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

Results from the Cottonwood Creek video station for years 2007-2011 for fall-run Chinook salmon escapement

By
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California Department of Fish and Game
Red Bluff Fisheries Office

RBFO Technical Report No. 01-2012

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Cover Photo: Image of Cottonwood Creek Video Station in 2009

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

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SUMMARY

This report provides fall-run Chinook salmon (*Oncorhynchus tshawytscha*) spawner escapement estimates based on the operation of a video monitoring station located on Cottonwood Creek, a tributary for the Sacramento River in Shasta and Tehama Counties, California for years 2007 through 2011.

The organizations facilitating the monitoring were the California Department of Fish and Game, Pacific States Marine Fisheries Commission, Cottonwood Creek Watershed Group, Western Shasta Resource Conservation District, and 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 Cottonwood 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 2007 through 2011.

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

- 1,250 salmon in 2007 or **1.3**% of total California Central Valley spawner escapement.
- 510 salmon in 2008 or **0.7**% of total California Central Valley spawner escapement.
- 1,065 salmon in 2009 or **2.0**% of total California Central Valley spawner escapement.
- 1,139 salmon in 2010 or **0.7**% of total California Central Valley spawner escapement.
- 2,144 salmon in 2011 or **0.9**% of total California Central Valley spawner escapement.

The Cottonwood Creek fall-run Chinook spawner escapement represented an average of 1.1% of the entire California Central Valley's totals over these five years, including in-river and hatchery totals.

The successful operation of the video monitoring station in Cottonwood Creek during the five-year period between 2007 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 fall-run Chinook salmon (fall-run) escapement in Cottonwood Creek (the border between Shasta and Tehama Counties). 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 the Pacific States Marine Fisheries Commission (PSMFC), the Western Shasta Resource Conservation District (WSRCD), the Cottonwood Creek Watershed Group (CCWG), the U.S Fish and Wildlife Service's (USFWS) Anadromous Fish Restoration Program (AFRP), the USFWS's Comprehensive Assessment and Monitoring Program (CAMP), and the U.S Bureau of Reclamation (USBR). Funding for this project was also provided by 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 estimates of the fall-run spawner Chinook escapement into Cottonwood Creek.
- Collect baseline data on salmon escapement that can be used to evaluate restoration activities occurring in the Cottonwood Creek watershed.
- Collect video data on the biological characteristics of the fall-run populations in Cottonwood 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 Cottonwood Creek watershed 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 Cottonwood Creek are needed to interpret fishery responses to habitat restoration activities and provide information to fisheries managers, landowners, and others interested in the Cottonwood Creek watershed.

Table 1 presents the annual escapement estimates for Cottonwood 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/Programs/AdditionalPrograms/CDFGRedBluff/tabid/105/Default.aspx)

The following description of the Cottonwood Creek watershed was excerpted from the Cottonwood Creek Watershed Assessment (CH2MHILL, 2002). "The Cottonwood Creek drainage area lies within Shasta and Tehama counties on the northwest side of northern California's Central Valley. The lower two-thirds of the drainage area lie in Central Valley uplands, and the upstream portion includes the east slope of the North Coast Mountain Range and Klamath Mountains and the southern slopes of the Trinity Mountains.

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

YEAR	Estimate	YEAR	Estimate
1953	3,000	**1983**	1,000
1954	1,000	**1984**	500
1955	800	**1985**	n/a
1956	660	**1986**	n/a
1957	358	**1987**	n/a
1958	600	**1988**	n/a
1959	3,300	**1989**	n/a
1960	350	**1990**	n/a
1961	1,500	**1991**	676
1962	6,000	**1992**	1,585
1963	3,500	**1993**	n/a
1964	3,450	**1994**	n/a
1965	900	**1995**	n/a
1966	2,900	**1996**	n/a
1967	600	**1997**	n/a
1968	8,540	**1998**	n/a
1969	4,967	**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	2,427	**2006**	n/a
1977	1,512	**2007**	1,250
1978	1,120	**2008**	510
1979	n/a	**2009**	1,065
1980	n/a	**2010**	1,139
1981	3,356	**2011**	2,144
1982	700		
AVERAGE all years			**1,981**
source GrandTab file-CDFG			

The creek flows eastward through the valley to the Sacramento River, the confluence lying approximately 16 miles north of Red Bluff and about 150 miles northwest of Sacramento. The pear-shaped watershed has three main tributaries: North Fork, Middle Fork (flowing along the Shasta-Tehama County line), and South Fork. The watershed drains approximately 938 square miles. With an annual runoff of 586,000 acre-feet (ac-ft), Cottonwood Creek is the third largest watershed tributary west of the Sacramento River." The assessment identifies the need for reliable and efficient monitoring of anadromous fisheries resources that collects baseline population data within the watershed. The video station on Cottonwood Creek serves this need and can provide fisheries agencies with accurate population stock assessments for management of state fisheries resources (i.e. ocean and in-river harvest management needs).

Historically, the Department has not monitored fall-run escapement into Cottonwood Creek on a consistent basis. Table 1 provides a summary of Cottonwood Creek fall-run escapement from 1953 to 2011. From 1953 to 1969 seventeen annual estimates were made based on carcass counts and occasional aerial redd (salmon nests) counts (CDGF, annual salmon spawning stock reports 1956-2005). 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 1961 three surveys reported 203 carcasses and this was expanded to 1,500 spawners based on the professional judgment of the counters. 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). During aerial redd counts, 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 often reported numbers rounded to the nearest hundred or thousand figures. Monitoring efforts after 1969 were done sporadically (in 9 of 37 possible years) when budgets allowed and typically in response to a specific need (e.g. potential water storage projects, or hatchery evaluations, etc).

In an effort to monitor the escapement of fall-run Chinook on a more regular basis in the Central Valley, the Department explored the option of using video recorders to count salmon. A similar video station has been constructed and operated in Battle Creek since 2003, and has been 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; beginning in 2006 the video station was the only method used to estimate salmon escapement in Battle Creek. As a result of the success in Battle Creek, the video station methodology was approved for use in other watersheds. Since 2006 a video station has been operated on Cow Creek (Killam, 2007). The Cottonwood Creek station began in 2007 and for years 2007 to 2010 a station was operated on Bear Creek. From 2008 till present day, a station has been operated on Mill Creek.

In March of 2007 a group meeting between different agencies and non-governmental parties was held to discuss the construction and operation of a video monitoring station on Cottonwood Creek. At this meeting there was a general consensus that the group was interested in operating a video station on Cottonwood Creek in the fall of 2007 and possible subsequent years. As mediators for the group, the WSRCD arranged to coordinate the video station details with the CDFG, USFWS and CCWG. In April of 2007 a survey of Cottonwood Creek was made to choose a site for the new 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 1.2-miles (2 kilometers) upstream of the mouth of the Sacramento River as detailed in Figure 1.

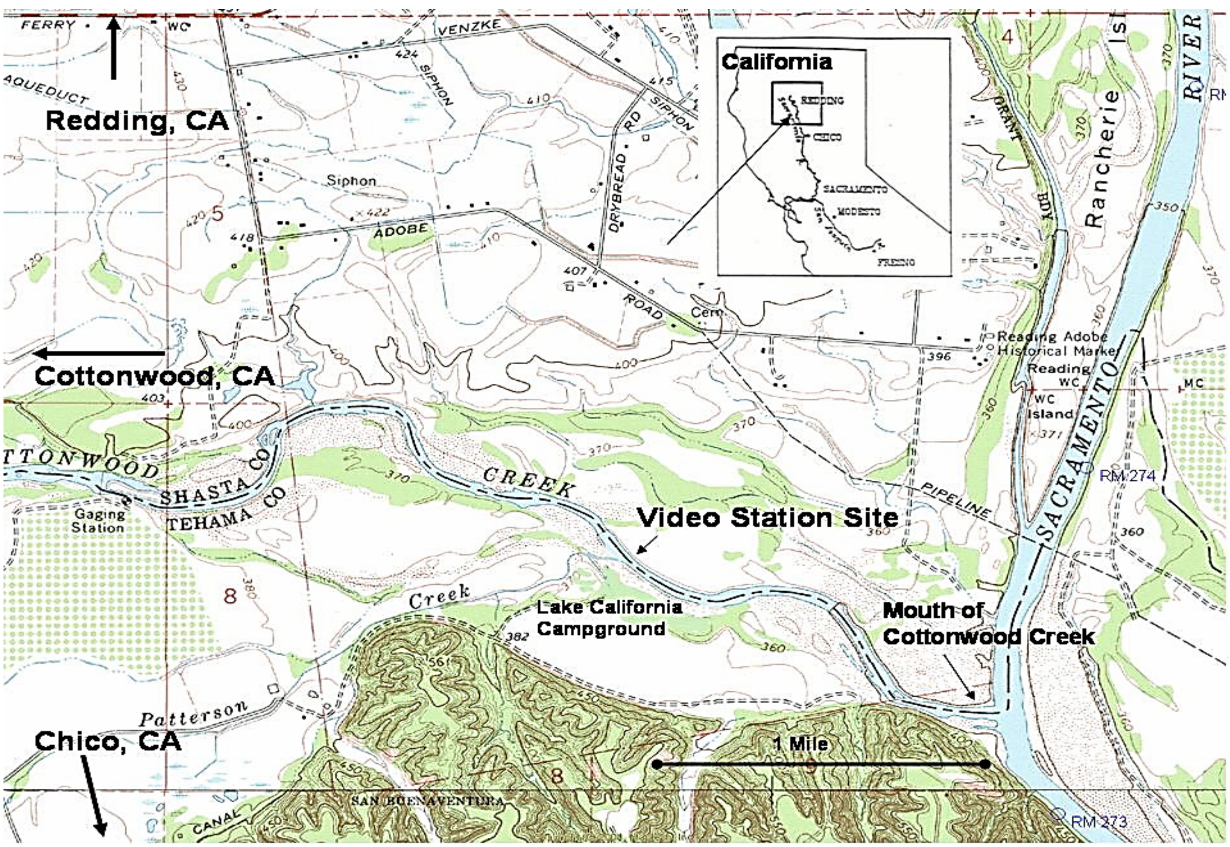

Figure 1. Map detailing the location of the video station on lower Cottonwood Creek near the confluence of the Sacramento River in California.

The Universal Transverse Mercator (UTM) coordinates of the video monitoring station are 4470333 North, 567075 East in a NAD-83, zone 10 projection and datum. The station has been installed in the same general location for all five years. During the years of 2007 through 2011 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, CCWG, and PSMFC cooperated to accomplish station set-up and removal, maintenance, VCR or DVR changing, video reading, and quality control of video footage.

METHODS AND MATERIALS

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

- From 17 September through 06 December 2007
- From 13 September through 29 December 2008
- From 21 September through 21 December 2009
- From 15 September through 30 November 2010
- From 12 September 2011 through 17 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 Cottonwood 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, they were video recorded by a camera positioned on cables directly overhead of the white plates.

Weir System

Up to four white, high-density polyethylene (HDPE) plates, measuring ¼-inch thick x 5 x 10-feet (6 mm x 1.2 m x 3 m) were staked to the creek bottom below the overhead camera to create a white background for better visibility of passing fish. The plates overlay each other slightly and have ¾-inch (1.9 cm) holes drilled around the perimeters to allow staking and a metal 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. Prior to 2010 two plates were used and provided a 10 x 10 foot (3 x 3 m) viewing area for monitoring salmon.

