California Department of Fish & Wildlife

Fisheries Restoration Grant Program Final Report for #P1550013

Ventura River Basin Population Abundance Surveys and Passive Integrated Transponder (PIT) Program

Grant Period: September 1, 2016 to April 30 2019.

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INTRODUCTION

Steelhead trout, an ocean-going form of *Oncorhynchus mykiss*, currently exist at a fraction of their historical abundance in southern California (Adams et al. 2011, NMFS 2012). Primary causes for this decline include the loss of freshwater habitat due to water withdrawals and land use practices which has resulted in limited access to historical spawning and rearing streams (NMFS 2012). Specifically, agricultural and urban development has impacted southern California in particular due to increasing water needs and a rapidly expanding human population (NMFS 2012). Following population assessment in 1996, the southern California steelhead distinct population segment (DPS), inhabiting anadromous streams from the U.S.-Mexico border to the Santa Maria River, was federally listed as endangered (ESA; NMFS 2012).

To facilitate the recovery of southern California steelhead, a Recovery Plan was outlined by NMFS to guide salmonid monitoring efforts with the goal of achieving viable steelhead populations, defined as those with less than five percent risk of extinction (NFMS 2012). In response, the state of California Department of Fish and Wildlife (CDFW) released Fish Bulletin 180 outlining a strategy for the collection of data required to execute the recovery efforts recommended by NMFS. Subsequently the California Coastal Salmonid Monitoring Plan (CMP) was created to implement Fish Bulletin 180 and standardize data collection of native salmonids throughout California. Both Fish Bulletin 180 and the CMP address the difficulty in collecting data pertaining to southern California *O. mykiss.* Drought conditions in addition to the construction of damns and water diversions have resulted in small and intermittent steelhead populations with unpredictable run and spawning events. Such populations are difficult to study and, as a result, little is understood regarding *O. mykiss* ecology in southern California (Boughton et al. 2010, Adams et al. 2011, NMFS 2012). Nevertheless, relatively recent monitoring efforts have sought to address this lack of data.

Recovery efforts highlight the need for current O. *mykiss* population status and trends in southern California where low abundances are associated with an elevated risk of extinction. To estimate juvenile *O. mykiss* abundances, a conventional method of snorkel surveys calibrated with electrofishing was used. To monitor *O. mykiss* spatial distribution and productivity, passive integrated transponder tagging was performed in conjunction with the design and construction of instream tag readers (PIT arrays). Passive integrated transponder telemetry is widely used as an effective tool for monitoring the movement, run size, and spatial distribution of salmonids (Zydlewski et al. 2003, Adams et al. 2011). Passive integrated transponders use radio frequency identification (RFID) technology identity and track individual fish with minimal disturbance to natural biological behavior (Hill et al. 2000). Additionally, the method of tagging juveniles and monitoring migrants (T-JAMM) using PIT tags stationary arrays as described in Boughton (2010), is specifically referenced in the NMFS Recovery Plan as a viable method for estimating steelhead runs (NMFS 2012). Tagging with PIT tags was performed during juvenile abundance surveys allow for the monitoring of out-migrating smolts and returning anadromous adults providing valuable information pertaining to *O. mykiss* productivity and abundances (Adams et al. 2011). The collective data is necessary to understanding *O. mykiss* life history and ecological differences in site-specific regions (Adams et al. 2011, NMFS 2012).

This report summarizes our field activities, collected data, and findings using PIT tagging and abundance estimation surveys in the Ventura River Watershed (Figure 1). Due to historically large steelhead runs, the Ventura River has been selected as a high priority watershed for recovery actions (Alagona et al. 2011, NFMS 2012). Due to low abundance and patchy distribution, reaches were designated as 100 percent census of anadromous streams in the Ventura River Watershed. Methods implemented helped shape protocol specific to southern California. These protocols will help lead to the establishment of standardized CMP data collection in the southern California region. This report will help inform the California Coastal Monitoring Program and meet data requirements identified in Fish Bulletin 180 for *O. mykiss* recovery (Adams et al. 2011).

Study Sites

Ventura River Watershed

Ventura River Watershed, located in Ventura County, California, resides in the Monte Arido Highlands Biogeographic Population Group (BPG) region of the western Transverse Range (NMFS 2012). The Ventura watershed flows south/southwest from the headwaters in the Topatopa Mountain Range into the Pacific Ocean (NMFS 2012). The Ventura River Basin drains a watershed of approximately 227 mi^2 and contains 409 stream miles, including 35 anadromous stream miles designated as southern California steelhead critical habitat (Figure 1). Two dams act as total barriers to fish passage within the Ventura watershed. The Casitas Dam was constructed in 1957 and forms Lake Casitas near the city of Ojai, California. The Casitas Dam blocks access to the Coyote Creek Basin, which drains into the Ventura River. The Robles Diversion, located on the Ventura River mainstem, diverts flow from the Ventura River to Lake Casitas, and since 2004, contains a fish-passage facility (NMFS 2012). The Matilija Dam was constructed in 1947 for flood control and water storage. The Matilija Dam is located on Matilija Creek approximately 0.5 miles upstream of the Matilija and North Matilija Creek confluence which merge to form the upper Ventura River.

Ventura River mainstem

The Ventura River mainstem is a fifth order stream comprising 16 stream miles of anadromous waters that flow to the Pacific Ocean. Elevations range from approximately 0 to 200 ft (USGS 2019).

San Antonio Creek

San Antonio Creek is a fourth order stream and the only known tributary in the lower Ventura River Basin that supports *O. mykiss* rearing and spawning habitat (Allen 2012). San Antonio Creek contains seven miles of stream draining 51 square miles, though drying and intermittency is common during the summer and fall months (NFMS 2012, Allen 2012). Elevations range from approximately 300 to 5,500 ft (USGS 2019). Much of San Antonio Creek is located within agricultural and residential land.

North Fork Matilija Creek

North Fork Matilija Creek is a tributary to the Ventura River, formed at the confluence of Matilija and North Fork Matilija Creeks. North Fork Matilija is a fourth-order stream draining a subwatershed of approximately 16 square miles (NMFS 2012). North Fork Matilija occurs entirely within the Los Padres National Forest with elevations ranging from 900 to 5000 ft (USGS 2019).

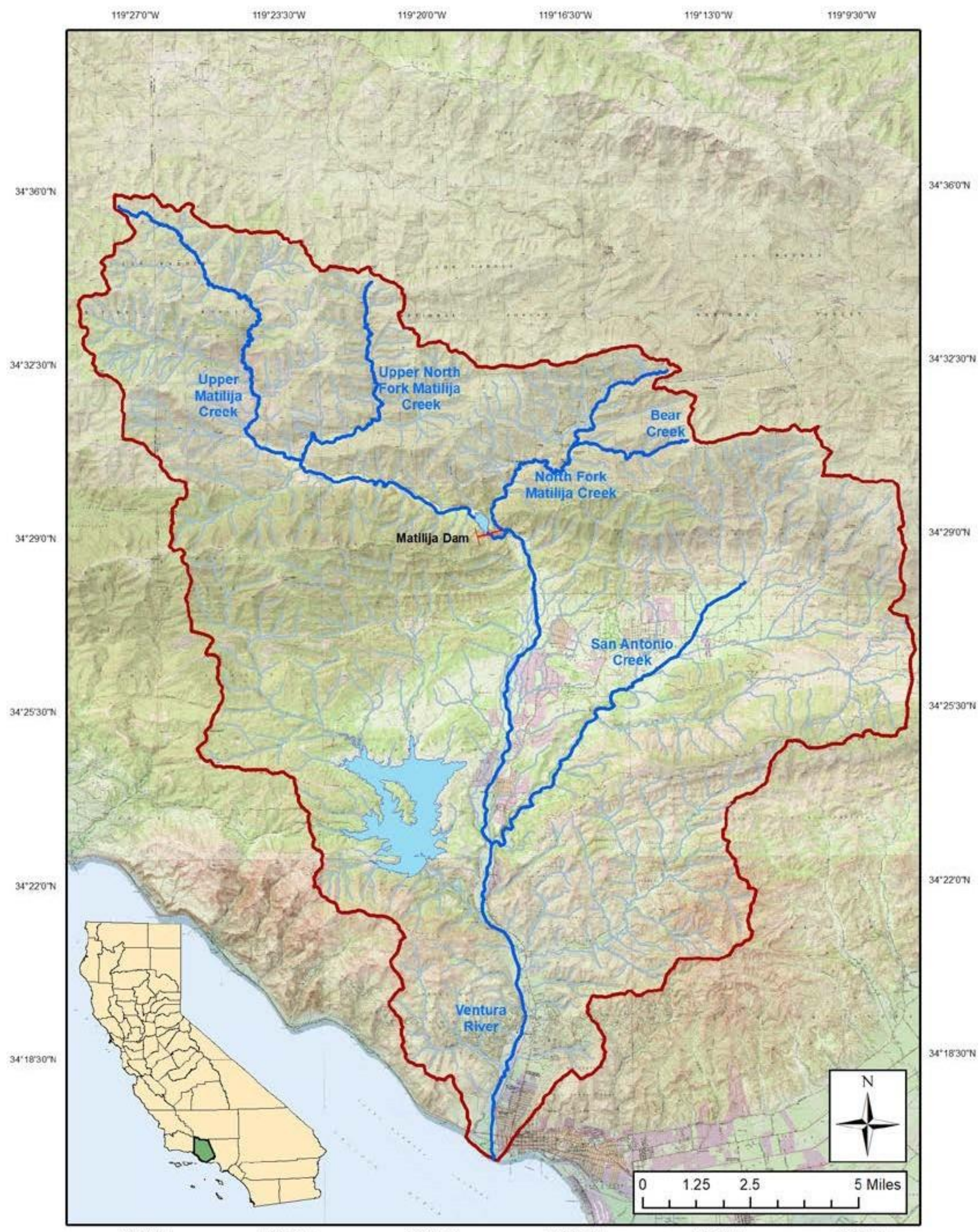
Upper Matilija Creek

Upper Matilija is a fifth-order stream that drains a subwatershed of approximately 12.5 square miles into the Matilija Reservoir. Upper Matilija Creek is formed by the Matilija Dam located approximately 0.5 miles upstream of the confluence of Matilija and North Fork Matilija Creeks. Elevations range from approximately 1000 to 6000 feet (USGS 2019). Most of Upper Matilija occurs on federally-protected United States Forest Service and agricultural properties.

Upper North Fork Matilija Creek

Upper North Fork Matilija Creek is a fourth-order stream that serves as a tributary to Upper Matilija Creek. Elevations range from approximately 1600 to 5700 feet (USGS 2019). Upper North Fork Matilija resides on United States Forest Service Land in the Los Padres National Forest.

Figure 1. Map of the Ventura River Watershed. The Ventura River Basin drains a watershed of approximately 227 mi^2 and contains 409 stream miles, including 35 anadromous stream miles designated as southern California steelhead critical habitat for southern California steelhead (*Oncorhynchus mykiss*). The Matilija Dam blocks fish passage to the upper Matilija subwatershed including Upper Matilija and Upper North Fork Matilija Creeks.



PROJECT SUMMARY

To promote long-term monitoring efforts and fulfill data requirements listed in Fish Bulletin 180, the Fisheries Restoration Grant Program funded a multi-year monitoring project focused on *O. mykiss* abundance surveys and PIT tagging in the Ventura River Watershed. Due to low *O. mykiss* abundances, reaches have been designated by NMFS as 100 percent census of anadromous streams within the watershed. This project was designed to collect data pertaining to *O. mykiss* abundance, spatial structure, and productivity in a watershed designated as high priority. Specifically, this project had two grant objectives: (1) Estimate the *O. mykiss* population abundance in the Ventura River Basin using snorkel surveys calibrated by electrofishing; and (2) estimate smoltification rates in the Ventura Basin by establishing a PIT array network. Funds provided by the Fisheries Restoration Grant Program were used to fulfill these objectives to the best of our ability, using methods recommended by Fish Bulletin 180. As a result, four studies were conducted that are described in this report.

Stationary PIT Array Design & Deployment

Stationary PIT tag detection arrays were designed and deployed at important locations within the Ventura River Watershed. Using radio frequency identification (RFID), these instream PIT antennas operate in conjunction with PIT tagging surveys to allow tracking of *O. mykiss* movement throughout a watershed. The three locations selected for antenna array deployments included: Ventura River mainstem (VEN), confluence of North Fork Matilija and Matilija Creeks (NFM), and confluence of San Antonio Creek and Ventura River (SNT). Following a test deployment of our AC-powered array in the Ventura River mainstem, we made a few alterations to increase the overall structural integrity. We reconstructed and deployed the Ventura River array in January 2018 and January 2019. This array comprises a key component of a life cycle monitoring (LCM) station to monitor freshwater and ocean productivity. Once we secured land access from a private landowner, we constructed and deployed a solar powered array at our North Fork Matilija Creek site in December 2018. We were unable to install the SNT array due to dry conditions and a large build-up of debris just upstream of the site. We anticipate using these designs and sites to install the entire network of arrays once additional tagging surveys are conducted in anadromous streams. This would allow us to estimate the number of outgoing smolts and incoming adult abundances, as well as identify source creeks of smolts and spawning creeks of adults. Such data contributes to valuable information regarding productivity and spatial structure of *O. mykiss* populations.

Oncorhynchus mykiss Abundance Estimation

To assess abundance and population trends, abundance estimation surveys using snorkeling and calibrated with electrofishing were conducted in two streams of the Ventura River Watershed. A modified double sampling method was used to calculate abundance estimations for all shallow habitat units. Upper North Fork Matilija Creek was surveyed from October 3, 2016 to December 1, 2016 and from May 14, 2018 to May 24, 2018. Data collected from Upper North Fork Matilija Creek show an estimated 274 ± 124 (95% CI) *O. mykiss* in 2016 and 0 ± 0 (95% CI) *O. mykiss* in 2018. An ESA Section 10(a)(1)(A) permit to allow sampling of *O. mykiss* in anadromous waters was secured in September 2018. Following the acquisition of this permit, North Fork Matilija Creek was surveyed from October 15, 2018 to November 28, 2018. Data collected show an estimated 5 ± 9 (95% CI) *O. mykiss* population in shallow units. These data collected provide much needed information regarding juvenile *O. mykiss* abundance and spatial distribution over time.

Oncorhynchus mykiss Habitat Availability and Use

Snorkel surveys were conducted during abundance estimation surveys in Upper North Fork Matilija Creek, North Fork Matilija Creek, and Upper Matilija Creek. Data collected contributed to *O. mykiss* relative abundance, distribution, and freshwater habitat associations. For each survey observations were recorded including habitat unit dimensions, total number and estimated sizes of *O. mykiss*, and *O. mykiss* cover availability and use. Our results show a stream habitat dominated by boulders and that *O. mykiss* use of boulders as refuge is prevalent. Our findings contribute to limited data on fine-scale habitat use by *O. mykiss* in southern California streams. Additionally, this study provides valuable information concerning the relationship between *O. mykiss* population health and stream conditions.

Fine-scale O. mykiss Movement Using Portable PIT Telemetry

Portable PIT scanning surveys utilize a relatively new technology allowing an entire survey reach to be scanned for PIT tag detection and/or recovery with a backpack reader and portable wand antenna. Due to the small size of our stream reaches, backpack PIT scanning surveys were conducted in all streams where *O. mykiss* were PIT tagged. To increase the number of *O. mykiss* tagged and released in Upper North Fork Matilija, additional electrofishing and tagging surveys were conducted targeting larger and deeper pool units. Three tagging effort surveys were conducted in December 2016, July 2017, and December 2018 during which a total of 103 *O. mykiss* were tagged and released. Due to the low number of *O. mykiss* observed during surveys in North Fork Matilija Creek, no additional electrofishing was conducted. Scanning surveys were conducted on a monthly basis following tagging surveys, except during periods of elevated flows. Data collected contributed to information regarding fine-scale movement and habitat associations.

ACKNOWLEDGEMENTS

Funding was provided to all Pacific States Marine Fisheries Commission staff by the California Department of Fish and Wildlife Fisheries Grant Restoration Program (grant #P1550013).

We would like to thank the multiple organizations who collaborated with us and assisted with data collection, including the California Department of Fish and Wildlife, National Oceanic and Atmospheric Administration (NOAA), California Conservation Corps/NOAA Veteran Fisheries Program, and the California Conservation Corps/Watershed Stewards Program.

We would specifically like to thank Yi-Jiun Tsai for her contributions to protocol development and stationary array design, both integral to the success of this project. We would like to thank Tanielle Redman (Pacific States Marine Fisheries Commission) and Shannon Mueller for their data collection and survey efforts for the duration of this grant. We would also like to thank Kyle Evans (California Department of Fish & Wildlife) for providing the maps included in this report.

We also gratefully acknowledge those landowners who willingly cooperated with us and allowed for this project to happen.

Design and implementation of stationary passive integrated transponder (PIT) arrays in the Ventura River Basin.

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INTRODUCTION

Stationary passive integrated transponder (PIT) tag detection systems utilize radio frequency identification (RFID) to monitor large scale movement of tagged individuals. When deployed, PIT tag antenna arrays emit a low frequency electromagnetic field that activates a PIT tag once the tag enters this field. When activated, the tag relays a unique identification number which is recorded by a tag reader along with the date and time of each detection. We designed and deployed AC and solar-powered arrays according to site needs and specifications. Three sites were strategically chosen for array locations within the Ventura River Basin including in the Ventura River mainstem and two large tributaries to the Ventura River (Figure 1). These locations were chosen because they would allow us to identify the source creeks of out-migrating smolts and spawning creeks of incoming anadromous adults. Specific sites for array deployments were selected according to location, land access, and stream hydrology. Following a test deployment, arrays were deployed at the Ventura River and North Fork Matilija Creek sites for a limited period of time due to high flows and the flashy and at times destructive nature of the Ventura system. Future deployments following additional PIT tagging efforts should adapt to weather intensity and changes to stream hydrology.

Study Sites

Ventura River Array

The PIT antenna array located in the Ventura River mainstem is approximately five miles upstream of the Ventura River estuary (34.34521°N, -119.29922°W) (Figure 1). Although locations closer to the estuary would be ideal for monitoring incoming anadromous adults, this site was chosen due to its security, river hydrology, and existing monitoring efforts by a partnering FRGP funded project. A land-access agreement with the Ojai Valley Sanitation District allows us to access the creek from gated property that is more secure and less open to the public than further downstream. The river channel at this location narrows so that outside of extremely high flow, our arrays can encompass the entire channel width maximizing the chances of detection. Additionally, this site is shared with a partnering project utilizing underwater sonar DIDSON cameras. This allows us to pair our array deployments with DIDSON camera deployments and simultaneous spawning surveys to complete a life cycle monitoring (LCM) station.

North Fork Matilija Creek Array

The stationary PIT array located near North Fork Matilija (34.48285°N, -119.29634°W), a large tributary to Ventura River, is approximately 0.25 miles downstream from the confluence of North Fork

Matilija and Matilija Creeks (Figure 1). This site was chosen due to river hydrology and land owner access. Although just downstream of the confluence, the stream is narrow at this site with relatively steep banks allowing arrays to encompass the entire channel. A road crossing and agreement with a private landowner allows easy access to the creek for repeat deployments, maintenance, and data collection. Additionally, the Matilija Dam limits passage in lower Matilija Creek to approximately 0.5 miles.

San Antonio Creek Array

The PIT antenna array located in San Antonio Creek, a large tributary to the Ventura River, is located approximately 0.5 miles upstream of the San Antonio Creek and Ventura River confluence (34.38257°N, -119.30265°W) (Figure 1). This site was selected due to security and land owner access. Private landowners own much of the property adjacent to San Antonio Creek near the confluence. However, due to a preexisting agreement with Rancho Arnez, we were able to secure this site for future deployments. Unfortunately, due to drought conditions and seasonal drying, San Antonio Creek remained intermittent for the majority of this grant period. Additionally, winter flows created a large debris pile just upstream of this array site further cutting off stream connectivity. To prevent unnecessary damage to equipment, plans for this array deployment was delayed until the debris was flushed further downstream.

METHODS & MATERIALS

Array Designs

General Design

Low frequency radio frequency identification (RFID) can function using two types of magnetic communication: Full duplex (FDX) RFID emits a continuous magnetic field while HDX generates pulses. While there are advantages to either type, we chose to use HDX RFID for a variety of reasons. HDX arrays can operate with larger and simpler antenna designs. Less power is required to operate HDX arrays since the charge field is pulsed instead of continuously generated. While FDX antennas need an air gap, antennas for HDX readers can be placed directly in water and function better in electrical noisy environments that could otherwise interfere with tag detection range (OregonRFID 2019). Although FDX tags can be made very small, recent advances in PIT technology have allowed HDX tags to be made as small as 12mm to allow injection in smaller fish such as juvenile trout (Roussel et al. 2000). Additionally, the closest PIT project operating out of Topanga and Malibu creek watersheds have used HDX tags (*personal communication*, R. Dagit, RCDSSM Senior Conservation Biologist).

Passive integrated transponder antenna arrays are comprised of five main components which include a power source, PIT tag reader, twinaxial cable, tuner box, and antenna wire (Figures 2 & 6). The antenna wire is strung in a loop and connected at both ends to a tuner box. When operating, the antenna loop creates the electromagnetic field capable of activating a PIT tag within range. The tuner box allows the antenna to be tuned to the correct radio frequency that will activate/read a PIT tag passing through. The tuner box is connected to a reader with twinaxial cable. When powered on, the reader continuously reads in and stores all data pertaining to each PIT tag detected including tag identification number, date, and time of detection. The reader is wired to batteries providing direct current (DC) voltage.

Antennas can be designed as either pass-through or pass-over according to how the loop is strung across the stream channel. A pass-through antenna is installed so that the bottom of the loop is secured to the substrate perpendicular to the stream channel so the fish swims through the loop when detected (Figures 2 & 6). A pass-over antenna is laid flat underwater so a fish passes over the antenna loop when detected (Figures 2). Pass-through antennas generate a greater magnetic field, but risk the danger of entanglement and displacement with high flows and associated debris. Conversely the magnetic field generated by a pass-over antenna is essentially cut in half, only allowing detection in the area above the loop. However, when secured properly this design minimizes displacement with high flows. Our antenna designs differed by site and were chosen based on stream hydrology, substrate composition, and channel structure.

Our stationary PIT arrays were designed with help from collaborators with the National Oceanic and Atmospheric Administration (NOAA) and Pacific States Marine Fisheries Commission, including Mark Zuspan (PSMFC), Brian Poxon (PSMFC), Ann-Marie Osterback (NOAA), David Boughton (NOAA), and Emerson Kanawi (NOAA). Arrays were designed to be either AC or solar powered according to site needs. All RFID specific equipment was purchased from Oregon RFID (Oregon RFID 2019) (Table I).

Ventura River Array

Due to ongoing monitoring activities and an agreement with Ojai Valley Sanitation District, the Ventura site was provided AC power (Figures 2 & 3). This array design consists of an extension cord plugged in to an outlet with a GFCI plug. The extension cord runs to a metal jobox where it is plugged into a surge protector. A plug-in 24-hr timer and battery charger are also plugged into a surge protector. Inside the jobox, a relay is wired to the battery charger, timer, PIT tag reader, and two 12-volt batteries (Figure 3). The relay is wired to allow power to be routed along two different paths at 12-hour intervals, so that one battery powers the reader while the other charges at any given time. This ensures battery charging is isolated from powering of the reader and reduces any electrical noise interference. The PIT tag reader is connected with two twinaxial cables that each run to a tuner box mounted on a metal T-posts installed near the stream bank. Each tuner box is connected to antenna wire looped across the stream channel. At this site, one antenna is secured upstream of two underwater sonar DIDSON cameras, and one antenna downstream (Figure 2). The upstream antenna is configured as a pass-over array with the antenna loop completely encased in PVC piping. The PVC piping is secured to the streambed using metal hose clamps attached to duckbill earth anchors that are driven into the substrate as deep as possible. The downstream antenna is constructed as a pass-through array with two t-posts installed on either side of the river. The antenna wire is encased in PVC piping along the bottom and anchored to the stream substrate using hose clamps and duckbill earth anchors. Each side is also encased in PVC piping and secured to either T-post using heavy duty zip ties. Truck rope tightly strung across the stream channel is used to suspend the antenna wire along the top.

During deployments, both antennas spanned the width of the stream that would allow fish passage (Figures 4a-c). Though the pass-over antenna did not span the entire wetted width due to bankside elevation, thick vegetation and root mass prevented passage along these margins. The pass-through antenna measured approximately 22’ x 3’, and the pass-over antenna measured 16.5 x 3’. Tag read range was tested using both 12-mm and 23-mm HDX PIT tags. When tested, the read range of the pass-through antenna was approximately 1 ft for 12-mm tag and 2.5 ft for the 23-mm tag. For the pass-over antenna, the tag read range measured around 0.5 ft for the 12-mm tag and 2.5 ft for the 23-mm tag. To minimize potential electrical noise interference, we avoided the use of an AC-DC adapter, instead using the batteries as an intermediary between the electrical load (reader) and power source (Figure 5). Additionally, the relay was used to electrically isolate the battery powering the reader and the battery charging, preventing the battery charger from creating interference with the reader.

North Fork Matilija Creek Array

The remote location of our PIT antenna array near the confluence of North Fork Matilija and Matilija Creeks only allowed for solar power (Figures 6 & 7). This array consisted of a 140-watt multicrystalline PV solar panel mounted in a metal frame and secured on an 8-ft metal fence post for optimal sun exposure. The post was secured in the ground using gravel and quick setting cement. Solar cables connect the solar panel to an MPPT charge controller housed in a metal jobox. The charge controller was also wired to two 12-volt batteries connected in parallel, and the PIT tag reader (Figures 8a-b). The charge controller regulates the amount of power (watts) from photovoltaic cells of the panel. This prevents the batteries from overcharging. Twinaxial cable connects the reader inside the jobox to two tuner boxes mounted on T-posts near the stream channel. Both antenna arrays are configured as pass-through using t-posts and truck rope to suspend the antenna. The antennas are encased in PVC piping along the bottom which is anchored to the streambed with hose clamps and duckbill earth anchors. The sides of the antenna are encased in PVC and secured to the T-posts using zipties. One antenna is located just upstream of the Camino Cielo Bridge measuring 26’ x 4’ and the second antenna, measuring approximately 16.5’ x 3’, is located just downstream of the bridge (Figures 9a-b)

RESULTS

Test Deployment

To test the structural integrity of our array design, a test deployment was conducted at the Ventura mainstem site on January 19, 2017. For this initial installation, both antennas were configured as pass-through. Prior to a large forecasted storm, all electrical RFID equipment was disconnected and removed, but the structural components of the array including, antenna, T-posts, and truck rope were left in the creek. Peak flows during this storm reached nearly 4,000 cubic feet per second (cfs), the largest reaction of the Ventura River since 2011 (USGS 2019). Consequently, all T-posts were damaged and the antennas were displaced downstream (Figures 10a-b). Following the test deployment, the following changes were made to improve on the structural integrity of our design: (1) All T-posts were replaced with heavy duty metal t-posts, and (2) upstream antenna was constructed as a pass-over array. This pass-over array would minimize any potential damages to the DIDSON cameras located approximately 20 feet downstream during high flows and associated debris.

Ventura River Array

On January 25, 2018, our Ventura River array was deployed at the Ventura mainstem site. Deployment followed an intense rain event which provided connectivity throughout the watershed. The array was configured with one pass-over antenna upstream of the DIDSON cameras and one pass-through antenna downstream. The array was operational for a total of 35 days and zero PIT tag detections were made.

The Ventura array was deployed the following year on January 8, 2019. Although at the time, sections of Ventura River remained unconnected, deployment occurred approximately two days before a forecasted storm expected to bring a substantial amount of rainfall. This array was operational for a total of eight days, during which zero tag detections were made.

North Fork Matilija Creek Array

Our North Fork Matilija Creek array was constructed and installed at our site on December 20, 2018. Deployment followed tagging surveys in North Fork Matilija Creek from October 15, 2018 to November 29, 2018. This array was configured with two pass-through arrays and was operational for a total of 27 days. Zero PIT tag detections were made.

San Antonio Creek Array

An array was never deployed at the San Antonio Creek site due to large debris piles located just upstream of the site for the duration of this project.

DISCUSSION

Deployments of our PIT antenna arrays were primarily limited by creek flows conditions. The structural support of our arrays were largely unable to withstand the reactive flows of the Ventura River during winter storms. However, we found the structural integrity of our arrays was largely dependent on antenna design. During high flows, the pass-through antennas were damaged or unanchored and carried downstream. When this occurred large trees or woody debris from associated debris flow was observed to be entangled with the top antenna wire. Meanwhile, our pass-over antenna remained in place.

When the Ventura array was installed in January 2018, stream height measured around 6.8 ft. with flows measuring around 5.5 cfs (USGS 2019). During the 35-day deployment flows peaked at 450 cfs with a stream height reaching 8.9 ft. During the second deployment in January 2019, stream height in the Ventura mainstem measured around seven feet and flows measured approximately 15 cfs. During deployment, the array withstood flows up to 730 ft and a stream height of 9.5 ft (USGS 2019). When the North Fork Matilija array was installed at our site in December 2018, stream height was approximately 1 ft and flows measured around 0.5 cfs ft. During the 27-day deployment, this array withstood flows up to 200 cfs and a maximum stream height of 3.5 ft (VCW 2019).

All array deployments ended due to a winter storm. In January 2019, a storm caused flows in the Ventura River mainstem to exceed 13,500 cfs. A USGS stream gage located just upstream of our Ventura site recorded flows increasing by about 3,000 cfs per hour causing stream height to reach 19 ft (USGS 2019). During that same storm flows measured in North Fork Matilija Creek exceeded 2300 cfs and the stream height increased from three to nearly seven feet. As a result, all pass-through antennas became dislodged and entangled in woody debris while the pass-over antenna remained in place (Figures 11, 12, & 13). Just two of the eight T-posts secured in the stream bed were lost. Although no longer anchored, two of the three pass-through antennas remained secured to standing T-posts and truck rope.

Despite issues with structural support, the RFID telemetry of both arrays were effective. During deployment periods, read ranges remained efficient when tested and minimal blind spots were detected within each antenna loop. Additionally, our reader logs show marker tags were detected consistently during all deployments. According to our reader logs, arrays remained operational throughout all deployment periods. The one exception occurred during our 2018 North Fork array deployment which temporarily powered down. Following six consecutive days of overcast weather, our solar panel was unable to supply our batteries with the wattage needed to power our reader. A potential solution for future deployments will be to upgrade the solar panel to one with a higher wattage rating or increase the battery bank for stored power.

Although zero *O. mykiss* detections were made, the tagged sample size for anadromous waters was small (n=2). Our deployments support future use of these array designs to be paired with additional PIT tagging efforts. Advancements in design should focus on improved substrate anchoring and achieving better read range for pass-over antennas.

TABLES

Table I – Stationary PIT Array Equipment. Equipment used to construct stationary passive integrated transponder (PIT) arrays for three sites within the Ventura River Basin**.** For each array component, details, brand and array site are specified.

Component	Details	Manufacturer	Array Site
Antenna wire	Marine duplex, 10-2 gauge	Ancor	VEN, NFM, SNT
Tuner board	Standard remote	OregonRFID	VEN, NFM, SNT
Twinaxial wire	100 Ohm	System ID	VEN, NFM, SNT
Reader	HDX multi-antenna	OregonRFID	VEN, NFM, SNT
Battery	12 V, 110 AH, deep cycle, gel-cell	Deka	VEN, NFM, SNT
Battery Charger	12v, gel-cell compatible	Samlex	VEN
Solar charge controller	MPPT, 15A	Morningstar	NFM, SNT
Solar cable	MC4, 10 gauge	Four Star	NFM, SNT
Solar panel	140W, 12V	Solarland	NFM, SNT

FIGURES

Figure 1. Map of the Ventura River Watershed and the locations of instream PIT tag detection sites. Three sites (indicated by orange squares) were secured for the deployment of stationary PIT arrays in conjunction with PIT tagging efforts including: (1) Ventura River (VEN), (2) near the confluence of San Antonio Creek and Ventura River (SNT), and (3) near the confluence of North Fork Matilija and Upper Matilija creeks (NFM).

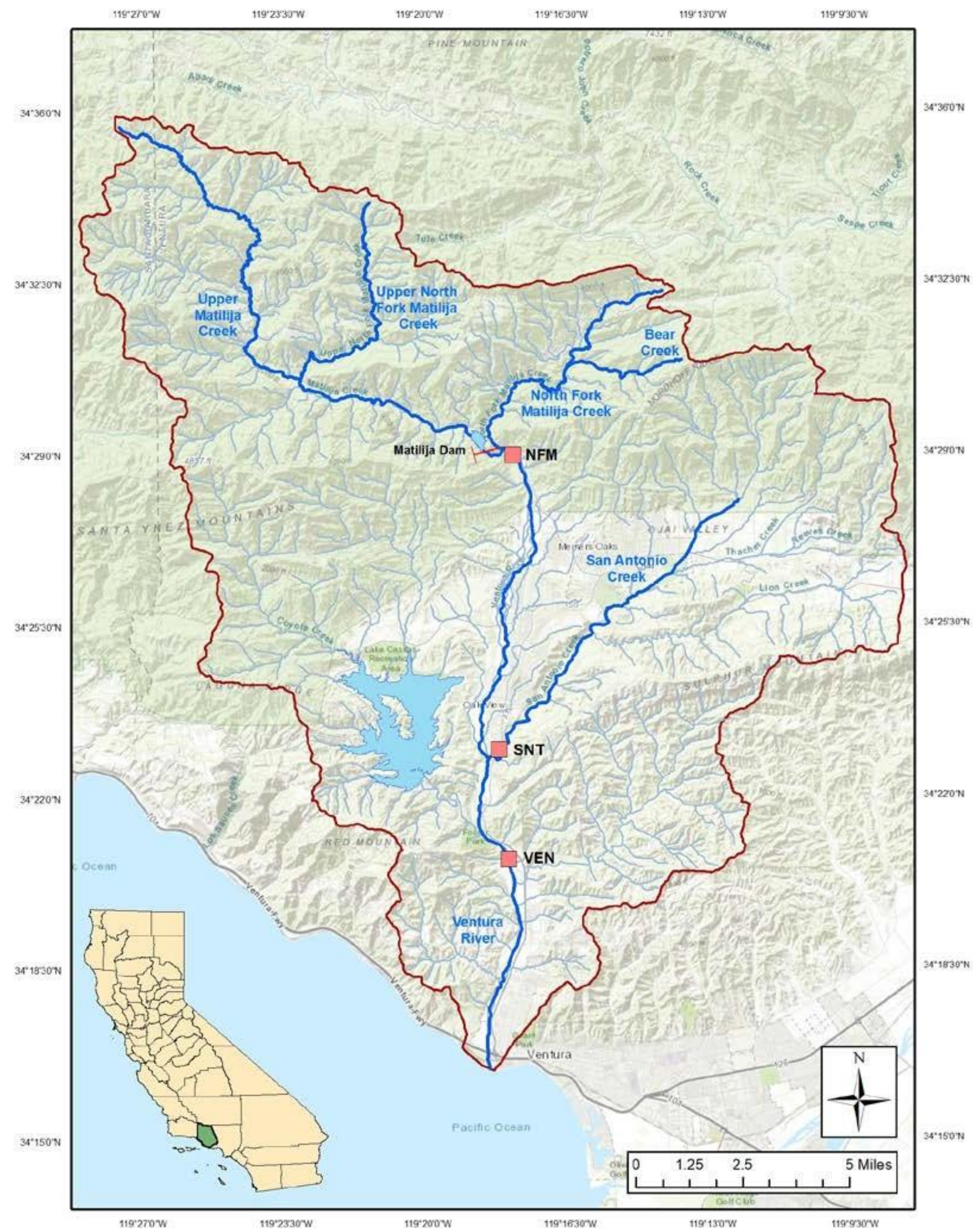


Figure 2. Diagram of the Ventura River mainstem stationary PIT array design. An AC-powered PIT tag antenna array was deployed in the Ventura River mainstem consisting of one pass-over and one pass-through antenna. This array was paired with sonar DIDSON cameras to complete a life cycle monitoring station at this site. Diagram created by Jean Tsai.

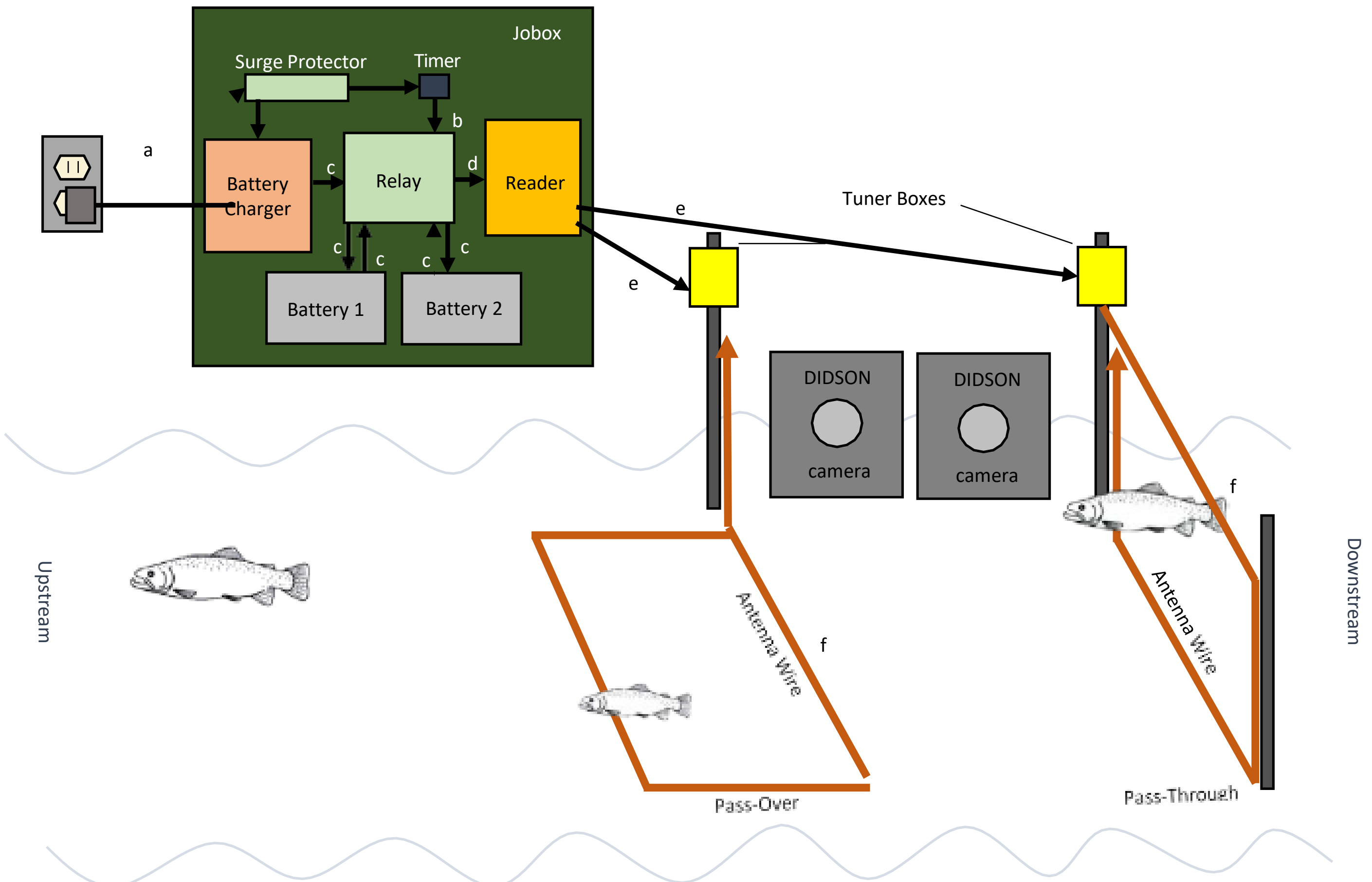


Figure 3. Wiring diagram of the Ventura mainstem AC-powered PIT antenna array. Diagram created by Jean Tsai.

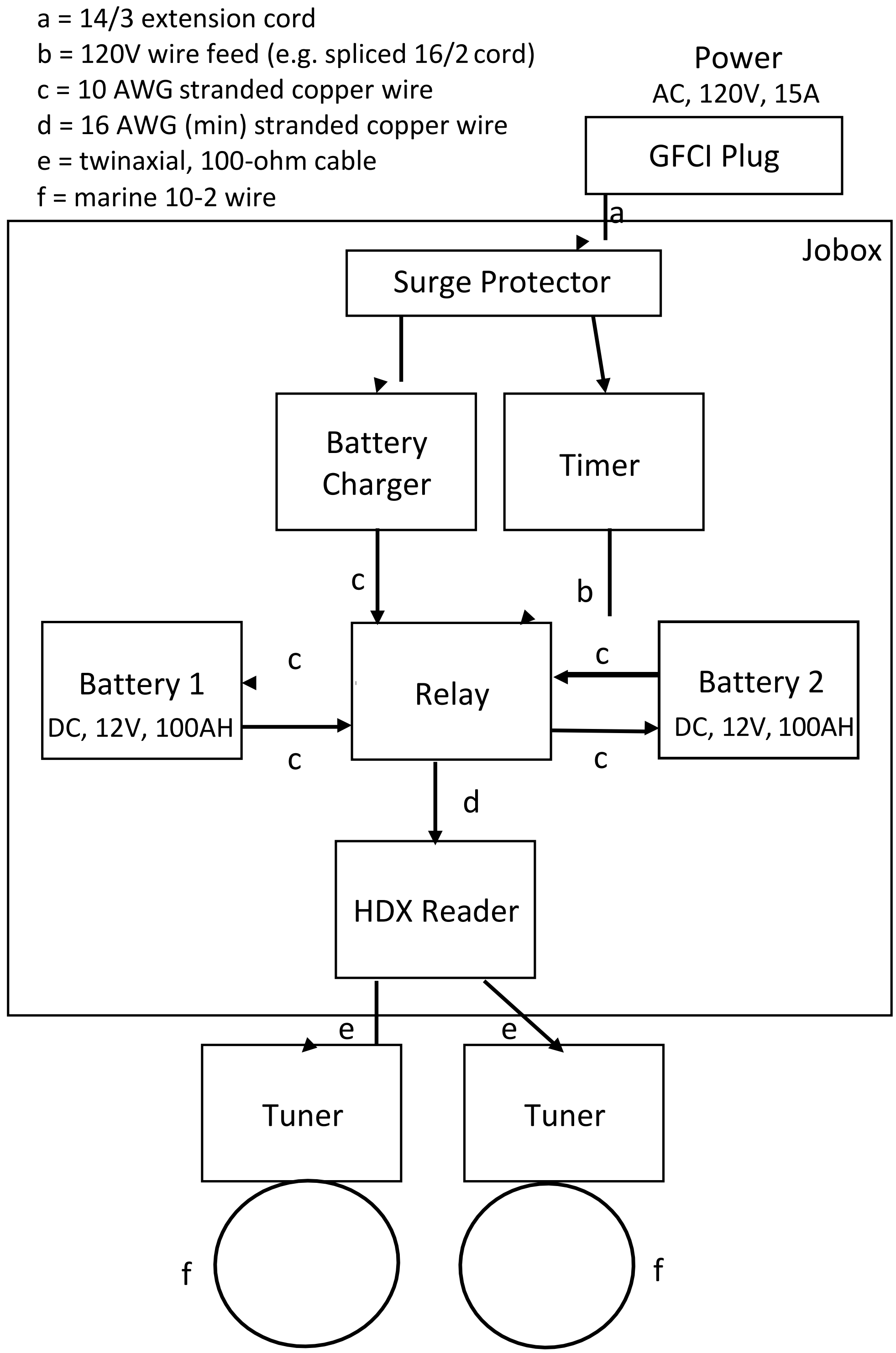


Figure 4. Images of the Ventura River mainstem (VEN) stationary PIT array site. (a) The VEN array (image taken facing upstream) was paired with two underwater sonar DIDSON cameras deployed on river-right in between (b) one-pass through antenna (image taken facing river-right) and (c) one pass-over antenna (image taken facing river-left).

