State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND GAME

Results from the Cow Creek Video Station for Years 2006-2011 for Fall-run Chinook Salmon Escapement

By
Douglas Killam
California Department of Fish and Game, Northern Region
Red Bluff Fisheries Office

Kate Merrick
Pacific States Marine Fisheries Commission
Red Bluff Fisheries Office

RBFO Technical Report No. 02-2012

State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND GAME

Results from the Cow Creek Video Station for Years 2006-2011 for Fall-run Chinook Salmon Escapement

Cover Photo: Image of Cow Creek Video Station in 2011

By
Douglas Killam
California Department of Fish and Game, Northern Region
Red Bluff Fisheries Office

Kate Merrick
Pacific States Marine Fisheries Commission
Red Bluff Fisheries Office

RBFO Technical Report No. 02-2012

This was a multi-year cooperative monitoring effort undertaken by the California Department of Fish and Game with funding for this effort from the Sport Fish Restoration Act Grant F-51 Project 57. Cooperative assistance from the Pacific States Marine Fisheries Commission 2007-2011, the Western Shasta Resource Conservation District 2007-2009, the U.S. Fish and Wildlife Service's Anadromous Fisheries Restoration Program 2007-09, the U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program 2009-2011, and the U.S Bureau of Reclamation (2011) made the monitoring possible

TABLE OF CONTENTS

TABLE OF CONTENTS……………………………………………………………….…..iii

TABLES AND FIGURES…………………………………………………….…......iv

SUMMARY……………………………………………………………………...vii

INTRODUCTION…………………………………………………………….…..1
Monitoring Objectives ………………………………………………………1
Historical Background………………..……….…………………………….1

METHODS and MATERIALS...…… ……………………………….............….5
Weir System…………………………………………………………….....5
Electronics…………………………………………………………………9
Video Station Operation and Maintenance……………………………….....13
Data Adjustments to Original Reader Counts…………………………………17
2011 Quality Control Methods….…………………………………………….17
Water Temperature Data and Flow Measurements……...……...…………….….18

RESULTS AND DISCUSSION…………………………………………………...19
Data Adjustments and Discussion by Year………...…………………………....21
2006…………………………………………………………………………21
2007…………………………………………………………………………22
2008…………………………………………………………………………22
2009……………………………………………………………………….....23
2010……………………………………………………………………….....23
2011……………………………………………………………………….....24
2011 Quality Control Results..…...25
Biological Results for Video Station……………………………….……27
Relationship between Passage Timing, Temperature and Flow…………………29

CONCLUSIONS………………………………………………………….........31

ACKNOWLEDGEMENTS..32

LITERATURE CITED…………………………………………………………..33

APPENDIX A: Data Tables…...……………………...……………………….……...34

APPENDIX B: Figures………………...………………………………………......39

APPENDIX C: Documents……………………………………..…………….……51

TABLES AND FIGURES

Table 1. Summary of fall-run Chinook salmon escapement into Cow Creek from 1953 to 2011…………..……………………….…....................……………....2

Table 2. Summary of adjusted counts of fall-run Chinook salmon passage at the Cow Creek video station by month and week for years 2006 through 2011 with downstream redds included………………………………………..……....20

Table 3. Summary of video viewing conditions by half-hour periods for each year at the Cow Creek video station during years 2006-2011……………… …..…..27

Table 4. Summary of biological data collected from upstream passing salmon at the Cow Creek video station for years 2009 and 2011..28

Table 5. Summary of yearly fall-run Chinook salmon passage by month at the Cow Creek video station with flows (cfs) and water temperature………………...30

Figure 1. Map detailing the location of the video station on lower Cow Creek near the confluence of the Sacramento River in California...4

Figure 2. The 2006 Cow Creek video station with camera box, lights, weir, and passage opening with white plates visible…………………………….....................6

Figure 3. Image of typical RBFO video station weir panel and its components………...7

Figure 4. Cow Creek video station power supply box. Cow creek is located behind and down the hill in this photo…………………………………………………....9

Figure 5. Images of the camouflaged lock box (a modified refrigerator) in 2009 containing DVR equipment, TV monitor, power supply and battery backup for the Cow Creek video station.………...………………………………..…10

Figure 6. Image of over-head camera box with power cords, lights and camera box suspended over the Cow Creek video station………………………………..11

Figure 7. Image of typical underwater camera system on Cow Creek with white background plates. This is a two camera set-up with each side by side camera facing in opposite directions……………………………......................12

Figure 8. Image of Honeywell software with 2011 Cow Creek video station footage uploaded for fish passage reading. Top two screens are images from the overhead cameras and bottom two screens are images from the underwater cameras across the stream bed white plates……………………………..…14

Figure 9. View from the overhead camera looking down on the fish passage opening of the 2006 Cow Creek video station….……..……..……………..................16

Figure 10. Image of weir during periods of turbid water and minor flooding during the 2008 season on Cow Creek. Weir is underwater and one of the panels was dislodged. Weir was rebuilt and continued operation after this flood.……..19

Figure 11. Fall-run Chinook salmon counts by month at the Cow Creek video station for years 2006-2011……..……………………………...……………….…...29

APPENDIX A: Data Tables

Appendix Table A1 Summary of Cow Creek video station components for years 2006 through 2011……………………………………………...….34

Appendix Table A2 Daily salmon passage during years 2006 through 2011 at the Cow Creek video station…………………..……………………...35

APPENDIX B: Figures

Appendix Figure B1. Photograph of "station brand" plaque positioned on white plates with letters C and W for video readers to identify Cow Creek…..39

Appendix Figure B2. 2011 Cow Creek video station "at creek" log for electronics and DVR equipment…………………..………………………....40

Appendix Figure B3. 2011 Cow Creek office log containing information on date, time and the creek DVR download in office.......................................41

Appendix Figure B4. Primary log used to keep track of external hard-drives for the 2011 Cow Creek video station………………………………...42

Appendix Figure B5. Example of a fish passage data sheet for Cow Creek video station in 2011……………………………………………………….. 43

Appendix Figure B6. Upper image of Cow Creek during major flooding, Lower image of Cow Creek during a period conducive for construction and operation of the video weir……………………………………44

Appendix Figure B7. Photograph of 2006 Cow Creek video station….………………..45

Appendix Figure B8. Photograph of 2007 Cow Creek video station………………...…46

Appendix Figure B9. Photograph of 2008 Cow Creek video station….……..………....47

Appendix Figure B10. Photograph of 2009 Cow Creek video station….…………...…48

Appendix Figure B11. Photograph of 2010 Cow Creek video station….…….……..….49

Appendix Figure B12. Photograph of the 2011 Cow Creek Video Station. Plate design proved to be less effective in tape reading than previous year designs. Greater plate length allows better visibility of fish size than a greater width, which only allows more fish to pass through at one time……………………………………………………50

APPENDIX C: Documents

Appendix C. West Inc. electronic file detailing QC methodology used to develop final estimate for the 2011 Cow Creek fall Chinook salmon population……..51

SUMMARY

This report provides adult fall-run Chinook salmon (*Oncorhynchus tshawytscha*) spawner escapement estimates based on the operation of a video monitoring station located on Cow Creek, a tributary to the Sacramento River in Shasta County, California between 2006 and 2011.

The organizations facilitating the monitoring were the California Department of Fish and Game, the Pacific States Marine Fisheries Commission, the Western Shasta Resource Conservation District, the United States Fish and Wildlife Service (USFWS) Anadromous Fisheries Restoration Program, the USFWS Comprehensive Assessment Monitoring Program and the United States Bureau of Reclamation.

Video cameras at the Cow Creek station site were used in conjunction with a partial weir to record the passage of upstream migrating fall-run Chinook salmon in the autumn and early winter from 2006-2011.

Counts of salmon based on the video monitoring were used to produce annual spawner population estimates for Cow Creek. The estimated number of adult fall-run Chinook salmon entering Cow Creek based on the video monitoring was as follows:

- 4,209 salmon in 2006 or **1.4**% of total California Central Valley escapement.
- 2,044 salmon in 2007 or **2.1**% of total California Central Valley escapement.
- 478 salmon in 2008 or **0.7**% of total California Central Valley escapement.
- 265 salmon in 2009 or **0.5**% of total California Central Valley escapement.
- 536 salmon in 2010 or **0.3**% of total California Central Valley escapement.
- 1,617 salmon in 2011 or **0.7**% of total California Central Valley escapement.

The Cow Creek fall-run Chinook spawner escapement represented an average of 1.0% of the entire California Central Valley's totals over these six years, including both natural in-river spawners and spawner totals from all Central Valley hatcheries.

The successful operation of the video monitoring station in Cow Creek during a six-year period between 2006 and 2011 demonstrates that video monitoring stations can provide a viable and cost-effective mechanism for monitoring the annual escapement of fall-run Chinook salmon in this watershed. Use of similar stations may provide opportunities to monitor fall-run Chinook adult salmon escapement in other Central Valley streams where such estimates are not currently being collected.

INTRODUCTION

A video monitoring station and weir were used to estimate adult fall-run Chinook salmon (fall-run) escapement in Cow Creek Shasta County, California. The station was constructed and operated by the Red Bluff Fisheries Office-RBFO (formerly Sacramento River Salmon-Steelhead Assessment Project) of the California Department of Fish and Game (CDFG) in cooperation with Pacific States Marine Fisheries Commission (PSMFC), the Western Shasta Resource Conservation District (WSRCD), the U.S Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Program-AFRP, the USFWS's Comprehensive Assessment and Monitoring Program-CAMP, and the U.S Bureau of Reclamation. Funding for this project was also provided through a Sport Fish Restoration Act-SFRA grant to the CDFG each year.

Monitoring Objectives

- The overall objective of this monitoring effort was to obtain annual salmon estimates of the fall-run Chinook spawner escapement into Cow Creek.
- Collect baseline data on salmon escapement that can be used to evaluate population responses to restoration or other fisheries related management activities occurring in the Cow Creek watershed.
- Collect video data on the biological characteristics of the fall-run populations in Cow Creek including: sex, length and hatchery-origin ratios.

Historical Background

Well-designed environmental monitoring programs are needed to provide information to guide sound decision-making processes for natural resource management in California's Central Valley. In the Cow Creek watershed, a tributary to the upper Sacramento River, reliable resource monitoring information is important to guide decisions and evaluate actions associated with an ecologically important watershed. Reliable data on salmon escapement in Cow Creek are needed to interpret fishery responses to habitat restoration activities and provide information to fisheries managers, landowners, and others interested in the Cow Creek watershed.

Table 1 presents the annual escapement estimates for Cow Creek which are updated annually in the CDFG's electronic GrandTab report file that summarizes salmon populations in the California Central valley. This reporting file can be found at the following link or by searching the words "GrandTab salmon" in an internet search browser.

http://www.calfish.org/portals/0/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/Default.aspx

The Cow Creek watershed encompasses 275,000 acres and contains 6 major tributaries. Combined, these tributaries total 164 miles of stream channel (SHN and VRI, 2001). The watershed is home to a variety of fish species including steelhead, Chinook salmon, and native cyprinids. In 2001 the Cow Creek Watershed Assessment identified the lack of data on resident and anadromous fish populations and recommended that studies collecting baseline population data be implemented (SHN and VRI, 2001). The video station on Cow Creek serves this need and also the need of government fisheries agencies to have accurate population stock assessment for management of coast wide fisheries resources (i.e. ocean and in-river harvest management needs). Prior to 2006, CDFG had not monitored fall-run escapement into Cow Creek on a consistent basis since 1969. Table 1 provides a summary of Cow Creek fall-run escapement from 1953 to present.

Table 1. Summary of fall-run Chinook escapement into Cow Creek from 1953 to 2011.

YEAR	Estimate	YEAR	Estimate
1953	3,000	**1983**	n/a
1954	4,500	**1984**	250
1955	1,300	**1985**	n/a
1956	3,200	**1986**	n/a
1957	700	**1987**	n/a
1958	3,300	**1988**	n/a
1959	680	**1989**	n/a
1960	650	**1990**	n/a
1961	n/a	**1991**	n/a
1962	1,500	**1992**	n/a
1963	n/a	**1993**	n/a
1964	1,000	**1994**	n/a
1965	1,000	**1995**	n/a
1966	7,600	**1996**	n/a
1967	520	**1997**	n/a
1968	7,540	**1998**	n/a
1969	n/a	**1999**	n/a
1970	n/a	**2000**	n/a
1971	n/a	**2001**	n/a
1972	n/a	**2002**	n/a
1973	n/a	**2003**	n/a
1974	n/a	**2004**	n/a
1975	n/a	**2005**	n/a
1976	726	**2006**	4,209
1977	n/a	**2007**	2,044
1978	n/a	**2008**	478
1979	n/a	**2009**	265
1980	n/a	**2010**	536
1981	n/a	**2011**	1,617
1982	n/a		
AVERAGE all years (1953-2011)			**2,119**
source Grandtab-CDFG			

From 1953 to 1969 fifteen annual estimates were made based on carcass counts and occasional aerial redd (salmon nests) counts (CDFG, Annual Reports 1956-2008). The carcass surveys involved crews walking in the creek counting spawned out salmon carcasses during the few weeks of the salmon spawning season (October-November). Biologists would then expand the total carcasses counted based on their judgment of what percentage of the population they actually saw, (for example in 1957 six surveys reported 70 carcasses judged to be 10 percent of the population resulting in a 700 total fish population estimate). Carcass surveys today use a much more scientific methodology, but during the 1950's this "estimation by best judgment" was sufficient for management purposes.

Similar estimates were made using aerial redd counts when no carcass surveys were conducted (e.g. 1962). A pilot and an observer in a small plane would count the number of new salmon redds in the creek and this number would be expanded based on "best judgment". Most early estimates made with these techniques will often be reported as numbers rounded to the nearest hundred or thousand figures. Prior to 2006 staffing constraints, budget shortages, logistics and landowner trespass concerns had resulted in only two annual (1976, 1984) fall-run estimates being made for Cow Creek since 1969.

The video station estimate represents a new method for estimating fall-run populations in Cow Creek. A similar video station was constructed and has been operated since 2003 in Battle Creek and was successful in replacing the traditional carcass survey on that creek. The data from the Battle Creek video station allowed biologists to compare the results of a carcass mark-recapture study and hatchery counts to the video station results (Killam, 2006). Over a three-year period the counts from the two independent methods were similar enough to give fisheries biologists the confidence to halt the labor intensive carcass survey, (since 2006 the video station was the only method used on Battle Creek). As a result of the success in Battle Creek the video station methodology was adopted for use in other watersheds. The Cow Creek station began in 2006. Similar stations on Cottonwood Creek (2007-present), Mill Creek (2008-present) and Bear Creek(s) (2007-2010) were also put into operation.

In October of 2005 a description of the Battle Creek video station was presented at a meeting of the Cow Creek Watershed Group. At this meeting there was a general consensus that the group was interested in developing a video station on Cow Creek for the fall of 2006. As mediators for the group, the WSRCD arranged to coordinate the video station details with the Department and Service. In early November of 2005 a kayak survey of Cow Creek was made to choose a site for the new video station. A single site just upstream of the Dersch Road Bridge fit all the criteria for a video station.

Criteria for the video station location included:

1. Limited public access to avoid vandalism and poaching opportunities.
2. A nearby power supply to run the station's DVR/VCR's and cameras.
3. Close to the mouth of the creek so most salmon entering the watershed to spawn would need to pass by the video monitoring station and therefore could be counted.
4. Landowner permission to construct and have daily access to the video station site.
5. Suitable stream geology to place the weir (shallow with even stream bottom)

A single site just upstream of the confluence with the Sacramento River fit all the criteria for a video station. It was located approximately 1.3-miles (2 kilometers) upstream of the mouth of the Sacramento River as detailed in Figure 1.

