FINAL REPORT
FOR
VENTURA RIVER STEELHEAD/RAINBOW TROUT SPAWNING SURVEY

CALIFORNIA ADAPTIVE WATERSHED IMPROVEMENT
GRANT AGREEMENT NO. P0750023

This is the final report for the Ventura River Steelhead/rainbow Trout Spawning Survey, Grant No. P0750023

1. Grant Number

P0750023.

2. Project Name

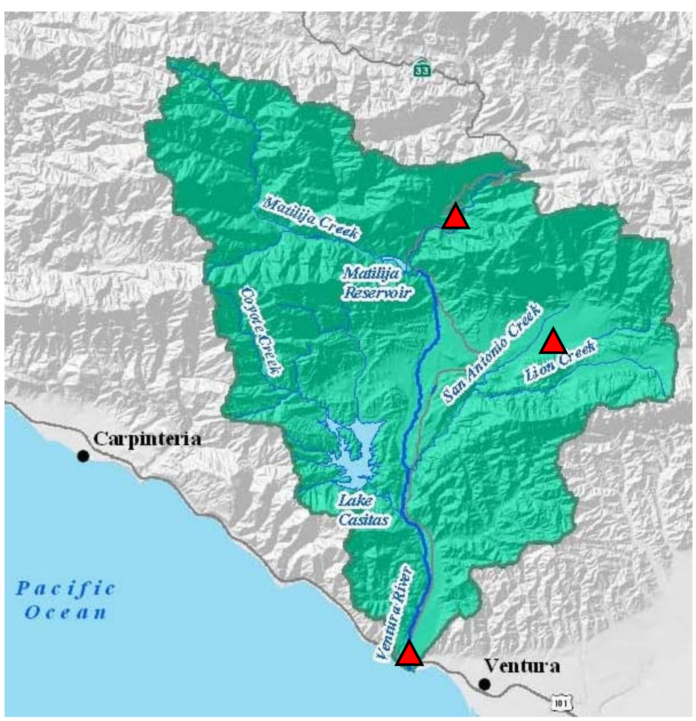
Ventura River Steelhead/rainbow Trout Spawning Survey.

3. Geographic Area

Ventura River Basin

4. Location of the Work

The general location includes the area from the mouth of the Ventura River in the south to the confluence of Thacher and McAndrews creeks in the east to Wheeler Gorge Campground in the north of the project area (see map below).



5. Geospatial Reference/Location

34.2742, -119.3077 (southern end of project)
34.2647, -119.1239 (eastern end of project)
34.5129, -119.2737 (northern end of project)

6. Project Start and End Dates

The project was started on May 1, 2008 and completed on April 6, 2010.

7. Fund Source

California Department of Fish and Game and Casitas Municipal Water District.

Services:

Personnel Costs	$14,535.00
Staff Benefits @ 35%	$0
Personnel CMWD Cost Share	$7,253.00
Materials and Supplies CMWD Cost Share	$450.00
Project Total	$22,238.00
Cost Share Total	$7,703.00
Subtotal	**$14,535.00**
Administrative Overhead at 5%	$727.00
Gross Billing	**$15,262.00**

Percent match of Casitas Municipal Water District cost share 34.6%

8. Benefits to Anadromous Salmonids from the Project

The benefits to anadromous salmonids from the project will be indirect. To date, no adult spawning population data has been collected in the Ventura River to determine the status of this core population. This project will estimate the steelhead and resident rainbow trout spawning populations in the mainstem of the Ventura River as well as the tributaries of San Antonio Creek, Matilija Creek (to Matilija Dam), and North Fork Matilija Creek. This information can be used to direct further recovery efforts.

9. Photos

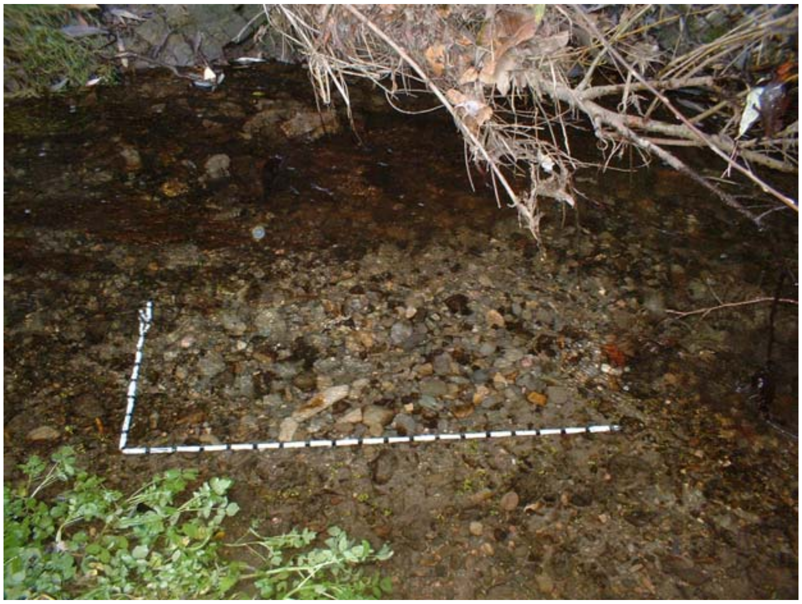


Figure 1. Photo of redd in the lower reach of San Antonio Creek during the survey period.

Figure 2. Photo taken during the data collection process after a redd was identified. This particular activity is demonstrating water velocity measurement.

10. Project Access

While driving on Federal Route Hwy 101, take the State Route Hwy 33 exit north. This area is the approximate southern end of the project area. Continuing north on 33 approximately 12 miles to State Route Hwy 150 and turning right and traveling approximately 5 miles to where 150 crosses Thacher Creek representing the eastern end of the project area. Traveling back on 150 to the 33 and turning right and traveling approximately 8 miles to Wheeler Gorge Campground representing the northern end of the project area.

11. Complete Analysis of Survey Data Collected

See attached report.

12. Project Data in Relation to other Available Data

The information obtained during the spawning surveys will be useful in relation to other monitoring that is currently being conducted by Casitas Municipal Water District. This includes snorkel surveys for *O. mykiss*, water quality, and habitat surveys. Other entities are also collecting water quality data. Together, this information will provide a more detailed picture of *O. mykiss* spawning, rearing, and habitat use and requirements.

13. Reporting Metrics

1. The project is directly related to the key anadromous salmonid management questions because it was intended to develop baseline trends of steelhead and rainbow trout in the Ventura River.