(a)

(b)

(c)

Figure 5. Image of the Ventura River mainstem (VEN) stationary PIT array design. Due to an agreement with Ojai Valley Sanitation District the Ventura River array was provided AC power. An extension cord plugged into a GCFI outlet runs to a metal jobox where it is connected to a relay is wired to the battery charger, timer, PIT tag reader, and two 12-volt batteries. The relay ensures battery charging is isolated from powering of the reader and reduces any electrical noise interference.

Figure 6. Diagram of North Fork Matilija Creek (NFM) stationary PIT array design. A solar-powered stationary PIT antenna array was deployed near the confluence of North Fork Matilija and Matilija creeks consisting of two pass-through antennas. This array was installed to monitor tagged *O. mykiss* movement in and out of North Fork Matilija Creek. Diagram created by Jean Tsai.

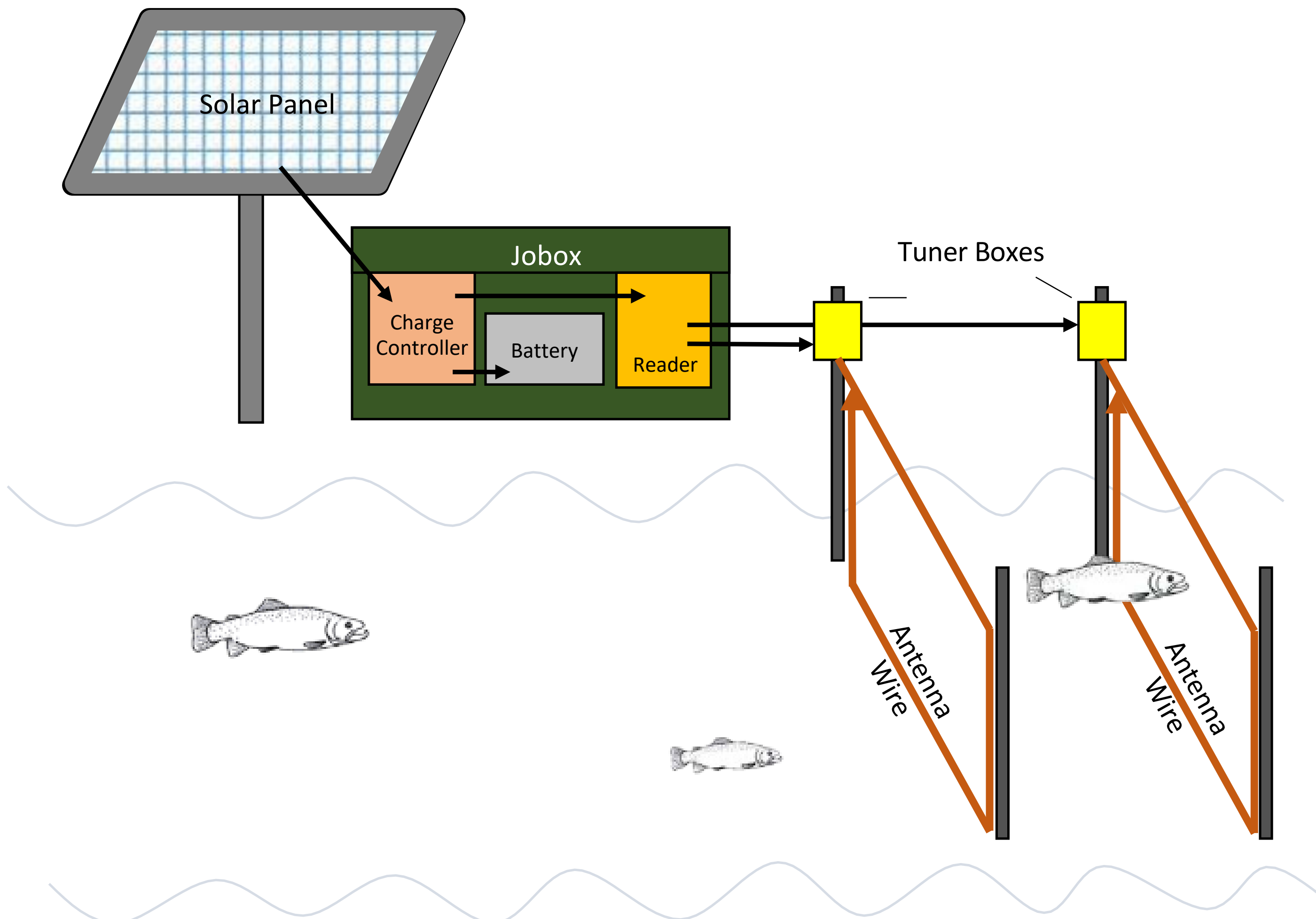
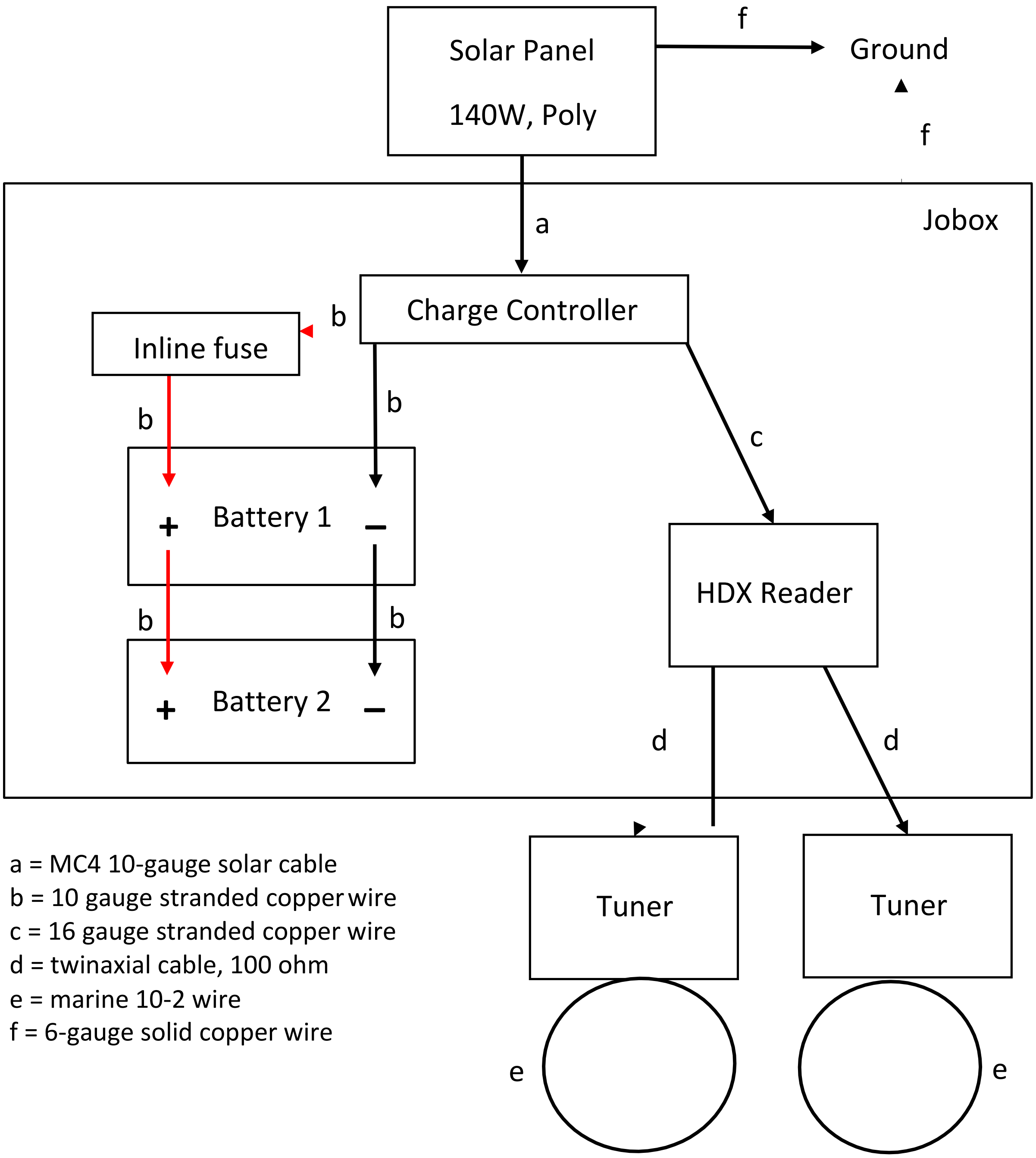


Figure 7. Wiring diagram of the North Fork Matilija (NFM) solar powered PIT antenna array. Diagram created by Jean Tsai



a = MC4 10-gauge solar cable
b = 10 gauge stranded copper wire
c = 16 gauge stranded copper wire
d = twinaxial cable, 100 ohm
e = marine 10-2 wire
f = 6-gauge solid copper wire

Figure 8. Images of the North Fork Matilija Creek (NFM) stationary PIT array design. The remote location of our NFM array only allowed for solar power. (a) Solar cables connected a 140W solar panel to an MPPT charge controller housed in a metal jobox. (b) The charge controller was also wired to two 12-volt batteries connected in parallel, and the PIT tag reader. Data was downloaded from the reader via a Bluetooth adapter and Android tablet device.

(a)

(b)

Figure 9. Images of the North Fork Matilija Creek (NFM) PIT antenna array site. Images of a stationary PIT array deployed at the NFM site, located just downstream of the Matilija and North Fork Matilija Creek confluence. This array was designed with two pass-through antennas, with (a) one secured downstream of a bridge crossing and (b) one antenna located upstream. Both images are taken facing upstream.

(a)

(b)

Figure 10. Test deployment of the Ventura River (VEN) PIT antenna array. The VEN array was test deployed in Janurary 2017 during a storm that caused flows in the Ventura River mainstem to peak near 4,000 cfs, the highest recorded since 2011. (a) As a result, metal T-posts were damaged and both antennas were dislodged from the streambed. (b) PSMFC Fisheries Biologist II Sam Bankston assesses damages to deflection panels installed near the deployment site of two underwater sonar DIDSON cameras in between both antennas. Both images are taken facing river-left.

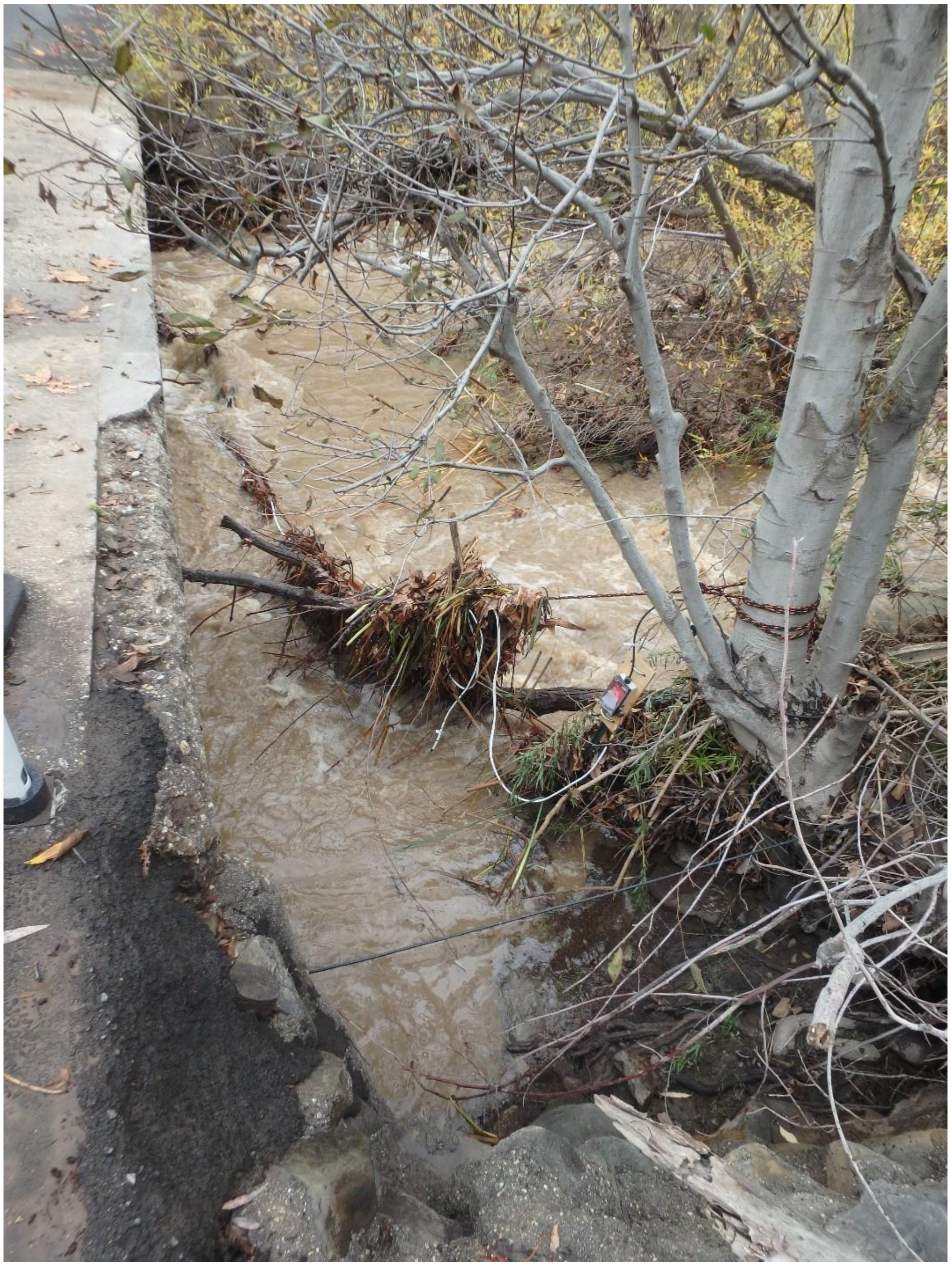
(a)

(b)

Figure 11. Image of the Ventura River (VEN) stationary PIT array in high flow. The VEN array pass-through antenna entangled in vegetation and woody debris as flows react to a storm in January 2019. The tuner box is pictured mounted on a metal T-post secured in the streambed on river-left. Image was taken facing downstream towards river-right.

Figure 12. Images of the North Fork Matilija Creek (NFM) stationary PIT array in high flows. The downstream pass-through antenna and upstream pass-through antenna at the NFM site during elevated flows on January 16, 2019. (a) The downstream antenna is pictured dislodged from the streambed but still secured to the metal T-post on river-left. (b) The upstream antenna is pictured entangled in vegetation and woody debris but remains secured as stream height reaches the bridge level. Both images were taken facing river-right.

(a)



(b)

Figure 13. Damage to the North Fork Matilija Creek (NFM) stationary PIT array caused by high flows. The final of three winter storms over the course of one week in January 2019 caused the Ventura River to exceeded 13,500 cfs. The associating debris flows damaged array equipment at both deployment sites, including the solar panel, pictured here. Image was taken on January 17, 2019 facing upstream.

Abundance Estimation of *Oncorhynchus mykiss* Populations in Upper North Fork and North Fork Matilija Creeks

Prepared by: Kathryn Carmody[1]

[1]Pacific States Marine Fisheries Commission

ABSTRACT:

Abundance estimation surveys were conducted to collect data on the southern California *Oncorhynchus mykiss* populations in Upper North Fork Matilija and North Fork Matilija Creeks. A modified double sampling method using snorkel surveys calibrated with electrofishing was used to estimate *O. mykiss* populations in shallow habitat. Upper North Fork Matilija Creek was surveyed during the winter of 2016 and spring of 2018. North Fork Matilija Creek was surveyed during the winter of 2018. From the data collected we estimated an *O. mykiss* abundance of 274 ± 124 (± 95% CI) in Upper North Fork Matilija in 2016, and 0 ± 0 (± 95% CI) in 2018. In North Fork Matilija Creek, we estimate an *O. mykiss* abundance of 5 ± 9 (95% CI) for shallow habitat. These surveys were conducted as part of a large monitoring effort gathering important data for the recovery of *O. mykiss* populations in southern California watersheds.

INTRODUCTION

Abundance estimation surveys were conducted to estimate the population of *Oncorhynchus mykiss* in two streams of the Ventura River Watershed. Sampling for abundance estimation contributes to the evaluation of *O. mykiss* population status and trends over time. Our methods utilize a double sampling design introduced by Hankin & Reeves (1984) in which juvenile snorkel surveys are calibrated with electrofishing. Juvenile snorkel surveys are recommended as an effective method for collecting data on trout behavior, density, habitat structure/complexity, and distribution (Adams et al. 2011). When calibrated by electrofishing surveys, these data will provide information on population abundance and spatial structure within the Ventura River watershed.

Sampling began in Upper North Fork Matilija Creek, located in the Upper Matilija Creek subwatershed above Matilija Dam. Although the concrete dam prevents passage of anadromous *O. mykiss* to this creek, resident *O. mykiss* remain genetically close to populations below the dam (Girman and Garza 2006, Clemento et al. 2008). Due to the amount of sedimentation Matilija Lake no longer serves as an effective reservoir, and plans, contingent on funding, are in place to remove the dam. Therefore, continued monitoring of resident *O. mykiss* is important to recovery efforts as these populations will contribute to the production of anadromous *O. mykiss* (Clemento et al. 2008). Two abundance estimation surveys were conducted in Upper North Fork Matilija Creek during the winter of 2016 and spring 2018. The second survey to estimate *O. mykiss* abundance occurred after a large wildfire impacted much of the upper Ventura watershed.

Under the authority of an Endangered Species Act (ESA) Section 10(a)(1)(A) permit (#16544), issued September 5, 2018, we conducted abundance estimation sampling in North Fork Matilija Creek from October 15, 2018 to November 28, 2018. Data was collected for this study with help from the California Department of Fish and Wildlife and the California Conservation Corps NOAA Veterans Corps Fisheries and Watershed Stewards Programs.

METHODS

Study Sites

Upper North Fork Matilija Creek

An abundance estimation survey of Upper North Fork Matilija Creek was conducted from October 3, 2016 to December 1, 2016 (Figure 1). Surveys started at the confluence of Upper Matilija and Upper North Fork Matilija Creeks (34.51011°N, -119.38307°W) and ended once the creek went dry (34.51606°N, -119.37746°W). A second survey to estimate *O. mykiss* abundance was conducted from May 14, 2018 to May 24, 2018. Due to elevated flows from winter storms in 2017-2018 and consequent changes to the hydrology of Matilija Creek, the location of the confluence had altered slightly (34.50905°N, -119.38358°W). Additionally, the endpoint of the previous survey was no longer dry so we continued to the reach end (34.51556°N, -119.37305°W).

North Fork Matilija Creek

An abundance estimation survey of North Fork Matilija Creek was conducted from October 15, 2018 to November 28, 2018 (Figure 1). The survey started approximately 0.45 miles upstream of the North Fork Matilija and Matilija Creek confluence (34.48883°N, -119.3059°W) due to construction work along Highway 33 by California Department of Transportation (Caltrans). North Fork Matilija Creek flows along this major highway, and for the duration of this project Caltrans had blocked off the section of creek using pumps to reroute the creek water. This survey continued upstream ending at a road crossing and total barrier to fish passage (34.51252°N, -119.27433°W) (CDFW PAD).

Data Collection

Habitat Typing

For this study, a double sampling method first introduced by Hankin & Reeves (1984) and modified by McCanne and Reisberger (2002) was used. This method consists of snorkel surveys followed by electrofishing to calibrate snorkel *O. mykiss* counts. Prior to sampling, habitat typing surveys were conducted in which the stream was delineated into natural units of similar habitat. Each unit was then described as either a pool, flatwater, or riffle based on certain geomorphological or hydrologic characteristics (Flosi et al. 2010). Measurements were taken of each unit including length, mean width, mean depth, and maximum depth (Figure 2). Water temperature was measured every ten units.

Only the units that met certain depth and length restrictions were considered for further sampling due to the ineffectiveness of our snorkeling and electrofishing methods in extremely shallow or deep water. These requirements included mean depths measuring no less than 0.3 ft and no greater than 3.0 ft, a maximum depth no greater than 3.5 ft, and minimum unit length of six feet or greater.

Snorkeling

All units with a mean depth greater than or equal to 0.7 ft and maximum depth less than 3.5 ft were snorkeled. During snorkel surveys, the number of trout, estimated size, and cover under which each trout was initially observed were recorded. The snorkeler then provided an assessment of all trout cover within the unit snorkeled, including estimated percent of the unit containing cover and all cover types present.

Electrofishing

Depletion electrofishing surveys were then conducted to calibrate snorkel counts. Units were electrofished if they met the following criteria: (1) they contained no undercuts greater than three feet (length of the electrofishing pole), (2) there were no structures within the unit to prevent effective netting or use of the electrofishing anode, and 3) the water cleared of disturbed sediment within one hour between passes. In order to provide a non-biased estimate of trout abundance, electrofishing units were selected by the following moderately random method. To determine which habitat units were electrofished, all units were separated by type (pool, flatwater, riffle) and depth (snorkeleable vs. nonsnorkeleable). All units in these categories were then grouped into 4-unit bins where one unit was randomly selected from each bin.

One to two backpack electrofishers were used for each survey depending on unit size and complexity. Prior to electrofishing, water quality was measured including water temperature (°F), dissolved oxygen (mg/L), and conductivity (mS/cm^3). Seine nets were used to block the inflow and outflow preventing any fish from entering or leaving the unit. For the depletion electrofishing, a maximum of five passes were used. Electrofishing ceased when the number of trout captured was less than 25% of the previous pass. A minimum of two netters accompanied each electrofisher throughout the unit. All species captured were immediately removed from the unit and placed in a five-gallon bucket filled with stream water. All *O. mykiss* were kept separate from other, incidentally captured species. Each bucket was equipped with a battery powered aerator and refilled with fresh stream water every ten minutes. All species were assessed for any deformities or signs of abnormal behavior. All *O. mykiss* were measured and photographed. Tagging efforts were conducted in conjunction with electrofishing surveys so *O. mykiss* that met the size requirement (>80 mm) and deemed in good condition, were injected with a 134.2 kHz HDX ISO PIT tag. All captured individuals were released back into the unit from which they were captured. Before release, the number of each incidentally captured species was recorded.

Data Analysis

Abundance Estimation Calculation

The abundance estimation method used is only applicable to shallow units (mean depth 0.3 to 3 feet and max depth less than 3.5 feet), so only units that met these depth restrictions were sampled. For calculations, unit length was used as the auxiliary variable (Hankin 1984, McCanne and Reisberger 2005). As described in McCanne and Reisberger (2005), a jack-knife estimator was calculated for each electrofished unit. These estimators were used to calculate an abundance for all snorkeleable and unsnorkeleable units (Appendix I). The sum of these estimates provided the total abundance estimate of *O. mykiss* for each stream reach. With-in reach variance was calculated for all snorkeleable and unsnorkelable units separately and the sum provided the total variance for each reach. These variances were used to generate 95 percent confidence intervals. All calculations were performed in R (version 3.4.1, R Core Team 2017) and RStudio (version 1.0.153, RStudio, Inc. 2016).

RESULTS

Upper North Fork Matilija Creek

From October 3, 2016 to December 1, 2016, Upper North Fork Matilija Creek was surveyed for 1.2 stream miles. The wetted stream reach was delineated into 233 habitat units, of which 193 units met the depth requirements to be sampled. A total of 72 units were snorkeled and 42 electrofished (Table I). From the data collected we estimated an *O. mykiss* abundance of 274 ± 124 (95% CI) in all shallow habitat units (Table II).

In May 2018, Upper North Fork Matilija Creek was surveyed for 1.25 stream miles and delineated into a total of 103 habitat units. Ninety-eight of these units were able to be sampled, of which 15 units were snorkeled and 17 electrofished (Table I). Zero *O. mykiss* were observed or captured during these surveys so we estimated an abundance of 0 ± 0 *O. mykiss* in shallow units (Table II).

North Fork Matilija Creek

A total of 3.76 stream miles of North Fork Matilija Creek was surveyed from October 15, 2018 to November 28, 2018. This stream reach was delineated into 273 habitat units, of which 19 units were snorkeled and 42 electrofished (Table I). Our estimated abundance of *O. mykiss* for all shallow units of North Fork Matilija Creek was 5 ± 9 (95% CI) (Table II).

DISCUSSION

From data collected in 2016 we estimated an *Oncorhynchus mykiss* population of 274 ± 124 (± 95% CI) in Upper North Fork Matilija Creek. In 2018 we estimated there were 0 ± 0 (± 95% CI) in Upper North Fork Matilija Creek and 5 ± 9 (95% CI) in North Fork Matilija Creek.

The sharp decrease in our population estimations from 2016 to 2018 is likely due to the impacts of a large wildfire that began in December 2017 and burned through much of the Ventura River Basin. The so-named Thomas Fire burned over 281,000 acres, including an estimated 96% of the Upper Matilija subwatershed and 97% of the North Fork Matilija subwatershed. The large amount of burned, loosened soils led to intense debris flows during the winter storms that followed. Notable changes to stream habitat throughout the watershed were observed, including loss of riparian canopy, increased water temperatures, and loss of pool habitat due to sedimentation (Figures 3a-b). The resulting habitat was much less suitable for *O. mykiss*, and as our results indicate, may have led to *O. mykiss* mortalities or movement out of these systems.

Our results support the use of this double sampling method as a conventional way to estimate juvenile *O. mykiss* populations in small streams. Our abundance estimations were limited for shallow units only because there is currently no effective method to snorkel or electrofish deeper pools (McCanne & Reisberger 2005). However, a total of just five deep pools were excluded from sampling during all three surveys combined. As demonstrated from our Upper North Fork Matilija Creek sampling, these estimates can be compared between streams and over time to provide valuable information pertaining to *O. mykiss* abundance and distribution within the watershed. Future surveys in the Ventura River Watershed should utilize these methods in order to continue monitoring *O. mykiss* population resilience and responses to environmental changes.

TABLES

Table I – Number of habitat units delineated and sampled for abundance estimation surveys in Upper North Fork Matilija Creek (2016, 2018) and North Fork Matilija Creek (2018). Units could be sampled if mean depth measured no less than 0.3 ft and max depth no greater than 3.5 ft. Units were snorkeled if: (1) mean depth was no less than 0.7 ft and no greater than 3.0 ft and (2) max depth was no greater than 3.5 ft. Subsets of snorkeleable and unsnorkelable units were electrofished.

Stream	Year	Total # Units	Snorkelable Units			Unsnorkelable Units	
			Total	# Snorkeled	# Snorkeled + E-fished	Total	# E-fished
Upper North Fork Matilija	2016	193	68	52	15	125	27
Upper North Fork Matilija	2018	103	15	12	3	83	17
North Fork Matilija	2018	196	18	12	6	178	35

Table II – Estimated abundance of *Oncorhynchus mykiss* in shallow habitat units (mean depth 0.3 to 3 feet and max depth less than 3.5 feet). Data was collected from Upper North Fork Matilija in 2016 and 2018, and North Fork Matilija in 2018.

Stream	Year	Estimated *O. mykiss* Abundance (95% CI)
Upper North Fork Matilija	2016	274 ± 124
Upper North Fork Matilija	2018	0 ± 0
North Fork Matilija	2018	5 ± 9

FIGURES

Figure 1. Map of sampled reaches in Upper North Fork Matilija and North Fork Matilija creeks sampled from 2016-2018. Upper North Fork Matilija Creek was sampled for *O. mykiss* abundance estimation in shallow habitat. Upper North Fork Matilija reach was surveyed from October 3, 2016 to December 1, 2016, and from May 15, 2018 to May 28, 2018. North Fork Matilija Creek (color) was sampled from October 15, 2018 to November 27.

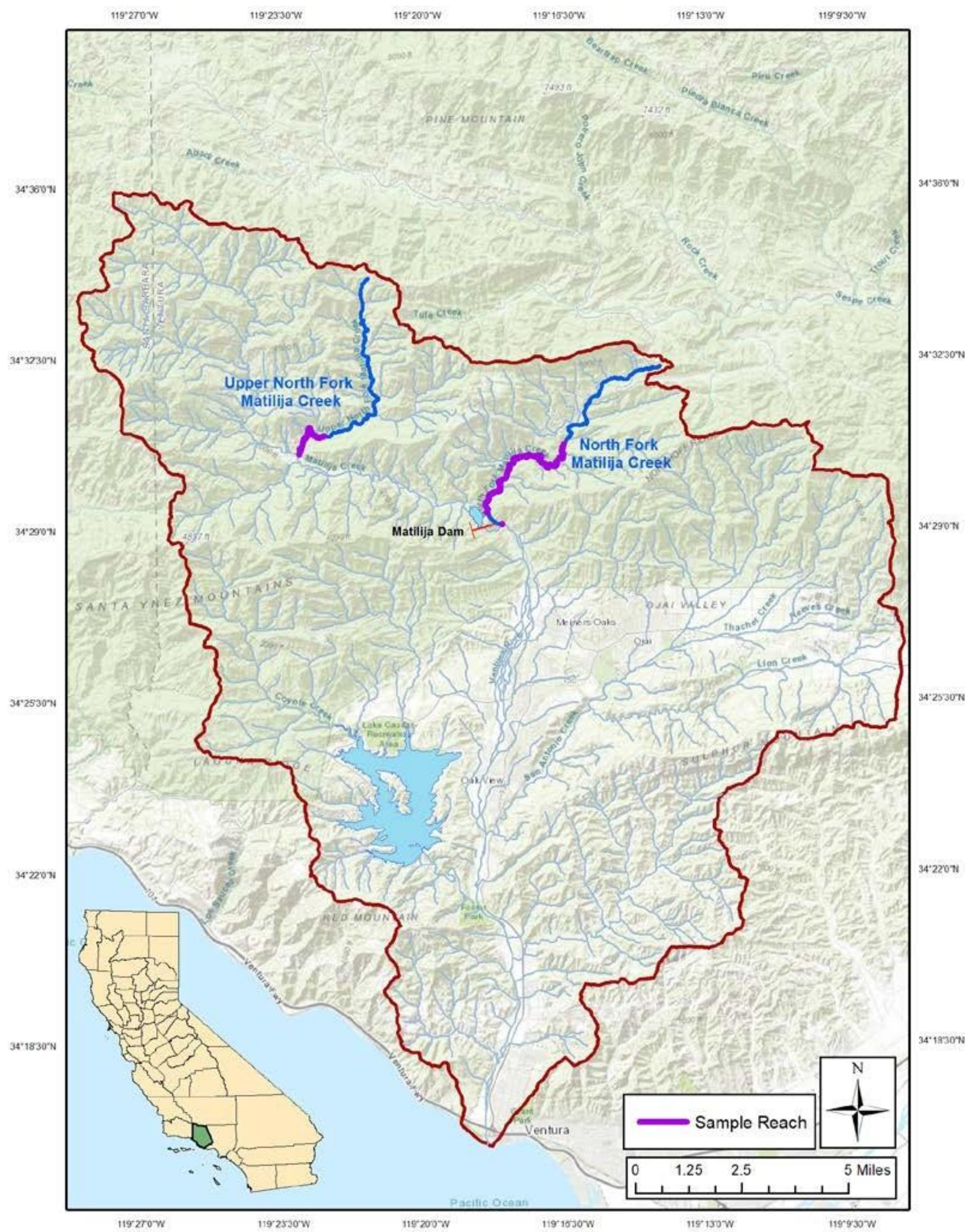


Figure 2. **Image of data collection during sampling of North Fork Matilija Creek in 2018**. PSMFC Fisheries Technician Tanielle Redman takes unit measurements during a habitat delineation survey in North Fork Matilija Creek. Each unit was measured for length, mean width, mean depth, and maximum depth (ft).

Figures 3. UNF stream habitat pictured during 2016 and 2018 surveys. (a) Habitat unit delineated as a pool during sampling for *O. mykiss* abundance estimation in Upper North Fork Matilija Creek in 2016. (b) The same unit pictured above is surveyed for *O. mykiss* abundance estimation in 2018. Both images were taken facing upstream.

(a)

(b)

Appendix I. Equations used to estimate fish abundances

Equation 1. Electrofishing Jackknife Estimation

Jackknife estimation for electrofishing data where the total number of fish ($\hat{y}_i$) and sampling variance ($\hat{V}(\hat{y}_i)$) in unit *i* are estimated by (modified from Pollock & Otto 1983, as notated in McCanne & Reisberger 2005):

$$\hat{y}_i = \sum_{j=1}^{r_i-1} c_{i \cdot j} + r_i c_{r_i}$$

$$\hat{V}\left(\hat{y}_i\right) = r_i(r_i - 1)c_{r_i}$$

where

r_i = the number of electrofishing passes conducted in the i^{th} habitat unit,

c_{r_i} = the number of fish captured in the r^{th} (last) pass in the i^{th} habitat unit, and

$c_{i \cdot j}$ = the number of fish captured in the j^{th} pass in the i^{th} habitat unit.

Equation 1. Abundance Estimation for Snorkelable Units

Abundance Estimation for snorkelable units. Snorkelable units included pools and flatwaters with a maximum depth no greater than 3.5 ft and a mean depth no less than 0.7 ft. All snorkelable units were snorkeled and a subset of these snorkeled units were electrofished (phase two sampling in McCanne & Reisberger 2005). We used unit length as an auxiliary variable (McCanne & Reisberger 2005, Hankin 1984).

The total number of fish in snorkelable units ($\hat{T}_s$) and sampling variance ($\hat{V}(\hat{T}_s)$) are estimated by (modified from Särndal et al.1992, as notated in McCanne & Reisberger 2005):

$$\hat{T}_s = N\hat{\bar{y}}_2\left(\frac{\bar{x}_1}{\bar{x}_2} + \frac{\bar{L} - \bar{l}_1}{\bar{l}_2}\right)$$

$$\hat{V}(\hat{T}_s) \approx N^2\left(1 - \frac{n_1}{N}\right)\left(\frac{\bar{L}}{\bar{l}_1}\right)^2\frac{s^2_{\hat{y}|a}}{n_1} + N^2\left(1 - \frac{n_2}{n_1}\right)\left(\frac{\bar{x}_1}{\bar{x}_2}\right)^2\frac{s^2_{\hat{y}|x}}{n_2}$$

$$s^2_{\hat{y}|a} = \frac{1}{n_2 - 1}\sum_{i=1}^{n_2}\left(\hat{y}_i - \hat{\bar{y}}_2\frac{l_i}{\bar{l}_2}\right)^2$$

$$s^2_{\hat{y}|x} = \frac{1}{n_2 - 1}\sum_{i=1}^{n_2}\left(\hat{y}_i - \hat{\bar{y}}_2\frac{x_i}{\bar{x}_2}\right)^2$$

where

N = the total number of snorkelable units,

$\hat{y}_i$ = the jackknife estimate of the true number of fish in the i^{th} unit (within snorkeled + e-fished units; calculated from Equation 1),

$\hat{\bar{y}}_2$ = the mean jackknife estimate of the true number of fish in all snorkeled + e-fished units,

x_i = the observed number of fish counted during snorkeling in the i^{th} unit (within snorkeled + e-fished units),

$\bar{x}_1$ = the mean number of fish counted during snorkeling in units that were snorkeled,

$\bar{x}_2$ = the mean number of fish counted during snorkeling in units that were snorkeled + e-fished,

$\bar{L}$ = the mean length of all snorkelable units,

l_i = the length of the i^{th} unit (within snorkeled + e-fished units),

$\bar{l}_1$= the mean length of units that were snorkeled,

$\bar{l}_2$= the mean length of units that were snorkeled + e-fished,

m_1 = the number of units that were snorkeled, and

m_2 = the number of units that were snorkeled + e-fished.

Equation 3. Abundance Estimation for Unsnorkelable Units

Unsnorkelable units were all riffles as well as pools and runs with a mean depth measuring less than 0.7 ft and a maximum depth greater than 3.5 feet. A subset of unsnorkelable units were electrofished.

The total number of fish in unsnorkelable units ($\hat{T}_U$) and sampling variance ($\hat{V}(\hat{T}_U)$) are estimated by (modified from Hankin 1984 and Cochran 1977, as notated in McCanne & Reisberger 2005):

$$\hat{T}_U = N\bar{\hat{y}}\left(\frac{\bar{L}}{\bar{l}}\right)$$

$$\hat{V}(\hat{T}_U) \approx N^2\left(1 - \frac{n}{N}\right)\frac{s^2_{\hat{y}|l}}{n} + \frac{N}{n}\sum_{i=1}^{n}\hat{V}(\hat{y}_i)$$

$$s^2_{\hat{y}|l} = \frac{1}{n-1}\sum_{i=1}^{n}\left(\hat{y}_i - \bar{\hat{y}}\frac{l_i}{\bar{l}}\right)^2$$

where

N = the total number of unsnorkelable units,

n = the number of electrofished units,

$\hat{y}_i$ = the jackknife estimate of the true number of fish in the i^{th} unit (within electrofished units; calculated in Equation 1),

$\bar{\hat{y}}$ = the mean jackknife estimate of the number of fish across all electrofished units,

$\bar{L}$ = the mean area of all unsnorkelable units,

l_i = the length of the i^{th} unit (within electrofished units), and

ll = the mean length of electrofished units.

Equation 4. Within-Reach Estimation

Because each stratum (snorkelable and unsnorkelable units in this case) was sampled independently, within-reach estimates ($\hat{T}_{reach}$) were calculated as the sum of both individual estimates (Hankin 1984):

$$\hat{T}_{reach} = \sum_{h=1}^{j} \hat{T}_{h}$$

where *j* is the total number of strata (in this case, there were two strata: snorkelable and unsnorkelable units).

The total sampling variance across ($\hat{V}(\hat{T}_{reach})$) was estimated by the sum of individual variances (Hankin 1984):

$$\hat{V}(\hat{T}_{reach}) = \sum_{h=1}^{j} \hat{V}(\hat{T}_{h})$$

where *j* is the total number of strata.

Ninety-five percent confidence intervals were estimated by (Cochran 1977, as notated in McCanne & Reisberger 2005):

$$t_{0.025,n-1}\sqrt{\hat{V}(\hat{T}_{reach})}.$$

Fine-scale *Oncorhynchus mykiss* habitat availability and use in the upper Ventura River Watershed

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[1]Pacific States Marine Fisheries Commission

ABSTRACT

Data was collected during abundance estimation sampling to examine fine-scale *Oncorhynchus mykiss* habitat availability and use. Habitat delineation and snorkel surveys were conducted in three streams of the upper Ventura watershed. From 2016 to 2018 we sampled Upper North Fork Matilija Creek, Upper Matilija Creek, and North Fork Matilija Creek. For each reach, we measured wetted habitat and snorkeled units that met certain depth restrictions. For each snorkeled unit, we recorded *O. mykiss* observations and estimated available trout cover and use. Our examination of *O. mykiss* cover show boulder/cobble is the most prevalent and used frequently by *O. mykiss* for refuge in all three streams. Following a large wildfire that burned much of the watershed, we surveyed Upper North Fork Matilija Creek a second time in May 2018. When comparing data, our results show changes to stream habitat and *O. mykiss* relative abundance likely due to impacts of the wildfire. All efforts described in this report were part of a large *O. mykiss* monitoring project within the Ventura River Basin.

INTRODUCTION

Recent declines in the ESA-listed southern California steelhead (*Oncorhynchus mykiss*) populations can be primarily attributed to habitat loss and degradation (Adams et al. 2011). The highly urbanized region of southern California has experienced widespread land-use, including the construction of dams and water diversions that limit fish passage (Adams et al. 2011, NMFS 2012). Drought conditions endured since 2011 have further contributed to low flows and increased intermittency (Boughton et al. 2009, Ventura River Watershed Council 2019, CDFW unpublished data 2019). As the only ocean anadromous salmonid native to southern California, *O. mykiss* are left with irregular access to critical spawning and rearing habitat which has resulted in small and fragmented steelhead populations that are difficult to study, and therefore, still not well understood (Boughton et al. 2009, Adams et al. 2011, NMFS 2012). A key to understanding the viability of these populations is understanding the relationship between *O. mykiss* population health and condition of the freshwater streams they inhabit (Adams et al. 2011). This includes quantifying the characteristics that define suitable *O. mykiss* habitat in their native regions.

