



## Santa Paula Creek Watershed Planning Project: Steelhead Habitat and Population Assessment

### TECHNICAL MEMORANDUM

*Prepared for*  
Santa Paula Creek Fish Ladder Joint Powers Authority  
California Department of Fish and Game

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## 1 INTRODUCTION

Coastal populations of *Oncorhynchus mykiss* may be composed of both anadromous and freshwater resident life histories. Individuals expressing anadromous life histories are referred to as steelhead, while those that remain in freshwater for the duration of their life cycle are referred to as rainbow trout. In Santa Paula Creek, a tributary to the Santa Clara River, Ventura County, California, opportunities for expression of the anadromous life history are restricted by migration barriers preventing the upstream return of adult steelhead. A residual population of *O. mykiss* now persists in suitable stream habitat above the Harvey Diversion (Stoecker and Kelley 2005). Restoring the migratory component of *O. mykiss* within the watershed has been identified as a priority management goal. In support of feasibility studies concerning the restoration of migratory fish passage within Santa Paula Creek, the California Department of Fish and Game requested an assessment of the residual rainbow trout population be conducted to meet the following objectives:

1. Determine the spatial distribution of *O. mykiss* in Santa Paula Creek and key tributaries.
2. Determine key habitat characteristics of stream reaches occupied by *O. mykiss*.
3. Determine the relative abundance and age class structure of *O. mykiss*.

This report describes the methods and results of work completed to date, consisting of a reconnaissance-level field effort conducted in May 2007 and a more detailed population assessment of *O. mykiss* during November 2007. Results from these field efforts provide baseline information on *O. mykiss* distribution, habitat, and abundance in the Santa Paula Creek watershed under conditions which do not allow anadromy.



## 2 METHODS

Stream habitat and fish surveys were conducted in May and November 2007 within the Santa Paula Creek watershed. Stream habitat surveys were conducted to identify dry stream reaches, determine maximum daily stream temperatures throughout the watershed, and continuously monitor temperature throughout the summer months. Fish surveys were conducted to determine the distribution, relative abundance, and age class structure of *O. mykiss*. High stream temperatures have been identified as a factor that may limit availability of summer rearing for *O. mykiss* in the southern end of their range (Boughton *et al.* 2006), and was therefore chosen as a key characteristic of summer rearing habitat to monitor within the Santa Paula Creek watershed. Surveys were conducted in three portions of the Santa Paula Creek watershed (Map 1). Each portion was selected to include potential rearing habitat for anadromous *O. mykiss* above Harvey Diversion Dam (RM 3.9), and therefore did not extend past natural (*e.g.*, waterfall) migration barriers identified by previous surveys (Stoecker and Kelly 2005). Accessible portions of Santa Paula Creek extend from Harvey Diversion Dam (RM 3.9) to the natural waterfall barrier upstream (RM 9.8). Accessible portions of Sisar Creek extend from the confluence (RM 0.0) to barriers identified by Stoecker and Kelly (2005) in Sisar Creek (RM 5.9) and East Fork Sisar Creek (RM 0.5). The survey reaches are:

- **Little Santa Paula Creek:** from the confluence with Sisar Creek (RM 6.6) to the East Fork of Santa Paula Creek just upstream of the natural waterfall barrier (RM 9.8).
- **Sisar Creek:** beginning at the confluence with Santa Paula Creek (RM 0.0) upstream past the Forest Service Gate (RM 4.1).
- **Mainstem Santa Paula Creek:** downstream of the Sisar Creek confluence, near the downstream end of Steckel Park (RM 4.5) upstream to the confluence with Santa Paula Creek and Sisar Creek (RM 6.6).

### 2.1 Dry Reach and Stream Temperature Surveys

Dry stream reaches were identified in May and November by walking the stream channel and mapping the extents of completely dry stream channel on aerial photographs (scale of 1:1,274). The field maps were then digitized in a geographic information system (GIS) and the length of dry channel was measured from using 2005 color orthophotos and 1 meter LIDAR DEM.

Summer stream temperature monitoring consisted of detailed mapping of maximum daily stream temperatures at the beginning of the dry summer season and continuous temperature monitoring at selected sites throughout the watershed. On May 23, 2007, instantaneous measurements of maximum daily stream temperature were collected with a YSI 85 thermometer and mapped on aerial photographs at 1°C intervals. All instantaneous measurements were taken between 2:00pm–4:30pm, when stream temperatures were hottest and temperature fluctuation was lowest. Preliminary continuous temperature data from confirmed that maximum daily stream temperatures occurred during the afternoon hours between 2:00pm and 4:30pm (Figure 2-1).

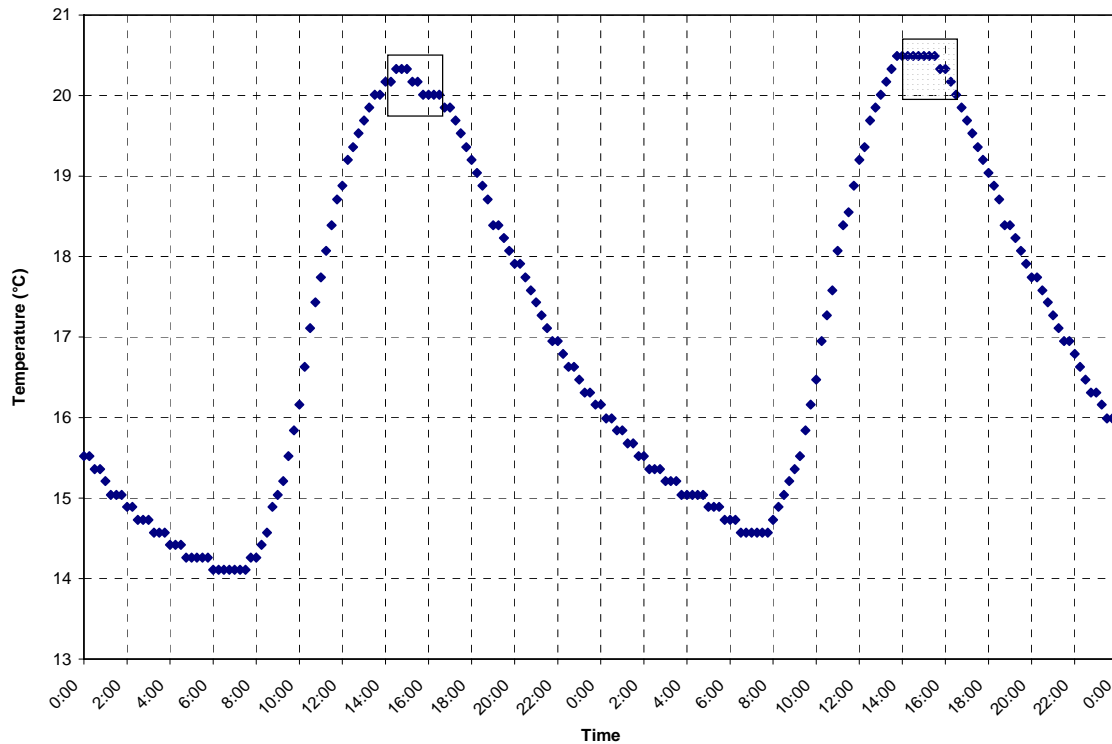


Figure 2-1. Continuous stream temperature in 15-minute intervals in Sisar Creek, above the confluence with Santa Paula Creek, May 2007. The time period during which instantaneous measurements of maximum daily stream temperature were taken is highlighted.

In addition to the maximum daily stream temperature measurements, continuous stream temperature monitoring was initiated during our May survey. Continuous temperature loggers were deployed at 22 locations throughout the watershed (Map 1). Sites were selected based on the results of maximum temperature mapping to capture the range of temperatures in potentially suitable summer rearing habitat. Thermographs used were Stowaway TidBits (Onset Computer Corporation, Pocasset, MA) and were set to record water temperature at 15-minute intervals. Two additional thermographs were attached to riparian vegetation to record ambient air temperature in areas adjacent to stream temperature monitoring sites. Upon retrieval in November, two thermographs were not recovered and six were no longer submerged (Table 2-1).



Table 2-1. Location and condition of continuous temperature monitors placed throughout the Santa Paula Creek watershed, from May to November 2007.

Creek	Thermograph ID	River Mile	Condition
Mainstem Santa Paula Creek	1A (air)	3.9	air temp
	1B (water)	3.9	missing
	2	6.6	in water
Little Santa Paula Creek	3	6.7	missing
	4	6.9	in water
	5	7.3	dry channel bed
	6	7.4	in water
	7	7.6	in water
	8	8.0	in water
	9	8.3	in water
	10	8.5	in water
	11	8.8	in water
	12	9.0	in water
	13	9.5	in water
Sisar Creek	14	0.0	in water
	15	0.5	dry channel bed
	16	0.6	dry channel bed
	17	1.6	not submerged
	18 A (air)	2.2	air temp
	18 B (water)	2.2	in water
	19	2.4	in water
	20	3.3	not submerged
	21	3.8	not submerged
	22	4.1	in water

## 2.2 *O. mykiss* Presence and Absence Surveys

To identify the distribution of *O. mykiss* during May, a protocol for quickly determining presence of *O. mykiss* in pool habitats within study reaches was developed using a combination of visual surveys and electrofishing. Although age 0+ *O. mykiss* were documented during the survey, we focused our effort on age 1+ and older *O. mykiss* (defined as fish >75 mm at the time of the May survey) because we believed that their survival through the previous summer made their presence a more reliable indicator of reaches providing suitable summer rearing habitat. Additionally, age 0+ *O. mykiss* may still have been emerging during the May survey, and so their potential absence from stream reaches might not be a reliable indicator of summer habitat quality.

