Estimation of Rearing Habitat Area for Age-0 Chinook and Coho Salmon during Winter Base Flows within the Sawmill Rehabilitation Site of the Upper Trinity River, 2010

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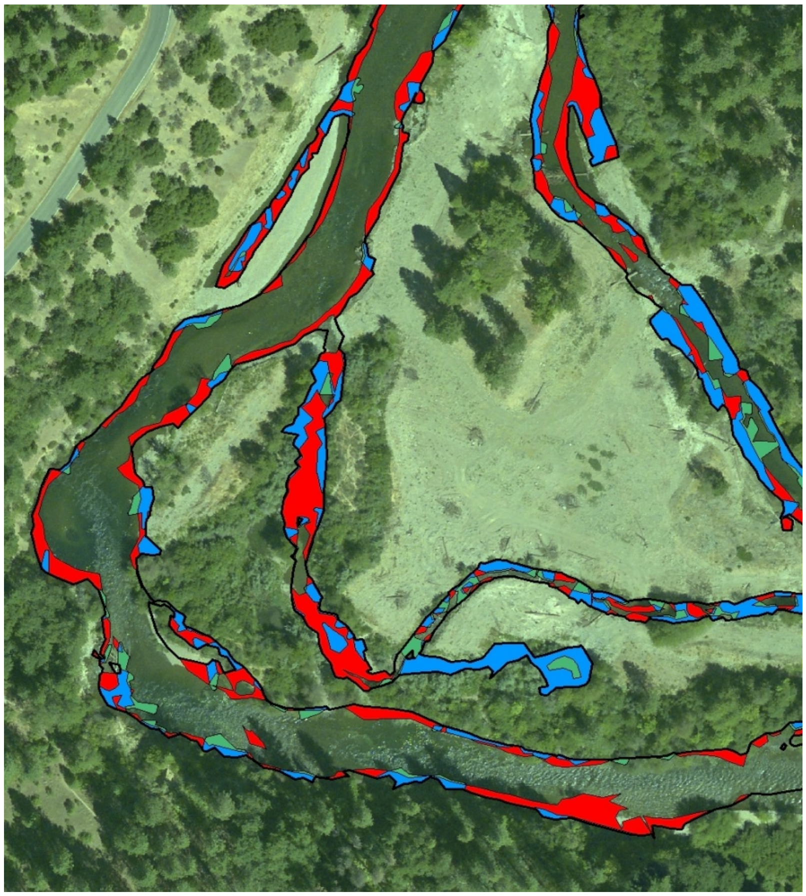

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Abstract. The goal of the Trinity River Restoration Program is to restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam. Channel rehabilitation of 47 sites within the 64 km restoration reach is one of the primary management tools being employed to accomplish the goal. Construction of the Sawmill Rehabilitation Site (Sawmill) was completed in 2009 and included mainstem re-alignment, course sediment placement, side channel manipulation, floodplain lowering and installation of the highest density of large wood on the Trinity River to date. The features constructed at Sawmill were predicted by site designers to increase and sustain the availability, quantity, and quality of habitat for all life stages of anadromous fish (including Chinook salmon *Oncorhynchus tshawytcha* and coho salmon *O. kisutch*) habitat between 8.5 and 56.6 cms (300 and 2,000 cfs). Surveys were conducted at a single streamflow of 8.5 cms (300 cfs) to evaluate rearing habitat conditions before and after construction that occurred in summer 2009. Construction increased total abundance of fry rearing habitat by 42% and presmolt habitat by 29%. In addition, abundance of what we defined as "optimal" rearing habitat increased by 96% for fry and 88% for presmolts. Side channels accounted for 79% and 77% of the increases in total habitat area for fry and presmolts. Post-construction densities (m^2 habitat/m of river) of optimal and total habitat ranked higher at the Sawmill Restoration Site than at other rehabilitation sites where fish habitat data are available. While post-construction results indicate a positive increase in rearing habitat, uncertainty exists about the long-term self-maintenance of the constructed side channels and evolution of mainstem features. It will be critical to revisit this site in the future to evaluate its long-term evolution and associated habitat benefits.

Introduction

The strategy to restore the fishery resources of the Trinity River is to rehabilitate instream habitats through actions that integrate riverine processes and instream flow dependent habitat needs (USFWS and HVT 1999). Implementation of this strategy is expected to lead to increased channel complexity and result in systemic increases in salmonid rearing habitat quantity and quality. Because the historical hydrologic and geomorphic effects of the dams are most pronounced between Lewiston Dam and the North Fork Trinity River, the improvements in salmonid habitat quantity and quality should also be most pronounced in this reach (hereafter referred to as the “restoration reach”). The restoration strategy is made up of four components including: (1) mechanical channel rehabilitation, (2) flow management to drive fluvial processes that create and maintain salmonid habitats and provide suitable thermal regimes, (3) coarse sediment augmentation, and (4) watershed restoration. Maximum change in salmonid rearing habitat is anticipated at channel rehabilitation sites. It is also hypothesized that the restoration strategy will create synergistic effects, improving habitat throughout the restoration reach (Barinaga 1996; USDI 2000).

The design and implementation of the Trinity River Restoration Program (TRRP) is conducted under an adaptive management framework by assessing the effects of restoration actions, learning from the results and adjusting management actions to achieve programmatic goals and objectives (Holling 1978). A fundamental assessment necessary to evaluate the effectiveness of TRRP actions is to determine the changes in habitat resulting from the synergistic effects of mechanical channel rehabilitation and restoration of fluvial processes that are expected improve and maintain riverine habitats. This assessment evaluates salmonid fry and presmolt rearing habitat response to restoration activities and contributes to the TRRP adaptive management framework by providing short-term feedback to improve management actions and information for long-term trend analyses.

Rearing habitat for age-0 Chinook *Oncorhynchus tshawytcha* and coho salmon *O. kisutch* has been identified as the primary limiting factor for salmonid populations in the Trinity River and the basis for the restoration activities (USFWS and HVT 1999).

