ASSESSING TRINITY RIVER SALMONID HABITAT AT CHANNEL REHABILITATION SITES, 2007-2008.

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This report is intended to be printed in color.

Keywords: River restoration; adaptive management; Chinook salmon; coho salmon; steelhead; validation of habitat predictions; effectiveness monitoring; Trinity River

On the Cover: Preconstruction conditions of Chinook and coho salmon presmolt (50-200 mm total length) rearing habitat mapped at a segment of the Cableway site at 2020 cfs. Beige polygons indicate areas within both depth/velocity and escape cover criteria, orange within depth/velocity criteria only, green within distance to escape cover criteria only and blue indicates areas within the wetted channel that fall outside of depth/velocity and escape cover criteria.

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Abstract.-A primary goal of the Trinity River restoration effort is to increase aquatic habitat quality and quantity to sustain anadromous salmonid populations at pre-dam levels. The goal of this study was to quantify changes in the quality and quantity of salmonid rearing and spawning habitat at mechanical bank rehabilitation sites. To accomplish this goal we developed a spatially explicit evaluation technique to locate and quantify habitat areas in the Trinity River. We conducted a rearing and spawning habitat validation study to evaluate if biological use was in concordance with predicted habitat areas. Rearing Chinook and coho salmon densities were significantly different among habitat qualities as defined by combinations of depth/velocity and escape cover criteria. The observed fish density differences matched predictions of habitat quality with the highest densities within high quality habitats. In contrast, we rejected the validity of spawning habitat predictions given that 36% of observed redds occurred within mapped spawning habitat areas. Future studies should attempt to refine the predictability of spawning habitat quality and quantity. The rearing habitat evaluation was applied to document pre-construction, post-construction and control site conditions. A post-construction survey of the Hocker Flat site demonstrated increases in available rearing habitat at all surveyed streamflows. Post-construction surveys at the Indian Creek site showed increased rearing habitat in a constructed side channel and in constructed berm notches. Rearing habitat quantity decreased from the as-built conditions at the constructed berm notches following a peak flow release event that deposited fine sediment in the treatment areas.

INTRODUCTION

The Trinity River has been drastically modified by a host of anthropogenic activities. Some of the major changes have stemmed from mining activities, logging and the construction and operations of Lewiston and Trinity Dams since the mid 1960's. Anadromous salmonid populations in the Trinity River are at depressed levels due, in part, to the loss of aquatic habitats above the dams. Downstream of the dams, the Trinity River streamflow has been sharply reduced via the Central Valley Project, the flow regime is highly regulated, and riverine habitat conditions have been degraded from the resulting shift in fluvial and ecological processes (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999).

The primary goal of the Trinity River Restoration Program (TRRP) is to restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam to pre-dam levels (Trinity River Restoration Program and ESSA Technologies Ltd. 2009). The restoration strategy adopted by the Secretary of the Interior by signing the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; DOI 2000) to meet the primary goal of TRRP is presented in the Trinity River Flow Evaluation (TRFE) (USFWS and Hoopa Valley Tribe 1999):

> *If naturally produced salmonid populations are to be restored and maintained, the habitat on which they depend must be rehabilitated. The most practical strategy to achieve fish habitat rehabilitation is a management approach that integrates riverine processes and instream flow dependent needs. This management approach physically reshapes selected channel sections, regulates sediment input, and prescribes reservoir releases to 1) allow fluvial processes to reshape and maintain a new dynamic equilibrium condition; and 2) provide favorable water temperatures. This strategy does not strive to recreate the pre-TRD mainstem channel morphology. Several sediment and flow constraints imposed by the TRD cannot be overcome or completely mitigated. The new alluvial channel will be smaller in scale, but it will exhibit almost all the dynamic characteristics of the ten alluvial attributes necessary to restore and maintain fisheries resources.*

Actions deemed necessary to restore and maintain the freshwater habitats for anadromous salmonids are: 1) mechanical rehabilitation of the channel; 2) flow management to restore fluvial processes that create and maintain suitable salmonid habitat and to meet water temperatures objectives; 3) coarse and fine sediment management; and 4) watershed restoration (DOI 2000). Prior to the signing of the ROD in 2000, bank rehabilitation projects were implemented at nine pilot sites between 1991 and 1993. Geomorphic, riparian, fish use, and fish habitat monitoring occurred at these sites after implementation, and information gained from that monitoring guided the restoration strategy and management actions contained in the TRFE and ROD (i.e., Krakker 1991; Hampton 1992; Glase 1994; Gallagher 1995; McBain and Trush 1997; USFWS 1997; Gallagher 1999a, 1999b, 1999c). Monitoring of these pilot sites ceased in 2001 and has recently resumed.

The TRFE identified an additional 44 channel rehabilitation sites and 3 side channel rehabilitation sites between Lewiston Dam and the North Fork Trinity River. Design and implementation of these projects has been conducted under an adaptive management framework. The components of the adaptive management process (in the context of the channel rehabilitation effort) include:

1. *Hypothesize and predict*: Assess channel rehabilitation site opportunities, predict geomorphic response and resulting habitat response of site for different rehabilitation alternatives.
2. *Design*: Develop channel rehabilitation designs (and assessments) based on predictions.
3. *Implement*: Implement channel rehabilitation designs and assessments.
4. *Monitor*: Monitor channel and habitat response, as well as fish and wildlife use and population response.
5. *Assess*: Compare habitat/channel responses to predictions. Improve designs to better achieve desired habitat/channel responses. Determine cause-and-effect relationships among habitat/channel response, channel design, flow management, sediment management, and large wood management.
6. *Adapt*: Alter management actions such as restoration designs, annual flow releases, coarse sediment augmentation, and large wood management.

A fundamental assessment to evaluate the effectiveness of TRRP restoration actions is determining changes in salmonid habitat resulting from both mechanical channel rehabilitation and restoration of fluvial processes. This study evaluates salmonid habitat response to mechanical channel rehabilitation actions and will provide feedback to improve management actions, specifically channel rehabilitation, coarse sediment augmentation, and annual flow management.

PROJECT OBJECTIVES

In 2007 and 2008 we addressed several objectives related to the bank rehabilitation sites:

1. Develop two habitat guild methods to delineate and quantify areas of: a) rearing habitat for Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*); and b) spawning habitat for Chinook salmon, coho salmon, and steelhead (*O. mykiss*) in the Trinity River;
2. Validate the rearing and spawning habitat guild methods;
3. Document pre-construction rearing habitat guild areas for Chinook and coho salmon at rehabilitation sites constructed in 2008; and
4. Evaluate changes in rearing habitat guild areas for following construction at sites rehabilitated before 2008.

This assessment is primarily intended to help evaluate channel rehabilitation sites relative to increasing available Chinook and coho salmon rearing habitat. Additionally, the study continues development of a salmonid spawning habitat assessment for use in future studies. We assessed rearing habitat abundance at channel rehabilitation sites prior to and immediately following construction to assess as-built channel rehabilitation site conditions and site design and future site evolution processes. Habitat abundance was also assessed following ROD spring high flow releases from Lewiston Dam to evaluate changes due to those releases as well as mechanical channel rehabilitation and high-flow gravel injections.

STUDY AREA, DRAINAGE AND BANK REHABILITATION SITE DESCRIPTIONS

The Trinity River is located in northwestern California within Humboldt and Trinity counties. The watershed has a drainage area of 7,679 km^2 (2,965 mi^2) with approximately one quarter of the drainage upstream of Lewiston Dam (USFWS 1989, United States Bureau of Reclamation 2009). The river's headwaters are in the Salmon-Trinity Mountains of northern California, from which it flows 274 km (170 mi) to its confluence with the Klamath River at Weitchpec, California, 180 km (112 mi) below Lewiston Dam.

This monitoring effort focuses on the 64 river kilometers (rkm; 40 mi) of the Trinity River located between Lewiston Dam and the confluence of the North Fork Trinity and mainstem Trinity rivers. We conducted rearing habitat mapping assessments at winter base flow at seven bank rehabilitation sites and one control site on the Trinity River in 2007 and 2008 (Figure 1). Both pre-construction and post-construction assessments were conducted at the Lower Indian Creek and Vitzhum Gulch sites. A post-construction assessment was conducted at Hocker Flat and compared with pre-construction habitat assessment data collected by Chamberlain et al. (2007). Pre-construction habitat assessments were conducted at four bank rehabilitation sites (Sven Olbertson, Lewiston Cableway, Hoadley Gulch and Dark Gulch). We conducted spawning habitat mapping assessments at winter base flow from the top of the Lewiston Cableway site to the top of the Cemetery side channel encompassing the entirety of the Cableway and Hoadley Gulch rehabilitation sites (rkm 176.5-178.0). Finally, a habitat assessment was conducted at Salt Flat, a site not planned for bank rehabilitation. Several rehabilitation actions were conducted at these sites. Gravel injections include adding coarse sediment to the channel. Sediment sizes were generally between 9.5 and 127 mm on the secondary axis. Feathered edges refer to removing heavily vegetated riparian berms, contouring the bank to a gentle slope and in some cases adding coarse sediments to create cobble bars. Floodplain lowering connects the floodplain with the river channel appropriate for inundation under the post-ROD peak streamflows. A description of the channel rehabilitation sites and associated rehabilitation techniques targeted for evaluation in this study is presented below.

Sven Olbertson

> As the channel rehabilitation closest to Lewiston Dam, the Sven Olbertson site consists of a left bank side channel complex (looking downstream). The side channel was constructed with three distinct network openings to increase habitat complexity and to increase the likelihood of at least one of the entrances being self-maintaining over time. Downstream of the side channel, a notch was cut in the cement weir that had previously ponded water. This formerly ponded area is now drained during low flows. In addition, this site is 320 m downstream of the Lewiston Hatchery coarse sediment augmentation site. In recent years, 2,206 metric tons (2,432 tons) of coarse sediment was added in 2006 and 5,897 (6,500) was added in 2007 (TRRP unpublished data). This coarse sediment is moved downstream with high streamflow events and interacts with the site. Bank construction took place here and elsewhere in 2008 unless otherwise noted.

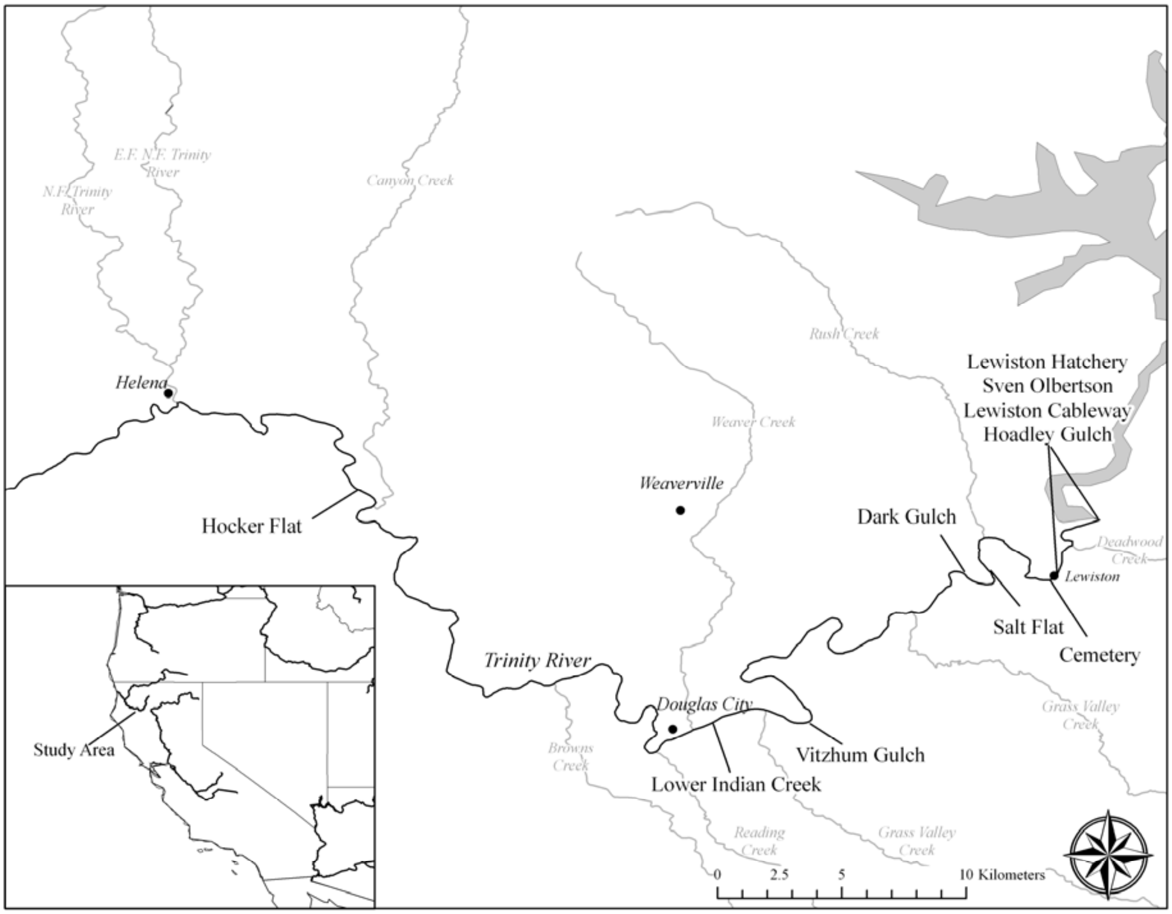


Figure 1. Bank rehabilitation and habitat assessment study sites in 2007 and 2008.

Lewiston Cableway

Located upstream of the Old Lewiston Bridge, the Lewiston Cableway site consists of a sequence of constructed gravel bars on both the left and right banks, decreasing the channel width, increasing channel confinement, adding coarse sediment to the channel, and increasing sinuosity. A side channel was also enhanced along the right bank and several in-channel rock weirs were removed or partially removed. A moderate amount of vegetation adjacent to the channel was also removed immediately upstream of the Old Lewiston Bridge.

Hoadley Gulch

Located immediately downstream of the Old Lewiston Bridge, the Hoadley Gulch site consists of a large gravel bar that has been constructed on the right bank of the river. A side channel with two entrances has been constructed at the upstream end of the gravel bar and exits as one channel at the downstream end of the feature. Floodplain lowering and vegetation removal were also components of the rehabilitated site.

Dark Gulch

The Dark Gulch site consists of a series of existing side channel complexes on the left side of the channel. An additional side channel was constructed on the right bank and the floodplain was lowered. Adjacent channel vegetation was also removed.

Salt Flat

The Salt Flat site was included as an untreated reference site. It includes an area with high banks on both sides where little change is occurring and a side channel on the right bank near the bottom of the site which provides valuable low flow rearing habitat. No habitat rehabilitation is planned at this site.

Vitzhum Gulch

The Vitzhum Gulch site consists of a series of 13 notches excavated from the existing berm along the inside of a right bank bend in the channel with the hypothesis that the remaining berm would be removed by fluvial processes. During high flows, the area behind the notches was inundated. The left bank of the channel is a steep, confined grade leading directly up to Highway 299. Construction occurred in 2007.

Lower Indian Creek

The Lower Indian Creek site extends from the top of the constructed side channel downstream to the Douglas City Bridge at Highway 299. The most prominent design feature at this site is the long side channel constructed along the right bank. Floodplain lowering and vegetation removal was done upstream and adjacent to the constructed side channel. Construction occurred in 2007.

Hocker Flat

Located immediately downstream of the confluence of Canyon Creek and the mainstem Trinity River, the Hocker Flat site rehabilitation consists of substantial berm removal and floodplain lowering on both the left and right banks. This site was rehabilitated in 2005 and was the first site constructed since the ROD was signed. After construction the channel spread out with increasing streamflow. This changed the sediment transport dynamic to facilitate coarse sediment deposition forming lateral and mid channel bar features within the site. This rehabilitation site has had the most time to interact and evolve with the ROD Lewiston Dam releases and riparian development. It is also the only site constructed since the ROD with no large wood installations.

METHODS

HABITAT GUILD DEFINITIONS

We developed three pairs of rearing habitat guilds for Chinook and coho salmon, jointly (Table 1). One pair of rearing habitat guild definitions was applied to all pre-construction surveys in 2008 and the post construction assessment of the Hocker Flat site. The other two pairs of habitat guild definitions were applied to facilitate comparisons with habitat assessments conducted before 2008. Our rearing habitat guilds included a Fry guild representing habitat requirements for Chinook and coho salmon with a fork length <50 mm (<2.0 in) and a Presmolt guild for Chinook and coho salmon with a fork length of 50 to 200

Table 1. Criteria for rearing habitat guild definitions. Rearing habitat guilds were defined by combined depth/mean column velocity (DV) and distance to in-water escape cover (C) criteria (vegetation or wood). Fry-I and Presmolt-I guilds were developed for and applied only at Indian Creek including the Vitzhum Gulch and Lower Indian Creek sites. Fry-H and Presmolt-H guild definitions were applied only at the Hocker Flat site. DV-H guild definitions do not include escape cover and were used to compare with earlier habitat assessment measurements that did not include distance to escape cover.

. Guild	Guild Category	Depth (m)		Velocity (m/sec)		Distance to Cover (m)
Fry	DV, C	<0.61	and	<0.15	and	<0.61
	No DV, No C	>0.61	or	>0.15	and	>0.61
Presmolt	DV, C	<1.00	and	<0.24	and	<0.61
	No DV, No C	>1.00	or	>0.24	and	>0.61
Fry-I	DV-I, C	0.15-0.61	and	<0.15	and	<0.61
	No DV-I, No C	<0.15 or >0.61	or	>0.15	and	>0.61
Presmolt-I	DV-I, C	0.15-1.61	and	<0.24	and	<0.61
	No DV-I, No C	<0.15 or >1.61	or	>0.24	and	>0.61
Fry-H	DV-H	<0.61	and	<0.15		NA
	No DV-H	>0.61	or	>0.15		NA
Presmolt-H	DV-H	<0.61	and	<0.24		NA
	No DV-H	>0.61	or	>0.24		NA

mm (2.0 in to 7.9 in). Our definitions for rearing and spawning habitat guilds use combined depth and mean column velocity criteria from TRFE (USFWS and Hoopa Valley Tribe 1999) treated as if they were one criterion. At sites evaluated in 2008, in-water escape cover was added to rearing habitat guild definitions from data collected in 2003-2004 on the Trinity River (USFWS and Yurok Tribe unpublished data). For this assessment "escape cover" was defined as any vegetation or wood that occurred in the wetted channel at the time of a survey.

