Sonar monitoring of southern California steelhead in Santa Barbara and Ventura Counties

2017 Annual Report for the California Department of Fish and Wildlife

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November 2017

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ABSTRACT

Obtaining reliable abundance estimates for endangered Southern California steelhead trout (*Oncorhynchus mykiss*) populations is a critical step toward assessing population status and trends in watersheds where steelhead recovery is a high priority (NMFS 2012). Dual Frequency Identification Sonar (DIDSON) and Adaptive Resolution Imaging Sonar (ARIS) cameras are the best available methods for gathering these data under the variety of dynamic southern California stream conditions (e.g. high turbidity, flashy hydrology, etc.) observed during the steelhead migration season. Standard DIDSON units were operated in high frequency mode (1.8 MHz) and used to document wildlife observations in Salsipuedes Creek, Carpinteria Creek and the Ventura River beginning in December of 2016 through May of 2017 when flow and connectivity thresholds were met. An ARIS unit operating in high frequency mode (3.0 MHz) was deployed in parallel with DIDSON at the Ventura River site to compare performance under southern California environmental conditions. A total of 5,398 hours of sonar footage were recorded from January 18, 2017 to May 30, 2017 for all three sites. Brief power outages and software malfunctions had minimal effects on operational efficiency (Table 1). All wildlife observations greater than 30 cm in length were recorded during data analysis. This process required an estimated 2,568 hours to complete. Sixty-two observations of targets measuring greater than or equal to 30 cm were recorded for Salsipuedes Creek, no observations were recorded in Carpinteria Creek and 26,389 observations of targets measuring greater than or equal to 30 cm were recorded in the Ventura River. Two observations in Salsipuedes Creek were designated as *O. mykiss* and measured 33 cm and 38 cm respectively. Both trout were observed swimming upstream and were not observed again. For the Ventura River site observations, 26,356 were classified as fish with 26,344 designated as Common Carp *Cyprinus carpio* and the remaining 12 as “unidentified fish species”. The mean $\pm$ SE for observed Carp lengths in cm was 45.68 $\pm$ 0.05 with a substantial 20,620 observed exceeding the expected minimum steelhead length of 40 cm (Figure 2).

INTRODUCTION

Southern California steelhead trout (*Oncorhynchus mykiss*) populations have undergone sharp declines throughout their range. Primary causes of this decline include the loss of freshwater and estuarine habitat due to water withdrawals and land use practices that have limited access to historical spawning and rearing areas (NMFS 2012). These practices, in combination with other anthropogenic factors, have contributed to steelhead trout populations occupying the area from the Santa Maria River to the Tijuana River at the U.S.-Mexico border being placed under protection by the U.S. Endangered Species Act in 1997 (ESA; NMFS 2012). ESA mandates require the implementation of a recovery plan to manage and recover the species (NMFS 2012). In 2012, the National Marine Fisheries Service (NMFS) produced a recovery plan designating the Santa Ynez River, Carpinteria Creek, and Ventura River as high priority systems for recovery action in southern California. Fish Bulletin 180, California Coastal Salmonid Population Monitoring: Strategy, Design and Methods, put forth by the California Department of Fish and Wildlife (CDFW) provides a blueprint for building effective monitoring programs to fulfill data needs as outlined in the NMFS recovery plan (Adams et al. 2011).

The California Coastal Salmonid Monitoring Plan (CMP) incorporates the concept of a Viable Salmonid Population (McElhany et al. 2000) which uses abundance, productivity, spatial structure, and diversity as parameters for assessing population viability (Adams et al. 2011). As described in Fish Bulletin 180, DIDSON can be used to provide adult abundance data in systems where traditional enumeration techniques are not feasible (Adams et al. 2011). Developed by Sound Metrics, DIDSON produces near video-quality imagery and allows for data collection under conditions where optical systems would fail, including at night and periods of high flow and turbidity when steelhead are likely to move. These conditions are commonplace in Southern California where flows are highly episodic resulting in dynamic hydrology. DIDSON cameras provide the most effective means of gathering quantitative data on Southern California steelhead abundance currently available. Furthermore, DIDSON allows for the passive collection of data, which avoids altering steelhead behavior or causing harm to an endangered species. Project findings address data requirements pertaining to abundance as described in the CMP.

This report summarizes the methodologies and findings of PSMFC efforts in DIDSON deployment, data collection, and data analysis in three focal watersheds. Findings will aid in the development of protocols specific to southern California and will inform resource managers on the status of steelhead populations in study systems.

Study Site

Salsipuedes Creek

Salsipuedes Creek is located southeast of the city of Lompoc in Santa Barbara County, California (Figure 1). It is the largest tributary to the lower Santa Ynez River and drains approximately 47.1 square miles (Santa Ynez River Technical Advisory Committee 2000). Salsipuedes Creek is 10 miles long; its confluence with the Santa Ynez River is located approximately 16.1 stream miles from the Pacific Ocean. The deployment site is located 0.6 stream miles upstream of the confluence with the Santa Ynez River.