Project Goals and Objectives

The goal of this assessment was to evaluate the effectiveness of TRRP restoration actions to create and maintain riverine habitats at the Sawmill rehabilitation site. The objective of this report is to quantify changes in Chinook and coho salmon rearing habitat that occurred throughout the Sawmill rehabilitation site (river kilometers [rkm] 176.5-175.4) resulting from mechanical channel rehabilitation, gravel introduction, and large wood (LWD) additions that occurred during the summer of 2009. Results will contribute to the TRRP’s adaptive management process through the evaluation of progress toward achieving TRRP goals and objectives. This can provide short-term feedback to improve management actions, specifically channel rehabilitation, coarse sediment augmentation, and annual flow management.

The TRRP has been implementing the channel rehabilitation components of the Record of Decision (ROD) since 2005; roughly half of the proposed 44 projects in the ROD are expected to be completed by the end of 2011. Evaluation of project performance is critical to inform future channel rehabilitation designs.

Drainage and Channel Rehabilitation Site Description

The Trinity River is located in northwestern California within Humboldt and Trinity counties. The watershed has a drainage area of 7,679 km2 (2,965 mi^2), approximately one quarter of which is upstream of Lewiston Dam and inaccessible to anadromous fishes (USFWS 1989; USBR 2009). The river's headwaters are in the Trinity-Scott Mountains of northern California, from which it flows 274 km (170 mi) to its confluence with the Klamath River in Weitchpec, California. The reach targeted for restoration is located within 64 km of the Trinity River between Lewiston Dam and the confluence of the North Fork Trinity River. Monitoring summarized in this report focuses on the Sawmill Rehabilitation Site located in Lewiston, California approximately 4 rkm downstream of the Lewiston Dam (Figure 1).

The Sawmill Rehabilitation Site encompasses 1,125 m of mainstem channel. Mainstem rehabilitation actions involved removal of two gabions and four rock weirs, addition of alluvial bars, floodplain lowering, and excavation of vegetated banks to increase channel sinuosity (HVT and McBain and Trush 2009). Contained within the construction area was the Cemetery Side Channel (Figure 2). This side channel was constructed in the mid-1980's to provide increased spawning and rearing habitat and has remained functional since. Cemetery Side Channel has provided quality rearing and spawning habitat at winter base flows (~8.5 cms, 300 cfs; 65 redds in 2009, USFWS unpublished data). However, portions of the channel were highly confined, offering less rearing habitat at higher flows than an unconfined channel. Therefore one element of the design included removing earthen piles associated with side channel construction in the 1980's and the lowering the floodplain adjacent to the Sawmill and Cemetery Side Channels to improve rearing habitat availability between 1,000 and 8,000 cfs flows and increase floodplain complexity (HVT and McBain and Trush 2009).

A component of the Sawmill rehabilitation design involved re-opening a side channel inlet that was plugged by coarse sediment that prevented water from passing through the channel until mainstem discharge reached at or above 14.1 cms (500 cfs; HVT and McBain and Trush 2009). For the purposes of this report, this side channel will be referred to as the Sawmill Side Channel (Figure 2). The entrance and upper section of the Sawmill Side Channel was re-aligned and large wood and slash was added at 25 locations (USFWS unpublished data).

Figure 1. Location of Sawmill rehabilitation site within the 64 km Upper Trinity River project reach. The primary restoration reach extends from Lewiston Dam near Lewiston to the confluence of the Trinity and North Fork Trinity Rivers at Helena.

Methods

The Sawmill Rehabilitation Site is located near Lewiston Dam and experiences flows that are derived from dam releases plus accretions from Deadwood Creek located about 2 km (1.25 miles) upstream of the site. Winter flows during the critical rearing period of January through May are predominately stable at approximately 8.5 cms (300 cfs). Therefore, the survey team focused their rearing habitat mapping efforts during periods of similar, winter base-flow conditions.

Habitat mapping was conducted using methods described in Goodman et al. (2010). In summary, parameters of interest were measured and geo-referenced to produce spatially explicit representations of habitat areas within each sample site. The habitat parameters mapped at each site are described in Table 1.