Presence and absence surveys proceeded in a stepwise fashion. First, streamside observations were made by slowly walking upstream along the streambank and observing all pool habitat for *O. mykiss*. In pools where no age 1+ or older fish were observed during streamside observations, the pool was snorkeled to search for age 1+ and older fish. If age 1+ and older fish were still not observed while snorkeling, the pool was subsequently electrofished using a single pass to verify the absence of fish. An exception to this protocol occurred in mainstem Santa Paula Creek where we relied solely on electrofishing to determine fish presence because water visibility was not sufficient for streamside or underwater observations.

The extent of stream surveyed varied by study reach. In Sisar Creek, where habitat quality and stream temperatures were relatively consistent, we focused pool habitat in areas near the upstream and downstream extent of wetted reaches to document where *O. mykiss* persisted in relation to stream de-watering. Presence and absence surveys in pool habitat was continuous in Little Santa Paula Creek (*i.e.*, all pools were sampled) to verify the presence of *O. mykiss* within portions of the stream that exhibited high temperature variability and habitat quality over relatively short distances. All pools sampled were given unique identification numbers, and locations were documented on aerial photographs and recorded using a GPS unit. Sample pools were then digitized in GIS.

In November, we revisited pool habitat within the warmest portions of Little Santa Paula Creek to determine if pools where fish were present in May still contained fish at the end of the dry season. We did not differentiate between age classes during the November survey because the sizes of some age 0+ and age 1+ fish were similar by the end of summer and we therefore did not have a practical sized-based determination of fish age to use in the field. Because the survey was inclusive of all age classes, it provides a conservative assessment of fish persistence over the summer (*i.e.*, the absence of fish of any age class should be a more reliable indicator of unsuitable habitat than the absence of a particular age class of fish).

### 2.3 *O. mykiss* Population Surveys

In November 2007, habitat and electrofishing surveys were conducted to determine *O. mykiss* densities and age class structure with Little Santa Paula Creek and Sisar Creek. Population surveys were conducted at three reaches within the Santa Paula Creek watershed (Map 2):

#### **Little Santa Paula Creek:**

- Middle Little Santa Paula Creek: from RM 8.0 to RM 8.3.

#### **Sisar Creek:**

- Lower Sisar Creek: just upstream of the Osborn road crossing (RM 2.2) to ~ 200 ft below the Koenigstein Road crossing (RM 2.4).
- Upper Sisar Creek: ~ 500 ft upstream of the Sisar Road crossing (RM 3.9) upstream to the confluence with a dry tributary (RM 4.0).

Study reaches were chosen to represent locations within Little Santa Paula Creek and Sisar Creek that appeared to provide relatively high quality habitat. The Little Santa Paula Creek and Lower Sisar Creek reaches were chosen because of relatively cool stream temperatures and previous observations of *O. mykiss* during the May survey. The Upper Sisar Creek reach was selected to determine whether densities or age classes of *O. mykiss* differed in a portion of Sisar Creek with different channel conditions (*e.g.*, higher channel gradient). However, we combined estimates in Sisar Creek after we determined that habitat-specific densities were similar in the two reaches. These population surveys were intended to compare densities of “good habitat” within the two creeks, and were not necessarily intended to provide values to extrapolate throughout the watershed. A more comprehensive population survey including a number of sites over a variety of reaches designated by differences in slope, confinement, and substrate would allow for extrapolation of densities to a watershed-wide population estimate.

Reach-level habitat measurements occurred by obtaining general habitat parameters such as habitat type, average length and average width to determine habitat type frequency and area

within each reach. Habitat types were determined using definitions described by the California Department of Fish and Game (Flosi *et al.* 1998). Four habitat types were identified during the course of the survey: pools, pocketwater, riffles, and runs. Pocketwaters were defined as a unit with exposed boulders creating eddies and scour holes throughout the unit (Flosi *et al.* 1998). Pools exhibited slow velocity habitat with consistent depth and scour throughout the majority of the channel width. Riffle and runs were rare habitat types, where riffles were shallow with little surface flow with exposed substrate, whereas runs had more volume, little surface agitation and exposed substrate. In cases where sections of creek seemed to be distinct habitat types but were not as long as they were wide, they were lumped in with adjacent habitat units.

Units chosen for electrofishing surveys were selected by identifying the two most dominant habitat types that existed within each reach that likely provided suitable habitat for *O. mykiss*. The two dominant habitat types were identified by the habitat measurements for each reach, and were determined to be pool and pocketwater habitat. Within each reach up to four units of the dominant habitat types (pools and pocketwater) were selected. These units were selected by choosing representative sample units that were spatially distributed throughout the length of each reach. Additional detailed habitat measurements were taken at each electrofished unit and included average lengths, widths, depths, maximum depth, and percent cover. All units were given a unique identification number, and locations were documented on aerial photographs and recorded using a GPS unit.

Electrofishing surveys occurred in each sample unit by using a Smith-Root LR-24 backpack electrofisher. Each unit was blocked off with nets to prevent movement of fish in or out of the sampling areas. The bottoms of the block nets were sealed off with rocks, and the tops of the nets were propped above the water surface with dowels or PVC pipe. Each field technician carrying a backpack electrofisher was accompanied by one or two netters. One backpack electrofisher with two netters was sufficient for coverage of the sampling areas. The sampling crew, to the degree possible, maintained a line perpendicular to the stream channel while moving upstream to maximize capture probabilities. A multiple-pass depletion method was employed at each sample unit, starting with a minimum of three passes and continuing with additional passes if a sufficient depletion was not obtained. After each pass, all fish were processed by measuring fork length (FL) to the nearest millimeter (mm) and weight to the nearest 0.1 gram. Scales were taken from a subset of *O. mykiss* over 80 mm (FL) to archive for aging if desired at a later date. After processing, fish were kept in a live well in an adjacent habitat unit and were released into their original habitat once they had sufficiently recovered from the effects of handling.

Densities were calculated by determining estimates of abundance for each sampled unit based on multiple-pass depletion electrofishing. A robust, jackknife estimator of abundance was applied (Pollock and Otto 1983), as proposed by Mohr and Hankin (2005) for estimation of fish abundance in small streams:

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

where  $\tilde{y}_J$  is the estimate of abundance for unit J,  $c_i$  is the number of fish captured on the  $i$ th pass,  $r$  is the total number of passes, and  $c_r$  is the number of fish captured on the final pass. These estimates of unit abundance were then divided by the respective measured habitat areas to obtain fish densities by unit.

Density estimates are often calculated separately for each age class of *O. mykiss* to determine variations of abundance for each age class. These calculations were not possible for the Santa Paula Creek watershed due to the difficulty of determining age class delineations by length frequency histograms (see *O. mykiss* Age Class Structure). Scale samples taken during electrofishing surveys could be analyzed at a later date to determine age class specific densities.

## 3 RESULTS AND DISCUSSION

### 3.1 Stream Temperature Surveys

The following sections provide results and discussion for stream temperature surveys conducted in May and November 2007.

#### 3.1.1 Dry Reaches

In May 2007, all tributaries to the Little Santa Paula Creek reach were completely dry, with the exception of Sisar Creek. An additional dry reach of 0.06 miles was identified within Little Santa Paula Creek (near RM 7.1) and two dry reaches were identified within Sisar Creek (RM 0.6 to RM 1.4 and RM 2.5 to RM 3.2). Dry reaches observed in May 2007 are shown in Map 1.

By the end of summer, the length of the dry reaches in Little Santa Paula and Sisar creeks increased significantly (Map 2). In Little Santa Paula Creek, the extent of the dry reach increased from a 0.06 miles in May to 0.3 miles in November, extending from RM 7.0 to RM 7.3. In Sisar Creek, the two dry reaches increased in length by 0.6 miles combined, with one reach extending from RM 0.2 to RM 1.4, and the other reach extending from RM 2.4 to RM 3.3. Cumulatively, the dry reaches in Sisar Creek reduced the available summer rearing habitat by 2.1 miles, which is equivalent to 32% of the stream length potentially accessible to anadromous *O. mykiss* in Sisar Creek. Recent surveys during the beginning of a wet water year, in November 2004, reported no dry reaches in either Little Santa Paula Creek or Sisar Creek (Stoecker and Kelley 2005). Although these surveys were not continuous in each creek, some of their sites were within reaches that were dry during our November 2007 surveys, indicating the extent of available habitat for *O. mykiss* may vary considerably from year to year.

#### 3.1.2 May Maximum Daily Stream Temperatures

Maximum daily stream temperatures in May ranged from 16 to 28 °C within the study reaches. Little Santa Paula Creek had the highest maximum daily stream temperatures and the highest variability in daily temperature. Maximum daily stream temperatures in Little Santa Paula Creek ranged from 19 to 28 °C. Measurements in Little Santa Paula Creek demonstrate a repeating pattern of cooling and warming of surface temperatures (Map 3). This pattern appears to correspond with variation in valley-bottom width (defined as the distance between valley walls perpendicular to the stream channel) and surface flow volume. As the valley-bottom widens, surface flow diminishes and maximum daily stream temperatures increase rapidly due to a combination of diminishing flow and direct insolation to the entire wetted channel (riparian shading is currently negligible). In areas where the valley-bottom width narrows, surface flow increases and temperatures cool abruptly, presumably due to increasing groundwater contributions to surface flow. The relationship of valley-bottom width (measured from using 2005 color orthophotos and 1 meter LIDAR DEM in GIS) and maximum daily stream temperature is illustrated in Figure 3-1 .

