Estimated changes to Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) habitat carrying capacity from rehabilitation actions for the Trinity River, North Fork Trinity to Lewiston Dam

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Introduction

The Trinity River Restoration Program (TRRP) aims to restore and maintain natural salmon and steelhead production in the Trinity River downstream of Lewiston Dam (Figure 1), primarily through flow restoration, gravel augmentation, channel and floodplain restoration projects, and watershed restoration. Each of these restoration components has been planned and is currently being implemented for the portion of the mainstem river between Lewiston Dam and the North Fork, and does not address either the tributaries or the >100 km of mainstem downstream of North Fork Trinity. The Trinity River Flow Evaluation (USFWS and Hoopa Valley Tribe 1999) recommended flow releases in each year scaled to the annual precipitation in that year. The gravel management plan (McBain and Trush, Inc. 2007) describes a plan for sediment augmentation at 59 potential sites distributed between Lewiston Dam and Indian Creek during the first few years of the project, and annual gravel replenishments of 10,000-15,000 m^3 annually thereafter at long-term sites near Lewiston. However, the TRRP is currently considering much lower gravel augmentation targets (Charles Chamberlain, personal communication). Channel rehabilitation projects have been and will be constructed throughout the study reaches to primarily increase juvenile salmon rearing habitat quantity and quality though salmon spawning is considered. The primary purpose of these actions is to change the current channel form into one that is similar to a more naturally functioning alluvial river within the constraints of the TRRP. One major expectation of the plan is that alluvial processes, through flow releases and coarse sediment augmentation, will create and maintain dynamic alluvial processes which will result in the creation and maintenance of the appropriate riverine habitats for salmonids over time. Thus while changes in habitat are expected as a result of rehabilitation projects, the plan assumes that larger scale changes and benefits will occur over time when riverine processes begin to create rearing habitats, in conjunction with changes due to rehabilitation projects.

This study was conducted by NWFSC under contract to the US Fish and Wildlife Service to estimate potential improvements in salmon and steelhead production from the Trinity River, California. In this report we assume that the planned actions will be implemented, and then estimate the change in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) rearing habitat carrying capacity that will likely result under a range of restoration scenarios. We examine two types of scenarios: (1) a scenario that focuses on changes in habitat quality due to rehabilitation actions, and (2) a set of scenarios that include increasing channel meandering through restoring fluvial processes and the development or construction of side channel habitats. We do not differentiate between habitats created by restored processes and habitats created through rehabilitation actions in our estimated change in carrying capacity for Chinook salmon and steelhead. Rather, we construct a range of scenarios that span relatively modest restoration achievements to those that assume dramatic changes in habitat quantity or quality. For each scenario, we estimated the amount of habitat quantity and quality that will likely be achieved, and then estimate the likely changes in rearing capacity that will result. Our estimates of habitat quantity and quality are based upon two pieces of empirical information.

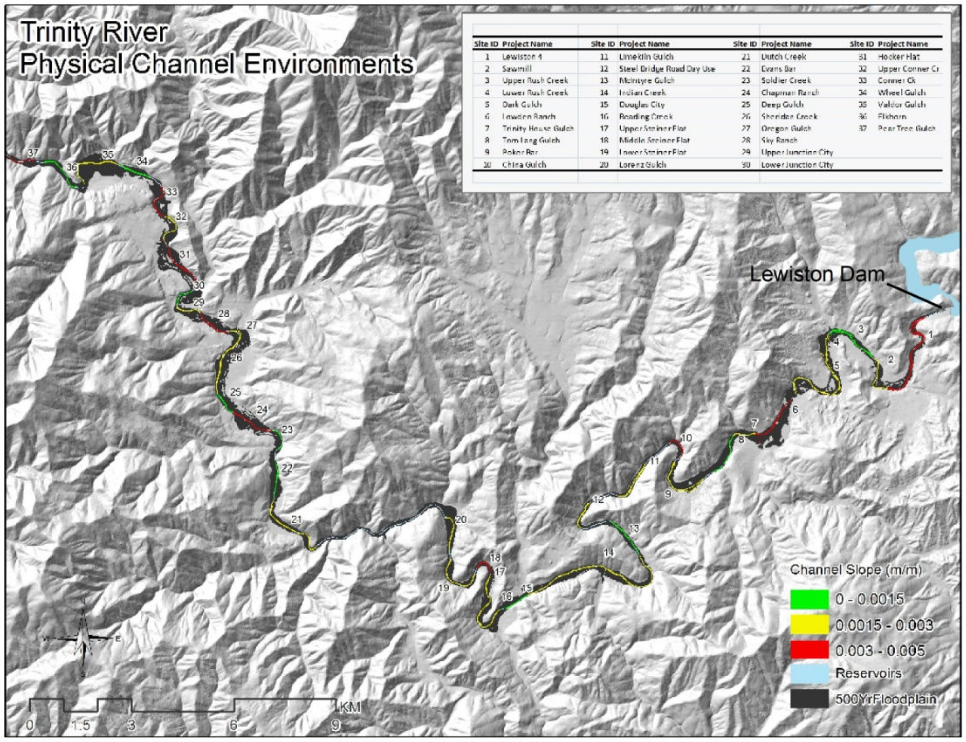


Figure 1. Study area map showing locations and channel slope classes for the Trinity River rehabilitation sites, which used as stream reaches for our analysis.

Purpose and approach

The primary purpose of this project was to estimate potential changes in juvenile salmonid habitat capacity with planned channel rehabilitation actions. Estimating restoration potential (1) provides quantitative hypotheses of restoration outcomes using the current design philosophy and an alternative design philosophy that includes greater channel manipulation and side channel construction or development, and (2) a context for establishing accuracy and resolution criteria for data collection and monitoring programs (Beechie et al. 2010). There are currently no estimates of potential improvement in Chinook salmon and steelhead fry and pre-smolt carrying capacity from channel rehabilitation projects. To fill this data gap, we estimated likely improvements in the fry and pre-smolt Chinook salmon and steelhead habitat carrying capacity, and included uncertainties to provide a common expectation of restoration success.

Estimating such changes in habitat carrying capacity due to channel rehabilitation projects is important because the Trinity River Flow Evaluation Study (TRFES) suggests that "at least a two-fold increase in smolt production is a desirable goal to restore and maintain anadromous salmonid populations toward pre-TRD levels " (page 227), and that recommended actions should lead to at least a doubling of anadromous salmonid smolt production (page 229). The TRFES also concluded that changes in stream flow regimes, gravel augmentation, and stream restoration actions were all required to increase salmon and steelhead production from the Trinity River below Lewiston Dam to the North Fork Trinity River.

As with previous studies that led to the current restoration plan (e.g., USFWS and Hoopa Valley Tribe 1999, Trush et al. 2000, McBain and Trush Inc. 2007) our approach is based on understanding of habitat-forming processes in rivers to estimate the potential extent of change in habitat availability under several restoration scenarios. It also includes a biological understanding of habitat selection by juvenile salmonids and influences of habitat type and attributes on the abundance of salmonids (Beechie et al. 2010).

We evaluated restoration potential in the Trinity River based on analyses of habitat availability at present compared to expected habitat availability post-restoration, and translation of those estimates into estimates of average juvenile salmonid carrying capacity (e.g., Reeves et al. 1989, Beechie et al. 1994, Greene and Beechie 2004). Restoration actions in the Trinity River include flow increases up to an 11,000 cfs (311 cms) maximum release out of Lewiston Dam, gravel augmentation, and habitat and riparian rehabilitation actions. These prescriptions impose certain constraints on restoration outcomes, which can be most simply accounted for using data from other gravel-bed rivers as analogs and focusing on flow regime and sediment supply as the key driving variables (e.g., Pess et al. 2005, Beechie et al. 2006b). Accounting for these constraints allows pre- and post-restoration classification of channel patterns, which can be used to stratify type and availability of habitats by reach type. Existing habitat data can then be related to reach type to quantify habitat restoration potential by reach type, and to estimate total habitat availability for the study area. Finally, habitat constraints can be identified using simple limiting factors assessments (e.g., Reeves et al. 1989, Beechie et al. 2003), life-cycle models (e.g., Greene and Beechie 2004) or the evaluation of individual life stages as potential population constraints (Pess et al. 2003, Beechie et al. 2006a). In this paper we used this last approach, and estimated potential increases in juvenile salmonid rearing habitat capacity that might result from rehabilitation actions. We estimated changes due to changes in habitat quality based on planned restoration actions, as well as potential changes based on much more optimistic estimates of changes in channel sinuosity and side-channel habitats.

Methods

We used a three step process to estimate potential changes in juvenile salmonid habitat capacity with planned channel rehabilitation actions (Table 1): (1) classification of Trinity River reaches by channel pattern and valley constraint, (2) estimation of currently available habitat area and fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity, and (3) estimation of how channel restoration actions change fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity. For the first step, we used information from reference sites that are geomorphically similar to the Trinity River between Lewiston Dam and the North Fork. Second, we estimated the current habitat potential, and then used juvenile Chinook salmon density, habitat area,

Table 1. Steps used to determine change in habitat carrying capacity as a function of rehabilitation actions that can be taken in the 64 km section of Trinity River from Lewiston (~ 3.9 from Lewiston Dam) to the confluence with the North Fork Trinity (~ 64 km from Lewiston Dam).

Step	**Purposes**
Reach classification	• We focus on valley constraint, slope, and channel forming discharge as drivers of channel pattern in order to evaluate which of the restoration reaches have the potential to develop multi-channel forms. • We calculated channel slope, channel width, potential valley floor width (disregarding dredge mine deposits), and confinement ratio directly from the digital elevation data (LiDAR) in order to identify which reaches can express multiple channels are have the capability to form complex channel patterns. • We use the reference reach data to describe typical ranges of side channel lengths for each channel pattern, and discuss the potential for Trinity River reaches to develop planforms with multiple channels.
Estimating habitat types and current fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity.	• We developed estimated distributions of juvenile Chinook and steelhead based upon depth, velocity, and cover categories to apply to current and potential restoration scenarios for each reach.
Changes to fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity due to channel rehabilitation actions.	• We compared the current habitat carrying capacity estimate to the potential change in capacity due to numerous rehabilitation actions that will likely occur in the Trinity River over the next several years. We used the geomorphic analog reach predictions as a guide for rehabilitation actions for each of the Trinity River reaches. These actions correspond to the potential process-based changes that could occur for each cluster type.

and habitat quality data from recent before-after monitoring studies on Trinity River restoration projects (Goodman et al. 2010) to estimate current rearing capacity. Third, we used Trinity River specific fish and habitat information, plus juvenile Chinook salmon and steelhead densities by habitat type from published studies (Beechie et al. 2005) to estimate change in carrying capacity under various restoration scenarios. To capture the range and uncertainty in estimates of both juvenile Chinook and steelhead densities, we used Monte Carlo simulations to estimate the range of potential habitat and fish responses that might result from restoration actions (Beechie et al. 2006a, Roni et al. 2011).

Reach classification and assignment of restoration scenarios

We grouped the restoration reaches of the Trinity River into classes of similar rehabilitation potential, based in part on potential development of alluvial channel patterns and in part on valley constraint. The four patterns encompass the dominant planforms observed in floodplain rivers (Figure 2), as suggested first by Leopold and Wolman (1957) and later modified to include an intermediate island-braided pattern between meandering and braided (Beechie et al., 2006b) (Table 2). The fundamental controls on these patterns include valley constraint, channel slope, discharge (or channel size), sediment supply, sediment caliber, bank strength, and wood availability (Beechie et al. in review). In this study we focused on valley constraint, slope, and channel-forming discharge as drivers of channel pattern to evaluate which of the restoration reaches have the potential to develop island-braided or meandering forms.

We initially attempted to identify a range of reference reaches in the upper Trinity River and South Fork Trinity River and its tributaries. However, we found that all but two reaches (at Hyampom and Hayfork) are confined between valley walls and/or exhibit the straight channel form. Therefore, we used reference data from previous studies in other forested mountain basins as reference reaches in order to represent the range of

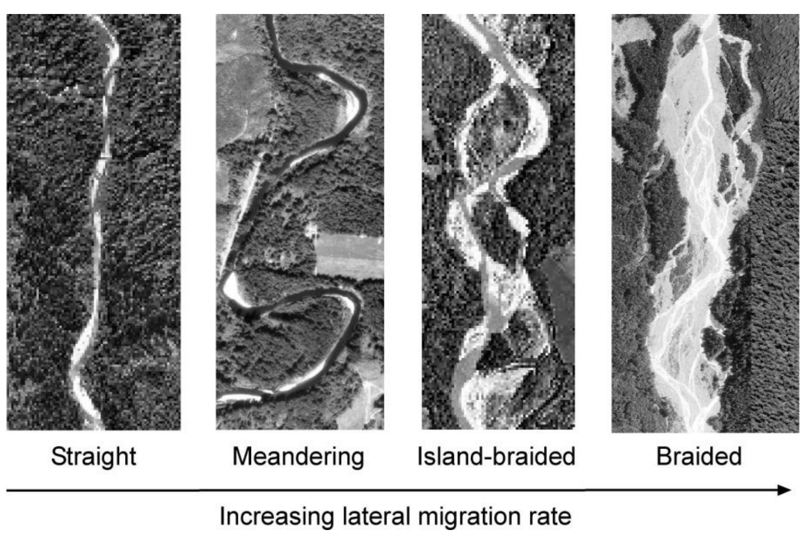


Figure 2. Examples of channel patterns in forested mountain river systems (from Beechie et al. 2006b).

