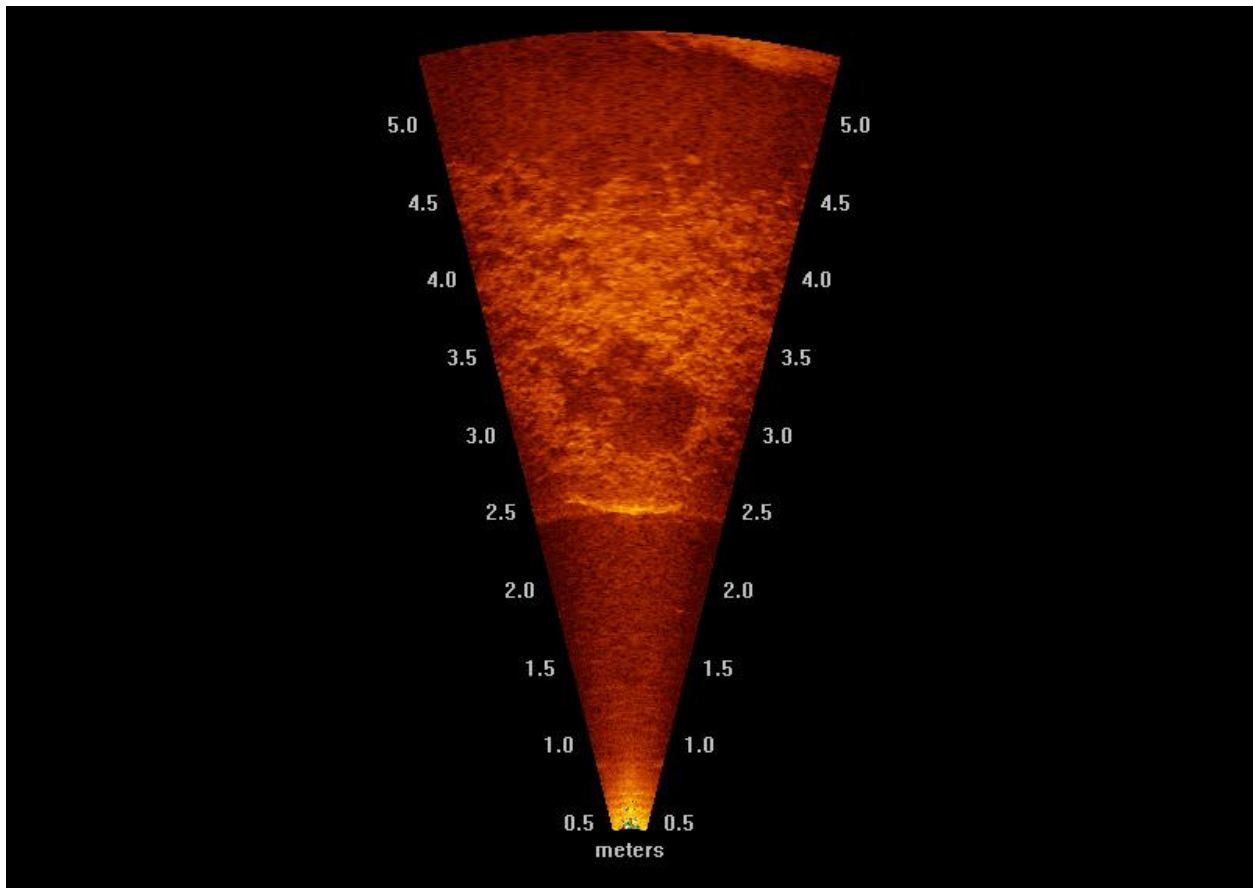


Monitoring of Adult Coho Salmon and Steelhead Trout Using Dual-frequency Identification Sonar (DIDSON) in Lagunitas Creek, California

2013 Annual Report



Prepared for:
California Department of Fish and Wildlife
Contract: #P1130420

Prepared by:
Point Reyes National Seashore Association
1 Bear Valley Rd
Point Reyes Station, CA 94956



ON THE COVER

DIDSON image of Adult Salmonid on Lagunitas Creek, Marin County, CA
Screenshot by: Benjamin Atencio

Monitoring of Adult Coho Salmon and Steelhead Trout Using Dual-frequency Identification Sonar (DIDSON) in Lagunitas Creek, California

2013 Annual Report

Benjamin Atencio¹ and Michael Reichmuth²

¹Point Reyes National Seashore Association, Coho and Steelhead Monitoring Program
1 Bear Valley Road
Point Reyes Station, California 94956

²National Park Service, San Francisco Bay Area Network Inventory and Monitoring Program,
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, California 94956

February 2014

The Long-term Coho and Steelhead Monitoring progress reports are intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols provided by the National Park Service and were analyzed and interpreted within the guidelines of the protocols.

Please cite this publication as:

Atencio, B., and M. Reichmuth. 2014. Monitoring of Adult Coho Salmon and Steelhead Trout Using Dual-frequency Identification Sonar (DIDSON) in Lagunitas Creek, California, 2013 annual report. Report to the California Department of Fish and Wildlife, Grant # P1130420, Point Reyes National Seashore Association, California.

Contents

	Page
Figures.....	v
Tables.....	vi
Abstract.....	vii
Acknowledgements.....	viii
List of Acronyms	ix
1 Introduction.....	10
2 Sampling Design and Methods	12
2.1 Equipment.....	12
2.2 Study Sites	12
2.3 Deployment.....	13
2.4 Data Processing	13
2.5 Data Review.....	14
2.6 Data Analysis.....	15
2.6.1 Escapement Estimates.....	16
2.6.2 Trend Analysis.....	17
3 Monitoring Results.....	18
3.1 Abiotic Factors.....	18
3.2 Data Recording	18
3.3 Daily Totals and Escapement Estimates.....	19
3.4 Salmonid Movement Trends.....	22
3.5 Otter Observations	27
4 Discussion and Recommendations for Study Year 2.....	29
5 Literature Cited	32

Contents "continued"

	Page
Appendix A.....	35

Figures

	Page
Figure 1 Daily upstream net counts of adult salmonid observations for the 2012-2013 DIDSON recording season.	20
Figure 2 Daily upstream counts of adult salmonids for the 2012-2013 DIDSON recording season.....	21
Figure 3 Daily downstream counts of adult salmonids for the 2012-2013 DIDSON recording season.....	21
Figure 4 Adult salmonid observations by hour of the day (24 hour clock) for the 2012-2013 DIDSON recording season.	22
Figure 5 Daily adult salmonid observations with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).	23
Figure 6 Daily upstream adult salmonid observations with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).....	24
Figure 7 Daily downstream adult salmonid observations with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).	24
Figure 8 Absolute value of daily net adult salmonid counts with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).	25
Figure 9 Adult salmonid lengths (cm) separated into 5cm intervals for the DIDSON recording period 12/13/2012 through 4/29/2013.	26
Figure 10 Adult coho lengths (cm) separated into 5cm intervals for the DIDSON recording period 12/13/2012 through 12/27/2012.	26
Figure 11 Adult steelhead lengths (cm) separated into 5cm intervals for the DIDSON recording period 1/31/2013 through 4/29/2013.	27
Figure 12 Otter Sightings by hour of the day for the 2012-2013 DIDSON recording season (n=255).....	28

Tables

	Page
Table 1 Summary of times of non-operation between initial instillation at Study Site 1 and the end of the 2012-2013 DIDSON recording season.	19
Table 2 Monthly and 2012-2013 DIDSON recording season totals for Fish Observations, New Decision Support Tool (DST) Count, Net Movement, and Percent Operational.....	20
Table 3 Correlation coefficients of mean daily flows, maximum daily flows, mean daily flow after 11 January 2013, maximum daily flow after 11 January 2013 compared to upstream adult salmonid observations, downstream adult salmonid observations, adult salmonid milling observations, total adult salmonid observations, and absolute value of the net adult salmonid count for the 2012-2013 DIDSON recording season.....	23

Abstract

In 2012, Lagunitas Creek was selected as a coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) life cycle monitoring station (LCMS) by the California Department of Fish and Wildlife (CDFW). A major component of LCMS is the use of adult counting stations to determine adult salmonid escapement. Dual-frequency identification sonar (DIDSON) technology was identified by CDFW as a potential non-intrusive survey method for meeting the adult counting station requirement. In addition, escapement estimates using a DIDSON camera could be compared to current adult escapement estimates using traditional spawner survey techniques. During the winter of 2012-2013, a DIDSON camera was installed in Lagunitas Creek by Point Reyes National Seashore Association (PRNSA) staff. Initial assembly, instillation, and site selection proved inadequate to produce accurate escapement results. By January of 2013 PRNSA staff corrected most of the factors that had prevented the DIDSON from being used as an adult counting station earlier in the season. The DIDSON was operational 81% of the time from December 13, 2012 through April 29, 2013. In the 2012-2013 recording season, there were 12,153 salmonid observations with 5,476 upstream passage events and 5,349 downstream events. Peak upstream and downstream migration both occurred on the same day, March 28, with 192 upstream and 212 downstream events. 68.7 percent of all salmonid passage events occurred at night. Although a 2012-2013 coho escapement estimate could not be calculated using the available DIDSON footage, steelhead escapement estimates of 388 and 395 adult steelhead were calculated for the first time on Lagunitas Creek.

Acknowledgements

Funding to support monitoring activities is provided through the National Park Service - San Francisco Bay Area Network (SFAN) Inventory and Monitoring Program and the California Department of Fish and Wildlife Fisheries Restoration Grant Program Contract P1130420. Many thanks to PRNSA and NPS program staff for their advice and help with this program, especially Blake Towarnicki, Kelly Church, and Katelyn Jordan for their efforts on footage review.

List of Acronyms

CCCESU	Central California Coast Evolutionarily Significant Unit
CDFW	California Department of Fish and Wildlife
CMP	California Coastal Salmonid Monitoring Plan
CSOT	Convolved Samples Over Threshold
DD	Downstream Downstream salmonid movement
DIDSON	Dual-Frequency Identification Sonar
DPS	Distinct Population Segment
DST	Decision Support Tool
I&M	Inventory and Monitoring Program
LCMS	Life Cycle Monitoring Station
MMWD	Marin Municipal Water District
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PIT	Passive Integrated Transponder
PRNSA	Point Reyes National Seashore Association
QA/QC	Quality Assurance and Quality Control
SFAN	San Francisco Bay Area Network
SD	Standard Deviation
UPS	Uninterruptable Power Supply
USGS	United States Geological Survey
UU	Upstream Upstream salmonid movement

1 Introduction

The Dual-Frequency Identification Sonar (DIDSON) was developed by the University of Washington's applied physics laboratory with the original purpose of underwater mine detection for the United States Navy (Belcher et al. 2001; Belcher et al. 2002). DIDSON has since found use in various fisheries research applications. It has been used for adult salmon enumeration by the Alaska Department of Fish and Game, the Nez Perce Tribe in Idaho, on the Columbia River, and in British Columbia (Maxwell and Gove 2004; Kucera and Faurot 2005 and 2006; Tiffan et al. 2004 and 2005; Cronkite et al. 2006). More recently DIDSON systems were installed within the Central California Coast (CCC) Evolutionary Significant Unit (ESU) on the Russian River, Pudding Creek, San Lorenzo River, and Scott Creek to determine adult salmonid abundance (Wheeler 2012; Parker et al. 2013; Pipal et al. 2010b; Pipal et al. 2012).

Lagunitas Creek is located in coastal Marin County, California, starting on the northern slope of Mount Tamalpais and flowing into Tamales Bay, outside the town of Point Reyes Station. Lagunitas Creek contains two federally listed salmonid species, coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*). Coho salmon of the Lagunitas Creek Watershed are considered part of the CCC ESU and are listed as endangered under State and Federal Endangered Species Acts (California Department of Fish and Game 2002; Federal Register 2005). Steelhead trout of the Lagunitas Creek Watershed are considered part of the CCC Distinct Population Segment (DPS) and are listed as threatened under the Federal Endangered Species Act (Federal Register 1997 and 2006). Although not recognized by the National Marine Fisheries Service (NMFS) as a listed population on Lagunitas Creek, chinook salmon (*O. tshawytscha*) are frequently observed in November and December along with the occasional adult chum salmon (*O. keta*) observation (Ettlinger et al. 2010; Ettlinger and Andrew 2013). Lagunitas Creek is a vital part of the CCC ESU, containing one of the largest, most southern populations of coho salmon in California (Ettlinger et al. 2010). Coho salmon have a three year life cycle, spending one year in their natal streams before migrating to the ocean. After two years in the ocean, adult coho salmon return to their natal streams to spawn. Spawner surveys of Lagunitas Creek have been tracking the parent generation of the 2012-2013 coho salmon adults since the 1997-1998 season. Coho spawner estimates for this cohort have ranged from 67 in 2009-2010 to 947 in 2003-2004 (Ettlinger et al. 2010). In 2012 the NMFS established a recovery target of 2,600 adult coho spawners on Lagunitas Creek (NMFS 2012). Observations of live adult steelhead, steelhead carcasses, and redds are reported annually but surveys are not conducted throughout the entire steelhead spawning run, making adult steelhead escapement results unreliable (Ettlinger and Andrew 2013).

October 2012 marked the start of the first year of a two year pilot project funded by the California Department of Fish and Wildlife (CDFW) and executed by staff of the Point Reyes National Seashore Association (PRNSA) and the National Park Service (NPS) San Francisco Bay Area Network (SFAN) Inventory and Monitoring (I&M) Program. The pilot project is designed to test new technology and its possible integration into the Life Cycle Monitoring Station (LCMS) on Lagunitas Creek as outlined in California Coastal Salmonid Monitoring Plan (CMP) (Adams et al. 2011). The

project utilizes a DIDSON unit to record the migration of returning adult salmonids. The goals of the first year of deployment included:

- test equipment and create a protocol for future operations;
- produce an escapement estimate for coho salmon and steelhead trout for the Lagunitas Watershed;
- improve and enhance current spawner survey techniques; and
- provide length measurements, migration timing, species interactions, and other biotic information of interest.

This report summarizes data from the first season of DIDSON operation which included recordings from December 13, 2012 (with some gaps due to storms, equipment problems, etc.) until it was removed on April 29, 2013.

2 Sampling Design and Methods

This program includes strategies to monitor adult coho salmon and steelhead returning to Lagunitas Creek to spawn. The methods used during this study include experimental designs utilized by other research groups monitoring adult salmonid movement with DIDSON technology. The methods associated with this project are consistent with suggested monitoring techniques as outlined by CDFW in the CMP (Adams et al. 2011).