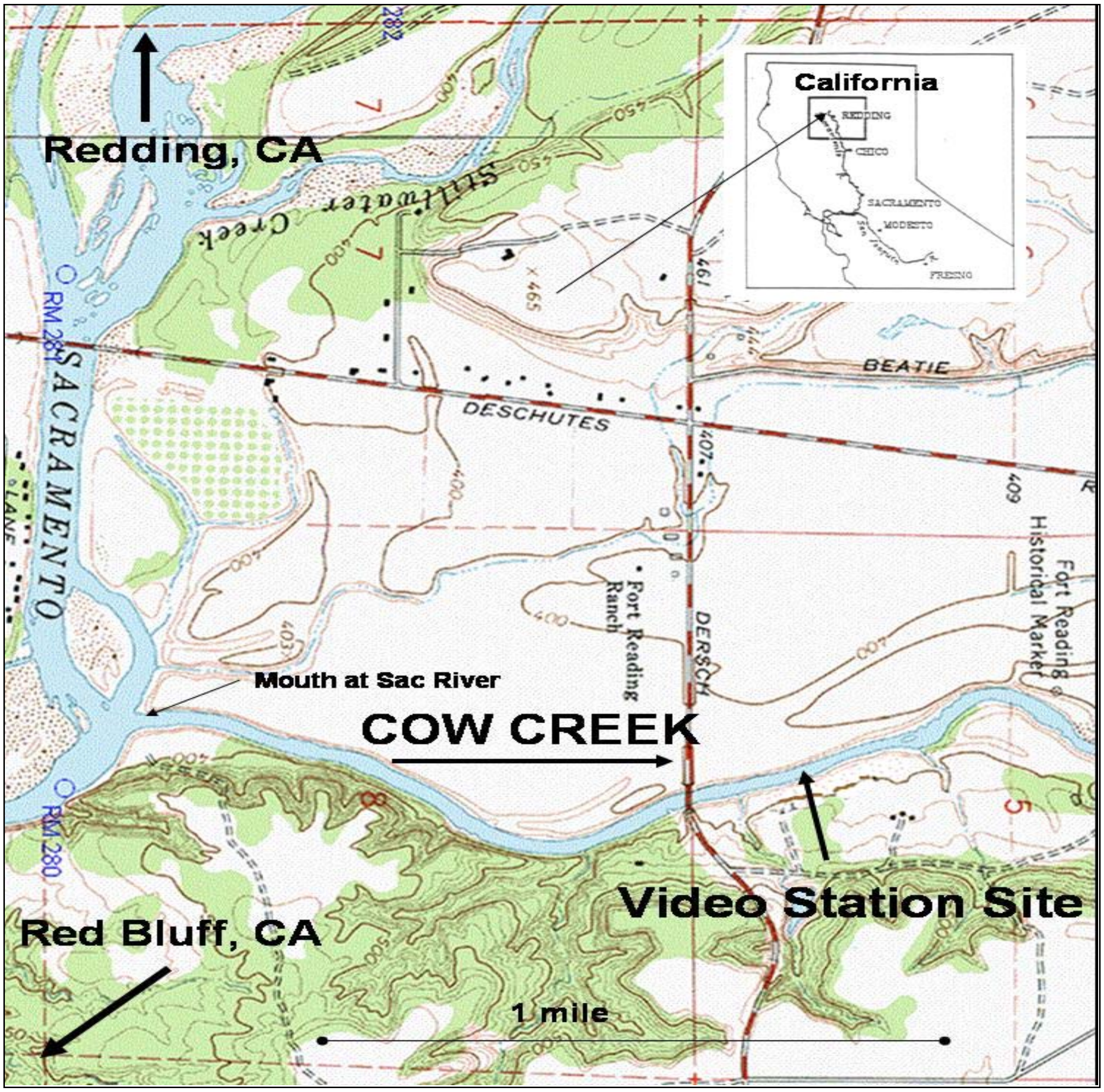


Figure 1. Map detailing the location of the video station on lower Cow Creek near the confluence of the Sacramento River in California.

The Universal Transverse Mercator coordinates of the video monitoring station are 4481311 North, 565289 East in a NAD-83, zone 10 projection and datum. The station has been installed in the same general location for all six years. During these years the video station was used to record the passage of fall-run and other species during a period commencing in September and ending from mid November to mid January. Personnel from the CDFG, WSRCD and PSMFC cooperated to accomplish station set-up and removal, maintenance, VCR or DVR changing and quality control of video footage.

METHODS AND MATERIALS

Video monitoring on Cow Creek was conducted during the following field seasons:

- From 11 September through 24 November 2006
- From 20 September through 6 December 2007
- From 13 September through 19 December 2008
- From 23 September through 21 December 2009
- From 28 September through 6 December 2010
- From 21 September 2011 through 16 January 2012

The video station was constructed from commonly available retail equipment and is divided into two basic groups of equipment for discussion purposes.

Weir System
- Stream bottom white plates
- Weir panels

Electronics
- Power supply
- DVR lock box and equipment
- Backup power supply
- Lights
- Overhead camera with supporting structural cables and electronic cables
- Underwater cameras with supporting plates and electronic cables
- Video recording devices

The Cow Creek video station as shown in Figure 2 functioned by video recording salmon and other migrating fish as they passed through an opening in a partial weir. The weir had a slight upstream facing “V” shape that funneled the upstream moving salmon towards the opening in the main channel of the creek. At the opening the fish swam above a number of white plates attached on the stream bottom. As the fish swam through the weir opening, they were video recorded by a camera positioned on cables directly overhead of the white plates.

Weir System

To create a white background for better visibility of passing fish, one-quarter inch (6-mm) thick, high-density polyethylene (HDPE) white plates were staked to the creek bottom below the overhead camera. The plates overlay each other slightly and have ¾-inch (1.9 cm) holes drilled around the perimeters to allow staking. A metal flat strip, also with holes, and measuring ¼-inch thick and four-inches wide (6 x 100 mm) is bolted to the upstream edge of all plates prior to placement in the creek to assist in installation and anchoring. Concrete form stakes, of various lengths with a two-inch (5 cm) washer welded to their tops were driven through the holes and into the stream bottom to secure the plates to the bottom. Components of each year’s weir setup are shown in Appendix Table A1.

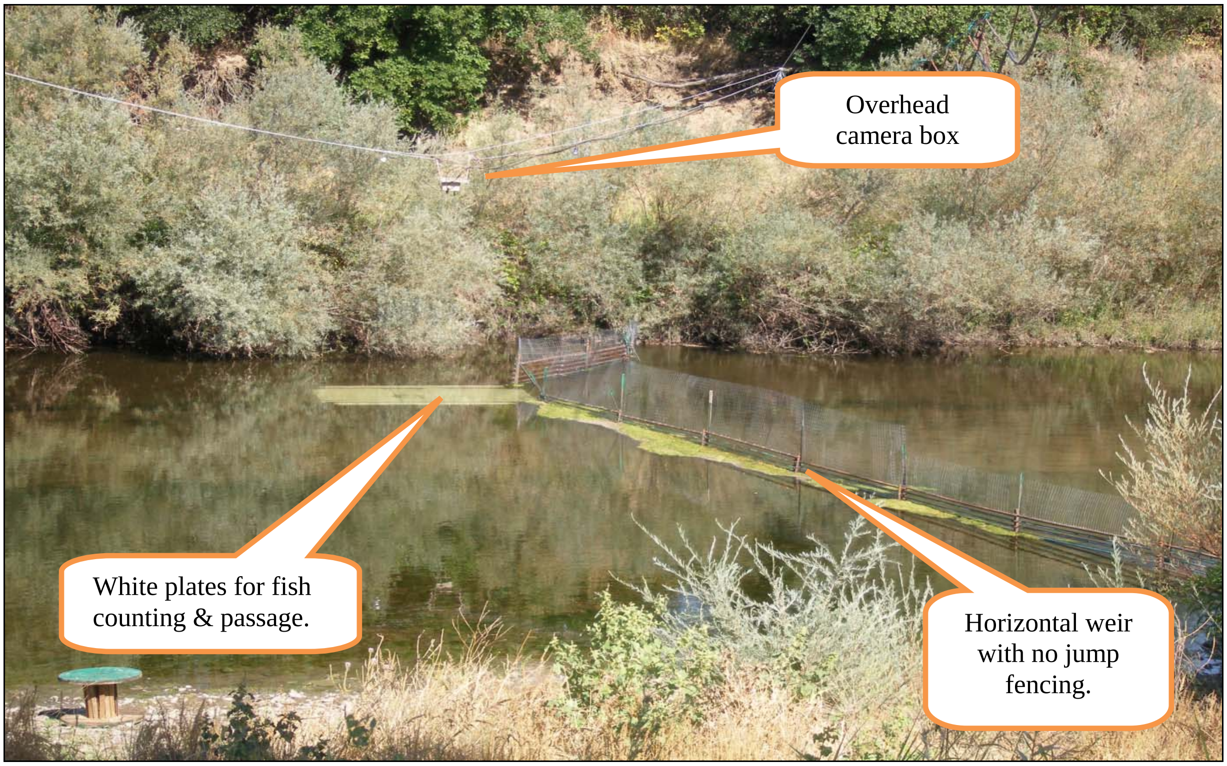


Figure 2. The 2006 Cow Creek Video station with camera box, weir, and passage opening with white plates visible.

In 2006, three overlapping 1/4" x 4 x 8-foot (6 mm x 1.2 x 2.4 m) plates were used to create an 11 x 8-foot wide (3.4 x 2.4 m) viewing area (see Figure 2 and 9). In years 2007 through 2009, two 5 x 10-foot (1.2 x 3 m) plates were used creating a 10 x 10-foot (3 x 3 m) viewing area. In 2010 three 5 x 10-foot (1.5 x 3 m) plates were used to create a 15 x 10-foot (4.6 x 3 m) viewing area. In 2011, four plates were laid end to end in a five-foot x 40-foot (1.5 x 12.2 m) design to allow higher flows to pass the video station without impacting the weir.

A welded metal rectangle shaped "station brand" measuring exactly 12 x 24-inch (305 mm x 610 mm) was staked to the white plates. The brand allowed tape readers to approximate fish size, and thereby classify the salmon by length as to large or small. This size classification (large salmon >610 mm length, and small <609 mm) is used on other RBFO surveys allowing annual comparisons to be developed that can approximate age compositions. The stations brand had a "station identity" welded into the center of the rectangle. During viewing, video readers were able to identify Cow Creek footage by the letters C and W incorporated into the center of the rectangle, visible in Appendix Figure B1. Other creeks had different letters in their brands (e.g. Battle Creek was B and T). In years 2010 and 2011 a larger "jack bar" measuring 24" in width was laid across the width of the white plates to ease the ability of readers to measure salmon lengths for distinguishing between two-year old salmon known as "jacks" and older "adult" salmon. This device is visible in Figure 8.

To direct salmon to the white bottom plates where they were easily counted, the RBFO staff developed a new style of weir designed and constructed to channel salmon under the area of view of the overhead camera. The weir, as pictured in Figure 2, was designed to avoid causing upstream passage delay. The "horizontal weir" was constructed of 10-foot x 1-inch (3.0 m x 2.54 cm) steel pipes welded to uprights with 3-inch (7.6 cm) spaces between pipes. Taller panels incorporated 1-¼ -inch (3.2 cm) electrical metallic tubing (EMT) conduit on the inner cross-members to lighten the overall weight of the finished panel. These conduits were slid over 12-inch (30.5 cm) pipe "stubs" that were welded to the uprights during construction. The horizontal pipe panels are designed to fit the depth of the creek at the weir site, (e.g. panels in shallow water have only two or three cross-members while panels in deeper water have more cross-members). Figure 3 provides details of the weir components. The horizontal design and spacing between bars of the weir panels allows leaves to easily pass downstream while preventing salmon from passing the weir except at the opening. Rebar stakes were driven vertically through the two uprights on each panel and into the stream bottom to prevent the panel from sliding on the bottom. Welded fittings termed "doglegs" by the RBFO staff were bolted to the upper horizontal pipe and a "weir arm" was slid through the dog leg fitting and pounded into the stream bottom at approximately a 45-degree angle downstream.

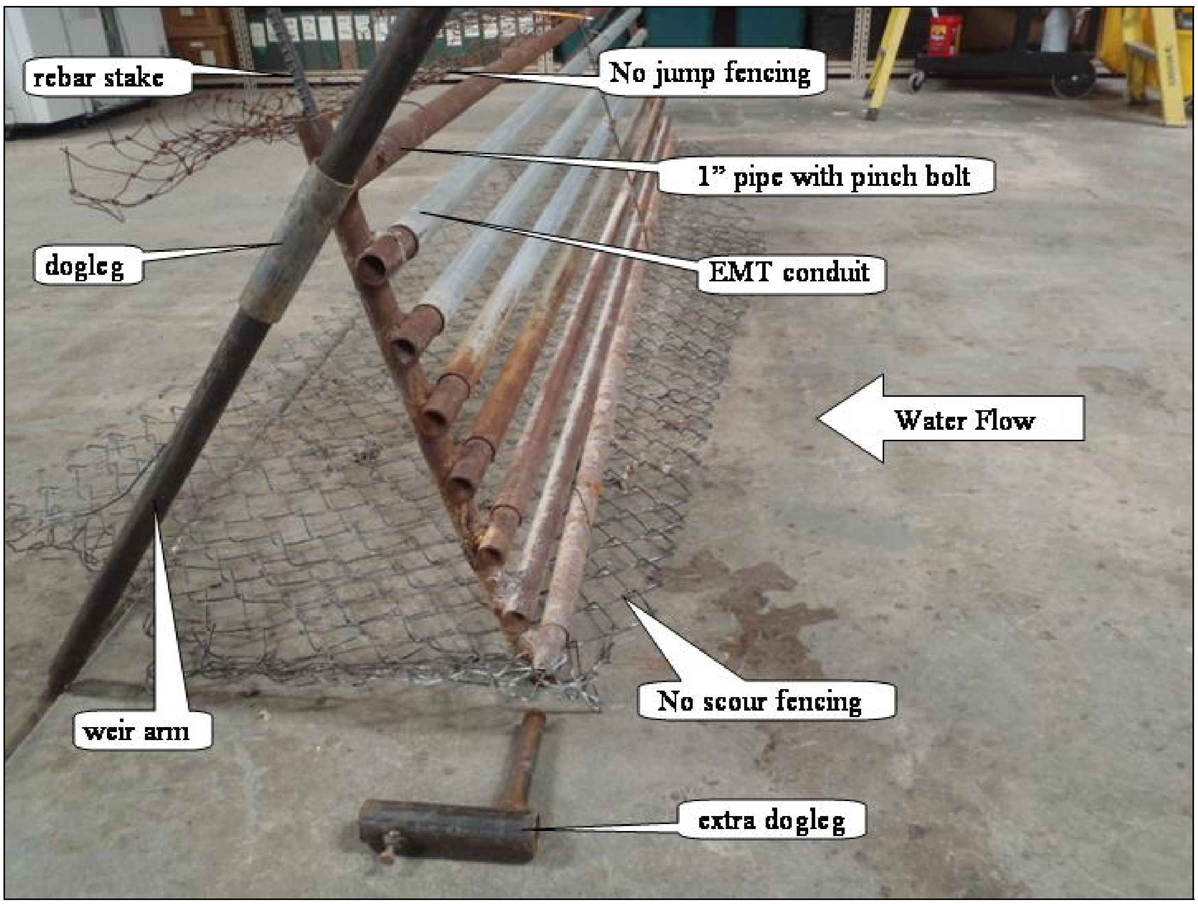


Figure 3. Image of typical RBFO video station weir panel and its components.

Dogleg fittings and other innovative designs provided the ability to position and support the weir in almost any configuration. The dogleg consisted of a one-inch (2.5 cm) solid steel round about six-inches (15.2 cm) in length welded to a 1-¼-inch (3.2 cm) pipe about six-inches (15.2 cm) in length. The two pieces formed a 90-degree angle. A 3/8-inch hole (9.5 mm) was drilled in the pipe opposite the welded round. A 3/8-inch (9.5 mm) standard thread nut was welded over this hole allowing a bolt to pass through both the nut and the pipe and "pinch" fit the pipe to another pipe inserted through it. This same hole and welded nut arrangement was also made about four inches (10.2 cm) from both ends of the top pipe on every weir panel. During weir construction crews would slide the solid part of a dogleg into the top pipe of a panel and could "lock" it in position by tightening a "grade 8" hardened bolt on the outside of the weir panel.   The doglegs were rotated around their solid piece to allow a weight supporting "weir arm" to be slid through the pipe part of the dogleg and into the stream bottom downstream of the weir panel. The weir arms were made from the same one-inch pipe as the weir panels.   Weir arms were of variable length. Each had a welded end forming a solid spike that was driven into the stream bottom. During construction crews selected weir arms of sufficient length to allow the arm to be driven into the stream bottom a distance between one or two feet (30.5 to 61 cm). The weir arms were slid through the doglegs and angled downstream of the weir panels at about a 45-degree angle and struck with a sledge hammer until the end of the weir arm was flush with the dogleg. The bolts on the dog leg and weir panels were then tightened, securely locking the components in place and forming a sturdy triangle between the stream bottom, the slightly leaning downstream panel, and the weir arm. In later years, crews constructed weirs in which every other weir panel was assembled in this way. In between these "double-weir armed" panels rested the remaining panels with no supports. These panels simply were leaned against the supported panels on either side of them. This design allowed crews to "lay-down" a good portion of the weir rapidly to allow high water to pass if a storm event was expected to bring floods (as seen in Figure 10).