The primary pair of habitat guild definitions was based on observations from Habitat Suitability Criteria (HSC) studies conducted on the Trinity River (USFWS and Hoopa Valley Tribe 1999; Yurok Tribe and USFWS unpublished data; Figure 2 through 4) and will be the standard definition applied to rearing habitat mapping in future assessments. Fry guild depth was 0 to 61 cm (24.0 in); Fry guild velocity was 0.0 to 0.15 mps (0.49 fps); and Fry guild distance to escape cover was less than 61 cm (24 in). Presmolt guild depth was 0 to 100 cm (39.4 in); Presmolt guild velocity was 0 to 0.24 mps (0.79 fps); and Presmolt guild distance to escape cover was less than 61 cm (24 in).

Fry-I and Presmolt-I guilds were applied at the Indian Creek site evaluation, including Vitzhum Gulch and Lower Indian Creek. Fry-I guild depth was 15 to 61 cm (5.9 to 24.0 in); Fry-I guild velocity was 0 to 0.15 mps (0.49 fps); and Fry-I guild distance to escape cover was less than 61 cm (24 in). Presmolt-I guild depth was 15 to 161 cm (5.9 to 63.4 in);

Presmolt-I guild velocity was 0 to 0.24 mps (0.79 fps); and Presmolt-I guild distance to escape cover was less than 61 cm (24 in). Both Fry-I and Presmolt-I guilds differed from Fry and Presmolt guilds in that both included a minimum depth criteria of 15 cm (5.9 in); Presmolt-I guild changed the maximum depth to 161 cm (63.4 in). Fry-H and Presmolt-H guilds were applied at the Hocker Flat site only. Fry-H guild depth was 0 to 0.61 m (24.0 in); Fry-H guild velocity was 0 to 0.15 mps (0.49 fps); and Fry-H guild distance to escape cover was less than 61 cm (24 in). Presmolt-H guild depth was 0 to 61 cm (24.0 in); Presmolt-H guild velocity was 0 to 0.24 mps (0.79 fps); and Presmolt-H guild distance to escape cover was less than 61 cm (24 in). The Presmolt-H guild differed from the Presmolt guild in that it included a maximum depth for Chinook and coho salmon of 61 cm (24.0 in).

We developed one spawning habitat guild for Chinook salmon, coho salmon and steelhead, jointly. Similar to the rearing habitat definitions, the spawning habitat guild encompasses a high percentage of HSC observations on the Trinity River (USFWS and Hoopa Valley Tribe 1999). Again, our definitions for rearing and spawning habitat guilds use combined depth and mean column velocity criteria from TRFE treated as if they were one criterion. We defined the spawning habitat guild criteria as depths from 0.15 to 0.76 m (5.9 to 29.9 in), mean column velocities from 0.15 to 0.79 m/sec (0.49 to 2.59 fps) and dominant surface substrate with secondary axis diameters from 50 to 150 mm (1.9 to 5.9 in). The criteria were set to include a high percentage of redds observed within the range of these variables during HSC studies conducted on the Trinity River (Figure 5 and 6).

HABITAT MAPPING

Habitat mapping uses guild definitions and delineations of areas that meet (or do not meet) the specific criteria. To conduct the mapping, surveyors identified the perimeter of areas that meet guild criteria, including the edge of water, joint depth/mean water column velocity, escape cover and substrate criteria. For rearing habitat surveys, attribute perimeters were typically measured as a series of transects starting at the bank and working toward the mid-channel. This process was then repeated from upstream to downstream. For undercut banks, the depth of the undercut was measured and the edge of water identified on the outside extent of water.

Depth and mean water column velocity were measured using hand-held Price AA (JBS Energy) or Flow Tracker (Son Tek) flow meters on top setting rods. Dominant in-water vegetation or wood escape cover was identified by ocular estimate and delineated when present. The secondary axis diameter of the dominant substrate size was visually estimated as within or outside of guild criteria.

After a habitat guild perimeter was identified, GPS points were taken to geographically reference the location. These polygons were subsequently used as vertices of polygons in GIS analysis and data post-processing to calculate habitat areas. We used poly-line shape files to trace the shape of habitat areas during each survey and facilitate post processing into polygons. Only habitat areas greater than or equal to 2 m^2 (22 ft^2) were surveyed to increase survey efficiency.

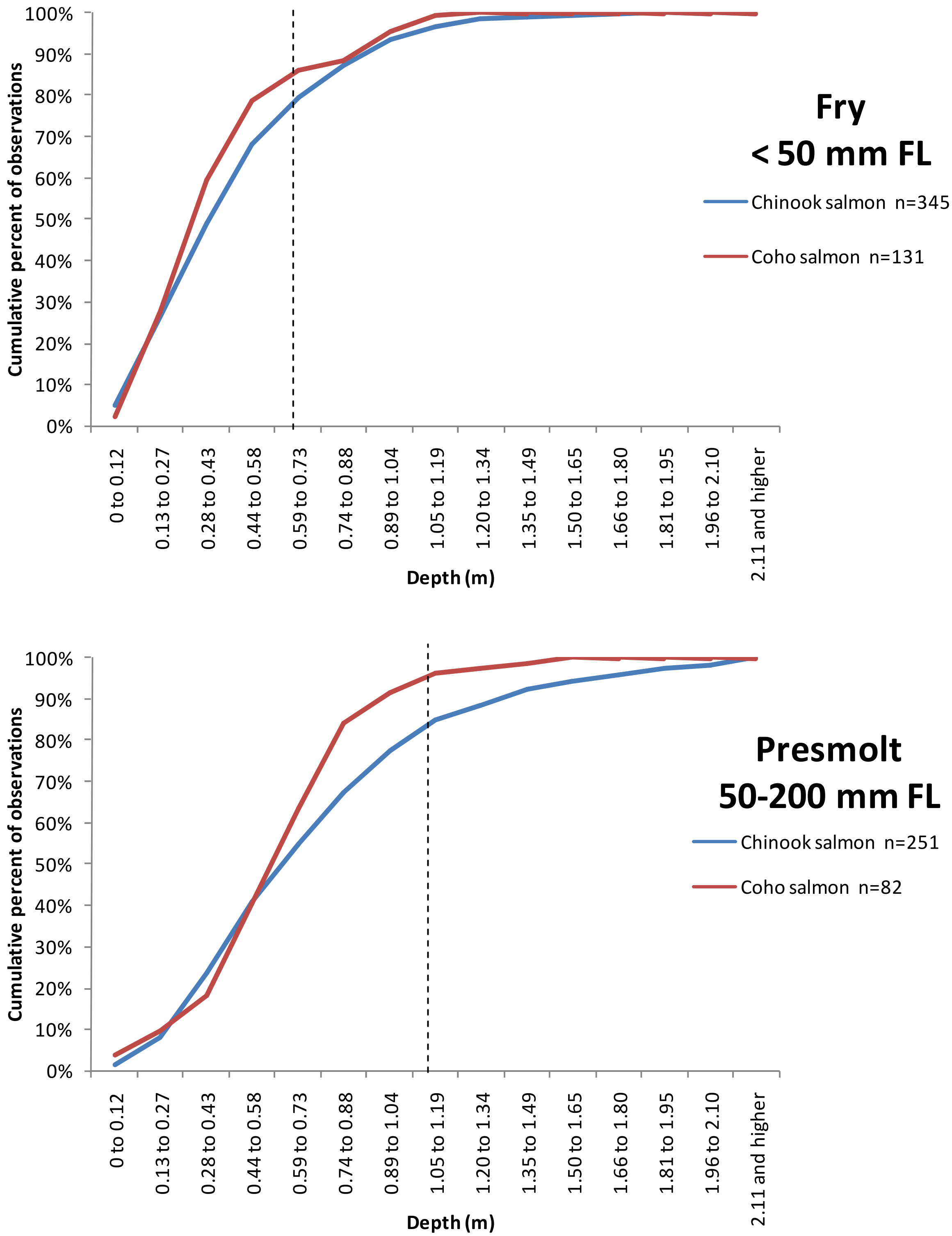


Figure 2. Cumulative percent of observations and water depth of rearing Chinook and coho salmon from HSC studies on the Trinity River (USFWS and Hoopa Valley Tribe 1999). Dashed line indicates maximum value for guild criteria.

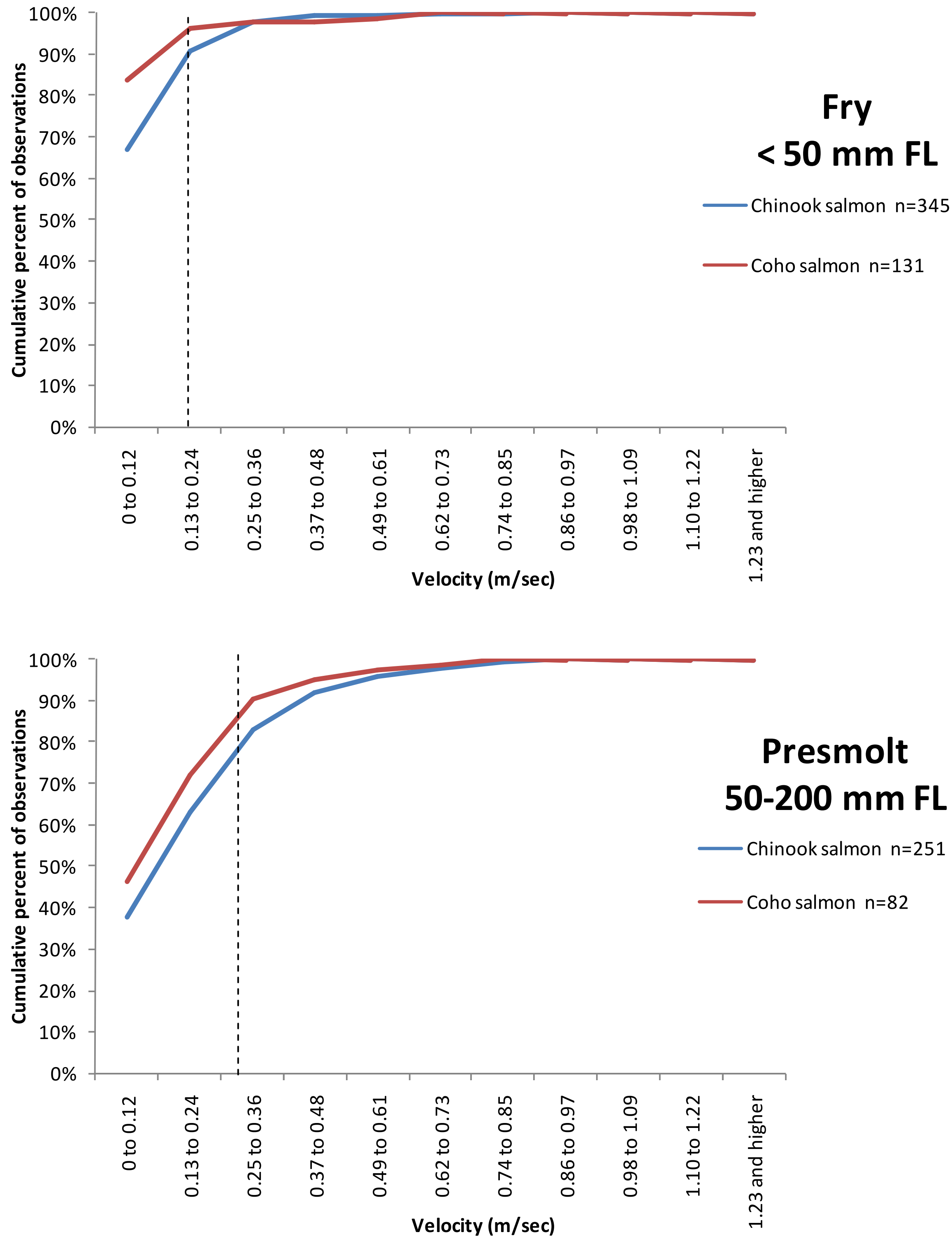
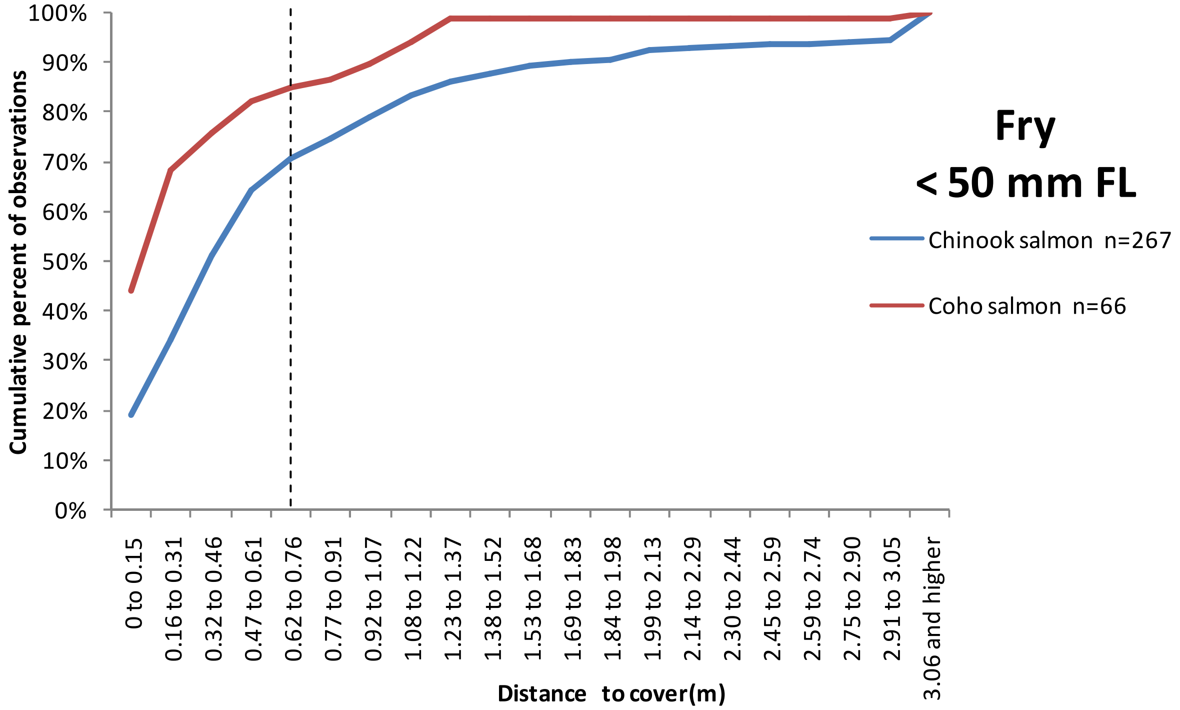


Figure 3. Cumulative percent of observations and mean column velocity of rearing Chinook and coho salmon from HSC studies on the Trinity River (USFWS and Hoopa Valley Tribe 1999). Dashed line indicates maximum value for guild criteria.



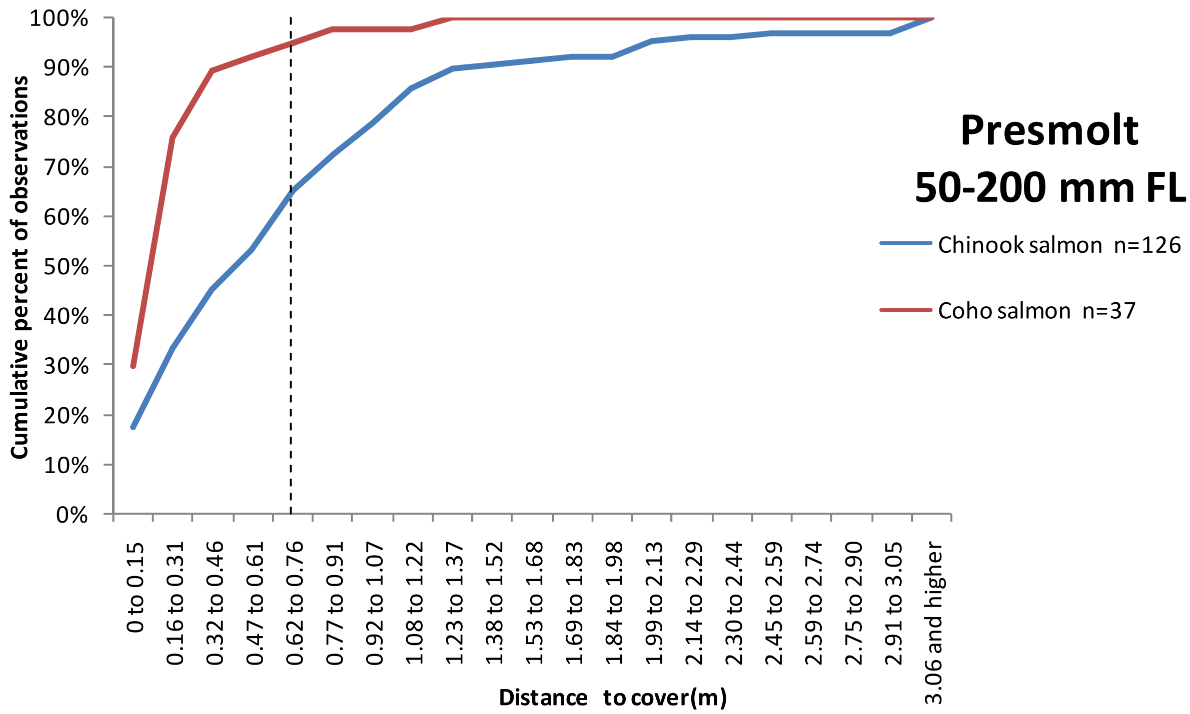


Figure 4. Cumulative percent of observations and distance to escape cover of rearing Chinook and coho salmon from HSC studies on the Trinity River (Yurok Tribe and USFWS unpublished data). Dashed line indicates maximum value for guild criteria.

