U.S. Fish & Wildlife Service

Trinity River Juvenile Fish Stranding Evaluation May – June, 2002

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Table of Contents

List of Figures

List of Tables

Abstract

Receding river flows can leave juvenile fish stranded in isolated pools or other depressions of natural or artificial features of the river channel. The channel morphology of the Trinity River downstream of Lewiston Dam deteriorated rapidly in response to the construction and operation of Trinity and Lewiston Dams in the early 1960's and is now dominated by a berm of encroaching mature riparian vegetation and fine sediment from Lewiston Dam downstream to the North Fork Trinity River. During events of moderate discharge, water can create fish habitat behind these berms. When flows subsequently recede, pools or other depressions in these zones become isolated from the river and can strand fish that have colonized this habitat. We conducted population estimation of stranded fish in three habitat strata of this reach using removal-depletion electrofishing. Our "Riparian Encroached" stratum (N = 142) were composed of potential rehabilitation sites identified by the Trinity River Restoration Program, and are a dominant habitat feature of the degraded channel. The other two strata were "Pilot Rehabilitation" sites (N = 9) constructed in the early 1990's by removal of the riparian berm, and "Natural" (N = 8) areas that have been maintained by tributary flows or geomorphic features that have prevented extensive riparian encroachment. The severity of stranding observed was highly variable and site-specific within all the strata, but generally higher in the "Riparian Encroached" sites. We estimate that during May and June 2002 when flows at Lewiston Dam ramped down from 6,000 to 450 cubic feet per second, 334 chinook fry, 4 coho fry, and 400 steelhead fry were stranded in "Natural" channel sites; 542 chinook fry, 11 coho fry, and 225 steelhead fry were stranded in "Pilot Rehabilitation" sites; and 26,057 chinook fry, 5,443 coho fry, and 5,183 steelhead fry were stranded in "Riparian Encroached" sites.

Introduction

Completion of the Trinity River Division (TRD) of the Central Valley Project (CVP) in 1963 and the subsequent diversion of Trinity River water to the Sacramento Basin resulted in dramatic alteration of the Trinity River channel downstream of Lewiston Dam. A once dynamic hydrograph that included flood events that sometimes exceeded 70,000 cubic feet per second (cfs) and a pronounced spring snowmelt signature was changed to static, low flow tailwater release (USFWS and Hoopa Valley Tribe, 1999). For nearly two decades roughly 90 percent of the mean annual discharge at Lewiston Dam was diverted to the Sacramento Basin. With high water events captured behind Trinity Dam for storage and trans-basin diversion of the winter and spring snowmelt hydrograph, and perpetually low flow releases of 150 to 300 cfs, riparian encroachment rapidly occurred. Sediment input from tributaries, once mobilized by natural river flows, began to aggrade near tributary mouths. The static conditions were conducive to germination and maturation of a woody riparian community along this now narrower water's edge (McBain and Trush, 1997). During moderate flow events from tributary input or Safety of Dams releases (discussed later), fine sediment is suspended in the water column. As rising waters flow into the newly established riparian community, energy is dissipated by the woody plants and fine sediments are deposited. The result is formation of a sand berm with thick riparian vegetation. Riparian berm is now a dominant channel feature of the Trinity River from Lewiston Dam to the North Fork Trinity River. From 1960 (pre-TRD) to 1989, the acreage of riparian community downstream of Lewiston Dam to the North Fork more than doubled (Wilson, 1993) and moved from higher floodplain benches to lower flow water's edge. Downstream of the North Fork, tributary accretion and valley narrowing greatly reduces riparian berm incidence, but does not completely eliminate this feature.

The outlet works and spillway of Trinity and Lewiston Dams do not have the capacity to pass historic flood events. To reduce the risk of catastrophic failure of Trinity Dam, the Bureau of Reclamation operates Trinity Dam according to a Safety-of-Dams (SOD) criteria rule curve that maintains variable amounts of unused storage in Trinity Lake based on the risk of hydrologic events that might fill the reservoir. The rule curve currently specifies that discharge of up to 6,000 cubic feet per second (cfs) be released from the reservoir based on hydrologic period and reservoir water surface elevation. The intent of SOD criteria is to maintain the level of the reservoir at an elevation that minimizes the risk that potential inflow to the reservoir will exceed the available storage capability and outlet works capacity of the reservoir, and overtop the dam. Operationally, SOD triggered releases of water to the Trinity River may occur multiple times over the course of winter and spring in wetter years, or might not occur at all depending on the timing and intensity of storms, the magnitude of rain-on-snow events, etc.

Overtopping of the riparian berm occurs at higher flows as the channel river corridor progresses downstream and gains tributary accretion of flow and sediment (Scott McBain personal communication). Even with no fluctuation in Lewiston discharge, overtopping of the berm can occur in downstream reaches from tributary accretion alone.

Juvenile fish stranding in off-channel features such as pools, small depressions, or side channels that become isolated from the river when river levels recede, is a natural phenomenon. Fry are especially vulnerable to stranding due to their greater use of shallow edgewater habitats.

However, the riparian encroachment and altered morphology of the Trinity River downstream of Lewiston Dam makes it especially susceptible to stranding when flows breach or overtop the riparian berm and then recede, leaving fish behind the berm (USFWS and Hoopa Valley Tribe, 1999). Prioritization of proposed mechanical restoration sites for the Trinity River Restoration Program was at least partially influenced by anecdotal and qualitatively documented incidences of stranding. The higher flows and mechanical restoration proposed by the Program are to create functional alluvial channel with surface features that frequently mobilize and scour young woody riparian seedlings, removing and preventing riparian encroachment. Proposed spring flow schedules are also designed to maintain higher water surface elevations during the germination periods of key woody riparian species to prevent riparian encroachment of the channel near the low summer water's edge and encourage riparian growth at higher elevation on the channel cross section. One of the expected benefits of the restored channel is a decreased susceptibility to stranding of fry and juvenile fish.

To quantitatively study the incidence of stranding in the Trinity River is a logistically challenging endeavor in that it involves a relatively intensive field investigation - the timing of which is entirely dependent on the occurrence of largely unpredictable high flow events. Most often these are SOD releases. The funding for this particular study was committed in year 2000, however, no SOD releases occurred in the relatively dry water years 2001 through 2002.

On 19 April 2002, Federal Judge Oliver Wanger of the Fresno U.S. Eastern District Court ordered an allocation of 468,000 acre-feet of water to the Trinity River from Lewiston Dam in response to motions made by the Hoopa Valley and Yurok Tribes, 100,000 acre feet more than the 368,000 acre feet cap previously imposed by the judge. A new flow schedule incorporating this additional volume was developed in late April and specified ramping up to a peak flow of 6,000 cubic feet per second (cfs) for three days in early May with a gradual downramp to 450 cfs by late June. Peak discharge of 6,000 cfs was achieved 3 May to 5 May, and flows were ramped down to 450 cfs by 24 June. This additional release volume and ramp-down period provided an opportunity to carry out this study.

Methods

Stranded Fish Enumeration

We identified three specific channel types to evaluate independently for the occurrence of stranding. The primary channel types of interest are "Riparian Encroached", "Natural", and "Rehabilitated". Using 1:2400 aerial photos taken in March 2000 (at a Lewiston Dam release of 5,000 cfs) and site visits for field verification, eight areas of the river that appeared to have little or no riparian encroachment were identified. These comprised the "Natural" strata. A total of 142 riparian encroached areas of the Trinity River have been identified by technical subcommittees of the Trinity Management Council as proposed restoration sites. These comprise the "Riparian Encroached" strata. Nine pilot channel rehabilitation sites constructed by the Trinity River Restoration Program in the early 1990's comprised the "Pilot Rehabilitation" strata.

Prior to random selection of sites within each stratum, property ownership was reviewed to eliminate all privately held sites from selection except those associated with one particularly cooperative landowner. Random selections were made only from sites without access concerns – sites either located entirely within public lands or held by the landowner mentioned above. In total, 14 sites were selected – six "Riparian Encroached" sites, four "Pilot Rehabilitation" sites, and four "Natural" sites (Table 1).

Beginning 14 May 2002, the 14 sites were visited weekly. Study site visits continued through the end of June with the exception of the week of 10 June. During this time, Lewiston Dam releases were slowly decreased to summer base-flows of 450 cfs on 24 June.

Table 1. Trinity River Juvenile Fish Stranding study sites selected for spring 2002 stranding investigation.

Strata	Study Site Identification	Site Length (meters)	Site Location (River Kilometer)
	A	184	178.3
Riparian Encroached (re)	AQ	234	158.0
N = 142 sites	BH	167	148.4
n = 6	BM	235	145.8
Mean site length = 229 meters	BP	418	143.9
	CM	310	125.7
Pilot Rehabilitation Site(pr)	Steiner Flat	309	150.3
N =9 sites	Bell Gulch	222	137.7
n = 4	Jim Smith	161	128.2
Mean site length = 204 meters	Pear Tree	151	119.4
Natural (nat)	Steiner	103	149.3
N = 8 sites	Lorenz Gulch	173	145.7
n = 4	Oregon Gulch	442	132.3
Mean site length = 265 meters	Junction City	408	130.8

Multiple pass depletion electrofishing was employed to estimate populations of stranded fish within fishable pools or puddles located within the study sites. Fish were identified to species and fork-lengths of all captured salmonids were measured to the nearest millimeter. In pools of relatively low cover complexity two depletion electrofishing passes were conducted and pool populations were estimated using the Seber-LeCren two-pass depletion estimator:

$$(1) \qquad \hat{y}_{SL} = \frac{c_1^2}{c_1 - c_2}$$

Where:

c_1 = first pass capture total

c_2 = second pass capture total

In pools of higher complexity, three to five passes were used to estimate unit population ($\hat{y}_k$) using either a jackknife estimator (Pollock and Otto, 1983):

(2) $$\tilde{y}_J = \sum_{i=1}^{r-1} c_i + rc_r$$

Where:
r = number of passes
c_i = number captured on pass i
c_r = number captured on last pass

Or a bias-adjusted jackknife estimator suggested by Hankin and Mohr (in prep):

(3) $$\tilde{y}_{BAJ} = \sum_{i-1}^{r-1} c_i + \frac{c_r}{\hat{p}}$$

Where:
$\hat{p}$ = estimate of capture probability (calculated in one of two ways as explained below)

If the circumstances warranted estimating capture probability for a particular unit or pool based solely on capture results for that particular unit of interest (e.g. there was only one stranding-pool sampled at a particular site on a particular date, or the characteristics of the unit were unique such that capture probability was expected to differ markedly from the other units on site), then a unit-specific estimate of capture probability ($\hat{p}_k$) was estimated as follows:

(4) $$\hat{p}_k = \frac{c_{1k} - c_{rk}}{\sum_{i=1}^{m} c_{ik} - c_{rk}}$$

Alternatively, if capture probabilities between a number of units could be considered similar (i.e. similar units at the same site and date of visit), an estimate of capture probability ($\hat{p}$) was employed that pools capture data from each of the similar units:

(5) $$\hat{p} = \frac{\bar{c}_1 - \bar{c}_r}{\sum_{i=1}^{r} \bar{c}_i - \bar{c}_r}$$

Where:
$\bar{c}_i$ = the average catch on pass i over all k units in which $\tilde{y}_{J,k} > 0$.

When there are low numbers of fish in a unit and/or the true capture probabilities are relatively low, the number of fish captured on the last pass (c_r) can equal or even exceed the capture on the first pass (c_1). Using the above estimators for capture probability (equations 4 and 5) *can* result in an estimate of $\hat{p}$ less than or equal to zero, which can return an undefined or negative population estimate using the bias adjusted estimator of equation (3). Under these conditions, the Moran-Zippen multiple pass depletion estimator is also likely to fail or yield unreliable estimates (Zippen, 1958; Raleigh and Short, 1981; Hankin and Mohr, in prep). In instances in this study where the estimator for capture probability failed (equations 4 and 5), the unadjusted jackknife estimator (equation 2) was used. Even though this estimator is shown to possess a moderate positive bias under circumstances of relatively low capture probability (Pollock and Otto, 1983; Hankin and Mohr, in prep), it generates an estimate of population blind to capture probability, is likely a better indicator of true unit population than simply using the total capture, and performs more reliably than the multiple pass Moran-Zippen estimator (Manning et al., 1995; Hankin and Mohr, in prep).

When dead fish were encountered or when capture or observation of fish were made within the sampled unit incidental to the collection effort of a quantified electrofishing pass, counts of these incidental fish are added to the total unit estimate. In instances when extremely shallow and non-complex puddles were encountered where the probability of capture or detection was virtually 1.0, capture and incidental observation totals from a single pass was treated as a complete census of the stranding-unit.