2. N/A

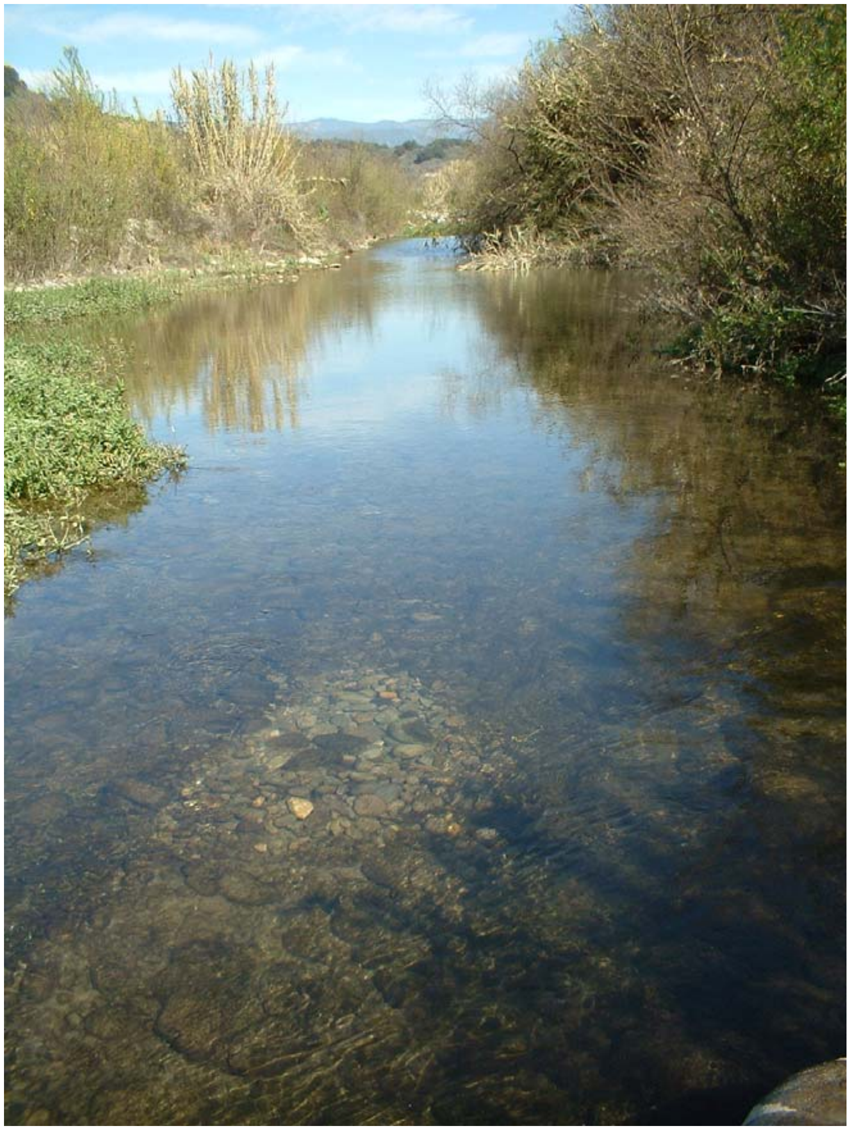
3. N/A

4. N/A

5. See attached report.

6. During the monitoring period, 140 km of stream habitat was surveyed.

Coastal Steelhead and Rainbow Trout (*Oncorhynchus mykiss irideus*) Spawning Surveys and Population Estimates in the Ventura River Basin, California



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Abstract

O. m. irideus spawning surveys were conducted over three years from 2008-2010. During the last two years, a stratified random sampling plan was used to allow for a total redd abundance estimate. The total redd abundance estimates were 16 and 159 redds for 2009 and 2010, respectively. Using a redd to spawner correction ratio, the spawner population was estimated to be 17 and 165 fish. The redd characteristics measured appeared to indicate that the vast majority of the redds were created by resident and not anadromous *O. m. irideus*. However, additional basin specific data needs to be collected to fully understand this *O. m. irideus* spawning population.

Introduction

Coastal steelhead and rainbow trout (*Oncorhynchus mykiss irideus*) of the Ventura River basin exist near the southern extent of the species range (Barnhart 1986; Behnke 1992; Busby et al. 1996; Boughton et al. 2005). Coastal steelhead were historically found as far south as the Otay (Behnke 1992) and Tijuana rivers (Swift et al. 1993), just north of the United States/Mexico border. Presently, the southernmost steelhead populations are presumed to originate from Malibu Creek (Nehlsen et al. 1991; Behnke 1992; Moyle 2002) and Topanga Creek (Swift et al. 1993; Boughton et al. 2005), which are approximately 80 km south of the Ventura River.

O. m. irideus that inhabit the southern portion of the species range persist in the face of many challenges from natural and anthropogenic sources (Boughton et al. 2005). Water in the Ventura Basin is naturally sparse because of the variable and sporadic nature of precipitation in southern California (Haston and Michaelsen 1994; Mo and Higgins 1998). Because of these challenges and low adult returns, Nehlsen et al. (1991) classified the steelhead population of the Ventura River, and many other southern California populations, as being at a high risk of extinction. The National Marine Fisheries Service (NMFS) later listed the southern California steelhead (as described by Busby et al. 1996) as endangered in 1997 under the Endangered Species Act (ESA) and began the recovery process (NMFS 1997).

Taxonomic Status—*O. m. irideus* are considered a subspecies of the larger taxonomic grouping of rainbow trout, *Oncorhynchus mykiss*, which exist in both inland and coastal systems. Rainbow trout, *O. mykiss*, are native to western North America and represent a diverse polytypic species. Presently, *O. mykiss* are generally organized into three large groups: 1) coastal rainbow trout, *O. m. irideus*, that extend from northern Baja California to northern Alaska and also the Kamchatkan Peninsula of northeastern Asia, 2) redband trout, *O. m. gairdneri,* of the inland Columbia River and Frazer River basins, and 3) redband trout, *O. m. aguabonita*, *O. m. gilberti*, and *O. m. stonei*, of the Sacramento Basin of California (Behnke 1992). The taxonomic group of coastal rainbow trout, *O. m. irideus*, exhibits two basic life history forms: anadromous and resident. The common name for the anadromous life history form is steelhead trout and the resident form is generally referred to as rainbow trout. Throughout the range of coastal rainbow trout, there is a widespread occurrence of the anadromous life history form; however, at the northern and southern ends of its distribution, the anadromous life history form is less prevalent (Behnke 1992; Brannon et al. 2004).

Study Area—The Ventura River basin is a relatively small coastal basin located in southern California that flows in a southerly direction to the Pacific Ocean (Figure 1). The basin covers an area of 590 km^2 and approximately half of the basin lies within the boundaries of the Los Padres National Forest. Elevation within the basin ranges from sea level to 1,663 m. Because of its steep topography and close proximity to the Pacific Ocean, the basin receives most of its precipitation from orographic uplift of extratropical cyclonic storms from December through April (Mo and Higgins 1998; Higgins et al. 2000). Wet and dry cycles occur on several time scales that include months, years, and decades

(Haston and Michaelsen 1994; Haston and Michaelsen 1997; MacDonald and Case 2005). Several oscillatory phenomena in the Pacific Ocean and atmosphere can interact together, or act alone, to explain much of the cyclic wet and dry periods (Haston and Michaelsen 1997; Mo and Higgins 1998). These include the Madden-Julian Oscillation (MJO), Quasi-Biennial Oscillation (QBO), El Niño Southern Oscillation (ENSO), and the Pacific Decadal Oscillation (PDO). The mean annual precipitation of the Ventura River basin is approximately 50 cm and ranges from 40 cm near the coast, to 90 cm at higher elevations (Daly et al. 1994).