2.1 Equipment

A DIDSON 300m short range sonar unit coupled with a Sound Metrics X2 pan-and-tilt motor were attached to a stainless steel tripod mount. The mount was built by Rodger's Welding in Petaluma, CA, based on designs obtained from Kerrie Pipal of the National Oceanic and Atmospheric Administration (NOAA), Southwest Fisheries Division. The DIDSON unit was housed in a standard DIDSON Silt Box. A 60m communication cable ran from the sonar unit to a modified storm proof case (Pelican Stormcase IM3075), located on the same stream bank, approximately 40m downstream. An Hp Pavilion dv6-7014nr laptop was stored on site and communicated with the sonar unit and motor using the provided DIDSON software (Sound Metrics Corp.). Recordings were saved directly to 1TB ADATA HD710 external hard drives, which were exchanged regularly. All the data for the project was stored on an eight bay B800fs drobo device (Drobo, Inc.) equipped with five 3TB SATA internal hard drives. The debris deflection fences were built using 6ft T-post, ¼ inch mesh steel hardware cloth, felt erosion cloth, and sandbags.

2.2 Study Sites

Two study sites were used in the 2012-2013 field season (Appendix A, Figure A1). Study Site 1 was located on NPS land, behind the Tocaloma office buildings at Latitude 38.044537 North, Longitude 122.749306 West. This site was approximately 10.4 km upstream from the start of tidal influence in Lagunitas Creek and 0.82 km downstream from the tributary confluence of Cheda Creek. Study Site 1 was located in a reach of Lagunitas Creek typically associated with spawning (Ettlinger et al. 2013). Power was supplied from the basement of the main office building via an outdoor extension cord. The site was selected for its ease of access and proximity to an electrical source.

Study Site 2 was located on Lagunitas Creek downstream of Study Site 1, approximately 3.7 km upstream from the start of tidal influence in Lagunitas Creek. Study Site 2 was located downstream of the typical spawning reaches on Lagunitas Creek (Ettlinger and Andrew 2013). The Marin Municipal Water District (MMWD) smolt trap, MMWD Passive Integrated Transponder (PIT) tag antenna, and the United States Geological Survey (USGS) Point Reyes Station stream gage were within close proximity to the DIDSON deployment Site 2. This site is the proposed location for the Lagunitas Creek LCMS (Adams et al. 2011). Power was supplied from an old water pumping station. Study Site 2 was the preferred site for the project due to the morphology of the creek at that location, proximity to other monitoring activities, and its location lower in the watershed (downstream of major spawning habitat).

By early December 2012, most project equipment had been received (excluding the pan-and-tilt motor) and the mount was completed. However, power was not connected at Study Site 2 until

early January 2013, so the unit was installed at Study Site 1 on December 13, 2012. The pan and tilt motor was received in early January 2013 and the unit was moved to Study Site 2 on January 11, 2013 where it remained until the completion of the field season on April 29, 2013.

2.3 Deployment

The DIDSON unit was mounted to the stainless steel tripod style mount. At Study Site 1, the unit was attached to the mount arm at an angle using a piece of wood because the pan and tilt motor had not yet arrived. When the unit was installed at Study Site 2, the pan and tilt motor was installed as well. The unit was placed in the creek and aimed perpendicular to the flow to create a cross section image of the creek (Appendix A, Figures A3 and A6). The unit was aimed remotely using the pan and tilt motor and the DIDSON software. The unit was aimed so the beams skim the stream bed while ensonifying as much of the water column as possible. The aiming of the camera was based on the assumption that salmonids will most likely swim low in the water column, close to the stream bed, on their upstream migration (Quinn 2005; Pipal et al. 2012). The unit and associated equipment was checked daily in the beginning of the season, then as little as once a week if no malfunctions with the unit were recently encountered and no change in flow was forecasted. The external hard drives were switched out every other week.

At Study Site 1, a deflection fence was installed directly upstream of the DIDSON and associated mount to prevent large debris floating downstream from damaging equipment (Appendix A, Figure A2 and A3). At Study Site 2, a deflection fence was also installed upstream of the DIDSON to prevent damage. Study Site 2 featured an undercut bank in the area ensonified by the DIDSON, an area that adult salmonids could swim past the unit and remain undetected. A second debris fence was installed to prevent salmonids from utilizing the undercut bank. The fence had the added benefit of making salmonids swim around it, into an area of optimal returns on DIDSON footage (Appendix A, Figures A4-A6).

2.4 Data Processing

The DIDSON program was set to record continuously, creating files one hour in length. Each file was between 1 and 1.4 gigabytes, depending on the stream width of the site and the turbidity of the creek. The 1 terabyte field hard drives could hold almost 30 days of data, however, they were switched out every other week to ensure adequate storage space remained on each hard drive and to initiate data review. Hard drives were brought back to the office, where the raw data was transferred to the drobo device. Files were organized by month, then into individual days.

Raw data files were analyzed first using the Convolved Samples Over Threshold (CSOT) feature of the DIDSON software. CSOT uses algorithms to reduce the raw footage to frames where motion or movement of objects over a set size threshold are detected. The user can adjust the thresholds. The standard CSOT settings were used for this project, with the exception that the “Persistence” was set to 8 and the “Insert Prequel” setting was turned on (Appendix A, Figure A7). Sometimes CSOT would record nearly an entire file if the substrate was disturbed. In order to conserve space on drobo drives and make review more straightforward, CSOT files larger than half of the original would be deleted and a shortcut to the raw data file would take its place. After CSOT analysis, CSOT files were organized into separate folders. Sometimes with the CSOT analysis of a file no movement of an

object over threshold size would be detected and zero frames would be exported. In these cases, a text file would take the place of the CSOT file. This text file was a placeholder to ensure the data reviewer did not think a raw file had not been analyzed using the CSOT feature and waste time repeating the CSOT process or watching empty raw data files.

2.5 Data Review

Each individual day was reviewed by a single reviewer, logging their data in excel files. When an object is observed, the reviewer first watches the clip to ensure fish detection instead of sticks, leaves, logs, or other inanimate objects passing through the field of view. The reviewer does this by looking for fish like body shape, movement of tail, upstream movement, or change in direction. Often an object will cast an acoustic shadow. With salmonids this shadow can clearly show the dorsal, adipose, caudal, and anal fins.

There are several species in the Lagunitas Creek Watershed that could be confused for a salmonid during review of DIDSON footage including: green sturgeon (*Acipenser medirostris*); sacramento suckers (*Catostomus occidentalis*); common carp (*Cyprinus carpio*); channel catfish (*Ictalurus punctatus*); california roach (*Lavinia symmetricus*); bluegill (*Lepomis macrochirus*); redear sunfish (*L. microlophus*); green sunfish (*L. cyanellus*); white crappie (*Pomoxis annularis*); and black crappie (*P. nigromaculatus*); and North American river otters (*Lontra canadensis*). Green sturgeon have different body morphology and would be much larger than an adult coho salmon or steelhead trout (Moyle 2002). Suckers have a very different body shape and have been noted to have a much different swimming pattern than salmonids on DIDSON footage (Pipal 2010a). Common carp have similar body morphology and length range as adult salmonids, but rarely occur in this section of Lagunitas Creek (Ettlinger et al. 2014; Eric Ettlinger pers comm 2014b). Catfish have a very different body shape and swimming behavior (Moyle 2002). California roach have similar body shape and swimming style to salmonids, but do not attain lengths of 30cm (Moyle 2002). Sunfish are an exotic in Lagunitas Creek with specimens over 30cm very rare and possess a very different body shape from salmonids (Moyle 2002). While river otters are a mammalian species, they often proved the most difficult to differentiate from salmonids. Reviewers looked for “clouds” of air bubbles being shed from fur, feet and paws active while swimming, body undulation in the vertical plane, very large size (often over one meter), and no fins or other fish like features in the acoustic shadow. All salmonids measuring over 30cm were recorded, with all those over 35cm included in the final counts. The 35cm size requirement was determined after reviewing Lagunitas Creek coho salmon jack and resident steelhead trout length data (Eric Ettlinger pers comm. 2013).

After determining that the object is indeed an adult salmonid, the reviewer rewound the footage to the first frame the fish appears on screen. The starting frame number and time are recorded in the excel file. Footage was continued until the fish was fully in view. Three measurements were taken for each fish with the first taken on a frame with clear returns, no arcing, and where the body of the fish is straight- not bent from swimming. Measurements were taken using the measure tool of DIDSON software. The box measuring method was used (Pipal et al. 2010a). A box is drawn from the first pixel of the snout to the last pixel of the caudal fin, resulting in a total length to the nearest cm (Appendix A, Figure A8). The zoom feature was always used while taking measurements. Other

software features that were useful were background subtraction and transmission loss correction. Background subtraction was used in most measurements. The second fish measurement was recorded when the fish entered the center of the field of view. The third length measurement was recorded within the last few frames the fish was fully in view. Each frame used to determine fish measurement was recorded. After recording measurements, footage was forwarded until the last frame the fish is present on screen and the end time was recorded. Salmonid direction was recorded as upstream, downstream, upstream/upstream (UU), or downstream/downstream (DD).

To help differentiate between salmonids actively migrating upstream or downstream and salmonids milling in the area of the DIDSON, a slightly modified version of the Decision Support Tool (DST) designed by Pipal et al. was used (2010a). The tool is used to compare the current salmonid being processed to past salmonid whose destination was the current salmonid's origin (ex: a salmonid went upstream, use DST to compare to a latter salmonid moving downstream). The DST is a much more objective method of differentiating between individual fish than the alternative and highly subjective method of relying on the viewer's opinion. The tool compares the two fish over four categories- size, time off camera, pairing, and distinctive swimming pattern. The DST assigns point values based on the difference between the two fish. Size is the most important factor in determining if it is the same fish or not and is given the most weight, with 4 points assigned to a difference of 0-2cm; 3 points assigned to a difference of 2.1-5cm; and 1 point assigned to a difference of 5.1-7cm. If the difference is larger than 7cm, the two fish are considered different. Time off camera is the time elapsed since the ending time of the first fish to the starting time of the second fish. Points for time off camera are assigned as follows: 3 points for less than 5 minutes, 2 points for less than 30 minutes, and 1 point for less than 60 minutes. Times over an hour are assigned zero points, and after two hours it is considered a different fish (i.e. a fish can pass the DIDSON again 1:59:59 after the first fish and still be considered the same fish, but will need points from pairing or distinctive swimming). Pairing can be a strong indication of whether it is the same fish or not. If it is paired in both the upstream and downstream directions, it is assigned 3 points. Distinctive swimming pattern is the most subjective category in the DST, as it relies on the viewer to assign points for patterns such as milling in a certain area. The points from size difference, time off camera, pairing, and distinct swim pattern are summed. If the point score is greater than or equal to 5, it is considered the same fish and given the same fish ID number.

2.6 Data Analysis

Sunrise and sunset times were calculated by averaging the daily sunrise and sunset times for the week. The sunrise and set times were calculated using Fairfax, CA, as the location because it was the closest town in the online registry (United States Naval Observatory). Weather data was obtained from the Olema Valley Remote Automated Weather Station (Western Regional Climate Center). Creek flow data was obtained from USGS Stream Flow Gaging Station #11460600, Point Reyes Station, California.

All the reviewer excel logs were compiled chronologically into excel spreadsheets for each month. Some slight edits were made to the logs, such as removing empty cells and redundant data, before

importing all the data into a Microsoft Access 2010 database. A second table was made which contains only adult salmonid observations from the season.

A third table was created using data from the second table for cataloging daily totals, such as: total fish observations, net movement, and percent operational. Daily salmonid observations were calculated by querying out each day from the salmonid only table and counting the number of observations. Daily net movement was calculated by subtracting the daily downstream event total from the daily upstream event total for each respective day. A positive number reflects net upstream movement for the day and a negative number reflects net downstream movement. Daily percent operation figures were calculated by dividing the hours the DIDSON was recording each day by 24 hours. Daytime observations were calculated by querying out each day in access and sorting for hours between sunrise and sunset. Nightly observations were calculated by subtracting the daytime observation from the respective day's observation total.

Daily totals were sorted further into nightly upstream and downstream counts, daylight upstream and downstream counts, and proportion the DIDSON was recording for day and night of each day. The main purpose of this data was for use in a statistical model designed to fill in data gaps and correct for reviewer error associated with DIDSON (Semmens 2011). The daylight upstream and downstream counts were determined by querying out each day in access, sorting for hours between sunrise and sunset, and counting the respective upstream or downstream events. Nightly upstream and downstream counts were calculated by subtracting the daylight upstream or downstream counts from the respective up or down daily total. Proportions of daylight operation were calculated by dividing the hours of daylight operation by the hours between sunrise and sunset. Proportions of nighttime operation were calculated by dividing the hours of nighttime operation by the sum of the hours between midnight (0:00:00) and sunrise and sunset to midnight (23:59:59).

2.6.1 Escapement Estimates

To facilitate species identification between coho and steelhead, an underwater video camera was installed with the DIDSON at Study Site 2. Video footage was reviewed after one week of operation and visibility was too low (<1m) to distinguish between species. It was determined that video footage did not produce useful imagery to distinguish between adult salmonid species and the video camera operation was discontinued. Since adult salmonid species identification could not be determined, spawner survey data was used to create proportions of coho or steelhead live fish and redds within the Lagunitas Creek Watershed for each week of the study. Coho and steelhead observations were obtained from spawner surveys performed by MMWD and NPS within the Lagunitas Creek Watershed upstream of the DIDSON Site 2 (Ettlinger and Andrew 2013; NPS unpublished data 2012). Weekly proportions of coho and steelhead were determined by dividing their respective live fish and redd count by the weekly total of live salmonids and redds. The weekly proportions of coho or steelhead were multiplied by their respective weekly total of the data point chosen to estimate escapement.

No data recorded before the DIDSON was moved to Study Site 2 (January 11, 2013) was used to create escapement estimates due to multiple factors that made Study Site 1 unsuitable to produce an estimate. Therefore, no coho salmon escapement estimate for the 2012-2013 spawner season could

be calculated. Pipal et al. suggest using DST counts to produce an escapement estimate (2010a). Due to the high number of observed milling behavior, DST analysis of footage was discontinued during the footage review process, so no estimate using DST counts could be produced.

Escapement estimates were calculated by summing the net daily counts to the date of the peak of the daily net count plus all subsequent positive daily net counts. Daily net counts were summed by week, then multiplied by the proportion of steelhead live fish or redds observed in the watershed for that week, producing weekly steelhead nets. Estimates were calculated by adding the adjusted weekly net counts through the week of the respective peak.