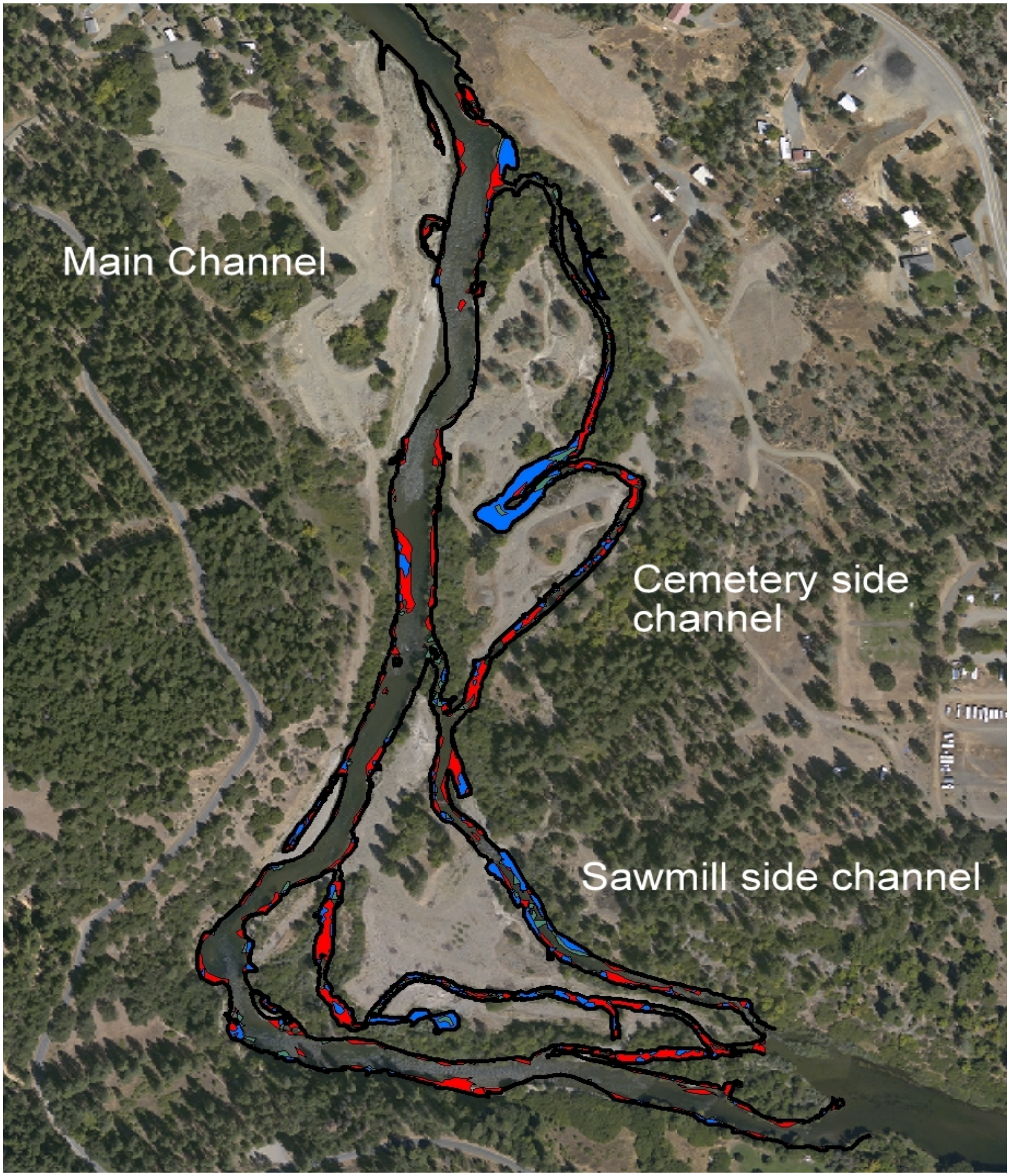

Figure 2. Aerial view of Sawmill rehabilitation site including associated side channels. Black lines indicate the wetted edge, blue areas indicate optimal habitat and red and green areas indicate suitable habitat during 2010 post-construction surveys.

Table 1. Guilds and their associated habitat criteria for age-0+ Chinook and coho Salmon winter rearing habitat mapping.

Habitat Guild	Variable	Criteria
Fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column	0 to 0.15 m/sec
	Distance to Cover	0 to 0.61 m
	Cover type	No cover, vegetation or wood
Presmolt (>50 mm)	Depth	>0 to 1 m
	Mean column	0 to 0.24 m/sec
	Distance to Cover	0 to 0.61 m
	Cover type	No cover, vegetation or wood

We refined the description of our habitat assessment to age-0 salmonid winter rearing habitat, rather than simply rearing habitat as used in past reporting. This refined habitat definition relates more directly to the life stage of interest to the TRRP (USFWS and HVT 1999) and the foundation of habitat suitability data used to derive mapping criteria (Hampton 1997). We also adjusted the size range of presmolts from 50-200 mm FL to ≥ 50 mm FL to fit the revised definition and anticipate this revised definition will be applied in future studies. Two types of habitat areas were mapped independently of each other in the field; depth/velocity and cover areas. A depth/velocity area must meet both depth and velocity criteria to be included. Cover areas must have cover in-water that can be used by fry or presmolts.

The survey data were developed as a series of spatially referenced geographic information system (GIS) layers. Within GIS, surveyed polygons (depth/velocity and/or cover) were overlaid and used to represent areas of fry and presmolt rearing. Once the GIS polygons were created that included the four qualities of habitat (Table 2), areas of the polygons for each type of habitat were summed. For this report, we assess “optimal” and total abundance of Chinook salmon habitat. We defined optimal habitat to include areas that met depth/velocity and cover criteria provided in Table 1. Total Chinook salmon habitat (total habitat) included areas that met any combination of depth/velocity or cover criteria (including optimal habitat areas). Trinity River rearing habitat validation studies (Goodman et al. 2010) and published literature (McMahon and Hartman 1989) all support a high preference for cover for coho salmon during this phase of their development. Therefore coho salmon rearing habitat was limited to areas that met both depth/velocity and cover criterion; all other areas were considered unsuitable habitat. Habitat densities were calculated to facilitate across site comparisons. For this report, habitat density is defined as the amount of measured rearing habitat (m^2) per length of 142 cms (5,000 cfs) channel centerline (m). Site specific streamflows evaluated in the habitat density analysis ranged from 8.6 to 20.3 cms (302-718 cfs). Hocker Flat was evaluated in summer 2008, Sawmill was evaluated in the spring of 2010, all other surveys were conducted in summer and fall 2009.

Table 2. Mapped habitat categories with resulting four associated habitat qualities. Chinook salmon total habitat was defined as areas that met any combination of depth/velocity and cover criteria. Optimal habitats for Chinook and coho salmon were defined as areas that simultaneously met depth/velocity and cover criteria.

	Depth/Velocity (DV)	**Outside Depth/Velocity (No DV)**
Cover (C)	**DV,C – Optimal habitat and ⅓ Total habitat**	**No DV, C – ⅓ Total habitat**
Outside Cover (No C)	**DV, No C – ⅓ Total habitat**	**No DV, No C – Unsuitable habitat (not reported)**

Results and Discussion

Rearing habitat surveys were conducted at a single streamflow before and after construction. Pre-construction rearing habitat surveys were completed in March 2009 at 8.3 cms (294 cfs) and post-construction surveys were done in April of 2010 at 8.5 cms (305 cfs).