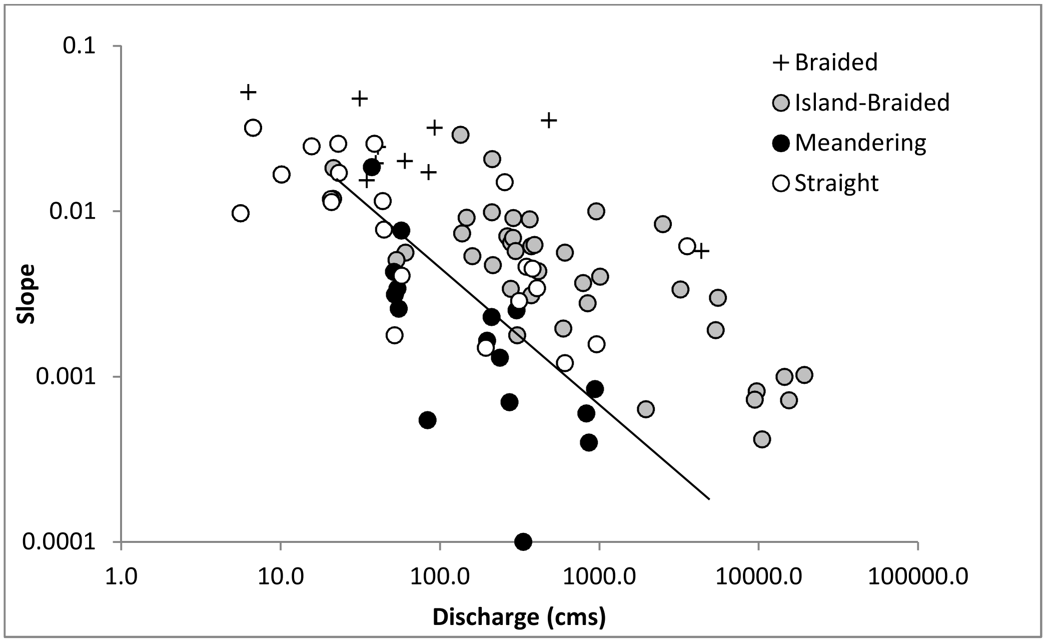
Table 2. Summary of channel pattern definitions used in this study (modified from Beechie et al. 2006b). Thresholds of bankfull width (8 m) and confinement ratio (3.8) are from Hall et al. (2007).

Channel pattern	Definition
Confined	Bankfull width > 8 m, confinement ratio < 3.8
Straight	Bankfull width > 8 m, confinement ratio > 3.8, primarily single thread channel, sinuosity < 1.5
Meandering	Bankfull width > 8 m, confinement ratio > 3.8, primarily single thread channel, sinuosity > 1.5
Island-braided	Bankfull width > 8 m, confinement ratio > 3.8, multiple channels, mainly separated by vegetated islands
Braided	Bankfull width > 8 m, confinement ratio > 3.8, multiple channels, mainly separated by unvegetated gravel bars

channel patterns that the Trinity River restoration reaches might develop (Beechie et al. 2006b, Beechie unpublished data). Reference reaches were located in two distinct physiographic regions: (1) the Puget Sound area of western Washington, which has higher mean annual precipitation than the Trinity River (30-180 inches/year compared to 30-80 inches/year; or 75-460 cm/yr compared to 75-200 cm/yr), and (2) the Blue Mountains in the interior Columbia River basin, which has lower mean annual precipitation than the Trinity River basin (15-60 inches/year compared to 30-80 inches/year, or 38-150 cm/yr compared to 75-200 cm/yr). We plotted channel slope against discharge for all reference reaches to illustrate slope-discharge domains for each channel pattern.

For each restoration reach we calculated channel slope from LIDAR data by calculating elevation change between the upper and lower ends of the reach and dividing by the channel length. We used peak flows from the TRRP Channel Design Guide, using normal and wet year estimates to bracket the potential channel forming flows (Hoopa Valley Tribe et al. 2011). We chose these two flow levels because they are near the 2-year recurrence interval, which is commonly considered the dominant channel-forming flow in alluvial channels. We then overlaid the study reaches on the reference reach plot to discern the channel pattern most likely to develop in each restoration reach (assuming a 'normal' bedload supply). The slope-discharge plot of all reference reaches from the Pacific Northwest (Figure 3A) shows a relatively distinct boundary between meandering reaches and island-braided reaches (fitted by eye, as in previous studies). The overlay of the Trinity River restoration sites shows that the prescribed "normal" year flow release puts three of the restoration reaches in the island-braided domain, whereas use of the

A.



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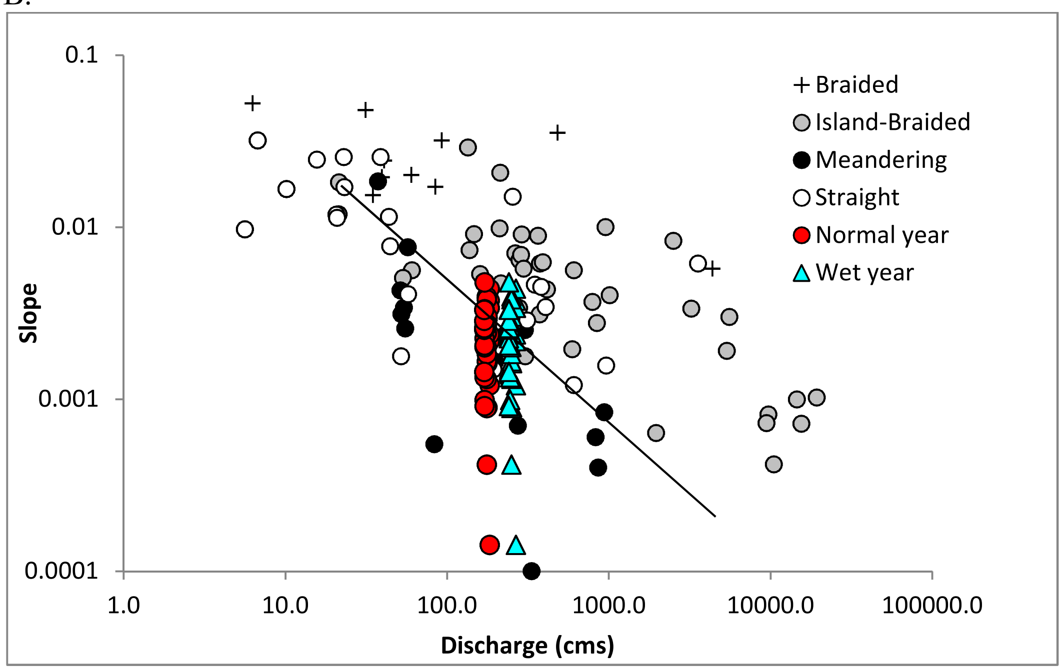


Figure 3. (A) Reference channel patterns from the Pacific Northwest USA, with diagonal line indicating approximate boundary between meandering and island-braided channels. (B) TRRP restoration reaches plotted against reference channel patterns, indicating that most reaches fall into the slope discharge range of meandering channels. Flows for normal year and wet year from Hoopa Valley Tribe et al. (2011). See also Table 3 for list of reaches and predicted channel types.

Table 3. Restoration reach attributes and probable channel patterns based on reach slope and normal year flow and wet year flow (discharge in cubic feet per second). Island-braided reaches are highlighted in blue. Flows from Hoopa Valley Tribe et al. (2011).

		Normal year flow		Wet year flow	
Reach name	Slope	Discharge	Channel pattern	Discharge	Channel pattern
Pear Tree Gulch	0.0037	184	Meandering	267	Island-braided
Elkhorn	0.0012	184	Meandering	267	Meandering
Valdor Gulch	0.0022	184	Meandering	267	Meandering
Wheel Gulch	0.0001	184	Meandering	267	Meandering
Conner Ck	0.0044	184	Island-braided	267	Island-braided
Upper Conner Cr	0.0024	184	Meandering	267	Meandering
Hocker Flat	0.0034	184	Meandering	267	Island-braided
Lower Junction City	0.0009	178	Meandering	253	Meandering
Upper Junction City	0.0029	178	Meandering	253	Meandering
Sky Ranch	0.0030	178	Meandering	253	Meandering
Oregon Gulch	0.0016	178	Meandering	253	Meandering
Sheridan Creek	0.0020	176	Meandering	250	Meandering
Deep Gulch	0.0013	176	Meandering	250	Meandering
Chapman Ranch	0.0039	176	Island-braided	250	Island-braided
Soldier Creek	0.0009	176	Meandering	250	Meandering
Evans Bar	0.0004	176	Meandering	250	Meandering
Dutch Creek	0.0017	176	Meandering	250	Meandering
Lorenz Gulch	0.0018	176	Meandering	250	Meandering
Lower Steiner Flat	0.0024	176	Meandering	250	Meandering
Middle Steiner Flat	0.0038	176	Meandering	250	Island-braided
Upper Steiner Flat	0.0026	176	Meandering	250	Meandering
Reading Creek	0.0028	176	Meandering	250	Meandering
Douglas City	0.0010	171	Meandering	246	Meandering
Indian Creek	0.0020	171	Meandering	246	Meandering
McIntyre Gulch	0.0013	171	Meandering	246	Meandering
Steel Bridge Road	0.0027	171	Meandering	246	Meandering
Limekiln Gulch	0.0023	171	Meandering	246	Meandering
China Gulch	0.0048	171	Island-braided	246	Island-braided
Poker Bar	0.0021	171	Meandering	246	Meandering
Tom Lang Gulch	0.0009	171	Meandering	246	Meandering
Trinity House Gulch	0.0028	171	Meandering	246	Meandering
Lowden Ranch	0.0033	171	Meandering	246	Island-braided
Dark Gulch	0.0025	170	Meandering	241	Meandering
Lower Rush Creek	0.0026	170	Meandering	241	Meandering
Upper Rush Creek	0.0014	170	Meandering	241	Meandering
Sawmill	0.0029	170	Meandering	241	Meandering
Lewiston 4	0.0033	170	Meandering	241	Meandering

"wet year" flow estimate puts seven reaches in the island-braided domain (Table 3) (Figure 3B).

We used cluster analysis to identify groups of reaches with similar confinement, channel size, and channel slope to help define restoration scenarios. For each reach, we calculated channel slope, channel width, width of the 500-year floodplain (disregarding dredge mine deposits), and confinement ratio directly from the digital elevation data (LiDAR). We disregarded the dredger tailings because we wanted to create optimistic scenarios of restoration potential, assuming that in some scenarios the tailings piles could be removed. Following the methods of Beechie et al. (in review), we first identified constrained reaches (floodplain width <4 times the channel width), moderately constrained reaches (4-10 times channel width), and unconfined reaches (>10 times the channel width) (Beechie et al. 2006b, Hall et al. 2007).

