

Summary of Southern California steelhead spawning surveys in the Conception
Coast, Ventura River, and Santa Clara River Watersheds

2019 Annual Report

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ABSTRACT

This study is a continuation and expansion of monitoring efforts initiated by the California Department of Fish and Wildlife (CDFW) and the Pacific States Marine Fisheries Commission (PSMFC) in 2013 to collect data on the abundance and spatial structure of southern California steelhead (*Oncorhynchus mykiss*). Data was collected through comprehensive spawning ground surveys in five southern California watersheds: Arroyo Hondo Creek, Mission Creek, Carpinteria Creek, Ventura River, and Santa Clara River. Arroyo Hondo, Mission, and Carpinteria creeks are three small coastal watersheds of the Conception Coast biogeographic population group (BPG) that drain the south-facing slopes of the eastern Transverse Mountain Range (NFMS 2012). The Santa Clara and Ventura River are large watersheds that belong to the Monte Arido Highlands BPG and drain the western half of the Transverse Range (NFMS 2012). Carpinteria Creek, Ventura River, and Santa Clara River are all designated as high priority watersheds for steelhead recovery action (Core 1; NMFS 2012).

Due to sampling concerns related to the low abundance of *O. mykiss* in southern California watersheds and patchy distribution, spawning surveys were conducted as a 100% census of reaches. During the 2018-2019 winter seasons, surveys were conducted from January through May on a bi-weekly basis or when environmental conditions allowed.

Spawner surveys conducted during this season were hindered due to above average rainfall and flow events that created hazardous conditions and affected surveyor effectiveness due to poor water clarity. During the 2018-2019 spawning season, 186 *O. mykiss* and two *O. mykiss* redds were observed in Arroyo Hondo Creek. A total of 79 *O. mykiss* and three *O. mykiss* redds were observed in the Santa Paula Creek subwatershed of the Santa Clara River Basin. One *O. mykiss* and zero *O. mykiss* redds were observed in the Ventura River Basin. Zero *O. mykiss* and zero *O. mykiss* redds were observed in the Carpinteria Creek and Mission Creek watersheds.

For each watershed surveyed, multiyear comparisons were performed for survey visibility, redd life (i.e. the duration of time redds remained detectable), redd area, total redd count, total number of bankside observations, and spatial distribution of *O. mykiss*. These analyses included only years where data collection was consistent. Our results show survey visibility significantly varied across years in Carpinteria Creek (2017-2019) and Ventura River (2014-2019) watersheds. Of the five watersheds surveyed, only three have recorded *O. mykiss* redds and/or *O. mykiss* bankside observations since the start of monitoring efforts: Arroyo Hondo Creek, Ventura River, and Santa Clara River. Mean redd life varied significantly in the Ventura River for years 2014-2019 but did not significantly vary by year in Arroyo Hondo Creek (2017-2019) or Santa Clara River basins (2017-2019). Mean redd size significantly varied by year in Arroyo Hondo Creek but did not significantly vary in the Ventura River or Santa Clara River basins. For all three watersheds, redd and *O. mykiss* bankside counts were negatively correlated with time.

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INTRODUCTION

Southern California steelhead trout (*Oncorhynchus mykiss*) populations have declined dramatically throughout their historic range. Consequently, steelhead trout inhabiting the area from the Santa Maria River to the U.S.-Mexico border have been listed as a federally endangered distinct population segment (DPS) (ESA; NMFS 2012). The ESA mandated recovery plan outlines goals to ensure the persistence of viable populations of anadromous *O. mykiss* across the DPS (NMFS 2012). The California Department of Fish and Wildlife has developed a framework to implement monitoring to track recovery progress (i.e., Fish Bulletin 180) (Adams et al. 2011). This framework is based on assessment of four viability metrics comprised of abundance, productivity, spatial structure, and diversity (McElhany 2000, NMFS 2016).

To provide an index of effective population size (abundance) and an estimation of spatial structure, redd surveys were conducted as a complete census of available spawning habitat in four watersheds of the Conception Coast and Monte Arido Highlands biogeographic population groups. Previous studies using redd surveys have demonstrated that steelhead and resident trout redds can be distinguished by size, specifically, total length and area (Zimmerman and Reeves 2000). This information can provide insight into the complex interplay between resident and anadromous life history strategies in focal watersheds.

This report summarizes the methodologies and data collected from spawning ground surveys in four southern California watersheds during the 2018-2019 spawning season. Three of these watersheds are identified as high priority for steelhead recovery efforts (NMFS 2012). Our findings will aid in the development southern California specific monitoring protocols, and will inform resource managers on the status of steelhead populations in these stream systems.

STUDY SITES

Arroyo Hondo Creek

Arroyo Hondo Creek is part of the Conception Coast Biogeographic Population Group (BPG). Consisting of one mainstem, Arroyo Hondo Creek flows from the headwaters of the Santa Ynez Mountains to the Pacific Ocean about 28 miles north of Santa Barbara, California. Arroyo Hondo Creek contains approximately 6.0 stream miles, 1.9 of which are accessible to anadromous *O. mykiss*. The lower watershed resides in the Arroyo Hondo Preserve, protected and managed by the Santa Barbara County Land Trust. The upper watershed is located within the Los Padres National Forest. Arroyo Hondo Creek was surveyed for 1.9 miles from the estuary to a total natural barrier to fish passage (PAD 2019).

Mission Creek

The Mission Creek watershed is located within the Conception Coast Biogeographic Population Group (BPG). The Mission Creek watershed consists of 16 miles of stream and drains an area of approximately 12 square miles to the Pacific Ocean (NMFS 2012). Mission Creek flows from headwaters in the Santa Ynez mountains through the city of Santa Barbara. The upper watershed is located within the Los Padres National Forest, open spaces, and low-density residential areas. The lower portion of the creek pass through highly urbanized land and has been heavily altered and channelized. Multiple concrete channels, gradient control structures, and road crossings throughout the lower portion of the creek pose

challenges to anadromous fish passage. Mission Creek was surveyed for 5.6 miles from the estuary to the Old Mission Dam, a total barrier to fish passage (PAD 2019).

Carpinteria Creek

The Carpinteria Creek watershed is part of the Conception Coast BPG and drains approximately 17 square miles from the Santa Ynez Mountains to the Pacific Ocean (NMFS 2012). The high gradient upper watershed transitions to lower elevation coastal terrace. The Carpinteria Creek watershed has a total length of 25 miles, approximately 7.3 of which are accessible to anadromous *O. mykiss* (NMFS 2012). The upper watershed is located within the Los Padres National Forest, while the lower watershed is characterized by agricultural or highly urbanized land (NMFS 2012). An estimated 99 percent of the Carpinteria Creek watershed was burned by the 2018 Thomas Fire (Klose et al. 2018).

Carpinteria Creek was surveyed for 4.1 stream miles from the estuary to a total natural barrier to fish passage (waterfall) (PAD 2019). Gobernador Creek, a tributary to Carpinteria Creek was surveyed for 3.2 miles from the confluence with Carpinteria Creek to a total natural barrier to fish passage (waterfall) (PAD 2019).

Ventura River

The Ventura River watershed consists of mountainous, high peak elevations that transition into a lower elevation coastal terrace before reaching the Pacific Ocean (NMFS 2012). It drains roughly 227 square miles and contains approximately 35 miles of anadromous water (NMFS 2012). Both the Casitas and Matilija dams act as total barriers to steelhead passage and prevent migration to spawning and rearing habitat in the upper watershed (NMFS 2012). The Robles Diversion, located on the Ventura main stem 1.5 miles downstream of the confluence of Matilija and North Fork Matilija Creeks, diverts flow from the Ventura River to Lake Casitas and contains a fish-passage facility (NMFS 2012).

Stream flows are highly dependent on rainfall and extensive sections of the main stem exhibit intermittent flows and drying over spring and summer. A seasonal sandbar prevents access to the watershed until the first large storm event of the season. Without consistent precipitation, flows drop quickly and access to the perennial upper watershed may be limited to short periods.

In 2018 the Thomas Fire burned 281,893 acres (InciWeb 2018, Figure 6) which included substantial portions of the Ventura River watershed (Klose 2018). A high intensity rain event following the fire lead to widespread flooding and debris flows resulting in road closures and observed changes to stream habitat.

Ventura River watershed was surveyed for a total of 49.2 stream miles, 32.5 of which are accessible to anadromous *O. mykiss*. Surveyed reaches located above the Matilija Dam provide data on persisting resident populations. Recent studies have demonstrated the genetic similarity between populations above and below fish passage barriers within the same system (Abadía-Cardoso et al. 2016; Clemento et al. 2009). We therefore considered these above-dam resident populations to be important to steelhead monitoring efforts.

Santa Clara River

The Santa Clara River watershed is located within the Monte Arido Highlands BPG. Originating in the northern San Gabriel Mountains of Los Angeles County, the Santa Clara River drains approximately 1,600 miles into the Pacific Ocean (NFMS 2012). Although extensive areas contain high quality riparian habitat, land use and the construction of dams, road crossings, and diversions have degraded stream conditions particularly in the lower watershed and limited water flow during dry seasons.

The Santa Paula Creek subwatershed drains approximately 15 miles into the Santa Clara River and includes Sisar Creek, which serves as a tributary to Santa Paula Creek. Santa Paula Creek flows south to the Santa Clara River, and Sisar Creek flows approximately 7.4 miles southeast to Santa Paula Creek. The upper portions of Santa Paula and Sisar creeks are located within the Los Padres National Forest. An estimated 89 percent of the Santa Paula Creek subwatershed, including all but two stream miles were burned during the Thomas Fire (BAER 2018).

Santa Paula Creek was surveyed for 3.1 stream miles and Sisar Creek was surveyed for 1.8 miles. The Santa Paula Creek survey reaches started at the confluence of Santa Paula and Sisar Creeks, while the Sisar Creek survey reach began several miles upstream of the confluence at a road crossing chosen for its accessibility. The survey reaches of both streams ended at a total natural barrier to fish passage (PAD 2019).

METHODS

Data Collection

Spawning ground surveys were conducted in accordance with standardized protocols developed by California Department of Fish and Wildlife scientists for southern California as part of the Coastal Salmonid Monitoring Program (CMP) (McLaughlin and Christianson 2016). Surveys were conducted from December 2018 through May 2019 of each year. All stream reaches were surveyed as a 100% census of available habitat. Individual reach designations were determined by the sampling frame currently under development by CDFW CMP and Fisheries Branch biologists. Reaches began and ended at easily identifiable landmarks (e.g. bridges or stream confluences) and were designed to be completed in a single day. These reaches ranged in length from 0.7 to 4.5 stream miles with a mean of 2.3 ± 0.17 miles (mean \pm SE).

Surveys were conducted every two weeks throughout the survey season when stream flows and weather permitted. Two weeks is the accepted minimum amount of time redds remain detectable in southern California stream systems (R. Bush, National Marine Fisheries Service, unpublished data). Teams of two to three surveyors walked reaches in an upstream direction recording observations on handheld data recorders. All fish observed were identified to species. For each *O. mykiss* observation, a total length estimate, location, and life history stage (when possible) were recorded.

When redds were first observed, measurements were taken for pot and tail spill dimensions. Pot length, width, and depth relative to the adjacent streambed were measured. For tail spill dimensions, the tail spill length and two width measurements (taken at 1/3 and 2/3 the distance from the upstream end of the tail spill) were recorded. Dominant substrate size was also recorded for both the pot and tail spill. Redds were identified with a flag denoting the redd record number, distance and bearing of the redd from

the flag location, date the redd was first identified, and redd age. Redd ages were categorized as the following: 1 - New since last survey, 2 - Previously identified and still measurable, 3 - No longer measurable but still visible, and 4 - No redd apparent. Redd ages were updated and recorded during subsequent observations. Redds were re-measured when pot and tail spill dimensions had noticeably changed following their initial observation.

Data Analysis

To examine survey frequency, we calculated the mean \pm SE number of days between surveys. Water visibility was examined as a metric for redd detectability. Visibility measurements were classified as either “clear” (i.e., visibility = 100%) or “not clear” (visibility < 100%) for each survey. The mean \pm SE number of surveys where visibility was 100% was calculated by reach and by watershed for each year.

Redd observations were mapped using ArcGIS 10.1 (ESRI, Redlands, California) and R Software (R Core Team. 2016). Total redd length was calculated as the sum of the pot and tail spill lengths and redd area was calculated as the sum of pot and tail spill areas per Gallagher et al. (2007). These measurements were used to compare the relative sizes of all redds observed in order to evaluate whether a redd was produced by anadromous or resident *O. mykiss*. Finally, we examined trout observation counts by size class and their spatial distribution by mapping observation locations. We examined redd life (i.e., the duration of time redds remained detectable) by calculating mean redd life by watershed. Only redds where a final status indicating they were not longer visible (i.e. redd age 4) was recorded were included in this evaluation.