Salsipuedes Creek experiences a Mediterranean climate consisting of long dry summers and brief, high intensity winter storms (NMFS 2012). Salsipuedes Creek flows through a deeply incised channel with banks composed of fine sediments that widens as it approaches its confluence with the Santa Ynez River (Block and Francis 2013, unpublished). While the Santa Ynez River exhibits intermittent flow and drying during the summer, Salsipuedes Creek may remain wetted. Perennial flow is supported by groundwater, while winter flows and connectivity to the ocean are highly dependent on precipitation. Intense and short-lived winter storms typically generate flows that connect Salsipuedes Creek with the Santa Ynez River.

Site selection was based on channel morphology, power availability and site security. The site has a trapezoidal channel that allows for complete ensonification of the streambed. Site substrate is fairly uniform, and composed primarily of sand and cobble. This substrate provides minimal cover, making fish easier to detect. The deployment location is in a riffle to discourage milling behavior. Site power is provided by a mobile solar trailer and battery bank capable of powering all equipment necessary for long-term deployments. The site is located on private property and accessed via a gated, private road resulting in a high-level of site security. The DIDSON is located immediately downstream of a migrant trap operated by the Cachuma Operation and Maintenance Board allowing for comparisons between DIDSON and trap data.

Carpinteria Creek

Carpinteria Creek flows through the city of Carpinteria located in Santa Barbara County, California (Figure 1). It drains approximately 17 square miles and contains approximately 7 miles of anadromous waters. The deployment site is located approximately two stream miles upstream of the Pacific Ocean.

In contrast to larger river systems in southern California that flow through gaps in coastal ranges (e.g., the Ventura and Santa Ynez Rivers), Carpinteria Creek is a short coastal stream draining mountains immediately adjacent to the ocean (NMFS 2012). Extensive sections of the main stem remain dry outside of winter flows, and serve primarily as migration corridor to perennial, upper reaches. Connectivity from the upper watershed to the ocean is highly dependent on rainfall and limited to periods following storm flows. A seasonal sand bar restricts access to the creek until displaced by rising flows.

The channel profile and dominant substrate allow for full ensonification of the wetted channel. The monitoring site is located along a seasonally wetted, migration corridor, which limits the potential for milling behavior. The site is located on U.S. Forest Service Property in close proximity to firefighting personnel residences. As a result, the site is relatively secure. Power is provided by an extension cord running to an adjacent residence.

Ventura River

The Ventura River flows through the cities of Ojai, Casitas Springs and Ventura in Ventura County, California (Figure 1). It drains approximately 227 square miles and contains approximately 35 miles of anadromous waters (California Department of Forestry and Fire Protection 1999). The deployment site is located approximately five stream miles upstream of the Ventura estuary and Pacific Ocean.

The Ventura River watershed is characterized by a Mediterranean climate and mountainous interior that flows across a coastal terrace before reaching the Pacific Ocean. Stream flows are highly dependent on rainfall and extensive sections of the main stem exhibit intermittent flows and drying over summer. Tributaries in the upper watershed exhibit perennial flow supported by groundwater through fractured rock along geologic fault lines (NMFS 2012). A seasonal sandbar prevents access to the watershed until the first large storm event of the season. Without recurrent precipitation, flows may drop quickly and access to the perennial upper watershed may be limited to short periods.

This site's channel profile and substrate composition allow observation of the entire channel bottom within the sonar's field of view. The site is located on property owned and operated by the Ojai Valley Sanitation District. Sanitation district staff facilitated the installation of a powered storage container that houses both equipment and staff when onsite. The storage container is located within a perimeter fence and behind two locked, electronic gates. Project staff remain on site for the initial 48 hours of sonar deployment to ensure equipment is functioning properly and that camera settings are optimized to changing stream conditions.

METHODS AND MATERIALS

Cameras were deployed once water depth (i.e., $\geq$ 30 cm) and connectivity thresholds (i.e., continuous surface water connectivity from the deployment site to the ocean) were met in study systems, beginning in December of 2016 through May of 2017. Cameras remained deployed as long as flow conditions allowed for fish passage from the ocean to the monitoring site and connectivity with the ocean was maintained. In anticipation of large storm events, cameras were removed from the stream to prevent loss of or damage to equipment. Cameras were re-deployed once stream flows returned to a safe working level. In the Ventura River, cameras remained deployed following river mouth closures to allow time for any fish that had entered the system time to reach monitoring sites while connectivity was maintained.

Data Collection

Salsipuedes Creek

A standard DIDSON unit (Sound Metrics, Lake Forest Park, Washington) operating in high frequency mode (1.8 MHz) was used to document wildlife observations in Salsipuedes Creek from January 23, 2017 to April 24, 2017 when conditions (e.g., stream depth and flow) allowed.

The camera was mounted to a track system allowing it to be moved up and down the bank without staff having to enter the stream channel under hazardous conditions. The camera was first housed in a Sound Metrics manufactured silt box to prevent sediment from obscuring the lens. The silt box was then attached to an X2 pan and tilt rotator (Sound Metrics, Lake Forest Park, Washington). The rotator was mounted to an aluminum sled and placed on the track where it could be raised and lowered by a winch tethered to the sled by aircraft cable. The sled moves on ball bearings held captive by the track to prevent the sled from being dislodged. The track is 9 meters in length and follows the river right bank's profile. The track is installed on steel legs set into the bank. The camera is set back into the bank at a distance of 1.25 m to prevent targets from passing to close to the camera to be observed clearly. The camera was positioned perpendicular to flow and as close to the substrate as possible while still maintaining a clear view of the whole stream channel. This was done both due to the assumption that migrating steelhead will swim close to the bottom where water velocities are lower (Quinn 2005) and to limit the potential for damage to the camera by floating debris.

