Estimation Of Age-0 Chinook And Coho Salmon Rearing Habitat Area Within The Restoration Reach Of The Trinity River At An Index Streamflow-Annual Report 2011

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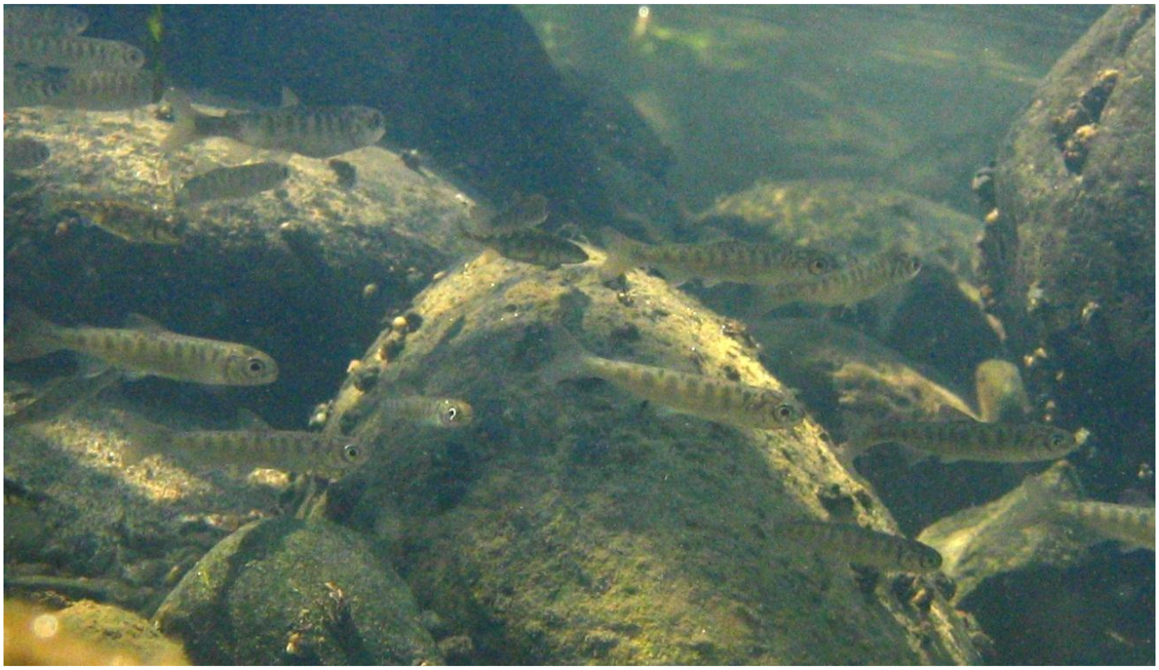

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Table of Contents

List of Tables

List of Figures

List of Appendices

Arcata Fisheries Technical Report TR 2013-18

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Abstract.—The Trinity River is the focus of a restoration effort designed to improve riverine function as a means for increasing anadromous fish populations. Chinook and coho salmon populations are limited by age-0 rearing habitat and are a primary focus of the restoration effort. We estimated the effects of restoration on Chinook and coho salmon rearing habitat over a 64-km restoration reach between 2009 and 2011. Each year rearing habitat area was measured at 32 randomly selected 400-m study sites at an index streamflow and then extrapolated to the restoration reach. Age-0 rearing habitat was divided into two developmental stages with different habitat requirements including fry and presmolt. The objectives of this assessment were to (1) estimate rearing habitat area in 2011 and compare with previous estimates in the context of restoration actions and (2) evaluate the effects of sample segment length and number of sample units on the standard errors of rearing habitat area estimates. Little change occurred in habitat estimates since 2009. However, a shift in the cumulative distribution function of total fry and presmolt habitat area was detected between 2010 and 2011 samples. For both life stages, 2011 had a lower proportion of sample units with a low total habitat area when compared to 2010. However, no significant difference was detected in the cumulative distribution function of total habitat area between 2009 and 2011. This discrepancy may be due to the effect of extreme values in the 2009 sample that were not as prevalent in the 2010 and 2011 samples. Varying sample segment length and number of sample units affected the standard error of rearing habitat estimates. Standard errors of optimal rearing habitat estimates were more sensitive to segment length than total rearing habitat estimates, and the magnitude of the sample segment length impact on standard error estimates varied by sample

year. In regards to the number of segments sampled, the upper tail of the distribution of standard errors was most sensitive, and the mean and confidence interval width of these distributions behaved as expected: decreasing asymptotically with an increasing number of sites sampled. These results provide context to further evaluate the length and number of habitat site samples to meet objectives of the Trinity River Restoration Program.

Introduction

Several noteworthy anthropogenic impacts have altered the ecology of the Trinity River. During the California Gold Rush, placer mining operations rearranged the river bed and floodplain of the Trinity River and its tributaries (Bailey 2008). The mine tailings from these operations are still clearly visible within the drainage and affect the geomorphic and biological aspects of the river system (Davis 1966; May et al. 2005; Bettaso and Goodman 2010; Fuller et al. 2011). More recently, the construction of the Trinity River Division led to additional impacts. Construction of Trinity and Lewiston dams were completed in 1964 and diverted 70 to 90% of Trinity Basin water to the Central Valley (USFWS and Hoopa Valley Tribe 1999). This led to reduced streamflows year-round, creating a stable environment mostly devoid of natural streamflow variation. In addition, the dams isolated anadromous fishes from historic habitats upstream of the dams. Other impacts from the dams included the interruption of sediment and large wood transport, a change in the riparian community, and a change in the overall size and shape of the Trinity River. More recently, Lewiston Hatchery was constructed to mitigate for production lost upstream of Lewiston Dam, but resulted in detrimental effects on naturally-produced rearing salmonids (Naman 2008). The combination of these factors has altered the restoration reach (system) and naturally-produced Chinook and coho salmon populations are a remnant of historic levels.

To improve the degraded physical habitat conditions, the Trinity River is the focus of a restoration effort that relies on the combination of mechanical channel rehabilitation and riverine processes to increase fish populations (USFWS and Hoopa Valley Tribe 1999). Restoration is anticipated to increase channel complexity and result in increases in salmonid rearing habitat quantity and quality. The historical hydrologic and geomorphic effects of the dams and historical mining are most pronounced between Lewiston Dam and the North Fork Trinity River; therefore, the improvements in salmonid habitat quantity and quality should be most pronounced in this reach (hereafter referred to as the “restoration reach”). Chinook and coho salmon populations are limited by the availability of age-0 habitat area (herein defined as rearing habitat; USFWS and Hoopa Valley Tribe 1999). The restoration strategy is made up of six components, including: (1) mechanical channel rehabilitation, (2) water-year specific streamflow management, (3) coarse sediment augmentation, (4) watershed restoration, (5) riparian management, and (6) adaptive environmental assessment and management. Although maximum change in salmonid rearing habitats anticipated at channel rehabilitation sites (see Goodman et al. 2010; Martin et al. 2012), it is hypothesized that the restoration strategy will create effects outside of channel rehabilitation sites, improving habitat throughout the restoration reach (Barinaga 1996; USDOI 2000).

