Summary of 2019 Southern California steelhead monitoring using underwater sonar (DIDSON)

2019 Annual Report

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ABSTRACT

This study is a continuation of monitoring efforts initiated by the California Department of Fish and Wildlife (CDFW) and the Pacific States Marine Fisheries Commission (PSMFC) in 2013 to collect data on abundance and spatial structure of southern California steelhead (*Oncorhynchus mykiss*). To provide unbiased counts of anadromous adults, DIDSON and ARIS sonar cameras were deployed in three watersheds: Salsipuedes Creek (Santa Ynez River), Carpinteria Creek, and Ventura River. All watersheds are designated as high priority watersheds for steelhead recovery action (Core 1; NMFS 2012). DIDSON deployments occurred in conjunction with comprehensive spawning/redd surveys to contribute additional information regarding *O. mykiss* abundance and spatial structure.

Sonar cameras are a reliable method of obtaining unbiased adult counts in southern California stream systems. Successful deployment of DIDSON cameras allow data collection even in poor visibility (e.g. at night or in high levels of suspended particulate) and under dynamic stream conditions (Adams et al. 2011). Sonar footage was analyzed for observations of targets ≥ 40 cm. In Salsipuedes Creek a total of 85 days of footage were recorded through DIDSON deployments. Of the 200 observations, three were identified as adult steelhead. In Carpinteria Creek, 133 days of footage was acquired through deployments. Twenty-two observations of targets ≥ 40 cm were recorded, zero of which were identified as *O. mykiss*. In the Ventura River, deployment of a DIDSON camera compiled 137 days of footage. An ARIS camera was deployed and recording alongside the DIDSON in Ventura for the same time period to provide backup and comparison footage. A total of 378 observations of targets ≥ 40 cm were recorded on the DIDSON at the Ventura River site and one was identified as an adult steelhead. Of these observations, 278 were identified as Common Carp, *Cyprinus carpio*.

Due to consistently large numbers of Common Carp observations at the Ventura River site, these data were further analyzed to explore means of differentiating between *C. carpio* and *O. mykiss*. This included examining differences in swimming motion, morphological features, and effects of environmental conditions (e.g. stream flow) on behavioral patterns. In contrast to previous years, carp detections per hour were not impacted by diel patterns and were loosely negatively associated with stream flow. As monitoring continues a stronger relationship between environmental factors and species identification may emerge. Overall, this project demonstrates the efficacy of sonar cameras for steelhead abundance monitoring in southern California streams. Continued refinement of deployment methods is recommended for maximizing DIDSON utility in southern California conditions.

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INTRODUCTION

Southern California steelhead trout (*Oncorhynchus mykiss*) populations have declined dramatically throughout their historic range. Primary causes of this decline include loss of freshwater habitat due to land use practices and the implementation of water diversions and dams effectively blocking access to historical steelhead spawning and rearing areas (NMFS 2012). Consequently, steelhead trout inhabiting the area from the Santa Maria River to the U.S.-Mexico border have been listed as a federally endangered distinct population segment (DPS) (ESA; NMFS 2012). The ESA mandated recovery plan outlines goals to ensure the persistence of viable populations of anadromous *O. mykiss* across the DPS (NMFS 2012). The California Department of Fish and Wildlife has developed a framework to implement monitoring to track recovery progress (i.e., Fish Bulletin 180) (Adams et al. 2011). This framework is based on assessment of four viability metrics (i.e., Viable Salmonid Population parameters) comprised of abundance, productivity, spatial structure, and diversity (McElhany 2000, NMFS 2016).

To assess abundance for populations encompassed by the DPS, unbiased estimates of anadromous adults are required (NMFS 2016). Fish Bulletin 180 suggests the use of sonar cameras (i.e., DIDSON) to collect counts of anadromous adults in focal streams. Developed by Sound Metrics, DIDSON produces near video-quality imagery and allows for data collection in poor visibility environments such as at night or during periods of high flow when steelhead are likely to migrate (Sound Metrics 2018). Turbid conditions are typical in southern California streams where flows are highly episodic resulting in dynamic hydrology. Additionally, DIDSON cameras allow for the passive collection of data without disruption to the behavior or inadvertent harm to a listed species (Pipal 2012).

The use of DIDSON was paired with spawning ground (redd) surveys to collect data that provide an index of effective population size (abundance) and an estimation of spatial structure. Redd surveys were conducted as a complete census of available spawning habitat in Carpinteria Creek and Ventura River watersheds. Pairing redd counts with abundance data provided by DIDSON allows calibration of a redd to spawner ratio to be used in nearby stream systems without counting stations thus fulfilling a critical role of life cycle monitoring stations (LCM).

This report summarizes the methodologies and findings of sonar deployment, data collection, and data analysis efforts in Salsipuedes Creek, Carpinteria Creek, and the Ventura River. All three watersheds are designated in the southern California steelhead recovery plan as being the first focus for recovery action (NMFS 2012). Findings will aid in the development of southern California specific monitoring protocols, and will inform resource managers on the status of steelhead populations in these high priority systems.

STUDY SITES

Data was collected in Salsipuedes Creek, Carpinteria Creek, and the Ventura River. Salsipuedes Creek and the Ventura River are located in the Monte Arido Highlands biogeographic population (BPG) region while Carpinteria Creek is one of ten small, coastal watersheds of the Conception Coast BPG assessed for steelhead recovery (NMFS 2012). Each watershed flows from a mountainous region with high peak elevations across a broad coastal terrace before entering the Pacific Ocean (NMFS 2012). All three watersheds experience a Mediterranean climate, typical of southern California, consisting of long dry summers and short, high intensity winter storms (NMFS 2012). Perennial flow is supported by groundwater and connectivity to the ocean and throughout the watershed is highly dependent on precipitation.

Salsipuedes Creek

Salsipuedes Creek is a second order stream and the largest tributary to the lower Santa Ynez River flowing from the south-facing slopes of the Sierra San Rafael and the north-facing slopes of the Santa Ynez Mountains (Santa Ynez River Technical Advisory Committee 2000, NMFS 2012). Salsipuedes Creek drains a watershed of approximately 52 square miles meeting with the Santa Ynez River at the confluence located approximately 16.1 stream miles from the Pacific Ocean. Connectivity to the ocean is dependent on a large sandbar that keeps the river mouth closed outside of high winter flows.

The areas of the Santa Ynez River watershed accessible to steelhead are home to a number of native and invasive fish species. The native fish species present include Threespine Stickleback (*Gasterosteus aculeatus*), Prickly Sculpin (*Cottus asper*), Pacific Lamprey (*Lampetra tridentate*), Arroyo Chub (*Gila orcutti*) and Tidewater Goby (*Eucyclogobius newberryi*) (Santa Ynez River Technical Advisory Committee 2000). The invasive fish species present consist of Fathead Minnow (*Pimephales promelas*), Mosquitofish (*Gambusia affinis*), Smallmouth Bass (*Micropterus dolomieui*), Largemouth Bass (*Micropterus salmoides*), Bluegill (*Lepomis macrochirus*), Green Sunfish (*Lepomis cyanellus*), Redear Sunfish (*Lepomis microlophus*), Black Crappie (*Pomoxis nigromaculatus*), Channel Catfish (*Ictalurus punctatus*), Black Bullhead (*Ameiurus melas*), Goldfish (*Carassius auratus*), and Common Carp (*Cyprinus carpio*) (Santa Ynez River Technical Advisory Committee 2000).