Stranding-unit population estimates within each site were used to generate study site population estimates as follows:

$$\hat{t}_{site} = N \frac{\sum_{k=1}^{n} \hat{y}_k}{n} \tag{6}$$

Where:

$\sum_{k=1}^{n} \hat{y}_k$ = sum of unit abundance estimates for all n stranding pools at the site

n = number of stranding pools sampled

N = total number of stranding pools on site

The sample based variance estimate for the site estimate $\hat{t}_{site}$ was calculated as:

$$\hat{V}(\hat{t}_{site}) = N^2 \frac{(1 - n/N)}{n} \frac{\sum_{k=1}^{n} (\hat{y}_k - \hat{\bar{y}})^2}{n-1} + \frac{N}{n} \sum_{k=1}^{n} \hat{V}(\hat{y}_k) \tag{7}$$

Where:

$\hat{\bar{y}} = \sum \hat{y}_k / n$

$\hat{V}(\hat{y}_k)$ for $\tilde{y}_{BAJ}$ or $\tilde{y}_J = r(r-1)c_r$

$\hat{V}(\hat{y}_k)$ for $\hat{y}_{SL} = \frac{c_1^2 c_2^2 (c_1 + c_2)}{(c_1 - c_2)^4}$

In most instances, every stranding pool on site was sampled (i.e. n = N). In these cases the estimators for site population and sample-based variance simplify to the following:

(8) $$\hat{t}_{site} = \sum_{k=1}^{n} \hat{y}_k$$

and

(9) $$\hat{V}(\hat{t}_{site}) = \sum_{k=1}^{n} \hat{V}(\hat{y}_k)$$

Similar equations to (6) and (7) were in turn used to estimate strata population and generate sample-based strata population variance estimates (equations 10 and 11):

(10) $$\hat{t}_h = N \frac{\sum_{h=1}^{n} \hat{y}_h}{n}$$

Where:

$\sum_{h=1}^{n} \hat{y}_h$ = sum of site abundance estimates for all n sites of stratum *h* sampled

n = number of sites of stratum *h* sampled

N = total number of sites of stratum *h* present from Lewiston Dam downstream to the North Fork Trinity River.

(11) $$\hat{V}(\hat{t}_h) = N^2 \frac{(1 - n/N)}{n} \frac{\sum_{h=1}^{n} (\hat{y}_h - \hat{\bar{y}})^2}{n-1} + \frac{N}{n} \sum_{h=1}^{n} \hat{V}(\hat{y}_h)$$

Where:

$$\hat{\bar{y}}_h = \sum \hat{y}_h / n$$

Mapping Flooded Habitat Behind Riparian Berm

Photo-interpretation of the same orthorectified 1:2400 color aerial photos that were used to identify "Natural" strata for stranded fish enumeration was performed to identify places where habitat appeared behind the riparian berm. These photos were taken in March 2000 at a Lewiston Dam release of 5,000 cfs. Using GIS software, visibly flooded areas behind encroached riparian were delineated for each bank from Lewiston Dam to the North Fork Trinity River. Field verification was attempted when discharge at Lewiston Dam was 4,500 cfs and higher by floating the river in whitewater raft, and using handheld Global Positioning System (GPS) receivers to locate all areas where flows had breached the riparian berm.

Results

The dominant species collected were chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, and steelhead *O. mykiss*. Fish species encountered in lower abundance included Pacific lamprey *Lampetra tridentata*, threespine stickleback *Gasterosteus aculeatus*, speckled dace *Rhinichthys osculus*, Klamath smallscale sucker *Catostomus rimiculus*, brown trout *Salmo trutta*, and green sunfish *Lepomis cyanellus*.

Except for three steelhead that measured over 100 millimeters (mm) fork-length (fl), all Pacific salmonids captured were young-of-year (age 0) and measured less than 100 mm fl (Figure 1). The incidence of Pacific salmonid fry stranding observed was highly variable among the study sites, even within stratum, but chinook and coho stranding was generally more pronounced in the "Riparian Encroached" stratum (Figure 2, Figure 3, Figure 4, Table 2.). For further analysis, stranding estimates were grouped into period by week. The highest numbers of stranded chinook and steelhead were observed in week two (Table 3 and Table 5) and the highest numbers of stranded coho were observed in week 4 (Table 4). Estimated mean numbers of stranded steelhead fry were highest at "Natural" stratum study sites. However, this estimate is overwhelmingly dominated by high catches of steelhead from the Oregon Gulch Natural site on 23 May. Weekly estimates of all species were often similarly influenced by the results from one or two sites within a stratum that contained high numbers of stranded fish.

Table 2. Estimated numbers of stranded Trinity River salmonids by stratum over the period, 14 May to 25 June 2002.

Species	Strata	Mean site population estimate $\hat{\bar{y}}_h$	Standard Error of mean	Estimated number of stranded fish $\hat{t}_h$	Sample based estimate of variance $\hat{V}(\hat{t}_h)$	Standard Error of total
Chinook salmon	Natural (N_{nat} = 8)	6.96	10.90	334	374.2	87
	Pilot Rehab (N_{pr} = 9)	9.71	15.36	542	575.8	138
	Encroached (N_{re} = 142)	30.58	42.06	26,057	342,996	5,972
Coho salmon	Natural (N_{nat} = 8)	0.08	0.14	4	3.3	1
	Pilot Rehab (N_{pr} = 9)	0.21	0.63	11	31.5	6
	Encroached (N_{re} = 142)	6.39	11.72	5,443	97,388.1	1,664
Steelhead	Natural (N_{nat} = 8)	8.33	13.51	400	609.0	108
	Pilot Rehab (N_{pr} = 9)	4.17	6.17	225	267.7	56
	Encroached (N_{re} = 142)	6.08	6.57	5,183	55,577.7	933

At site BM, some of the units encountered were too deep to effectively sample with a backpack electrofisher. And some units at sites A, BM, and Oregon Gulch were covered almost entirely with woody debris or thick blackberry vines, conditions that resulted in capture probabilities of almost zero. When other pools at the site were fishable, site estimates of stranded fish were based on expansion of the fishable pools to the total number of pools on site. Juvenile salmonids often seek woody debris for cover and these complex and deep pools may have harbored higher densities of stranded fish than the shallower fishable pools. As a result, site estimates of stranding at these sites are likely conservative when these complex units prevented effective electrofishing. At site BM on 4 June (sample week 4), the *only* newly stranded units present were four pools that were too deep to effectively sample. Estimates were not generated for these extremely deep and complex units for this date and site, and Riparian Encroached stratum estimate totals for week 4 are likely significantly underestimated as a result.

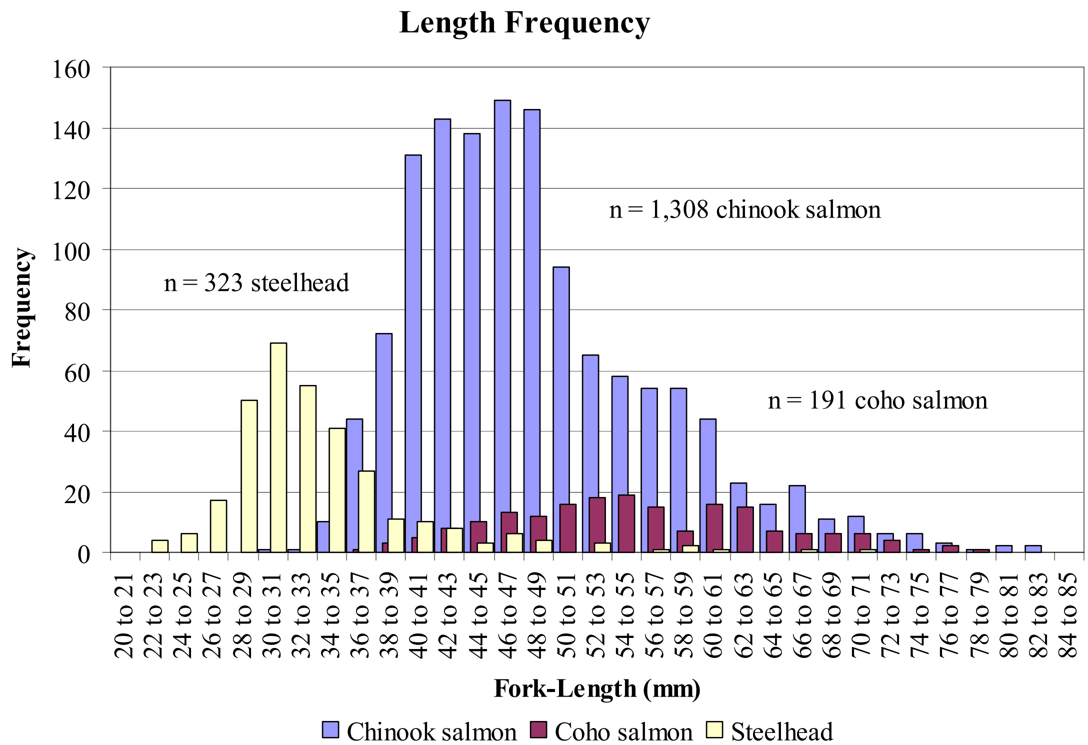

Figure 1. Length frequency of Pacific salmonids captured in 14 study sites for Trinity River Stranding Survey, 14 May to June 25 2002.

In some pools with very low abundance of some species, two electrofishing passes were performed but the Seber-LeCren estimator failed because the capture on the second pass equaled or exceeded capture on the first pass. In these cases, total capture was treated as the population estimate for that pool for that species. In every such case, the number of fish encountered was very small and this deficiency does not significantly influence the total site population estimate.

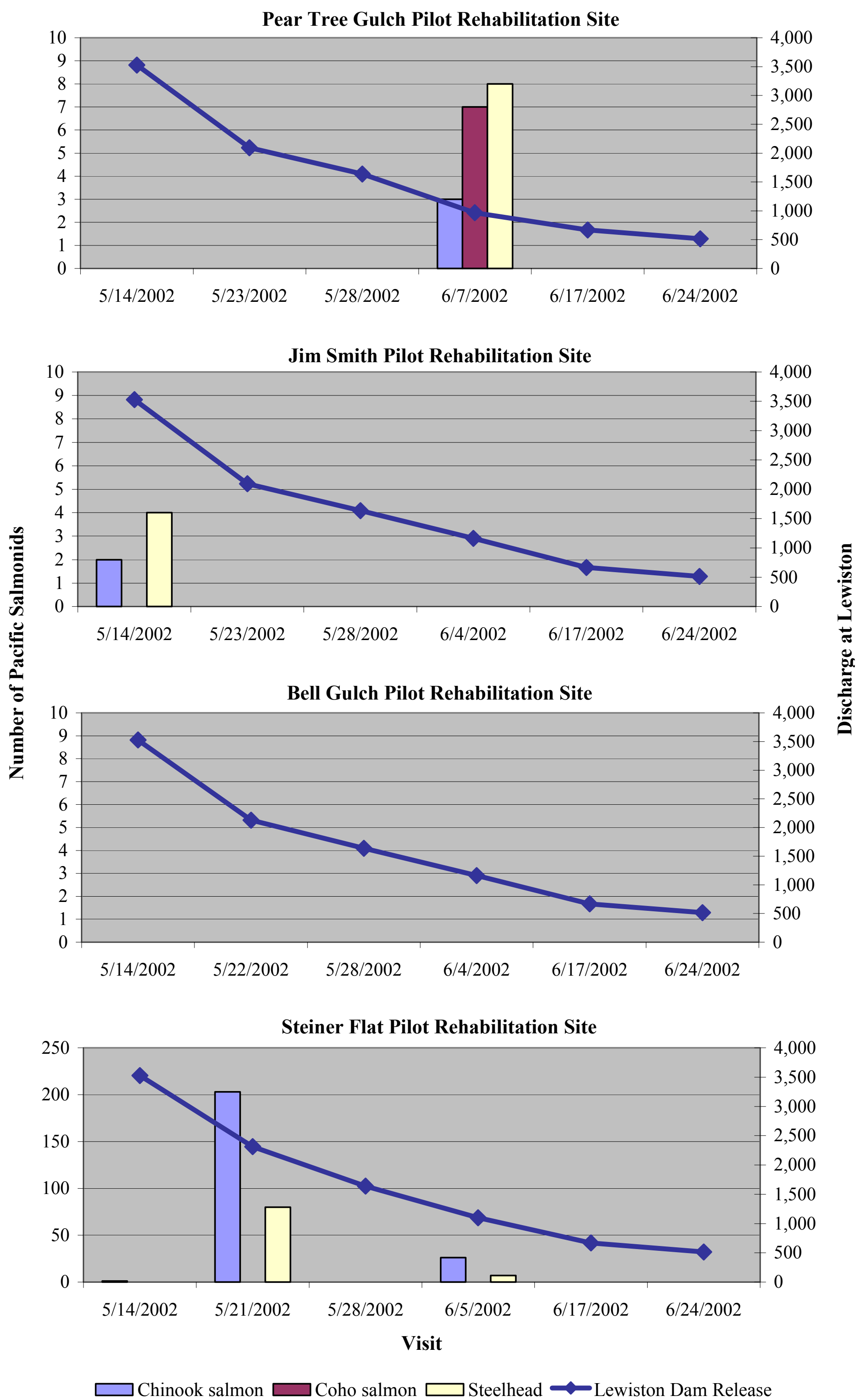

Figure 2. Estimated populations of stranded Pacific salmonids encountered each visit at Trinity River Stranding Study Pilot Rehabilitation Sites, 14 May to 25 June 2002.