Experience on Cow Creek and other fall-run streams has shown that flood events in the fall-run migration period are normally for a short periods. Turbid or muddy water can prevent video recordings of fish passage during these floods. The weir is designed to resist damage in minor floods by allowing water to over top it and by allowing crews to pull forward and rest on the stream bottom some of the weir panels. This design enabled crews to quickly rebuild the weir and enabled video recording of fish passage to resume as soon as turbidity cleared after a storm event

In sandy areas or areas susceptible to undercutting, a three-foot wide (0.9 m) chain link fencing, or other suitable fencing material underlay the weir panels to prevent scour during high flows. The weir bottom fencing was situated so that about six-inches (15.2 cm) of fencing protruded upstream of the weir bottom pipe and the remainder was downstream of the weir. This locked in smaller rocks that could be swept away in higher flows. Two upstream facing weir panels were placed along the outside edges of the white bottom plates just below the water surface noticeable in Figure 9, to act as guidance panels at the fish passage opening to prevent fish from skirting around the ends of the weir and allow for easier counting. On some weir panels a "no jump" fence (Figure 3) was wired above the top of the panel and angled downstream to prevent salmon from jumping over the weir in deeper water. The no jump fence was typically animal pen fencing with two-inch square (5.1 cm^2) openings cut to 18-inch (45.7 cm) wide and 10-foot (3.0 m) lengths.

Electronics

One criteria of the Cow Creek video station power supply was that it be located near a conventional "on-grid" Pacific Gas and Electric Co. power supply. The Cow Creek station did not have sufficient funding to purchase solar panels and related equipment similar to the remote Battle Creek station so it was necessary to select a site with existing power. The selected site had an existing 240 volt incoming power supply. This power box shown in Figure 4 provided a close-by source of power to the station.

This box was formerly used to power an electric irrigation pump in the creek but was currently not in use. A 240 to 120 volt transformer was setup in the existing box and provided a 120 volt alternating current (AC) typical of a household power supply to run the camera lights and equipment.

Figure 4. Cow Creek video station power supply box. Cow creek is located behind and down the hill in this photo.

An underground conduit line was trenched about 75 feet (24 m) from the power supply box to an electronic lock box where the station's equipment was located. An in-line ground fault interrupt circuit (GFIC) device was used to provide automatic power shut-off of the system in the electronic lock box should any part of the stations electronic devices have a faulty circuit

The station's electronic lock box shown in Figure 5 contained a back-up power supply used to provide power for a 1-2 day period should a power outage occur in the regular power supply.

The backup power supply consisted of four 6-volt "golf cart type" linked batteries providing a 12-volt direct current (DC) power supply to a modified 300 watt APC brand Uninterruptible Power Supply (UPS). The original batteries from the UPS were removed and the larger golf-cart batteries were connected giving a much greater power reserve if the grid power failed. All of the stations electronics were routed through the UPS to ensure continual video coverage in the event of a power failure.

Figure 5. Images of the camouflaged electronic lock box (a modified refrigerator) in 2009 containing DVR equipment, TV monitor, power supply and battery backup for the Cow Creek video station.

From 2006 to the middle of the 2008 Cow Creek station video footage was recorded onto three video cassette recorders (VCR's). The VCR's (shown in Figure 5) were capable of recording eight hours each and were programmed to record sequentially for 24-hours.

From October 2008 on, digital video recorders (DVR's) were used to record data, and were housed in the lockbox to secure and shelter the station's video equipment, electrical accessories and batteries (shown in Figure 5).

Lighting for the video cameras was provided by two to three compact outdoor fluorescent spotlights mounted on an overhead cable system (three 90-watt bulbs in 2011) as shown in Figure 6. A photocell sensor, similar to those used on streetlights, turned the lights on at dusk and off at dawn. During daily station checks crews checked the lights for proper operation by reviewing the video footage from the previous early morning hours to determine if lights were functioning properly.

The overhead camera used to count fish passage was a weatherproof black and white camera (Supercircuits Inc. Model # PC88WR) was chosen because it provided a high quality image in various lighting conditions. The camera attached to the outside of a larger box containing remote lighting and other wiring hookups. The camera box and camera are shown in Figure 6. The camera box was suspended from two ¼-inch (6.3 mm) galvanized steel cables directly over the white plates where salmon passed as they migrated upstream.

The two cables, about 300-feet (91.4 m) each, stretched across the creek and were anchored to riparian trees on the far side of the stream as seen in Figure 2. These two trees were spaced about 100-feet (22 m) apart from each other along the edge of the creek. The two cables terminated at a single tree on the near side of the creek (Figure 2) located behind the electronic lock box in Figure 5.

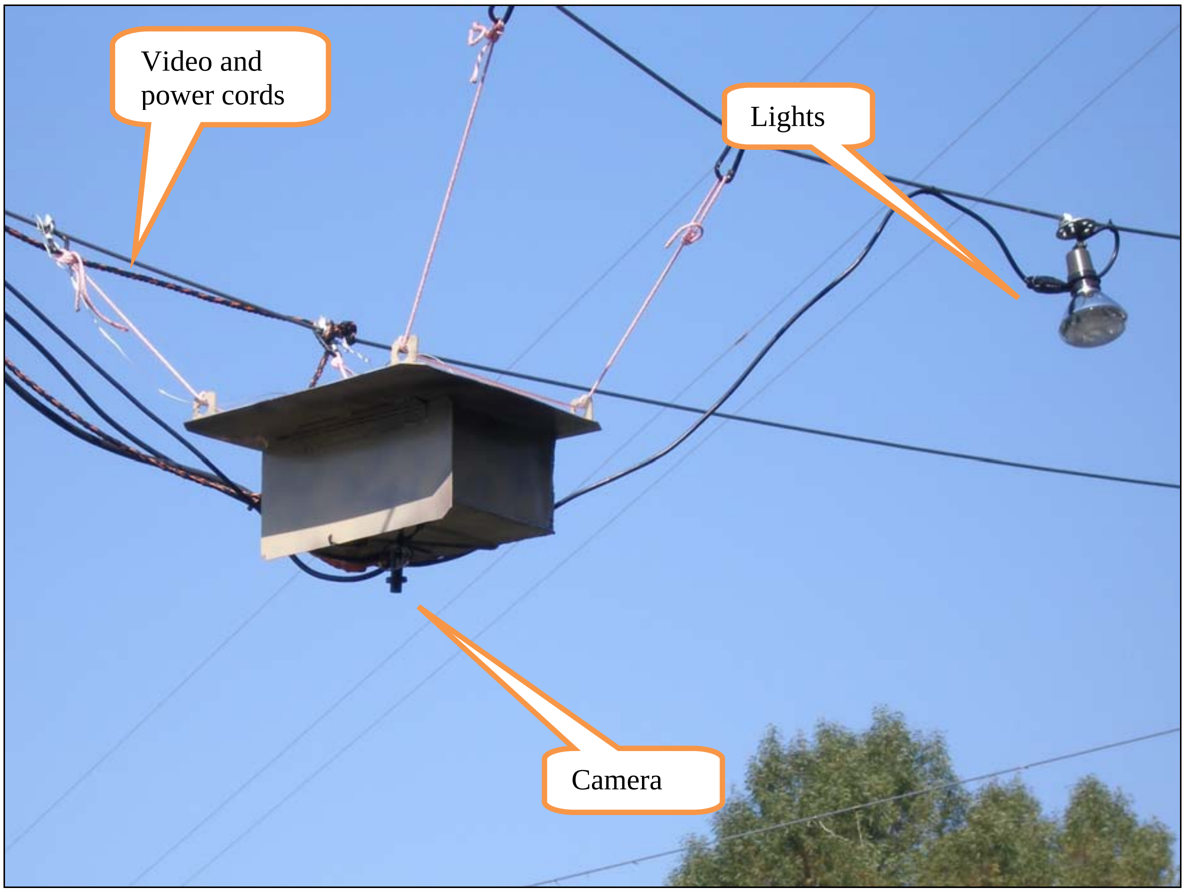


Figure 6. Image of over-head camera box with power cords, lights and camera box suspended over the Cow Creek video station.

This connection point in the tree was designed to allow easy movement up and down with a vehicle mounted winch so the camera could be raised or lowered to adjust for proper orientation over the white plates or when camera maintenance or cleaning was required. The camera box was attached by ropes to the cables, which reduced vibration caused by inclement weather. Power cords and camera co-axial cables were wired to the support cables with short plastic coated utility wire were run from the overhead stream camera box (see Figure 6) to the station's electronic lock box (see Figure 5). In years 2006 through 2010 a single overhead camera was used to record fish passage. In 2011, two overhead cameras were used over a wider opening in an attempt to maximize the size of the opening available for fish passage. In response to the need for identifying passing fish species at video stations, the RBFO, over a period of years, developed low cost underwater cameras that enabled video readers to view fish from underwater views. Commercially available underwater cameras proved expensive and unreliable in identifying passing fish. RBFO staff designed and built enclosures to house economical, wide angle retail cameras that proved suitable for video station needs. Four Supercircuits brand models of cameras were used in the underwater camera housings on various video stations including: PC164, PC222, PC165-HR, and PC221-HR models. All were low light capable, and models PC165-HR and the PC221-HR were color cameras that were used to help identify rainbow trout (*Oncorhynchus mykiss*) and other species at the video stations.

Up to three underwater cameras were typically installed in the stream to monitor salmon passage. Cameras were oriented perpendicular to the stream to record the passage of salmon as they move upstream past white plates anchored to the streambed as seen in Figure 7.

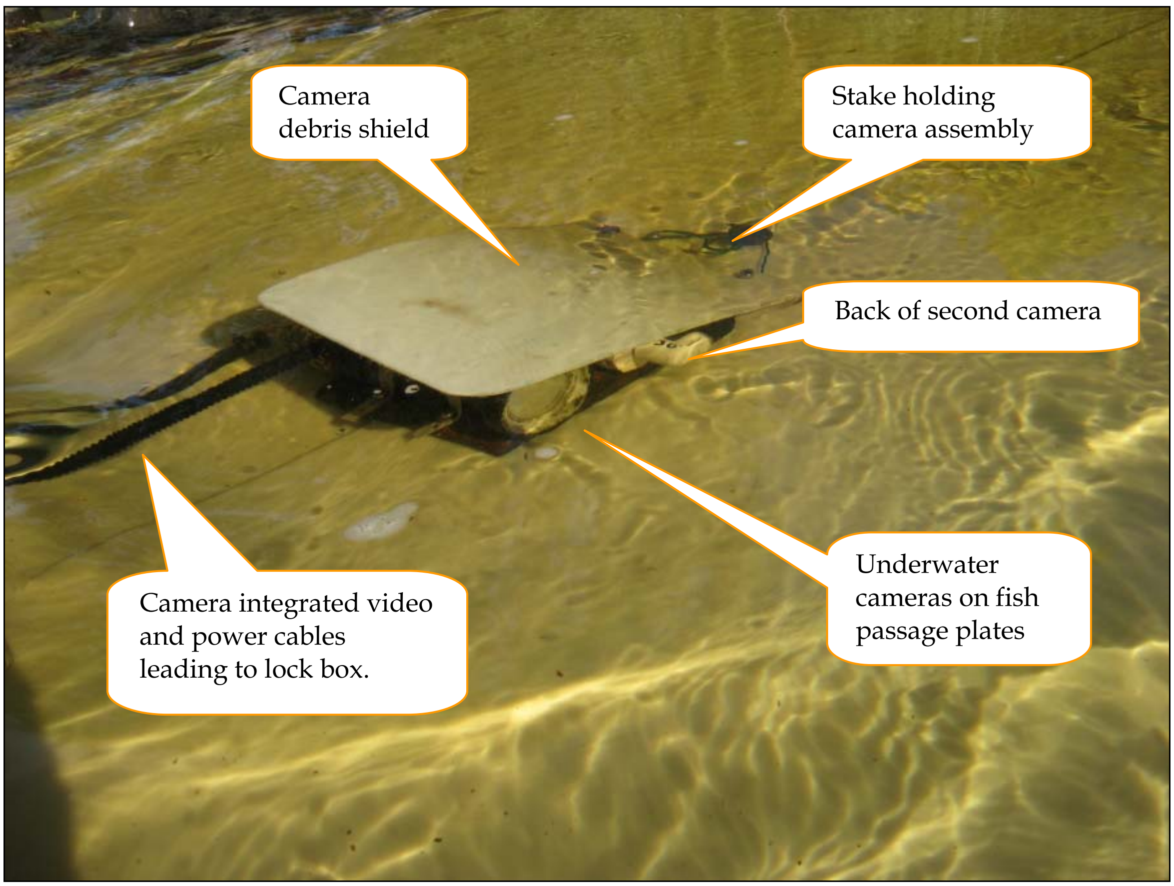


Figure 7. Image of typical underwater camera system on Cow Creek with white background plates. This is a two camera set-up with each side by side camera facing in opposite directions.

The underwater cameras monitor upstream and downstream fish passage and help in species identification and determining biological characteristics such as sex and adipose fin clips. The cameras were protected inside a custom-made poly vinyl chloride (PVC) enclosure with a waterproof seal. The cameras were strapped to heavy metal plates that were wired to the stakes securing the white plates in order to withstand the force of the current during high flows. A small piece of the same HPDE material used in the white plates was secured to the upstream edge of the metal plate of each underwater camera assembly. This piece layed over the cameras and helped prevent debris (leaves, algae) from accumulating on the cameras between station cleanings. The underwater camera's integrated video and 12-volt DC power cable ran atop the weir panels, out of the creek, and was buried underground to the electronic lock box to avoid damage and vandalism.

The images from the cameras were recorded on both a primary recorder (VCR or DVR) and a backup recorder to ensure continuous video coverage in the event of a malfunction of either machine. A small TV monitor was used to observe the image from the cameras and to check the recorders for proper operation throughout the season. Appendix Table A1 provides details of the various components used during each year at the video station.

Video Station Operation and Maintenance

The Cow Creek video station was checked nearly every day during each year's field season. Daily activities included:

- Checking the recording equipment for correct operation and camera function.
- Checking power levels and normal operation of equipment (lights, DVR's, etc.).
- Cleaning the weir and white plates of algae, debris, and carcasses.
- Recording comments and time of visit in the station logbook.
- Transporting video tapes to WSRCD office (year 2006) and video tapes and DVR's to the RBFO in years 2007-2011.
- Downloading creek recordings into Honeywell DVR years 2007 to 2011.
- Viewing recordings and counting fish.

The Cow Creek video station is installed each September and normally takes between 3 and 4 days with a crew of 4 to 7 personnel. Because many other fall-run surveys are occurring each year the RBFO attempts to construct and begin operation of all stations prior to the first salmon passage. With this method, RBFO staff were free to conduct other surveys once salmon spawning commences (normally late-September) and the Cow Creek and other stations are in normal operational status requiring only a single person to service them once per day for a short period typically less than 15 minutes per visit.