The Salispuedes Creek DIDSON 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 stream location is characterized by a trapezoidal stream channel shape allowing for complete ensonification of the streambed. The camera deployment location is in a pool tail out just upstream of a riffle to discourage milling behavior. Substrate is primarily composed of sand and cobble which provides minimal trout cover and allows easier fish detection. 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. The site is located on private property and accessed via a gated, private road resulting in a high-level of site security. Site power is provided by a mobile solar trailer and battery bank capable of powering all equipment necessary for long-term deployments.

Carpinteria Creek

Carpinteria Creek is a small, coastal stream that drains from the Santa Ynez mountains immediately adjacent to the ocean (NMFS 2012). Carpinteria Creek drains a watershed of approximately 15 square miles and contains just over seven miles of anadromous waters (PAD 2019). Extensive sections of the main stem remain dry outside of winter flows, and serve primarily as migration corridor to perennial, upper reaches. A seasonal sand bar restricts fish access to the creek until displaced by rising flows.

In areas of the Carpinteria Creek watershed accessible to steelhead, a small number of native fish species comprised of Threespine Stickleback (*Gasterosteus aculeatus*), Prickly Sculpin (*Cottus asper*), Pacific Lamprey (*Lampetra tridentate*), and Tidewater Goby (*Eucyclogobius newberryi*) have been documented (Padre and Associates Inc. 2002, Ecology Consultants 2003).

The DIDSON deployment site in Carpinteria Creek is located approximately two miles upstream of the estuary. The stream channel profile and dominant substrate at this site allow full ensonification of the wetted channel. The location is along a seasonally wetted migration corridor, which limits the potential for milling behavior. The site is relatively secure, located on U.S. Forest Service Property and in close proximity to firefighting personnel residences. Power is provided by a partnering land owner with an extension cord running to their adjacent residence.

Ventura River

The Ventura River watershed drains roughly 227 square miles and contains approximately 35 miles of anadromous water (NMFS 2012). Both the Casitas and Matilija dams act as total barriers to steelhead passage and prevent migration to spawning and rearing habitat in the upper watershed (NMFS 2012) (Figure 1). The Robles Diversion, located on the Ventura main stem 1.5 miles downstream of the confluence of Matilija and North Fork Matilija Creeks, diverts flow from the Ventura River to Lake Casitas and contains a fish-passage facility (NMFS 2012). Extensive sections of the main stem exhibit intermittent flows and drying over spring and summer and connectivity to the Pacific Ocean is dependent on a seasonal sandbar. Without consistent precipitation, flows drop quickly and access to the perennial upper watershed may be limited to short periods.

The DIDSON deployment site is located five stream miles upstream of the Pacific Ocean (**Error! Reference source not found.**). This site's channel profile and substrate composition allow unobstructed views of the full stream channel. The site is located on property owned and operated by the Ojai Valley Sanitation District. The sanitation district staff facilitated the installation of a powered storage container to house topside equipment. The storage container is secured with a padlock and located within a perimeter fence and two locked, electronic gates.

Areas of the Ventura River accessible to anadromous adult *O. mykiss* are inhabited by a number of native and invasive fish species. Native fish species consist of Threespine Stickleback (*Gasterosteus aculeatus*), Prickly Sculpin (*Cottus asper*), Pacific Lamprey (*Lampetra tridentate*) Arroyo Chub (*Gila orcutti*), and Tidewater Goby (*Eucyclogobius newberryi*) (Walter 2015). Invasive fish species present consist of Common Carp (*Cyprinus carpio*), Black Bullhead (*Ameiurus melas*), Channel Catfish (*Ictalurus punctatus*), Green Sunfish (*Lepomis cyanellus*), Fathead Minnow (*Pimephales promelas*), and Largemouth Bass (*Micropterus salmoides*).

METHODS

Data Collection

Sonar cameras were deployed once unobstructed surface flow was established between the site and the ocean and remained deployed as long as conditions allowed for fish migration from the ocean to the monitoring site including periods of heavy rainfall and high flow. Additionally, cameras remained deployed following river mouth closures to allow time for any fish that had entered the system time to migrate to monitoring sites.

Salsipuedes Creek

A standard DIDSON 300 m unit (Sound Metrics, Lake Forest Park, Washington) operating in high frequency mode (1.8 MHz and 3.0 MHz respectively), was used for all deployments in Salsipuedes Creek from January 17, 2019 to May 1, 2019. The DIDSON was housed in a Sound Metrics manufactured silt box to prevent lens fouling and attached to a X2 pan and tilt rotator to aim the camera remotely (Sound Metrics, Lake Forest Park, Washington). The camera and X2 were affixed to a steel, sled foot A- frame mount as described in Larson 2013. The A-frame was held in place by gravel bags placed on the sled feet. To safeguard against theft and potential loss of equipment during peak flows, the camera was tethered to a large nearby tree. When deployed, the camera is positioned on the river right bank perpendicular to flow and as close to the substrate as possible while maintaining a clear view of the entire stream channel. This positioning was based on two assumptions: (1) migrating steelhead will swim close to the stream bottom during high flow where water velocities are reduced, and (2) floating debris is less likely to come in contact and cause damage to the cameras. In previous years, the camera and rotator were mounted to an aluminum sled which could be lowered along a stationary 9 m track as described in Lopez 2015 (Lopez, unpublished). During the first large storm of the 2018 to 2019 winter season, the track was buried in sediment and the stream channel altered, rendering the sled and track system unusable for the remainder of the season.

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 either 5 m or 10 m for 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 powered by and held in a locked, mobile solar trailer located safely outside the floodplain as suggested by Pipal et al. 2010.

Flow data for the Salsipuedes Creek site were obtained from a U.S. Geological Survey (USGS) stream gauge located 2.9 miles upstream of the DIDSON site. 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 7, 2019 to May 30, 2019. 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 sled foot A-frame mount as described in Larson 2013 which was held in place by rocks and a cable staked into the substrate. An aircraft cable tethered to a large nearby tree and secured to the camera housing with a padlock served as a safeguard against theft and to prevent equipment from being swept away. The camera was positioned along the river right bank, facing perpendicular to flow and the camera angel was level with the water surface. The camera was set as close to the bottom as possible while still fully ensonifying the channel. This was necessary to accommodate persistent, shallow depths (i.e., < 0.6 m) throughout the season.

The DIDSON was connected to a topside control box via a 60 m DIDSON cable and the topside box was 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 either 5 m or 10 m for deployments, depending on the channel width during and following storm events. 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 extension cord running to an adjacent private residence. Support electronics and components were held in a locked, weatherproof job box located outside the flood plain. Site visits were conducted regularly to ensure that the camera was working properly and to change hard drives as needed.

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 7, 2019 through May 30, 2019. Cameras were deployed in parallel to compare functionality under southern California stream conditions (Figure 3). The DIDSON was housed in a Sound Metrics manufactured silt box to prevent lens fouling and a custom aluminum box to prevent damage by floating debris and attached to the X2 pan and tilt rotator (Sound Metrics, Lake Forest Park, Washington) to aim the camera remotely. The camera and X2 were affixed to a steel, sled foot A-frame mount as described in Larson 2013. The ARIS was housed in a custom stainless-steel box to protect against damage by floating debris. This assembly was attached to an AR2 dual-axis pan/tilt rotator to aim the camera remotely. The AR2 was then affixed to an A-frame mount. Both A-frames were held in place by gravel bags placed on their sled feet, tethers running from the A-frames to adjacent t-posts, and by Duckbill Earth Anchors set into the substrate. To safeguard against theft and potential loss of equipment during peak flows, cameras were tethered to large nearby trees and to an earth anchor installed outside the stream channel (Figure 4). As an added layer of security, motion detecting trail cameras were installed. Deflection panels, consisting of aquaculture mesh fastened to PVC frames, were anchored upstream 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 cameras 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. DIDSON camera window length was set to either 10 m or 5 m depending on stream channel width. ARIS window length was kept 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 uninterruptable power sources connected to permanent onsite power. Site visits were conducted on a daily basis to ensure proper camera operation. Prior to removing the cameras, walking surveys were conducted to verify that steelhead migration from the ocean to the camera location was no longer feasible.