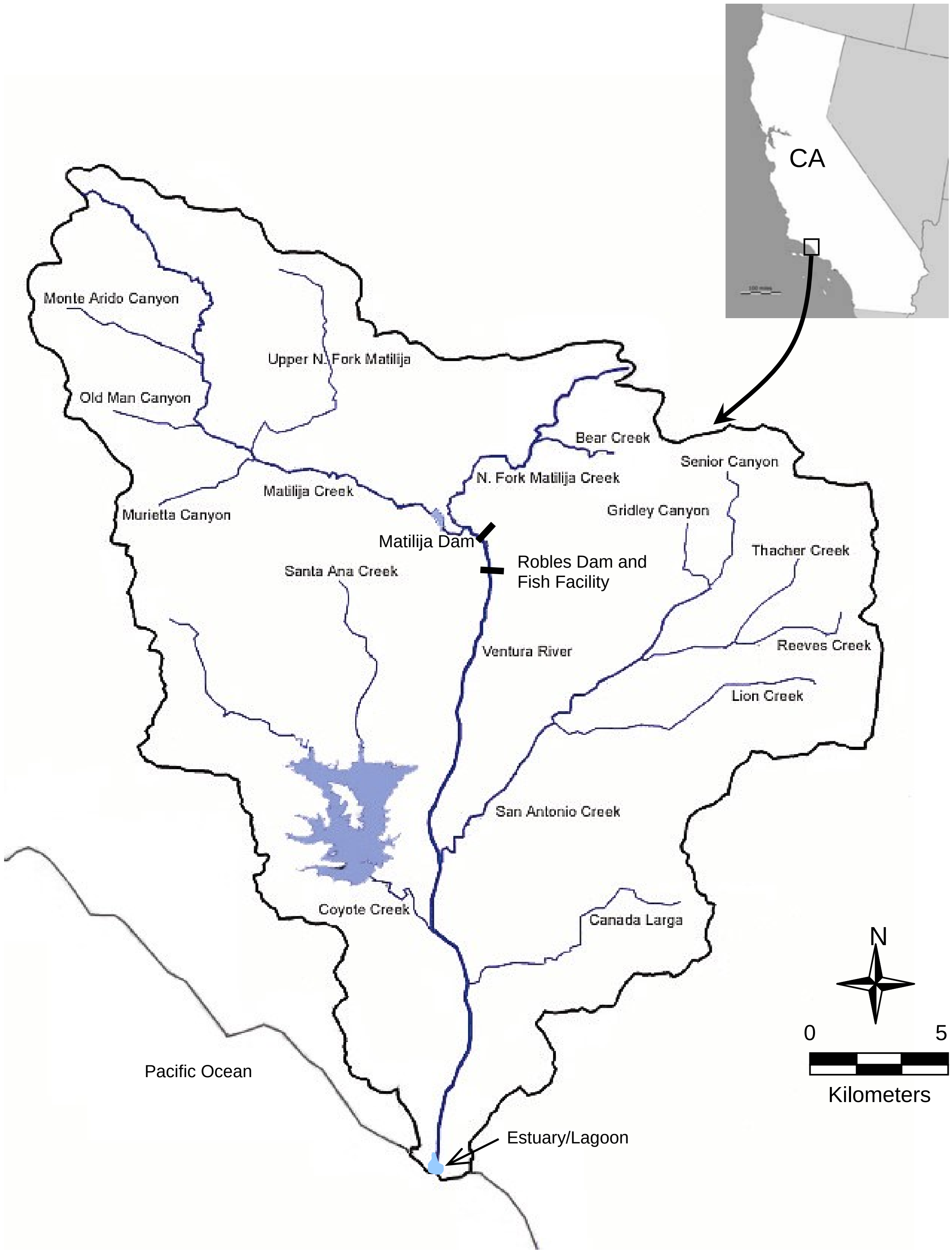

Figure 1. Study area of Ventura River basin and its major tributaries and location of the basin in southern California.

Because of the basin's precipitation patterns, inter- and intra-annual river discharges can fluctuate dramatically. At the United States Geological Survey (USGS) gage station near Foster Park and downstream of Coyote Creek (station # 11118500), mean annual discharge can range from < 0.05 m^3/s to over 10 m^3/s and peak discharge can range from < 0.05 m^3/s to 1,800 m^3/s. The mean annual peak discharge is about 300 m^3/s; however, because the mean is skewed by the higher readings, the median of approximately 100 m^3/s is more representative of typical peak flows. The mean monthly discharges of the Ventura River range from a low of 0.01 m^3/s in October to a high of 8.8 m^3/s in February.

The geology of the Ventura Basin is composed mostly of Tertiary age (2-65 million years old) marine sedimentary deposits of the west to east running Transverse Range (Inman and Jenkins 1999). Due to the range's relatively young geologic age, easily eroded formations, tectonically active faults, and steep topology, its coastal rivers have exceptionally high sediment loads; some of the greatest in the United States (Inman and Jenkins 1999; Willis and Griggs 2003). For the period of 1944-1995, the annual net yield of suspended sediment from the Ventura River was estimated at 1070 $tonnes/km^2 \cdot yr$ (Inman and Jenkins 1999). However, Willis and Griggs (2003) estimated that existing dam developments in the Ventura Basin have reduced annual sand and gravel discharge by 53%. Annual total sediment load was probably much greater historically than current loads, even after accounting for increases due to anthropogenic causes.

The mainstem of the Ventura River runs for approximately 26 km and has five primary tributaries, moving in an upstream direction: Cañada Larga Creek, Coyote Creek, San Antonio Creek, North Fork Matilija Creek, and Matilija Creek (Figure 1). Geomorphically, the Ventura River and its tributaries can be characterized as having high gradient channels in the upper portions of the basin that quickly transition to moderate and low gradient alluvial channels in the lower portions of the basin. The mainstem of the Ventura River flows through a wide alluvial valley with ephemeral flow in the upper half and perennially intermittent flow in the lower half because of rising ground water and treated wastewater returns (ENTRIX 2007). Robles Dam was constructed at RKM 23 in 1956 as part of a United States Bureau of Reclamation (BOR) project. Water is diverted from the dam to a storage reservoir in the Coyote Creek basin for domestic and agricultural use. A fish facility was completed in 2005 at the dam and fish passage is now possible for both upstream and downstream migrating fish (Lewis and Gibson 2010). Habitat for steelhead in the mainstem of the Ventura River is considered to be relatively low-quality (TRPA 2004). Cañada Larga Creek typically flows only during wet periods and is dry most years in the mid and lower reaches. Coyote Creek was impounded in 1956 at RKM 3.5 by Casitas Dam as part of the same BOR project. Water from Coyote Creek now only flows to the Ventura River once the reservoir is full and spill from the dam is necessary (Steve Wickstrum, personal communication, Casitas Municipal Water District). San Antonio Creek drains much of the eastern part of the basin and typically is dry in the mid reaches most of the year; the upper and lower reaches are perennial except during extended droughts (ENTRIX 2003). The stream channel of lower portion of San Antonio Creek is located in lower gradient topography that has been characterized as having smaller substrate and little pool habitat (ENTRIX 2003). North Fork Matilija Creek is typically perennial and drains from a higher gradient portion of the basin. Because of this, the stream channel tends to have larger substrate and more pool habitat (ENTRIX 2003). Matilija Creek represents 20% of the Ventura Basin in area and is located upstream of Matilija Dam. Matilija Dam was completed in 1947 for water supply and flood control, but because of the high sediment loads, the reservoir has almost completely filled with sediment and has lost approximately 93% of its original capacity (US Army Corps of Engineers 2004). An estimated 28 km of accessible habitat upstream of Matilija Dam (US Army Corps of Engineers 2004) is considered to be of high quality for spawning and rearing steelhead (TRPA 2004). Because of operational, safety, and environmental concerns, the dam has been designated for removal beginning in 2010 (US Army Corps of Engineers 2004).

The Ventura River has a relatively small estuary at its mouth that changes seasonally to a lagoon depending on river discharge and sandbar development (Lewis and Gibson 2010), a common geomorphic pattern typical in many California coastal rivers (Busby et al. 1996). During low-flow periods, a sandbar develops at the mouth stopping surface flow to the ocean and creates a lagoon. During winter storms, increased river discharge opens the sandbar allowing a surface connection to the ocean. When low-flow conditions return in late spring to late summer, the sandbar has an opportunity to close again and form a lagoon. The surface area of the estuary/lagoon is approximately 3 ha and 5 ha during the open and closed phases, respectively (Lewis and Gibson 2010). However, historically the Ventura River estuary/lagoon was larger before anthropogenic development (Ferrn et al. 1990). Maximum depth of the estuary/lagoon can be as much as 4 m and salinity ranges from 0.5 to 30.0 ppt, depending on flow and sandbar phase (Lewis and Gibson 2010).

Because little was known about the status of adult steelhead and rainbow trout, this study was implemented to determine the current spawning population status and distribution by estimating spawning steelhead and resident rainbow trout populations, timing, geographical distribution, and spawning microhabitat selection criteria such as water depth, water velocity, and gravel selection. This baseline population estimation is important to assessing this core ESA population within the Southern California Steelhead ESU (Boughton et al. 2007).

Methods

Spawning surveys were conducted throughout the Ventura Basin that was accessible to adult steelhead using two different survey methods. The first spawning survey methodology was a stratified random sampling of available adult steelhead habitat, similar to the methods of Gallagher and Gallagher (2005). This method allowed the total number of redds to be estimated. The areas of the watershed that was accessible to the anadromous form of *O. mykiss* were stratified into five study reaches. The five study reaches were 1) lower Ventura River from the mouth to the confluence with San Antonio Creek, 2) middle Ventura River from the confluence with San Antonio Creek to the Robles Fish Facility, 3) upper Ventura River from the Robles Fish Facility to the Wheeler Gorge Campground on North Fork Matilija Creek, including Matilija Creek to Matilija Dam, 4) lower San Antonio Creek from the Ventura River to approximately Fox Creek, and 5) upper San Antonio Creek that would extend upstream to the confluence of Senior and Gridley canyons and the confluence of Thacher and McAndrews creeks. Within each of the five strata, all 0.5 km subreaches were identified, and from those, five were randomly selected for monitoring (Table 1). The total redd population estimate was calculated by multiplying the mean density of redds in the selected 0.5 km sub-reaches of each stratum and then summing all five strata (Gallagher and Gallagher 2005). Dry reaches were surveyed after a rain event as soon as the turbidity is low enough to identify any potential redds. Each 0.5 km sub-reach was surveyed every two weeks from 01 January through 31 May.