We then ran the cluster analysis and set the number of clusters at five based on consistency of clusters with channel pattern predictions and confinement ratios. Of the five clusters identified (Figure 4), the reaches most likely to develop island-braided forms

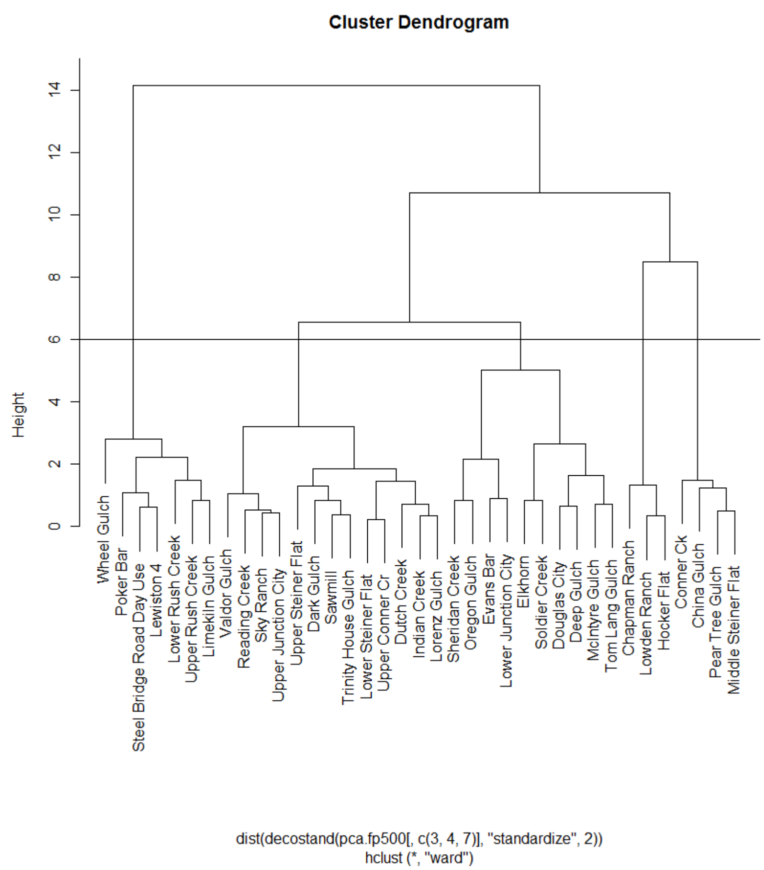


Figure 4. Cluster analysis of restoration reaches based on confinement, slope, and bankfull width, resulting in four main groups of channels (see also Table 4 for description of clusters).

are in Clusters 3 and 4. Cluster 3 includes the unconfined reaches Lowden Ranch, Chapman Ranch, and Hocker Flat (confinement ratio >10), whereas Cluster 4 includes predominantly moderately confined reaches (confinement ratio between 4 and 10) (Figure 5, Table 4). Therefore, Cluster 3 has the greatest potential for side-channel development. The channels in Cluster 4 (Pear Tree Gulch, China Gulch, Conner Creek, and Middle Steiner Flat) were either tightly confined or moderately confined and have little space to develop multiple channels and islands. The remaining clusters were meandering channels that were mostly moderately confined (Cluster 1), mostly confined (Cluster 2), or had variable confinement (Cluster 5). The reach type clusters are mapped in Figure 6.

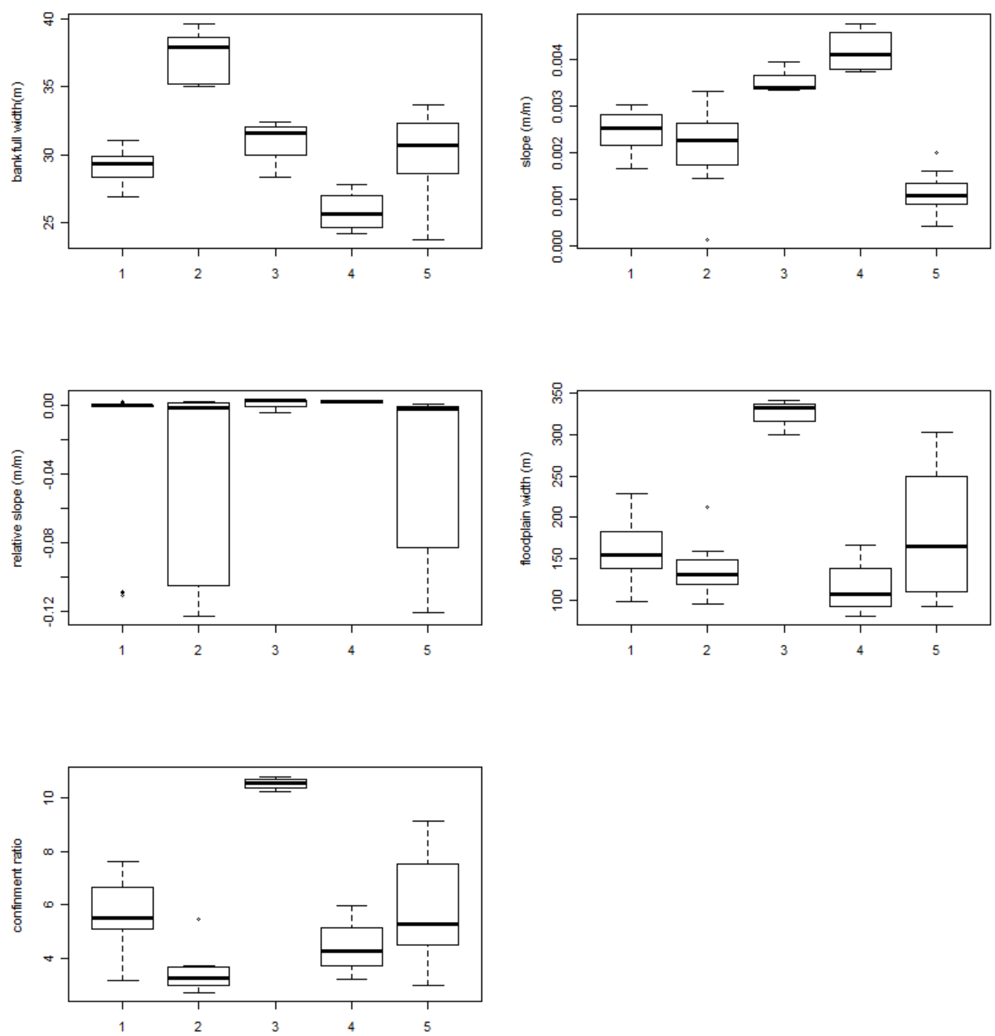


Figure 5. Box and whiskers plots of individual attributes for each reach type cluster.

Table 4. Summary of channel attributes by cluster.

Cluster	Bankfull width	Floodplain width	Predominant confinement range	Description
1	27-31 m	98-228 m	4-8	Meandering, moderately confined, some secondary channels possible
2	35-40 m	100-16 m	<4	Meandering, confined, little room for multiple channels
3	28-32 m	300-350 m	>10	Island-braided, unconfined, many secondary channels possible
4	24-28 m	81-166 m	4-6	Island-braided, moderately confined, few secondary channels possible in most reaches
5	29-32 m	92-302 m	3-9	Meandering, variable confinement

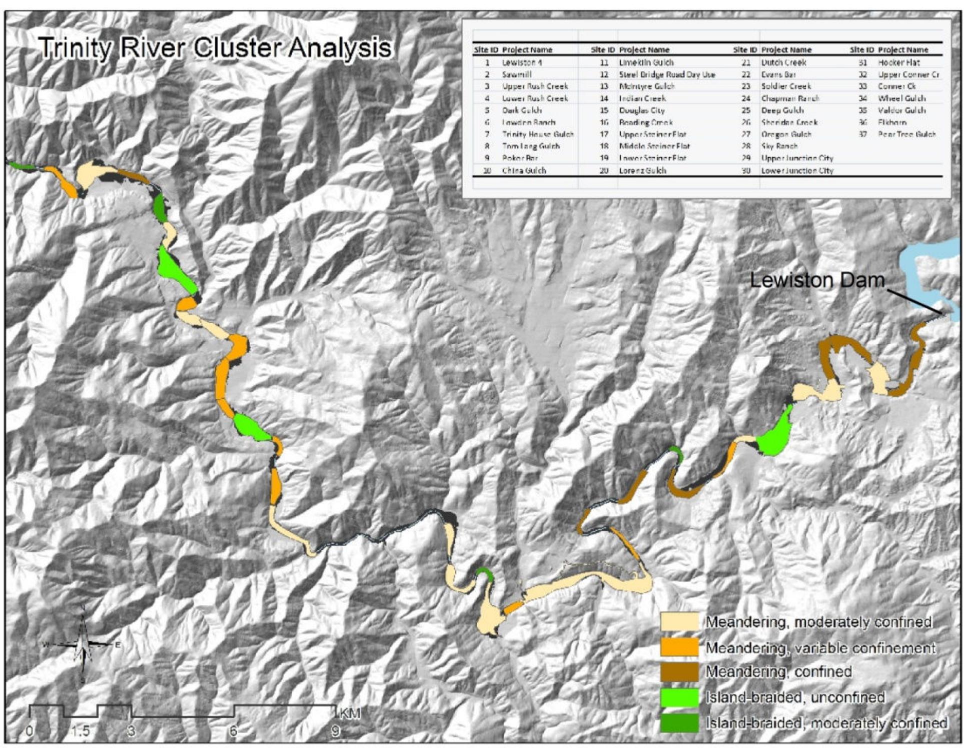


Figure 6. Map of cluster types for the Trinity River restoration reaches.

Once we identified the reach clusters, we assigned restoration scenarios to each reach based on potential channel patterns, clusters, and confinement ratios. For channels expected to be meandering channels, we estimated that increased sinuosity through restoration could possibly reach 50% (or sinuosity of roughly 1.5, illustrated in Figure 7), except where reaches are confined and the floodplain is not wide enough to accommodate 50% more channel length (i.e., reaches with confinement ratio <4). In those cases we limited the potential increase to 20% (or a sinuosity of 1.2) (Table 5). For side channel development or construction, we first assumed that island-braided reaches with confinement ratios >10 (Cluster 3) could support the maximum number of side channels and an increase in sinuosity of 50% (Table 5). By contrast, for island-braided reaches that were moderately confined (Cluster 4) and the meandering channels (Clusters 1, 2, and 5) we used a side-channel length equal to the mainstem length for confined reaches (confinement <4) and side-channel length 2 times the mainstem length for moderately confined channels. While meandering channels do not naturally develop more than one side-channel per unit mainstem length (Figure 8), we made the optimistic assumption that they could support multiple constructed side-channels across their floodplain to maximize the potential habitat increase through rehabilitation actions.

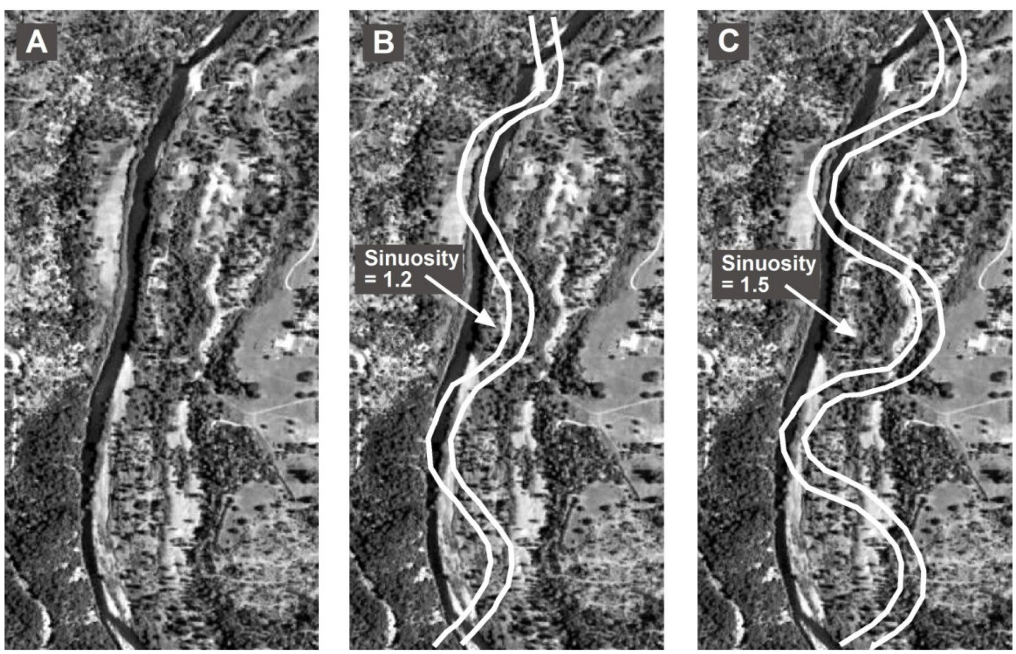


Figure 7. Illustration of channels with sinuosity of 1.2 and 1.5, overlain on the Sheridan Creek restoration site, which is in the unconfined cluster of reaches. Unconfined and moderately confined reaches were considered to potentially achieve sinuosity of 1.5 after restoration actions, and confined reaches could potentially achieve a sinuosity of 1.2.

Table 5. Expected increases in edge habitat length (meander length) and side channel length due to restoration actions based upon cluster type in the Trinity River.

