Age-0 Chinook and Coho Salmon Rearing Habitat Assessment: Sawmill Rehabilitation Site, Three Years after Construction at Winter Base Flow, Upper Trinity River

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Table of Contents

List of Tables

List of Figures

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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 is a primary management tool employed to accomplish restoration goals and 44 sites were planned for the Trinity River. The Sawmill channel rehabilitation site was completed in 2009 and included several construction features such as mainstem re-alignment, coarse sediment placement, side channel manipulation, floodplain lowering, and installation of the highest density of large wood on the Trinity River at the time of construction. The features constructed at Sawmill were predicted to increase and sustain the availability, quantity, and quality of habitat for all life stages of anadromous fish between 8.5 and 56.6 cms (300 and 2,000 cfs). We evaluated the changes to age-0 Chinook and Coho salmon winter rearing habitats at typical winter streamflows before construction, after construction and again three years later after three high streamflow events over 170 cms (6,000 cfs). Habitat availability increased from construction. Some of the initial benefits and features, however, were not sustained three years after construction. We measured a 13% to 47% decrease in rearing habitat indicators throughout the entire site between post-construction and the site revisit conducted three years later. Changes in habitat area area between the post construction and revist surveys were not evenly distributed across construction features, with the largest reductions occurring in side channel features. While construction increased habitat area at the site, some features provided only short-term benefits.

Introduction

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 to facilitate full participation in harvest opportunities for dependent tribal, commercial, and sport fisheries (TRRP and ESSA Technologies Ltd. 2009, USBOR 2009). Construction of channel rehabilitation sites is one of the primary tools used to accomplish this restoration goal. The TRRP has been implementing channel rehabilitation since 2005, with roughly half of the 44 projects proposed in the Record of Decision (ROD) completed by the end of 2011. Evaluation of project performance is critical to inform the remaining channel rehabilitation designs. 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 Sawmill rehabilitation site was constructed in the summer of 2009. Habitat monitoring occurred at Sawmill rehabilitation site (rkm 176.5-175.4) before construction in spring of 2009 (pre-construction) and after construction in spring of 2010 (post-construction). Three high flow events occurred in the Upper Trinity River between 2010 and 2012. These included a 342 cms (12,100 cfs) event in 2011. Changes were noted through qualitative observation at the Sawmill site following these high flow events. This triggered a revisit assessment in 2012 (revisit).

The primary objective of this report is to quantify changes in habitat that occurred between 2012 and the post-construction visit in 2010. A secondary objective is to place the 2012 conditions in context with pre-construction habitat values. These assessments contribute to the TRRP’s adaptive management process by providing short-term feedback to improve future management actions such as mechanical channel rehabilitation, coarse sediment augmentation, and annual flow operations.

Drainage and Channel Rehabilitation Site Description

The Trinity River is located in northwestern California within Humboldt and Trinity counties and the Hoopa Valley Indian Reservation. The watershed has a drainage area of 7,679 km^2, approximately one quarter of which is upstream of Lewiston Dam and inaccessible to anadromous fishes (USFWS 1989; USBOR 2009). The river’s headwaters are in the Salmon-Trinity Mountains of northern California, from which it flows 274 km to its confluence with the Klamath River in Weitchpec, California. This monitoring effort focuses on the Sawmill rehabilitation site located in Lewiston, California approximately 4 river kilometers (rkm) downstream of the Lewiston Dam (Figure 1).

The Sawmill rehabilitation site encompasses 1,125 m of mainstem river channel. Mainstem rehabilitation actions involved the removal of 2 gabions and 4 rock weirs, addition of alluvial bars and excavation of vegetated banks to increase channel sinuosity (Figure 2; HVT and McBain and Trush 2009). Contained within the construction area was the Cemetery side channel. This side channel was previously constructed in the mid-1980's to provide increased spawning and rearing habitat and has remained functional since its construction. Cemetery side channel has provided

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.