Staff from the RBFO and in years 2006-2009 staff from the WSRCD would coordinate to visit the station once a day to change VCR tapes, check electronics and brush algae, aquatic vegetation, and leaves from the weir and white plates. Typically one person would check all operating stations by driving a set route each day. In 2006 the VCR tapes were transported to the WSRCD office and the tape footage was viewed on an office VCR. In early 2007 tapes were transported to the RBFO office and placed into office VCR's connected to a Honeywell Fusion III DVR (Honeywell) in a process identical to the DVR process described below. The purchase of three creek DVR units for Cow Creek in October of 2008 replaced the need for daily tape changes with once a week DVR changes. The four-camera creek DVR's (model DVQ-2) with internal 500 gigabyte hard-drives were capable of recording up to four cameras for up to ten days and were used from 2008 to 2011.

The use of creek DVR's enabled RBFO staff to visit the station once a week (normally Monday) to swap the at-site creek DVR with another one that had an empty hard-drive. The creek DVR with a now full hard-drive was transported back to the RBFO and was attached to the Honeywell DVR via a video cable. The creek DVR was set to playback its recording of the previous week's passage from the beginning of the previous Monday. Playback into the Honeywell was done at real-time speed so it took one week for the creek DVR to download its complete recording into the Honeywell. The creek DVR's could record up to four cameras simultaneously. The output of the creek DVR was through a single video cable so the image going to the Honeywell was of a split four camera view with a time and date "stamp" on the image. Figure 8 provides an example of the video images and screen readers used to view and record fish passage. The more advanced Honeywell was capable of recording up to four individual creek DVR's at full resolution and 30 frames-per-second (i.e. approximately what the human eye views).

Figure 8. Image of Honeywell software with 2011 Cow Creek video station footage uploaded for fish passage reading. Top two screens are images from the overhead cameras and bottom two screens are images from the underwater cameras across the stream bed white plates.

Because of multiple fall-run video stations the Honeywell DVR was in constant use doing multiple tasks. Apart from downloading the creek DVR's the Honeywell was also "backing up" the recording onto two separate external one terra-byte hard-drives and also serving as a reader station for readers tallying fish passage. Once the creek DVR download to the Honeywell was complete, the creek DVR's internal hard-drive was cleared and deleted to free up space for future recording. The creek DVR was shelved until the next Monday when it was put back into use at the creek. With this rotation, an individual creek DVR was recording fish passage during every third week of the fall-run migration into Cow Creek.

The complexity of having multiple video stations operating simultaneously each fall resulted in the need to document the variety of events occurring at all times, using log books. A log was kept at the electronic lockbox at the creek to record date and time of cleanings, DVR changes, back up tests and any other noteworthy events. Appendix Figure B2 provides an example of a page from this log from 2011. In addition to the creek side log, two other logs were kept near the RBFO Honeywell DVR. The first office log contained information detailing the time, dates and numbers of the creek DVR's that were returned to the office for downloading into the Honeywell DVR. Appendix Figure B3 provides an example of such a log for the 2011 Cow Creek video station. The second log was used to keep track of the identification of the numerous one-terabyte external hard-drives (LaCie model 301304U) that the Honeywell DVR, stored the recordings on. This log (shown in Appendix Figure B4) was the primary tool used by readers to find which external hard-drive contained the footage they were searching for to complete the fish counts for each day. In addition each hard-drive was individually numbered and labeled as to what creeks and dates in contained. Readers would use the logs to select a hard-drive from the storage shelf then plug it into one of a number of desktop computer workstations via a universal serial bus (USB) cable. The Honeywell "Proprietary Viewer" software was then opened and reading would commence.

The Honeywell Fusion software allowed readers to rapidly locate the desired periods of creek recorded time. The software provided options for reading faster or slower than "real time". Readers could pause, move frame by frame, zoom, or any combination of these options to aid their ability to view recorded fish passage. Both the creek DVR units and the Honeywell DVR were capable of continuous and motion detection recordings. Motion detection recordings would, in theory, only record periods of time that fish were present and thus greatly reduce the time required to review and count fish passage. RBFO staff found after repeated trials on Battle Creek and the other video stations that the changing environmental conditions during the daily cycles made the use of motion detection software unreliable. Conditions (as viewed from the overhead camera) such as shadows, camera wind induced movement, reflective sun and night light, rain, wind ripples, aquatic debris, and turbidity levels all fluctuating on a daily basis impacted the reliability of the software to detect fish and to reduce record times. As a result, the majority of recordings were made on a continuous or 24/7 basis after previous motion recordings were determined to either miss passing salmon if motion threshold settings were too high or to record in an almost continuous mode if motion threshold settings were too low. Consequently in later years nearly all periods were subsequently recorded continuously and the entire season was reviewed in continuous recording format for passage events.

Each day was divided into 48 half-hour long viewing periods. Reader personnel reviewed recorded footage and any salmon that passed up or downstream of the upper end of the white plates were counted (Figures 8 and 9). The number of salmon passing upstream and downstream of the white plates was tallied on a datasheet. Appendix Figure B5 provides an example of a completed datasheet from 06 November 2011. Other species were also counted on the datasheet. Fish moving downstream were subtracted from the total moving upstream for each period to maintain an accurate net upstream count. All recording devices recorded the time of fish passage, therefore, accurate determinations could be made regarding the daily timing of fish movements as shown in Figure 9. Readers were instructed to read recorded footage from season beginning to end. Normally readers could read two to four days of creek recording per reader work-day. Reader fatigue was a potential problem and all readers were encouraged to take breaks if they were experiencing viewing fatigue. In earlier years results from the Battle Creek video station determined that some personnel from the experienced field survey crews were not well suited to video reading. These individuals had difficulty remaining alert and seated for long periods of time required to review footage. In 2007 the RBFO began utilizing staff specifically employed for their ability to read footage on a continuous basis.

The completed paper datasheets containing the reader counts were scanned into Adobe pdf format files and archived for perpetuity. The reader data was transferred each year into electronic Microsoft Excel and Microsoft Access files for analysis.

Figure 9. View from the overhead camera looking down on the fish passage opening of the 2006 Cow Creek video station.

These electronic files were then used to further develop the overall population estimates for each year shown in Table 1. At the beginning of each new season the previous year's external hard-drive data was cleared to make room for the new data. Beginning in 2011 the data was archived in perpetuity in two locations once funding was made available for the purchase of archive specific external hard-drives.

Data Adjustments to Original Reader Counts

The Cow Creek video station estimates began with a series of half-hour period counts of fish passing the station from the time it was first operated through the time it was removed. These counts were made for all periods in which readers could visually see the passing fish. These original counts formed the beginning of the estimate. There were three other data adjustment steps that were typically applied to the original counts to reach a final estimate.
These included:

1. During periods of turbid creek flows or electronic failures the video recordings may not have provided an accurate estimate of the number of salmon that migrated past the weir. To compensate for the lack of recorded passage resulting from such events, RBFO biologists would use averaging techniques and best judgments to augment counts for the missing recorded periods for years 2006-2010. In 2011 a statistical methodology incorporating a general additive model (GAM) was developed to impute for the "missing" video periods.

2. Quality control checks (QC) on the original reader counts were made at various levels and techniques each year. Staff and budget shortfalls made it difficult to conduct a thorough QC of each year's data. During years 2006 to 2010 no attempt was made to develop a statistical methodology to provide confidence intervals around the estimate. In 2011 a methodology was developed that enabled confidence intervals around the final estimate to be developed.

3. Once or twice each season walking or kayak surveys were made downstream of the station to the Dersch Road Bridge or the confluence with the Sacramento River to determine if any salmon were spawning downstream of the station. These surveys of salmon redds downstream of the weir were conducted by RBFO personnel. Each new redd was assumed to reflect the presence of two adult salmon per redd, and these numbers were added to the video count total after all other adjustments were made.

2011 Quality Control Methods

In years 2006 through 2010 staffing and funding levels resulted in a patchwork of quality control efforts for re-reading the original counts and comparing the QC counts to the original counts. The comparatively low numbers of salmon entering into Cow Creek (CDFG-GrandTab file) made QC of the video station a low priority at the RBFO office. State furloughs and budget reductions were being implemented at this time and staff time was focused on collecting data to enable at least a single count of recordings from multiple stations. The desire by agency managers to develop standardized methods for salmon population estimates drove the implementation of a statistical methodology that allowed a rigorous QC of the Cow Creek station and other video stations beginning in 2011.

The Central Valley Chinook Salmon In-River Escapement Monitoring Plan (Bergman et al, 2012) was written to provide a blue print for monitoring salmon populations throughout

California's Central Valley to avoid the patchwork methods and population analysis that typically occurred in past years on a watershed to watershed basis. This Plan recommends that counting stations for fall-run be implemented on many smaller streams and incorporate a standardized methodology for reporting confidence intervals, (Bergman, 2012). This plan was finalized in 2012 and is available on the CDFG website at the following link:

http://www.nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=42213

In 2012 a quality control method was developed by statistician R. Neilson of West Inc. that allowed (for the first time) calculation of confidence intervals around the Cow Creek station estimate. This method is discussed in the results section and is presented in depth in Appendix C and was used for the Cow Creek 2011 data.

Water Temperature and Flow Measurements

Water temperature data were collected using an Onset thermograph (continuous data recorder) placed at the video station location each year. This data was collected and summarized to allow comparison between water temperature and fish passage.

Continuous water flow data was also available for Cow creek by accessing stream gauge data on the internet based California Data Exchange Center (CDEC) at the following link: http://cdec.water.ca.gov/cgi-progs/queryDaily?=COW. This data is collected at the U.S. Geological Survey's (USGS) Cow Creek stream gauge located about a mile (1.6 km) upstream from the weir site.

Creek flows are measured in cubic-feet-per-second (cfs) and can typically reach levels of 300-500 cfs from one storm over a few days. Large floods and high flows (>1000 cfs) are typical for Cow Creek in mid-winter. In most years during periods of the fall-run migration, mild autumn weather patterns cause flows and turbidity to rise and fall within a day or two enabling successful video station recordings. Appendix Figure B6 provides examples of the flow fluctuations typically observed at the video station site each year.

At any time, when a major storm was forecast, a decision to remove the weir had to be considered. Concern for damage or loss of components of the weir (as in Figure 10) and other in-stream equipment dictated that weather forecasts were closely observed during station operation on an annual basis. The first of November was used as the unofficial annual goal to maintain station operations because experience has shown that the majority of fall-run Chinook in Battle Creek have already passed by this date (Killam 2006). For Cow Creek, earlier years, (see Table 2) indicated that the majority of the total passage had occurred by this date each year. Prior to the first of November large efforts by RBFO and WSRCD crews were undertaken to repair flood damage and keep the station operating. After the first of November the flooding forecasts were carefully monitored and the risks of damaging or losing the equipment were weighed against the value of continued operation. If a major flood as shown in upper portion of Appendix Figure B6 was expected, the station was removed for the year.

Figure 10. Image of weir during periods of turbid water and minor flooding during the 2008 season on Cow Creek. Weir is underwater and one of the panels was dislodged. Weir was rebuilt and continued operation after this flood.

In years 2008 and 2009 the station operated into late-December and to mid-January in 2011. The data collected during those years showed very little passage and provided biologists with knowledge that Cow Creek does not have a late-fall-run Chinook population similar to the populations on the mainstem Sacramento River and Battle Creek.

RESULTS AND DISCUSSION

Since their first use in the Central Valley in 2003, the RBFO video stations have undergone many changes to simplify and streamline the process for collecting data on salmon populations in tributary streams. Their use has enabled agency biologists with limited staff and budgets to expand the amount and quality of information collected each year on fall-run Chinook. The Cow Creek video station was first operated in 2006, following successful operation of the Battle Creek station beginning in 2003 (Killam 2004, 2006, 2007).

Table 2 provides count data for each month and for each week that the station was operated. The data in Table 2 reveals that the peak passage for the fall-run at Cow Creek occurred in October, with the most fish typically passing in the middle of this month. This was generally similar to the other stations in the Upper Sacramento River Basin.

Table 2. Summary of adjusted counts of fall-run Chinook salmon passage at the Cow Creek video station by month and week for years 2006 through 2011 with downstream redds included.

MONTH		2006	2007	2008	2009	2010	2011
September		13	6	1	0	0	0
October		2875	1687	124	224	355	1341
November		1321	334	350	41	181	281
December		n/a	11	3	0	0	-6
January		n/a	n/a	n/a	n/a	n/a	1
Week	**Dates**						
37	7-Sep - 13-Sep	0	n/a	0	n/a	n/a	n/a
38	14-Sep - 20-Sep	4	0	0	n/a	n/a	n/a
39	21-Sep - 27-Sep	9	0	0	0	n/a	0
40	28-Sep - 4-Oct	188	8	1	0	1	112
41	5-Oct - 11-Oct	686	1,040	7	0	7	463
42	12-Oct - 18-Oct	757	262	34	122	50	148
43	19-Oct - 25-Oct	767	251	34	81	209	263
44	26-Oct - 1-Nov	587	169	179	26	94	394
45	2-Nov - 8-Nov	608	112	183	25	58	167
46	9-Nov - 15-Nov	450	120	27	1	61	36
47	16-Nov - 22-Nov	150	48	6	1	40	-2
48	23-Nov - 29-Nov	5	15	3	7	15	39
49	30-Nov - 6-Dec	0	13	2	2	2	-1
50	7-Dec - 13-Dec	0	0	1	0	0	-3
51	14-Dec - 20-Dec	0	0	1	0	0	-1
52	21-Dec - 27-Dec	0	0	0	0	0	0
1	28-Dec - 3-Jan	n/a	0	0	0	0	0
2	4-Jan - 10-Jan	n/a	n/a	n/a	n/a	n/a	1
3	11-Jan - 17-Jan	n/a	n/a	n/a	n/a	n/a	0
Redd Expansion		0	6	0	0	0	0
Total Counts		**4,209**	**2,044**	**478**	**265**	**536**	**1,617**

Peak passage in the basin can vary a few weeks between years and waterways depending on the weather (i.e. water temperature and creek flows). Spawning would probably have commenced one or two weeks after passage so peak spawning activity in Cow Creek may have occurred in late-October through early-November. The data in the first and last weeks of Table 2 are partial counts for each year since the video station was only in operation during a portion of those weeks in some years.

Improvements to the video stations through design changes and equipment upgrades were made continually. As the stations evolved, the data processing and analysis work that generated the final estimates evolved. Although the data analysis methodology used each year followed an adaptive management process, (i.e. retain the good, improve or eliminate the bad), there were some common steps followed each year to generate a final estimate.

The Cow Creek video station estimates began with a series of half-hour counts of fish passing the station from the time it was first operated through the time it was removed. These counts were made for all periods in which readers could visually see the passing fish. These original counts formed the beginning of the estimate. Three additional adjustment steps were applied to the original counts to reach a final estimate, and included:

Step 1. Adjustment of missing time periods due to turbid water events, or equipment failures with the electronics, and adjustment for periods when the weir was deliberately lowered.
Step 2. Quality control (QC) adjustments to original counts.
Step 3. Adjustment to the final QC count to account for salmon which may have spawned in the stream length (1.3-miles (2.09 km)) below the weir site.

Data Adjustments and Discussion By Year

As a result of annual fluctuations in budgets, RBFO staffing priorities, and environmental conditions (flooding, run sizes, etc.) each year was slightly different from the others in regards to data analysis. What follows is a discussion of each year highlighting the important steps to develop the yearly estimate.

2006

The final adjusted estimate of fall-run salmon entering Cow Creek for the 2006 season was 4,209. In the 2006 Cow Creek (Killam, 2007) report, the final estimate of 4,130 is being revised. Analysis of underwater camera footage revealed that 79 smaller fish originally tallied as unknowns were subsequently identified as jacks (2-year old), smaller but mature salmon.

- The original number of salmon counted on the upward migration was 4,030.
- The dates of operation were from 11 September through 17 November. The weir was removed on 17 November due to a poor weather forecast (heavy rain) for the remainder of the week. Salmon were still actively migrating into Cow Creek on 16 November (Appendix Table A2). Adjustment by the RBFO author added 88 fish to the original counts. This adjustment was based on typical fall-run fish migration trends. This adjustment was simply a reduction by 1/3 for each previous day's passage until the passage counts were reduced to a total of two fish after seven days, effectively ending the season on 24 November as shown in Appendix Table A2.
- Table 3 shows there were 78 half-hour periods of turbidity and 15 half-hours of equipment failures where missing time periods of fish passage occurred. Salmon counts were increased through a process of averaging previous and post normal condition counts and best judgment based on biologist experience. This resulted in the addition of 100 fish from turbid water conditions and the addition of 13 fish from electronic malfunctions.
- The QC adjustment resulted in the subtraction of 22 salmon from the original counts. In 2006 the QC process stratified the data by reader and type of count (low, medium and high). Details of the 2006 QC process are given in Killam, 2007.