Table 1. *O. mykiss* random spawning reaches in the Ventura Basin.

Reach	Site	Start km	End km	Start Lat	Start Long	End Lat	End Long
LVR	1	0.5	1	34° 17.085'N	119° 18.520'W	34° 17.363'N	119° 18.481'W
LVR	2	3	3.5	34° 18.329'N	119° 18.038'W	34° 18.557'N	119° 18.014'W
LVR	3	5.5	6	34° 19.567'N	119° 17.708'W	34° 19.815'N	119° 17.819'W
LVR	4	7.5	8	34° 20.662'N	119° 17.949'W	34° 20.922'N	119° 18.016'W
LVR	5	11	11.5	34° 22.170'N	119° 18.538'W	34° 22.438'N	119° 18.476'W
MVR	1	1	1.5	34° 23.332'N	119° 18.619'W	34° 23.586'N	119° 18.553'W
MVR	2	3.5	4	34° 24.559'N	119° 18.081'W	34° 24.852'N	119° 18.074'W
MVR	3	6	6.5	34° 25.800'N	119° 18.016'W	34° 26.061'N	119° 18.010'W
MVR	4	6.5	7	34° 26.061'N	119° 18.010'W	34° 26.347'N	119° 17.947'W
MVR	5	7.5	8	34° 26.541'N	119° 17.834'W	34° 26.803'N	119° 17.746'W
UVR	1	0	0.5	34° 28.049'N	119° 17.398'W	34° 28.314'N	119° 17.435'W
UVR	2	3	3.5	34° 29.294'N	119° 18.320'W	34° 29.531'N	119° 18.404'W
UVR	3	7	7.5	34° 30.517'N	119° 17.070'W	34° 30.354'N	119° 16.978'W
UVR	4	7.5	8	34° 30.354'N	119° 16.978'W	34° 30.314'N	119° 16.751'W
UVR	5	8	8.5	34° 30.314'N	119° 16.751'W	34° 30.446'N	119° 16.587'W
LSA	1	0	0.5	34° 22.844'N	119° 18.440'W	34° 22.790'N	119° 18.151'W
LSA	2	3.5	4	34° 23.879'N	119° 17.181'W	34° 24.045'N	119° 17.007'W
LSA	3	6.5	7	34° 25.113'N	119° 16.163'W	34° 25.281'N	119° 15.930'W
LSA	4	7.5	8	34° 25.508'N	119° 15.856'W	34° 25.493'N	119° 15.542'W
LSA	5	8.5	9	34° 25.689'N	119° 15.508'W	34° 25.889'N	119° 15.311'W
MSA	1	0	0.5	34° 26.045'N	119° 14.865'W	34° 26.221'N	119° 14.516'W
MSA	2	1	1.5	34° 26.369'N	119° 14.276'W	34° 26.503'N	119° 14.015'W
MSA	3	2.5	3	34° 26.898'N	119° 13.543'W	34° 27.132'N	119° 13.382'W
MSA	4	3.5	4	34° 27.383'N	119° 13.282'W	34° 27.589'N	119° 13.084'W
MSA	5	5.5	6	34° 26.540'N	119° 13.910'W	34° 26.620'N	119° 13.588'W

LVR = lower Ventura River, MVR = middle Ventura River, UVR = upper Ventura River, LSA = lower San Antonio Creek, MSA = middle San Antonio. All km locations are from the downstream end of each respective study reach.

The second survey method was the surveying of 16 index sites subjectively selected (Table 2) with small to medium size gravel that was suitable for steelhead spawning (Shapovalov and Taft 1954; Orcutt et al. 1961). The sites ranged from small pool tailouts to 200 m reaches that consisted of numerous areas for potential spawning. The location of the selected index sites were distributed broadly within the basin to capture general spawning locations, timing, and relative abundance. This spawning survey methodology was initiated in 2008.

Table 2. *O. mykiss* spawning index sites in the Ventura Basin.

Site No.	Unit No.	River/Tributary	River km	General Location Description	Lat. N	Long. W	Length (m)	Width (m)	Area (m^2)[a]
1	1	Ventura River	1.2	Upstream of Main St. bridge	34 17.068	119 18.533	199.0	36.0	480
2	1	Ventura River	7.9	Near treatment plant	34 20.417	118 17.869	90.0	18.0	1080
	2		8.1	Near treatment plant	34 20.524	119 17.910	39.0	20.0	468
3	1	Ventura River	10.0	Near Foster Park	34 21.310	119 18.587	132.0	14.0	524
	2		11.0	Upstream of Foster Park	34 21.796	119 18.660	19.4	6.0	17
	3		9.5	Downstream of Foster Park	34 21.105	119 18.419	7.0	7.0	11
4	1	Ventura River	15.5	Near Santa Ana Blvd bridge	34 23.967	119 18.514	26.7	8.0	28
5	1	Ventura River	18.7	Upstream of Hwy 150	34 25.583	119 18.136	18.0	10.0	72
6	1	Ventura River	22.1	Land Conservancy pool tailout	34 27.201	119 17.585	18.1	19.5	96
	2		22.2	Land Conservancy pool tailout	34 27.267	119 17.579	16.3	14.7	63
7	1	Ventura River	23.3	Robles-1st weir pool	34 27.799	119 17.436	15.4	23.9	42
	2		23.4	Robles-tailout of entrance pool	34 27.862	119 17.427	18.2	21.9	108
8	1	Ventura River	23.6	Upstream of Robles forebay	34 27.968	119 17.380	14.0	5.0	70
	2		24.3	Upstream of Robles forebay	34 28.448	119 17.440	6.2	15.4	27
9	1	San Antonio Cr.	0.0	Upstream of confluence	34 22.815	119 18.444	211.6	7.0	286
10	1	San Antonio Cr.	0.8	Upstream of Old Creek Road	34 22.938	119 18.074	114.1	7.0	233
	2		1.2	Upstream of Old Creek Road	34 23.097	119 18.074	77.8	9.0	195
11	1	San Antonio Cr.	9.5	Off of Creek Road	34 25.960	119 15.056	14.0	6.0	42
	2		9.6	DS of Stewart/San Antonio conf.	34 25.995	119 14.987	22.0	7.0	110
12	1	NF Matilija Cr.	0.7	Lower NF Matilija Cr.	34 29.295	119 18.315	41.0	9.0	132
13	1	NF Matilija Cr.	6.6	DS of Wheeler Gorge Camp	34 29.535	119 16.785	23.0	8.0	19
	2		6.6	DS of Wheeler Gorge Camp	34 30.575	119 16.517	22.3	8.0	24
14	1	Matilija Cr.	1.9	Matilija reservoir delta	34 29.400	119 18.868	26.2	14.6	210
15	1	Matilija Cr.	8.4	End of Matilija Road	34 30.274	119 22.467	20.0	19.0	120
16	1	NF Matilija Cr.	4.1	Near Wheeler's Springs	34 30.495	119 17.374	6.1	8.1	15

[a]Represents estimated area of suitable spawning gravel.

Observations at each site or reach were made to identify and count steelhead redds; redds were identified by typical distinguishing characteristics (Needham and Taft 1934; Orcutt et al. 1968; Chapman 1988, Zimmerman and Reeves 2000). Recently constructed redds generally have physical characteristics that can be used to help identify them. Once a female has selected a potential spawning site that appears to meet her innate spawning needs, redd construction will begin. During construction of a redd, the female *O. mykiss* turns sideways and fans her caudal fin rapidly against the streambed to create a depression in the gravel, defined here as a “pit”. The dislodged sediment drifts downstream and creates a mound of sediment or “tailspill”. The gravel exposed in the pit and the accumulated in the tailspill is usually lighter in color than surrounding gravel, which is useful identifying recent redds. Undisturbed gravel develops a layer of periphyton that darkens the gravel surface. If, during the process of redd construction, the female determines the site is not suitable to complete the redd and the act of spawning, she will abandoned the site. These abandoned sites were defined as test redds.