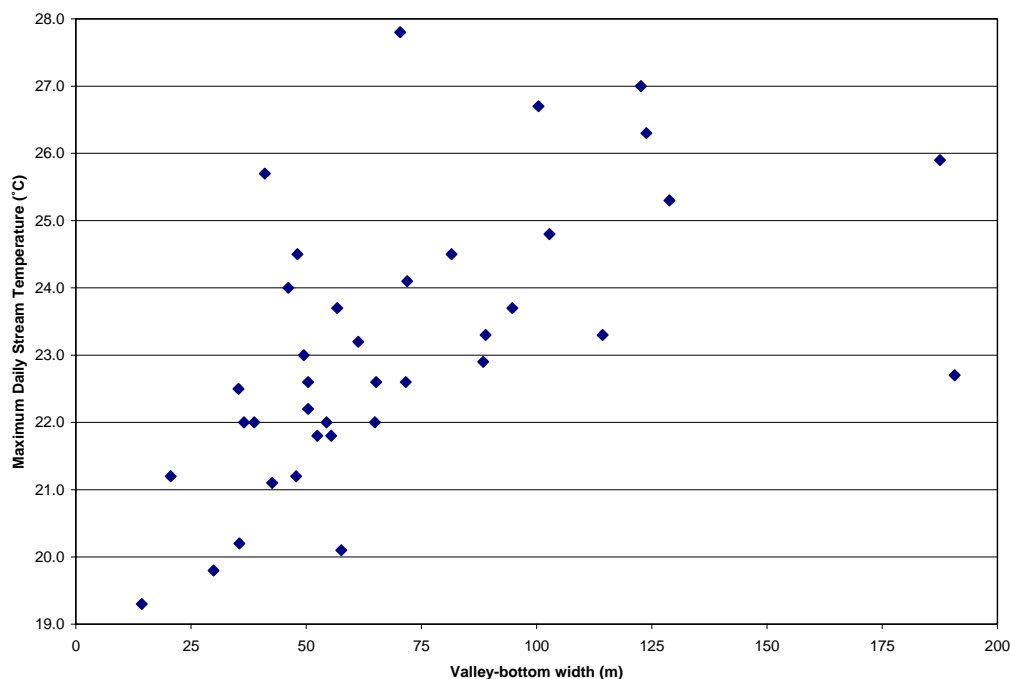


Figure 3-1. Relationship of valley-bottom width and maximum daily stream temperature in Little Santa Paula Creek, May 2007.

Sisar Creek maintained cooler and less variable stream temperatures than Little Santa Paula Creek, likely due to the extensive riparian cover throughout Sisar Creek. Maximum daily stream temperatures in May were below 18.0°C (Map 3) with the exception of the lower 0.6 miles of Sisar Creek, in which temperatures reached 21°C. Within this portion of Sisar Creek stream temperature increased from 16.0°C to 19.0°C within 330 ft, likely due to a near total absence of riparian shading. Variation in valley-bottom width was less significant in Sisar Creek than in Little Santa Paula Creek, and although groundwater recharge was observed, it was less obvious from field observations how the geology and geomorphology of Sisar Creek contribute to patterns of surface flow. Dry reaches tended to be found in areas where water diversions or in-channel pumping occurred, suggesting that human water use contributes to stream drying in Sisar Creek.

Mainstem Santa Paula Creek had consistently high maximum daily stream temperatures ranging from 21.6°C to 26°C (Map 3), although fewer stream measurements were taken in this reach due to the small number of *O. mykiss* observed (see *O. mykiss presence and absence surveys* below).

### 3.1.3 Continuous Temperature Monitoring

Temperature was monitored continuously from May through November. Stream temperatures reached maximum weekly average temperatures (MWAT) in early September. The greatest variability in MWAT occurred in Little Santa Paula Creek, ranging from 21.4°C to 25.8°C. Sisar Creek had lower and more consistent MWAT values than Little Santa Paula Creek, ranging from 20.4°C to 21.8°C (Figure 3-2). Longitudinal patterns in MWAT were similar to the repeated cooling and warming observed in maximum daily temperature in May (Figure 3-2; Map 3).

Two thermographs were deployed in mainstem Santa Paula Creek but only one was retrieved in November 2007. The only retrieved thermograph was immediately below the confluence and

was not representative of the reach, therefore preventing comparisons of MWAT to other creeks. The retrieved thermograph was located just downstream of the confluence with Little Santa Paula Creek and resulted in an MWAT of 22.0°C, a value in-between the most downstream sites in both creeks above the confluence. Although the most downstream thermograph was not retrieved, we can infer by the close relationship of MWAT to maximum daily measurements in May, that stream temperatures warm with distance downstream from the confluence of Sisar Creek and Santa Paula Creeks.

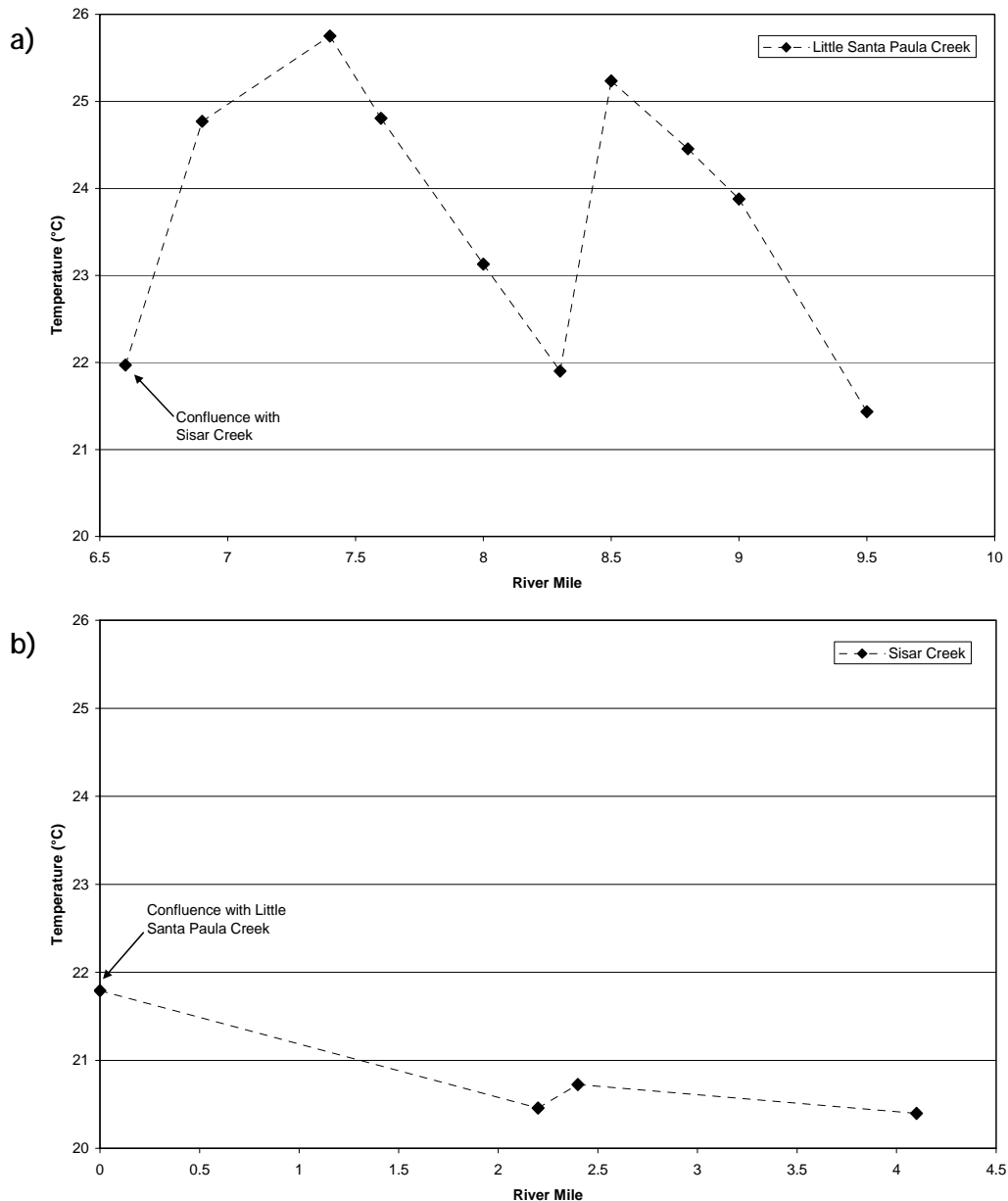


Figure 3-2. Maximum Weekly Average Temperature (MWAT) in a) Little Santa Paula Creek and b) Sisar Creek. All MWATS occurred during weeks ending in early September (9/4, 9/5, or 9/6), 2007.

Instantaneous data during the warmest week of the year indicated that sites with the highest stream temperatures also had the greatest daily fluctuation. Figure 3-3 show a daily fluctuation in stream temperature from representative “hot”, “warm”, and “cool” sites in Little Santa Paula Creek and a representative site in Sisar Creek. Instantaneous measurements indicate that at sites where MWAT remains below reported lethal limits for *O. mykiss*, instantaneous stream temperatures may exceed these limits for a significant portion of the day. Sites 6 (RM 7.4) and 7 (RM 7.6) exceeded critical thermal maximum temperatures in early September (Figure 3-3), defined as 29.6°C for the Central Valley steelhead (Myrick and Cech 2001).

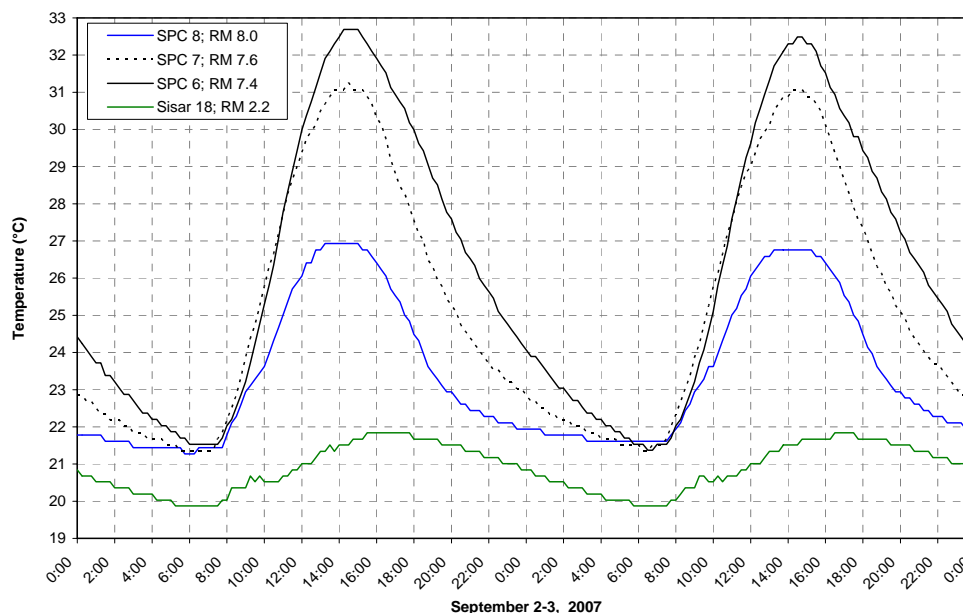


Figure 3-3. Continuous stream temperature in 15-minute intervals at four locations within the Santa Paula Creek watershed, September 4-5, 2007.