2.6.2 Trend Analysis

Daily totals were compared to daily max and mean flows using excel to produce correlation coefficients. Data from the daily totals table of the database was pasted into an excel workbook with daily flow data excluding days where the camera was not recording. The correlation function of excel was used with the two desired columns as arrays. Mean or max daily flow were used in array 1 and daily fish observations, upstream count, downstream count, milling count, or absolute value of net count were used in array 2. Further comparisons were made using only data recorded after the DIDSON was moved to Study Site 2 (January 11, 2013). A final comparison was made using only days where the camera was 99% or more operational.

3 Monitoring Results

Monitoring data presented below include a summary of observed abiotic factors, data recording, observed daily totals, escapement estimates, observed salmonid movement, and otter observations.

3.1 Abiotic Factors

During the recording season, December 13, 2012 through April 29, 2013, there was 308.57 mm of precipitation recorded at the Olema Valley RAWs station located within the Bear Valley Headquarters area of Point Reyes National Seashore. The max daily precipitation was 52.32 mm on December 23, 2012, during a storm (from December 20 to December 26) that produced 160.52 mm of precipitation. An instantaneous peak flow of 6,430 cfs was recorded December 23, 2012 at the USGS Point Reyes Station gage.

3.2 Data Recording

The DIDSON unit was installed on December 13, 2012, with recording initiated at 15:53:38. There were a number of recording data gaps due to storms, power outages, or equipment maintenance (Table 1). On December 21, 2012, recording was stopped at 15:18:53 when the unit was removed to avoid equipment damage during storm flows. Recording resumed on December 27, 2012 at 14:55:27. Power supply issues caused data gaps from January 5, 2013 at 14:06:13 through January 7, 2013 at 14:06:46, and 20:40:45 on January 7, 2013 through 09:38:23 on January 9, 2013. On January 10, 2013, recording was stopped at 15:01:55 as the unit was moved from Study Site 1 to Study Site 2, where recording was resumed at 16:03:36 on January 11, 2013. Temporary power outages caused data gaps from 10:56:08 on January 24, 2013 through 13:47:53 on January 28, 2013 and on January 31, 2013 at 01:24:32 through January 31, 2013 at 14:26:07.

In February, temporary power outages caused data gaps on February 11, 2013 at 16:15:21 through 0:00:01 on February 12, 2013; from 23:57:19 on February 20, 2013 through 14:59:22 on February 21, 2013; and from 10:24:48 on February 28, 2013 until 15:12:19 on March 1, 2013. March recorded continually after recording was restarted on the first.

In April, temporary power outages caused a data gap on April 3, 2013 at 16:33:36 through 16:18:37 on April 5, 2013; and April 13, 2013 at 01:46:22 through 15:10:41 on April 15, 2013. On April 19, 2013 the recording was stopped from 13:59:28 to 14:29:32 due to equipment maintenance. Power supply issues caused an additional data gap from 17:00:22 on April 24, 2013 through 12:57:51 on April 26, 2013. Recording was stopped and the camera was removed for the end of the season on April 29, 2013 at 9:50:00. The DIDSON was recording 81.69% of the time from December 13, 2012 through April 29, 2013.

Table 1 Summary of times of non-operation between initial instillation at Study Site 1 and the end of the 2012-2013 DIDSON recording season.

Date Stopped	Stop Time	Date Restarted	Start Time	Explanation
12/21/2012	15:18:53	12/27/2012	14:55:27	Removed for storm
1/5/2013	14:06:13	1/7/2013	14:06:46	Power Outage
1/10/2013	15:01:55	1/11/2013	16:03:36	Moved to Study Site 2
1/24/2013	10:56:08	1/28/2013	13:47:53	Power Outage
1/31/2013	1:24:32	1/31/2013	14:26:07	Power Outage
2/11/2013	16:15:21	2/12/2013	0:00:01	Power Outage
2/20/2013	23:57:19	2/21/2013	14:59:22	Power Outage
2/28/2013	10:24:48	3/1/2013	15:15:19	Power Outage
4/3/2013	16:33:36	4/5/2013	16:18:37	Power Outage
4/19/2013	13:59:28	4/19/2013	14:29:32	Equipment Maintenance
4/24/2013	17:00:22	4/26/2013	12:57:51	Power Outage

3.3 Daily Totals and Escapement Estimates

DIDSON footage processing and review is time intensive. Footage review began in late January 2013 and was completed in early December 2013. Over the course of the review process 13,299 events were recorded, 12,153 of which were fish observations (Table 2). Although DST analysis of fish passage events was discontinued during the review season to expedite the review process, there were 2,142 unique fish observations identified.

For Study Site 1 (December 13, 2012 through January 10, 2013), there were 2,100 fish observations, 895 different DST fish, a net movement of 21 upstream, and the system was recording 63.28% of the time. In January at Study Site 2 (January 11, 2013 through January 31, 2013), there were 600 fish observations, 324 new DST fish, a net movement of 32 upstream, and the system was recording 74.18% of the time. In February, there were 1,818 fish observations, 731 new DST fish, a net movement of 125 upstream, and the system was recording 94.59% of the time. In March, there were 5,641 fish observations, 164 new DST fish (DST analysis of March incomplete), a net movement of 70 upstream, and the system was recording 97.96% of the time. In April, there were 1,994 fish observations, 28 new DST fish (only April 1, 2013 was partially analyzed), a net movement of 121 downstream, and the system was recording 75.69% of the time (Table 2).

Table 2 Monthly and 2012-2013 DIDSON recording season totals for Fish Observations, New Decision Support Tool (DST) Count, Net Movement, and Percent Operational.

Site	Date	Fish Observations	New DST Count	Net Movement	Percent Operational
Study Site 1	12/13/12-1/10/13	2100	895	21	63.28%
Study Site 2	1/11/13-1/31/13	600	324	32	74.18%
Study Site 2	2/1/13-2/28/13	1818	731	125	94.59%
Study Site 2	3/1/13-3/31/13	5641	164*	70	97.96%
Study Site 2	4/1/13-4/30/13	1994	28*	-121	75.69%
2012-2013 Total	12/13/12-4/30/13	12153	2142	127	81.69%

The peak net daily count occurred on March 8, with a net movement of 41 upstream (Figure 1). The peak upstream and downstream counts occurred on the same day, March 28, with 192 upstream events and 212 downstream events (Figures 2 and 3).

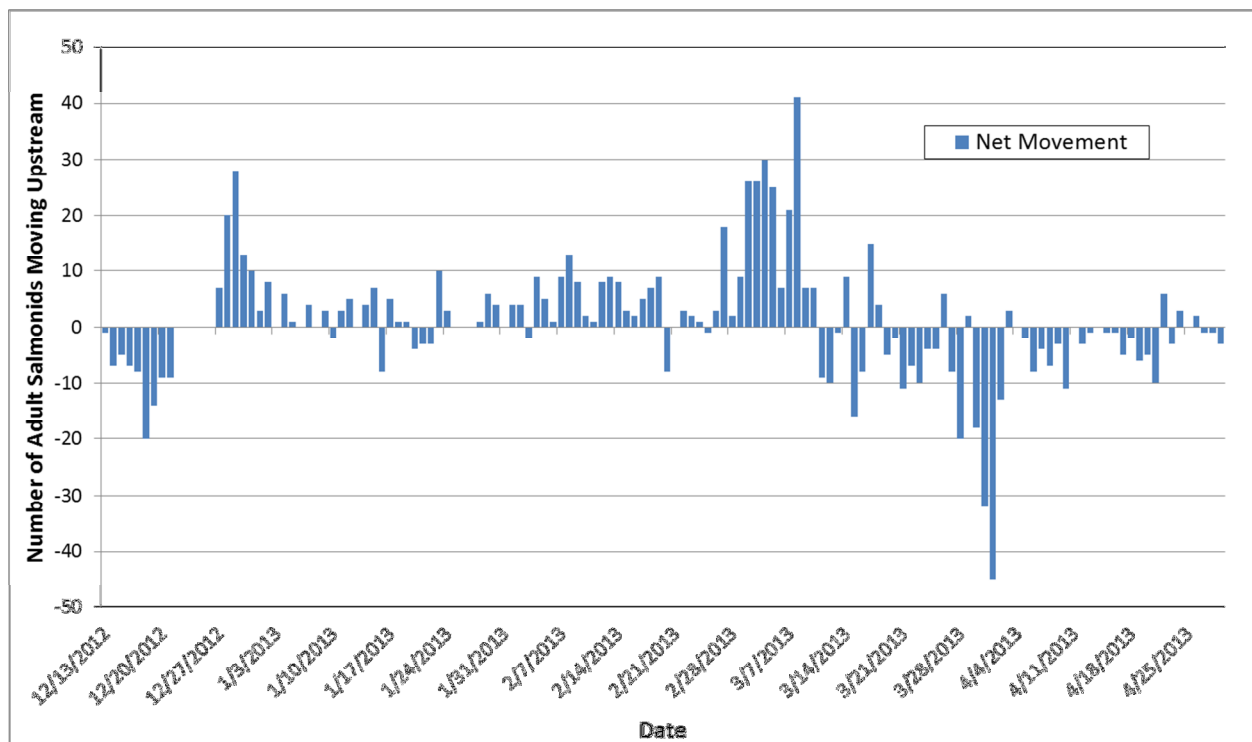


Figure 1 Daily upstream net counts of adult salmonid observations for the 2012-2013 DIDSON recording season. Positive counts reflect net upstream movement of adult salmonids and negative counts reflect net downstream movement of adult salmonids.

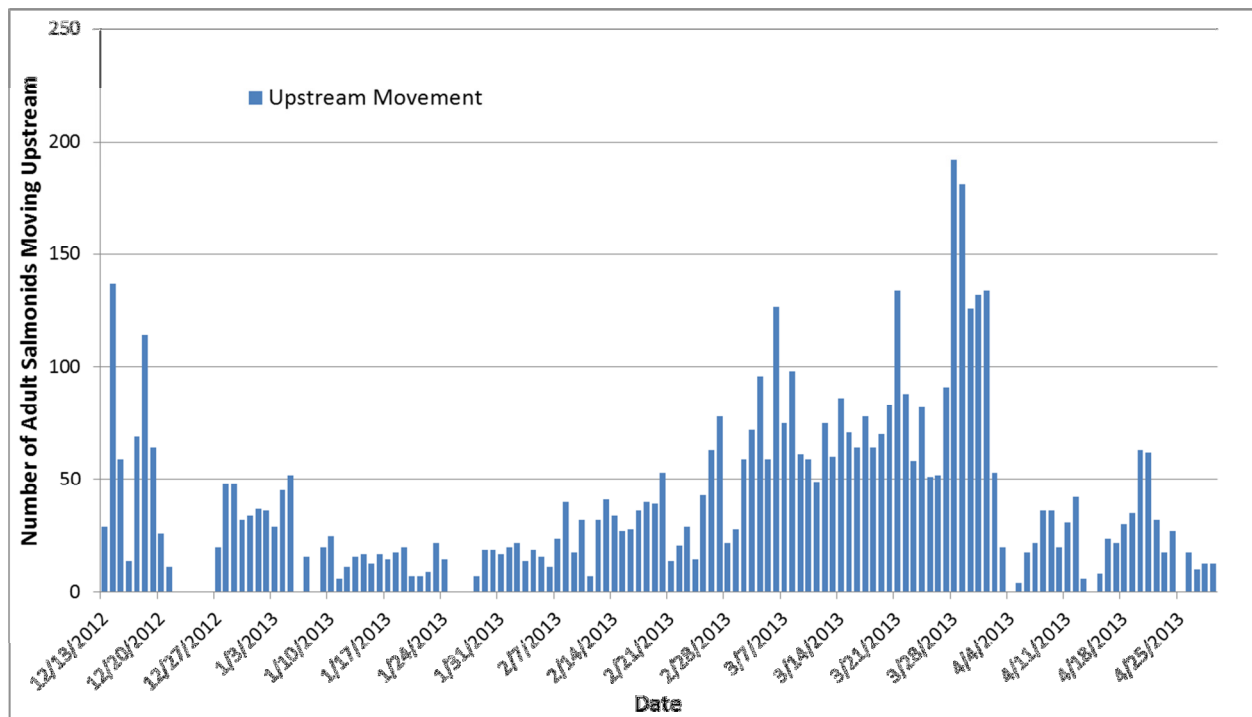


Figure 2 Daily upstream counts of adult salmonids for the 2012-2013 DIDSON recording season.

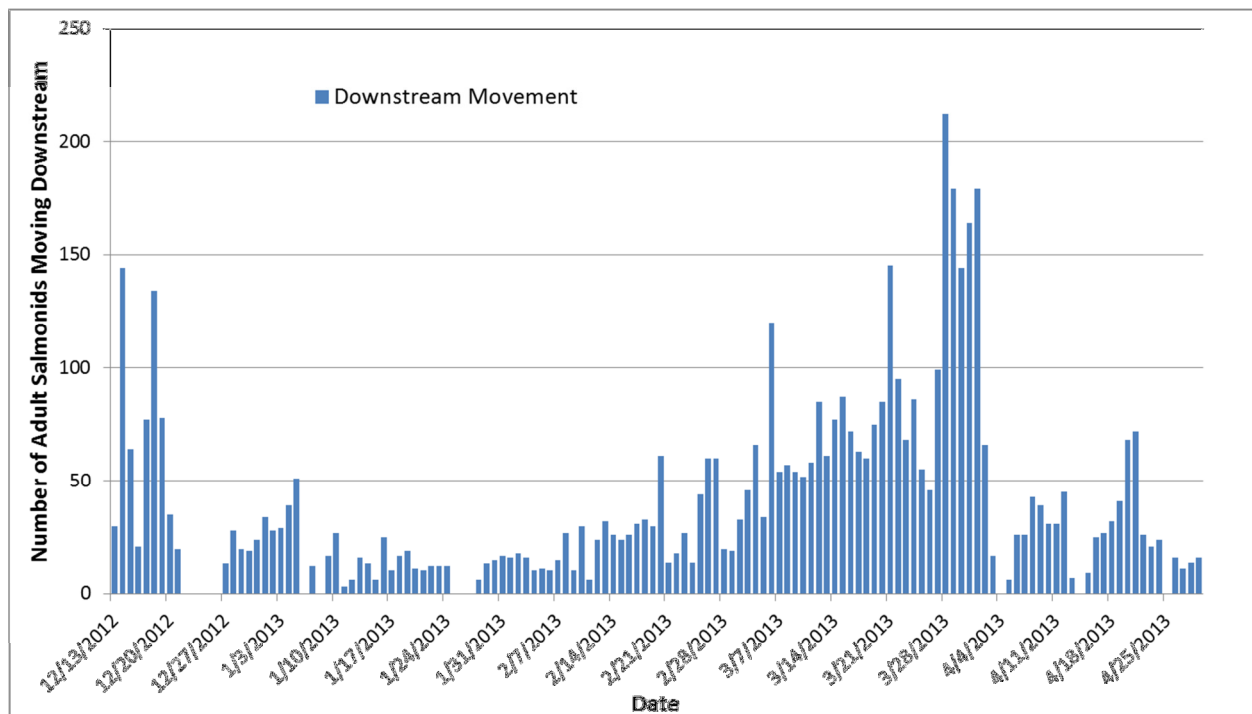


Figure 3 Daily downstream counts of adult salmonids for the 2012-2013 DIDSON recording season.