Habitat areas of like polygons, expressed as surface area (m^2), were calculated and were compared between pre and post-construction surveys for the main channel, side channels (Cemetery and Sawmill), and sum of mainstem and side channels (combined total; Table 3). The combined total of fry and presmolt rearing habitat increased by approximately 4,196 m^2 and 3,967 m^2 or 42% and 29%, respectively following construction (Figure 3). Optimal habitat increased 2,588 m^2 or 96% for fry and 3,258 m^2 or 88% presmolt after construction. There was an 881 m^2 (20%) and 448 m^2 (7%) increase in total habitat for fry and presmolts within the mainstem channel (Figure 4) following construction.

These results are not informative with regard to post-construction habitat gains that may occur at flows higher than the winter base conditions (8.5 cms) surveyed in this study. However, numerous design features were constructed to allow inundation at flows between 8.5 and 56.6 cms (300–2000 cfs, and greater), and we hypothesize that rearing habitat would also increase at flows above winter base flow conditions, post-construction (HVT and McBain and Trush 2009).

The re-opening of the Sawmill Side Channel and addition of woody debris created a new low-flow channel that accounted for increases of 2,348 m^2 of fry and 2,821 m^2 of presmolt total habitat (Figure 5). These increases in habitat area accounted for 56 % of the fry and 71% of the presmolt total habitat increases throughout the entire site.

The rehabilitation work at Sawmill included enhancement of the Cemetery Side Channel. Actions taken with Cemetery Side Channel include channel re-alignment; lowering surfaces adjacent to the side channel and large wood additions at 43 locations (USFWS unpublished data). Following the rehabilitation effort at the

Cemetery Side Channel, total rearing habitat increased by 967 m² and 698 m² or 20% and 11% for fry and presmolt, with an optimal habitat increase of 65% and 61% (Figure 6).

A project goal of the Sawmill rehabilitation site was to "Increase and sustain the availability, quantity and quality of anadromous fish habitat between 300 cfs and 2000 cfs for all life stages" (HVT and McBain and Trush 2009). Analysis of the habitat mapping results demonstrated increases in total rearing habitat of 42% for fry and 29% for presmolts and increases of 96% and 88% of optimal habitat for fry and presmolts. These increases in both quantity (total habitat) and quality (optimal habitat) are the second largest increases observed to date for any of the TRRP channel rehabilitation sites where monitoring data are available (Sven Olberston was the highest; HVT, Yurok Tribal Fisheries, and USFWS unpublished data).

Table 3. Habitat conditions at winter base flows before and after construction at Sawmill rehabilitation site. Habitat categories correspond to areas (m²) meeting the depth/velocity dual criteria of rearing habitat for Chinook and coho salmon fry (<50mm FL) and presmolt (≥50 mm FL). Average channel width was calculated by dividing the total wetted area by the length of the site. *Discharges were measured in 2011.

						Habitat category			
Evaluation type	Location	Length (m)	Avg. Channel Width (m)	Life stage	Disch. (cms)	DV, C	DV, No C	No DV, C	Total habitat
Sawmill pre-construction	Main channel	1125	27	Fry	8.3	853	2844	811	4508
				Presmolt	8.3	1150	4888	515	6553
	Cemetery side channel	1050	9	Fry	1.4	1602	1822	1298	4722
				Presmolt	1.4	2259	3385	641	6285
	Sawmill side channel	157	7	Fry	0.36	244	275	128	646
				Presmolt	0.36	304	516	67	888
	Entire site	1125		Fry	8.3	2699	4941	2237	9877
				Presmolt	8.3	3713	8790	1223	13725
Sawmill post-construction	Main channel	1125	26	Fry	8.5	1429	3006	954	5389
				Presmolt	8.5	1841	4618	542	7001
	Cemetery side channel	1050	10	Fry	1.1*	2638	1123	1928	5689
				Presmolt		3631	2417	935	6983
	Sawmill side channel	520	8	Fry	0.3*	1220	1238	535	2994
				Presmolt		1499	1953	257	3709
	Entire site	1125		Fry	8.5	5287	5368	3418	14073
				Presmolt	8.5	6971	8987	1734	17692

