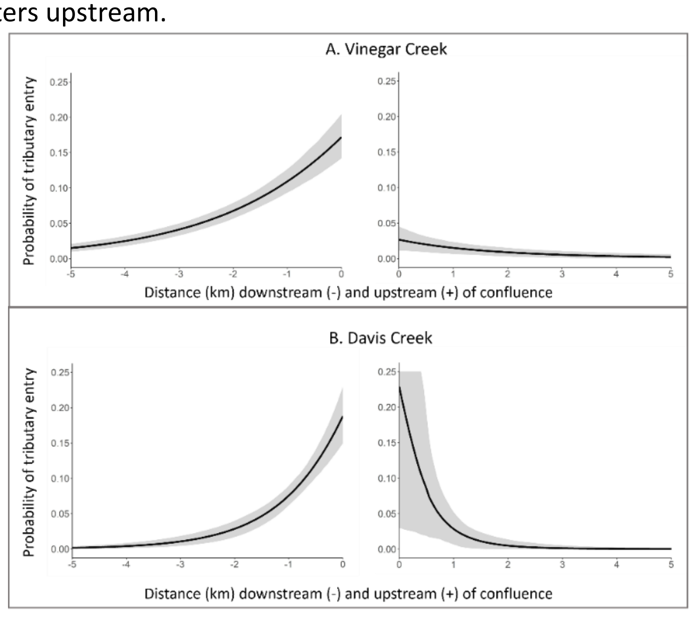

Figure. 1.6. The probably of a *O. tshawytscha* entering either Vinegar Creek (A), or Davis Creek (B) was inversely related to the distance from confluence that *O. tshawytscha* were tagged in the Middle Fork John Day River. Negative distances reflect distance downstream from the confluence and positive distances reflect upstream distances from the confluence. Black lines show predicted values, and shaded bands reflect nonparametric, bootstrapped 95% confidence intervals for predicted values from a logistic regression. *O. tshawytscha* were PIT tagged during 2020 and 2021 sampling.

We hypothesize movement into tributaries, or movement into cold water plumes at tributary confluences, is an important thermoregulation strategy for rearing salmonids and is essential to survival during heat waves like the one experienced in 2021. Our results indicate salmonids who are residing in proximity, particularly downstream, of tributary confluences, have a higher probability of using tributary habitat. As such, restoration actions aimed at improving spawning and rearing habitat should critically consider the location of cold water refugia in restoration prioritization, as proximity to these thermal refugia may become increasingly more important as stream temperatures rise. Additionally, when prioritizing and monitoring habitat improvement projects it may be important to consider and evaluate how the re-distribution of redd locations impacts rearing salmonids access to, and density in, cold water refugia like cold water plumes at tributary confluences and in tributaries.

Finally, it is important to note the included findings describe the movement and tributary use of *O. tshawytscha* parr once they have reached PIT-taggable size (i.e., > 55 mm). Our 2022 analysis, which leverages a genetic parentage analysis, will focus on the movement and tributary use of *O. tshawytscha* fry.

Juvenile salmonid abundance monitoring

In June and August, we conducted single pass snorkel herding at the 11 habitat/abundance monitoring sites. Of these tagging locations, three were located in C2V, four were in V2V, one was in V2B, three were in B2E and one was in R2G. We did not conduct mark/recapture sampling in 2021 due to the elevated stream temperature, we therefore we used the mean 2020 CE to estimate 2021 abundances. Mean (± 1 SD) 2020 mark/recapture capture efficiency was 0.30 ± .12, and 0.42 ± .18 for *O. mykiss* ≥ 50 mm, and juvenile *O. tshawytscha,* respectively. August *O. mykiss* densities were stable between 2020 and 2021 at all monitoring sites (Fig. 1.7-A; table S1.2). August *O. tshawytscha* densities were notably lower in 2021 than in 2020 at all monitoring sites, except three (Fig. 1.7-B; table S1.2). August *O. tshawytscha* densities were stable from 2020 to 2021 at one site in B2E and were higher in 2021 than 2020 at one site in C2V and one site in V2V.