Cover is an important habitat feature and is commonly used by fisheries managers as an indicator of suitable trout habitat (Cox 2010). The presence of cover is critical for trout species, such as *O. mykiss,* that demonstrate a behavioral tendency to take refuge in their freshwater environments (Meyer and Gregory 2000, Cox 2010, Mitro and Zale 2015). There are many functional roles of in-stream cover such as shading, predator avoidance and minimizing competition (Tabor and Wurtsbaugh 1991, Allouche et al. 2001, Cox 2010). Some cover types directly influence biological productivity and hydrological processes (Allouche et al. 2001, Roni et al. 2015). Studies on large woody debris have shown many natural functions that help create a more favorable environment for trout species (Roni and Quinn 2001, Dolloff and Warren 2003, Thompson et al. 2008). For example, biofilms associated with woody debris act as an important food source for juveniles by attracting other organisms (Allouche et al. 2001). Large fallen tree logs provide scouring and contribute to the formation of pools, sediment storage, and overall habitat complexity (Thompson et al. 2008, Roni et al. 2015, Mitro and Zale 2015).

Snorkel surveys are widely used to estimate relative and total abundances (O'Neal 2007). Additionally, snorkel surveys are recommended for monitoring ESA listed salmonids because there is minimal impact to the target species, they are cost effective, and provide reasonably accurate data (O'Neal 2007, Adams et al 2011).

In this study we examined *O. mykiss* available freshwater habitat and habitat use in three streams of the Upper Ventura Watershed. Specifically, we estimated relative abundance and cover availability and use by *O. mykiss*. The collective data from all stream reaches was further analyzed to uncover patterns of habitat usage by *O. mykiss* in southern California. This study was conducted as part of a large monitoring effort of *O. mykiss* in the Ventura River Basin in accordance with recommendations by state and federal agencies for the recovery of native steelhead populations.

METHODS

Study Sites

Field data was collected in three streams of the Upper Ventura Watershed with help from the California Department of Fish and Wildlife, California Conservation Corps NOAA Fisheries Corps and Watershed Stewards Programs. Surveys were conducted in Upper North Fork Matilija, Upper Matilija and North Fork Matilija Creeks from 2016 to 2018.

Data was collected according to protocol developed and written by Tsai and van Meeuwen (2016, unpublished) for standardized data collection in southern California stream conditions. Theses protocols were adapted from the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998), Salmonid Field Protocol Handbook (O'Neil 2007), and the Underwater Methods for the Study of Salmonids in the Intermountain West (Thurow 1994).

Upper North Fork Matilija Creek

Surveys in Upper North Fork Matilija Creek were conducted from October 4, 2016 to November 30, 2016. Upper North Fork Matilija Creek was surveyed for 1.2 mi, starting at the confluence of Upper North Fork Matilija and Upper Matilija Creeks (34.50901°N, -119.38362°W). The survey endpoint (34.51606°N, -119.37746°W) was the start of a prolonged dry section (Figure 1a).

Following a large wildfire which impacted much of the upper Ventura watershed, Upper North Fork Matilija Creek was sampled a second time from May 14, 2018 to May 24, 2018. The reach was surveyed for 1.25 miles due to a shift in location of the Upper North Fork Matilija and Upper Matilija confluence

(Figure 1b). Data collected were compared to examine differences in habitat composition and *O. mykiss* relative abundances before and after the wildfire.

Upper Matilija Creek

Data was collected in Upper Matilija Creek from August 1, 2017 to November 29, 2017. The starting point was upstream of the Matilija Reservoir (34.49416°N, -119.33051°W) and we ended just before a low flow barrier (34.52749°N, -119.40128°W). The total surveyed distance was 6.2 mi (Figure 2).

North Fork Matilija Creek

North Fork Matilija Creek was surveyed for 3.8 stream miles from October 15, 2018 to November 28, 2018 (Figure 3). Highway construction near the creek prevented surveys from beginning at the reach start near the confluence of North Fork Matilija and Matilija Creeks. Surveys began above a construction barrier at the most downstream start of natural flow (34.48883°N, -119.3059°W), approximately 0.45 miles upstream of the confluence, and ended at a total barrier to fish passage (34.51252°N, -119.27433°W) (CDFW PAD) (Figure 3).

Data Collection

Habitat Delineation

We delineated the wetted stream channel into discrete, natural units of similar habitat (Hankin 1984). Habitat units were classified as riffles, pools, or flatwaters based on characteristics outlined in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). Riffles were characterized by relatively fast flowing water, usually shallow depths, and medium to high gradient, and a large amount of exposed substrate. Flatwater units contained slow moving water with a smooth surface. Pools generally were bowl-shaped with collected, still water. Once classified by type, units were measured for: (1) unit length, usually measured from inflow to outflow along the thalweg, (2) mean width, usually measured perpendicular to the length, (3) maximum depth, and (4) mean depth.

All units that were snorkelable were snorkeled. Units were considered snorkelable if they: (1) were categorized as a flatwater or pool (excluded all riffles), (2) had a mean depth of 0.7–3 ft and a maximum depth no greater than 3.5 ft, (3) did not contain any potential hazards to snorkelers, and (4) had good visibility. Trout could not be reliably counted at very low or very high depths, so riffles (usually very shallow), very shallow units (less than 0.7 feet in mean depth), and very deep units (greater than 3 feet in mean depth or greater than 3.5 feet in maximum depth) were excluded (O'Neal 2007).

Snorkel Surveys

Snorkel surveys were conducted using one to two snorkelers. The snorkeler(s) approached each unit from the downstream end and moved in a zig-zag like pattern upstream (Thurow 1994; O'Neal 2007), ensuring that the entire unit was surveyed and avoiding disturbance to the substrate.

Snorkeler(s) examined every available hiding space for trout while moving through each unit at a consistent pace.

A single snorkeler was used for units with clear visibility bank-to-bank, which generally included units less than or equal to 15 feet wide and units without complex cover. For larger or more complex units, two divers conducted the survey adjacent to one another and proceeded upstream in tandem (Figure 4) (Thurow 1994). For each trout observed, snorkeler(s) recorded the size class and cover type in which the trout was found. Size classes consisted of two-inch bins (e.g. 0–1.99 in, 2–3.99 in, etc.). Cover types were boulder, bedrock, small woody debris (SWD), large woody debris (LWD), root mass, soil undercut, bubble curtain, aquatic vegetation, terrestrial vegetation, and open water (described in Table I). Assessments of available *O. mykiss* cover were conducted in two parts. First the snorkeler(s) visually estimated the total percent of the wetted unit's surface area comprised of possible trout cover. Then, the snorkeler(s) a visually estimated the percentage of each cover type that comprised the total trout cover available within a unit. For example, a given unit contains 40% trout cover and 60% open. Within the 40% of trout cover, 75% of the total available cover is comprised of boulders and 25% of small woody debris.

To ensure that trout sizes were estimated accurately, each snorkeler calibrated their visual size estimation when they completed snorkeling of the first unit and every tenth unit thereafter. Calibration consisted of a non-diver placing three haphazardly-chosen PVC pipes of varying lengths (ranging from 2–16 inches) into the unit. Snorkeler(s) then estimated the size of each pipe underwater. If any estimated size was not within five centimeters of the pipe's true size, then snorkeler(s) repeated the calibration until all three pipe sizes were estimated accurately. Water temperature was measured at the start of each survey and after every ten units snorkeled.

Data Analyses

Wetted Habitat Assessment

To examine the overall wetted habitat structure of each stream, we calculated the percentage wet vs. dry of the entire sampled reach, as well as the total wetted area, and length sampled. We then examined the number and percentage of pools, flatwaters, and riffles. We also calculated the mean unit dimensions of snorkeled units, including unit length, unit area, mean width, mean depth, and maximum depth. Surface area was calculated by multiplying the measured unit length by mean width. We then subtracted the area of exposed substrate, which was estimated as a percent of the entire wetted surface area for each unit.

O. mykiss Relative Abundances

Density of *O. mykiss* for each reach was examined in two ways: (1) the mean number of *O. mykiss* per unit (total number of trout divided by total number of units in which *O. mykiss* were observed), and (2) the mean density of *O. mykiss* per 100 ft^2. We determined *O. mykiss* density per ft^2 by dividing the number of *O. mykiss* observed in a given unit by the unit's surface area (for units in which *O. mykiss* were observed). To determine mean number of trout per 100 ft^2, we multiplied each *O. mykiss* density by 100 ft^2, and calculated the mean. To evaluate the diversity of life stages observed, we examined the number and percentage of *O. mykiss* observed by size class.

Cover Availability and Use

To examine available *O. mykiss* cover, we calculated the mean percentage of trout cover for all units snorkeled We also calculated the mean percentage of each cover type comprising the total available cover across all units snorkeled. We then examined cover availability relative to trout cover use. Cover use by *O. mykiss* was examined by the total number of *O. mykiss* observed using each cover type and the percentage of total *O. mykiss* observed using each cover type.

Assessment of Habitat and O. mykiss Occurrence

Multiple analyses were performed to test the relationship between stream habitat and observed *O. mykiss* relative abundance using our collective data from all stream reaches. A nonparametric Wilcoxon rank sum test was used to test for significant differences in mean number of *O. mykiss* observed in pool versus flatwater units. We performed correlation analyses to test habitat parameters as independent variables against the total number of observed *O. mykiss*. For each test, a Pearson's correlation coefficient was calculated. Parameters tested included unit length, mean width, mean depth, maximum depth, surface area, water volume, percent cover, and water temperature. Multiple regression was performed to test for a relationship between a set of physical habitat features and *O. mykiss* occurrence. Due to the proportion of zero *O. mykiss* counts creating over-dispersion of our data, we chose to run a binomial negative regression model (Figure 5). For this model, unit surface area and volume were excluded to avoid multicollinearity.

RESULTS

Upper North Fork Matilija Creek

Wetted Habitat Assessment

During surveys in 2016, Upper North Fork Matilija Creek was approximately 73% wet (Figures 1a). Dry sections at the start and end of the 1.3-mile reach comprised 1800 ft (0.34 mi). Approximately 41,601 ft^2 of wetted habitat was sampled and delineated into 233 natural habitat units. Units were comprised of 93 pools (39.9%), 77 (33.0%) riffles, and 63 (27.0%) flatwaters (Table II, Figure 4). For all wetted habitat surveyed, the mean unit length was 21.9 ± 1.1 (mean ± SE), mean unit width was 9.6 ± 0.28 ft (mean ± SE), and the mean adjusted unit area was 178.6 ± 13.3 (mean ±SE). Mean depth was measured at 0.6 ±0.02 ft (mean ± SE) and mean maximum depth was 1.1 ± 0.05 ft. (mean ± SE) (Table III). A total of 68 units were snorkeled (Table II).

Data collected from surveys in May 2018 show Upper North Fork Matilija Creek was 100% wetted (Figure 1b). Approximately 41,991 ft^2 wetted habitat sampled and delineated into 105 habitat units. These units comprised 18 (17%) pools, 11 (10%) flatwaters, and 76 (72%) riffles (Table II, Figure 6). Measurements of the wetted habitat show a mean unit length of 63.6 ± 7.4 (mean ± SE), mean unit width of 7.0 ± 0.2 (mean ± SE), with a mean unit area of 399.9 ± 49.9 ft (mean ± SE) (Table III). Mean depth was measured and calculated at 0.47 ± 0.02 ft (mean ± SE) and mean maximum depth was 0.97 ± 0.03 ft (mean ± SE). Out of the 105 total units, 15 were snorkeled (Table II).

O. mykiss Relative Abundance

In 2016, 88 trout were observed within 68 snorkeled habitat units (Table IV, Figure 7). Total density of trout was calculated at a mean 0.48 (±0.083) trout per 100 ft^2 and a mean 1.3 (±0.25) trout per unit snorkeled (Table 4). Of 88 total trout observed, 36 (40.9%) were 2–3.99 in, 38 (43.2%) were 4–5.99 in, 12 (13.6%) were 6–7.99 in, 1 (1.1%) was 8–9.99 in, and 1 (1.1%) was 12–13.99 in.

Zero O. mykiss observations were made during surveys in 2018 (Table IV, Figure 7).

Cover Availability and Use

In 2016, the mean percentage of available *O. mykiss* cover in Upper North Fork Matilija Creek was 41.6 ± 2.2% (mean ± SE) (Table VII). This was primarily composed of boulder (37.2 ± 2.5% [mean ± SE]) and small woody debris (26.4 ± 2.0%) (Table VIII). Root mass and aquatic vegetation comprised 14.0% ± 1.5% and 13.2% ± 2.0% of total cover, respectively. All other cover types comprised less than 10% of the total available cover.

Data collected in 2016 show 83 trout of 88 total trout (94.3%) were observed using cover. Of the 83 trout using cover, 65 (73.9%) were observed under boulder, 12 (13.6%) were observed using bedrock, 4 (4.5%) using root mass, and two (2.2%) using small woody debris (Table IX). Zero trout were observed in aquatic vegetation, terrestrial vegetation, bubble curtain, large woody debris, or soil undercut. No assessment could be made from data collected in 2018 due to lack of *O. mykiss* observations.

In 2018, data collected from Upper North Fork Matilija Creek show the mean percentage of available *O. mykiss* cover was 50.7 ± 6.6 % (mean ± SE) (Table VII). Boulder (49.7 ± 5.7% [mean ± SE]) and bubble curtain (40.3 ± 5.0%) comprised the majority of total available cover (Table VIII). Bedrock comprised 5.0 ± 3.4% (mean ± SE) and all other cover types made up less than five percent of total cover.

Zero observations of O. mykiss were made during 2018 surveys so no data was collected regarding *O. mykiss* cover use (Figure 7).

Upper Matilija Creek

Wetted Habitat Assessment

In 2017, Upper Matilija Creek was surveyed for 6.2 stream miles and 367,031 ft^2 of wetted habitat. The surveyed reach of Upper Matilija Creek was an estimated 76% wet with approximately 1.5 miles of dry channel recorded during surveys (Figure 2). Of the delineated 1368 habitat units, 634 (46%) were characterized as pools, 389 (28%) as flatwaters, and 345 (25%) as riffles (Table II, Figure 6). For all wetted habitat surveyed, mean unit length was calculated at 24.0 ± 0.8 ft (mean ± SE), mean unit width was 10.3 ± 0.2 ft (mean ± SE), mean unit area was 266 ± 18.2 ft^2 (mean ± SE), with a mean depth of 0.6 ± 0.01 ft (mean ± SE), and mean maximum depth of 1.1 ± 0.02 ft (mean ± SE) (Table III). A total of 444 habitat units were snorkeled (Table II).

O. mykiss Relative Abundance

In Upper Matilija Creek, a total of 379 trout were observed in 444 snorkeled units, with 368 (97%) trout observed in pools and 11 (2.9%) observed in flatwaters (Table II, Figure 6). Trout densities in Upper Matilija Creek were calculated at a mean 0.0037 ± 0.04 trout per 100 ft^2 and mean 0.85 (±0.07) trout per unit snorkeled (Table IV). One hundred (26%) trout were observed to be 2-3.99 in, 189 (50%) were 4-5.99 in, 55 (14.5%) were 6-7.99 in, 19 (5.0%) were 6-7.99 in, 13 (3.4%) were 10-11.99, two (0.5%) were 12-13.99, and one (0.3%) was 0-1.99 inches.

Cover Availability and Use

The mean percentage of available *O. mykiss* cover in Upper Matilija Creek was 55.0% ± 8.3% (mean ± SE) (Table VII). This was primarily made up of boulder (58.8 ± 0.9%) and aquatic vegetation (15.8 ± 0.7%) (Table VIII). Of the 379 total *O. mykiss* observed, 361 (95.3%) were observed using cover. Of these, 307 (81.0%) were observed under boulder, 34 (9.0%) were observed using bedrock, 9 (2.4%) using root mass, 6 (1.6%) using bubble curtain, 3 (0.8%) using small woody debris, and 2 (0.5%) using aquatic vegetation (Table IX). Zero *O. mykiss* were observed in terrestrial vegetation, large woody debris, or soil undercut.

North Fork Matilija Creek

Wetted Habitat Assessment

Data collected from Upper North Fork Matilija Creek in 2018 show the entire reach was 100% wetted with approximately 112,989 ft^2 wetted habitat sampled (Figure 3). The 3.8 stream miles surveyed were delineated into 273 habitat units, comprising 64 (23%) pools, 82 (30%) flatwaters, and 127 (47%) riffles (Table II, Figure 6). Mean unit area was calculated at 413.9 ± 32.2 ft^2 (mean ± SE), with a mean unit length of 72.8 ± 5.3 ft (mean ± SE) and mean width of 6.2 ± 0.2 ft (mean ± SE) (Table III). Mean depths calculated included a mean depth of 0.39 ± 0.01 ft (mean ± SE) and mean maximum depth of 0.87 ± 0.03 ft (mean ± SE). A total of 19 units were snorkeled (Table II).

O. mykiss Relative Abundance

One *O. mykiss* was observed during all snorkel surveys and trout densities were calculated to be 0.013 ± 0.013 (mean ± SE) *O. mykiss* per 100 ft^2 and mean 0.05 *O. mykiss* per snorkeled unit (Table IV). The *O. mykiss* (n=1) was estimated to be 8-10 inches in size.

Cover Availability and Use

Data collected during snorkel surveys in North Fork Matilija Creek show the mean percentage of available *O. mykiss* cover was 36.6 ± 5.0% (mean ± SE) (Table VII). The majority of the cover observed was comprised of boulder (47.6 ± 4.8% [mean ± SE]), bubble curtain (18.4 ± 4.15%), and small woody debris (14.5 ± 4.1%) (Table VIII). All other cover types comprised less than five percent of total cover.

The individual *O. mykiss* (n=1) observed was seen using small woody debris for cover (Table IX).

Assessment of Stream Habitat & *O. mykiss* Occurrence

The results of our non-parametric Wilcoxon rank sum test showed a significant difference in the mean number of *O. mykiss* observed in pool versus flatwater units (p-value = 2.157e-06) (Figure 8).

Examination of our Pearson's correlation coefficient results did not reveal any strong relationships (coefficient > 0.5) between any one habitat parameter and observed *O. mykiss* occurrence ($P > 0.05$ for all tests) (Table V, Figure 9). Maximum depth had the largest coefficient ($r = 0.35$, p-value = 2.157e-06.), and percent cover had the smallest ($r = 0.10$, p-value = 0.018).

The results of our multiple regression model showed max depth to have the most significant relationship with *O. mykiss* occurrence (r = 0.75, p-value = 7.0E—03) (Table VI). For each 1-ft increase in max depth, the expected log count of trout changes by 0.75. Water temperature had the second most significant relationship with a coefficient of -0.10 (p-value = <2.0E-16).

DISCUSSION

Wetted Habitat Assessment

During the time of surveys stream reaches ranged from 73 to 100% wet. Upper Matilija Creek contained the longest dry sections during surveys in 2017 comprising 1.5 stream miles. This is characteristic of Matilija Creek which contains large sections of low gradient with little riparian cover that are prone to seasonal drying. While Upper North Fork Matilija Creek was an estimated 27% dry during surveys in 2016, the reach was 100% wet when surveyed in May 2018. Annual rainfall during the 2016-2017 rain year was above normal contributing to increased connectivity (Ventura Watershed Protection District 2019).

There were notable changes to stream habitat following a wildfire (the Thomas Fire) that occurred during the 2017-2018 winter season. A rapid burn assessment of the Ventura River Watershed estimated the fire burned over 95 percent of the Upper Matilija and North Fork Matilija subwatersheds (Klose et al. 2018). Subsequently, a winter storm in January 2019 brought rain intensities of 0.5-inch per 15 minutes creating large water and debris flows in Ventura River Basin (Ventura Watershed Protection District 2018).

When comparing our data collected from Upper North Fork Matilija Creek in 2016 and 2018, we can see differences in habitat composition and amount of wetted habitat available (Table III). During our 2016 survey, Upper North Fork Matilija Creek was dominated by pools and riffles comprising 40% and

33% of habitat units respectively (Table II, Figure 6). Of the wetted stream length, pool units made up approximately 1,997 feet (0.38 mi), flatwaters comprised 1,844 feet (0.35 mi), and riffles 1,271 feet (0.24 mi). Surveys conducted in 2018 show stream habitat dominated by riffles which comprised 72% of all delineated habitat (Table II, Figure 6). Riffle units made up approximately 6,302 feet (1.2 mi) of the total 1.3-mile reach, while pools comprised just 200 ft.

Our habitat delineation of North Fork Matilija Creek, surveyed after the Thomas Fire, show similar results. Mean depths ranged from 0.1 to 2.0 ft (n=273), and habitat units were dominated by riffles (47%) and flatwaters (30%) (Table II, Figure 6). Pool habitat made up just 1,170 ft (0.22 mi) of the 3.8-mile reach. This disappearance of pools is likely a result of lower stream channel stability and increased sediment transport, which are common wildfire impacts in stream systems (Sestrich et al. 2011, Bixby et al. 2015).

Oncorhynchus mykiss Relative Abundances

A total of 468 trout were observed within all three streams based on direct observational counts. Mean trout densities ranged from 0 ± 0 *O. mykiss* per 100 ft^2 in Upper North Fork during 2018 surveys to 0.48 *O. mykiss* per 100 ft^2 in Upper North Fork Matilija Creek in 2016 (Table IV). The largest proportion of *O. mykiss* observed in all streams fell in the 2–3.99 inch (29.1%) and 4–5.99 inch (48.5%) size classes (Figure 10). These results are consistent with data collected by CDFW in 2015 from Upper North Fork Creek, which found 64 of the 119 (53.8%) *O. mykiss* sampled to be in the 2–3.99-inch size range and 28 trout (23.5%) to be 4-5.99 inches. The larger proportion of 2-3.99-inch trout are likely contributed to the timing of both studies. For the 2015 study, data was collected during the summer months of July and August. Surveys for this study were conducted from September through December allowing any young-of-year additional time to grow.

Ninety-five percent of all trout observed were observed in pool units (n=445), while just 4.9% were observed in flatwaters (n=23) (Figure 8). Pools are important habitat that contain water depth heterogeneity which contributes to thermal refugia and predator-prey interactions (Allouche 2002). Multiple studies show pools serve as primary refugia for *O. mykiss,* especially in small streams where they are vulnerable to increased water temperatures that often approach stress or near-stress levels (Thompson et al. 2008, Sloat and Osterback 2013). Additionally, in many southern California streams, pools are important for native trout as they typically provide the only wetted habitat year-round (Boughton et al. 2009, May and Lee 2004).

Assessment of Habitat and O. mykiss Occurrence

Our Pearson's correlation coefficients testing for a relationship between individual habitat parameters and number of *O. mykiss* observed ranged from 0.10 to 0.35 (Table V, Figure 9). Maximum depth had the strongest positive relationship (r = 0.35, p-value = 2.20E-16) and water temperature had the strongest negative relationship (r = -0.27, p-value = 9.73E-11) with *O. mykiss* counts. The results of our negative binomial model showed mean width, max depth, percent cover, and water temperature were statistically significant, but all calculated coefficients were small (Table VI). Both results supported maximum depth and water temperature as the strongest influencers of *O. mykiss* presence. These results further support the importance of pool habitat, providing depth and thermal refugia, for persisting *O. mykiss* populations in southern California (Boughton 2009, Sloat & Osterback 2013).

The results of both correlation and regression analyses indicate stream habitat parameters do not explain much of *O. mykiss* occurrence (Tables V & VI). These results can be expected with populations native to dynamic streams that are subject to seasonal variation in physical and biological conditions (Boughton 2009, Krug et al. 2012). Furthermore, previous studies on *O. mykiss* suggest habitat complexity is favored by trout indicating multiple physical parameters contribute to trout suitable habitat (Mitro and Zale 2015). Correlations between habitat parameters and *O. mykiss* occurrence have been used to improve abundance estimates and refine habitat suitability models. These relationships can help explain observed trout abundances and habitat associations (Allen 2012, Cox 2010). However strong correlations are difficult to determine with small and patchy *O. mykiss* abundances that characterize southern California populations. Future studies should focus on collecting additional standardized data to help quantify *O. mykiss* habitat and habitat relationships in southern California.

Cover Availability and Use

As far as we are aware, this is the first examination of fine-scale *O. mykiss* cover use within the Ventura River watershed. Mean unit cover for all surveys ranged from 41.6 to 55.0% with an overall mean of 52.5 ± 0.8% (mean ± SE) (Figure 11). Boulders comprised the greatest percentage of all cover available (mean = 55.5 ± 0.9% [mean ± SE]; range = 37.2 ± 2.5 – 58.8 ± 0.9% [mean ± SE]) and 79.7% of *O. mykiss* (n=467) were observed in association with boulders (Figures 12 & 13). In contrast, only two trout were observed under aquatic vegetation, which made up 14.6 ± 0.6% of cover available. Our results are consistent with habitat studies of southern California streams, which found that these systems are typically dominated by bedrock outcrops and in-stream boulders (Boughton 2009; Keller, Bean, & Best 2015). Notably, there was minimal large woody debris observed in all units surveyed. The majority of large woody debris was observed in North Fork Matilija Creek comprising a mean 2.1 ± 1.5 % (mean ± SE) of unit coverage. This is likely due to these surveys occurring after the wildfire and mass debris movement during the 2017-2018 winter season. The availability of boulders in our reaches, combined with the lack of large woody debris, may correspond to the prevalence of boulder use as cover by *O. mykiss*.

While boulder was observed to be the dominant cover type for all surveys, there were differences in cover composition and availability prior to and post wildfire. Specifically, we observed an increase in bubble curtain and decrease in aquatic vegetation (Table VIII). When comparing data collected from Upper North Fork Matilija, the estimated proportion of cover comprising bubble curtain increased from 1.9 ± 0.4% (mean ± SE) to 40.3 ± 5.0% (Figure 14). Meanwhile, the estimated proportion of aquatic vegetation decreased from 13.2 ± 2.0% (mean ± SE) to 1.9 ± 0.4%. Differences in stream flow during the time of surveys likely contributed to these changes in trout cover availability. Generally, faster moving water creates more water turbulence producing bubble curtain. Annual precipitation for Ventura County from 2013 to 2015 ranged from 38 to 53 percent of normal creating low flow conditions during surveys in 2016 (Ventura Water Protection District 2019). In 2018, increased precipitation resulted in greater sustained stream flow throughout the river basin. Similarly, large flows from intense rainfall in

January 2018, likely led to the removal of instream vegetation, and surveys conducted in May did not allow time for seasonal regrowth.

While these results suggest that *O. mykiss* predominantly use boulder for cover in the upper Ventura River Basin, there are several caveats that must be considered carefully. In particular, we could not make any assumptions regarding cover type preference without further experimental tests. Additionally, *O. mykiss* observations during snorkel surveys are biased by differential trout observation probabilities between cover types. For example, *O. mykiss* could be easily observed when using shallow bedrock ledges as cover (Figure 15). However, aquatic vegetation can grow in thick patches that are difficult for snorkelers to search or observe hiding trout. Thus, we could not make any comparisons regarding the use of cover types relative to one another.

This study acts as a step towards quantifying characteristics of quality trout habitat in southern California. Many salmonid habitat restoration studies focus on the importance of large woody debris in streams, but few have addressed the similar role boulders play in stream processes and productivity (e.g. forming pools and transporting sediment). Branco (et al. 2013) found boulder placement in fragmented stream habitat would increase available habitat space, substrate heterogeneity, and river connectivity. Additionally, Meyer and Griffith (1997) demonstrated the importance of cobbler-boulder substrate which increased available cover for wintering trout. The lack of large woody debris in our streams highlights the importance of boulders as a potential indicator of healthy trout habitat. While additional data are needed to support our findings, the results from this study clearly show that boulders are both prevalent and frequently used by trout in a southern California stream system.

TABLES

Table I – Definitions of trout cover types. Table of the definitions used to characterize each cover type. We counted the number of trout in association with each cover type, as well as the percentage of total available cover comprised by each cover type.

Cover Type	Description
Open/No cover	Percentage of the unit that is open and without trout cover. Trout are not hiding, instead milling or swimming in an open area of the unit.
Cobble/Boulder	Rocks less than the size of a Volkswagen Beetle. This category includes instances in which trout hide in the crevices of a boulder cluster and underneath the ledge of the boulder.
Small Woody Debris	Fallen (dead) twigs, leaves, tree-related debris, and logs less than 1 foot in diameter or less than 6 feet long that is in the water and capable of providing cover to at least a 3-inch fish.
Large Woody Debris	Logs at least 1 foot in diameter and at least 6 feet long touching the water and capable of providing cover to at least a 3-inch fish.
Bedrock Ledge	Rocks larger than a Volkswagen Beetle that overhang the water such that a 3-inch trout could hide underneath (approximately 6-inch deep).
Terrestrial Vegetation	Any live, terrestrial vegetation touching or overhanging within a foot of the water's surface that is large or complex enough to hide a 3-inch trout.
Aquatic Vegetation	Any live, aquatic vegetation that is large or complex enough to hide a 3-inch trout.
Bubble Curtain	Bubbles created by flow that could provide cover a 3-inch trout.
Root Mass	A mat or cluster of live roots (e.g. willow mats or thick roots from a large tree) that could provide cover to a 3-inch trout.
Soil Undercut	An area along the margins of the unit comprised mostly of soil that has eroded only underneath the surface to create a ledge. This undercut should be able to hide a 3-inch trout (approximately 6 inches deep).

Table II – Summary of habitat delineations. Habitat delineation results from surveys conducted in three stream reaches from 2016 to 2018. All stream habitat was delineated into discrete units of similar habitat and classified as a pool, flatwater, or riffle. All pool and flatwater units of a certain depth (mean depth ≥ 0.7ft, max depth ≤ 3.5 ft) were snorkeled.

Stream Reach	Year	Delineated Units				Snorkeled Units		
		Total	**Pools**	**Flatwaters**	**Riffles**	**Total**	**Pools**	**Flatwaters**
Upper North Fork Matilija	2016	233	93	63	77	68	59	9
Upper Matilija	2017	1368	634	389	345	444	364	80
Upper North Fork Matilija	2018	105	18	11	76	15	14	1
North Fork Matilija	2018	273	64	82	127	19	18	1

Table III – Wetted habitat measurements. Descriptive statistics for all wetted habitat of three stream reaches surveyed in the Ventura River Watershed from 2016 to 2018. For each survey, all flagged habitat units were measured for length, mean width, mean depth, and maximum depth. Exposed substrate (not wetted) was estimated and subtracted from unit volume calculations. Standard error is given for each mean (mean ± SE).

Stream Reach	Year	Mean Length (±SE ft)	Mean Width (±SE ft)	Mean Depth (±SE ft)	Mean Max Depth (±SE ft^2)	Mean Volume (±SE ft^3)
Upper North Fork Matilija Creek	2016	21.9 (±1.1)	9.6 (±0.3)	0.6 (± 0.02)	1.1 (±0.05)	142.6 (±17.4)
Upper Matilija Creek	2017	24.0 (±0.8)	10.3 (±0.2)	0.6 (±0.01)	1.1 (±0.02)	243.3 (±22.6)
Upper North Fork Matilija Creek	2018	63.6 (±7.4)	7.0 (±0.2)	0.5 (±0.02)	1.0 (±0.03)	163.4 (±19.7)
North Fork Matilija Creek	2018	72.8 (±5.3)	6.2 (0.2)	0.4 (±0.01)	0.9 (±0.03)	149.2 (±13.4)

Table IV - *Oncorhynchus mykiss* relative abundances. *O. mykiss* observations recorded from snorkel surveys conducted in three streams of the Ventura River Watershed from 2016 to 2018. Trout densities are calculated as total number of trout observed, mean trout per 100 square foot and mean number of trout per unit snorkeled.

Stream Reach	Year	Total # Trout	Mean Trout/100ft^2	Mean Trout/Unit
Upper North Fork Matilija Creek	2016	88	0.48 (±0.08)	1.3
Upper Matilija Creek	2017	379	0.37 (±0.04)	0.85
Upper North Fork Matilija Creek	2018	0	0.0 (0±0.0)	0.0
North Fork Matilija Creek	2018	1	0.013 (±0.013)	0.05

Table V – Results of Pearson's correlation analyses testing physical habitat features with observed O. mykiss during snorkel surveys. Independent variables tested include habitat unit length, mean width, mean depth, maximum depth, surface area, volume, estimated percent cover, and water temperature. Data was collected in Upper Matilija, Upper North Fork, and North Fork Matilija creeks from 2016-2018. For each calculated coefficient (r_P), degrees of freedom (DF) and p-value are given.

Habitat Parameter	DF	Pearson's Correlation Coefficient (r_P)	p-value
Length (ft)	544	0.18	2.08E-05
Mean Width (ft)	544	0.20	1.62E-06
Mean Depth (ft)	544	0.24	2.31E-08
Maximum Depth (ft)	544	0.35	2.20E-16
Surface Area (ft^2)	544	0.16	1.20E-04
Volume (ft^3)	544	0.16	1.50E-04
Percent Cover (%)	544	0.10	0.018
Water Temperature (°F)	544	-0.27	9.73E-11

Table VI - Results of negative binomial multiple regression model. Physical habitat features were tested against observed *O. mykiss* during snorkel surveys. Independent variables tested include habitat unit length, mean width, mean depth, maximum depth, estimated percent cover, and water temperature. Data was collected in Upper Matilija, Upper North Fork, and North Fork Matilija creeks from 2016-2018. For each calculated coefficient, the standard error and p-value are given.

Habitat Parameter	Coefficient Estimate (*r*)	Standard Error	p-value
Intercept	2.83	0.70	5.19E-05
Length (ft)	2.06E-03	1.78E-03	0.25
Mean Width (ft)	0.053	0.013	5.68E-05
Mean Depth (ft)	-9.07E-03	0.44	0.98
Maximum Depth (ft)	0.75	0.22	7.03E-04
Percent Cover (%)	0.022	3.93E-03	2.59E-08
Water Temperature (°F)	-0.10	0.011	<2.0E-16

Table VII – Estimated total *O. mykiss* cover availability. (a) Total available cover observed for all habitat units snorkeled during surveys in Upper North Fork Matilija Creek (2016, 2018), Upper Matilija Creek, and North Fork Matilija Creek. Coverage was estimated as a percent of wetted habitat capable of providing cover to a 3-inch fish or larger. For all estimations, a mean percent is given with standard error.

Stream Reach	Year	Unit Covered (± SE%)	Unit Open (± SE%)
Upper North Fork Matilija	2016	0.70	58.4 (±2.2)
Upper Matilija	2017	1.78E-03	45.1 (±0.8)
Upper North Fork Matilija	2018	0.013	49.3 (±6.6)
North Fork Matilija	2018	0.44	63.4 (±5.0)

Table VIII – Estimated *O. mykiss* cover availability by type. Available cover observed by type for all habitat snorkeled during surveys in Upper North Fork Matilija Creek (2016, 2018), Upper Matilija Creek, and North Fork Matilija Creek. For all cover types observed, a mean (± standard error) percent of total available cover is given.

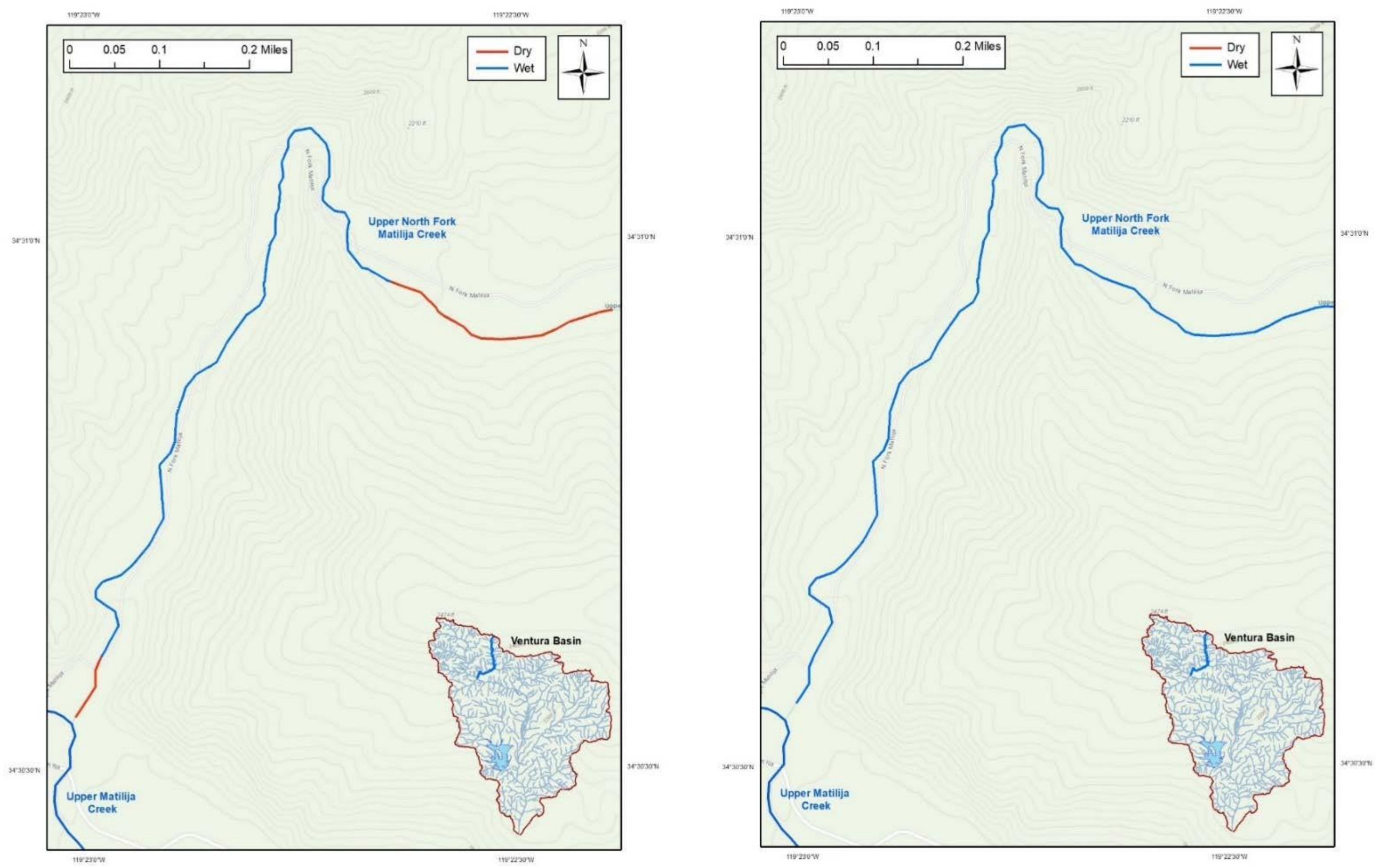
Stream Reach	Year	Boulder (± SE%)	Bedrock (± SE%)	Small Woody Debris (± SE%)	Large Woody Debris (± SE%)	Aquatic Veg (± SE%)	Terrestrial Veg (± SE%)	Root Mass (± SE%)	Soil Undercut (± SE%)	Bubble Curtain (± SE%)
Upper North Fork Matilija	2016	37.2 (±2.5)	5.0 (±1.7)	26.4 (±2.0)	0.0 (±0.0)	13.2 (±2.0)	2.4 (±1.2)	14.0 (±1.5)	0.0 (±0.0)	1.9 (±0.4)
Upper Matilija	2017	58.8 (±0.9)	2.4 (±0.4)	7.5 (±0.4)	0.0 (±0.0)	15.8 (±0.7)	1.4 (±0.2)	7.5 (±0.4)	0.3 (±0.1)	6.2 (±0.3)
Upper North Fork Matilija	2018	49.7 (±5.7)	5.0 (±3.4)	2.3 (±1.0)	0.0 (±0.0)	0.3 (±0.3)	0.0 (±0.0)	2.3 (±1.2)	0.0 (±0.0)	40.3 (±5.0)
North Fork Matilija	2018	47.6 (±4.8)	4.7 (±1.9)	14.5 (±4.1)	2.1 (±1.5)	2.9 (±1.5)	1.3 (±0.5)	8.4 (±3.1)	0.0 (±0.0)	18.4 (±4.1)

Table IX – Observed cover use by *O. mykiss.* Total number of *Oncorhynchus mykiss* observed taking refuge in all cover types. Observations of *O. mykiss* were made during snorkel surveys conducted in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016 to 2018. Zero *O. mykiss* were observed during the Upper North Fork Matilija survey in 2018 so there is no data to show here.

Stream Reach	Year	Open	Boulder	Bedrock	Small Woody Debris	Large Woody Debris	Aquatic Veg	Terrestrial Veg	Root Mass	Soil Undercut	Bubble Curtain
Upper North Fork Matilija	2016	5	65	12	1	0	0	0	4	0	0
Upper Matilija	2017	18	307	34	3	0	2	0	9	0	6
North Fork Matilija	2018	0	0	0	1	0	0	0	0	0	0

FIGURES

Figure 1. Map of Upper North Fork Creek which serves as a tributary to Upper Matilija Creek located in the upper Ventura River Basin. Sections of the stream channel that were wet at the time of surveys are shown in blue and dry sections in red. (a) The 1.3-mile stream reach was surveyed from October 4, 2016 November 30, 2016 and was estimated to be 73% wet. (b) When the reach was surveyed from May 14, 2018 to May 24, 2018, the reach was 100% wet.



(a) (b)

Figure 2. Map of Upper Matilija Creek located in the upper Ventura River Basin above Matilija Dam. Upper Matilija Creek was surveyed for 6.2 miles from August 1, 2017 to November 29, 2017 and estimated to be 76% wet.