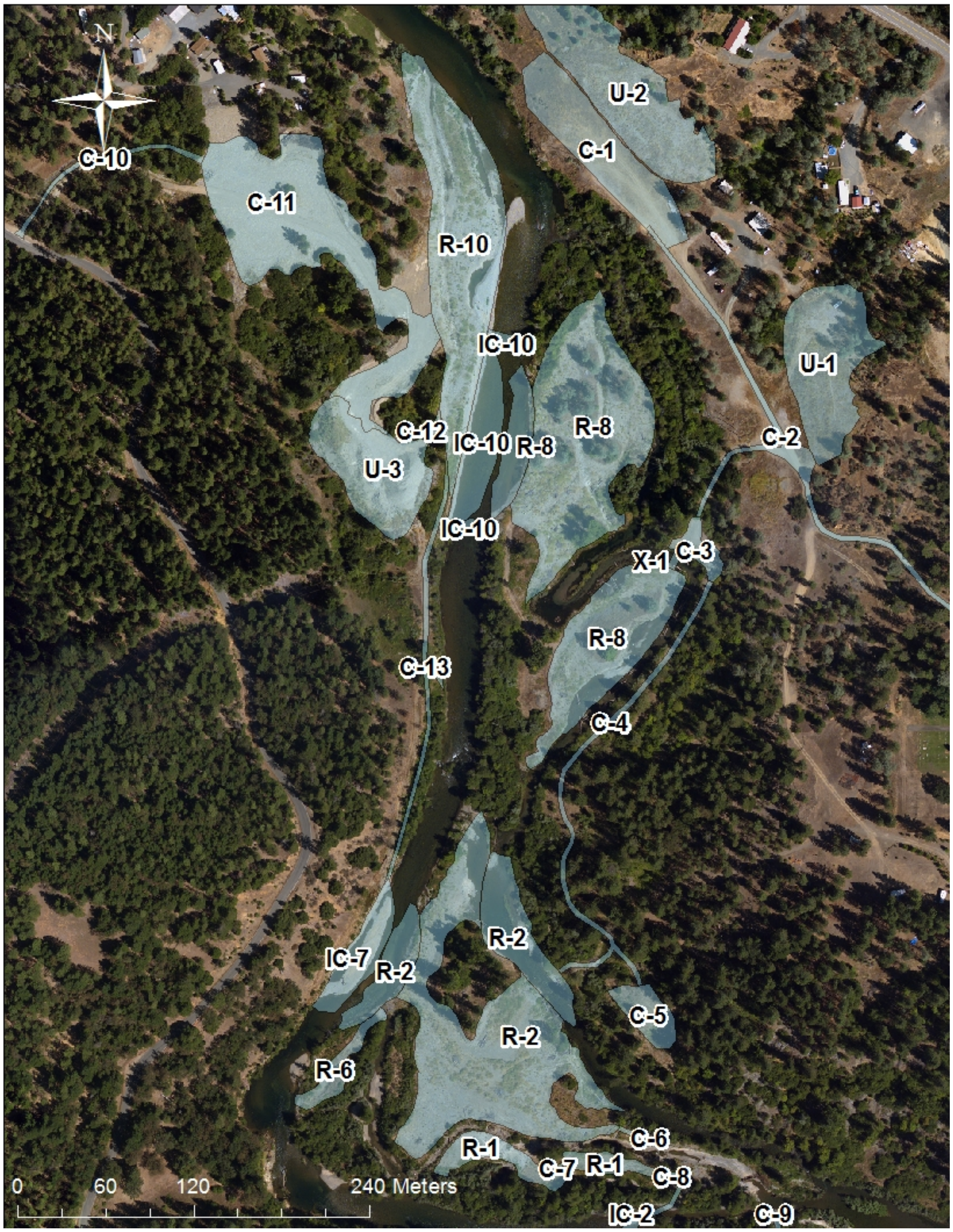


Figure 2. Aerial photos of Sawmill rehabilitation site design elements taken in 2011. Blue polygons indicate design rehabilitation site design elements (HVT and McBain and Trush 2009). 'IC' indicates an in-channel feature, 'R' is a riverine/floodplain feature, 'C' indicates contractor use areas, 'U' identifies spoil locations and 'X' is a construction crossing.

quality rearing and spawning habitat (65 redds in 2009) at winter base flows (Chamberlain et al. 2012, Martin et al. 2012). However, portions of the channel were highly confined, offering limited rearing habitat at higher flows. Therefore one element of the design included removing earthen piles associated with side channel construction in the 1980's and lowering of the adjacent floodplain. These features were designed to improve rearing habitat availability between 1,000 and 8,000 cfs flows and increase floodplain complexity (HVT and McBain and Trush 2009).

A feature of the design involved re-opening a side channel inlet that was plugged by coarse sediment that blocked side channel inflow at river discharges less than 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. The entrance and upper section of the Sawmill side channel were re-aligned and large wood and slash was added at 25 locations (Fiori and Martin 2011).

Methods

Surveys were conducted at winter base flow and are a good representation of conditions experienced during the critical winter rearing period. The Sawmill site is proximal to the dam with only one small tributary adding streamflow. The winter rearing period ranges from January to May, with flow releases from Lewiston Dam to the Trinity River managed at a stable 8.5 cms (300 cfs).

Rearing habitat was characterized and quantified by developing planar maps of the study area following methods described by Goodman et al. (2010). Rearing habitat definitions for fry and presmolt life stages are summarized in Table 1. The habitat definitions were 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) and are commonly applied for rearing habitat assessments evaluating channel rehabilitation sites (Goodman et. al. 2010). Optimal Chinook salmon rearing habitat includes areas that meet all depth, velocity and cover criteria (Table 2). Suitable Chinook salmon rearing habitat includes areas

Table 1. Rearing habitat definitions and associated criteria for habitat mapping.

Habitat Guild	Variable	Criteria
Chinook salmon and coho salmon fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.12 m/sec
	Distance to Cover	0 to 0.61 m
	Cover type	No cover, vegetation or wood
Chinook salmon and coho salmon presmolt (50 to 200 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/sec
	Distance to Cover	0 to 0.61 m
	Cover type	No cover, vegetation or wood

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

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

*Total habitat reported includes optimal habitat + all suitable habitats present that meet both depth and velocity or cover criteria, but not both. Total Chinook salmon rearing habitat (total habitat) included both suitable and optimal habitats. Unsuitable Chinook salmon rearing habitat includes areas outside of all depth/ velocity and cover criteria. Coho salmon rearing habitat is limited to areas that meet all depth, velocity and cover criteria, described as optimal habitat in this report. All other areas are considered unsuitable habitat for Coho salmon fry and presmolts.

Fish habitat surveys were conducted to delineate areas within the Sawmill rehabilitation site that met habitat definitions defined in Table 2. Survey data were developed as a series of spatially referenced geographic information system (GIS) layers. Within GIS, surveyed polygons were used to represent areas of fry and presmolt rearing habitat based on binary depth, velocity, and cover criteria. Once the GIS polygons were created that depicted the four categories of habitat quality, areas of the polygons for each type of habitat were summed and compared over time.

Results and Discussion

A goal of the Sawmill rehabilitation site was to “increase and sustain the availability, quantity and quality of anadromous fish habitat between 300 cfs and 2,000 cfs for all life stages” (HVT and McBain and Trush 2009). Immediately after construction, monitoring in 2010 documented total rearing habitat increases of 42% for fry and 29% for presmolts and increases in optimal habitat of 96% and 88% for fry and presmolts at winter base flow compared to pre-construction conditions (Martin et al. 2012). The increases in quantity (total habitat) and quality (optimal habitat) of rearing habitat were the second largest observed at that time for any of the TRRP channel rehabilitation sites (Sven Olberston was the highest; HVT, Yurok Tribal Fisheries, and USFWS unpublished data).

This report evaluates the Sawmill rehabilitation site at a site level and separately for the site’s three main areas, the mainstem, Cemetery side channel, and Sawmill side channel (Figure 3). The three areas of the site responded differently to the high flow events that occurred since construction was completed in 2009.

Comparison of the post-construction site evaluation conducted in 2010 with the revisit survey conducted in 2012 showed a decrease in the total habitat area for fry and presmolt of 13% and 15%, respectively. Optimal habitat decreased 43% and 47% for fry and presmolt, respectively, since post-construction for the entire site (Table 3, Figure 4). However, in all cases habitat areas estimated from the 2012 site revisit survey remained above pre-construction levels. Total habitat area increased between 24% for fry and 10% for presmolt when compared to pre-construction conditions. Optimal habitat increased 11% for fry and remained stable (0.3% reduction) for presmolt compared with pre-construction estimates.