This assessment evaluates the combined effects of restoration actions on rearing habitat area within the restoration reach at 12.7 cms summer baseflow (Appendix A). This study was designed and implemented to address the Integrated Assessment Plan Objective 3.2.1 (Trinity River Restoration Program [TRRP] and ESSA Technologies Ltd. 2009) and is ranked among the top priorities for the TRRP science program. More specifically, the study was designed to develop annual rearing habitat estimates and track changes in these metrics with restoration actions. This report focuses on a single annual assessment; however, it is a component of a broad suite of habitat assessments being applied concurrently to evaluate rearing and spawning habitat on the Trinity River (California Department of Fish and Game et al. 2010). Other ongoing evaluations include rehabilitation site assessments, two-dimensional hydrodynamic habitat modeling, resource selection function development, geomorphic assessments and riparian assessments. Reports documenting the results of these other evaluations will be provided in separate technical reports. In the future, the information reported here may be used to address additional objectives when combined with other studies.

Estimation of rearing habitat area within the restoration reach began in 2009. The sample design was developed using the best available information to address the Integrated Assessment Plan Objective as listed above (TRRP and ESSA Technologies Ltd. 2009). This study design has not been formally evaluated since implementation therefore an evaluation of how effectively the design addresses TRRP goals and objectives is in order. Using the three years of data collected under this study we initiate the process of formally evaluating the study design to help inform the TRRP on the effects of modifications. In particular, we evaluate the effects of changing the length and number of sample units on the standard error of habitat area estimates. These results, coupled with ancillary budget and crew scheduling information, provide the TRRP the opportunity to assess modifications of the sample design in the context of TRRP needs. The objectives of this study are:

1. Estimate rearing habitat area over the restoration reach at the summer index streamflow in 2011 and compare to previous estimates in the context of TRRP restoration actions.
2. Evaluate the effects of sample segment length and number on the standard errors of rearing habitat area estimates.

In a previous report, this assessment was associated with an evaluation of the effects of site-specific variables on habitat area (Goodman et al. 2012). However, the assessment of site-specific predictor variables associated with data in this 2011 report will be addressed in a separate report.

Study Area

The Trinity River is located in northwestern California, USA (Lat. 40.708, Long. -122.808; Figure 1). The headwaters are in the Trinity Mountains from which it flows 274 km to its confluence with the Klamath River. The watershed has a drainage area of 7,679 km^2, approximately one quarter of which is upstream of Lewiston Dam (USFWS 1989; USBOR 2009). The restoration reach is the 64-km of the Trinity River between Lewiston Dam and the confluence of the North Fork Trinity River, and all study sites for this assessment are located within this restoration reach.

Methods

The sampling framework for this study includes: (1) sample site definitions, (2) sample site selection protocol and (3) revisit design. Sample sites were 400-m segments of the 142 cms centerline derived from HEC-RAS modeling in 2006 (DWR unpublished data). The 400-m sample site size was selected based on survey efficiency and recommendations from multidisciplinary planning meetings in anticipation that, if appropriate for specific study objectives, it could be adopted by other disciplines to facilitate future multi-disciplinary assessments. The sample universe was defined as the restoration reach, Lewiston Dam to the North Fork Trinity River confluence. Sample units were selected using the generalized random tessellation stratified (GRTS) sample unit selection protocol (Stevens and Olsen 2004). We implemented a rotating panel revisit design (McDonald 2003) to evaluate status and trends in rearing habitat availability in relation to annual restoration and streamflow events (California Department of Fish and Game et al. 2010). The rotating panel design is composed of five panels with 16 GRTS sample sites per panel. Two panels, or 20% of the restoration reach, are sampled within each year (Table 1). In each subsequent year, one panel is repeated and one new panel is added until all five panels are sampled. By sampling sites in consecutive years, panel response can be correlated with specific management actions such as peak streamflow events or construction of channel rehabilitation sites. In the fifth year the first panel is sampled again providing sufficient time for sites to experience a range of management actions and the pattern continues. The five panels make up 50% of the sample universe.

This report represents the third year of the study and in combination with the 2009 and 2010 data provides information before and after normal and wet water-year streamflow releases. The Record of Decision defined five water year types from critically dry to extremely wet based on annual precipitation and historical

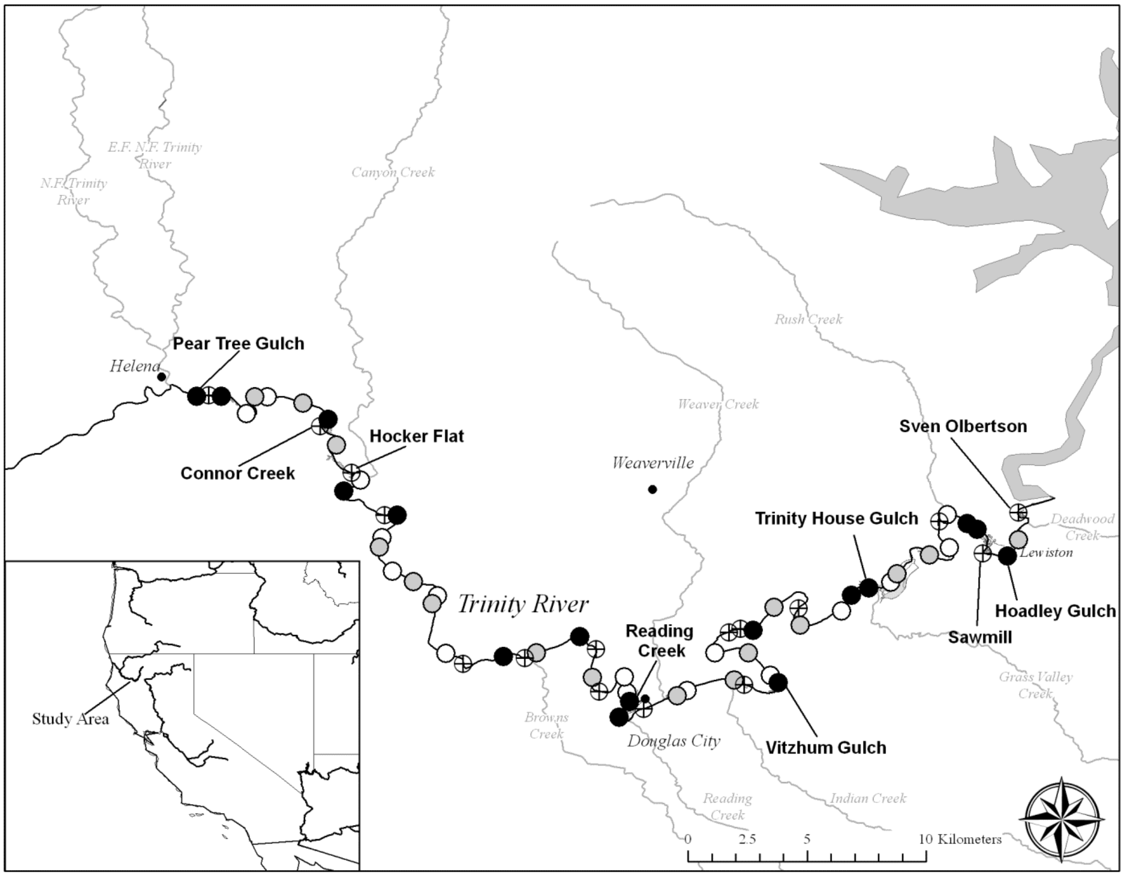

Figure 1. Systemic rearing habitat assessment sample sites on the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River. Each dot indicates a 400-m sample unit selected using the GRTS protocol. White dots indicate panel #1 sampled in 2009, grey dots indicate panel #2 sampled in 2009 and 2010, black dots indicate panel #3 sampled in 2010 and 2011 and dots with crosses indicate panel #4 sites sampled in 2011. Bold labels indicate constructed post-ROD channel rehabilitation sites sampled in 2011. Trinity River streamflow is from right to left.