To examine any changes over time, we compared our data to spawning survey data collected in previous years. Only data where survey effort was consistent was used for comparison. Mission Creek was excluded due to small sample size of surveys conducted since 2018 ($n = 7$). For Arroyo Hondo Creek we compared data collected from 2017 to 2019, Carpinteria Creek from 2017 - 2019, Ventura River from 2014-2019, and Santa Paula Creek from 2017-2019. We examined survey visibility, redd area, mean redd life, redd counts, and *O. mykiss* bankside observation totals for trends per Gallagher (2005). For each watershed we performed the following analyses: (1) Chi-square test of independence to determine if the number of clear surveys significantly differed by year, (2) analysis of variance to determine if mean redd life or mean redd area significantly differed by year, and (3) correlation analysis to determine trends in *O. mykiss* and redd counts by year. All analyses were completed using R (version 3.4.1, R Core Team 2017) and R Studio (version 1.0.153, RStudio, Inc 2017).

RESULTS

Arroyo Hondo Creek

From January 3, 2019 to May 22, 2019, 11 redd surveys were conducted in Arroyo Hondo Creek. The mean number of days between surveys was 25.9 ± 6.4 (mean \pm SE) days (Table 2). All surveys ($n = 11$) were conducted with 100% clear water visibility (Figure 7). Only one *O. mykiss* redd was observed on Arroyo Hondo with a redd length of 0.59 meters and a redd area of 0.11 meters squared (Table 10). A total of 186 *O. mykiss* were observed (Table 3). These observations ranged in size class from 0-2 inches to 10-12 inches with 60.8% ($n = 113$) of the observed *O. mykiss* in the 0-2 inch size class (Table 4). Of the

remaining *O. mykiss* observations, 17.7% (n = 33) were in the 4-6 inch size class, 11.8% (n = 22) were in the 2-4 inch size class, and a combined 9.7% (n = 18) were recorded in all other size classes.

Mission Creek

Four redd surveys were conducted in Mission Creek from February 25, 2019 to April 18, 2019. Surveys had a mean frequency of 17.3 ± 3.0 (mean \pm SE) days in between (Table 2). Seventy-five percent of the surveys (n = 3) were completed with clear (i.e. 100%) water visibility. Zero *O. mykiss* and zero *O. mykiss* redds were observed in Mission Creek during the survey season (Table 3).

Carpinteria Creek

From January 24, 2019 to May 15, 2019, 25 redd surveys were completed on four survey reaches within the Carpinteria Creek Watershed. Redd surveys were completed with a mean frequency of 19.1 ± 1.7 (mean \pm SE) days between surveys (Table 2). Of the 25 surveys, 23 (92%) were recorded as having 100% water visibility (Figure 8). Zero *O. mykiss* and zero *O. mykiss* redds were observed during the 2018-2019 survey season in the Carpinteria Creek watershed (Table 3).

Ventura River

From December 12, 2018 to May 21, 2019, 93 redd surveys were conducted over 19 reaches in the Ventura River basin (Tables 1 and 2). Mean survey frequency by reach ranged from 13.8 ± 1.2 (mean \pm SE) to 37 ± 22.3 days in between surveys (Table 2). Of the 93 surveys completed, 74 (84%) were conducted with 100% visibility (Figure 9). Zero *O. mykiss* redds and one *O. mykiss* were observed in the Ventura River watershed during the 2018-2019 survey season (Table 3). The single *O. mykiss* was observed in Murietta Creek on May 21, 2019 and estimated to be 4-6 inches in length (Table 5).

Santa Clara River

From January 7, 2019 to May 15, 2019, 19 redd surveys were completed within the Santa Clara River Watershed. All surveys were conducted in three stream reaches along Santa Paula and Sisar Creeks (Figure 5). Redd surveys were conducted with a frequency of 19.31 ± 3.19 (mean \pm SE) days between surveys (Table 2). Sixty-eight percent (n = 13) of surveys were completed with 100% water visibility (Figure 10). Two *O. mykiss* redds were observed within the Santa Paula subwatershed of the Santa Clara River Basin, both of which were observed in Santa Paula Creek reach 2. The redds had a mean \pm SE length of 0.94 ± 0.21 (mean \pm SE) m and a mean area of 0.23 ± 0.09 (mean \pm SE) m² (Table 12). During the 2018-2019 survey season, 79 *O. mykiss* were observed in the Santa Clara River watershed (Table 3). The *O. mykiss* ranged in size class from 0-2 inches to 8-10 inches. Of the *O. mykiss* 79 recorded, 72.2% (n = 57) were estimated to be in the 0-2 inch size class, 12.7% (n = 10) in the 4-6 inch size class, 6.3% (n = 5) in the 6-8 inch size class, and a combined 9.9% (n = 7) in all other size classes (Table 6). Four observed *O. mykiss* were recorded without size estimations.

Multi-year Comparisons

Arroyo Hondo Creek

In Arroyo Hondo Creek, the number of surveys with clear (i.e. 100%) visibility did not vary significantly for years 2017-2019 (Chi-square test: $X^2 = 2.06$, d.f. = 2, p-value > 0.05). Age 4 (indicating redd is no longer visible) was only recorded for redds observed in 2017 so we were unable to make a multi-year comparison of mean redd life for this watershed. Additionally, small sample size of observed redds in 2018 (n=1) and 2019 (n=1) did not allow an analysis of variance testing for significant differences in mean redd size by year could not be performed. Although our correlation analysis indicated a strong negative correlation between redd counts and year, these results were not significant (Pearson's $r = -0.87$; $p > 0.05$). Additionally, there were no significant correlation of *O. mykiss* bankside observations across years 2017-2019 (Pearson's $r = -0.09$; $p > 0.05$).

Carpinteria Creek

The proportion of surveys with clear visibility varied significantly in Carpinteria Creek across years 2017-2019 (Chi-square test: $X^2 = 8.41$, d.f. = 2, $p < 0.05$). Post-hoc pairwise t-tests showed survey visibility in 2018 significantly differed from 2017 and 2019 ($p < 0.05$). Zero redd or *O. mykiss* observations have been made during spawning surveys in Carpinteria Creek since 2017, so no additional multi-year analyses could be performed.

Ventura River

The number of surveys with clear visibility varied significantly in the Ventura River from 2014-2019 ($X^2 = 46.34$, d.f. = 5, p-value < 0.01). Post-hoc pairwise t-tests showed survey visibility significantly differed in 2018 from all years in the Ventura River (p-value < 0.01).

An analysis of variance showed mean redd life significantly differed by year where redds were observed in the Ventura River watershed (2014-2017) (ANOVA: $f = 6.1$; d.f. = 1, 30; $p < 0.05$). A post-hoc pairwise t-test using Bonferroni adjusted alpha levels ($\alpha = .008$) showed mean redd life significantly varied between years 2015 and 2017 (p-value < 0.01).

An analysis of variance showed mean redd area did not significantly vary between years 2014-2017 in the Ventura River (ANOVA: $f = 0.83$; d.f. = 3, 62; $p > 0.5$)

Total redd count and survey year were negatively correlated for years 2014 – 2019 but not significant (Pearson's $r = -0.74$; $n = 5$; $p > 0.05$). Similarly, there was no significant correlation found between total *O. mykiss* bankside observations and year (Pearson's $r = -0.47$; $n = 5$; $p > 0.05$).

Spatial distribution of *O. mykiss* bankside observations across all years in the Ventura River (i.e., 2014 – 2019), show the majority of observations ($n = 871$; 99.0%) were recorded in the upper watershed (i.e., upstream of the confluence of North Fork Matilija Creek and Matilija Creek). Redd observations ($n = 74$) recorded during the same timeframe exhibited a similar distribution pattern with 90.5% ($n = 67$) of redds being observed in the upper watershed.

Santa Paula Creek (Santa Clara River)

The proportion of surveys with clear visibility did not significantly vary in the Santa Paula Creek sub-watershed from 2017-2019 ($X^2 = 4.47$; d.f. = 2, p-value > 0.05). Analysis of variance tests indicated no significant differences in mean redd life (ANOVA: $f = 0.42$; d.f. = 2, 25; $p > 0.05$) or mean redd area across years 2017-2019 (ANOVA: $f = 0.52$; d.f. = 2, 25; $p > 0.05$). For these years, our correlation analyses showed no significant correlation between redd or *O. mykiss* counts over time.

DISCUSSION

The 2018-2019 spawning season was characterized by above-average rainfall for Santa Barbara and Ventura counties (Santa Barbara County Public Works Department 2019, Ventura Watershed Protection District 2019). Peak flows reached $975 \text{ ft}^3 \text{ s}^{-1}$ in Carpinteria Creek, $16,000 \text{ ft}^3 \text{ s}^{-1}$ in the Ventura River mainstem, and $3,480 \text{ ft}^3 \text{ s}^{-1}$ in Santa Paula Creek (USGS 2019). Elevated flows led to persistent turbidity and increased depths preventing the completion of scheduled surveys during the months of February and March. This interruption in sampling coincided with what has historically been an active spawning period in the Ventura River watershed and may have influenced redd counts.

Redd Observations

For all five watersheds surveyed, a total of three redds were observed. All redds were observed in the upper watershed of Arroyo Hondo ($n = 1$) and Santa Paula ($n = 2$) creeks. Zero redds were recorded in the Carpinteria Creek, Mission Creek, or Ventura River basins during the 2018 – 2019 spawning season. It is possible that the storm events obscured or destroyed redds during peak flows in February and March. Due to these low counts, no meaningful analysis can be used to evaluate redd distribution or lifespan. However, redd dimensions observed in Arroyo Hondo and Santa Paula Creeks coincided with those observed in previous years. The mean total length of redds observed in Arroyo Hondo Creek (0.59 m) and Santa Paula Creek ($0.94 \pm 0.21 \text{ m}$ [mean \pm SE]) are much smaller than those recorded in northern California stream systems, which typically exceed 2.0 m (Zimmerman and Reeves 2000). The observed redd sizes (range: $0.11\text{-}0.32 \text{ m}^2$) suggest all were created by resident *O. mykiss*, who are typically smaller in size than anadromous adults (Kendal et al. 2014). The number of barriers to anadromous fish passage recorded in the lower Santa Clara River further support that the redds observed in Santa Paula Creek were made by resident *O. mykiss* (PAD 2019). However, additional data is needed to decipher between resident vs anadromous *O. mykiss* redds in southern California watersheds.

***Oncorhynchus mykiss* Observations**

The largest number of *O. mykiss* observations were made in Arroyo Hondo Creek ($n = 186$). This is consistent with data collected in previous years. Of the 186 *O. mykiss* observations, 60.8% ($n = 113$) were estimated to be 0-2 inches. This size class represents what would be expected for trout born within the past year (i.e., young of the year). These data indicate successful *O. mykiss* spawning occurred in this

watershed. Despite being the smallest of our surveyed stream systems, Arroyo Hondo Creek contains ideal stream habitat, which is relatively undisturbed due to effective management and protection.

A total of 79 *O. mykiss* were observed in the Santa Paula Creek subwatershed of the Santa Clara River Basin. The majority of these observations occurred in Sisar Creek (88.6%, n = 70). Additionally, 81.4% (n = 57) of the observed in Sisar Creek *O. mykiss* were estimated to be 0-2 inches. The presence of trout this size suggests successful *O. mykiss* spawning occurred in this reach despite zero redds observed. This could be due to a lower sampling frequency for reaches in the upper watershed due to increased flow and reduced visibility.

One *O. mykiss* was observed during spawning surveys conducted in the Ventura River watershed during the 2018-2019 season. This fish was observed in Murietta Creek, above the Matilija Dam and the limit to anadromy. In previous years, data collected in the Ventura River show a larger *O. mykiss* presence in the upper Ventura watershed. Spatial distribution of *O. mykiss* bankside observations across all years in the Ventura River (i.e., 2014 – 2019), show the majority of observations (i.e., 99.6%) were recorded near the upstream of the confluence of North Fork Matilija and Matilija creeks. Additionally, the majority of *O. mykiss* observations were recorded in reaches above Matilija Dam (n = 556, 69.9%). Redd observations recorded during the same timeframe exhibited a similar distribution pattern with 95.1% (n = 58) of redds being observed in the upper watershed. Forty-seven percent (n = 29) of all redds observed were located above Matilija Dam, indicating these are resident redds. Historical habitat data collected show the upper watershed contains critical spawning and wintering *O. mykiss* habitat (Allen 2012, NFMS 2012). Although cut off from anadromy, streams above the Matilija Dam provide similar critical habitat to resident *O. mykiss* populations. With plans for the removal of Matilija Dam in progress, these resident populations are genetically important and have the potential to contribute to future anadromous populations (Abadía-Cardoso et al. 2016, Matilija Dam Ecosystem Restoration Project 2019).