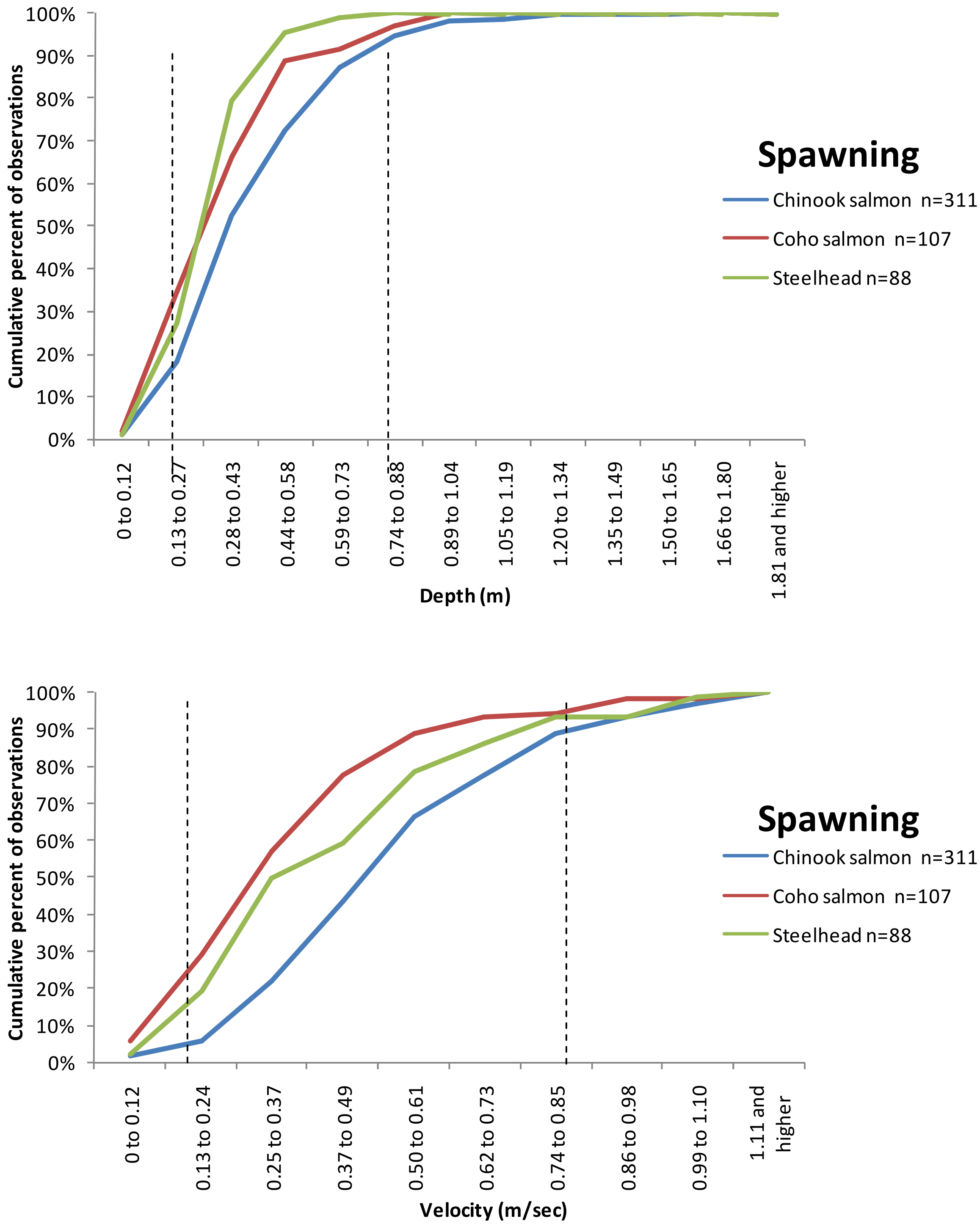


Figure 5. Cumulative percent of observations, water depth (above) and mean column velocity (below) of spawning Chinook salmon, coho salmon and steelhead from HSC studies on the Trinity River (USFWS and Hoopa Valley Tribe 1999). Dashed line indicates minimum and maximum values for guild criteria.

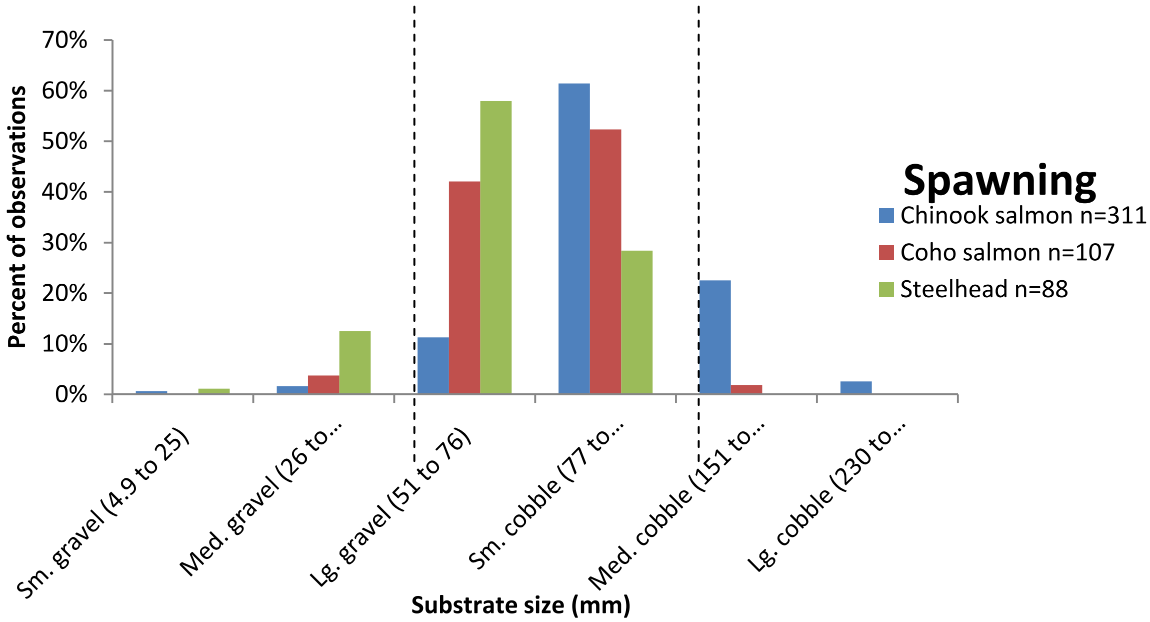


Figure 6. Percent of observations and substrate size for spawning Chinook salmon, coho salmon and steelhead from HSC studies on the Trinity River (USFWS and Hoopa Valley Tribe 1999). Dashed line indicates minimum and maximum values for guild criteria.

GPS points were taken using a Trimble ProXH GPS receiver with a Zephyr antenna paired with a tablet PC. Tablet PCs used in the survey include Getac model CA27, Xplore iX104C3 Plus and Mobile Demand T-8700. The points were collected in ArcPad (ESRI ver. 7.1) with GPS Correct software (Trimble ver. 2.20). When needed, GPS points were offset using either a Laser Atlanta Advantage or Trupulse 360 laser range finder with internal compass and inclinometer. The accuracy of the ProXH gps unit was <30 cm (<1.0 ft) and the accuracy of the Laser Atlanta Advantage and Trupulse 360 range finders was 15.2 cm (0.5 ft) and 30 cm (1.0 ft), respectively (see manufacturer specifications). The cumulative spatial accuracy of the GPS and laser range finder has not yet been evaluated. In the field, we validated the accuracy of each GPS point using geographically referenced high resolution 2007 aerial photographs on the tablet PC. All GPS data were collected in NAD 1983 State Plane California I FIPS 0401 (feet).

After data collection, field GPS data were differentially corrected in Pathfinder Office (Trimble ver. 4.0) to improve data accuracy using H-Star carrier and code processing with proximal base file providers. All data then went through a rigorous multi-step QA/QC post-processing stage to ensure that: 1) finalized polygons were the most accurate representation of guild areas; 2) all editing was transparent and reproducible; and 3) original field data were preserved (Figure 7). Spatial habitat data were analyzed in ArcMap (ESRI ver. 9.3) using the overlay toolset and Xtools Pro (Data East ver. 5.3) to calculate habitat polygon areas. For each site and flow, data were summed by guild (fry or presmolt) and habitat category. We calculated site-specific streamflow for each survey using daily average USGS gauging station data. Daily streamflows were averaged for sites that were mapped over multiple days. Survey dates, flows and gauge stations used for streamflow at each site are listed in Appendix A and B.

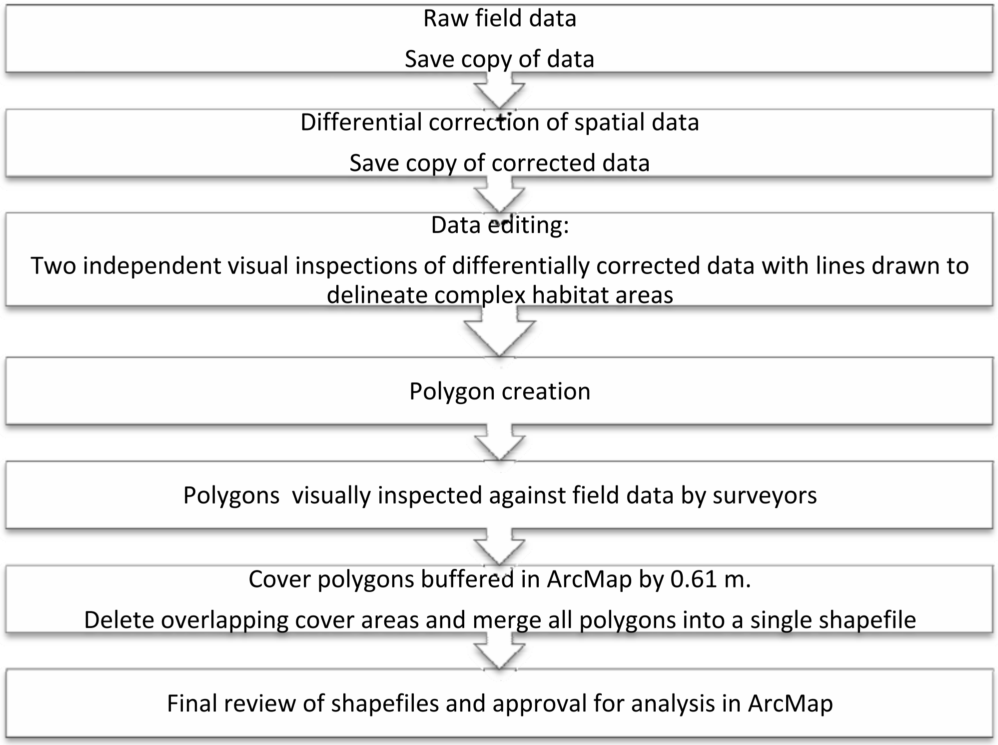


Figure 7. Spatial data post processing flow chart. The flow chart outlines the process that was used to edit spatial field data and create polygon shapefiles for data analysis.

At the Hocker Flat site, pre-construction and post-construction surveys were conducted at different streamflows to develop our understanding of flow-habitat relationships. Since flow-habitat curves are not linear (for long), three or four flows cannot be used to develop flow-habitat mathematical, graphical or statistical relationships, To compare pre-construction to post-construction flow-habitat relationships at Hocker Flat, we used linear interpolation between adjacent values of habitat abundance and survey date streamflows. Streamflows with measured habitat abundance values were then compared to habitat abundance modeled using the linear interpolation.

REARING HABITAT VALIDATION

The rearing habitat validation evaluated fish density differences among the four mapped habitat categories which included: within depth/velocity and escape cover (DV, C) criteria; within depth/velocity and outside of escape cover (DV, No C) criteria; outside of depth/velocity but within escape cover (No DV, C) criteria; and outside of both depth/velocity and escape cover (No DV, No C) criteria. Second, we evaluated differences due to channel locations being either near shore (<3 m {9.8 ft} from bank) or mid-channel (> 3 m from bank). This validation was conducted from the top of the Lewiston Cableway site to the top of the Cemetery side channel encompassing the entirety of the Cableway and Hoadley Gulch rehabilitation sites (rkm 176.5-178.0).

Habitat areas were mapped using the guild definitions and mapping methods described above. Habitat areas were then processed to develop polygons that delineated the entire channel into one of the four habitat categories. Polygons were then divided into near shore and mid-channel. A priori, we set sampling unit sizes to range from 12-31 m^2. This size range was selected using divers' experience to select an appropriate sampling unit size as large enough to reduce sample variance while small enough to facilitate efficient data collection with the desired number of sample units. To create the sampling units we preserved all polygons between 12 and 31m^2, divided all polygons >31m^2 into smaller units using a grid function in Xtools Pro and ArcMap. We deleted all sampling units smaller than 12m^2. The resulting sampling units had an average size of 25.5 m^2 (n=1808, SD=5.9) for Fry and 24.6 (1907, 6.0) for Presmolt.

We selected polygon segments to collect fish density information using a systematic sample with a random start. The systematic sample was applied separately for each of the four habitat categories for Fry and Presmolt guilds (Table 2). We applied selective random sampling to increase sampling effort in near shore areas to 80%. If less than the desired number of sampling units were available within a given category, then all of the units were sampled. For fry, n = 75; for presmolts, n = 67.

We conducted snorkel surveys for Chinook and coho salmon only at the selected habitat areas. First, we located dive segment perimeters using the aerial photography, GPS, tablet pc and laser range finder. Then a diver swam from the down-current edge of the unit moving up-current enumerating fishes that occurred within each polygon with a single pass count. We applied dives separately for fry and presmolt life stages and counted only the target life stage based on size classes. We sampled the fry polygons on March 26 and April 7, 2008, and the presmolt polygons on April 16 and 17, 2008.

Table 2. The number of dive segments selected for Chinook and coho salmon fry (<50 mm FL) and presmolts (50-200 mm FL) within depth/velocity and escape cover (DV,C), within depth/velocity and outside of escape cover (DV, No C), outside of depth/velocity within escape cover (No DV, C) and outside of depth/velocity and escape cover (No DV, No C) for the rearing habitat validation study. In the study area, only four edge sample units were present outside of depth/velocity and within escape cover creating an unbalanced study design.

		Habitat Category			
Guild	**Channel type**	**DV, C**	**DV, No C**	**No DV, C**	**No DV, No C**
Fry	Edge	16	16	15	15
	Mid-channel	2	4	3	4
Presmolt	Edge	16	16	4	16
	Mid-channel	3	4	4	4

The species- and life stage-specific data were analyzed separately to test for habitat selection. First we calculated fish density of each sampling unit. Since the resulting data were not normally distributed, we applied a square root transformation to the fish densities. We then tested the two factors using a general linear model (GLM) with type III error at α=0.05 (Minitab Ver. 5.1). We treated fish densities as the dependent variable and the two factors (four habitat and two distance to shore categories) as independent variables in each GLM. Once the null hypothesis (no difference among factors) was rejected, we employed a Tukey's post hoc pair-wise test for honestly significant differences between habitat categories.

SPAWNING HABITAT VALIDATION

We conducted a spawning habitat guild validation study in 2007 and 2008 to compare actual redd locations with predicted spawning habitat. We conducted this study from the top of the Hoadley Gulch site at Old Bridge in Lewiston to the Rush Creek boat launch (rkm 170-172.7). The side channel complex was not surveyed due to time constraints. We also surveyed from the top of the Salt Flat site to the bottom of the Dark Gulch site (rkm 165.5-177.3). We mapped redd locations on December 12, 2007, at a dam release of 305 cfs, after 98% of redds had been surveyed in that reach as part of the Trinity River redd survey (Hoopa Valley Tribe, USFWS and Yurok Tribe unpublished data). Redds were mapped by placing a point in the center of the pit of each redd that was clearly identifiable at the time of the survey. This survey was conducted using 2007 high resolution aerial photography, ProXH GPS and tablet pc in ArcPad with GPS Correct data collection software. All redd locations and mapped spawning habitat areas were differentially corrected in Pathfinder Office. To avoid surveyor bias, we mapped redd habitat between March 27 and April 14, 2008 at dam releases of 309 and 296 cfs when redd locations were no longer clearly visible. Redd validation analyses were conducted by overlaying the redd locations with the mapped spawning habitat areas. Redd locations were then tallied by either occurring within or outside of habitat areas using the Overlay toolset in ArcToolbox.

RESULTS

REARING HABITAT VALIDATION

Mean fish densities varied widely and significantly among habitat categories. For both Chinook and coho salmon fry and presmolts, mean fish density was highest in the habitat category that met both depth/velocity and escape cover criteria (Table 3; Figure 8-9). For both species, mean fish densities were lowest in the habitat category that met neither the depth/velocity nor the escape cover criterion. Coho salmon were present in the sample areas in much lower densities than Chinook salmon. The total fry count was 4,481 Chinook salmon and 267 coho salmon. The total presmolt count was 3,652 Chinook and 582 coho salmon.

As a potentially useful expansion factor for our assessments, Chinook salmon fry were 2.9 to 3.3 times more numerous where both the depth/velocity and escape cover criteria were met than where only one criterion was met. Chinook salmon fry were 5.0 to 5.6 times more numerous in areas that met either the depth/velocity or the escape cover criterion than where neither criterion was met. Chinook salmon fry were 26.9 times more numerous when both habitat criterion were met in any combination than where neither criterion were met.

Chinook salmon presmolts were 1.6 to 2.5 times as numerous where both criteria were met than where only one criterion was met. Chinook salmon presmolts were 2.8 to 4.3 times more numerous in areas that met either depth/velocity or escape cover criterion than where neither were met. Chinook salmon presmolts were 14.2 times more numerous when both habitat criterion were met in any combination than where neither criterion were met.

Fish densities were significantly different ($P < .001$) among habitat categories for all species/life stages (Table 4). No significant differences in fish density were identified between near shore or mid-channel areas ($P > 0.15$ for all). Pair-wise tests among habitat categories indicated that areas within depth/velocity and escape cover criteria had significantly higher densities of fish than other habitat categories for all species and life stages ($P < 0.001$) for all except presmolt Chinook salmon DV, no C where $P = 0.017$. Chinook salmon fry and presmolt densities in areas within the depth/velocity criterion, but outside the escape cover criterion and areas that were outside the depth/velocity criterion, but within the escape cover criterion were significantly higher than areas outside of both depth/velocity and escape cover criteria ($P < 0.03$ for all). This was not significant for coho salmon fry or presmolts ($P > 0.05$ for all). In no case for any species/life stage were fish densities significantly different between areas within depth/velocity but outside of escape cover criterion and areas outside of depth/velocity but within escape cover criterion ($P > 0.05$).

Table 3. Mean fish density and standard error (SE) by species and life stage in the four habitat categories: within both depth/velocity and escape cover (DV, C), within depth/velocity and outside of escape cover (DV, No C), outside of depth/velocity within escape cover (No DV, C) and outside of both depth/velocity and escape cover (No DV, No C) from the rearing habitat validation study. Values are not transformed.

