Dual-Frequency Identification Sonar (DIDSON) and Adaptive Resolution Imaging Sonar (ARIS) monitoring of southern California steelhead in Santa Barbara and Ventura Counties

2016 Annual Report for the California Department of Fish and Wildlife

Prepared by:

Sam Bankston[1]

Kyle Evans[1]

Dana McCanne[2]

Pacific States Marine Fisheries Commission[1]

California Department of Fish and Wildlife[2]

1933 Cliff Drive, Suite 27, Santa Barbara CA 93109

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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 NMFS designated high priority watersheds (NMFS 2012). Dual Frequency Identification Sonar (DIDSON) and Adaptive Resolution Imaging Sonar (ARIS) cameras, capable of producing near-video quality imagery, are the best available method for gathering data under a variety of dynamic southern California stream conditions (e.g. high turbidity, flashy hydrology, etc.). Standard DIDSON units were operated in Salsipuedes Creek, Carpinteria Creek and the Ventura River beginning in December of 2015 through May of 2016 when flow and connectivity thresholds were met. Persistent drought conditions combined with below average rainfall lead to relatively few deployable days (0, 4 and 20 days for each site respectively). An ARIS unit was deployed in parallel with DIDSON at the Ventura River site to compare performance under southern California environmental conditions. All collected digital sonar footage was analyzed for fish passage using DIDSON and ARIS provided software. No *O. mykiss* were detected at any of our sonar monitoring stations. ARIS and DIDSON cameras performed comparably in general, with the ARIS providing higher quality imagery leading to greater confidence in species designation under a particular subset of conditions (e.g. low turbidity and ideal aspect angle of targets relative to the lens).

INTRODUCTION

Southern California steelhead trout (*Oncorhynchus mykiss*) populations have undergone sharp declines throughout their range and remain at a fraction of their historical abundance. The Santa Ynez River for example, was once home to what was likely the largest steelhead run in southern California and supported a popular sport fishery (Mears 1947). 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). Agricultural development in southern California has historically had a major influence on water and land use and remains a major factor today as Ventura County is one of the most productive agricultural regions in the country with a 2014 gross value of $2.14 billion dollars (2014 Ventura County annual crop report). Land and water use, 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, the Southern California Distinct Population Segment, 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 which designates 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, was put forth by the California Department of Fish and Wildlife (CDFW) to provide 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). 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 for 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 focal watersheds.

Study Site

Salsipuedes Creek

Salsipuedes is located southeast of the city of Lompoc in Santa Barbara County, California (FIGURE 1). Salsipuedes Creek 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. Salsipuedes Creek is particularly valuable from a monitoring perspective as it represents the most viable steelhead spawning and rearing in the lower Santa Ynez River (USFS 1997). The deployment site is located 0.6 stream miles upstream of the confluence with the Santa Ynez River. Site selection was based on channel morphology, power availability and site security. The chosen location exhibits a channel profile which allows for complete ensonification of the streambed's full width under varying flow scenarios. This was a primary concern for this location, as this system has historically demonstrated dynamic flow regimes. This makes it critical that the camera be able to accommodate fluctuations in water depth. Site substrate is fairly uniform, and composed primarily of finer material (e.g. sand, silt and cobble) which limits the potential for acoustic dead zones (i.e. obscured areas where fish could potentially bypass the sonar's field of view). The site is located in either riffle or run habitat depending on flow conditions. These habitat types discourage milling behavior which can greatly complicate footage analysis. Site power was hardwired into preexisting infrastructure by a licensed electrician. The site, located on private property, is accessed via a gated private road resulting in relatively high site security. This site has the added benefit of being located immediately downstream of a migrant trap operated by the Cachuma Operation and Maintenance Board allowing for potential 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. Quality spawning habitat exists in the upper watershed; however access is limited to times of the year when connectivity with lower reaches is maintained.