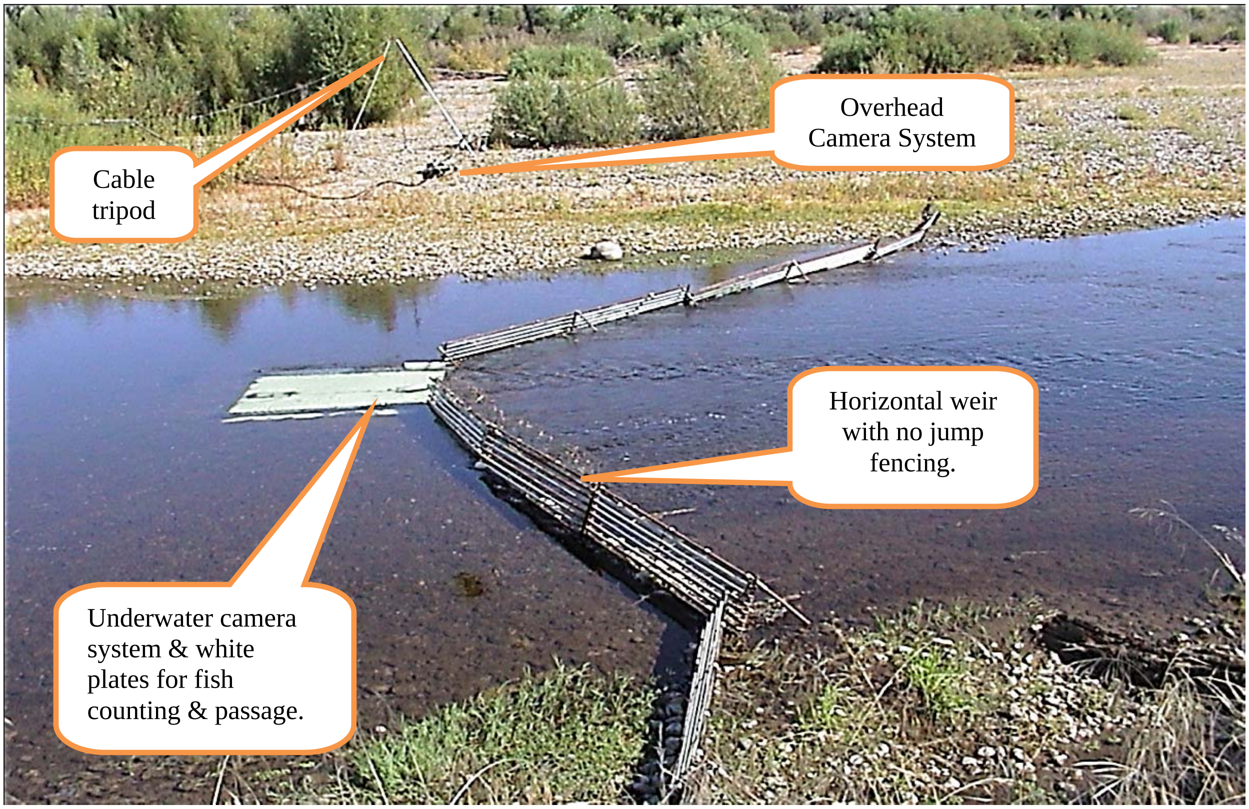

Figure 2. The 2009 Cottonwood Creek video station with camera box, lights, weir, and passage opening with white plates visible.

In 2010 three 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 5 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 rebar metal rectangle "measuring brand" measuring exactly 12 x 24 inches (305 mm x 610 mm) was staked to the white plates. The rectangle 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 fork length, small <609 mm) is used on other RBFO surveys allowing annual comparisons to be developed that can approximate age compositions. The measuring brand had a "station identity" welded into the center of the rectangle. During viewing, video readers were able to identify Cottonwood Creek footage by the letters C and T incorporated into the center of the rectangle, visible in Figure 6. 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 7.

To direct salmon to the white background plates where they were easily counted, the RBFO staff developed a new style of weir that was 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

(3.04 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 and other debris to easily pass downstream while preventing salmon from passing the weir except at the opening. Weir construction and panel placement started at the white plates and moved towards either shoreline. 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 a 45-degree angle downstream.

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 as shown in Figure 3. 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 to two feet (30 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 dogleg 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. This was done on both ends of each panel as it was placed. In later years, crews constructed weirs in which every other weir panel was assembled in this way. In between these “double-dogleg” supported 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 soon expected to bring floods.

Experience on Cottonwood 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 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 was wired along the top of the panel and rested facing downstream (Figure 3) 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 cm²) openings cut to 18-inch (45.7 cm) wide and 10-foot (3.0 m) lengths.

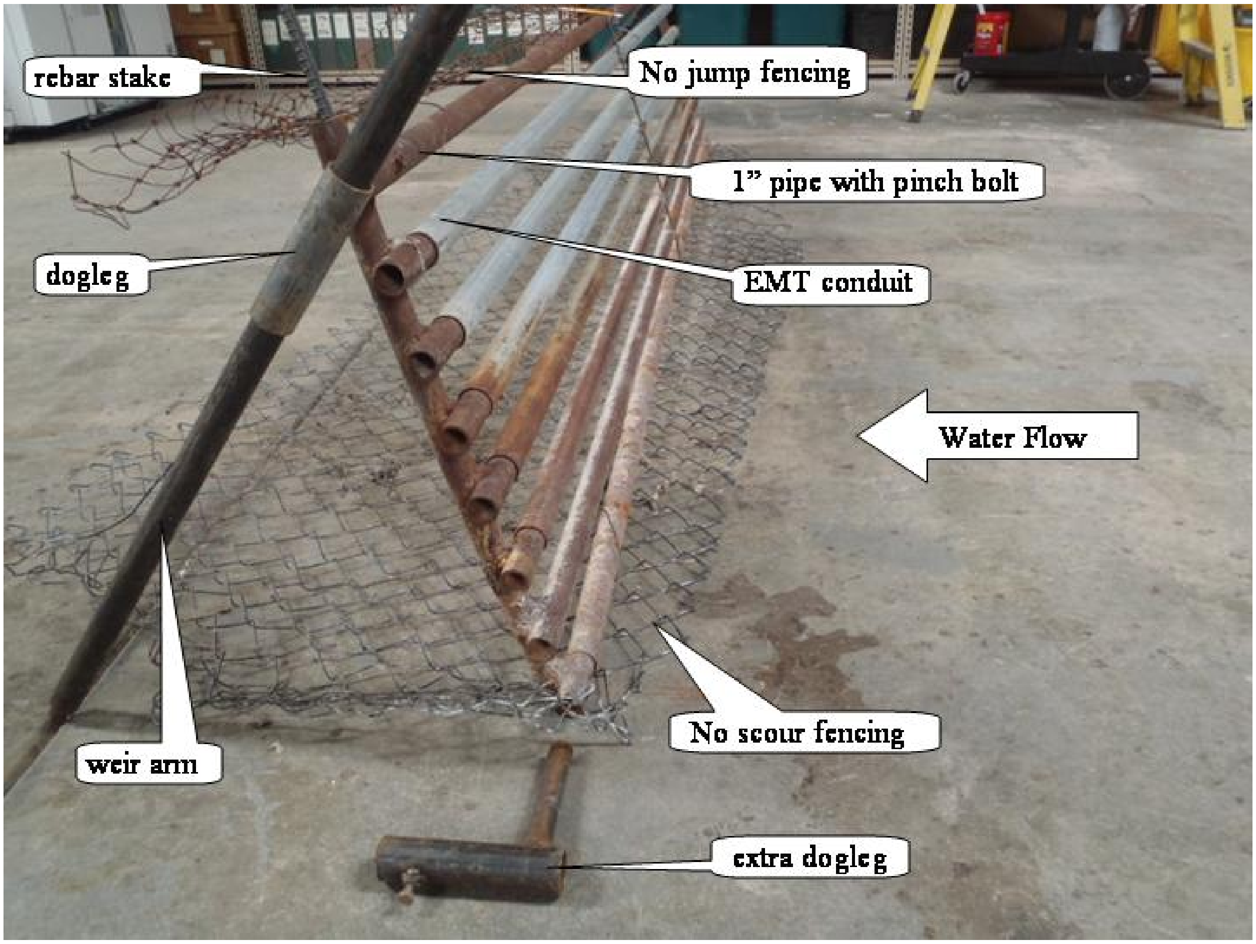

Figure 3. Image of typical RBFO video station weir panel and its components.

Electronics

One criteria of the Cottonwood Creek video station was that it be located near a conventional "on-grid" Pacific Gas and Electric Co. power supply. The Cottonwood Creek video 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 was located at the Lake California Campground with an existing 120-volt power supply. This provided a nearby source of power to the station.

In 2007, an on-site trailer was used to house the electronic equipment and video footage generated by the cameras. From the trailer, coaxial video (RG-6) and 120-volt AC (alternating current) power cords were trenched approximately 750 feet (229 m) to the creek. An in-line Ground Fault Interrupt Circuit (GFIC) device was used to provide automatic shut-off of the system should the power supply short out or have contact with water. The original battery from a 300-watt APC brand Uninterruptible Power Supply (UPS) was removed and larger golf-cart batteries were connected giving a much greater power reserve if the on-grid power failed.

From October 2008 on, DVR's were used to record data, and were housed in a refurbished locking refrigerator to secure and shelter the station's video equipment, electrical accessories and batteries as shown in Figure 4.

Figure 4. Image of the camouflaged lockable refrigerator in 2009 containing DVR equipment, TV monitor, power supply and battery backup for the Cottonwood Creek video station.

A back-up power supply was 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 the UPS to ensure continual video coverage in the event of a power failure.

Lighting for the video cameras at night was provided by two compact outdoor fluorescent spotlights mounted on an overhead cable system (three 90-watt bulbs in 2011) as shown in Figure 5. 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) and was chosen to provide a high quality image in various lighting conditions. The camera attached to the bottom of a specialized RBFO designed box containing remote lighting and other wiring hookups. 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.