Mainstem

Availability of total fry habitat in the mainstem during the revisit decreased 21% since post-construction. Total presmolt habitat availability decreased 11%. Optimal habitat decreased by 70% and 67% for fry and presmolt respectively throughout the mainstem. Total habitat area was similar between pre-construction and revisit. However, the area of optimal habitat for fry and presmolt was lower during the revisit than what was observed pre-construction, by 49% and 48%, respectively (Figure 5).

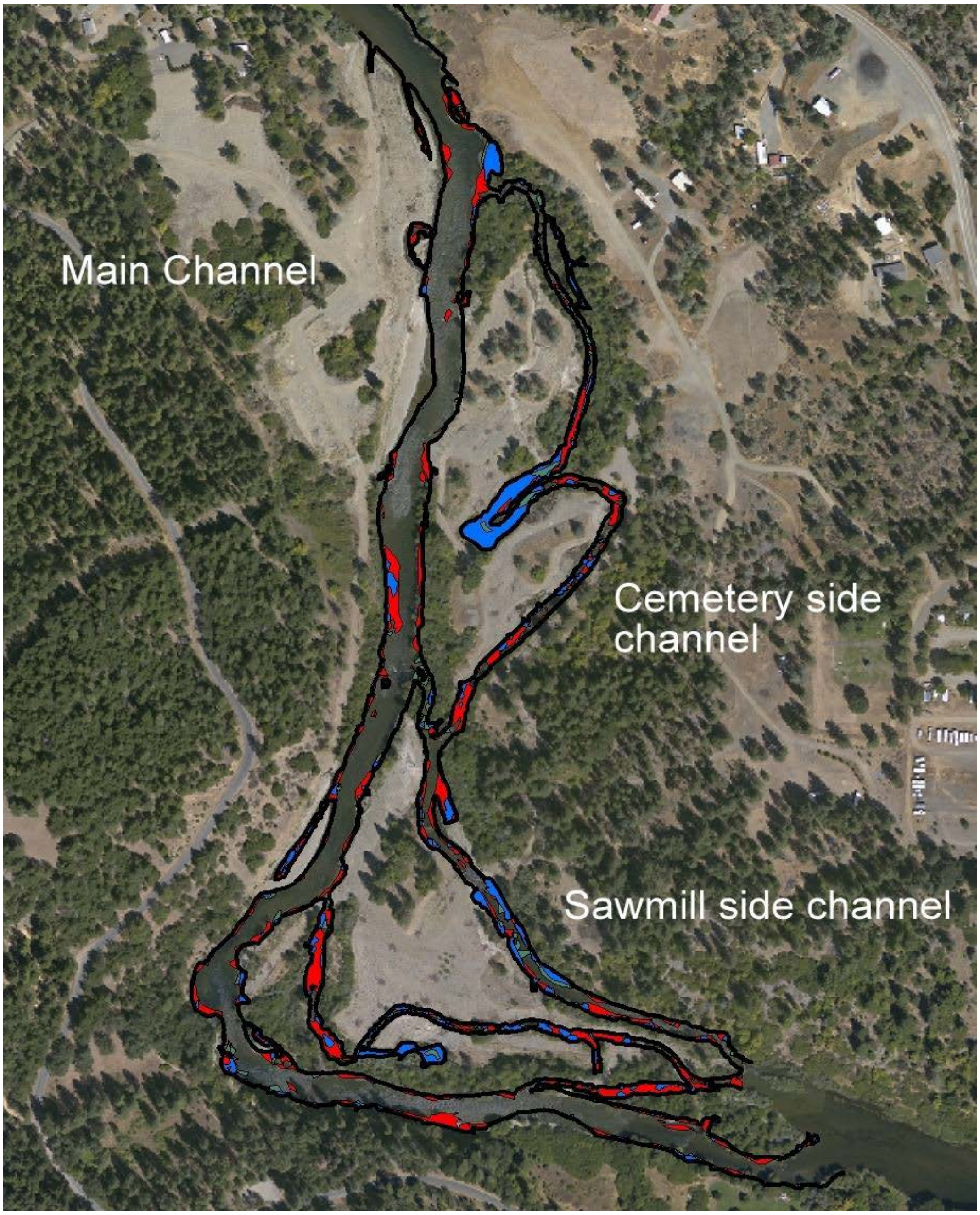


Figure 3. Aerial view of Sawmill rehabilitation site. Black lines indicate the wetted edge, blue areas indicate optimal presmolt habitat and red and green areas indicate suitable presmolt habitat during 2010 post-construction surveys.

Table 3. Habitat conditions at winter base flows before and after construction, and upon revisit 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). All discharges (Q) were measured during site assessments except those indicated with an asterisk. Those indicated with an asterisk were measured in 2011.

					Categorical habitat areas (m^2)			
Evaluation type	Location	Length (m)	Life stage	Q (cms)	Optimal DV, C	Suitable DV, NoC	Suitable NoDV,C	Total habitat
Pre-construction	Mainstem	1,125	Fry	8.3	853	2,846	825	4,524
			Presmolt	8.3	1,150	4,894	528	6,572
	Cemetery side channel	1,050	Fry	1.4	1,602	1,820	1,284	4,706
			Presmolt	1.4	2,259	3,385	641	6,285
	Sawmill side channel	157	Fry	0.36	234	266	125	626
			Presmolt	0.36	294	490	66	850
	Entire site	1,125	Fry	8.3	2,689	4,932	2,234	9,856
			Presmolt	8.3	3,702	8,764	1,221	13,687
Post-construction	Mainstem	1,125	Fry	8.5	1,424	3,018	979	5,422
			Presmolt	8.5	1,837	4,673	567	7,077
	Cemetery side channel	1,050	Fry	1.1*	2,635	1,116	1,903	5,653
			Presmolt		3,628	2,407	909	6,945
	Sawmill side channel	520	Fry	0.3*	1,220	1,213	535	2,968
			Presmolt		1,498	1,873	257	3,628
	Entire site	1,125	Fry	8.5	5,279	5,347	3,417	14,043
			Presmolt	8.5	6,963	8,953	1,733	17,650
Revisit	Mainstem	1,125	Fry	8.5	433	3,018	603	4,291
			Presmolt	8.5	600	5,258	436	6,296
	Cemetery side channel	1,050	Fry	2.2	2,513	2,037	2,489	7,039
			Presmolt		3,036	2,838	1,966	7,839
	Sawmill side channel	157	Fry	0.01	43	791	10	844
			Presmolt		53	868	0	921
	Entire site	1,125	Fry	8.5	2,989	6,082	3,102	12,174
			Presmolt	8.5	3,689	8,964	2,402	15,056