Calculating steelhead escapement using the sum of the daily net count from January 11 through March 8, watershed species proportions derived from live salmonid and redd observations during this time period, plus the sum of the positive daily net counts from March 9 through April 29, produces

escapement estimates of 388 using live salmonid proportions and 395 using redd composition (Ettlinger and Andrew 2013; NPS unpublished data 2012).

3.4 Salmonid Movement Trends

In the 2012-2013 recording season, 31.3% (3,801) of salmonid observations occurred during the daytime and 68.7% (8,352) of salmonid observations occurred at night. When salmonid observations for the entire season were pooled and plotted by hour, there were observations recorded in every hour (Figure 4). The hour of 20:00 had the most activity with 817 salmonid observations, while the hour of 11:00 had the least activity with 190 salmonid observations.

There were 3,085 fish (25.4%) that received the paired distinction. The largest group of salmonids travelling together was 16 on March 30, 2013. The longest time a fish spent on camera was 5:43:27, when it stayed mostly still behind the deflection fencing on March 16, 2013.

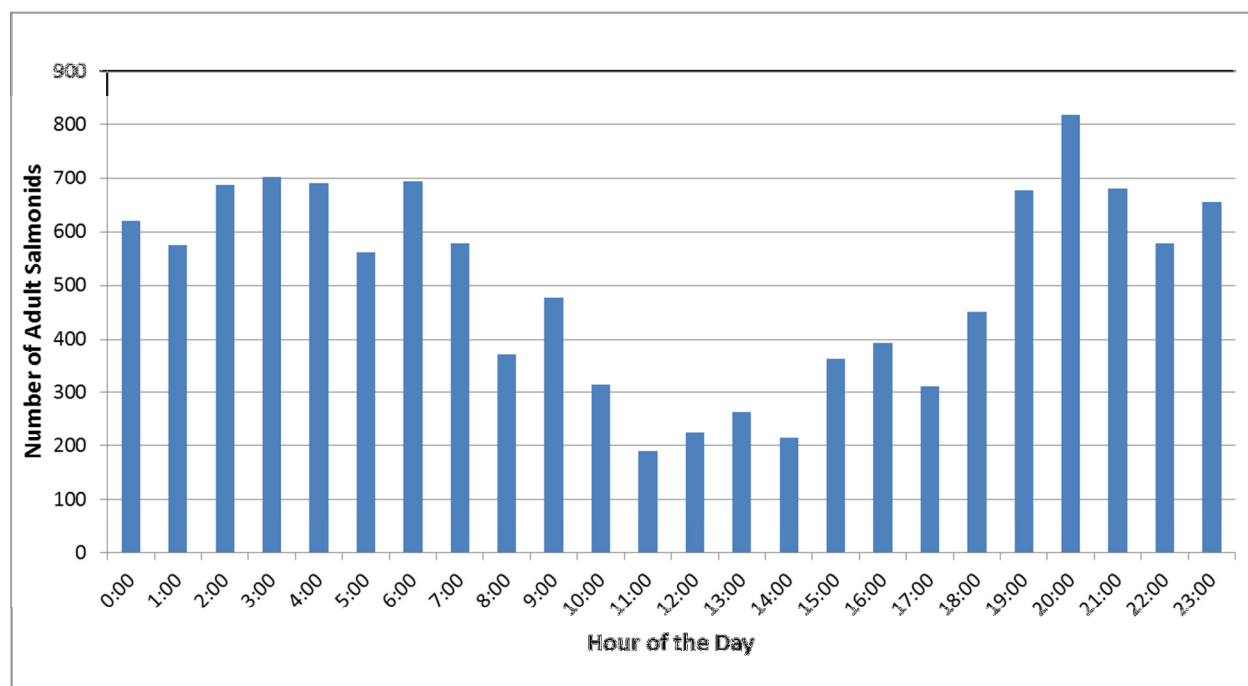


Figure 4 Adult salmonid observations by hour of the day (24 hour clock) for the 2012-2013 DIDSON recording season.

Correlations between daily mean or max flow and salmonid observations, upstream count, downstream count, milling count, or absolute value of net count were low ($r^2 < 0.35$) (Table 3). Max flow compared to daily salmonid observations, daily upstream and downstream counts, and the absolute value of daily net count are displayed in Figures 5-8.

Table 3 Correlation coefficients of mean daily flows, maximum daily flows, mean daily flow after 11 January 2013, maximum daily flow after 11 January 2013 compared to upstream adult salmonid observations, downstream adult salmonid observations, adult salmonid milling observations, total adult salmonid observations, and absolute value of the net adult salmonid count for the 2012-2013 DIDSON recording season. All days the DIDSON was not recording were removed.

	Mean Daily Flow	Maximum Daily Flow	Mean Daily Flow (after 1/11/13)	Maximum Daily Flow (after 1/11/13)
Upstream adult salmonid observations	$r^2 = -0.113$	$r^2 = -0.112$	$r^2 = -0.268$	$r^2 = -0.249$
Downstream adult salmonid observations	$r^2 = -0.150$	$r^2 = -0.125$	$r^2 = -0.302$	$r^2 = -0.276$
Milling adult salmonid observations	$r^2 = -0.200$	$r^2 = -0.171$	$r^2 = -0.162$	$r^2 = -0.151$
Total adult salmonid observations	$r^2 = -0.148$	$r^2 = -0.132$	$r^2 = -0.289$	$r^2 = -0.266$
Absolute value of net adult salmonid count	$r^2 = 0.126$	$r^2 = 0.097$	$r^2 = -0.051$	$r^2 = -0.008$

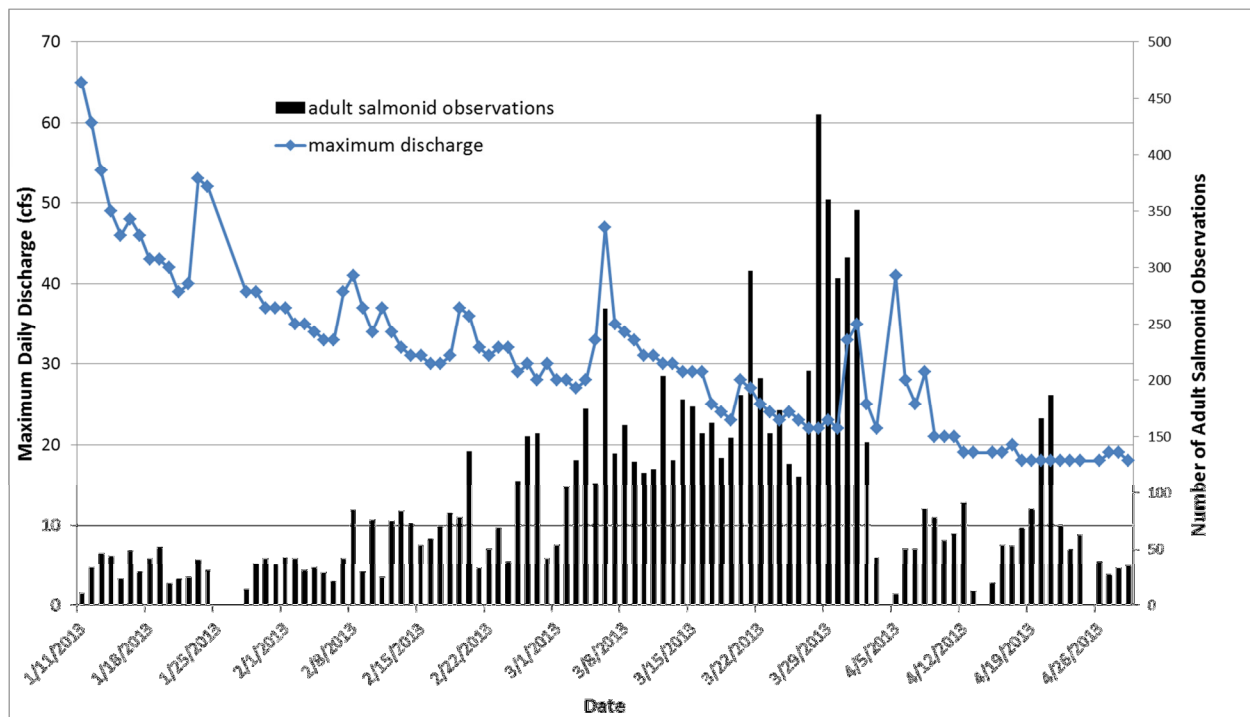


Figure 5 Daily adult salmonid observations with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).

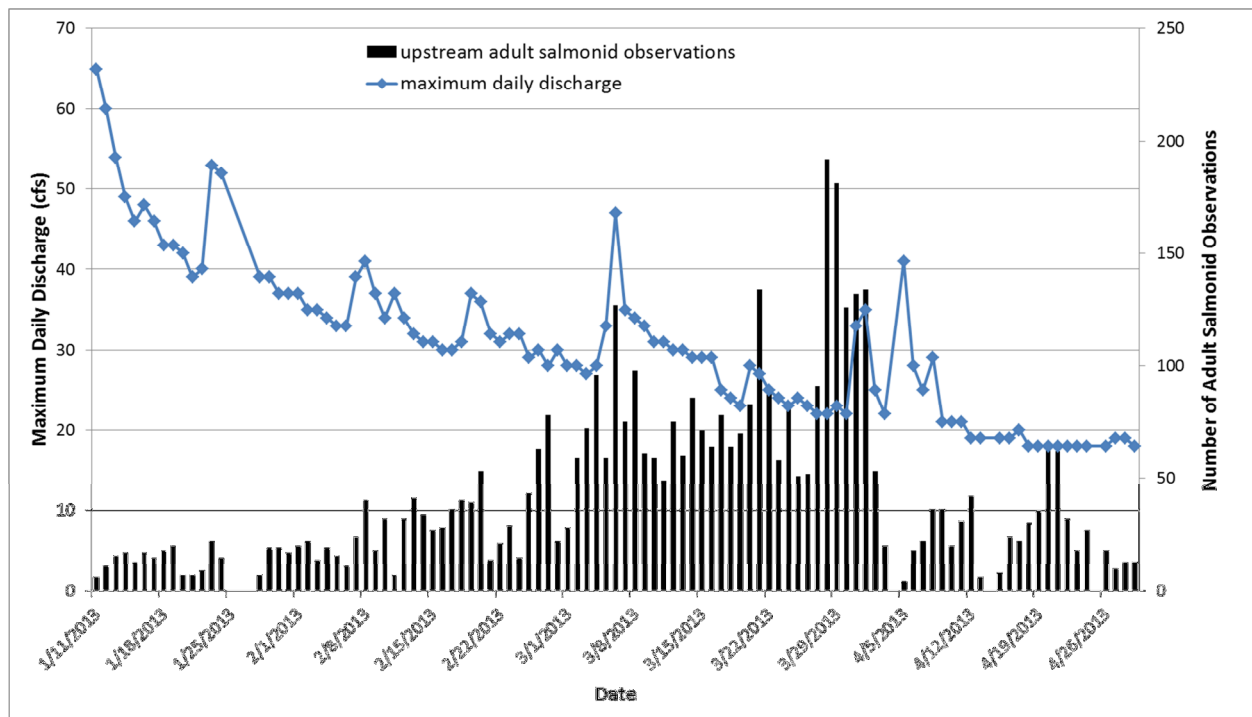


Figure 6 Daily upstream adult salmonid observations with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).

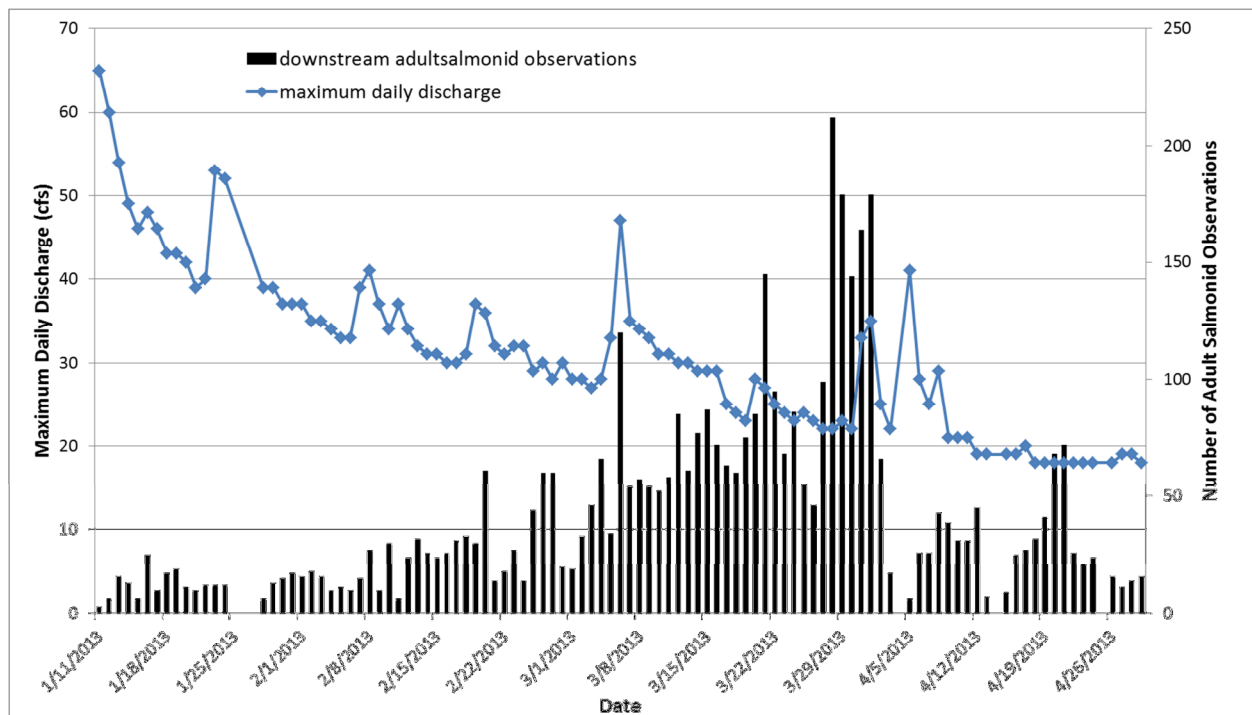


Figure 7 Daily downstream adult salmonid observations with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).