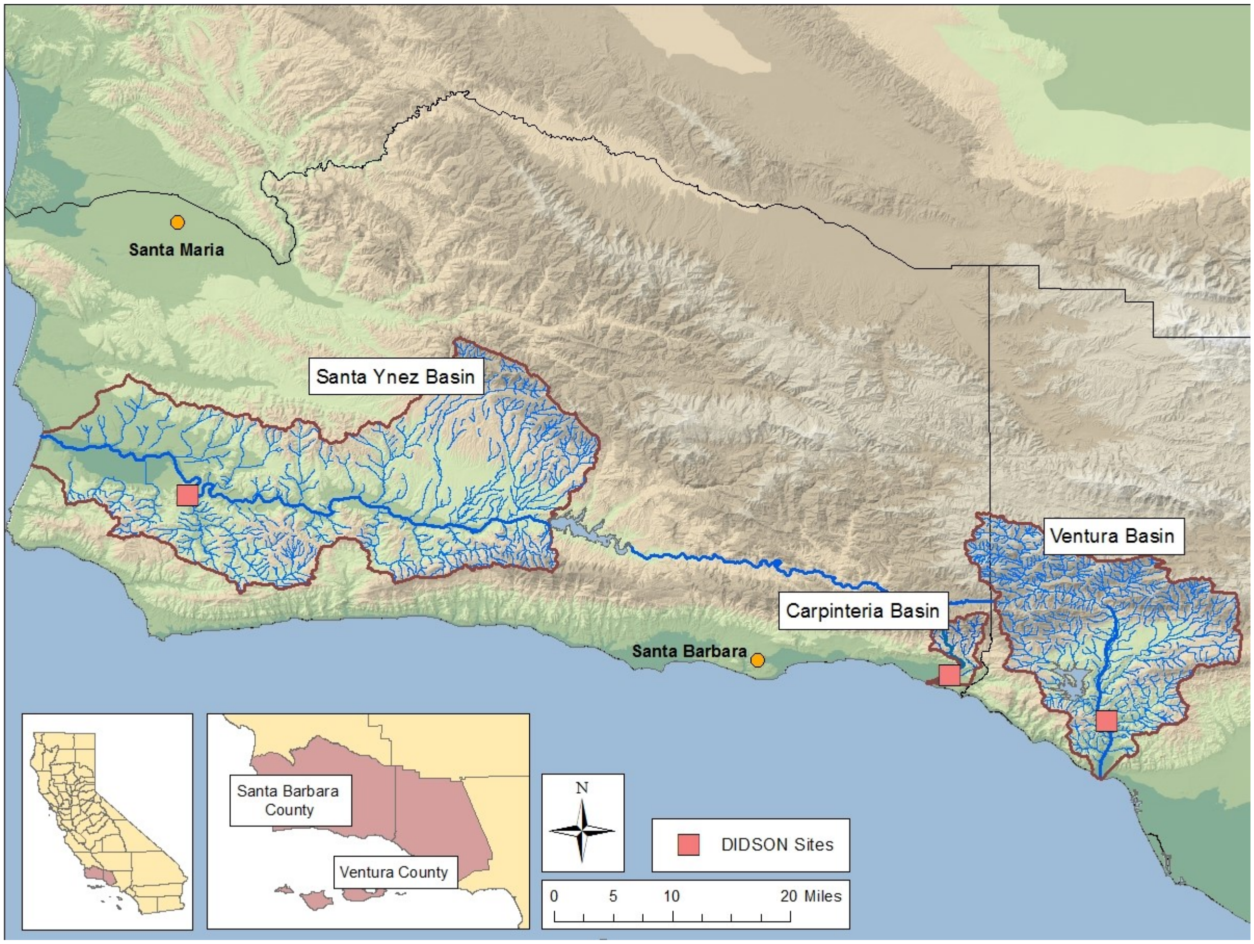
The channel profile and dominant substrate allow for full ensonification of the wetted channel under deployable conditions. The monitoring site is located along a migration corridor that only flows episodically, limiting the potential for milling behavior. The site is located on US Forest Service Property in close proximity to firefighting personnel residences. As a result, the site is fairly 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).

This site's associated channel profile and substrate composition are compatible with consistent ensonification 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 gates that remained locked outside normal business hours. This site is located in close proximity to areas that have historically been occupied by a sizeable transient population. Consequently security concerns are high and staff maintains a regular presence on site including continuous coverage during the initial days of deployment.

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



METHODS AND MATERIALS

Cameras were deployed once flow and connectivity thresholds were met in study systems, beginning in December of 2015 through May of 2016. 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 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 in-basin flow remained sufficient.

Data Collection

Salsipuedes Creek
During the 2015-2016 data collection season, stream flows never reached levels allowing for DIDSON deployment in Salsipuedes Creek.