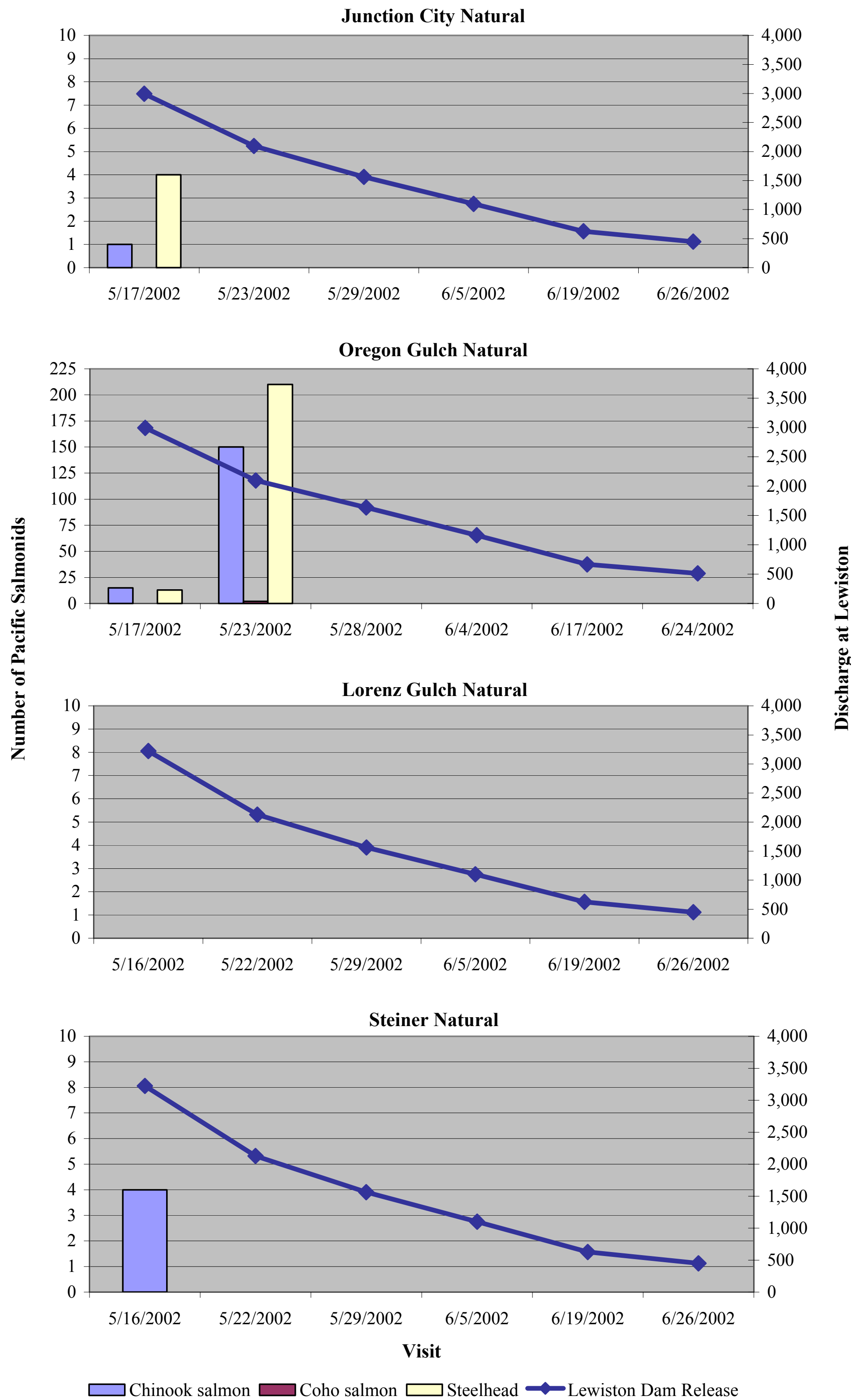

Figure 3. Estimated populations of stranded Pacific salmonids encountered each visit at Trinity River Stranding Study "Natural" un-encroached study sites, 14 May to 25 June 2002.

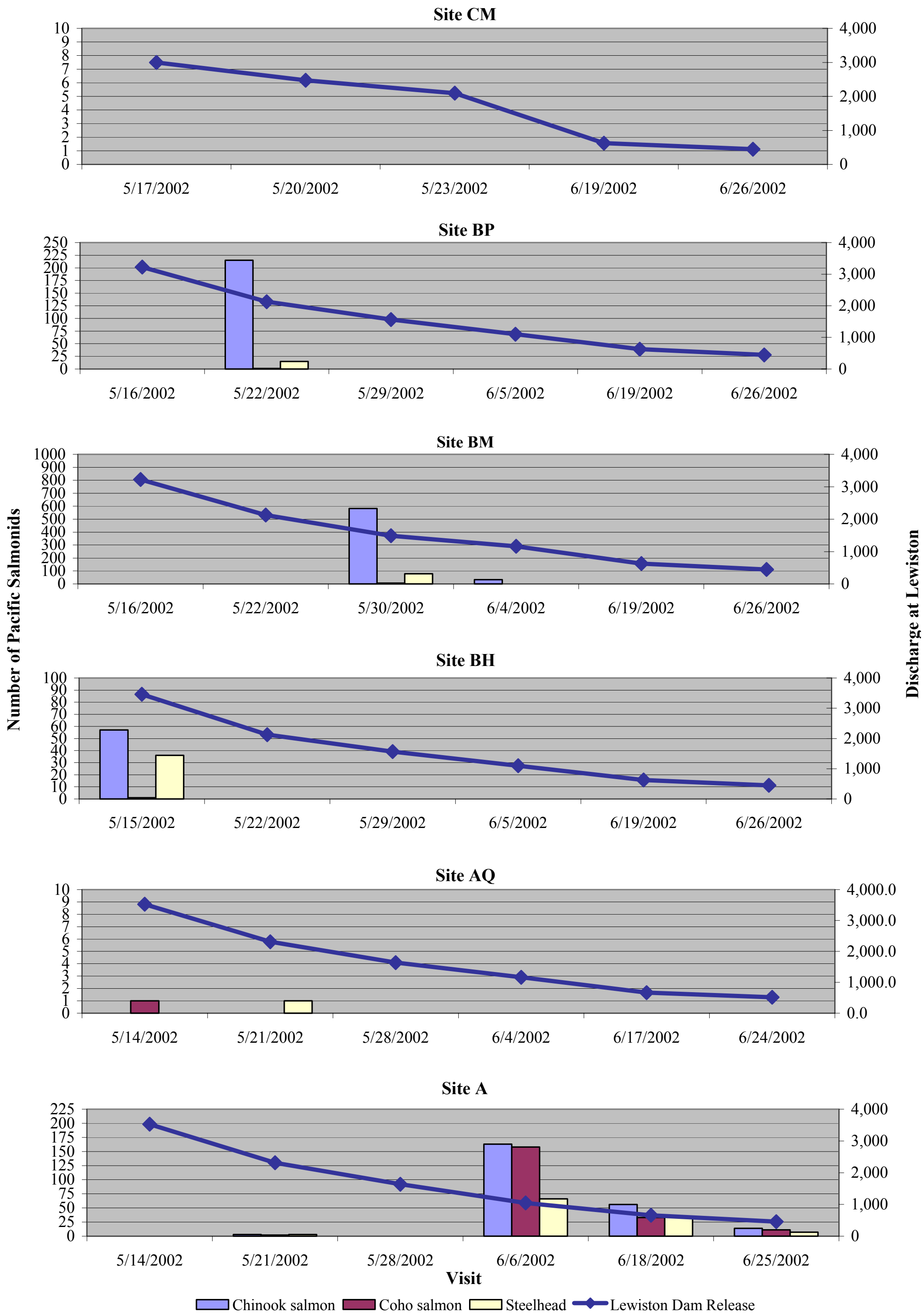

Figure 4. Estimated populations of stranded Pacific salmonids encountered each visit at Trinity River Stranding Study Riparian Encroached study sites, 14 May to 25 June 2002.

*** June 4 estimates at site BM do not include four large and complex pools that were too deep to electrofish. Population estimates for the this site and visit are likely significantly underestimated**

Table 3. Estimated numbers of stranded Trinity River chinook salmon *Oncorhynchus tshawytscha* for all strata for each sample week of the study period, 13 May through 28 June 2002.

Sample Period	Strata	Mean site population estimate $\hat{\bar{y}}_h$	Standard Error of mean	Estimated number of stranded Chinook salmon $\hat{t}_h$	Sample based estimate of variance $\hat{V}(\hat{t}_h)$	Standard Error of total
Week 1	Natural (N_{nat} = 8)	4.00	1.94	32	63.5	16
May 13 to	Pilot Rehab (N_{pr} = 9)	0.75	0.36	7	10.8	3
May 17	Encroached (N_{re} = 142)	9.50	9.30	1,349	74,958.9	1,320
Week 2	Natural (N_{nat} = 8)	37.75	26.49	302	706.7	212
May 20 to	Pilot Rehab (N_{pr} = 9)	50.25	37.47	452	1,238.6	337
May 24	Encroached (N_{re} = 142)	35.50	34.16	5,041	275,329.1	4,850
Week 3	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
May 27 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
May 31	Encroached (N_{re} = 142)	97.00	94.93	13,774	765,421.3	13,480
Week 4	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
June 3 to	Pilot Rehab (N_{pr} = 9)	7.25	4.70	65	147.1	42
June 7	* Encroached (N_{re} = 142)	* 29.83	* 29.20	* 4,236	* 238,306.9	* 4,146
Week 6	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
June 17 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
June 21	Encroached (N_{re} = 142)	9.33	9.13	1,325	73,814.1	1,297
Week 7	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
June 24 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
June 28	Encroached (N_{re} = 142)	2.33	2.28	331	18,399.0	324

* Week 4 estimates do not include four large and complex pools at site BM that were too deep to electrofish. Population estimates for the Riparian Encroached strata this week are likely significantly underestimated.

Table 4. Estimated numbers of stranded Trinity River coho salmon *Oncorhynchus kisutch* for all strata for each sample week of the study period, 13 May through 28 June 2002.

Sample Period	Strata	Mean site population estimate $\hat{\bar{y}}_h$	Standard Error of mean	Estimated number of stranded Coho salmon $\hat{t}_h$	Sample based estimate of variance $\hat{V}(\hat{t}_h)$	Standard Error of total
Week 1	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
May 13 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
May 17	Encroached (N_{re} = 142)	0.33	0.20	47	1,662.1	29
Week 2	Natural (N_{nat} = 8)	0.50	0.36	4	8.0	3
May 20 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
May 24	Encroached (N_{re} = 142)	0.50	0.33	71	2,692.9	47
Week 3	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
May 27 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
May 31	Encroached (N_{re} = 142)	1.17	1.14	166	9,198.1	162
Week 4	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
June 3 to	Pilot Rehab (N_{pr} = 9)	1.25	1.05	11	48.1	10
June 7	* Encroached (N_{re} = 142)	* 29.00	* 28.38	* 4,118	* 231,655.4	* 4,030
Week 6	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
June 17 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
June 21	Encroached (N_{re} = 142)	5.50	5.38	781	43,386.6	764
Week 7	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
June 24 to	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
June 28	Encroached (N_{re} = 142)	1.83	1.79	260	14,454.6	255

* Week 4 estimates do not include four large and complex pools at site BM that were too deep to electrofish. Population estimates for the Riparian Encroached strata this week are likely significantly underestimated.

Table 5. Estimated numbers of stranded Trinity River steelhead *Oncorhynchus mykiss* for all strata for each sample week of the study period, 13 May through 28 June 2002.

Sample Period	Strata	Mean site population estimate $\hat{\bar{y}}_h$	Standard Error of mean	Estimated number of stranded Steelhead $\hat{t}_h$	Sample based estimate of variance $\hat{V}(\hat{t}_h)$	Standard Error of total
Week 1 May 13 to May 17	Natural (N_{nat} = 8)	3.25	2.03	26	85.5	16
	Pilot Rehab (N_{pr} = 9)	1.00	0.75	9	22.5	7
	Encroached (N_{re} = 142)	4.50	4.40	639	35,550.4	625
Week 2 May 20 to May 24	Natural (N_{nat} = 8)	46.75	32.65	374	1,001.4	261
	Pilot Rehab (N_{pr} = 9)	20.00	14.94	180	534.0	134
	Encroached (N_{re} = 142)	3.33	2.34	473	18,953.8	332
Week 3 May 27 to May 31	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
	Encroached (N_{re} = 142)	9.83	9.62	1,396	77,628.9	1,367
Week 4 June 3 to June 7	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
	Pilot Rehab (N_{pr} = 9)	4.00	1.75	36	52.8	16
	* Encroached (N_{re} = 142)	* 11.83	* 11.58	* 1,680	* 94,607.6	* 1,645
Week 6 June 17 to June 21	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
	Encroached (N_{re} = 142)	5.83	5.71	828	47,123.0	811
Week 7 June 24 to June 28	Natural (N_{nat} = 8)	0.00	0.00	0	0.0	0
	Pilot Rehab (N_{pr} = 9)	0.00	0.00	0	0.0	0
	Encroached (N_{re} = 142)	1.17	1.14	166	9,210.1	162

* Week 4 estimates do not include four large and complex pools at site BM that were too deep to electrofish. Population estimates for the Riparian Encroached strata this week are likely significantly underestimated.