Once a redd was identified, physical measurements were collected to characterize the spawning habitat similar to Zimmerman and Reeves (2000). Each observed redd was also classified according to its visibility as being: a new redd, obvious and still measurable but not new, no longer measurable but still identifiable, no longer apparent, or a test redd (Garrison 2002; Gallagher and Gallagher 2005). Redd length was measured from the upstream end of the pit to the downstream end of the tailspill and width was measured at the widest point of the tailspill (Figure 4). Water depth was measured at four locations: in the pit, on the side of the pit, upstream of the pit, and at the tailspill. Water velocity upstream and on the side of the pit was measured at 60% of the depth to estimate mean velocity. The predominate surface substrate size adjacent to the redd and on the tailspill was estimated for all redds observed. All side measurements were collected on the thalweg side of the redd. The surface substrate size was estimated by collecting surface gravel samples and randomly measure the first 30 substrate diameters at the intermediate axis. Photos and GPS locations were also recorded for all redds identified.

The spawning surveys were conducted biweekly from January through June and observations were made at each site, if surface water was present, to count and record redd characteristics.

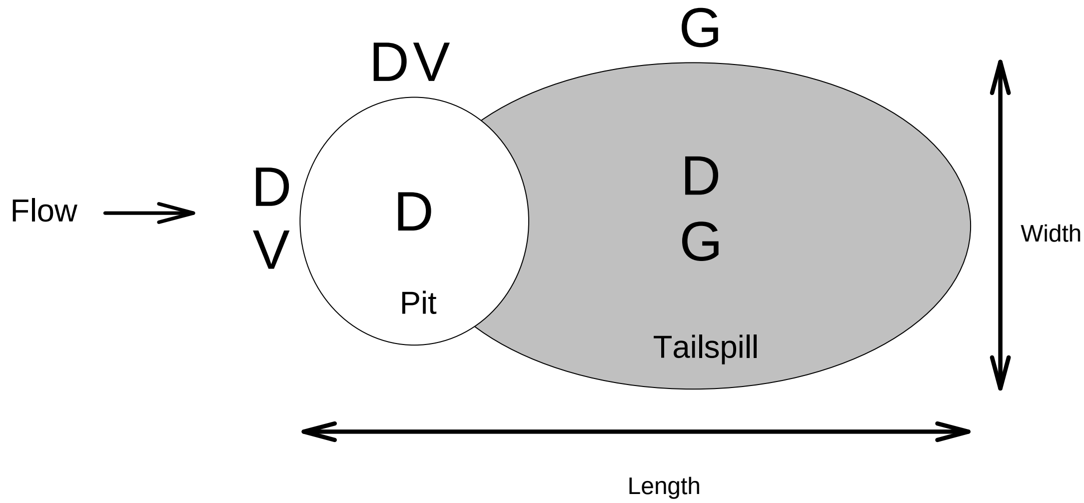

Figure 2. Diagram of measurements collected on all identified *O. mykiss* redds. D = locations of depth measurements, V = location of water velocity measurements, and G = location of gravel substrate sampling.

Results

A total of 65 *O. mykiss* redds were identified during 2008-2010 spawning surveys. This included the random and index sites and reaches, as well as other redds found during the course of other *O. mykiss* monitoring projects (Table 3). Three redds were included in the 2010 total count that were not included in subsequent analysis because redd data was not collected or date could not be confirmed.

Table 3. Number of *O. mykiss* redds identified during the 2008-2010 spawning surveys.

	Survey Type			
Year	Random	Index	Other	Total Redds
2008	-	3	-	3
2009	4	4	2	10
2010	39	21	6	52[a]
Total Redds	43	28	8	65[a]

[a]The total number of redds during 2010 and the total for all survey types and years reflect a correction for index sites that were within a random survey reach.

Random Surveys—During 2009, only 4 redds were identified; of those, 3 redds were found in North Fork Matilija Creek of the upper Ventura River survey reach and 1 redd was found in the first 0.5 km of the lower San Antonio study reach. During 2010, 39 redds were identified in the same two study reaches; 4 redds in the upper Ventura River reach and 28 redds in the lower San Antonio reach. In addition, 7 redds were also found in the middle San Antonio Creek study reach. Over the course of the two-year survey, no redds were found in the lower Ventura River and middle Ventura River study reaches. The expanded redd population estimate for all five study reaches in 2009 was 16 total redds (95% CI = 21). The expanded redd abundance estimate for the same study reaches in 2010 was 159 total redds (95% CI = 153); (Table 4).

Table 4. Total *O. mykiss* redd estimates for 2009 and 2010 and corresponding 95% confidence intervals and ranges. The lower end of both ranges equals redds observed since the calculated lower confidence interval range was less.

Year	Redds counted	Total redds estimated	95% confidence interval	95% confidence interval range
2009	4	16	21	4 to 37
2010	39	159	153	39 to 312

Index Surveys—The total number of redds counted in index sites increased from 3 redds in 2008, to 4 redds in 2009, and finally 21 redds in 2010. In addition to the regular index sites, redds were found at locations not included in the index sites and were found during other *O. mykiss* monitoring projects in the basin. In 2009, 2 redds were found; one in Matilija Creek upstream of Matilija Dam and one in North Fork Matilija Creek. During 2010, 5 redds were found in San Antonio Creek and one in the Ventura River just downstream of the San Antonio Creek confluence.

Redd Distributions—Approximately 24% of the mainstem Ventura River was surveyed in both 2009 and 2010, which included both the random and index surveys. All 4 redds observed were located downstream of San Antonio Creek (Figure 3). The spawning surveys covered approximately 26% of North Fork Matilija Creek and 9 of the 10 redds found in both years were located in the upper portions of the study area (Figure 4). In San Antonio Creek, 38% of the creek was surveyed in both years. There were two main groupings of redds; the lower 2 km had approximately 65% of the redds observed and remaining redds were found between rkm 6 and 11 (Figure 5).

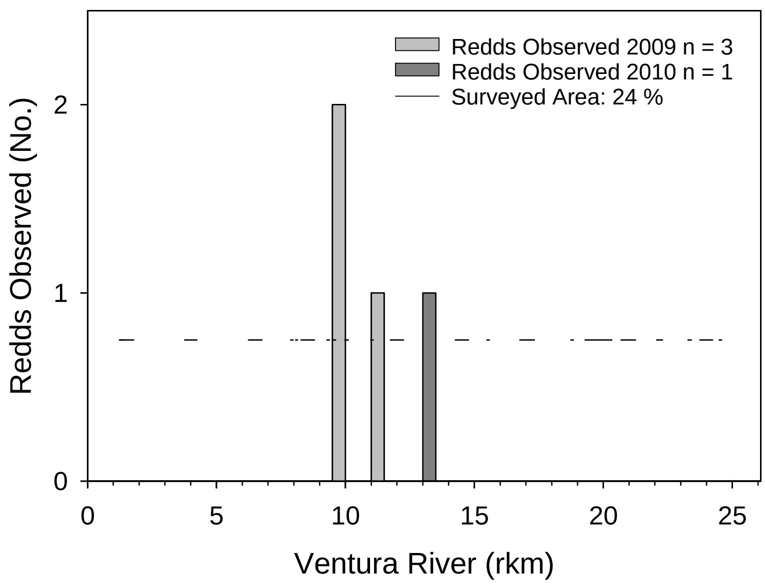

Figure 3. Distribution of redds observed in 2009 and 2010 in the mainstem Ventura River.

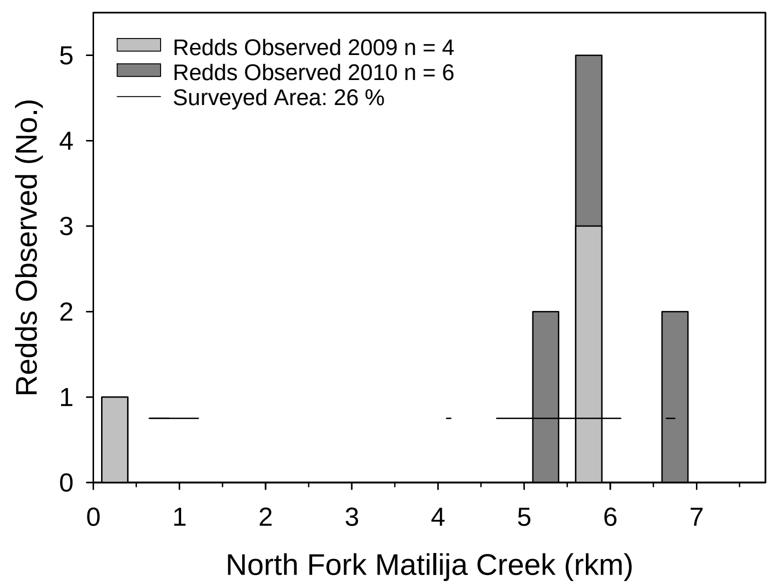

Figure 4. Distribution of redds observed in 2009 and 2010 in North Fork Matilija Creek.