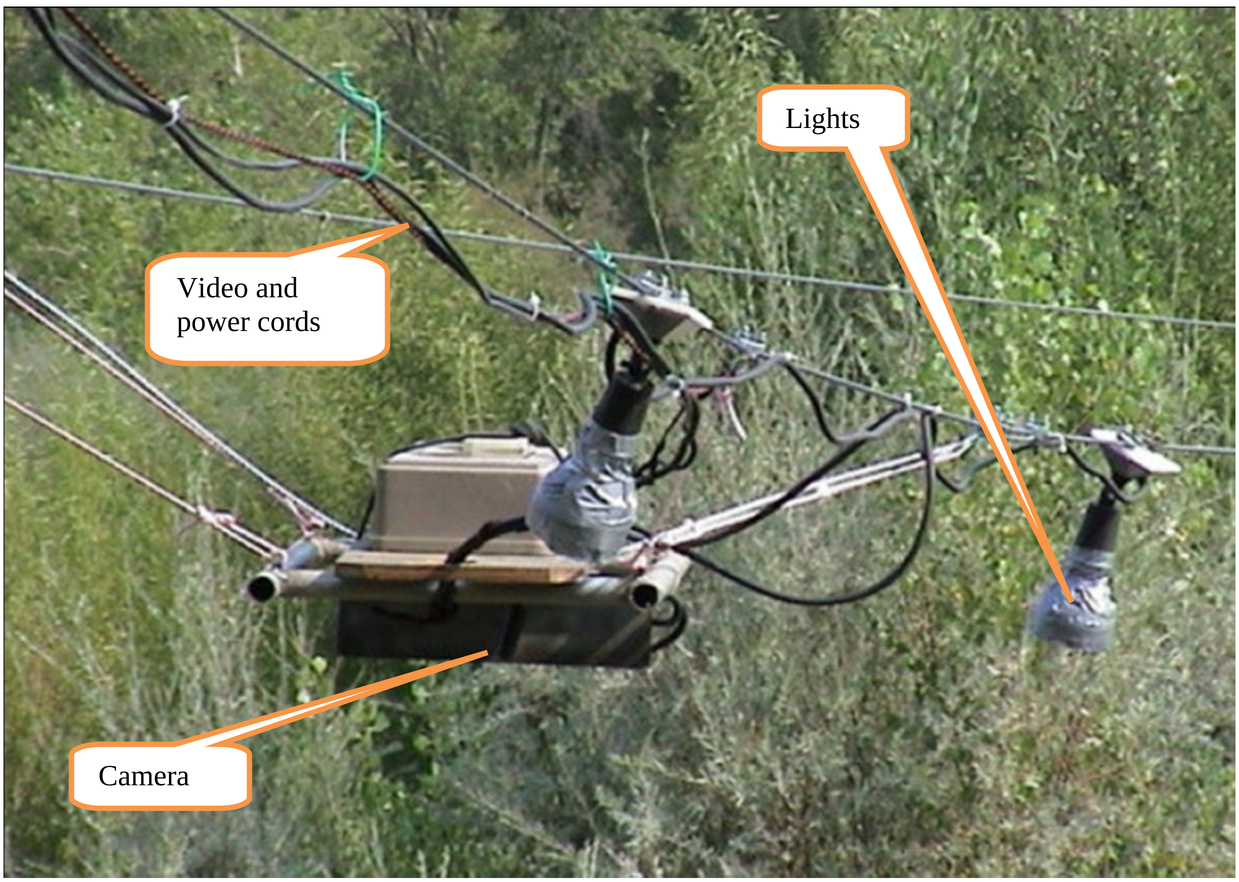

Figure 5. Image of over-head camera box with power cords, lights and camera box suspended over the Cottonwood Creek video station.

The two cables, about 300-feet (91.4 m) each, stretched across the creek and were anchored to a tree and to two large pipe tripods (Figure 3) positioned on each side of the stream. The tripods were constructed from 2.5-inch (6.3 cm) galvanized metal pipes 16 feet in length, and anchored in place using fence posts driven into the ground and cabled to the legs of the tripod. The end of the main cable closest to the DVR-battery box was designed to allow easy movement up and down with a mechanical "come-along" so the camera could be raised or lowered to adjust for proper orientation and when camera maintenance or cleaning was required. During construction the cables and white plates were carefully positioned so that the overhead camera was directly overhead of the downstream edge of the middle of the white plates. Camera height above the plates was about 15-feet (4.6 m) allowing the entire white plate area to be in the field of view of the camera. 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 and were run from the overhead stream camera box shown in Figure 5 to the station's electronic lock box seen in Figure 4. In years 2007 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.

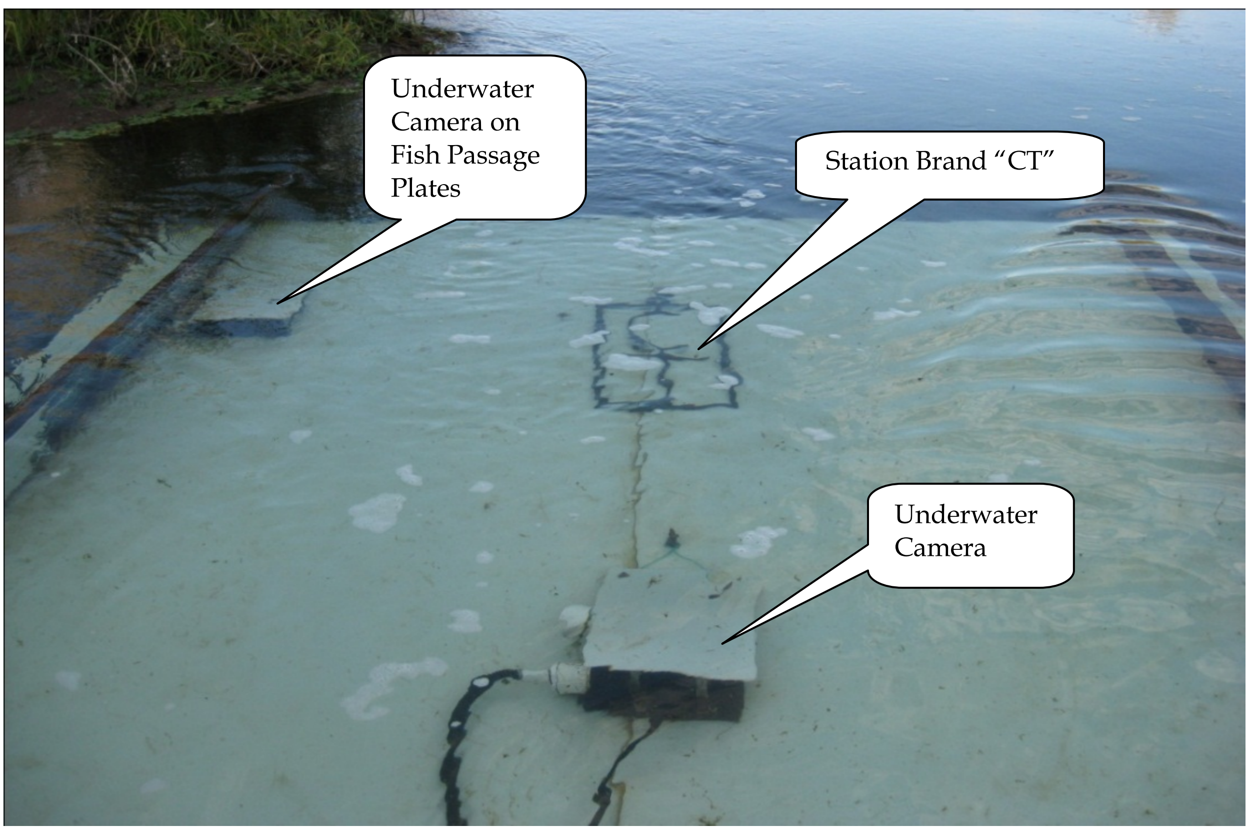

Figure 6. Image of underwater camera system on Cottonwood Creek with white plates and station measuring brand with creek identifier "CT". Three camera set-up with two in the middle facing opposite directions and one at the top left.

In response to the need for identifying passing fish species at video stations the RBFO staff developed low-cost underwater camera housings 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, PC165HR, and PC221-models. All were low light capable and models PC165HR 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 at the video station to monitor salmon passage. Cameras were oriented perpendicular to the stream flow to record the passage of salmon as they move upstream past white plates anchored to the streambed seen in Figure 6. The underwater cameras helped monitor upstream and downstream fish passage. They also helped in species identification and determining biological characteristics such as sex and presence of adipose fin-clipped hatchery-origin salmon. The cameras were protected inside custom-made Poly Vinyl Chloride (PVC) enclosures with a water-proof 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. The 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 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 Cottonwood 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 (2007) and creek DVR's to the RBFO.
- Downloading creek recordings into Honeywell DVR.
- Reading recordings.

The Cottonwood Creek video station was more complex to install than other similar stations in use (2011 Battle, Cow and Mill Creeks). The lack of riparian trees in the wide flood plain and sharp cut bank at the site necessitate installation of two tripods to hold the overhead cables. Additionally, the station must be removed completely each year to avoid damaging floods and vandalism. At most other stations, equipment can remain partially installed during the off season which reduces construction time each season. The Cottonwood Creek video station is installed each September and normally takes between three and four days with a crew of four to seven personnel. Due to numerous fall-run surveys 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) when the Cottonwood Creek station is in low maintenance operational status.

Staff from the RBFO and in years 2007-2009 staff from the WSRCD would coordinate to visit the station once a day to 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 2007 and early in the 2008 field season VCR tapes were switched daily. The purchase of three creek DVR units for Cottonwood Creek in October of 2008 replaced the need for daily tape changes with once a week DVR changes. The four-camera creek DVR's with their internal hard-drives were capable of recording up to four cameras for seven 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 (Mondays) to change 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 a Honeywell Fusion III DVR (Honeywell) 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 7 provides an example of the video images the 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).

Because of multiple fall-run video stations the Honeywell 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 Cottonwood 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 in a electronic lockbox at the creek to record date and time of cleanings, DVR changes, back up tests, and any other noteworthy events. Appendix Figure B6 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. The first office log contained information detailing the time, dates, and numbers of the DVR's that were returned to the office for downloading into the Honeywell. Appendix Figure B7 provides an example of such a log for the 2011 Cottonwood station.

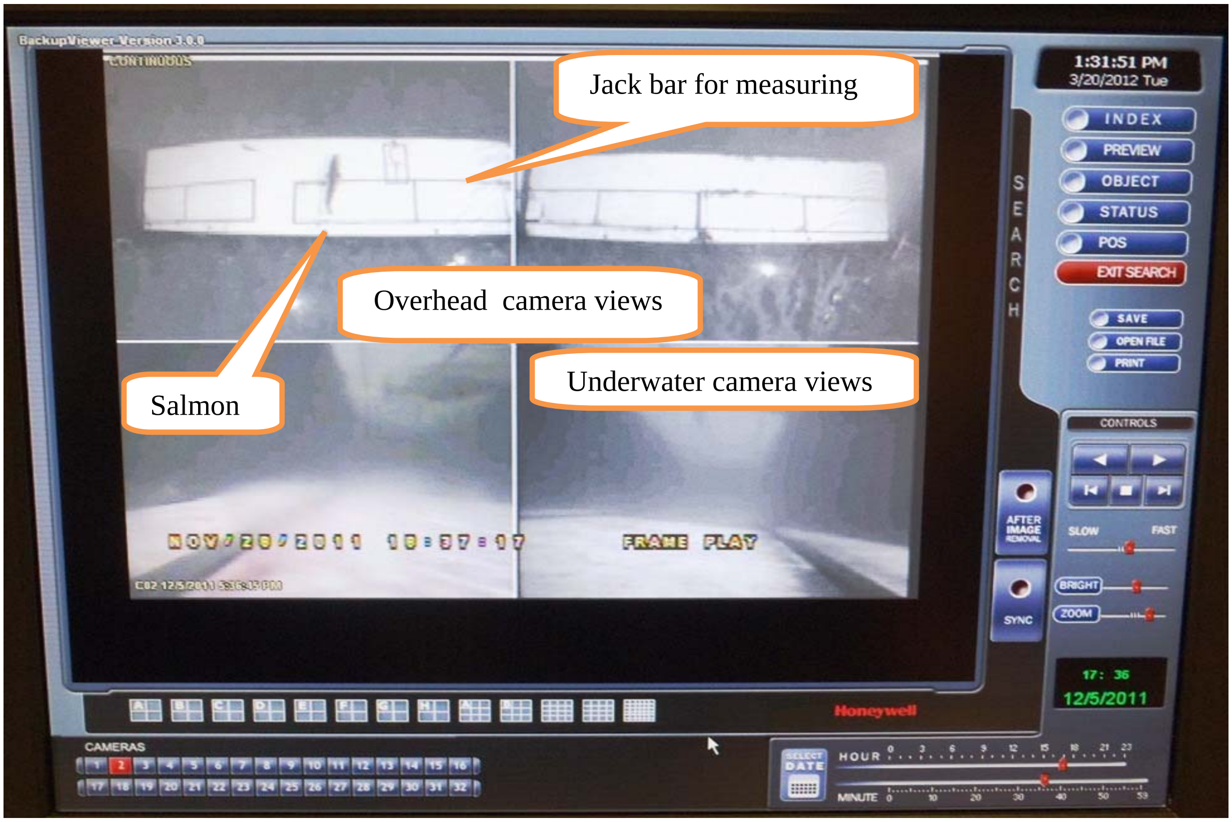

Figure 7. Image of Honeywell DVR computer screen with 2011 Cottonwood Creek video station footage uploaded for fish passage reading.