Mapping Flooded Habitat Behind Riparian Berm

Based on interpretation of aerial photos taken in May 2000 when discharge from Lewiston Dam was 5,000 cfs, there is a total of approximately 42.5 km of riparian berm breached at 5,000 cfs between Lewiston Dam and the North Fork Trinity River on at least one side of the river. This is roughly 2/3 of the reach length between these points. This estimate should be considered conservative. Because of the density of encroached riparian vegetation on the river, it is difficult or impossible in many areas to detect flooded habitat behind the riparian berm from photo interpretation alone.

Lewiston flows were at or above 5,000 cfs during only one field week. During this week, we floated the river and attempted to “mark” areas where water flooded habitats behind the riparian berm using a handheld Global Positioning System (GPS) receiver for use in ground-truthing the photo interpretation. However, the density of riparian vegetation made identification of locations where the river breached the riparian berm, and flooded habitat behind it, very difficult from a vantage point on the mainstem side of the berm where we could float. Without walking the bank on the historic floodplain, it was impossible in most areas to see the habitat behind the berm. Because of private property concerns and remoteness of much of the river channel, access to the floodplain side of the riparian berm over much of the river corridor is very limited. Additionally, adequate satellite coverage to accurately triangulate position with GPS occurred in very limited windows during this period, often only a couple of hours a day in many locations. Because of these difficulties, ground-truthing efforts for the photo interpretation were abandoned.

Discussion

The flow schedule implemented in spring of 2002 was not one specified by the Trinity River Environmental Impact Statement (TREIS) or Record of Decision (ROD). In order to achieve a maximum flow of 6,000 cfs yet still remain within the total 468,000 acre-feet allocation authorized in court, the declining limb of the flow schedule was steeper than those prescribed in the TREIS and ROD. In those documents, slower down-ramping rates are proposed largely for geomorphic and temperature reasons, but also to minimize stranding. The Restoration Program may want to monitor stranding as it occurs if and when ROD flow schedules are followed to compare stranding in each of the water-year type flow prescriptions.

As rehabilitation and flow actions of the Trinity River Restoration Program are implemented and geomorphic processes are reinitiated, the river channel should respond with reduced incidence of riparian berm formation and it is expected that the channel will become less likely to strand fish. Stranding should be periodically monitored to document potential reduction of fish stranding as a result of changes in channel morphology.

Salmonid vulnerability to stranding is related to fish size. Therefore, fry emergence timing and the timing of flow fluctuations can influence the severity of stranding impacts to any one species. In the Trinity River, peak chinook salmon fry emergence occurs January through mid-April, coho salmon emergence February through May, and steelhead mid-March through June (USFWS and Hoopa Valley Tribe, 1999). It follows that early stranding events would have a greater impact on chinook when their numbers are high and when they are still at a size where they have a greater preference for edgewater or off-channel habitats. Later events would be expected to have larger impacts to coho, followed by steelhead even later. Trinity Dam SOD releases most often occur mid to late winter when chinook salmon fry are most vulnerable. Spring-time flow releases of the ROD occur when chinook may have reduced susceptibility, but steelhead or coho may be more vulnerable.

The average length of young-of-year coho salmon captured in this study was larger than the average length of chinook salmon (54 vs. 48 mm fl, see Figure 1). One would expect the opposite based on emergence timing. No characterization of the lengths of fish rearing in the mainstem-river at the study sites was made during this study. Future stranding studies may benefit from characterization of length frequencies of fish in the mainstem-river and may help explain unexpected results such as these.

The predominance of riparian berms in the Trinity River from Lewiston Dam to the North Fork Trinity River is exemplified by the difficulty of finding un-encroached sites to include in our

"Natural" stratum. A mini-berm was present even in the most "Natural" of the eight un-encroached sites that could be identified in the upper 40 miles, and was being re-established in many of the nine pilot rehab sites (Figure 5), indicating that post-construction flow conditions have been inadequate for these sites to self-maintain. The stranding observed within Natural and Pilot Rehabilitation sites most often occurred behind this early successional berm feature.

The Steiner Flat Pilot Rehabilitation site exhibited far more stranding than the other three pilot restoration sites within this study. This site had an early successional riparian berm, but also may have been made more vulnerable to stranding due to frequent vehicle traffic immediately behind the developing berm. One pool in particular accounted for 89 percent of the site's total estimated salmonid stranding for the entire study period when it separated from the main channel as Lewiston discharge decreased from about 3,500 to 2,300 cfs. A vehicle access trail directly through this particular pool may be contributing to the localized depression in terrain that creates this stranding feature (Figure 6). The effects of vehicle traffic on rehabilitation sites have not been investigated, but the Restoration Program may wish to consider the potential impact vehicle traffic may have on channel function and self-maintenance of these sites.

There were two potential strata not included in this study. One of these was riparian stands not proposed for restoration by the Trinity River Restoration Program. We made no attempt to quantify the occurrence of stranding in these habitats. While not targeted by the Restoration Program for mechanical alteration, these habitats have likely been influenced by channel degradation and may exhibit a response to restoration actions such as altered flow regime and gravel introductions. Also not included in this investigation were side channels constructed by the Restoration Program in the early 1990's. Qualitative observation of the Oregon Gulch side channel and the Rush Creek side channel in 2002 indicated that the occurrence of stranding in these side channels can be significant. The channel morphology near the entrance of both of these particular side-channels has changed post-construction such that they receive surface flow only during high discharge. Future quantitative stranding investigations would be enhanced by inclusion of these strata.

Because sites were visited weekly, stranding that occurred in small depressions that became isolated from the river and dried between visits were not quantified. "Dry" depressions were observed on a few occasions, especially early in the study period shortly after the peak flow when the down-ramping rate was at its highest and the difference in river stage between visits was also high. To observe every occurrence of stranding at some sites would require daily visits at a minimum. As it was, weekly visits of all 14 sites each week were challenging to accomplish with a crew of two to four people.

Figure 5. Early successional riparian berm at Bell Gulch (above) and Steiner Flat (below) Pilot Rehabilitation Sites - 14 May 2002.

Both photos show the early stages of a riparian berm re-encroaching on the channel. Mature willow and alder dominated riparian berms were removed from these sites 1991 to 1993. Stranding locations on pilot rehabilitation sites during this study were typically observed behind this early successional berm feature - common within our "Pilot Rehabilitation" strata.

Figure 6. Stranding pool located on vehicle access trail adjacent to developing berm at Steiner Flat Pilot Rehabilitation Site - 21 May 2002.

High quality rearing habitat can be created when waters reach floodplains. Water temperature and food availability in floodplain zones or off-channel habitats can be more conducive to growth than higher velocity habitats in the main channel. Off-channel habitats can also provide slow water and cover complexity sought by salmonids in cold-water winter conditions (Cunjak, 1996). Sommer et al. (2001) observed growth rates of chinook salmon rearing in the Yolo bypass, a shallow agricultural floodplain bordering the Sacramento River, to be higher than the growth exhibited by fish in the main Sacramento River channel. Peterson (1982) observed lower overwintering survival but higher growth rates of coho in a shallow pond versus those in a deep off-channel pond. Off-channel ponds that are isolated but then later reconnected to the main river may provide significant benefits to fish growth as a result of optimum temperature or productivity of food items. The risk to a fish that dewatering or otherwise lethal conditions may be reached in some off channel ponds may be compensated by the potential reward of significantly greater growth than possible in habitats available in the mainstem.

Some of the deepest pools at study site BM during this study had yearling bullfrog tadpoles *Rana catesbeiana* in them, indicating that these pools were wetted through the summer of 2001. Depending on tributary accretion, these pools disconnect from the mainstem river at around 1,500 cfs release from Lewiston Dam. In years when Lewiston flows ramp above 1,500 cfs on more than one occasion, fish that colonize and temporarily strand in these particular pools may reap benefits in growth if they reenter the river if and when the habitats are reconnected. It is unlikely that stranded salmonids would survive through the summer in these pools due to high water temperature and predation.

Site A is located immediately downstream from a site used by the Trinity River Restoration Program as a gravel introduction site, and the substrate here was unique from the other study sites. Fines are mechanically washed from gravels before placement into the river at the introduction site upstream. Because of the lack of fines in this gravel, the permeability of the substrate here is higher than it would be if fines were present. This may contribute to the stranding that was observed here. During this study, there were isolated habitats on occasion here that still had flowing surface water. The persistent flowing condition of these habitats may have lacked the "cue" that might have otherwise encouraged juvenile fish to leave as flows receded. With it's proximity to Lewiston Dam, this area of the river is "gravel starved" and gravel introduction here is intended to re-infuse the system so that geomorphic processes can reinitiate (USFWS and Hoopa Valley Tribe, 1999). This site would be expected to evolve over time with continued gravel introductions and its susceptibility to stranding may change in response. It may be desirable to introduce substrates that incorporate a suite of sizes including fines that would be mobilized by the flow regime from Lewiston Dam if sediment transport were not interrupted by Trinity and Lewiston Dams.

At a Lewiston discharge of 6,000 cfs, flooded riparian berm exists throughout much of the river corridor from Lewiston to the North Fork Trinity River. We did not attempt to quantify the flows at which rising waters began to beach the riparian berms. In and around our study sites over the course of the study, the flows at which habitats behind the berm were observed to be flooded were variable. Typically, a high-flow entrance-channel cut though the berm at one or more locations and was the first source of surface flow that flooded the habitat behind the berm during rising river flows. These entrance channels sometimes were overgrown with vegetation and were difficult to find without probing into the thick riparian vegetation of the berm itself. The height of these channels did not appear to be consistent and some locations flooded before others. Moreover, as river levels rise in some locations, subsurface water may percolate through and flood habitats behind the berm before they can be colonized by fish.

Ground-truthing of the aerial photo interpretation of flooded habitat behind the riparian berm from Lewiston Dam releases of 5,000 cfs in May 2000 has not occured. This effort will involve gaining access from multiple private landowners and should be coordinated well in advance of anticipated flows of 5,000 cfs or greater.

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Personal Communications

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Appendices

Appendix A. Trinity River Juvenile Stranding Study, May to June 2002. Stranding-pool capture data and estimates by species

Date	Week	Site	Strata	Pool	Species *	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Incidental capture (not part of depletion estimate)	Number of Passes	Total Capture	Depletion Capture Estimate	Capture estimate plus incidental	Sample based variance estimate of depletion estimator	Estimator
5/21	2	A	RE	1	Brown Trout	3	0					2	3	3	3	0.0	Seber LeCren
5/21	2	A	RE	1	Chinook	3	0					2	3	3	3	0.0	Seber LeCren
5/21	2	A	RE	1	Coho	1	1					2	2	2	2	0.0	Total Capture
5/21	2	A	RE	1	Steelhead	2	0				1	2	3	2	3	0.0	Seber LeCren
6/6	4	A	RE	4	Chinook	0					1	1	1	1	1		Total Capture
6/6	4	A	RE	7	Chinook	2						1	2	2	2		Total Capture
6/6	4	A	RE	1	Chinook	4	0					2	4	4	4	0.0	Seber LeCren
6/6	4	A	RE	2	Chinook	65	35					2	100	141	141	639.0	Seber LeCren
6/6	4	A	RE	3	Chinook	11	2					2	13	13	13	1.0	Seber LeCren
6/6	4	A	RE	6	Chinook	1	1					2	2	2	2	0.0	Total Capture
6/6	4	A	RE	7	Coho	1						1	1	1	1		Total Capture
6/6	4	A	RE	1	Coho	3	0					2	3	3	3	0.0	Seber LeCren
6/6	4	A	RE	2	Coho	87	37					2	124	151	151	205.6	Seber LeCren
6/6	4	A	RE	3	Coho	1	1					2	2	2	2	0.0	Total Capture
6/6	4	A	RE	6	Coho	1	0					2	1	1	1	0.0	Seber LeCren