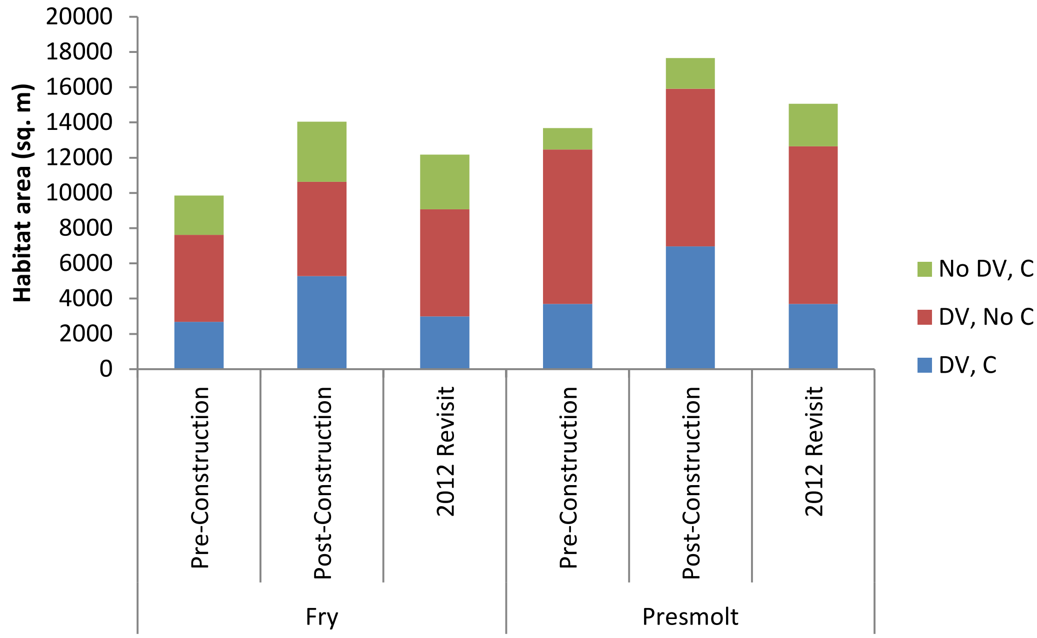


Figure 4. Area of rearing habitat types across the entire Sawmill rehabilitation site during pre-construction, post-construction and revisit surveys. All surveys were conducted at approximately 8.5 cms (300 cfs). Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.

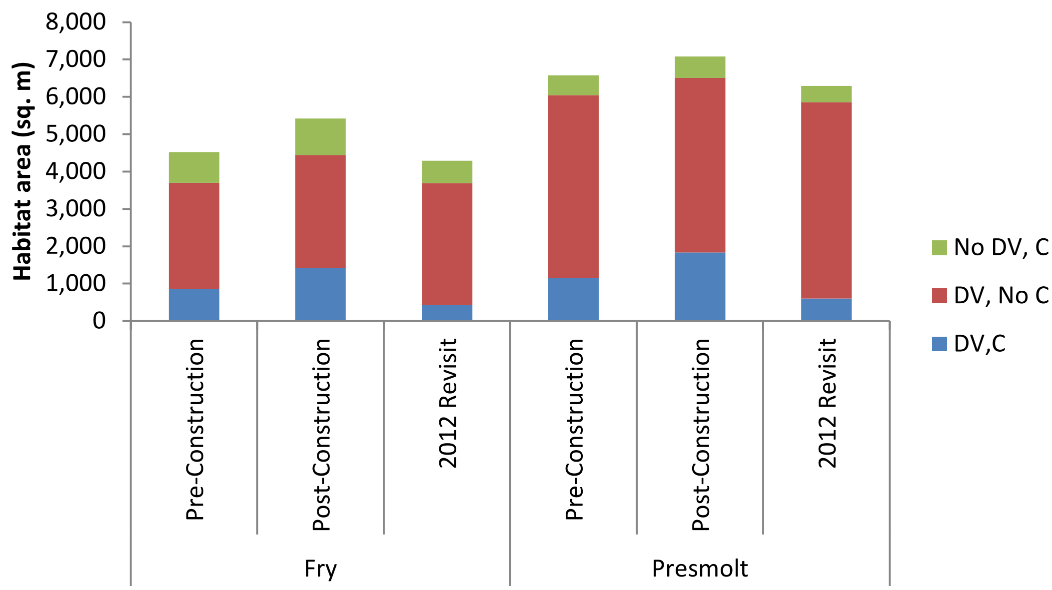


Figure 5. Area of rearing habitat types within the mainstem portion of the Sawmill rehabilitation site during pre-construction, post-construction and revisit surveys. All surveys were conducted at approximately 8.5 cms (300 cfs). Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.

One mainstem feature that exhibited a substantial change was an area of coarse sediment augmentation in the lower half of the site, referred to as IC-10 (HVT and McBain and Trush 2009). The goal of the coarse sediment addition was to increase the sinuosity and lower the radius of curvature to promote alluvial processes and increase habitat. This bar was mobilized by the ROD flows, resulting in the channel shifting to the left and re-occupying its pre-construction location. The channel migration created a lower velocity area on river right. This resulted in a large area of suitable habitat for presmolt but not fry, adjacent to the coarse gravel augmentation site (Figure 6). This slow water feature is showing signs of deposition and may not persist. Therefore, questions remain as to the longevity of this feature.