		Habitat Category (mean fish per sq. m and SE)			
Species	**Life Stage**	**DV, C**	**DV, No C**	**No DV, C**	**No DV, No C**
Chinook salmon	Fry	7.8 ± 1.3	2.7 ± 0.63	2.4 ± 0.41	0.48 ± 0.17
	Presmolt	5.2 ± 0.53	3.2 ± 0.24	2.1 ± 0.62	0.74 ± 0.12
Coho salmon	Fry	0.64 ± 0.13	0.09 ± 0.04	0.09 ± 0.05	0.01 ± 0.03
	Presmolt	1.3 ± 0.21	0.23 ± 0.06	0.06 ± 0.04	0.08 ± 0.25

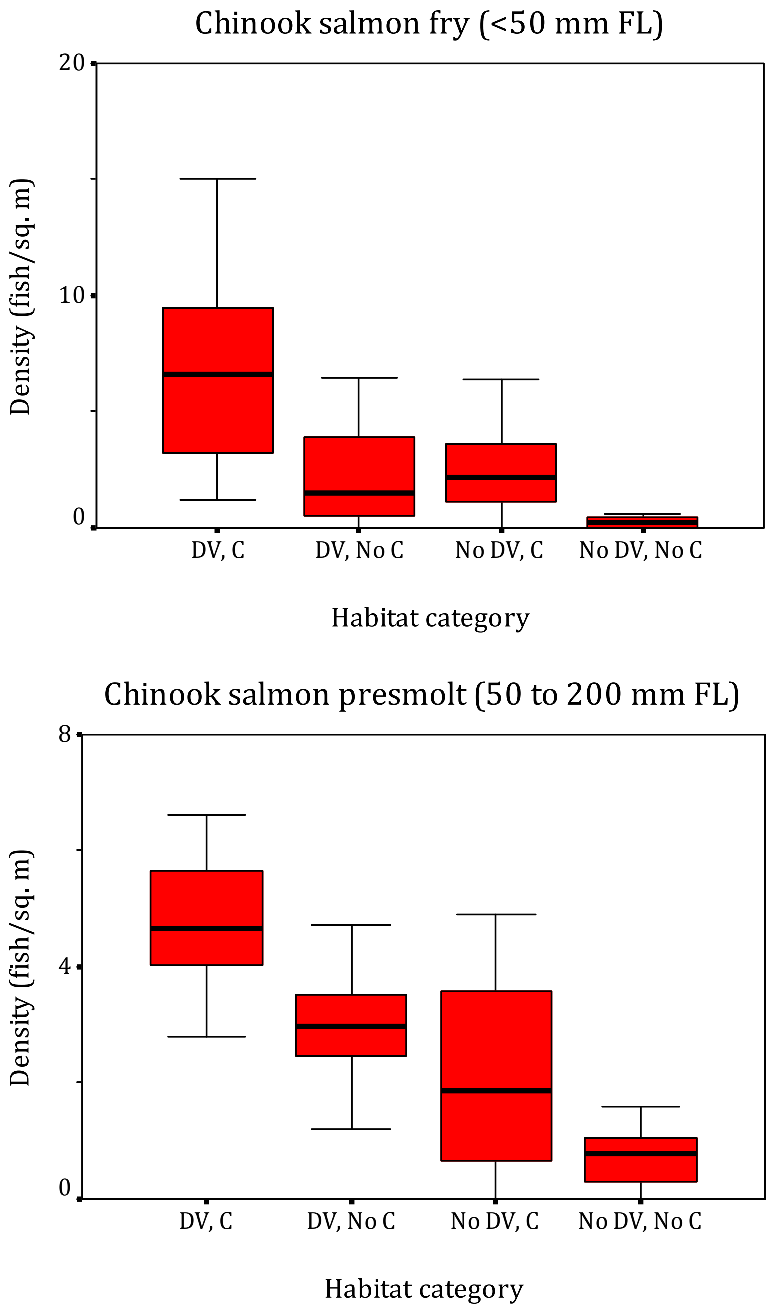
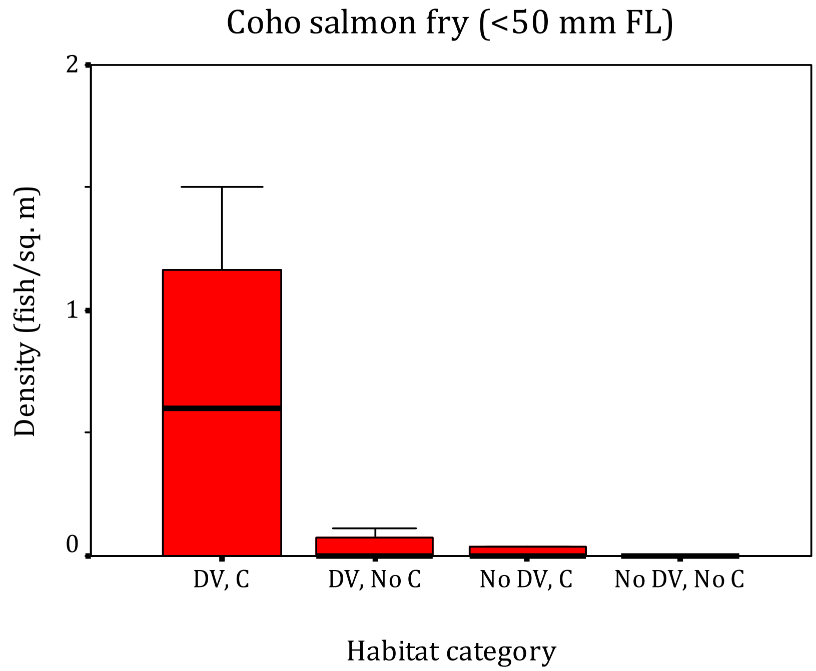


Figure 8. Chinook salmon fry and presmolt densities for four habitat categories. The four habitat categories are combinations of depth/velocity (either DV for within both the dual criteria or No DV for outside either of the dual criteria and proximity to escape cover (either C for within the criterion or No C for outside of the criterion). The following variables are represented in the plot: (1) a horizontal line is drawn at the median observation, (2) the boxes represent the first (Q1) and third quartile (Q3) values, (3) whiskers are defined by the values adjacent to the lowest and highest observations using the following limits (a) lower limit: Q1-1.5*(Q3-Q1) and b) upper limit: Q3+1.5*(Q3-Q1).



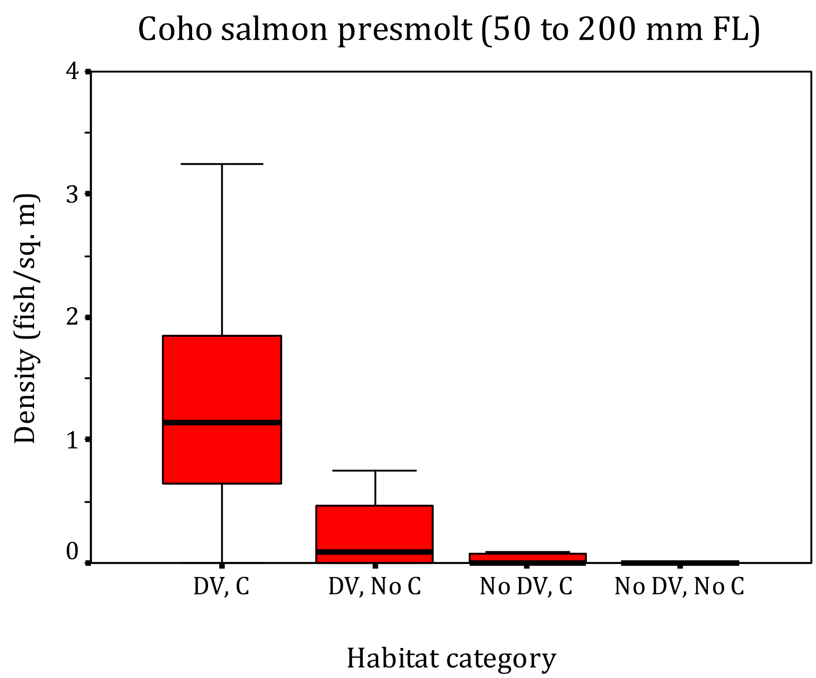


Figure 9. Coho salmon fry and presmolt densities for four habitat categories. The four habitat categories are combinations of depth/velocity (either DV for within both the dual criteria or No DV for outside either of the dual criteria and proximity to escape cover (either C for within the criterion or No C for outside of the criterion). See Figure 8 for explanation of the box and whisker plots.

Table 4. General linear model analysis of differences between fish densities among channel locations and habitat categories. Channel locations were defined as either <3m or >3m from each bank and habitat categories refer to depth/velocity and escape cover combinations.

Life stage	**Species**	**Source**	**DF**	**Adj. SS**	**Adj. MS**	**F**	***P***
Fry	Chinook salmon	Channel location	1	1.1590	1.1590	1.9700	0.1650
		Habitat category	3	41.6170	13.8720	23.5600	<0.0001
		Error	70	41.2180	0.5890		
	Coho salmon	Channel location	1	0.1659	0.1659	1.8900	0.1740
		Habitat category	3	4.1770	1.3923	15.8400	<0.0001
		Error	70	6.1523	0.0879		
Presmolt	Chinook salmon	Channel location	1	0.1684	0.1684	0.7800	0.3800
		Habitat category	3	22.3083	7.4361	34.5800	<0.0001
		Error	62	13.3325	0.2150		
	Coho salmon	Channel location	1	0.1614	0.1614	1.2100	0.2760
		Habitat category	3	9.3255	3.1085	23.2700	<0.0001
		Error	62	8.2832	0.1336		

SPAWNING HABITAT VALIDATION

A total of 131 redd locations were identified in the spawning habitat guild validation study areas. At the Hoadley Gulch site, of the 46 redds identified just six were within mapped spawning habitat areas. At the Salt Flat site none of the 10 redds identified on the site fell within mapped spawning habitat areas. At the Dark Gulch site, 41 of the 75 redds identified were within mapped spawning habitat areas. In total, 64% of the redd locations were found outside of the mapped spawning habitat areas (e.g., Figure 10).

SITE SPECIFIC HABITAT MAPPING

Our monitoring allowed comparison between pre- and post-construction areas at the Vitzhum Gulch, Lower Indian Creek, and Hocker Flat sites. Across site comparisons are not possible when different habitat definitions were used (i.e. Vitzhum Gulch and Lower Indian Creek vs. Hocker Flat). The before-after comparisons conducted at these sites are intended to help us better understand the effects of channel rehabilitation efforts and improve rehabilitation site design and implementation in the future.

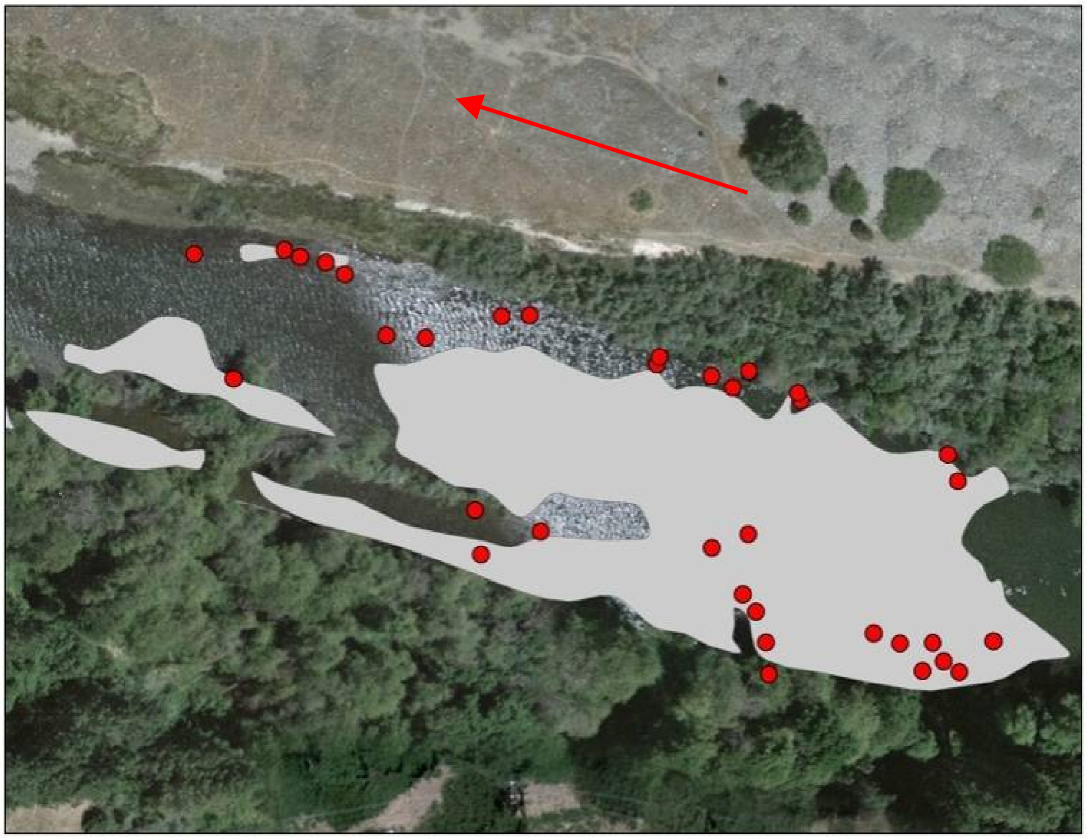


Figure 10. An example of spawning habitat validation data within Dark Gulch bank rehabilitation site (rkm 171.15 to 171.35). The grey areas represent mapped spawning habitat areas and the redd dots represent redd centroids. The flow direction is indicated by the red arrow.

Summary data for pre-construction evaluations conducted in 2008 and the survey of the Salt Flat site are presented in Appendix C. An aerial view and extent of the sites are presented in Appendix D through Appendix H. These data (aerial views and extents) will be reviewed in detail following construction and post-construction data collection or, in the case of the Salt Flat site, another survey will be conducted after a ROD wet or extremely wet water year. A more detailed review of the Indian Creek study area, including the Lower Indian Creek, Vitzhum Gulch and Hocker Flat rehabilitation sites, is presented below.

INDIAN CREEK REHABILITATION SITE

In August of 2007, we conducted a pre-construction rearing habitat survey at the Indian Creek site at a mean streamflow of 436 cfs[1]. The evaluation started upstream of the Vitzhum Gulch site at an island complex and extended downstream of the Lower Indian Creek site to

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[1] Throughout the 2008 field efforts, there were significant discrepancies between flows at Trinity River below Limekiln Gulch near Douglas City and the gauges above and below. Therefore, we used the total of Trinity River at Lewiston gauge plus the downstream tributaries listed above to arrive at the Lower Indian Creek streamflows.

the confluence with Weaver Creek (rkm 151.1 through 155.9; Appendix I). This area was divided into two subsections for the post-construction assessment to target areas that changed the most from bank rehabilitation actions: (1) Vitzhum Gulch (rkm 154.7-155.8; Appendix J) and (2) Lower Indian Creek (151.5-152.4; Appendix K). Escape cover was not mapped in the pre-construction survey. All comparisons between pre-construction and post-construction conditions at either the Vitzhum Gulch or the Lower Indian Creek sites refer to depth/velocity criteria (DV-I) habitat definitions only.

At the Vitzhum Gulch site we surveyed: 1) pre-construction in August 2007, 2) post-construction in April 2008 and 3) post-construction/post-high flow habitat conditions in September 2008. We mapped post-construction/post-high flow habitat conditions to document dramatic changes from a single managed spring release. Rearing habitat abundance for Chinook and coho salmon increased after construction by 224% (2,736 m^2) and 71% (3,476 m^2) for fry and presmolts, respectively (Table 5). The increases occurred primarily within the 13 construction riparian berm notches that mimicked backwater or alcove type habitat.

A combination of spring snow melt and a ROD normal water year spring release in May, 2008, brought the daily averaged streamflow up to approximately 6,609 cfs at Vitzhum Gulch (Figure 12 and Table 6). After the release, Chinook and coho salmon fry and presmolt rearing habitat decreased by 24% (947 m^2) and 12% (1,018 m^2) as fine sediment was deposited within some of the notches (Figure 11). Some berm notches were maintained, which is apparently related to a channel that formed behind the riparian berm during the high flow release. We analyzed the areas within the notches separately to evaluate changes at the berm notches from the managed spring release including an evaluation of escape cover. Within the berm notches, depth/velocity only habitat areas (DV-I, No C) decreased by 726

Table 5. Habitat conditions before and after construction at the Indian Creek site. Habitat categories correspond to areas (m^2) meeting the depth/velocity dual criteria of rearing habitat for Chinook and coho salmon fry (<50 mm FL) and presmolts (50-200 mm FL) m^2 (57%) for Chinook and coho salmon fry and presmolts (Figure 13), while depth/velocity and escape cover areas (DV-I, C) increased by 230 m^2 (51%).

Evaluation Type	**Disch. (cfs)**	**Habitat Category (sq. m)** Fry (DV-I)	Presmolt (DV-I)
Indian Creek pre-construction	436	5,520	20,859
Vitzhum Gulch pre-construction	436	1,224	4,872
Vitzhum Gulch post-construction	411	3,960	8,348
Vitzhum Gulch post-construction/post-high flow	474	3,013	7,330
Lower Indian Creek pre-construction	439	1,029	3,214
Lower Indian Creek post-construction/post-high flow	439	3,515	6,920

At the Lower Indian Creek site, we surveyed before construction at 436 cfs and after construction at 439 cfs. Chinook and coho salmon fry and presmolt rearing habitat abundance increased by 241% (2,486 m^2) and 115% (3,706 m^2), respectively, following construction (Figure 14). The habitat gains were due, in part, to the construction of a side channel that parallels approximately 900 m of the main channel within the site, increasing shallow low velocity areas that fall within guild criteria. The constructed side channel contributed 25% (541 m^2) of fry habitat and 24% (1,106 m^2) of presmolt habitat.

We conducted a multiple flow survey at a 0.5 rkm segment of the Lower Indian Creek site, which we refer to as Lower Indian Creek (A). We mapped habitat abundance at four streamflows between 375 and 2,170 cfs. The surveys were conducted on the ascending and descending limbs of the managed spring release. Chinook and coho salmon fry habitat within depth/velocity and escape cover criteria (DV-I, C) decreased by 34% (167 m^2) between the maximum value at 375 cfs and the minimum at 2,170 cfs (Figure 16). Presmolt habitat abundance varied by streamflow, but did not change more than 23% (203 m^2). Alternatively, areas of Chinook and coho salmon fry and presmolt rearing habitat within the depth/velocity criteria and outside of the escape cover criterion decreased with streamflow by 79% (1,430 m^2) and 70% (2,463 m^2) for Chinook and coho salmon fry and presmolts. The decrease in habitat abundance with increasing streamflow in the side channel was due to the steep slope of the constructed stream banks. The constructed side channel contributed a minimum of 19% (168 m^2) of presmolt DV-I, C at 1,392 cfs up to 72% (651 and 706 m^2) of presmolt DV-I, No C at 1,392 cfs and 2,170 cfs, respectively (Figure 16). These increases in rearing habitat are dependent on the persistence of the side channel with annual Lewiston Dam releases. With riparian development and recruitment of large wood, the rearing habitat abundance in the side channel may continue to increase.