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

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6/6	4	A	RE	7	Steelhead	2						1	2	2	2		Total Capture
6/6	4	A	RE	1	Steelhead	10	7					2	17	33	33	1,028.4	Seber LeCren
6/6	4	A	RE	2	Steelhead	17	3					2	20	21	21	1.4	Seber LeCren
6/6	4	A	RE	3	Steelhead	5	2					2	7	8	8	8.6	Seber LeCren
6/6	4	A	RE	6	Steelhead	1	1					2	2	2	2	0.0	Total Capture
6/6	4	A	RE	9	Stickleback	0					1	1	1	1	1		Total Capture
6/6	4	A	RE	1	Stickleback	2	0					2	2	2	2	0.0	Seber LeCren
6/6	4	A	RE	2	Stickleback	2	4					2	6	6	6	24.0	Total Capture
6/18	6	A	RE	2	Chinook	20	11					2	31	44	44	228.7	Seber LeCren
6/18	6	A	RE	3	Chinook	5	1					2	6	6	6	0.6	Seber LeCren
6/18	6	A	RE	6	Chinook	0	1					2	1	1	1	0.0	Total Capture
6/18	6	A	RE	1	Chinook	1	1	1	0			4	3	3	3	0.0	Bias Adjust Jackknife
6/18	6	A	RE	5	Chinook	1	1	0	0			4	2	2	2	0.0	Bias Adjust Jackknife
6/18	6	A	RE	2	Coho	13	1					2	14	14	14	0.1	Seber LeCren
6/18	6	A	RE	3	Coho	2	1					2	3	4	4	12.0	Seber LeCren
6/18	6	A	RE	4	Coho	6	0					2	6	6	6	0.0	Seber LeCren

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

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6/18	6	A	RE	6	Coho	1	0					2	1	1	1	0.0	Seber LeCren
6/18	6	A	RE	7	Coho	2	1					2	3	4	4	12.0	Seber LeCren
6/18	6	A	RE	1	Coho	1	1	1	0			4	3	3	3	0.0	Bias Adjust Jackknife
6/18	6	A	RE	5	Coho	0	1	0	0			4	1	1	1	0.0	Bias Adjust Jackknife
6/18	6	A	RE	2	Lamprey	2	0					2	2	2	2	0.0	Seber LeCren
6/18	6	A	RE	2	Steelhead	5	3					2	8	13	13	112.5	Seber LeCren
6/18	6	A	RE	4	Steelhead	1	0					2	1	1	1	0.0	Seber LeCren
6/18	6	A	RE	6	Steelhead	2	1					2	3	4	4	12.0	Seber LeCren
6/18	6	A	RE	7	Steelhead	4	3					2	7	16	16	1,008.0	Seber LeCren
6/18	6	A	RE	5	Steelhead	1	0	0	0			4	1	1	1	0.0	Bias Adjust Jackknife
6/18	6	A	RE	3	Stickleback	1	1					2	2	2	2	0.0	Total Capture
6/18	6	A	RE	4	Stickleback	0	1					2	1	1	1	0.0	Total Capture
6/18	6	A	RE	1	Stickleback	1	0	0	0			4	1	1	1	0.0	Bias Adjust Jackknife
6/18	6	A	RE	5	Stickleback	0	0	1	1			4	2	5	5	12.0	Bias Adjust Jackknife
6/25	7	A	RE	1	Chinook	7	2					2	9	10	10	2.8	Seber LeCren
6/25	7	A	RE	4	Chinook	1	0					2	1	1	1	0.0	Seber LeCren

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

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6/25	7	A	RE	9	Chinook	1	0	0				3	1	1	1	0.0	Seber LeCren
6/25	7	A	RE	8	Chinook	0	2	0	0			4	2	2	2	0.0	Jackknife
6/25	7	A	RE	1	Coho	6	1					2	7	7	7	0.4	Seber LeCren
6/25	7	A	RE	9	Coho	1	1	0				3	2	2	2	0.0	Bias Adjust Jackknife
6/25	7	A	RE	8	Coho	1	1	0	0			4	2	2	2	0.0	Bias Adjust Jackknife
6/25	7	A	RE	4	Lamprey	1	1					2	2	2	2	0.0	Total Capture
6/25	7	A	RE	1	Steelhead	1	1					2	2	2	2	0.0	Total Capture
6/25	7	A	RE	4	Steelhead	2	1					2	3	4	4	12.0	Seber LeCren
6/25	7	A	RE	9	Steelhead	1	0	0				3	1	1	1	0.0	Bias Adjust Jackknife
6/25	7	A	RE	1	Stickleback	2	0					2	2	2	2	0.0	Seber LeCren
6/25	7	A	RE	4	Stickleback	1	0					2	1	1	1	0.0	Seber LeCren
5/14	1	AQ	RE	1	Coho	0					1	1	1	1	1		Total Capture
5/21	2	AQ	RE	2	Steelhead	1						1	1	1	1		Total Capture
5/15	1	BH	RE	1	Chinook	13	12	8	5		3	4	41	54	57	60.0	Bias Adjust Jackknife
5/15	1	BH	RE	1	Coho	1	0	0	0			4	1	1	1	0.0	Bias Adjust Jackknife
5/15	1	BH	RE	1	Steelhead	0	4	5	6		3	4	18	33	36	72.0	Bias Adjust Jackknife

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

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5/30	3	BM	RE	1	Brown Trout	9	2	0	0	0		5	11	11	11	0.0	Bias Adjust Jackknife
5/30	3	BM	RE	7	Chinook	6						1	6	6	6		Total Capture
5/30	3	BM	RE	5	Chinook	12	7					2	19	29	29	214.5	Seber LeCren
5/30	3	BM	RE	6	Chinook	1	0					2	1	1	1	0.0	Seber LeCren
5/30	3	BM	RE	3	Chinook	55	32	8			1	3	96	105	106	48.0	Bias Adjust Jackknife
5/30	3	BM	RE	4	Chinook	22	9	1				3	32	33	33	6.0	Bias Adjust Jackknife
5/30	3	BM	RE	8	Chinook	59	46	26				3	131	162	162	156.0	Bias Adjust Jackknife
5/30	3	BM	RE	1	Chinook	65	100	15	19	12	1	5	212	244	245	240.0	Bias Adjust Jackknife
5/30	3	BM	RE	8	Coho	0	1	0				3	1	1	1	0.0	Jackknife
5/30	3	BM	RE	1	Coho	4	1	1	0	0		5	6	6	6	0.0	Bias Adjust Jackknife
5/30	3	BM	RE	8	Green Sunfish	5	1	2				3	8	10	10	12.0	Bias Adjust Jackknife
5/30	3	BM	RE	3	Lamprey	2	1	1				3	4	5	5	6.0	Bias Adjust Jackknife
5/30	3	BM	RE	8	Lamprey	1	0	0				3	1	1	1	0.0	Bias Adjust Jackknife
5/30	3	BM	RE	1	Lamprey	8	6	4	7	2	1	5	28	33	34	40.0	Bias Adjust Jackknife
5/30	3	BM	RE	7	Steelhead	2						1	2	2	2		Total Capture
5/30	3	BM	RE	5	Steelhead	1	1					2	2	2	2	0.0	Total Capture

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

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5/30	3	BM	RE	3	Steelhead	5	2	5				3	12	20	20	30.0	Bias Adjust Jackknife
5/30	3	BM	RE	4	Steelhead	9	2	0				3	11	11	11	0.0	Bias Adjust Jackknife
5/30	3	BM	RE	8	Steelhead	2	3	2				3	7	10	10	12.0	Bias Adjust Jackknife
5/30	3	BM	RE	1	Steelhead	13	8	4	0	3		5	28	33	33	60.0	Bias Adjust Jackknife
5/30	3	BM	RE	3	Stickleback	0	1	0				3	1	1	1	0.0	Jackknife
5/30	3	BM	RE	4	Stickleback	0	0	1				3	1	3	3	6.0	Jackknife
5/30	3	BM	RE	8	Stickleback	1	1	0				3	2	2	2	0.0	Jackknife
5/30	3	BM	RE	1	Stickleback	0	1	0	0	2		5	3	11	11	40.0	Bias Adjust Jackknife
6/4	4	BM	RE	9	Bullfrog Tadpole	3						1	3	3	3		Total Capture
6/4	4	BM	RE	10	Bullfrog Tadpole	1						1	1	1	1		Total Capture
6/4	4	BM	RE	10	Chinook	5						1	5	5	5		Total Capture
6/4	4	BM	RE	11	Chinook	1						1	1	1	1		Total Capture
6/4	4	BM	RE	9	Green Sunfish	1						1	1	1	1		Total Capture
6/4	4	BM	RE	10	Green Sunfish	3						1	3	3	3		Total Capture
6/4	4	BM	RE	9	Stickleback	2						1	2	2	2		Total Capture
6/5	4	BM	RE	11	Bullfrog Tadpole	6						1	6	6	6		Total Capture
6/5	4	BM	RE	12	Chinook	1						1	1	1	1		Total Capture

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

Appendix A. Trinity River Juvenile Stranding Study, May to June 2002. Stranding-pool capture data and estimates by species (continued)

Date	Week	Site	Strata	Pool	Species *	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Incidental capture (not part of depletion estimate)	Number of Passes	Total Capture	Depletion Capture Estimate	Capture estimate plus incidental	Sample based variance estimate of depletion estimator	Estimator
6/5	4	BM	RE	11	Chinook	26						1	26	26	26		Total Capture
6/5	4	BM	RE	11	Lamprey	1						1	1	1	1		Total Capture
6/5	4	BM	RE	11	Stickleback	3						1	3	3	3		Total Capture
5/22	2	BP	RE	1	Brown Trout	1	0					2	1	1	1	0.0	Seber LeCren
5/22	2	BP	RE	1	Chinook	135	49				2	2	186	213	215	147.2	Seber LeCren
5/22	2	BP	RE	1	Coho	1	0					2	1	1	1	0.0	Seber LeCren
5/22	2	BP	RE	1	Steelhead	5	3				2	2	10	13	15	112.5	Seber LeCren
5/22	2	BP	RE	1	Stickleback	0	1					2	1	1	1	0.0	Total Capture
5/14	1	Jim Smith PR	Pilot	1	Chinook	1						1	1	1	1		Total Capture
5/14	1	Jim Smith PR	Pilot	3	Chinook	0	0				1	2	1	0	1	0.0	Seber LeCren
5/14	1	Jim Smith PR	Pilot	3	Steelhead	2	0				2	2	4	2	4	0.0	Seber LeCren
5/14	1	Jim Smith PR	Pilot	3	Steelhead	2	0				2	2	4	2	4	0.0	Seber LeCren
5/17	1	Junction City Natural	Natural	1	Steelhead	0	0				2	2	2	0	2	0.0	Seber LeCren
5/20	2	Junction City Natural	Natural	1	Chinook	1	0					2	1	1	1	0.0	Seber LeCren
5/20	2	Junction City Natural	Natural	1	Lamprey	2	9					2	11	11	11	1.5	Total Capture
5/20	2	Junction City Natural	Natural	1	Steelhead	2	2					2	4	4	4	0.0	Total Capture

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

Appendix A. Trinity River Juvenile Stranding Study, May to June 2002. Stranding-pool capture data and estimates by species (continued)

Date	Week	Site	Strata	Pool	Species *	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Incidental capture (not part of depletion estimate)	Number of Passes	Total Capture	Depletion Capture Estimate	Capture estimate plus incidental	Sample based variance estimate of depletion estimator	Estimator
5/16	1	Lorenz Gulch Natural	Natural	1	Stickleback						1	0	1		1		NA
5/17	1	Oregon Gulch Natural	Natural	3	Chinook	6						1	6	6	6		Total Capture
5/17	1	Oregon Gulch Natural	Natural	6	Chinook	4	4				1	2	9	8	9	0.0	Total Capture
5/17	1	Oregon Gulch Natural	Natural	2	Steelhead						1	0	1		1		NA
5/17	1	Oregon Gulch Natural	Natural	3	Steelhead	4						1	4	4	4		Total Capture
5/17	1	Oregon Gulch Natural	Natural	6	Steelhead	4	2					2	6	8	8	24.0	Seber LeCren
5/17	1	Oregon Gulch Natural	Natural	1	Stickleback						1	0	1		1		NA
5/17	1	Oregon Gulch Natural	Natural	6	Sucker	0	1					2	1	1	1	0.0	Total Capture
5/23	2	Oregon Gulch Natural	Natural	2	Brown Trout	1	2	0	0			4	3	3	3	0.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	1	Chinook	8	7	2	1			4	18	20	20	12.0	Bias Adjust Jackknife

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

Appendix A. Trinity River Juvenile Stranding Study, May to June 2002. Stranding-pool capture data and estimates by species (continued)