Flow data for the Ventura River site were obtained from a U.S. Geological Survey (USGS) stream gauge located 0.7 miles upstream of the DIDSON site. The proximity, and lack of any substantial flow inputs between the DIDSON site and flow gage, make this value a reasonable approximation of flow at the deployment site.

Data Analysis

Sonar files were processed using the echogram function with background subtraction enabled in the Sound Metrics software. Echograms produce a visual representation of the entire file by compressing a given frame into a single pixel width along the full image range and background subtraction allows static objects to be filtered out (Sound Metrics 2012). These processes make moving objects easier to detect and expedites footage review.

Data recorded during footage review varied slightly by site, with different minimum length requirements of targets depending on site. For Carpinteria creek footage, all targets were recorded, regardless of size, to record any species present following the 2018 debris flows. For Salsipuedes Creek, all observations 15 cm or greater in length were recorded to compare with COMB trap data and determine the accuracy of species identification on smaller targets. For the Ventura River, all fish observations ≥ 30 cm and other species ≥ 40 cm were recorded, as fish smaller than 30 cm could not confidently be identified to species. For all sites, data was analyzed for all wildlife observations greater than or equal to 40 cm in length which is considered the minimum size needed to assign species and corresponds with 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 per Pipal et al. (2010). The box method requires the reviewer to pause the footage, drag a box around the object seen in frame, and record the value for either the diagonal or width depending on the object's orientation relative to the camera (Pipal et al. 2010). For each observation, up to three measurements were taken from separate frames and then averaged as described in Pipal et al. 2010. Reviewers assigned species to fish observation 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 designated as either "unidentified terrestrial species", "frog", "turtle", "waterfowl", "snake", "unidentified fish species" or "unknown". In instances where a reviewer was unsure of species designation (e.g. "unknown"), files were flagged for further review by a more experienced reviewer. For cases where this occurred in the Ventura River, footage from an ARIS camera or a DIDSON with an alternate view was consulted when available, before determination of species was finalized. For each observation, length, direction of travel, species, range from the camera to the target, timestamp, footage quality, confidence in species designation, and pertinent metadata (e.g. site location, date of recording, filename, reviewer name, and date viewed) were recorded.

Ten percent of footage analyzed by each staff member was randomly selected and checked for accuracy by an experienced biologist. Data were entered into an Access database where data rules were enforced to limit entry errors. Data proofing was completed using R software (R Core Team. 2016) to flag potential erroneous values, which were either corrected or omitted as appropriate.

For anadromous *O. mykiss* observations, net movement is calculated to estimate escapement. To calculate net movement (N) for focal species, the total number of downstream observations (D) were subtracted from the total number of upstream observations (U) as recommended by Xie et al. (2002) and put into practice by Larson (2013).

$$N = U - D$$

A net positive number would indicate net movement upstream and vice versa. Considerations for potential confounding of counts by downstream movement of post-spawning adults (i.e., kelts) would be addressed on a case-by-case basis.

Two species in the Ventura River (i.e., Common Carp and Pacific Lamprey) have the potential to be misidentified as steelhead due to the overlap in spatial distribution, temporal cycles and range in typical adult lengths. To learn more about these species, and how they may be differentiated from steelhead; additional analyses were done for Common Carp observations in the Ventura River. These observations were compared with synchronous flow data to explore the effect of flow on movement patterns. Additionally, Ventura River Common Carp observations were binned by hour of the day and classified as either "day" (i.e., the hours from 0600 to 1800) or "night" to characterize patterns in diurnal rhythms. The mean observed length of Common Carp ≥ 40 cm was reviewed. All analyses were completed using R software.

RESULTS

Salsipuedes Creek

Eighty-five days of sonar footage were recorded in Salsipuedes Creek from January 17, 2019 to May 1, 2019. A total of 200 observations of targets with an estimated length ≧ 40 cm were recorded. Of these observations, eight were identified as *O. mykiss* (Table 4). Six of the observations appear to be the same individual O. *mykiss* repeatedly swimming in front of the camera over a short time period. This O. *mykiss* was initially observed swimming upstream on February 6, 2019 at 19:52. Over the next 5 minutes of footage, the *O. mykiss* was observed 4 more times alternating between swimming downstream and upstream, before the final observation of the fish swimming downstream at 19:57. Over all observations, this *O. mykiss* was estimated to have a mean length of 82.9 ± 1.57 (mean ± SE) cm. Another fish identified as an *O. mykiss* measuring 44 cm was observed swimming upstream on February 27, 2019, at 02:18. On March 1, 2019, an *O. mykiss* measuring an estimated 79 cm was observed swimming downstream at 01:47. Steelhead escapement was estimated to be zero since the number of net upstream and downstream observations were the same.

Carpinteria Creek

From January 7, 2019 to May 30, 2019, 133 days of sonar footage were recorded in Carpinteria Creek. A total of 22 species observations estimated to be ≥ 40 cm in length were recorded. None of these observations were identified as *O. mykiss*. Additionally, none of the 22 observations were identified as a fish of any species.

Ventura River

One hundred and thirty-seven days of sonar footage were recorded from January 7, 2019 to May 30, 2019 (Table _). A total of 378 observations of targets estimated to be ≥ 40 cm in length were recorded. Of these observations, 1 was identified as *O. mykiss* and 278 were identified as Common Carp (Table 5). The *O. mykiss*, measuring 62 cm, was observed migrating upstream February 28, 2019 at 21:53. At this time, a USGS stream gauge located 0.7 miles upstream recorded an increase in flow earlier that day (Figure _). The net movement of migrating *O. mykiss* observed by DIDSON in the Ventura River was upstream.

A total of 337 Common Carp observations were recorded for the Ventura River, with 278 of those observations ≥ 40 cm. These observations ranged in length from 28 cm to 71 cm. Observations smaller than 30 cm generally weren't recorded as identification of fish to species is difficult below that size. The mean length of Carp observed was 53.4 ± 0.45 (mean ± SE) and for all Carp measured ≥ 40 cm, the mean ± SE length was 55.01 ± 0.32 cm. Of the 337 Common Carp observations, 68.8% occurred under relatively low flow conditions (≤ 50 ft^3s^{-1}) with the remaining observations split between moderate (50-100 ft^3s^{-1}) and high (>100 ft^3s^{-1}) flow conditions (Table 6; Figure _). Of all 337 Carp recorded, no significant diel patterns were observed, with 174 Carp observed during the day (i.e., 0600 – 1800) and 163 Carp observed at night.