Zero *O. mykiss* were observed during spawning surveys conducted in the Carpinteria Creek watershed during the 2018-2019 season. Previous data collected in Carpinteria Creek indicate a critically low *O. mykiss* abundance. Since 2015 there have been zero observations of *O. mykiss* or *O. mykiss* spawning activity in Carpinteria or Gobernador creeks (CDFW unpublished data). Such low abundances are sensitive to additional impacts such as drought conditions or wildfire.

Zero *O. mykiss* were observed in Mission Creek during spawning surveys conducted from January to , 2019. Spawning surveys have been conducted in Mission Creek since 2018, and during the 2017-2018 spawning season, one *O. mykiss* was observed bankside (CDFW, unpublished data).

Environmental Challenges

Due to the above average rainfall, elevated turbidities were problematic during the 2018 – 2019 survey season, particularly from January to March. However, the proportion of surveys conducted under sub-optimal conditions (i.e. poor water visibility) in 2019 was 24 which is similar to previous years (2013-2017). Turbidity levels during the 2017-2018 season was exceptionally high due to the immediate effects of the Thomas Fire, including loss of vegetation and loosened soils. High turbidity levels continued to be observed in the 2018 – 2019 survey season, as loose soils and little vegetation persisted following the Thomas Fire. This led to 15.8% (n = 24) of spawning surveys conducted under sub-optimal conditions including 8% (n = 2) in Carpinteria Creek, 25% (n = 1) in Mission Creek, 16% (n = 15) in the

Ventura River watershed, and 32% ($n = 6$) in Santa Paula subwatershed. The degree to which poor water clarity influenced surveys watersheds affected by the 2018 Thomas Fire is further emphasized when comparing this data using a chi-square test of independence. A post-hoc pairwise test showed that 2018 was the only year where the proportion of surveys where visibility was $< 100\%$ differed from all other years. We surmise that this significant change in turbidity was a secondary effect of the Thomas Fire due to destabilization of stream hillslopes resulting from loss of vegetation to the fire (Klose 2018). As banks revegetate in the years post fire we expect the 2017-2018 turbidity levels to remain an outlier. However, additional years of data are needed to further explore the long-term effects of wildfires on redd survey efficacy in southern California watersheds.

Our survey effort is supported by southern California *O. mykiss* redd data collected in recent years. The 95% CI [32.30, 39.40] of the mean estimated redd life (35.8 ± 1.8 [mean \pm SE] days) for all redds observed from 2014 – 2019 suggests a survey frequency of two weeks should allow detection of a new redd before the redd degrades to an extent where they are no longer visible. This can process can be complicated by high flow events that may erase redds before they can be observed. However, in cases where high flow events were anticipated, we attempted to survey reaches where the risk for redds to be obscured was highest (i.e., reaches where stream gradient and wildfire burn severity were both relatively high). Continued tracking of redd life in subsequent years will further increase our understanding of redd longevity in southern California systems and its implications for survey methodology.

The 2018 Thomas Fire likely impacted the Ventura River basin *O. mykiss* population. The Thomas Fire burned an estimated 64 percent of the Upper Ventura River, including 96% of the North Fork Matilija Creek subwatershed which contained over four miles of designated critical steelhead habitat. Due to the burned soil and loss of vegetation, subsequent rain events created particularly large and destructive debris flows during the 2017-2018 spawning season. We found the number of bankside *O. mykiss* observations recorded during spawning surveys before and after the Thomas Fire to vary significantly. From 2015 to 2017 the mean (\pm SE) number of *O. mykiss* observed during spawning surveys each year was 281 ± 39 trout. In 2018 the total number of *O. mykiss* observed bankside was two and in 2019 decreased to one. These data suggest the negative effects of wildfire and subsequent debris flows likely lead to a severe decrease in the *O. mykiss* populations. Continued monitoring of the Ventura River Basin has been assigned a high priority for recovery action (Core 1; NFMS 2012). Future spawning surveys will be a critical step toward better understanding of southern California steelhead recovery in response to extreme environmental conditions (NMFS 2012).

Figure 1. Arroyo Hondo Creek reach for southern California *O. mykiss* spawning/redd surveys. Surveys occurred on a biweekly interval or when environmental conditions allowed.



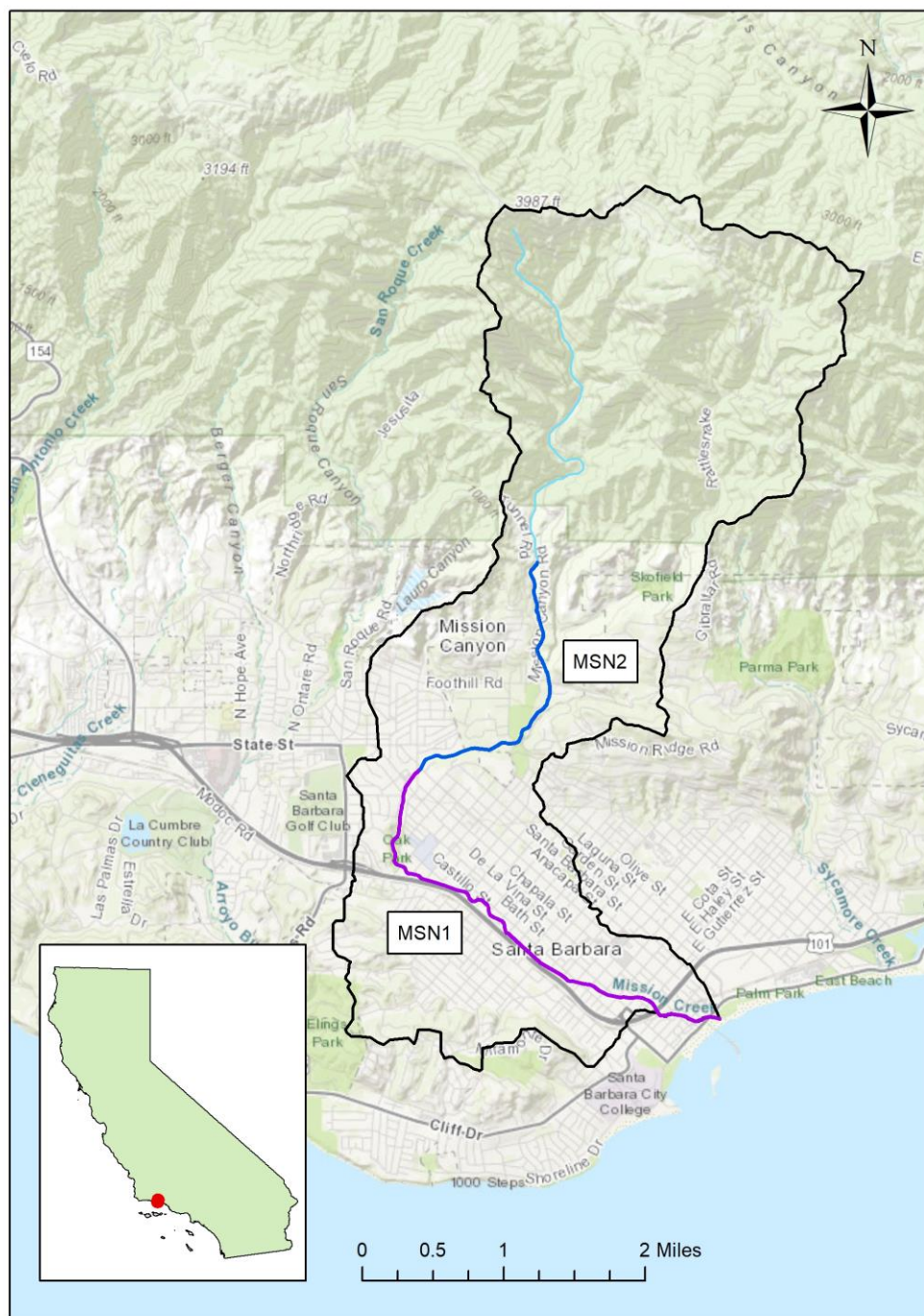


Figure 2. Mission Creek reach for southern California *O. mykiss* spawning/redd surveys. Surveys occurred on a biweekly interval or when environmental conditions allowed

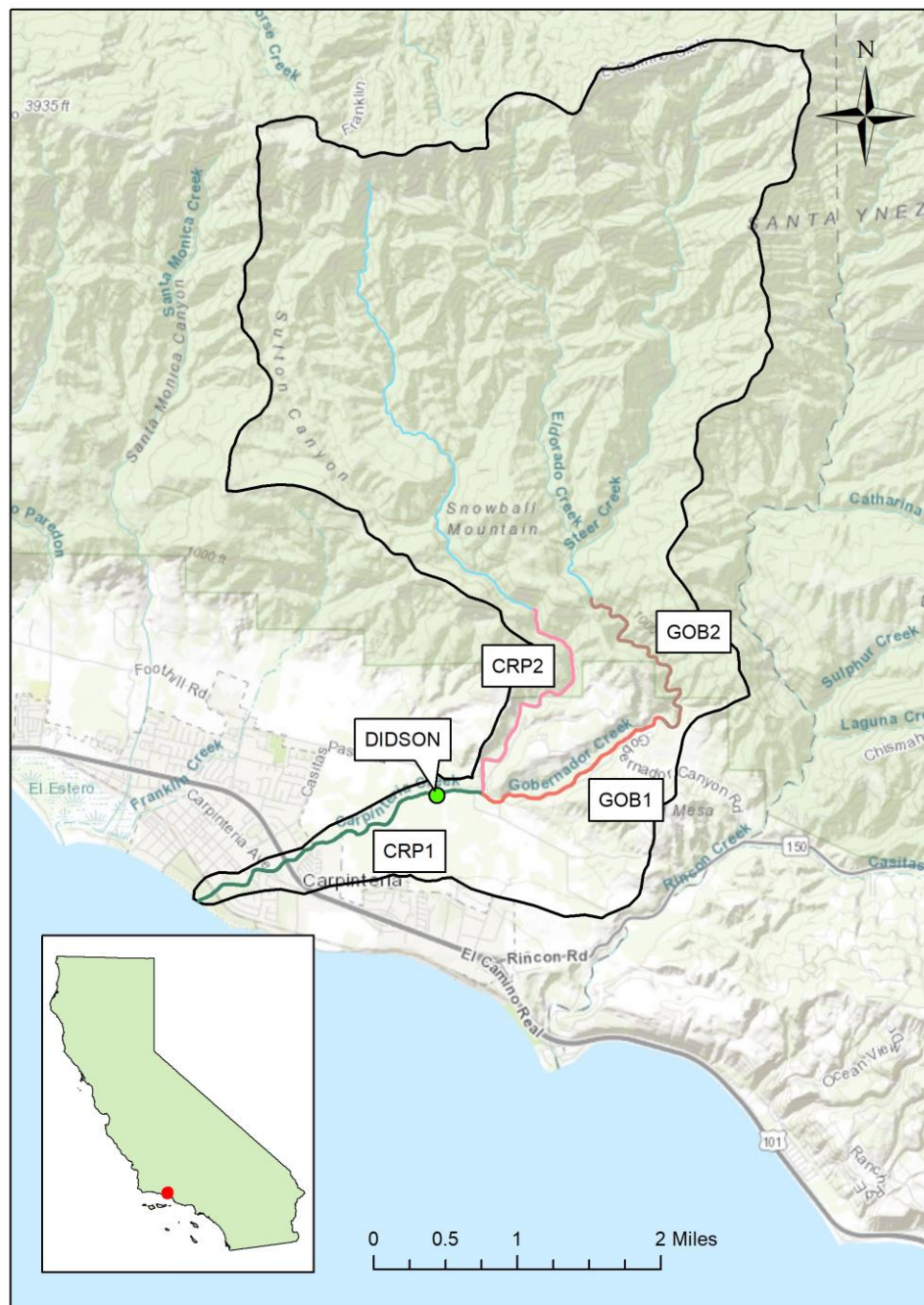


Figure 3. Carpinteria Creek watershed reaches for southern California *O. mykiss* spawning/redd surveys. Surveys occurred on a biweekly interval or when environmental conditions allowed and were paired with the deployment of a DIDSON underwater sonar camera (site shown).