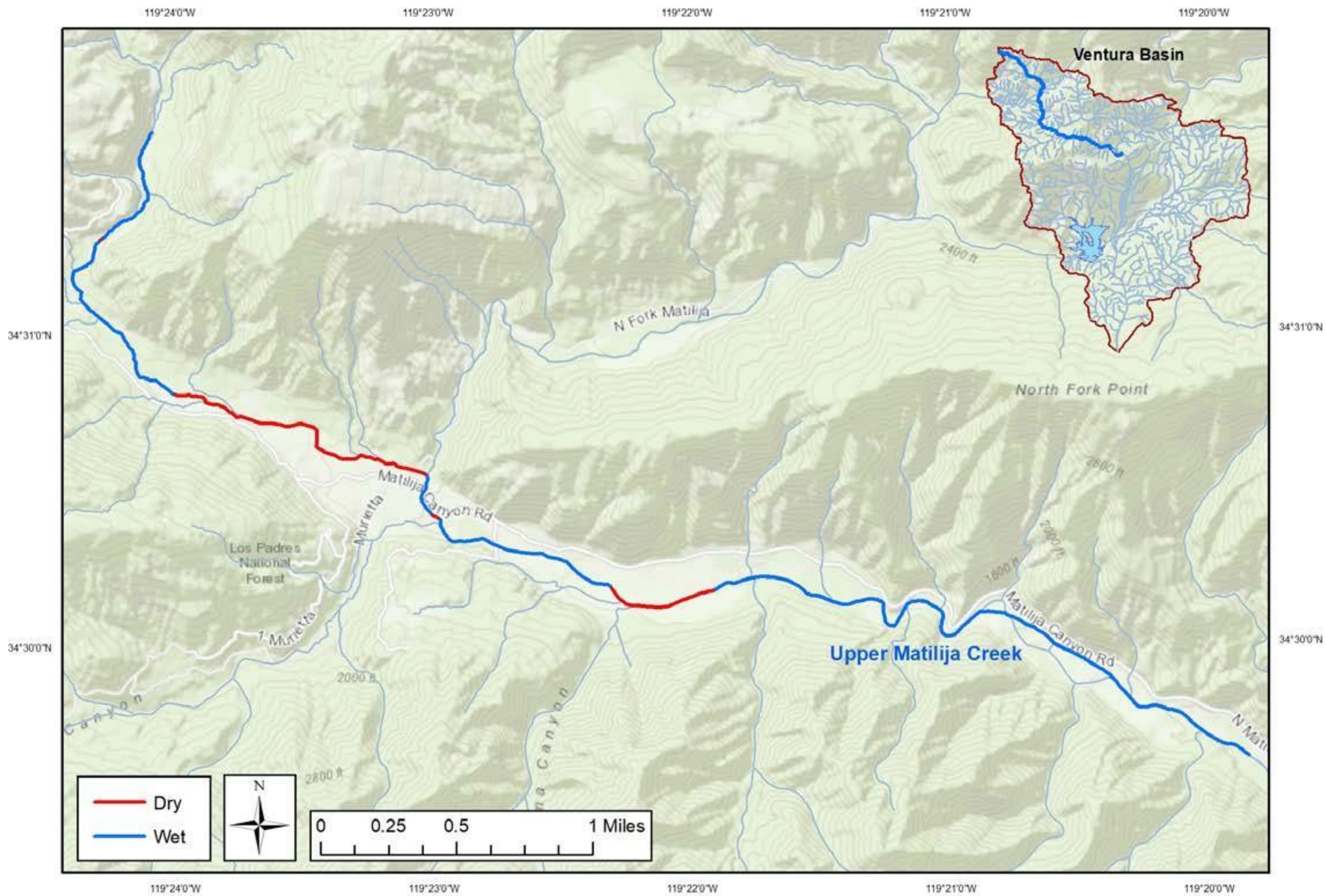


Figure 3. Map of North Fork Matilija Creek located in the upper Ventura River Basin. North Fork Matilija was surveyed for 3.8 miles from October 15, 2018 to November 28, 2018 and was 100% wet. Data collection started upstream of the Matilija and North Fork Matilija confluence to avoid a highway construction zone at the time.

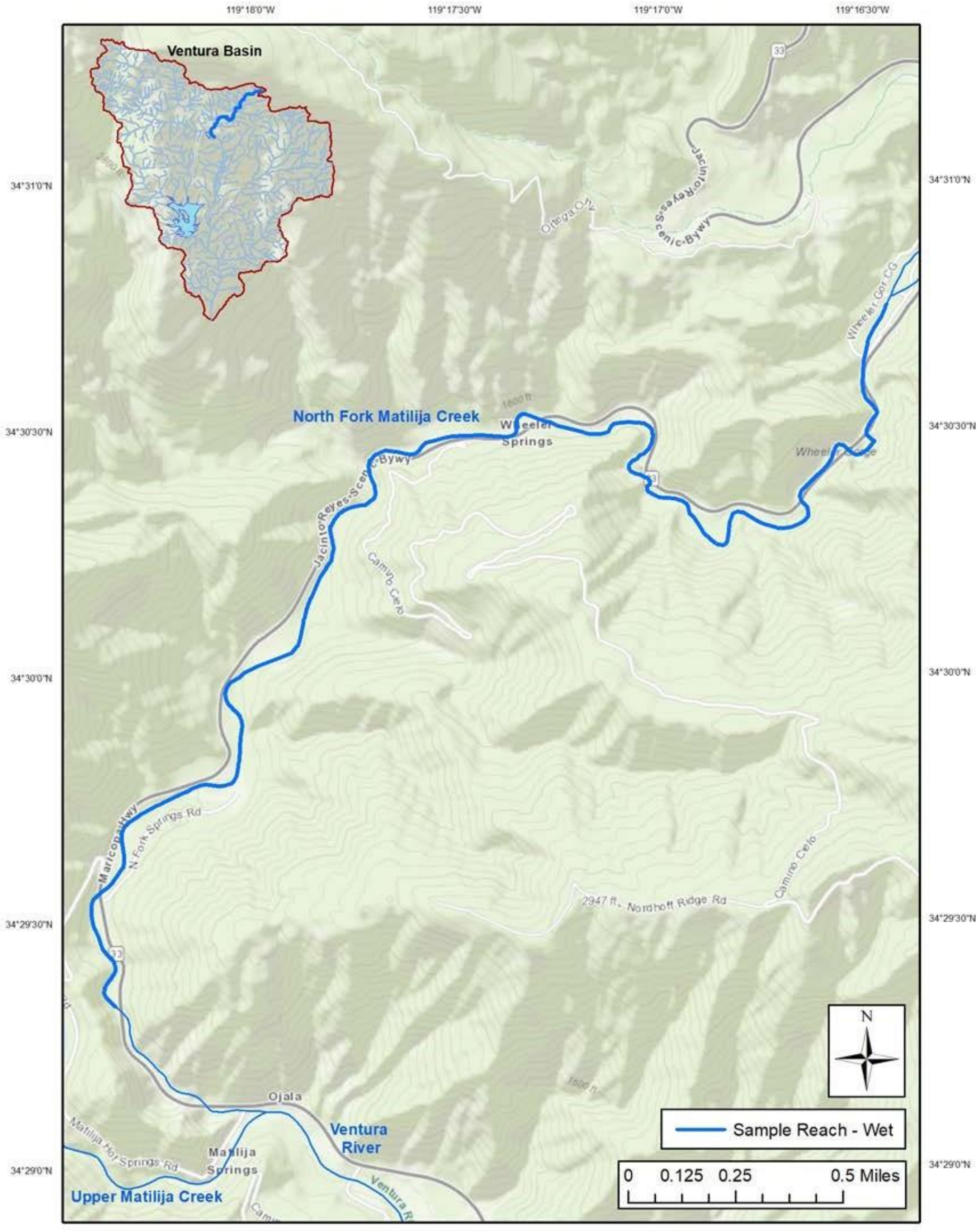


Figure 4. Image of data collection during a snorkel survey of Matilija Creek in 2017. PSMFC Fisheries Biologist Kathryn Carmody and PSMFC Fisheries Technician Shannon Mueller conduct a snorkel survey of Matilija Creek to collect data on *O. mykiss* relative abundance, instream cover availability and use. For wide habitat units (mean width > 15ft) two snorkelers would progress upstream in side-by-side to cover the entire wetted area.

Figure 5. Dispersion of *O. mykiss* count data for all measured habitat parameters. Data was collected from snorkel surveys conducted in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016-2018. Habitat unit parameters tested are: length (ft), mean width (ft), mean unit depth (ft), mean maximum depth (ft), surface area (ft^2), volume (ft^3), estimated percent cover (%), and water temperature (°F).

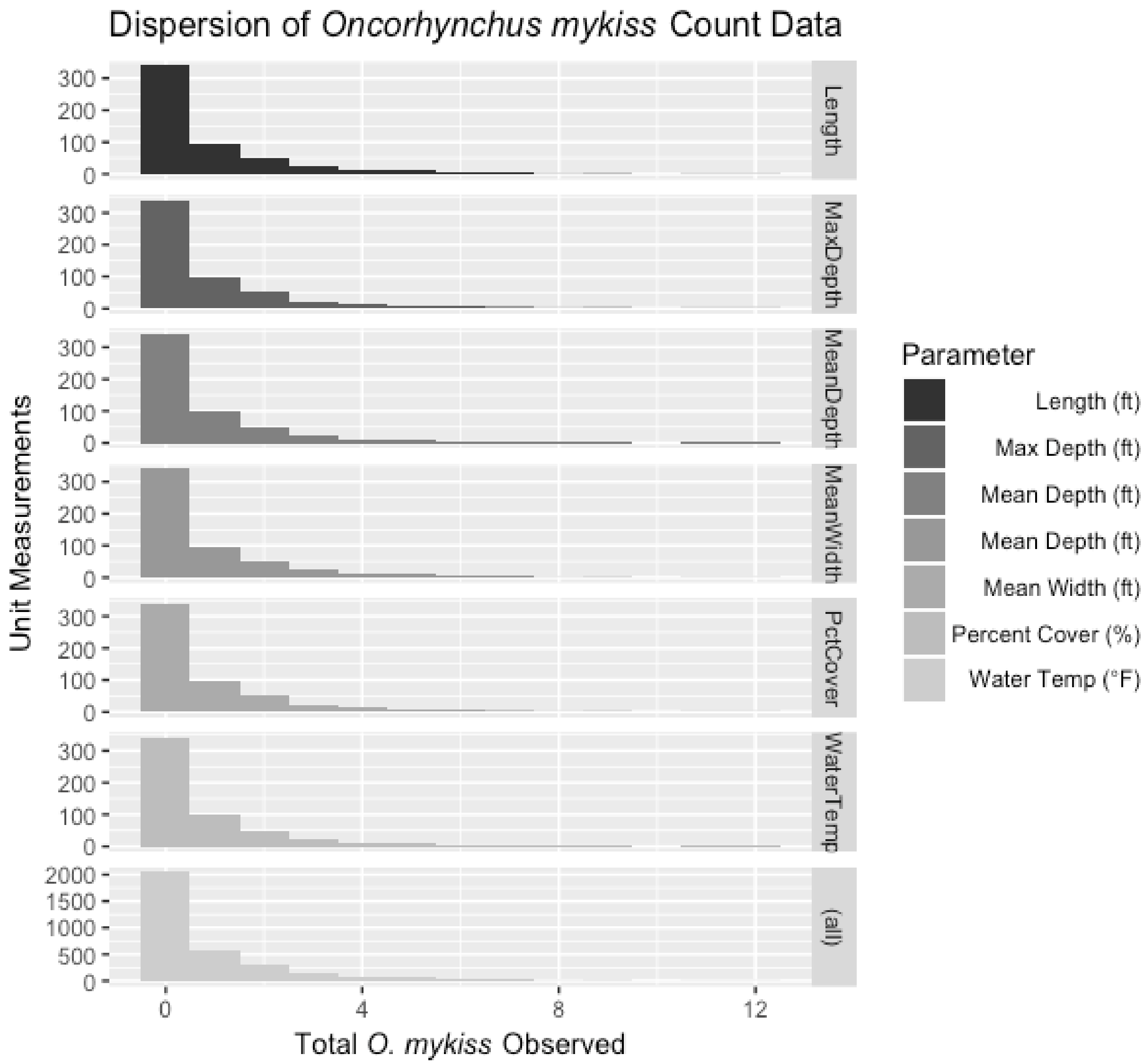


Figure 6. Stream habitat delineation by survey. Bar graph showing the number of habitat units classified as riffles, flatwaters, or pools for each survey. Data was collected from four surveys in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016-2018. Sample sizes are shown within each bar.

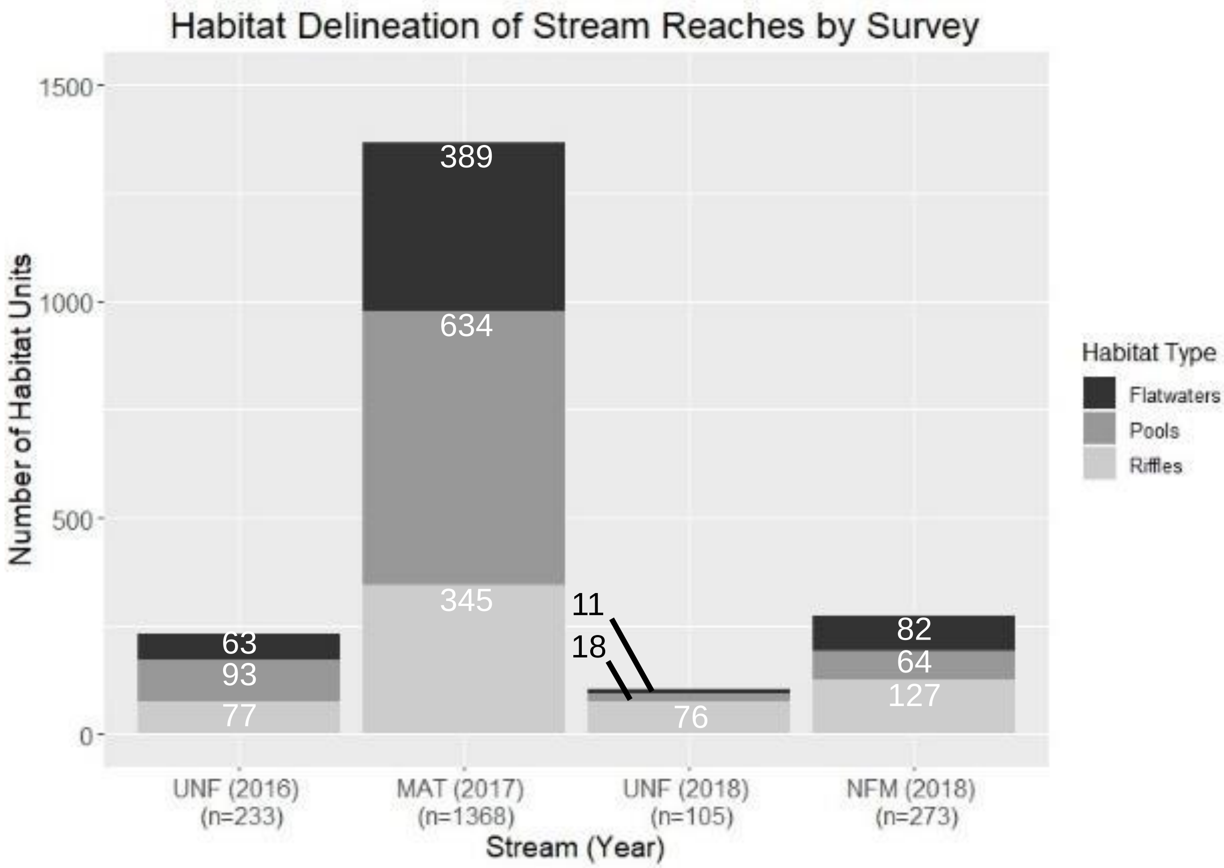


Figure 7. Observed *O. mykiss* relative abundance by survey. Bar graph showing the total number of *Oncorhynchus mykiss* observed during snorkel surveys in the upper Ventura River watershed. Data was collected from four surveys in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016-2018. The total number of *O. mykiss* is indicated above each bar.

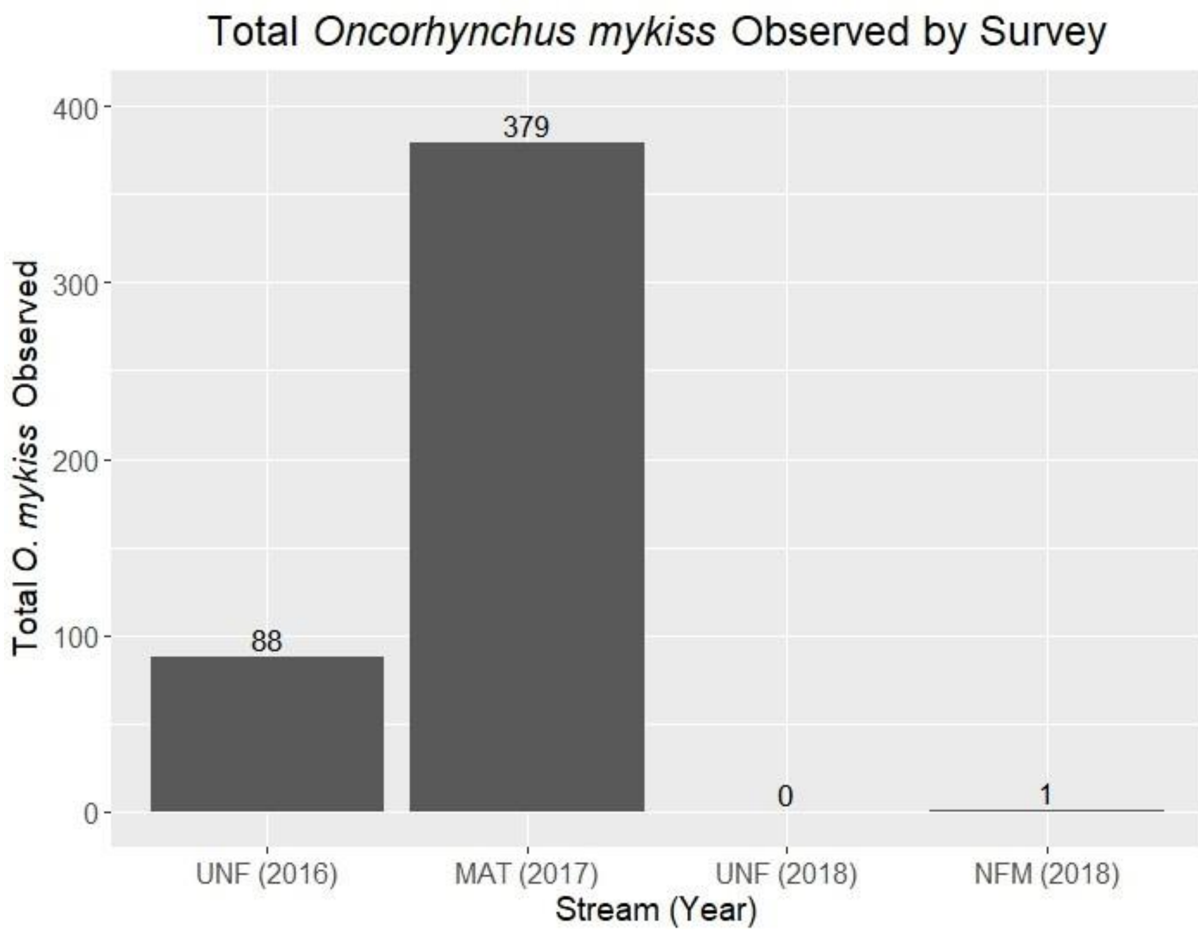


Figure 8. **Total *O. mykiss* by habitat type.** Boxplot showing the range of *O. mykiss* observations made in habitat units categorized as pools versus flatwaters. Data was collected from snorkel surveys conducted in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016-2018.

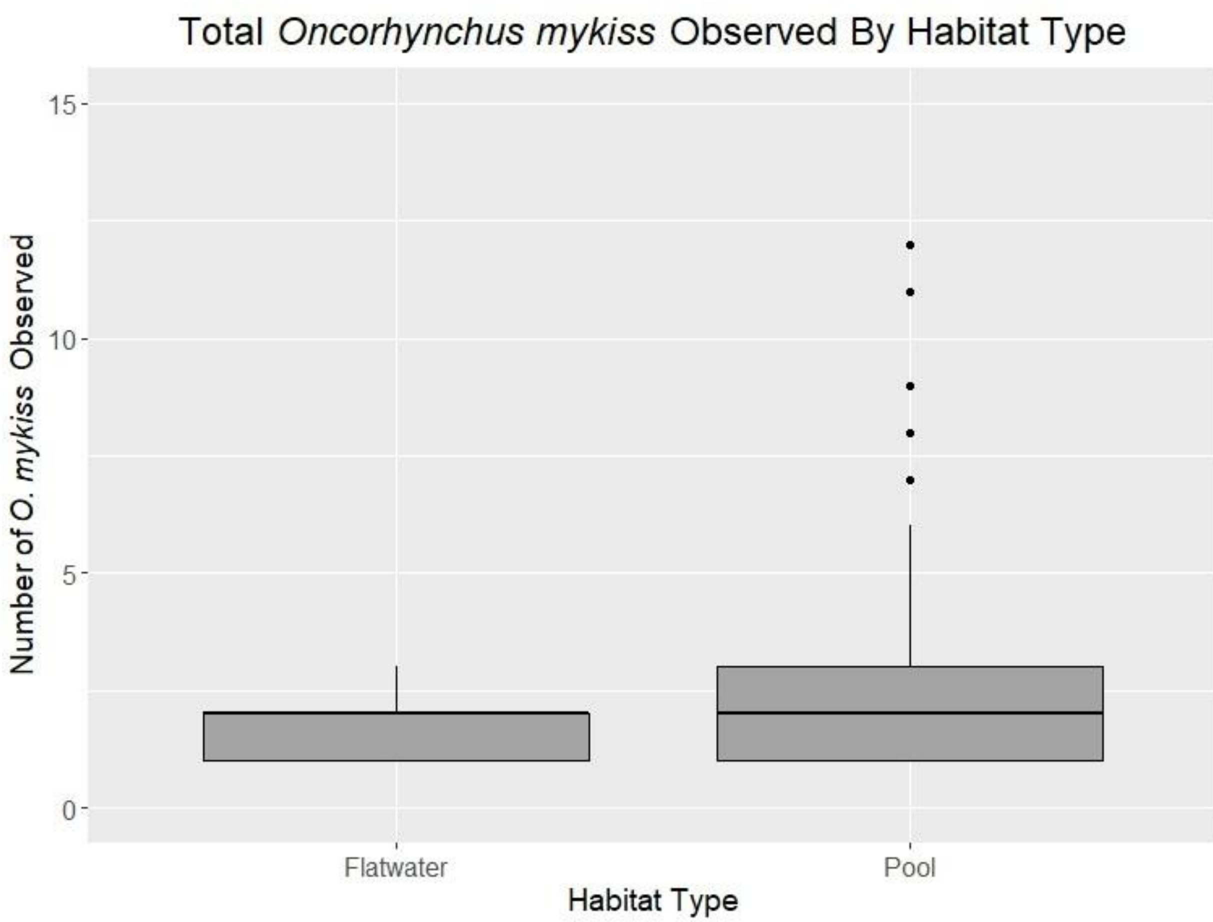


Figure 9. **Correlation plots of *Oncorhynchus mykiss* counts vs. measured habitat parameters.** The total number of *O. mykiss* observations tested against habitat measurements made for each unit. Data was collected from snorkel surveys conducted in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016-2018. Habitat unit parameters tested are: length (ft), mean width (ft), mean unit depth (ft), mean maximum depth (ft), surface area (ft^2), volume (ft^3), estimated percent cover (%), and water temperature (°F).

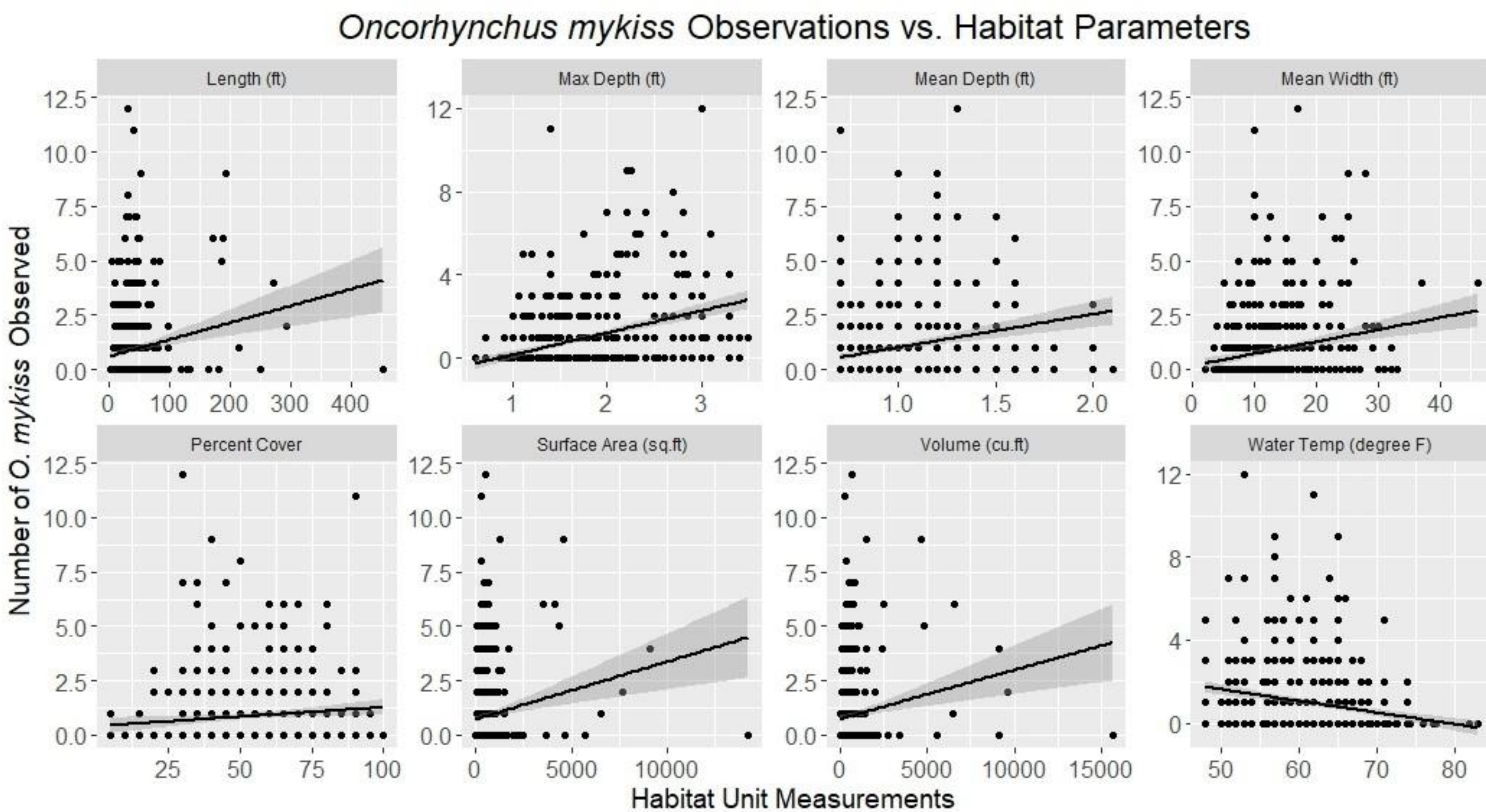


Figure 10. Observed *O. mykiss* relative abundances by size class. Bar graph showing the total number of *Oncorhynchus mykiss* observed in each two-inch size bin. Data was collected from snorkel surveys conducted in Upper North Fork Matilija, Upper Matilija, and North Fork Matilija creeks from 2016-2018. The total number of *O. mykiss* is indicated above each bar.

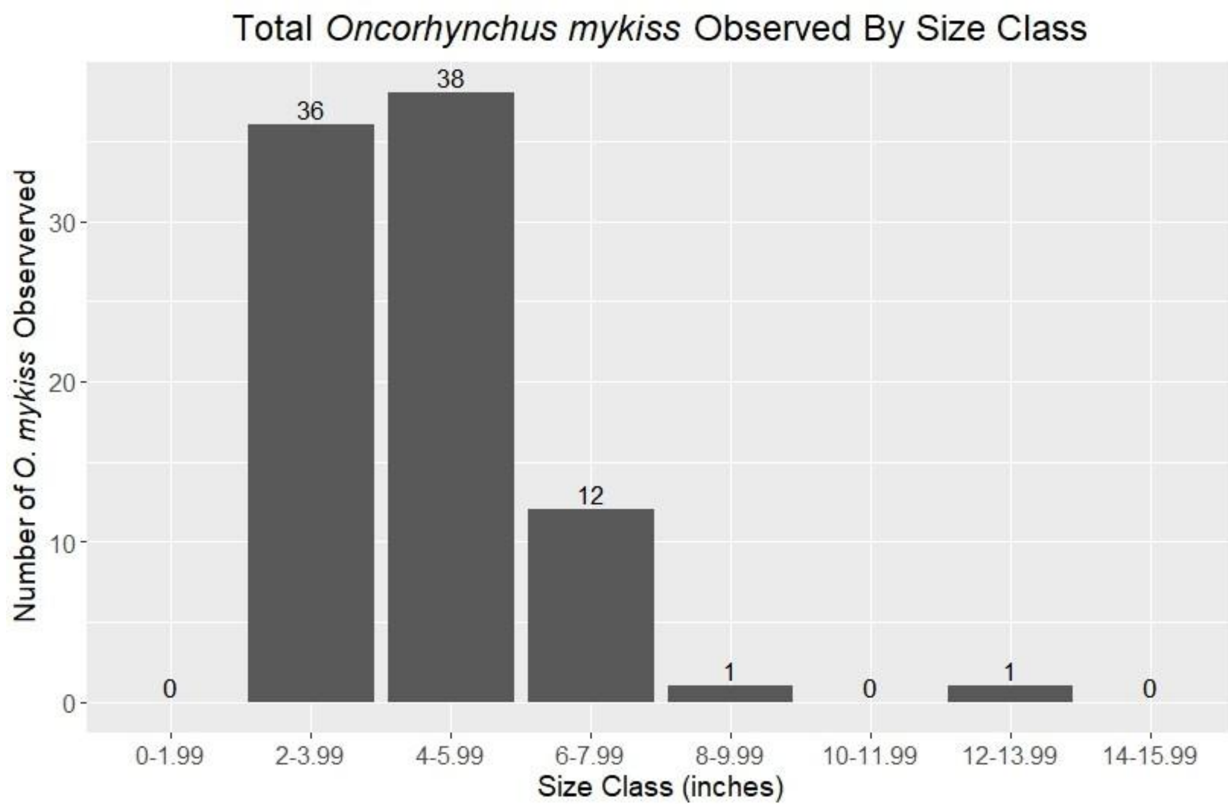


Figure 11. **Available *O. mykiss* cover observed by survey.** Boxplot showing the range of unit cover observed during four snorkel surveys. Data was collected in Upper North Fork Matilija (UNF), Upper Matilija (MAT), and North Fork Matilija (NFM) creeks from 2016-2018. Available cover was estimated as the percent of each habitat unit containing *O. mykiss* cover.

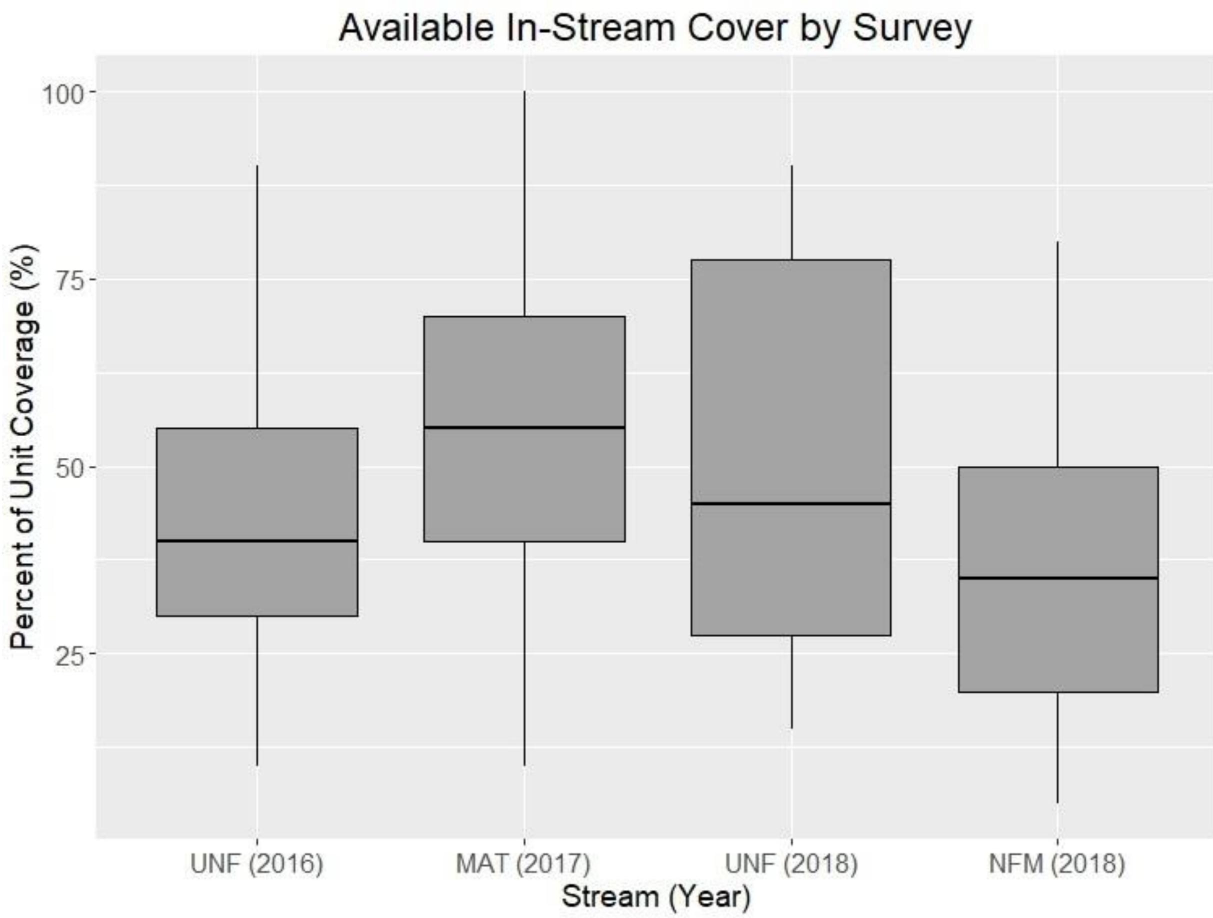


Figure 12. Mean available *O. mykiss* cover by type for all surveys. Mean percent of total available trout cover by cover type. Cover types are: cobble/boulder (Boulder), bedrock, small woody debris (small wood), large woody debris (large wood), aquatic vegetation (Aquatic Veg), terrestrial vegetation (Terrestrial Veg), root mass, soil undercut, and bubble curtain. Mean percent ± standard error is indicated above each bar for graph.

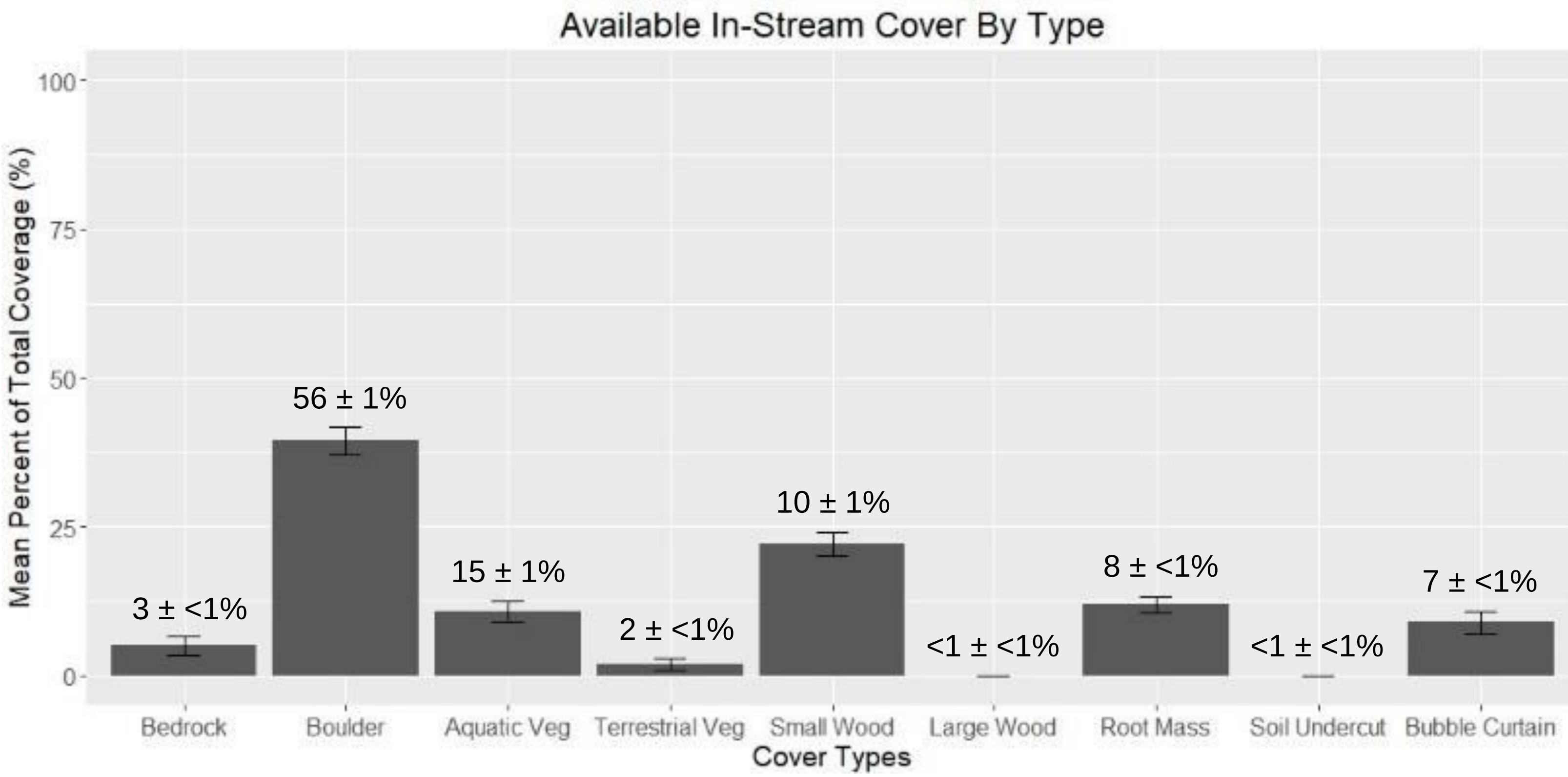


Figure 13. Total *O. mykiss* cover use observed by type. Total number of *O. mykiss* observed using each cover type as refuge. Cover types are: open water, cobble/boulder (Boulder), bedrock, small woody debris (small wood), large woody debris (large wood), aquatic vegetation (Aquatic Veg), terrestrial vegetation (Terrestrial Veg), root mass, soil undercut, and bubble curtain. The total number of *O. mykiss* is indicated above each bar.

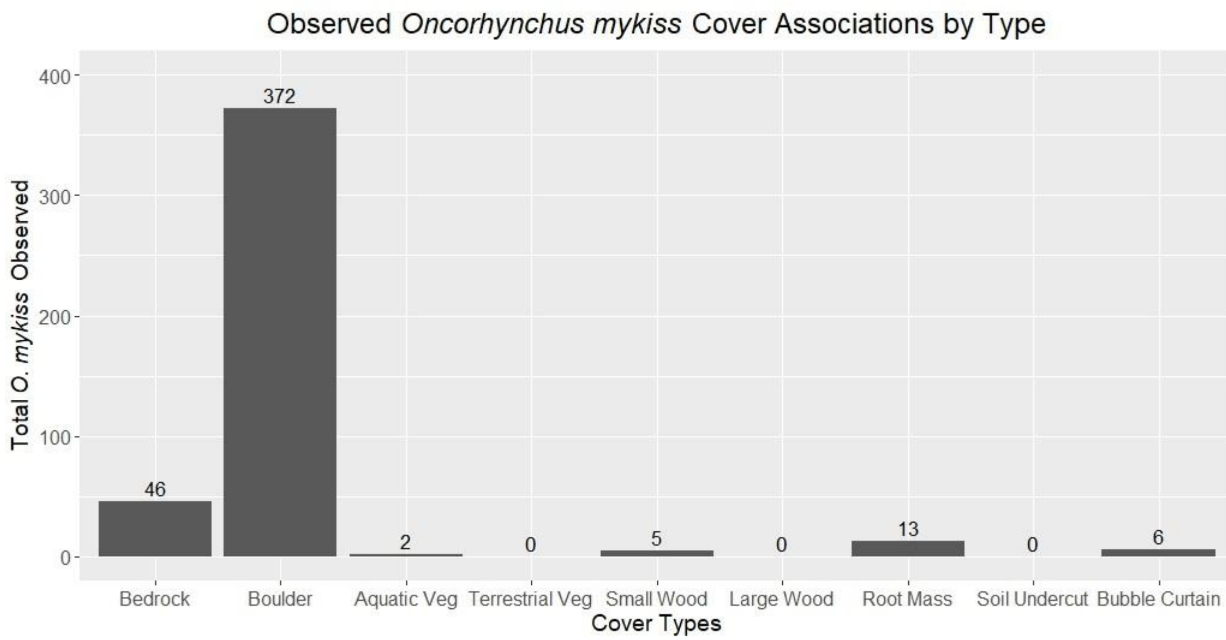


Figure 14. Mean available *O. mykiss* cover in Upper North Fork Matilija Creek 2016 vs 2018. Data collected from snorkel surveys in 2016 and 2018. Cover types are: cobble/boulder (Boulder), bedrock, small woody debris (Small Wood), large woody debris (Large Wood), aquatic vegetation (Aquatic Veg), terrestrial vegetation (Terrestrial Veg), root mass, soil undercut, bubble curtain. Mean percent ± standard error is indicated above each bar.