HOCKER FLAT REHABILITATION SITE[2]

Preconstruction conditions at the Hocker Flat study site consisted of a channel confined by riparian berms along most of both banks (Chamberlain et al. 2007). Preconstruction conditions of the Hocker Flat site were surveyed in 2003. We conducted the post-construction/post-high flow survey of the Hocker Flat site in 2008 during the third water year following construction. Between construction and our survey, the site had experienced several managed spring releases including dry, normal and extremely wet water year types (Figure 17). Between construction and the post-construction/post-high flow survey, riparian establishment occurred in some locations.

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[2] Habitat categories designated by DV-H correspond to the Hocker Flat site-specific definitions; see rearing habitat guild definitions section.

Table 6. Post-construction rearing habitat at the Lower Indian Creek site in 2008. The Lower Indian Creek (A) site corresponds to segments of the base flow survey that were used for a flow-habitat evaluation. Habitat categories refer to areas (m^2) of depth/velocity and escape cover combinations of rearing habitat for Chinook and coho salmon fry and presmolts.

			Habitat Category (sq. m)			
Evaluation Type	**Life Stage**	**Disch. (cfs)**	**DV-I, C**	**DV-I, No C**	**No DV-I, C**	**No DV-I, No C**
Vitzhum Gulch post-construction	Fry	411	1,621	2,339	2,551	25,718
	Presmolt	411	2,949	5,399	1,224	22,658
Vitzhum Gulch post-construction/post-high flow	Fry	474	1,808	1,204	3,047	25,651
	Presmolt	474	3,706	3,624	1,149	23,231
Lower Indian Creek post-construction	Fry	439	850	2,665	1,429	29,267
	Presmolt	439	1,441	5,479	837	26,452
Lower Indian Creek (A) post-construction	Fry	375	485	1,813	436	12,078
		720	343	898	566	13,944
		1,392	347	383	1,198	14,737
		2,170	318	428	1,364	16,040
	Presmolt	375	761	3,523	159	10,368
		720	689	2,278	220	12,564
		1,392	892	1,299	653	13,821
		2,170	752	1,060	930	15,408

Figure 11. Effects of a spring ROD Lewiston Dam release on the berm notch bank rehabilitation treatment type at the Vitzhum Gulch site. The berm notch treatments created large habitat gains post-construction (A; Fall 2007). These gains, however, were greatly diminished after the spring 2008 Lewiston Dam flow release which resulted in the deposition of large quantities of fine sediment in the berm notches (B; Summer 2008)

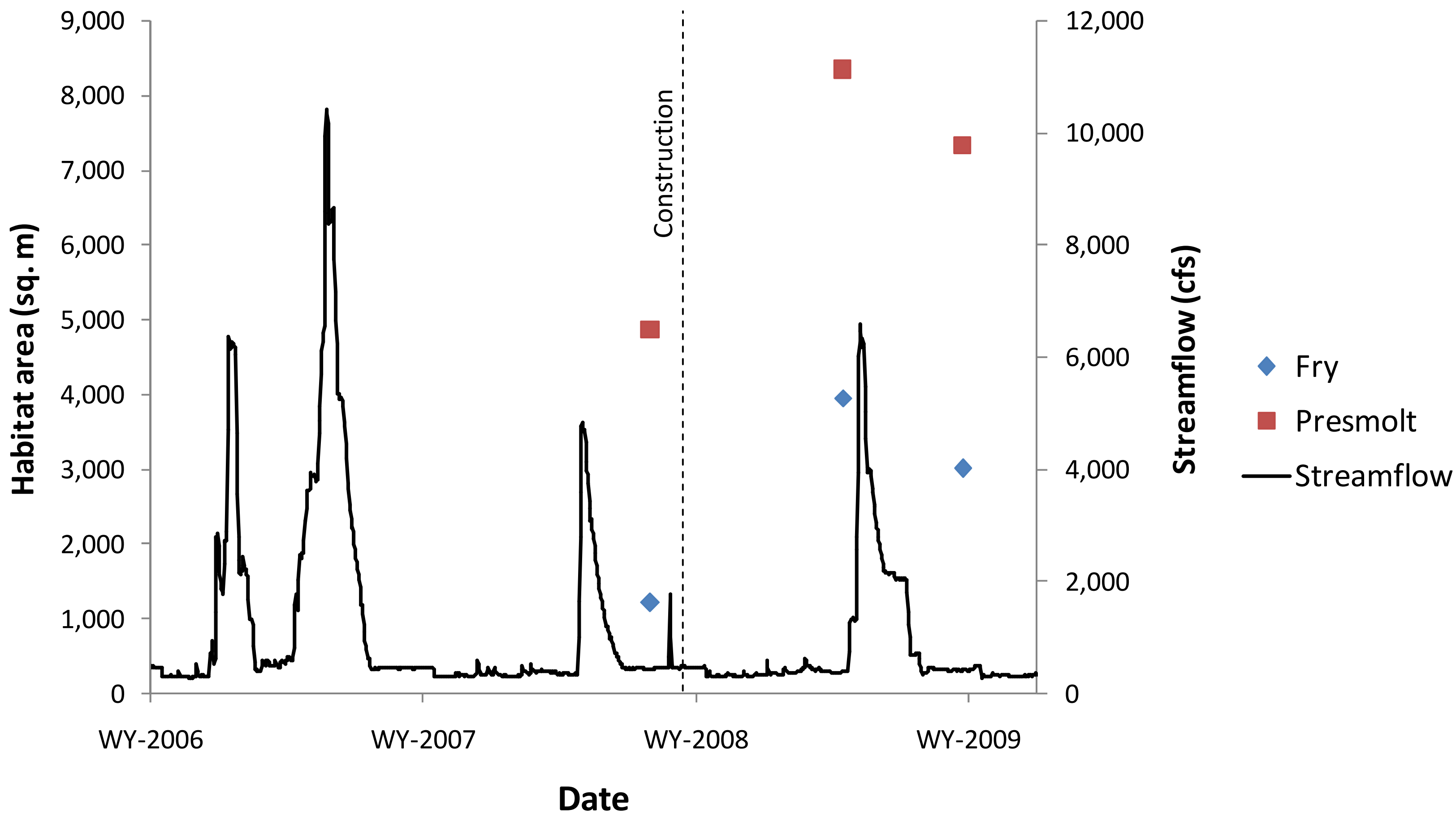

Figure 12. Fry and presmolt habitat before construction, following construction and following the initial managed spring release at the Vitzhum Gulch site. Chinook and coho salmon fry and presmolt habitat categories correspond to depth/velocity habitat definitions only.

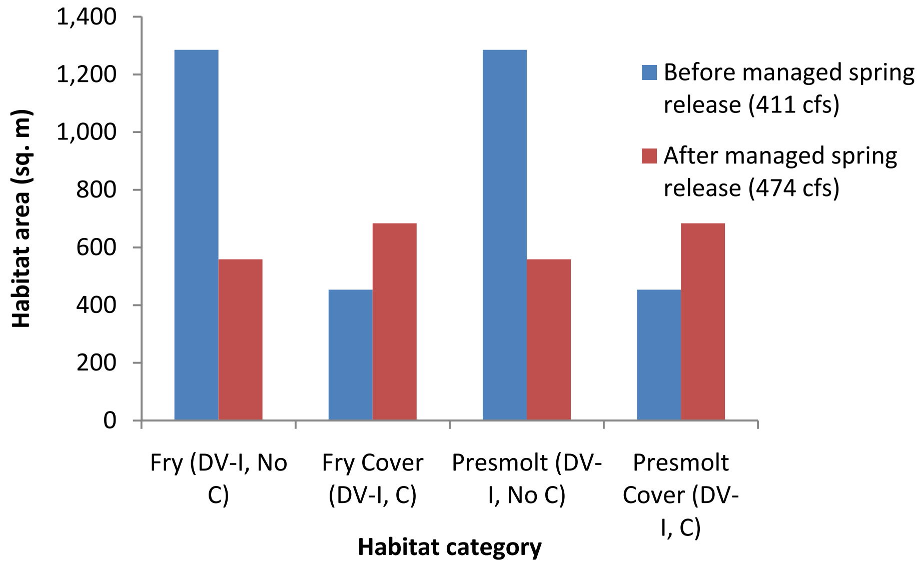

Figure 13. Chinook and coho salmon rearing habitat within the constructed notches only at the Vitzhum Gulch site before the spring flow release of 2008 and after the spring flow release of 2008. All of the area within the constructed notches was within the depth/velocity criteria, therefore the No DV habitat categories were excluded from the figure.

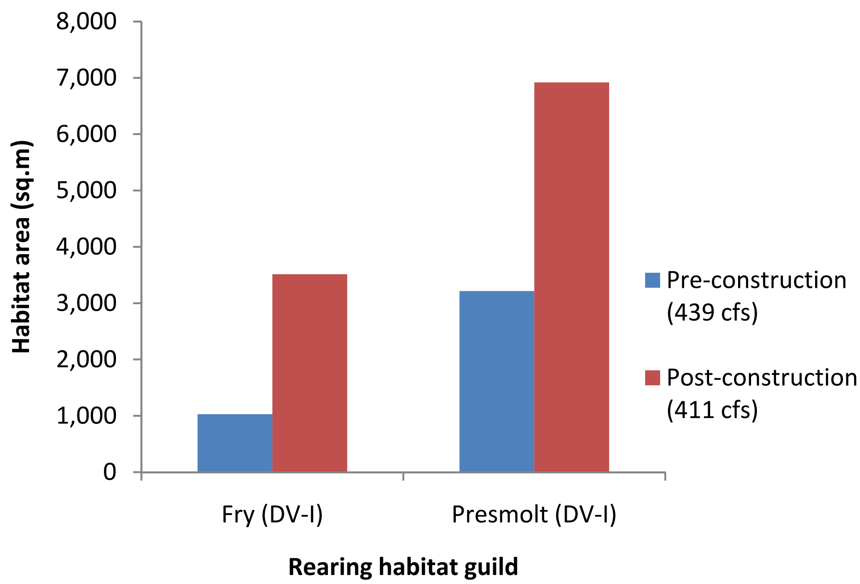

Figure 14. Pre-construction and post-construction rearing habitat of the Lower Indian Creek site conducted in 2007 and 2008. The Chinook and coho salmon fry and presmolt habitat categories correspond to depth/velocity habitat definitions only.

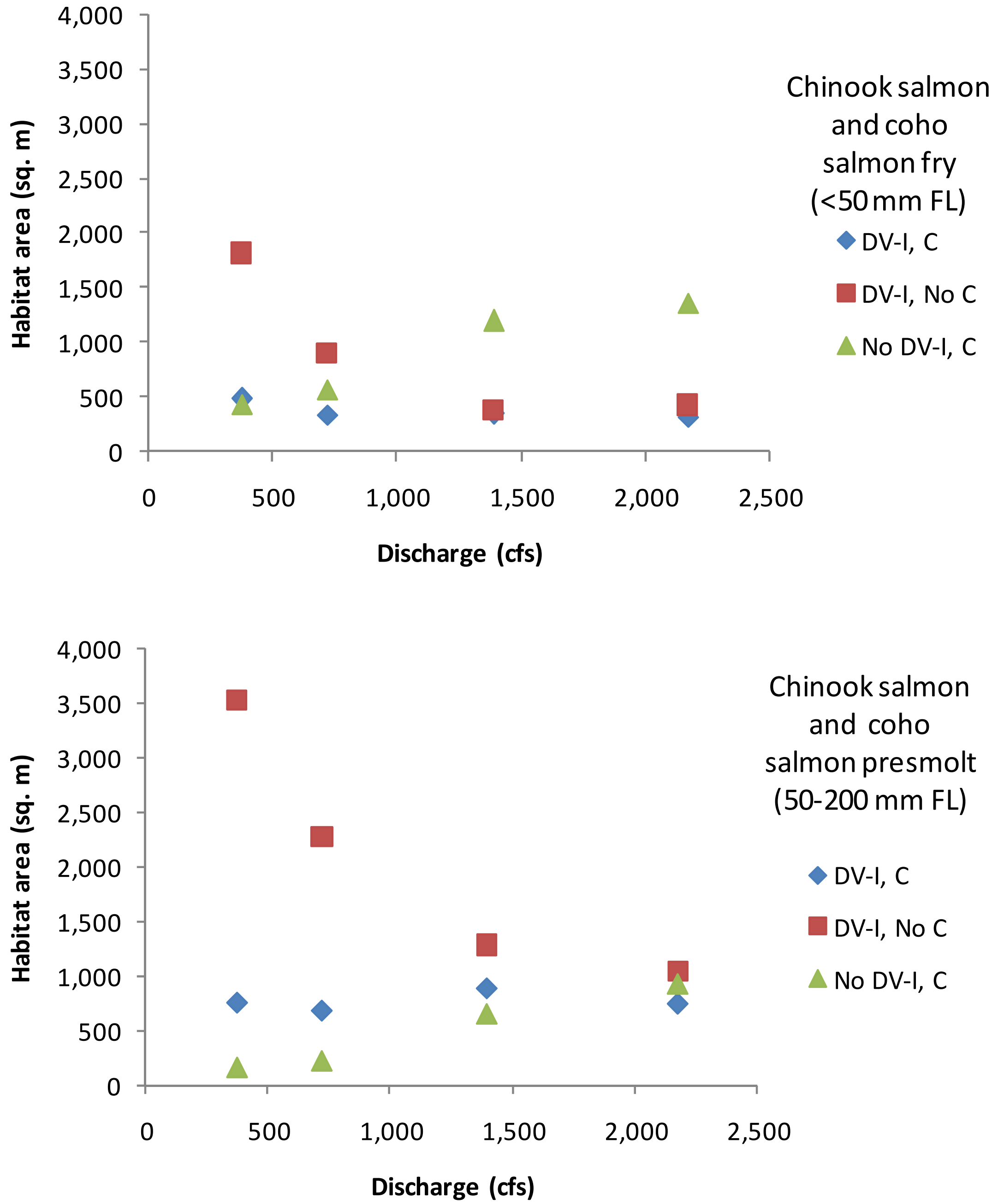

Figure 15. Rearing habitat abundancey by streamflow for Chinook and coho salmon fry (upper) and presmolts (lower) at the Lower Indian Creek (A) site. Habitat categories correspond to areas (m^2) of depth/velocity (DV) and escape cover (C) combinations.

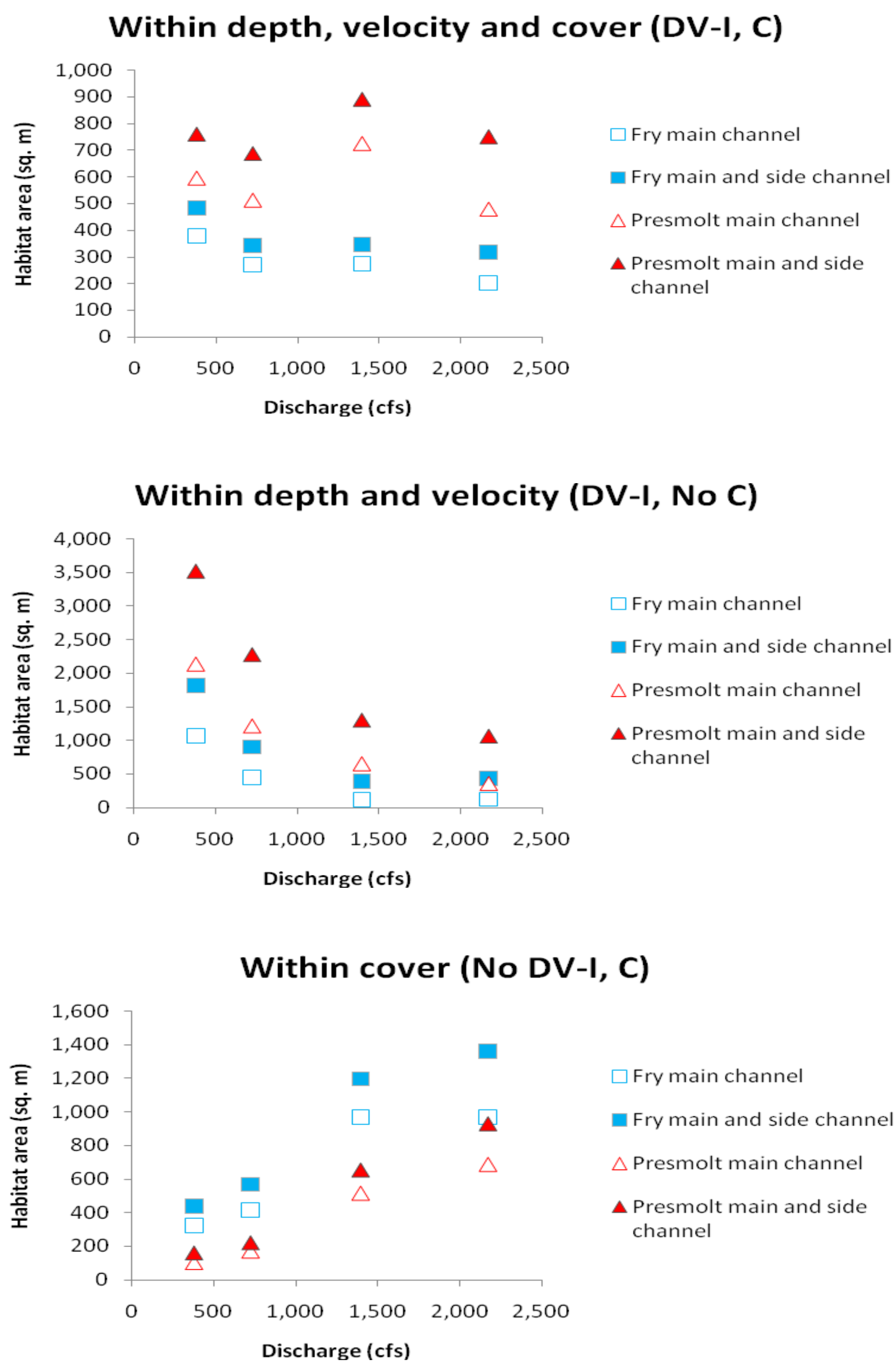

Figure 16. Chinook and coho salmon rearing habitat abundance at the Lower Indian Creek (A) site in the main channel and side channel. White squares indicate fry habitat in the main channel while blue squares indicate fry habitat in the main and side channel combined. White triangles indicate presmolt habitat in the main channel while red triangles indicate fry habitat available in the main and side channels.