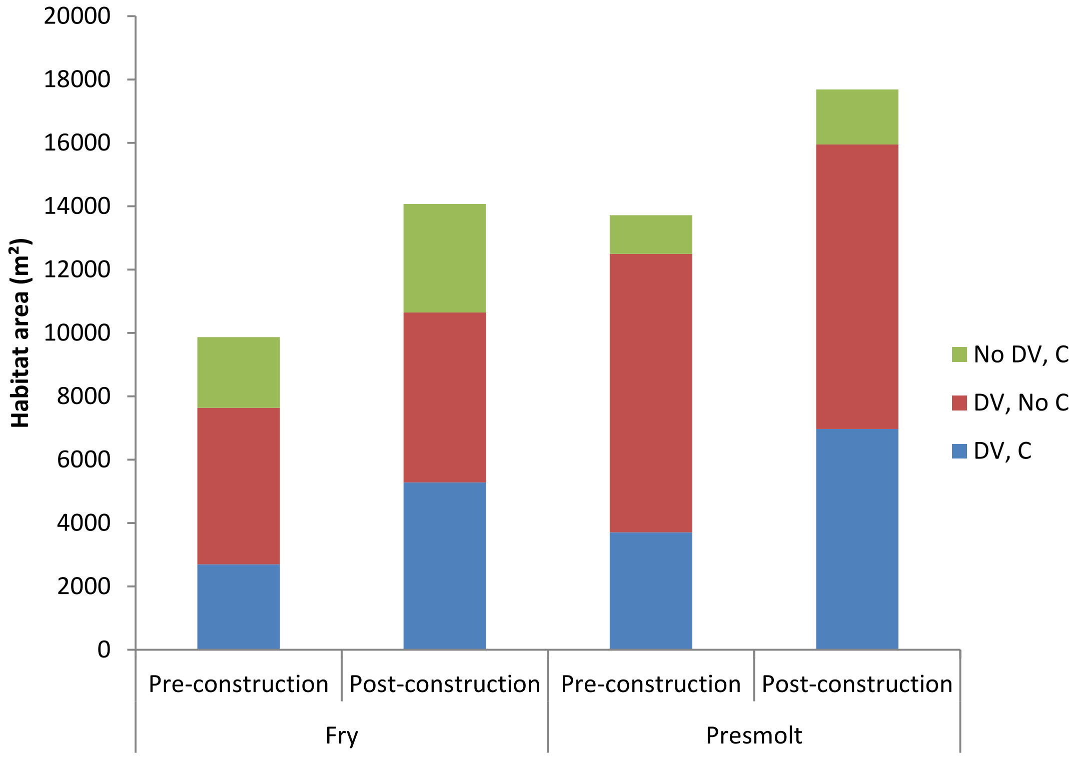

Figure 3. Chinook and coho Salmon rearing habitat quantities at the entire Sawmill rehabilitation site (rkm 176.5-175.4). Pre-construction estimates were conducted at 8.3cms (294 cfs) in 2009 and post-construction at 8.5 cms (306 cfs) in 2010. Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.

When habitat density (m^2/m of channel) at Sawmill was compared to other rehabilitation sites, Sawmill ranked highest in optimal habitat density and second highest in total habitat density (Figure 7).

The Trinity River Large Wood Analysis and Recommendation Report (Cardno Entrix, CH2MHILL, 2011) recommended between 50-60 pieces of LWD per 100 m of channel length as an appropriate target for the Upper Trinity River project reach. The Trinity River Channel Design Guide (HVT and McBain and Trush 2011) recommended 5-23 pieces per 100m length of channel. Large wood surveys at Sawmill identified densities of around 51 pieces of LWD per 100 m of channel length (HVT, YTF, and USFWS unpublished data) falling within the recommended ranges. The density of LWD at Sawmill post-construction is an important component to the increases in habitat observed.

Figure 4. Chinook and coho salmon rearing habitat quantities throughout the mainstem portion of the Sawmill rehabilitation site (rkm 176.5-175.4). Pre-construction estimates were conducted at 8.3cms (294 cfs) in 2009 and post-construction at 8.5 cms (306 cfs) in 2010. Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.

Total habitat densities within the side channels were calculated and compared with other recently constructed side channels (Table 4). Habitat densities at Sawmill and Cemetery Side Channels ranked second and third respectively amongst all side channels analyzed. Increases in total habitat density within the two side channels ranged from 11% to 40%, in Cemetery and Sawmill respectively.

A unique and highly valuable habitat feature developed upon activation of the Sawmill Side Channel. Water was able to flow sub-surface from the side channel and emerge approximately 20 m away as a seep forming a heavily vegetated backwater feature. The backwater is 60 m long and covers an area of 425 m^2. It connects back to the main Sawmill Side Channel and visual observations while mapping detected the presence of Chinook and coho salmon rearing within the feature.

Favorable changes have occurred in the Cemetery Side Channel since construction.

The area that received floodplain lowering with the construction of a 42.5 cms (1500 cfs) inundation surface (HVT and McBain and Trush, 2009) and LWD augmentation has experienced significant positive changes. The re-constructed channel is more complex and sinuous and should provide valuable rearing and spawning habitat over a greater range of flows than prior to construction (Figure 9). The interaction of LWD and high flows over the past two seasons since construction have also played a major role contributing to the side channel's present state.

Mainstem rehabilitation actions at Sawmill included specific design features and actions, including the removal of two man-made wire gabions and four rock weirs. Two forced meanders were also built along with constructed bar features on the opposite bank (HVT and McBain and Trush 2009). A new design element

Figure 5. Chinook and coho salmon rearing habitat quantities within the Sawmill Side Channel portion of the Sawmill rehabilitation site (rkm 176.5-175.4). Pre-construction estimates were conducted at a mainstem discharge of 8.3 cms (294 cfs) in 2009 and post-construction at a mainstem discharge of 8.5 cms (306 cfs) in 2010. Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

incorporated into the constructed bar features included a scour channel and alcove on the backside of the bar connecting with the river at the downstream end (Figure 10). Total habitat on the left bank around the constructed bar including the alcove increased by 308 m² or 134%. These scour channels and alcoves provide valuable fry and presmolt rearing habitat and are naturally occurring features in unregulated rivers.

Recommendations

Habitat mapping and analysis indicate the Sawmill rehabilitation site to be among the highest density habitat area of any post-ROD channel rehabilitation site evaluated to date, the year after construction. The fact that a mainstem channel and two side channels (Sawmill and Cemetery Side Channel) are occupying the same section of river valley contributes greatly to the high habitat densities.