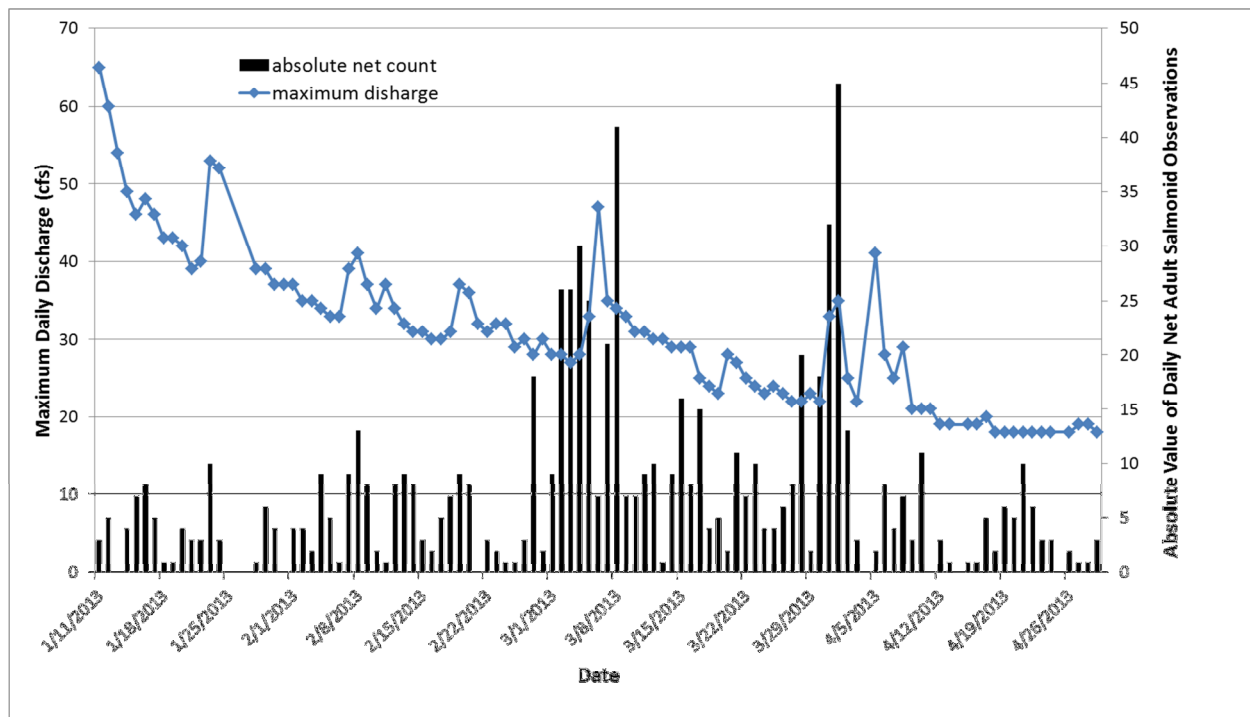


Figure 8 Absolute value of daily net adult salmonid counts with maximum daily flow (cfs) for DIDSON recording at Study Site 2 (1/11/13 - 4/29/13).

Of the 12,153 fish observations, 10,018 (82.4%) received length measurements. Length measurements were grouped in 5cm intervals from 35 to 95 cm (Figure 9). The most populated interval was 70-74 cm, with 3,135 measurements. There were two fish length measurements of 90 cm, the season high, recorded on February 14, 2013. There were 13 fish that received measurements of 35 cm, the cut-off for being considered an adult salmonid. Average fish length for the season was 69 cm with a standard deviation (SD) of 9 cm and median of 71 cm. The maximum average daily length was 78 cm (n=33), which occurred on February 21, 2013. The minimum average daily length was 61 cm (n=16) on December 21, 2012.

There were 1,089 fish observations with length measurements before the first steelhead was seen in the Lagunitas Creek Watershed on December 28, 2012 (NPS unpublished data 2012, Ettlinger and Andrew 2013). Lengths recorded prior to this date are assumed to be for coho. The average coho length was 67 cm with a SD of 12 cm and a median of 70 cm. Coho length measurements were grouped in 5 cm intervals from 35 to 95 cm (Figure 10). The most populated interval was 70-74 cm, with 350 measurements, however, there is a smaller peak in the 40-44 cm interval with 81 measurements.

There were 7,838 fish observations with length measurements after the last new coho redd in the Lagunitas Creek Watershed was observed on January 30, 2013 (Ettlinger and Andrew 2013). All salmonid detections after January 30, 2013 were assumed to be steelhead. The average steelhead length was 70 cm with a SD of 8 cm and a median of 71 cm. Steelhead length measurements were grouped in 5 cm intervals from 35 to 95 cm (Figure 11). The most populated interval was 70-74 cm, with 2,398 measurements.

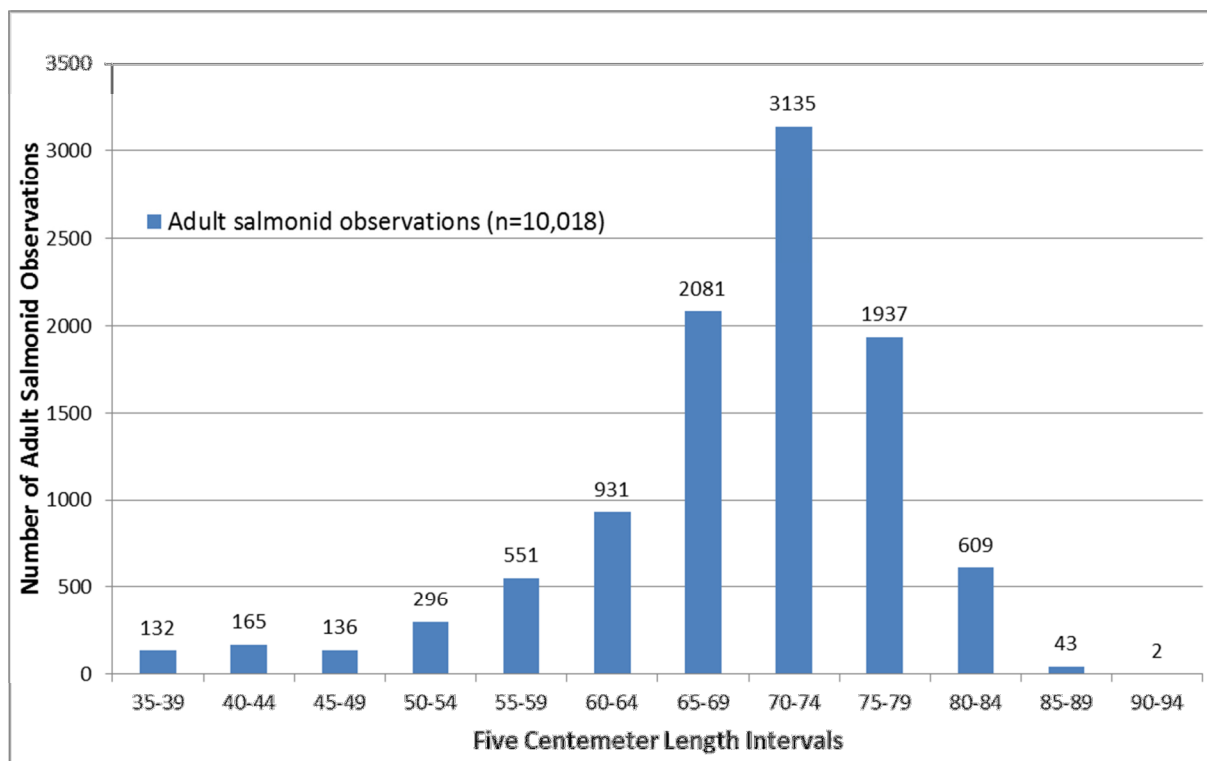


Figure 9 Adult salmonid lengths (cm) separated into 5cm intervals for the DIDSON recording period 12/13/2012 through 4/29/2013.

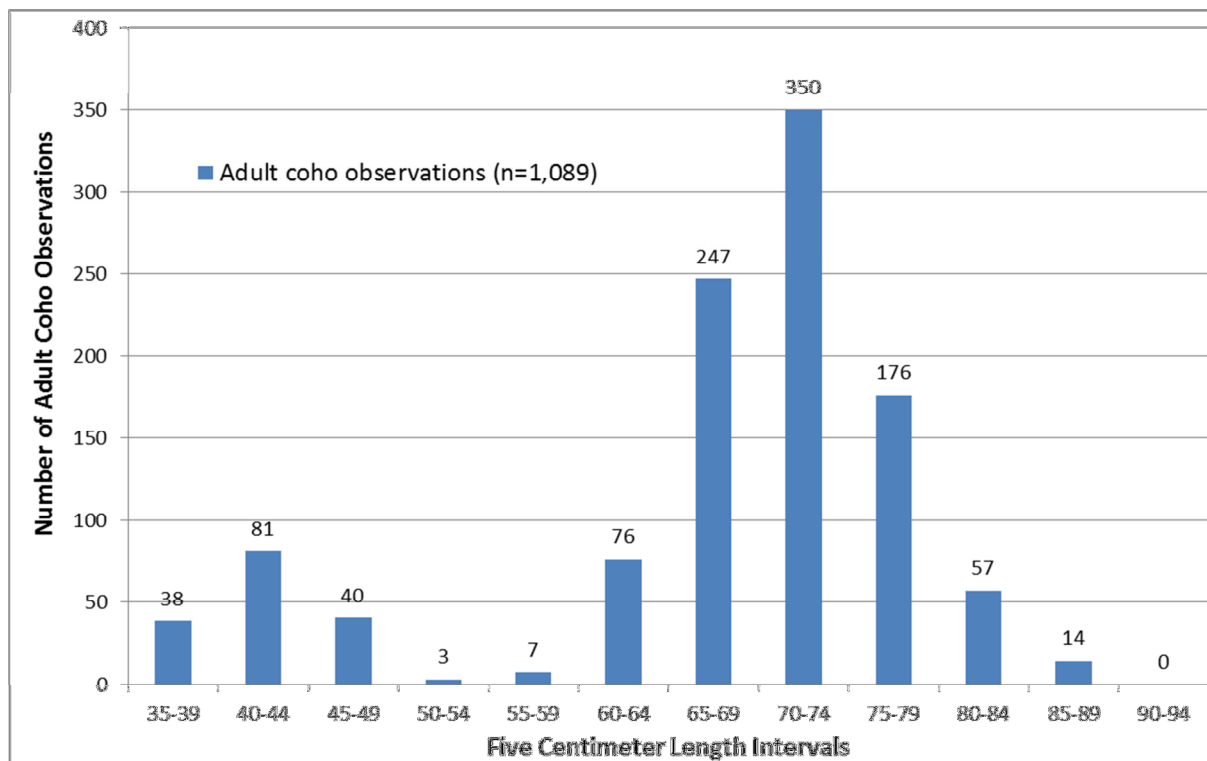


Figure 10 Adult coho lengths (cm) separated into 5cm intervals for the DIDSON recording period 12/13/2012 through 12/27/2012.

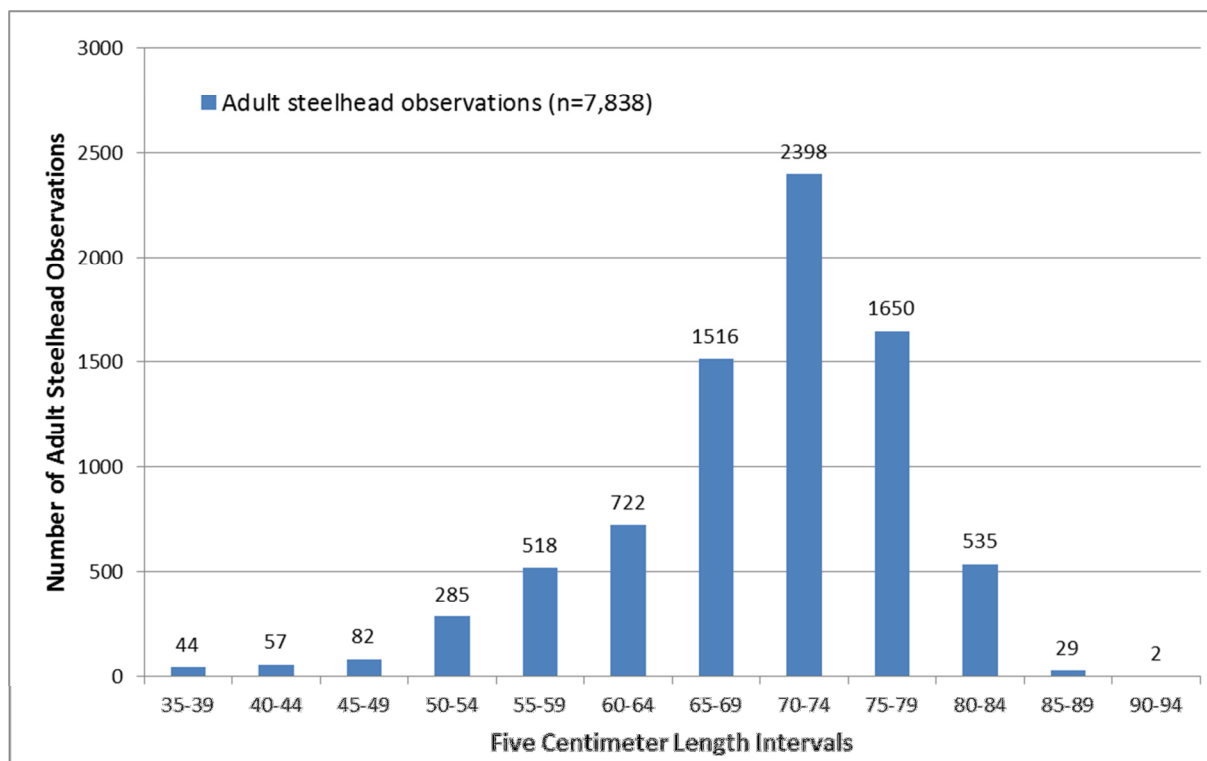


Figure 11 Adult steelhead lengths (cm) separated into 5cm intervals for the DIDSON recording period 1/31/2013 through 4/29/2013.