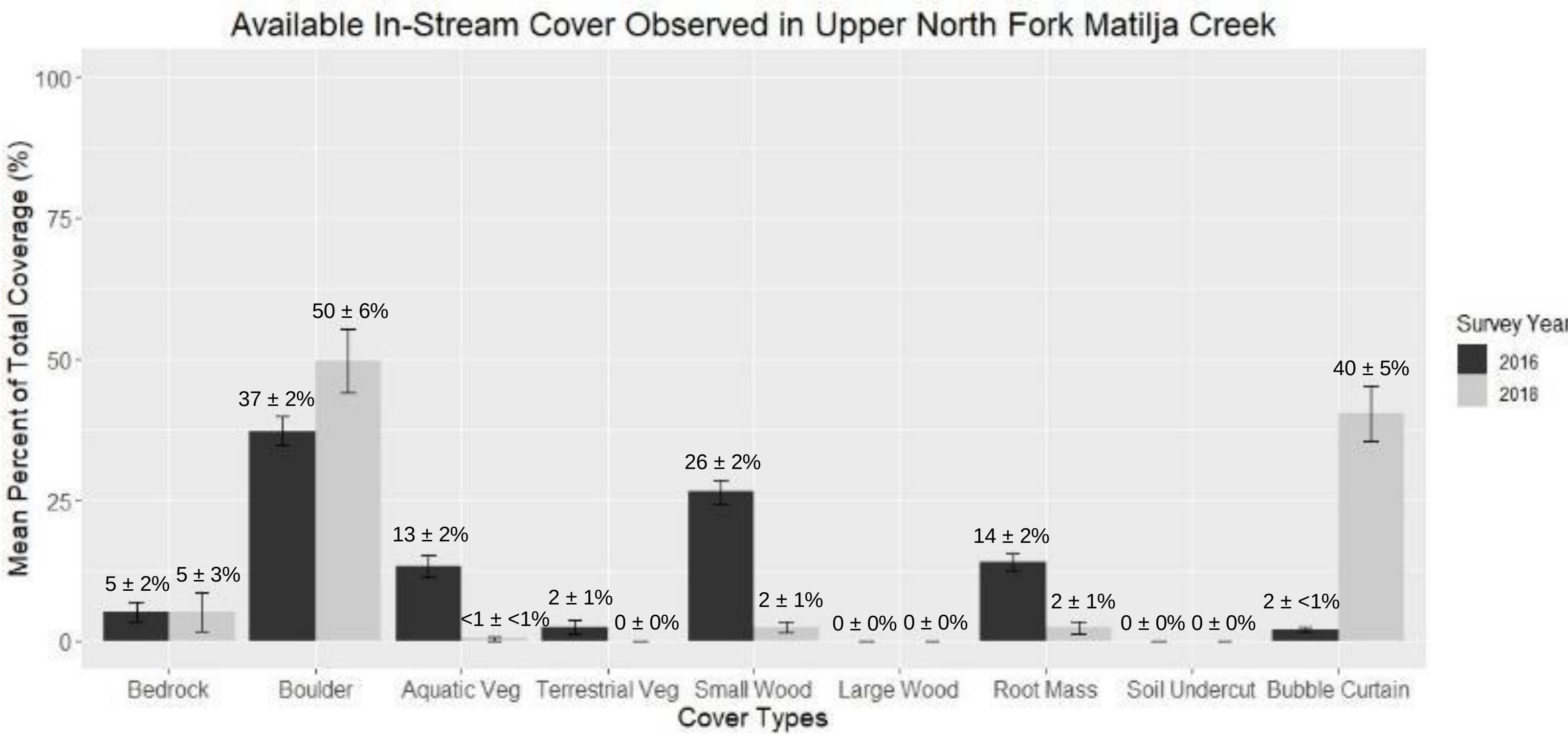


Figure 15. Observed *O. mykiss* in Upper Matilija Creek. An *O. mykiss* is observed taking refuge under a bedrock ledge during a snorkel survey in Upper Matilija Creek. Data collected in three streams of the upper Ventura River Basin from 2016 to 2018 contributed to an assessment of *O. mykiss* relative abundance, cover availability and use.

Use of portable passive integrated transponder (PIT) telemetry to assess *Oncorhynchus mykiss* fine-scale movement in Upper North Fork and North Fork Matilija Creeks

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ABSTRACT

Passive integrated transponder (PIT) tagging and the use radio frequency identification (RFID) technology allow unique identification of a species-of-interest in remote regions. Unrestricted by battery life, these tags allow long-term monitoring of an individual at low costs. Data collected can provide critical information used to evaluate species movement, survival, and growth. We used a portable antenna following PIT tagging surveys to monitor fine scale movement of *Oncorhynchus mykiss* in the Ventura River Basin. These efforts combined with the deployment of fixed in-stream antennas aimed to maximize PIT tag detections and *O. mykiss* monitoring within our focal watershed. Two streams were surveyed for abundance estimation and tagging efforts. Following tagging surveys, portable backpack antenna was used to scan the entire sampled stream reach for PIT detections. Data collected contributed to an evaluation of fine-scale *O. mykiss* movement as well as the effectiveness of using portable PIT antennas for future monitoring.

INTRODUCTION

First used to monitor fish movement, passive integrated transponder (PIT) tags allow for study of movement and habitat use by individual fish (Roussel et al. 2000, Hill et al. 2006, Zydlewski et al. 2006). PIT tags are used widely because they are small, inexpensive and are not reliant on battery power. PIT tags range in size from 10-mm to 32-mm and consist of an antenna coil, capacitor, and microchip encased in a small glass tubule (Hill et al. 2006, Roussel et al. 2000). These passive tags communicate magnetically with transceivers via low frequency radio frequency identification (RFID). A transceiver electrically charges an attached antenna causing the antenna to emit an electromagnetic field (OregonRFID 2019). Once a PIT tag enters this field, the capacitor within the tag is energized and transmits the unique identification number back to the receiver (Hill et al 2006, Roussel et al. 2000). Stationary in-stream PIT detection sites are typically constructed in conjunction with tagging efforts to monitor fish passage. Many fish passage facilities within water diversion or large dams have installed PIT antennas for large scale monitoring (Zydlewski et al. 2003).

Due to the small sizes, PIT tags can be inserted into the peritoneal cavity of small fish, such as juvenile salmonids (Roussel et al 2000). Most PIT tagging studies in small streams involve physically recapturing tagged fish to collect data (Zydlewski et al. 2003). However, improvements made in PIT technology has led to the design of portable PIT detection systems that enable less invasive monitoring of tagged fish (Roussel et al. 2000). These portable PIT antenna systems vary in design, but essentially consist of a pole containing a small antenna loop at one end and a battery powered transceiver connected to the other end. The transceiver, or PIT reader, is typically designed to be carried on the back for mobility (Hill et al. 2006).

For this study, we used an Oregon RFID HDX portable backpack reader and pole antenna to conduct PIT scanning surveys following tagging efforts in Upper North Fork Matilija and North Fork Matilija creeks. All stream surveys were conducted with help by the California Department of Fish and Wildlife, California Conservation Corps NOAA Veterans Corps Fisheries and Watershed Stewards programs. Electrofishing and PIT tagging surveys were conducted according to protocol written by Tsai (2016, unpublished) for standardized data collection in southern California stream conditions. Electrofishing protocol was adapted from published guidelines by Smith-Root (2012) and National Marine Fisheries Service (2000), with recommendations from CDFW (pers. comm.). Tagging protocol was adapted from the PTAGIS (2014). Data collected from tag detections contributed to an assessment of fine scale movement by *O. mykiss* and the use of portable PIT detection systems in the Ventura River Basin.

METHODS

Study Sites

Upper North Fork Matilija Creek

Four tagging surveys were conducted in Upper North Fork Matilija Creek from October 2016 to December 2018. PIT tagging occurred during two types of survey efforts: (1) sampling for abundance estimation and (2) sampling deep units. Upper North Fork Matilija Creek was surveyed once for abundance estimation and three times thereafter for deep unit sampling. All surveys starting at the confluence of Upper North Fork Matilija and Matilija Creeks (34.50915°N, -119.38357°W) and proceeded upstream ending at a designated end reach point (34.51564°N, -119.37294°W). Data collected for abundance estimation occurred from October 3, 2016 to December 1, 2016. Deep units were sampled December 6-7, 2016, July 24-26, 2017, and December 4, 2017.

North Fork Matilija Creek

North Fork Matilija Creek was surveyed once for abundance estimation from October 15, 2018 to November 28, 2018. Surveys started just upstream of the confluence of North Fork Matilija and Matilija confluence (34.48883°N, -119.30590°W) ending at a road crossing and barrier to fish passage (34.51268°N, -119.27418°W).

Data Collection

GPS coordinates were recorded at the downstream end of each unit to be electrofished. Prior to electrofishing each unit, water quality was measured including water temperature (°F), dissolved oxygen (mg/L), and conductivity (mS/cm^3). Water temperature and dissolved oxygen was measured again before each additional pass. All species captured were immediately removed from the unit and placed in a five-gallon bucket filled with stream water. Each bucket was equipped with a battery powered aerator and periodically refreshed with new stream water. The total number of organisms captured by electrofishing was recorded by species. All individuals were released back into the unit once the survey was completed.

Abundance Estimation Sampling

Abundance estimation methods consisted of habitat typing followed by a double sampling method utilizing snorkel and electrofishing surveys. During habitat typing surveys, the stream was delineated into discrete natural units of similar habitat. Each unit was then classified as either a pool, flatwater, or riffle according to the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). Measurements were taken of each unit including length, mean width, mean depth, and maximum depth. Only the units that met certain depth and length restrictions were considered for further sampling due to the ineffectiveness of our snorkeling and electrofishing methods in extremely shallow or deep water. These requirements included mean depths measuring no less than 0.3 ft and no greater than 3.0 ft, a maximum depth no greater than 3.5 ft, and minimum unit length of six feet or greater. For the purpose of abundance estimation, units that met this size requirement were subselected and electrofished to depletion. During depletion electrofishing, a maximum of five passes were used. Electrofishing ceased when the number of trout captured was less than 25% of the previous pass, or after two consecutive passes of zero trout captures. Seine nets were secured at the inflow and outflow of each unit preventing any fish from entering or leaving the unit. One to two backpack electrofishers were used for each survey depending on unit size and complexity. A minimum of two netters accompanied each electrofisher operator as they progressed upstream sampling the entire unit (Figure 1).

Deep Unit Sampling

During habitat delineation, larger units with mean depths greater than or equal to 1-ft were flagged and photographed. A total 26 pool units were designated for repeated sampling and served as landmarks from which we could monitor *O. mykiss* movement. Surveys to sample these units were conducted every six months to add to the tagged *O. mykiss* population in the system. Deep unit sampling was conducted to target high-trout density areas and tag as many trout as possible. For electrofishing these units, a one-pass method was used and no seine nets were placed at the inflow or outflow. Given the size and depth of these units, two electrofishers and a minimum of three netters were used for all sampling.

PIT Tagging

All tagging operations were conducted according to protocol adapted from PTAGIS (Tsai 2016, unpublished). Prior to any tagging efforts during surveys, a training was held at Fillmore Hatchery (Fillmore, CA). During this time, all field staff were trained to safely immobilize and insert hatchery raised *O. mykiss* with PIT tags.

During all electrofishing surveys, *O. mykiss* that met a minimum size requirement of 80mm (FL) were injected with a 134.2 kHz HDX ISO PIT tag. If a trout measured 80-175mm, a 12mm PIT tag was inserted, and if measuring larger than 175mm, a 23mm PIT tag was inserted. Trout were placed in buckets filled with stream water and equipped with at least one aerator and a thermometer. Stream water was replaced in the bucket every 10 minutes to minimize any thermal stress. Once the trout was assessed and determined to be healthy for tagging, the trout was placed in an anesthetic bath of stream water and Alka-Seltzer Gold (aspirin-free). Once the trout exhibited signs of loss of equilibrium, the trout was measured by fork length (FL) and photographed (Figure 2a). Based on the size of the trout, a 12mm or 23mm tag was scanned with a proximity HDX PIT tag reader and the ID recorded. A scalpel was used to make a small incision near the pelvic girdle posterior tip of the pectoral fin and the anterior point of the pelvic girdle on the abdomen to the right or left of the mid-ventral line (PTAGIS). A syringe was then used to insert the PIT tag bevel down (Figure 2b). Prior to each use, all instruments were sanitized in isopropyl alcohol for a minimum of ten minutes. The trout was then placed in a separate shaded bucket equipped with fresh stream water and an aerator for recovery. All tagged trout were monitored and assessed for the return of normal swimming behavior before being released into the same unit from which they were captured. During the release, the trout was scanned with a proximity PIT tag reader to check for tag retention and ensure the correct tag ID had been recorded.

PIT Scanning

Scanning surveys were conducted in Upper North Fork Matilija from December 2016 to April 2018 and North Fork Matilija December 2018 to January 2019. These surveys were done on a monthly basis except months during which flows were too high to walk in the creek. An HDX backpack reader equipped with a piezo buzzer and pole antenna (OregonRFID 2019) were used to scan the wetted stream. Prior to each survey, equipment was tested and tuned as necessary. Real-time data was downloaded using a backpack reader Bluetooth adapter (OregonRFID 2019) and handheld Android tablet (Samsung Galaxy Tab). Scanning was performed as single-pass survey by moving in a zig-zag like pattern bank to bank ensuring the entire stream channel width was covered (Figure 3). While keeping the antenna approximately 4-6 inches off the bottom substrate, the pole was slowly moved in wide, lateral arcs to cover as much wetted habitat as possible. The pole was maneuvered under root mass, in between woody debris, or under boulder or bedrock spaces to cover spaces where *O. mykiss* were likely to take refuge. Surveys ended when the entire stream reach was scanned or when all PIT tags deployed in the system had been detected.

When a detection occurred, as indicated by the piezo buzzer, the tag ID was recorded along with the GPS location. For each tag detected, we recorded whether the tag was moving or stationary, if the tag was confirmed still in a trout, and if the tag was recovered. No assumptions were made regarding whether tags were in *O. mykiss* or had been shed. Tags were recorded as “in-trout” only when there was clear indication, such as when *O. mykiss* was observed in location where a tag detection occurred. Efforts were made to observe *O. mykiss* using a snorkel and mask or flush *O. mykiss* from hiding when possible. A flag indicating the tag ID number and survey date was secured as close to the detection location as possible. If the previous location was known and the distance was less than 200 ft. upstream or downstream, the distance was measured using a hip chain and hip chain string. All other tag displacement distances were calculated using GPS coordinates. Data from scanning surveys was input in an Excel spreadsheet, quality assured/quality controlled, and analyzed using R (version 3.4.1, R Core Team 2017) and RStudio (version 1.0.153, RStudio, Inc. 2016).

Data Assessment

Detection efficiency (E_i) was calculated by dividing the number of detections (D_i) during the *i*th survey by number of tags deployed in the system (T_i). The assumed number of tags in system was based on the number of tags deployed during the previous electrofishing sampling. This method was used in Hodge et al. (2015) and modified from Cucherousset et al. (2010). From these detection efficiency calculations, a mean detection rate was calculated.

To examine small-scale movement by *O. mykiss*, we calculated distances for individual tag displacement. We then calculated mean distances including movement upstream vs. downstream. Due to our mean GPS error of 9 ft, all distances under 10 ft were excluded from assessment of *O. mykiss* movement. Recovered tags were eliminated from this assessment as well.

RESULTS

Upper North Fork Matilija Creek

A total of 103 *O. mykiss* were inserted with HDX PIT tags and released in Upper North Fork Creek during surveys from 2016 to 2018. During abundance estimation sampling in Upper North Fork Matilija Creek, we PIT tagged a total of 30 tagged *O. mykiss*. An additional 33 and 26 *O. mykiss* were PIT tagged during deep unit sampling surveys in December 2016 and July 2017 respectively. A deep unit sampling survey that began December 4, 2018 was cut short due to the outbreak of the Thomas Fire. During this survey seven unit were sampled and 16 *O. mykiss* PIT tagged. All-together, 93 12-mm and ten 23-mm PIT tags were deployed.

Two *O. mykiss* (n=2) recaptures occurred during deep unit tagging surveys in Upper North Fork Matilija Creek. One *O. mykiss* tagged during abundance estimation sampling in October 2016 was recaptured 48 days later in December 2016 approximately 600 f upstream of tagging location. When recaptured, this *O. mykiss* measured the same in length, at 119mm. The second recapture occurred during a survey in July 2017, 230 days after being tagged and released during the previous tagging survey in December 2016. This *O. mykiss* initially measuring 110mm was found approximately 480 ft upstream of the tagging location when recaptured and measured 175mm (Figures 4a-b).

From December 2016 to April 2018, 11 scanning surveys were conducted in Upper North Fork Matilija Creek. Mean detection efficiency for scanning surveys in Upper North Matilija Creek was calculated at 22.6 ± 5.4 % (mean ± SE), ranging from 0 to 68 percent (Table I). Eleven *O. mykiss* observations were made to confirm tags not shed at the time of detection, and four tags (12-mm) were recovered. Of the 189 total detections made that did not result in tag recovery, 141 (74.6%) indicated tag displacement from previous locations. Eighty-one (42.9%) of these detections were made upstream and 60 (31.7%) were downstream of previous locations (Figure 5). Tag displacement, estimated from GPS coordinates, ranged from 0 to 3,730 ft with a mean movement of 158.1 ± 35.3 ft (Table II). Mean tag displacement upstream was determined to be 254.5 ± 75.8 ft and mean tag displacement downstream was 149.9 ± 38.4 ft.

North Fork Matilija Creek

During abundance estimation surveys in North Fork Matilija Creek, two *O. mykiss* were tagged in North Fork Matilija Creek during surveys conducted in 2018. Both *O. mykiss* were injected with 23-mm PIT tags. Two scanning surveys were conducted following tagging surveys and a total of three detections were made. Detection efficiency for scanning surveys in North Fork Matilija Creek ranged from 50 to 100 percent (Table I). During the first scanning survey in December 2018, both *O. mykiss* were detected. During a scanning survey in January 2019, one *O. mykiss* was detected. Observations of *O. mykiss* were made at the time of all three detections to confirm tags were not shed. One detection (33%) was made upstream of the previous location and two detections (67%) were made downstream of previous locations (Figure 5). Tag displacement ranged from 73.1 to 412.2 ft. with a mean distance of 231.3 ± 98.6 ft. (mean ± SE (Table II). Mean downstream movement was 310.4 ± 101.8 (mean ± SE) and the one tag detected upstream of the previous location had moved an estimated 73.1 ft.

DISCUSSION

The number of detections per survey in both streams ranged from 0 to 43 with a detection efficiency ranging between 0-100% (Figure 6). Mean detection efficiency for all scanning surveys was 30.1 ± 7.4% (mean ± SE), which is consistent with previous studies using mobile PIT detection devices in an open system. Using a portable antenna system to detect five fish species in an open stream reach, Cucherousset (et al. 2010) demonstrated a mean detection efficiency of 34 ± 12% (mean ± SE) with a range of 16 - 51%. While conducting one pass surveys of 50 m stream segments isolated by block nets, Hill (et al. 2006) demonstrated a mean detection efficiency of 25% using one operator and 38% using two (Hill et al. 2006).

For all surveys in Upper North Fork Matilija Creek (n=11), mean detection efficiency was calculated at 22.6 ± 5.4 % (mean ± SE), ranging from 0 to 68% (Table I). We detected 45 of the 62 tags deployed during the first scanning survey following tagging efforts in Upper North Fork Matilija Creek (Figure 6). This detection rate of 73% is high when taking into account multiple aspects of our study. Our stream reach was unblocked, tagging occurred between 12 to 32 days prior to scanning, and most of the tags deployed (n=93, 90.3%) were 12-mm in size. Larger PIT tags (23-mm, 32-mm) contain a bigger coil that can be detected from a larger distance. Conditions during this survey likely contributed to our high rate of detection. Minimal rain had occurred between tagging and scanning surveys contributing to low flow and narrow channel of wetted habitat, which potentially restricted *O. mykiss* movement within the survey reach.

Although our surveys in North Fork Matilija Creek demonstrated the highest detection efficiency (75 ± 25% [mean ± SE]), not much can be inferred from this data due to the small tagged sample size (n=2). During our first scanning survey in North Fork Matilija, we detected all tagged *O. mykiss* with a detection efficiency of 100%. This survey was conducted 32-47 days following tagging events. Both tags were confirmed not shed due to visual observations made at the time of each detection. All three detections made during two scanning surveys in North Fork Matilija Creek, indicated upstream or downstream movement (Figure 5).

Of the 79 tags detected, 34 (43.0%) remained stationary and 45 (57.0%) demonstrated movement (estimated greater than 10 ft) from previous locations (Table II). For all tag detections, tag displacement ranged from 0 – 3,731 ft. with an overall mean movement of 57.4 ± 36.4 ft (mean ± SE). Of the 196 total detections made, 144 (73.5%) indicated upstream or downstream movement. A total of four tags were recovered, and these data were removed from tag displacement analysis. With our limited data, no inferences can be made regarding tag shedding or habitat preference. However, our results show that within our tagged population*, O. mykiss* frequently demonstrate small-scale movement within these systems.

Environmental factors impeded data collection efforts for the duration of this study. A series of storm events during the 2016-2017 winter delayed all monitoring survey efforts in the Ventura River Basin due to high flows and muddy waters with low visibility (Figure 6). This delayed scanning surveys in Upper North Fork Matilija Creek until March 2017. During this survey our rate of detection decreased to 29% from 68% during our December 2016 survey (Table I).

Our December 4, 2017 tagging survey in Upper North Fork Matilija Creek was cut short due to the outbreak of a wildfire. The Thomas Fire burned over 280,000 acres including an estimated 97% of the Matilija Creek and 96% of the North Fork Matilija Creek subwatersheds (Klose et al. 2018, CalFire 2019). Subsequent storms accompanied by high rain intensities created large mud and debris flows which further delayed survey efforts due to persistent high flows and poor water visibility. For all scanning surveys (n=3) of Upper North Fork Matilija Creek conducted in 2018, we detected just one tag (Table I). This tag was ultimately recovered, indicating the tag had been shed or the *O. mykiss* had perished. During our abundance estimation sampling in Upper North Fork Matilija in May 2018, zero *O. mykiss* were observed or captured. Although this sampling was limited to shallow habitat, these results help explain our lack of tag detections during surveys in 2018.

Despite a small sample size (n=105), we were able to gather information on localized *O. mykiss* movement. The small and patchy *O. mykiss* populations in southern California streams highlight the importance of individual monitoring in order to gather as much information as possible pertaining to *O. mykiss* distribution, habitat utilization, and survival. The results based on this study support the application of portable PIT antennas to monitor fine scale movement of *O. mykiss*. However, more data is needed to determine how effective these methods are for gathering additional information such as habitat use and survival. We recommend additional PIT tagging surveys to increase the tagged *O. mykiss* population for continued monitoring and assessment of portable PIT detection devices.

TABLES

Table I – PIT detection efficiency of portable antenna surveys in two streams. A PIT backpack reader and portable antenna (OregonRFID) were used to survey two stream reaches following tagging efforts. Surveys were conducted each month when conditions allowed. Detection efficiency (E_i) was calculated as number of detections divided by total number of tags deployed in the system at the time of survey multiplied by 100.

Stream	Survey Date (Month-Year)	Total Tag Detections	Total Tags in System	[a]Detection Efficiency
Upper North Fork Matilija Creek	Dec-2016	43	63	68.3
Upper North Fork Matilija Creek	Mar-2017	18	63	28.6
Upper North Fork Matilija Creek	Apr-2017	14	63	22.2
Upper North Fork Matilija Creek	May-2017	18	63	28.6
Upper North Fork Matilija Creek	June-2017	13	63	20.6
Upper North Fork Matilija Creek	July-2017	9	63	14.3
Upper North Fork Matilija Creek	Aug-2017	30	88	34.1
Upper North Fork Matilija Creek	Sep-2017	24	88	27.3
Upper North Fork Matilija Creek	Oct-2017	23	88	26.1
Upper North Fork Matilija Creek	Feb-2018	0	103	0.0
Upper North Fork Matilija Creek	April-2018	1	103	1.0
Upper North Fork Matilija Creek	Dec-2018	0	103	0.0
North Fork Matilija Creek	Dec-2018	2	2	100.0
North Fork Matilija Creek	Jan-2018	1	2	50.0

[a] Detection efficiency (E_i) is based on the calculation used in Cucherrousset et al. 2010, where E_i = number of tag detections (D_i) divided by the number of tags deployed in system (T_i) during *i*th survey multiplied by 100 [$E_i = (D_i/T_i)*100$].

Table II – Tag displacement. Displacement of passive integrated transponder (PIT) tags inserted in *Oncorhynchus mykiss* in Upper North Fork Matilija (n=103) and North Fork Matilija (n=2) creeks from 2016 to 2018. Displacement of tags were determined by detetections made using a portable PIT backpack reader and pole antenna.

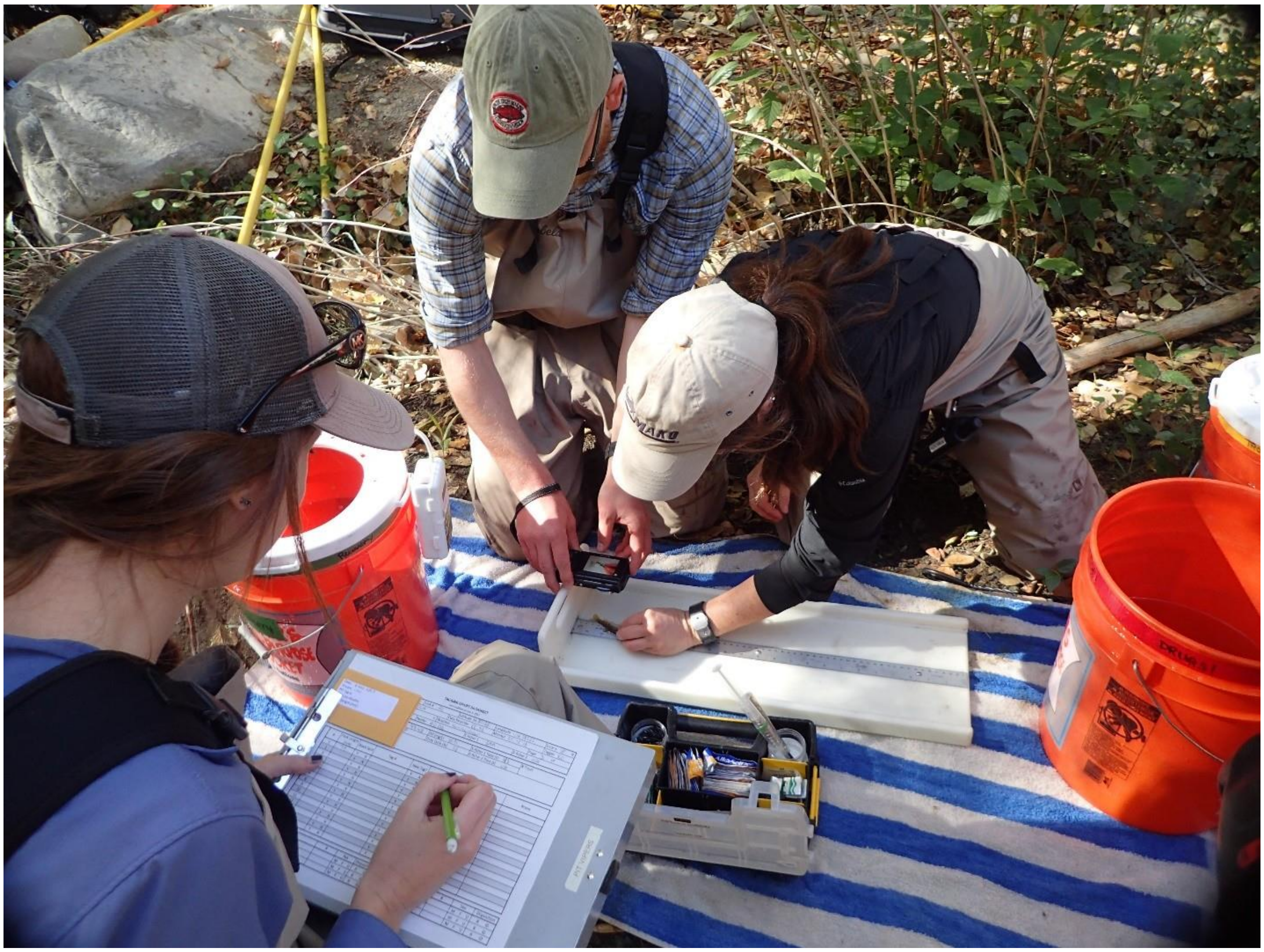
Stream	Total # Detections[a] (N)	Total # Stationary Detections[b]	Total # Displaced	Mean Tag Displacement ±SE (ft)	Total # Upstream Detections	Mean Upstream Movement ±SE (ft)	Total # Downstream Detections	Mean Downstream Movement ±SE (ft)
Upper North Fork Matilija Creek	193[a]	48[b]	141	158.1 ± 35.3	81	254.5 ± 75.8	60	149.9 ± 38.4
North Fork Matilija Creek	3	0	3	231.3 ± 98.6	1	73.1	2	310.4 ± 101.8

[a]Total number of tag detections includes recovered tags (n=4), data not included in assessment of tag displacement.
[b]Detected tags were considered stationary if site of detection was less than 10 ft away from previous location determined by tagging or scanning surveys.

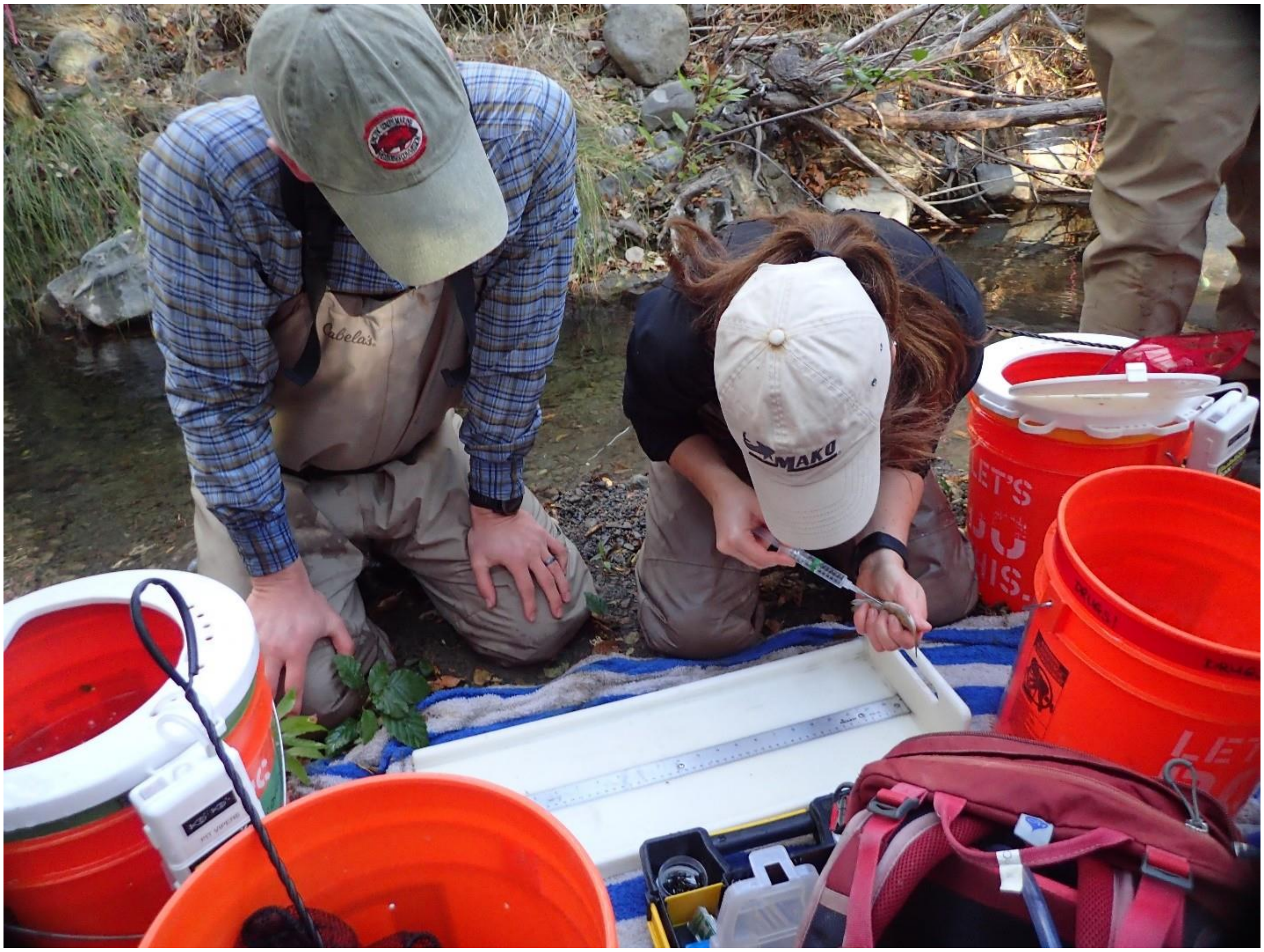
FIGURES

Figure 1. Image of PSMFC field staff electrofishing a habitat unit during *O. mykiss* sampling of Upper North Fork Creek in October 2016. During abundance estimation sampling, captured *O. mykiss* that met a minimum size requirement (> 80 mm) were injected with an HDX passi ve integrated transponder (PIT) tag and released for future monitoring.

Figures 5. Captured *O. mykiss* measured, photographed and PIT tagged during a tagging effort survey in Upper North Fork Matilija Creek on December 4, 2017. PSMFC Fisheries Biologist II Sam Bankston photographs a captured *O. mykiss* while PSMFC Fisheries Technician Tanielle Redman records data, and (b) PSMFC Fisheries Biologist Kathryn Carmody injects a 12-mm HDX PIT tag into the peritoneal cavity using a syringe injector.



(a)



(b)

Figure 3. Image of PIT scanning survey in Upper North Fork Matilija Creek in March 2017. PSMFC Fisheries Biologist Jean Tsai operates a portable passive integrated transponder (PIT) detection device to scan all wetted habitat while progressing upstream. Following HDX PIT tagging surveys, tag scanning surveys were performed every month or when conditions allowed.

Figures 4. Images of a PIT tagged *O. mykiss* recaptured during electrofishing survey in Upper North Fork Creek. (a) The *O. mykiss* was captured during abundance estimation sampling of Upper North Fork Creek December 2016, and measured 110mm. (b) During a tagging effort survey in July 2017, the *O. mykiss* was recaptured approximately 480 ft upstream of the tagging location and measured 175 mm.

(a)

(b)

Figure 5. Summary of PIT tag displacement by detections. Tag displacement was determined by previous PIT tag detections during surveys using portable PIT detection device. Surveys were conducted in Upper North Fork Matilija (n=11) and North Fork Matilija (n=2) creeks following *Oncorhynchus mykiss* PIT tagging surveys. Detection sample sizes are shown for each bar. Detections that resulted in recovered tags were removed from displacement analysis.

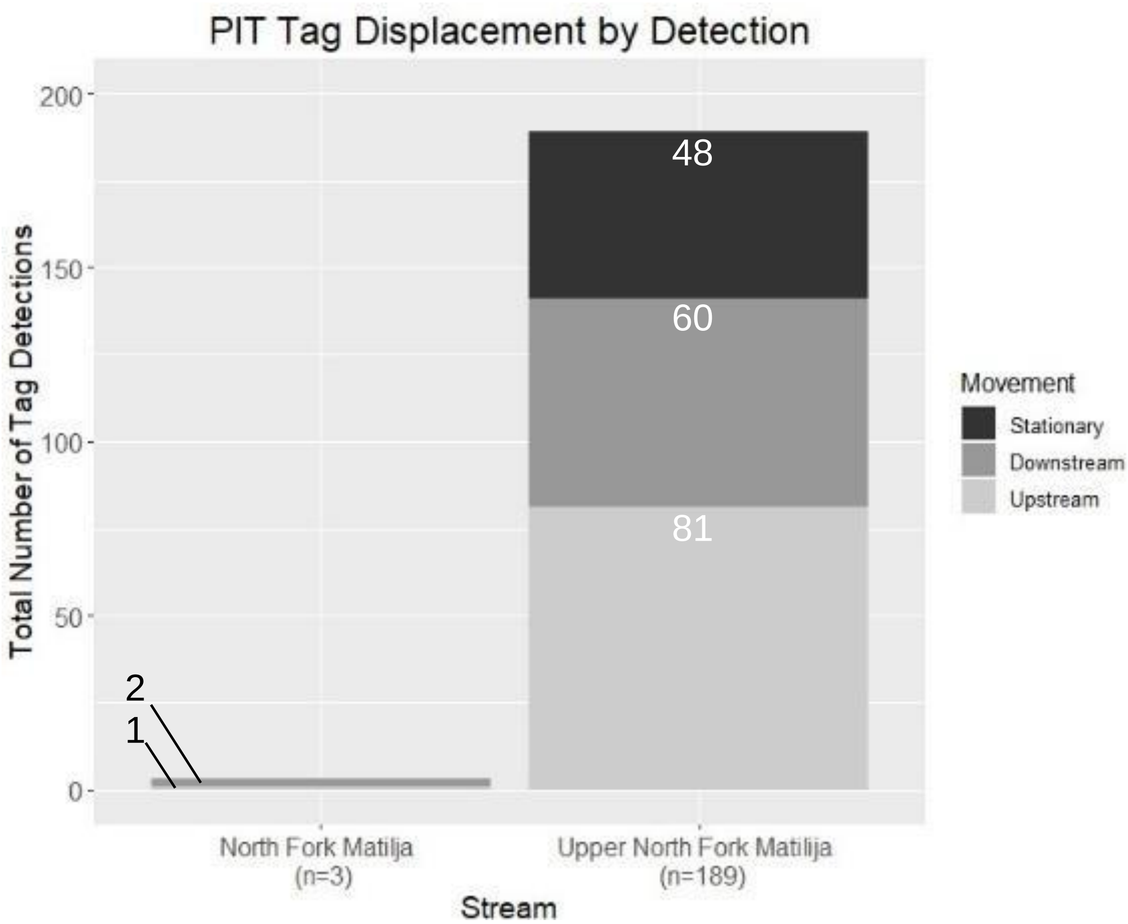
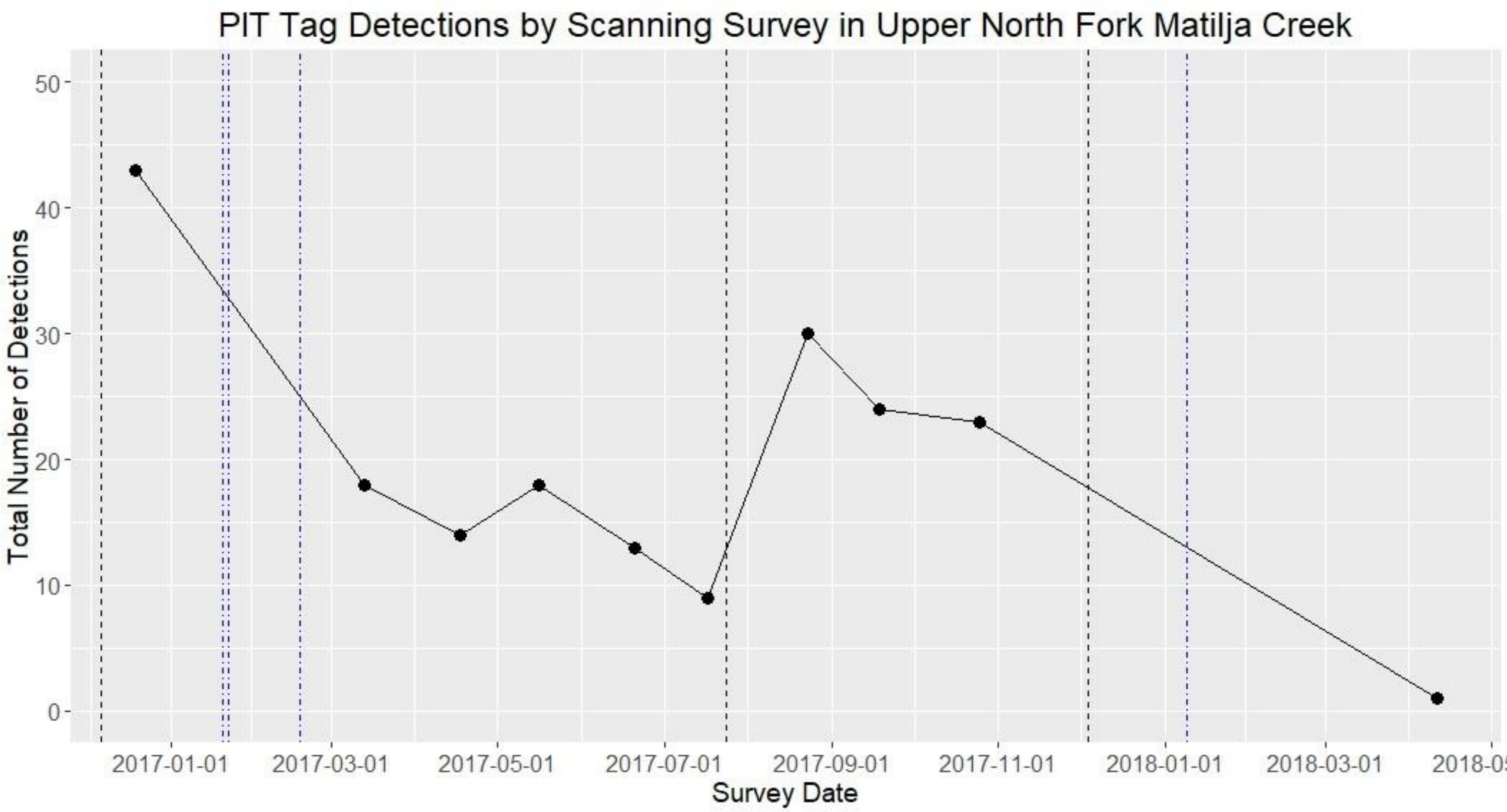


Figure 6. Total PIT Tag Detections by Scanning Survey in Upper North Fork Matilija Creek. Total number of passive integrated transponder (PIT) tags detected during surveys of Upper North Fork Matilija Creek using a portable PIT detection device (indicated by black dots). Scanning surveys were conducted from 2016 to 2018 following tagging surveys (black dashed line) during which *Oncorhynchus mykiss* of a certain size (≥ 80mm) were injected with HDX PIT tags. A series of winter storms (indicated by blue dashed line) impeded survey efforts in the Ventura River Basin due to high flows and muddy waters with low visibility.



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APPENDIX A.

Additional Monitoring Efforts: Snorkel survey summary reports of four streams in the Ventura River Watershed following the Thomas Fire

INTRODUCTION

On December 4, 2017 the Thomas Fire broke out in just north of the city of Santa Paula and quickly moved into the Santa Ynez mountain range. The north and west facing slopes of the Santa Ynez are characterized by steep slopes dominated by chaparral and oak vegetation, much of which had not burned since 1932 Matilija Fire. Prolonged drought conditions contributed to stressed vegetation and growth of annual grasses (Klose et al. 2018). These conditions in addition to strong Santa Ana winds (with gusts up to 60 miles per hour) and below average relative humidity created an ideal environment for the growth of wildfire.

The Thomas Fire burned approximately 281,853 acres (CalFire 2019). A total of 26 subwatersheds were impacted by the Thomas Fire, including five within the Ventura River Basin (Klose et al. 2018). All five of these subwatersheds contain designated steelhead critical habitat (NMFS 2012). Due to intensity and widespread effects of the Thomas Fire, monitoring efforts were recommended to evaluate the status of *O. mykiss* populations and post-fire effects on critical steelhead habitat (Klose et al. 2018).