DISCUSSION

A total of nine *O. mykiss* observations ≥ 40 cm were recorded from DIDSON footage collected during the 2019 spawning season. Eight of the nine *O. mykiss* observations were recorded in Salsipuedes Creek and one observation was made in the Ventura River. In Salsipuedes Creek, Cachuma Operation and Maintenance Board (COMB), which operates a trap just downstream of the camera site, was not able to confirm any of the large (≥ 40cm) *O. mykiss* observations. The first observed steelhead did not enter the COMB fish trap. Instead, this adult O. mykiss was recorded moving upstream and downstream in front of the camera six times and last observed moving downstream. Due to the stream channel profile and flow conditions at this time, this swimming behavior is likely influenced by the presence of the trap. The following steelhead observations occurred when the trap was likely not deployed due to high flows. The steelhead recorded in the Ventura River was visually confirmed by the Casitas Municipal Water District. This observation described a steelhead of a similar size at the Robles Diversion approximately 8.5 miles upstream and occurred within one week of the DIDSON recording (S. Lewis, personal communication). Subsequent walking surveys provided no additional observations.

This project demonstrates the efficacy of sonar cameras for steelhead abundance monitoring in southern California streams. Given the scarcity of southern California steelhead in these watersheds, the use of passive data collection methods that do not alter or otherwise negatively influence potential spawning activity (i.e., DIDSON and ARIS), will likely remain at the forefront of preferred approaches to tracking adult abundance. Continued refinement of methods to differentiate between steelhead and non-target species and development of deployment methods that will allow sonar deployment during peak flows will be critical steps toward maximizing DIDSON and ARIS utility under southern California conditions.

Environmental Challenges

Impacts of the 2018 Thomas Fire continued to influence data collection efforts in Carpinteria Creek and Ventura River. Due to a substantial portion of these watersheds burned, large amounts of sediment mobilized by post-fire rain events continued to move through the system. This reduced sonar visibility during moderate flow events and deposited sediment in the camera housing during high flow events requiring removal from the water for cleaning.

In previous years, cameras were not operational in high flows. Instead, cameras were removed prior to large storm events to protect against loss or damage of equipment. Re-deployment was then delayed until project personnel could safely work in and around the stream channel (approximately 400 cfs). This led to interruptions in data collection during high flows when steelhead may migrate (McEwan 2001). To limit any potential observational bias imposed by stream flows additional security anchors were installed and the cameras remained deployed through all flow events in the 2019 winter season. In theory this would allow continuous data collection during flow events outside an initial loss in sonar range caused by a pulse in turbidity associated with rapidly increasing flows. However, during high flow events in Carpinteria and Ventura River, each camera housing filled with extremely fine sediment, jamming the focus arm blocking the camera from transmitting. Cameras remained non-operational until staff were able to take apart and clean the camera housing. This created a similar interruption in collection as cleaning was delayed until flows receded to a safe working level. The presence of fine sediment and increase in sedimentation is most likely a temporary problem stemming from the Thomas Fire as opposed to a side effect of high flow deployments. The DIDSON deployed in Salsipuedes Creek, unburned by the Thomas Fire, did not experience this fine sediment accumulation even following high flows (~7000 cfs). Additionally, deployments under moderate flows (~3,000 cfs) in Carpinteria Creek and Ventura River prior to the 2018 Thomas Fire never experienced this fine sediment impairment (CDFW unpublished data).

Outside high flow events where fine sediment disabled camera operation entirely, elevated turbidity limited sonar camera effectiveness. When turbidity reached extreme levels (> 400 NTU) the sonar's range dropped to < 1 meter (Santa Barbara Channel Keeper 2018). Image range would then gradually increase as suspended sediments settled out of the water column. These periods were brief (i.e., < 48 hours) and followed peak flows. To the best of our knowledge, the limiting effects of turbidity on acoustic camera functionality are unavoidable. Further understanding of the relationship between turbidity and sonar effectiveness is needed. To assess this relationship, continuous turbidity readings, collected concurrently with sonar deployments, are needed. These data can be compared with sonar imagery to establish mathematical relationships between the two. This will allow for a quantifiable characterization of turbidity effects on sonar data collection and a better understanding of the implications for observational bias.

Operational Findings

The continued side-by-side operation of DIDSON and ARIS in the Ventura River site has allowed us to identify key differences in performance under dynamic conditions. We found during times of increased turbidity, the DIDSON is more consistent in providing clear images while the maximum viewing range of the ARIS decreases considerably. However, when turbidity was not a factor, ARIS imagery was noticeably superior to DIDSON. This was expected given that ARIS resolution is almost twice as high (1.8 and 3.0 MHz respectively). The increased resolution limits range and turbidity because higher frequency sound attenuates more rapidly with distance and increased suspended particulate concentration (Maxwell and Grove 2008). This increased resolution also contributes to larger file sizes for storing footage. Operating under similar settings ARIS files are typically three times larger than DIDSON files of the same length. This increased file size complicated file storage and added to the amount of time required to process files during analysis. 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 determined 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, footage from the other camera was still available. This kept gaps in data collection to a minimum.

Species Determination

The most considerable and well documented challenge posed by DIDSON monitoring in project systems is species identification (Pipal et al. 2012, Burwen et al. 2007, Burwen et al. 2010). A number of methods have been suggested to address this problem, including the use of tail-beat frequencies (Mueller et al. 2010), acoustic shadows (Langkau et al. 2012), paired optical video system (Killam 2012), and trapping methods (Denton et al. 2015). The feasibility of each option is under review for southern California steelhead monitoring applications. The current means of differentiating between species relies on evaluating swimming behavior and body morphology on a case-by-case basis. This method is problematic because it is subjective and depends heavily on reviewer experience.

In watersheds where species overlap in size with steelhead identifying small adults (around 40cm) can be difficult. In Salsipuedes Creek, three fish estimated to be 35-40cm in length were unidentifiable due to the known presence of large invasives (e.g. bass, catfish) and lack of distinguishing swimming characteristics. However, due to the large number of *C. carpio* encountered in the Ventura River, this project has been able to explore additional means of differentiating between species by further examining observable characteristics such as swimming motion and morphological features. Relationships between stream conditions (i.e., flow), temporal distribution (i.e., time of day observed) and behavioral patterns were explored as suggested by Pipal et al. (2012).

The number of *C. carpio* observations greater than or equal to 40cm (n= 278) was much less than the numbers observed in 2018 (n = 4,156) or 2017 (n= 20,625). This could be due to higher sustained flows in the Ventura River this year. The proportion of *C. carpio* observations that occurred in low flow conditions ((i.e., < 50 ft^3s^{-1}) was 99.1% in 2018 and 68.8% in 2019. According to the nearby USGS stream gauge, daily flow was much higher on average in 2019 (164.3 ± 34.9 ft^3s^{-1}[mean ± SE]) than in 2018 (22.2 ± 1.3 ft^3s^{-1}) (USGS 2019). Higher flows likely prevented the mobility of *C. carpio*, reducing the frequency of observations at the DIDSON site. While a higher proportion of carp are observed under low flow conditions these results suggest stream flow itself cannot be used as a means of distinguishing *O. mykiss* from *C. carpio*.

Although previous assessments of diel patterns in Carp movement in the Ventura River suggested a tendency towards nocturnal activity, data collected in 2019 does not support this. In 2018, 43.5% (n = 1,989) of all *C. carpio* observations were detected during the day (i.e., 0600 – 1800) (Bankston 2018, unpublished). In 2019, a similar number of *C. carpio* observations occurred during the day (n = 174;

51.6%) versus night (n = 163; 48.4%). As more data is collected a more defined relationship between the diel rhythms, stream flows, and *C. carpio* observations may emerge.