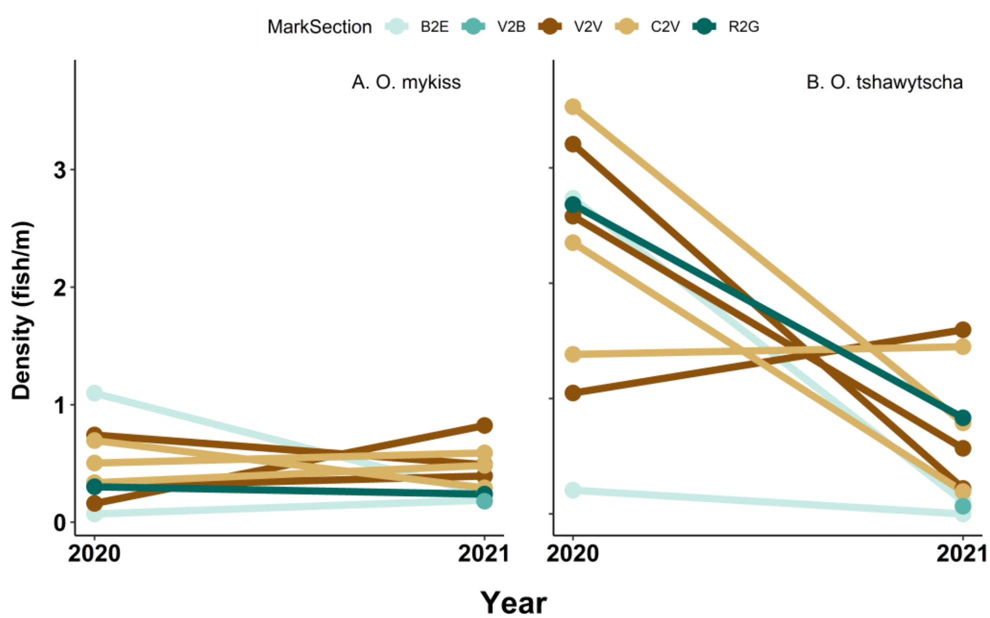

Figure. 1.7. August density (fish/m) of *O. mykiss* ≥ 50 mm (A) and *O. tshawytscha* (B) observed at each abundance monitoring site in the Middle Fork John Day River from 2020-2021. Densities are color coded by treatment.

O. tshawytscha survival analysis

We observed similar over-summer and parr-to-smolt *O. tshawytscha* survival estimates among tagging reaches in 2020 (Fig. 1.8). Over-summer survival is described as survival from tagging on July 8, 2020 to the mobile survey on October 3, 2020 . Parr-to-smolt survival is described as survival from tagging on July 8, 2020 to the Galena array. Over-summer parr survival (mean ± 1SD) was 0.37 ± 0.16, 0.30 ± 0.05, and 0.33 ± 0.10 for fish tagged in B2E, V2V, and C2V, respectively. Over-summer parr suvival of all *O. tshawytscha* tagged on July 8, 2020, was 0.29 ± 0.04. Parr-to-smolt survival of all *O. tshawytscha* tagged on July 8, 2020, was 0.22 ± 0.37.

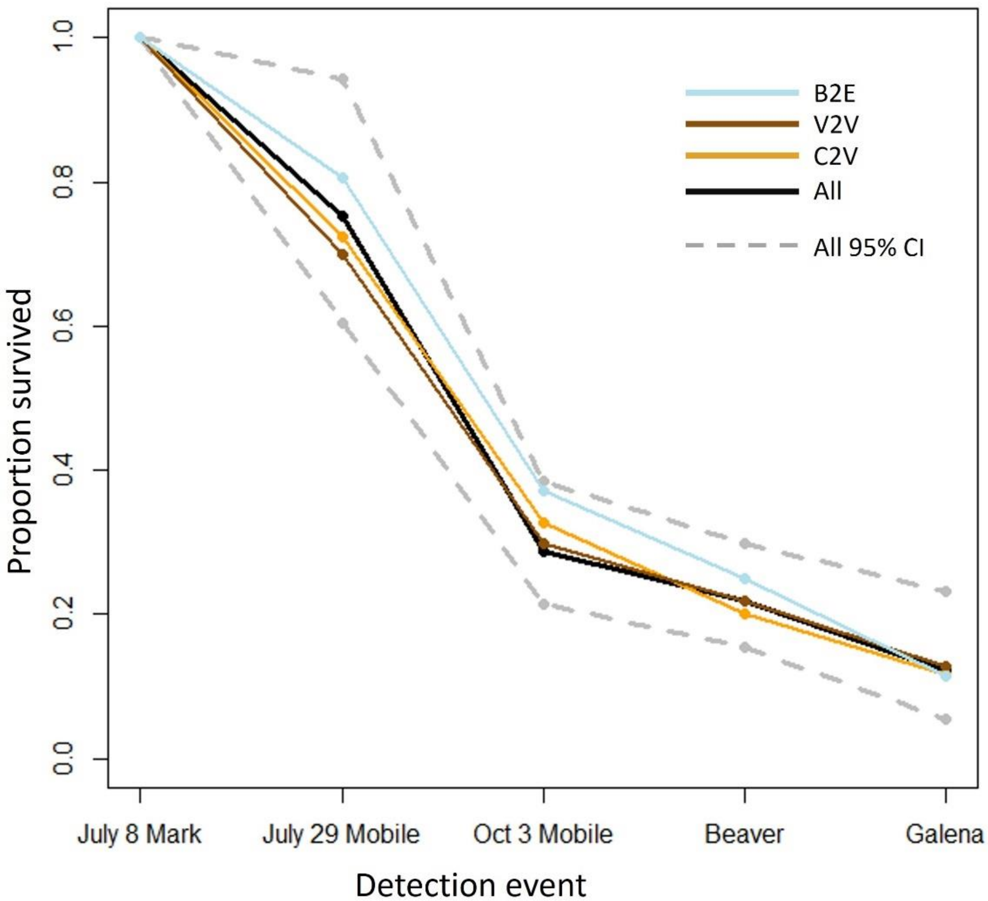

Figure 1.8. *O. tshawytscha* survival to four detection locations (x-axis) plotted to compare survival of all *O. tshawytscha* tagged in the MFJDR (estimate ± CI; black line ± grey dotted line) to the survival of *O. tshawytscha* tagged in each treatment (estimate; B2E = blue line, V2V = brown line, C2V = tan line). All *O. tshawytscha* were tagged on July 8, 2020.