- Three overlapping white plates were used resulting in an 11 x 8-foot (3.3 x 2.4 m) fish passage opening.
- 2006 was the first year a video monitoring station was constructed on Cow Creek. Design was based on the Battle Creek video station.
- The highest flow levels recorded for the season on Cow Creek were 252 cfs on 14 November.
- There were no redds observed downstream of the station.
- Appendix Figure B7 illustrates the 2006 video monitoring station on Cow Creek**.**

2007

The final adjusted estimate of fall-run salmon entering Cow Creek for the 2007 season was 2,044.

- The dates of operation were from 20 September through 06 December.
- The original number of salmon counted on the upward migration was 2,038.
- Table 3 shows there were 138 half-hour periods of turbidity and two half-hour periods of tape malfunctions where missing time periods of fish passage occurred.
- Salmon counts were increased through a process of averaging previous and post clear water counts and best judgment based on biologists experience.
- Two white plates were used to create a uniformed opening to aid in flood flow passage resulting in 5 x 10-foot (1.5 x 3.0 m) fish passage opening.
- The QC adjustment resulted in addition of 187 salmon from the original counts. In 2007 the QC process stratified the data by reader and type of count (low, medium and high) (detailed in Killam, 2008).
- There were three redds found below the weir on 2 November resulting in 6 salmon added to the final adjusted count as shown at bottom in Table 2.
- The highest flow levels recorded for the season on Cow Creek were 480 cfs on 20 October and the station was removed on 6 December as a result of a predicted large storm.
- Appendix Figure B8 illustrates the 2007 video monitoring station on Cow Creek.

2008

The final adjusted estimate of fall-run salmon entering Cow Creek for the 2008 season was 478.

- The dates of operation were from 13 September through 19 December.
- The original number of salmon counted on the upward migration was 333.
- Table 3 shows there were 157 half-hour periods of turbidity and 25 half-hours of equipment failures where missing time periods of fish passage occurred. Equipment failures were due to overhead cameras not recording and malfunctioning.
- Salmon counts were increased through a process of averaging previous and post clear water counts for a period from 2 November through 5 November due to muddy water. This resulted in the addition of 145 salmon to the final count.
- Efforts to QC the original count data were not made due to PSMFC employee lay-offs that occurred on 01 January 2009.
- There were no redds observed downstream of the station.

- In 2008, flows reached 376 cfs on 3 November washing out a portion of the weir panels and fish passage could not be observed, as shown in Figure 10. The weir was repaired and counting resumed operation on 5 November.
- Appendix Figure B9 illustrates the 2008 video monitoring station on Cow Creek

2009

The final adjusted estimate of fall-run salmon entering Cow Creek for the 2009 season was 265.

- The dates of operation were from 23 September through 21 December.
- The original number of salmon counted on the upward migration was 232.
- Table 3 shows there were 98 half-hours of turbidity, 21 half-hour periods of equipment failures and 92 half-hours of time where panels of the weir were laid down to prevent damage. Equipment failures were related to a malfunctioning overhead camera.
- During the turbid periods an additional 33 salmon were estimated to have passed using a process of averaging previous and post clear water counts and best judgment based on biologist experience.
- Periods with the weir partially lowered down were first used late in the 2009 season to prevent damage to the weir from expected floods. Every other panel was lowered flat on the stream bottom to allow flood flow passage. At times, the panels were lowered before turbid water arrived so fish counts were adjusted during these normal periods by multiplying the original counts by two.
- No QC of the original counts were made for this year due to state of California work furloughs and PSMFC staffing limitations.
- Underwater cameras were used to identify adipose fin-clips. Readers reported 11 adipose-fin clipped salmon (indicating hatchery-origins) observed out of a total of 190 salmon able to be observed for these clips; Table 4 presents this data.
- There were no redds observed below the weir.
- Damage to the weir occurred during the 2009 season on 16 December when the flows reached 614 cfs and some weir panels were washed just downstream by the high flows.
- Appendix Figure B10 illustrates the 2009 video monitoring station on Cow Creek

2010

The final adjusted estimate of fall-run salmon entering Cow Creek for the 2010 season was 536.

- The dates of operation were from 28 September through 6 December.
- The original number of salmon counted on the upward migration was 393.
- Table 3 shows there were 487 half-hours of turbidity and 254 half-hours of time where the weir was partially lowered to prevent flood damage during high flows.
- During these turbid water periods an additional 143 salmon were estimated to have passed using a process of averaging previous and post clear water counts and best judgment based on biologist experience.
- Periods with the weir partially lowered down were used in 2010 to prevent damage to the weir from expected floods. At times, the panels were lowered before turbid water arrived so fish counts were adjusted during these periods by multiplying the original counts by two.
- No QC checks on original counts were performed due to State of California work furloughs and staffing limitations.

- Underwater cameras were used to identify fish of hatchery-origin (adipose-clip vs. no-clip), and fish sex, see Table 4.
- There were no redds found below the weir.
- The 2010 video station experienced major flooding. Flows reached a high of 1,673 cfs on 24 October completely submerging the weir. Counting resumed just 55-hours later as the creek cleared and video recording resumed. Once the first storm had saturated the watershed additional storms brought rapid flooding. The station site was flooded three additional times during this year but partial lowering of the weir helped avoid similar damage to that of the 2009 weir panels. Flows reached 3,770 cfs on 6 December after the station was removed.
- Appendix Figure B11 illustrates the 2010 video monitoring station on Cow Creek.

2011

The final adjusted estimate of fall-run salmon entering Cow Creek for the 2011 season was 1,617 with 90% confidence intervals of 1,442 low to 1,747 upper.

- The dates of operation were from 21 September through 16 January, 2012.
- The original number of salmon counted on the upward migration was 1,444.
- Table 3 shows there were 167 half-hour periods of turbidity and two half-hours of equipment failures where missing time periods of fish passage occurred and readers were unable to discern fish passage.
- Beginning in 2011 adequate funding enabled the development of a statistical based QC device counter analysis (DCA) methodology designed to produce confidence intervals around the final estimate and impute counts for missing periods. The results of this effort are discussed in the following section. This methodology replaced the previous averaging of pre-and-post missing periods.
- A total of 184 salmon were added to the original counts using the new DCA methodology to impute for the missing 169 half-hour periods that readers could not view.
- Underwater cameras were used to identify fish of hatchery-origin (adipose-clip vs. no-clip), and fish sex, see Table 4.
- There were no redds observed downstream of the station.
- The highest flow levels recorded for the season on Cow Creek were 320 cfs on 11 October.
- As a result of the abundant spring rainfall and relatively high summer water flows during 2011 it was anticipated that flooding in the 2011 fall video season might be a problem. As a result, the white plate opening was redesigned to maximize the width of the opening and reduce the width of the weir. Four white plates were placed end to end creating a 40 x 5-foot (12.2 x 1.2 m) fish passage opening. This opening width required two overhead cameras to span the entire width (see Figure 8). Readers reported difficultly in viewing both overhead images simultaneously and underwater fish viewing was impacted by the placement of only two underwater cameras and the wide area of limited view between underwater cameras. RBFO staff determined that this method would not be continued in future years.
- Appendix Figure B12 illustrates the 2011 video monitoring station on Cow Creek.

2011 Quality Control Results

In early 2012 a quality control methodology was developed by statistician R. Neilson of West Inc. and the CDFG author that allowed (for the first time) calculation of confidence intervals around the Cow Creek station estimate. The Device Counter Analysis (DCA) methodology also uses a general additive model (GAM) with bootstrap replications for imputing counts for missing original reader counts due to flooding or equipment failures. This process to impute for missing counts replaces in most cases the need for a biologist to impute for missing counts using the older averaging prior-and-post missing period methods used in years 2006-2010. This method is detailed in depth in Appendix C.

The DCA method uses a combination of statistical (R-program) and database (Excel, Access) software to develop the final estimate from original counts to final QC adjusted numbers. The DCA was first used for the 2011 data. Earlier years are unable to use this method as a systematic QC of the counts was unable to be undertaken due to lack of funding and the video data for those years was deleted. The DCA involved several steps using the original and adjusted counts to calculate the estimate, impute for missing counts, and develop 90% confidence intervals. These steps and results of the process were as follows:

Step 1. Select a subset of the original half-hour periods with high counts to re-read. For 2011 all periods with original counts greater than three (n = 81) were re-read by multiple readers to determine a “consensus final count”. These QC high counts replaced the original counts and were treated as direct counts and no further adjustment was made to them throughout subsequent adjustments. The consensus approach was used to ensure that multiple readers agreed on a count. In 2011 the fall-run in the Central Valley consisted of a large proportion of two-year old “jack” salmon. These smaller jacks closely resemble other similar sized species (e.g. Sacramento pikeminnow (Ptychocheilus grandis)) making identification from above views difficult. The consensus approach determined a single final count for each period reviewed. The total of the original counts for the 81 periods was 426 salmon and the QC high total was 430 reflecting an increase of 4 salmon for the high count periods based on the QC review.

Step 2. Systematically conduct QC reads on the remaining “low count” periods. Original low count periods greater than zero (n = 93 of 817) were randomly chosen (i.e. every 12^{th} period) and re-read using the same consensus QC approach. These QC low counts replaced the corresponding original counts. The total fish from the 93 original low counts was 137 salmon and the QC low count total was 135 reflecting a decrease of two fish. The results of the QC low counts were compared to the corresponding original counts and the variance between these was used to generate an adjustment factor that was applied (original/adjustment factor) to the remaining non-QC low counts (n = 5,313). In 2011 counts of zero (n = 4,386) and negatives (n = 203) were not selected for QC review as they were assumed to have no net effect on the overall estimate or variance of the estimate (note: negative counts reflect a downstream net movement during the half-hour and ranged between negative 3 (n = 2) negative 2 (n = 24) and negative 1 (n = 177) salmon). The adjustment factor (x = 1.015) was applied to them but had no effect on the zero counts (i.e. 0 / 1.015 = 0).

Step 3. Once all the high and low QC counts were made the next step was to place the entire season's data into a comma separated value (.csv) Excel file (Cow 2011.csv). This file had four columns including date, time, original count, QC count. Periods with missing counts from the turbid or equipment failure periods were listed as "NA" in the original count column. Periods where no QC count occurred were also listed as "NA" in the QC count column. This file was then uploaded into the free statistical software "R" and was analyzed by an R-based code package developed by R. Nielson termed "Device counter analysis .r". The R software outputs a text based summary that provides a final estimate (1,617 in 2011) with 90% confidence intervals (1,442-1,747) based on the Cow 2011.csv file. The R software also outputs an "Adjusted count" csv file that includes a summary of the final counts for all periods except the imputed counts. This file, when linked with the R output text summary detailing the imputed counts, enables the compilation of daily counts to allow analysis of daily, weekly and monthly passage trends (Tables 2, 5 and A2). The entire estimate from start to finish is documented in a yearly Microsoft Excel file (e.g. CWVS 2011) with multiple worktabs created each year by the RBFO biologists.

The DCA method is an important step forward towards the evolution of the video station as an escapement monitoring management tool. In previous years missing periods have traditionally been adjusted by RBFO biologists using an averaging process or best judgment to "fill-in" or impute the fish counts for the missing periods. The data on missing periods for all years is shown in Table 3. The previous process involved utilizing the average of observable counts pre-and-post time periods to the missing counts. A hypothetical example of the previous averaging procedure is to use the average of the 12 noon to 12:30 PM period from the day before and the day after a mid-season flood to impute for a missing 12 noon period of a flood event. In future years the Central Valley Chinook Salmon In-River Escapement Monitoring Plan (Bergman, 2012) recommends using a Dual-frequency Identification Sonar (DIDSON) camera to count fish during turbid water events, but in years 2006-2011 these expensive ($80,000) devices were not available to RBFO staff. Experience has shown that even with a DIDSON camera there will be periods of missing counts so the DCA will continue to be an important tool in developing escapement estimates. In addition the judgment of the biologist will continue to play a role in determining if the missing counts should be adjusted differently from the DCA as a result of atypical environmental conditions at the creek. These adjustment methods can be modified if fish passage conditions in the creek changed as a result of short pulse flows or flooding. An example might be if a storm or irrigation pulse flow triggered a short term initial fish movement. In this hypothetical case the biologist might use knowledge of the creek patterns (judgment) to modify the DCA imputed counts if passage was not possible or some other circumstance dictated that a modification to the counts was reasonable in a "biological sense".

A summary of the yearly viewing conditions for all half-hour periods of the video station data is provided in Table 3. This table shows that the video monitoring station was functioning in a normal condition with suitable water clarity to view fish passage for the majority of time each year. Normal conditions ranged from a low of 77% in 2010 to 97% in 2011. No adjustments were made for normal conditions other than QC adjustments. When the creek was turbid, counts were averaged by the RBFO biologist based on periods immediately before and after the turbid water conditions for years 2006-2010. In 2011 turbid counts were imputed by using the DCA based analysis. Turbid conditions ranged from a low of 2.3% in 2009 to a high of 14.7% of total time in 2010. Periods of equipment failures were experienced in all years except 2010 and averaged 1.8% of the total time. Partial equipment failure can sometimes be overcome by using the backup recording devices or the other camera views to assist in viewing fish passage. In other cases total failure of the recordings occurs and the numbers are adjusted using similar methods as for turbid events. Weir panels were sometimes lowered (years 2009-2010) during periods of normal conditions to prevent expected flood damage (e.g. rain was predicted to cause flooding at night, so crews would lower portions of the weir during the day).

Table 3. Summary of video viewing conditions by half-hour periods for each year at the Cow Creek video station during years 2006-2011.

Number of half-hour periods and (%) by video viewing condition type					
Year	Normal (clear water)	Turbid (flooding)	Equipment failure	Weir lowered (avoid damage)	Totals
2006	3,139 **(97.1%)**	78 **(2.4%)**	15 **(0.5%)**	0 **(0%)**	3,232
2007	3,546 **(96.2%)**	138 **(3.74%)**	2 **(0.1%)**	0 **(0%)**	3,686
2008	3,946 **(95.6%)**	157 **(3.8%)**	25 **(0.6%)**	0 **(0%)**	4,128
2009	4,054 **(95.1%)**	98 **(2.3%)**	21 **(0.5%)**	92 **(2.2%)**	4,265
2010	2,570 **(77.6%)**	487 **(14.7%)**	0 **(0%)**	254 **(7.7%)**	3,311
2011	5,487 **(97.0%)**	167 **(3.0%)**	2 **(0.0%)**	0 **(0%)**	5,656

When the weir was lowered fish passage outside of camera views was possible and the original camera counts were multiplied by a factor of two during these “weir down” good counts normally immediately before or after the floods. This condition occurred in only two years and ranged from 2.2% in 2009 to 7.7% in 2010 of the total yearly time.

Biological Results for Video Station Survey

In years 2009-2011 data from the video station cameras provided some data on the characteristics of the salmon populations fulfilling some of the need for biological information. Table 4 provides a summary of the information collected on salmon passing upstream within the observable viewing range of the underwater cameras during years 2009 through 2011. Readers were instructed to provide data for each upstream swimming salmon they were able to observe during these years. Categories included length, sex and adipose fin-clip status. If readers were unable to discern the characteristics of passing salmon they tallied them as unknown. Lengths were determined from the overhead camera and salmon were tallied (years 200-2011) as large for salmon equal or greater than 24-inches (610 mm) and small for salmon shorter than this. Lengths were determined by comparing the size of the fish to the measuring devices (brand, and jack bar) on the white plates. Sex was determined through use of the underwater cameras. Sex was tallied (years 2010-2011) for salmon that could be differentiated by appearance (jaws, body shape, and adipose fin size). Adipose fin-clip status was determined with the underwater cameras and salmon were tallied as not-clipped if the adipose fin was present and clipped if the fin was missing as a result of hatchery practices associated with coded-wire tagging operations.