The large number of *C. carpio* observed in the Ventura River provided abundant opportunities to develop a better understanding of differences in *C. carpio* swimming behavior, morphological characteristics and behavioral responses to environmental conditions. Unfortunately, DIDSON footage of southern California *O. mykiss* is scarce. Project staff was able to obtain footage of large *O. mykiss* in non-study watersheds which has been helpful in providing a limited basis for comparison between the species but cannot substitute for imagery obtained of both species under identical conditions. Species designation will remain a problem until more steelhead imagery is obtained, more definite metrics for species determination can be evaluated, or methods of confirmation can be implemented (i.e. trap or optical system).

FIGURES

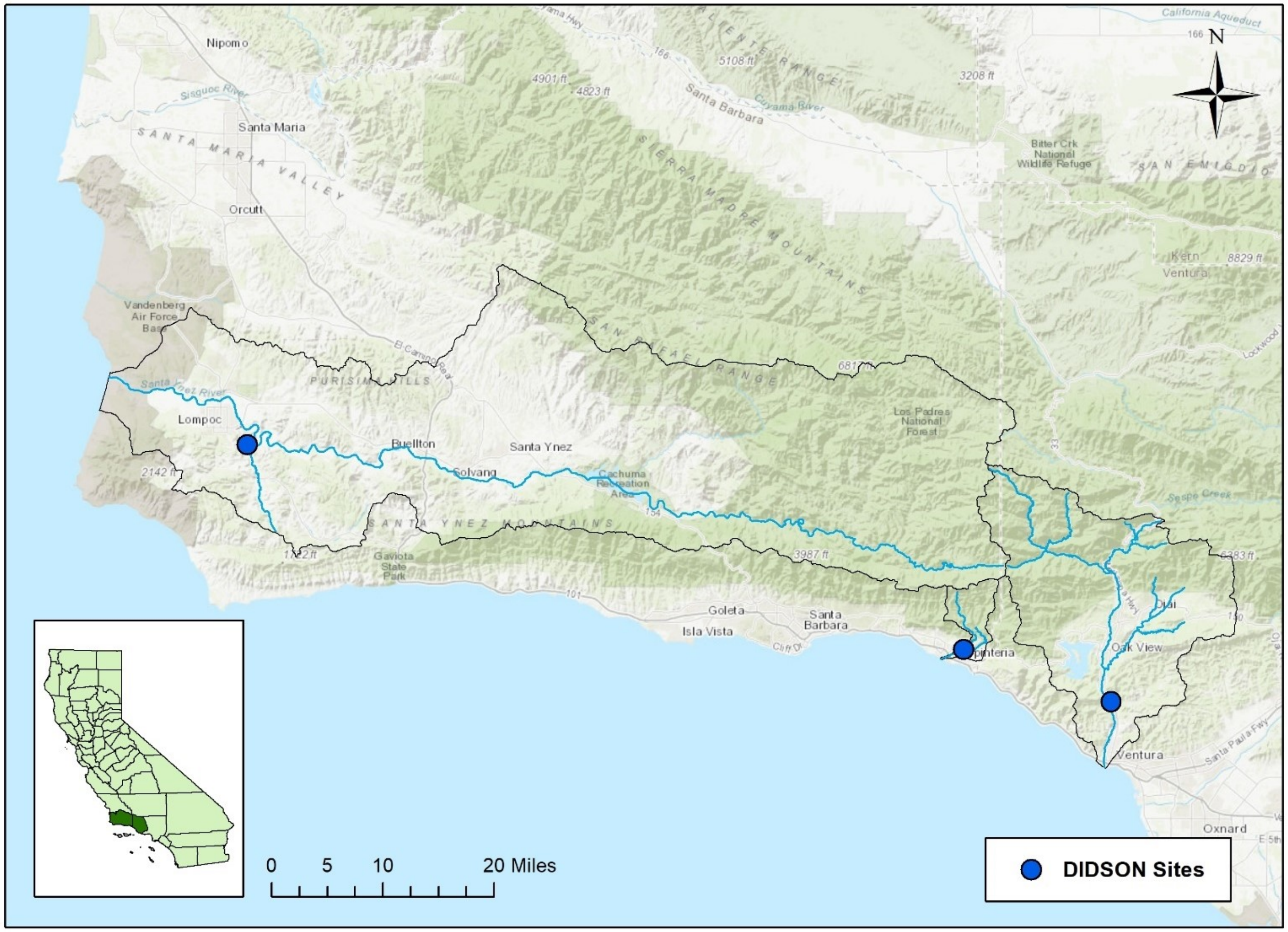

Figure 1. DIDSON monitoring sites in three southern California watersheds located in Santa Barbara and Ventura counties: Santa Ynez River (Monte Arido Highlands BPG), Carpinteria Creek (Conception Coast BPG), and the Ventura River (Monte Arido Highlands BPG).

Figure 2. Salsipuedes Creek DIDSON monitoring site in 2019 with key features labeled. (A) winch; (B) track; (C) cross-bracing cables; (D) deflection panels; (E) DIDSON/X2/sled assembly.