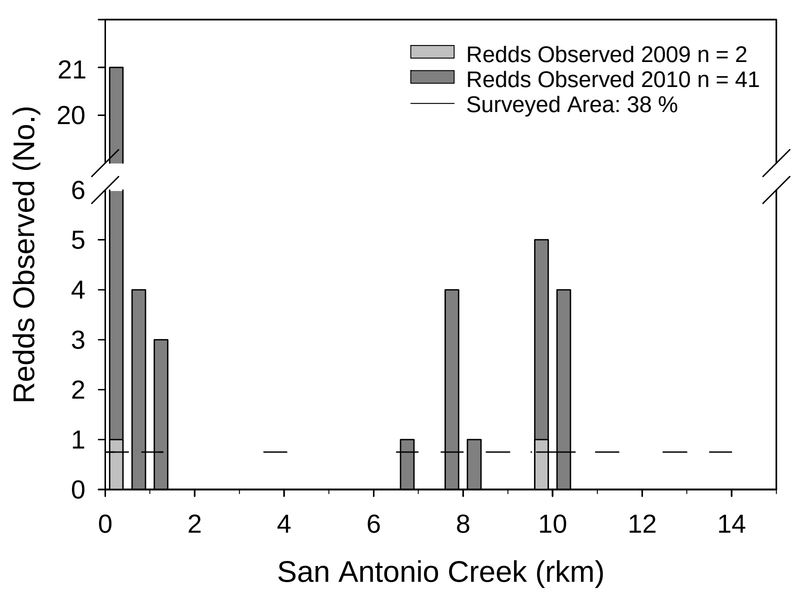

Figure 5. Distribution of redds observed in 2009 and 2010 in San Antonio Creek.

Spawn Timing—The timing distribution of observed redds during 2009 and 2010 ranged from 14 January to 27 April (Figure 6). During 2009, the first redd was observed on 26 February and the last on 14 April. The median spawn date was approximately 01 April 2009. During 2010, the first redds was observed on 14 January and the last on 27 April. The median spawn date was approximately 10 March 2010.

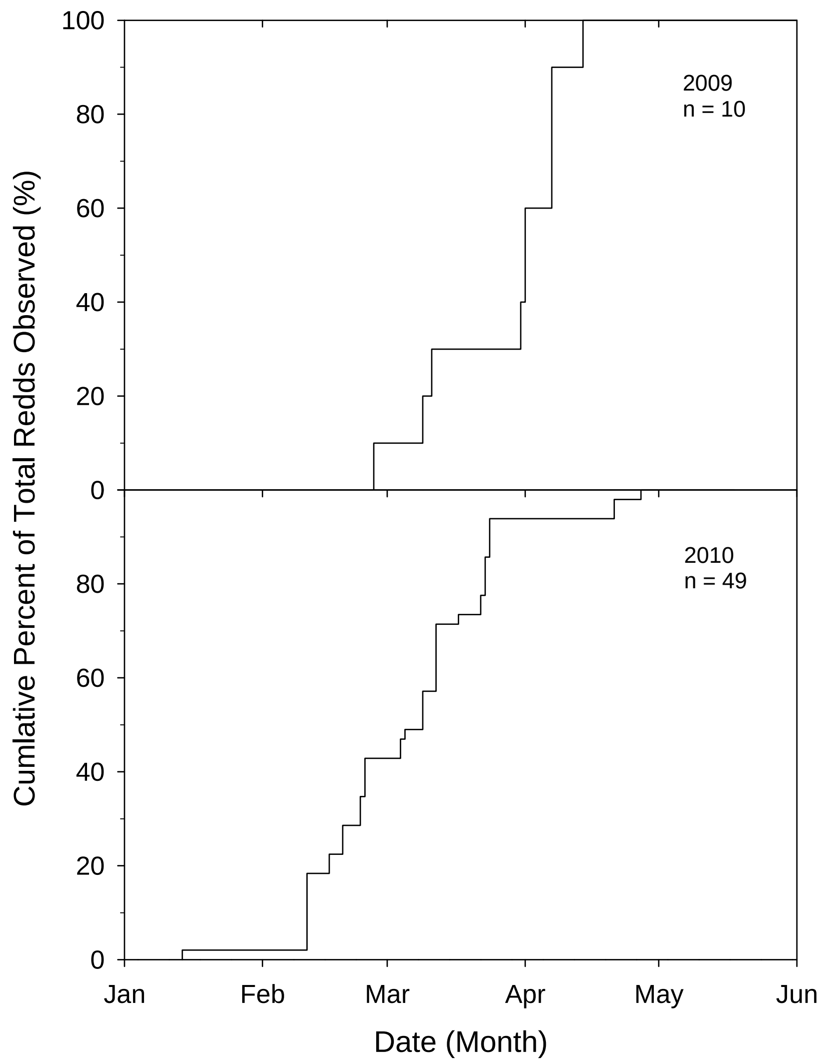

Figure 6. Spawn timing distribution of *O. mykiss* redds observed during 2009 and 2010 in the Ventura River basin.

Microhabitat measurements—The microhabitat variables measured was intended to help describe the characteristics that spawning *O. mykiss* may use in selecting locations to spawn and the resulting redd characteristics. The mean distance to cover of redds was 10 m. In San Antonio Creek this distance was less, but the larger distances of the mainstem redds skewed the mean slightly. The median distance to cover was more representative at 8 m. Measured redds ranged from a length of 35 to 203 cm with a mean of 97 cm. Redd widths ranged from 27 to 118 cm with a mean of 54 cm (Figure 7).

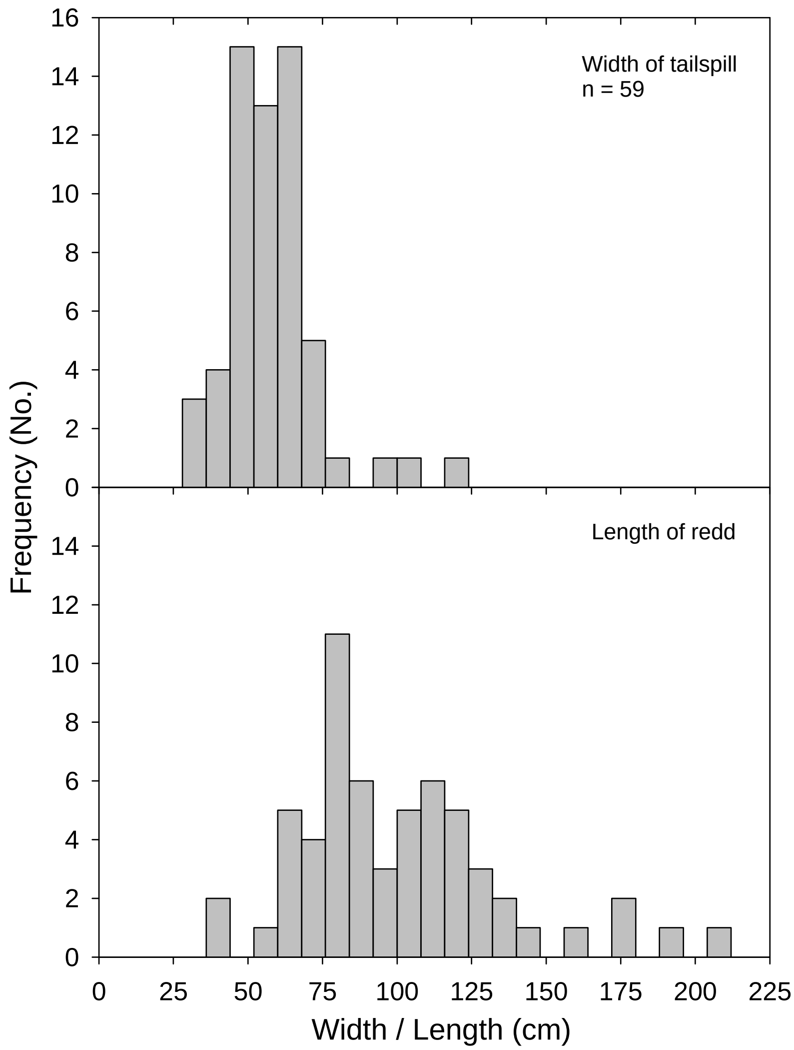

Figure 7. Measured redds lengths and widths from 2009 and 2010 in the Ventura River basin.