Date	Week	Site	Strata	Pool	Species *	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Incidental capture (not part of depletion estimate)	Number of Passes	Total Capture	Depletion Capture Estimate	Capture estimate plus incidental	Sample based variance estimate of depletion estimator	Estimator
5/23	2	Oregon Gulch Natural	Natural	2	Chinook	41	46	18	8		1	4	114	129	130	96.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	1	Coho	1	0	0	0			4	1	1	1	0.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	2	Coho	1	0	0	0			4	1	1	1	0.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	2	Lamprey	3	7	4	4			4	18	30	30	48.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	1	Steelhead	8	12	7	6			4	33	108	108	72.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	2	Steelhead	12	13	13	16			4	54	102	102	192.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	1	Stickleback	0	0	1	1			4	2	5	5	12.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	2	Stickleback	0	0	1	1			4	2	5	5	12.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	1	Sucker	1	1	3	3			4	8	17	17	36.0	Bias Adjust Jackknife
5/23	2	Oregon Gulch Natural	Natural	2	Sucker	5	7	3	3			4	18	38	38	36.0	Bias Adjust Jackknife
6/7	4	Pear Tree Pilot	Pilot	1	Chinook	0	1	0	2	0		5	3	3	3	0.0	Jackknife

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

Appendix A. Trinity River Juvenile Stranding Study, May to June 2002. Stranding-pool capture data and estimates by species (continued)

Date	Week	Site	Strata	Pool	Species *	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Incidental capture (not part of depletion estimate)	Number of Passes	Total Capture	Depletion Capture Estimate	Capture estimate plus incidental	Sample based variance estimate of depletion estimator	Estimator
6/7	4	Pear Tree Pilot	Pilot	1	Coho	0	0	1	1	1		5	3	7	7	20.0	Bias Adjust Jackknife
6/7	4	Pear Tree Pilot	Pilot	1	Dace	3	0	1	2	1		5	7	9	9	20.0	Bias Adjust Jackknife
6/7	4	Pear Tree Pilot	Pilot	1	Steelhead	5	1	1	1	0		5	8	8	8	0.0	Bias Adjust Jackknife
6/7	4	Pear Tree Pilot	Pilot	1	Stickleback	0	1	0	0	0		5	1	1	1	0.0	Jackknife
6/7	4	Pear Tree Pilot	Pilot	1	Sucker	0	0	0	0	1		5	1	5	5	20.0	Jackknife
5/14	1	Steiner Pilot	Pilot	2	Chinook	1						1	1	1	1		Total Capture
5/14	1	Steiner Pilot	Pilot	2	Dace	0					1	1	1	1	1		Total Capture
5/14	1	Steiner Pilot	Pilot	1	Lamprey	0					1	1	1	1	1		Total Capture
5/14	1	Steiner Pilot	Pilot	3	Lamprey	0					4	1	4	4	4		Total Capture
5/21	2	Steiner Pilot	Pilot	1	Brown Trout	2	1	0	0			4	3	3	3	0.0	Bias Adjust Jackknife
5/21	2	Steiner Pilot	Pilot	1	Chinook	98	54	30	9		2	4	193	200	202	108.0	Bias Adjust Jackknife
5/21	2	Steiner Pilot	Pilot	1	Dace	0	1	0	0		1	4	2	1	2	0.0	Jackknife
5/21	2	Steiner Pilot	Pilot	1	Lamprey	0	2	2	6			4	10	28	28	72.0	Bias Adjust Jackknife
5/21	2	Steiner Pilot	Pilot	1	Steelhead	13	17	6	7		2	4	45	78	80	84.0	Bias Adjust Jackknife
5/21	2	Steiner Pilot	Pilot	1	Stickleback	0	1	0	1			4	2	5	5	12.0	Bias Adjust Jackknife
5/22	2	Steiner Pilot	Pilot	2	Chinook	0					1	1	1	1	1		Total Capture

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

Appendix A. Trinity River Juvenile Stranding Study, May to June 2002. Stranding-pool capture data and estimates by species (continued)

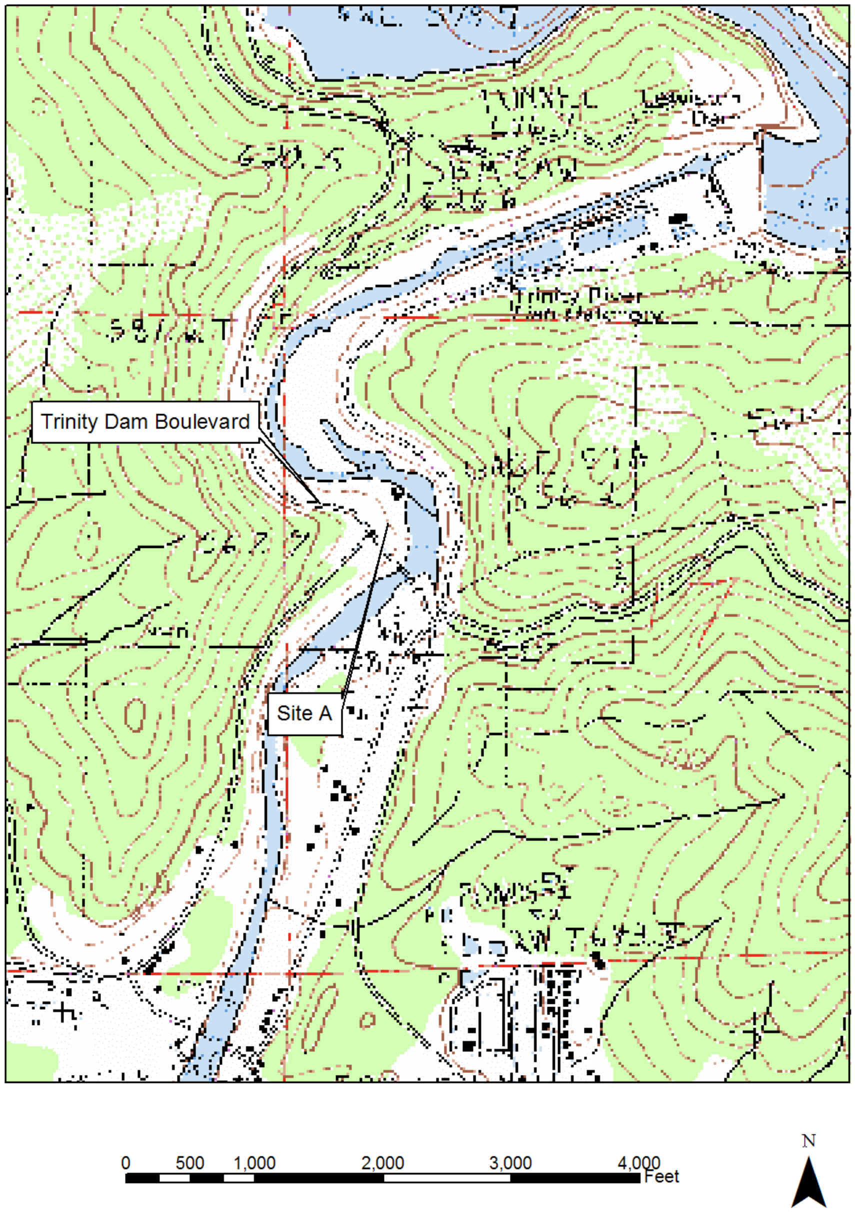
Date	Week	Site	Strata	Pool	Species *	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Incidental capture (not part of depletion estimate)	Number of Passes	Total Capture	Depletion Capture Estimate	Capture estimate plus incidental	Sample based variance estimate of depletion estimator	Estimator
6/5	4	Steiner Pilot	Pilot	1	Chinook	19	5					2	24	26	26	5.6	Seber LeCren
6/5	4	Steiner Pilot	Pilot	1	Lamprey	0	1					2	1	1	1	0.0	Total Capture
6/5	4	Steiner Pilot	Pilot	1	Steelhead	7	0					2	7	7	7	0.0	Seber LeCren
6/5	4	Steiner Pilot	Pilot	1	Stickleback	2	0					2	2	2	2	0.0	Seber LeCren

* Brown trout = *Salmo trutta*, chinook salmon = *Oncorhynchus tshawytscha*, coho salmon = *O. kisutch*, steelhead = *O. mykiss*, Pacific lamprey = *Lampetra tridentata*, threespine stickleback = *Gasterosteus aculeatus*, dace = *Rhinichthys osculus*, sucker = *Catostomus rimiculus*, green sunfish = *Lepomis cyanellus*, bullfrog = *Rana catesbeiana*

Appendix B. Trinity River Juvenile Stranding Study, May to June 2002. Number of stranding pools present and number sampled at each study site for each week.

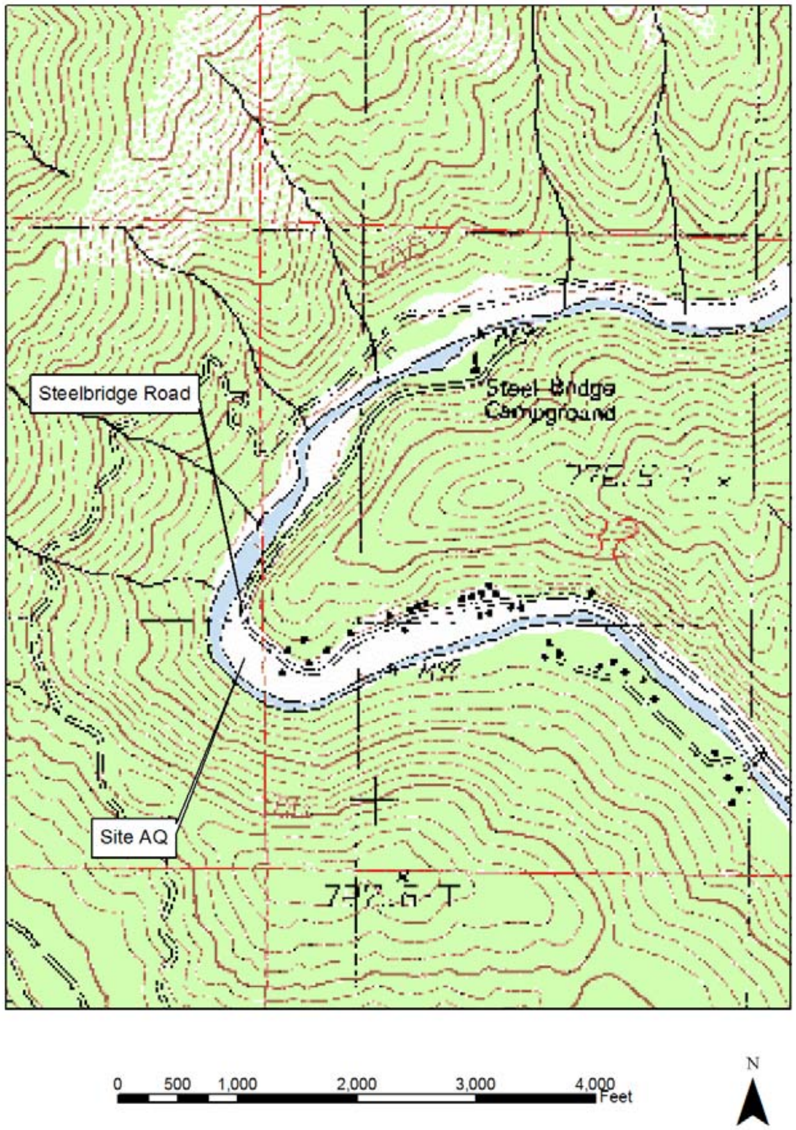
Site	Week 1		Week 2		Week 3		Week 4		Week 6		Week 7	
	Number of pools on site	Number of pools sampled	Number of pools on site	Number of pools sampled	Number of pools on site	Number of pools sampled	Number of pools on site	Number of pools sampled	Number of pools on site	Number of pools sampled	Number of pools on site	Number of pools sampled
Junction City Natural	1	1	1	1	0	0	0	0	0	0	0	0
Oregon Natural	6	5	3	3	0	0	0	0	0	0	0	0
Lorenz Gulch Natural	0	0	0	0	0	0	0	0	0	0	0	0
Steiner Natural	3	3	0	0	0	0	0	0	0	0	0	0
Pear Tree PR	0	0	0	0	0	0	1	1	0	0	0	0
Jim Smith PR	6	6	0	0	0	0	0	0	0	0	0	0
Bell Gulch PR	0	0	0	0	0	0	0	0	0	0	0	0
Steiner PR	3	3	2	2	0	0	1	1	0	0	0	0
CM	0	0	1	1	0	0	0	0	0	0	0	0
BP	0	0	1	1	0	0	0	0	0	0	0	0
BM	0	0	0	0	7	7	4	0	0	0	0	0
BH	1	1	0	0	1	1	0	0	0	0	0	0
AQ	1	1	2	2	0	0	0	0	0	0	0	0
A	0	0	1	1	0	0	10	9	9	9	9	9