### 3.2 *O. mykiss* Presence and Absence Surveys

Potential summer rearing habitat for anadromous fish is primarily limited to Little Santa Paula Creek extending upstream 3.2 miles from the confluence with Sisar Creek to waterfall barriers, and all portions of Sisar Creek below the barriers at RM 5.9. All other tributaries to Santa Paula Creek were completely dry by May. A total of 278 pools were surveyed for *O. mykiss* within the Santa Paula Creek watershed. The rates of observation for age 1+ *O. mykiss* in May were highest in Sisar Creek (75 out of 86 pools), lower in Little Santa Paula Creek (102 out of 148 pools), and extremely low in mainstem Santa Paula Creek, where only two age 1+ *O. mykiss* were observed (2 out of 44 pools). A summary of pools with observed age 1+ *O. mykiss* is provided in Table 3-1.



Table 3-1. Age 1+ *O. mykiss* presence in pools within the Santa Paula Creek watershed, May 2007.

Reach	# of Pools with Age 1+	Total Pools Surveyed	% of Total Pools with Age 1+
Little Santa Paula	102	148	69%
Sisar Creek	75	86	87%
Mainstem Santa Paula	2	44	<1%
<b>Totals</b>	<b>179</b>	<b>278</b>	<b>64%</b>

The mainstem Santa Paula Creek, downstream of the confluence with Sisar Creek, supported age 1+ *O. mykiss* in only 2 out of the 44 pools surveyed in this reach (Table 3-1; Map 4), but also provided habitat for other species such as Santa Ana Sucker, Arroyo Chub, and threespine stickleback. This is consistent with observations made by Stoecker and Kelley (2005), where stream bank and direct observation surveys below the confluence of Sisar Creek and Little Santa Paula Creek resulted in zero observations of *O. mykiss* and the most consistent observations of non-salmonid species. This reach had the lowest pool frequency and exhibited warmer temperatures in comparison to locations throughout Little Santa Paula Creek and Sisar Creek. In addition to these habitat characteristics, natural oil and tar seeps, as well as milky sulfur seeps contribute to poor habitat quality for *O. mykiss* in the mainstem Santa Paula Creek.

Of the three main reaches surveyed, Sisar Creek contained the highest percentage of pools containing age 1+ *O. mykiss* (87%; Table 3-1, Map 5). In wetted reaches between RM 0.6 and RM 4.1, almost every pool surveyed contained age 1+ *O. mykiss*. Riparian cover was more consistent in this section of Sisar Creek, resulting in cooler stream temperatures that provided habitat for a higher frequency of age 1+ *O. mykiss* than the first 0.6 mile of Sisar Creek. Our May 2007 surveys did not extend upstream of RM 4.1 to the two barriers identified by Stoecker and Kelley in 2005 (Sisar Creek at RM 5.9 and East Fork Sisar Creek RM 0.5). Within this reach, Stoecker and Kelley (2005) observed the highest densities of *O. mykiss* over 6", indicating good habitat quality and suggesting *O. mykiss* presence would likely extend to the two barriers. Our May 2007 field work did not repeat Soecker and Kelley's (2005) survey of this upper reach because our objective was to survey areas that had not already been surveyed.

Fewer observations of age 1+ *O. mykiss* within the first 0.6 miles of Sisar Creek may be a result of lower surface flow and decreased riparian shading. Although this reach exhibited the warmest temperatures in Sisar Creek, temperatures did not exceed 21.0° C (a temperature at which *O. mykiss* were commonly observed in Little Santa Paula Creek) indicating other factors may be acting in concert with stream temperature to influence habitat quality for age 1+ *O. mykiss* within this reach (Map 3, Map 5).

In Little Santa Paula Creek, age 1+ *O. mykiss* were observed throughout the reach for the exception of one portion, between the confluence with Sisar Creek (RM 6.6; Map 6) and La Broche Creek (RM 7.9). The relatively low rate of occurrence in this section of Little Santa Paula Creek could be related to high stream temperatures in that reach. At the time of the May survey, maximum daily stream temperatures were already at 27.8°C, approaching previously reported lethal limits for *O. mykiss* (29.6°C; Myrick and Cech 2001). Even though there was a low rate of occurrence in this reach, *O. mykiss* were present, indicating these temperatures did not exceed lethal values during May.

During our November 2007 survey, *O. mykiss* were not present in the warmest location where relatively low rate of occurrence was observed in May, near thermograph Site 6 (RM 7.4; Map 7). This location consistently exceeded 30.0°C for three months, from July through August, with maximum temperatures over 33°C during the hottest day of the year (Figure 3-3; Map 7). However, *O. mykiss* were observed just upstream near thermograph Site 7 (RM 7.6), where temperatures exceeded 30°C for a much shorter duration (only 6 days out of the summer), but reached 31.4°C during the hottest day of the year (Figure 3-3; Map 7). These temperatures and the presence of *O. mykiss* are not consistent with laboratory experiments where 29.6°C is defined as the critical thermal maximum temperature for steelhead (Myrick and Cech 2001), and indicates southern steelhead may have higher critical thermal maximum temperature than northern populations.

An exception to these patterns of temperature and *O. mykiss* presence was the observation of one age 1+ *O. mykiss* that was observed in an isolated pool in the middle of the dry reach (RM 7.1; Map 7). Although data on small seeps was not gathered, some observations of local pockets of cool water in warm pools was observed during the previous survey, and may explain the rare presence of age 1+ *O. mykiss* within the dry reach. Stream temperature data is not available within the proximity of this isolated pool, making it difficult to come to conclusions on thermal tolerances at this location.

### 3.3 *O. mykiss* Population Surveys

The following sections provide results and discussion for *O. mykiss* habitat and population surveys conducted in May and November 2007.

#### 3.3.1 Habitat measurements

Reach-level habitat measurements identified pool and pocketwater habitat as the most common habitat types in both Little Santa Paula Creek and Sisar Creek and were therefore chosen as the two habitat types to compare *O. mykiss* densities for the November 2007 population surveys. Riffles occurred infrequently, and quick single-pass electrofishing in these habitats confirmed they provided little or no habitat for *O. mykiss* within our surveyed reaches. Run habitat was present at only one site, and comprised a small percentage of the stream channel when it was present. Table 3-2 summarizes the area of each habitat type within each reach.

Table 3-2. Habitat type areas (m<sup>2</sup> and percent of total) in reaches of Little Santa Paula Creek (SPC) and Sisar Creek (Lower Sisar Creek [LSC] and Upper Sisar Creek [USC]), November 2007.

Creek	Reach	Pool Area		Pocketwater Area		Riffle Area		Run Area		Total Area
		m <sup>2</sup>	%	m <sup>2</sup>	%	m <sup>2</sup>	%	m <sup>2</sup>	%	m <sup>2</sup>
Little Santa Paula Creek	SPC	401	22.4	1,305	73.0	0	0.0	82.5	4.6	1,788
Sisar Creek	LSC	237	32.3	468	63.9	28	3.8	0	0.0	733
	USC	174	42.8	223	54.6	10	2.6	0	0.0	408

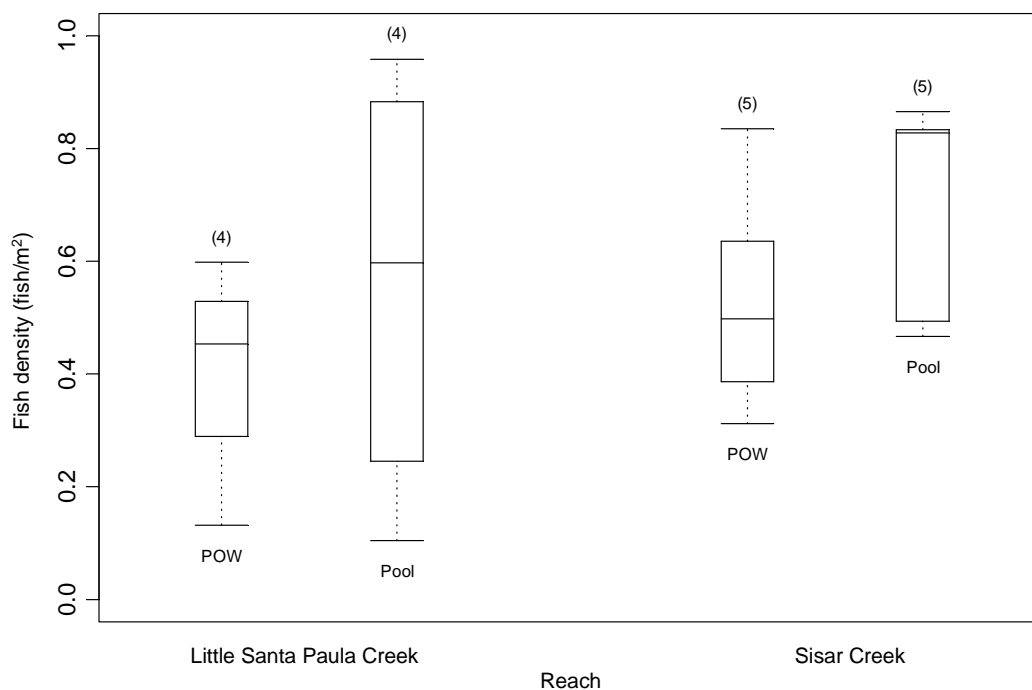
Detailed habitat measurements were taken at each habitat unit that was electrofished. Maximum depths in the units sampled in Little Santa Paula Creek ranged from 2.1 to 2.8 ft (0.64 to 0.85 m) deep for pools and from 1.0 to 1.8 ft (0.30 to 0.55 m) deep for pocketwater habitat. Maximum

pool depth in units sampled in Sisar Creek ranged from 2.0 to 2.5 ft (0.61 to 0.76 m) at the lower sample reach and 2.7 to 3.2 ft (0.82 to 0.98 m) at the upper sample reach. Pocketwater depth in Sisar Creek was consistent at all sites, ranging from 1.2 to 1.4 ft (0.36 to 0.43 m) deep. The amount of available cover varied little between reaches and primarily consisted of unembedded cobble/boulder complexes and some aquatic vegetation at most sampled units. One exception was a unit in Little Santa Paula Creek, that was a bedrock dominated pool with little cobble/boulder substrate for cover. This unit also resulted in the lowest *O. mykiss* densities out of all the sites, indicating cobble/boulder substrate may provide the majority of usable cover within the Santa Paula Creek watershed.