Table 1. The rotating panel revisit sampling design for the rearing habitat assessment on the Trinity River, CA. Each panel is unique (sampling without replacement) and composed of 16 randomly selected spatially balanced sample units

	Year				
Panel #	2009	2010	2011	2012	2013
1	X				X
2	X	X			
3		X	X		
4			X	X	
5				X	X

information (USDOI 2000). Each water year type was associated with a water volume to be released for restoration purposes from Lewiston Dam. Each annual hydrograph for normal or wetter years included a spring peak release event focused on inducing sediment transport and geomorphic changes that create and maintain riverine habitats. This study was initiated in the summer of 2009, with surveys of panels #1 and #2 implemented from July 7th to September 29th. The National Weather Service and California Department of Water Resources designated 2010 as a normal water year (www.trrp.net) with releases from Lewiston Dam peaking at 193.71 cms (Figure 2). At the downstream extent of the restoration reach streamflows peaked at 218.35 cms due to tributary accretions. After peak streamflows in 2010, we surveyed panels #2 and #3 from August 2nd to September 30th. The TRRP designated 2011 as a wet water year with releases from Lewiston Dam peaking at 328.51 cms (Krause 2012). This was the highest streamflow release for restoration purposes and the largest release since 1974. The release was higher than a wet water year as prescribed by the ROD and more similar to that of an extremely wet water year. At the downstream extent of the restoration reach streamflows peaked at 351.17 cms. After peak streamflows in 2011, we surveyed panels #3 and #4 from August 1st to October 12th.

Sites were surveyed during summer base streamflow with a planned Lewiston Dam release of 12.7 cms. This streamflow was selected because: (1) it occurs during a time period with little effect from tributary accretions or storm events (consistency of field sampling), (2) it is similar to streamflows in a high proportion of the restoration reach during the critical winter and early spring rearing period, and (3) it is unlikely to change in the near future because of its objective to meet adult spring-run Chinook salmon temperature requirements (consistency for future comparisons). This measure of habitat provides an index of winter and early spring rearing habitat availability. However, small variations in streamflow occurred at each site due to tributary accretions. Sample units had a mean of 14.37 cms with a range of 12.43 to 17.07 cms and SD of 1.32 cms. Streamflows were calculated using daily average values from proximal USGS gauges (waterdata.usgs.gov). The differences in surveyed streamflows among years were always less than the measurement error of USGS gauges (up to ±15%; Krause 2012).

Rearing habitat was mapped using methods described in Goodman et al. (2010), where depth, velocity, and distance to cover were delineated at specified thresholds (Table 2). Rearing habitat was divided into two developmental phases for each species within their first year of growth (age-0): (1) fry or fish <50 mm FL, and (2) presmolt or fish 50 to 100 mm FL. Optimal Chinook salmon rearing habitat (optimal habitat) for fry and presmolt life stages included areas that simultaneously meet depth, velocity, and cover criteria. Total rearing habitat included areas that meet any combination of depth and velocity or cover criteria (including optimal habitat areas). Coho salmon show extremely high preference for optimal habitat areas over other categories in validation studies (Goodman et al. 2010; unpublished data). Therefore coho salmon rearing habitat was limited to optimal areas following Martin et al. (2012). Habitat categories were delineated throughout the wetted area of each study

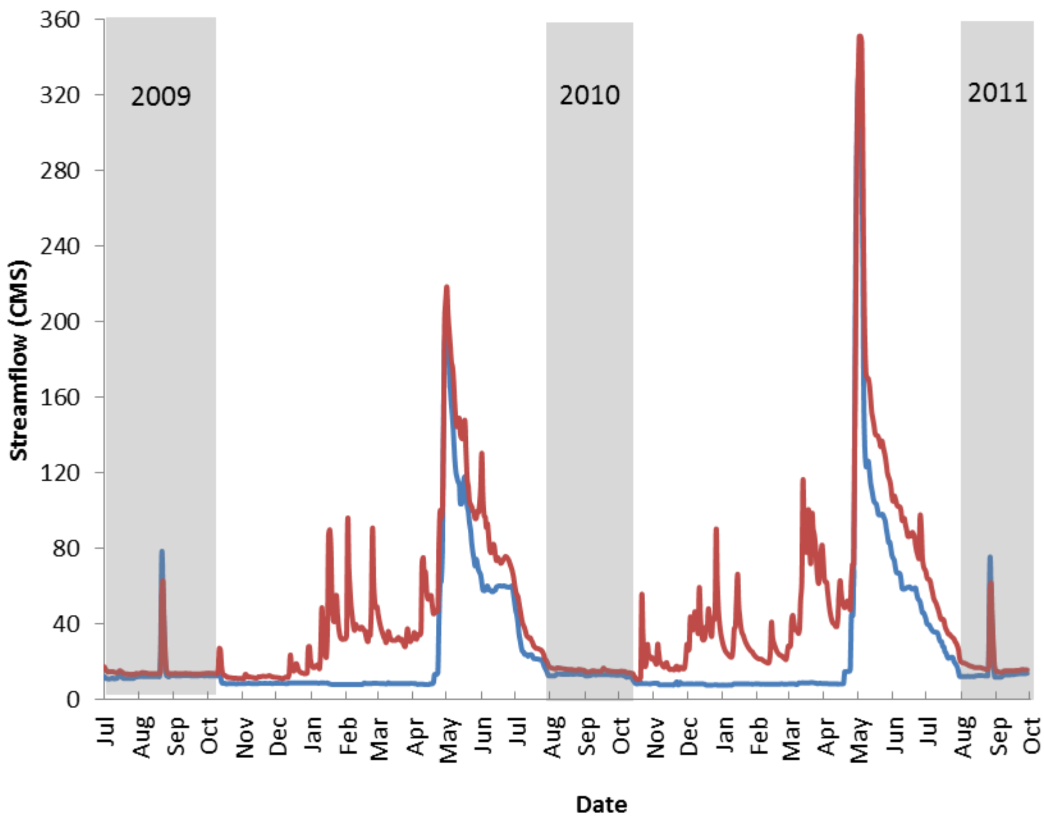

Figure 2. Hydrograph at the upstream and downstream extent of the Trinity River restoration reach during and between the 2009 and 2011 sampling periods. The blue line indicates streamflow measured near the top of the restoration reach just downstream of Lewiston Dam (USGS gauge # 1152550) and the blue line indicates streamflow at the bottom of the restoration reach upstream of the confluence with the North Fork Trinity River (USGS gauge # 11526400). Gray boxes indicate annual survey periods.