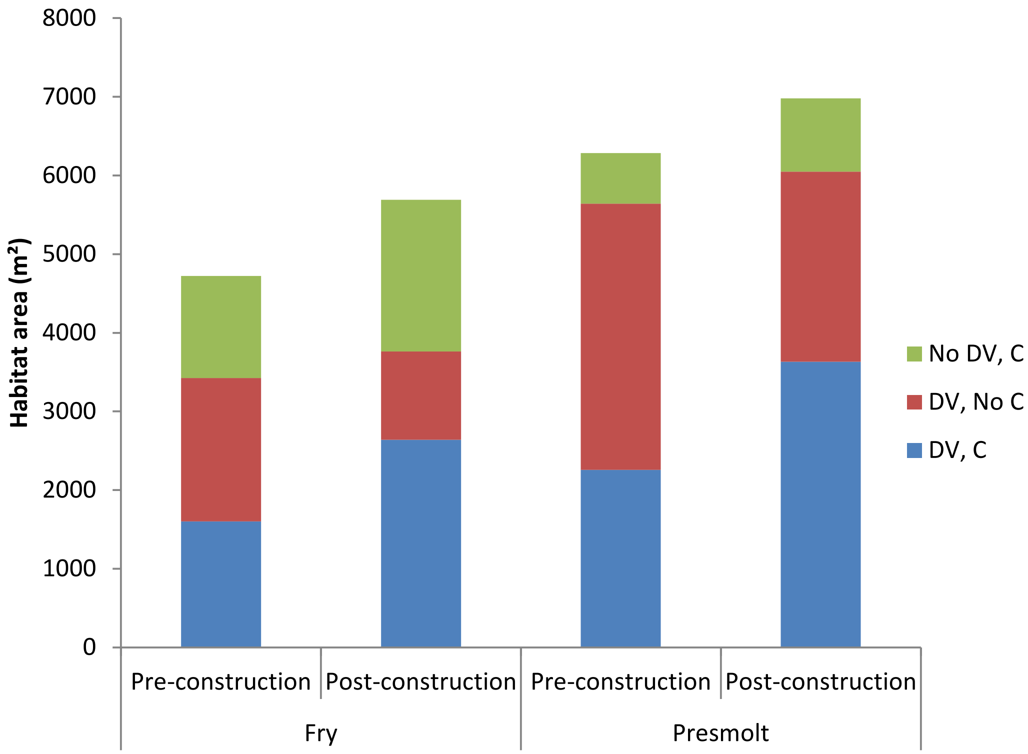

Figure 6. Chinook and coho salmon rearing habitat quantities within the Cemetery Side Channel portion of the Sawmill rehabilitation site (rkm 176.5-175.4). Pre-construction estimates were conducted at a mainstem discharge of 8.3cms (294 cfs) in 2009 and post-construction at a mainstem discharge of 8.5 cms (306 cfs) in 2010. Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.

Large woody debris and other vegetative cover also play a major part in the rehabilitation efforts contributing to the overall habitat gains. Vegetative slash was used at Sawmill in all LWD installations. The slash provides vital escape cover for fry and juvenile rearing immediately after construction when other types of vegetative cover have not yet established (Figure 11). The authors recommend that TRRP continue to incorporate cover components such as LWD, small wood, slash, as well as promote the growth of natural vegetation such as grasses along the wetted channel in all future restoration sites.

Alcoves and backwaters associated with the downstream edge of rehabilitated gravel bars also resulted in positive habitat gains and we recommend that these features be incorporated into future rehabilitation designs when possible and monitored for effectiveness.

The major goal of the Sawmill rehabilitation site was to immediately increase and over the long-term, sustain the quality and quantity of anadromous fry and pre-smolt habitats. A key element required to sustain the present habitat densities at the Sawmill site is the prolonged existence of the side channels and their openings. Over 70% of the increases to presmolt habitat were accounted through the opening of the Sawmill Side Channel. The entrance to this channel closed off at winter base flow as a result of the 2011 high-flow release and deposition of material just below its entrance. There will be a substantial reduction in base flow habitat as a result of this change.

We highly recommend that the Sawmill site be revisited in the future, to not only monitor the maturation and habitat gains or losses, but also provide the insights from future observations that can be incorporated into the ongoing adaptive management processes, thereby, increasing the effectiveness of future rehabilitation efforts.