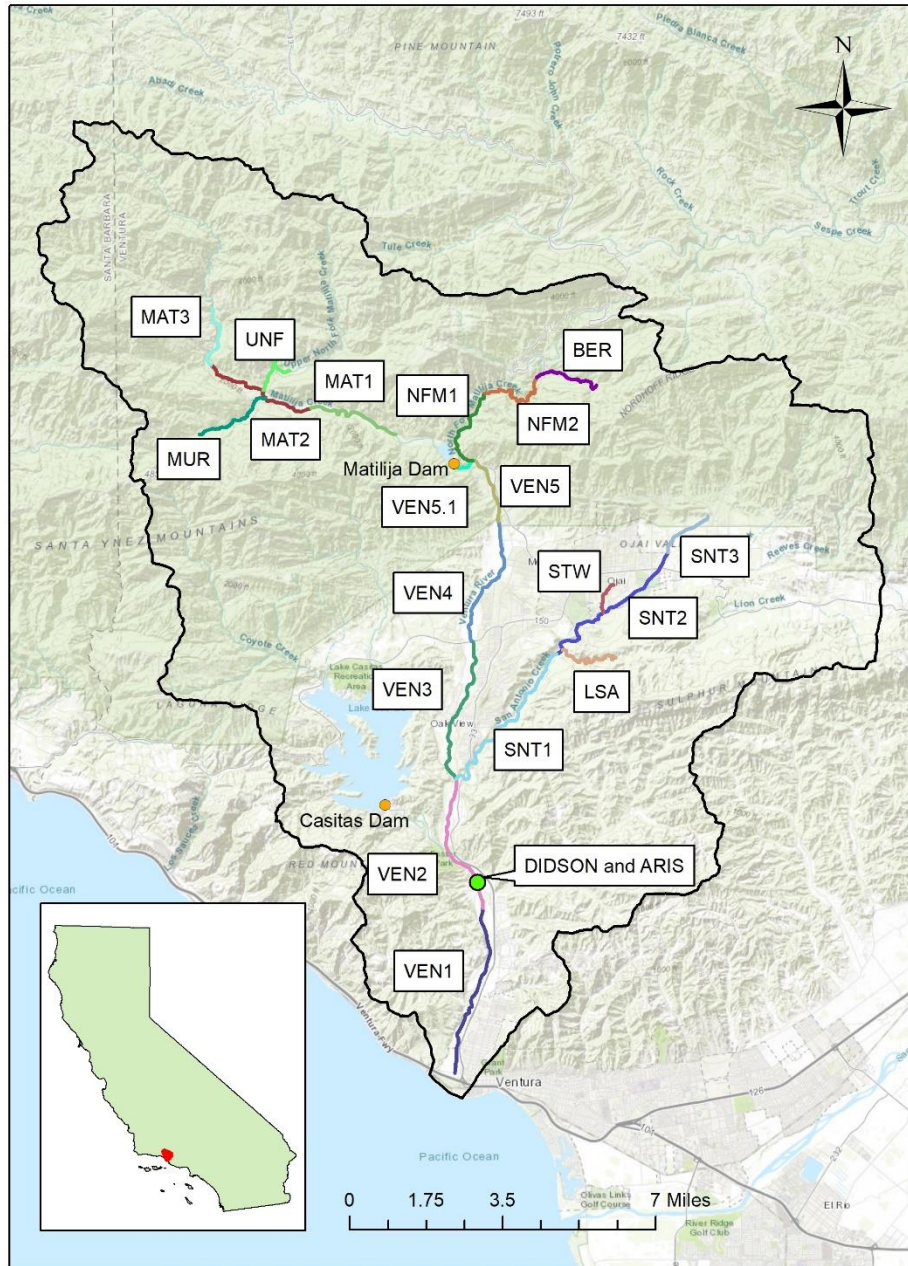
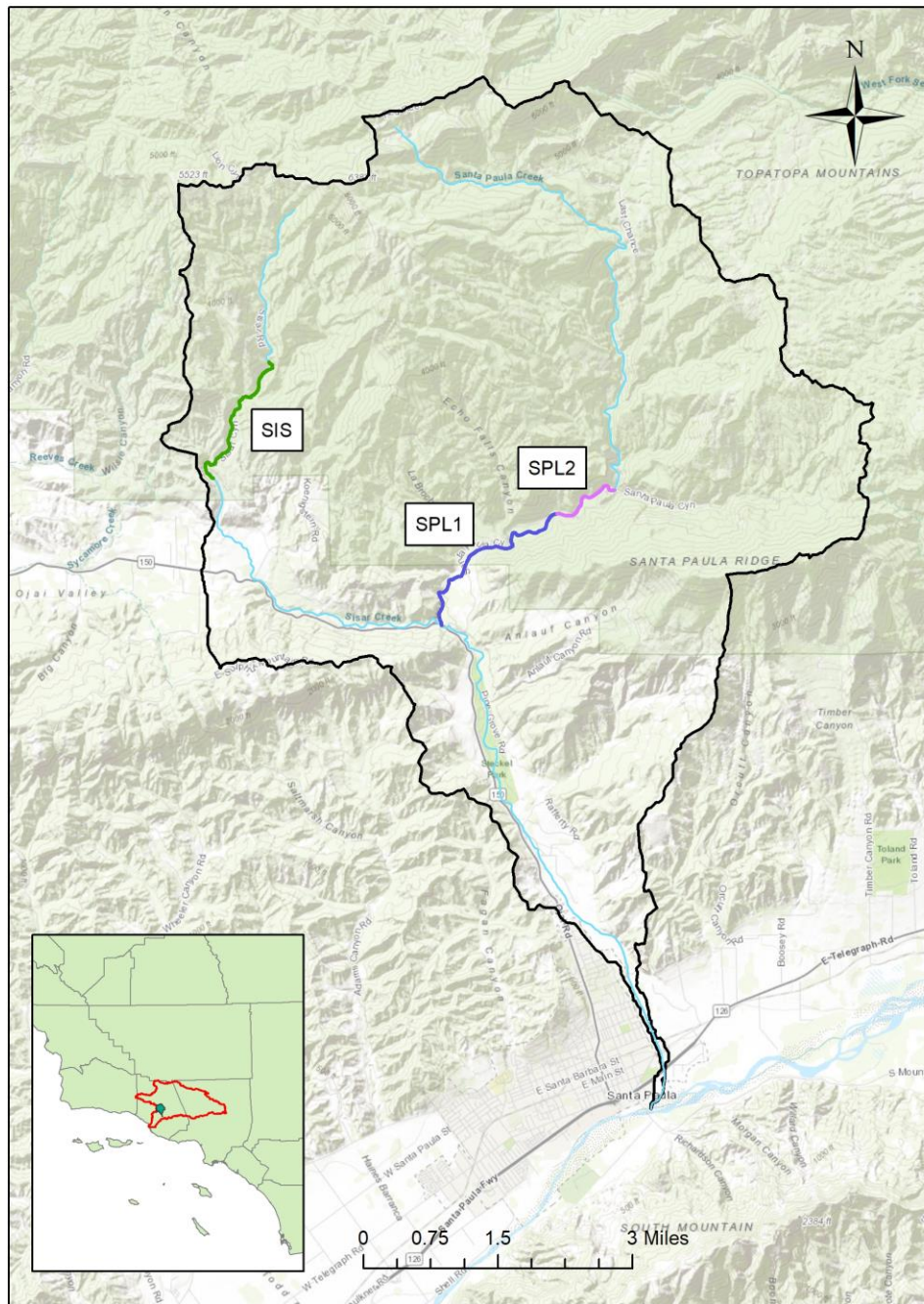


Figure 4. Ventura River watershed reaches for southern California *O. mykiss* spawning/redd surveys. Surveys occurred on a biweekly interval or when environmental conditions allowed and were paired with the deployment of a DIDSON underwater sonar camera and PIT tag antenna array. Reaches located above the Matilija Dam are surveyed due to genetic similarity between populations above and below barriers to fish passage and the planned removal of said dam.



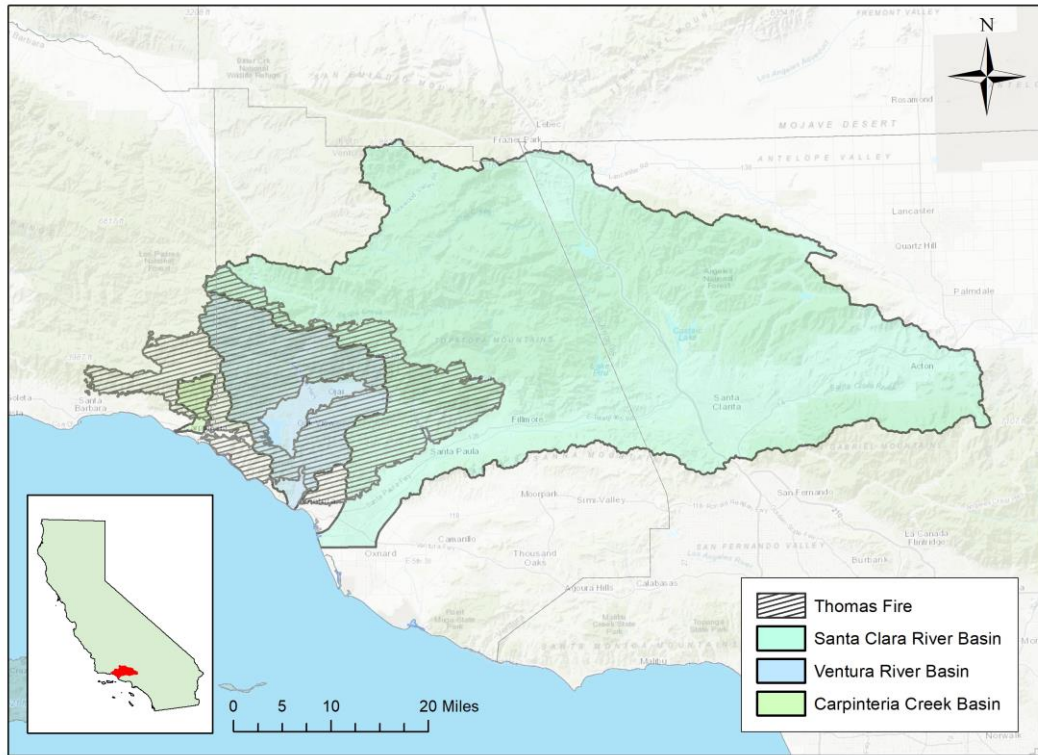


Figure 6. The Carpinteria Creek, Ventura River, and Santa Clara basin boundaries overlaid by the area affected by the 2018 Thomas Fire.

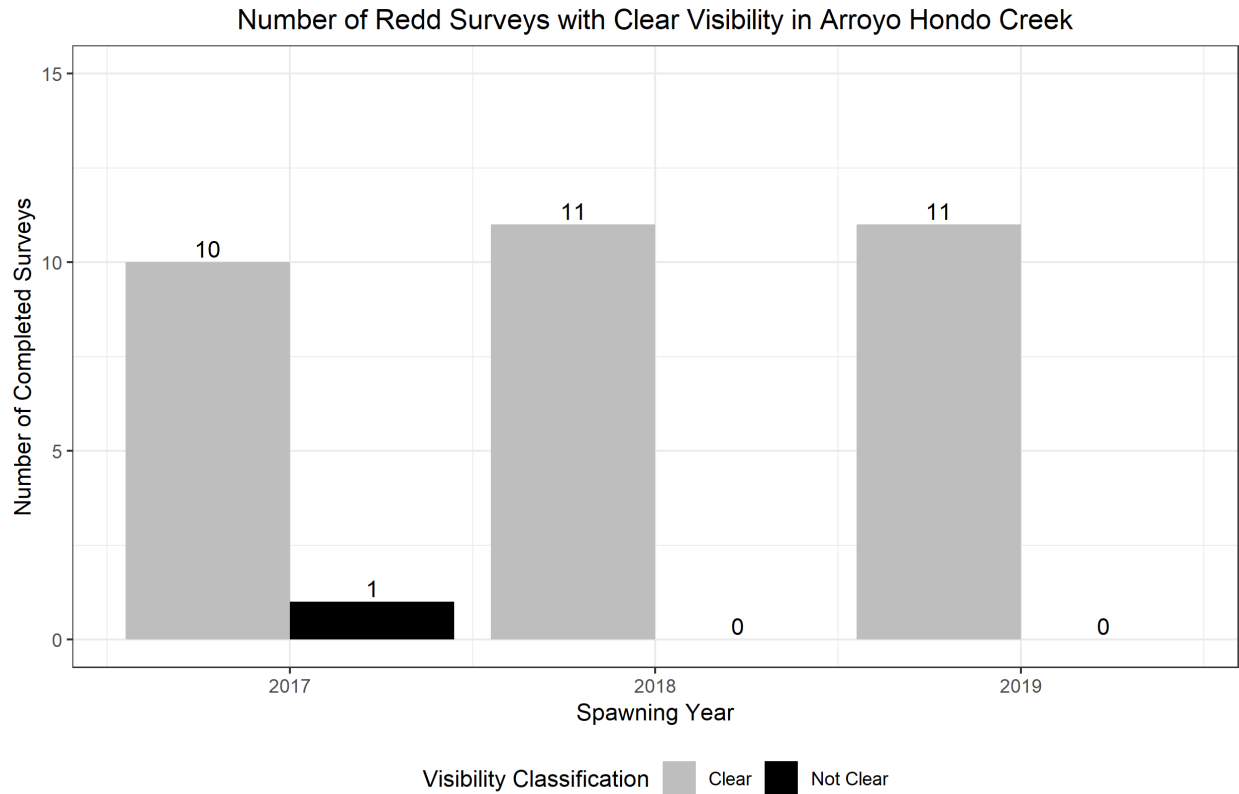


Figure 7. The proportion of redd surveys where visibility was 100% (i.e., Clear) and the proportion of surveys where visibility was less than 100% (i.e., Not Clear) for all surveys conducted in Arroyo Hondo Creek from 2017-2019.