3.5 Otter Observations

There were 255 otter observations during the 2012-2013 recording season. Five otters traveling together was the largest group size observed, recorded on February 19, February 20, and March 11, 2013. Multiple times otters were observed at the same time and only a few meters away as a milling salmonid without any change in behavior by either the otter or salmonid. When pooled over the entire season, otter sightings occurred in every hour of the day with 21:00 having the most observations at 20 and 10:00 having the least with two (Figure 12).

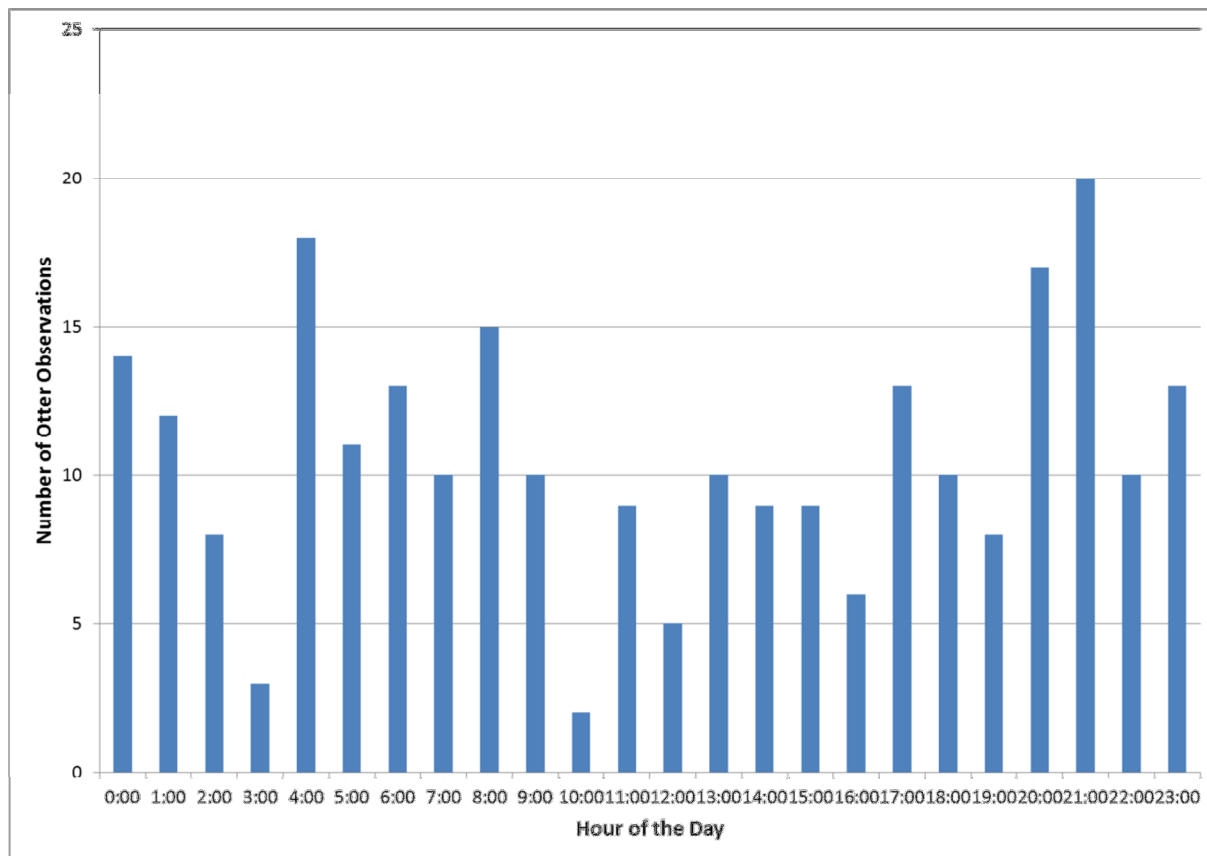


Figure 12 Otter Sightings by hour of the day for the 2012-2013 DIDSON recording season (n=255).

4 Discussion and Recommendations for Study Year 2

This was the first year of a two year pilot project designed to test the feasibility of using DIDSON technology to produce escapement estimates for coho salmon and steelhead trout on Lagunitas Creek. As can be expected, there were multiple delays and setbacks. There were several data gaps during the recording season that cannot be attributed to site and equipment maintenance. Most gaps were caused by temporary losses of power to the DIDSON, which would not record again until manually restarted. Another common cause of recording downtime was jostling of equipment resulting in a vital cable (such as the Ethernet from DIDSON to the computer or the external hard drive USB cable) becoming disconnected. For year two, an Uninterruptable Power Supply (UPS) will be used to prevent short blackouts or brownouts from causing data gaps. Also, additional training of DIDSON field technicians to recognize potential problems along with increased communication among site partners of the sensitivity of the equipment will reduce system failures. Checking the camera more than once a week to decrease the length of data gaps in the event of a system failure should be implemented in year two.

This was the first attempt to continuously record the spawning runs of coho and steelhead on Lagunitas Creek. The amount of fish activity recorded was much higher than anticipated, making complete footage processing and review a very time intensive process. In over five months of footage there were 12,135 salmonid observations, 1,328 (10.9%) of which were recorded as milling on screen, with many more undoubtedly milling off screen. Pipal et al. saw similar milling with 990 salmonid observations over 4 months on Big Creek, Santa Cruz County, with a resulting estimate of only 22-33 steelhead (2010a). DST analysis of Big Creek data was not attempted due to time constraints (Pipal et al. 2010a). Excessive milling in our data made DST processing of salmonids impractical given processing time without an automated system and DST was discontinued midway through the review season. Even with incomplete DST analysis, there were 2,142 unique salmonid observations. For year two, automation of the DST process would be a vast improvement. Coyle and Reed describe using the free software R to automate the process (2012). Project staff will investigate opportunities to utilize this or similar software to automate the DST process using the year 2 dataset. A redesign of deflection fencing to discourage milling and adding a downstream fence behind the DIDSON to prevent salmonids from going behind or too close to the camera is also recommended for year two. The DIDSON will record exclusively at Study Site 2 in year two to avoid active spawning habitat, and will begin recording in October in order to record the entire spawning season. The camera should be placed in an area with less cover (no undercut bank, roots, and overhanging branched) than the year one placement but still within the immediate vicinity of Study Site 2.

The camera was removed on April 29, 2013 with salmonid activity still being observed. Adult steelhead of the Lagunitas Creek Watershed have been caught in MMWD and NPS smolt traps in May, so it is not surprising that steelhead were still active in late April (Ettlinger et al. 2014; Carlisle and Reichmuth, 2012). In year two, recording should continue into late May or until no activity is observed.

There was no coho escapement estimate that could be calculated using DIDSON data in year one. This is due to the late start of the recording season, December 13, 2012, after spawning had already begun and because the camera was located in an area of active spawning, with four active coho redds observed in the area (Ettlinger and Andrew 2013). The 2012-2013 DIDSON steelhead trout escapement estimates of 388 and 395 is slightly than the Lagunitas Creek Watershed estimate of 344 using observed redds multiplied by two, which assumes two spawners per redd (Ettlinger and Andrew 2013; NPS unpublished data 2012). However, the DIDSON escapement estimate was not calculated with the DST numbers as suggested in Pipal et al. (2010a), but instead used daily net counts. Using net count to estimate steelhead escapement may under estimate escapement because a fish can be recorded as a zero count by moving upstream (+1) and then later moves downstream (-1) as a kelt resulting in a net count equal to 0. However, using the peak of the daily net count (March 8) allows most of the steelhead to be counted before they move back downstream as kelts. Adding the positive daily net counts that occur after the peak includes new steelhead moving into the system, instead of discounting all fish movement after the peak as kelt activity. This is important because there were new steelhead redds observed after the peak of daily net counts. On MMWD's last survey of the season, March 11, 35 new steelhead redds were reported (Ettlinger and Andrew 2013). That being said, it was primarily downstream kelt movement recorded by the DIDSON after March 8. Of the 49 days with data recorded between March 9 and April 29, 11 days had positive daily net counts totaling 64, 37 days had negative daily net counts totaling -300, and one day had a net count of zero, for a net count of -236 for the period of March 9 to April 29. For year two, as mentioned above, recording must be started earlier in order to produce a coho escapement estimate and the DST process should be automated so it can be completed and used to estimate total steelhead escapement. Another tool that could be utilized in year two is an R model designed to fill in data gaps and adjust for reviewer error associated with DIDSON (Semmens 2011). The 2012-2013 DIDSON data was formatted for the Semmens R model, but staff were unable to get it to function before the writing of this report. If this project continues past year two, another method of deriving steelhead and coho watershed composition proportions should be utilized. It will be difficult to accomplish the project goal of assessing current spawner survey techniques and accuracy as long as survey data is used to produce DIDSON escapement estimates.

Abiotic factors such as daylight hours, precipitation, creek levels (flow), and temperature can affect salmonid migration timing. However, no significant correlation could be found between this year's counts and the flow data. Graphs of the data do not show corresponding peaks of salmonid counts to peaks in flows, as would be expected if salmonid movement was largely determined by flow. Problems with the correlations could arise from data gaps and the high occurrence of milling behavior observed during the season, causing daily counts to reflect small groups of salmonids continually swimming up and down past the camera.

A majority, 68.7%, of all fish observations this season occurred at night which confirms reports from existing literature (Coyle and Reed 2012; Parker et al. 2013). One of the advantages of DIDSON over traditional video camera systems or monitoring techniques is that it is able to image at night, when most fish activity occurs. However, this complicates the use of standard video equipment to validate counts and should be considered when designing alternate methods to differentiate between salmonid species.

Fish length measurements for the season were within the expected size range for adult coho salmon and steelhead trout (Moyle 2002). The average length for the season was 69 cm and 70-74 cm was the most populated length interval. For just the coho spawning season (before 12/28/12), the average measured length was 67 cm with a median of 70 cm and a SD of 12 cm (n=1,089). There were 21 coho carcasses measured by MMWD staff during the 2012-2013 spawning season, with a mean length of 60 cm, maximum of 69 cm, and minimum of 42 cm. However, only five coho carcasses were measured before December 28, 2012, with an average length of 64 cm (Eric Ettlinger pers comm 2014a). For just the steelhead spawning season (after 1/30/13), the average length was 70 cm with a median of 71 cm and a SD of 8 cm (n=7,838). There were two steelhead carcasses measured by MMWD staff during the 2012-2013 spawning season, one of 69 cm and another of 85 cm (Eric Ettlinger pers comm 2014a). With only five coho carcass and two steelhead carcass measurements, there is insufficient data to compare observed fish carcass lengths to DIDSON measured lengths. Also, fish length measurement comparisons need to take into account that the total fish length is measured in DIDSON, while surveyors measure fork length of carcasses.

A graph of coho length measurements grouped into 5 cm intervals (Figure 10, page 26) shows two peaks, one in the 40-44 cm range and another in the 70-74 cm range. The 40-44 cm peak represents jacks, two year old coho who return a year early, while the 70-74 cm peak represents fully mature adults. Jacks, coho measuring between 35 and 49 cm, represent 15% (159) of coho length measurements while fully grown adults represent 84% (920) of coho length measurements. Only 1% (10) of coho length measurements were in the 50-59 cm range, suggesting a length attainment gap: two year olds grow to be 49 cm or less and three year olds grow to be 60 cm or more in total length. In the steelhead length intervals (Figure 11, page 27), the 70-74 cm interval is the only peak and length intervals display a bell curve.

DIDSON has the advantage of being able to accurately measure most, 82.4% for 2012-2013, adult salmonids that are observed as opposed to traditional survey techniques that use observed lengths of live adult salmonids from wading surveys and only measure carcasses. In year two, objects of known size should be used to calibrate length measurements and there should be a Quality Assurance and Quality Control (QA/QC) protocol that cross compares reviewers to produce more accurate escapement and length estimates.

The 2012-2013 DIDSON footage produced some spectacular images of river otters. Distinguishing between otters and adult salmonids was difficult at first but reviewers were able to establish criteria such as body undulation, length, the presence of limbs, and acoustic shadow as means to easily distinguish between the two. During year two, reviewers will watch sample clips of otter detections from the 2012-2013 DIDSON season as part of their preseason DIDSON review training.

5 Literature Cited

- Adams, P.B., L.B. Boydstun, S.P. Gallagher, M.K. Lacy, T. McDonald, and K.E. Shaffer. 2011. CDFG Fish Bulletin 180; California coastal salmonid population monitoring: strategy, design, and methods. California Department of Fish and Game.
- Belcher, E.O., B. Matsuyama, and G.M. Trimble. 2001. Object identification with acoustic lenses. Pp. 6-11 in Conference proceedings MTS/IEEE Oceans, volume 1, session 1. Honolulu Hawaii, November 5-8.
- Belcher, E.O., W. Hanot, and J. Burch. 2002. Dual-frequency identification sonar. Pp. 187-192 in Proceedings of the 2002 International Symposium on underwater technology. Tokyo, Japan, April 16-19.
- California Department of Fish and Game (CDFG). 2002. Status review of California coho salmon north of San Francisco. Report to the California Fish and Game Commission. 234pp.
- CDFG. 2004. Recovery Strategy for California Coho Salmon. Report to the California Department of Fish and Game Commission. 594pp.
- Carlisle, S. and M. Reichmuth. 2012. Long-term coho salmon and steelhead trout monitoring in coastal Marin County: Smolt trapping 2011 progress report. Report to California Department of Fish and Game, Grant # P0830407, Point Reyes National Seashore Association, Point Reyes Station, California.
- Coyle, C.L. and D.J. Reed. 2012. Assesment of the performance of a DIDSON (Dual Frequency IDentification SONar) to count steelhead in Peterson Creek, 2009. Alaska Department of Fish and Game, Fisheries Data Series No. 12-42, Anchorage.
- Cronkite, G. M. W., H. J. Enzenhofer, T. Ridley, J. Holmes, J. Lilja, and K. Benner. 2006. Use of high frequency imaging sonar to estimate adult sockeye salmon escapement in the Horsefly River, British Columbia. Canadian Technical Reports of Fisheries and Aquatic Science 2647.
- Ettlinger, E., D. Morrell, A. Wolf, and G.M. Andrew. 2010. LagunitasCreek Salmon Spawner Survey Report 2009-2010. MMWD Report October 2010.
- Ettlinger, E., B. Schleifer, M. Horwitz, G. Andrew. 2013. Lagunitas Creek 2012 Smolt Survey Report. MMWD Report February 2013.
- Ettlinger, Eric. 2013. "Minimum Jack size on lagunitas creek." E-mail. Feburary 7, 2013.
- Ettlinger, E., G. Andrew. 2013. Adult salmonid monitoring in the Lagunits Creek Watershed- 2012-13. MMWD Report November 2013.
- Ettlinger, E., A. Chiapella, M. Paccassi, and G. Andrew. 2014. Smolt Monitoring in the Lagunitas Creek Watershed- 2013. MMWD Report January 2014.