A standard DIDSON unit was assigned to this site and a previously established track/sled system designated as the camera mount (FIGURE 2**)**. The track is 30 feet in length and follows the bank's profile at a shallow angle. The track is mounted to steel legs that have been set into the bank at a depth of at least 3 feet. Further stability is achieved by cross-bracing the structure with aircraft cable. The space between the track and bank below has been blocked with gravel bags to prevent fish from passing below or behind the camera. The DIDSON is affixed to an X_2 pan and tilt rotator. The X_2 is controlled by the DIDSON topside software, allowing for remote aiming of the DIDSON. The DIDSON and X_2 are mounted to an aluminum sled using hardware produced by Sound Metrics. The sled is then placed on the track where it can be raised and lowered by a winch tethered to the sled by aircraft cable. This allows for the camera height to be adjusted as needed without having to physically enter the stream when conditions may be unsafe.

The camera is connected to the topside box through a 60m DIDSON sonar cable. Topside electronics and components were contained in a weatherproof job-box located safely outside the floodplain as suggested by Pipal et al. 2010.

FIGURE 2. Salsipuedes Creek DIDSON deployment track system as seen during its last deployment in 2014 with key features labeled. (A) winch; (B) track; (C) cross-bracing cables; (D) gravel bag berm; (E) DIDSON/X2/sled assembly.

Carpinteria Creek
A long range DIDSON 300 m unit operating in high frequency mode (1.2 MHz) was used for all deployments in Carpinteria Creek. The long range model operates at a lower resolution than the standard model when in high frequency mode; however, imagery produced was sufficient to monitor fish passage as *O. mykiss* is the only extant fish species in the basin making fine detail unnecessary for species determination. The camera was positioned along the bank, facing perpendicular to flow and set at

shallow angle to allow for complete ensonification of the stream channel contained within the sonar's field of view (Pipal 2010). The camera was housed in a Sound Metrics manufactured siltbox as well as a custom aluminum "debris box" to prevent sediment accumulation on the lens and to provide a measure of protection from debris flows. The housings were then secured with a padlock. The camera was attached to a steel, sled foot "A- frame" mount using a RAM double socket ball joint as described by Larson et al. 2013. The sled was anchored using gravel bags and by an aircraft cable tether running from the housing's padlock to a large nearby tree. The cable served as both a safeguard against equipment being swept away and theft. The mount was flanked by berms composed of native cobbles and positioned to direct fish to an optimal distance from the lens (~1.25 m) while preventing fish passage behind the camera. The DIDSON was connected to topside electronics via a 60 m cable assembly.

Topside electronics and components were contained in a weatherproof job box as described in Pipal 2010. All electronics were powered through an uninterruptible power source (UPS) which provides short term battery back up in the event of brief power outages routed. The UPS was connected to a permanent power source by extension cord. A Dell Toughbook was used to run DIDSON software. Footage was captured in 20 minute increments which were written to an external 3 Tb hard drive. Focus and frame rate were set automatically by the software. Gain was left at the default maximum value. Wetted width remained relatively narrow for all observed conditions and the window length was set to 5m for all deployments.

FIGURE 3.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.