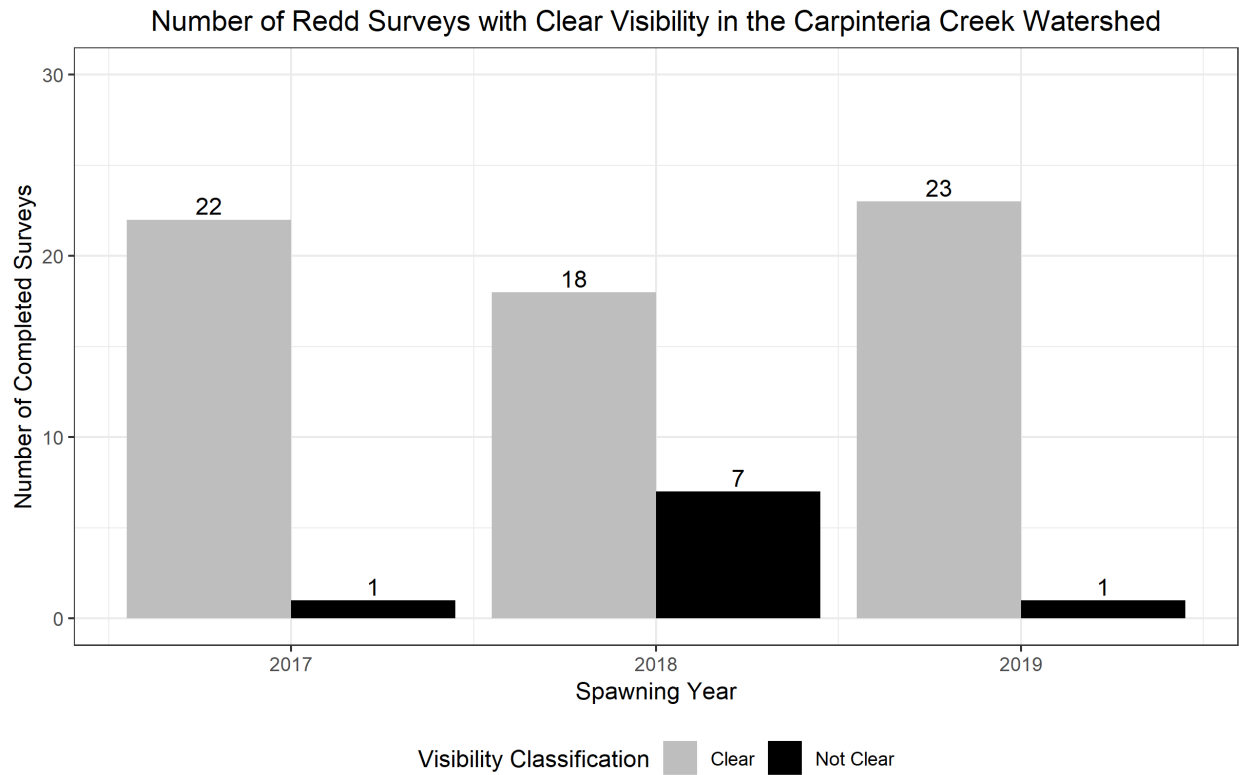


Figure 8. The proportion of redd surveys where visibility was 100% (i.e., Clear) and the proportion of surveys where visibility was less than 100% (i.e., Not Clear) for all surveys conducted in Carpinteria Creek from 2017-2019.

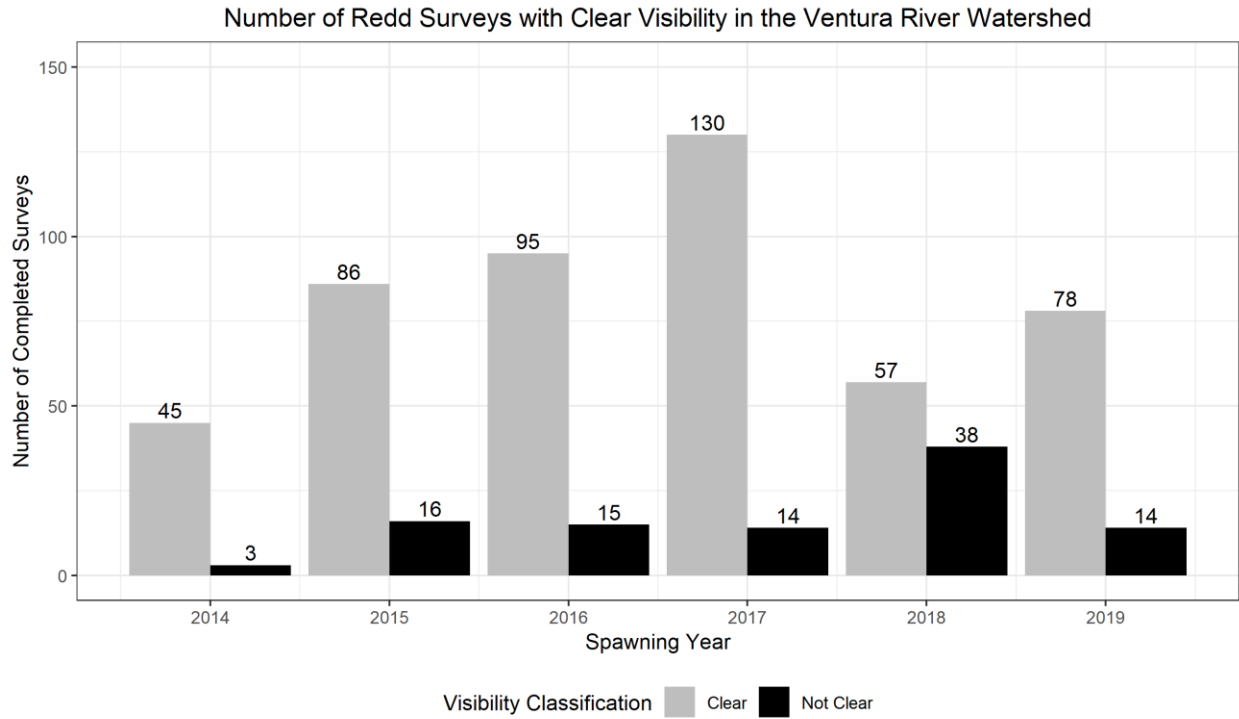


Figure 9. The proportion of redd surveys where visibility was 100% (i.e., Clear) and the proportion of surveys where visibility was less than 100% (i.e., Not Clear) for all surveys conducted in the Ventura River Basin from 2014-2019.

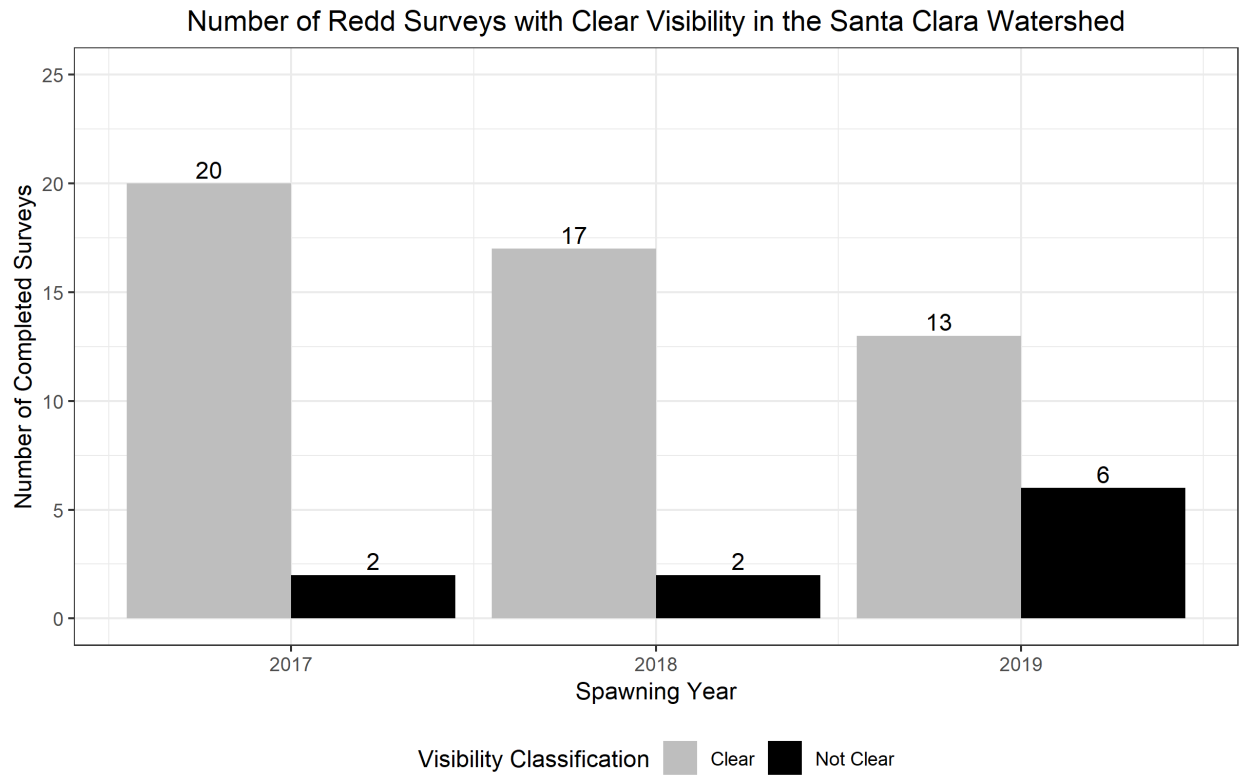


Figure 10. The proportion of redd surveys where visibility was 100% (i.e., Clear) and the proportion of surveys where visibility was less than 100% (i.e., Not Clear) for all surveys conducted in the Santa Paula Creek subwatershed from 2017-2019.

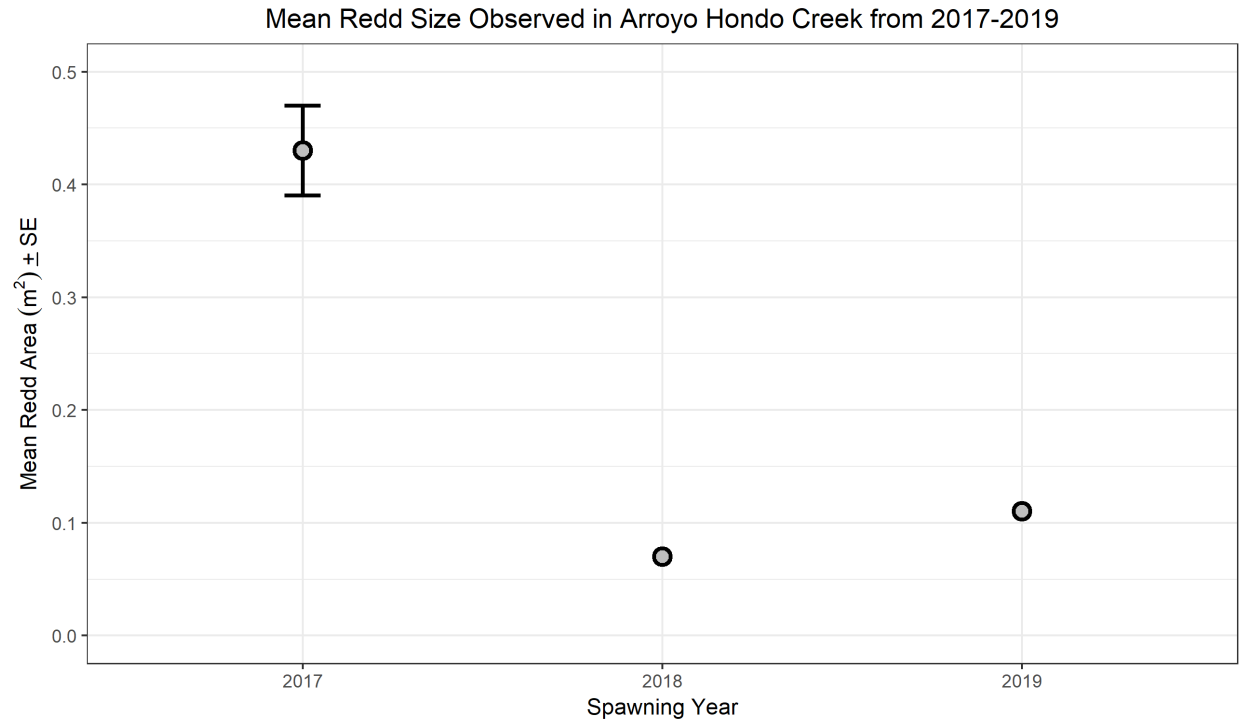


Figure 11. Mean *O. mykiss* redd size in Arroyo Hondo Creek. Data was collected from a 1.9-mile stream reach from 2017 to 2019. Vertical bars indicate standard error. Only one redd was recorded in 2018 and 2019.