Sample site selection was not random. We chose relatively “good habitat” in both Little Santa Paula Creek and Sisar Creek and these habitat measurements are not necessarily representative of habitat in other reaches potentially supporting *O. mykiss*. Extrapolations of our densities could lead to an overestimate of the *O. mykiss* population in Santa Paula Creek. A more comprehensive habitat and population survey including representative reaches would be necessary to determine the *O. mykiss* population throughout the watershed.

### 3.3.2 *O. mykiss* Density Surveys

A total of 18 units (nine pools and nine pocketwaters) were surveyed for *O. mykiss* densities within Little Santa Paula Creek and Sisar Creek. Densities were similar in Little Santa Paula Creek (ranging from 0.10 fish/m<sup>2</sup> to 0.96 fish/m<sup>2</sup>) and in Sisar Creek (ranging from 0.31 fish/m<sup>2</sup> to 0.87 fish/m<sup>2</sup>). Densities were also similar between habitat types, although pool habitats resulted with the highest densities of *O. mykiss* in both creeks. Since age classes were difficult to distinguish (see *O. mykiss* Age Class Structure), *O. mykiss* densities were inclusive of all age classes. Figure 3-4 shows densities for both habitat types in each reach.



**Figure 3-4. Boxplots for *O. mykiss* densities in pocket water (POW) and pool habitat types between Little Santa Paula Creek and Sisar Creek.** Center line of the box is the median; upper and lower edges are upper quartile and lower quartile respectively. The range is represented by horizontal bars above and below the boxes. Sample sizes are in parentheses above the boxplots.

Pool habitat in Little Santa Paula Creek exhibited the largest range of *O. mykiss* densities, ranging from 0.10 fish/m<sup>2</sup> to 0.96 fish/m<sup>2</sup>. The pool with the lowest density was in the only unit that was a bedrock controlled pool and provided little cobble/boulder complexes for cover. Pocketwater habitat ranged from 0.13 fish/m<sup>2</sup> to 0.60 fish/m<sup>2</sup> and resulted in slightly lower *O. mykiss* densities than pool habitat, but field observations during electrofishing surveys noted sections of pocketwater that provided a combination of depth and cobble/boulder cover often provided habitat for *O. mykiss*. This suggests that *O. mykiss* use both pool and pocketwater habitat as long as cobble/boulder cover and depth are available. More detailed habitat measurements within each unit would be required to determine if there is a minimum depth requirement for *O. mykiss* in this reach.

Sisar Creek had similar ranges for *O. mykiss* densities in both pool and pocketwater habitat, ranging from 0.47 fish/m<sup>2</sup> to 0.87 fish/m<sup>2</sup> and 0.31 fish/m<sup>2</sup> to 0.84 fish/m<sup>2</sup>, respectively. When compared to Little Santa Paula Creek, *O. mykiss* densities in Sisar Creek are similar, indicating both creeks provide important habitat for juvenile rearing.

*O. mykiss* densities observed in pool habitat in the Santa Paula Creek watershed resulted in higher densities than most tributaries in Sespe Creek, the neighboring watershed east of Santa Paula Creek (Dvorsky 2000). Although snorkel surveys were used in Sespe Creek, we have used them as a comparison to densities in Santa Paula Creek because previous studies within the region show results from electrofishing and snorkel surveys are similar (Chubb, USFS, unpublished data, as cited in Dvorsky 2000). The relatively high densities in Santa Paula creek are consistent with

previous reports that suggest Santa Paula Creek has high habitat quality relative to other Santa Clara River tributaries, and has been identified as one of the greatest potential creeks for recovery of the Southern California *O. mykiss* DPS (Stoecker and Kelley 2005).

### 3.3.3 *O. mykiss* Age Class Structure

A total of 440 *O. mykiss* were captured during the electrofishing surveys. Throughout the watershed, fork lengths ranged from 52–214 mm, with over 90% of all captured *O. mykiss* measuring between 70–140 mm. Length frequency histograms can usually be used to determine length at age for *O. mykiss* populations, however differentiating length at age for populations in Santa Paula Creek watershed is difficult.

Up to four age classes are potentially identifiable from the length frequency data. In Little Santa Paula Creek, over 62% of the *O. mykiss* measured ranged from 70–145 mm (FL) and most likely were comprised of a combination of age 0+ and age 1+ fish (Figure 3-5). Similar to Little Santa Paula Creek, a majority of *O. mykiss* were in a similar range of 55–145 mm and also display a possible overlap of age 0+ and age 1+ fish. The exact size range of each age class is difficult to determine because of the lack of obvious modes in length frequencies. In more northern populations such as Devil's Gulch, a tributary to Lagunitas Creek (Marin County, California), length at age is better identifiable because seasonality separates growing seasons and results in a clearer separation in modes for each age class (Figure 3-5).

The difficulty in distinguishing between the age 0+ and age 1+ fish length frequency graphs could indicate that sublethal effects of temperature have influenced the growth potential for *O. mykiss*. The length frequencies indicate age 0+ *O. mykiss* are large at the end of their first summer suggesting good growth opportunities, however, age 1+ fish are relatively small. Previous studies in the Napa River (Napa County, California) have found that smaller fish are able to achieve positive growth under warm conditions whereas the larger age 1+ fish have difficulty achieving bioenergetic demands in warm reaches. Without scale analyses, it is impossible to reach conclusions about age class structure and to determine whether the growth of age 1+ *O. mykiss* is reduced due to bioenergetic limitations in Santa Paula Creek.

Another pattern apparent of the length frequency is the observation of few *O. mykiss* over 145 mm in both creeks. From Figure 3-5, fish above 145 mm could be potentially separated into two additional age classes, with an age 2+ class ranging from 170–195 mm (FL) and an age 3+ class with lengths above 210 mm (FL). There are two possible explanations for the few observations of *O. mykiss* in these age classes. The first possibility is that food availability was not sufficient for larger fish (*e.g.*, >145 mm) to meet the metabolic demands required to forage in the relatively warm reaches, and resulted in reduced survival. The second possibility is the high flows in January and February 2005 (maximum flood of record) resulted in redd scour and displacement of fry in 2005, which would have represented the age 2+ and older age classes we observed few of during our 2007 surveys. Conclusions regarding these hypotheses cannot be reached without aging from scale samples to determine growth and age class structure.

Scale samples were taken from each unit during the electrofishing surveys, but the limitations of the scope of this project did not include analyses of these samples. Future studies could potentially analyze these scale samples, resulting in determination of age class specific densities and to determine difference in growth rates for each age class.