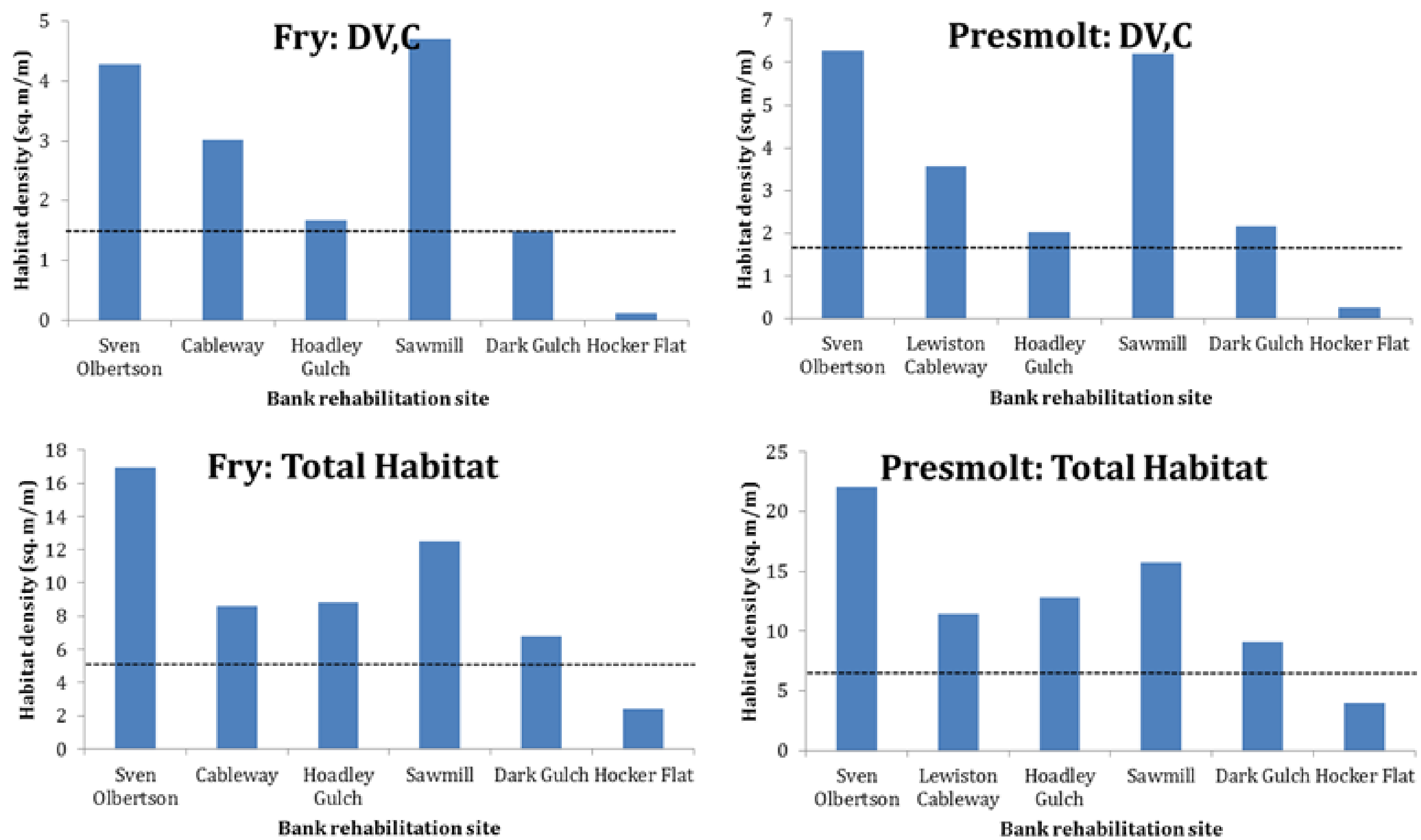

Figure 7. Post-construction habitat density by bank rehabilitation site. DV,C indicates optimal Chinook salmon and coho salmon rearing habitat and total habitat indicates all qualities of rearing habitat. Dotted lines indicate mean values within the primary restoration reach at 12.7 cms (450 cfs). The fry life stage indicates fish < 50 mm FL and presmolt ≥ 50mm FL.

Table 4. Side channel attributes among bank rehabilitation sites. Main channel discharge was measured by proximal USGS gauges. Side channel discharges were measured by handheld flow rod. Main channel length was measured by channel centerline. Total rearing habitat relates to fry and presmolt habitat quantities within the side channel. Habitat density for both fry and presmolt was measured using total habitat within the side channel divided by main channel length. *Discharges were measured in 2011.

Site	Main channel disch. (cms)	Side channel disch. (cms)	Main channel length (m)	Total fry habitat (m^2)	Fry habitat density (m^2/m)	Total presmolt habitat (m^2)	Presmolt habitat density (m^2/m)
Sven Olbertson	8.6	1.1	595	6,234	10.5	7,589	12.8
Lewiston Cableway	8.7	1.3	380	2,039	5.4	2,403	6.3
Hoadley Gulch	8.7	0.3	272	857	3.2	1,191	4.4
Sawmill	8.5	0.3*	520	2994	5.8	3709	7.1
Cemetery	8.5	1.1*	1050	5689	5.4	6983	6.7
Upper Dark Gulch	8.6	0.9	260	623	2.4	851	3.3
Lower Dark Gulch	8.6	< 0.1	186	797	4.3	827	4.4
Lower Indian Creek	13.4	1.37*	900	1,644	1.8	2,652	2.9