2002 Trinity River Juvenile Stranding Study
Study Site A



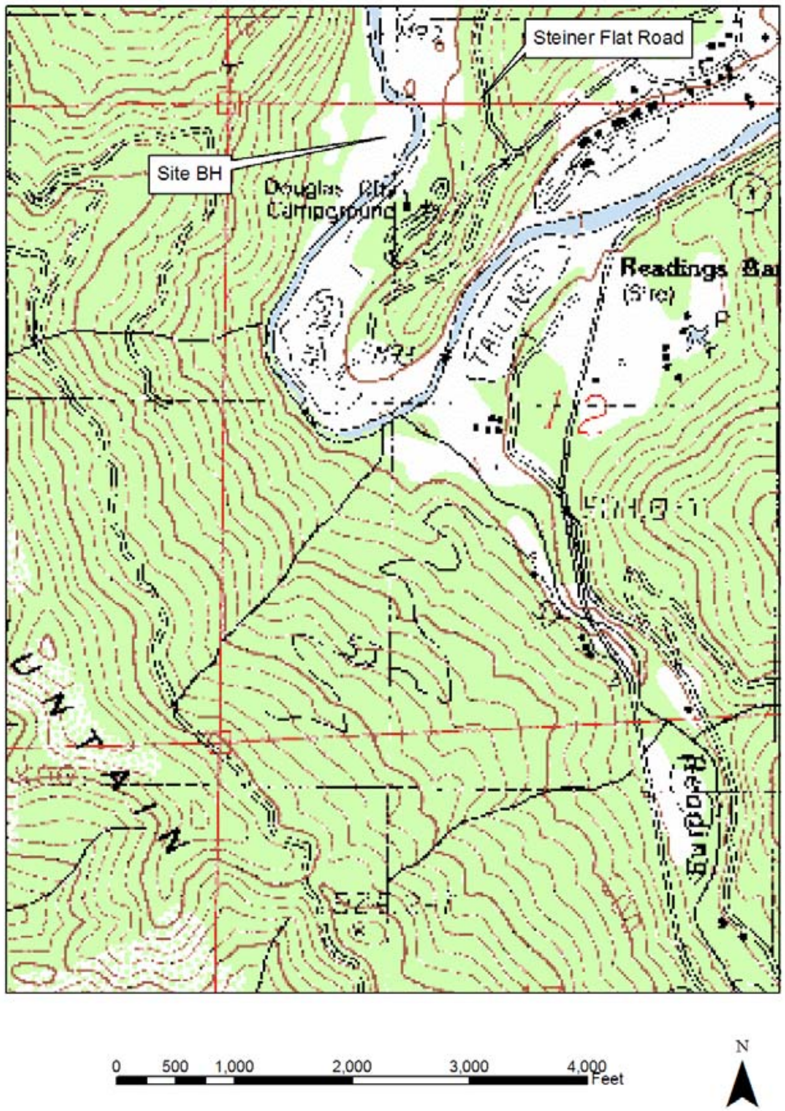
Site "A" is entirely within public land and is located immediately upstream of the New Lewiston Bridge (Trinity Dam Boulevard) in Lewiston, CA. The site is on river-right (right side looking downstream). Best access to the site is from the parking area adjacent to the USGS gage on the West side of the river immediately upstream of the bridge.

2002 Trinity River Juvenile Stranding Study
Study Site AQ



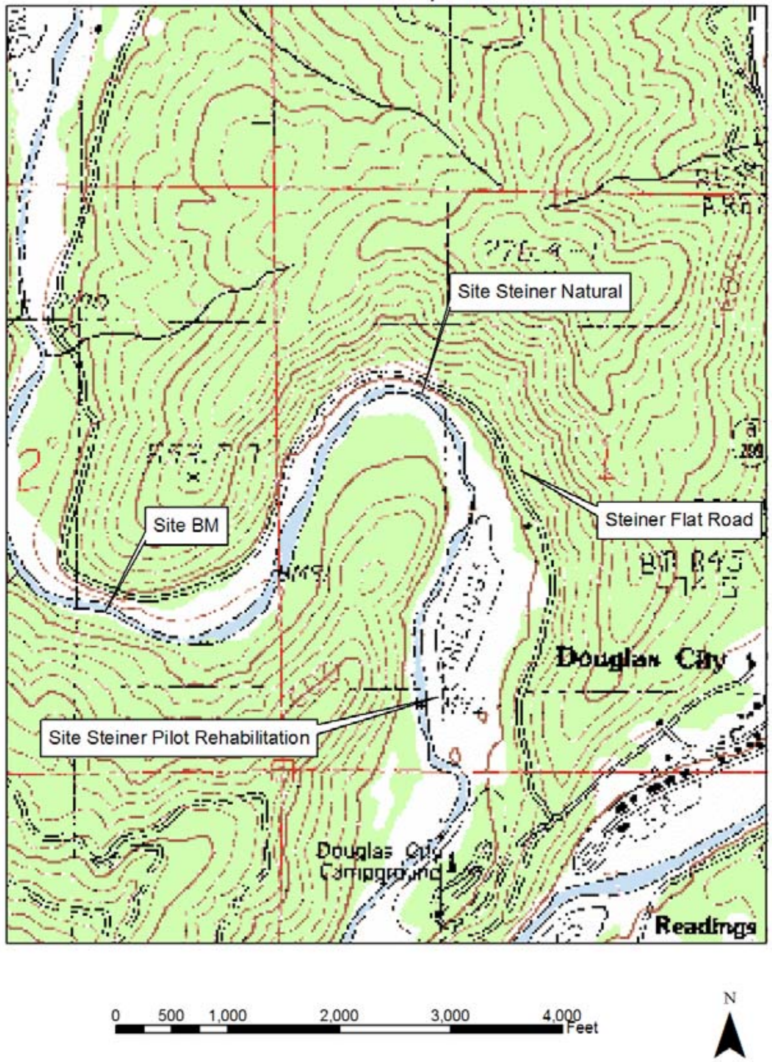
Site "AQ" is entirely within public land and is just downstream of Bureau of Land Management Steelbridge River Access near the upstream end of Steelbridge Road. The site is on river-left. There is a parking area adjacent to the site 1.8 miles from Highway 299 on Steelbridge Road.

2002 Trinity River Juvenile Stranding Study
Study Site BH



Site "BH" is entirely within public land and is a point bar on the opposite side of the river just downstream of the BLM Douglas City Campground. The site is on river-left. Best access to the site is by boat from the BLM Douglas City Campground.

2002 Trinity River Juvenile Stranding Study
Study Sites Steiner Pilot Rehabilitation,
Steiner Natural, and BM

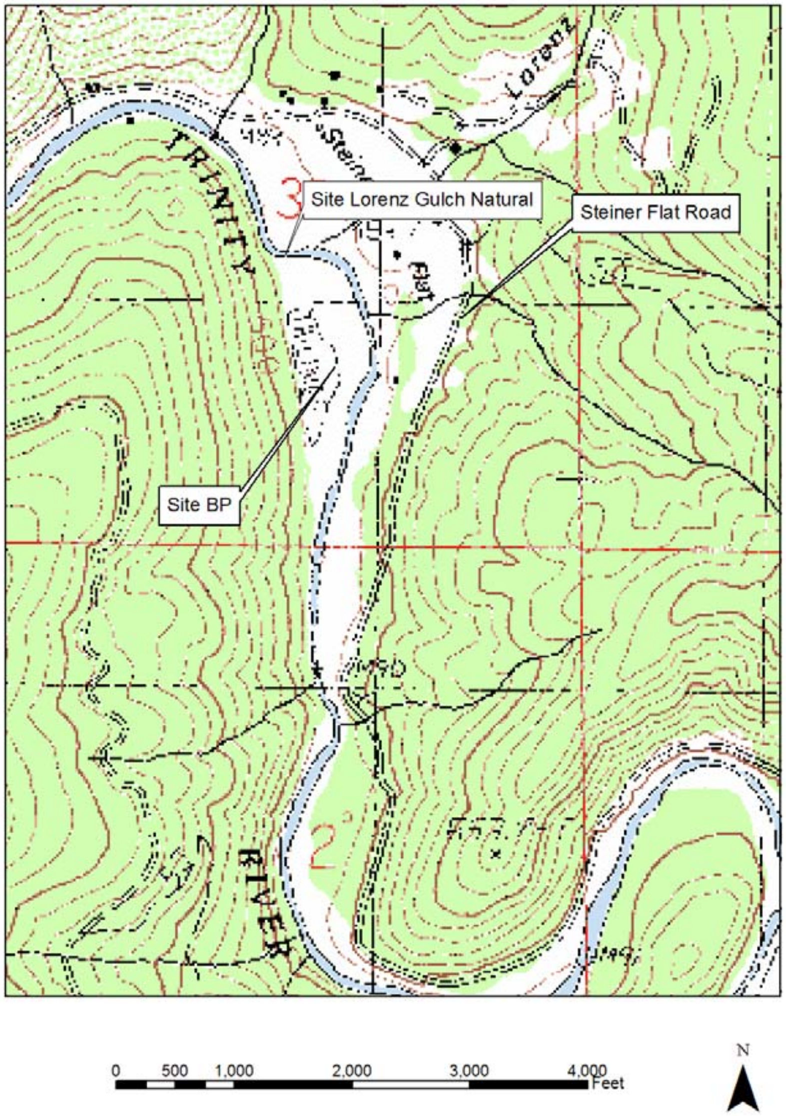


Site "Steiner Flat Pilot Rehabilitation" is entirely within public land and is located at the upstream end of the BLM Steiner Flat River Access. The site is on river-right.

Site "Steiner Natural" is entirely within public land and is a point bar downstream of the BLM Steiner Flat River Access on the opposite side of the river from Steiner Flat Road. The site is on river-left. Access the site by boat from one of several public river access locations upstream.

Site "BM" is entirely within public land and is opposite Steiner Flat Road. Access the site by boat from one of several public river access locations upstream.

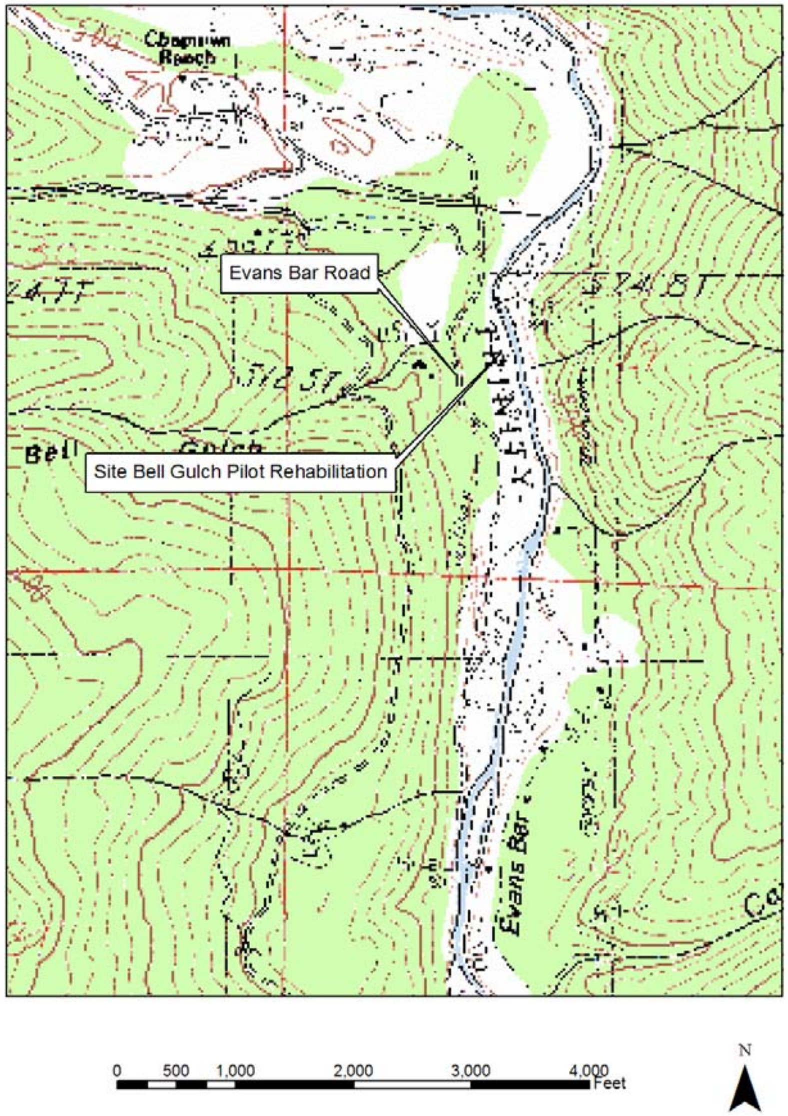
2002 Trinity River Juvenile Stranding Study
Study Sites BP and Lorenz Gulch Natural



Site "BP" is entirely within public land and is on the opposite side of the river from Steiner Flat near the end of Steiner Flat Road. The site is on river-left. Access the site by boat from one of several public river access locations upstream.