The camera was controlled by a topside box connected to the camera by a 60 m DIDSON sonar cable. The topside box was connected to a Dell Toughbook running DIDSON software to interface with the camera and adjust record settings. Focus and frame rate were set automatically by the software based on camera settings. Gain was left at the default maximum value. Window length was set to 10 m for all deployments to ensure full channel coverage. This was determined by the stream's wetted width. Footage was captured in 20-minute files written to an external hard drive. This was done to limit loss of data in the event of a file being lost or becoming corrupted. Support electronics and components were held in a locked, mobile solar trailer located safely outside the floodplain as suggested by Pipal et al. 2010.

Site visits were conducted on a regular basis during deployment to ensure proper camera operation under continually changing streams flows and to exchange hard drives as needed.

Carpinteria Creek

A long-range DIDSON 300 m unit (Sound Metrics, Lake Forest Park, Washington) operating in high frequency mode (1.2 MHz) was used for all deployments in Carpinteria Creek from January 20, 2017 to March 23, 2017. The camera was housed in a Sound Metrics manufactured silt box to prevent lens fouling and a custom aluminum box to prevent damage by floating debris. The aluminum box was secured with a heavy-duty padlock. The camera was attached to a steel, sled foot A- frame mount using a RAM double socket ball joint as described by Larson 2013. The sled was held in place by gravel bags placed on the sled feet and by an aircraft cable tether running from the housing's padlock to a large nearby tree. The cable served as a safeguard against theft and to prevent equipment from being swept away. The mount was flanked by berms composed of native cobbles to direct fish to an appropriate imaging range and to prevent fish from passing behind the camera.

The camera was positioned along the river right bank, facing perpendicular to flow. The camera was set at as close to the bottom as possible while still fully ensonifying the channel. This was necessary to accommodate persistent, shallow depths (i.e., $\leq$ 0.6 m) throughout the season. The angle of the camera was level with the water's surface.

The DIDSON was connected to a topside control box via a 60 m DIDSON cable. The topside box was in turn connected to a Dell Toughbook laptop to interface with the camera and adjust settings. Focus and frame rate were set automatically by the software based on camera settings. Gain was left at the default maximum value. Window length was set to 5 m for all deployments, which was reflective of the narrow channel width. Footage was captured in 20-minute files written to an external hard drive. All support electronics were powered by an uninterruptible power source (UPS) to provide short term battery back up in the event of brief power outages. The UPS was powered by an adjacent private residence via an extension cord. Support electronics and components were held in a locked, weatherproof job box located outside the flood plain.

Site visits were conducted on a daily basis throughout deployment to ensure proper camera operation under continually changing streams flows.

Ventura River

A standard DIDSON 300 m unit (Sound Metrics, Lake Forest Park, Washington) and an ARIS Explorer 3000 (Sound Metrics, Lake Forest Park, Washington), both operating in high frequency mode (1.8 MHz and 3.0 MHz respectively), were used for all deployments in the Ventura River from January 18, 2017 through May 30, 2017. Units were deployed in parallel to compare functionality under southern California environmental conditions. The DIDSON was mounted on an A-frame as described for Carpinteria Creek deployments. The ARIS was housed in a custom stainless steel box to protect against damage by floating debris. The stainless steel box and ARIS were attached to an AR2 dual-axis pan/tilt rotator to aim the camera. The AR2 was then affixed to an A-frame mount using manufacturer-supplied hardware. Both A-frames were held in place by gravel bags placed on their sled feet and by aircraft cable tethers running from the A-frames to adjacent t-posts anchored into the substrate. To safeguard against theft and potential loss of equipment during peak flows, cameras were tethered to large nearby trees via aircraft cable and to an earth anchor installed outside the stream channel with security chain. As an added layer of security motion detecting trail cameras with night vision capability were installed to record any potential attempts at vandalism, tampering, or theft. Deflection panels, consisting of aquaculture mesh fastened to PVC frames, were anchored up and downstream of the cameras on both banks. These panels both prevented fish from passing behind cameras and guided them to an optimal imaging range.

The DIDSON camera was connected to a topside control box via a 60 m DIDSON cable while the ARIS was connected to a command module via a 150 m ARIS cable. Both were connected to Dell Toughbook laptops running DIDSON and ARIS software respectively to interface with the camera and adjust record settings. Dell Toughbook laptops were used to run DIDSON and ARIS software. Focus and frame rate were set automatically by the software based on camera settings. Gain was left at the default maximum value. DIDSON camera window length was set to either 10 m or 5 m depending on water levels. ARIS window length remained at 5 m for all deployments to keep the camera operating in high frequency mode. Footage was captured in 20-minute files and written to external hard drives. Topside electronics and components were powered through UPS's connected to permanent onsite power.