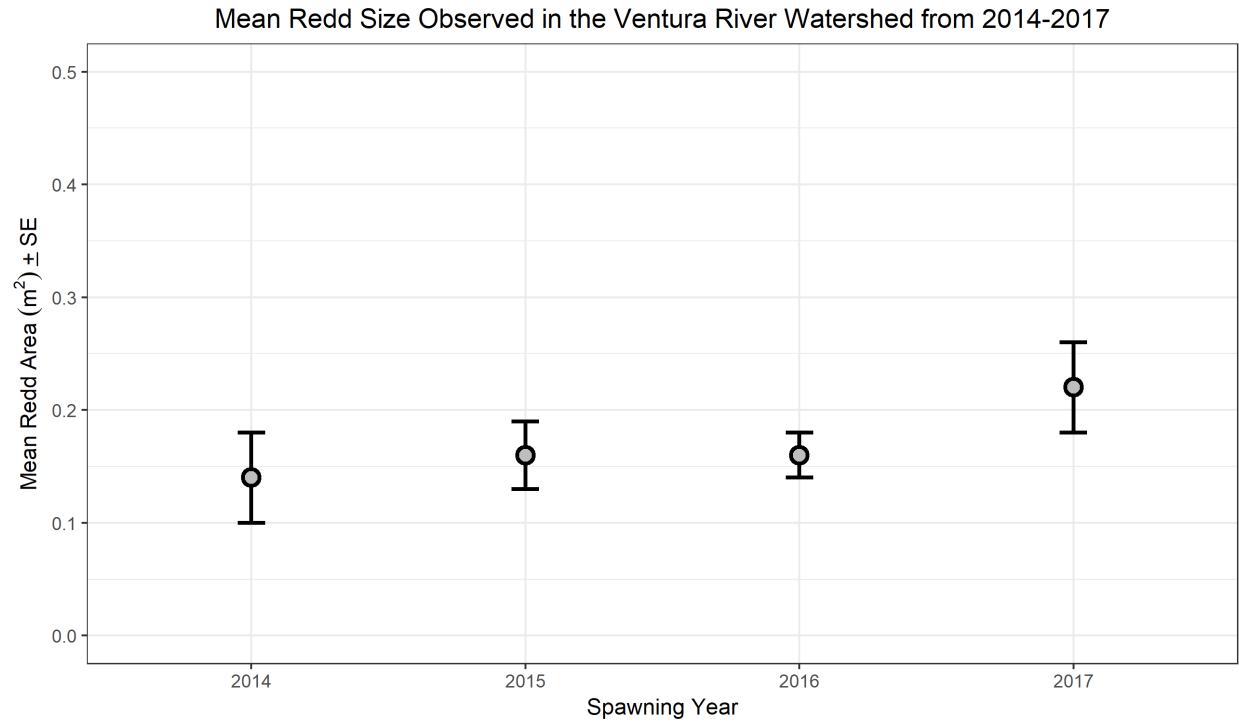


Figure 12. Mean *O. mykiss* redd area (m²) in the Ventura River Basin. Data was collected in 19 stream reaches from 2014 to 2019. Zero redds were observed in 2018 and 2019 so those years are excluded. Vertical bars indicate standard error.

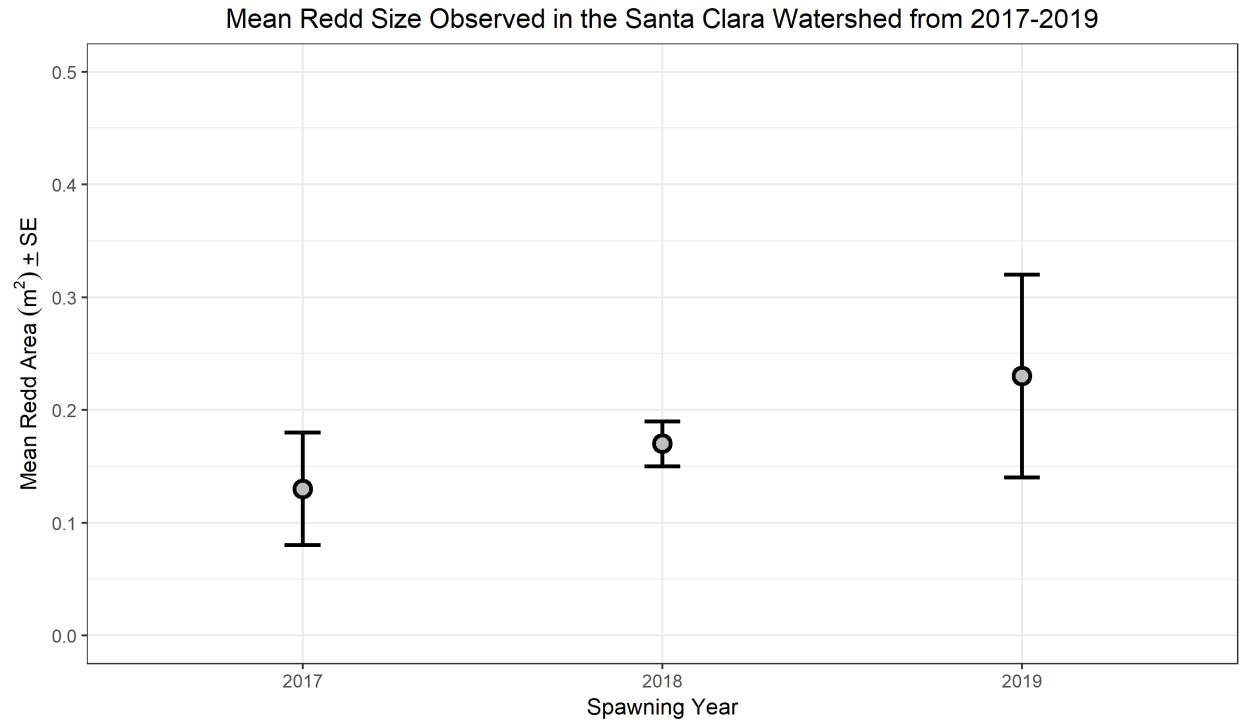


Figure 13. Mean *O. mykiss* redd size (m²) in the Santa Paula Creek subwatershed of the Santa Clara River Basin. Data was collected in three stream reaches from 2017 to 2019. Vertical bars indicate standard error.

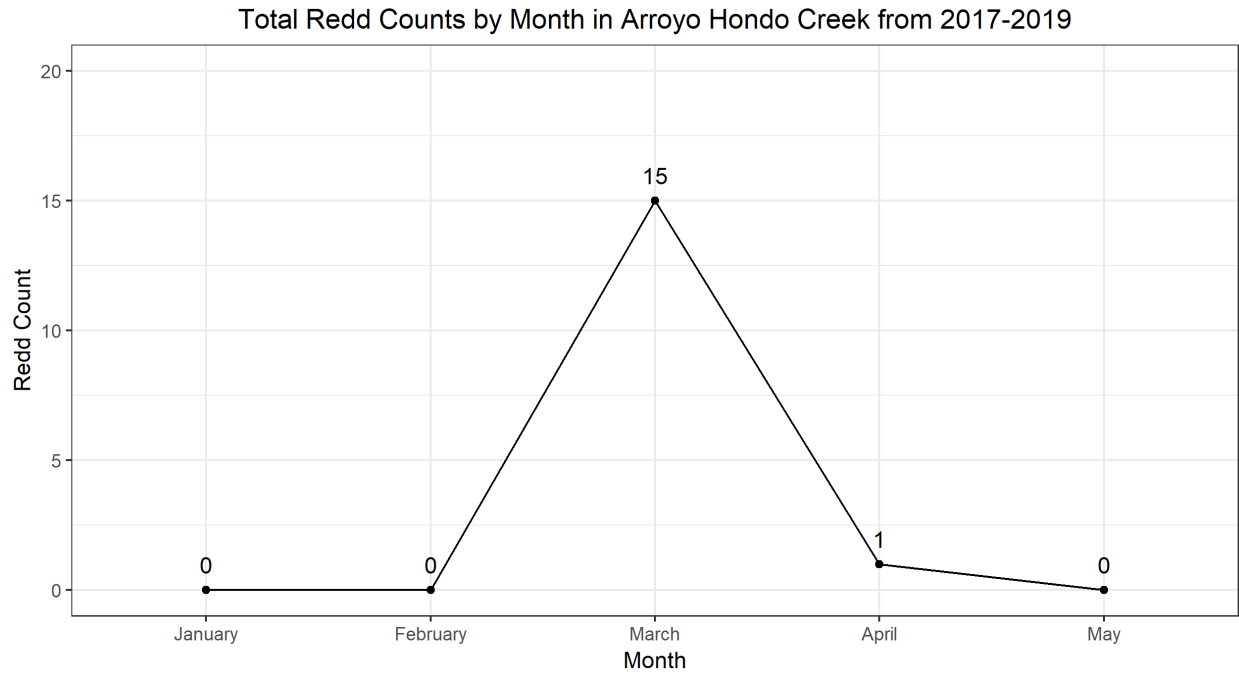


Figure 14. Number of *O. mykiss* redds observed by month for years 2017 – 2019 in the Arroyo Hondo Creek watershed.

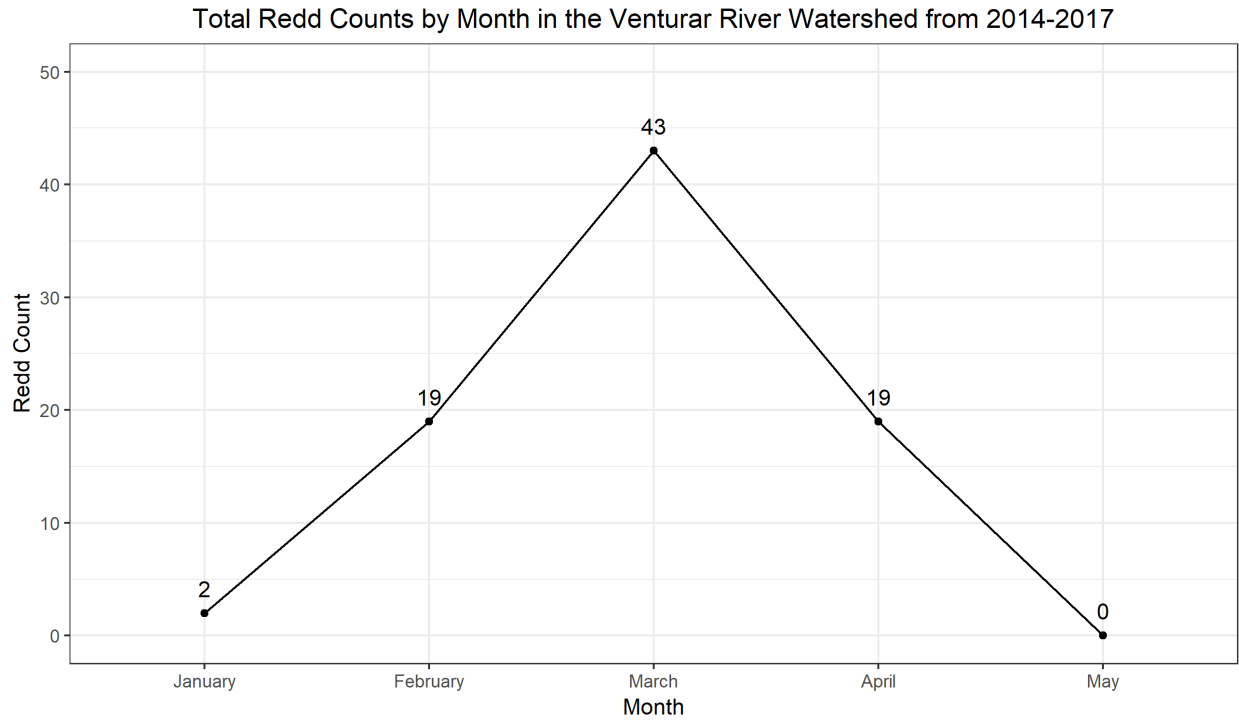


Figure 15. Number of *O. mykiss* redds observed by month for years 2014 – 2017 in the Ventura River watershed. Zero redds were recorded in 2018 and 2019 so those years are excluded.