Seasonal spawning surveys resumed in 2018 following the Thomas Fire. During these surveys we observed major changes to stream habitat, including loss of riparian cover, decreased water quality, increased sedimentation, and elevated water temperatures. Data collected from spawning surveys within the Ventura River Watershed, resulted in zero *O. mykiss* and zero redd observations. Due to these results, additional survey efforts were designed to collect data in stream reaches most affected by the Thomas Fire. Specifically, we conducted snorkel surveys in four stream reaches to determine *O. mykiss* presence or absence. Surveys were conducted from May to August 2018, during which data was collected on stream habitat and *O. mykiss* observations. Our findings were summarized in four reports.

STUDY SITES

San Antonio Creek

San Antonio Creek serves as the only tributary to the lower mainstem Ventura River accessible for fish passage (Allen 2012). San Antonio Creek contains approximately seven miles of anadromous stream with important spawning and rearing habitat for steelhead. Characterized by low gradient and lack of riparian canopy, San Antonio Creek is susceptible to seasonal drying and intermittency during the summer and fall months. The Thomas Fire burned an estimated 73 percent of the San Antonio Creek subwatershed including approximately 6.7 miles of designated steelhead critical habitat (NMFS 2012, Klose et al 2018).

North Fork Matilija Creek

North Fork Matilija Creek merges with Matilija Creek mainstem to form the Ventura River. Located entirely in the Los Padres National Forest, North Fork Matilija Creek contains approximately eight miles of stream, including 4.5 miles anadromous stream. A road crossing in the U.S. Forest Service Wheeler Gorge Campground creates a barrier to fish passage. The Thomas Fire burned an estimated 96 percent of the North Fork Matilija Creek subwatershed, including 4.1 miles of steelhead critical habitat, and the soil burn severity was moderate. North Fork Matilija Creek is located in a high debris flow hazard area.

Bear Creek

Bear Creek serves as a tributary to North Fork Matilija Creek forming the upper North Fork Matilija Creek subwatershed. Bear Creek subwatershed drains approximately 2.6 square miles and occurs entirely within the Los Padres National Forest. Bear Creek was part of the North Fork Matilija subwatershed burn assessment, which estimated 96 percent of this subwatershed was burned and soils in this area burned moderately (Klose et al. 2018).

Upper Matilija Creek

Matilija Creek starts at the confluence of Matilija and North Fork Matilija Creeks to begin the Upper Ventura watershed. Matilija Creek contains approximately 15 miles of stream habitat (Klose et al. 2018). About 0.5 miles upstream of the confluence, the stream is interrupted by the Matilija Dam which was constructed in 1947 for water storage and flood control (NMFS 2000). As a result, the upper Matilija Creek Basin is no longer open to fish passage. However, previous studies show the *O. mykiss* populations in Upper Matilija are closely related their anadromous cousins in the Ventura watershed and can contribute to future steelhead populations (Clemento et al. 2009, Girman and Garza 2006). With efforts to remove the dam currently in progress, these populations remain important for steelhead monitoring. From the dam, Upper Matilija runs approximately seven miles to a series of high waterfalls. The upper Matilija Creek Basin includes two main tributaries: Upper North Fork Matilija Creek and Murietta Creek. Resident *O. mykiss* and suitable *O. mykiss* habitat have commonly been observed in this subwatershed (Allen 2012, CDFW 2019 unpublished data).

An estimated 96 percent of the Matilija subwatershed including 0.7 stream miles of designated steelhead critical habitat was burned by the Thomas Fire. Located in an area of high debris flow hazard, the severity of soil burn ranged from low to moderate (Klose et al. 2018.)

San Antonio Creek Snorkel Survey Report 2018

Prepared by Tanielle Redman[1], Shannon Mueller[1], and Casey Horgan[1]
[1]Pacific States Marine Fisheries Commission

Abstract

From June 26, 2018 to July 12, 2018, a snorkel survey was conducted on an 8.5 mile sampled reach of San Antonio Creek. Data collected contributed to estimating southern California steelhead (*Oncorhynchus mykiss*) relative abundance and distribution as well as quantifying stream habitat type and trout cover types available. Snorkelable stream habitat was dominated by flatwaters (63%) and pools (37%). On average, the surveyed habitat units contained little habitat complexity, with unit's surface area containing a mean of 47.5 ± 1.9% (mean ± SE) of trout cover. The cover mostly consisted of aquatic vegetation (47.0 ± 2.0% [mean ± SE]) and cobble/boulder (28.7 ± 1.8%). No inferences could be made about trout abundance or distribution trends as no *O. mykiss* were observed through the course of the survey. Changes in average habitat unit measurements, cover complexity, and *O. mykiss* observations from surveys conducted in previous years appear to be the result of persisting drought conditions followed by a large wildfire and subsequent winter rain events. Future monitoring efforts are recommended to continue collecting data on *O. mykiss* relative abundance and habitat availability and potential anadromous *O. mykiss* repopulation in San Antonio Creek.

Introduction

Steelhead (*Oncorhynchus mykiss*) along the west coast of North America have been divided into Distinct Population Segments (DPS) based on discrete factors separating populations from each other. The southern California steelhead DPS comprises the southernmost extent of the specie's range (NOAA 1997). Since 1997 this DPS has been listed as endangered under the U.S. Endangered Species Act due to dramatic declines in abundance caused by habitat loss and degradation (NOAA 1997). In response, a recovery plan for the southern California DPS was released in 2012 by the National Marine Fisheries Service (NMFS). This recovery plan determined multiple factors that affect the current endangered status of southern California steelhead (SCS) and the ability for recovery. Critical to steelhead recovery is the understanding of the interactions between steelhead and their freshwater habitat (NMFS 2012).

In southern California, steelhead fresh water habitat is dominated by short streams and rivers with flashy, intermittent flows and seasonal accessibility for anadromous trout. Since 2011, Southern California has experienced persistent drought conditions (NOAA 2018) further limiting the freshwater habitat use and availability for steelhead. The Thomas Fire, which burned from December 2017 through January 2018, impacted 1,909 miles of stream habitat within the fire perimeter, nearly 80 miles of which are designated critical habitat for southern California steelhead (Klose 2018). Shortly after, during the winter of 2018, strong rain events caused extremely high flows and the movement of boulders, debris, and sediment through creeks impacted by the fire. Fish mortalities and extirpation of small populations have been observed as a result of flooding and debris flows following wildfires (Bozek and Young 1994; Rinne 1996; Howell 2006). Monitoring efforts following these events are important for understanding

steelhead trout abundance, distribution, and habitat utilization in affected critical SCS habitat (Klose 2018).

An important aspect of understanding how trout interact with their freshwater habitat is observing how trout utilize cover within their environment. Cover types utilized by trout include overhanging and instream vegetation, woody debris, boulders, bedrock crevices, root wads, undercut banks, and surface water turbulence. Cover is recognized as one of the essential components affecting trout abundance and distribution in streams (Raleigh et al. 1984). For individual fish, cover functions as protection from predators, reduction of competition, and shelter from water flow (Allouche 2002). In addition to providing instream shelter for fish, certain cover (e.g. large woody debris and boulders) aid in the creation of scours and pools which trout can utilize as habitat (Fausch and Northcote 1992; Allouche 2002).

A snorkel survey was conducted on San Antonio Creek between June 26, 2018 and July 12, 2018 by Pacific States Marine Fisheries Commission (PSMFC). The purpose of this study was to estimate the relative abundance, distribution, cover availability, and cover use of *O. mykiss* within the survey reach.

San Antonio Creek begins with headwaters in the Topatopa Mountains of the Traverse Range and flows along the city of Ojai to a confluence with the Ventura River. The San Antonio Creek watershed drains approximately 32,746 acres out of a total of 144,967 acres that makes up entire Ventura River watershed. According to the Thomas Fire Burned Area Emergency Response (BAER) assessment, approximately 73 percent of the San Antonio subwatershed and 6.7 stream miles of San Antonio Creek's designated steelhead critical habitat was burned by the fire (Klose 2018). The survey reach began at the confluence of San Antonio Creek and the Ventura River (34.38071, -119.30747) and extended 8.5 miles ending the Grand Ave. bridge (34.45434, -119.22169). This end point was chosen as it is an established break between survey reaches and San Antonio Creek upstream of this point was observed to be dry at the time of the survey.

Methods

This study was conducted using elements of a snorkel survey protocol written by Tsai & Van Meeuwen (2016, unpublished). This protocol was adapted from the Salmonid Field Protocol Handbook (O'Neil 2007) and the Underwater Methods for the study of Salmonids in the Intermountain West (Thurow 1994). Snorkel surveys were used to gather relative abundance estimates of trout and quantify the available trout habitat and cover usage.

Snorkel surveys were conducted in teams of two to three, which included at least one data recorder and one snorkeler. During surveys, the wetted stream channel was delineated into discrete, natural units of similar habitat (Hankin 1984). Units were classified as either riffles (R), pools (P), or flatwaters (F) according to certain defining characteristics. These habitat types are adopted from definitions outlined in Flosi et al. (1998).

For this study, all snorkelable units with a maximum depth of 0.7 ft or greater were snorkeled once. The snorkeler entered the water at the downstream end of each habitat unit while being careful to minimize disturbance to the water and sediment. Once in the water, the snorkeler moved in a zig-zag pattern towards the upstream end of the unit making sure to visually search the entire area of the unit. The snorkeler searched the margins of the unit, boulder crevices, and other areas of potential fish cover. Cover was defined as any natural or artificial stream feature capable of hiding a 3-inch trout from the surface. To avoid duplicate counts, trout were counted as the snorkeler moved past them.

Once each unit was surveyed, all observations were reported to the bankside data recorder. For each trout observed, the associated cover and estimated length were given. Trout sizes were estimated by 2-inch size bins (0-1.99 inches, 2-3.99 inches, 4-5.99 inches, etc.). Counts were also made for special status species of amphibians and reptiles including Southern Western Pond Turtle (*Actinemys pallida*), Two-striped Gartersnakes (*Thamnophis hammondii*), and California Red-legged Frog (*Rana draytonii*). Additionally, presence and visual estimates of other native fish species were recorded including Arroyo Chub (*Gila orcutti*) and Three-spined Stickleback (*Gasterosteus aculeatus*). For trout cover, snorkelers noted the type of cover used by each trout when first observed. Cover types included open (no cover used), boulder, small woody debris, large woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain, bedrock ledge, undercut bank, and other/artificial cover (Table A.1). Other/artificial cover consisted of any manmade products, such as plastic or mesh netting, sandbags, and plywood that potentially provided cover for fish within a habitat unit.

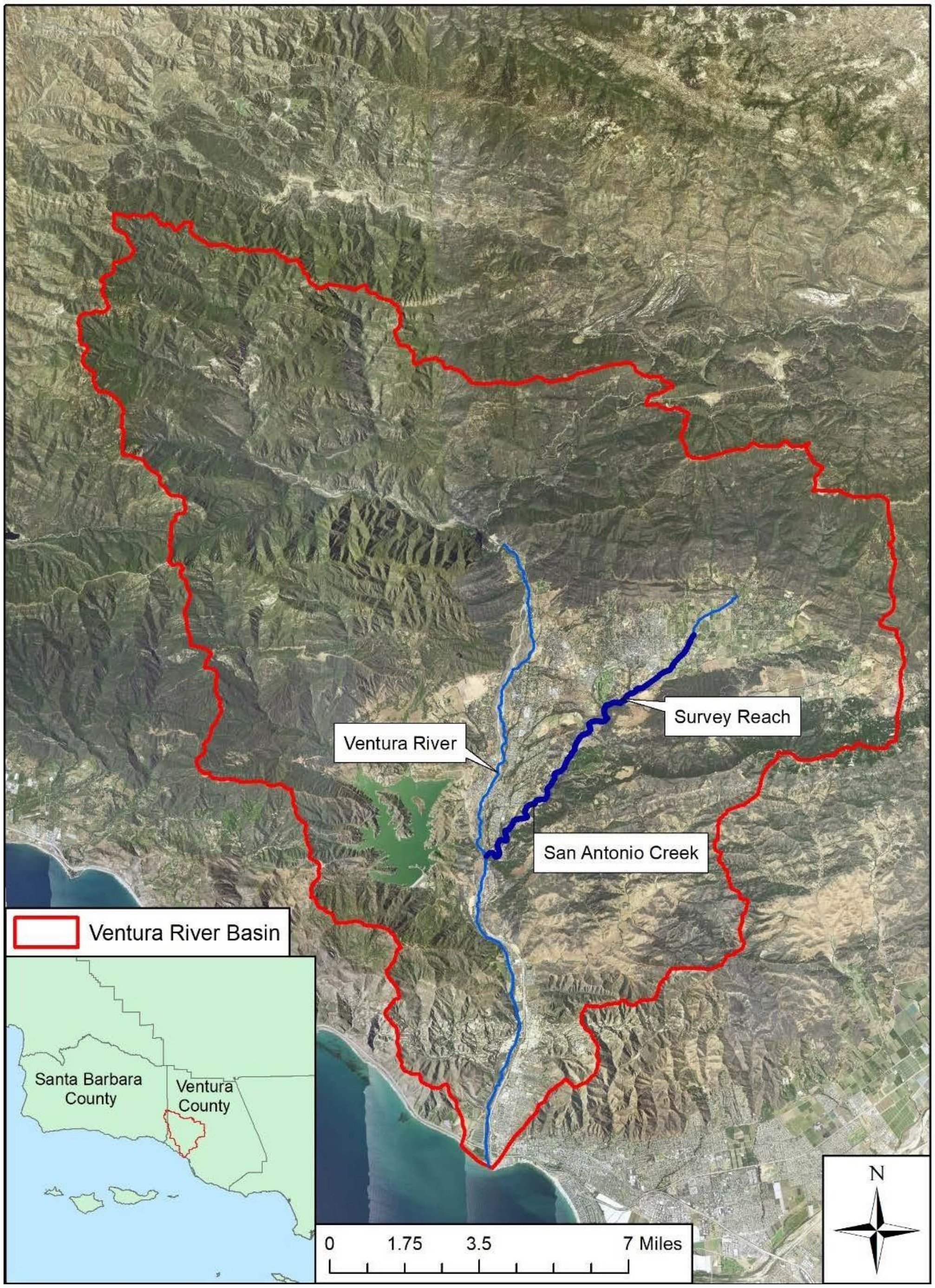
The snorkeler assessed the total trout cover available in each unit by estimating the percent of surface area containing trout cover and surface area containing no cover. The snorkeler also estimated the percentage of total cover each cover type in the unit comprised.

Water visibility was recorded on a scale of zero to three. A value of zero indicates the snorkeler was unable to perform the survey due to a lack of visibility, one was poor visibility, two was adequate visibility, and three was clear visibility.

All habitat units were measured for length, mean width, mean depth, and maximum depth. Length was measured along the thalweg (line of lowest elevation within a valley or watercourse) and mean unit width was measured perpendicular to the length (thalweg) line. The percentage of surface area that contained exposed substrate, usually comprised of gravel, boulders, or bedrock, was estimated for each unit. Exposed substrate included areas of dry exposed substrate not accounted for in measurements of unit length or mean width. This allowed for a more accurate surface area calculation of the available wetted trout habitat.

Snorkelers’ trout size estimations were calibrated after snorkeling the first habitat unit and subsequently every tenth unit. Three randomly chosen PVC pipes of known lengths were tossed into the unit, after snorkeling was completed, and sampled by the snorkeler. The snorkeler estimated the size bin of each pipe and then confirmed with the data recorder. If an incorrect estimate was given, calibration was repeated until the snorkeler accurately estimated the sizes of all three pipes.

Figure 1. Map of the Ventura River Basin (outlined in red) which drains into the Pacific Ocean and is located approximately 60 miles north of Los Angeles, California. Snorkel surveys were conducted from June 28, 2018 to July 12, 2018 along an 8.5 mile reach of San Antonio Creek (highlighted in dark blue) which serves as a tributary to the Ventura River (highlighted in blue). Data collected contributed to *Oncorhynchus mykiss* relative abundance, stream habitat availability and use.



Water and air temperatures were measured with a thermometer at the beginning of each survey day and subsequently after every tenth unit surveyed.

All data was entered into a computer database and analyzed using R (version 3.4.1, R Core Team 2017) and R Studio (version 1.0153, RStudio, Inc 2016). To examine trout relative abundances, trout density was calculated in three ways, including mean number of trout per unit, mean number of trout per foot, and mean number of trout per square foot. To evaluate trout life stage diversity, the total number of trout per size class was calculated. To examine wetted habitat the total length surveyed, mean unit length, total unit area, mean unit area, mean unit depth, mean unit maximum depth, total unit volume, and mean unit volume were calculated. To quantify available trout cover, the mean percent of habitat units containing trout cover and the mean percent each cover type comprised was calculated. Trout cover use was examined by calculating the total number of trout observed using each cover type. For each mean the standard error was calculated.

Results

San Antonio Creek was surveyed from June 26 to July 12, 2018, for 8.5 miles (44,616 ft). A total of 8,516 ft of stream length was snorkeled with a mean unit length of 61.7 ± 4.3 ft (mean ± SE) and a mean unit width of 10.16 ± 0.4 ft. The total unit area snorkeled was 93,584 ft^2, with a mean unit area of 678.2 ± 66.2 ft^2 (mean ± SE). A total of 138 habitat units were snorkeled. Of the snorkeled units, 63% (n=87) were classified as flatwaters and 37% (n=51) as pools. No riffles were snorkeled through the course of this survey. The mean depth of units surveyed was 0.7 ± 0.0 ft (mean ± SE) and units had a mean maximum depth of 1.3 ± 0.1 ft (mean ± SE). The total volume snorkeled through the course of the survey was 73,711 ft^3, with a mean unit volume of 534.1 ± 73.9 ft^3 (mean ± SE).

The mean percentage of available trout cover by surface area in units surveyed was 47.5 ± 1.9% (mean ± SE), with 52.5 ± 1.9% open. The predominant cover types observed consisted of aquatic vegetation (47.0 ± 2.0% [mean ± SE]) and cobble/boulder (28.7 ± 1.8%). Root Mass made up 8.9 ± 1.2% (mean ± SE) of the total cover, small woody debris made up 7.8 ± 1.1%, and terrestrial vegetation made up 5.1 ± 0.8%. Bedrock, bubble curtain, artificial cover, soil undercut, and large woody debris each made up less than two percent of the total mean cover (Table 1).

Water temperatures recorded using thermometers ranged from 62^oF at the beginning of surveys to 84^oF by midafternoon. One shallow section of creek lacking any riparian canopy measured 92^oF, prompting the end of the survey day for the safety of the survey crew. The mean water temperature recorded over the course of the survey was 70.0 ± 0.5^oF (mean ± SE). This mean temperature calculation only considers water temperatures that were recorded once every 10 habitat units sampled and not any additional temperatures recorded at the end of the survey day made to assess whether the survey should be ended for heat safety.

Zero *O. mykiss* were observed through the course of this snorkel survey. Large numbers of Arroyo Chub (*Gila orcutti*) and Three-spined Stickleback (*Gasterosteus aculeatus*) were observed throughout the survey reach, although specific counts were not recorded. Observations of species of concern included eight Western Pond Turtles (*Actinemys marmorata pallida*), one adult California Red-legged Frog (*Rana draytonii*) and numerous *R. draytonii* tadpoles. Additionally, numerous Baja California Treefrogs (*Pseudacris hypochondriaca*) and *P. hypochondriaca* tadpoles were observed during this survey, although counts were not recorded.

Table 1. Mean Percent and standard error of habitat unit cover types recorded during the 2018 San Antonio Creek snorkel survey.

Cover Type	Mean Percentage (%)	Standard Error (±%)
Open	52.50	1.87
Covered	47.50	1.87
Aquatic Vegetation	47.03	1.96
Cobble/Boulder	28.70	1.79
Root Mass	8.95	1.22
Small Woody Debris	7.75	1.13
Terrestrial Vegetation	5.11	0.81
Bedrock	1.05	0.45
Bubble Curtain	0.62	0.34
Other / Artificial Cover	0.40	0.28
Soil Undercut	0.22	0.11
Large Woody Debris	0.18	0.15

Table 2. A comparison of mean habitat unit measurements recorded in San Antonio Creek between snorkel surveys conducted in 2016 and 2018.

Habitat Unit Measurement	2016		2018	
	Mean	SE	Mean	SE
Length (ft)	53.28	7.42	61.72	4.33
Width (ft)	8.49	0.65	10.16	0.36
Mean Depth (ft)	0.74	0.07	0.67	0.03
Max Depth (ft)	1.43	0.13	1.29	0.06
Area (ft^2)	517.57	111.43	678.15	66.15
Volume (ft^3)	505.75	151.98	534.14	73.92

Discussion

The 8.5-mile reach of San Antonio Creek was snorkeled from June 26, 2018 to July 12, 2018. A total of 138 habitat units comprising 8,516 ft of stream length were snorkeled within the stream reach. Of the habitat units surveyed, flatwaters were the most abundant habitat type, comprising 63% (n=87) of the total habitat units surveyed. The remaining 37% (n=51) of habitat units were classified as pools. No riffles were sampled through the course of the survey. Water depth was limited throughout the survey reach, with a mean unit depth of 0.7 ± 0.0 ft (mean ± SE) and a mean maximum unit depth of 1.3

± 0.1 ft (mean ± SE). Although the majority of the habitat surveyed consisted of shallow flatwaters, several pools with substantial depth were recorded, with the deepest point measured at 6.6 ft deep. Large adult *O. mykiss* require pool habitat in order to thrive due to protection provided from terrestrial predation and lower velocities which contribute to energy conservation, while shallow riffles and flatwaters are suitable habitat for fry and small juveniles due to the protection they provide from predation and competition (Raleigh et al. 1984; Rosenfeld and Boss 2001). Although a few deep pools were observed throughout the survey, the overall shallow depths of the surveyed units suggest limited available habitat for adult *O. mykiss* to seek refuge.

Zero *O. mykiss* were observed through the course of this survey. As a result, no inferences could be made about trout habitat type and cover utilization. On average, habitat units contained slightly less covered area than open area, with 47.5 ± 1.9% (mean ± SE) covered and 52.5 ± 1.9% open. Of the available cover recorded, the majority consisted of aquatic vegetation (47.0 ± 2.0% [mean ± SE]) followed by cobble/boulder (28.7 ± 1.8%). Root mass, small woody debris, and terrestrial vegetation made up 8.9 ± 1.2% (mean ± SE), 7.8 ± 1.1%, and 5.1 ± 0.8% of the available cover respectively, while all other cover types made up a combined 2.5% of the available cover. Trout abundance in streams has been observed to increase along with the quality and abundance of cover available (Bjornn and Reiser 1991). The data collected through this survey show that approximately half of habitat units' surface area contained cover, suggesting that cover was available for potential fish within the survey reach to use as protection from predation, competition, and high flow events. Yet habitat units in San Antonio Creek lacked in cover type complexity, indicated by the dominance of aquatic vegetation and cobble/boulder cover and small percentage of all other cover types.

Since trout were not observed in San Antonio Creek during this survey, no inferences could be made about trout densities or distribution trends. In 2016, a snorkel survey was conducted on San Antonio Creek by the California Department of Fish and Wildlife (CDFW) following the same survey methods. A total of 10 *O. mykiss* were observed through the course of the 2016 survey. Prior to that, a 2015 snorkel survey conducted by CDFW resulted in the observation of 32 *O. mykiss*. This number of observations indicates *O. mykiss* relative abundance is the lowest ever recorded in San Antonio Creek (CDFW, unpublished data). The drastic reduction in trout observations could be attributed to one or more factors, including the persisting drought conditions and impacts of the Thomas Fire and subsequent rain events.

Physical changes to the riparian zone and streambed of San Antonio Creek have been noted in surveys following the Thomas fire and winter rain events. Redd surveys conducted by CDFW and PSMFC staff following the Thomas Fire documented significant amounts of riparian vegetation burned by the fire. Snorkel survey data show that habitat unit parameters have changed between 2016 and 2018, with habitat units on average having greater lengths and widths but shallower depths in 2018 (Table 2). The reduced channel depth could be attributed to sediment washed into the creek by strong winter storms in 2017 and 2018. At the time of the 2018 snorkel survey, San Antonio Creek contained more wetted habitat meeting the snorkeling depth requirement compared to the 2016 survey, with 8,516 ft of stream length snorkeled in 2018 compared to 1,545 ft of stream length snorkeled in 2016 and potentially contributed to the increased mean habitat unit width and lengths observed in 2018. Potential factors contributing to the increase in wetted habitat in 2018 include increased precipitation during the winters of 2017 and 2018 compared to 2016, a drastic reduction of vegetation in the riparian zone and subwatershed caused by the Thomas Fire, and completion of the snorkel survey in July of 2018 compared to September of 2016.

Water temperatures varied greatly throughout the survey. As expected for the warm summer months in which this survey was conducted, temperatures rose throughout the survey day, with a range of 62°F to 73°F measured in the mornings to a range of 65°F to 84°F measured in the afternoons. Measured water temperatures were lower in sections of creek that contained deeper habitat units and riparian canopy than in sections of creek that were shallow and contained little to no riparian vegetation. One such shallow, exposed section of creek had a recorded water temperature of 92°F at 1340 hours. Although southern California *O. mykiss* strains have shown the ability to survive higher maximum temperatures, these daily maximum temperatures recorded in large portions of the survey reach are well above the accepted 75.2°F (24°C) lethal temperature for *O. mykiss* (Spina 2007). The deeper habitat units in areas with riparian canopy cover could provide thermal refuge for *O. mykiss*, but high water temperatures would certainly restrict trout movement and survival in the shallow, uncovered portions of San Antonio Creek observed at the time of the survey.

Although snorkel surveys are an ideal method for collecting in-water data, there are limitations. One potential limiting factor is the dependency of the observational data collected on the individual snorkeler. To minimize error, each snorkeler was trained according to the protocol used. Differences in snorkeler observations are possible due to variable observation probabilities. Water depth is one such factor that can influence snorkeler observations. In San Antonio Creek, many habitat units contained shallow sections that were difficult to snorkel effectively. Additionally, snorkelers' ability to observe fish was heavily influenced by the clarity of the water. Thick mats of algae covered the entire surface of many habitat units, creating difficulty for some habitat units to be snorkeled entirely and effectively and resulting in some habitat units not being snorkeled due to lack of water visibility even though depth requirements were met.

This study aimed to describe *O. mykiss* relative abundance and stream habitat in San Antonio Creek in 2018 following the December 2017 Thomas Fire and subsequent winter rain events. Our results found no *O. mykiss* within the survey reach. Physical changes in the creek were recorded, with a reduction of average water depth but an increase in overall wetted habitat compared to previous years. We attribute these changes to the occurrence of strong winter storms over the past two years. In particular, storms following the Thomas Fire have lead to increased sediment filling in the stream channel, reduced vegetation in the subwatershed, and increased wetted habitat due to the increased precipitation.

In order to make reliable population abundance estimates, electrofishing surveys are typically conducted to calibrate snorkel counts (Hankin 1984). However, the use of electrofishing to sample *O. mykiss* is ill-advised in high stress environments including elevated water temperatures. Therefore, future monitoring efforts will likely rely on snorkel surveys to continue collecting data on *O. mykiss* relative abundance and habitat availability. These data will serve as important indicators of anadromous *O. mykiss* repopulation in San Antonio Creek.

Acknowledgements

We would like to thank all PSMFC and CDFW staff who participated in the planning and implementation of this project, and recognize the field efforts of Kathryn Carmody and Sam Bankston from PSMFC. We would like to acknowledge the Fisheries Restoration Grant Program which provides funding for this project through grant P1550013.

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Appendix

Figure A.1. Tanielle Redman, a Fisheries Technician with the Pacific States Marine Fisheries Commission (PSMFC), conducts a snorkel survey of a habitat unit typical of the portions of San Antonio Creek with riparian canopy cover.

<u>Figure A.2.</u> Kathryn Carmody, a Fisheries Biologist with the Pacific States Marine Fisheries Commission (PSMFC), conducts a snorkel survey of a habitat unit typical of the portions of San Antonio Creek with little or no riparian canopy cover.

Table A.1. Table of the cover types used to quantify the amount of trout cover available within a unit (percentage) and the type of cover being used by trout observed during snorkeling.

Cover Type	Description
Open/No cover	Percentage of the unit that is open and without trout cover. Trout are not hiding, instead milling or swimming in an open area of the unit.
Cobble/Boulder	Rocks less than the size of a Volkswagen Beetle. This category includes instances in which a 3-inch trout could hide in the crevices of a boulder cluster and underneath the ledge of the boulder.
SWD	Small Woody Debris. Fallen (dead) twigs, leaves, tree-related debris, loose roots (“free-wheeling”), and logs less than 12 inches in diameter or less than 6 feet long that is in the water and capable of providing cover to at least a 3-inch fish.
LWD	Large Woody Debris. Logs at least 12 inches in diameter and at least 6 feet long touching the water and capable of providing cover to at least a 3-inch fish.
Bedrock ledge	Rocks larger than a Volkswagen Beetle that overhang the water such that a 3 inch trout could hide underneath (approximately 6 inches deep or greater).
Terrestrial vegetation	Any live, terrestrial vegetation touching or overhanging within 1-foot of the water's surface that is large or complex enough to hide a 3-inch trout.
Aquatic vegetation	Any live, aquatic vegetation that is large or complex enough to hide a 3-inch trout.
Bubble curtain	Bubbles or agitated water created by flow that could provide cover a 3-inch trout.
Root mass	A mat or cluster of live roots (e.g. willow mats) that could provide cover to a 3 inch trout.
Soil Undercut	An area along the margins of the unit comprised mostly of soil that has eroded only underneath the surface to create a ledge. This undercut should be able to hide a 3 inch trout (approximately 6 inches deep or greater).
Other	Snorkeler could not identify the cover type used by the trout, or the cover type used did not fit into the above categories. Details should be included in the comments section. This category should very rarely be used.

North Fork Matilija Creek Snorkel Survey Report 2018

Prepared by Tanielle Redman[1], Shannon Mueller[1], and Casey Horgan[1]
[1]Pacific States Marine Fisheries Commission

Abstract

From June 4, 2018 to June 18, 2018 a snorkel survey was conducted on a 4.35 mile sampled reach of North Fork Matilija Creek. Data collected contributed to estimating southern California steelhead (*Oncorhynchus mykiss*) relative abundance and distribution as well as quantifying stream habitat type and trout cover types available. Stream habitat within the survey reach was dominated by shallow riffles (86.7%). On average, the surveyed habitat units contained little habitat complexity, with approximately one-third of units' surface area containing cover. Dominant cover types observed were bubble curtain (44.1 ± 1.2% [mean ± SE]) and cobble/boulder (42.9 ± 1.0%). No inferences could be made about trout abundance or distribution trends because only one *O. mykiss* was observed through the course of the survey. Changes in habitat type, cover complexity, and *O. mykiss* observations from surveys conducted in previous years appear to be a result of the December 2017 Thomas Fire and subsequent winter rain events. Future monitoring efforts are recommended to continue collecting data on *O. mykiss* relative abundance and habitat availability and potential anadromous *O. mykiss* repopulation in North Fork Matilija Creek.

Introduction

Steelhead (*Oncorhynchus mykiss*) along the west coast of North America have been divided into Distinct Population Segments (DPS) based on discrete factors separating populations from each other. The southern California steelhead DPS comprises the southernmost extent of the specie's range (NOAA 1997). Since 1997 this DPS has been listed as endangered under the U.S. Endangered Species Act due to dramatic declines in abundance caused by habitat loss and degradation (NOAA 1997). In response, a recovery plan for the southern California DPS was released in 2012 by the National Marine Fisheries Service (NMFS). This recovery plan determined multiple factors that affect the current endangered status of southern California steelhead (SCS) and the ability for recovery. Critical to steelhead recovery is the understanding of the interactions between steelhead and their freshwater habitat (NMFS 2012).

In southern California, steelhead fresh water habitat is dominated by short streams and rivers with flashy, intermittent flows and seasonal accessibility for anadromous trout. Since 2011, Southern California has experienced persistent drought conditions (NOAA 2018) further limiting the freshwater habitat use and availability for steelhead. The Thomas Fire, which burned from December 2017 through January 2018, impacted 1,909 miles of stream habitat within the fire perimeter, nearly 80 miles of which are designated critical habitat for southern California steelhead (Klose 2018). Shortly after, during the winter of 2018, strong rain events caused extremely high flows and the movement of boulders, debris, and sediment through creeks impacted by the fire. Fish mortalities and extirpation of small populations have been observed as a result of flooding and debris flows following wildfires (Bozek and Young 1994; Rinne 1996; Howell 2006). Monitoring efforts following these events are important for understanding

steelhead trout abundance, distribution, and habitat utilization in affected critical SCS habitat (Klose 2018).

An important aspect of understanding how trout interact with their freshwater habitat is observing how trout utilize cover within their environment. Cover types utilized by trout include overhanging and instream vegetation, woody debris, boulders, bedrock crevices, root wads, undercut banks, and surface water turbulence. Cover is recognized as one of the essential components affecting trout abundance and distribution in streams (Raleigh et al. 1984). For individual fish, cover functions as protection from predators, reduction of competition, and shelter from water flow (Allouche 2002). In addition to providing instream shelter for fish, certain cover types such as large woody debris and boulders aid in the creation of scours and pools which trout can utilize as habitat (Fausch and Northcote 1992; Allouche 2002).

A snorkel survey was conducted on North Fork Matilija Creek between June 4 and June 18, 2018 by Pacific States Marine Fisheries Commission (PSMFC). The purpose of this study was to estimate the relative abundance, distribution, cover availability, and cover use by *O. mykiss* within the survey reach.

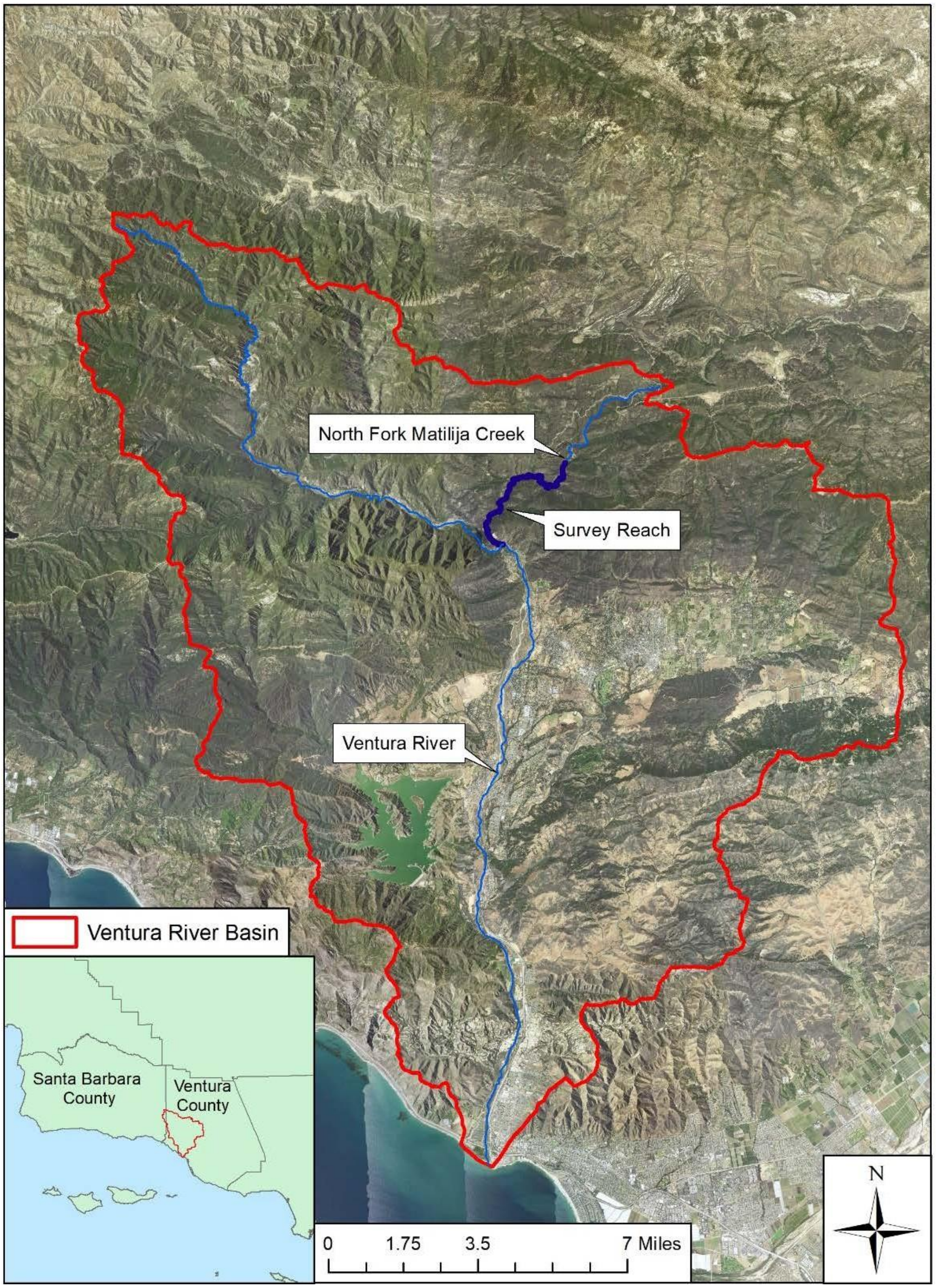
North Fork Matilija Creek is located in the Los Padres National Forest north of the city of Ojai in Ventura County, California. North Fork Matilija Creek begins with headwaters in the Topatopa Mountains of the Traverse Range and flows to a confluence with Matilija Creek to form the Ventura River. The North Fork Matilija Creek watershed drains approximately 10,297 acres out of a total of 144,967 acres that make up entire Ventura River watershed. According to the Thomas Fire Burned Area Emergency Response (BAER) assessment, approximately 96 percent of the North Fork Matilija subwatershed and 4.1 stream miles of North Fork Matilija Creek's designated steelhead critical habitat was burned by the fire (Klose 2018). The survey reach began at the confluence of Matilija Creek and North Fork Matilija Creek (34.48530, -119.29973) and extended 4.35 miles ending at total barrier at Wheeler Gorge Campground (34.51270, -119.27442).

Methods

This study was conducted using elements of a snorkel survey protocol written by Tsai & Van Meeuwen (2016, unpublished). This protocol was adapted from the Salmonid Field Protocol Handbook (O'Neil 2007) and the Underwater Methods for the study of Salmonids in the Intermountain West (Thurow 1994). Snorkel surveys were used to gather relative abundance estimates of trout and quantify the available trout habitat and cover usage.

Snorkel surveys were conducted in teams of two to three, which included at least one data recorder and one snorkeler. During surveys, the wetted stream channel was delineated into discrete, natural units of similar habitat (Hankin 1984). Units were classified as either riffles (R), pools (P), or flatwaters (F) according to certain defining characteristics. These habitat types are adopted from definitions outlined in Flosi et al. (1998).

<u>Figure 1.</u> Map of the Ventura River Basin (outlined in red) which drains into the Pacific Ocean and is located approximately 60 miles north of Los Angeles, California. Snorkel surveys were conducted from June 4, 2018 to June 18, 2018 along a 4.4 mile reach of North Fork Matilija Creek (highlighted in dark blue) which serves as a tributary to the Ventura River (highlighted in blue). Data collected contributed to *Oncorhynchus mykiss* relative abundance, stream habitat availability and use.



For this study, all snorkelable units with a maximum depth of 0.7 ft or greater were snorkeled once. The snorkeler entered the water at the downstream end of each habitat unit while being careful to minimize disturbance to the water and sediment. Once in the water, the snorkeler moved in a zig-zag pattern towards the upstream end of the unit making sure to visually search the entire area of the unit. The snorkeler searched the margins of the unit, boulder crevices, and other areas of potential fish cover. Cover was defined as any natural or artificial stream feature capable of hiding a 3-inch trout from the surface. To avoid duplicate counts, trout were counted as the snorkeler moved past them.

Once each unit was surveyed, all observations were reported to the bankside data recorder. For each trout observed, the associated cover and estimated length were given. Trout sizes were estimated by 2-inch size bins (0-1.99 inches, 2-3.99 inches, 4-5.99 inches, etc.). Counts were also made for special status species of amphibians and reptiles including Southern Western Pond Turtle (*Actinemys pallida*), Two-striped Gartersnakes (*Thamnophis hammondii*), and California Red-legged Frog (*Rana draytonii*). Additionally, presence and visual estimates of other native fish species were recorded including Arroyo Chub (*Gila orcutti*) and Three-spined Stickleback (*Gasterosteus aculeatus*). For trout cover, snorkelers noted the type of cover used by each trout when first observed. Cover types included open (no cover used), boulder, small woody debris, large woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain, bedrock ledge, undercut bank, and other/artificial cover (Table A.1). Other/artificial cover consisted of any manmade products, such as plastic or mesh netting, sandbags, and plywood that potentially provided cover for fish within a habitat unit.

The snorkeler assessed the total trout cover available in each unit by estimating the percent of surface area containing trout cover and surface area containing no cover. The snorkeler also estimated the percentage of total cover each cover type in the unit comprised.

Water visibility was recorded on a scale of zero to three. A value of zero indicates the snorkeler was unable to perform the survey due to a lack of visibility, one was poor visibility, two was adequate visibility, and three was clear visibility.

All habitat units were measured for length, mean width, mean depth, and maximum depth. Length was measured along the thalweg (line of lowest elevation within a valley or watercourse) and mean unit width was measured perpendicular to the length (thalweg) line. The percentage of surface area that contained exposed substrate, usually comprised of gravel, boulders, or bedrock, was estimated for each unit. Exposed substrate included areas of dry exposed substrate not accounted for in measurements of unit length or mean width. This allowed for a more accurate surface area calculation of the available wetted trout habitat.

Snorkelers' trout size estimations were calibrated after snorkeling the first habitat unit and subsequently every tenth unit. Three randomly chosen PVC pipes of known lengths were tossed into the unit after snorkeling was completed and sampled by the snorkeler. The snorkeler estimated the size bin of each pipe and then confirmed with the data recorder. If an incorrect estimate was given, calibration was repeated until the snorkeler accurately estimated the sizes of all three pipes.