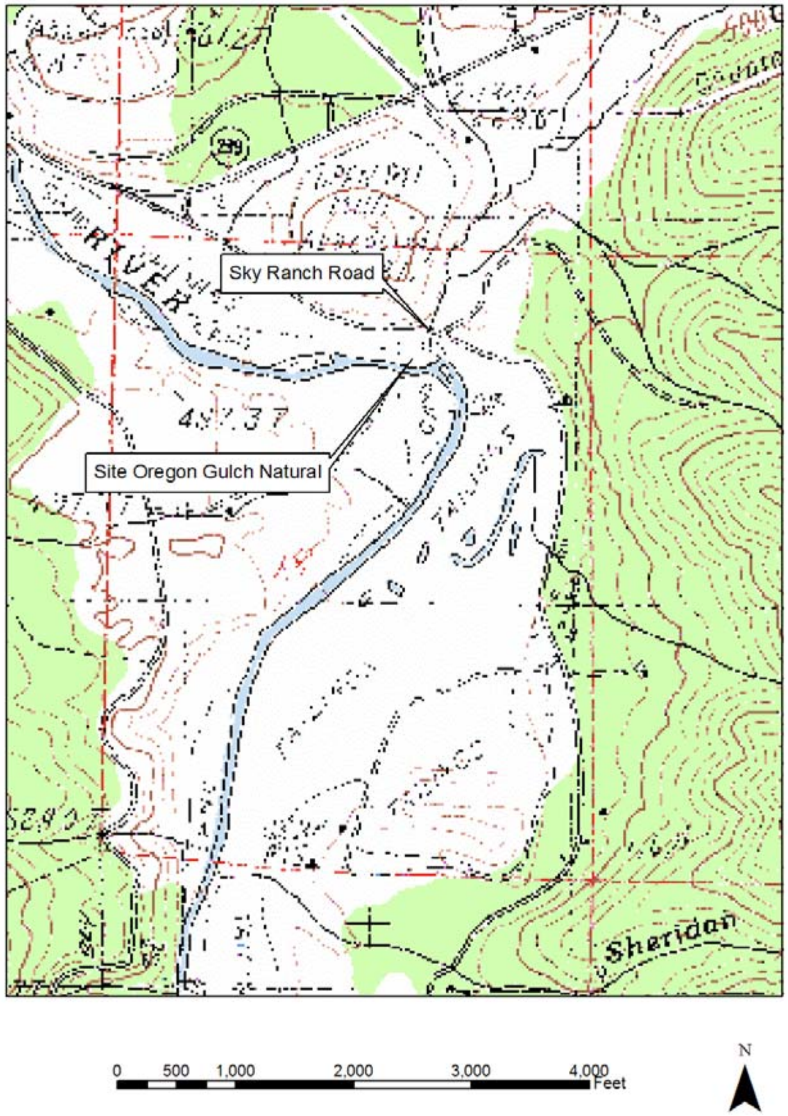
Site "Lorenz Gulch Natural" is entirely within public land and is located on Steiner Flat just downstream of the tributary Lorenz Gulch. The site is on river-right. It is on the same side of the river as Steiner Flat Road but road access here requires crossing private property. We accessed the site by boat. River access to the site is available by boat from one of several public river access locations upstream.

2002 Trinity River Juvenile Stranding Study
Study Site Bell Gulch Pilot Rehabilitation



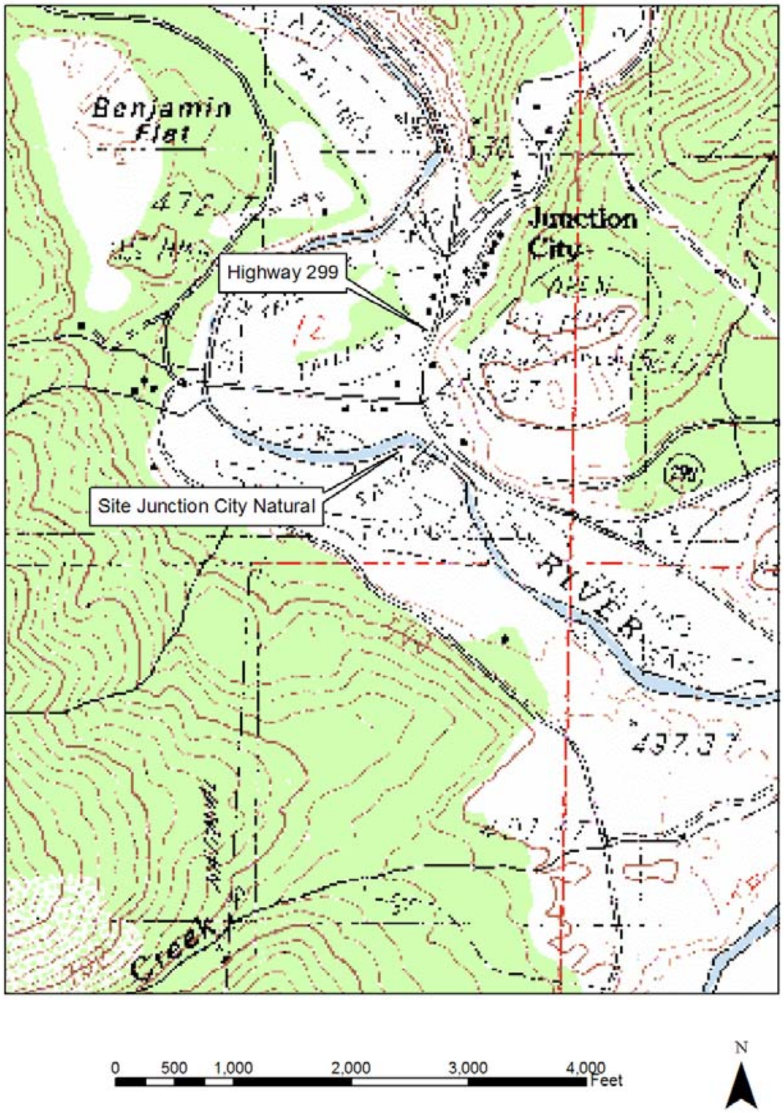
Site "Bell Gulch Pilot Rehabilitation" is entirely within public land and is a public river access point accessible from Evans Bar Road. The site is on river-left.

2002 Trinity River Juvenile Stranding Study
Study Site Oregon Gulch Natural



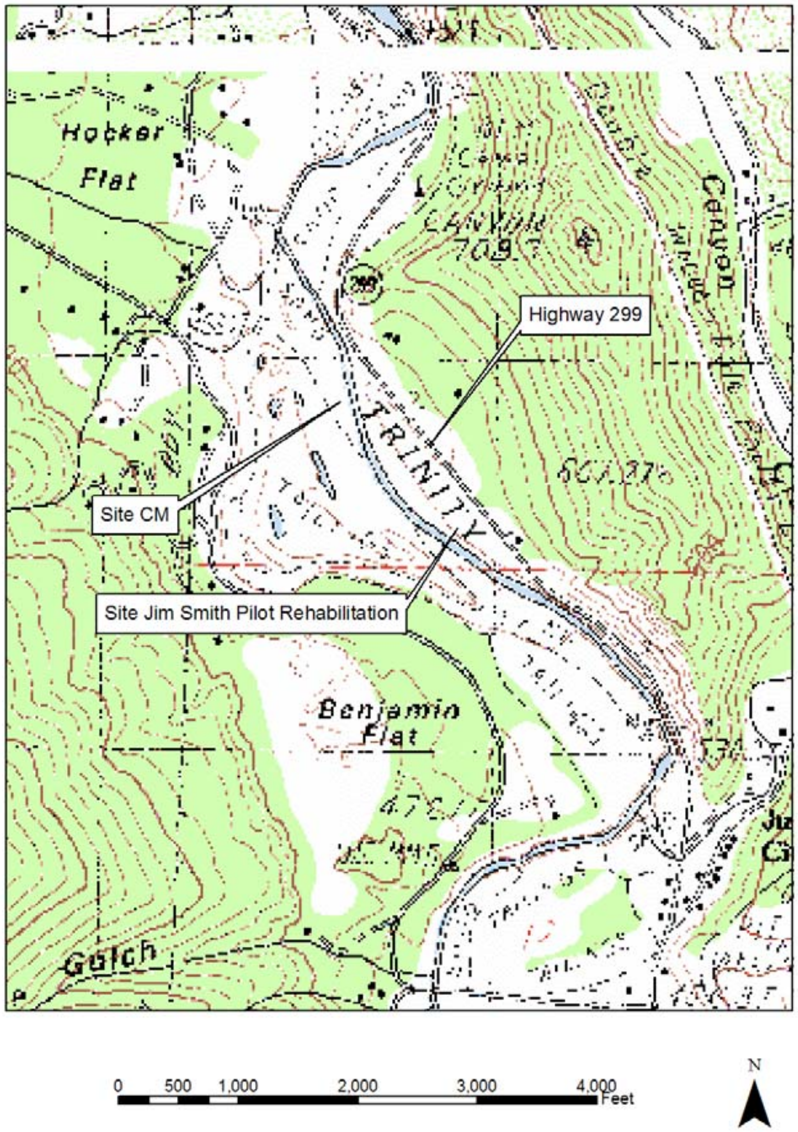
Site "Oregon Gulch Natural" is entirely within public land and is accessible from Sky Ranch Road. The site is on river-right.

2002 Trinity River Juvenile Stranding Study
Study Site Junction City Natural



Site “Junction City Natural” is entirely within public land. The site is an alternating river bar. The upstream end of the site is on river left, the downstream end is on river right. The site is best accessed by boat from one of several public river access locations upstream.

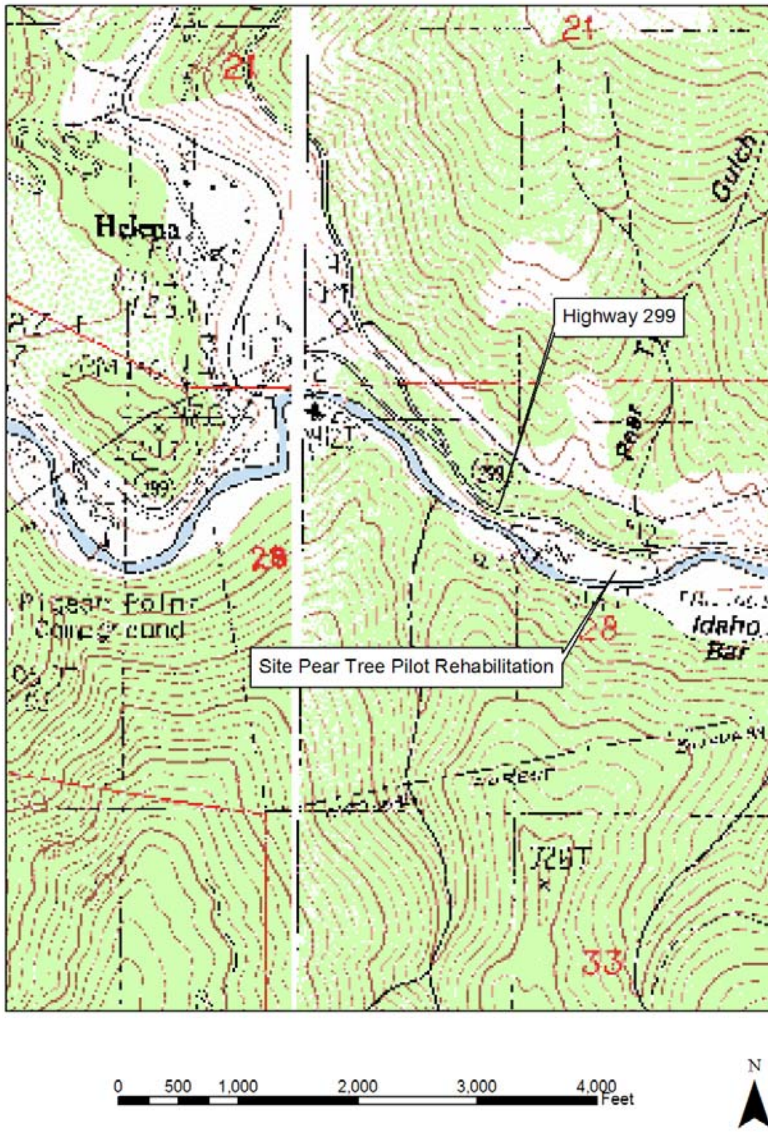
2002 Trinity River Juvenile Stranding Study
Study Sites Jim Smith Pilot Rehabilitation and CM



Site "Jim Smith Pilot Rehabilitation" is accessible from Highway 299 through private property. The site is on river-right. Access permission for U.S. Fish and Wildlife Service activities in 2002 at this site was granted by Jim Smith, P.O. Box 310, Junction City, CA 96048.

Site "CM" is entirely within public land and is across the river from Highway 299. The site is on river-left. The site is best accessed by boat from one of several public river access locations upstream.

2002 Trinity River Juvenile Stranding Study
Study Site Pear Tree Pilot Rehabilitation



Site “Pear Tree Pilot Rehabilitation” is entirely within public land and is accessible by foot from Highway 299. The site is on river-right. Park at milepost 37.50 on a narrow turnout of Highway 299 to access the site by foot.

U.S. Fish & Wildlife Service
Arcata Fish and Wildlife Office
1655 Heindon Road
Arcata, California 95521

April 2003