Cluster	Description	Increase in meander length	Maximum increase in side channel length
1	Meandering; moderately confined	50% (except one confined reach at 20%)	Side-channel length 3 times the mainstem length
2	Meandering, confined	20% (except one moderately confined reach at 50%)	Side-channel length equal to mainstem length
3	Island-braided, unconfined	50%	Side-channel length 3 times the mainstem length
4	Island-braided, confined to moderately confined	Confinement <4: 20% Confinement 4-6: 50%	Side-channel length 2 times the mainstem length depending on confinement ratio
5	Meandering, variable confinement	Confinement <4: 20% Confinement 4-6: 50% Confinement >6: 50%	Side-channel length 3 times the mainstem length

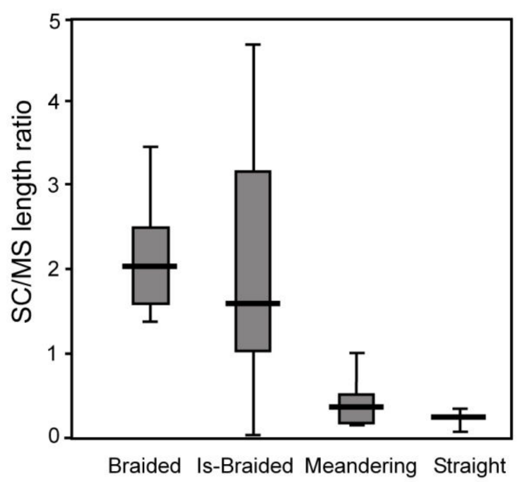


Figure 8. Side-channel length to mainstem length ratios by channel type (based on data in Beechie et al. 2006b).

Estimating habitat types and current fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity

We used existing stream habitat and juvenile salmonid data (i.e stream gradient, confinement, wetted area, and relative fish density by depth, velocity, and cover) from current and previous studies in the Trinity River (Goodman et al. 2010), as well as data from other watersheds in the Pacific Northwest (i.e. Skagit River basin, see Beechie et al. 2005) to determine current and restored carrying capacity. The wetted area of each reach was calculated based on GIS derived lengths and widths using a "base flow" layer during typical flows for the summer (~12.75 m^3/s at Lewiston Dam) or winter season (8.5 m^3/s) for each salmonid at the juvenile life stage (GIS data from TRRP). Habitat areas were measured by Goodman et al. (2010) as part of a system-wide probabilistic random sampling of habitat area during 2007-2008 (Goodman et al. 2010). We stratified those habitat area measurements by the reach types described previously, and calculated mean proportions of each habitat type (described below) for each of the reach types. We then extrapolated habitat areas for each reach type to the remaining reaches of similar type to estimate habitat areas for the entire restoration area.

The probabilistic random sampling of habitat classified habitat areas according (1) no depth, no velocity, and no cover (none of the three attributes are favorable for salmonid rearing), (2) depth, velocity, and cover (all three are favorable for salmonid rearing), (3) no depth, no velocity, and cover (depth and velocity are not favorable, but cover is available), and (4) depth, velocity, and no cover (depth and velocity are favorable but there is no cover). The proportion of habitat type for each sample location was then used to extrapolate overall habitat capacity to an entire reach based on sampling location (i.e. river kilometer). We used existing juvenile Chinook utilization data from the Trinity River (i.e. non-transformed mean fish density and standard error (SE) by species and life stage) in the four habitat categories from the Trinity River to determine the relative usage (Table 6) (Goodman et al. 2010). It is important to note that there was no fish use for some depth, velocity, and cover categories for a given life stage. Pair-wise tests among habitat categories were found to be significantly different for Chinook by life stage with the exception of one presmolt Chinook category (Depth, velocity, and no cover) (Goodman et al. 2010).

We did not have existing steelhead utilization data from the Trinity River so we used the Skagit River data to estimate current carrying capacity (Table 7) (Beechie et al. 2005). We compared limited depth, velocity, cover criteria, and habitat type (bank v. non-bank) for juvenile salmonids from the Trinity to the Skagit River data, and found that the proportion of fish utilizing depths less than 0.61 meters and velocities less than 0.15m/sec were almost the same (79% ± 3% SD) (Goodman et al. 2010) (Figure 9). The difference between fish densities with and without nearby cover (i.e. wood, substrate, aquatic vegetation, and habitat type) were also similar for all species. Therefore, we assumed that those criteria were also applicable to the Trinity River, even though they have different population sizes of Chinook and steelhead, and are in different ecoregions of the western United States.

We estimated the average and standard deviation of juvenile Chinook and steelhead carrying capacity for each stream reach using a Monte Carlo simulation (Manly 2006,

Table 6. Juvenile Chinook salmon densities (fish/m^2) (± SE) in the Trinity River by depth, velocity, and cover (Goodman et al. 2010).

Category	<50 mm	50—200 mm
Suitable depth, velocity, and cover (D,V,C)	7.80 ± 1.30	5.20 ± 0.53
Suitable depth and velocity, but not cover (D, V, NC)	2.70 ± 0.63	3.20 ± 0.24
Suitable velocity and cover, but not depth (ND, V, C)	?	?
Unsuitable depth and velocity, but suitable cover (ND, NV, C)	2.40 ± 0.41	2.10 ± 0.62
Unsuitable depth, velocity, and cover (ND, NV, NC)	0.48 ± 0.17	0.74 ± 0.12

Table 7. Juvenile steelhead densities (fish/m^2) (± SE) in the Skagit River by location, season, and depth, velocity, and cover (Beechie et al. 2005). Number sampled in parentheses.

	Less than 50mm				Greater than 50mm, less than 200mm			
	Summer		Winter		Summer		Winter	
	bank	non-bank	bank	non-bank	bank	non-bank	bank	non-bank
Suitable depth, velocity, cover	0.45 ± 0.05 (190)	0.45 ± 0.04 (182)	0.06 ± 0.0002 (1385)	0.02 ± 0.0002 (883)	0.04 ± 0.02 (190)	0.07 ± 0.0004 (182)	0.01 ± 0.0002 (1385)	0.001 ± 0.0007 (883)
Suitable depth & velocity, not cover	0.14 ± 0.05 (20)	0.02 ± 0.09 (75)						
Suitable velocity & cover, but not depth	0.14 ± 0.02 (116)				0.04 ± 0.014 (116)			
Suitable cover, but not depth or velocity								
Unsuitable depth, velocity, cover								

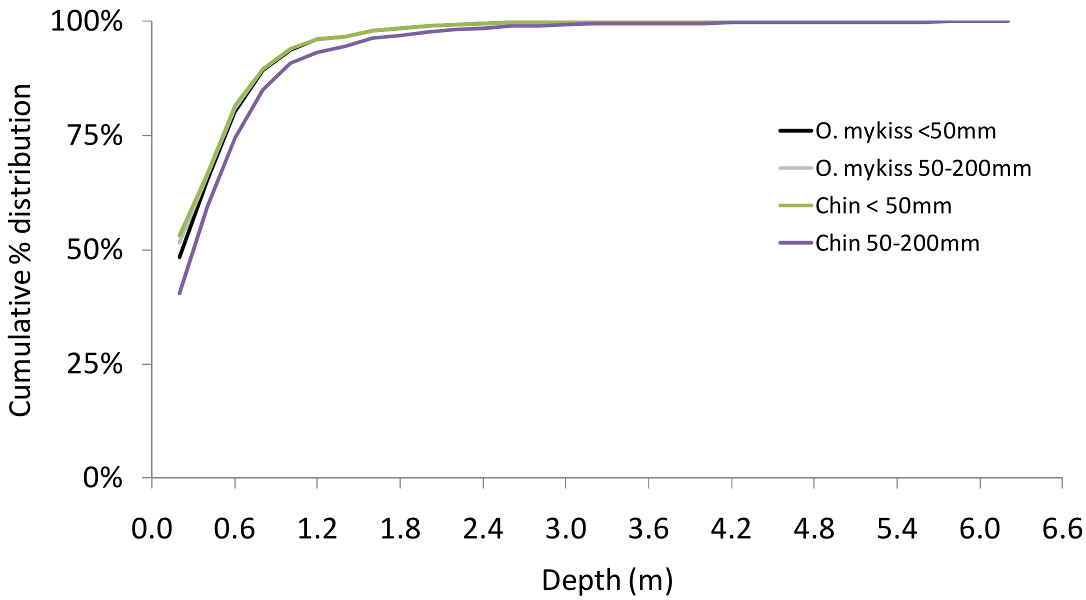


Figure 9. Cumulative % distribution of depth for juvenile Chinook and steelhead (0 and 1+) in the Skagit River Basin, Washington State (Beechie et al. 2005).

Beechie et al. 2006a, Roni et al. 2010). We used the mean and standard error of juvenile Chinook and steelhead densities from the Skagit River data to generate distributions of input densities for suitable depth, velocity, and cover, and then ran a Monte Carlo simulation with 1,000 model runs to estimate the distribution of density estimates for each of the four depth, velocity, and cover categories described above (Figure 10). We then multiplied each of the 1,000 density estimates by the total amount of estimated habitat area of each category in each stream reach. Finally, we took the average carrying capacity for each depth, velocity, and cover category by reach and summed all the categories to get an average (± SD) carrying capacity by species and size class for each reach.

Changes to fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity due to channel rehabilitation actions.

We compared the current average carrying capacity to the potential change in carrying capacity due to the restoration actions that will likely occur in the Trinity River over the next several years (http://www.trrp.net/?page_id=43). Some of the main restoration concepts that have been identified in the Trinity River include flow management, gravel augmentation in the mainstem Trinity River, bank rehabilitation in the form of wood placement, the development of gravel bars, an increase in main stem stream length, and the reconnection or creation of single or multiple side channels in the floodplains, and lowered floodplains (http://www.trrp.net). We did not model all of these rehabilitation actions individually, but instead focused our analysis on the desired outcomes of these actions: the development of gravel bars, an increase in main stem

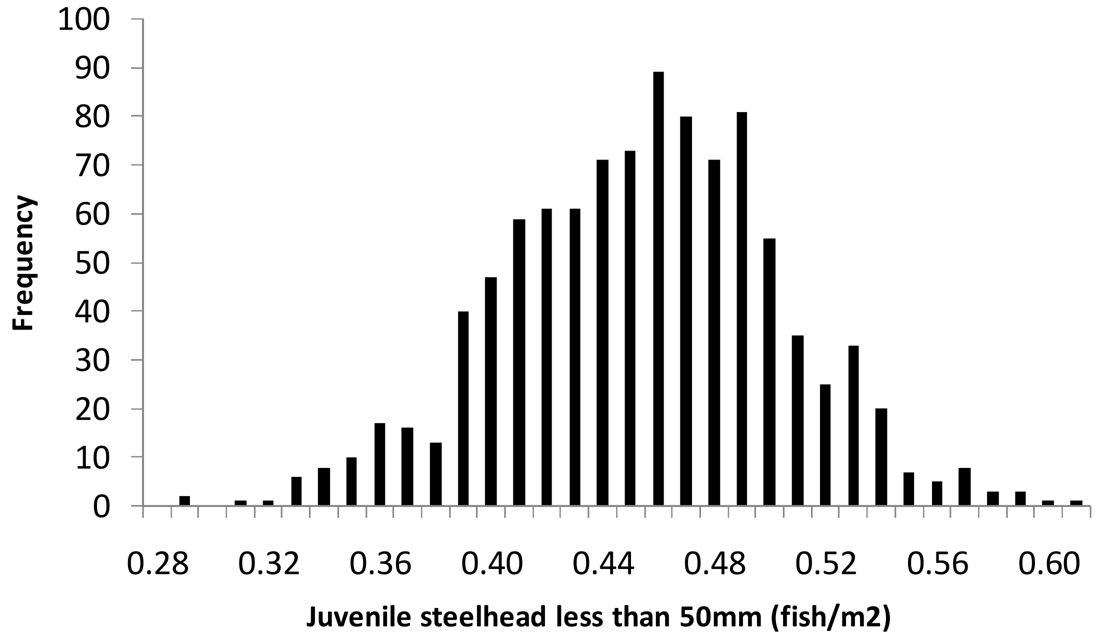


Figure 10. Example of Monte Carlo predictions of densities of juvenile steelhead <50 mm where there is appropriate depth, velocity, and cover. Distribution generated from data from Beechie et al. (2005). The simulation was run 1,000 times.

length, and the reconnection or creation of single and multiple side channels in the floodplain.

We used differences in the amount of habitat area between analog reaches and the Trinity reaches to determine the potential increase in gravel bar area, channel length, or side channel length which could occur. The main factor that determined the amount of habitat quantity or quality increase by rehabilitation action for each cluster was the likelihood of developing multiple channels, which was based on valley confinement and the potential channel pattern. For each cluster we created two general restoration scenarios. In our first scenario we assumed there would be an increase in habitat quality but not quantity, which we based on the types of rehabilitation actions that have already occurred in the Lewiston and Sawmill reaches over the last several years. In those reaches, Goodman et al (2010) found that suitable depth, velocity, and cover for juvenile Chinook salmon < averaged 12% of the total area with restoration actions in those reaches. In contrast, suitable depth, velocity, and cover averaged 2% (±1%) of the total area in the remaining reaches where similar rehabilitation had not occurred. Therefore, we assumed rehabilitation in all stream reaches and a similar increase from 2% to 12% in habitat quality to all stream reaches in the study area. In our second scenario we assumed there would be an increase in both habitat quality and quantity for each reach in the study area based upon the cluster type. In this scenario we began with the same increases in habitat quality as in scenario 1, and then added increases in habitat quantity. Increases in habitat quantity for gravel bar area and meander length were combined for each reach, but increases in side channel length and area were estimated separately for each reach.