Middle Fork John Day River supplementary figures and tables

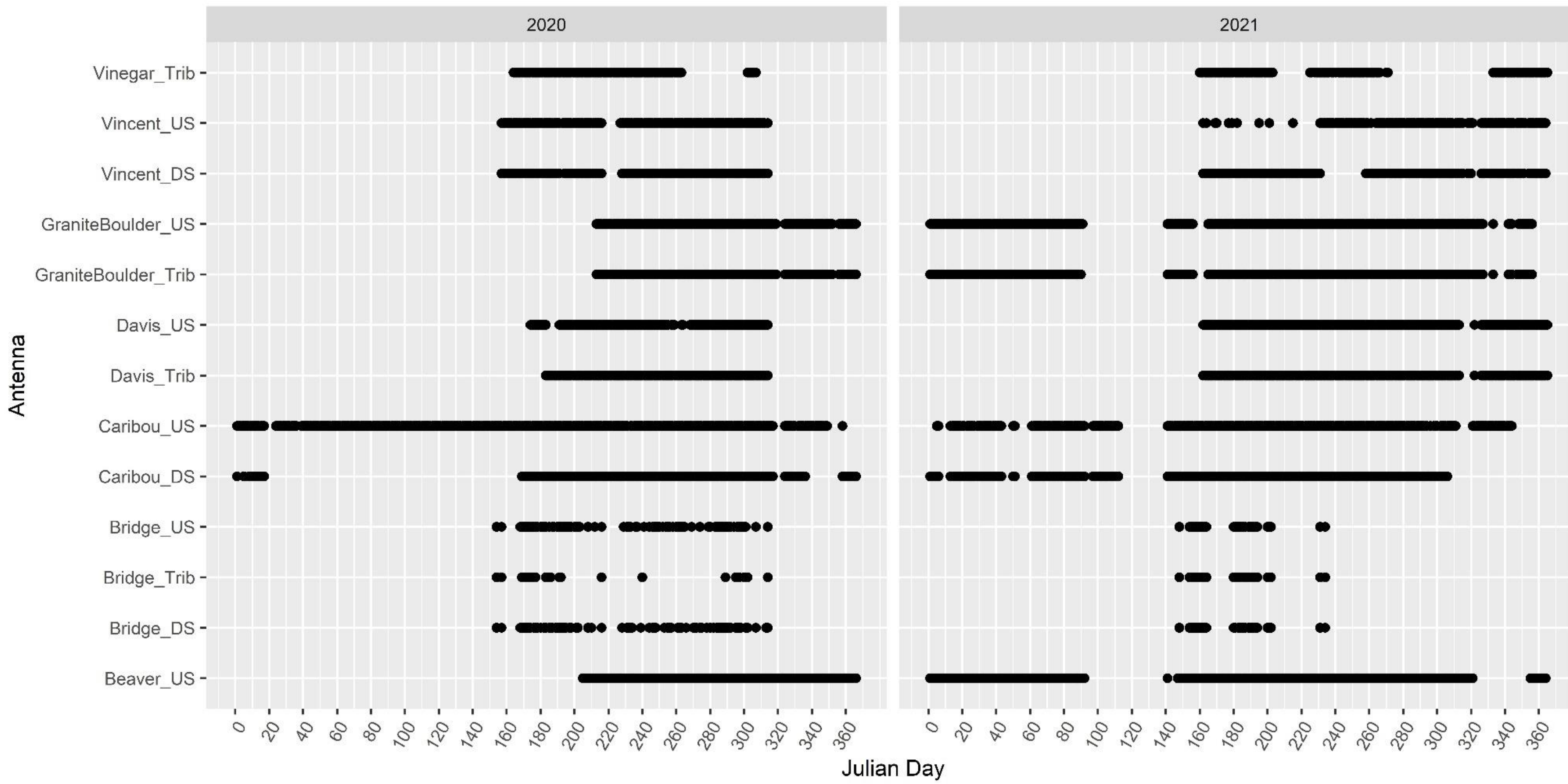

Figure S1.1. Operational record of each stationary antenna located in the upper Middle Fork John Day River basin. The black lines represent when each antenna on.

Table S1.1. Location of 2018 – 2021 PIT tagging sites in the Middle Fork John Day basin.

Site	Bottom of site latitude	Bottom of site longitude	Years sampled
VCL	44.60460	-118.53874	2018, 2019, 2020
DC1	44.58625	-118.53837	2018, 2019, 2020
VCU	44.64281	-118.50401	2018, 2019, 2020
Summit001	44.58975	-118.42108	2019
Summit003	44.58169	-118.40228	2019
Summit005	44.58049	-118.38065	2019
R2G	44.64574	-118.66445	2019, 2020, 2021
V2B	44.59704	-118.52511	2019, 2021
V2V	44.60329	-118.53929	2019
B2E	44.59477	-118.49929	2019
C2V	44.61631	-118.55991	2019
OJD03458-000534	44.61727	-118.56175	2020, 2021
CBW05583-207602	44.59373	-118.51400	2020, 2021
CBW05583-285426	44.59599	-118.49436	2020, 2021
CBW05583-289522	44.60021	-118.53113	2020, 2021
CBW05583-338674	44.59337	-118.50384	2020, 2021
CBW05583-350962	44.60720	-118.54620	2020, 2021
CBW05583-416498	44.60271	-118.53829	2020, 2021
CBW05583-449266	44.61162	-118.55563	2020, 2021
CBW05583-482034	44.61927	-118.56796	2020, 2021

Table S1.2. August density (fish/m) of juvenile *O. tshawytscha* and *O. mykiss* observed at abundance monitoring sites in Middle Fork John Day River from 2019-2021.