The second log was used to keep track of the identification of the numerous external hard-drives (LaCie model 301304U) that the Honeywell DVR, stored the recordings on. This log (shown in Appendix Figure B8) was the primary tool used by readers to find the external hard-drive that contained the footage they were searching for to complete the fish counts for each day. Each external hard-drive was individually numbered and labeled as to what creeks and dates it 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 (Figure 7) was then opened and reading would commence.

The Honeywell 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 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 earlier video stations (Battle and Cow Creeks) that the changing environmental conditions during daily cycles made the use of motion detection software unreliable. Conditions (as viewed from the overhead camera) such as shadows, camera movement induced by wind, sun reflections and glare, night light reflections, 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 or other species that passed up or downstream of the upper end of the white plates were counted as shown in Figures 7 and 8.

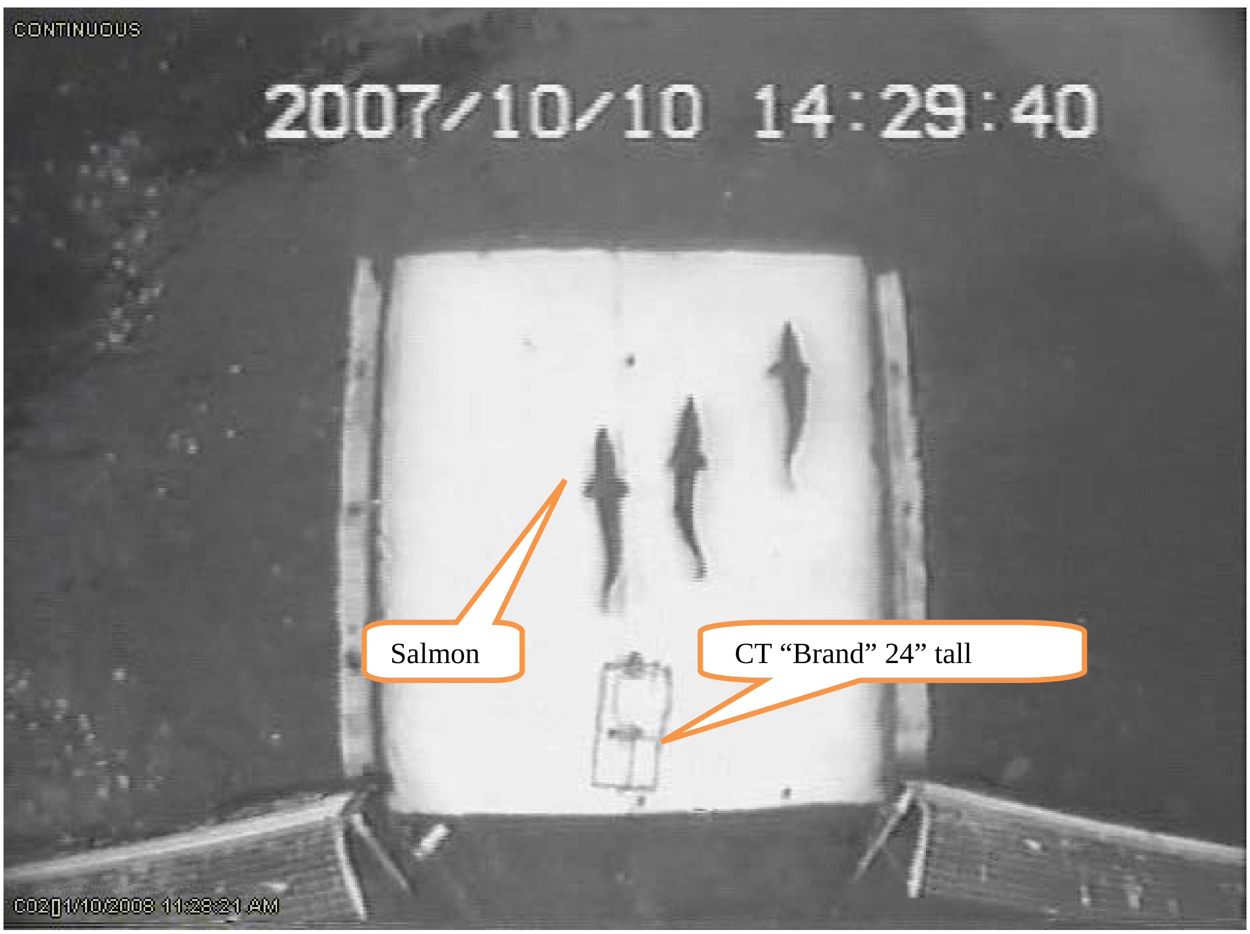

Figure 8. View from the overhead camera looking down on the fish passage opening of the 2007 Cottonwood Creek Video Station.

The number of salmon passing upstream and downstream of the white plates was tallied on a datasheet. Appendix Figure B9 provides an example of a completed datasheet from 24 October

2011. Other species were also counted on the data sheet. 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. Readers were instructed to read recorded footage from each season beginning to end. Normally readers could read two to four days of creek recordings per reader work-day. At times 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 a Microsoft Excel file and Microsoft Access file. 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 external hard-drives.

Data Adjustments to Original Reader Counts

The Cottonwood 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.

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 2007 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 to be developed.

3. A few times each year a walking survey was made downstream of the station to the confluence with the Sacramento River. 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.

2011 Quality Control Methods

In years 2007 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 Cottonwood 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 Cottonwood 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, 2010). 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 Cottonwood Creek station estimate. This method is presented in depth in Appendix C and was used for the Cottonwood station 2011 data.

Water Temperature Data 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 Cottonwood 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/queryF?s=CWA. This data is collected at the U.S Geological Survey's Cottonwood Creek stream gauge located about a mile 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 Cottonwood Creek in mid-winter. In most years, during periods of 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 B10 provides an example of the flow differences that can be observed at the video station during the year.

At any time when a major storm was forecast, a decision to remove the weir had to be considered. Concern for damage as shown in Figure 9 or loss of the weir 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 in Battle and Cow Creeks have already passed by this date (Killam 2006, 2007). Early years of Cottonwood Creek data as shown in Table 2 also indicated that the majority of the passage had also 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 in operation. 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 B10 was expected, the station was removed for the year. In years 2008 and 2011 the station operated until late-December (2008) and mid-January (2011). The data collected during those years showed very little fish passage after mid-December and provided biologists with knowledge that Cottonwood Creek does not have a late-fall-run Chinook salmon population similar to the populations of late-fall-run on the mainstem Sacramento River and Battle Creek.

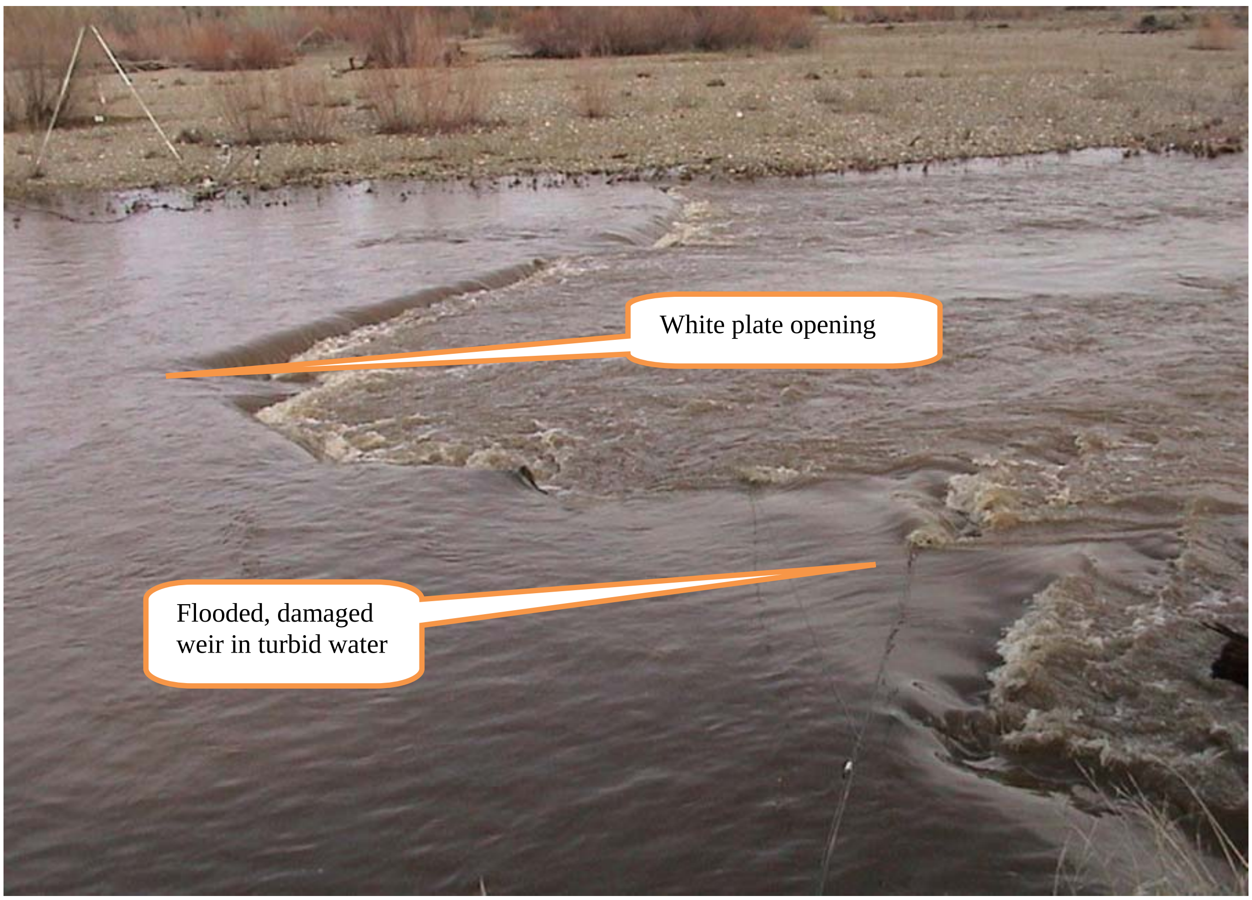

Figure 9. Image of weir during period of turbid water and minor flooding during the 2009 season at Cottonwood Creek. Weir was rebuilt and continued operation after this flood.