Table 2. Habitat categories and their associated habitat criteria for rearing habitat mapping. Chinook salmon total habitat was defined as areas that meet combinations of depth/velocity and cover criteria. Optimal Chinook or coho salmon habitat were defined as areas that simultaneously meet depth, velocity and cover criteria.

Habitat category	Variable	Criteria
Fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.15 m/sec
	Distance to Cover	0 to 0.61 m
Presmolt (≥50 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/sec
	Distance to Cover	0 to 0.61 m

segment (including side or split channels) by ground-based GPS surveys. Each habitat measurement was geo-referenced to produce spatially explicit representations of rearing habitat areas. Survey data were processed into ArcGIS polygon shapefile format and archived in a geodatabase.

Rearing Habitat Estimates

Rearing habitat area estimates were calculated for each life stage and habitat category. Estimates were calculated by multiplying the mean value of the sample by the number of GRTS sample units in the restoration reach. Sample error was calculated using a neighborhood variance estimator developed for use with GRTS sample designs (Stevens and Olsen 2002). The neighborhood variance estimator incorporated spatial location of sample units into error estimation. Analyses were conducted in R (R Development Core Team 2009) using Spatial Survey Design and Analysis (spsurvey ver. 2.15.2, Kinkaid and Olsen 2009) and displayed using cumulative distribution function plots which display the distribution of habitat quantities and the associated error within the sample. Total estimate comparisons between 2009, 2010 and 2011 were conducted using a cumulative distribution function test in spsurvey. Differences in estimated rearing habitat area at panel #2 sites between 2010 and 2011 were evaluated with t-tests. When modest departures from the normality assumption were present, non-parametric tests were also conducted, and results compared to parametric tests. We evaluated differences in habitat area between channel rehabilitation sites and sites where not targeted mechanical restoration work was done. For this analysis channel rehabilitation sites were classified if greater than or equal to 25% of a site was within construction boundaries following Goodman et al. 2012 (Table 3).

Sample Unit Evaluation

The current sampling protocol calls for 32 sampling sites, each 400 m in length, to be measured in a given year. These 32 sites represent 16 sites from two of the rotating panels, as described above. It has been suggested that measuring smaller lengths of the GRTS sites, or fewer of the GRTS sites per year, could reduce program costs. Reductions in either case will increase the standard errors of total habitat area estimates. We evaluated the effects of changing the length and number of GRTS sampling sites on rearing habitat area estimates. Our investigation focuses on annual rearing habitat estimates at the restoration reach scale, and does not address trend estimation as a complete panel of study sites has yet to be measured.

For the unit length evaluation, we began with the 400-m GRTS sites data that has been collected since the inception of the rearing habitat assessment. These spatially-referenced data allowed partitioning into 100-m, 200-m, and 300-m site lengths. We then computed estimates of total habitat area and their standard errors, and evaluated these values relative to those achieved via the 400-m site lengths.

Table 3. Channel rehabilitation sites within sample units that were constructed at the time of survey. All sites had channel rehabilitation efforts within at least 25% of the sample unit. A indicates pre-construction conditions, B indicates post-construction conditions and C indicates surveyed during construction. Channel rehabilitation sites are listed from upstream to downstream.

Site	Year of Construction	Panel #1	Panel #2	Panel #3	Panel #4
Sven Olbertson	2008				B
Lewiston Cableway	2008		B		
Hoadley Gulch	2008			B	
Sawmill	2009				B
Dark Gulch	2008	B	B		
Lowden Ranch	2010	A	C		
Trinity House Gulch	2010			A,B	
Vitzhum Gulch	2007			B	
Indian Creek	2007		B		
Lower Indian Creek	2007	B	B		
Reading Creek	2010			A,B	
Hocker Flat	2005	B			B
Connor Creek	2006				B
Valdor Gulch	2006		B		
Pear Tree Gulch	2006			B	

We used a simulation exercise to evaluate the impact of the number of sites sampled per year on standard error estimates. We began with the habitat area data collected to date. These data include 64 unique 400-m segments, most of which have been measured in two adjoining years, according to the rotating panel design. These data were used to estimate a non-linear model describing the observed pattern in habitat area with increasing distance from the Lewiston Dam,

$$T_i = \alpha\left(D_i^{\beta}\right) + \varepsilon_i$$

where T is the total amount of fry habitat in segment i, D is segment i's distance from Lewiston Dam, α and β are parameters to be estimated, and ε ~ N(0, σ2). The parameters for this model were estimated via the nls function in R (R Development Core Team 2009), using the Gauss-Newton algorithm. This model was used to simulate habitat areas for the entire 64-km restoration reach. We considered sample numbers per panel that ranged from 8 to 30, which encompasses the sample size of 16 per panel used in the current study. For computational speed, we considered only even numbers in the specified range of sample numbers per panel. We maintained the current sampling characteristics of 400-m segment lengths, and samples arranged in two panels. Our simulation exercise process was as follows, and was repeated 2,000 times for each number of sample sites per panel:

1. Simulate habitat areas for the entire 64-km restoration reach.

2. Select a rotating panel GRTS sample using the grts function from the R package spsurvey (Kincaid and Olsen 2009), and select the current number of samples per panel from the first two panels of the created sampling design.
3. Given the sample, estimate the total habitat area of the entire 64-km restoration reach and its associated standard error.

Results

Rearing Habitat Estimates

In 2011, we estimated 66,878 m^2 (CI = 54,707 to 79,048) optimal and 326,658 m^2 (CI = 289,604 to 363,713) total fry habitat area and 94,719 m^2 (CI = 78,416 to 111,022) optimal and 424,328 m^2 (CI = 381,013 to 467,642) total presmolt habitat area in the restoration reach. In 2011, all habitat categories had a small number of sample units with larger habitat values compared to the rest of the samples (Figure 3). In general, no differences were observed between annual rearing habitat estimates from 2009 to 2011 (Figure 4; Table 4). However, there was moderate evidence for a shift in the cumulative distribution function of total habitat area between 2010 and 2011 for fry ($F = 3.616$, $p = 0.033$) and presmolt ($F = 3.483$, $p = 0.037$) life stages (Table 5). For both life stages, 2011 had a lower proportion of sample units with a low total habitat area when compared to 2010. Despite the modest differences in the distribution of total habitat area between 2010 and 2011, there was no evidence to suggest differences in the distribution of estimated total or optimal habitat areas between 2009 and 2011 ($p = 0.307$ to 0.624). There was no evidence of differences in the distribution of habitat area among years for optimal habitat for either life stage ($p = 0.307$ to 0.935).