Site	Sample Date	*O. mykiss* ≥ 50 mm	Juvenile *O. tshawytscha*	Section
CBW05583-207602	8/17/2021	0.24	0.11	B2E
CBW05583-285426	8/17/2021	0.19	0.00	B2E
CBW05583-289522	8/9/2021	0.49	0.57	V2V
CBW05583-338674	8/17/2021	0.25	0.00	B2E
CBW05583-350962	8/18/2021	0.39	0.22	V2V
CBW05583-416498	8/10/2021	0.82	1.60	V2V
CBW05583-449266	8/19/2021	0.29	0.19	C2V
CBW05583-482034	8/9/2021	0.48	1.45	C2V
OJD03458-000534	8/19/2021	0.59	0.79	C2V
R2G	8/18/2021	0.24	0.83	R2G
V2B	8/11/2021	0.18	0.07	V2B
CBW05583-207602	8/25/2020	1.10	2.74	B2E
CBW05583-285426	8/28/2020	0.07	0.21	B2E
CBW05583-289522	8/25/2020	0.74	2.58	V2V
CBW05583-350962	8/26/2020	0.41	2.79	V2V
CBW05583-416498	8/26/2020	0.16	1.05	V2V
CBW05583-449266	8/28/2020	0.69	2.35	C2V
CBW05583-482034	8/27/2020	0.34	1.38	C2V
OJD03458-000534	8/27/2020	0.50	3.53	C2V
R2G	8/25/2020	0.30	2.68	R2G
B2E	8/22/2019	0.28	0.02	B2E
C2V	8/20/2019	0.65	1.33	C2V
R2G	8/20/2019	0.49	0.83	R2G
V2B	8/21/2019	1.08	0.47	V2B
V2V	8/21/2019	1.38	0.40	V2V

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Appendix 2.A: 2019 MFJDR Habitat Survey Protocol

The 2019 MFJDR habitat survey protocol was adapted from Columbia Habitat Monitoring Program 2014 and Aquatic Inventories Project Methods for Stream Habitat and Snorkel Surveys.

Site Layout

Objective: Determine width category and delineate channel units.

Step 1. Determine the site width category and site length.

i. Measure and record the bankfull width perpendicular to the bankfull channel at the bottom of the site.
ii. Measure and record 4 additional bankfull width measurements at distances upstreams (as measured in a straight line from the center of the wetted channel), equal to the first bankfull width measurement.
iii. Average the 5 bankfull width measurements and consult Table 1 to determine the site width category and site length.

Table 1. Width category and site lengths according to the site average bankfull width determined during site layout.

Average Bankfull Width (m)	Width Category (m)	Site Length (m)
≤ 6	6	120
>6 and ≤ 8	8	160
>8 and ≤ 10	10	200
>10 and ≤ 12	12	240
>12 and ≤ 14	14	280
>14 and ≤ 16	16	320
>16 and ≤ 18	18	360
>18 and ≤ 20	20	400
>20 and ≤ 22	22	440
>22 and ≤ 24	24	480
>24 and ≤ 26	26	520
>26 and ≤ 28	28	560
>28	30	600

Channel Segments and Side Channels

Objective: Identify and label the main channel and different side channel types.

Step 1. Identify the main channels.

i. Main (primary) channel: Contains the greatest amount of stream flow at a site.

Step 2. Identify side channels.

i. Side channel: To be considered a side channel, the channel must be separated from another channel by an island that is ≥ the bankfull elevation for a length ≥ the average bankfull width. At small sites that are 120 m in length, an island must be ≥ 6 m to qualify.
   a. The side channel is ignored if:
      i. The elevation of the streambed is above bankfull at any point
      ii. Channel lacks a continuously defined streambed or developed streambanks
      iii. Channel contains terrestrial vegetation

Step 3. Identify side channel type

i. Large side channel: Has between 16 – 49% flow at either end
ii. Small side channel: Has < 16% flow at both ends.

Step 4. Assign segment numbers to channels

i. The main channel is assigned "Segment 1" throughout the site.
ii. The first large or small side channel while moving upstream is designated "Segment 2).

Step 5. What to measure in each side channel

i. Main channel
   a. Classify channel units, and collect channel unit attributes
ii. Large side channels
   a. Classify channel units, collect channel unit attributes

iii. Small side channels
   a. Classify the entire side channel (both wet and dry portions) as a small side channel unit.
   b. Quantify large woody debris
   c. Categorize the side channel as cont. wet, partially wet, or dry.
   d. Estimate the total length of the side channel centerline.
   e. Estimate the average bankfull width of the side channel.
   f. Estimate the percent of the bankfull channel area that is wet at the time of sampling.

Channel Unit Classification and measurements

Objective: Delineate channel unit boundaries and classify channel units.

Step 1: Identify channel units and their boundaries.
Use the following criteria as a guide when identifying distinct channel units.

i. In general, channel units are at least as long as the average wetted channel width. At larger sites (width category ≥ 12m), channel units may be shorter than the average wetted channel width. Channel units are relatively homogeneous, localized areas of the stream channel characterized by four elements:
   a. Water surface gradient
   b. Bedform (concavity)
   c. Bed material composition
   d. Flow characteristic (e.g., velocity, turbulence)

   Look for distinct changes in these elements to determine unit boundaries. See table 2.

Channel Unit	**Gradient**	**Bedform Profile**	**Substrate**	**Flow Character**
Riffle (RIFF)	>1%	Topographic high points in the bed profile	Generally have coarse substrates (cobbles and boulders)	Fast, turbulent flow
Fast non-turbulent (FNT)	<1%	Uniform depth, low complexity	Generally small cobble, gravels and find substrate	Smooth, even flow (laminar), minimal surface turbulence
Pool (SP)	0-1%	Laterally and longitudinally concave.	Variable, generally smaller and sorted substrate	Generally laminar flow
Alcove	Classifies as an alcove if the bankfull measurement is > 2 m and the alcove is isolated from the channel.			
Side Channel	Side channel separated by an island. Record length, bankfull width, percent of bankfull channel that is wet, and quantify woody debris.			