We surveyed Hocker Flat at summer base flow (718 cfs). The study site extended from the confluence of the Trinity River with Canyon Creek downstream 1.5 rkm to near the Junction City Campground (Appendix L). The multiple-flow habitat survey of Hocker Flat (A) was conducted from below the confluence with Canyon Creek downstream 0.4 rkm to the first bedrock pool. The Hocker Flat (A) survey included four streamflows from 443 to 2,490 cfs. Pre-construction data did not include escape cover. All before and after construction comparisons of rearing habitat abundance data relate to DV-H habitat definitions only. Data were also collected using the standard (not Hocker Flat) habitat guild definitions but not used in comparisons among bank rehabilitation sites (Appendix M).

At the Hocker Flat site Chinook and coho salmon fry and presmolt rearing habitat increased by 49% (811 m^2) and 67% (1,936 m^2) between pre-construction (conducted at 602 cfs) and post-construction/post-high flow surveys (conducted at 718 cfs) (Table 7). At the multiple flow evaluation site, Hocker Flat (A), Chinook and coho salmon fry and presmolt habitat areas increased post-construction/post-flow at all surveyed streamflows except possibly for presmolts at 2490 cfs (Figure 18). From linear interpolation, at 596 cfs fry rearing habitat area increased by 238% (1,253 m^2) and presmolt habitat area by 180% (1668 m^2), which were the largest differences observed between pre-construction and post-construction/post-high flow conditions (Figure 17). The smallest changes in linearly interpolated rearing habitat area were observed at the highest streamflow, 2490 cfs; habitat area increased by 140% (340 m^2) and 77% (315 m^2) for fry and presmolts, respectively.

A more accurate and precise analysis of post-construction/post-high flow rearing habitat is possible when escape cover is included. Chinook and coho salmon fry habitat areas that included depth/velocity and escape cover (DV, C) had a minimum value at 803 cfs and increased with streamflow by 187% (146 m^2) at 2,490 cfs, the highest measured streamflow (Figure 19 and 20). Depth/velocity and escape cover (DV, C) habitat abundance for Chinook and coho presmolts also had a minimum value at 803 cfs and increased by 205% (174 m^2) to a maximum value at 1,920 cfs. The areas within depth/velocity and outside of escape cover criteria (DV, No C) were greatest at 443 cfs and decreased by 84% (1,848 m^2) and 85% (2,839 m^2) with increasing streamflow to a minimum measured area at 2,490 cfs for fry and presmolt life stages, respectively. Escape cover areas outside of the depth/velocity criterion for salmon fry and presmolts had a minimum value at 443 cfs and increased with streamflow at 2,490 cfs by 540% (362 m^2) and 1,064% (383 m^2), respectively.

DISCUSSION

The TRRP is implementing a host of management actions to reduce limiting factors of the Trinity River system below Lewiston Dam with particular emphasis on anadromous salmonid populations. As the primary limiting factor of Chinook and coho salmon populations, habitat abundance is one of the primary metrics of interest in evaluating progress of the TRRP toward restoration goals of population increases (USFWS and HVT 1999; Trinity River Restoration Program and ESSA Technologies Ltd. 2009). In this project we developed and evaluated a rearing and spawning habitat assessment methodology. In addition, we applied the rearing habitat assessment methodology to develop quantitative estimates of changes from mechanical bank rehabilitation actions.

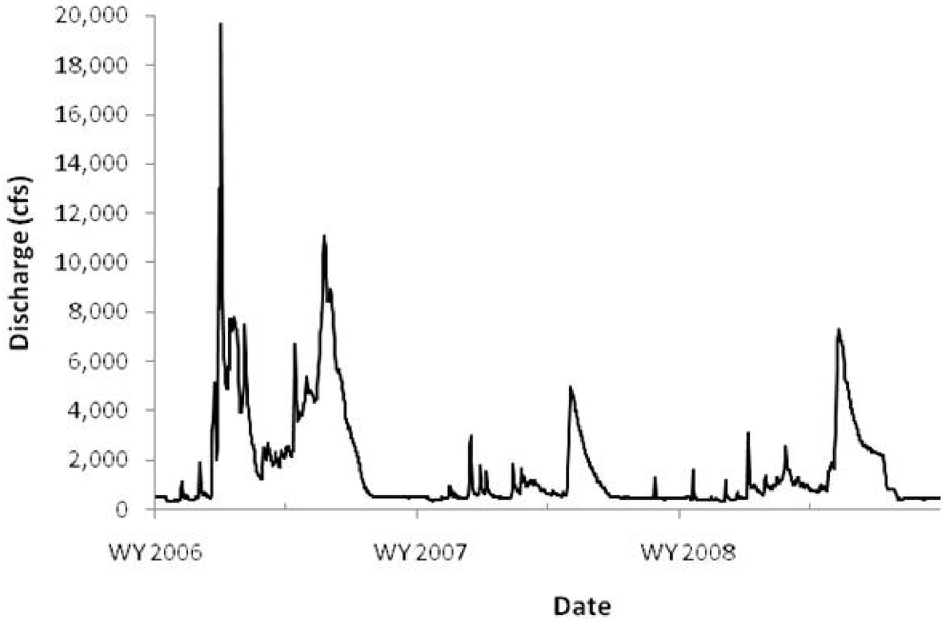

Figure 17. Post-construction Lewiston Dam release at the Hocker Flat site, 2006-2008 water years. Record of Decision water year types were extremely wet, dry and normal from 2006 to 2008, respectively. X-axis labels indicate beginning of each water year.

METHODOLOGY AND VALIDATION

The 2007 and 2008 studies were the first time these methods for habitat assessment and validation have been employed. The habitat evaluation methods are an ongoing modification and improvement of past efforts to assess habitat rehabilitation on the Trinity River. The habitat evaluation for salmonid populations in the Trinity River reported in the TRFE and leading to the ROD used one-dimensional (perpendicular to flow) crosses sections. The one-dimensional habitat evaluation method has been criticized for, among other things, performing poorly in complex channels (Davis 2007; Williams 2009). The Biomonitoring method, developed and applied on the Trinity River, improves on the cross section-based effort by developing planar representations of habitat at study sites and characterizing habitat variables over sections of river (Chamberlain et al. 2007). Spatially explicit data from Biomonitoring method were useful for evaluating habitat at a site level as well as specific features within a rehabilitation site. This method was limited by the use of survey techniques that were slow and cumbersome in the field and during post processing. The Biomonitoring method also did not include escape cover in habitat definitions, a variable identified as a key component to high value salmonid rearing habitat (Hardy et al. 2006). Another habitat assessment methodology developed and applied on the Trinity River, Judgment Based Habitat Mapping, was similar to the Biomonitoring method in that it produces planar representations of habitat within a study area, but relied on observers' ability to make accurate ocular estimates of habitat variables and delineate habitat areas by hand on aerial photographs (Gard 2009; Goodman et al. 2009). This method allowed observers to cover entire river study areas with a low level of effort, but was not repeatable at acceptable levels on the Trinity River.

Table 7. Comparisons of pre-construction vs. post-construction/post-flow rearing habitat available at the Hocker Flat site. Hocker Flat (A) corresponds to segments of the base flow survey that were used for a flow-habitat evaluation. Habitat categories correspond to areas (m^2) of depth/velocity combinations for rearing habitat of Chinook and coho salmon fry and presmolts.

			Habitat Category (sq. m)	
Evaluation Type	**Life Stage**	**Disch. (cfs)**	**DV-H**	**No DV-H**
Hocker Flat pre-construction	Fry	602	1,672	45,584
	Presmolt	602	2,905	44,350
Hocker Flat post-construction/post-flow	Fry	718	2,483	49,763
	Presmolt	718	4,841	47,405
Hocker Flat (A) pre-construction	Fry	596	526	13,084
		1,305	520	13,990
		2,756	181	15,306
	Presmolt	596	928	12,681
		1,305	775	13,735
		2,756	329	15,157
Hocker Flat (A) post-construction/post-flow	Fry	443	2,290	9,866
		803	1,087	12,411
		1,920	907	15,137
		2,490	583	15,944
	Presmolt	443	3,440	8,716
		803	1,454	12,044
		1,920	1,175	14,869
		2,490	726	15,800

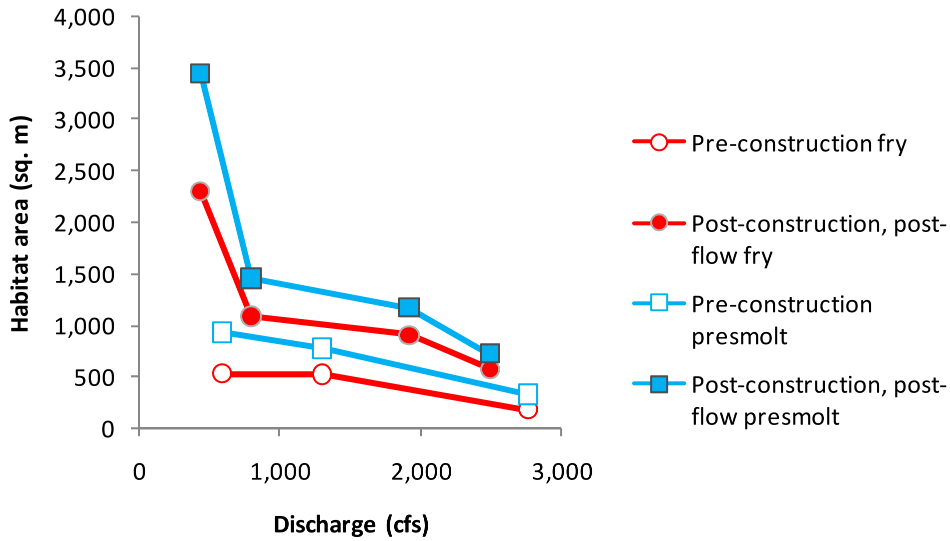

Figure 18. A pre-construction and post-construction/post-flow evaluation of the Hocker Flat (A) site conducted in 2003 and 2008 using depth/velocity only habitat definitions applied at this site only. Linear interpolations were assumed between measured values to facilitate comparisons between surveys.

The methodology developed and applied in this study relies on the strengths of and experience with previous habitat evaluations. The method implemented in this report is most similar to Biomonitoring methodology but our planar mapping incorporates near-cadastral survey accuracy. With the use of global positioning satellites, laser range finders, high resolution aerial photography and ruggedized tablet computers, we have been able to obtain survey accuracy and facilitate comparisons with the Biomonitoring project data while reducing the effort needed for surveying and post-processing. A key difference from Biomonitoring methodology is the inclusion of escape cover, a key variable in rearing habitat assessments (McMahon and Hartman 1989; Roni and Quinn 2001; Moyle 2002; Hardy et al. 2006). As indicated by the rearing habitat validation study results, Chinook and coho salmon fry and presmolt densities were highest in areas with escape cover, along with appropriate depths and velocities.

We evaluated differences in fish use of mapped rearing and spawning habitat areas. We tested whether mapped habitat areas were appropriate predictors of fish preference. The results of these studies varied between rearing and spawning habitat by species and life stage. In the case of rearing habitat, significant differences identified in fish density among habitat categories demonstrates the validity of rearing habitat guilds for predicting fish habitat use. This indicates that habitat areas defined by depth/velocity and escape cover are appropriate for predicting rearing habitat preference of fry and presmolt salmon at the locations evaluated in this study. We believe it may be appropriate to assign habitat relative value categories (or even quantitative values) in accordance with the significant differences we found in Chinook salmon densities (i.e., high/optimum value habitat is inside both depth/velocity and escape

Table 8. Post-construction/post-flow rearing habitat measured at the Hocker Flat site conducted in 2008. Hocker Flat (A) corresponds to segments of the base flow survey that were used for a flow-habitat evaluation. Habitat categories correspond to areas (m^2) of depth/velocity and escape cover combinations of rearing habitat for Chinook and coho salmon fry (<50 mm FL) and presmolts (50-200 mm FL).

			Habitat Category (sq. m)			
Evaluation Type	**Life Stage**	**Disc (cfs)**	**DV-H, C**	**DV-H, No C**	**No DV-H, C**	**No DV-H, No C**
Hocker Flat post-construction/post flow	Fry	718	186	2,669	944	51,068
	Presmolt	718	714	4,886	1,504	45,012
Hocker Flat (A) post-construction post flow	Fry	443	79	2,212	67	9,798
		803	78	1,023	203	12,305
		1,920	164	423	299	15,346
		2,490	224	364	429	15,706
	Presmolt	443	109	3,331	36	8,679
		803	85	1,368	196	11,959
		1,920	259	916	204	14,853
		2,490	234	492	419	15,579

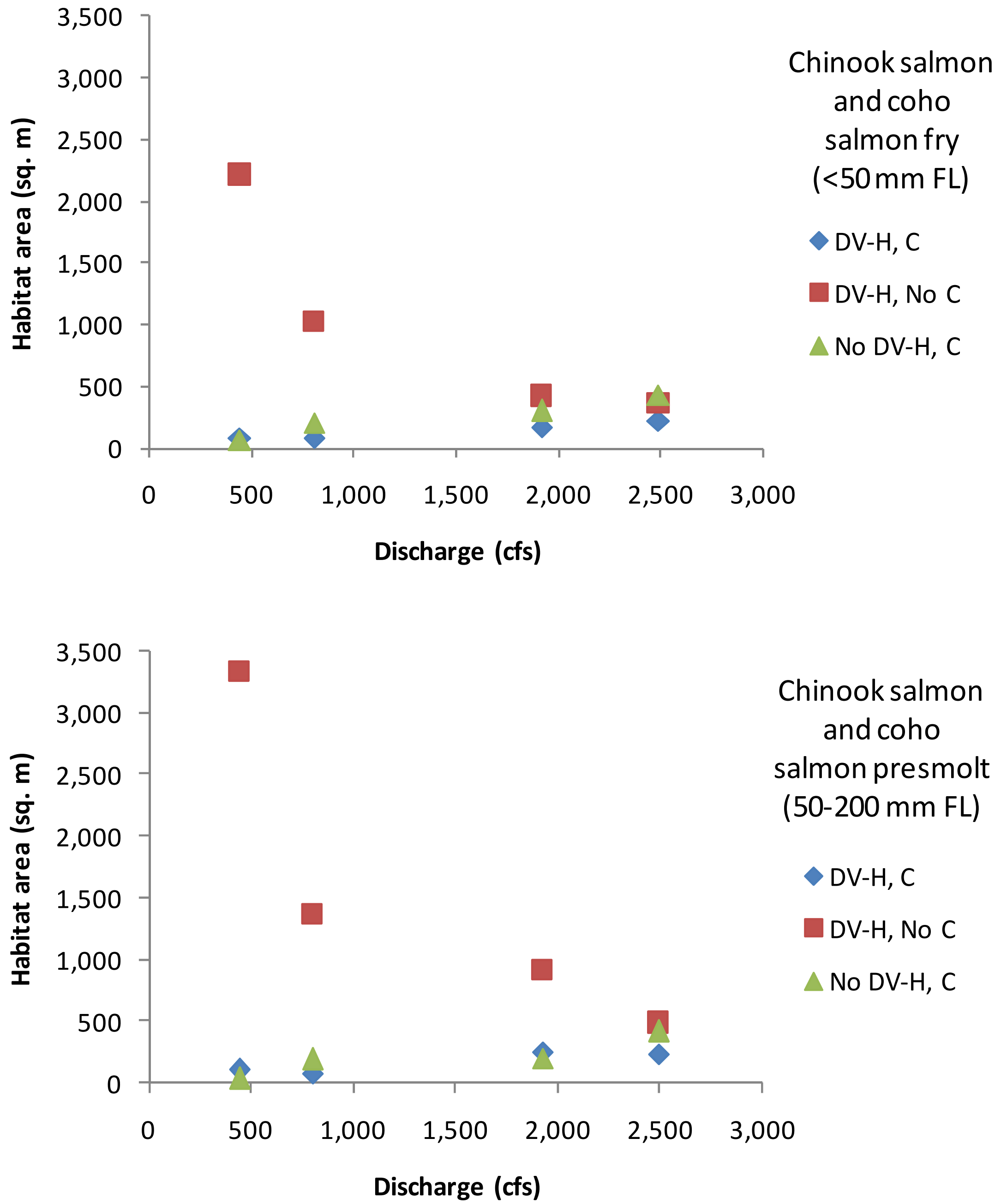

Figure 19. Rearing habitat area (m^2) by streamflow at the Hocker Flat (A) site using depth/velocity and escape cover combinations.

Figure 20. An example of Chinook and coho salmon presmolt (DV-H) habitat at the Hocker Flat site at 443 cfs. Habitat areas are indicated by grey polygons and the red arrow indicates flow direction. This site is located just downstream of the upper boundary.

cover criteria, tolerable/usable value habitat is inside depth/velocity but outside escape cover criteria or inside escape cover but outside depth/velocity criteria, and very low/unusable value habitat is outside both depth/velocity and escape cover criteria). For coho salmon, densities were highest in areas that met both the depth/velocity and escape cover criteria (high/optimum value habitat) with little use of any other habitat categories (very low/unusable habitat). Future evaluations should consider limiting the definition of coho salmon rearing habitat to only those areas within both the depth/velocity and escape cover criteria (McMahon and Hartman 1989; Roni and Quinn 2001; Moyle 2002).

The rearing habitat validation study has at least the following limitations: 1) sampled at a limited geographical distribution within the rehabilitation reach; 2) sampled during daytime hours and at winter base flow only; and 3) did not evaluate or quantify non-detection (underestimation) probabilities. The results of this study may be applicable to locations outside winter base flow and at locations outside of the study area with at least the following two assumptions: 1) habitat preference is consistent among sites; and 2) habitat preferences are independent of flows. A longitudinal gradient of spawning density of salmonid species has been documented in the Trinity River with the highest densities of redds located near Lewsiton Dam and rapidly decreasing downstream (Sinnen et al. 2009). In selecting validation sites, we assumed that spawning distribution coincides with the early distribution and densities of Chinook and coho salmon fry (Beard and Carline 1991). The location of the validation study site (furthest downstream) was selected to take advantage of data being collected for pre-construction habitat surveys as well as an area with high, but not supersaturated densities of rearing Chinook and coho salmon. We plan to conduct habitat validation at another location in the Trinity River in 2009 and address the potential for spatial variation in habitat preference (Hoopa Valley Tribe, Yurok Tribe and USFWS 2008). Due to the limited amount of time available at streamflows above winter base flow, we were not able to evaluate changes in habitat preference at multiple streamflows. Diurnal differences in habitat use may be related to feeding behavior (Heggenes et al. 1993) or daytime concealment behaviors and related changes in detection probabilities (Bradford and Higgins 2001). We plan to quantitatively evaluate the effects of diurnal differences in utilization of habitat areas in the 2009 habitat assessment study.