Water and air temperatures were measured with a thermometer at the beginning of each survey day and subsequently after every tenth unit surveyed. Additionally, a HOBO U26 Dissolved Oxygen Data Logger was deployed within the survey reach to continuously record dissolved oxygen and water temperature.

All data was entered into a computer database and analyzed using R (version 3.4.1, R Core Team 2017) and R Studio (version 1.0153, RStudio, Inc 2016). To examine trout relative abundances, trout density was calculated in three ways, including mean number of trout per unit, mean number of trout per foot, and mean number of trout per square foot. To evaluate trout life stage diversity, the total number of trout per size class was calculated. To examine wetted habitat the total length surveyed, mean unit length, total unit area, mean unit area, mean unit depth, mean unit maximum depth, total unit volume, and mean unit volume were calculated. To quantify available trout cover, the mean percent of habitat units containing trout cover and the mean percent each cover type comprised was calculated. Trout cover use was examined by calculating the total number of trout observed using each cover type. For each mean the standard error was calculated.

Results

North Fork Matilija Creek was surveyed for 4.4 miles (22,968 ft) from June 4 to June 18, 2018. A total of 11,993.8 ft of stream length was snorkeled with a mean unit length of 47.0 ± 3.0 ft (mean ± SE) and mean unit width of 6.2 ± 0.2 ft (mean ± SE). The total unit area snorkeled was 66,375.2 ft^2, with a mean unit area of 260.3 ± 18.1 ft^2 (mean ± SE). A total of 255 habitat units were snorkeled. Of the snorkeled units, 86.7% (n=221) were classified as riffles, 11.8% (n=30) as pools, and 1.5% (n=4) as flatwaters. The mean depth of units surveyed was 0.5 ± 0.0 ft (mean ± SE) and units had a mean maximum depth of 1.1 ± 0.0 ft (mean ± SE). The total volume snorkeled through the course of the survey was 34,785.9 ft^3, with a mean unit volume of 136.4 ± 9.7 ft^3 (mean ± SE). Water visibility varied between snorkeled units throughout North Fork Matilija Creek with 61 units (24%) rated as having poor visibility, 127 units (49.8%) with average visibility, and 67 units (26.7%) with excellent visibility.

The mean percentage of available trout cover by surface area in units surveyed was 30.1 ± 1.1% (mean ± SE), with 69.9 ± 1.1% open. The predominant cover types observed consisted of bubble curtain (44.1 ± 1.2% [mean ± SE]) and cobble/boulder (42.9 ± 1.0%). Aquatic vegetation made up 5.1 ± 0.4% (mean ± SE) and small woody debris made up 3.4 ± 0.4%. Bedrock ledge, root mass, terrestrial vegetation, other/artificial cover, and large woody debris each made up less than two percent of the total mean cover (Table 1).

Water temperatures recorded using thermometers at the beginning of surveys ranged from 57^{o}F to 67^{o}F and by midafternoon measured as high as 80^{o}F. A HOBO data logger was deployed from June 14 to June 21, 2018, to continuously record water temperature and dissolved oxygen in the habitat unit where the single *O. mykiss* was observed. During the duration of deployment, temperatures ranged from a low of 59.2^{o}F to a high of 81.8^{o}F with a daily mean temperature of 66.8 ± 0.3^{o}F (mean ± SE). Daily mean temperature was calculated by averaging the temperatures of the 6 complete 24-hour periods of deployment, disregarding days in which the logger was only deployed for a portion of the day.

Temperature data from a HOBO logger deployed approximately 0.2 miles downstream during the same dates in 2017 recorded a low of 62.6^{o} F, high of 75.0^{o}F, and daily mean of 68.8 ± 0.1^{o}F (mean ± SE) (Figure 2).

Daily fluctuations in dissolved oxygen (DO) were also recorded by the HOBO data logger (Figure 3). DO ranged from a high of 9.53 mg/L on June 18, 2018, to 7.41 mg/L on June 20, 2018. The daily mean DO was 8.69 ± 0.02 mg/L (mean ± SE), which was also calculated from averaging the recorded DO of the 6 complete 24-hour periods of deployment.

One *O. mykiss* was observed under a bubble curtain and was estimated to be between 6 to 7.99 inches in length (Figure A.1). Additional wildlife observations of species of concern were recorded, resulting in nine Arroyo Chub (*Gila orcutti*), two Western Pond Turtles (*Actinemys marmorata pallida*), and one Two-striped Gartersnake (*Thamnophis hammondii*). Additionally, numerous California Treefrogs (*Pseudacris cadaverina*) and tadpoles were observed during this survey, although counts were not recorded.

Table 1. Mean Percent and standard error of habitat unit cover types recorded during the North Fork Matilija Creek snorkel survey.

Cover Type	Mean Percentage (%)	Standard Error (±%)
Open	69.94	1.11
Covered	30.06	1.11
Bubble Curtain	44.10	1.17
Cobble / Boulder	42.88	0.98
Aquatic Vegetation	5.10	0.40
Small Woody Debris	3.43	0.39
Bedrock Ledge	1.51	0.34
Root Mass	1.08	0.27
Terrestrial Vegetation	1.02	0.18
Other / Artificial Cover	0.59	0.35
Large Woody Debris	0.29	0.15
Soil Undercut	0.00	0.00

Table 2. A comparison of mean habitat unit measurements recorded in North Fork Matilija Creek between surveys conducted in 2013, 2015 and 2018.

Habitat Unit Measurement	2013, 2015		2018	
	Mean (ft)	SE (±ft)	Mean (ft)	SE (±ft)
Width	12.80	0.34	6.19	0.15
Mean Depth	1.23	0.05	0.52	0.01
Max Depth	2.35	0.08	1.07	0.02

Figure 2. North Fork Matilija Creek water temperatures recorded by continuously recording HOBO loggers from 6/14 – 6/21 in 2017 and 2018.

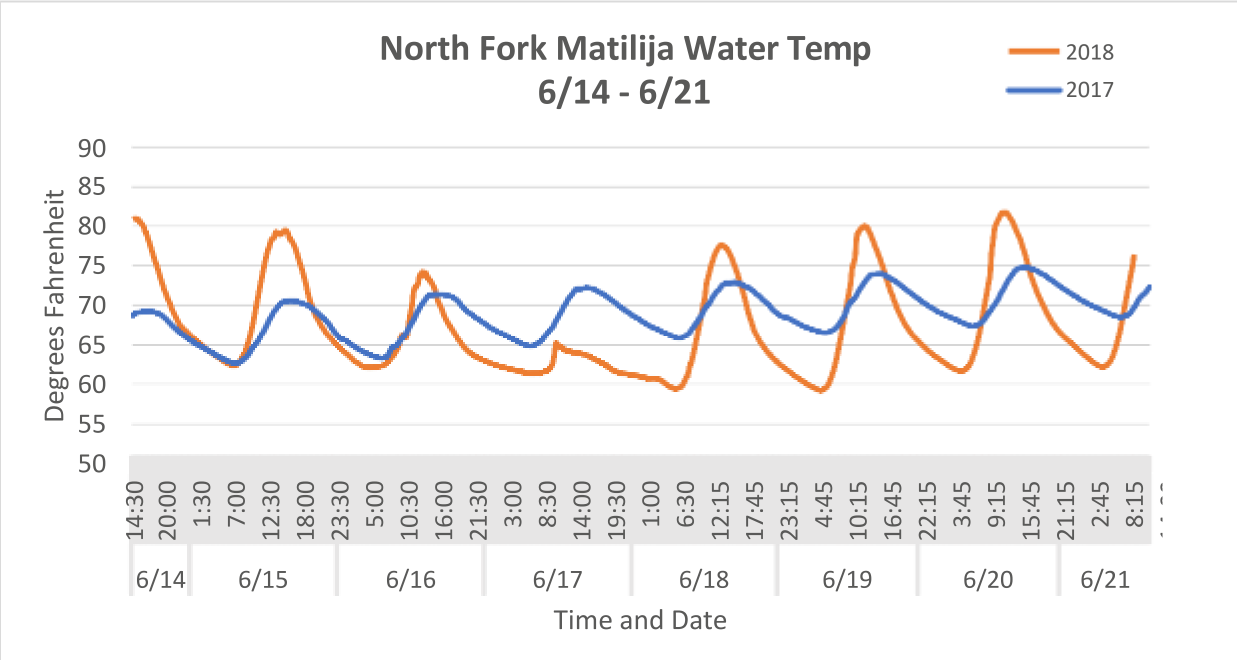
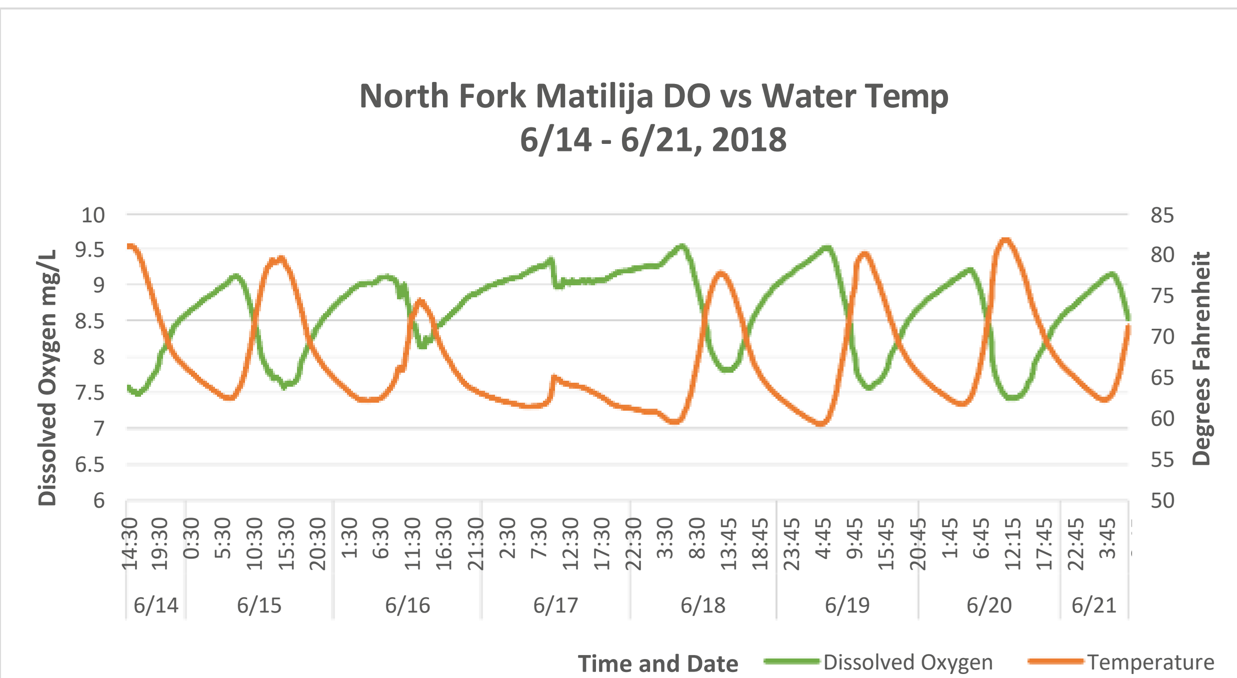


Figure 3. North Fork Matilija Creek dissolved oxygen levels recorded by continuously recording HOBO logger from 6/14 – 6/21, 2018.



Discussion

The entire 4.4 mile surveyed portion of the creek was wetted at the start of this survey. A total of 255 habitat units comprising 11,993.8 ft were snorkeled within the stream reach and just one *O. mykiss* observed. Riffles were the most common habitat type recorded, comprising 86.7% of units snorkeled (n=221). Pool and flatwater units made up just 11.8% (n=30) and 1.5% (n=4) respectively. Depth was limited throughout the surveyed stream with a mean depth of 0.5 ± 0.0 ft (mean ± SE) and a mean maximum depth of 1.1 ± 0.0 ft (mean ± SE). The deepest point measured over the course of the entire survey was 4.2 feet and occurred in a manmade pool while the deepest naturally occurring point measured at 3.5 feet.

Two small sections of this stream were not surveyed due to water visibility and landowner access issues. The first 0.2 miles of the reach starting at the confluence of Matilija and North Fork Matilija Creeks were not snorkeled due to ongoing poor water visibility. Another 0.3 miles were not snorkeled due to lack of landowner permission on private property.

One *O. mykiss* was observed in a 1 ft deep scour at the head of a long riffle with a mean depth of 0.4 ft and an estimated 10% of total cover. The trout was observed using bubble curtain as cover. However, no conclusions can be made about trout habitat type and cover utilization due to the small sample size. The data show an overall lack of complex cover throughout the North Fork Matilija Creek survey reach. On average, habitat units contained much more open (69.9 ± 1.1% [mean ± SE]), uncovered area than covered (30.1 ± 1.1%). Of that cover, bubble curtain and cobble/boulder made up the majority, comprising a mean 44.1 ± 1.2% (mean ± SE) and 42.9 ± 1.0% respectively. All other cover types made up a combined 13.0% of the total available cover. The low percentage of cover availability and lack of cover type complexity suggest that fish within the survey reach have limited protection from predation, competition, and high flow events (Allouche 2002).

Due to the single *O. mykiss* observed through the course of the survey, no inferences could be made about trout densities or distribution trends. While previous snorkel surveys have varied in survey methods, this number of observations indicate *O. mykiss* relative abundance is the lowest ever recorded in North Fork Matilija Creek (California Department of Fish and Wildlife, unpublished data). During double pass snorkel surveys conducted in 2014, a total of 78 *O. mykiss* were observed in the first pass and 105 *O. mykiss* in the second pass (van Meeuwen, unpublished data). The drastic reduction in trout observations could be attributed to one or more factors, including the persisting drought conditions and impacts of the Thomas Fire and subsequent rain events. These events have caused significant changes within North Fork Matilija Creek, overall reducing and degrading available *O. mykiss* habitat.

Physical changes to the riparian zone and streambed of North Fork Matilija Creek from the Thomas fire and winter rain events were noted during spawning surveys conducted from February through May of 2018. As a result of the fire, sediment was easily shifted during the rain flows which led to sediment filling in much of the stream channel. This led to a reduction in overall streambed depth and likely accounted for the reduced number of pools documented during this study. Data collected from North Fork Matilija Creek surveys conducted in 2013 and 2015 show habitat characterized by numerous pools and riffles with fewer flatwater units (CDFW, unpublished data). In addition to changes in habitat type composition, our data show a decrease in mean channel width and mean and maximum unit depths from previous years (Table 2). This study indicated a shift in stream structure, with habitat now dominated by long shallow low gradient riffles intermixed with few small pools and flatwater units. While shallow riffles are suitable habitat for *O. mykiss* fry and small juveniles due to the protection they provide from predation and competition, larger adults require pool habitat in order to thrive (Raleigh et al. 1984; Rosenfeld and Boss 2001). The reduced stream depth and number of pools limit the available habitat for adults to access in future spawning seasons.

Daily temperature fluctuations measured during this survey were much greater than measured in previous years, with temperatures fluctuating as much as 20.8°F throughout a single 24-hour period. Water temperature recorded during the same date range in 2017 showed a maximum daily temperature fluctuation of 8.1°F (Figure 2). The highest temperature recorded by the temperature logger during its 2018 deployment was 81.8°F, with sustained temperatures above 75°F occurring for multiple hours during most days. These temperatures are much higher than temperatures recorded throughout all of 2017 with an annual high of 77.4°F recorded on September 2nd (CDFW, unpublished data). Although southern California *O. mykiss* strains have shown the ability to survive higher maximum temperatures, these daily maximum temperatures are well above the accepted 75.2°F (24°C) lethal temperature for *O. mykiss* (Spina 2007). Such drastic changes in the temperature profile of North Fork Matilija Creek may be attributed to several factors. The most noticeable factors being the loss of riparian canopy burned by the fire and/or washed away by the high storm flows and the overall shallowing of the reach due to sedimentation following storm events. These changes have attributed to an increase in the amount of direct sunlight reaching the creek channel and its water column thus heating the water and contributing to higher temperatures. Additionally, the lack of deep pools reduces potential thermal refuge for trout.

Dissolved oxygen (DO) measured and recorded by the deployed HOBO logger showed healthy levels, ranging from 7.41 mg/L to 9.53 mg/L. Levels of DO below 3 mg/L sustained for 3.5 days is considered lethal to salmonids, and sustained levels below 6 mg/L can significantly impair salmonid swimming, feeding, and growth (Carter, 2005). DO levels measured during this survey indicate that unlike water temperature, DO likely did not have negative impact on *O. mykiss* health. Although this is just a sample measured DO from a single habitat unit, these data provide insight into what DO levels were at the time the surveys were conducted. A longer deployment of a DO logger would be needed to get a better understanding of DO trends in North Fork Matilija Creek and its potential implications on *O. mykiss* distribution.

Although snorkel surveys are an ideal method for collecting in-water data, there are limitations. One potential limiting factor is the dependency of the observational data collected on the individual snorkeler. To minimize error, each snorkeler was trained according to the protocol used. Differences in snorkeler observations are possible due to variable observation probabilities. Water depth is one such factor that can influence snorkeler observations. Due to the changes in the streambed following the fire and rain events, many units contained shallow sections that were difficult to snorkel effectively. Additionally, snorkelers' ability to observe fish was heavily influenced by the clarity of the water. Fine sediment had been washed into the creek contributing to poor water visibility which lasted for months following the winter storms. At the start of this study, suspended fine sediment in the water had still not completely washed out of the system, significantly reducing water clarity in the lower portion of the reach. Diminished water clarity was further worsened by extensive construction efforts on highway 33 taking place in the creek channel 0.2 miles upstream from the North Fork Matilija confluence with the Ventura River. Water clarity through the rest of the surveyed portion of North Fork Matilija creek ranged from poor to excellent.

This study aimed to describe *O. mykiss* relative abundance and stream habitat in North Fork Matilija Creek in 2018 following the December 2017 Thomas Fire and subsequent winter rain events. Our results found a loss in wetted habitat and elevated water temperatures contributing to freshwater habitat not suitable for *O. mykiss* persistence. We attribute these changes to a loss of canopy cover and increased sedimentation which reduced water depths and increased solar thermal heating.

In order to make reliable population abundance estimates, electrofishing surveys are typically conducted to calibrate snorkel counts (Hankin 1984). However, the use of electrofishing to sample *O. mykiss* is ill-advised in high stress environments including elevated water temperatures. Therefore, future monitoring efforts will likely rely on snorkel surveys to continue collecting data on *O. mykiss* relative abundance and habitat availability. These data will serve as important indicators of anadromous *O. mykiss* repopulation in North Fork Matilija Creek.

Acknowledgements

We would like to thank all PSMFC and CDFW staff who participated in the planning and implementation of this project. We would like to thank cooperating partner organizations, Watershed Stewards Program and California Conservation Corps, who helped make the scope of this project possible, and recognize the field efforts of Danielle Fitts and Lisa Rachal from WSP. We would like to acknowledge the Fisheries Restoration Grant Program which provides funding for this project through grant P1550013.

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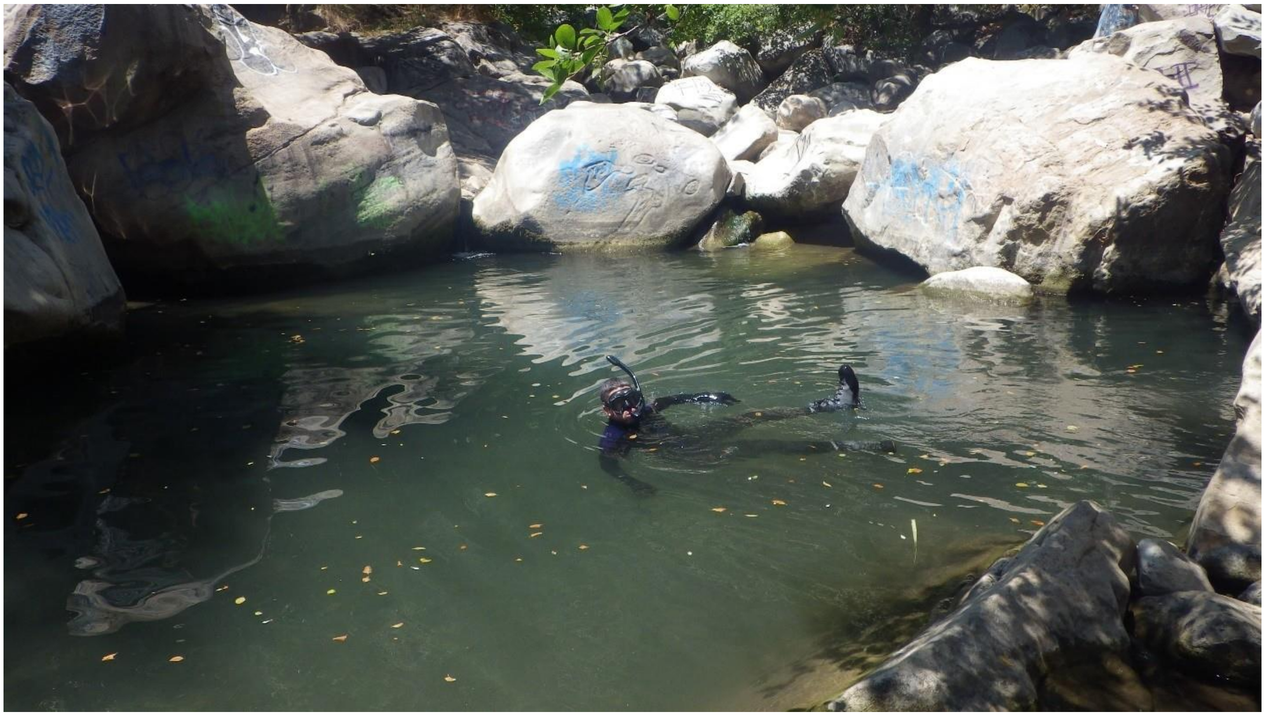
Appendix

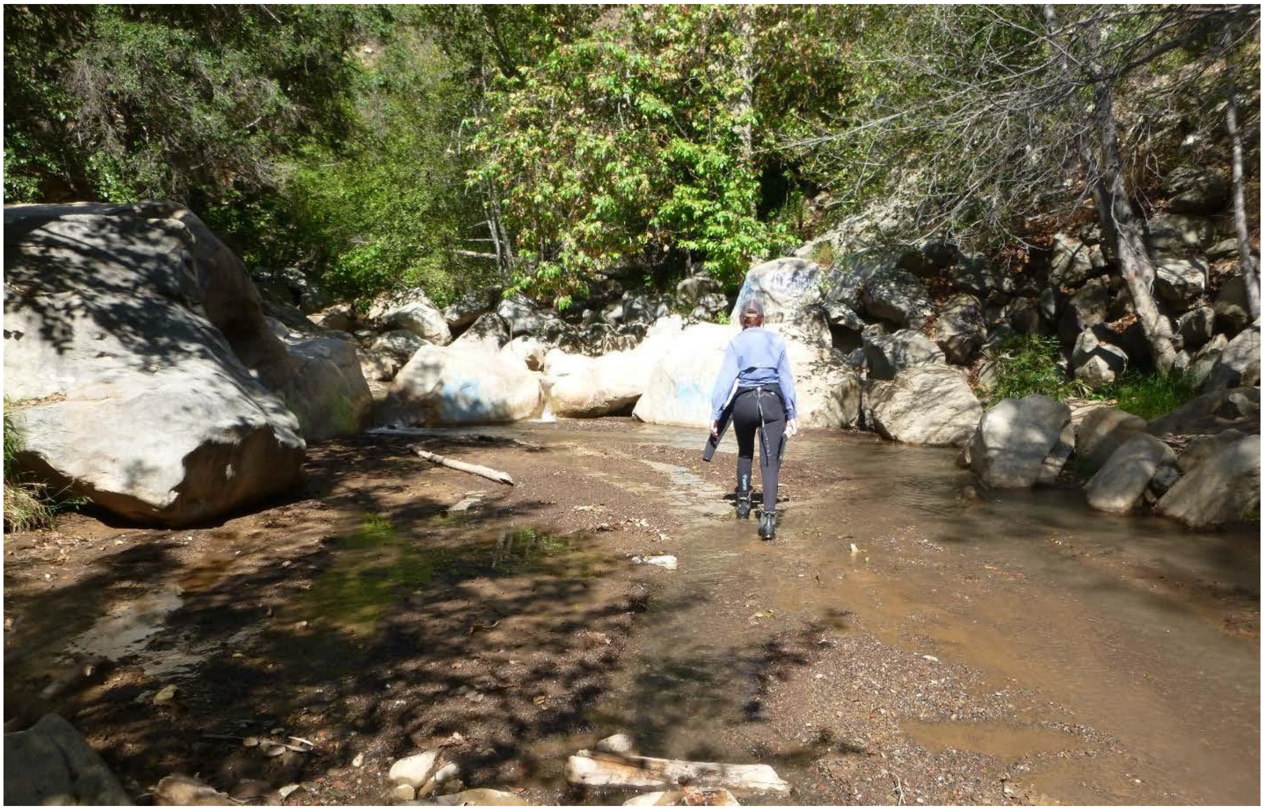
Figure A.1. One southern California steelhead (*Oncorhynchus mykiss*) observed during the 2018 snorkel survey in North Fork Matilija Creek. This was the only trout observed in the 4.35 mile stream survey reach.

Figure A.2. Casey Horgan, a Fisheries Technician with the Pacific States Marine Fisheries Commission (PSMFC) conducts a snorkel survey of a riffle unit in North Fork Matilija Creek. This unit is where the single *O. mykiss* was observed.

Figure A.3. Habitat unit in North Fork Matilija Creek located around 0.8 miles from the survey start. Images of this unit were taken (a) during snorkel surveys conducted in 2016 and (b) during surveys in 2018 following the Thomas Fire and subsequent winter rain events.



(a)



(b)

Table A.1. Table of the cover types used to quantify the amount of trout cover available within a unit (percentage) and the type of cover being used by trout observed during snorkeling.

Cover Type	Description
Open/No cover	Percentage of the unit that is open and without trout cover. Trout are not hiding, instead milling or swimming in an open area of the unit.
Cobble/Boulder	Rocks less than the size of a Volkswagen Beetle. This category includes instances in which a 3-inch trout could hide in the crevices of a boulder cluster and underneath the ledge of the boulder.
SWD	Small Woody Debris. Fallen (dead) twigs, leaves, tree-related debris, loose roots ("free-wheeling"), and logs less than 12 inches in diameter or less than 6 feet long that is in the water and capable of providing cover to at least a 3-inch fish.
LWD	Large Woody Debris. Logs at least 12 inches in diameter and at least 6 feet long touching the water and capable of providing cover to at least a 3-inch fish.
Bedrock ledge	Rocks larger than a Volkswagen Beetle that overhang the water such that a 3 inch trout could hide underneath (approximately 6 inches deep or greater).
Terrestrial vegetation	Any live, terrestrial vegetation touching or overhanging within 1-foot of the water's surface that is large or complex enough to hide a 3-inch trout.
Aquatic vegetation	Any live, aquatic vegetation that is large or complex enough to hide a 3-inch trout.
Bubble curtain	Bubbles or agitated water created by flow that could provide cover a 3-inch trout.
Root mass	A mat or cluster of live roots (e.g. willow mats) that could provide cover to a 3 inch trout.
Soil Undercut	An area along the margins of the unit comprised mostly of soil that has eroded only underneath the surface to create a ledge. This undercut should be able to hide a 3 inch trout (approximately 6 inches deep or greater).
Other	Snorkeler could not identify the cover type used by the trout, or the cover type used did not fit into the above categories. Details should be included in the comments section. This category should very rarely be used.

Bear Creek Snorkel Survey Report 2018

Prepared by Tanielle Redman[1], Shannon Mueller[1], and Casey Horgan[1]
[1]Pacific States Marine Fisheries Commission

Abstract

From May 30 to June 6, 2018, a snorkel survey was conducted on a 1.8 mile sampled reach of Bear Creek. Data collected contributed to estimating southern California steelhead (*Oncorhynchus mykiss*) relative abundance and distribution as well as quantifying stream habitat type and trout cover types available. Stream habitat was dominated by small pools (62.0%) and shallow riffles (34.8%). On average, the surveyed habitat units contained little habitat complexity, with unit's surface area containing a mean of 41.5 ± 2.3% (mean ± SE) cover, mostly consisting of cobble/boulder (51.2 ± 2.6% [mean ± SE]) and aquatic vegetation (27.2 ± 2.6%). No inferences could be made about trout abundance or distribution trends as no *O. mykiss* were observed through the course of the survey. Changes in habitat type, cover complexity, temperature profile, and *O. mykiss* observations from surveys conducted in previous years appear to be the result of the December 2017 Thomas Fire and subsequent winter rain events. Future monitoring efforts are recommended to continue collecting data on *O. mykiss* relative abundance and habitat availability and potential anadromous *O. mykiss* repopulation in Bear Creek.

Introduction

Steelhead (*Oncorhynchus mykiss*) along the west coast of North America have been divided into Distinct Population Segments (DPS) based on discrete factors separating populations from each other. The southern California steelhead DPS comprises the southernmost extent of the specie's range (NOAA 1997). Since 1997 this DPS has been listed as endangered under the U.S. Endangered Species Act due to dramatic declines in abundance caused by habitat loss and degradation (NOAA 1997). In response, a recovery plan for the southern California DPS was released in 2012 by the National Marine Fisheries Service (NMFS). This recovery plan determined multiple factors that affect the current endangered status of southern California steelhead (SCS) and the ability for recovery. Critical to steelhead recovery is the understanding of the interactions between steelhead and their freshwater habitat (NMFS 2012).

In southern California, steelhead fresh water habitat is dominated by short streams and rivers with flashy, intermittent flows and seasonal accessibility for anadromous trout. Since 2011, Southern California has experienced persistent drought conditions (NOAA 2018) further limiting the freshwater habitat use and availability for steelhead. The Thomas Fire, which burned from December 2017 through January 2018, impacted 1,909 miles of stream habitat within the fire perimeter, nearly 80 miles of which are designated critical habitat for southern California steelhead (Klose 2018). Shortly after, during the winter of 2018, strong rain events caused extremely high flows and the movement of boulders, debris, and sediment through creeks impacted by the fire. Fish mortalities and extirpation of small populations have been observed as a result of flooding and debris flows following wildfires (Bozek and Young 1994; Rinne 1996; Howell 2006). Monitoring efforts following these events are important for understanding

steelhead trout abundance, distribution, and habitat utilization in affected critical SCS habitat (Klose 2018).

An important aspect of understanding how trout interact with their freshwater habitat is observing how trout utilize cover within their environment. Cover types utilized by trout include overhanging and instream vegetation, woody debris, boulders, bedrock crevices, root wads, undercut banks, and surface water turbulence. Cover is recognized as one of the essential components affecting trout abundance and distribution in streams (Raleigh et al. 1984). For individual fish, cover functions as protection from predators, reduction of competition, and shelter from water flow (Allouche 2002). In addition to providing instream shelter for fish, certain cover types (e.g. large woody debris and boulders) aid in the creation of scours and pools which trout can utilize as habitat (Fausch and Northcote 1992; Allouche 2002).

A snorkel survey was conducted on Bear Creek between May 30, 2018 and June 6, 2018 by Pacific States Marine Fisheries Commission (PSMFC). The purpose of this study was to estimate the relative abundance, distribution, cover availability, and cover use of *O. mykiss* within the survey reach.

Bear Creek is located in the Los Padres National Forest north of the city of Ojai in Ventura County, California. With headwaters in the Topatopa Mountains of the Traverse Range, Bear Creek flows to a confluence with North Fork Matilija Creek, which in turn is a tributary to the Ventura River. The survey reach began at the confluence of Bear Creek and North Fork Matilija (34.51256, -119.27419) and extended 1.8 miles ending at a large waterfall total barrier (34.50996, -119.24998).

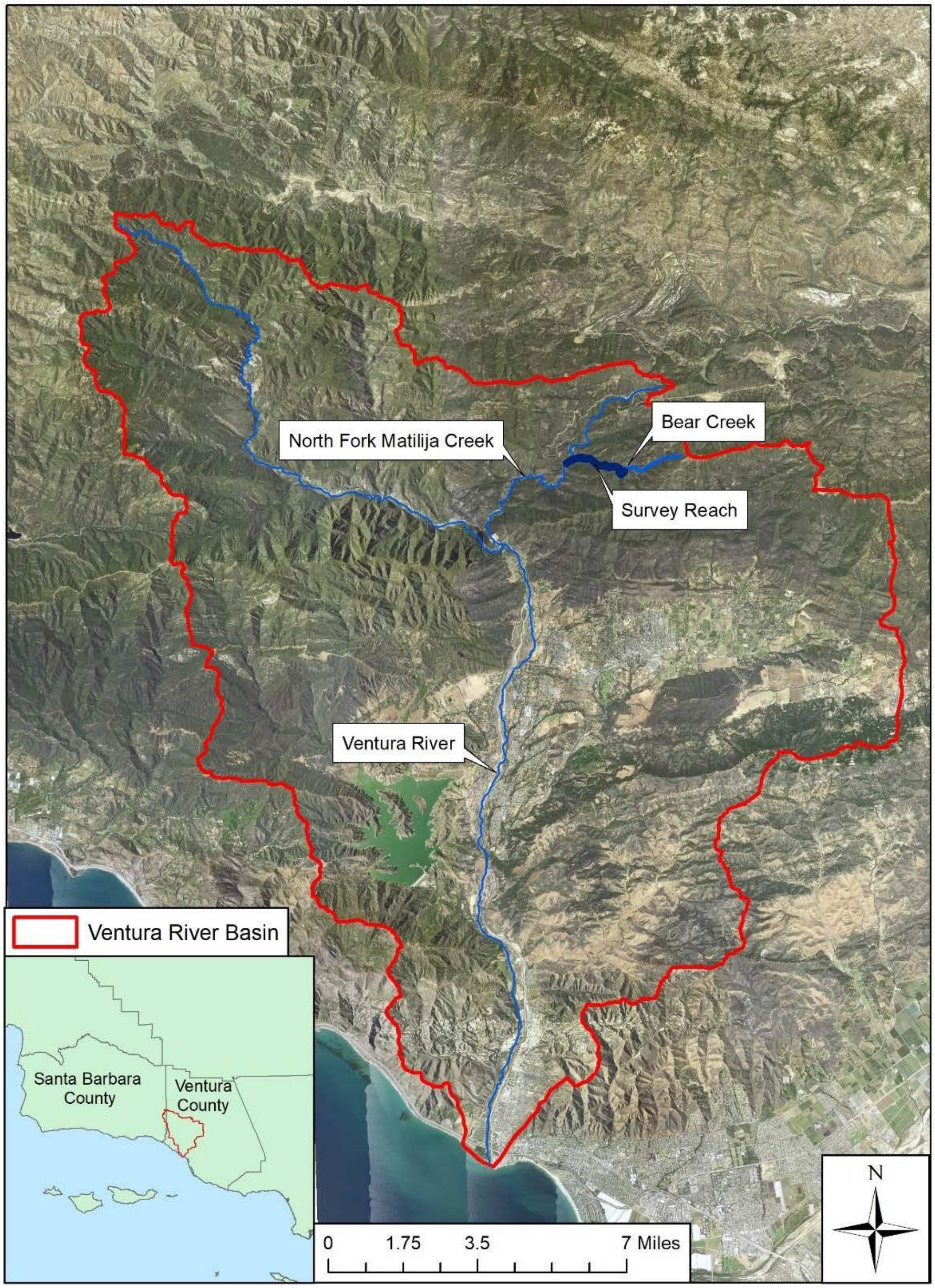
Methods

This study was conducted using elements of a snorkel survey protocol written by Tsai & Van Meeuwen (2016, unpublished). This protocol was adapted from the Salmonid Field Protocol Handbook (O'Neil 2007) and the Underwater Methods for the study of Salmonids in the Intermountain West (Thurow 1994). Snorkel surveys were used to gather relative abundance estimates of trout and quantify the available trout habitat and cover usage.

Snorkel surveys were conducted in teams of two to three, which included at least one data recorder and one snorkeler. During surveys, the wetted stream channel was delineated into discrete, natural units of similar habitat (Hankin 1984). Units were classified as either riffles (R), pools (P), or flatwaters (F) according to certain defining characteristics. These habitat types are adopted from definitions outlined in Flosi et al. (1998).

For this study, all snorkelable units with a maximum depth of 0.7 ft or greater were snorkeled once. The snorkeler entered the water at the downstream end of each habitat unit while being careful to minimize disturbance to the water and sediment. Once in the water, the snorkeler moved in a zig-zag pattern towards the upstream end of the unit making sure to visually search the entire area of the unit. The snorkeler searched the margins of the unit, boulder crevices, and other areas of potential fish cover.

Figure 1. Map of the Ventura River Basin (outlined in red) which drains into the Pacific Ocean and is located approximately 60 miles north of Los Angeles, California. Snorkel surveys were conducted from May 30, 2018 to June 6, 2018 along a 1.8 mile reach of Bear Creek (highlighted in dark blue) which serves as a tributary to North Fork Matilija Creek (highlighted in blue). Data collected contributed to *Oncorhynchus mykiss* relative abundance, stream habitat availability and use.



Cover was defined as any natural or artificial stream feature capable of hiding a 3-inch trout from the surface. To avoid duplicate counts, trout were counted as the snorkeler moved past them.

Once each unit was surveyed, all observations were reported to the bankside data recorder. For each trout observed, the associated cover and estimated length were given. Trout sizes were estimated by 2-inch size bins (0-1.99 inches, 2-3.99 inches, 4-5.99 inches, etc.). Counts were also made for special status species of amphibians and reptiles including Southern Western Pond Turtle (*Actinemys pallida*), Two-striped Gartersnakes (*Thamnophis hammondii*), and California Red-legged Frog (*Rana draytonii*). Additionally, presence and visual estimates of other native fish species were recorded including Arroyo Chub (*Gila orcutti*) and Three-spined Stickleback (*Gasterosteus aculeatus*). For trout cover, snorkelers noted the type of cover used by each trout when first observed. Cover types included open (no cover used), boulder, small woody debris, large woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain, bedrock ledge, undercut bank, and other/artificial cover (Table A.1). Other/artificial cover consisted of any manmade products, such as plastic or mesh netting, sandbags, and plywood that potentially provided cover for fish within a habitat unit.

The snorkeler assessed the total trout cover available in each unit by estimating the percent of surface area containing trout cover and surface area containing no cover. The snorkeler also estimated the percentage of total cover each cover type in the unit comprised.

Water visibility was recorded on a scale of zero to three. A value of zero indicates the snorkeler was unable to perform the survey due to a lack of visibility, one was poor visibility, two was adequate visibility, and three was clear visibility.

All habitat units were measured for length, mean width, mean depth, and maximum depth. Length was measured along the thalweg (line of lowest elevation within a valley or watercourse) and mean unit width was measured perpendicular to the length (thalweg) line. The percentage of surface area that contained exposed substrate, usually comprised of gravel, boulders, or bedrock, was estimated for each unit. Exposed substrate included areas of dry exposed substrate not accounted for in measurements of unit length or mean width. This allowed for a more accurate surface area calculation of the available wetted trout habitat.

Snorkelers' trout size estimations were calibrated after snorkeling the first habitat unit and subsequently every tenth unit. Three randomly chosen PVC pipes of known lengths were tossed into the unit, after snorkeling was completed, and sampled by the snorkeler. The snorkeler estimated the size bin of each pipe and then confirmed with the data recorder. If an incorrect estimate was given, calibration was repeated until the snorkeler accurately estimated the sizes of all three pipes.

Water and air temperatures were measured with a thermometer at the beginning of each survey day and subsequently after every tenth unit surveyed. Additionally, a HOBO Water Temperature Pro v2 Data Logger was deployed within the survey reach to continuously record water temperature.

All data was entered into a computer database and analyzed using R (version 3.4.1, R Core Team 2017) and R Studio (version 1.0153, RStudio, Inc 2016). To examine trout relative abundances, trout density was calculated in three ways, including mean number of trout per unit, mean number of trout per foot, and mean number of trout per square foot. To evaluate trout life stage diversity, the total number of trout per size class was calculated. To examine wetted habitat the total length surveyed, mean unit length, total unit area, mean unit area, mean unit depth, mean unit maximum depth, total unit volume, and mean unit volume were calculated. To quantify available trout cover, the mean percent of habitat units containing trout cover and the mean percent each cover type comprised was calculated. Trout cover use was examined by calculating the total number of trout observed using each cover type. For each mean the standard error was calculated.

<u>Results</u>

Bear Creek was surveyed from May 20 to June 6, 2018, for 1.75 miles (9,240 ft). At the time of the survey, 1.54 miles (88%) of the survey reach were wetted, with the remaining 0.21 miles dry. A total of 1,272.6 ft of stream length was snorkeled with a mean unit length of 13.8 ± 1.5 ft (mean ± SE) and a mean unit width of 4.0 ± 0.2 ft. The total unit area snorkeled was 4,057.3 ft^2, with a mean unit area of 46.8 ± 0.4 ft^2 (mean ± SE). A total of 92 habitat units were snorkeled. Of the snorkeled units, 62.0% were classified as pools (n=57), 34.8% as riffles (n=32), and 3.2% as flatwaters (n=3). The mean depth of units surveyed was 0.42 ± 0.0 ft (mean ± SE) and units had a mean maximum depth of 0.9 ± 0.0 ft (mean ± SE). The total volume snorkeled through the course of the survey was 1,596.1 ft^3, with a mean unit volume of 17.4 ± 1.3 ft^3 (mean ± SE).

The mean percentage of available trout cover by surface area in units surveyed was 41.5 ± 2.3% (mean ± SE), with 58.5 ± 2.3% open. The predominant cover types observed consisted of cobble/boulder (51.2 ± 2.6% [mean ± SE]) and aquatic vegetation (27.2 ± 2.6%). Bubble curtain made up 13.4 ± 1.1% (mean ± SE) and small woody debris made up 4.8 ± 0.8%. Root mass, bedrock ledge, soil undercut, and terrestrial vegetation each made up less than two percent of the total mean cover (Table 1).