Table 4. Summary of biological data collected from upstream passing salmon at the Cow Creek video station for years 2009 through 2011.

YEAR	VALUE	LENGTH		SEX			ADIPOSE FIN STATUS		
		LARGE	SMALL	FEMALE	MALE	UNKNOWNS	NO-CLIP	CLIPPED	UNKNOWNS
2009	Number	n/a	n/a	n/a	n/a	n/a	179	11	60
	Percent	n/a	n/a	n/a	n/a	n/a	**71.6%**	**4.4%**	**24% of total**
2010	Number	396	25	49	212	159	206	25	190
	Percent	**94%**	**6%**	**19%**	**81%**	**38% of Total**	**89%**	**11%**	**45% of Total**
2011	Number	536	1,388	10	84	1,830	102	23	1,801
	Percent	**28%**	**72%**	**11%**	**89%**	**95% of Total**	**82%**	**18%**	**94% of Total**

The large number of two-year old jack salmon present in the 2011 escapement in the Central Valley is revealed in Table 4 by the larger percentages of both small and male salmon in 2011 compared with 2010. Table 4 also demonstrates the difficulties experienced with the white plate arrangement in 2011. The width of the opening was increased in expectation of early flooding (which never occurred). This required two overhead cameras that made reading the side by side images difficult (see Figure 8). It also reduced the number of underwater cameras to two and increased the distance each camera was expected to view through the sometimes turbid water. As a result, viewers were unable to distinguish the sex and fin-clip status of 95% of the upstream passing salmon in 2011 as compared to a range of 38 to 45% of unknowns in 2010. These unknown fish counts in Table 4 did not include the downstream salmon (n = 482) so this summary may include multiple counts of the same fish. In future years the width of the white plate opening will likely return to a one overhead camera view with a 20-foot (6 m) wide opening that should allow a more comprehensive review of the biological characteristics of the population.

The Central Valley Chinook Salmon In-River Escapement Monitoring Plan (CVEMP) recommends that video station data be augmented by other in-stream surveys designed to collect further information from spawned out salmon carcasses for each stream, (Bergman, 2012). These surveys plans are designed to supplement the video counts by providing data on biological characteristics of the population including: age ratios, sex ratios, hatchery-origin information (coded-wire-tags, adipose fin-clips), and biological samples (scales, tissue, otoliths). Due to current lack of funding of the CVEMP no supplemental surveys were conducted on Cow Creek in 2011. In future years a kayak survey of the upstream portions of Cow Creek would allow a thorough analysis of age, sex, and hatchery origin characteristics of the salmon population in Cow Creek.

Beginning in 2007 an intensive Constant Fractional Marking (CFM) Program was begun at all California Central Valley salmon hatcheries in an attempt to allow biologists quantify the number of hatchery fish in each population of salmon. Details of this program can be found in Buttars, 2010. The program is designed to tag a defined proportion (constant fraction) of fall-run salmon from each hatchery. Because only a fraction (typically 25%) of most fall-run are currently marked with fin-clips and coded-wire tags, biologists must expand the hatchery estimates for the unmarked fall-run released each year. An additional consideration for this expansion is that some groups and runs of salmon found in fall-run populations have received up to 100% marks. In order to develop an accurate hatchery estimate for each population, biologists must recover the coded-wire tag in each adipose fin-clipped salmon and determine how many non-adipose fin-clipped salmon of hatchery-origin it represented.   The data in Table 4 represent only the proportions of non-clipped to clipped salmon observed at the video station. This ratio is useful in a comparative sense, but an additional carcass survey would produce the actual coded-wire-tags that allow for development of expanded hatchery-origin salmon estimates in Cow Creek.

Relationship between Passage Timing, Temperature and Flow

An illustration of the passage count by month is provided in Figure 11. Peak passage occurred in October of each year except 2008 with nearly 100% of fall-run salmon passage taking place in the months of October and November each year.

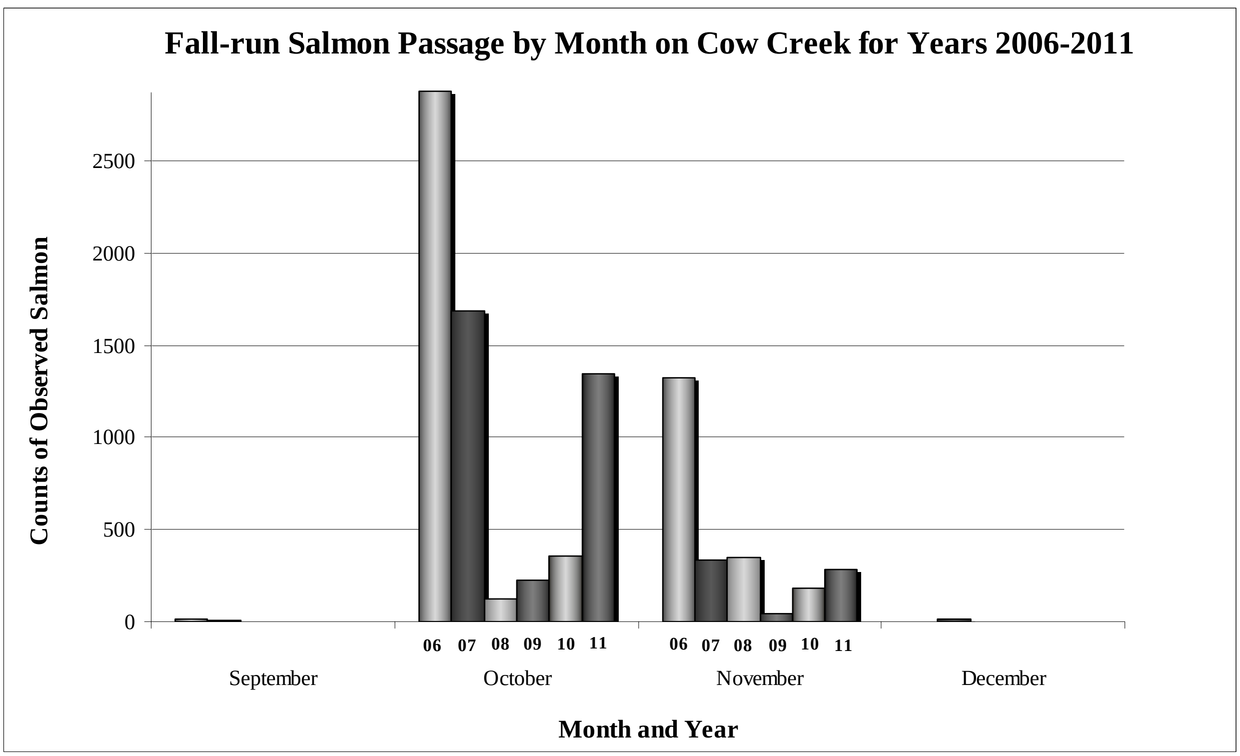


Figure 11. Fall-run Chinook salmon counts by month at the Cow Creek video station for years 2006-2011.

Fall-run salmon begin migrating into the Upper Sacramento River Basin as early as June of each year, (Killam 2009) but these fish do not enter Cow Creek until later in the year. In a typical year the flows in Cow Creek and similar tributaries are at a yearly minimum by late-August and the water temperatures at the mouth of the creek are in the 70+ degree Fahrenheit range (>21^{o} Celsius). These high water temperatures combined with low flows resulting from irrigation diversions and months of hot dry weather preclude fall-run from entering into Cow Creek. As air temperatures cool in the late summer and early fall the water temperature also begins to cool and first fall-run begin to enter into the creek. Daily passage by year can be found in Appendix Table A2. This table shows that few salmon migrate into the creek before the first of October. The trigger for the upstream fall-run migration in Cow Creek to begin is likely due to cooling water temperatures and to a lesser extent higher water flows.

Table 5 provides the monthly passage data with average flows and water temperatures at the video station each year. Peak passage occurred during the month of October each year corresponding to water temperatures ranging from 60-64 degrees Fahrenheit, (18^{o}C), (water temperature was obtained from a thermograph at the video station). Table 5 includes the total passage per month in numbers, the percentage of passage per month and the cumulative percent passage of the run for the end of each month.

Table 5. Summary of yearly fall-run Chinook salmon passage by month at the Cow Creek video station with flows (cfs) and water temperature.

Month	Total Salmon Passage	Percent Passage by Month	Cumulative Percent Passage	Average Water Flow (cfs)	Average Water Temp
2006					
September	13	0%	0%	78	68.9
October	2,875	68%	69%	93	60.2
November	1,321	31%	100%	147	52.8
2007					
September	6	0%	0%	40	69.8
October	1,687	83%	83%	107	61.9
November	334	16%	99%	87	54.2
December	11	1%	100%	166	46.1
2008					
September	1	0%	0%	12	70.6
October	124	26%	26%	28	61.8
November	350	73%	99%	104	52.5
December	3	1%	100%	93	43.1
2009					
September	0	0%	0%	11	72.2
October	224	84%	84%	45	61.1
November	41	16%	100%	73	49.5
December	0	0%	100%	145	41.6
2010					
September	0	0%	0%	34	71.7
October	355	66%	66%	141	63.0
November	181	34%	100%	219	49.9
December	0	0%	100%	951	47.2
2011					
September	0	0%	0%	61	71.7
October	1,341	83%	83%	125	61.0
November	281	17%	100%	139	48.3
December	-6	0%	100%	112	41.2
January	1	0%	100%	107	41.1

Table 5 also lists average stream discharges collected at the USGS's Cow Creek (COW) flow gauge upstream of the video station, which allows comparison for fish passage and flow events. There are many small agriculture diversions upstream in the Cow Creek watershed and these usually stop water diversion when the autumn rains start or after the irrigators determine that they no longer require diversions for their land usage. This can allow the in-creek flows to increase substantially without significant rainfall. But as Table 5 shows (i.e. October-November 2009) even relatively low flows allow fall-run to enter the creek and move upstream if water temperatures are suitable. As a result RBFO biologists consider fall-run passage opportunities on Cow Creek to be driven by primarily by decreasing water temperatures in the fall of each year.

CONCLUSIONS

1. The use of a video monitoring station on Cow Creek enables estimates of salmon escapement in the creek. It is cost-effective, efficient, uses less manpower than carcass surveys, and when the equipment is not compromised by flood events or turbid conditions, can function 24 hours a day, 7 days a week. Primary use on Cow Creek is between the months of September and December.

2. The number of fall-run salmon in Cow Creek represented an average of 1.0% of the total spawner escapement to California's Central Valley between the years of 2006-2011.

3. Population estimates of fall-run Chinook with confidence intervals can now be made for each future year on Cow Creek. Additionally the use of underwater cameras can enable biologists to develop limited data on the biological characteristics of annual populations.

4. The installation of similar stations in tributaries currently unmonitored in the Upper Sacramento River Basin should be initiated. Use of a DIDSON camera on Cow and other stations would expand the capabilities of data collection during turbid water events and improve the accuracy of the final estimate.

5. A kayak survey on Cow Creek should be initiated to collect information on biological characteristics and hatchery tags from salmon carcasses.

ACKNOWLEDGMENTS

Many individuals facilitated the Cow Creek station design, operation, data handling and analysis and ultimately contributed to the success of this monitoring effort.

Our thanks go out to Mr. and Mrs. Bagely, Dr. Robinson and Mr. Wood who allowed us yearly access to their property on Cow Creek. Thanks go to Randy Benthin, Mike Berry and Alice Low (CDFG) for their support of the project and fund raising capabilities to provide funding in tough budget times.

Brenda Olson and Tricia Parker from the USFWS were instrumental in making the Cow Creek station a reality and purchased much of the electronics that made the station possible in 2006. Rob and Valerie Emge also USFWS were instrumental in helping locate salvageable old material and purchase the new material necessary to build the station in 2006.

Staff of the PSMFC including: Matt Johnson (now CDFG), Dale Morrison, Ryan Revnak, Patrick Jarrett, Darin Olsen and Zach Sigler from the CDFG's RBFO for their help in most seasons. Andy Holland, Jeremy Notch, Brian Kreb and Amber Leininger for the 2007- 2008 seasons. And Kate Merrick for her help and assistance in collating all the information presented in this report.

Special thanks to Brett Rohrer from the CDFG who assisted with construction, set-up, and removal of weir each year and his design of the Rohrer Strap that prevents weir panels from vibrating and wearing out in high flows shown in Figure 3 middle of panel.

PSMFC video readers Paula Wittner, Vicky Van Gundy, Lisa Mitchell, Gail Grifantini and Robin Souza who did the continuous reads and still managed to smile at the end of the day.

From the WSRCD thanks go to Ryan Teubert, Kelly Miller, and Gail Grifantini (Gail also helped in retirement in 2010 as a PSMFC reader), and to Jim Chichester, who did the large majority of tape changing, weir cleaning and video reading during the 2007-08-09 seasons. Also thanks are due to the WSRCD crew who helped install the weir in 2007 (Gretchen Garwood, Joe Andrus, Matt Jacobs, Allen Houck, Daniel Borich, and Eric Corella). Also special thanks to Dennis Knight and staff from the Cottonwood Creek watershed Association to enable Dennis to service the stations on weekends and holidays of years 2007-2009.

Thanks to Ryan Nielson of WEST Inc (Western Ecosystems Technologies) of Laramie, WY for his work with the statistical analysis of the 2011 data and formulation and development of QC methodologies and R software DCA package.

Special thanks to Doug Threloff from the USFWS's Comprehensive Assessment and Monitoring Program (CAMP) in Sacramento, CA. for his continued funding of the Cow and Cottonwood video stations and his support as the driving force behind the writing of this report.

Thanks to all of them (and any who may have been missed), for their generous assistance, without which this project could not have been completed.

LITERATURE CITED

Bergman, J. M., R. M. Nielson, and A. Low. (2012). *Central Valley in-river Chinook salmon escapement monitoring plan*. Report number 2012-1. California Department of Fish and Game, Sacramento, CA,

Buttars, B. (2010). *Constant Fractional Marking/Tagging Program for Central Valley fall-run Chinook salmon.* 2010 marking season. Pacific States Marine Fisheries Commission

CDFG, Annual Reports, *King (Chinook) Salmon Spawning Stocks in California's Central Valley, all years 1956-2005.* (Authors note: These reports detail the Central Valley's escapements and in earlier years had slightly different titles and formats: contact author for a comprehensive Adobe PDF file with all reports included: dkillam@dfg.ca.gov.)

CDFG, Grand Tab electronic file summarizing salmon stocks in the Central Valley of California. Available on line. URL: http://www.calfish.org/IndependentDatasets/CDFGRedBluff

Killam, D. S. (2004). *Results of an Experimental Video Station for Fall-Run Chinook Salmon Escapement into Battle Creek in 2003*. SRSSAP Tech. Report No. 04-2, 2004. 32p.

Killam, D. S. (2006). *Results of the Experimental Video Station for Fall-Run Chinook Salmon Escapement into Battle Creek for Years 2003-2005*. SRSSAP Tech. Report No. 06-1, 2006. 31p.

Killam, D. S. (2007). *Results of the 2006 Cow Creek Video Station Fall-Run Chinook Salmon Escapement.* SRSSAP Tech. Report No. 07-1, 2007. 19p.

Killam, D. S. (2008). *Results of the 2007 Cow Creek Video Station Fall-Run Chinook Salmon Escapement.* SRSSAP Tech. Report No. 08-2, 2008. 21p.

Killam, D. S. (2009). *Chinook Salmon Populations for the Upper Sacramento River Basin in 2008*. SRSSAP Tech Report No. 09-1, 2009. p.67

USGS. (2007). *Division of Flood management query tool*. URL: http://cdec.water.ca.gov/cgi-progs/queryFx?s=CWA 06 Dec 2007.

SHN Consulting Engineers & Geologists (SHN) and Vestra Resources Inc (VRI). 2001. *Cow Creek Watershed Assessment*. Western Shasta Resource Conservation District and Cow Creek Watershed Mangement Group.

APPENDIX A: Data Tables

Appendix Table A1. Summary of Cow Creek video station components between 2006 through 2011.