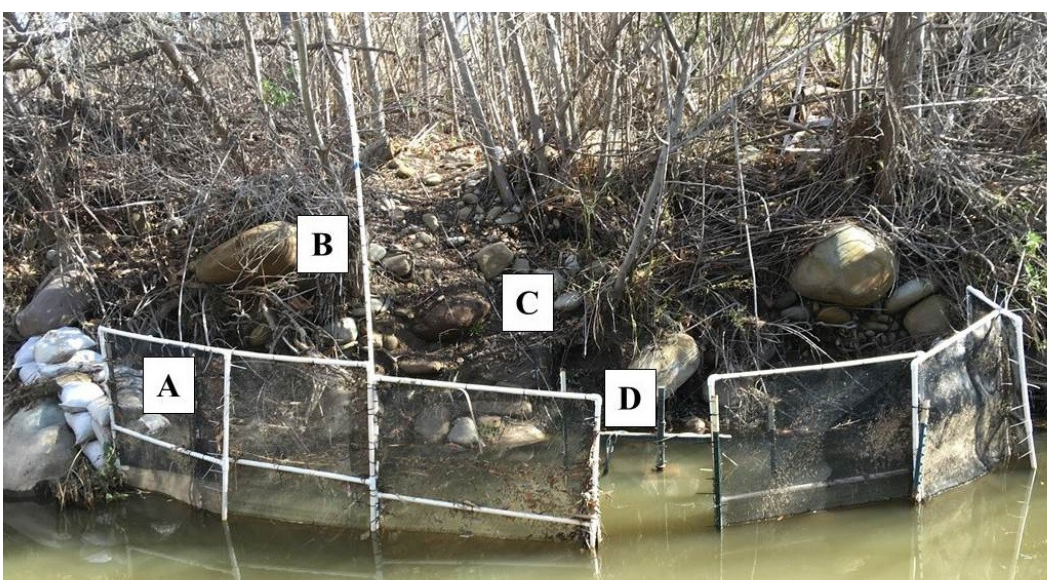
Ventura River

A standard DIDSON 300 m unit and an ARIS Explorer 3000, both operating in high frequency mode (1.8 MHz and 3.0 MHz respectively) were used for all deployments in the Ventura River. Units were deployed in parallel at a distance of ~1 m to compare functionality under southern California environmental conditions. The DIDSON was mounted on an A-frame as described in the Carpinteria Creek set up with the addition of an X2 rotator. The X2 rotator attaches to the center arm of the A-frame and gives the user pan and tilt control through the DIDSON topside software. The ARIS was also mounted to an A-Frame and housed in a modified stainless steel debris box. The ARIS setup included the use of an AR_2 pan tilt rotator which operates in the same manner as the DIDSON X2. The cameras were positioned and aimed as previously described. A-frames were anchored using gravel bags and tethered to large, nearby trees via aircraft cable as described for Carpinteria Creek. This again served to both prevent loss of equipment to high flows and deter potential theft. Motion detecting trail cams with night vision capabilities were installed to record any potential attempts at vandalism, tampering, or theft. Deflection panels, consisting of aquaculture mesh fastened to PVC frames, were anchored both up and downstream of the cameras. These panels both prevented fish from passing behind cameras and guided them to an optimal imaging range (~1.25 m). The DIDSON camera was connected to topside electronics via a 60 m DIDSON cable assembly while the ARIS was connected via a 150 m ARIS cable assembly. Both cables were routed to an onsite storage container located outside the flood plain.

Topside electronics and components were housed in a 10 ft x 10 ft mobile storage container. Topside electronics and components were powered through a UPS connected to a permanent power source. Dell Toughbooks were used to run DIDSON and ARIS software. Footage was captured in 20 minute increments for both cameras and was written to separate external 3 Tb hard drives. Wetted width varied slightly as dictated by flow but remained relatively narrow. Window lengths were set to 10m only briefly and remained at 5 m for the majority of data collection. Focus and frame rate were set automatically by the software. Gain was left at the default maximum value.

Due to security concerns, the site was staffed 24 hours per day for the initial 72 hours of deployment. For the remainder of deployments staffing was limited to daylight hours. A project vehicle remained on site whenever staff was present for safety and logistical reasons. Prior to removing the cameras, surveys were conducted to verify that migration was no longer feasible either due to low flow barriers or to lost surface water connectivity preventing access to sonar monitoring site.

FIGURE 4. Ventura River DIDSON/ARIS monitoring site with key features labeled. (A) Deflection panels; (B) depth gage; (C) security tether; (D) paired deployment of DIDSON and ARIS.



Data Analysis

Sonar data files were analyzed using DIDSON and ARIS (ARISfish) software. Software performance is directly related to installed memory and processor speed so analysis was completed on machines with the most available resources. Performance was consistent across a variety of machines with the exception of instances where processing ARIS files caused software failure. 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. The sum of these functions makes motion tracks easier to detect and highlights passage events. In this way, users are able to filter through 800 (DIDSON) or 1,000 (ARIS) frames at a time and work through files fairly quickly. On average, 24 hours of footage was reviewed in approximately 8 hours. All observations of fish greater than 30 cm TL were recorded. Fish were measured using the box method in both programs. The box method has the reviewer pause the footage before dragging a box around the object being measured and recording the diagonal length. For each object three box measurements were taken at different frames and then averaged. Reviewers used behavioral and morphological cues to determine whether fish were *O. mykiss* or other non-target aquatic species (e.g. Common Carp, turtles, water fowl, etc.). In instances where a reviewer was unsure of species designation, files were flagged for further review by a lead biologist. For each relevant observation, size (averaged from three frames), direction of travel, species, timestamp and pertinent header data (e.g. site location, date of recording, filename, reviewer name, and date viewed) were recorded.