There was no evidence of differences between the 16 panel #3 sites sampled in 2010 and again in 2011 for any habitat category or life stage ($p = 0.214$ to 0.910; Table 6, 7). Within panel #3 sites, channel rehabilitation sites showed a slightly higher median change in habitat area in all categories ranging from 24 to 71 m^2 relative to non-rehabilitation sites that ranged from -67 to 29 m^2. The channel rehabilitation site effect was not evaluated with formal statistical tests due to the low number of channel rehabilitation sites in panel #3 ($n = 5$).

Sample Unit Evaluation

Sample Unit Lengths

There were differences in the patterns of the standard error estimates between the total and optimal habitat areas, but the differences among the fry and presmolt life stages were inconsequential. As such, for brevity we present here the fry life stage results. For both total and optimal fry habitats, standard error estimates show decreases with increasing sample unit lengths (Figure 5). Several patterns are evident from this figure. First, there is variation among years in the relative benefits

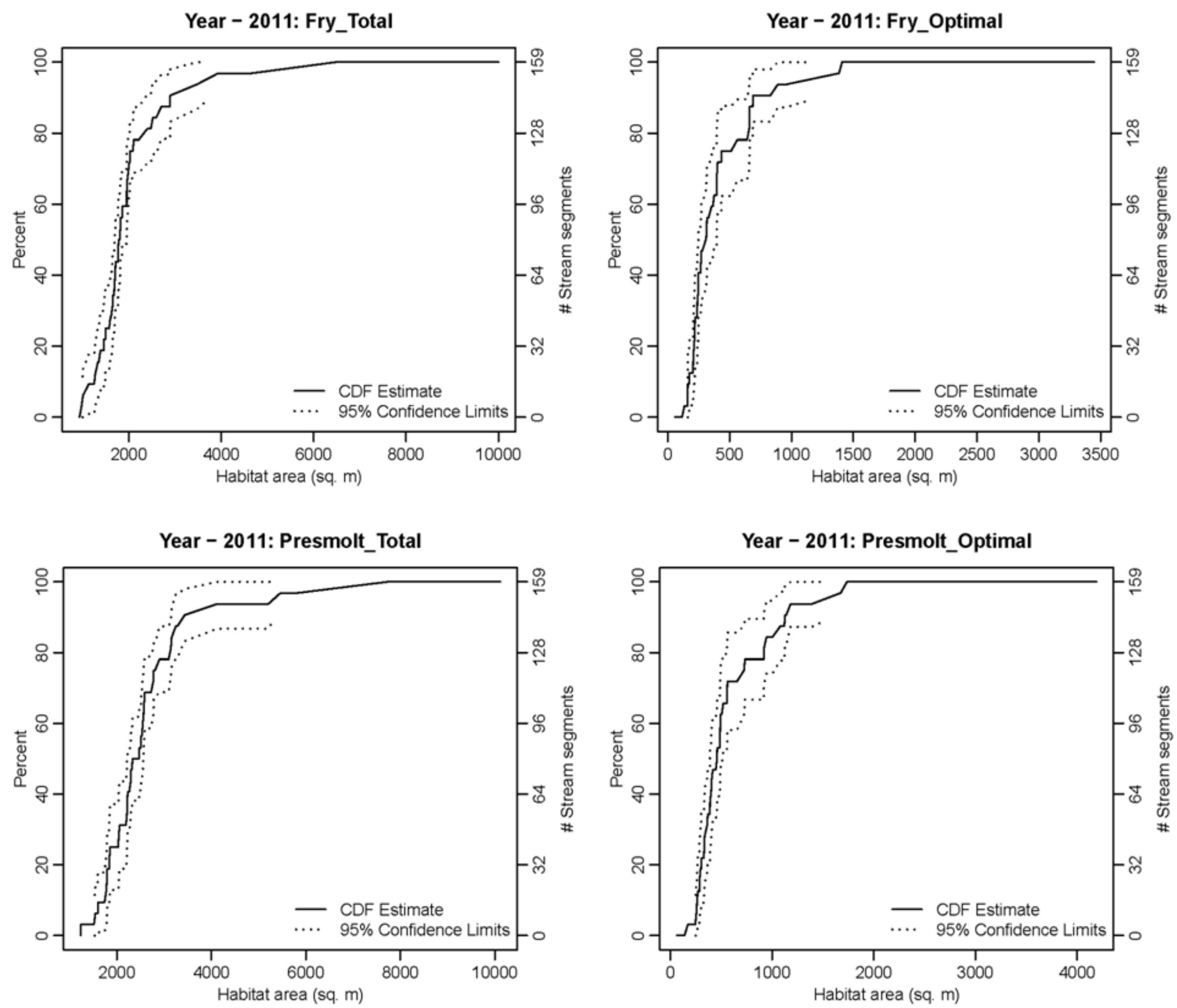

Figure 3. Cumulative distribution functions of fry and presmolt habitat from 32 GRTS sample units from the 2011 Trinity River restoration reach rearing habitat estimate. The primary y-axis corresponds to the percent of the restoration reach estimated to contain the specific quantity of rearing habitat. Alternatively, the secondary y-axis indicates the number of 400-m segments estimated to contain the specific quantity of rearing habitat.

of increasing sample unit lengths, with 2009 showing modest standard error reductions when compared to 2010. This is particularly true when considering the reduction from 400-m to 300-m lengths, where no consequence of a shorter length is revealed in 2011, in contrast to 2010. Second, the standard error estimates for optimal habitat are more sensitive to sample unit lengths than total habitat estimates. Again considering the reduction to 300-m lengths from the current 400-m length protocols, the standard error estimates increase by around 45% and 31% in 2010 and 2011, respectively.

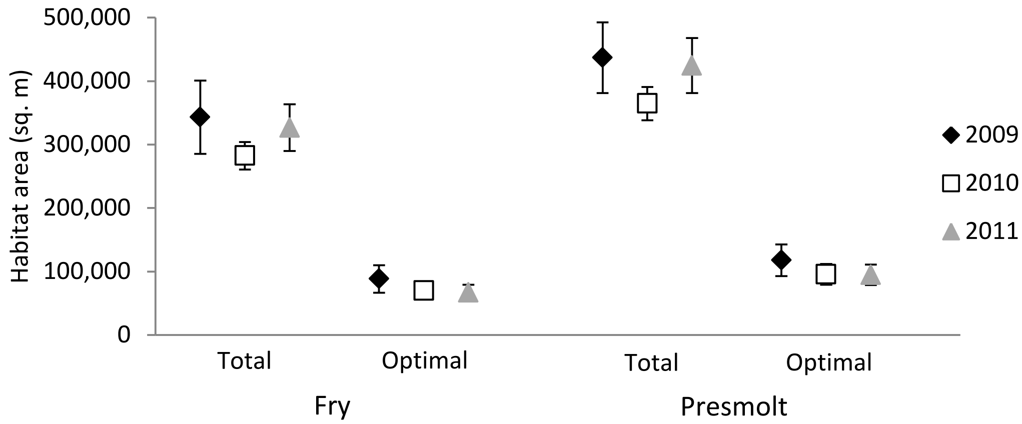

Figure 4. Total and optimal fry and presmolt rearing habitat area estimates in 2009 through 2011. Error bars indicate a 95-percent confidence interval.