Sawmill side channel:

The largest changes since the post-construction survey occurred in the Sawmill side channel (Figure 7). During the revisit the discharge from Sawmill side channel had decreased to 0.01 cms (0.4 cfs). Therefore the major arm that was reopened in this side channel was no longer flowing at winter base flows during the revisit. As a result, total available habitat decreased from post-construction levels by 72% for fry and 75% for presmolt (Figure 8). However, habitat quantities did not drop below pre-construction levels with increases of 35% more fry and 8% more presmolt habitat compared to pre-construction conditions. Optimal habitat decreased by 96% for both fry and presmolt life stages since post-construction and 82% from pre-construction (for both fry and presmolt).

Cemetery side channel:

Of the three areas in the rehabilitation site, only Cemetery side channel showed overall increases in total habitat during the revisit, compared to what was observed post-construction. Total habitat within the side channel increased 25% and 13%, for fry and presmolt, respectively. There was a decrease in optimal habitat compared to post-construction observations of 5% for fry and 16% for presmolt. However, Cemetery side channel was the only area where the availability of optimal habitat remained higher during the revisit than what was observed pre-construction (Figure 9). Discharges measured during the revisit in Cemetery side channel doubled since the post-construction visit, increasing from 1.1 cms (38.8 cfs) to 2.2 cms (76.2 cfs). In all cases habitat area was greater for the revisit survey than pre-construction survey with 50% and 25% increase in total and 57% and 34% increase in optimal habitat for fry and presmolt, respectively.

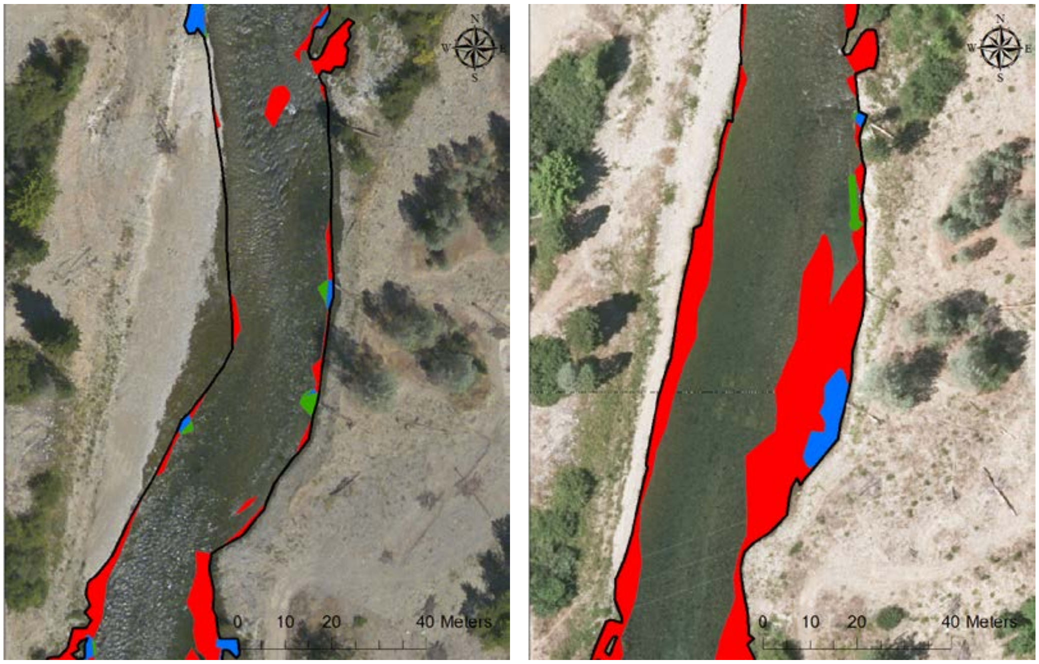


Figure 6. Aerial views of the mainstem IC-10 location. 2010 post construction (left) and 2012 revisit (right). Black lines indicate wetted edge. Red and green polygons indicate suitable juvenile habitat and blue polygons indicate optimal juvenile habitat. *The aerial photo on the right was taken after the ROD flow in 2011.

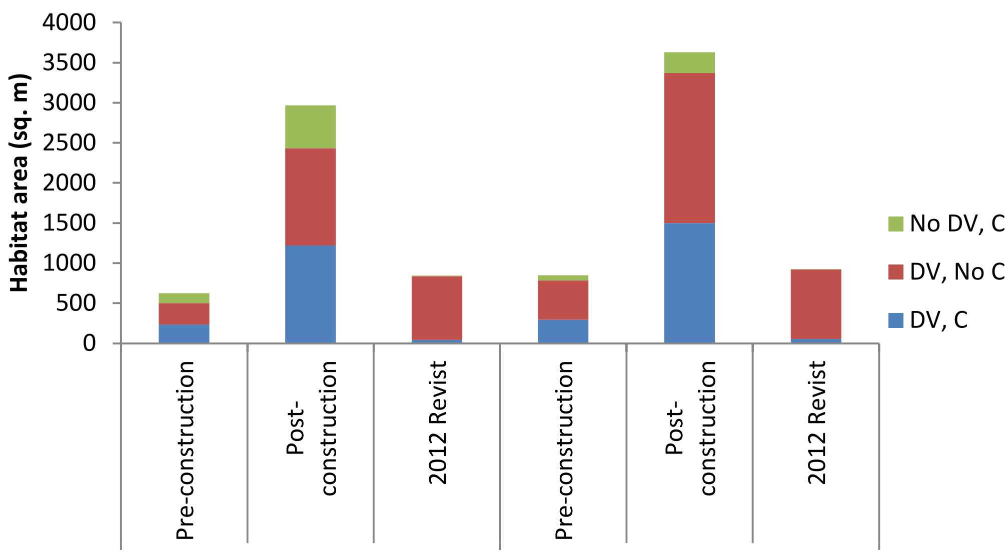
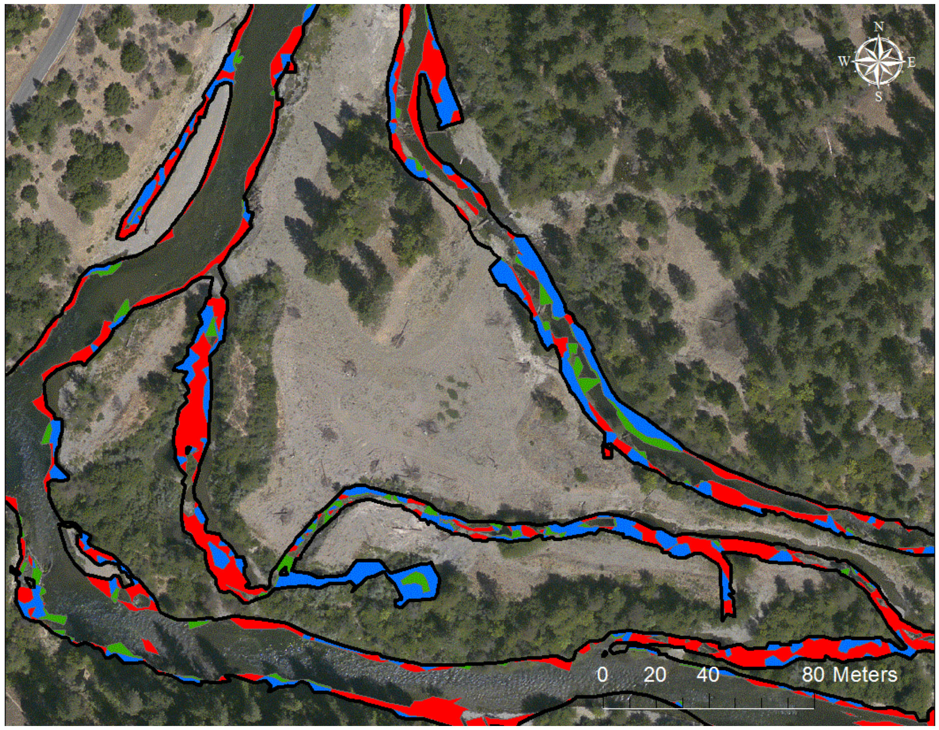