Step 2: Measure the channel unit.

i. Measure the total length of the channel unit, from the downstream center of the channel to the upstream center of the channel unit.

ii. Measure the wetted and bankfull width at 25, 50 and 75% along the length of the channel unit.
iii. At 25, 50 and 75% along the length of the channel unit record an average depth of the cross section.
iv. At one location in each channel unit record the bankfull height - bankfull heights are recorded from the surface of the water (i.e. the distance between the surface of the water and the bankfull height).
v. In each channel unit record the max depth of the channel unit.
vi. In SP channel units record the depth of the pool-tail crest (PTC). The pool-tail crest is generally the deepest spot on the downstream end of the pool unit.
vii. In each channel unit estimate the percent of the channel unit that is slow juvenile salmonid holding habitat. Then estimate the percent of the holding habitat that is created by wood, sedge, or boulder. The total percent of the holding habitat that is wood, sedge, boulder and *other* should add to 100%.

% Holding Habitat

Objective: Estimate the total area holding habitat located within each channel unit. Holding habitat is defined as water velocities <=.2 m/s and must be > 10 cm deep.

Step 1. Visually estimate the proportion of the channel unit that contains holding habitat.
Step 2. Identify the proportion of the holding habitat that is created by wood, sedge, boulder or other. The proportion of the holding habitat that is created by wood, sedge, boulder, or other must add to 100%.

Fish Cover %

Objective: Estimate the type and total area of cover available to fish within each channel unit.
Fish cover is defined as the proportion of the channel unit area that provides refuge to salmonids.

Step 1. Visually estimate the proportion of the wetted surface area within each channel unit that is covered by each of the fish cover elements listed in Table 3.

i. All fish cover elements must be within the wetted channel or <1 m above the water's surface.
ii. Round measurements to the nearest 5%.
iii. The sum of all fish cover elements should be at least 100%. If fish cover of different categories overlaps, count overlapping areas twice, resulting in a total percentage >100%.
iv. For fish cover that is classified as woody debris estimate the percent of the woody debris that is wet and the percent of the woody debris that is dry (and within 1 meter of the water's surface).

Table 3. Definitions of fish cover elements evaluated at each channel unit.

Cover Element	Cover Element Definition
Woody debris	Wetted area of the channel unit covered by dead woody debris. There is no size requirement for woody debris to be considered fish cover. Include boards, railroad ties, wood placed for restoration purposes, etc.
Overhanging vegetation and live tree roots	Wetted area of the channel unit covered by live, terrestrial vegetation. Includes non-qualifying undercuts, live tree roots suspended over the water and/or submerged.
Aquatic vegetation and algae	Wetted area of the channel unit covered by aquatic macrophytes and filamentous algae.
Artificial structures	Wetted area of the channel unit covered by artificial structures including materials discarded in the stream (tires, old cars, concrete, etc.), or those placed in the stream for diversions, impoundments, channel stabilization, or other purposes. Rip-rap and logs placed for restoration purposes are not included in this category.
Total NO fish cover	Wetted area of the channel unit that does NOT provide fish cover by any of the above elements (i.e., open water).

Substrate Cover % (Ocular Estimate)

Objective: Visually estimate the substrate composition of each channel unity and record the percentage of each size class.

Step 1: Estimate the distribution of substrate classes relative to the total wetted area of the channel unit rounding each class to nearest 5% for a total of 100%. Refer to table 4 for substrate composition types and size classes.

i. If a thin layer of fine sediment is covering a larger particle, then measure the fine sediment, not the larger particle. Conversely, if individual fine sediment particles are resting on top of a larger rock; measure the rock.

Table 4. Ocular channel unit substrate composition types and size classes.

Substrate Type	Size class (mm)	Description
Bedrock	> 4000	Surface rock bigger than a car
Boulders	> 250 to 4000	Basketball to car size
Cobbles	> 64 to 250	Tennis ball to basketball size
Coarse gravel	> 16 to 64	Marble to tennis ball size
Fine gravel	> 2 to 16	Small pebble to marble size
Sand	> 0.06 to 2	Smaller than ladybug size, but visible as particles and gritty between fingers
Fines	< 0.06	Silt, clay, muck and not gritty between fingers

Pebble Count

Objectives: 1) Quantify size distribution of substrate in fast water habitats by measuring 11 particles from 10 cross-sections for a total of 110 particles per site 2) estimate embeddedness of cobbles.

Step 1. Determine where to place cross-sections.

i. Count the number of riffle channel units that occur within the main channel and qualifying side channels.
   a. If there are more than 10 riffles, place one cross-section in each of the first 10 riffles (working upstream).
   b. If there are less than 10 riffles, evenly distribute additional cross-sections into riffles according to the proportion of stream length that each unit comprises relative to the other riffles. If there is not enough space to conduct all measurements in riffles (see Step 1, ii, c), then evenly distribute remaining cross-sections into non-turbulent units (working upstream). If there is not enough space to conduct all measurements in riffles and non-turbulent units, then distribute remaining cross-sections into rapids.

ii. Cross-section location and spacing.
   a. When there is only one cross-section in a unit, place the cross-section at the midpoint of the unit.
   b. When there are multiple cross-sections in a unit, equally space the cross-sections throughout the unit. Cross-sections should be oriented perpendicular to the bankfull channel.
   c. Cross-sections should not be closer than 1/100th of the site length apart. Move additional cross-sections to the next largest unit if too crowded. For example, the minimum spacing between cross-sections at a 120 m long site would be 1.2 m.
   d. Cross-sections should not cross two or more laterally adjacent channel units.