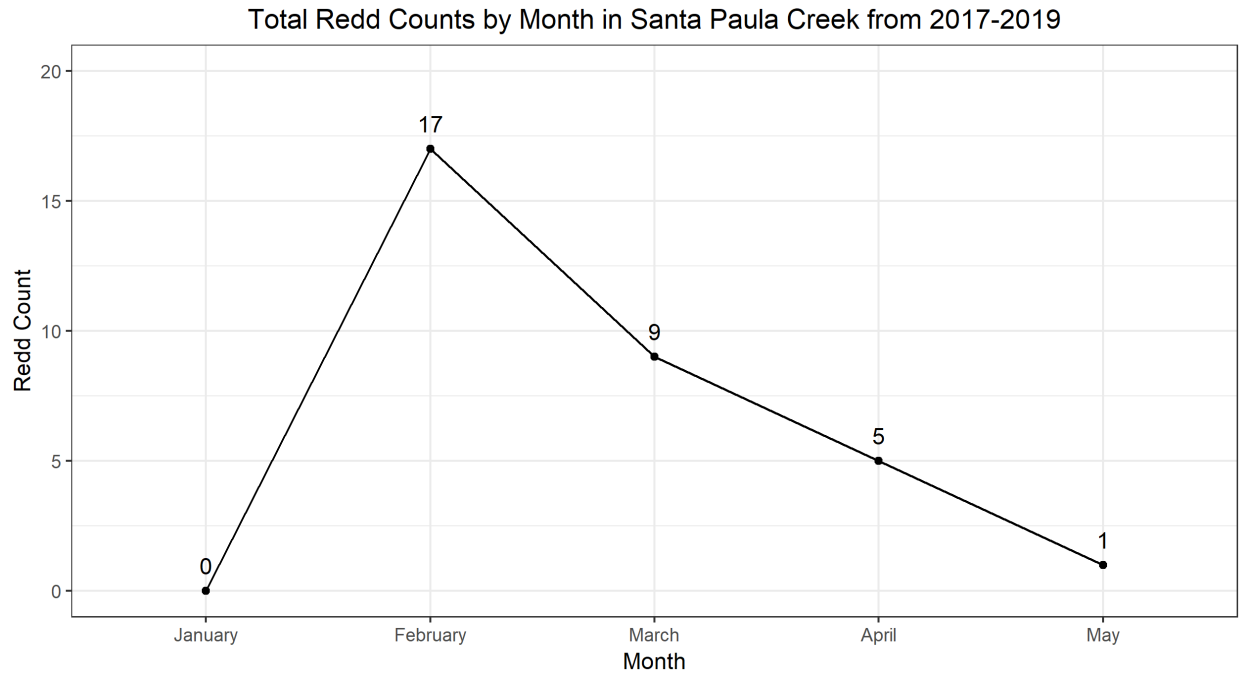


Figure 16. Number of *O. mykiss* redds observed by month for years 2017 – 2019 in the Santa Paula subwatershed of the Santa Clara River Basin.

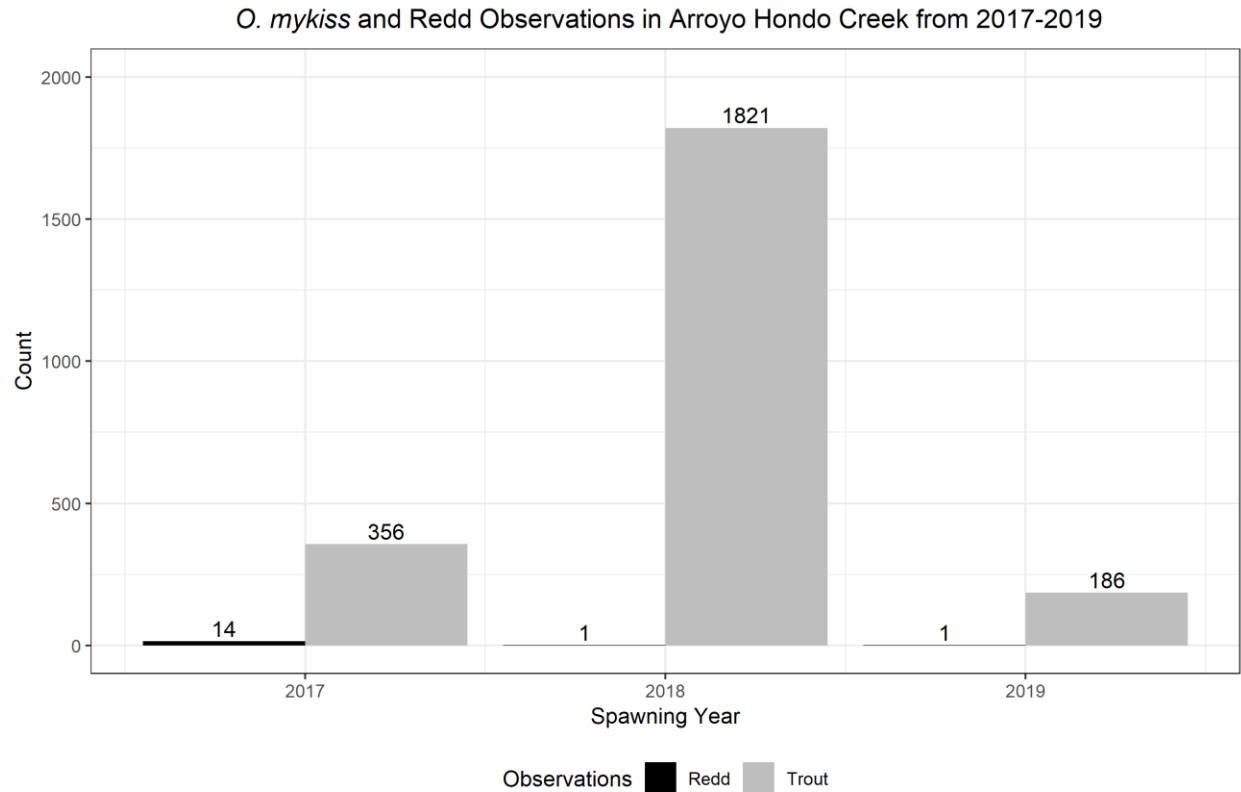


Figure 17. Number of *O. mykiss* redds and *O. mykiss* bankside observations recorded for years 2017 – 2019 in Arroyo Hondo Creek.

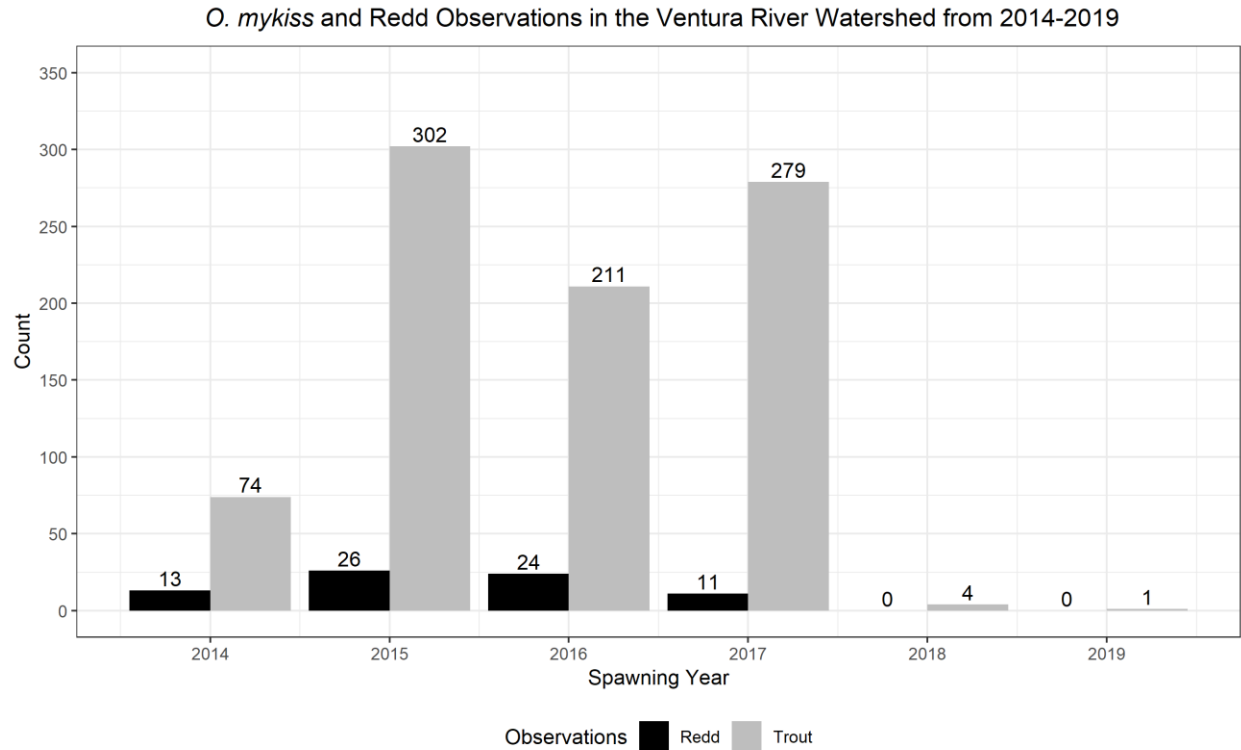


Figure 18. Number of *O. mykiss* redds and *O. mykiss* bankside observations recorded for years 2014 – 2019 in the Ventura River watershed.

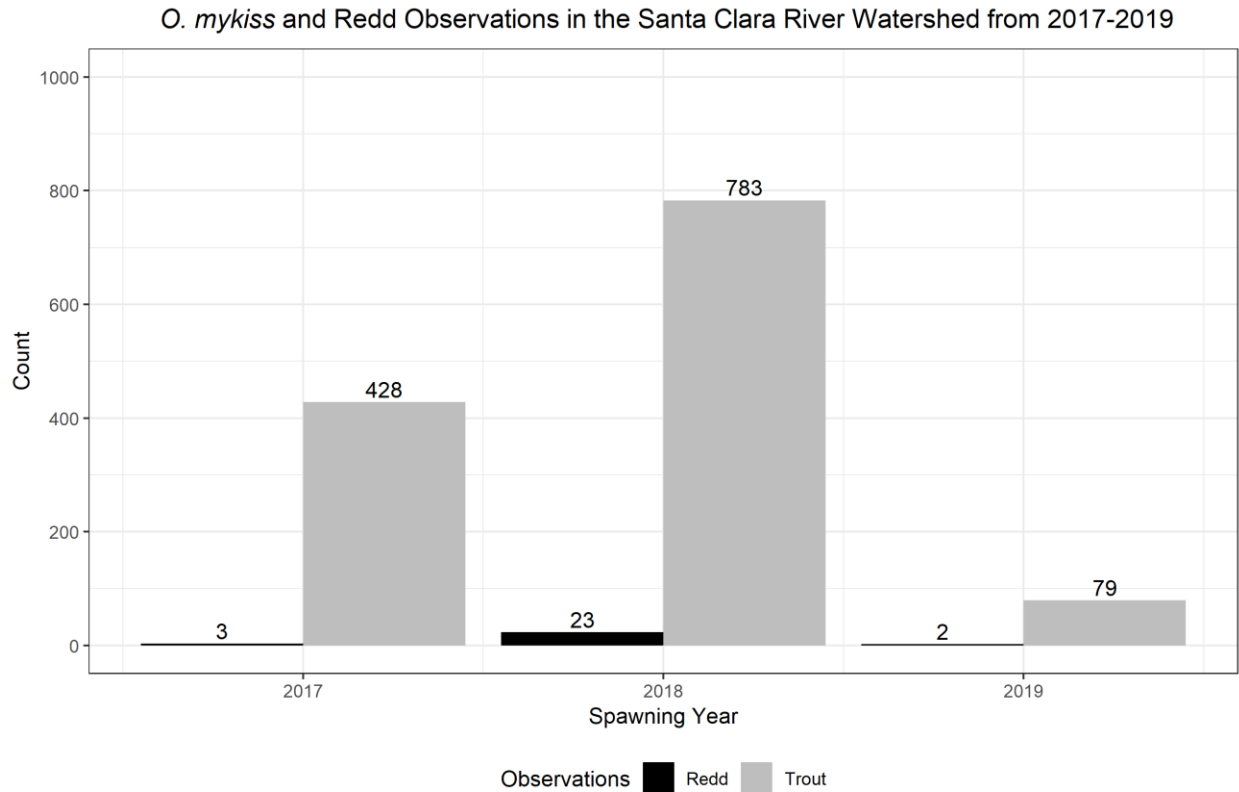


Figure 19. Number of *O. mykiss* redds and *O. mykiss* bankside observations recorded for years 2017 – 2019 in the Santa Paula subwatershed of the Santa Clara River Basin.