Depths of measured redds at both the head of the pit and adjacent to the pit were similar. Depths adjacent to the pits ranged from 4 to 28.5 cm with a mean of 13.5 cm. Depths at the head of the pits ranged from 5 to 29.5 cm also with a mean 13.5 cm. Pit depths ranged from 8 to 36 cm with a mean of 18 cm. Tailspill depths ranged from 2 to 26 cm and had a mean of 10 cm (Figure 8).

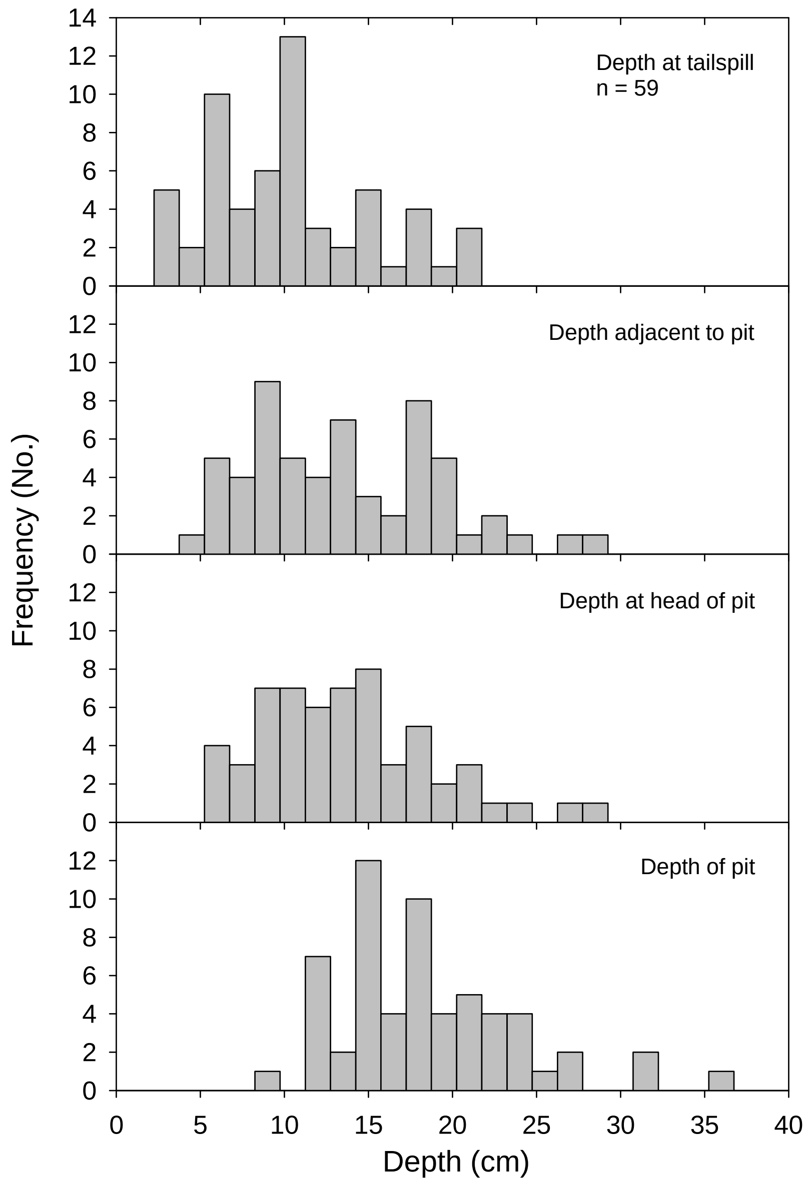

Figure 8. Depth frequency distributions of measurements for redds during 2009 and 2010 in the Ventura River basin.

Water velocity measurements of redds adjacent to the pits and at the head of the pits were very similar. Velocity adjacent to pits ranged from 0.06 to 0.54 m/sec and the mean was 0.31 m/sec. Water velocity at the head of pits ranged from 0.07 to 0.61 m/sec and the mean was 0.33 m/sec (Figure 9).

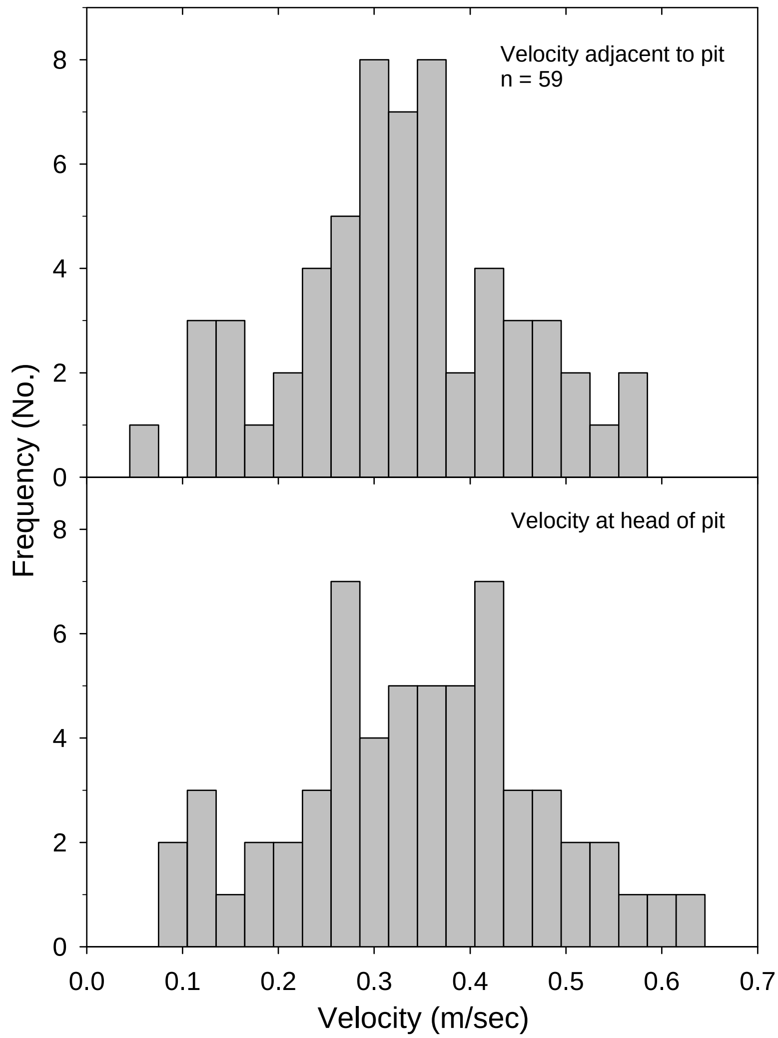

Figure 9. Water velocities at the head and adjacent to the pit for redds measured during 2009 and 2010 in the Ventura River basin.

Gravel size of redds measured during 2009 and 2010 for both the tailspill and adjacent to tailspill were somewhat similar. As would be expected, the undisturbed gravel adjacent to the tailspill was larger and ranged from a mean of 10 to 40 mm. The mean gravel size of the tailspills ranged from 8 to 37 mm and a mean of 19 mm (Figure 10).