RESULTS

No *O. mykiss* were detected at either Carpinteria Creek or Ventura River DIDSON monitoring stations during the 2016 data collection season (TABLE 1). Equipment, infrastructure and personnel all performed well allowing for uninterrupted data collection resulting in approximately 500 hours of digital sonar footage. Footage was of sufficient quality to reliably detect adult steelhead with the exception of periods where extreme turbidity limited the sonar's maximum effective range. This phenomenon was observed at both sites and was associated with peak flows. These effects were more pronounced during the first major flow event of the season (TABLE 1). Reductions in range at the Carpinteria Creek site caused by turbidity were impossible to distinguish from fluctuations caused by changes in channel width due to flow.

TABLE 1. Dates, duration and peak flows for 2016 deployment events.

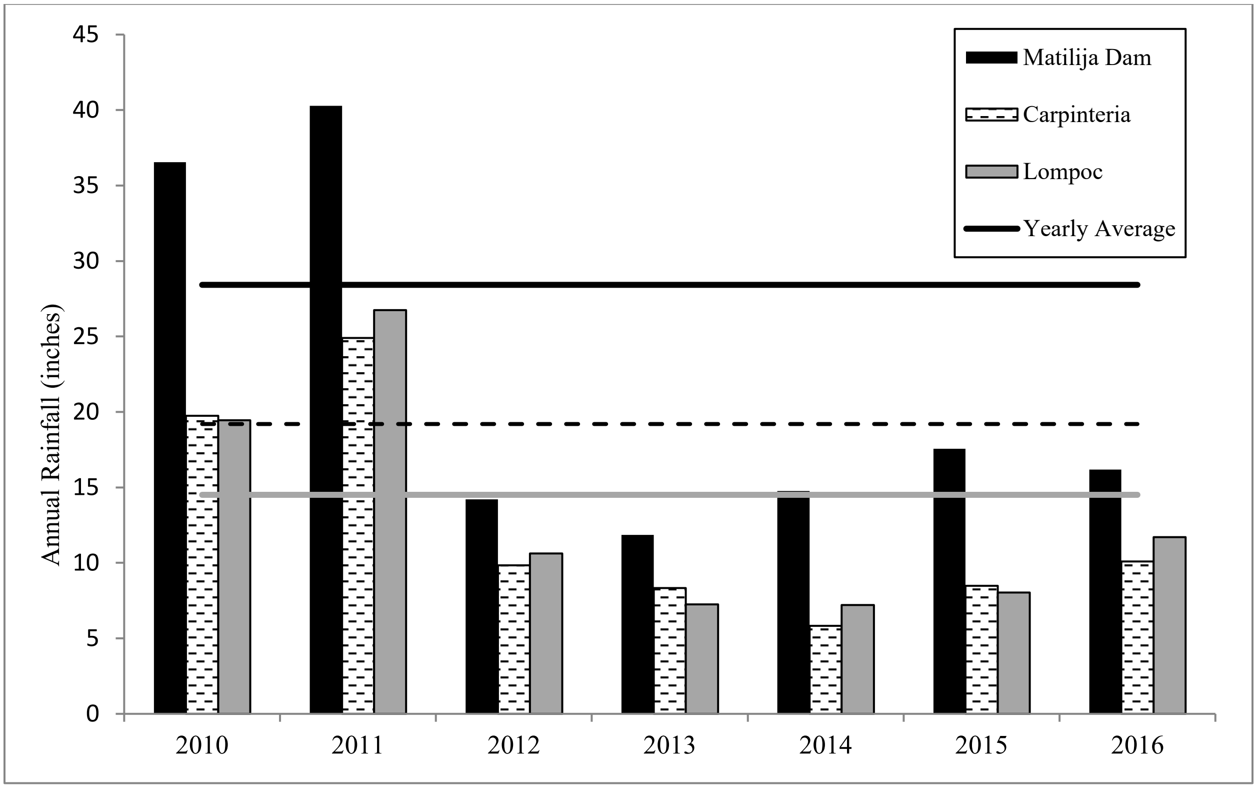
Site location	Date in	Date out	Number of days deployed	Peak flow (cfs)	Percent of deployed hours with incomplete channel coverage
Carpinteria Creek	1/7/2016	1/8/2016	1	0.47	NA
	03/06/16	03/08/16	2	17	NA
Ventura River	01/05/16	01/11/06	7	906	20.8
	01/31/16	02/02/16	3	160	15.06
	03/05/16	03/14/16	10	72	1.86