- Ettlinger, Eric. 2014a. "Spawner lengths." E-mail. January 30, 2014.
- Ettlinger, Eric. 2014b. "Common carp in screw trap." E-mail. February 4, 2014.
- Federal Register. August 18, 1997. Endangered and Threatened Species: Listing of Several Evolutionary Significant Units (ESUs) of West Coast Steelhead. Federal Register 62(159): 43937-43954.
- Federal Register. June 28, 2005. Final rule. Endangered and threatened species: Final listing determinations for 16 ESUs of west coast salmon and final 4(d) protective regulations for threatened salmonid ESUs. Federal Register 70(123): 37160-37204.
- Federal Register. January 5, 2006. Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. Federal Register 71(3): 834-862.
- Kucera, P. A. and D. Faurot. 2005. Chinook salmon (*Oncorhynchus tshawytscha*) adult abundance monitoring in Lake Creek and Secesh River, Idaho 2004. Annual report to the Bonneville Power Administration. Nez Perce Tribe, Department of Fisheries Resources Management, Lapwai, Idaho.
- Kucera, P. A. and D. Faurot. 2006. Chinook salmon (*Oncorhynchus tshawytscha*) adult abundance monitoring in Lake Creek and Secesh River, Idaho 2005. Annual report to the Bonneville Power Administration. Nez Perce Tribe, Department of Fisheries Resources Management, Lapwai, Idaho.
- Maxwell, S. L. and Gove, N. E. 2004. The feasibility of estimating migrating salmon passage rates in turbid rivers using a dual frequency identification sonar (DIDSON), 2002. Alaska Department of Fish and Game, Regional Information Report No. 2A04-05. Anchorage, Alaska.
- Moyle, Peter B. 2002. Inland Fishes of California- Revised and Expanded; illustrations by Chris Mari van Dyck and Joe Tomelleri. University of California Press, Berkeley and Los Angeles, California.
- National Park Service. 2012. Cheda Creek Spawner Survey Datasheets from 12/4/12 to 12/28/12. Unpublished Data.
- National Marine Fisheries Service. 2012. Final Recovery Plan for Central California Coast coho salmon Evolutionarily Significant Unit. National Marine Fisheries Service, Southwest Region, Santa Rosa, California.
- Parker, S., N. Cooley, and S. Gallagher. 2013. Summary of DIDSON Operations on Pudding Creek, CA, During the 2011/2012 Field Season. California Department of Fish and Wildlife, January 2013.

- Pipal, K., M. Jessop, G. Holt, and P. Adams. 2010a. Operation of dual-frequency identification sonar (DIDSON) to monitor adult steelhead (*Oncorhynchus mykiss*) in the central California coast. U.S. Department of Commerce, NOAA Technical Memorandum NMFS SWFSC-454.
- Pipal, K., M. Jessop, D. Boughton, and P. Adams. 2010b. Using dual-frequency identification sonar (DIDSON) to estimate adult steelhead escapement in the San Lorenzo River, California. California Department of Fish and Game 96(1): 90-95.
- Pipal, K., J.J. Notch, S.A. Hayes, and P. Adams. 2012. Estimating Escapement for a Low Abundance Steelhead Population Using Dual-Frequency Identification Sonar (DIDSON). North American Journal of Fisheries Management 32: 880-893.
- Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society, Bethesda, Maryland.
- United States Geological Survey. USGS 11460600 LAGUNITAS C NR PT REYES STATION CA. Accessed January 2014. < http://waterdata.usgs.gov/ca/nwis/uv?site_no=11460600>
- United States Naval Observatory. Sun or Moon Rise/Set Table for One Year. Accessed January 2014. < http://aa.usno.navy.mil/data/docs/RS_OneYear.php>
- Semmens, Brice X. June 15, 2011. Bayesian analysis of a time series of DIDSON fish-passage counts. Accessed January 2014.<<http://conserver.iugocafe.org/user/brice.semmens/DIDSON%20run%20reconstruction%20tools>>
- Tiffan, K.F., D.W. Rondorf, and J. L. Skalicky. 2004. Imaging Fall Chinook Salmon Redds in the Columbia River with a Dual-Frequency Identification Sonar. North American Journal of Fisheries Management 24:1421–1426.
- Tiffan, K.F., D.W. Rondorf, and J.J. Skalicky. 2005. Diel spawning behavior of chum salmon in the Columbia River. Transactions of the American Fisheries Society 134: 892-900.
- Western Regional Climate Center, Desert Research Institute. Olema Valley California RAWS data. Accessed January 2014. < <http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?caCOLV>>
- Wheeler, Michael. 2012. Use of hydro-acoustic (DIDSON) camera system on migrating adult salmonids with Denil style baffle fishways. Unpublished report received September 14, 2012.

Appendix A.

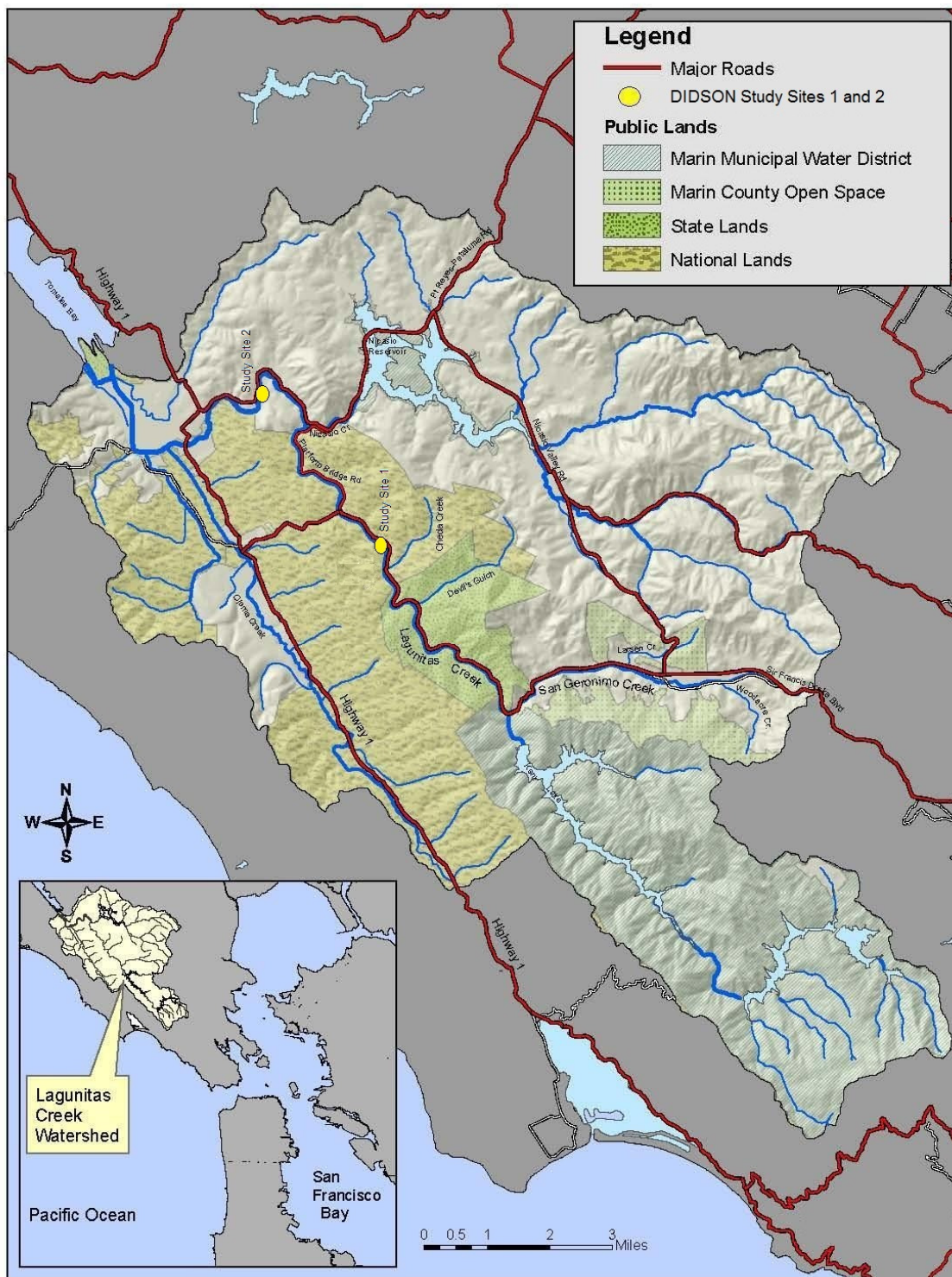


Figure A1 Map of Lagunitas Creek Watershed with DIDSON Study Sites 1 and 2.

Study Site 1

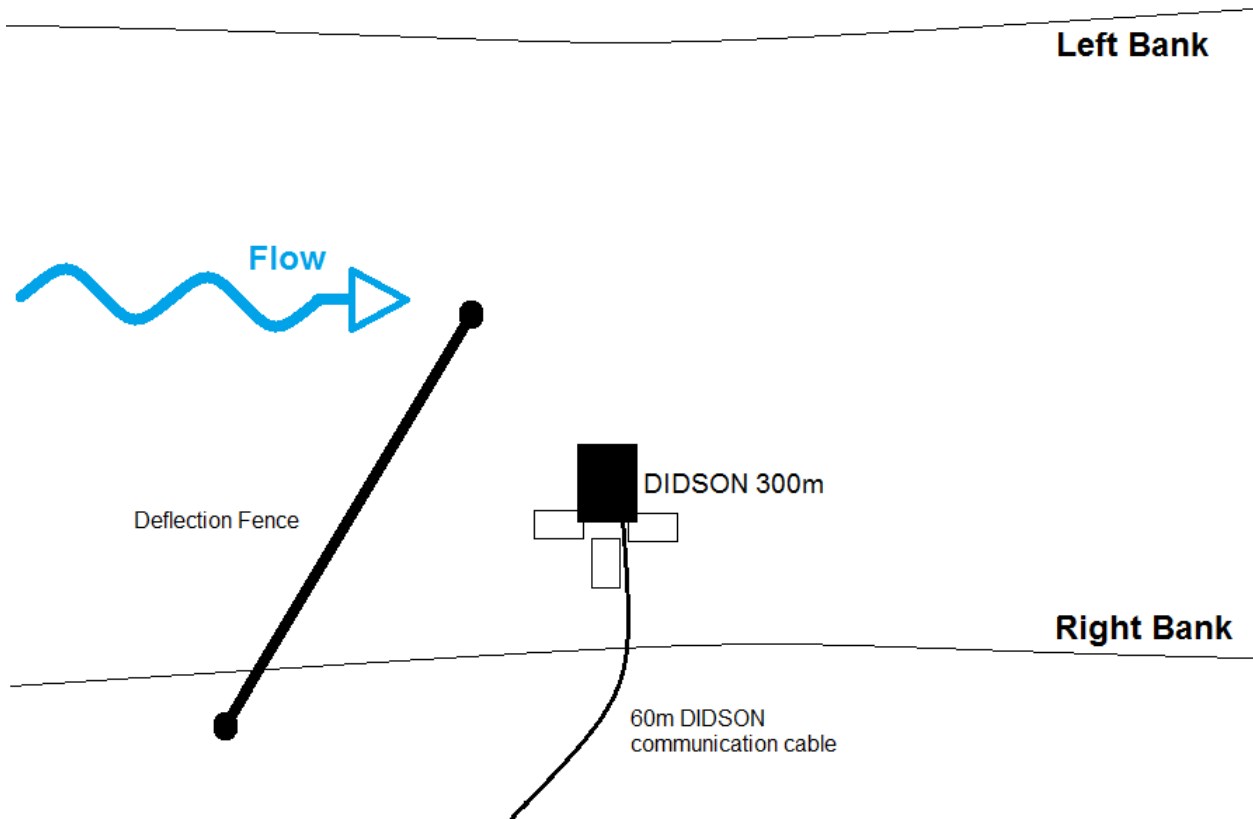


Figure A2 Diagram of Study Site 1 showing stream banks, deflection fence, and DIDSON position.

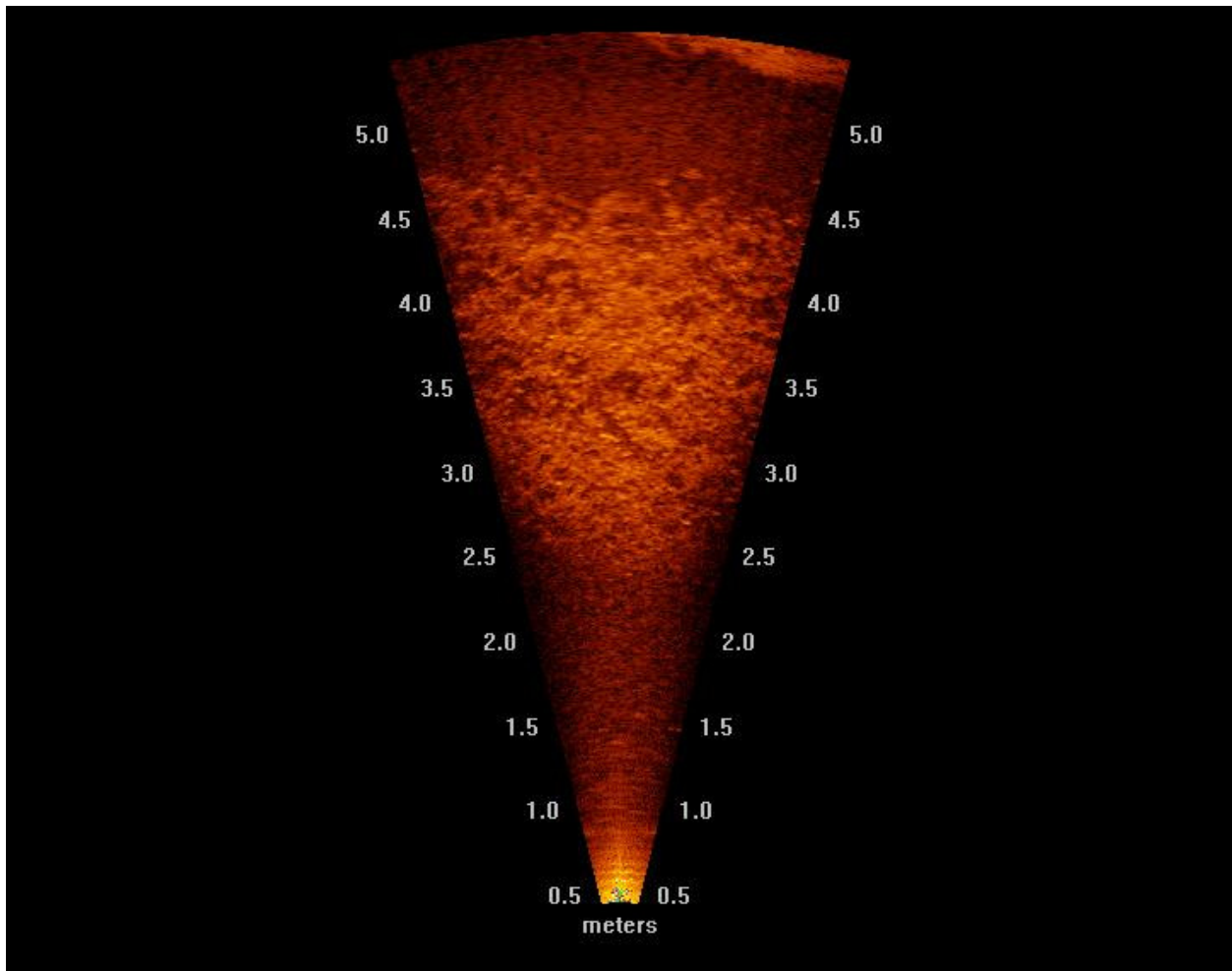


Figure A3 Screenshot of DIDSON review footage taken at Study Site 1.