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 Cottonwood Creek video station was first operated in 2007, following successful operations on Cow Creek in 2006 and modeled after Battle Creek station beginning 2003 (Killam).

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 Cottonwood Creek occurred in October, with the most fish passing in the second week of this month.

Table 2. Summary of adjusted counts of fall-run Chinook salmon passage at the Cottonwood Creek video station by month and week for years 2007 through 2011.

MONTH		2007	2008	2009	2010	2011
September		1	2	3	0	5
October		1,051	364	910	827	1,477
November		153	137	140	312	660
December		9	7	12	0	2
January		n/a	n/a	n/a	n/a	0
Week	**Dates**					
37	07-Sep - 13-Sep	n/a	n/a	n/a	n/a	n/a
38	14-Sep - 20-Sep	n/a	0	n/a	0	0
39	21-Sep - 27-Sep	1	1	21	0	5
40	28-Sep - 04-Oct	17	14	176	25	596
41	05-Oct - 11-Oct	666	43	537	17	148
42	12-Oct - 18-Oct	258	155	121	294	113
43	19-Oct - 25-Oct	75	93	59	452	497
44	26-Oct - 01-Nov	63	83	84	166	370
45	02-Nov - 08-Nov	57	90	26	131	271
46	09-Nov - 15-Nov	38	8	22	38	122
47	16-Nov - 22-Nov	16	9	6	15	19
48	23-Nov - 29-Nov	15	7	1	1	-1
49	30-Nov - 06-Dec	8	0	0	n/a	2
50	07-Dec - 13-Dec	0	0	11	n/a	2
51	14-Dec - 20-Dec	0	0	1	n/a	0
52	21-Dec - 27-Dec	0	6	n/a	n/a	0
1	28-Dec - 03-Jan	0	1	n/a	n/a	0
2	04-Jan - 10-Jan	n/a	n/a	n/a	n/a	0
3	11-Jan - 17-Jan	n/a	n/a	n/a	n/a	0
Total Counts		**1,214**	**510**	**1,065**	**1,139**	**2,144**

This was generally similar to the other video monitored tributaries (Cow and Battle creeks) in the Upper Sacramento River Basin. 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

Cottonwood 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 consistent steps followed each year to generate a final estimate.

The Cottonwood 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. Missing time periods due to turbid water, adjustment for periods when the weir was deliberately lowered, and equipment failures.
Step 2. Quality control (QC) adjustments to raw counts.
Step 3. Adjustment to the final QC count to account for salmon which may have spawned in the creek's 1.2-miles (1.93 km) below the weir site.

Data Adjustments and Discussion by Years

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.

2007

The final adjusted estimate of fall-run salmon entering Cottonwood Creek for the 2007 season was 1,250.

- The dates of operation were from 17 September through 06 December.
- The original number of salmon counted on the upward migration was 1,241.
- There were four half-hour periods of turbidity where readers were unable to discern fish passage; this data is available in Table 3.
- The QC adjustment resulted in subtraction of 27 salmon from the original counts. In 2007 the QC process stratified the data by reader and type of count (low, medium and high). Details of the 2007 QC process are given in Killam, 2008.
- There were 18 redds found below the weir resulting in 36 salmon added to the final adjusted count.
- 2007 was the first year a video monitoring station was constructed on Cottonwood Creek. Design was based on Battle and Cow Creek video stations.
- The highest flow levels recorded for the season on Cottonwood Creek were 318 cfs on 6 December when the weir was removed.
- Appendix Figure B1 illustrates the 2007 video monitoring station on Cottonwood Creek.

2008

The final adjusted estimate of fall-run salmon entering Cottonwood Creek for the 2008 season was 510.

- The dates of operation were from 13 September through 29 December.
- The original number of salmon counted on the upward migration was 462.
- Table 3 shows there were 123 half-hour periods of turbidity and 175 half-hours of equipment failures where missing time periods of fish passage occurred. Equipment failures were related to a malfunctioning overhead camera and the underwater cameras were used to provide fish passage counts.
- 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 and equipment failures. This resulted in the addition of 48 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 393 cfs on 4 November. Fish passage could not be observed due to muddy water at this time.
- Appendix Figure B2 illustrates the 2008 video monitoring station on Cottonwood Creek.

2009

The final adjusted estimate of fall-run salmon entering Cottonwood Creek for the 2009 season was 1,065.

- The dates of operation were from 21 September through 21 December.
- The original number of salmon counted on the upward migration was 742.
- Table 3 shows there were 389 half-hours of turbidity and 156 half-hours of time where panels of the weir were laid down to prevent damage.
- During these turbid periods an additional 313 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 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 first used to identify adipose fin clips. Readers reported five adipose-fin clipped salmon (indicating hatchery origins) observed out of a total of 643 salmon observed for these clips.
- There were five redds found below the weir resulting in ten salmon added to the final adjusted count.
- Damage to the weir occurred early during the 2009 season on 19 October when the flows reached 465 cfs and some weir panels were washed just downstream by the high flows shown in Figure 9.
- Appendix Figure B3 illustrates the 2009 video monitoring station on Cottonwood Creek.

2010

The final adjusted estimate of fall-run salmon entering Cottonwood Creek for the 2010 season was 1,139.

- The dates of operation were from 15 September through 30 November.
- The original number of salmon counted on the upward migration was 761.
- Table 3 shows there were 217 half-hours of turbidity and 166 half-hours of time where the weir was partially lowered to prevent flood damage during high flows.
- Three white plates were used for the first time to create a larger opening to aid in flood flow passage resulting in 15 x 10 foot (4.6 x 3.0 m) fish passage opening.
- During these turbid water periods an additional 376 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 was one redd found below the weir resulting in an addition of two salmon to the final adjusted count.
- The 2010 video station experienced major flooding. Flows reached a high of 2,120 cfs on 24 October. The weir was completely submerged during this event but counting resumed just 52-hours later as the creek cleared and the weir panels were placed upright again. This flow was the highest on record for the creek when the station was in operation.
- 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 2009 shown in Figure 9.
- Appendix Figure B4 illustrates the 2010 video monitoring station on Cottonwood Creek.

2011

The final adjusted estimate of fall-run salmon entering Cottonwood Creek for the 2011 season was 2,144 with 90% confidence intervals from 2,038 to 2,250.

- The dates of operation were from 12 September through 19 January, 2012. One fish was documented after 15 December and included in the estimate of 2,144 but was likely to be a late-fall-run salmon which had strayed.
- The original number of salmon counted on the upward migration was 2,031.
- Table 3 shows there were no periods of adjustment due to turbidity or equipment failures. The 2011 season was exceptionally dry compared to previous years.
- Beginning in 2011 funding enabled development of a statistical based QC methodology designed to produce confidence intervals around the final estimate. The results of this effort are discussed below.

- 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.
- In 2011, flows remained between 100-200 cfs during the entire season and did not result in any disturbance to video counts.
- In 2011, there was a simultaneous effort between the USFWS, PSMFC and the CDFG to conduct in-creek carcass surveys and operate the video monitoring station on Cottonwood Creek. These surveys are described below and data collected is presented in Figure 10.
- 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 10 foot (12.2 x 3.0 m) fish passage opening. This opening width required two overhead cameras to span the entire width (see Figure 7). 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 blind area between underwater cameras. RBFO staff determined that this method would not be continued in future years.
- Appendix Figure B5 illustrates the 2011 video monitoring station on Cottonwood Creek.

2011 Quality Control Results

The quality control methodology designed to develop confidence intervals for the video station data in 2011 involved several steps to the original and adjusted counts to calculate the estimate and confidence intervals. These steps and results of the process were as follows:

Step 1 Select a subset of the original high count periods to re-read. For 2011 all periods with original counts greater than four (n = 82) 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. 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 82 periods was 595 salmon and the QC high total was 634 reflecting an increase of 39 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 = 89 of 904) were randomly chosen (i.e. every 20th period) using the same consensus QC approach. These QC low counts replaced the corresponding original counts. The total fish from the 89 original low counts was 153 salmon and the QC low count total was 161 reflecting an increase of 8 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 = 6,046). In 2011 counts of zero (n = 5,147) and below (n = 84) 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: below reflects a downstream net movement of one (n = 78) or two (n = 6) salmon). The adjustment factor (x = 0.9503) was applied to them but had no effect on the zero counts (i.e. 0 / 0.9503 = 0).

Step 3 Sum the QC high counts, the QC low counts, and the adjusted non-QC low counts to determine a final population estimate. The confidence intervals were then developed using the formulas in Appendix C. The 2011 estimate of 2,144 that resulted was the sum of 634 (QC-high) plus 161 (QC- low) plus 1,349 (non-QC adjusted-low). Confidence intervals of 2,038 and 2,250 were made at the 90% level around this estimate. The final estimate of 2,144 differs by 114 salmon (5.6%) from the original count of 2,030 reflecting the increase in fish counts during the high and low QC re-reads.

This process can be repeated with similar QC efforts on other video stations. In 2011 there were no flooded or equipment failure periods on the Cottonwood data. These 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. This process involves utilizing the average of observable counts pre and post time periods to the missing counts. 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 2007-2011 these expensive ($80,000) devices were not available to RBFO staff. The judgment of the biologist plays a role in determining if the missing counts should be adjusted differently as a result of environmental conditions at the creek. A hypothetical example of the 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. These methods can be adjusted if fish passage conditions in the creek changed as a result of the flooding. An example might be that a storm triggered initial fish movement. In this hypothetical case the biologist might use knowledge of the creek patterns (judgment) to average the two post-flood periods since there would have been no movement of fish before the storm due to low water and using the pre-period to average for the missing turbid period would not make biological sense.

A new methodology is being developed to eliminate the need for the averaging methods for video station data with a large number of flooded periods (e.g. 2009 data, see Table 3). This method, currently in development, will utilize a general additive model (GAM) bootstrapping approach to impute for the missing periods (R. Nielson, WEST, personal communication). The new GAM method will not replace the need for careful analysis and judgment from the biologist analyzing the data, but will produce a statistically valid method of imputing for missing periods and provide a final estimate and confidence intervals.

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 89% in 2009 to 100% in 2011. No adjustments were made for normal conditions. When the creek was turbid, counts were averaged by the

RBFO biologist based on periods immediately before and after the turbid water conditions. Turbid conditions ranged from a low of 0% in 2011 to a high of 8% of total time in 2009. Weir panels were sometimes lowered during periods of normal conditions to prevent expected flood damage (e.g. rain was predicted to cause flooding at night, so crews would lower weir during the day). 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. This condition occurred in only two years and ranged from 3.2% in 2009 to 4.6% of the total yearly time in 2010. Periods of equipment failures were experienced in only 2008 and occurred for 3.2% 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.

Table 3. Summary of viewing conditions by half-hour periods and percentage of total for each year at the Cottonwood Creek video station during years 2007-2011.

Number of half-hour periods and (%) by condition type					
Year	Normal (clear water)	Turbid (flooding)	Weir lowered (avoid damage)	Equipment failure	Totals
2007	3,758 (**99.9**%)	4 (**0.1**%)	0 (**0**%)	0 (**0**%)	3,762
2008	5,129 (**94.5**%)	123 (**2.3**%)	0 (**0**%)	175 (**3.2**%)	5,427
2009	4,374 (**88.9**%)	389 (**7.9**%)	156 (**3.2**%)	0 (**0**%)	4,919
2010	3,256 (**89.5**%)	217 (**6.0**%)	166 (**4.6**%)	0 (**0**%)	3,639
2011	6,219 (**100**%)	0 (**0**%)	0 (**0**%)	0 (**0**%)	6,219

Biological results for video station and kayak carcass survey

The Central Valley Chinook Salmon In-River Escapement Monitoring Plan 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 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). In 2010 and 2011 data from the video station cameras provided 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 within observable viewing range of the underwater cameras during years 2010 and 2011. Readers were instructed to provide data for each 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 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 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 passing salmon at the Cottonwood Creek video station for years 2010 and 2011.