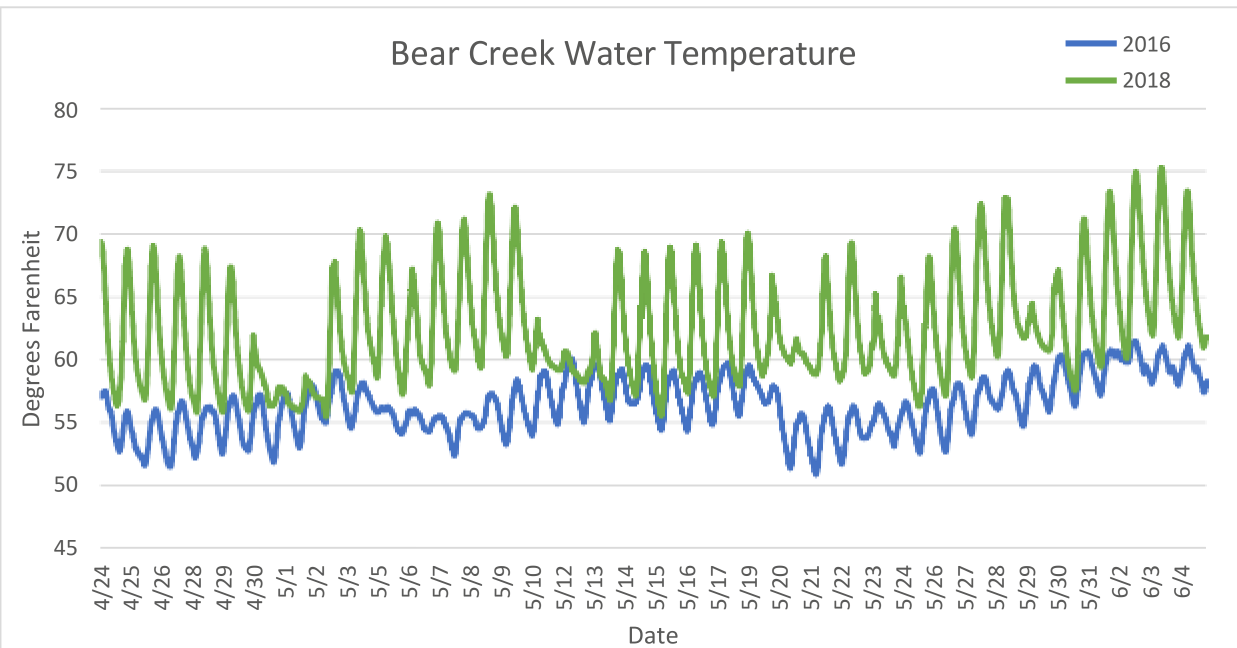
Water temperatures recorded using thermometers ranged from 59^{o}F at the beginning of surveys to 80^{o}F by midafternoon. A HOBO temperature logger was deployed on April 24, 2018, near the same location as a temperature logger deployed in previous years, approximately 0.3 miles upstream of the start of the survey reach. Water temperatures recorded from the time of deployment through the end of the snorkel survey on June 6 ranged from a low of 55.5^{o}F to a high of 75.2^{o}F with a daily mean temperature of 62.3 ± 0.1^{o}F (mean ± SE) (Figure 2). Water temperatures recorded by the logger during the same dates in 2016 show a low of 50.9^{o}F to a high of 61.5^{o}F with a daily mean of 56.3 ± 0.0^{o}F (mean ± SE).

Zero *O. mykiss* were observed through the course of this snorkel survey. Additionally, zero fish of any species were observed within the Bear Creek survey reach. Only two species of concern were recorded, one two-striped garter snake (*Thamnophis hammondii*) and one western pond turtle (*Actinemys pallida*).

Table 1. Mean Percent and standard error of habitat unit cover types recorded during the Bear Creek snorkel survey.

Cover Type	Mean Percentage (%)	Standard Error (±%)
Open	58.48	2.27
Covered	41.52	2.27
Cobble/Boulder	51.20	2.64
Aquatic Vegetation	27.17	2.56
Bubble Curtain	13.37	1.08
Small Woody Debris	4.84	0.81
Root Mass	1.52	0.61
Bedrock	1.25	0.59
Soil Undercut	0.38	0.25
Terrestrial Vegetation	0.27	0.18
Large Woody Debris	0.00	0.00
Other / Artificial Cover	0.00	0.00

Figure 2. Bear Creek water temperatures recorded by continuously recording HOBO loggers from 4/24-6/6 in 2016 and 2018.



Discussion

The 1.8-mile reach of Bear Creek was snorkeled from May 30 to June 6, 2018. At the time of the survey, 88% of the reach was wetted, with 0.2 miles of creek dry and thus not snorkeled. A total of 92 habitat units comprising 1,272.6 ft were snorkeled within the stream reach. Of the habitat units surveyed, pools were the most abundant, comprising 62.0% (n=57) of the total habitat units. Riffles made up 34.8% (n=32) of habitat units while flatwaters made up only 3.2% (n=3). Although pools were the most numerous habitat type, in terms of surface area surveyed Bear Creek was dominated by riffles, comprising 2,676.8 ft^2 of the total snorkeled area of 4,057.3 ft^2. Water depth was limited throughout the survey reach, with a mean unit depth of 0.4 ± 0.0 ft (mean ± SE) and a mean maximum unit depth of 0.9 ± 0.0 ft (mean ± SE). The deepest point measured throughout the survey reach was only 1.6 ft. While shallow riffles are suitable habitat for *O. mykiss* fry and small juveniles due to the protection they provide from aquatic predation and competition, larger adults require pool habitat in order to thrive as pools have lower velocities contributing to energy conservation and provide refuge from terrestrial predation (Raleigh et al. 1984; Rosenfeld and Boss 2001). The reduced stream depth and small size of pools limits the available habitat for adults to access in future spawning seasons and seek refuge in throughout the year.

Zero *O. mykiss* were observed through the course of this survey. As a result, no inferences could be made about trout habitat type and cover utilization. The data collected through this survey show that Bear Creek contained cover that could be utilized by trout, although it lacked complexity. Our results show habitat units contained slightly less covered area than open area, with 41.5 ± 2.3% (mean ± SE) covered and 58.5 ± 2.3% open. Of the cover available, the majority consisted of cobble/boulder (51.2 ± 2.6% [mean ± SE]). Aquatic vegetation and bubble curtain made up 27.2 ± 2.6% (mean ± SE) and 13.4 ± 1.1% of the available cover respectively, while all other cover types made up a combined 8.2% of the available cover. The low percentage of cover availability and lack of cover type complexity suggest that fish within the survey reach have limited protection from predation, competition, and high flow events (Allouche 2002).

Since zero trout were observed in Bear Creek during this survey, no inferences could be made about trout densities or distribution trends. No snorkel surveys had been conducted in Bear Creek prior to this survey, so we have no *O. mykiss* relative abundance estimations within this survey reach to use as comparison. There have been bankside observations of individual *O. mykiss*, redds, and young of the year recorded in Bear Creek from 2014 through 2017 by California Department of Fish and Wildlife and Pacific States Marine Fisheries Commission (CDFW, unpublished data). However, zero *O. mykiss* observations have been recorded by CDFW and PSMFC staff following the Thomas Fire and 2018 winter storm flows. These results indicate the lowest *O. mykiss* abundance since monitoring efforts began in Bear Creek. The lack of trout observations could be attributed to impacts to stream habitat due to the persisting drought conditions combined with the impacts of the Thomas Fire and subsequent rain events. These events have led to significant changes observed within Bear Creek, resulting in reduced and degraded available *O. mykiss* habitat. Specifically, changes to the creek’s thermal profile indicate limited survival of *O. mykiss* during the time of snorkel data collection

Water temperature data recorded by the HOBO logger in Bear Creek in 2018 show higher temperatures and greater fluctuations than recorded in previous years. Daily temperature fluctuations measured before and during this survey were much greater than measured in previous years, with temperatures fluctuating as much as 14.8^oF throughout a single 24-hour period, compared to a maximum daily fluctuation of 5.5^oF during the same date range in 2016 (Figure 2). From April 24 through the end of the survey on June 6, 2018, the highest temperature recorded was 75.2^oF with a daily mean temperature of 62.3 ± 0.1^oF (mean ± SE). Maximum temperatures recorded by thermometers exceeded 80^oF in exposed, sunny portions of the reach. Maximum temperatures recorded by the logger reached 75.2^oF (24^oC), the accepted lethal temperature for *O. mykiss* (Spina 2007). Although southern California *O. mykiss* strains have shown the ability to survive higher maximum temperatures (Spina 2007), a warming trend observed through the temperature logger data suggest water temperatures continued to peak above 75.2^oF following the data collection period. These changes in the temperature profile of Bear Creek may be attributed to factors such as the loss of riparian canopy burned by the fire and/or washed away by the high storm flows and the overall shallowing of the reach due to sedimentation following storm events. These changes have attributed to an increase in the amount of direct sunlight reaching the creek channel and its water column thus heating the water and contributing to higher temperatures. Additionally, the lack of deep pools reduces potential thermal refuge for trout (Spina 2007).

Although snorkel surveys are an ideal method for collecting in-water data, there are limitations. One potential limiting factor is the dependency of the observational data collected on the individual snorkeler. To minimize error, each snorkeler was trained according to the protocol used. Differences in snorkeler observations are possible due to variable observation probabilities. Water depth is one such factor that can influence snorkeler observations. Due to the changes in the streambed following the fire and rain events, many units contained shallow sections that were difficult to snorkel effectively.

This study aimed to describe *O. mykiss* relative abundance and stream habitat in Bear in 2018 following the December 2017 Thomas Fire and subsequent winter rain events. Our results found a lack of habitat depth, size, and cover complexity and elevated water temperatures contributing to freshwater habitat not suitable for *O. mykiss* persistence. We attribute these changes to a loss of canopy cover and increased sedimentation which reduced water depths and increased solar thermal heating.

In order to make reliable population abundance estimates, electrofishing surveys are typically conducted to calibrate snorkel counts (Hankin 1984). However, the use of electrofishing to sample *O. mykiss* is ill-advised in high stress environments including elevated water temperatures. Therefore, future monitoring efforts will likely rely on snorkel surveys to continue collecting data on *O. mykiss* relative abundance and habitat availability. These data will serve as important indicators of anadromous *O. mykiss* repopulation in Bear Creek.

Acknowledgements

We would like to thank all PSMFC and CDFW staff who participated in the planning and implementation of this project, and recognize the field efforts of Kathryn Carmody and Sam Bankston from PSMFC. We would like to acknowledge the Fisheries Restoration Grant Program which provides funding for this project through grant P1550013.

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Appendix

Figure A.1. Tanielle Redman, a Fisheries Technician with Pacific States Marine Fisheries Commission (PSMFC) conducts a snorkel survey of a small pool in Bear Creek.

Figure A.2. A portion of the Bear Creek survey reach photographed by CDFW and PSMFC staff during a redd survey conducted in April 2017 showing average habitat units and riparian vegetation.

Figure A.3. A portion of the Bear Creek survey reach photographed by CDFW and PSMFC staff during a redd survey conducted in February 2018 following the Thomas Fire and subsequent winter rain events.

Table A.1. Table of the cover types used to quantify the amount of trout cover available within a unit (percentage) and the type of cover being used by trout observed during snorkeling.

Cover Type	Description
Open/No cover	Percentage of the unit that is open and without trout cover. Trout are not hiding, instead milling or swimming in an open area of the unit.
Cobble/Boulder	Rocks less than the size of a Volkswagen Beetle. This category includes instances in which a 3-inch trout could hide in the crevices of a boulder cluster and underneath the ledge of the boulder.
SWD	Small Woody Debris. Fallen (dead) twigs, leaves, tree-related debris, loose roots (“free-wheeling”), and logs less than 12 inches in diameter or less than 6 feet long that is in the water and capable of providing cover to at least a 3-inch fish.
LWD	Large Woody Debris. Logs at least 12 inches in diameter and at least 6 feet long touching the water and capable of providing cover to at least a 3-inch fish.
Bedrock ledge	Rocks larger than a Volkswagen Beetle that overhang the water such that a 3 inch trout could hide underneath (approximately 6 inches deep or greater).
Terrestrial vegetation	Any live, terrestrial vegetation touching or overhanging within 1-foot of the water's surface that is large or complex enough to hide a 3-inch trout.
Aquatic vegetation	Any live, aquatic vegetation that is large or complex enough to hide a 3-inch trout.
Bubble curtain	Bubbles or agitated water created by flow that could provide cover a 3-inch trout.
Root mass	A mat or cluster of live roots (e.g. willow mats) that could provide cover to a 3 inch trout.
Soil Undercut	An area along the margins of the unit comprised mostly of soil that has eroded only underneath the surface to create a ledge. This undercut should be able to hide a 3 inch trout (approximately 6 inches deep or greater).
Other	Snorkeler could not identify the cover type used by the trout, or the cover type used did not fit into the above categories. Details should be included in the comments section. This category should very rarely be used.

Matilija Creek Snorkel Survey Report 2018

Prepared by Tanielle Redman[1], Shannon Mueller[1], and Casey Horgan[1]
[1]Pacific States Marine Fisheries Commission

Abstract

From July 25, 2018 to September 20, 2018 a snorkel survey was conducted on a 6.9 mile sampled reach of Matilija Creek. Data collected contributed to estimating southern California steelhead (*Oncorhynchus mykiss*) relative abundance and distribution as well as quantifying stream habitat type and trout cover types available. Stream habitat within the survey reach was dominated by shallow flatwaters (45.9%) and pools (35.1%). On average, the surveyed habitat units contained little habitat complexity, with approximately one-quarter of units' surface area containing cover. The dominant cover type observed was cobble/boulder (61.6 ± 0.8% [mean ± SE]). No inferences could be made about trout abundance or distribution trends because only two *O. mykiss* was observed through the course of the survey. Changes in habitat type, cover complexity, and *O. mykiss* observations from surveys conducted in previous years appear to be a result of the December 2017 Thomas Fire and subsequent winter rain events. Future monitoring efforts are recommended to continue collecting data on *O. mykiss* relative abundance and habitat availability and potential *O. mykiss* repopulation in Matilija Creek.

Introduction

Steelhead (*Oncorhynchus mykiss*) along the west coast of North America have been divided into Distinct Population Segments (DPS) based on discrete factors separating populations from each other. The southern California steelhead DPS comprises the southernmost extent of the specie's range (NOAA 1997). Since 1997 this DPS has been listed as endangered under the U.S. Endangered Species Act due to dramatic declines in abundance caused by habitat loss and degradation (NOAA 1997). In response, a recovery plan for the southern California DPS was released in 2012 by the National Marine Fisheries Service (NMFS). This recovery plan determined multiple factors that affect the current endangered status of southern California steelhead (SCS) and the ability for recovery. Critical to steelhead recovery is the understanding of the interactions between steelhead and their freshwater habitat (NMFS 2012).

In southern California, steelhead fresh water habitat is dominated by short streams and rivers with flashy, intermittent flows and seasonal accessibility for anadromous trout. Since 2011, Southern California has experienced persistent drought conditions (NOAA 2018) further limiting the freshwater habitat use and availability for steelhead. The Thomas Fire, which burned from December 2017 through January 2018, impacted 1,909 miles of stream habitat within the fire perimeter, nearly 80 miles of which are designated critical habitat for southern California steelhead (Klose 2018). Shortly after, during the winter of 2018, strong rain events caused extremely high flows and the movement of boulders, debris, and sediment through creeks impacted by the fire. Fish mortalities and extirpation of small populations have been observed as a result of flooding and debris flows following wildfires (Bozek and Young 1994; Rinne 1996; Howell 2006). Monitoring efforts following these events are important for understanding

steelhead trout abundance, distribution, and habitat utilization in affected critical SCS habitat (Klose 2018).

An important aspect of understanding how trout interact with their freshwater habitat is observing how trout utilize cover within their environment. Cover types utilized by trout include overhanging and instream vegetation, woody debris, boulders, bedrock crevices, root wads, undercut banks, and surface water turbulence. Cover is recognized as one of the essential components affecting trout abundance and distribution in streams (Raleigh et al. 1984). For individual fish, cover functions as protection from predators, reduction of competition, and shelter from water flow (Allouche 2002). In addition to providing instream shelter for fish, certain cover types (e.g. large woody debris and boulders) aid in the creation of scours and pools which trout can utilize as habitat (Fausch and Northcote 1992; Allouche 2002).

A snorkel survey was conducted on Matilija Creek between July 25, 2018 and September 20, 2018 by Pacific States Marine Fisheries Commission (PSMFC). The purpose of this study was to estimate the relative abundance, distribution, cover availability, and cover use of *O. mykiss* within the survey reach.

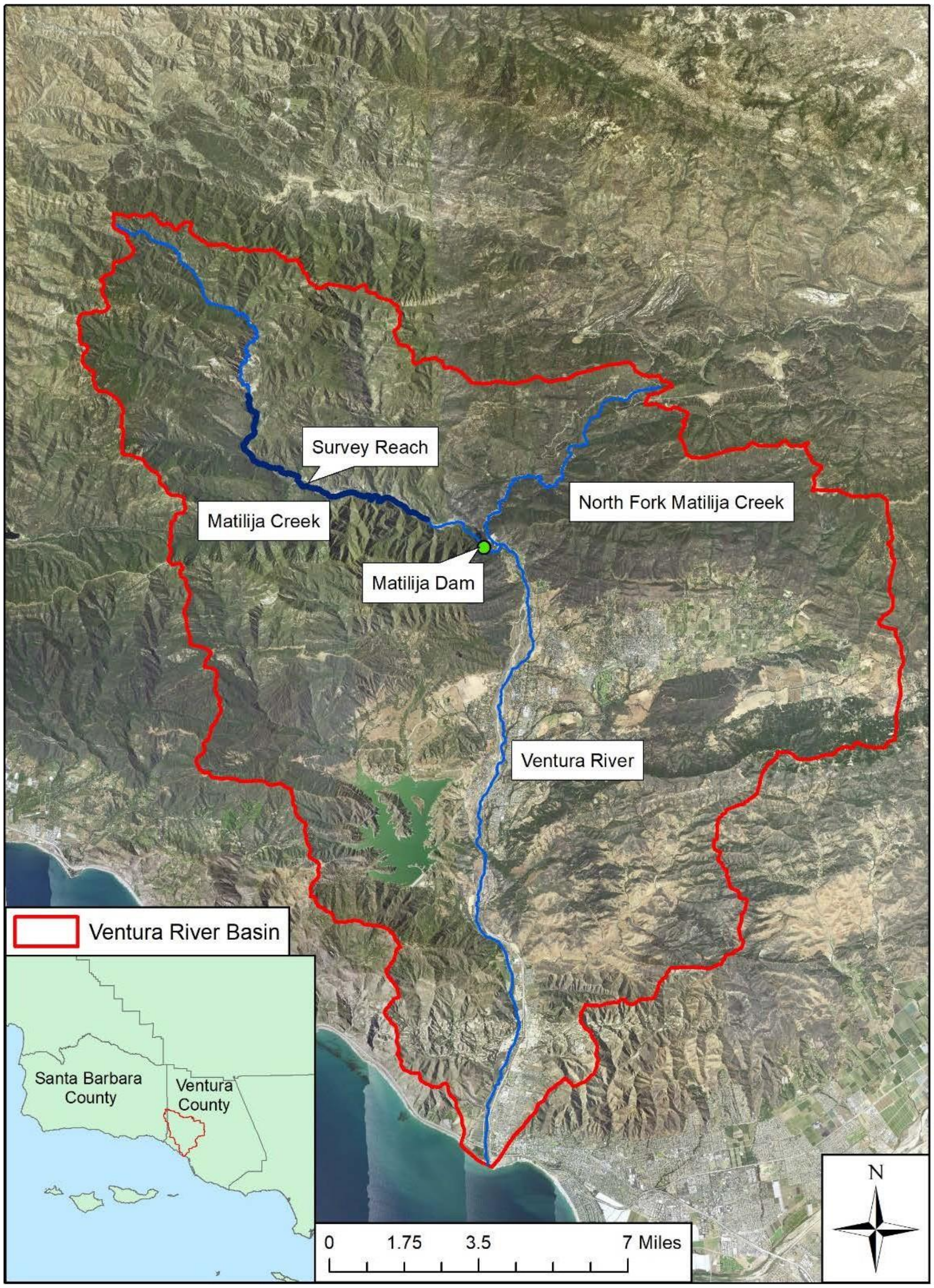
Matilija Creek begins with headwaters in the Santa Ynez Mountains and flows through the Matilija Wilderness to a confluence with North Fork Matilija Creek to form the Ventura River. The Matilija Dam is located approximately 0.5 miles upstream of the mouth of Matilija Creek, blocking access of anadromous steelhead to the rest of the creek upstream. The Matilija Creek watershed drains approximately 34,927 acres out of a total of 144,967 acres that make up entire Ventura River watershed. According to the Thomas Fire Burned Area Emergency Response (BAER) assessment, approximately 97 percent of the Matilija subwatershed and 0.5 stream miles of Matilija Creek's designated steelhead critical habitat (below the Matilija dam) was burned by the fire (Klose 2018). The survey reach began at an established survey reach start above the Matilija Dam and Reservoir (34.49418, -119.33022) and extended 6.94 miles ending at a large waterfall barrier to fish passage (34.53699, -119.40395).

Methods

This study was conducted using elements of a snorkel survey protocol written by Tsai & Van Meeuwen (2016, unpublished). This protocol was adapted from the Salmonid Field Protocol Handbook (O'Neil 2007) and the Underwater Methods for the study of Salmonids in the Intermountain West (Thurow 1994). Snorkel surveys were used to gather relative abundance estimates of trout and quantify the available trout habitat and cover usage.

Snorkel surveys were conducted in teams of two to three, which included at least one data recorder and one snorkeler. During surveys, the wetted stream channel was delineated into discrete, natural units of similar habitat (Hankin 1984). Units were classified as either riffles (R), pools (P), or flatwaters (F) according to certain defining characteristics. These habitat types are adopted from definitions outlined in Flosi et al. (1998).

Figure 1. Map of the Ventura River Basin (outlined in red) which drains into the Pacific Ocean and is located approximately 60 miles north of Los Angeles, California. Snorkel surveys were conducted from July 25, 2018 to September 20, 2018 along a 6.9 mile reach of Matilija Creek (highlighted in dark blue) which serves as a tributary to the Ventura River (highlighted in blue). Data collected contributed to *Oncorhynchus mykiss* relative abundance, stream habitat availability and use.



For this study, all snorkelable units with a maximum depth of 0.7 ft or greater were snorkeled once. The snorkeler entered the water at the downstream end of each habitat unit while being careful to minimize disturbance to the water and sediment. Once in the water, the snorkeler moved in a zig-zag pattern towards the upstream end of the unit making sure to visually search the entire area of the unit. The snorkeler searched the margins of the unit, boulder crevices, and other areas of potential fish cover. Cover was defined as any natural or artificial stream feature capable of hiding a 3-inch trout from the surface. To avoid duplicate counts, trout were counted as the snorkeler moved past them.

Once each unit was surveyed, all observations were reported to the bankside data recorder. For each trout observed, the associated cover and estimated length were given. Trout sizes were estimated by 2-inch size bins (0-1.99 inches, 2-3.99 inches, 4-5.99 inches, etc.). Counts were also made for special status species of amphibians and reptiles including Southern Western Pond Turtle (*Actinemys pallida*), Two-striped Gartersnakes (*Thamnophis hammondii*), and California Red-legged Frog (*Rana draytonii*). Additionally, presence and visual estimates of other native fish species were recorded including Arroyo Chub (*Gila orcutti*) and Three-spined Stickleback (*Gasterosteus aculeatus*). For trout cover, snorkelers noted the type of cover used by each trout when first observed. Cover types included open (no cover used), boulder, small woody debris, large woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain, bedrock ledge, undercut bank, and other/artificial cover (Table A.1). Other/artificial cover consisted of any manmade products, such as plastic or mesh netting, sandbags, and plywood that potentially provided cover for fish within a habitat unit.

The snorkeler assessed the total trout cover available in each unit by estimating the percent of surface area containing trout cover and surface area containing no cover. The snorkeler also estimated the percentage of total cover each cover type in the unit comprised.

Water visibility was recorded on a scale of zero to three. A value of zero indicates the snorkeler was unable to perform the survey due to a lack of visibility, one was poor visibility, two was adequate visibility, and three was clear visibility.

All habitat units were measured for length, mean width, mean depth, and maximum depth. Length was measured along the thalweg (line of lowest elevation within a valley or watercourse) and mean unit width was measured perpendicular to the length (thalweg) line. The percentage of surface area that contained exposed substrate, usually comprised of gravel, boulders, or bedrock, was estimated for each unit. Exposed substrate included areas of dry exposed substrate not accounted for in measurements of unit length or mean width. This allowed for a more accurate surface area calculation of the available wetted trout habitat.

Snorkelers' trout size estimations were calibrated after snorkeling the first habitat unit and subsequently every tenth unit. Three randomly chosen PVC pipes of known lengths were tossed into the unit, after snorkeling was completed, and sampled by the snorkeler. The snorkeler estimated the size bin of each pipe and then confirmed with the data recorder. If an incorrect estimate was given, calibration was repeated until the snorkeler accurately estimated the sizes of all three pipes.

Water and air temperatures were measured with a thermometer at the beginning of each survey day and subsequently after every tenth unit surveyed.

All data was entered into a computer database and analyzed using R (version 3.4.1, R Core Team 2017) and R Studio (version 1.0153, RStudio, Inc 2016). To examine trout relative abundances, trout density was calculated in three ways, including mean number of trout per unit, mean number of trout per foot, and mean number of trout per square foot. To evaluate trout life stage diversity, the total number of trout per size class was calculated. To examine wetted habitat the total length surveyed, mean unit length, total unit area, mean unit area, mean unit depth, mean unit maximum depth, total unit volume, and mean unit volume were calculated. To quantify available trout cover, the mean percent of habitat units containing trout cover and the mean percent each cover type comprised was calculated. Trout cover use was examined by calculating the total number of trout observed using each cover type. For each mean the standard error was calculated.

Results

Matilija Creek was surveyed from July 25, 2018 to September 20, 2018, for 6.9 miles (36,643 ft). A total of 23,282 ft of stream length was snorkeled with a mean unit length of 35.0 ± 2.0 ft (mean ± SE) and a mean unit width of 7.9 ± 0.2 ft. The total unit area snorkeled was 207,961 ft^2, with a mean unit area of 312.7 ± 23.8 ft^2 (mean ± SE). A total of 663 habitat units were snorkeled. Of the snorkeled units, 45.9% (n=304) were classified as flatwaters, 35.1% (n=233) as pools, and 19.0% (n=126) as riffles. The mean depth of units surveyed was 0.6 ± 0.0 ft (mean ± SE) and the mean maximum depth of units was 1.1 ± 0.0 ft. The total volume snorkeled through the course of the survey was 119,936 ft^3, with a mean unit volume of 180.4 ± 16.1 ft^3 (mean ± SE).

The mean percentage of available trout cover by surface area in surveyed units was 27.1 ± 0.6% (mean ± SE), with 72.9 ± 0.6% open. Cover in Matilija Creek consisted predominantly of cobble/boulder (61.6 ± 0.8% [mean ± SE]). Bubble curtain made up 17.7 ± 0.6% (mean ± SE) of the total cover and aquatic vegetation made up 11.4 ± 0.6%. Root mass, small woody debris, bedrock, terrestrial vegetation, other/artificial cover, large woody debris, and soil undercut each made up less than four percent of the total mean cover (Table 1).

Water temperatures recorded using thermometers ranged from 60^{o}F to 80^{o}F at the beginning of surveys to 73^{o}F to 89^{o}F by midafternoon. The mean water temperature recorded over the course of the survey was 76.7 ± 0.2^{o}F (mean ± SE).

Two *O. mykiss* were observed through the course of this snorkel survey, both under cobble/boulder cover and estimated to be between 6 to 7.99 inches in length (Figure 2). Species of concern observations recorded resulted in 150 Arroyo Chub (*Gila orcutti*), one Three-spined Stickleback (*Gasterosteus aculeatus*), 17 Western Pond Turtles (*Actinemys marmorata pallida*), and 12 Two-striped Gartersnakes (*Thamnophis hammondii*). Numerous California Treefrogs and Baja California Treefrogs (*Pseudacris* spp.) and tadpoles were observed during this survey, although counts were not recorded.

Additionally, approximately 250 juvenile black bass (*Micropterus* sp.), an invasive species in Matilija Creek, were observed throughout the first 0.57 miles of the survey reach.

Table 1. Mean Percent and standard error of habitat unit cover types recorded during the 2018 Matilija Creek snorkel survey.

Cover Type	Mean Percentage (%)	Standard Error (±%)
Open	27.13	0.59
Covered	72.87	0.59
Cobble/Boulder	61.59	0.76
Bubble Curtain	17.74	0.59
Aquatic Vegetation	11.36	0.57
Root Mass	3.47	0.26
Small Woody Debris	2.68	0.22
Bedrock	2.14	0.36
Terrestrial Vegetation	0.74	0.17
Other / Artificial Cover	0.17	0.05
Large Woody Debris	0.08	0.06
Soil Undercut	0.03	0.02

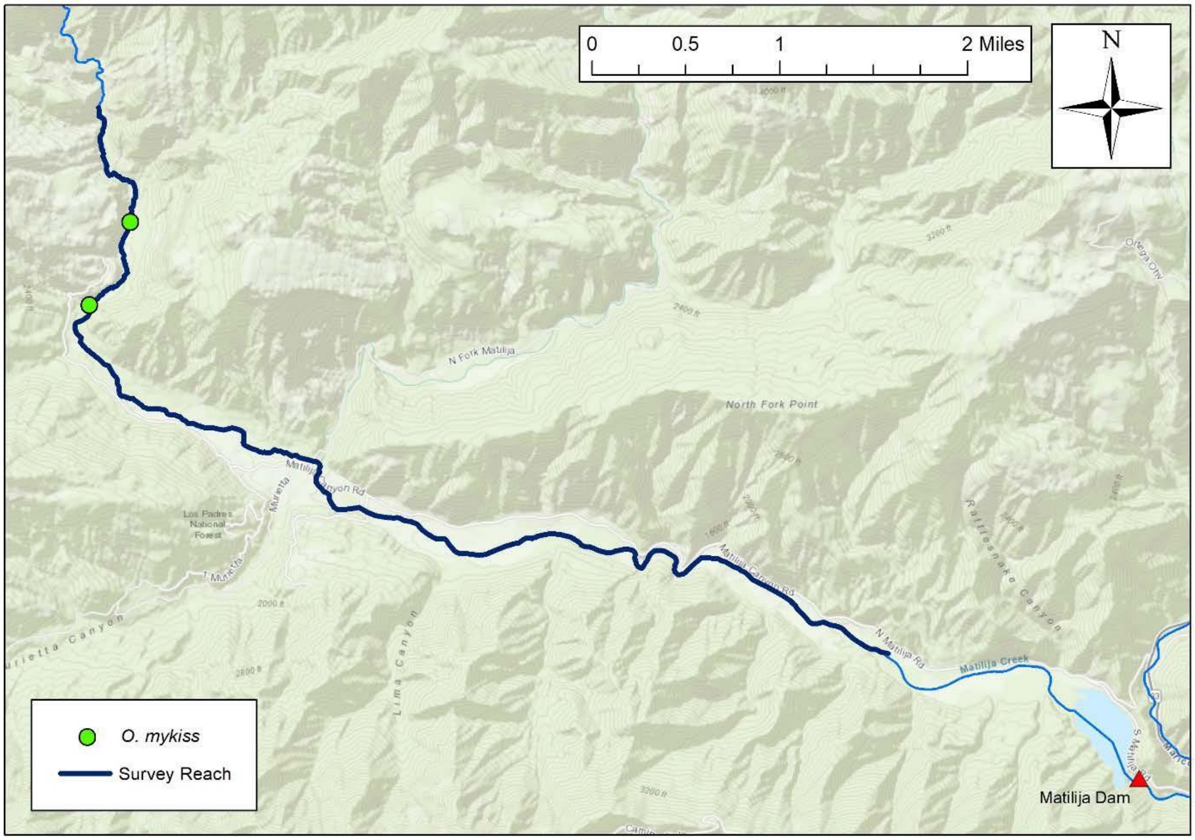
Table 2. A comparison of survey data between surveys conducted in 2017 and 2018 in Matilija Creek. The 2018 survey reach extended 0.8 miles (4,224 ft) further than the 2017 survey reach.

	2017	2018
Total Length of Survey Reach (ft)	32,419	36,643
Total Length of Units with a Max Depth Greater than 0.7 ft (ft)	27,990	23,282
Total Number of Units with a Max Depth Greater than 0.7 ft	1,009	663
Total Number of Pools with a Max Depth Greater than 0.7 ft	618	233
Total Number of Flatwaters with a Max Depth Greater than 0.7 ft	269	304
Total Number of Riffles with a Max Depth Greater than 0.7 ft	122	126

Table 3. A comparison of mean habitat unit measurements recorded in Matilija Creek between surveys conducted in 2017 and 2018.

Habitat Unit Measurement	2017		2018	
	Mean	SE	Mean	SE
Length (ft)	27.74	0.97	35.01	1.95
Width (ft)	11.33	0.19	7.94	0.16
Mean Depth (ft)	0.71	0.01	0.58	0.01
Max Depth (ft)	1.31	0.02	1.10	0.02
Area (ft^2)	335.68	24.20	312.72	23.84
Volume (ft^3)	322.88	30.20	180.35	16.61

<u>Figure 2.</u> Map of the Matilija Creek snorkel survey reach. The locations of the two *O. mykiss* observations are indicated by green circles.



Discussion

The entire 6.9 mile surveyed portion of the Matilija Creek was wetted at the start of this survey. A total of 663 habitat units comprising 23,282 ft were snorkeled within the stream reach and just two *O. mykiss* observed. Flatwaters were the most common habitat type recorded, comprising 45.9% (n=304) of units snorkeled. Pool and riffle units made up 35.1% (n=233) and 19.0% (n=126) of the recorded habitat units respectively. Water depth was limited throughout the survey reach, with a mean unit depth of 0.6 ± 0.0 ft (mean ± SE) and a mean maximum unit depth of 1.1 ± 0.0 ft (mean ± SE). The deepest point measured over the course of the survey was 4.1 ft and occurred in a natural pool formed by the large waterfall at the end of the survey reach.

Two *O. mykiss* were observed within the Matilija Creek survey reach during the 2018 snorkel survey. Both trout were observed in pools using boulders as cover. However, no conclusions can be made about *O. mykiss* habitat type and cover utilization due to the small sample size. The data show and overall lack of cover availability and complexity through the Matilija Creek survey reach. On average, habitat units contained much more open area than covered, with 72.9 ± 0.6% (mean ± SE) open and 27.1 ± 0.6% covered. Of the available cover recorded, the majority consisted of cobble/boulder (61.6 ± 0.8% [mean ± SE]). Bubble curtain and aquatic vegetation made up 17.7 ± 0.6% (mean ± SE) and 11.4 ± 0.6% of the available cover respectively, while all other cover types made up a combined 9.3% of the available cover. The low percentage of cover availability and lack of cover type complexity suggest that fish within the survey reach have limited protection from predation, competition, and high flow events (Allouche 2002).

Due to the small number of *O. mykiss* observed through the course of the survey, no inferences could be made about trout densities or distribution trends. While previous snorkel surveys have varied in survey methods, this number of observations indicate *O. mykiss* relative abundance is the lowest ever recorded in Matilija Creek (California Department of Fish and Wildlife and PSMFC, unpublished data). During a snorkel survey conducted in 2017, a total of 379 *O. mykiss* were observed. During double pass snorkel surveys conducted in 2014, a total of 184 *O. mykiss* were observed in the first pass and 115 *O. mykiss* in the second pass. Both the 2014 and 2017 survey reaches were just under a mile shorter than the 2018 survey reach. The drastic reduction in trout observations could be attributed to one or more factors, including the persisting drought conditions and impacts of the Thomas Fire and subsequent rain events. These events have caused significant changes within Matilija Creek, overall reducing and degrading available *O. mykiss* habitat.

Physical changes to the riparian zone and streambed of Matilija Creek have been noted in surveys following the Thomas fire and winter rain events. Redd surveys conducted by CDFW and PSMFC staff following the Thomas Fire and subsequent storms documented changes in stream channel location, depth, and width and significant amounts of riparian vegetation cleared by high flows and burned by the fire. As a result of the fire, boulders, debris, and sediment were easily shifted during the rain flows which led to sediment filling in much of the stream channel. This led to a reduction in overall streambed depth and likely accounted for the reduced number of pools documented during this study. While 2018 data show stream habitat unit type dominated by flatwaters with fewer pools and riffles, data collected from

Matilija Creek surveys conducted in 2017 show habitat characterized by numerous pools intermixed with riffle and flatwater units (Table 2). The 2017 survey documented 30 pools with a depth of 3 feet or greater, while the 2018 survey found only 3 pools within this same depth range. In addition to changes in habitat type composition, our data show an increase in mean habitat unit length along with a decrease in mean channel width and mean and maximum unit depths from the previous year (Table 3). While shallow riffles and flatwaters are suitable habitat for *O. mykiss* fry and small juveniles due to the protection they provide from predation and competition, larger adults require pool habitat in order to thrive due to protection provided from terrestrial predation and lower velocities which contribute to energy conservation (Raleigh et al. 1984; Rosenfeld and Boss 2001). The reduced stream depth and number of pools limit the available habitat for adults to access in future spawning seasons.

Water temperatures varied greatly throughout the survey. As expected for the warm summer months in which this survey was conducted, temperatures rose throughout the survey days, with recorded temperatures ranging from 60^{o}F to 89^{o}F. Although southern California *O. mykiss* strains have shown the ability to survive higher maximum temperatures, these daily maximum temperatures recorded in large portions of the survey reach are well above the accepted 75.2^{o}F (24^{o}C) lethal temperature for *O. mykiss* (Spina 2007). While the entire survey reach was wetted at the time of the survey, miles of creek contained shallow habitat units with little to no riparian vegetation or canopy cover. These portions of creek saw the greatest temperature fluctuations and highest daily maximum temperatures. These stretches of open, shallow habitat were seen in parts of the creek that have been historically observed to dry out in the summer months as well as parts of the creek in which the 2018 winter debris flow destroyed the riparian canopy and altered the stream channel. The two *O. mykiss* were observed in heavily exposed and altered portion of creek, in small pools that had seeps of cool underground water. In the pool in which the first *O. mykiss* observation was made, the water temperature under the boulder that the fish was using as shelter measured 68^{o}F while the rest of the pool measured 83^{o}F. These observations indicate that *O. mykiss* in Matilija Creek were dependent on habitat that provided thermal refuge from the potentially lethal maximum daily temperatures recorded throughout the survey. The high water temperatures observed in the shallow, uncovered portions of Matilija Creek would restrict *O. mykiss* movement and survival at the time of the survey.

While snorkel surveys are an ideal method for collecting in-water data, there are limitations. One potential limiting factor is the dependency of the observational data collected on the individual snorkeler. To minimize error, each snorkeler was trained according to the protocol used. Differences in snorkeler observations are possible due to variable observation probabilities. Water depth is one such factor that can influence snorkeler observations. Due to the changes in the streambed following the fire and rain events, many units contained shallow sections that were difficult to snorkel effectively.

This study aimed to describe *O. mykiss* relative abundance and stream habitat in Matilija Creek in 2018 following the December 2017 Thomas Fire and subsequent winter rain events. Our results found a reduction in wetted habitat depth and complexity and elevated water temperatures contributing to freshwater habitat not suitable for *O. mykiss* persistence. We attribute these changes to a loss of canopy cover and increased sedimentation which reduced water depths and increased solar thermal heating.

In order to make reliable population abundance estimates, electrofishing surveys are typically conducted to calibrate snorkel counts (Hankin 1984). However, the use of electrofishing to sample *O. mykiss* is ill-advised in high stress environments including elevated water temperatures. Therefore, future monitoring efforts will likely rely on snorkel surveys to continue collecting data on *O. mykiss* relative abundance and habitat availability. These data will serve as important indicators of *O. mykiss* repopulation in Matilija Creek.

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Appendix

Figure A.1. Habitat unit in Matilija Creek located approximately 1.4 miles from the survey start. Images of this unit were taken (a) during snorkel surveys conducted in 2017 and (b) during surveys in 2018 following the Thomas Fire and subsequent winter rain events.

(a)

(b)

Figure A.2. Habitat unit in Matilija Creek located approximately 1.9 miles from the survey start. Images of this unit were taken (a) during snorkel surveys conducted in 2017 and (b) during surveys in 2018 following the Thomas Fire and subsequent winter rain events.

(a)

(b)

Figure A.3. The habitat unit in which the first *O. mykiss* was observed during the 2018 Matilija Creek snorkel survey.

Figure A.4. One of the two southern California steelhead (*Oncorhynchus mykiss*) observed during the 2018 snorkel survey in Matilija Creek. This was the trout observed in the habitat unit pictured above.

Table A.1. Table of the cover types used to quantify the amount of trout cover available within a unit (percentage) and the type of cover being used by trout observed during snorkeling.

Cover Type	Description
Open/No cover	Percentage of the unit that is open and without trout cover. Trout are not hiding, instead milling or swimming in an open area of the unit.
Cobble/Boulder	Rocks less than the size of a Volkswagen Beetle. This category includes instances in which a 3-inch trout could hide in the crevices of a boulder cluster and underneath the ledge of the boulder.
SWD	Small Woody Debris. Fallen (dead) twigs, leaves, tree-related debris, loose roots (“free-wheeling”), and logs less than 12 inches in diameter or less than 6 feet long that is in the water and capable of providing cover to at least a 3-inch fish.
LWD	Large Woody Debris. Logs at least 12 inches in diameter and at least 6 feet long touching the water and capable of providing cover to at least a 3-inch fish.
Bedrock ledge	Rocks larger than a Volkswagen Beetle that overhang the water such that a 3 inch trout could hide underneath (approximately 6 inches deep or greater).
Terrestrial vegetation	Any live, terrestrial vegetation touching or overhanging within 1-foot of the water's surface that is large or complex enough to hide a 3-inch trout.
Aquatic vegetation	Any live, aquatic vegetation that is large or complex enough to hide a 3-inch trout.
Bubble curtain	Bubbles or agitated water created by flow that could provide cover a 3-inch trout.
Root mass	A mat or cluster of live roots (e.g. willow mats) that could provide cover to a 3 inch trout.
Soil Undercut	An area along the margins of the unit comprised mostly of soil that has eroded only underneath the surface to create a ledge. This undercut should be able to hide a 3 inch trout (approximately 6 inches deep or greater).
Other	Snorkeler could not identify the cover type used by the trout, or the cover type used did not fit into the above categories. Details should be included in the comments section. This category should very rarely be used.