Due to security concerns, the site was staffed 24 hours per day for the initial 48 hours of deployment. For the remainder of deployments site visits were conducted on a daily basis to ensure proper camera operation. Prior to removing the cameras, surveys were conducted to verify that migration from the ocean to the camera location was no longer feasible.

Data Analysis

Sonar data files were analyzed using DIDSON and ARIS software. The echogram function in conjunction with background subtraction was used for both DIDSON and ARIS files to expedite footage review. Echograms produce a visual representation of the entire file by compressing all beams for a given frame into a single pixel width along across the full image range (Sound Metrics 2012). Background subtraction uses a Sound Metrics proprietary algorithm to remove static objects from processed footage. These functions make moving objects easier to detect, highlight motion tracks and allows users to view 800 to 1000 frames at a time depending on software settings.

All wildlife observations greater than 30 cm in length were recorded. This is the minimum size needed to reliably designate species and is below the California Department of Fish and Wildlife's listed lower size limit for steelhead of 40 cm (California Department of Fish and Wildlife 2017). Targets were measured using the box method in both programs. The box method requires the reviewer to pause the footage before dragging a box around the object and recording either the value for diagonal or width depending on the object's orientation relative to the camera. For each observation, up to three measurements were taken from different frames and then averaged. Reviewers assigned fish observations to species when possible based on behavioral and morphological cues. In instances where this was not feasible, observations were classified as "unidentified fish species". Observations of non-target aquatic species were designates as either "unidentified terrestrial species", "frog", "turtle", "waterfowl", "snake", "unidentified fish species" or "unknown". In instances where a reviewer was unsure of species designation, files were flagged for further review by a lead biologist. For cases where this occurred in the Ventura River, ARIS footage taken during the same time period was reviewed to take advantage of the increased image quality. For each observation, length, direction of travel, species, timestamp and pertinent meta data (e.g. site location, date of recording, filename, reviewer name, and date viewed) were recorded.

Observations were entered into an Access database and imported into RStudio (R Core Team, 2016) for QA/QC procedures and analysis. Frequency distribution and SE for Ventura River fish observations greater than or equal 30 cm were examined in RStudio and graphed in Excel. Operational efficiency per DIDSON deployment was calculated by dividing the actual time data were recorded by total possible time data could be recorded as described by Larson 2013.

RESULTS

A total of 5,398 hours of sonar footage were recorded from January 18, 2017 to May 30, 2017 for all three sites. Extended sonar deployments in all focal streams were made possible by persistent base flows leading to prolonged opportunities for steelhead to migrate from the ocean to spawning habitat. Peak winter flows reached levels that required cameras to be removed from deployment sites to prevent loss or damage to equipment. High flows altered channel profiles at deployment sites requiring adaptation of camera angles and placement. Brief power outages and software malfunctions had minimal effects on operational efficiency (Table 1). Footage was of sufficient quality to reliably detect steelhead-sized targets throughout the deployment season, with the exception of short-term periods where extreme turbidity limited the sonar's range. Sonar footage analysis required an estimated 2,568 hours to complete.

Salsipuedes Creek

A season total of 1,601 hours (70 days) of sonar footage were recorded in Salsipuedes Creek over the course of three deployments (1). Sixty-two observations of targets measuring greater than or equal to 30 cm were recorded. Of these observations, two were designated as *O. mykiss* based on body shape, size and swimming motion. The remaining observations were classified as either "Beaver", "Frog", "Snake", "Turtle", "Waterfowl", "Unknown terrestrial species" or "Unknown". The first *O. mykiss* observation occurred on February 26, 2017 at 0410 hours. The trout was observed swimming upstream and measured 33 cm in length. The second *O. mykiss* observation occurred on March 13, 2017 at 1840 hours. This trout was observed swimming upstream and measured 38 cm. Neither fish was observed returning downstream.

Carpinteria Creek

A season total of 875 hours (37 days) of sonar footage were recorded in Carpinteria Creek over the course of five deployments; however, no observations of targets greater than or equal to 30 cm were recorded.

Ventura River

A season total of 2,920 hours (123 days) of sonar footage were recorded in the Ventura River over the course of three deployments. A total of 26,389 observations of targets measuring greater than or equal to 30 cm were recorded. Of these observations, 26,351 were designated as Common Carp *Cyprinus carpio* with the remaining 38 observations being classified as either "Frog", "Turtle", "Waterfowl" or "Unknown". The mean $\pm$ SE for observed Carp lengths in cm was 45.68 $\pm$ 0.05 and a substantial 20,625 of Carp observed exceeded the expected minimum steelhead length of 40 cm (Figure 2).