YEAR	VALUE	LENGTH		SEX			ADIPOSE FIN STATUS		
		LARGE	SMALL	FEMALE	MALE	UNKNOWNS	NO-CLIP	CLIPPED	UNKNOWNS
2010	Number	718	137	105	461	279	582	51	213
	Percent	**84%**	**16%**	**19%**	**81%**	**33% of Total**	**92%**	**8%**	**25% of Total**
2011	Number	119	224	48	295	1,951	312	38	1,944
	Percent	**35%**	**65%**	**14%**	**86%**	**85% of Total**	**89%**	**11%**	**85% of Total**

The large number of two-year old jack salmon present in the escapement in the Central Valley is also 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 7). It also reduced the number of underwater cameras to two and increased the width each was expected to view. As a result, viewers were unable to distinguish the sex and fin-clip status of 85% of the upstream passing salmon in 2011 as compared to a range of 25 to 33% of unknowns in 2010. 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) opening.

The biological data collected by the cameras at the video station is of greater utility when analyzed with other data sources. In 2011 the USFWS Comprehensive Monitoring Program funded the PSMFC to conduct kayak surveys of Cottonwood Creek overseen by the USFWS Red Bluff Fish and Wildlife Office. The results of this survey are detailed in a separate USFWS report, in progress, (R Null, USFWS, personal communication) and are provided in summary in here. The kayak carcass surveys were completed between 12 October and 14 December, 2011. During 30 surveys, a total of 339 non-clipped and 54 adipose fin-clipped salmon (13.7%) were observed. In comparison, the video station observed 312 non-clipped and 38 adipose fin-clipped salmon (10.9%), (see Table 4 and Figure 10). The similarity in results between the two independent surveys in Figure 10 demonstrates the effectiveness of the underwater camera imaging in documenting adipose fin-clips at the video station.

The kayak surveys allowed crews to retrieve coded-wire tags, scales, and other useful information on the spawning population in Cottonwood Creek that the video station alone could not. The data on the adipose fin-clipped salmon from the kayak surveys and video station was important because it provided information on the management of hatchery programs designed to increase the overall knowledge of how hatchery salmon are interacting with natural-origin salmon populations in California.

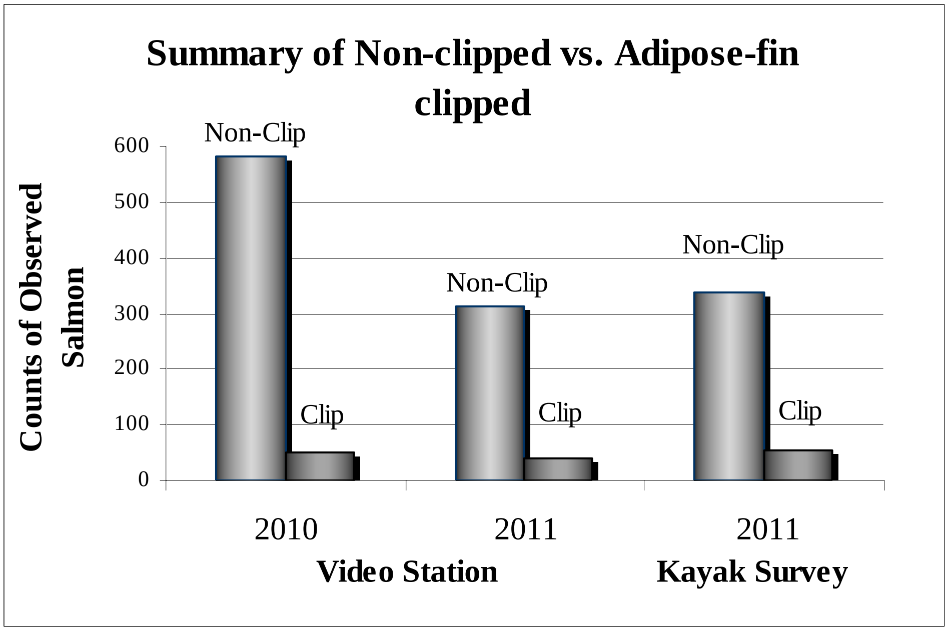

Figure 10. Video station and kayak survey adipose fin-clip data for years 2010 and 2011 on Cottonwood Creek.

Beginning in 2007 an intensive Constant Fractional Marking 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 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 the kayak survey produces the actual coded-wire-tags that allow for development of expanded hatchery-origin salmon estimates in Cottonwood Creek.

An estimate of the number of hatchery-origin fish in Cottonwood Creek was developed using the preliminary kayak survey coded-wire-tag results and expanding these for the number of unmarked hatchery fish associated with each tag code, (e.g. for every one tag recovered there could have been three additional unmarked (not clipped) hatchery raised fish). By summing the number of fish with tags, and the numbers of fish from the expansion factors for each tag code a total hatchery-origin estimate could be determined. A total of 1,176 or 54.8% of the Cottonwood Creek spawner escapement of 2,144 was determined to be of hatchery-origin using this method.

Relationship between passage timing, temperature and flow

A summary of the passage count by month is provided in Figure 11. Peak passage occurred in the October of each year with nearly 100% of fall-run salmon passage taking place in the months of October and November each year. 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 Cottonwood Creek until later in the year. In a typical year the flows in Cottonwood Creek 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 preclude fall-run from entering into Cottonwood Creek. As air temperatures cool in the late-summer and early fall the 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 Cottonwood Creek to begin is likely due to cooling water temperatures and to a lesser extent higher water flows.

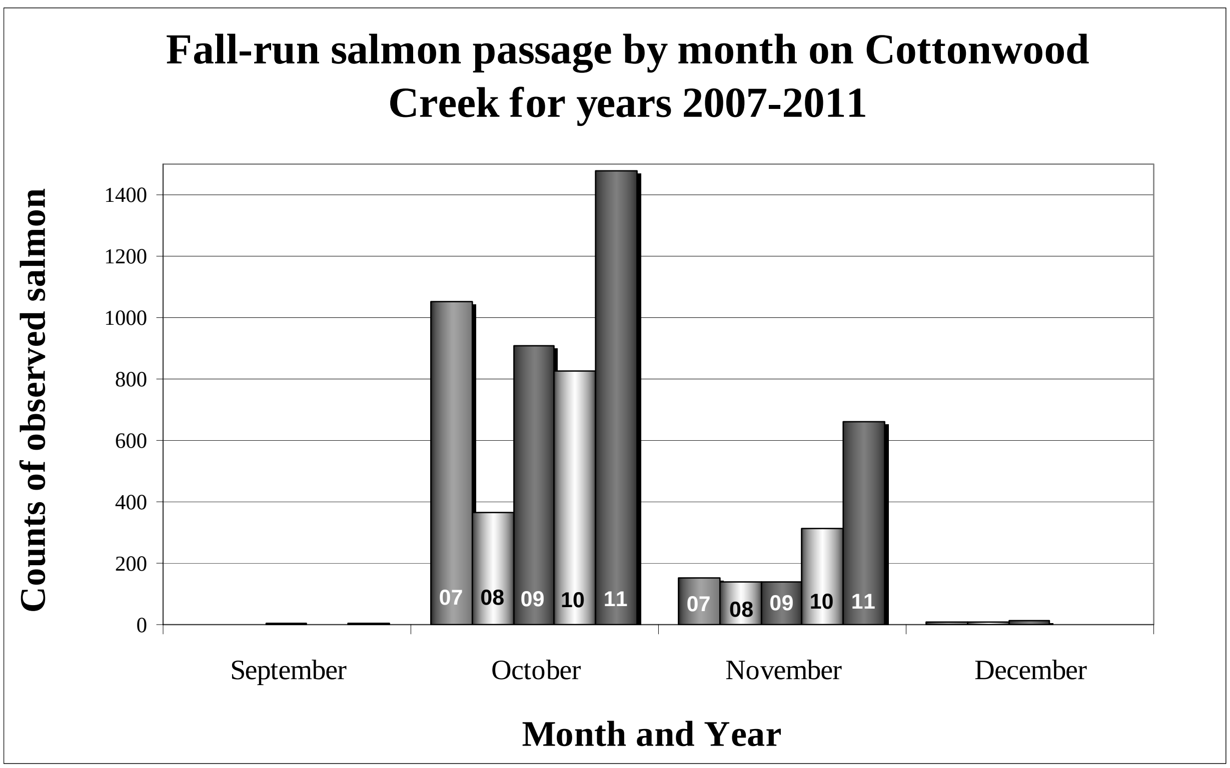

Figure 11. Fall-run Chinook salmon counts by month at the Cottonwood Creek video station for years 2007-2011.

Table 5 provides the monthly passage data with average flows and water temperatures for the video station each year. Peak passage occurred during the month of October each year corresponding to water temperatures ranging from 62-65 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 each month. Table 5 also lists average stream discharges collected at the

USGS's Cottonwood Creek (CWA) flow gauge upstream of the video station, which allows comparison for fish passage and flow events. Cottonwood Creek lacks any large scale water diversions (CH2MHILL, 2002) so flows are primarily related to storm events and typically increase as the fall rainy season begins. But as Table 5 shows (i.e. October-November 2007) 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 Cottonwood Creek to be driven by lowering water temperatures in the fall of each year.

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

Month	Total Salmon Passage	Percent Passage by Month	Cumulative Percent Passage	Average Water Temperature	Average Water Flow (cfs)
2007					
September	1	0%	0.1%	67.8	57
October	1,051	87%	86.7%	62.0	69
November	153	13%	99.3%	56.0	54
December	9	1%	100.0%	49.2	132
2008					
September	2	0%	0.4%	71.3	66
October	364	71%	71.8%	63.5	90
November	137	27%	98.5%	55.7	155
December	7	1%	100.0%	50.5	110
2009					
September	3	0%	0.3%	74.0	60
October	910	86%	85.8%	65.0	130
November	140	13%	98.0%	55.0	128
December	12	1%	100.0%	46.0	207
2010					
September	0	0%	0.0%	70.2	101
October	827	73%	72.7%	63.6	223
November	312	27%	100.0%	52.3	275
2011					
September	5	0%	0.2%	73.0	106
October	1,477	69%	68.5%	63.9	129
November	660	31%	99.9%	52.4	130
December	2	0%	100.0%	45.4	118
January	0	0%	100.0%	44.2	97

CONCLUSIONS

1. The use of a video monitoring station on Cottonwood 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 Cottonwood Creek is between the months of September and December.

2. The number of fall-run salmon in Cottonwood Creek represented an average of 1.3% of the total fall-run spawner escapement to California's Central Valley between the years of 2007-2011.

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

4. Video station monitoring in Cottonwood Creek should be done in conjunction with in-creek kayak carcass surveys that provide data on the biological characteristics of the salmon population including: age, sex, hatchery-origins, and other data important to salmon management in California.