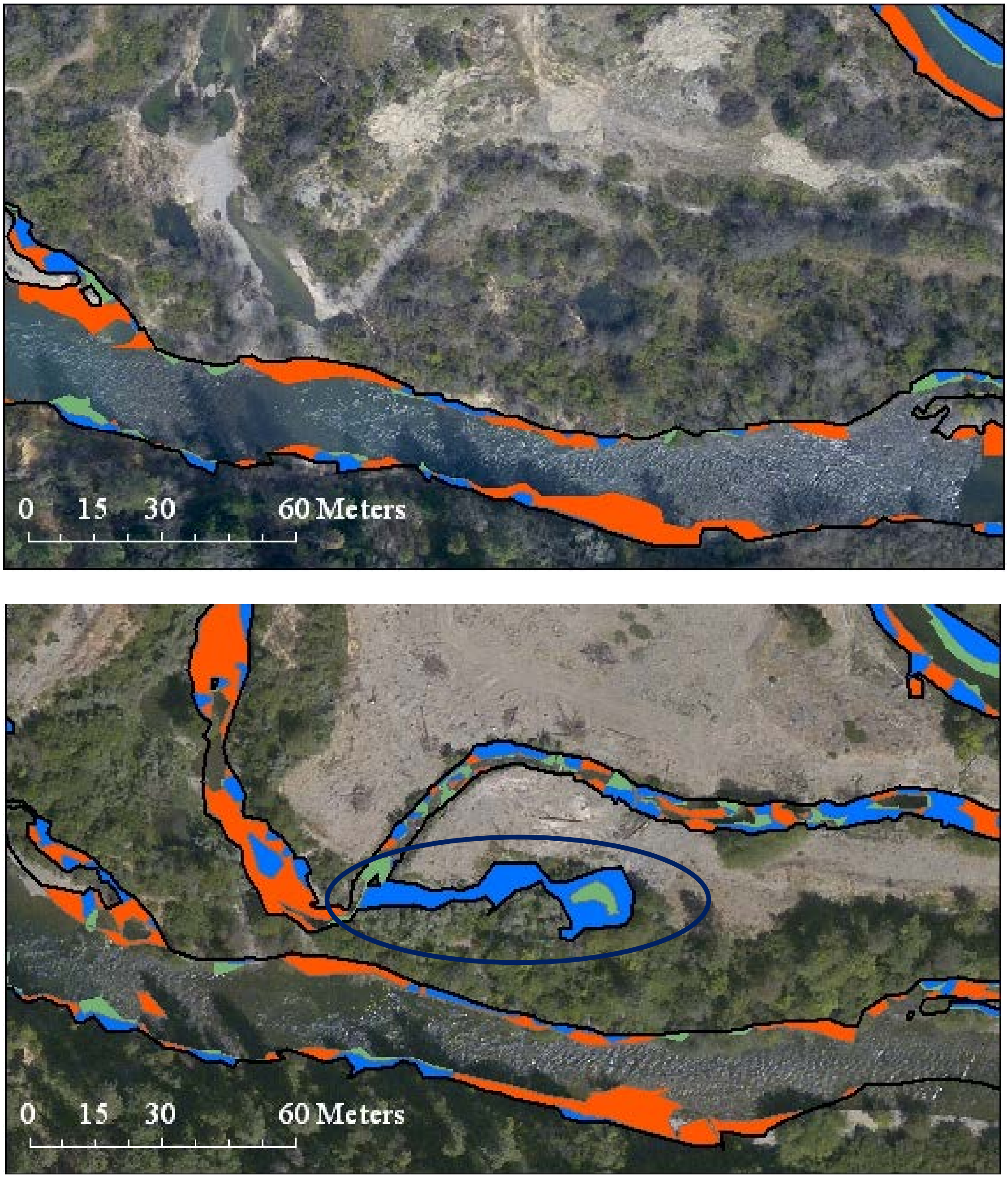

Figure 8. Aerial views of Sawmill Side Channel and mainstem prior to construction (upper photo), and the flowing side channel with newly formed backwater, post-construction (lower photo; rkm 176.2). Black lines indicate the wetted edge, blue areas indicate optimal presmolt habitat and red and green areas indicate suitable presmolt habitat.

Figure 9. Aerial views of Cemetery Side Channel (rkm 175.75) prior to construction in 2009 (left photo) and post construction, post two high flows in 2011 (right photo). Both photos were taken at summer base flow ~12.7 cms (450 cfs).

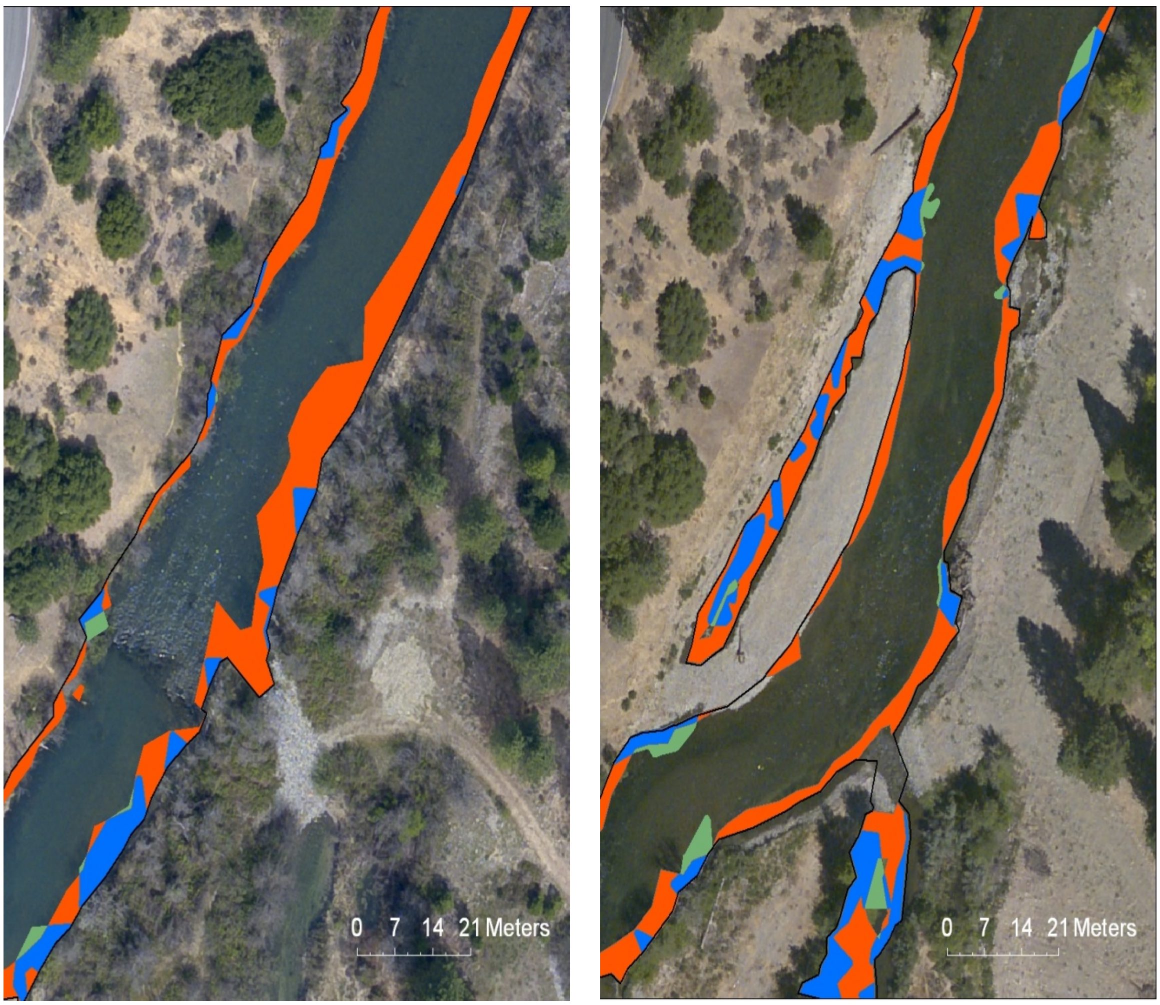

Figure 10. Aerial views of forced meander location at Sawmill rehabilitation site (rkm 176.0) before construction (left photo) and after construction (right photo). Black lines indicate the wetted edge, blue areas indicate optimal presmolt habitat and red and green areas indicate suitable presmolt habitat. Mainstem discharge pre-construction was 8.3 cms (294 cfs) and 8.5 cms (304 cfs) post-construction.

Figure 11. Slash incorporated into a large wood installation at Sawmill rehabilitation site. Large wood installations at previous sites did not incorporate slash, which increases the benefit of these installations to rearing salmonids. Slash increases the physical complexity of these features and therefore increases the quality of the escape-cover attributes for fish habitat.

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