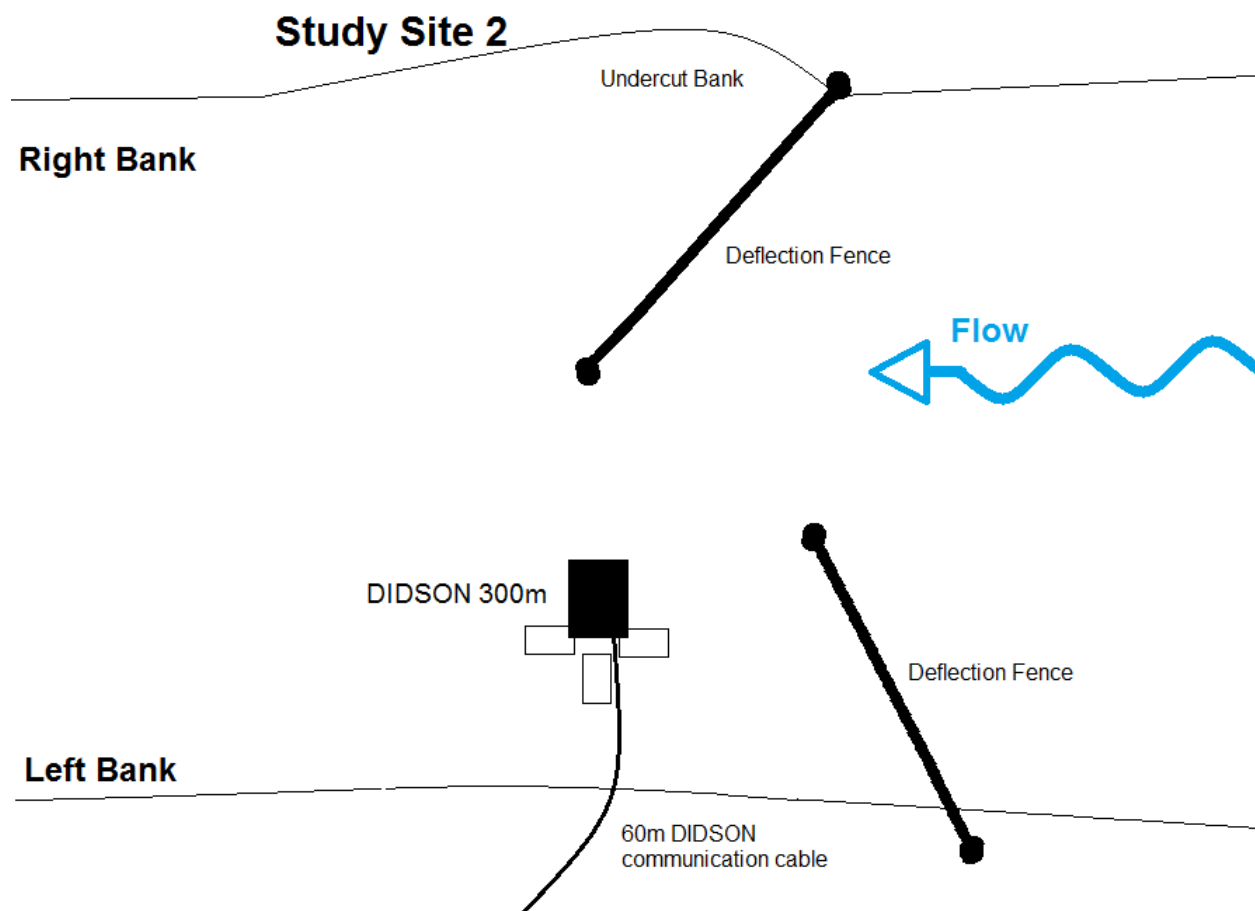


Figure A4 Diagram of Study Site 2 showing stream banks, deflection fence, and DIDSON position.



Figure A5 DIDSON unit at Study Site 2 showing camera location and deflection fences.

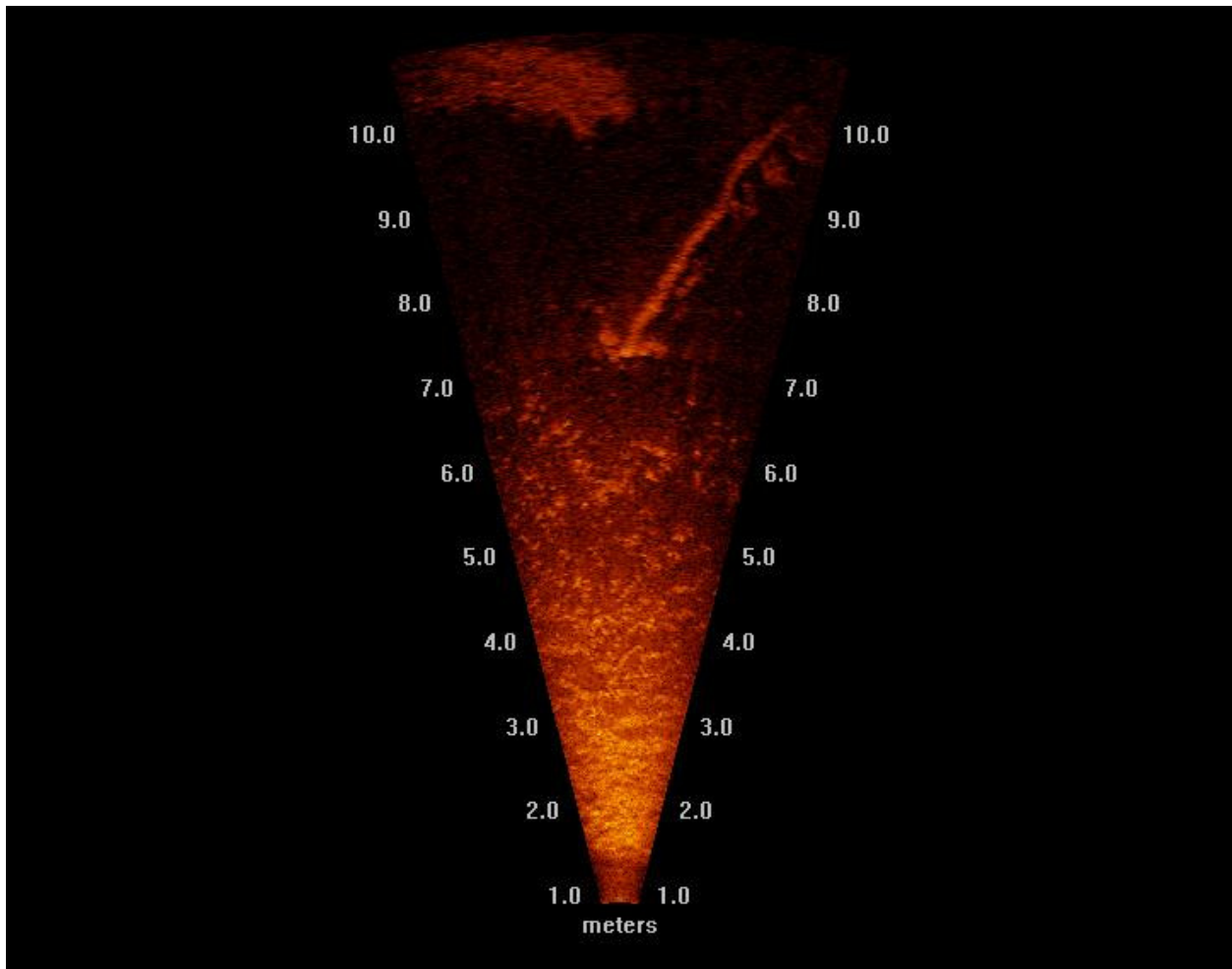


Figure A6 Screenshot of DIDSON review footage taken at Study Site 2.

Basic | 3D | Advanced | Transducer

CSOT/Cluster/Echogram

Process Angle

0

Min Track Size

12

Process N Beams

1

☐ Avg Over Threshold
☒ Max Over Threshold

Min Cluster Area

200

Max Cluster Area

10000

Max Speckle

5

Max Fish/Frame

32

RAM Buffer: 0.000 Mb

Motion

Min Threshold (dB)

6

☒ Show Cluster Statistics

☐ Upstream Motion L->R
☒ Upstream Motion R->L

☐ Subtract Opp Motion

Limits

	Frame	Range (m)	Angle (deg)
Min	0	2.5002	-15
Max	100	7.5018	15

☒ Entire File ☒ All Ranges ☒ All Beams

Save

Cancel

Apply

Defaults

Basic | 3D | Advanced | Transducer

Bathymetry

☒ Track on Local Maxima Track +/- N Samp 10
☒ First Return > Threshold
☒ Maximum Return

Save

Cancel

Apply

Defaults

Basic | 3D | Advanced | Transducer

Image Transformation

Factor A

0.95

Factor B

0.05

Factor C

0.65

Factor D

0.35

Convolve Beams

4

Convolve Samples

4

Transmission Loss - $2 * \text{Alpha} * R + N * \text{Log} (R)$

Alpha (dB/m)

Man 0 Auto 0.9666

N

20

☐ Normalize to 0 dB TL at Start Range
☒ Normalize to 0 dB TL at End Range
☐ Normalize to 0 dB TL at Range R R 1

☐ Apply +TL only to samples over Display Threshold

File Creation

☒ Auto Countfile Name ☐ Biomass File (.txt)
☐ Binary Count File (.dat) ☐ Echogram File (.ech)
☒ New Countfile on Open ☒ Delete Empty Files (.ech)

Save

Cancel

Apply

Defaults

Basic | 3D | Advanced | Transducer

Crosstalk Reduction Factors

Threshold

Suppression

☒ Set to Display Threshold
☐ Reduce by Suppression Level
☐ Modify Local Average

Beam Pattern Correction

Threshold (dB)

15

Max Correction (dB)

10

☐ Set to Display Threshold

Save

Cancel

Apply

Defaults

Figure A7 Screenshot of Convolved Samples Over Threshold (CSOT) setting used during the 2012-2013 DIDSON recording season.

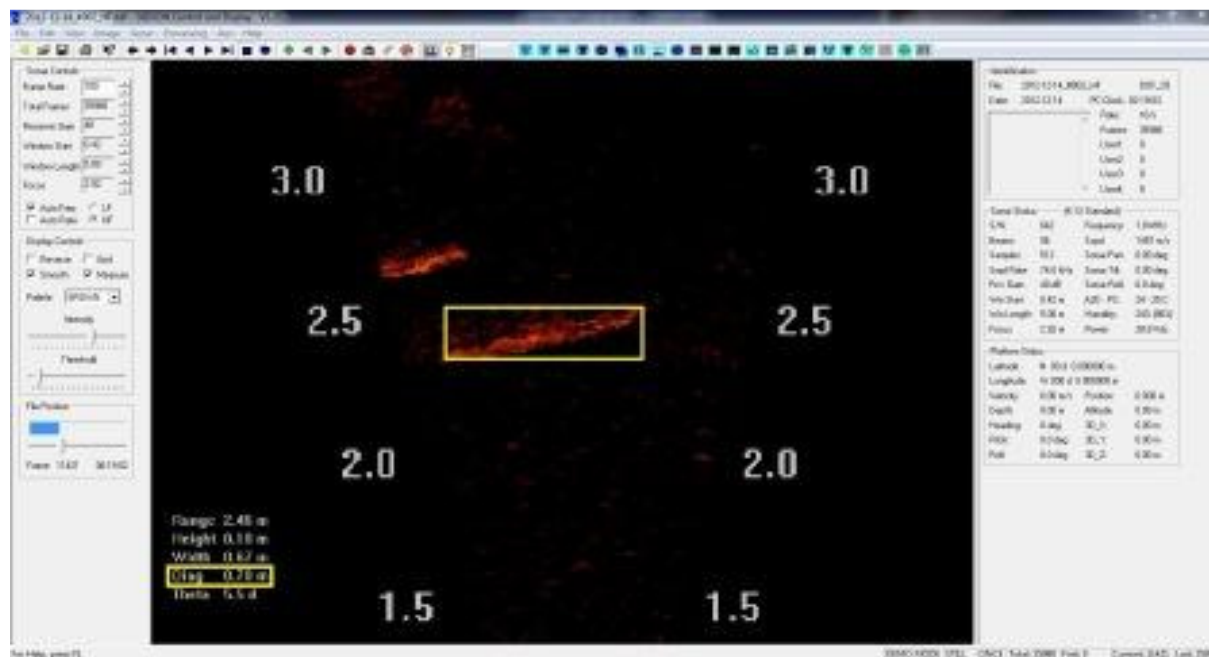


Figure A8 Screenshot of a reviewer using the DIDSON program to measure an adult salmonid.