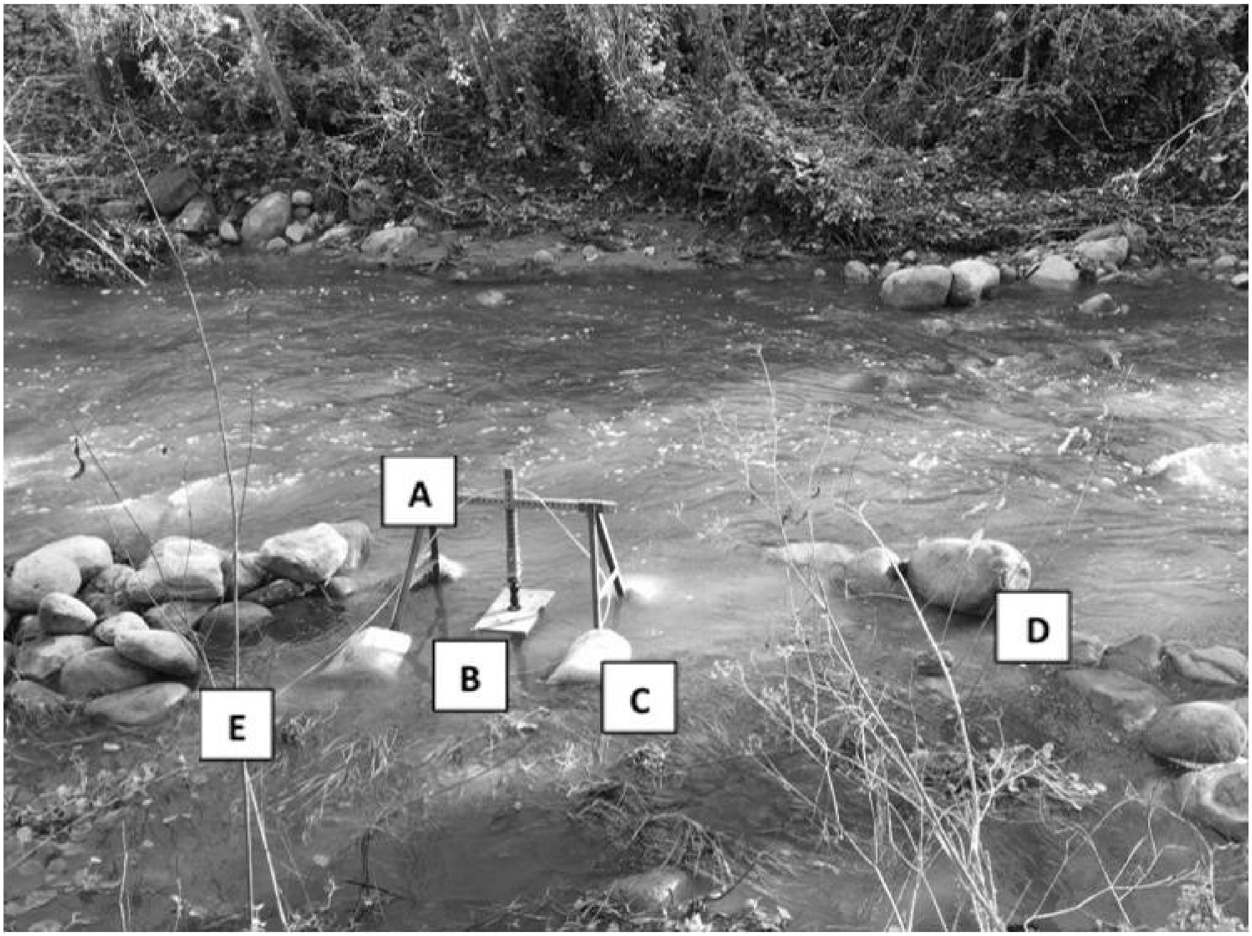

Figure 3. Carpinteria Creek DIDSON monitoring site in 2019 with key features labeled. (A) A-frame camera mount (B) DIDSON housed in a debris box and silt box; (C) gravel bags anchoring sled feet; (D) deflection panels; (E) security tether.

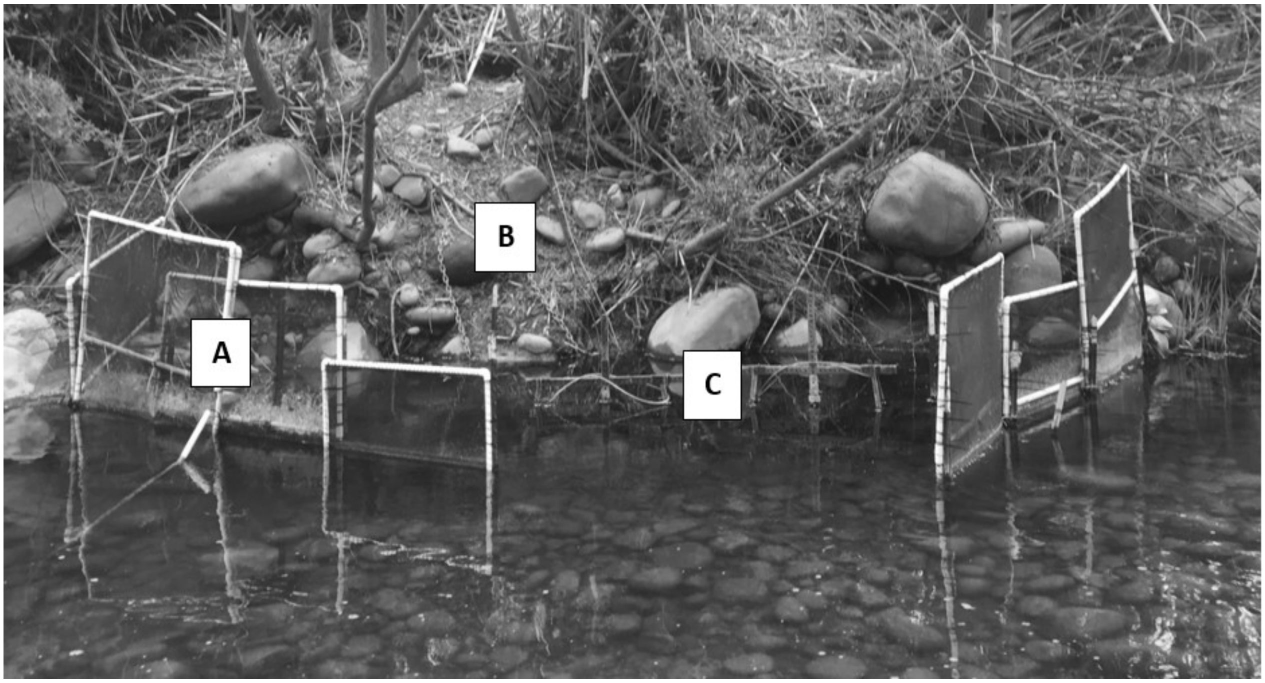

Figure 4. Ventura River monitoring site in 2019 with key features labeled. (A) Deflection panels; (B) security tether; (C) paired deployment of DIDSON and ARIS.

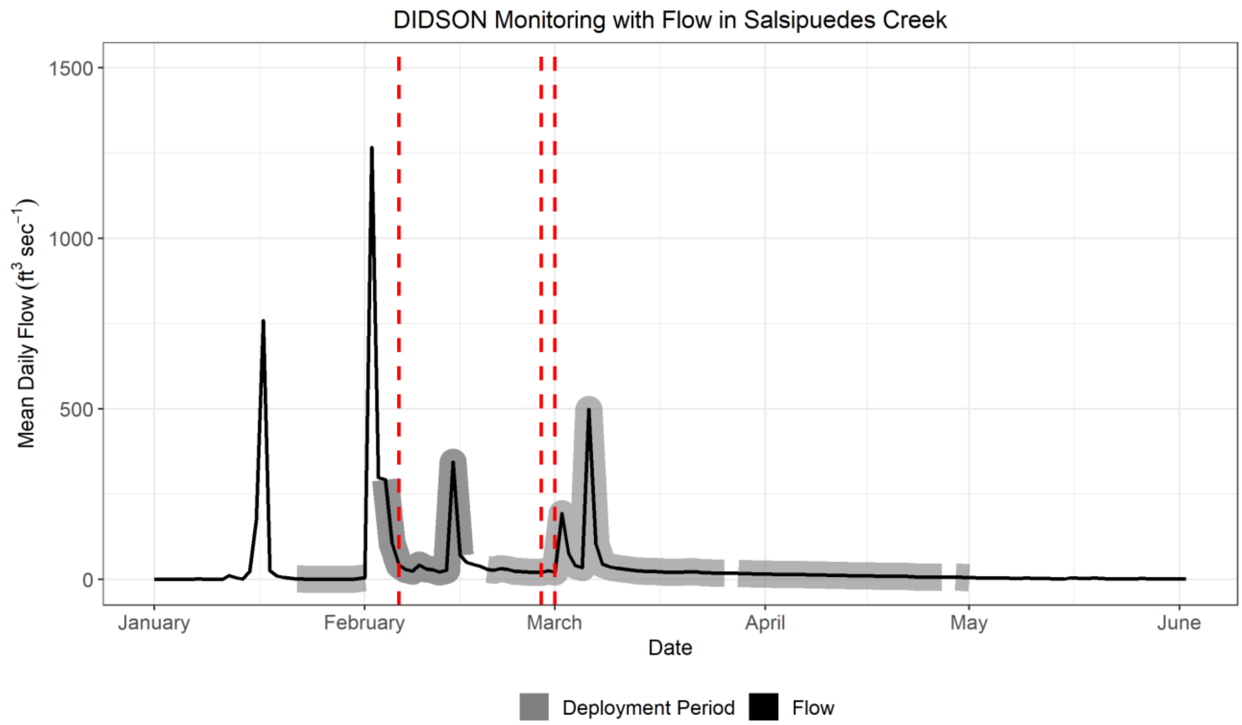

Figure 5. Salsipuedes Creek stream flow plotted against time for 2019 survey season. Steelhead observations (n=3) were recorded on February 6, February 27, and March 1, 2019 (indicated by red dashed lines). Data was recorded on a standard DIDSON 300m camera operating in high frequency (1.8 Hz) from January 7, 2019 to May 1, 2019.