DISCUSSION

Observed carp lengths in the Ventura River generally coincide with what we would expect for migrating steelhead. Furthermore, physical characteristics and swimming behaviors used to differentiate between carp and steelhead are difficult to identify using sonar footage. These factors lead to a high degree of difficulty when making species designations for Ventura River fish observations. High carp density and observation frequency caused additional complications. These combined challenges increased the time needed to review Ventura River files. Of the estimated total 2,568 required to complete footage analysis, 2,040 were dedicated to Ventura River data. To address carp related complications, actions are being considered to conduct intensive, localized removal efforts at the monitoring site. If these efforts prove successful, footage review times may be greatly reduced. Actions are also being taken to modify Ventura River sonar deployment infrastructure to improve image quality. This will be accomplished by installing additional deflection panels on both banks to direct fish toward the center of the sonar's field of view where image clarity is best. These modifications increase the utility of sonar footage when making species designations by making morphological cues more obvious.

The 2016-2017 DIDSON deployment season was characterized by above average rainfall in all study systems leading to peak flows considerably higher than those observed in the previous five years (Table 3). These flows generated substantial debris flows and sediment discharge causing brief interruptions in data collection for both the Salsipuedes Creek and the Ventura River sites. DIDSON deployment in Salsipuedes Creek was delayed by three days following the highest recorded flow of the season (USGS 2017) when the lower six meters of the track was buried in sand and had to be excavated. Deployment of DIDSON and ARIS cameras in the Ventura River were similarly delayed following the same storm system due to extensive accumulation of woody debris. Storm flows also reformed stream channels at sonar deployment sites, which affected sonar performance. This had positive effects on Carpinteria Creek and the Ventura River sites where channel depths and streambed substrate were noticeably more uniform following peak flows. These changes made target detection easier because larger substrate and troughs in the streambed that had previously limited the DIDSON's viewable area were removed. The opposite occurred at the Salsipuedes Creek site, where the section of stream monitored by DIDSON was transformed from an extended riffle to a pool tail out. This had the effect of dramatically reducing stream depth making the first five meters of the image overly bright and limiting the sonar's ability to detect targets moving along the far bank. Regular site visits were essential to ensure that camera position and angle best suited evolving stream conditions throughout the deployment season at all sites.

Ventura River sonar camera operations in 2017 continued to demonstrate the differences between the DIDSON 300 unit and ARIS 3000 explorer, which were operated in parallel for the entirety of the data collection season. The DIDSON exhibited more consistent image quality and target detection across the entire stream channel under a wider range of stream conditions (e.g., turbidity levels and channel width) than the ARIS camera. When turbidity and stream width (i.e., less than five meters in order to keep the ARIS operating in high frequency mode) were at suitable levels, the ARIS image was noticeably superior to that of DIDSON. This was expected given that ARIS footage resolution is twice as high due its increased operating frequency. This increased frequency is the reason for ARIS' limitations regarding range and turbidity because higher frequencies degrade more rapidly with distance and increased suspended particulate concentration. ARIS' increased resolution also has a direct effect on file size. ARIS files are typically three times larger than comparable DIDSON files. This results in a substantial increase in time to process raw ARIS files for review relative to DIDSON files. For this reason, as well as the greater consistency in image quality and target detection, DIDSON footage was primarily used throughout the review process for the Ventura River site. ARIS files were reviewed in instances when a large fish was observed and species could not be confidently assigned based on DIDSON footage alone. The dual deployment of DIDSON and ARIS cameras had the additional benefit of providing redundancy in the event one of the cameras experienced technical difficulties so that gaps in data collection were kept to a minimum.

The two *O. mykiss* recorded in Salsipuedes Creek measured below the CDFW listed lower size limit for steelhead (40 cm) at 33 cm and 38 cm respectively. These sizes suggest that these fish derive from a resident life history, however further research is needed to explore relationships between growth rates and life history strategies in southern California before any meaningful conclusions can be inferred. Findings for sites in Carpinteria Creek and the Ventura River were supported by concurrent redd surveys in both watersheds, during which no steelhead were observed.

Figure 1. DIDSON monitoring site locations in Santa Barbara and Ventura Counties.