Step 2. Select 11 sampling points at each cross-section.

i. At each cross-section, visually divide the cross-section into 11 equally spaced sampling points running perpendicular to the stream channel, and spanning the width of the bankfull channel.

Step 3. Select and measure particles.

i. Select particles at sample points while turning your eye away and extending your finger down and picking up the first particle that you feel at the tip of your boot.
   a. Use a gravelometer to classify the b-axis of each particle. Record the size category (Table 5) for the largest square opening that the particle does not fit through. For example, if the particle fits through the 180 mm square but does not fit through the 128 mm square it is classified as the 128-180 mm size class and is recorded as 128 mm.
   b. Record silt and clay particles that are < 0.06 mm in the 0.0002-0.06 mm size class. Silt and clay particles are smooth when rubbed between the thumb and fingers whereas sand rolls between the fingers (is gritty).
   c. Use the thin edge of the gravelometer to determine sand particles between 0.06 and 2 mm. (Note the thin edge of the gravelometer is 2 mm wide).
   d. For particles >128 mm and <512 mm, measure the b-axis using the notches at the top of the gravelometer.
   e. For particles > 512 mm, measure and record the length of the b-axis using the top edge of the gravelometer or a depth rod.
   f. Record "bedrock" when encountered at sample points.
   g. If your finger touches a thin layer of fine sediment covering a larger particle, then measure the fine sediment, not the larger particle.
   h. **Do not measure stream bank particles.**
   i. For embedded particles that cannot be removed from the stream bed, use the notched edge of the gravelometer or the depth rod to measure the b-axis, and record the appropriate size class.

Table 5. Size categories for sediment in the range of silt and clay to boulders. Record the lower size range that the particle falls within (e.g., a partical that falls 45-64 would be recorded as 45).

Description of particle size		Size Range Lower	Upper
Boulder		Measure discrete values for all particles > **512** mm	
	small	**362**	512
		256	362
Cobble	large	**180**	256
		128	180
	small	**90**	128
		64	90
Gravel	very coarse	**45**	64
		32	45
	coarse	**22.5**	32
		16	22.5
	medium	**11.3**	16
		8	11.3
	fine	**5.7**	8
		4	5.7
	very fine	**2**	4
Sand		**0.06**	2
Silt/Clay		**0.002**	0.06

Cobble Embeddedness

Embeddedness is the percentage of a cobble's surface that is surrounded by fine sediment (< 2 mm). High cobble embeddedness results in a reduction of interstitial spaces between particles and makes the substrate more difficult to move (think of a fish's tail).

a. Estimate embeddedness for all cobble-sized particles (64 mm – 256 mm) that are selected during particle size distribution sampling. Record estimates to the nearest 5%.
b. Embeddedness is estimated as the product of two values:
    a. The percentage of the cobble's surface that is buried below the surface of the streambed, and
    b. The percentage of fine sediment < 2 mm in the substrate immediately surrounding the cobble.

Step 1. Estimate percent buried.

ii. Before removing a particle from the streambed for measurement, feel around the edge of the particle to determine at what point the particle is below the stream bed surface and note the boundary between the portion of the particle that was buried and the portion that was not buried.

iii. Remove the particle and estimate the percent that is buried by comparing the proportion of the particle's surface that was exposed vs. buried.
Note: If a cobble cannot be removed from the streambed, the particle is at least 50% buried. Measure the b-axis of the particle and confirm that it is a qualifying cobble.

Step 2. Estimate percent fines.

i. Examine the substrate within the depression immediately surrounding the cobble where the buried portion of the cobble was removed, and visually estimate the percent of the substrate that is composed of fine sediment <2 mm. If the substrate is not clearly visible due to water surface turbulence or turbidity, manually collect a small grab sample of the substrate, hold the sample above the water surface, and visually estimate percent fines for the sample.

Pool Tail Fines

Objective: Quantify the percentage of surface substrate <2 mm and between 2-6 mm at the tails of pools and non-turbulent channel units.

Step 1. Identify measurement locations.

1. Collect measurements at the first 10 scour and plunge pools encountered within the main channel and qualifying side channels (16-49% flow) while moving from the bottom of site upstream. Do not sample in dam pools.
2. If fewer than 10 pools exist at a site, extend sampling into only main channel non-turbulent units (starting from the bottom of site) until ten measurements are collected or there are no more qualifying units. Sample at the bottom end of non-turbulent channel units in a similar fashion to pool tails.

Step 2. Sample surface fines.

1. Assess surface fines using a 14 x 14 inch grid with 49 evenly distributed intersections. Include the top right corner of the grid for a total of 50 intersections.
2. Take 3 measurements per pool or non-turbulent unit.

    1. Place the center of the grid at 25, 50, and 75% of the distance across the wetted channel, making sure the grid is parallel to the shape of the pool tail crest (Figure 1).
    2. The bottom edge of the grid should be upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less.
    3. If a portion of the fines grid lands on substrate 512 mm or larger in size (b-axis), record the intersections affected as non-measurable.
    4. Do not overlap fines grid placements/measurements at a pool tail. If all three grids do not fit within the pool tail without overlapping, record the overlapping grid as "not measured". State in notes that "grids overlapped".