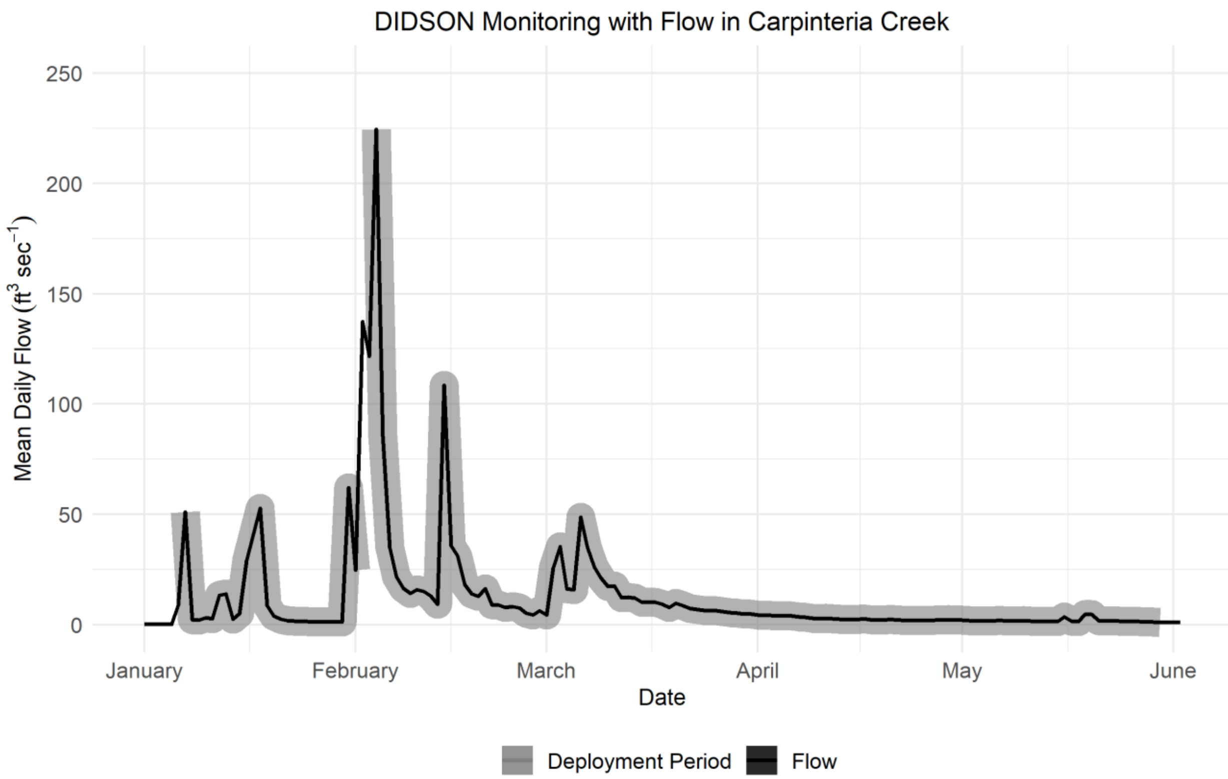

Figure 6. Carpinteria Creek stream flow plotted against time for 2019. Zero fish observations were recorded during the deployment of a long-range DIDSON 300 m camera from January 7, 2019 to May 30, 2019.

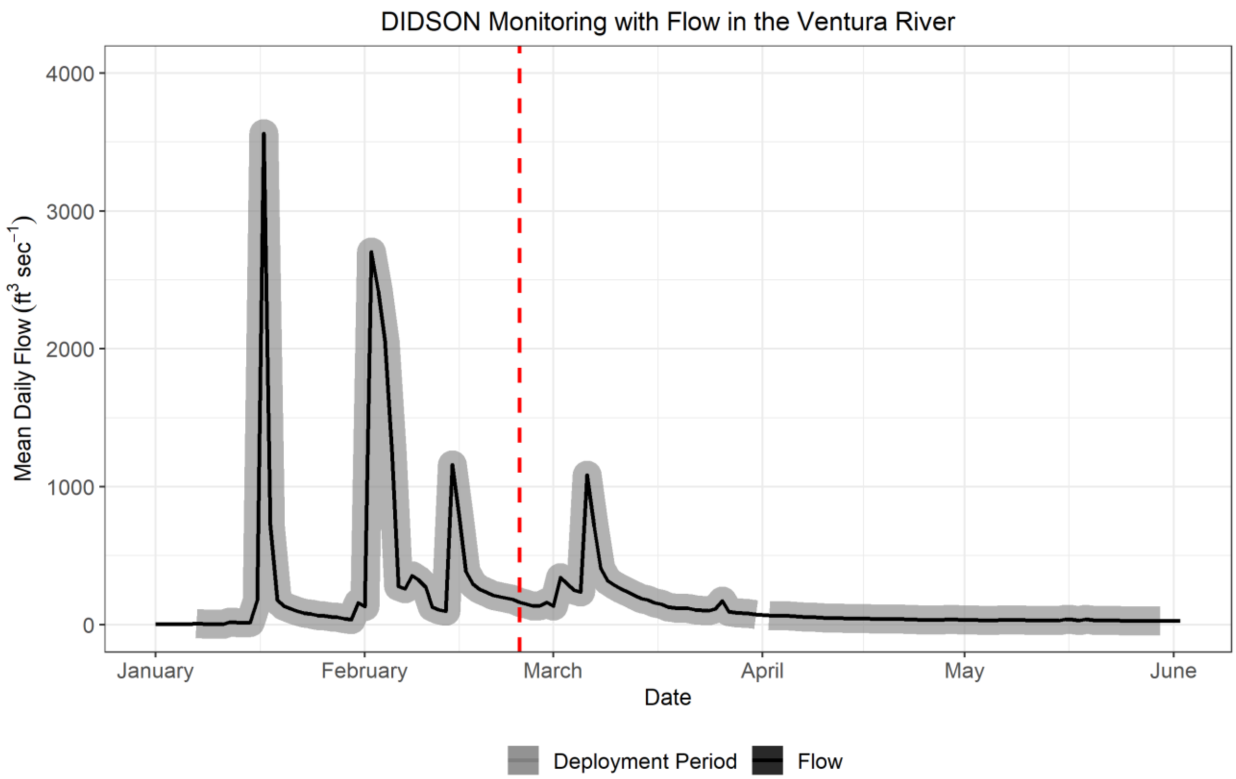

Figure 7. Ventura River stream flow plotted against time for 2019. All steelhead observations (n=1) were recorded on February 28, 2019 (indicated by red dashed line). Data was recorded by a standard DIDSON 300m camera operating in high frequency (1.8 Hz) deployed in the Ventura River from January 7, 2019 to May 30, 2019.