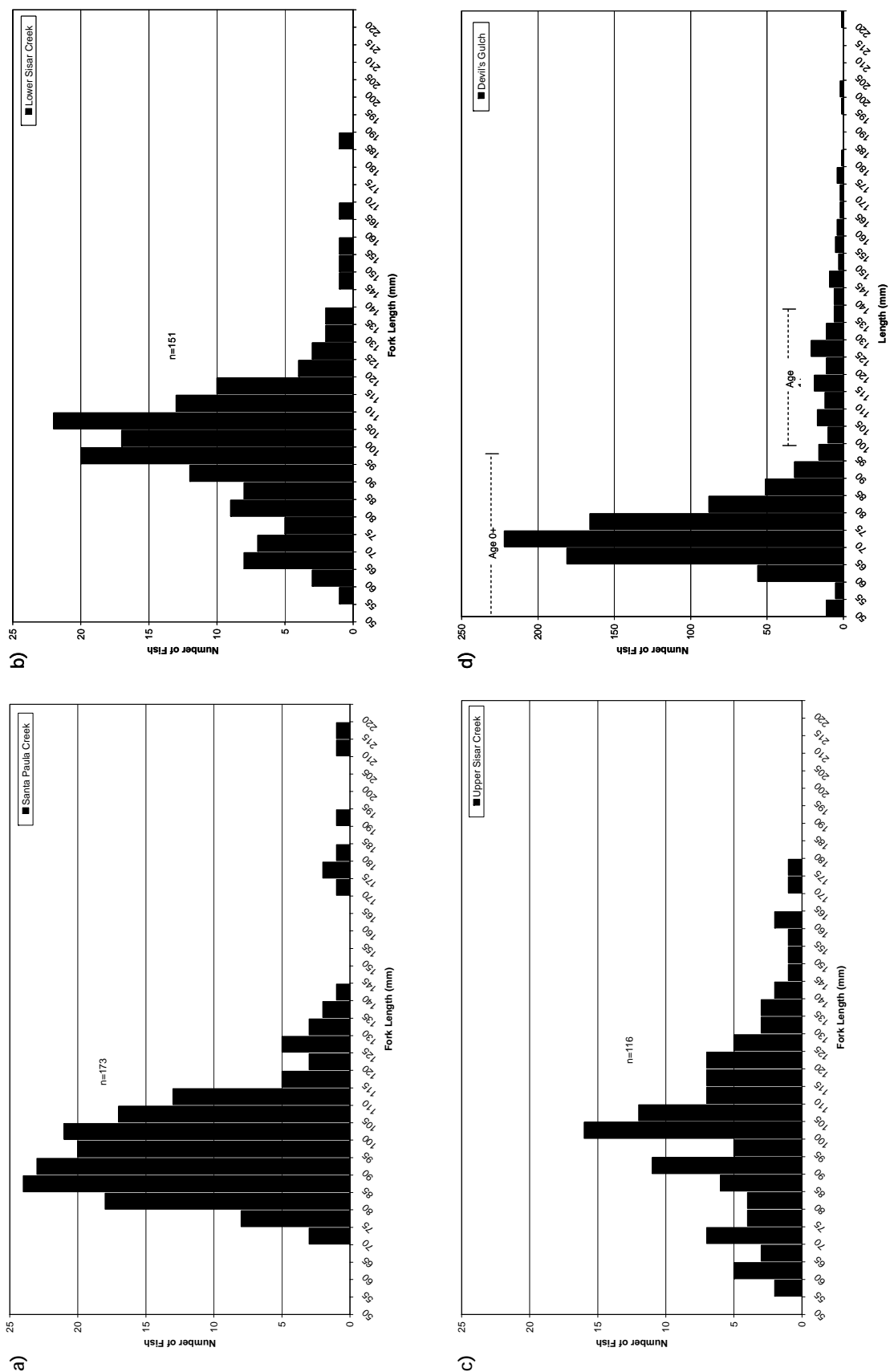


Figure 3-5. Comparison of length frequency histograms for *O. mykiss* in a) Little Santa Paula Creek, b) Lower Sisar Creek, and c) Upper Sisar Creek in November 2007, and d) Devil's Gulch (Lagunitas Creek, Marin Co.) in October 2006 (Stillwater Sciences, in progress).

## 4 CONCLUSIONS

Potential summer rearing habitat for restored anadromous populations of *O. mykiss* is limited to the extent of Little Santa Paula Creek from the confluence with Sisar Creek upstream to the natural waterfall barrier at the confluence of Little Santa Paula Creek and East Fork Santa Paula Creek (RM 9.8), and in Sisar Creek from its mouth upstream to barriers on Sisar Creek (RM 5.9) and East Fork Sisar Creek (RM 0.5). These creeks provided consistent observations of age 1+ *O. mykiss* during our May survey, and similar densities during our November survey. This indicates both creeks provide important juvenile rearing habitat for these species and passage restoration efforts should focus on access allowing migration to upstream of their confluence. The densities observed were high compared to neighboring streams and supports previous reports suggesting Santa Paula Creek as having some of the highest potential for restoration of anadromous *O. mykiss* within the Santa Clara watershed. In the few locations where *O. mykiss* were not observed in these reaches, it was a result of either a dry channel or relatively warm stream temperatures, indicating dry reaches and temperature are the primary environmental controls on juvenile rearing habitat quality.

The mainstem Santa Paula Creek appeared to provide poor habitat for *O. mykiss* based on the few observations of age 1+ fish during our May survey. Although temperatures were relatively warm in this reach, qualitative observations of poor visibility and water quality also likely contribute to the lack of *O. mykiss*. Natural oil and tar seeps, as well as milky sulfur seeps throughout the mainstem Santa Paula Creek contribute to poor habitat quality for *O. mykiss*.

Spatial patterns of stream temperature are markedly different between Sisar Creek and Little Santa Paula Creek. In Sisar Creek, extensive riparian shading maintains relatively cool stream temperatures in the majority of the wetted reaches despite the stream losing surface flow in two locations. The effects of riparian shading are evident in the lower portion of Sisar Creek which in May heated from approximately 16.0°C to 19.0°C in just 330 ft in a reach that completely lacked riparian vegetation. In comparison to Sisar Creek, Little Santa Paula Creek had much greater variability in stream temperature. In contrast to a more typical pattern in which stream temperature gradually increases as a stream flows to lower elevations, temperature in Little Santa Paula Creek exhibits a repeated pattern of cooling and warming. This pattern is predictable, with warmer temperatures occurring in reaches with wider valley-bottom widths and diminishing surface flow, and cooler temperatures occurring in reaches with narrower valley-bottom widths where cool hyporheic flow resurfaces. Because Little Santa Paula Creek currently has virtually no riparian vegetation, water temperature heats rapidly in wider valley segments, approaching 33°C maximum daily temperature in some areas.

The consequence of these temperature dynamics is that *O. mykiss* may be restricted from some reaches due to high stream temperatures. In Little Santa Paula Creek, we found *O. mykiss* in habitat with stream temperatures exceeding 29.6°C, the reported lethal limit for the Central Valley steelhead (Myrick and Cech 2001). Central Valley steelhead temperature thresholds were used for comparison because we are not aware of published temperature thresholds for southern steelhead, and the presence of *O. mykiss* in temperatures exceeding this published value provides evidence for higher thermal tolerances in southern populations. However, despite potential adaptation for warmer conditions, we also found that fish did not persist over the summer in the warmest reach of Little Santa Paula Creek. The results of a comparison of fish presence in May and November suggests that fish were found in pools where maximum daily stream temperature

approached 31.5°C, but were absent in pools exceeding in 33°C, suggesting upper thermal limits for *O. mykiss* in Santa Paula Creek may be within this range.

In addition to acute effects of temperature on fish persistence, there may be sublethal effects of high stream temperature on fish growth. Length frequency histograms may provide some evidence for sublethal effects of high stream temperatures. Although we were not able to conclusively differentiate between age 0+ and age 1+ fish from their length frequencies, the unimodal pattern in November suggests that growth of age 0+ fish was good but opportunities for age 1+ and older fish may be limited.

Together, these results provide important information on habitat conditions and fish abundance in the Santa Paula Creek watershed that can be readily incorporated into an expanded study of factors limiting the *O. mykiss* populations. In and of themselves, the results suggest that, to the extent possible, maintenance of riparian vegetation and protection of groundwater resources would be important components of a management plan for *O. mykiss* in the watershed. The results also suggest several future studies that could reduce uncertainty about factors limiting the *O. mykiss* populations. First, we recommend that scale samples be analyzed to confirm the length-at-age for fish. This information would help test hypotheses regarding growth potential and bioenergetic limitations for fish. If high warm temperatures are preventing large fish from reaching suitable sizes for successful smolting, then bioenergetic studies including analyses of macroinvertebrate food availability could help identify reasons for limited growth. The information could also be used to develop age-class specific density information from the data already collected and could be an important tool for identifying potential recruitment bottlenecks for fish populations. Second, continuous stream temperature monitoring could be paired with additional studies to document the persistence of *O. mykiss* using pit tags. Individually marked fish in different thermal environments would provide more detailed empirical evidence for stream temperature thresholds for southern populations of *O. mykiss*.



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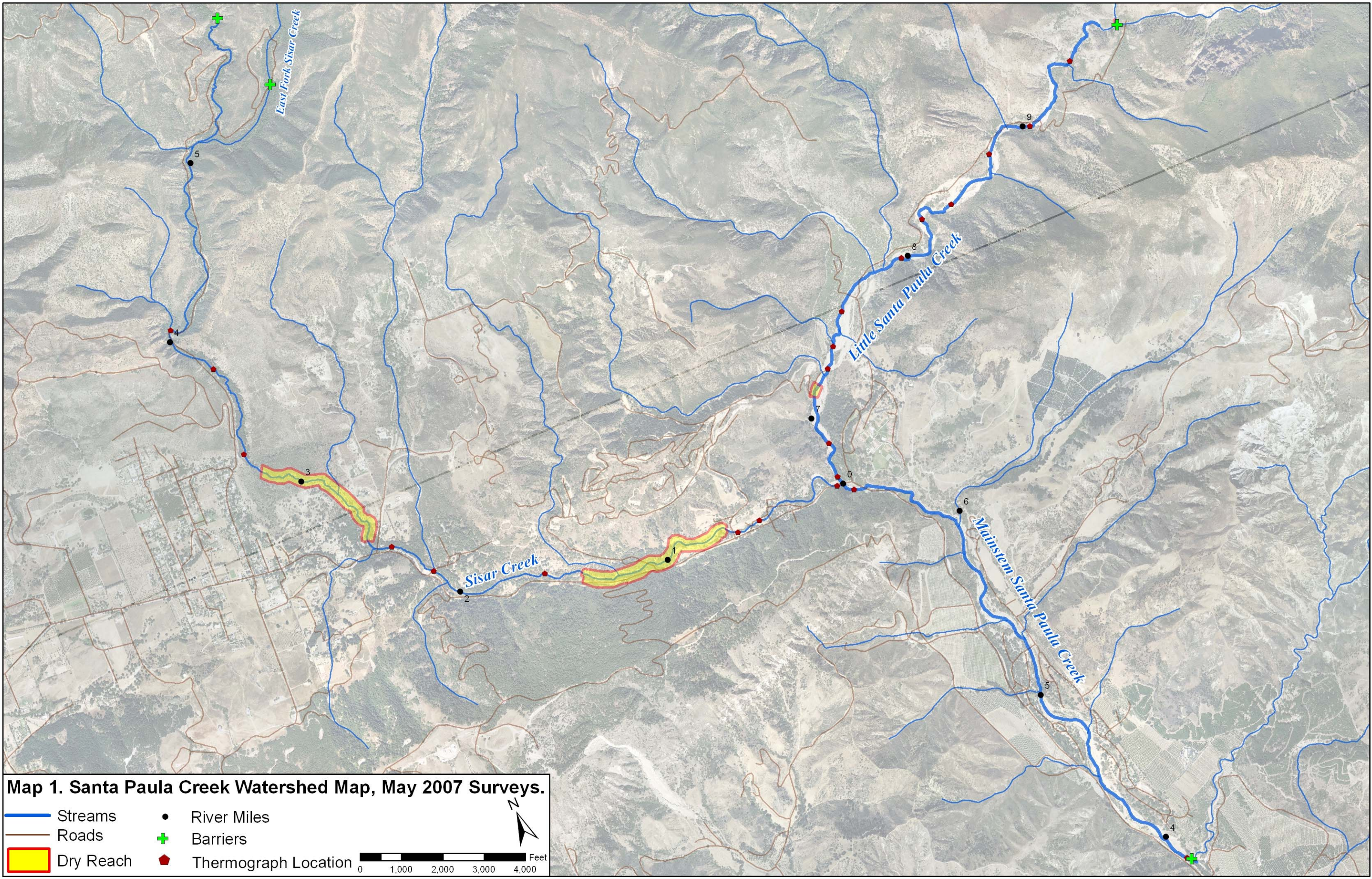
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## MAPS