Table 4. Habitat area estimates for the restoration reach of the Trinity River from 2009 to 2011. Habitat values reported in m^2. SE indicates standard error while LCB and UCB indicate lower and upper confidence bounds.

		Fry		Presmolt	
Year	Statistic	Optimal	Total	Optimal	Total
2009	Estimate	88,174	343,201	117,623	436,613
	SE	10,961	29,429	12,724	28,413
	LCB 95%	66,690	285,521	92,685	380,924
	UCB 95%	109,658	400,881	142,561	492,302
2010	Estimate	69,935	282,353	95,540	364,482
	SE	6,430	11,094	8,440	13,354
	LCB 95%	57,333	260,608	78,997	338,309
	UCB 95%	82,536	304,097	112,082	390,654
2011	Estimate	66,878	326,658	94,719	424,328
	SE	6,210	18,906	8,318	22,100
	LCB 95%	54,707	289,604	78,416	381,013
	UCB 95%	79,048	363,713	111,022	467,642

Table 5. Comparisons of habitat category estimates among years. Year A and Year B indicate comparisons for cumulative distribution tests. Significance at $\alpha = 0.05$ is indicated with an asterisk.

Indicator	Year A	Year B	Wald - F	p - value	
Fry optimal	2009	2010	0.149	0.862	
	2009	2011	1.205	0.307	
	2010	2011	0.654	0.524	
Fry total	2009	2010	2.173	0.123	
	2009	2011	0.637	0.532	
	2010	2011	3.616	0.033	*
Presmolt optimal	2009	2010	0.733	0.484	
	2009	2011	0.980	0.381	
	2010	2011	0.068	0.935	
Presmolt total	2009	2010	1.621	0.206	
	2009	2011	0.476	0.624	
	2010	2011	3.483	0.037	*

Table 6. Changes in habitat estimates at panel #3 sites sampled in 2010 and again in 2011. Tests conducted as two - sided paired t – tests at $\alpha = 0.05$. Habitat values reported in m^2.

Indicato r	95%CI	Mean of diff.	t - value	p - value
Fry optimal	-31 to 126	48	1.13	0.214
Fry total	-183 to 164	-9	-0.12	0.910
Presmolt optimal	-59 to 165	53	1.01	0.327
Presmolt total	-274 to 193	-41	-0.37	0.716

Table 7. Changes in habitat estimates at panel #3 sites sampled in 2010 and again in 2011 assessed using non-parametric tests. Tests conducted using a Wilcoxon signed rank test for paired samples at $\alpha = 0.05$. Habitat values reported in m^2.

Indicator	Median dif.	V	p - value
Fry optimal	18	88	0.3225
Fry total	20	65	0.8999
Presmolt optimal	-8	72	0.8603
Presmolt total	-50	59	0.6685

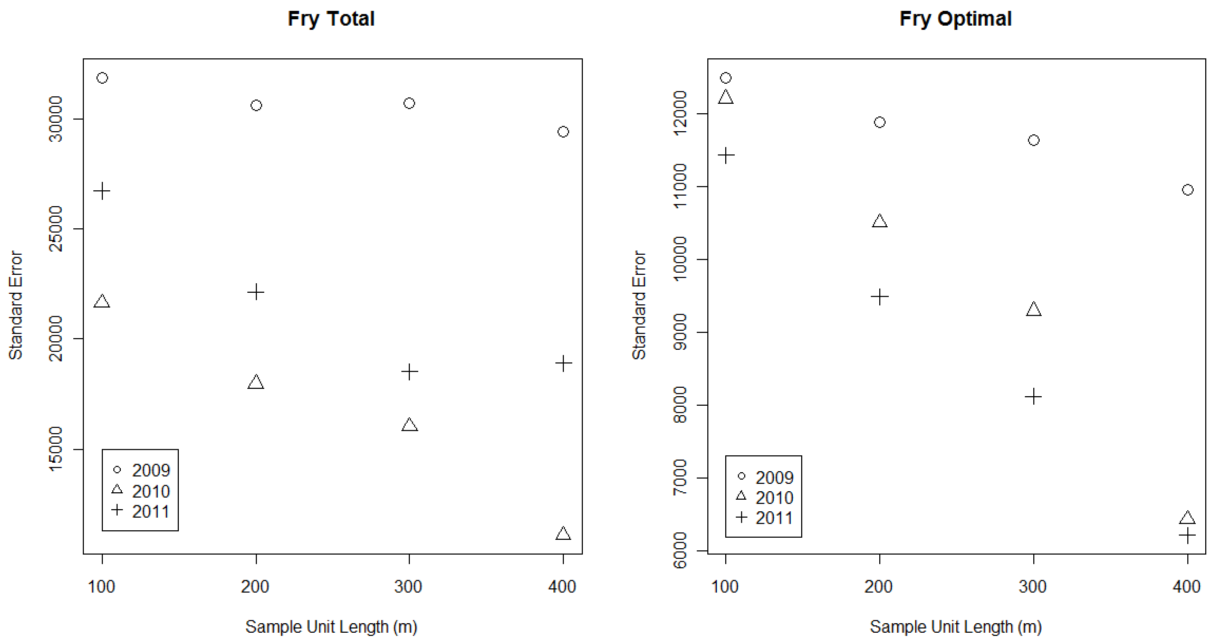

Figure 5. Standard errors of restoration reach total and optimal fry habitat estimates with increasing sample unit lengths, plotted by year.

Sample Unit Numbers

We present the results from the estimates of simulated total fry habitat, as the observed patterns among fry and presmolt sizes/ages with optimal and total habitat areas were quite similar. Table 8 reveals the estimated parameter values from our non-linear model estimated using observed data, and Figure 6 displays an example of the output from our total habitat area simulator. The results from our simulation study are summarized in Figure 7, which displays the mean and median standard error values for each number of sites sampled per panel, and additionally the 0.025 and 0.975 quantiles from the distribution of standard errors for each number of sites sampled per panel. The average standard errors and skewness of their distributions decrease with increasing number of sites sampled per panel (Figure 7). Additionally, the most pronounced decreases appear at the upper tails of these standard error distributions. This indicates that increasing the number of sites sampled per panel more drastically curtails the likely upper range of standard error estimates.

Table 8. Estimated parameters from a non-linear model estimating total fry habitat area with increasing distance from Lewiston Dam.