For both scenarios we assumed that habitat utilization would be the same for each species and size class prior to and after restoration actions, regardless of the change in habitat quality and quantity. That is, the estimated distributions of fish densities from the Monte Carlo simulation were the same for each habitat category, and only the change in abundance of each habitat category determined the change in habitat carrying capacity at the reach scale. These were then summed across the entire 64 km reach to gain a better understanding of the total change in habitat carrying capacity as a function of all the potential rehabilitation actions that could be completed.

We attempted to incorporate changes in density of salmonids with respect to time since the effectiveness of the restoration actions may vary over time (Pess et al. in press, White et al. 2011, Whiteway et al. 2010). We modeled three different time-dependent scenarios. First, we assumed no change in the habitat carrying capacity of salmonids once the rehabilitation action had taken place, and that fish density and habitat carrying capacity would remain the same over a 10 year period. Second, we assumed that once the restoration actions were implemented, gradual increases in habitat carrying capacity occurred over the ten year time period, allowing for an increase in fish utilization over time. Third, we assumed that a decrease in habitat carrying capacity occurred over the ten year time period and resulted in a decrease in fish density during that time period. We assumed a simple power function with either a positive or negative exponent in order to estimate an increase or decrease over time, where j is the stream reach and t is year. The exponent of 1.067 was used based on existing data on the relative increase or decrease in juvenile salmon fish densities observed with constructed logjam placements in the Elwha River (Pess et al. in press). We assumed that a similar fish response would occur over time in the Trinity because many of the actions have to do with channel rehabilitation, and it is a river of a similar size. The ten year time period we chose is arbitrary.

$$fishdensity_{j,t+1} = fishdensity_{j,t}^{\;1.067}$$

$$fishdensity_{j,t+1} = fishdensity_{j,t}^{\;-1.067}$$

Equation (1)

Results

Estimating habitat types and current fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity

The estimated current habitat area (m^2) available for fry and pre-smolt Chinook and steelhead in the Trinity River between Lewiston Dam and the North Fork Trinity, is over 1.6 million m^2 based on average summer flow conditions (Table 8). However, a significant portion of the habitat is classified as having inappropriate depth, velocity, or cover for both juvenile Chinook and steelhead (Table 8). The estimated habitat carrying

Table 8. Estimated current habitat area (m^2) in the Trinity River for juvenile Chinook salmon and steelhead by depth (D), velocity (V), and cover (C) from Lewiston (~ 3.9 km downstream of Lewiston Dam) to the confluence with the North Fork Trinity (~ 64 km downstream of Lewiston Dam).

	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total
Total	63,370	97.215	72,493	1,390,343	1,623,422
Mean/reach (±S.E.)	1,713 (±451)	2,627 (±337)	1,959 (±473)	22,755 (±3,741)	43,876 (±4,531)

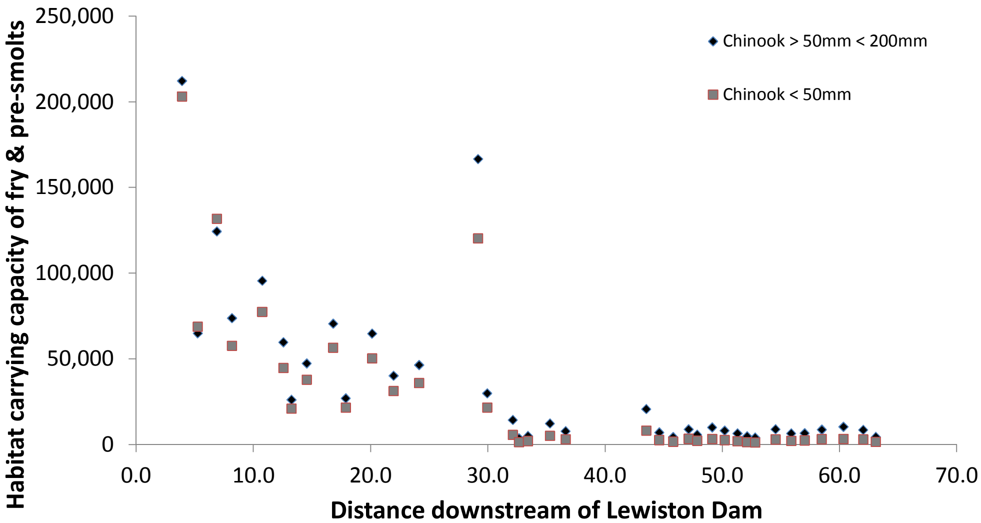
Table 9. Estimated current habitat carrying capacity in the Trinity River for juvenile Chinook salmon and steelhead by size class from Lewiston (~ 3.9 from Lewiston (~ 3.9 km downstream of Lewiston Dam) to the confluence with the North Fork Trinity (~ 64 km downstream of Lewiston Dam).

	Chinook salmon		Steelhead	
	Less than 50mm	Greater than 50mm, less than 200mm	Less than 50mm	Greater than 50mm, less than 200mm
Total	1,596,595	2,006,245	87,255	65,894
Mean/reach (±S.E.)	43,151 (±6,212)	54,223 (±6,628)	2,358 (±364)	1,781 (±186)

capacity for fry and pre-smolt Chinook salmon is 11 to 20 times greater than for steelhead (Table 9). Among size classes, the estimated current habitat carrying capacity for juvenile Chinook is lower for juvenile Chinook salmon <50mm than for juvenile Chinook salmon 50—200 mm (Figure 11a). By contrast, the production potential for steelhead <50mm is higher than for those 50—200 mm (Figure 11b). Notably, t\The estimated habitat carrying capacity for juvenile Chinook salmon <50mm is comparable to the estimated population size of outmigrating wild young-of-the-year (YOY) Chinook salmon for the reach below Lewiston and above the North Fork Trinity (Figure 12). However, it is important to note that our habitat carrying capacity is an underestimate because it does not incorporate any estimate of tributary habitat.

There are several spatial trends in the habitat carrying capacity estimates. Overall habitat carrying capacity estimates for Chinook salmon and steelhead, regardless of size class decreases in the downstream direction of the Lewiston Dam (Figure 13). There is also less habitat carrying capacity of juvenile Chinook <50mm than those that are 50—200 mm across the vast majority of reaches with the exception of the Sawmill and upper Rush Creek areas (Figure 11). In contrast, juvenile steelhead potential

A



B

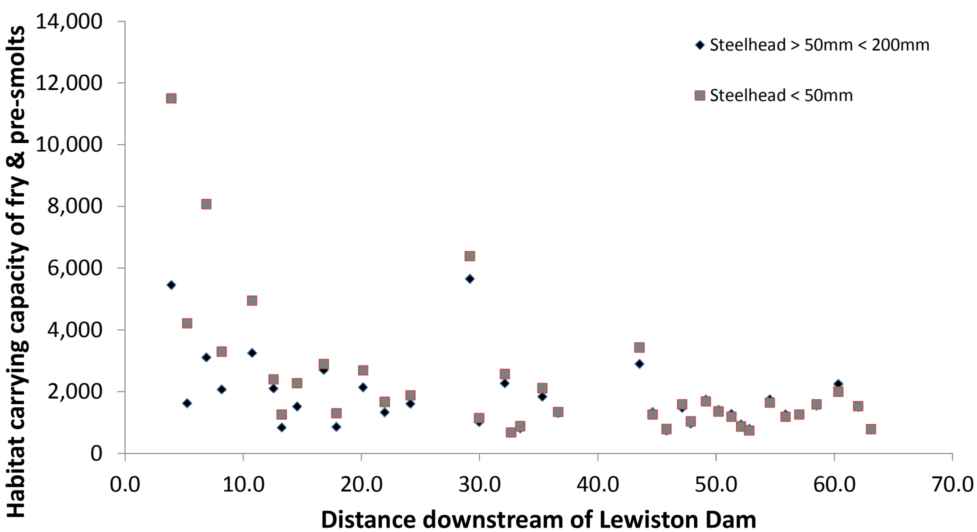


Figure 11. Estimated habitat carrying capacity for juvenile Chinook salmon and steelhead by reach, size class, depth, velocity, and cover in the Trinity River study area, for (A) Chinook salmon <50mm and Chinook salmon 50—200 mm, and (B) steelhead <50mm and steelhead 50—200 mm.

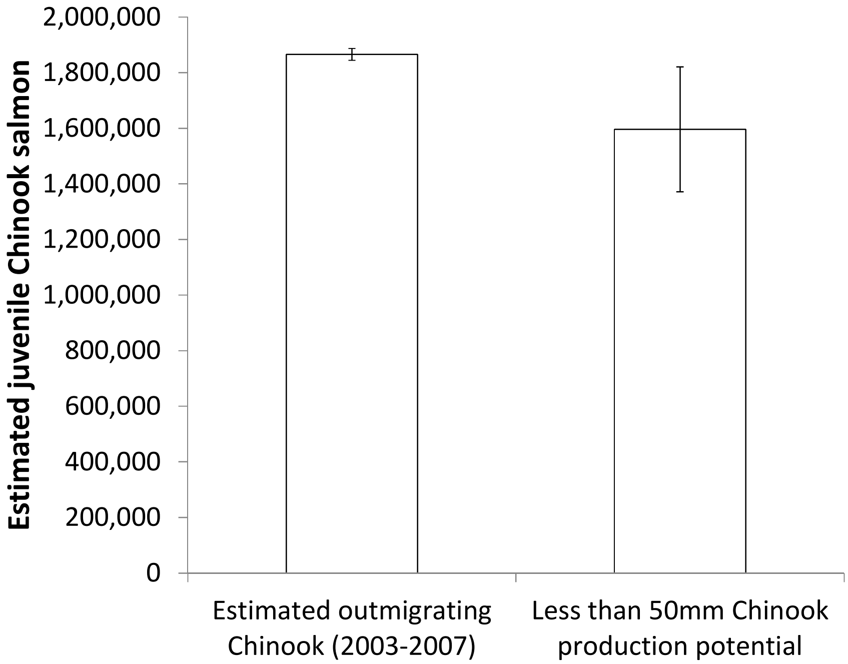


Figure 12. A comparison of the estimated number of wild outmigrating young-of-the-year (YOY) Chinook salmon (Schwarz et al. 2009) and habitat carrying capacity for Chinook < 50mm.

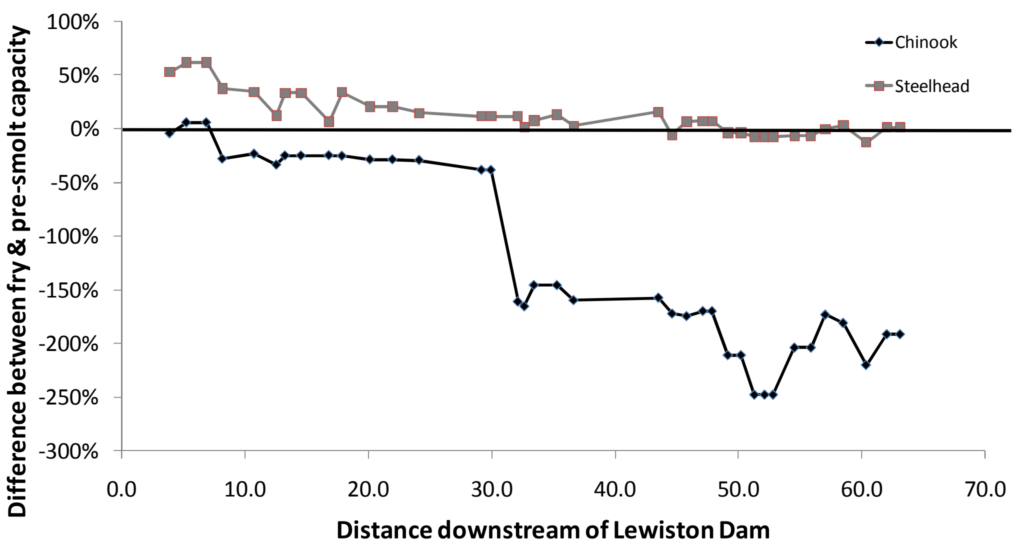


Figure 13. Difference in production potential between juvenile Chinook and steelhead <50 mm and those 50—200 mm in the Trinity River below Lewiston Dam.

production for fish <50mm is greater than for those 50—200 mm in the first 40 kilometers downstream of Lewiston Dam. After Evans Bar (~45km downstream of Lewiston), capacity for juvenile steelhead 50—200 mm becomes similar to those <50mm.