Figure 7. Area of rearing habitat types in the Sawmill side channel during pre-construction, post-construction and revisit surveys. All surveys were conducted at approximately 8.5 cms (300 cfs). Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.



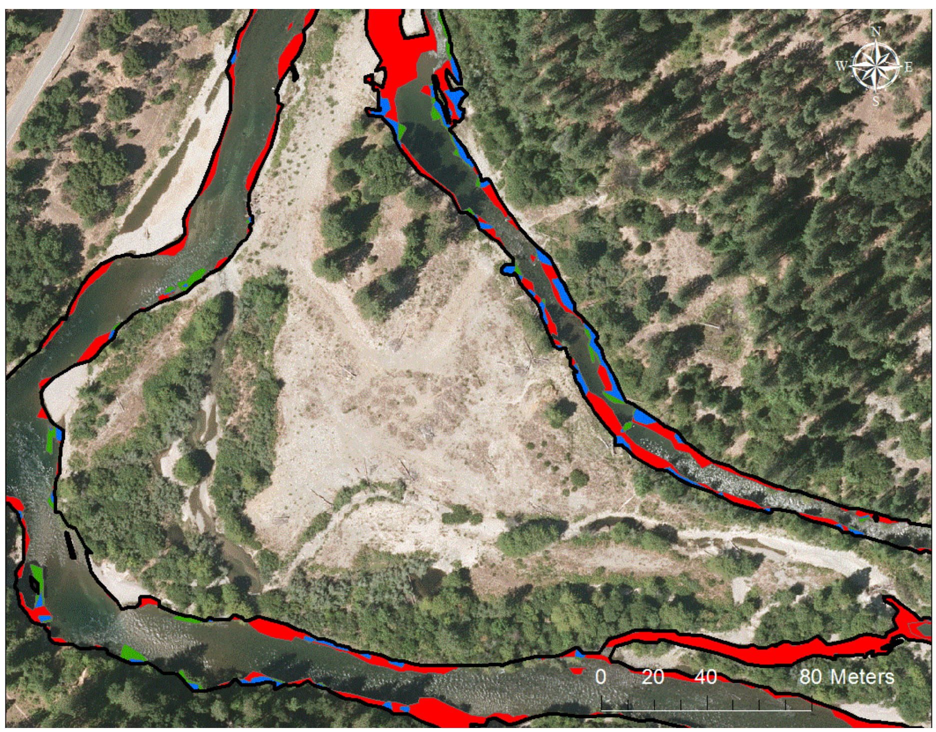


Figure 8. Aerial views of the Sawmill side channel (2010 post construction above, 2012 revisit below). Black lines indicate wetted edge. Red and green polygons indicate suitable juvenile habitat and blue polygons indicate optimal juvenile habitat. *The aerial photo on the bottom was taken after the ROD flow in 2011.