Parameter	Estimate	Std. Error	t - value	p - value
α	6262.54	619.55	10.11	<0.0001
β	-0.376	0.037	-10.21	<0.0001

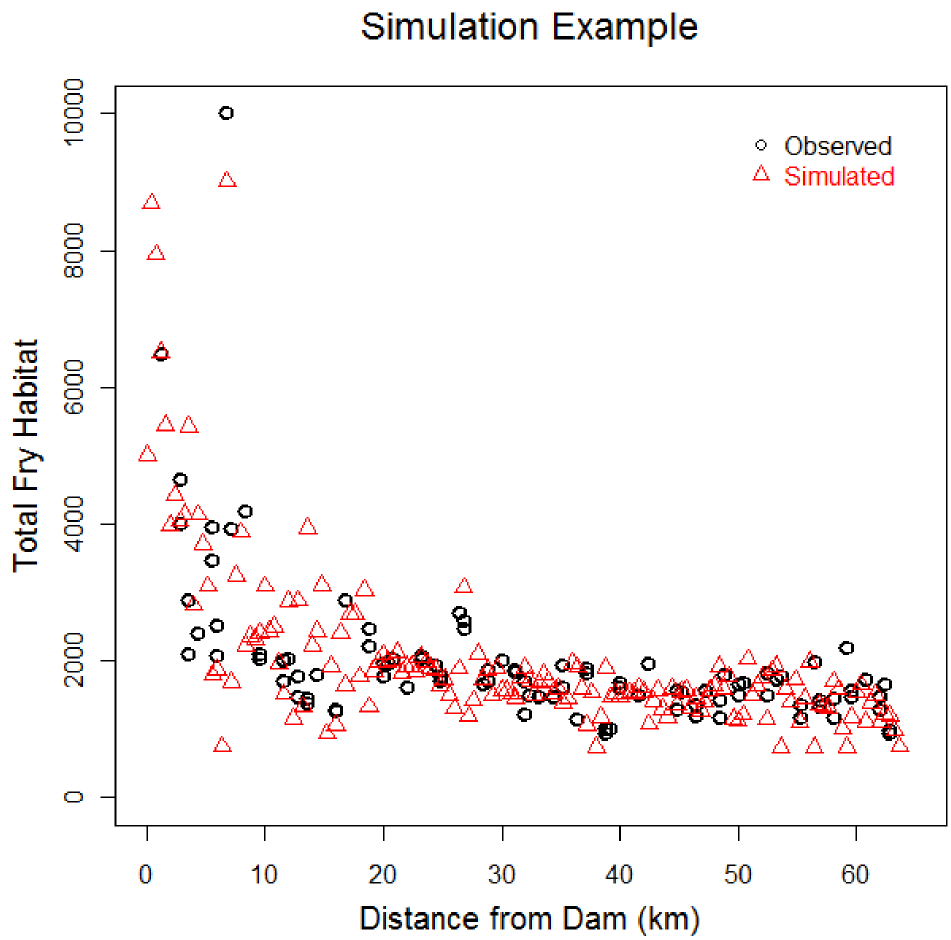

Figure 6. Observed (black circles) and simulated (red triangles) total fry habitat areas (m^2) along the restoration reach of the Trinity River. The observed data include the 64 400-m segments where habitat data has been collected since the inception of the habitat assessment. The simulated values occur at all 160 delineated segments of the restoration reach.

Discussion

Rearing Habitat Estimates

Peak streamflow releases are one of the primary TRRP management actions affecting the entire restoration reach. These releases are intended to induce geomorphic channel changes and in turn, improve and maintain riverine habitats. In addition, higher peak streamflows are expected to create more geomorphic change. Over the course of this study (2009 to 2011), we developed habitat estimates before and after a normal and then a wet water year. After a normal water year, no significant differences were observed in restoration reach estimates. After a wet water year, a

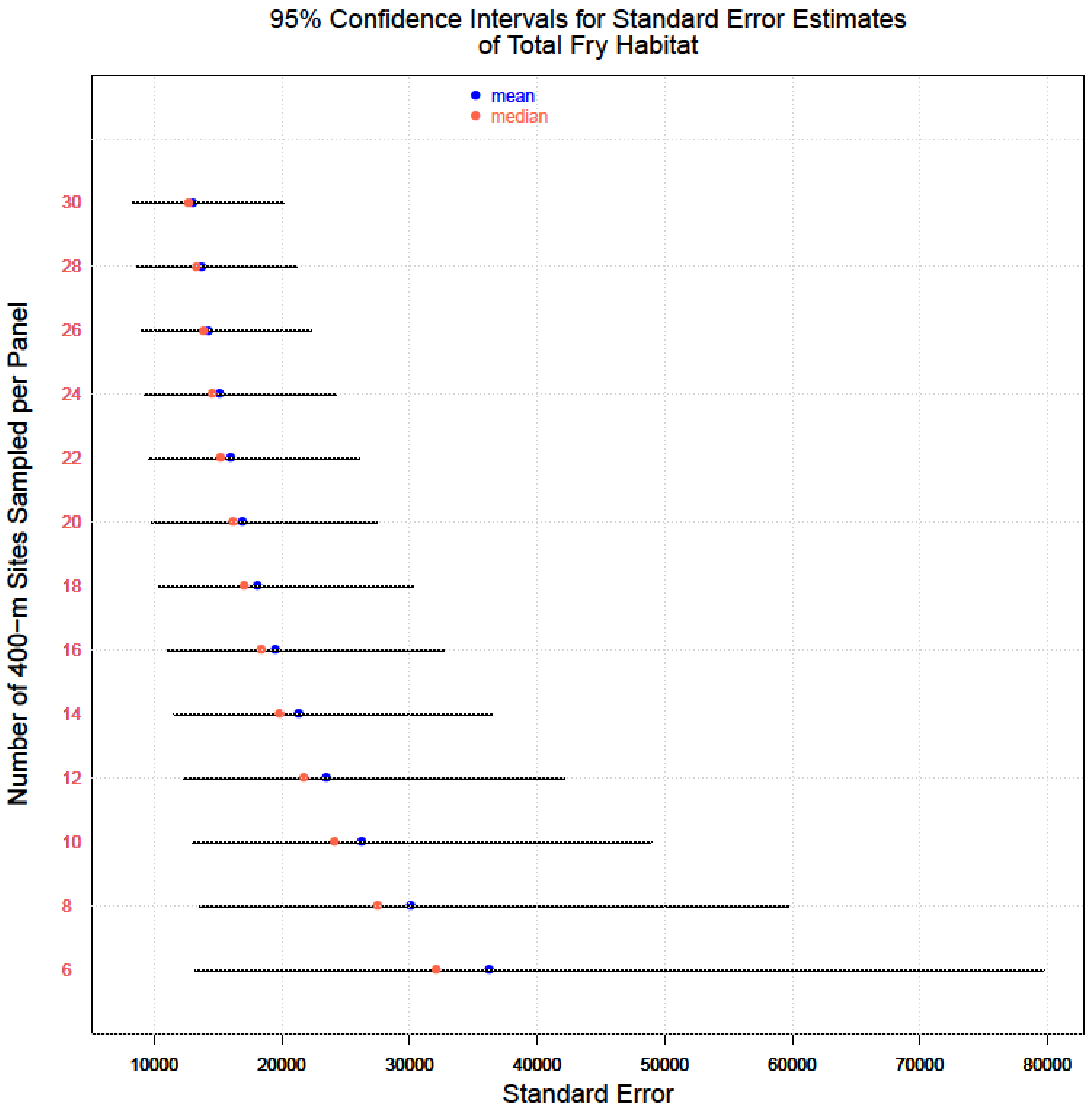

Figure 7. Mean (blue circles), median (red circles), and the 0.025 and 0.975 quantiles (black lines) of standard error estimates for each number of 400-m sites sampled per panel from our simulation exercise.

slight but significant increase in total habitat area was observed. This matches our anticipated response of the system with more increases in habitat area occurring from higher magnitude streamflow events (USFWS and Hoopa Valley Tribe 1999).