DISCUSSION

Flow regimes in southern California are expected to be highly episodic, but persistent drought effects combined with another year of below normal rainfall (FIGURE 6) have exacerbated this condition. As a result deployment opportunities were extremely limited and short in duration (FIGURE 7). In the Ventura River, sequential drought years have allowed instream vegetation, normally removed by seasonal flushing, to proliferate and form channel spanning mats. This vegetative material combined with displaced woody debris to form temporal fish passage barriers. These barriers restricted potential fish movement in the lower watershed and were a contributing factor in limiting deployment duration **(**FIGURE 5**)**.

FIGURE 5. A channel spanning low flow fish passage barrier composed of woody debris and vegetation in the lower Ventura River.

FIGURE 6.Annual rainfall totals from 2010 to 2016 for study areas. Representative rain gages were chosen for each system with the Matilija Dam gage for the Ventura River basin, the central Carpinteria gage for Carpinteria Creek and central Lompoc for Salsipuedes Creek.



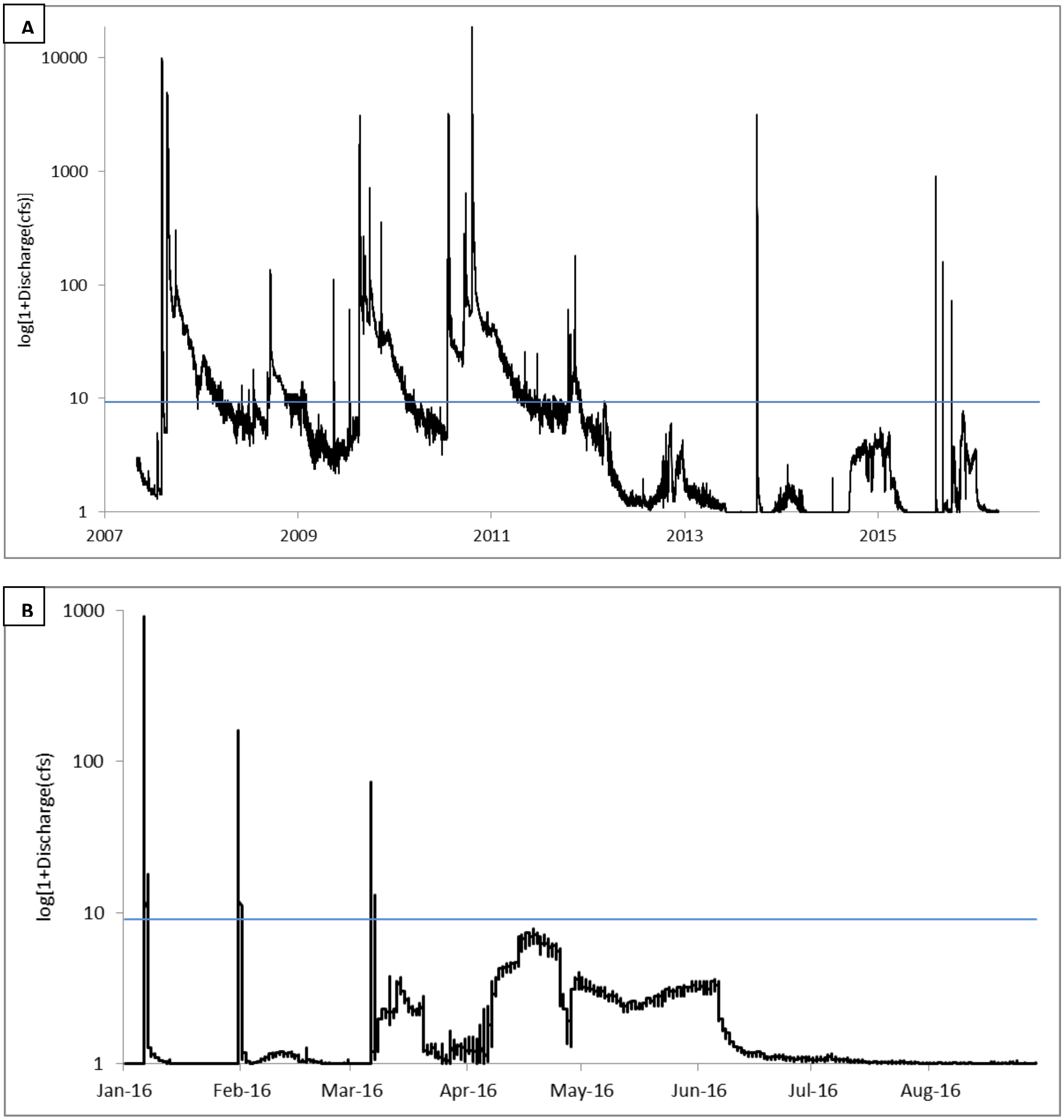
At our Ventura River monitoring site, a side by side deployment of a standard DIDSON 300 m unit and an ARIS Explorer 3000 allowed for direct comparison of performance under real world conditions. As anticipated, the ARIS unit produced higher quality footage when operating in high frequency due to its higher operating resolution. The utility of this higher resolution varied. If a fish passed through the beam at an optimum angle, then useful morphological features were visible making species identification more certain. These types of observations were infrequent and highly dependent on fish position relative to the camera in addition to stream conditions (e.g. turbidity). The ARIS was more impacted by elevated turbidities when operating in high frequency mode (3 MHz) than the adjacent DIDSON unit operating in its respective high frequency (1.8 MHz). In general higher frequency soundwaves are expected to attenuate more rapidly with increased range, so while not surprising, this does represent a potential problem with regard to field deployment (Maxwell and Gove 2007). This was addressed in the field by setting the ARIS to low frequency (1.8 MHz) during periods of high turbidity, at which point image quality was equivalent to DIDSON. Deployment protocol and interfacing with topside components was comparable between DIDSON and ARIS units with only minor modifications, necessitated by differences in the software and topside components. Differences between DIDSON and ARIS software were more evident during data analysis. ARIS files were on average three times larger than DIDSON files of the same length. As a result, generating echograms with background subtraction for ARIS files required more computer processing power and lead to frequent software crashes. This was addressed by running background subtraction and echograms for multiple files in “batch mode” prior to reviewing individual files. This drastically improved software stability and greatly reduced the time needed to view individual echograms. The “batch mode” process is detailed in the ARISfish software manual (Sound Metrics 2012).