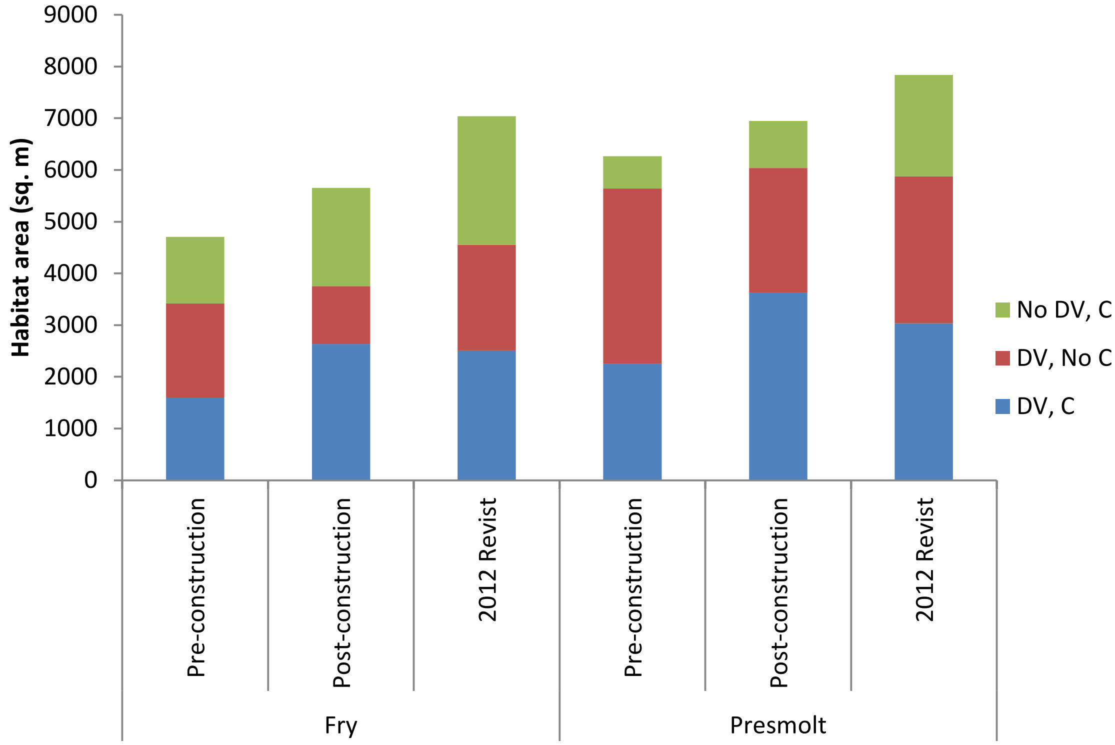


Figure 9. Area of rearing habitat types in the Cemetery Side Channel during pre-construction, post-construction and revisit surveys. All surveys were conducted at approximately 8.5 cms (300 cfs). Habitat categories correspond to combinations of depth/velocity (DV) and in-water escape cover (C) criteria.

Cemetery side channel has a central outlet into the mainstem Trinity River, which flows through dense vegetation and is relatively stable. Upstream of the original central outlet, the river has scoured the floodplain and is now over 33 m closer to the mainstem than it was post-construction, as of the revisit in 2012. This large, shallow, low-flow area has resulted in substantial gains in suitable habitat (Figure 10). There are also two additional outlets that are open at winter base flows of 8.5 cms (300 cfs), and several sites where large amounts of subsurface flow are permeating the substrate and entering the mainstem. It appears that rather than losing access to cover, as the other two areas did, Cemetery side channel showed a 10% increase in habitat with a cover component (No DV, C + DV, C) for fry and presmolt. Much of the observed increases are attributed to the complex central outlet. This change may also be related to a change in discharge in Cemetery side channel between post-construction and revisit surveys.

A positive change took place in the upstream area of R8 (see Figure 2) where floodplain lowering was conducted. Although the area was constructed to be inundated at 42.5 cms (1500 cfs; HVT and McBain and Trush 2009) much of it is now engaged at 8.5 cms (300 cfs). Since the post-construction evaluation, the channel has spread out across this lowered surface creating a more complex channel that includes large wood components, shallow slow velocity rearing areas for fry and juvenile salmonids, as well as spawning habitat for adults.

Recommendations

The TRRP and its partners should consider the possibility of channel rehabilitation site maintenance in-light of habitat losses. This point needs to be considered in relationship to alluvial processes, time lags expected for physical processes and distance of a site from Lewiston Dam (as a surrogate to level of natural streamflow variability). One of the most significant developments observed during the revisit was the "closed" arm of Sawmill side channel that was re-opened during construction.

The fact that this arm did not remain open, and is no longer flowing during winter base flow, drastically decreases the amount of habitat gained as a result of construction at winter base flow. However, this side channel will continue to provide high flow habitat as it did pre-construction. Re-opening this arm and modifying the channel entrance is something to consider if heavy equipment is mobilized in this area in the future. Redesigning side channels to include the use of hard point features such as large wood or boulders may help maintain functioning side channel entrances and should be considered in future designs (Abbe et al. 2003; Montgomery et al. 2006).