Changes to fry and pre-smolt juvenile Chinook salmon and steelhead carrying capacity due to channel rehabilitation actions.

Scenario one – an increase in habitat quality, and no increase in habitat quantity

An increase in the preferred depth, velocity, and cover type from 2% to 12% of the total habitat area of the 64 km of the Trinity (while total habitat area remains the same in all the remaining reaches) results in a three-fold increase in preferred habitat area (Table 10). A three-fold increase in the preferred depth, velocity, and cover category assuming total habitat area remains the same, results in an average reach increase in juvenile Chinook salmon <50mm fry habitat carrying capacity of 45% (±6%), and an overall increase of 39% for the entire study reach (~1.6 million Chinook salmon fry to ~2.5million Chinook salmon fry) (Figure 14). The overall increase in capacity is 16% greater (~3.0 million) if we assume an continued non-linear increase in habitat quality over a 10 year time period, and 14% less (~2.2 million) if we assume that habitat quality decreases in a non-linear fashion over a 10 year time period.

Table 10. Estimated increase in habitat quality (m^2) in the Trinity River for juvenile Chinook salmon and steelhead by depth (D), velocity (V), and cover (C) from Lewiston (~ 3.9 km downstream of Lewiston Dam) to the confluence with the North Fork Trinity (~ 64 km downstream of Lewiston Dam), assuming an average increase from 2% to 12% in preferred depth, velocity, and cover for all reaches.

	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total
Current habitat area	63,370	97.215	72,493	1,390,343	1,623,422
Increase in habitat area	194,811	97,215	72,493	1,258,903	1,623,422

Table 11. Increase in habitat area (m^2) by rehabilitation scenario for the 64km study reach of the Trinity River. Number in parentheses is the estimated increase due to the rehabilitation actions.

Total current habitat area	All actions (gravel bars, meanders, side channels)	Increase in meanders and gravel bars	Increase one side channel	Increase all side channels possible
1,623,422	2,369,593	1,697,499	2,249,462	2,295,517
	(746,171)	(74,077)	(626,040)	(672,095)

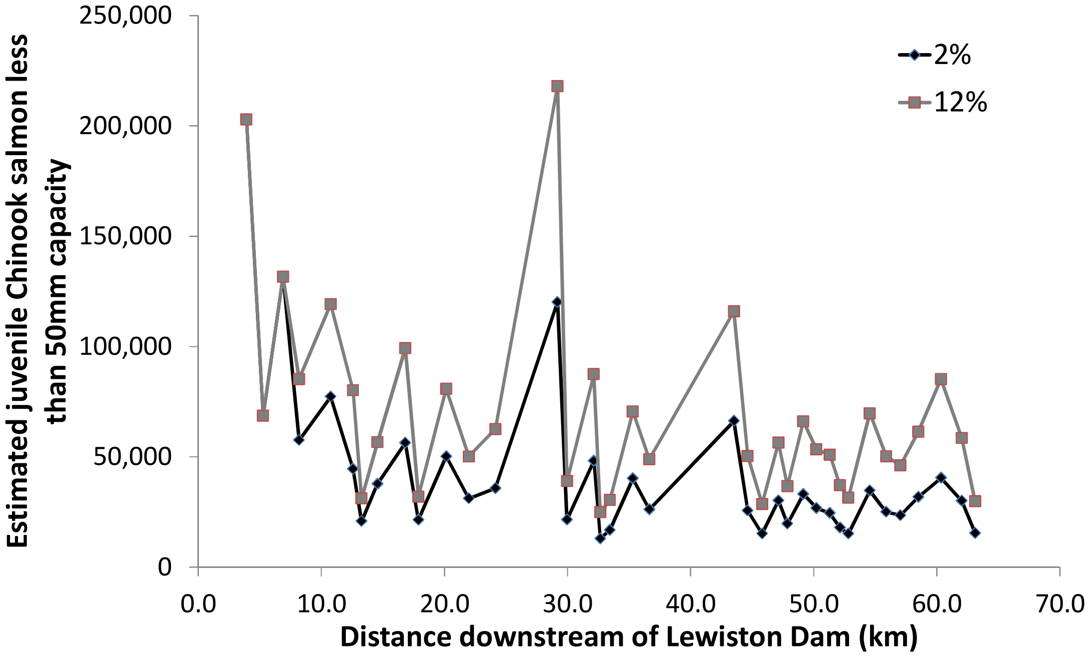


Figure 14. Estimated increases in juvenile Chinook salmon less than 50mm production potential assuming an increase from 2% to 12% in preferred depth, velocity, and cover for all reaches of the 64km of the Trinity.

Scenario two - an increase in habitat quantity and quality

Overall habitat quantity can increase from approximately 1.62 million to 2.37 million m^2 (~46%) assuming all rehabilitation actions were implemented in the entire 64 km section of the main stem Trinity River (Table 11). Increases based upon different rehabilitation actions results in an increase in habitat area that ranges between 5% and 41% (Table 11). It is important to note that the actions are not necessarily additive, and an increase from one rehabilitation action such as side channel development may preclude an increase in another rehabilitation action such as an increase meander length or gravel bar area. This is the primary reason why the total increase in habitat area for all rehabilitation actions is similar to single rehabilitation actions such as the development of side channels (Table 11). These increases in habitat quantity result in a change in habitat carrying capacity between 5 and 44% for both juvenile Chinook salmon and steelhead which is similar to the increases in habitat area (Table 12).

The combination of the preceding increase in habitat quantity with an assumed increase in preferred depth, velocity, and cover category type from 2% to 12% results in large changes to habitat carrying capacity for juvenile Chinook salmon and steelhead (Figures 15 and 16). The result of implementing one or all potential rehabilitation actions and a subsequent increase in habitat quantity and the amount of preferred habitat for each species and size class combination in the entire 64 km study area of the Trinity River results in an estimated increase in habitat carrying capacity between 40% and 96% (Figures 15 and 16). Potential increases in habitat carrying capacity for both size classes of juvenile Chinook salmon and one size class of steelhead were greater than one

Table 12. Increase in smolt production potential by species and size class (total number of fish) due to an increase in habitat area alone from rehabilitation actions in the 64 km study reach of the Trinity River.

Species & size class	Current habitat capacity	All actions (gravel bars, meanders, side channels)	Increase in meanders and gravel bars	Increase one side channel	Increase all side channels possible
Chinook < 50 mm	1,596,599	2,304,436	1,668,119	2,196,640	2,234,479
Chinook salmon 50—200 mm	2,006,246	2,733,434	2,077,153	2,519,075	2,567,161
Steelhead < 50mm	87,255	115,061	83,521	109,783	111,606
Steelhead 50—200 mm	65,895	94,653	62,807	89,855	91,694

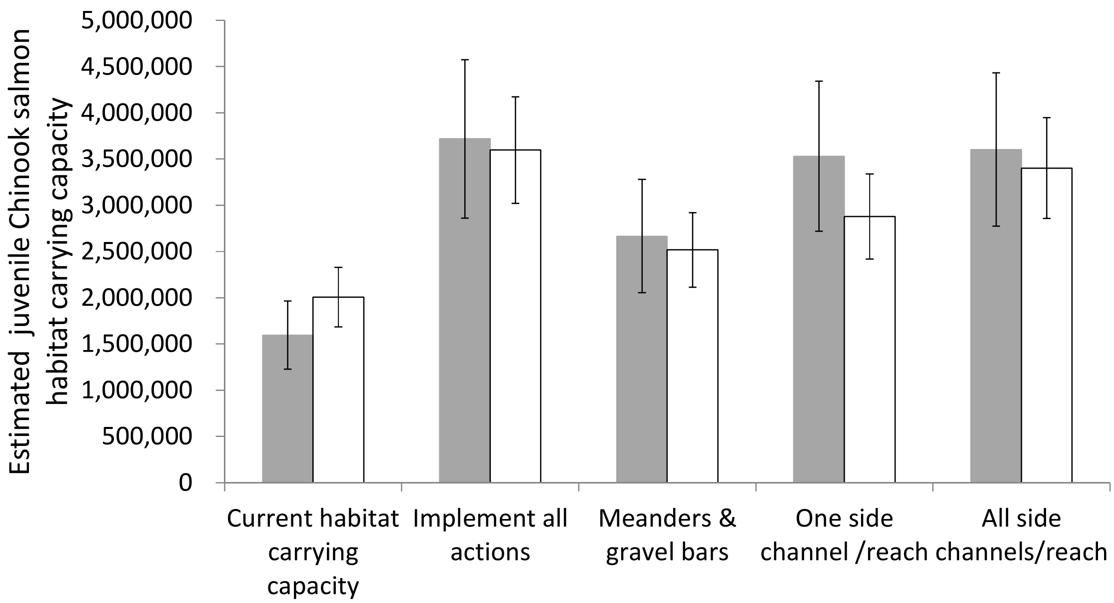


Figure 15. Estimated increases in juvenile Chinook salmon habitat carrying capacity, assuming an increase in habitat area and habitat quality, by rehabilitation action in all reaches of the 64km of the Trinity from Lewiston Dam to the confluence of the North Fork Trinity River. Gray bars are juvenile steelhead <50 mm. Clear bars are juvenile steelhead 50—200 mm. Solid black bars with perpendicular lines at top and bottom of bars is representative of one standard deviation of the estimate.

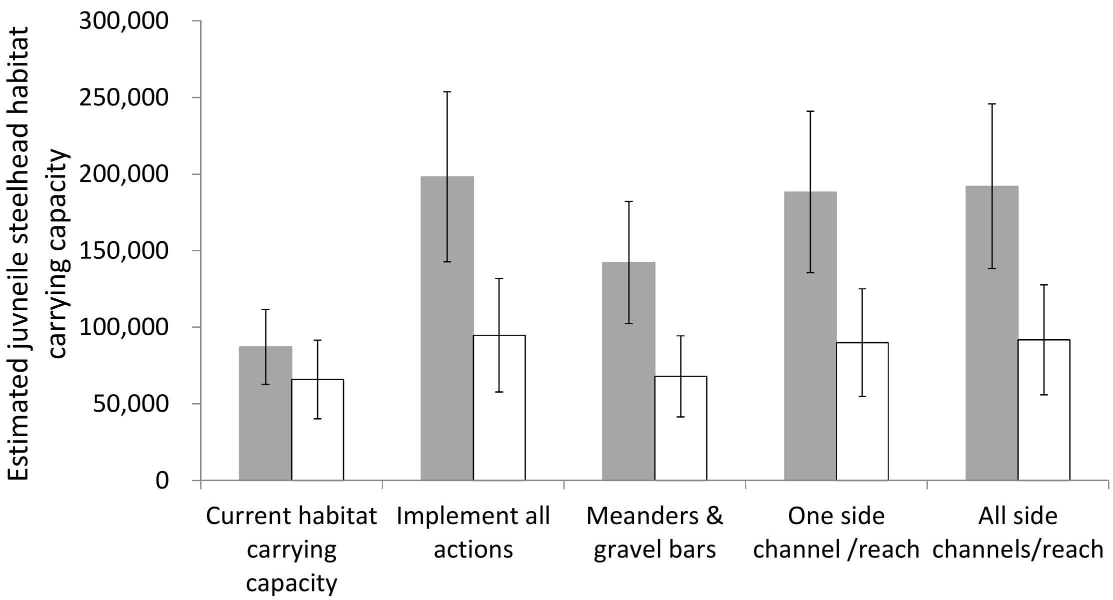


Figure 16. Estimated increases in juvenile steelhead carrying capacity, assuming an increase in habitat area and habitat quality, by rehabilitation action in all reaches of the 64km of the Trinity from Lewiston Dam to the confluence of the North Fork Trinity River. Gray bars are juvenile steelhead <50 mm. Clear bars are juvenile steelhead 50—200 mm. Solid black bars with perpendicular lines at top and bottom of bars is representative of one standard deviation of the estimate.

standard deviation than estimated current habitat carrying capacity regardless of the assumed rehabilitation action (Figures 15 and 16). However, this was not the case for steelhead 50—200 mm (Figure 16).