We were dissatisfied with the spawning habitat evaluation method based on the results of the validation study. Many redds were located in the vicinity of habitat areas but not inside mapped polygons. One potential source of error is the ocular estimation of substrate composition. A major potential source of error is that depth/velocity and substrate criteria are not sufficient to characterize spawning habitat in the Trinity River (Mull and Wilzbach 2007). To refine this method for improved validation and possible use in the future, habitat suitability criteria breaks and the methodology for estimating spawning habitat need to be re-examined. A more detailed investigation into redd habitat is planned for future habitat assessment projects.

HABITAT ASSESSMENT

This project documents the first quantitative estimates of changes in Chinook and coho salmon rearing habitat abundance on the Trinity River in response to restoration actions. The results of the assessments are encouraging with increased habitat abundance in post-construction conditions in all cases. This documents progress from the restoration actions toward restoration goals of increasing habitat abundance at mechanical bank rehabilitation sites.

Although encouraging, the results of this study need to be qualified as an initial step in evaluating the performance of the mechanical bank rehabilitation sites. The true assessment of these bank rehabilitation sites will come through time and with channel evolution (i.e. riparian development, wood recruitment, channel migration, etc.). The restoration strategy and goals include a sustaining system that continues to improve and increase with fluvial processes. Conversely, post-rehabilitation evolution of the Vitzhum Gulch bank rehabilitation site shows a decreasing trend in habitat abundance, following the ROD spring flow release. Although the reduction in habitat abundance did not reach pre-construction levels, it does raise concerns about the sustainability of the bank rehabilitation site. If the reduction in habitat abundance continues, this rehabilitation site may be deemed a failure and will require additional mechanical bank rehabilitation actions. This bank rehabilitation site, as well as others, should be revisited in future years to track the evolution and the trajectory of habitat abundance at bank rehabilitation sites.

Due to the high level of variation among restoration techniques applied as part of the TRRP the results at Vitzhum Gulch may not be representative of the response of bank rehabilitation sites to channel evolution. An example of this is the Hocker Flat site. Although an as-built assessment is not available at this site, it is encouraging that habitat abundance is higher than pre-construction conditions at all surveyed streamflows three water years after construction.

These assessments were conducted at bank rehabilitation sites where we anticipate maximum change from TRRP restoration actions. Although evaluations of bank rehabilitation sites seem to be an appropriate focus of evaluation efforts, future work should also include project reach scale assessments. The project reach scale (Lewiston Dam to the confluence of the North Fork Trinity River) could assess how habitat is responding to the host of restoration actions applied by the TRRP and provide an additional evaluation of the progress toward restoration goals.

ACKNOWLEDGMENTS

We would like to thank Sam Williamson of the United States Geological Survey and Nina Hemphill and Andreas Krause of the Bureau of Reclamation for their support in the review of this report.

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Appendix A. Stream gauge information used to develop river streamflow values for sites evaluated in the 2007-2008 habitat assessment[3].

Monitored Site(s)	Gauge Name(s)	Gage Number(s)
Sven Olbertson Deadwood Lewiston Cableway Hoadley Gulch	Trinity River at Lewiston	USGS 11525500
Dark Gulch, Salt Flat	Trinity River at Lewiston summed with Rush Creek near Lewiston	USGS 11525500 USGS 11525530
Vitzhum Gulch	Trinity River at Lewiston summed with Rush Creek near Lewiston and Grass Valley Creek near Lewiston	USGS 11525500 USGS 11525530
Lower Indian Creek*	Trinity River at Lewiston summed with Rush Creek near Lewiston, Grass Valley Creek near Lewiston, and Indian Creek near Douglas City	USGS 11525500 USGS 11525530 USGS 11525630 USGS 11525670
Hocker Flat	Trinity River above North Fork Trinity near Helena	USGS 11526400

[3] Throughout the 2008 field efforts, there were significant discrepancies between flows at Trinity River below Limekiln Gulch near Douglas City and the gauges above and below. Therefore, we used the total of Trinity River at Lewiston gauge plus the downstream tributaries listed above to arrive at the Lower Indian Creek streamflows.

Appendix B. Habitat mapping survey locations, dates and daily streamflow. All streamflows are reported in cfs and all survey dates are in 2008 except for Indian Creek which was surveyed in 2007.

Site	RKM	Mean Daily Streamflow (range)	Dates Mapped
Sven Olberston	179.0-179.6	304 (302-305)	3/6, 3/11, 4/8
Lewiston Cableway	177.3-178.0	305 (305)	3/4, 3/5
Cableway (A)	177.4-177.9	1,210 (1,190-1,220)	4/24, 5/1
		2,020 (2,010-2,030)	6/24, 6/25, 6/26
		681 (675-687)	7/14, 7/16
		393 (393)	7/29
Hoadley Gulch	176.5-177.3	307 (305-309)	2/28, 3/3, 3/27
Salt Flat	172.2-172.7	370 (370)	8/4
Dark Gulch	169.5-172.2	363 (348-388)	3/12, 3/13, 3/17, 3/18, 3/19, 3/20, 3/24, 4/14
Upper Dark Gulch	171.8-172.2	1,283 (1,283)	4/25
		2,145 (2,145)	6/18
		703 (703)	7/21
		349 (349)	7/30
Lower Dark Gulch	170.5-170.9	1,280 (1,280)	4/28
		2,149 (2,143-2,155)	6/17, 6/18, 6/19
		692 (692)	7/16
		371 (371)	8/5
Vitzhum Gulch	154.7-155.8	410 (396-423)	4/14, 4/15, 4/16
		433 (431-434)	9/22, 9/23, 9/24
Indian Creek	151.1-155.9	436 (433-442)	4/9, 4/10, 7/1-8/17
Lower Indian	151.3-152.4	439 (438-439)	4/21, 4/22
Lower Indian (A)	151.3-151.8	1,392 (1,392)	4/30
		2,170 (2,170)	6/16
		720 (720)	7/15
		375 (375)	7/31
Hocker Flat	126.0-127.5	718 (716-722)	4/9, 4/10
Hocker Flat (A)	127.1-127.5	1,920 (1,920)	4/29
		2,490 (2,490)	6/19
		803 (803)	7/21
		443 (443)	8/1

Appendix C. Pre-construction and control site rearing habitat evaluations conducted in 2008. Habitat categories correspond to areas (in m^2) of depth/velocity (DV) and escape cover (C) combinations of rearing habitat for fry (<50 mm FL) and presmolt (50-200 mm FL) Chinook and coho salmon.

				Habitat Category (sq. m)			
Site	**RKM**	**Life Stage**	**Disch. (cfs)**	**DV, C**	**DV, No C**	**No DV, C**	**No DV, No C**
Sven Olbertson	179.0-179.6	Fry	304	1,167	5,168	391	18,171
		Presmolt	304	1,344	7,715	214	15,624
Cableway	177.3-178.0	Fry	305	1,250	2,205	582	18,059
		Presmolt	305	1,586	4,199	246	16,066
Cableway (A)	177.4-177.9	Fry	305	1,010	1,351	392	11,761
			393	454	795	581	13,279
			681	1,549	2,156	500	13,826
			1,210	2,881	413	2,150	15,721
			2,020	5,602	279	3,902	16,841
		Presmolt	305	1,261	2,342	141	10,770
			393	547	1,399	488	12,675
			681	1,753	2,923	296	13,059
			1,210	3,767	1,007	1,264	15,127
			2,020	6,560	457	2,944	16,663
Hoadley Gulch	176.5-177.3	Fry	307	945	3,459	760	23,809
		Presmolt	307	1,338	8,673	367	18,595

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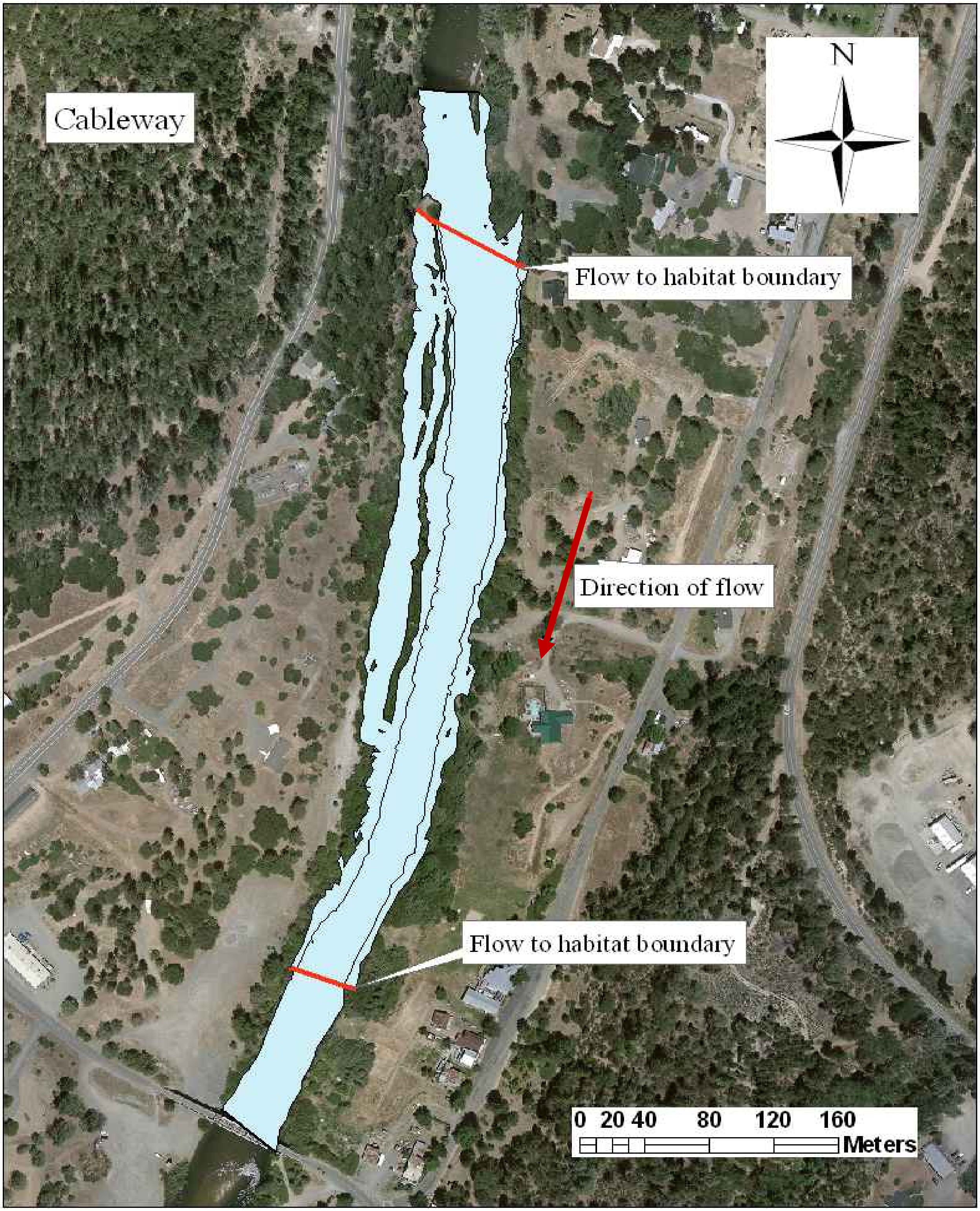
Appendix C. Pre-construction and control site rearing habitat evaluations conducted in 2008. Habitat categories correspond to areas (in m^2) of depth/velocity (DV) and escape cover (C) combinations of rearing habitat for fry (<50 mm FL) and presmolt (50-200 mm FL) Chinook and coho salmon.

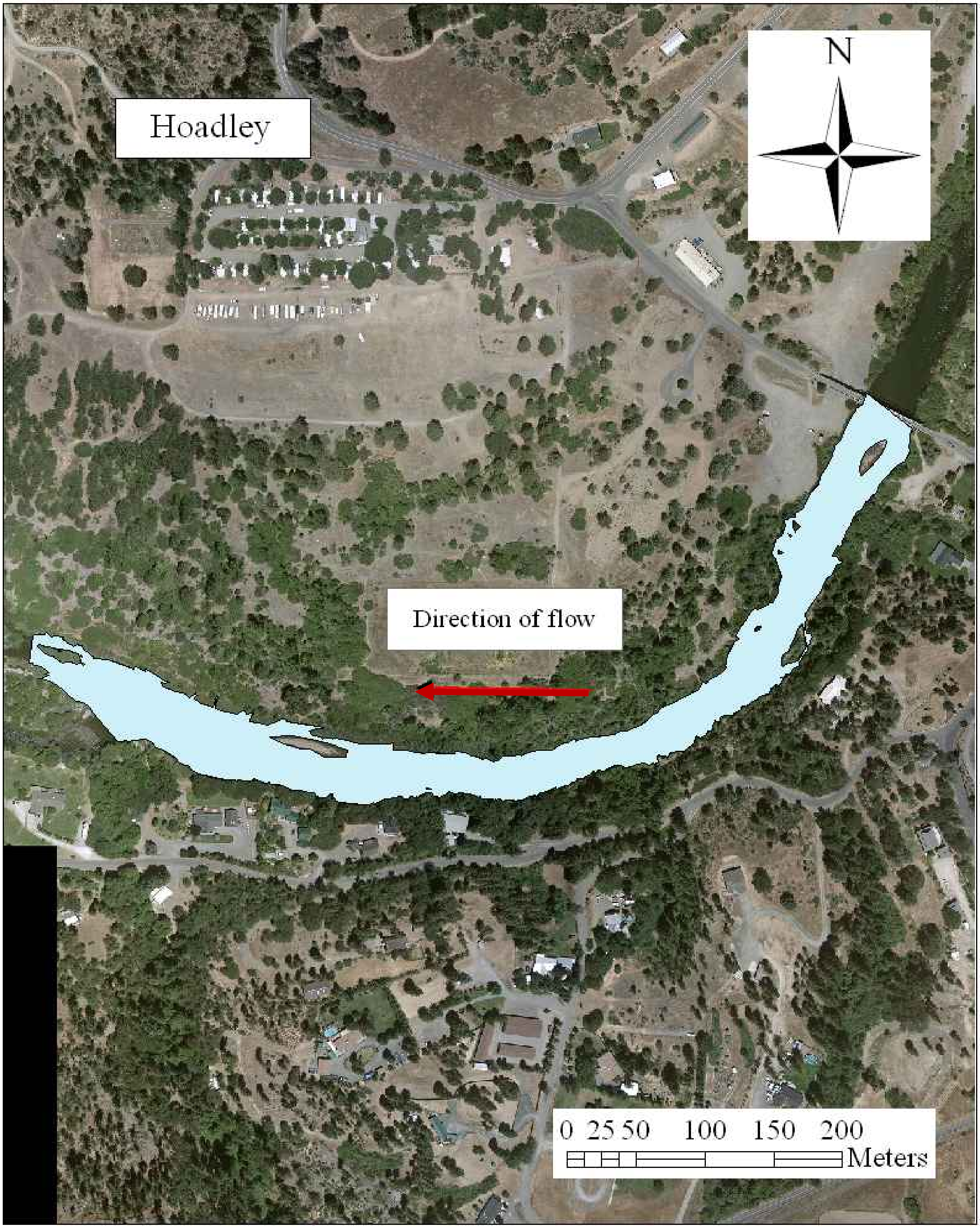
				Habitat Category (sq. m)			
Site	**RKM**	**Life Stage**	**Disch. (cfs)**	**DV, C**	**DV, No C**	**No DV, C**	**No DV, No C**
Dark Gulch	169.5-172.2	Fry	363	2,931	6,176	4,847	71,470
		Presmolt	363	4,423	11,960	3,355	65,686
Upper Dark Gulch	171.8-172.2	Fry	349	418	1,135	432	9,128
			703	256	394	516	10,990
			1,283	241	102	530	11,707
			2,145	547	44	763	12,065
		Presmolt	349	644	1,942	207	8,321
			703	426	835	346	10,549
			1,283	365	387	405	11,423
			2,145	716	108	595	12,001
Lower Dark Gulch/Bucktail	170.5-170.9	Fry	371	131	1,131	192	7,957
			692	187	490	282	8,949
			1,280	519	171	500	9,795
			2,149	1,911	173	827	10,427
		Presmolt	371	206	1,577	117	7,511
			692	252	893	217	8,546
			1,280	655	399	364	9,568
			2,149	2,066	248	672	10,352
Salt Flat	172.2-172.7	Fry	370	532	1,457	708	12,676
		Presmolt	370	882	2,746	358	11,387

Appendix D. Aerial view and extent of the Sven Olbertson rehabilitation site.

Appendix E. Aerial view and extent of the Lewiston Cableway rehabilitation site.

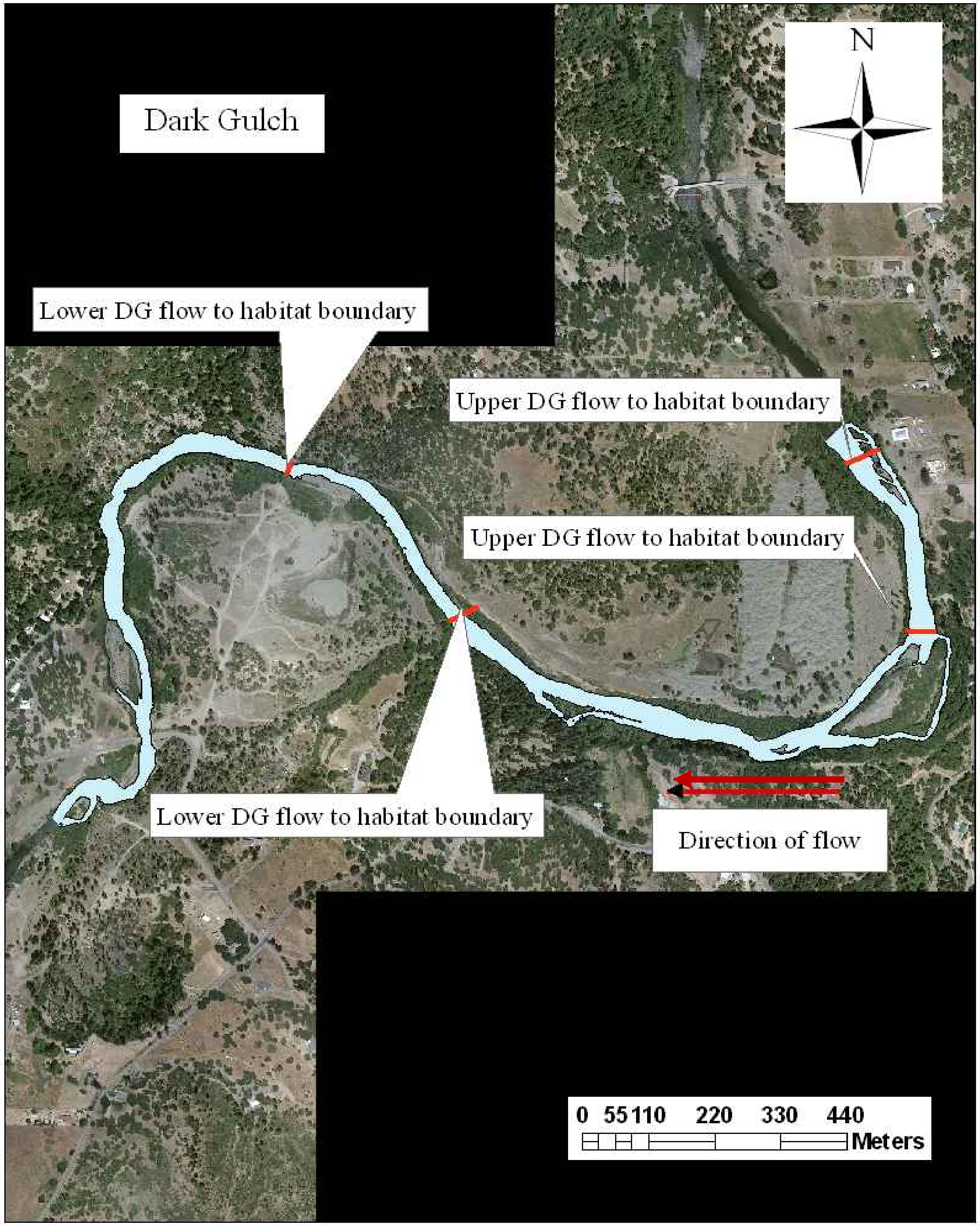


Appendix F. Aerial view and extent of the Hoadley Gulch rehabilitation site.