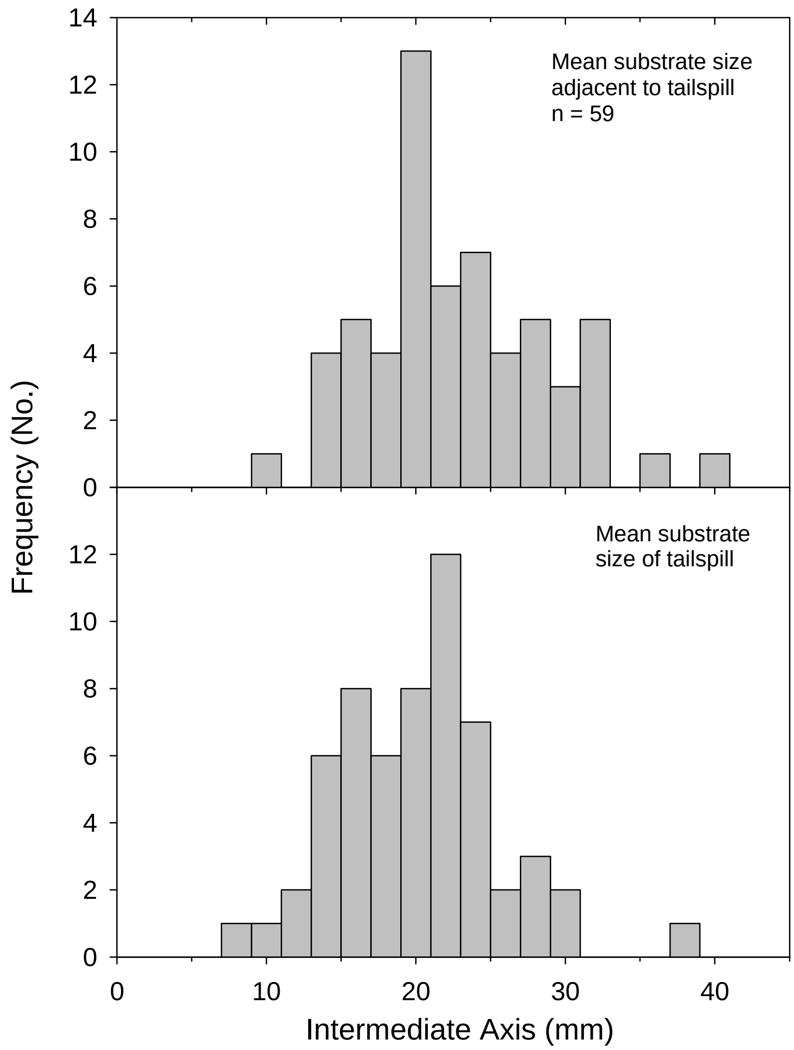

Figure 10. Mean substrate size adjacent to the tailspill and the surface of the tailspill for redds measured during 2009 and 2010 in the Ventura River basin.

Discussion

The two spawning survey methods used in 2009 and 2010 did result in a difference in total number of redds observed. This should not be too surprising since the random spawning survey covered 23% of the potential spawning area and the index covered only 2%. In 2009, both survey methods found 4 redds. The overall redd count was low, likely due to a dry water year, and comparisons would seem pointless. During 2010, however, there was an average rain year and comparisons do provide some insight. Even though over 10 times as much of the basin was covered for the random survey, only about 2 times the number of redds were counted. It would seem likely that the reason for this is the subjective selection of the index sites were in locations where much of the total *O. mykiss* spawning occurs in the basin. This was the original intent of the index survey and this seems to confirm that the sites were selected appropriately. The index sites were selected after much of the potential spawning areas had been surveyed using stream survey methods, or at least some reaches visited. This allowed the index sites to be placed in areas that seemed to be suitable for spawning, mainly the presence of suitable gravel. As with all, only relative abundance of redds can be determined. Therefore, 2008 and 2009 were similar in spawning abundance and 2010 represented a large increase. The disadvantage of subjectively selected monitoring sites is that total abundance cannot be estimated.

The stratified random surveys did reveal more redds, but most importantly, an expansion of the mean counts allowed the total abundance to be estimated. The estimated total of 16 redds in 2009 and a large increase to 159 redds in 2010 represents the first attempt to estimate redd abundance in the Ventura River basin to our knowledge. Due to the large variability of the 0.5 km reach counts, however, the resulting 95% confidence intervals were very large also. In both years, the actual redd counts represent approximately 25% of the abundance estimates, which indicates some measure of method precision or repeatability. The bias of the abundance estimates relative to the true redd abundance was unknown.

The ultimate goal of redd abundance estimation is the determination of the adult spawner population, which has been accomplished using several methods. Duff (2005) recommends using a correction factor of 1.93 redds per female for steelhead, which was based on Gallagher and Gallagher (2005). Applying this correction, and assuming a sex ration of 1:1, yields an estimate of 17 spawning *O. mykiss* in 2009 and 164 in 2010. Other methods of redd to spawner estimates yielded mostly larger estimates. In Oregon, for example, 1.54 females per redd is used and in Washington, 2.5 spawners per redd is use (Gallagher et al. 2007). These other redd to spawner methods would estimate about 490 and 400 spawners for 2010, respectively. The estimate of 17 *O. mykiss* spawners in 2009 and 164 in 2010 appears to be closer to what we would have expected, although we have no way to confirm this. If the sex ratio was known, the estimates could have changed slightly. More work to understand *O. mykiss* spawning in the Ventura River basin should help to determine which redd to spawner correction ratio should be used.

The distribution of redds in the Ventura River basin seem to be closely correlated with the presence of suitable spawning gravel. In the mainstem Ventura River, the few redds located were downstream of the San Antonio Creek confluence. San Antonio Creek appears to be a good source of spawning gravel recruitment for the mainstem Ventura River, which is reflected in the larger amount of gravel estimated from a habitat assessment downstream of the confluence (Gibson and Lewis 2011). San Antonio Creek appears to be a very important tributary to *O. mykiss* spawning in the Ventura River. In 2010, approximately 90% of the observed redds in the stratified random survey were located in San Antonio Creek. San Antonio Creek has large amounts of suitable spawning gravel relative to the rest of the Ventura Basin (Gibson and Lewis 2011). This, coupled with relatively better water conditions than other parts of the lower Ventura River basin, is the reason San Antonio Creek should be considered key in the recovery of steelhead in the Ventura River. Restoration work to create better rearing habitat for *O. mykiss* should be of primary importance.

The physical redd characteristics were difficult to compare with other similar data since few studies have measured *O. mykiss* redds in southern California. Zimmerman and Reeves (2000) estimated mean steelhead and rainbow trout redd lengths at 208 and 150 cm, respectively. Our estimated mean redd length of 97 cm was smaller than the rainbow trout redds of Zimmerman and Reeves (2000). The majority of their resident *O. mykiss* were in the in the 20-35 cm range and would likely indicate that the vast majority of the redds measured in this study were created by resident *O. mykiss*. In fact, all other comparable redds characteristics (i.e., width, depth, velocity, and gravel size) were less for the Ventura River redds. Undoubtedly, some of this is due to dissimilarities of the river systems and more comparable data from southern California would be useful.

Identification of redds can be a rather subjective task. Disturbances in the gravel have to first be identified, which is not always easy. Gravel disturbances can be caused by a variety of sources other than fish (e.g., hydraulic scour, humans, ducks, and horses) and have to be eliminated. Once it has been determined that a disturbance is a redd, determining if it has been completed (i.e., eggs have been deposited in the gravel) becomes an issue. During this study, only four gravel disturbances were determined to be test redds and it was not known how accurate this was. Without observing the actual fish spawning on a redd, or excavating the redd to determine if eggs are present, it is difficult to be fully confident that the redd was completed. If the tailspill seems long enough to include an egg pocket and the redd seems to be in suitable habitat, then redd completion seems likely, however this type of criteria cannot be verified. Ultimately, the determination of a redd as being created by resident or anadromous *O. mykiss* is a bigger issue. Depending on the river system, there can be an overlap of redd characteristics. Additional basin specific data can help with this determination, but it is no guarantee. In San Antonio Creek, for example, a few large redds were found in 2008 that produce good numbers of fry. This cohort had been followed since then using snorkeling methods and it seems plausible that much of the spawning in 2010 could be attributed to that cohort (Lewis and Gibson 2010); however, this cannot be confirmed. Additional data collection like scales samples would be useful in this determination. Even if the vast majority of the spawning activity in 2010 could be attributed to resident *O. mykiss*, the maternal origin of those spawners was in all likelihood anadromous *O. mykiss*.

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