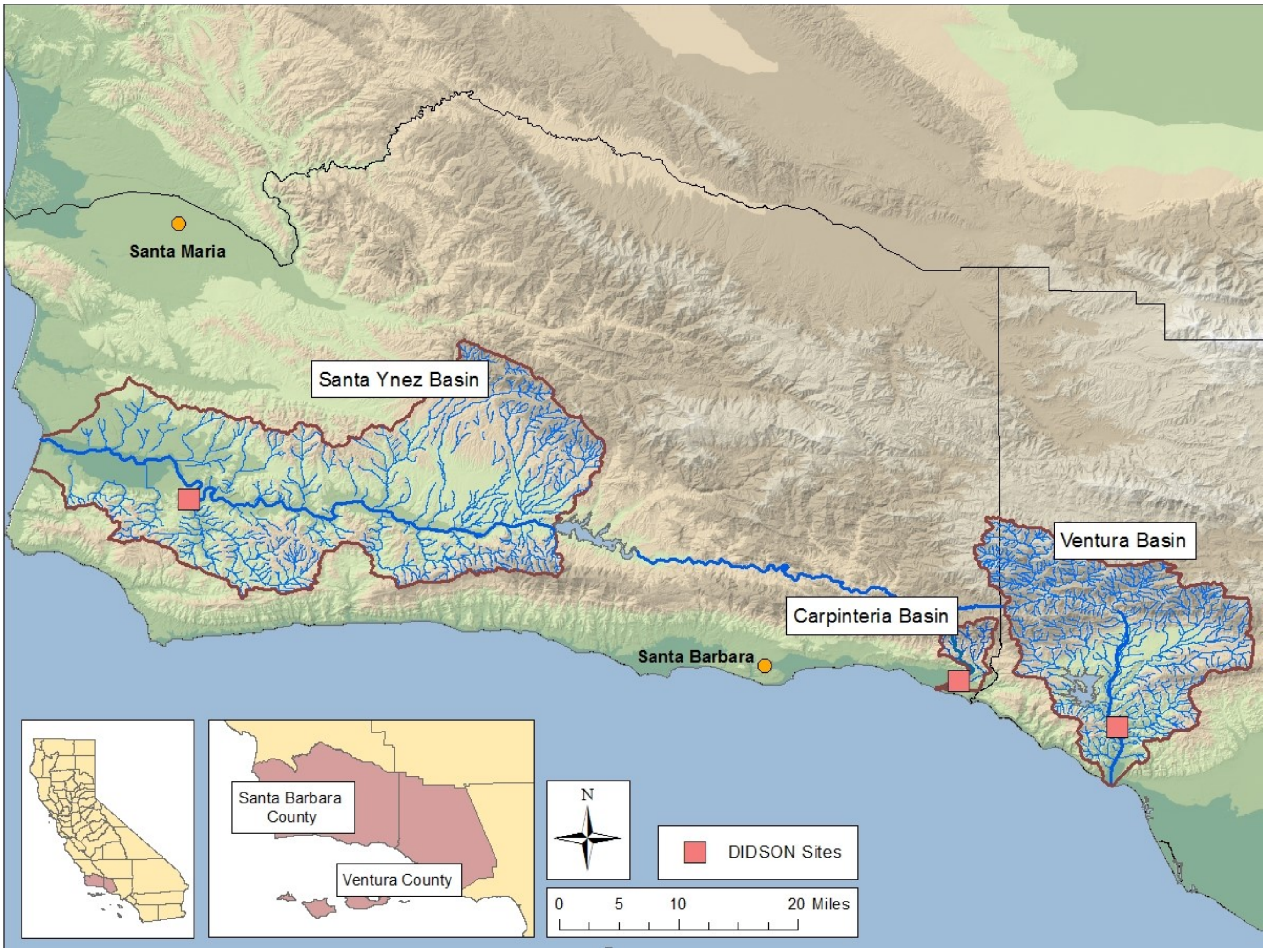

Figure 2. Frequency distribution of Common Carp *Cyprinus carpio* observations at the Ventura River DIDSON monitoring site with an average length greater than or equal to 30 cm (n = 26,351). Observations are grouped into size bins of two cm. Carp observations with an average length greater than or equal to 40 cm are shown in gray (n = 20,625).