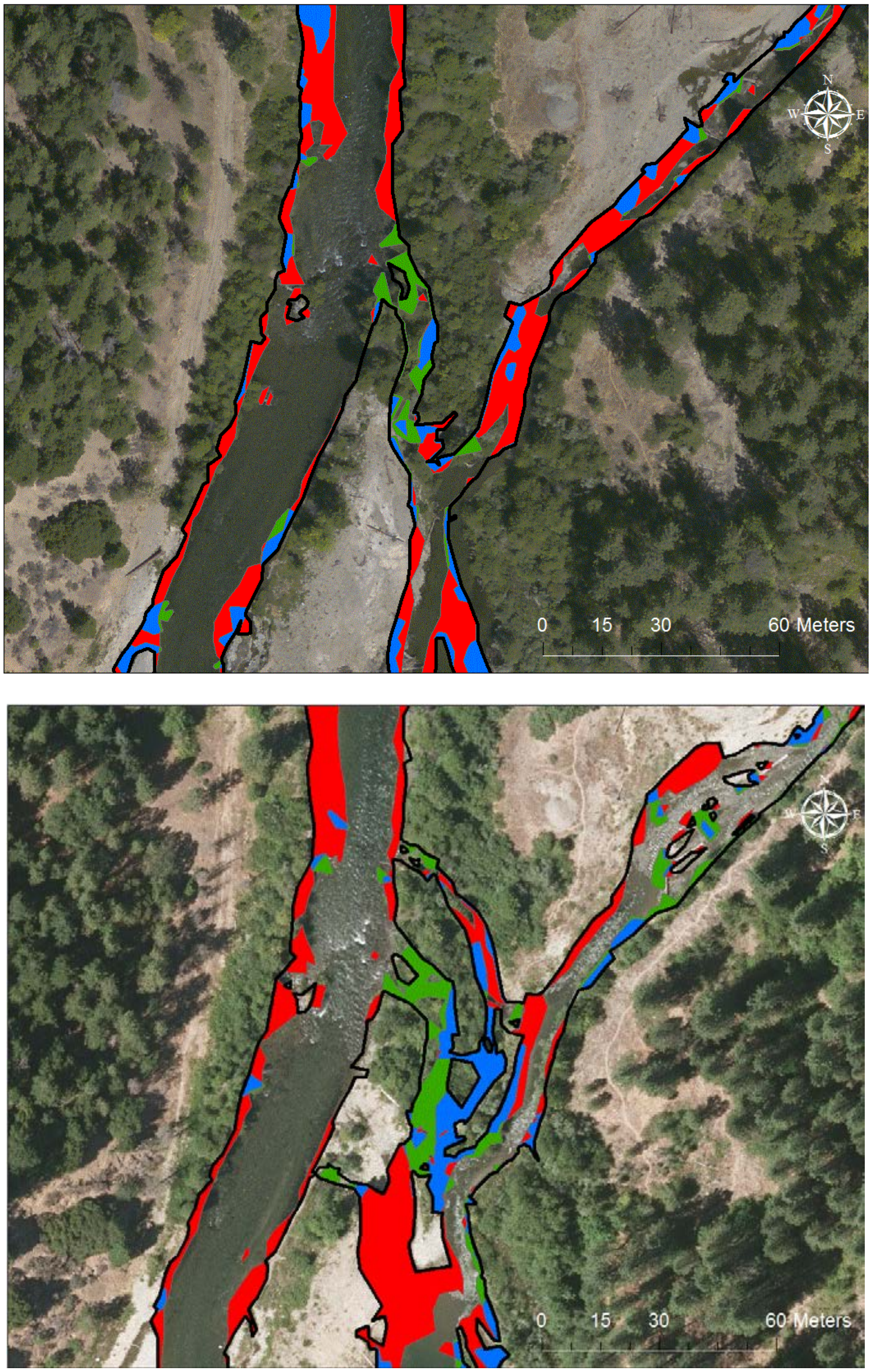


Figure 10. Aerial views of the Cemetery side channel central outlet into the mainstem Trinity River (2010 post construction above, 2012 revisit below). Black lines indicate wetted edge. Red and green polygons indicate suitable juvenile habitat and blue polygons indicate optimal juvenile habitat.

Another major concern is the scour that has occurred above the central outlet of Cemetery side channel. The new developments in this area pose some very troubling possibilities for the future of this site. If the channel continues to scour towards the mainstem, the majority of the flow could be lost to the lower portion of the side channel at winter base flow, where significant effort has been invested resulting in a large amount of rearing and spawning habitat.

This section represents roughly 70% of the total fry and presmolt habitat of Cemetery side channel and roughly 35% of total fry and presmolt habitat across the entire site. One significant flow event may lead to cutting off the lower section of Cemetery side channel causing further habitat reductions. Consideration should be given to place a combination of coarse sediment and large woody debris in this location to prevent the loss of critical habitat.

The mobilization of the IC-10 gravel augmentation element has returned the channel to its original left bank edge. Therefore increases in sinuosity have not occurred. The mobilization of this feature combined with floodplain lowering downstream on the left bank has also resulted in aggradation in an adult holding pool at the lower end of the site (Gaeuman and Krause 2013). The addition of a hard point feature and/or use of larger substrate at the upstream end of this feature could have greatly increased its chances of persisting and changing the nature of the existing thalwag as intended during site design. It should be noted that this is not the only feature that was mobilized in this matter during the high flow release that occurred in the spring of 2011. As this was the highest release post ROD on the Trinity River many lessons were learned after 2011 concerning sediment mobility. In the future, designers should consider the short and long term goals of the feature when deciding how to construct bars (including shape, material, and wood).

Maintenance of channel rehabilitation sites is not something that was planned. However, through adaptive management techniques partners and stakeholders may see major benefits and an opportunity to realize the original goals of construction after seeing how ROD flow events interact with these constructed features. This may especially apply to areas in the upper reaches of the river where juvenile fish densities are highest and dynamic river processes are diminished due to the Central Valley Project diversion and associated infrastructure.

Literature Cited

Abbe, Tim B., and David R. Montgomery. 2003. Patterns and processes of wood debris accumulation in the Queets river basin, Washington. Geomorphology 51.1: 81-107.

Chamberlain, C. D., S. Quinn, and W. Matilton. 2012. Distribution and abundance of Chinook salmon redds in the mainstem Trinity River 2002 to 2011. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report TR 2012-16, Arcata, California.

Fiori, R. and A. Martin. 2011. Sawmill Rehabilitation Site Wood Loading, Post Construction Report. Fiori Geosciences, Klamath, California.

Gaeuman, D. and A. Krause. 2013. Assessment of pool depth changes in the Trinity River between Lewiston Dam and the North Fork Trinity River. TRRP Technical Report TR-TRRP-2013-1, Trinity River Restoration Program, Weaverville, California.

Goodman, D., Martin, A., Alvarez, J., Davis, A., and Polos, J. 2010. Assessing Trinity River Salmonid habitat at channel rehabilitation sites, 2007-2008. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Yurok Tribe, and Hoopa Valley Tribe, Arcata, California.

HVT (Hoopa Valley Tribal Fisheries Department) and McBain & Trush, Inc. 2009. Trinity River-Sawmill (River Mile [RM] 108.88-109.73) and Reading Creek (RM 92.7-93.4) Rehabilitation Sites. Final Design Technical Memorandum. Hoopa Valley Tribe, Hoopa, California.

Martin, A., D.H. Goodman and J. Alvarez. 2012. 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. Yurok Tribal Fisheries Program, Willow Creek, CA. U.S. Fish and Wildlife Service Arcata Data Series Report Number DS 2012-26.

Montgomery, David R., and Tim B. Abbe. 2006. Influence of logjam-formed hard points on the formation of valley-bottom landforms in an old-growth forest valley, Queets River, Washington, USA. Quaternary Research 65.1: 147-155.

TRRP (Trinity River Restoration Program) and ESSA Technologies Ltd. 2009. Integrated Assessment Plan, Version 1.0-September 2009. Trinity River Restoration Program, Weaverville, California.

USBOR (United States Bureau of Reclamation). 2009. Trinity River Restoration Program, channel rehabilitation and sediment management for remaining phase 1 and phase 2 sites--Part 1: draft master EIR and Part 2: Environmental Assessment/draft EIR. Trinity River Restoration Program, Weaverville, California.

USFWS (United States Fish and Wildlife Service) and HVT (Hoopa Valley Tribe). 1999. Trinity River Flow Evaluation Final Report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California and Hoopa, California.

USFWS (United States Fish and Wildlife Service). 1989. Annual report, Trinity River flow evaluation. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California.