Data management remains an ongoing issue for large DIDSON and ARIS files. Files are housed on dedicated external hard drives, where they are stored and analyzed. This becomes problematic for long term data storage and backup. File transfer times quickly become prohibitive when dealing with a field season’s worth of data. To best address this issue a dedicated server would be required, but associated costs are high and many monitoring projects lack the resources to establish and maintain an appropriate backup system. Our current long term data storage solution is to write files containing noteworthy observational data to Blu-ray discs.

Extreme turbidities were problematic at both the Carpinteria Creek and Ventura River sites. Turbidities were not sampled at either site, but were recorded in excess of 800 NTUs for the lower Ventura River in past years (Santa Barbara Channelkeeper 2016). During these periods of extreme turbidity the sonar’s maximum range is reduced, at times to less than 1 meter. This results in incomplete beam coverage of the channel and the potential for missed observations (TABLE 1). To address these concerns our project is acquiring a continuous turbidity logger. Turbidity data will then be correlated with sonar functionality. This will inform sonar operators on methods for ascertaining the upper turbidity limit for camera operation in study streams and provide a framework for assessing the extent of potential data gaps.

Sonar camera effectiveness and efficiency in focal watersheds remains somewhat ambiguous. Ancillary sampling efforts at sonar monitoring sites such as PIT tagging or migrant trapping would be needed in order to assess detection rates. This is described in Fish Bulletin 180 (Adams et al. 2011) and expanded upon on the 5-Year Review of the southern California coast distinct population segment (NMFS 2016) as the framework for a life cycle monitoring station. A PIT tagging project is newly underway in the Ventura River that will work in cooperation with DIDSON monitoring activities to address questions regarding sonar effectiveness and efficiency.

FIGURE 7. Hydrographs depicting recorded discharge of the Ventura River from USGS stream gauge located at 34.352465°, -119.307823°, approximately one mile upstream of the Ventura River DIDSON site. (A) Flow data for 2007 through 2016 highlighting the downward trend in observed flows beginning in 2012. Ten cubic feet per second (cfs), denoted by the blue line, is the approximate threshold for DIDSON deployment. (B) 2016 flow data for the USGS Ventura River stream gage. Only three storm events generated flows exceeding 10 cfs.



ACKNOWLEDGEMENTS

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