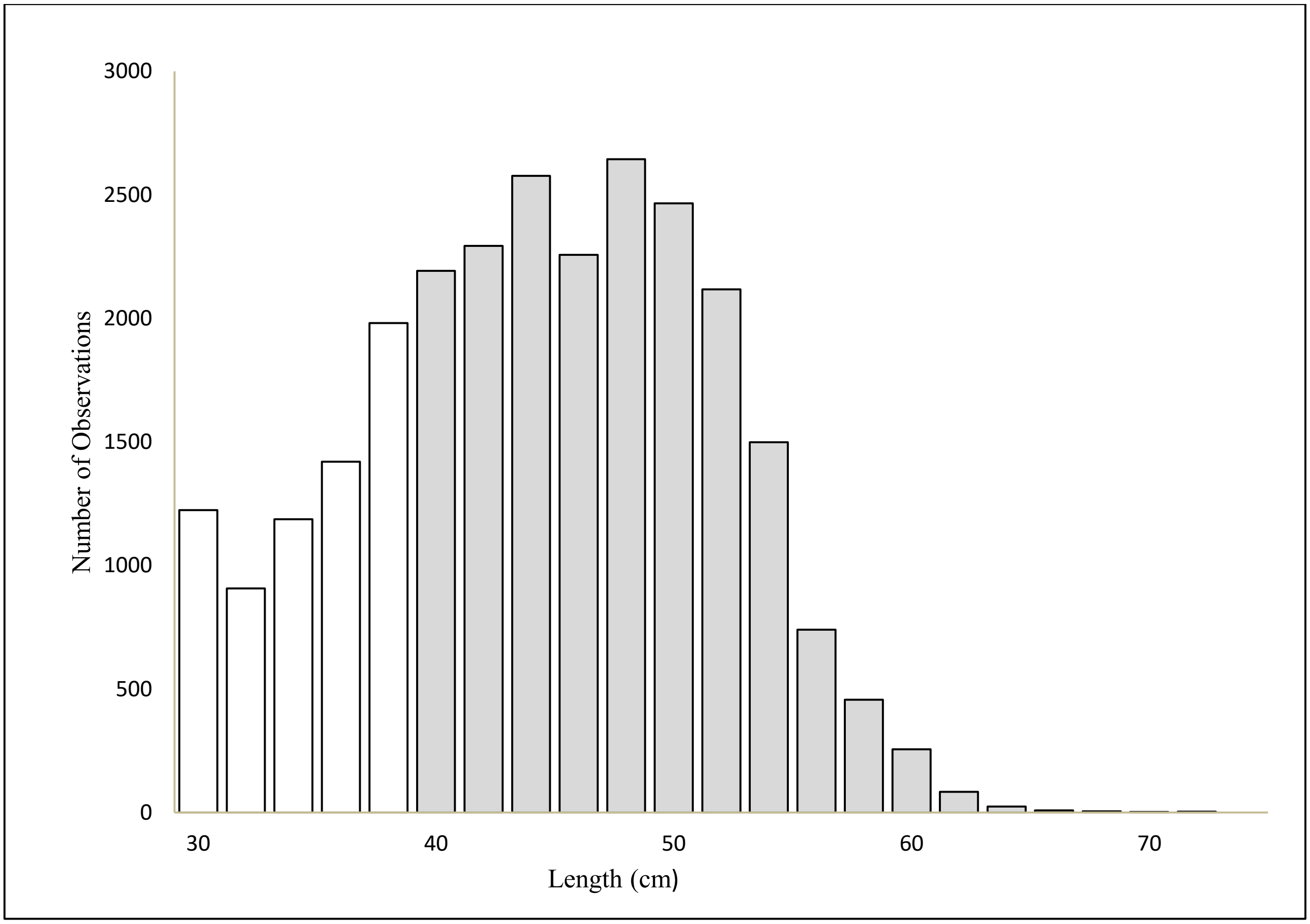

Figure 3. Salsipuedes Creek DIDSON deployment track system as seen during its last deployment in 2017 with key features labeled. (A) winch; (B) track; (C) cross-bracing cables; (D) deflection panels; (E) DIDSON/X2/sled assembly.

Figure 4. Carpinteria Creek DIDSON deployment infrastructure with key features labeled. (A) A-frame; B) DIDSON housed in a debris box and silt box; (C) gravel bags anchoring sled feet; (D) deflection panels; (E) security tether.

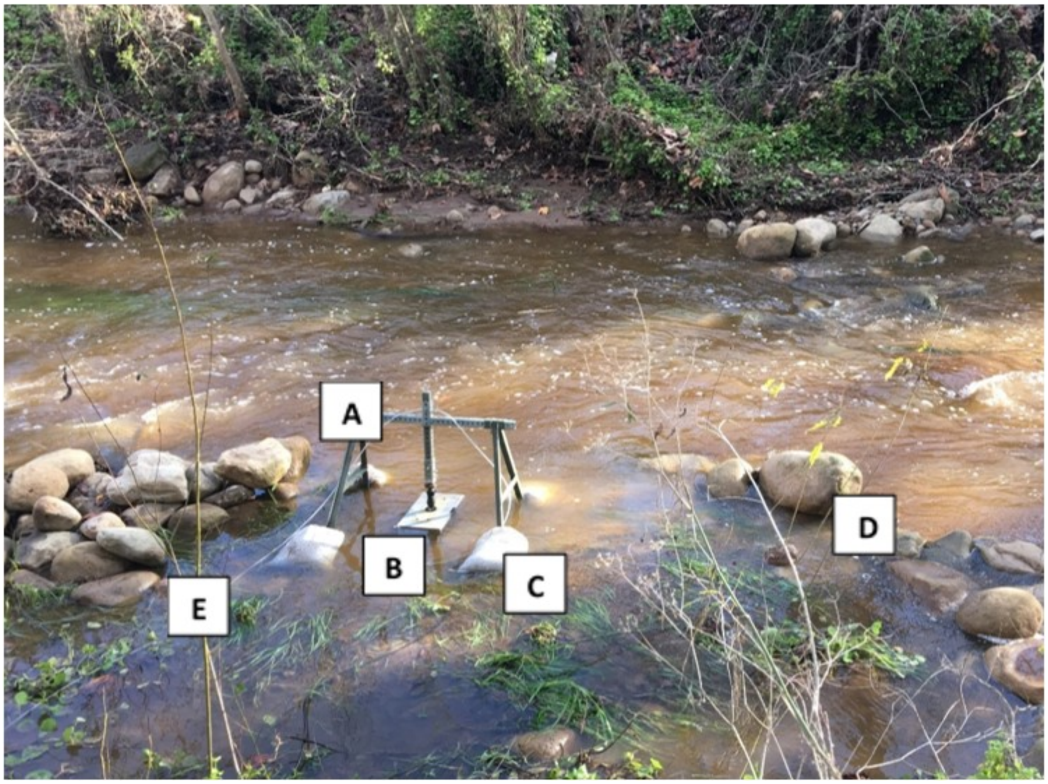

Figure 5. Ventura River DIDSON/ARIS monitoring site with key features labeled. (A) Deflection panels; (B) security tether; (C) paired deployment of DIDSON and ARIS.