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

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APPENDIX A: Data Tables

Appendix Table A1. Summary of Cottonwood Creek Video station components for years 2007 through 2011.

Station Component	YEAR				
	2007	2008	2009	2010	2011
VCR	yes	1st half	no	no	no
DVR	no	2nd half	yes	yes	yes
Recording Back-up	VCR	VCR	VCR	DVR	DVR
Quad Processor	no	yes	no	no	no
Color Monitor	no	no	yes	yes	yes
Underwater Cameras	none	3	3	3	2
White Plates	2	2	2	3	4
Lights	2	2	2	2	3
Overhead Camera	1	1	1	1	2

Appendix Table A2. Daily salmon passage during years 2007 through 2011 at the Cottonwood Creek video station.

DATE	Salmon Passage 2007	Salmon Passage 2008	Salmon Passage 2009	Salmon Passage 2010	Salmon Passage 2011
12-Sep	n/a	n/a	n/a	n/a	0
13-Sep	n/a	0	n/a	n/a	0
14-Sep	n/a	0	n/a	n/a	0
15-Sep	n/a	0	n/a	0	0
16-Sep	n/a	0	n/a	0	0
17-Sep	0	0	n/a	0	0
18-Sep	0	0	n/a	0	0
19-Sep	0	0	n/a	0	0
20-Sep	0	0	n/a	0	0
21-Sep	0	0	0	0	0
22-Sep	0	0	0	0	0
23-Sep	1	0	0	0	0
24-Sep	0	1	0	0	0
25-Sep	0	0	0	0	0
26-Sep	0	0	0	0	0
27-Sep	0	0	0	0	2
28-Sep	0	1	0	0	3
29-Sep	0	0	1	0	0
30-Sep	0	0	2	0	0
1-Oct	1	0	1	0	0
2-Oct	0	0	1	0	10
3-Oct	0	7	16	0	51
4-Oct	1	6	53	15	80
5-Oct	0	18	17	4	196
6-Oct	15	4	10	1	126
7-Oct	11	0	11	-1	92
8-Oct	2	1	9	1	24
9-Oct	19	0	33	5	23
10-Oct	344	13	43	1	33
11-Oct	121	7	33	11	59
12-Oct	114	26	76	4	11
13-Oct	55	20	171	0	12
14-Oct	5	21	116	0	3
15-Oct	9	41	92	1	7

Appendix Table A2 Continued. Daily salmon passage during years 2007 through 2011 at the Cottonwood Creek video station.

DATE	Salmon Passage 2007	Salmon Passage 2008	Salmon Passage 2009	Salmon Passage 2010	Salmon Passage 2011
16-Oct	118	19	30	0	5
17-Oct	27	17	20	38	7
18-Oct	22	11	18	41	12
19-Oct	41	15	27	13	10
20-Oct	36	9	23	21	24
21-Oct	17	22	20	51	19
22-Oct	7	20	19	39	30
23-Oct	10	9	9	91	43
24-Oct	15	8	6	101	72
25-Oct	10	10	8	95	72
26-Oct	9	5	16	70	91
27-Oct	7	9	0	39	82
28-Oct	5	8	8	48	69
29-Oct	11	15	2	53	61
30-Oct	14	6	3	47	56
31-Oct	5	17	22	39	67
1-Nov	7	23	21	31	41
2-Nov	12	27	15	20	60
3-Nov	9	25	12	20	40
4-Nov	5	18	8	21	54
5-Nov	14	16	7	23	45
6-Nov	13	2	13	12	64
7-Nov	8	-1	9	29	69
8-Nov	7	3	10	28	37
9-Nov	6	1	2	27	32
10-Nov	4	1	4	21	20
11-Nov	8	2	2	11	24
12-Nov	9	2	3	9	21
13-Nov	11	1	2	6	24
14-Nov	4	0	3	12	27
15-Nov	1	1	10	8	24
16-Nov	4	4	3	8	20
17-Nov	1	2	5	2	19
18-Nov	3	-1	0	6	10
19-Nov	3	1	2	3	0

Appendix Table A2 Continued. Daily salmon passage during years 2007 through 2011 at the Cottonwood Creek video station.

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

Appendix Table A2 Continued: Daily salmon passage during years 2007 through 2011 at the Cottonwood Creek video station.

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

APPENDIX B: Figures

*Note to viewers, please use zoom function of your software to clearly view Appendix B images***.**

Appendix Figure B1. Photograph of 2007 Cottonwood Creek video station.

Appendix Figure B2. Photograph of 2008 Cottonwood Creek video station.

Appendix Figure B3. Photograph of the 2009 Cottonwood Creek video station.

Appendix Figure B4. Photograph of the 2010 Cottonwood Creek video station.

Appendix Figure B5. Photograph of the 2011 Cottonwood Creek video station.

THE COTTONWOOD 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	Did you Switch DVR DVR # you put in	TV Image good	CLEAN ? WEIR Plates	Clean UW Cameras?	DOES STATION NEED ATTENTION? ANY COMMENTS?
10/7/11	Friday	1333	MOZS	N	Y	Y	Y	clear conditions, lights good
10/8/11	Saturday	1125	DM	N	Y	Y	Y	armored panels far side
10/9/11	Sunday	1030	DM	N	Y	Y	Y	armored panels far side
10/10/11	Monday	1145	DM	Y 15	Y	N	N	rain
10/11/11	Tuesday	1115	DM	N	Y	Y	Y	normal clear flows, minimal debris
10/12/11	Wednesday	1430	MO	N	Y	Y	Y	all ok
10/13/11	Thursday	11:30	DK	N	Y	Y	Y	✓ Thermo Bat ✓ ok
10/14/11	Friday	12:30	DD	N	Y	Y	Y	ok
10/15/11	Saturday	1200	DM	N	Y	Y	Y	armored panels far side
10/16/11	Sunday	1315	DM	N	Y	Y	Y	finished armoring panels far side
10/17/11	Monday	1110	DM	14	Y	n	n	
10/18/11	Tuesday	1425	DM	N	Y	Y	Y	looking good :)
10/19/11	Wednesday	1116	BR	N	Y	Y	Y	(Checked Lights OK)
10/20/11	Thursday							
10/21/11	Friday	1130	DD	N	Y	Y	Y	plates Dirty
10/22/11	Saturday							
10/23/11	Sunday	1215	DM	N	Y	Y	Y	Alls well, mouse building nest in fridge
10/24/11	Monday	1115	DM	17	Y	N	N	
10/25/11	Tuesday							
10/26/11	Wednesday	1230	DM	N	Y	Y	Y	Alls seemingly well
10/27/11	Thursday	1110	DM	N	Y	Y	Y	
10/28/11	Friday	1145	DD	N	Y	Y	Y	looks good
10/29/11	Saturday	1350	DM	N	Y	N	N	self sufficent
10/30/11	Sunday							
10/31/11	Monday	1195	DM	15	Y	Y	Y	lights good, bat ✓ good
11/1/11	Tuesday	1215	DM	N	Y	Y	Y	
11/2/11	Wednesday	1245	DM	N	Y	Y	Y	light ✓ good bat ✓ good
11/3/11	Thursday							over head light in top right corner very dark
11/4/11	Friday	1219	DD	N	Y	Y	Y	Saw a Fish Swim across white plate :)
11/5/11	Saturday	1450	DM	N	Y	N	N	
11/6/11	Sunday	1030	DM	N	Y	Y	Y	light ✓ bat ✓
11/7/11	Monday	1245	DM	14	Y	N	N	light ✓ bat ✓ Fall back @ 1300

Appendix Figure B6. 2011 Cottonwood Creek video station “at creek” log for electronics and DVR equipment.

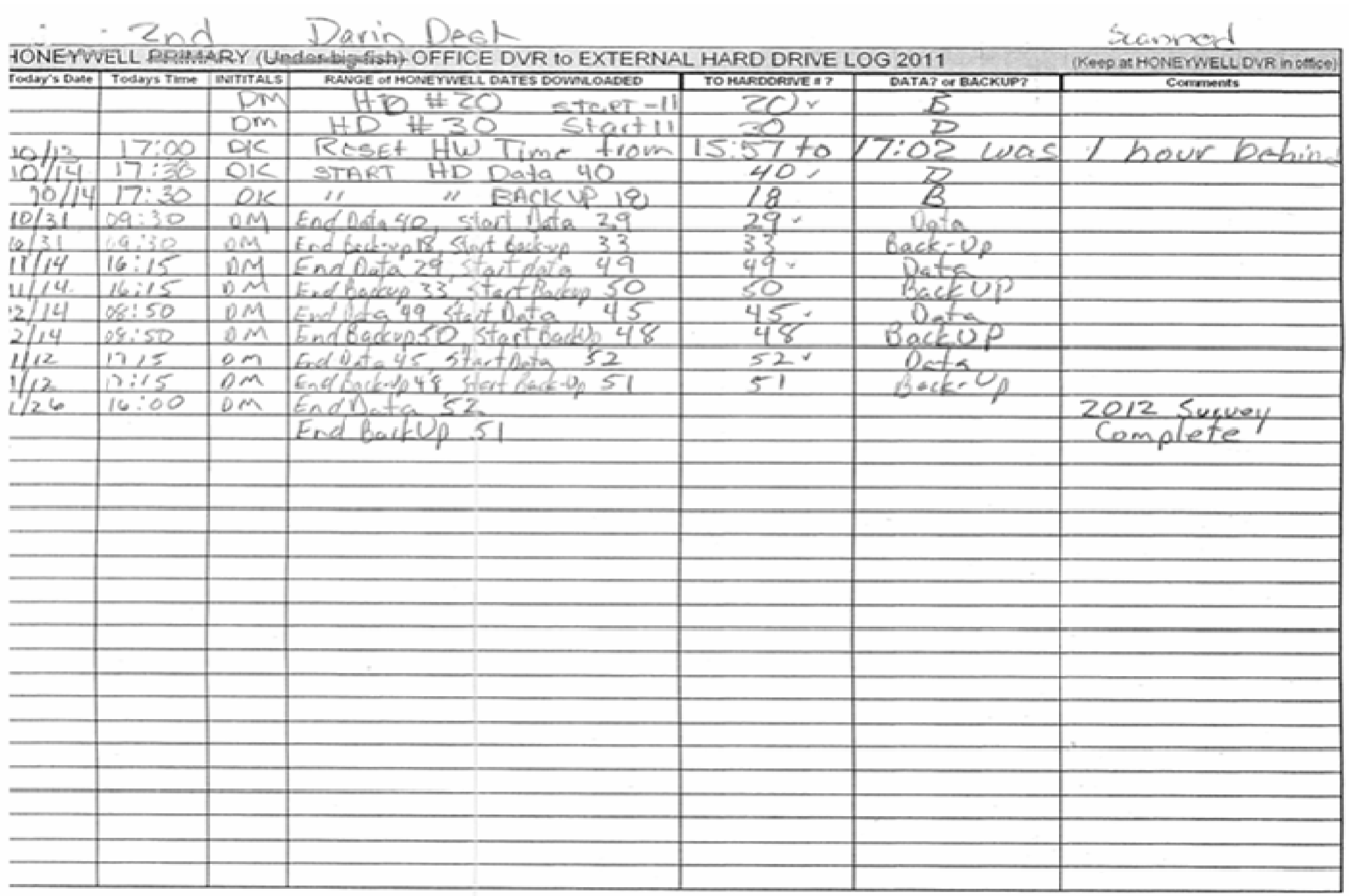
COTTONWOOD CREEK VIDEO STATION OFFICE DVR LOG 2011