Record the number of intersections that are underlain with fine sediment or sand < 2 mm in diameter at the b-axis.
Record the number of intersections that are underlain with sediment 2-6 mm in diameter at the b-axis.
Aquatic vegetation, organic debris, roots, or wood may be covering the substrate. First attempt to identify the particle size under each intersection. If this is not possible, then record these intersections as non-measurable.
Do not count substrate that is suspended in aquatic vegetation or surface algae.

Enter the channel unit number where measurements were collected.
Note: If the grid is located in an area that has greater than 75% non-measureable intersections, shift the grid to a location where more grid measurements can be made.

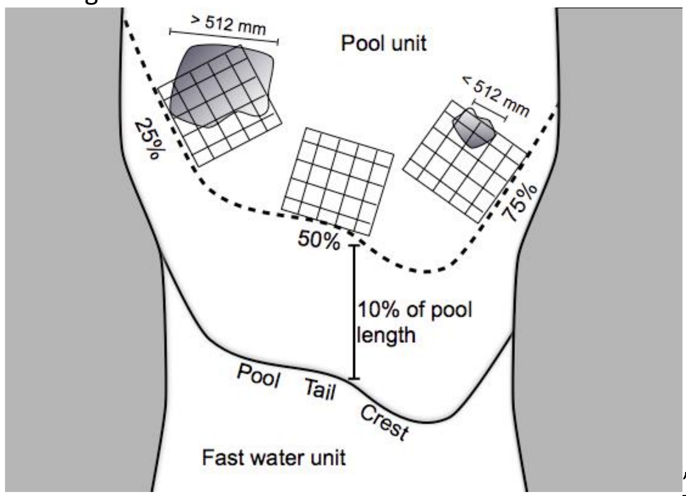

Figure 1 - Location and orientation of pool tail fines grid relative to the pool tail crest. In this figure, all intersections of the fines grid at the 50% and 75% placements will be counted and recorded. For the 25% placement, the intersections of the fines grid that land on the boulder (substrate =512 mm) will be recorded as non-measurable

Large Woody Debris

Objective: Quantify the number and dimensions of qualifying LWD pieces for each channel unit within the site.

Step 1. Identify qualifying LWD within the bankfull channel and prism.

1. LWD and root wads must be dead with the exception of newly fallen trees that are uprooted from the bank but still have green foliage.
2. LWD size qualifications:
    1. Must have a b-axis diameter ≥ 10 cm, measured at the midpoint of the piece. For LWD with attached roots, the diameter is measured at the midpoint between where the main stem joins the root mass (e.g., root collar) and the top of the piece (Figure 2).
    2. Must be ≥ 1 m in length. The length of LWD with attached roots is measured from the end of the main root mass to the top of the trunk.
3. For LWD embedded in the stream bank, the exposed portion must meet the minimum length and diameter requirements to qualify. Quantify the length and diameter of the exposed portion of the piece.
4. If a LWD piece is broken or cracked, consider it one piece if the two pieces are attached at any point along the break.

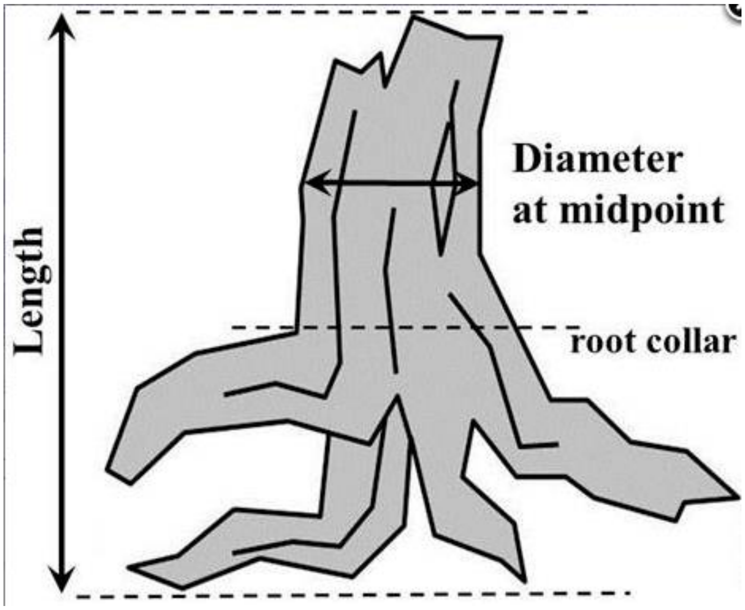

Figure 2. Depiction of diameter and length measurement locations for LWD with attached roots.

Step 2. Classify qualifying LWD as “wet” or “dry”.

1. All LWD located within the bankfull channel is classified as either “wet” or “dry” (Figure 25).
    1. Classify piece as “wet” if a portion of the main stem or root that touches the water is ≥ 10 cm in diameter (Figure 3).
    2. Classify piece as “dry” if a portion of the main stem or root ≥ 10 cm in diameter is within the bankfull channel but outside of the wetted channel (i.e. would get wet at bankfull flows).

    ii. Classify pieces outside the bankfull channel but within the bankfull prism as “dry” if they meet both of the criteria below. The bankfull prism refers to the area directly above the bankfull channel elevation (Figure 25).

    1. Piece is in the bankfull prism and is suspended vertically above the bankfull channel by other pieces of LWD. Piece would fall into the bankfull channel if the supporting LWD was removed (Figure 2)

    Note: These pieces frequently occur in large wood aggregates or “jams”.