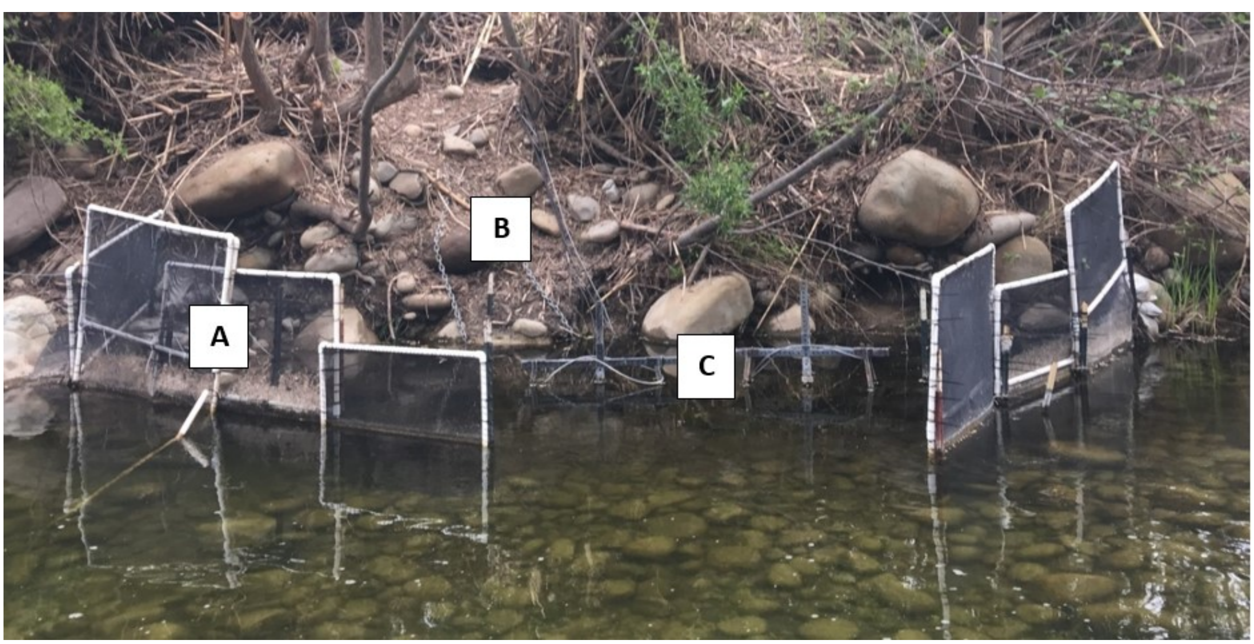

Table 1. Dates, durations and operational efficiencies of sonar camera deployments in 2017.

Deployment Site	Date In	Date Out	Days Deployed	Operational Efficiency
Salsipuedes Creek	1/23/2017	1/26/2017	3	100%
	2/10/2017	2/16/2017	6	100%
	2/22/2017	4/24/2017	61	95%
Carpinteria Creek	1/20/2017	1/21/2017	1	100%
	1/23/2017	1/26/2017	3	100%
	2/6/2017	2/16/2017	9	100%
	2/18/2017	3/13/2017	23	100%
	3/22/2017	3/23/2017	1	100%
Ventura River	1/18/2017	1/21/2017	3	100%
	1/23/2017	2/16/2017	24	100%
	2/22/2017	5/30/2017	97	99%

Table 2. Average flow in ft^3/s (mean ± SE) from December through May for years 2012 to 2017. (Ventura flow data provided by USGS site 11118500 (34.35222, -119.30750) located approximately 0.75 miles upstream of the Ventura River DIDSON monitoring site. Carpinteria Creek flow provided by USGS gauge 11119500 (34.40130, -119.48672) located approximately 0.25 miles upstream of the Carpinteria Creek DIDSON monitoring site. Salsipuedes creek flow data provided by USGS gauge 11132500 (34.58934, -120.40888) located approximately three miles upstream of the Salsipuedes Creek DIDSON monitoring site.)

Deployment Site	2012	2013	2014	2015	2016	2017
Salsipuedes Creek	2.14 ± 0.01	0.89 ± 0.01	0.64 ± 0.03	0.26 ± 0.01	0.44 ± 0.02	30.76 ± 2.09
Carpinteria Creek	0.06 ± 0.00	0.00 ± 0.00	0.06 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	6.60 ± 0.48
Ventura River	8.33 ± 0.04	0.86 ± 0.01	4.27 ± 0.68	1.27 ± 0.01	1.49 ± 0.09	91.58 ± 5.17

Table 3. Peak flows in ft^3/s recorded at USGS gages located upstream of DIDSON monitoring stations from 2012 to 2017.

Deployment Site	2012	2013	2014	2015	2016	2017
Salsipuedes Creek	18	8	158	90	92	7,840
Carpinteria Creek	11	3	37	3	2	1,970
Ventura River	180	5	3,180	4	906	21,300

ACKNOWLEDGEMENTS

Funding for this work was provided by the California Department of Fish and Wildlife Fisheries Restoration Grants Program. Field assistance was provided by The California Conservation Corps (CCC) Watershed Stewards Program, the NOAA/CCC Veterans Corps Fishery Program and the California Department of Fish and Wildlife. We gratefully acknowledge the landowners, whose cooperation and willingness to work with our staff made this project possible.

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