Juvenile Chinook salmon <50 mm result in the largest estimated average increase in habitat carrying capacity (112%, ±30%) regardless of rehabilitation action for the entire study area (Figure 15). Estimated average habitat carrying capacity increases for juvenile Chinook salmon 50—200 mm is 54% (±25%) depending upon the amount and type of rehabilitation actions (Figure 15). The maximum estimated habitat carrying capacity for juvenile Chinook salmon ranged between 3.2 and 4.3 million, respectively, if we assume over a ten year time period either a 14% decrease or a 10% increase in habitat quality. Juvenile steelhead <50mm habitat carrying capacity was estimated to have increased in a similar fashion to juvenile Chinook salmon of the same size range with an average of 107% (±29%)) (Figure 16). Steelhead 50—200 mm also followed the same pattern as juvenile Chinook of the same size range (31%, ±19%) (Figure 16). Assuming the same proportionate increase or decrease over a ten year time frame results in an overall habitat carrying capacity for juvenile steelhead <50 mm of approximately 0.23 million and 0.17 million, and between 0.11 million and 0.08 million for juvenile steelhead 50—200 mm.

Examination of the data by rehabilitation action suggests that regardless of the action type significant changes in habitat carrying capacity can occur (Figure 17). Increases in habitat average carrying capacity range between 40% and 96% (±31% to 45%) and fall within the range of one another (Figure 17). Examination of the data spatially and normalizing for the number of fish/km reveals an increase in potential habitat carrying capacity gains per kilometer (post- treatment fish/km minus pre-treatment fish/km) in the downstream direction from Lewiston Dam (Figure 18).

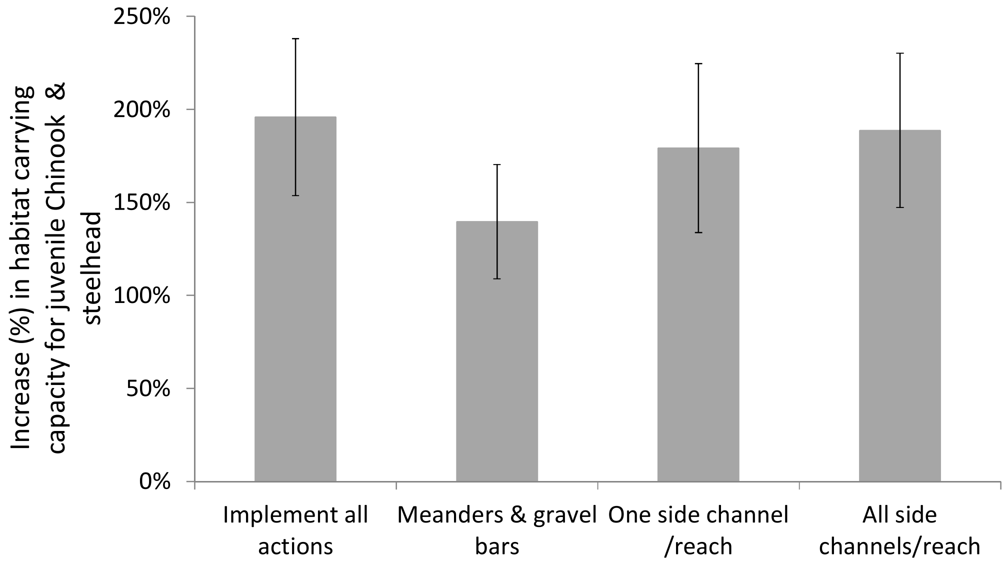


Figure 17. Increase in habitat carrying capacity (%), assuming an increase in habitat area and habitat quality, by rehabilitation type in the 64 km study area of the Trinity River.

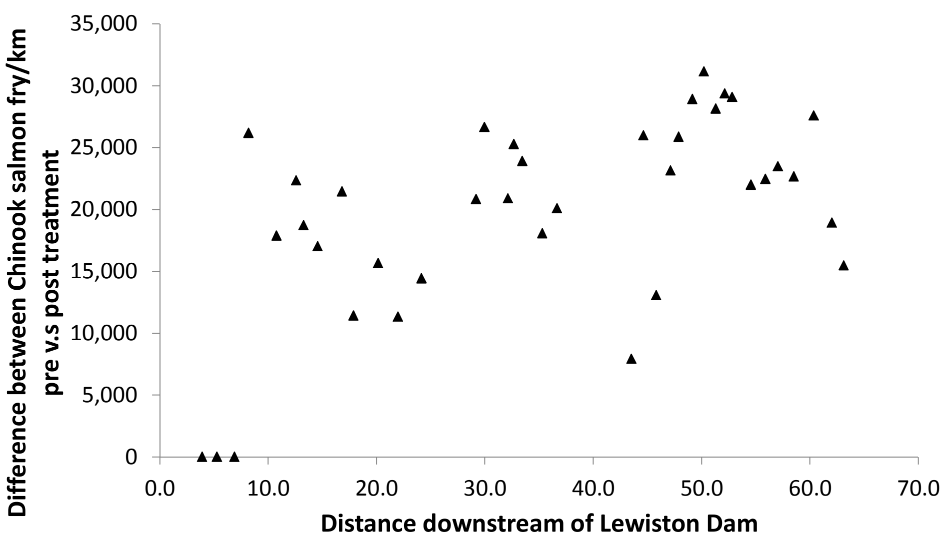


Figure 18. Potential habitat capacity by reach in the 64 km study are of the Trinity River.

Discussion

In this study we have analytically linked the potential development of channel patterns, rehabilitations actions, habitat capacity and potential salmonid rearing habitat capacity in the Trinity River from Lewiston Dam to the North Fork. Each of these linkages warrants examination of assumptions. Here we discuss each of these steps, and the likelihood that restoration objectives might be achieved under various habitat rehabilitation scenarios.

Low sediment supply and likelihood of achieving a sinuous alluvial river

One of the primary assumptions of the TRRP is that restoration of flood flows and sediment supply will be sufficient to create a more natural, meandering alluvial channel between Lewiston and the North Fork Trinity River. However, meandering channels have a sinuosity greater than 1.5 (Leopold and Wolman 1957), which is substantially greater than current sinuosities of the Trinity River reaches (which range from 1 to 1.3) (see Figure 7). Moreover, such highly sinuous channels are commonly characterized by low lateral migration rates and bounded by natural levees, which are geomorphically similar to the riparian berms that that the TRRP hopes to eliminate through its rehabilitation actions. By contrast, actively meandering channels such as those expected under the TRRP plan typically have a relatively high bed load supply, which promotes bar formation and active channel migration. For the Trinity River, meandering channels with high sinuosity may be unlikely to naturally develop because even the augmented sediment supply is relatively low, and such low-sediment supply channels tend to develop a straight channel pattern (Beechie et al. in review).

Given sufficient sediment and wood supply, some reaches of the Trinity River would be expected to develop an island-braided form. However, both sediment and wood supply in Trinity River are likely to remain relatively low relative to naturally island-braided channels which have both high sediment supply and high wood supply. Restoration of sediment supply to high levels might induce some side channel development, although the island-braided pattern with stable islands is unlikely to form in the absence of a high wood supply (Beechie et al. 2006). Nevertheless, unconfined reaches with wide floodplains are suitable for construction of side channels due to their low channel slopes, wide floodplain, and low migration rates. That is, on optimistic restoration option (from a habitat capacity point of view) is to construct and maintain side channels as a substitute for their natural development.

We note here that most of our restoration scenarios are extremely optimistic, particularly those that will increase sinuosity from current levels to 1.5 (see Figure 7). Even increasing sinuosity from 1 to 1.2 occupies a substantial floodplain width, which may be unlikely given the limitations in potential floodplain width from infrastructure or dredge deposits from historical mining. Note that in our scenarios we assumed that aggressive removal of dredge deposits was a restoration option, and therefore that dramatic increases in sinuosity were possible. However, such increases may be unlikely to occur naturally, or even with modestly increased sediment supply and stream flows that are part of the Trinity River restoration program. Rather, they would likely require active channel reconstruction to achieve such large changes in sinuosity.

Estimates of capacity change

Our estimates of potential Chinook smolt production were slightly less than smolt trap outmigration estimates suggesting that we may have underestimated potential production from our habitat estimates. The habitat estimates were developed using average wetted widths during base flow conditions, and did not include all edge habitat that can potentially occur in the 63 km study reach. We found the capacity for juvenile Chinook salmon <50mm is less than for Chinook salmon 50—200 mm, and this was consistent throughout the entire study reach. This result is similar to that of the Flow Evaluation Study (U.S. Fish and Wildlife Service and Hoopa Valley Tribe, 1997), and it implies that Chinook fry habitat capacity is potentially “limiting” in the entire study reach, and that restoration actions oriented toward watershed processes that create and maintain “preferred” habitats for that life stage for Chinook will be important. We did not identify the same pattern for steelhead. However, there was a general pattern of decreasing habitat capacity in the downstream direction for both species and size classes.

Increase of habitat quantity and quality were estimated to have a maximum increase of ~1.46 fold. These increases in habitat quantity and quality can potentially increase juvenile Chinook and steelhead production potential by 1.5 to 2.5 times the current capacity, assuming that multiple restoration actions are implemented in each reach of the study area. This increase in habitat quantity and production potential is less than the hypothesized “3 to 4 fold increase in salmon rearing habitat that could occur, and could potentially result in a doubling of smolt production” (Trinity River Restoration Program 2009). While our estimates do not incorporate all possible restoration actions, they do focus on those that had the greatest potential change to both habitat quantity and fish productivity. Thus they are representative of what potentially can occur from within a geomorphic context, and include empirical fish use data that helps reduce potential uncertainty in the range of estimates we included in the report.

Identifying the limiting life stage for salmonids is an important component in assessing potential problems that can help identify and prioritize future restoration efforts (Beechie et al. 2010). Our empirical modeling estimates identify that increases in habitat quality can have a potentially large effect on the habitat capacity for juvenile Chinook salmon and steelhead. The amount of preferred habitat in terms of depth, velocity, and cover can result in more preferred area and allow for potentially higher densities of both juvenile Chinook salmon and steelhead. However, we do not know if such increases in potential capacity eventually result in increases in overall smolt productivity because other life stages or food resources may become limiting as fry capacity increases.

The production potential analysis has several constraints worth noting. First, the simplified set of assumptions we used does not incorporate changes to growth or survival, which can have large, positive effects to overall population size. However those are truly difficult to measure with respect to habitat projects, thus much empirical data is not available. While our analysis incorporates a distribution of estimates for both habitat and fish utilization it is ultimately a static, point-in-time estimate, although we did evaluate the effect of changing habitat condition over a 10 year time period based on the non-linear estimate from other studies (Pess et al. 2011 in press).

There are also several strengths to such an analysis including that it is empirically based and relies on fish density data from the Trinity and other watersheds that have similar fish-habitat relationships. The Monte Carlo method used for fish and habitat estimates incorporates the distribution of potential values, giving a greater understanding of the range of potential values. Our assumptions are transparent and can be easily changed to include other action types, fish density estimates, or habitat change estimates.

Perhaps the most important question to consider is what can we learn from this change in habitat exercise with respect to implementing restoration? Three things come to mind. First, it is important to attempt to quantify habitat area, type, quality, and fish use prior to restoration so changes that do occur can be compared to hypothesized outcomes. Second, it is important to understand the geomorphic potential of a given stream reach because the potential reach morphology helps to determine the types of actions that are suitable for each reach and likely increase in habitat capacity. Lastly, it is important to clearly identify restoration objectives and to develop measurable and quantifiable restoration targets. Without such targets, it is difficult develop specific restoration scenarios that focus on achieving long-term goals, and to ascertain whether restoration actions are successful.

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Appendix

Table A-1. Estimated current potential habitat area (m^2) in the Trinity River for juvenile Chinook salmon and steelhead by reach, and habitat category (four combinations of depth (D), velocity (V), and cover (C) suitability) from Lewiston (~ 3.9 km downstream of Lewiston Dam) to the confluence with the North Fork Trinity (~ 64 km downstream of Lewiston Dam).