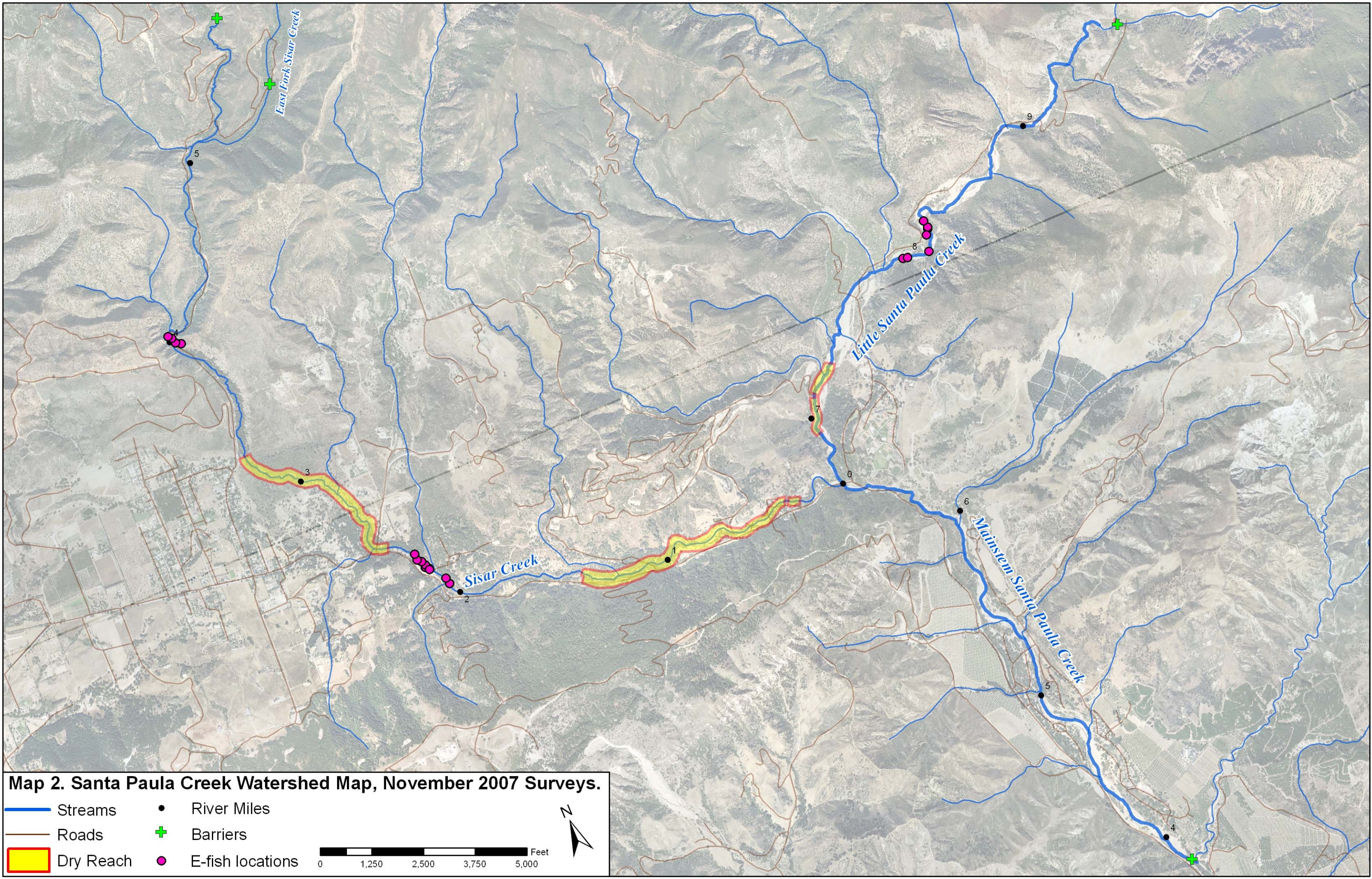
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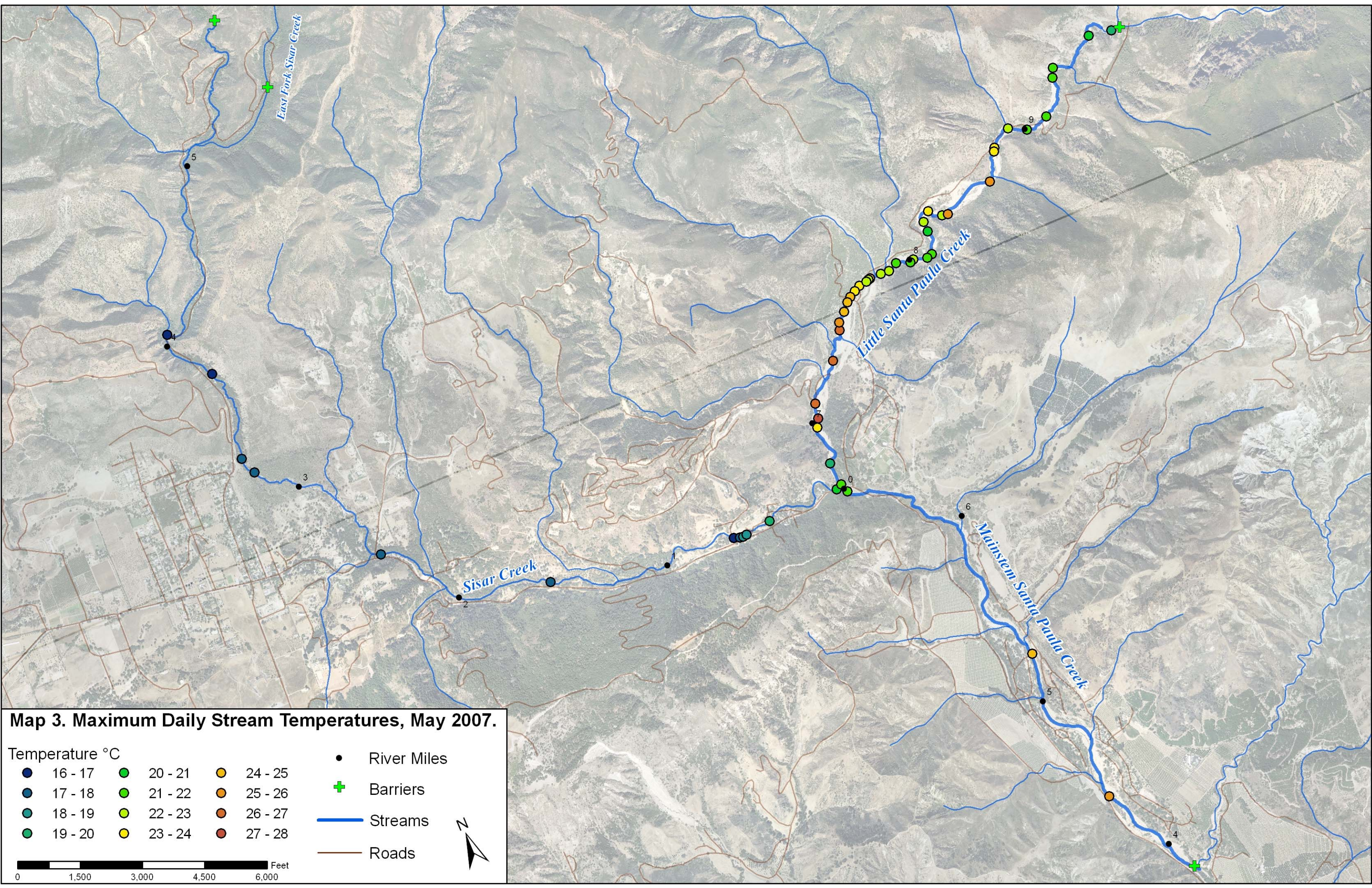


**Map 2. Santa Paula Creek Watershed Map, November 2007 Surveys.**

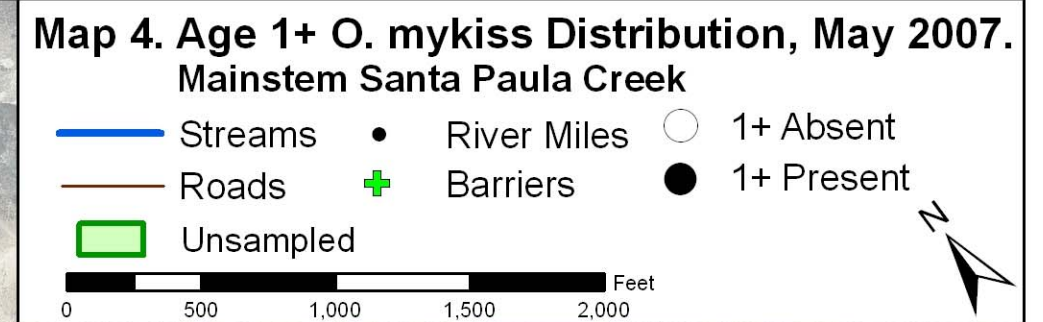
Streams	River Miles
Roads	Barriers
Dry Reach	E-fish locations