However, we also anticipated a trend of increasing habitat area with restoration effort which was not observed. The total habitat area estimate was not significantly different between 2009 and 2011 despite channel rehabilitation efforts and peak streamflow releases. This result does not align with our expectations, but may be explained in relation to the sample population and its effects on the habitat estimate, as follows. In all study years, a proportion of sample sites had much higher habitat values than the rest of the population. In all cases the extreme values were located in proximity to Lewiston Dam, contain features associated with channel complexity (i.e. high bank length) and were related to either channel rehabilitation or coarse sediment augmentation sites. Extreme values have a larger effect on mean values than other sample units. In addition the extreme values reduce our ability to detect changes by increasing the confidence intervals or error associated with an estimate. The extreme values were more prevalent and more extreme in 2009 creating a positive effect on restoration reach estimates and larger confidence intervals. This reduces our ability to detect changes between 2009 and other study years. It is possible that a similar level of change occurred between 2009 and 2011 but was not detectable given the effect of extreme values on the estimate. As the TRRP continues to apply and expand the restoration effort, we anticipate that habitat values that are now considered extremely high will become more common in the sample. As this occurs, the study will detect increases in habitat area with restoration effort.

Anticipated responses should be more pronounced when comparing paired-sites sampled across a single high streamflow event. Although it is still early in the study, a response was not detected between paired-sites across the two water years. Panel #2 was sampled on either side of a normal water year, and slight but significant decreases in habitat area were observed in all cases. As described in Goodman et al. (2012) the factors causing this decline are unclear and may be related to a combination of factors. Panel #3 was sampled on either side of a wet water year but we did not detect any significant changes. This may indicate that habitat area is not changing as fast as anticipated during the development of the study design. However, we also anticipated that the rate of change in habitat indicators will increase with the amount of restoration effort. Panel #1 sites were originally sampled in 2009 and will be revisited in 2013, providing information about the amount of change in habitat indicators over four water years.

Sample Unit Evaluation

Sample Unit Lengths

As has been previously reported, the GRTS derived estimates of habitat areas, and their standard errors, are sensitive to the inclusions of several sites in the upstream most sections of the restoration reach. As these sites factor in and out of the rotating panel design, there was large between-year variation in our study of sample site length reductions. In some years, a drop to 300-m revealed sharp standard error increases relative to the current 400-m length, while this effect was negligible in other years. In all years, standard error increases with decreasing site length were more pronounced for optimal habitat values than total habitat values. By definition, optimal habitat occurs less frequently along the restoration reach, and our study reveals that even 100-m length reductions decrease the precision with which it can be estimated. Formal decisions regarding a reduction in site length would need to consider the savings associated with length reductions balanced with the priority of estimating optimal habitat areas.

Sample Unit Numbers

Sample units are used because complete systemic measurement is cost prohibitive. As sample sizes increase, standard errors tend to decrease asymptotically towards zero. Often, a sample size is chosen along this standard error curve where increases in sample sizes result in relatively minor decreases in standard error size. These characteristics are apparent in Figure 7, where the differences between panel sample sizes of 6 and 8 are larger than those observed between samples sizes of 28 and 30. The monetary and time savings associated with sample size reductions are often not realized in a unit by unit basis, especially when crew scheduling, travel to and among sampling sites, and conditions suitable for river access are considered. The appropriate amount of precision needed to monitor programs goals and benchmarks should also be considered when sample size decisions are made

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Appendices

Appendix A. Conversion Table and Survey Basis.

TRRP documents generally report metric units. Exceptions are noted in the text of a particular report. Below is a concise list in conversion factors for common units of measure used in the TRRP.

Quantity	English Unit	Metric Unit	Multiplication Factor,	Multiplication Factor,
Length	inches (in)	millimeters (mm)	25.4	0.0393
	inches (in)	centimeters (cm)	2.54	0.3937
	feet (ft)	meters (m)	0.3048	3.2808
	US survey feet	meters(m)	12/39.37	39.37/12
	miles (mi)	kilometers (km)	1.6093	0.62139
Area	square feet (ft^2)	square meters (m^2)	0.092903	10.764
	square miles (mi^2)	square kilometers (km^2)	2.59	0.3861
	square yards (yd^2)	square meters (m^2)	0.836127	1.19599
	acres (acre)	hectare (ha)	0.4047	2.471
Volume	cubic feet (ft^3)	cubic meters (m^3)	0.028317	35.315
	cubic yards (yd^3)	cubic meters (m^3)	0.76455	1.308
	acre-feet (ac-ft)	cubic meters (m^3)	12.33.5	0.0008107
	acre-feet (ac-ft)	cubic decameters (dam^3)	1.2335	0.8107
	thousand acre-feet (TAF)	cubic decameters (dam^3)	1233.5	0.0008107
Flow	cubic feet per second (cfs)	cubic meters per second (cms)	0.028317	35.315
Velocity	feet per second (ft/s)	meters per second (m/s)	0.3048	3.2808
Mass	pounds (lb)	kilograms (kg)	0.4536	2.2046
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F - 32) /1.8	(1.8 x °C) + 32

SURVEY BASIS

TRRP collects and uses a great deal of sub-foot accuracy topographic and bathymetric data. These data are spatially tied to established survey monuments to ensure that accuracy is maintained for analyses of change over time and for comparisons between projects. These "survey-grade" data are established from the following:

Basis of Coordinates

NAD 1983 (EPOCH 1992 – 1991.35 ADJUSTMENT), State Plane Coordinates, California Zone 1, U.S. Survey Feet (USFT). Based on static GPS ties to NGS stations (P.I.D.s) AC8624, AC8625, AC8627, LU2289 AND AC8626.

Basis of Elevations

NAVD 1988. Based upon static GPS ties and differential leveling from NGS stations (P.I.D.s) AC8624, AC8625, AC8627, LU2289 AND AC8626.

Notes

1. PRIMARY CONTROL NETWORK ESTABLISHED BY CA DWR IN 1999 BY STATIC GPS METHODS.
2. SECONDARY CONTROL ESTABLISHED BY CA DWR (VARIOUS DATES) BY RTK GPS METHODS.
3. ALL PROJECT DATA AND CONTROL IS BASED UPON THE STATED PROJECT DATUMS. NO OTHERS WILL BE USED OR ACCEPTED.
4. NGS STATIONS, FOR REFERENCE:

P.I.D.	DESIGNATION
AC8624	HPGN D CA 02 JC
AC8625	HPGN D CA 02 JD
AC8627	HPGN D CA 02 KE
LU2289	HPGN CA 02 17
AC8626	HPGN D CA 02 JF

S.A. SURVEY MONUMENT DATABASE WITH X,Y, AND Z VALUES IS AVAILABLE AT http://odp.trrp.net/Data/Packages/PackageDetails.aspx?package=33