Reach	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total
Lewiston 4	14,847	7,876	7,463	100,523	130,709
Sawmill	4,557	648	8,015	25,456	38,676
Upper Rush Creek	8,742	1,244	15,376	48,840	74,202
Lower Rush Creek	2,295	5,320	2,389	40,752	50,756
Dark Gulch	3,823	853	4,760	70,345	79,781
Lowden Ranch	1,341	1,874	2,940	45,748	51,904
Trinity House Gulch	1,023	810	891	17,696	20,421
Tom Lang Gulch	1,859	1,472	1,619	32,147	37,096
Poker Bar	2,124	1,773	2,519	60,324	66,740
China Gulch	1,059	768	1,013	18,035	20,875
Limekiln Gulch	2,102	3,142	1,352	45,985	52,582
Steel Bridge Road Day Use	1,304	1,949	839	28,528	32,620
McIntyre Gulch	1,083	2,470	1,747	34,349	39,649
Indian Creek	3,388	10,055	3,055	123,465	139,964
Douglas City	607	1,801	547	22,109	25,063
Reading Creek	1,359	4,034	1,226	49,531	56,150
Upper Steiner Flat	332	697	525	14,970	16,525
Middle Steiner Flat	540	883	675	17,923	20,021
Lower Steiner Flat	1,264	2,772	1,594	39,621	45,251
Lorenz Gulch	740	1,164	1,372	29,003	32,279
Dutch Creek	1,787	6,551	2,254	60,992	71,584
Evans Bar	570	1,702	990	29,670	32,932
Soldier Creek	332	1,418	450	15,954	18,154
Chapman Ranch	788	2,417	801	32,498	36,504
Deep Gulch	514	1,575	522	21,184	23,796
Sheridan Creek	660	2,254	1,349	38,865	43,128
Oregon Gulch	533	1,821	1,090	31,398	34,842
Sky Ranch	190	3,262	314	27,984	31,751
Upper Junction City	139	2,382	229	20,437	23,188
Lower Junction City	118	2,022	195	17,348	19,683
Hocker Flat	415	4,557	364	38,105	43,441
Upper Conner Cr	299	3,284	263	27,462	31,308
Conner Ck	651	1,010	791	28,776	31,228
Wheel Gulch	531	3,659	735	33,304	38,229
Valdor Gulch	579	3,356	1,005	51,010	55,949
Elkhorn	577	2,871	809	33,092	37,350
Pear Tree Gulch	295	1,468	414	16,915	19,091
Total	63,370	97,215	72,493	1,390,343	1,623,422

Table A-2. Estimated current potential production for juvenile Chinook and steelhead by reach, size class, and habitat category (four combinations of depth (D), velocity (V), and cover (C) suitability) in the Trinity River: (a) Chinook <50 mm (b) Chinook 50—200 mm, (c) Steelhead < 50mm, and (d) Steelhead 50—200 mm.

a. Chinook <50 mm

Reach	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total ave capacity	SD (±) by reach
Lewiston 4	115,510	21,189	17,863	48,358	202,921	45,295
Sawmill	35,451	1,748	19,172	12,247	68,618	14,145
Upper Rush Creek	68,014	3,353	36,783	23,497	131,647	27,139
Lower Rush Creek	17,857	14,304	5,716	19,601	57,478	6,175
Dark Gulch	29,741	2,298	11,388	33,834	77,262	14,965
Lowden Ranch	10,436	5,041	7,034	22,002	44,513	7,584
Trinity House Gulch	7,962	2,179	2,132	8,512	20,785	3,518
Tom Lang Gulch	14,464	3,959	3,873	15,462	37,757	6,391
Poker Bar	16,523	4,770	6,025	29,013	56,332	11,262
China Gulch	8,236	2,067	2,424	8,674	21,401	3,592
Limekiln Gulch	16,355	8,450	3,236	22,117	50,159	8,358
Steel Bridge Road	10,146	5,242	2,008	13,721	31,117	5,185
McIntyre Gulch	8,428	6,642	4,180	16,520	35,769	5,344
Indian Creek	26,360	27,038	7,311	59,380	120,089	21,603
Douglas City	4,720	4,842	1,309	10,633	21,504	3,868
Reading Creek	10,575	10,847	2,933	23,822	48,176	8,666
Upper Steiner Flat	2,587	1,875	1,256	7,200	12,917	2,702
Middle Steiner Flat	4,202	2,376	1,615	8,620	16,812	3,138
Lower Steiner Flat	9,833	7,453	3,815	19,056	40,157	6,501
Lorenz Gulch	5,755	3,129	3,283	13,949	26,116	5,091
Dutch Creek	13,906	17,614	5,391	29,334	66,245	9,934
Evans Bar	4,437	4,576	2,368	14,269	25,651	5,334
Soldier Creek	2,583	3,813	1,077	7,673	15,145	2,822
Chapman Ranch	6,132	6,498	1,918	15,629	30,178	5,777
Deep Gulch	3,997	4,236	1,250	10,188	19,672	3,766
Sheridan Creek	5,134	6,062	3,227	18,691	33,114	7,042
Oregon Gulch	4,148	4,897	2,607	15,100	26,752	5,689
Sky Ranch	1,481	8,771	751	13,458	24,462	6,089
Upper Junction City	1,082	6,406	549	9,829	17,864	4,447
Lower Junction City	918	5,437	466	8,343	15,164	3,775
Hocker Flat	3,227	12,252	872	18,326	34,677	8,093
Upper Conner Cr	2,326	8,830	628	13,207	24,992	5,833
Conner Ck	5,068	2,716	1,892	13,839	23,516	5,475
Wheel Gulch	4,132	9,838	1,758	16,017	31,744	6,366
Valdor Gulch	4,501	9,023	2,404	24,532	40,461	10,000
Elkhorn	4,492	7,720	1,936	15,915	30,064	6,079
Pear Tree Gulch	2,296	3,946	990	8,135	15,367	3,107
Total	493,016	261,436	173,439	668,704	1,596,595	224,634

b. Chinook 50—200 mm

Reach	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total ave capacity	SD (±) by reach
Lewiston 4	84,625	46,734	10,153	70,509	212,020	32,567
Sawmill	28,718	2,547	14,701	18,821	64,786	10,836
Upper Rush Creek	55,097	4,886	28,204	36,109	124,296	20,789
Lower Rush Creek	16,189	26,587	2,655	28,248	73,680	11,787
Dark Gulch	31,875	7,544	4,817	51,206	95,442	21,916
Lowden Ranch	9,309	12,892	4,845	32,483	59,530	12,187
Trinity House Gulch	7,600	4,985	800	12,631	26,016	4,953
Tom Lang Gulch	13,806	9,056	1,453	22,945	47,259	8,997
Poker Bar	12,575	9,315	4,502	43,979	70,371	17,901
China Gulch	7,880	5,185	987	12,815	26,867	4,957
Limekiln Gulch	13,149	17,284	1,617	32,562	64,613	12,792
Steel Bridge Road	8,157	10,723	1,003	20,201	40,083	7,935
McIntyre Gulch	6,956	11,727	2,944	24,668	46,295	9,439
Indian Creek	24,149	51,820	3,146	87,280	166,394	36,398
Douglas City	4,324	9,279	563	15,629	29,796	6,518
Reading Creek	9,688	20,789	1,262	35,014	66,753	14,602
Upper Steiner Flat	2,371	3,302	806	10,873	17,351	4,477
Middle Steiner Flat	3,448	4,640	1,084	12,905	22,077	5,141
Lower Steiner Flat	8,151	13,446	2,510	28,409	52,516	11,122
Lorenz Gulch	4,678	5,841	2,456	21,062	34,037	8,485
Dutch Creek	11,307	30,033	3,624	43,256	88,220	17,966
Evans Bar	3,332	7,527	1,863	21,557	34,278	8,985
Soldier Creek	2,342	6,367	641	11,433	20,783	4,802
Chapman Ranch	5,615	12,571	924	23,043	42,153	9,612
Deep Gulch	3,660	8,195	602	15,021	27,478	6,266
Sheridan Creek	4,573	13,089	2,184	27,541	47,387	11,462
Oregon Gulch	3,695	10,574	1,765	22,250	38,283	9,260
Sky Ranch	1,482	14,342	403	19,878	36,105	9,614
Upper Junction City	1,082	10,474	294	14,517	26,368	7,021
Lower Junction City	919	8,891	250	12,323	22,382	5,960
Hocker Flat	2,210	18,846	688	27,303	49,047	12,969
Upper Conner Cr	1,593	13,582	496	19,677	35,348	9,347
Conner Ck	4,945	6,499	931	20,631	33,005	8,580
Wheel Gulch	3,529	14,665	1,163	24,050	43,407	10,587
Valdor Gulch	4,217	15,519	1,529	36,773	58,037	16,033
Elkhorn	4,002	13,376	1,222	23,608	42,208	10,139
Pear Tree Gulch	2,045	6,837	625	12,067	21,574	5,182
Total	413,295	489,968	109,706	993,277	2,006,245	366,633

c. Steelhead <50 mm.

Reach	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total ave capacity	SD (±) by reach
Lewiston 4	7,309	1,112	1,051	2,022	11,495	7,309
Sawmill	2,480	95	1,117	513	4,206	2,480
Upper Rush Creek	4,759	182	2,143	984	8,069	4,759
Lower Rush Creek	1,398	743	334	816	3,291	1,398
Dark Gulch	2,753	123	665	1,409	4,949	2,753
Lowden Ranch	804	262	410	915	2,391	804
Trinity House Gulch	656	114	125	354	1,249	656
Tom Lang Gulch	1,192	207	227	644	2,270	1,192
Poker Bar	1,086	249	352	1,207	2,894	1,086
China Gulch	681	108	142	361	1,292	681
Limekiln Gulch	1,136	440	190	920	2,686	1,136
Steel Bridge Road	705	273	118	571	1,666	705
McIntyre Gulch	601	345	244	687	1,877	601
Indian Creek	2,086	1,404	428	2,469	6,386	2,086
Douglas City	374	251	77	442	1,144	374
Reading Creek	837	563	172	990	2,562	837
Upper Steiner Flat	205	97	73	299	675	205
Middle Steiner Flat	298	124	94	358	874	298
Lower Steiner Flat	704	387	223	792	2,106	704
Lorenz Gulch	404	163	191	580	1,338	404
Dutch Creek	977	914	315	1,220	3,425	977
Evans Bar	288	238	138	593	1,256	288
Soldier Creek	202	198	63	319	782	202
Chapman Ranch	485	337	112	650	1,584	485
Deep Gulch	316	220	73	424	1,033	316
Sheridan Creek	395	315	188	777	1,674	395
Oregon Gulch	319	254	152	628	1,353	319
Sky Ranch	128	454	44	559	1,185	128
Upper Junction City	93	332	32	408	866	93
Lower Junction City	79	282	27	347	735	79
Hocker Flat	191	635	51	761	1,638	191
Upper Conner Cr	138	458	37	549	1,181	138
Conner Ck	427	141	110	575	1,254	427
Wheel Gulch	305	510	103	666	1,583	305
Valdor Gulch	364	468	140	1,019	1,991	364
Elkhorn	346	400	113	661	1,520	346
Pear Tree Gulch	177	205	58	338	777	177
Total	35,698	13,601	10,128	27,828	87,255	35,698

d. Steelhead 50—200 mm.

Reach	D,V,C	D,V,NC	ND,NV,C	ND,NV,NC	Total ave capacity	SD (±) by reach
Lewiston 4	818	315	299	4,021	5,453	1,788
Sawmill	251	26	321	1,018	1,616	428
Upper Rush Creek	482	50	615	1,954	3,100	822
Lower Rush Creek	126	213	96	1,630	2,065	744
Dark Gulch	211	34	190	2,814	3,249	1,337
Lowden Ranch	74	75	118	1,830	2,096	871
Trinity House Gulch	56	32	36	708	832	333
Tom Lang Gulch	102	59	65	1,286	1,512	606
Poker Bar	117	71	101	2,413	2,702	1,159
China Gulch	58	31	41	721	851	339
Limekiln Gulch	116	126	54	1,839	2,135	871
Steel Bridge Road	72	78	34	1,141	1,324	540
McIntyre Gulch	60	99	70	1,374	1,602	649
Indian Creek	187	402	122	4,939	5,650	2,354
Douglas City	33	72	22	884	1,012	421
Reading Creek	75	161	49	1,981	2,267	944
Upper Steiner Flat	18	28	21	599	666	288
Middle Steiner Flat	30	35	27	717	809	343
Lower Steiner Flat	70	111	64	1,585	1,829	752
Lorenz Gulch	41	47	55	1,160	1,302	556
Dutch Creek	98	262	90	2,440	2,890	1,147
Evans Bar	31	68	40	1,187	1,326	570
Soldier Creek	18	57	18	638	731	304
Chapman Ranch	43	97	32	1,300	1,472	622
Deep Gulch	28	63	21	847	960	405
Sheridan Creek	36	90	54	1,555	1,735	748
Oregon Gulch	29	73	44	1,256	1,402	604
Sky Ranch	10	130	13	1,119	1,273	537
Upper Junction City	8	95	9	817	930	392
Lower Junction City	7	81	8	694	789	333
Hocker Flat	23	182	15	1,524	1,744	730
Upper Conner Cr	16	131	11	1,098	1,257	526
Conner Ck	36	40	32	1,151	1,259	558
Wheel Gulch	29	146	29	1,332	1,537	634
Valdor Gulch	32	134	40	2,040	2,247	987
Elkhorn	32	115	32	1,324	1,503	633
Pear Tree Gulch	16	59	17	677	768	324
Total	3,492	3,889	2,900	55,614	65,894	26,097