0 1,250 2,500 3,750 5,000 Feet












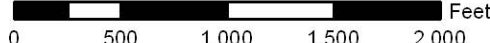





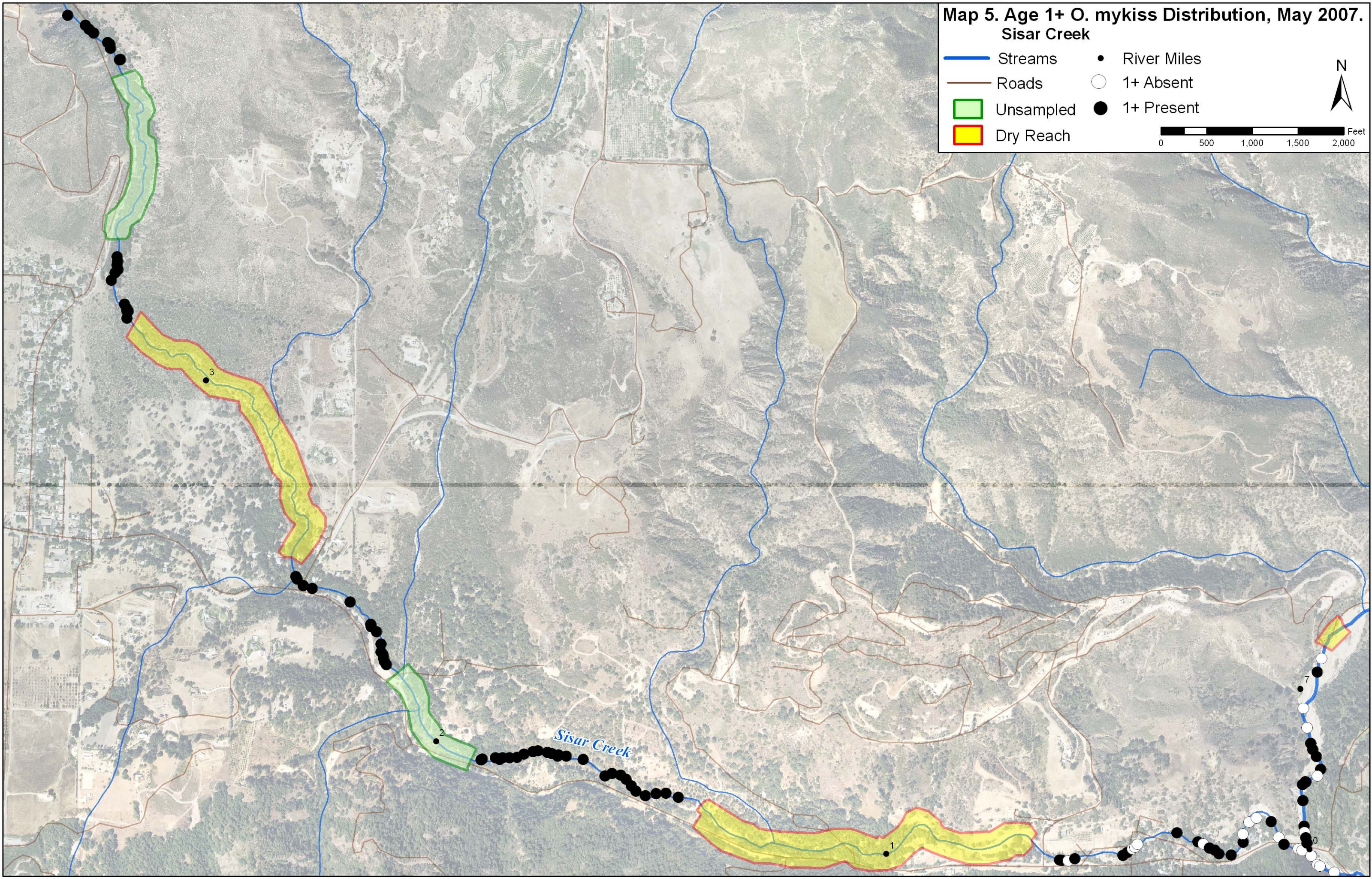


**Map 5. Age 1+ *O. mykiss* Distribution, May 2007.**  
**Sisar Creek**

	Streams		River Miles
	Roads		1+ Absent
	Unsampled		1+ Present
	Dry Reach		

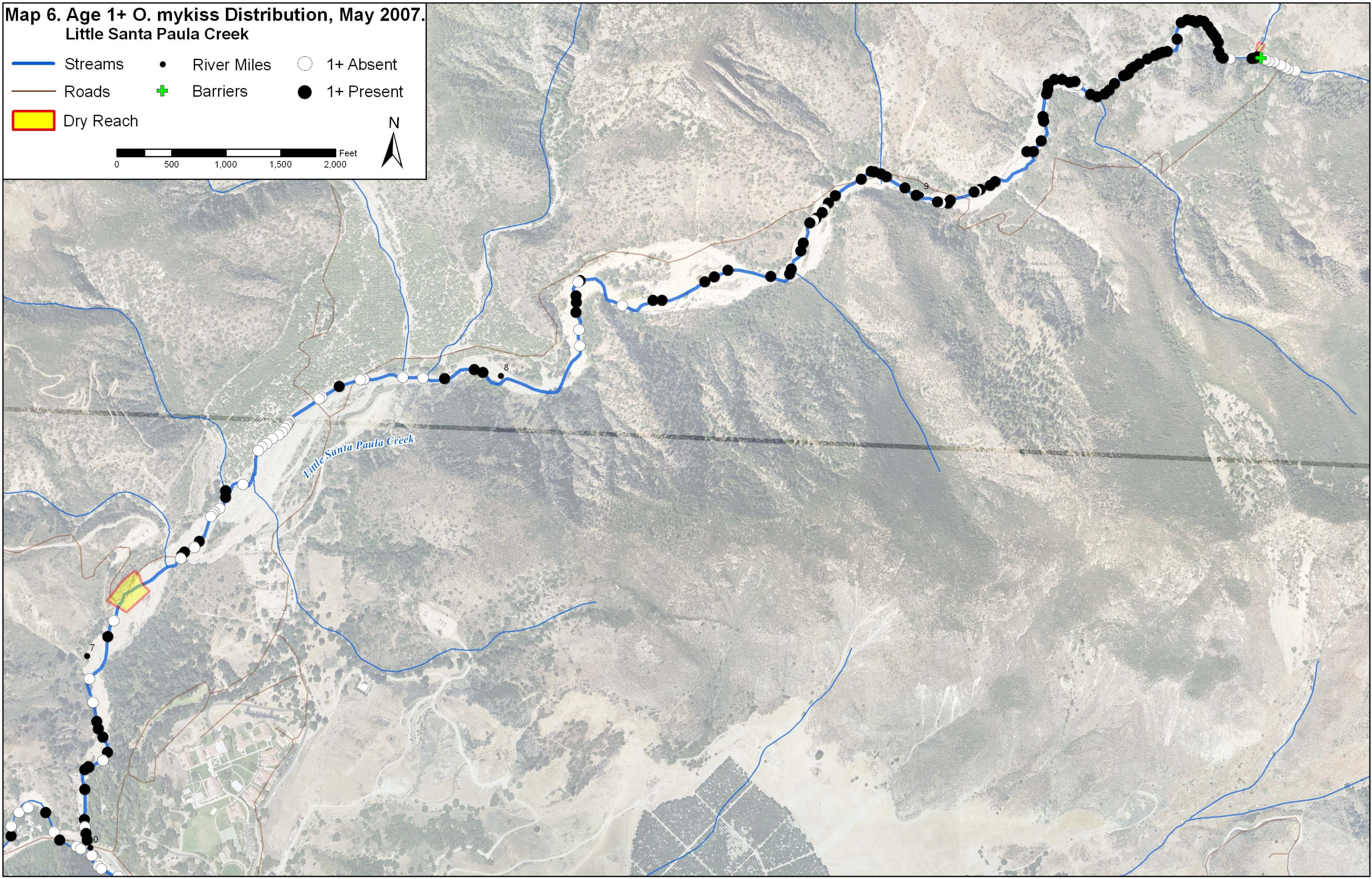
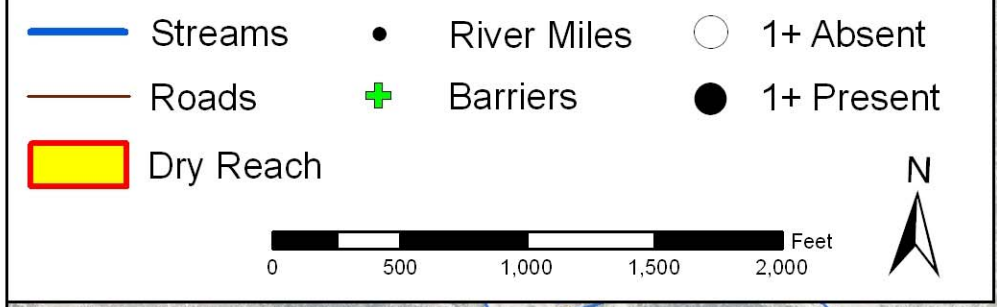
 0 500 1,000 1,500 2,000 Feet

 N





Map 6. Age 1+ *O. mykiss* Distribution, May 2007.  
Little Santa Paula Creek





Maximum Daily Temperature May 2007



May 2007 Age 1+ Presence and Absence



November 2007 Age 0+ and 1+ Presence and Absence



Map 7. *O. mykiss* Distribution and Maximum Daily Stream Temperature Comparisons.

— Santa Paula Creek  
+ River Miles

— Dry Reaches