Station Component	YEAR					
	2006	2007	2008	2009	2010	2011
VCR	yes	yes	1st half	no	no	no
DVR	no	no	2nd half	yes	yes	yes
Recording Back-up	VCR	VCR	VCR	VCR	DVR	DVR
Quad Processor	no	no	yes	no	no	no
Color Monitor	no	no	no	yes	yes	yes
Underwater Cameras	1	1	3	3	3	2
White Plates	3	2	2	2	3	4
Lights	2	2	2	2	2	3
Overhead Camera	1	1	1	1	1	2

Appendix Table A2. Daily salmon passage during years 2006 through 2011 at the Cow Creek video station.

Date	Salmon Passage 2006	Salmon Passage 2007	Salmon Passage 2008	Salmon Passage 2009	Salmon Passage 2010	Salmon Passage 2011
11-Sep	0	n/a	n/a	n/a	n/a	n/a
12-Sep	0	n/a	n/a	n/a	n/a	n/a
13-Sep	0	n/a	0	n/a	n/a	n/a
14-Sep	0	n/a	0	n/a	n/a	n/a
15-Sep	0	n/a	0	n/a	n/a	n/a
16-Sep	1	n/a	0	n/a	n/a	n/a
17-Sep	0	n/a	0	n/a	n/a	n/a
18-Sep	0	n/a	0	n/a	n/a	n/a
19-Sep	0	n/a	0	n/a	n/a	n/a
20-Sep	3	0	0	n/a	n/a	n/a
21-Sep	3	0	0	n/a	n/a	0
22-Sep	2	0	0	n/a	n/a	0
23-Sep	3	0	0	0	n/a	0
24-Sep	0	0	0	0	n/a	0
25-Sep	0	0	0	0	n/a	0
26-Sep	1	0	0	0	n/a	0
27-Sep	0	0	0	0	n/a	0
28-Sep	1	0	0	0	0	0
29-Sep	-1	2	0	0	0	0
30-Sep	1	4	1	0	0	0
1-Oct	5	0	0	0	0	0
2-Oct	6	0	0	0	0	4
3-Oct	46	2	0	0	0	26
4-Oct	130	0	0	0	1	83
5-Oct	184	41	6	0	1	108
6-Oct	180	13	-1	0	0	65
7-Oct	60	8	0	0	0	40
8-Oct	32	32	0	0	1	23
9-Oct	39	115	0	0	3	31
10-Oct	153	581	2	0	2	80
11-Oct	37	250	0	0	0	117
12-Oct	91	45	0	9	0	48
13-Oct	45	6	8	37	2	30
14-Oct	74	6	6	28	3	19

Appendix Table A2 continued. Daily salmon passage during years 2006 through 2011 at the Cow Creek video station.

Date	Salmon Passage 2006	Salmon Passage 2007	Salmon Passage 2008	Salmon Passage 2009	Salmon Passage 2010	Salmon Passage 2011
15-Oct	98	14	5	17	5	12
16-Oct	136	13	15	12	8	13
17-Oct	199	117	2	15	16	8
18-Oct	114	62	-2	5	16	20
19-Oct	105	72	3	19	5	18
20-Oct	131	48	7	17	10	34
21-Oct	115	10	17	6	20	33
22-Oct	134	12	2	6	23	22
23-Oct	107	25	2	9	58	46
24-Oct	68	38	0	16	51	57
25-Oct	106	45	3	8	42	54
26-Oct	55	26	2	3	19	41
27-Oct	60	21	5	8	15	67
28-Oct	104	10	1	3	14	68
29-Oct	60	32	8	3	20	59
30-Oct	79	10	22	1	10	61
31-Oct	121	33	11	3	10	57
1-Nov	108	37	130	5	6	41
2-Nov	183	8	60	8	4	54
3-Nov	199	4	71	0	6	29
4-Nov	90	20	28	3	13	26
5-Nov	65	21	7	7	9	13
6-Nov	21	30	3	1	7	13
7-Nov	21	21	10	5	10	21
8-Nov	30	8	5	1	9	12
9-Nov	46	12	6	0	12	19
10-Nov	49	30	5	-1	6	0
11-Nov	98	21	1	2	13	4
12-Nov	54	23	6	2	4	3
13-Nov	96	11	5	-1	12	14
14-Nov	60	7	3	0	8	1
15-Nov	47	16	1	-1	6	-5
16-Nov	34	5	2	0	5	2
17-Nov	34	8	1	0	3	0
18-Nov	48	5	0	-1	2	0
19-Nov	15	15	2	1	3	-5

Appendix Table A2 continued. Daily salmon passage during years 2006 through 2011 at the Cow Creek video station.

Date	Salmon Passage 2006	Salmon Passage 2007	Salmon Passage 2008	Salmon Passage 2009	Salmon Passage 2010	Salmon Passage 2011
20-Nov	10	7	0	0	9	-3
21-Nov	6	2	2	1	11	5
22-Nov	4	6	-1	0	8	-1
23-Nov	3	0	0	1	3	9
24-Nov	2	0	1	0	3	15
25-Nov	n/a	1	0	1	1	11
26-Nov	n/a	3	1	0	6	3
27-Nov	n/a	6	1	2	2	-2
28-Nov	n/a	1	0	1	2	1
29-Nov	n/a	4	0	2	0	2
30-Nov	n/a	2	1	2	2	1
1-Dec	n/a	0	0	1	0	0
2-Dec	n/a	0	1	0	0	-2
3-Dec	n/a	0	-1	-1	0	0
4-Dec	n/a	4	0	0	0	0
5-Dec	n/a	5	0	0	0	0
6-Dec	n/a	2	1	0	0	0
7-Dec	n/a	n/a	0	0	n/a	0
8-Dec	n/a	n/a	0	0	n/a	0
9-Dec	n/a	n/a	0	0	n/a	0
10-Dec	n/a	n/a	1	0	n/a	-3
11-Dec	n/a	n/a	0	0	n/a	0
12-Dec	n/a	n/a	0	0	n/a	0
13-Dec	n/a	n/a	0	0	n/a	0
14-Dec	n/a	n/a	0	0	n/a	0
15-Dec	n/a	n/a	1	0	n/a	0
16-Dec	n/a	n/a	0	0	n/a	0
17-Dec	n/a	n/a	0	0	n/a	0
18-Dec	n/a	n/a	0	0	n/a	0
19-Dec	n/a	n/a	0	0	n/a	0
20-Dec	n/a	n/a	n/a	0	n/a	-1
21-Dec	n/a	n/a	n/a	0	n/a	0
22-Dec	n/a	n/a	n/a	n/a	n/a	0
23-Dec	n/a	n/a	n/a	n/a	n/a	0

Appendix Table A2 continued. Daily salmon passage during years 2006 through 2011 at the Cow Creek video station.

	Salmon Passage 2006	Salmon Passage 2007	Salmon Passage 2008	Salmon Passage 2009	Salmon Passage 2010	Salmon Passage 2011
24-Dec	n/a	n/a	n/a	n/a	n/a	0
25-Dec	n/a	n/a	n/a	n/a	n/a	0
26-Dec	n/a	n/a	n/a	n/a	n/a	0
27-Dec	n/a	n/a	n/a	n/a	n/a	0
28-Dec	n/a	n/a	n/a	n/a	n/a	0
29-Dec	n/a	n/a	n/a	n/a	n/a	0
30-Dec	n/a	n/a	n/a	n/a	n/a	0
31-Dec	n/a	n/a	n/a	n/a	n/a	0
1-Jan	n/a	n/a	n/a	n/a	n/a	0
2-Jan	n/a	n/a	n/a	n/a	n/a	0
3-Jan	n/a	n/a	n/a	n/a	n/a	0
4-Jan	n/a	n/a	n/a	n/a	n/a	0
5-Jan	n/a	n/a	n/a	n/a	n/a	0
6-Jan	n/a	n/a	n/a	n/a	n/a	0
7-Jan	n/a	n/a	n/a	n/a	n/a	0
8-Jan	n/a	n/a	n/a	n/a	n/a	1
9-Jan	n/a	n/a	n/a	n/a	n/a	0
10-Jan	n/a	n/a	n/a	n/a	n/a	0
11-Jan	n/a	n/a	n/a	n/a	n/a	0
12-Jan	n/a	n/a	n/a	n/a	n/a	0
13-Jan	n/a	n/a	n/a	n/a	n/a	0
14-Jan	n/a	n/a	n/a	n/a	n/a	0
15-Jan	n/a	n/a	n/a	n/a	n/a	0
16-Jan	n/a	n/a	n/a	n/a	n/a	0

APPENDIX B: Figures

Appendix Figure B1. Photograph of “station brand” plaque positioned on white plates with letters C and W for video readers to identify Cow Creek.

THE COW CREEK VIDEO STATION TAPE LOG

PLEASE FILL OUT THE FOLOWING LOG FOR EACH VISIT: CALL Doug Killam at 527-8893 W or 526-0579 C if you have problems

DATE	DAY	TIME OF VISIT	YOUR INITIALS	Does TV HAVE Good Picture?	Change DVR? DVR # in	CLEAN ? weir & plates	Clean UW Cameras?	Battery Check light ✓ ~~Change VCR backup?~~	DOES STATION NEED ATTENTION? ANY COMMENTS?
10/21/11	Friday	1040	DKS	Y	N	Y	Y	Y	plates were very dirty
10/22/11	Saturday								
10/23/11	Sunday	1300	DM	Y	N	Y	Y	Y	Alls well
10/24/11	Monday	1035	DM	Y	12	N	N	Y	
10/25/11	Tuesday								
10/26/11	Wednesday	1330	DM	Y	N	Y	Y	Y	Alls well
10/27/11	Thursday	1020	DM	Y	N	Y	Y	Y	
10/28/11	Friday	1230	DO	Y	N	Y	Y	Y	looks good
10/29/11	Saturday	1430	DM	Y	N	N	N	Y	light check good, alls well
10/30/11	Sunday								
10/31/11	Monday	1100	DM	Y	D	Y	Y	Y	
11/1/11	Tuesday	1130	DM	Y	N	Y	Y	Y	Windy, minimal debri
11/2/11	Wednesday	1415	DM	Y	N	N	N	Y	Photos, light ✓ good
11/3/11	Thursday	1330	DM	Y	N	Y	Y	Y	light ✓
11/4/11	Friday	1123	DO	Y	N	Y	Y	Y	looks good
11/5/11	Saturday	1525	DM	Y	N	N	N	Y	light ✓
11/6/11	Sunday	1215	DM	Y	N	Y	Y	Y	light ✓ light rain
11/7/11	Monday	1145	DM	Y	11	N	N	✓	Fall back @ 1200
11/8/11	Tuesday	1200	DM	Y	N	N	N	✓	light ✓, insulated DVR'S, stacked, duct taped holes
11/9/11	Wednesday	1200	DM	Y	Y	Y	Y	✓ ✓	
11/10/11	Thursday								
11/11/11	Friday	0640	DM	Y	N	N	N	✓ ✓	Freezing temps. box warm, insulation stack working
11/12/11	Saturday	11:40	ZS	Y	N	Y	Y	✓	observed unspawned Jack Carcass on weir
11/13/11	Sunday	1530	DM	Y	N	N	N	✓ ✓	
11/14/11	Monday	1100	DM	Y	12	N	N	✓ ✓	
11/15/11	Tuesday	1015	DM	Y	N	Y	Y	✓ ✓	
11/16/11	Wednesday								
11/17/11	Thursday	1500	DM	Y	N	Y	Y	✓ ✓	
11/18/11	Friday	1127	DO	Y	N	Y	Y	✓	
11/19/11	Saturday	~~1550~~	~~DM~~						
11/20/11	Sunday	1550	DM	Y	N	Y	Y	✓ ✓	All is well
11/21/11	Monday	1145	DM	Y	D	Y	Y	✓ ✓	thermo download

Appendix Figure B2. 2011 Cow Creek video station "at creek" log for electronics and DVR equipment.

COW CREEK VIDEO STATION OFFICE DVR LOG 2011 (Keep near the HONEYWELL DVR in office)

Today's Date	Time Today	DVR #	Creek Start Date	Creek Start Time	Creek End Date	Creek End Time	Honeywell Camera #	Motion or Continous	Comments
9/26	15:00	12	9/21	14:46	9/26	12:34	3	C	start of survey
10/3	1720	11	9/26	12:34	10/3	14:23	3	C	
10/10	1320	12	10/3	14:22	10/10	11:01	4	C	
10/17	1215	D	10/10	11:01	10/17	10:27	3	C	
10/24	1230	11	10/17	10:27	10/24	10:39	4	C	
10/31	1430	12	10/24	10:39	10/31	11:00	3	C	
11/7	1415	D	10/31	11:00	11/7	12:00	4	C	
11/14	1350	11	11/7	12:00	11/14	11:16	3	C	
11/21	1430	12	11/14	11:16	11/21	11:49	4	C	
11/28	1700	1	11/21	11:49	11/28	14:41	3	C	emergency back-up
12/5	1435	11	11/28	14:41	12/5	12:12	4	C	
12/12	1615	12	12/5	12:12	12/12	14:16	3	C	
12/19	1630	17	12/12	14:16	12/19	14:55	4	C	
12/26	1500	11	12/19	14:55	12/26	13:53	3	C	
1/2	1510	12	12/26	13:53	1/2	14:04	3	C	electrical interruption, 1 day delay
1/9	1430	17	1/2	14:04	1/9	13:05	4	C	
1/16	1530	11	1/9	13:05	1/16	14:19	4	C	
1/23	2000	D	1/16	14:19	1/17	09:50	4	C	End of survey

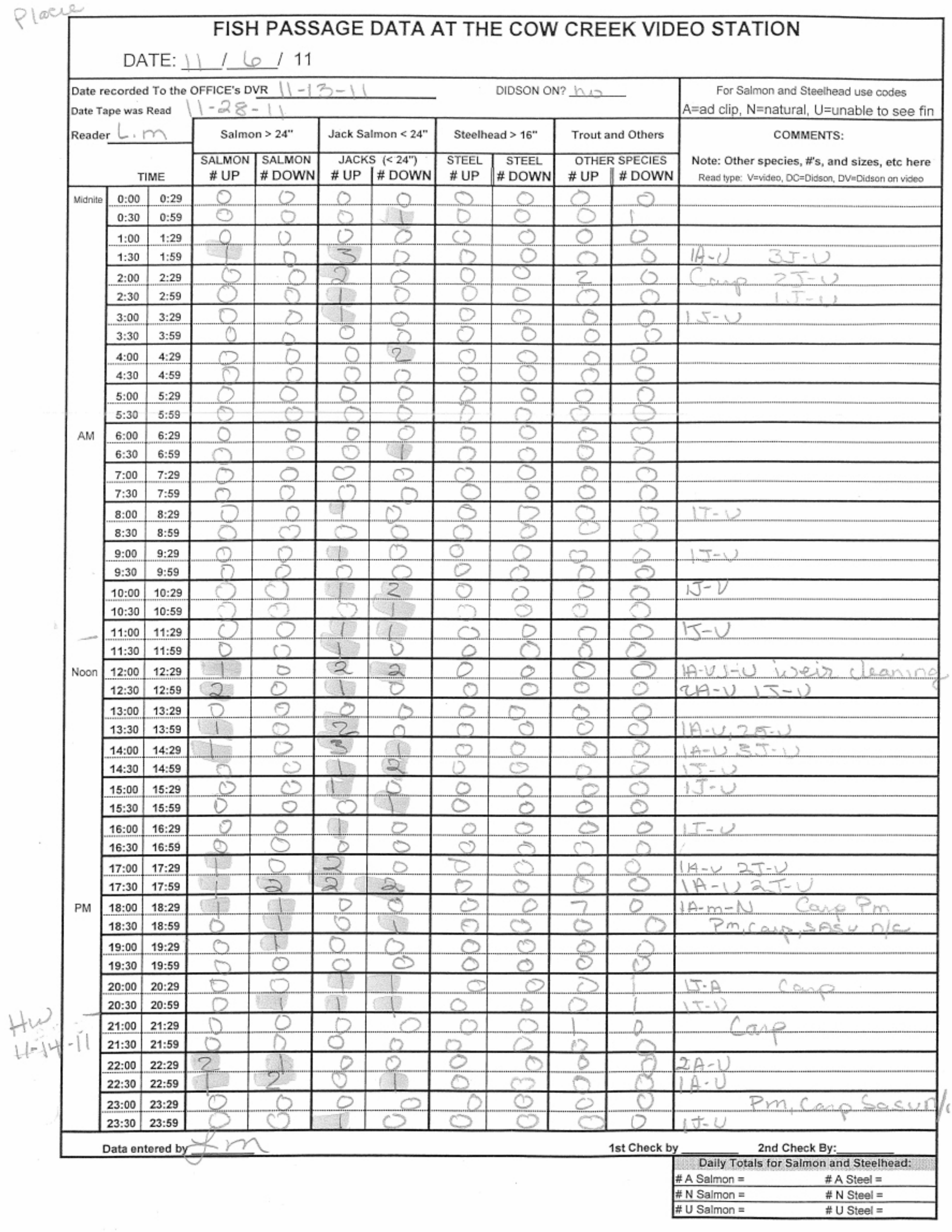
Appendix Figure B3. 2011 Cow Creek office log containing information on date, time and the creek DVR download in office.