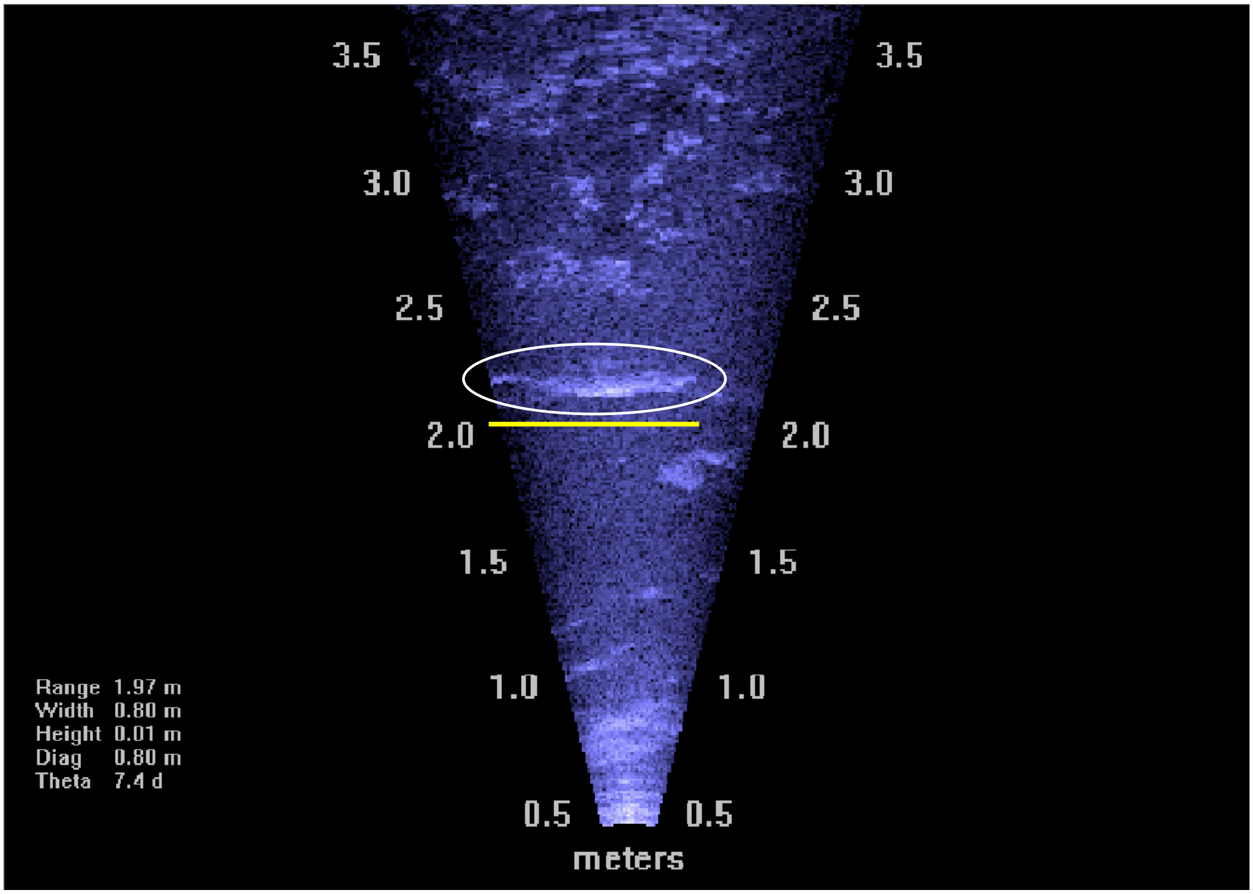

Figure 8. A still taken from DIDSON footage of a steelhead recorded at the Salsipuedes Creek site at 0147 on March 1, 2019. For scale, the yellow line below the steelhead measures 80 cm.

TABLES

Table 1 – Deployment duration for each DIDSON monitoring site.

Site	*Deployment Start*	*Deployment End*	[a]*Deployment Duration (days)*
Carpinteria Creek	2019-01-07	2019-05-30	142
Salsipuedes Creek	2019-01-17	2019-05-01	94
[b]Ventura River	2019-01-07	2019-05-30	143

[a]*Gaps occurred in footage due to storm conditions/power outages.*
[b]*Two sonar cameras (ARIS Explorer 3000, DIDSON 300) were deployed in parallel at this site to compare efficacy of each model.*

Table 2 – Recorded footage in hours and days for each DIDSON site.

Deployment Site	*Recorded Hours*	*Recorded Days*
Carpinteria Creek	3189.4	132.9
Salsipuedes Creek	2036.9	84.9
Ventura River	3294.6	137.3

Table 3 – Number of observations recorded at each DIDSON monitoring site (excludes observations identified as "unknown" or "Person"). DIDSON 300m cameras operating at high frequency (1.8 Hz) were deployed to collect data during the southern California steelhead spawning season from January to May 2019.

Site	*n*	*≥ 40 cm*
Carpinteria Creek	17	2
Salsipuedes Creek	702	37
Ventura River	424	285

Table 4 – O. mykiss observations in Salsipuedes Creek during the 2018-2019 spawning season.

Date of Footage	*Time of Footage*	*Time in Frame (s)*	*Direction of Net Movement*	*Mean Length (cm)*
2019-02-06[A]	19:52:03	6	Upstream	92
2019-02-06[A]	19:52:48	8	Downstream	87.3
2019-02-06[A]	19:55:22	21	Upstream	81
2019-02-06[A]	19:57:06	3	Downstream	76
2019-02-06[A]	19:57:23	15	Upstream	78.3
2019-02-06[A]	19:57:57	5	Downstream	79
2019-02-27	2:18:20	3	Upstream	43.7
2019-03-01	1:47:59	2	Downstream	79.3

[A]Likely the same individual O mykiss based on time, direction, and estimated length recorded

Table 5 - Total observations of adult *O. mykiss* recorded in the Ventura River during the 2018-2019 spawning season. DIDSON 300m operating at high frequency (1.8 Hz) were deployed to collect data from January 7, 2019 to May 30, 2019.

Date of Footage	*Time of Footage*	*Time In Frame (sec)*	*Direction of Movement*	*Mean Length (cm)*
2019-02-24	21:53:09	8	Upstream	61.5

Table 6 – Ventura River Common Carp observations binned by increments of 25 ft3 s -1 for 2019.

Flow Bin (25 cfs)	*n*	*Percent of Observations*	*Cumulative Percent*
0-25	176	52.2	52.2
25-50	56	16.6	68.8
50-75	34	10.1	78.9
75-100	13	3.9	82.8
100-125	16	4.7	87.5
125-150	27	8	95.5
150-175	6	1.8	97.3
175-200	2	0.6	97.9
>200	7	2.1	100

Table 7 – Total species observations recorded on DIDSON deployed at each stream site (excludes "unknown" species and "Person" observations). Data was collected during the southern California steelhead spawning season from January to May 2019.

Site	**Species*	*n*	*≥ 40 cm*
Carpinteria Creek	Frog	2	0
	Turtle	1	0
	Unidentified Terrestrial	12	2
	Waterfowl	2	0
Salsipuedes Creek	Frog	44	16
	North American Beaver	2	2
	O. mykiss	43	8
	Sunfish	3	0
	Turtle	12	0
	Unidentified Fish	551	7
	Unidentified Terrestrial	5	4
	Waterfowl	42	0
Ventura River	Common Carp	337	278
	Frog	2	0
	O. mykiss	1	1
	Turtle	2	0
	Unidentified Fish	40	6
	Waterfowl	42	0

*Note data was not collected consistently for observations <25 cm in Salsipuedes or <30cm in Carp or Ventura.

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