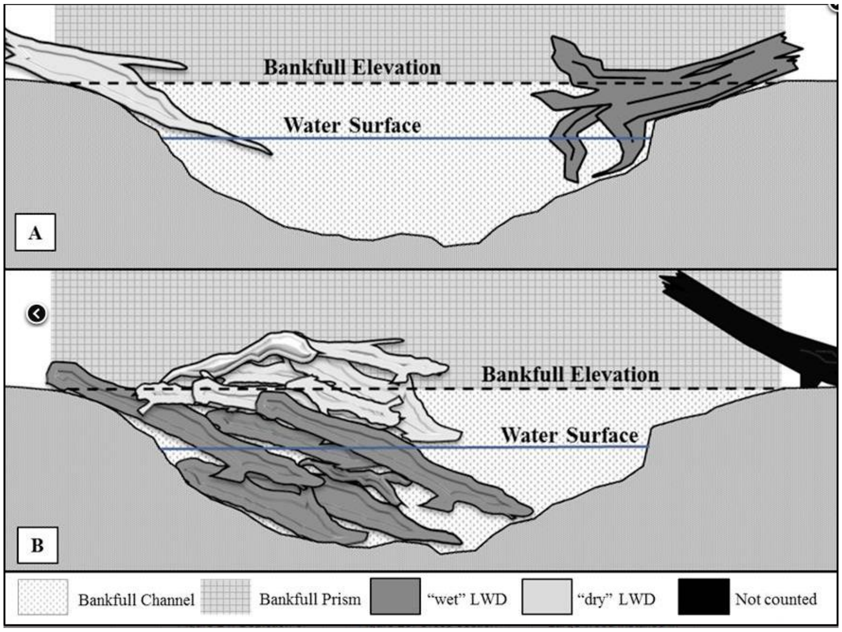

Figure 3. Cross-section view depicting LWD wet/dry scenarios for qualifying pieces. Grey pieces are classified "wet" and light grey pieces "dry". Panel A) LWD piece on left is "dry" because the portion of the main stem touching the water is < 10 cm. LWD piece on right is "wet" because a root = 10 cm diameter touches the water. Panel B) Note that "dry" pieces above the bankfull elevation but within the bankfull prism are supported by other LWD pieces and are counted (see Step 2)

Step 3. Record the length and diameter of qualifying LWD pieces.

1. Measure and record the length and diameter of the first 10 qualifying LWD pieces encountered at the site.
2. Estimate and record the length and diameter of the next 9 LWD pieces and measure the 10th. Repeat this process of measuring every 10th piece (#20, #30, #40, etc.) until all qualifying pieces have been quantified.
3. In addition to measuring pieces described in steps i and ii above, also measure the first 10 LWD pieces that are ≥ 15m long.
4. Record length to the nearest 0.1 m, and diameter measurements to the nearest 0.01 m.
5. If a piece cannot be measured accurately, estimate the length and diameter and measure a different qualifying piece.

Step 4: Assign qualifying LWD pieces to a channel unit.

1. Assign each piece of LWD to one channel unit. If a piece of LWD is present in two or more channel units, assign it to the unit that contains the highest proportion of the piece's volume.
2. If a piece of LWD is outside wetted portion of the channel but within the bankfull channel, assign this 'dry' piece to the nearest channel unit.

Note: Tally all qualifying LWD pieces within the entire bankfull channel including those pieces within all large and small side channels.

Undercut Banks

Objective: To quantify cover from undercut banks available to fish at the time of sampling.

Step 1. Identify qualifying undercut banks.

i. Undercut banks are continuous cave-like features in the stream bank formed by overhanging bank material and/or tree roots.

ii. Qualifying undercut banks:

a. Provide fish cover at the time of sampling.

b. Have a width ≥20 cm.

c. Are ≥1 m long, measured along the edge of water.

d. Include undercuts with ceilings ≤ 1 m above the water surface.

Step 2. Estimate the length of the undercut.

i. Determine the upstream and downstream boundaries of the undercut and measure the length along the edge of water.

ii. Only measure the portion of the undercut that meets the minimum width requirement.

iii. When there are two or more qualifying undercuts separated by a distance of less than 0.5 m, consider them one undercut but do not account for the distance between them in the length estimate.

Step 3. Measure and record the width of qualifying undercuts.

i. Measure the wetted widths of the undercut parallel to the water's surface and perpendicular to the direction of flow.

ii. Undercut width is measured as the wetted horizontal distance from the outermost edge of the overhanging bank to the back "wall" of the undercut at its widest point.

iii. Measure undercut widths at 3 points located at 25, 50 and 75% of the qualifying undercut length. The average width of the three points must be ≥ 20 cm to qualify.

Step 4. Record GPS coordinates and EPE at the midpoint of each undercut.

Step 5. Assign qualifying undercuts to their corresponding channel unit and stream bank.

i. Record the channel unit that the undercut falls within.

ii. Assign each undercut to the corresponding stream bank (left/right bank or island).

iii. Some undercuts extend between two channel units:

a. If a single undercut extends between two channel units, consider it two distinct undercuts separated at the channel unit boundary (Figure 33). Each individual undercut must meet length and width requirements.

b. If a single undercut extends between two channel units and one of the portions does not meet the minimum length requirement, consider it one undercut and assign the undercut to the channel unit that contains the greater proportion of its length. Similarly, if a single qualifying undercut extends between two channel units but neither portion qualifies based on length, consider it one undercut and assign it to the unit with the greater proportion.