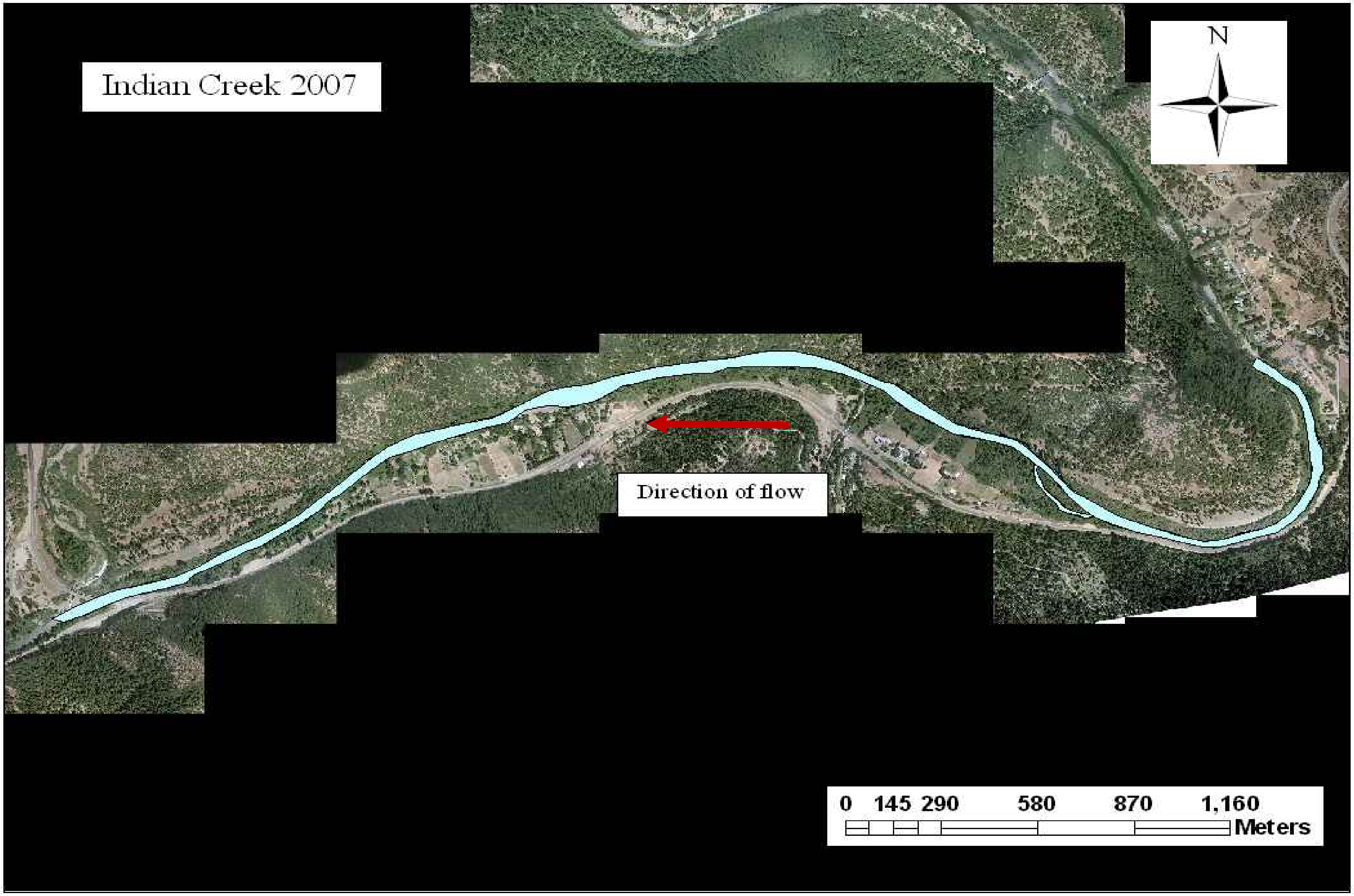


Appendix G. Aerial view and extent of the Salt Flat untreated site.

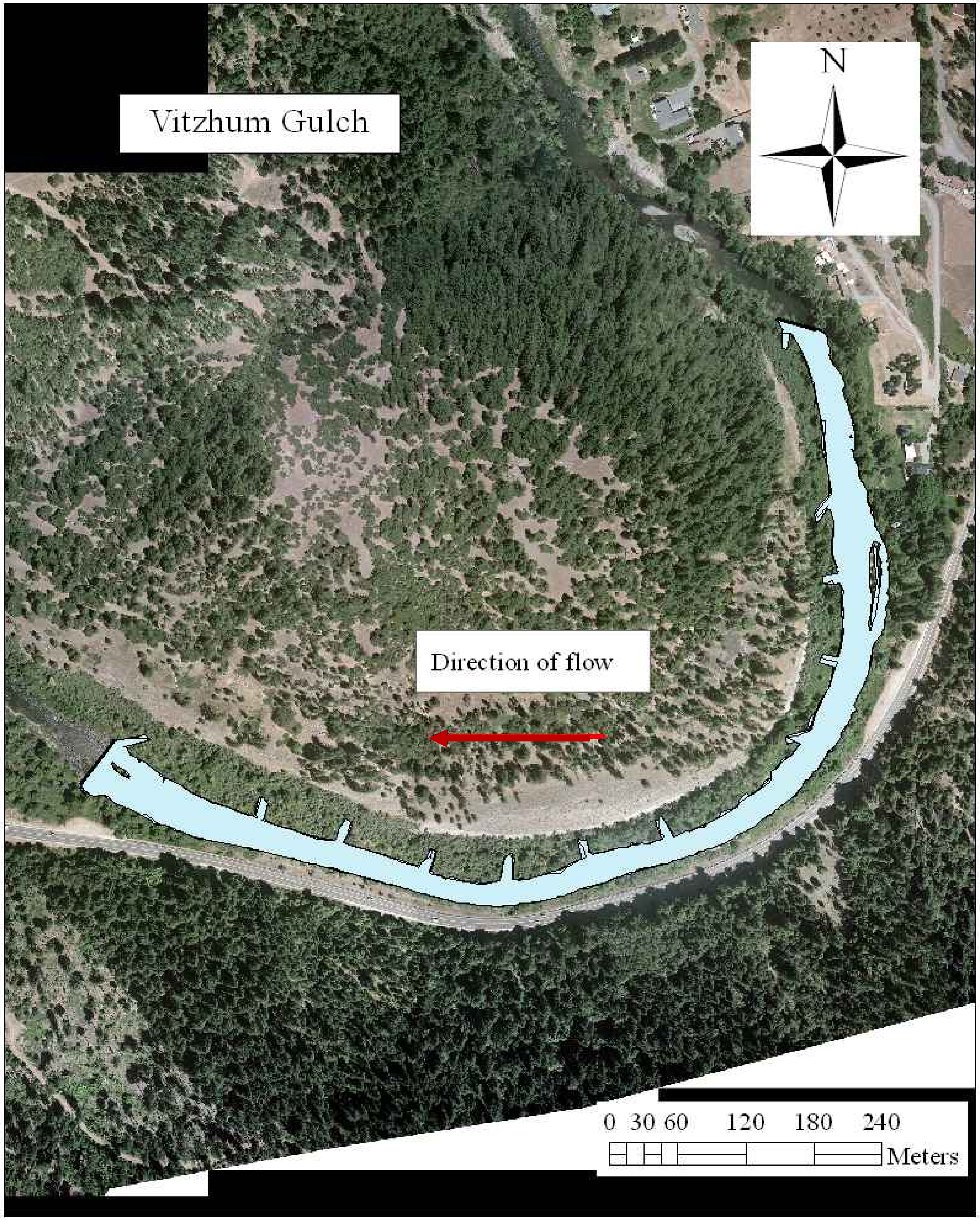
Appendix H. Aerial view and extent of the Dark Gulch rehabilitation site. Flow to habitat boundary indicates the Dark Gulch (A) site where multiple flows were mapped.



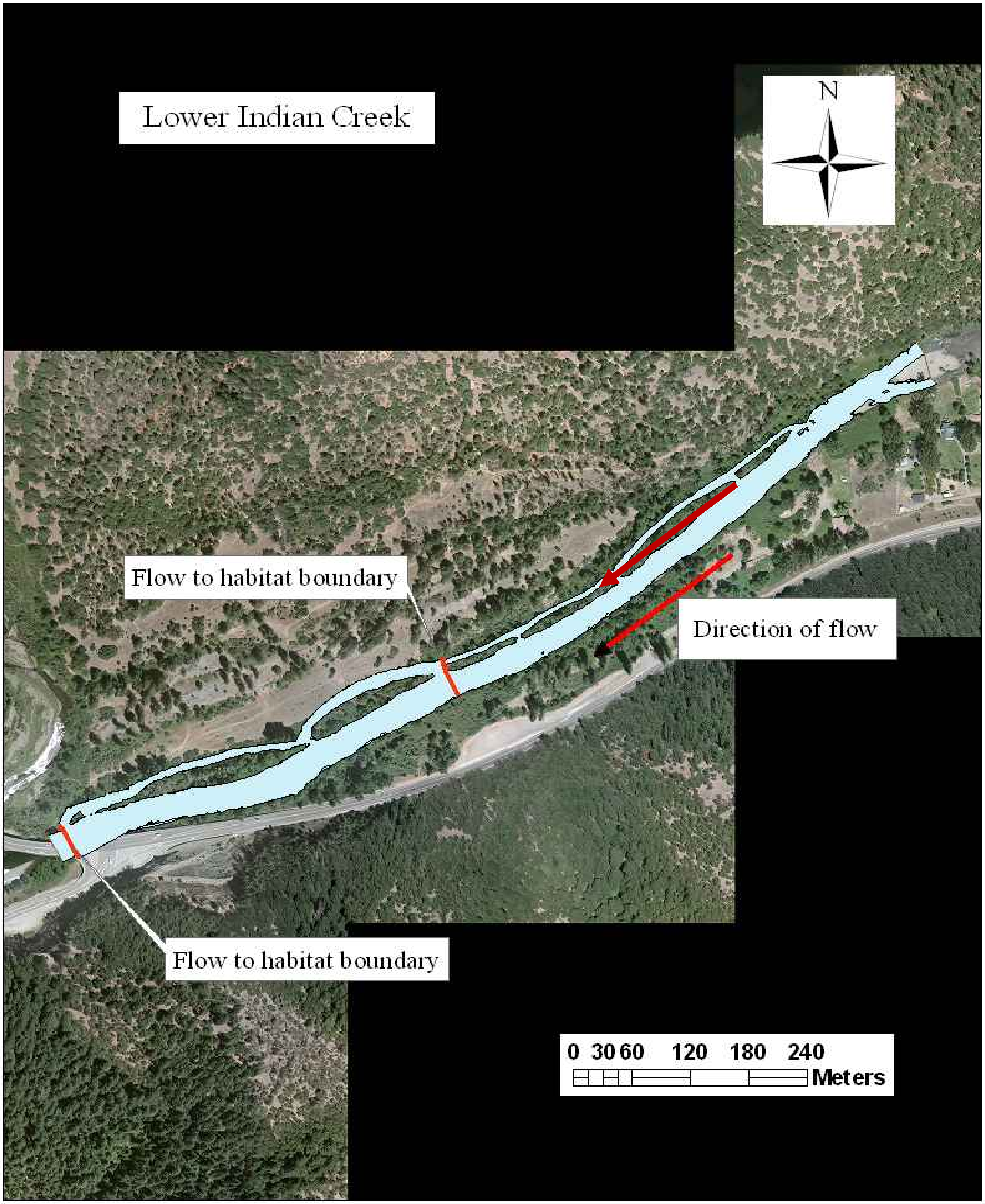
Appendix I. Aerial view and extent of the Indian Creek rehabilitation site during the 2007 habitat assessment pilot study.



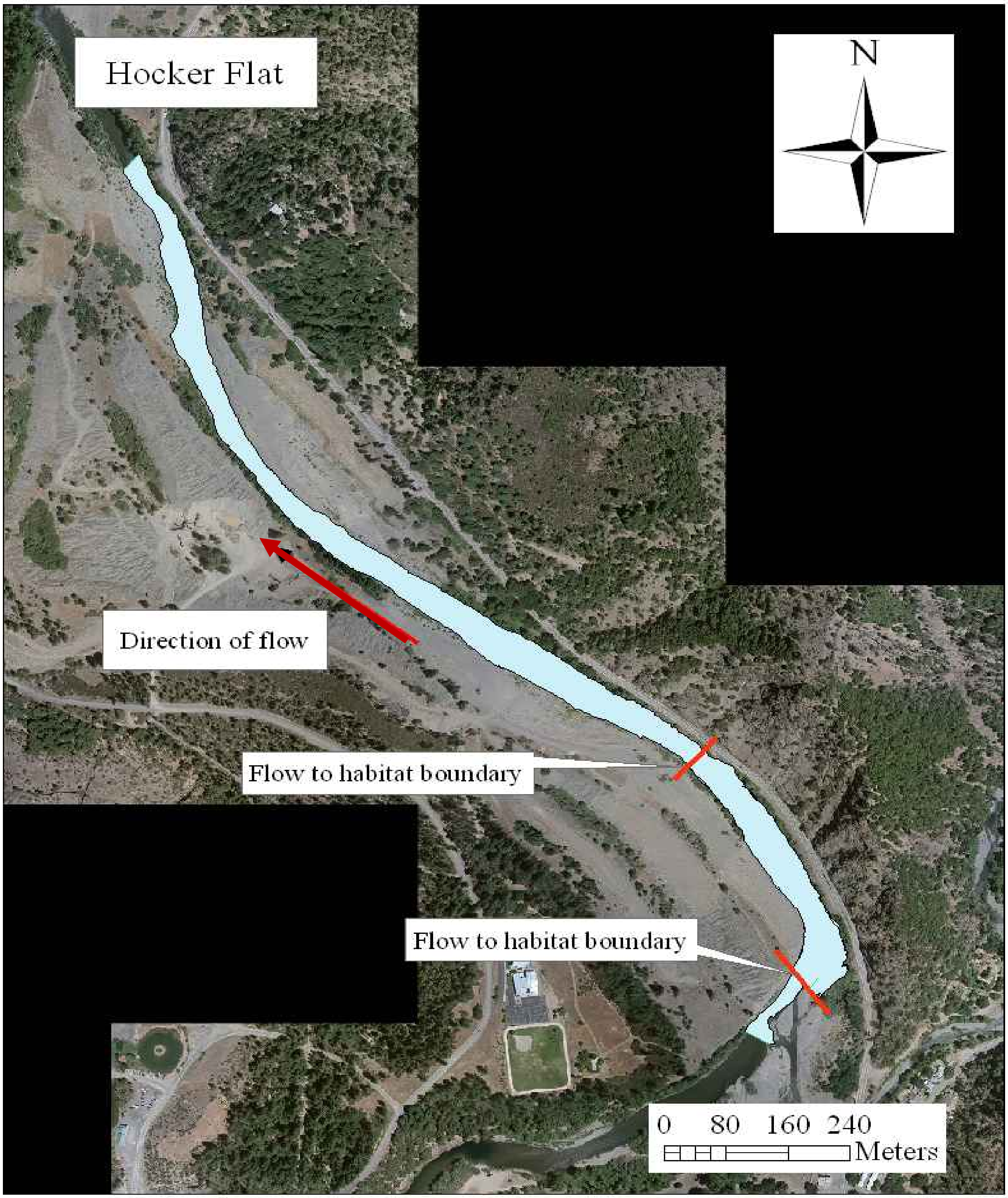
Appendix J. Aerial view and extent of the Vitzhum Gulch rehabilitation site.



Appendix K. Aerial view and extent of the Lower Indian Creek rehabilitation site. Flow to habitat boundary indicates the Lower Indian Creek (A) site where multiple flows were mapped.



Appendix L. Aerial view and extent of the Hocker Flat rehabilitation site. Flow to habitat boundary indicates the Hocker Flat (A) site where multiple flows were mapped.



Appendix M. Post-construction/post-flow habitat data at the Hocker Flat site using our standard rearing habitat guild definitions. The fry rearing habitat guild definition is the same one applied in Chamberlain et al. (2007). This data may be useful in future comparisons among sites that were mapped using these definitions.

				Habitat category (sq. m)			
Site	**RKM**	**Life stage**	**Disc (cfs)**	**DV, C**	**DV, No C**	**No DV, C**	**No DV, No C**
Hocker Flat	126.0-127.5	Fry	718	186	2,669	944	51,068
		Presmolt	718	421	5,171	703	45,821
Hocker Flat (A)	127.1-127.5	Fry	443	79	2,212	67	9,798
			803	78	1,023	203	12,305
			1,920	164	423	299	15,346
			2,490	224	364	429	15,706
		Presmolt	443	114	3,431	32	8,579
			803	106	1,606	175	11,722
			1,920	259	926	204	14,843
			2,490	246	557	406	15,514