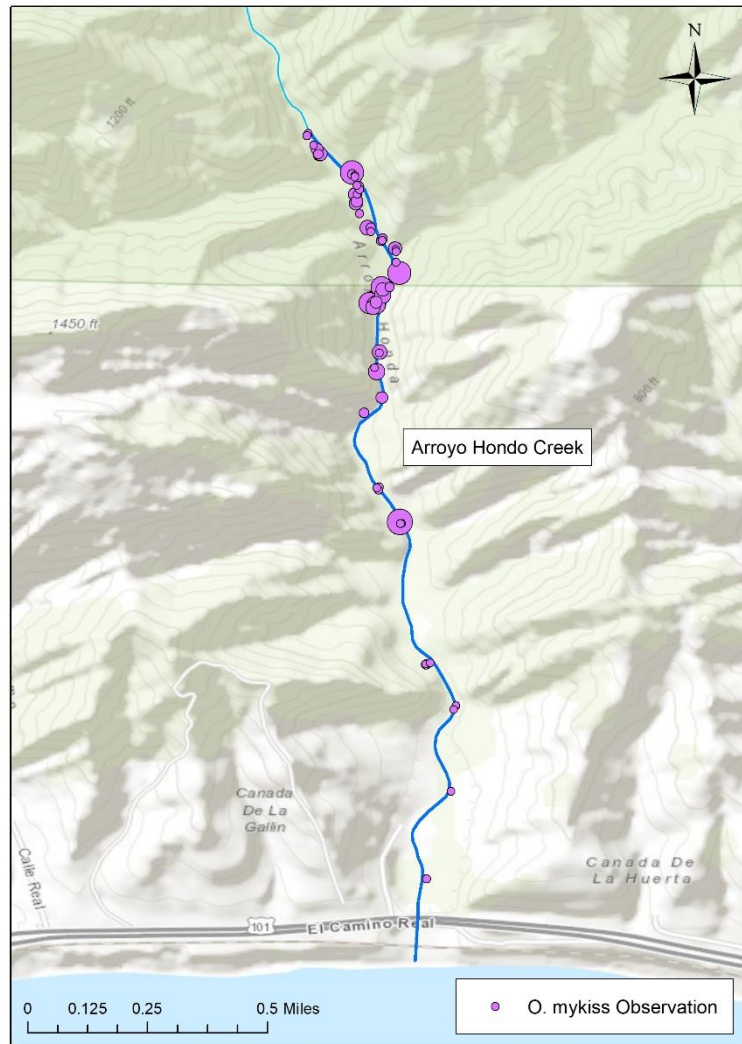


Figure 20. Distribution of *O. mykiss* (n=186) and *O. mykiss* redd (n=1) observations recorded during spawning surveys in Arroyo Hondo Creek. Eleven surveys were conducted along the 1.9-mile stream reach from January 3, 2019 to May 22, 2019. The survey reach is indicated in dark blue.



Figure 21. Distribution of *O. mykiss* (n=1) observations recorded during spawning surveys in the Ventura River Basin. Surveys (n=93) were completed in 19 stream reaches from December 12, 2018 to May 21, 2019. The single *O. mykiss* was observed in Murietta Creek located above the Matilija Dam. Survey reaches are indicated in dark blue.

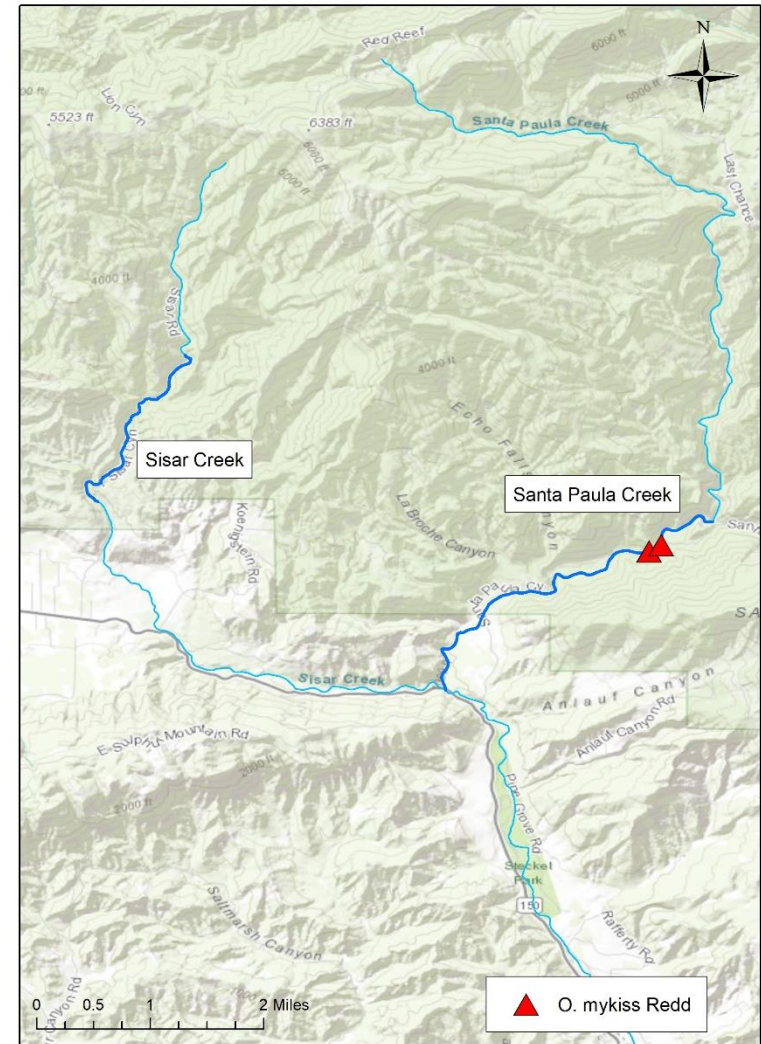


Figure 22. Distribution of *O. mykiss* (n=79) and *O. mykiss* redd (n=2) observations recorded during spawning surveys in the Santa Paula Creek subwatershed of the Santa Clara River Basin. Surveys (n=19) were completed in three reaches along Santa Paula and Sisar creeks from January 7, 2019 to May 15, 2019. Survey reaches are indicated in dark blue.

TABLES

Table 1 – Survey start and end dates for *O. mykiss* spawning surveys conducted in five southern California watersheds located in Santa Barbara and Ventura counties. Mission Creek, Carpinteria Creek, Ventura River, and Santa Clara River are designated as high priority for *O. mykiss* monitoring and recovery.

<i>Watershed</i>	<i>Surveys Start Date</i>	<i>Surveys End Date</i>
Arroyo Hondo Creek	2019-01-03	2019-05-22
Carpinteria Creek	2019-01-24	2019-05-15
Mission Creek	2019-02-25	2019-04-18
Santa Clara River	2019-01-07	2019-05-15
Ventura River	2018-12-12	2019-05-21

Table 2 – Redd survey frequency measured in mean days in between surveys completed by watershed in during the 2018 – 2019 *O. mykiss* spawning season. All surveys were conducted when environmental conditions allowed.

<i>Watershed</i>	<i>N</i>	<i>Mean Survey Frequency (days)</i>	<i>SE (\pm days)</i>
Arroyo Hondo Creek	11	25.9	6.38
Mission Creek	4	17.33	2.96
Carpinteria Creek	25	19.14	1.7
Ventura River	93	18.64	1.81
Santa Clara River	19	19.31	3.29

Table 3 – Number of *O. mykiss* and *O. mykiss* redds observed during redd surveys in five southern California watersheds during the 2018-2019 spawning season.

<i>Watershed</i>	<i>Total O. mykiss Observed</i>	<i>Total Redds Observed</i>
Arroyo Hondo Creek	186	1
Carpinteria Creek	0	0
Mission Creek	0	0
Santa Clara River	79	2
Ventura River	1	0

Table 4 – Number of *O. mykiss* bankside observations by size in Arroyo Hondo Creek of the Conception Coast BPG. Data was collected from redd surveys completed during the 2018-2019 *O. mykiss* spawning season.

<i>Size Class (inches)</i>	<i>N</i>	<i>Percent Observations</i>
0 – 2	113	60.8
2 – 4	22	11.8
4 – 6	33	17.7
6 – 8	12	6.5
8 – 10	1	0.5
10 – 12	3	1.6
*NA	2	1.1

**Size estimation could not be made*

Table 5 – Number of *O. mykiss* bankside observations by size in the Ventura River Basin. Data was collected from redd surveys completed in 19 reaches during the 2018-2019 *O. mykiss* spawning season.

<i>Size Class (inches)</i>	<i>N</i>	<i>Percent Observations</i>
4 – 6	1	100

Table 6 – Number of *O. mykiss* bankside observations by size in the Santa Paula subwatershed of the Santa Clara River. Data was collected from redd surveys completed in three reaches during the 2018-2019 *O. mykiss* spawning season.

<i>Size Class (inches)</i>	<i>N</i>	<i>Percent Observations</i>
0 – 2	57	72.2
2 – 4	2	2.5
4 – 6	10	12.7
6 – 8	5	6.3
8 – 10	1	1.3
*UNK	4	5.1

**Size estimation could not be made*

Table 7 – Mean *O. mykiss* redd life in days for years 2017 – 2019 in Arroyo Hondo Creek. Only redds where age code 4 (i.e. redd is no longer detectable) were included for the analysis. Age code 4 was only recorded for redds observed in 2017 so a multi-year comparative analysis could be performed.

<i>Spawning Year</i>	<i>N</i>	<i>Mean Redd Life (days)</i>	<i>SE (\pm days)</i>
2017	12	32.25	6.12

Table 8 – Mean *O. mykiss* redd life in days for years 2014 – 2019 in the Ventura River Basin. Only redds where age code 4 (i.e. redd is no longer detectable) were included for the analysis. Zero redds were observed in 2018 and 2019 so those years were excluded from the analysis. Means followed by the same letter did not differ significantly (Tukey test, $p < 0.01$).

<i>Spawning Year</i>	<i>N</i>	<i>Mean Redd Life (days)</i>	<i>SE (days)</i>
2014	4	40.25 _A	8.8
2015	13	54.31 _B	4.68
2016	8	45.62 _A	6.75
2017	7	24 _B	5.01

Table 9 – Mean *O. mykiss* redd life in days for years 2017 – 2019 in the Santa Paula subwatershed of the Santa Clara River Basin. Only redds where age code 4 (i.e. redd is no longer detectable) were included for the analysis. Due to the small sample size for years 2017 (n=1) and 2019 (n=1), analysis of variance could not be performed.

<i>Spawning Year</i>	<i>N</i>	<i>Mean Redd Life (days)</i>	<i>SE (days)</i>
2017	1	26	NA
2018	13	21	0
2019	1	28	NA

Table 10 – Mean *O. mykiss* redd area in meters squared for years 2017 – 2019 in Arroyo Hondo Creek. Redd area was calculated as the sum of pot and tail spill areas per Gallagher et al. (2007). Due to the small sample size for years 2018 (n=1) and 2019 (n=1) a comparative analysis could not be performed.

<i>Spawning Year</i>	<i>N</i>	<i>Mean Redd Area (m²)</i>	<i>SE (± m²)</i>
2017	14	0.43	0.04
2018	1	0.07	NA
2019	1	0.11	NA

Table 11 – Mean *O. mykiss* redd area (m²) for years 2014 – 2019 in the Ventura River Basin. Redd area was calculated as the sum of pot and tail spill areas per Gallagher et al. (2007). Means followed by the same letter did not differ significantly (Tukey test, $p < 0.05$). Zero redds were recorded in 2018 and 2019 so those years were excluded from the analysis.

<i>Spawning Year</i>	<i>N</i>	<i>Mean Redd Area (m²)</i>	<i>SE (± m²)</i>
2014	10	0.14 _A	0.04
2015	25	0.16 _A	0.03
2016	20	0.16 _A	0.02
2017	11	0.22 _A	0.04

Table 12 – Mean *O. mykiss* redd area (m²) for years 2017 – 2019 in the Santa Paula Creek subwatershed of the Santa Clara River Basin. Redd area was calculated as the sum of pot and tail spill areas per Gallagher et al. (2007) Means followed by the same letter did not differ significantly (Tukey test, $p < 0.05$).

<i>Spawning Year</i>	<i>N</i>	<i>Mean Redd Area (m²)</i>	<i>SE ($\pm m^2$)</i>
2017	3	0.13 _A	0.05
2018	23	0.17 _A	0.02
2019	2	0.23 _A	0.09

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