2nd Darin Deck Scanned

HONEYWELL ~~PRIMARY~~ (~~Under big fish~~) OFFICE DVR to EXTERNAL HARD DRIVE LOG 2011 (Keep at HONEYWELL DVR in office)

Today's Date	Todays Time	INITITALS	RANGE of HONEYWELL DATES DOWNLOADED	TO HARDDRIVE # ?	DATA? or BACKUP?	Comments
		DM	HD #20 start-11	20 ✓	B	
		DM	HD #30 Start 11	30	D	
10/13	17:00	OK	Reset HW Time from	15:57 to	17:02 was	1 hour behind
10/14	17:30	OK	START HD Data 40	40 ✓	D	
10/14	17:30	OK	" " BACKUP 18	18	B	
10/31	09:30	DM	End Data 40, start Data 29	29 ✓	Data	
10/31	09:30	DM	End Back-up 18, Start Back-up 33	33	Back-Up	
11/14	16:15	DM	End Data 29, Start data 49	49 ✓	Data	
11/14	16:15	DM	End Backup 33, Start Backup 50	50	BackUP	
12/14	08:50	DM	End Data 49 Start Data 45	45 ✓	Data	
12/14	08:50	DM	End Backup 50, Start BackUp 48	48	BackUP	
1/12	17:15	DM	End Data 45 Start Data 52	52 ✓	Data	
1/12	17:15	DM	End Backup 48 Start Back-Up 51	51	Back-Up	
1/26	16:00	DM	End Data 52			2012 Survey Complete!
			End BackUp 51			

Appendix Figure B4. Primary log used to keep track of external hard-drives for the 2011 Cow Creek video station.



Place

FISH PASSAGE DATA AT THE COW CREEK VIDEO STATION

DATE: 11 / 6 / 11

Date recorded To the OFFICE's DVR 11-13-11 DIDSON ON? no

Date Tape was Read 11-28-11

Reader L.m

For Salmon and Steelhead use codes A=ad clip, N=natural, U=unable to see fin

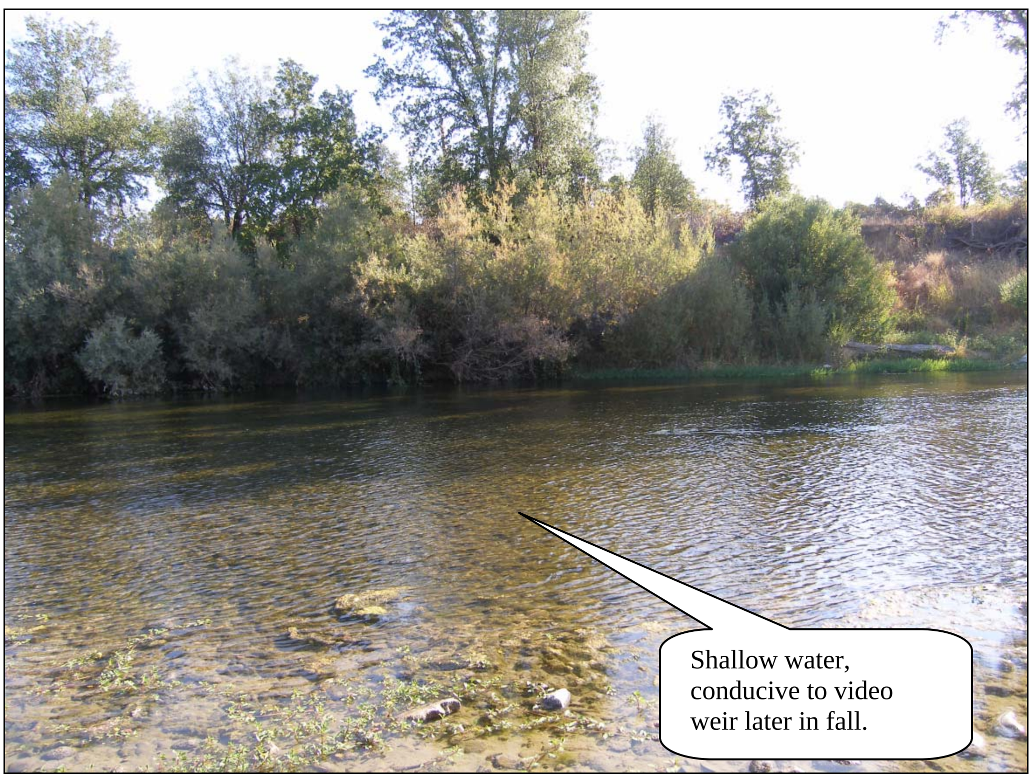
			Salmon > 24"		Jack Salmon < 24"		Steelhead > 16"		Trout and Others		COMMENTS:
	TIME		SALMON # UP	SALMON # DOWN	JACKS (< 24") # UP	# DOWN	STEEL # UP	STEEL # DOWN	OTHER SPECIES # UP	# DOWN	Note: Other species, #'s, and sizes, etc here Read type: V=video, DC=Didson, DV=Didson on video
Midnite	0:00	0:29	0	0	0	0	0	0	0	0	
	0:30	0:59	0	0	0	1	0	0	0	1	
	1:00	1:29	0	0	0	0	0	0	0	0	
	1:30	1:59	1	0	3	0	0	0	0	0	1A-U 3J-U
	2:00	2:29	0	0	2	0	0	0	2	0	Camp 2J-U
	2:30	2:59	0	0	1	0	0	0	0	0	1J-U
	3:00	3:29	0	0	1	0	0	0	0	0	1J-U
	3:30	3:59	0	0	0	0	0	0	0	0	
	4:00	4:29	0	0	0	2	0	0	0	0	
	4:30	4:59	0	0	0	0	0	0	0	0	
	5:00	5:29	0	0	0	0	0	0	0	0	
	5:30	5:59	0	0	0	0	0	0	0	0	
AM	6:00	6:29	0	0	0	0	0	0	0	0	
	6:30	6:59	0	0	0	1	0	0	0	0	
	7:00	7:29	0	0	0	0	0	0	0	0	
	7:30	7:59	0	0	0	0	0	0	0	0	
	8:00	8:29	0	0	1	0	0	0	0	0	1J-U
	8:30	8:59	0	0	0	0	0	0	0	0	
	9:00	9:29	0	0	1	0	0	0	0	0	1J-U
	9:30	9:59	0	0	0	0	0	0	0	0	
	10:00	10:29	0	0	1	2	0	0	0	0	1J-U
	10:30	10:59	0	0	0	1	0	0	0	0	
	11:00	11:29	0	0	1	1	0	0	0	0	1J-U
	11:30	11:59	0	0	1	0	0	0	0	0	
Noon	12:00	12:29	1	0	2	2	0	0	0	0	1A-U 1J-U weir cleaning
	12:30	12:59	2	0	1	0	0	0	0	0	2A-U 1J-U
	13:00	13:29	0	0	0	0	0	0	0	0	
	13:30	13:59	1	0	2	0	0	0	0	0	1A-U, 2J-U
	14:00	14:29	1	0	3	1	0	0	0	0	1A-U 3J-U
	14:30	14:59	0	0	1	2	0	0	0	0	1J-U
	15:00	15:29	0	0	1	0	0	0	0	0	1J-U
	15:30	15:59	0	0	0	1	0	0	0	0	
	16:00	16:29	0	0	1	0	0	0	0	0	1J-U
	16:30	16:59	0	0	0	0	0	0	0	0	
	17:00	17:29	1	0	2	0	0	0	0	0	1A-U 2J-U
	17:30	17:59	1	2	2	2	0	0	0	0	1A-U 2J-U
PM	18:00	18:29	1	1	0	0	0	0	7	0	1A-m-N Carp Pm
	18:30	18:59	0	1	0	1	0	0	0	0	Pm, Carp, SASU n/c
	19:00	19:29	0	1	0	0	0	0	0	0	
	19:30	19:59	0	0	0	0	0	0	0	0	
	20:00	20:29	0	0	1	1	0	0	0	1	1J-A Carp
	20:30	20:59	0	1	1	1	0	0	0	1	1J-U
	21:00	21:29	0	0	0	0	0	0	1	0	Carp
	21:30	21:59	0	0	0	0	0	0	0	0	
	22:00	22:29	2	1	0	0	0	0	0	0	2A-U
	22:30	22:59	1	2	0	1	0	0	0	0	1A-U
	23:00	23:29	0	0	0	0	0	0	0	0	Pm, Carp Sasu n/c
	23:30	23:59	0	0	1	0	0	0	0	0	1J-U

HW 11-14-11

Data entered by Lm 1st Check by ________ 2nd Check By: ________

Daily Totals for Salmon and Steelhead:	
# A Salmon =	# A Steel =
# N Salmon =	# N Steel =
# U Salmon =	# U Steel =

Appendix Figure B5. Example of a fish passage data sheet for Cow Creek video station in 2011.



Appendix Figure B6. Upper-image of Cow Creek during major flooding. Lower-image of Cow Creek during a period conducive for construction and operation of the video weir.

Appendix Figure B7. Photograph of 2006 Cow Creek Video Station.

Appendix Figure B8. Photograph of 2007 Cow Creek Video Station.

Appendix Figure B9. Photograph of 2008 Cow Creek Video Station.

Appendix Figure B10. Photograph of the 2009 Cow Creek Video Station.

Appendix Figure B11. Photograph of the 2010 Cow Creek Video Station.

Appendix Figure B12. Photograph of the 2011 Cow Creek Video Station. Plate design proved to be less effective in tape reading than previous year designs. Greater plate length allows better visibility of fish size than a greater width, which only allows more fish to pass through at one time.

APPENDIX C: Documents

Appendix C. West Inc. electronic file detailing QC methodology used to develop final estimate for the 2011 Cow Creek fall Chinook salmon population.

Estimating Escapement Using Device Counters

This document describes how to estimate escapement from device counter (e.g., video camera) monitoring data using R (R Development Core Team 2012) and code developed by WEST, Inc. A statistical analysis has been developed for the following situations:

1. Device counter results are recorded for each 'segment' of each day during the season. Segments are likely to be 1/2-hour or 1-hour in length. Segments when the device counter was not operational, or results are not reliable, are represented in the data with count=NA.
2. A portion of the original counts are reviewed by an 'expert' or preferably a team (e.g., 3 or more) of experts who arrive at a consensus on what is the true net upstream count. For example, a systematic sample of segments with non-missing counts is reviewed by 3 observers who come to a consensus on the true net count. These 'truths' are then compared to the original counts. Another example involves reviewing and coming to a consensus for all extremely large counts (counts >= x), and then getting consensus on a sample of counts < x.
3. A combination of 1) and 2) above.

For simplicity, the statistical analysis is described below using video monitoring data as an example, but these methods could also apply to fish counts from Vaki Riverwatcher® or dual frequency identification sonar (DIDSON) equipment. See Bergman et al. (2012; Chapter 2) for more discussion on use of device counters for monitoring Chinook salmon escapement.

First (Situation 1), a trained observer views each video segment and records the net number of fish passing upstream. Thus, fish passing downstream are subtracted from the total passing upstream. This net passage is referred to as the original count for a video segment. If the device counter was not 100% operational (Situation 1), a generalized additive model (GAM; Wood 2006) is used to impute the missing counts. The model relates the net daily count, which is a combination of adjusted counts and consensus counts for all video segments during the day, divided by the proportion of the day the video equipment was operational, to a smoothed function of the daily totals. This results in adjustments of counts for days when the video equipment was operational for only a portion of the day, and imputation of counts for days when the equipment was not in use.

During GAM estimation, Akiake's information criterion (AIC; Burnham and Anderson 2002) is used to choose the basis-dimension for the smoothing, and then generalized cross validation is used for smoothness selection. A Poisson GAM is used if the counts are whole numbers and there is no adjustment from consensus counts (Situation 2). If counts are whole numbers but some are negative (net fish passage upstream), the counts are transformed prior to modeling by adding the absolute value of the lowest net count, and then the counts are back-transformed for imputation and final escapement estimation. If an adjustment is estimated by comparing consensus counts to the original counts for a portion of the data, these adjusted counts are modeled and will likely not be whole numbers, so a Normal distribution is assumed rather than a Poisson. In this case negative net counts are allowed and so no transformation is needed.

Second (Situation 2), if there is uncertainty in original video counts, a systematic sample of segments is viewed by one or more (preferably 3) experts. The experts reach a consensus on the net count for each sampled segment. A systematic sample can be obtained by arranging the video segments in sequential order, sorted by date and time, and then selecting every i^{th} segment for review. The recommended minimum sample size is 75, but obviously more is better, and the number of segments reviewed should depend on the uncertainty in the original counts.

The analysis code developed for this type of data allow for an alternative to this approach, which involves a thorough review of all video segments with an original count $\geq x$, and then review of a sample of segments with counts $< x$. This scenario was developed on the idea that larger original counts may be less precise, and thus require a higher level of review. Regardless, the ratio of original counts to consensus counts based on the reviewed video segments is used to adjust the remaining original counts. For example, if the sum of the consensus counts is 100, and the sum of original counts for the same video segments is 95, the net counts from video segments not sampled are adjusted by dividing by 0.95 – if the sample of original counts are on average lower than the consensus counts by 5%, then the original counts need to be adjusted by 5%. In this situation Total escapement is estimated by summing the adjusted counts

If a sample of segment counts is reviewed and a consensus count is obtained (Situation 2), the ratio of original/consensus counts is used to adjust all non-consensus counts. The consensus and adjusted counts are used as the response in the GAM in place of the original counts if there are missing values.

Finally, given Situation 1 and/or 2, total escapement is estimated using a combination of daily totals of consensus counts (Situation 2), adjusted counts (Situation 1 or 2), and imputed counts (Situation 1). A ninety percent confidence interval (CI) for the final escapement estimate is calculated by bootstrapping (Manly 2006) the segment counts and re-running the entire analysis 500 times on the re-sampled data.

See 'DeviceCount1.csv' for example data with missing counts (Situation 1). See 'DeviceCount12.csv' for an example of Situations (1) and (2). When creating data for use with "DeviceCounterAnalysis.r", follow the same data format as shown in the examples, including the names and order of the columns.

If you don't have R installed on your computer, see "Installing R.pdf". You will also need the **chron** and **mgcv** contributed packages (instructions for downloading packages are in "Installing R.pdf").

Analysis Steps:

1) Place the following files in the same folder on your computer (**not** on your desktop):
    a. “DeviceCounterAnalysisV2.r”,
    b. A .csv file containing the device counter data. See “DeviceCount1.csv” and "DeviceCount12.csv",

2) Open R by double-clicking on the R icon on your desktop or via the Start menu.
    a. Direct R to the folder described in Step (1) via
    File –> Change dir.. ,

3) At the R Console command prompt, type
    source("DeviceCounterAnalysisV2.r") .

LITERATURE CITED

Bergman, J. M., R. M. Nielson, and A. Low. 2012. Cetral Valley in-river Chinook salmon escapement monitoringplan. California Department of Fish and Game, Sacramento, CA, USA.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer.

Manly, B. F. J. 2006. Randomization, Bootstrap and Monte Carlo Methods in Biology, Third Edition. Third edition. Chapman and Hall/CRC.

Wood, S. N. 2006. Generalized Additive Models: An Introduction with R. Chapman & Hall, London, England.