Fill this out for DVR downloads from the creek DVR 's

(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
9/25	14:45	17	9/12	10:45	9/19	10:10	1	C	start of survey
9/26	15:00	15	9/19	10:10	9/26	10:10	2	C	
10/3	1720	14	9/26	10:10	10/3	16:18	1	C	
10/10	1315	17	10/03	16:21	10/10	11:49	2	C	
10/17	1200	15	10/10	11:49	10/17	11:11	1	C	
10/24	1230	14	10/17	11:11	10/24	11:15	2	C	
10/31	1430	17	10/24	11:15	10/31	11:47	1	C	
11/7	1415	15	10/31	11:47	11/7	13:00	2	C	
11/14	1355	14	11/7	13:00	11/14	11:53	1	C	
11/21	1430	17	11/14	11:53	11/21	11:52	2	C	
11/28	1700	15	11/21	11:52	11/28	15:32	1	C	
12/5	1440	14	11/28	15:32	12/5	11:13	2	C	
12/7	1400	17	12/5	11:13	12/7	11:55	1,3	M, M	Emergency Back-up DVR brought in, freezing weather
12/12	1630	10	12/7	11:55	12/12	13:42	1	C	
12/19	1615	15	12/12	13:42	12/19	13:59	2	C	
12/26	1500	14	12/19	13:59	12/26	13:19	1	C	
1/2	1510	10	12/26	13:19	1/2	13:03	1	C	electrical interruption 1 day delay
1/9	1430	E	1/2	13:03	1/9	12:32	2	C	
1/16	1530	14	1/9	12:32	1/16	13:43	2	C	
1/23	2000	C	1/16	13:43	1/17	12:57	2	C	End of Survey

Appendix Figure B7. 2011 Cottonwood Creek office log containing detailed information of date, time and creek DVR's.

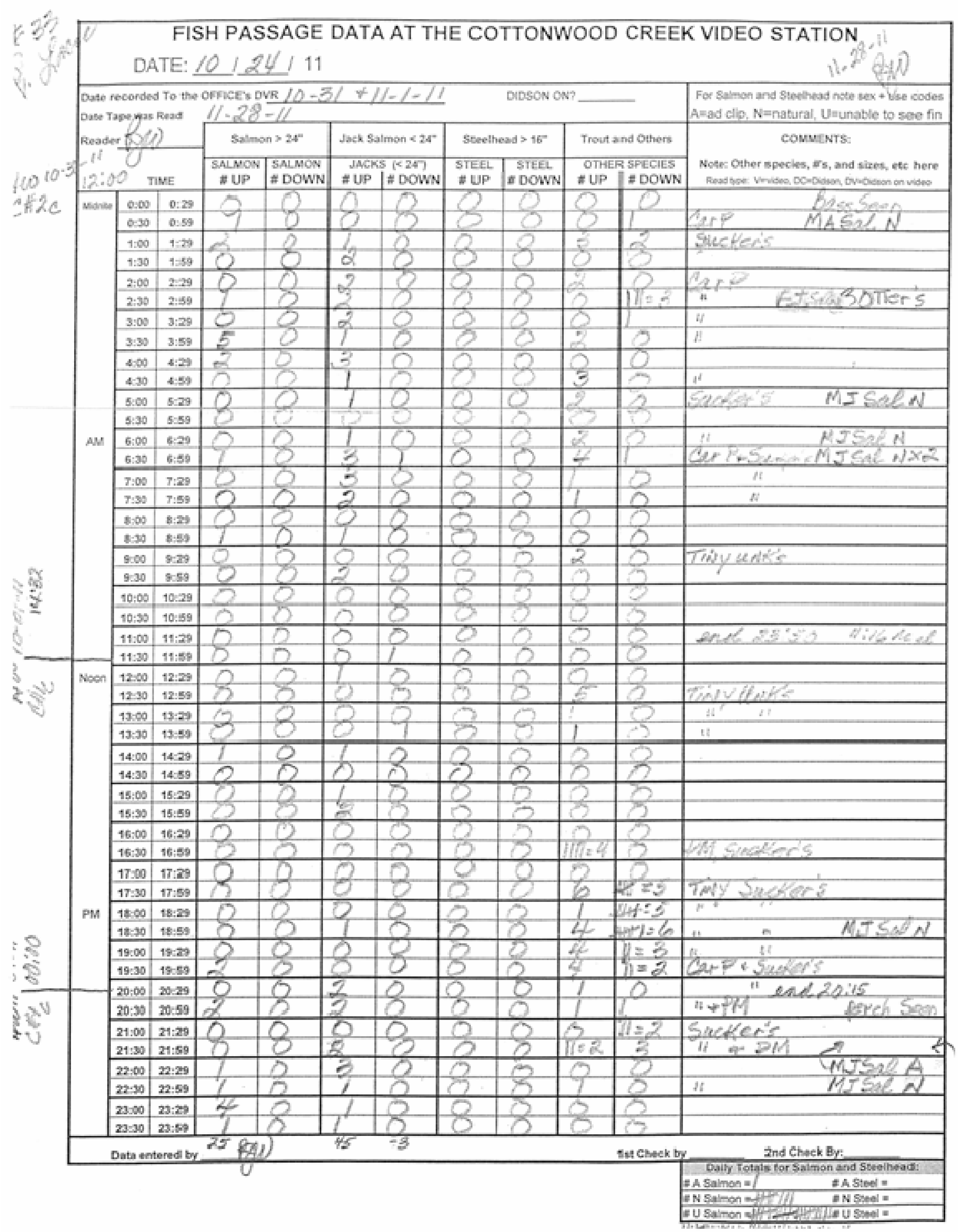


2nd Darin Deck Scanned

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	DK	Reset HW Time from	15:57 to	17:02 was	1 hour behind
10/14	17:30	DK	START HD Data 40	40 ✓	D	
10/14	17:30	DK	" " 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 backup 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
			End BackUp 51			Complete!

Appendix Figure B8. Primary log used to keep track of external hard-drives for the 2011 Cottonwood Creek video station.



FISH PASSAGE DATA AT THE COTTONWOOD CREEK VIDEO STATION

DATE: 10 / 24 / 11

Date recorded To the OFFICE's DVR 10-31 + 11-1-11 — DIDSON ON? ________

Date Tape was Read: 11-28-11

Reader: BAJ

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

	TIME		Salmon > 24" SALMON # UP	SALMON # DOWN	Jack Salmon < 24" JACKS (< 24") # UP	JACKS # DOWN	Steelhead > 16" STEEL # UP	STEEL # DOWN	Trout and Others OTHER SPECIES # UP	OTHER SPECIES # DOWN	COMMENTS: 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	Bass Seen
	0:30	0:59	1	0	0	0	0	0	0	1	Carp MA Sal N
	1:00	1:29	2	0	1	0	0	0	3	2	Sucker's
	1:30	1:59	0	0	2	0	0	0	0	0	
	2:00	2:29	0	0	2	0	0	0	2	0	Carp
	2:30	2:59	1	0	3	0	0	0	0	||=2	" 3 Otter's
	3:00	3:29	0	0	2	0	0	0	0	1	"
	3:30	3:59	5	0	1	0	0	0	2	0	"
	4:00	4:29	2	0	3	0	0	0	0	0	
	4:30	4:59	0	0	1	0	0	0	3	0	"
	5:00	5:29	0	0	1	0	0	0	2	2	Sucker's MJ Sal N
	5:30	5:59	0	0	0	0	0	0	0	0	
AM	6:00	6:29	0	0	1	0	0	0	2	0	" MJ Sal N
	6:30	6:59	1	0	3	1	0	0	4	1	Carp + Sucker's MJ Sal N x2
	7:00	7:29	0	0	3	0	0	0	1	0	"
	7:30	7:59	0	0	2	0	0	0	1	0	"
	8:00	8:29	0	0	0	0	0	0	0	0	
	8:30	8:59	1	0	1	0	0	0	0	0	
	9:00	9:29	0	0	0	0	0	0	2	0	Tiny unk's
	9:30	9:59	0	0	2	0	0	0	0	0	
	10:00	10:29	0	0	0	0	0	0	0	0	
	10:30	10:59	0	0	0	0	0	0	0	0	
	11:00	11:29	0	0	0	0	0	0	0	0	end [illegible]
	11:30	11:59	0	0	0	1	0	0	0	0	
Noon	12:00	12:29	0	0	1	0	0	0	0	0	
	12:30	12:59	0	0	0	0	0	0	5	0	Tiny Unk's
	13:00	13:29	0	0	0	0	0	0	1	0	" "
	13:30	13:59	0	0	0	1	0	0	1	0	"
	14:00	14:29	1	0	1	0	0	0	0	0	
	14:30	14:59	0	0	0	0	0	0	0	0	
	15:00	15:29	0	0	1	0	0	0	0	0	
	15:30	15:59	0	0	2	0	0	0	0	0	
	16:00	16:29	0	0	0	0	0	0	0	0	
	16:30	16:59	0	0	0	0	0	0	||||=4	0	VM Sucker's
	17:00	17:29	0	0	0	0	0	0	0	0	
	17:30	17:59	0	0	0	0	0	0	6	卌=5	Tiny Sucker's
PM	18:00	18:29	0	0	0	0	0	0	1	卌=5	" "
	18:30	18:59	0	0	1	0	0	0	4	卌|=6	" " MJ Sal N
	19:00	19:29	0	0	0	0	0	0	4	||=3	" "
	19:30	19:59	2	0	0	0	0	0	4	||=2	Carp + Sucker's
	20:00	20:29	0	0	2	0	0	0	1	0	" end 20:15
	20:30	20:59	2	0	2	0	0	0	1	1	" + PM Perch Seen
	21:00	21:29	0	0	0	0	0	0	0	||=2	Sucker's
	21:30	21:59	0	0	2	0	0	0	||=2	3	" + PM
	22:00	22:29	1	0	3	0	0	0	0	0	MJ Sal A
	22:30	22:59	1	0	1	0	0	0	1	0	" MJ Sal N
	23:00	23:29	4	0	1	0	0	0	0	0	
	23:30	23:59	1	0	1	0	0	0	0	0	
Data entered by			25 (BAJ)		45	-3					

1st Check by ________ 2nd Check By: ________

Daily Totals for Salmon and Steelhead:	
# A Salmon = 1	# A Steel =
# N Salmon = 卌 |||	# N Steel =
# U Salmon = [illegible]	# U Steel =

Appendix Figure B9. Cottonwood Creek video station example datasheet complete after reader has completed video footage for the day.

Appendix Figure B10. Upper image is of Cottonwood Creek during major flooding. Lower image is of Cottonwood Creek during typical flows for operation of the video station.

APPENDIX C: Documents

Appendix C: Methodology used to develop final estimate and confidence intervals for the 2011 Cottonwood Creek fall Chinook salmon population.

Estimating Escapement Using Video Monitoring Only

This document describes how to estimate escapement from video monitoring data when not paired with dual frequency identification sonar (DIDSON). In these situations, the video camera is set at a narrow passage through which migrating fish must pass to go upstream. The following Steps 1 – 8 describe how to analyze data from the video monitoring, assuming the video equipment runs nearly continuously throughout the season, and the video can be broken into equal-interval segments (e.g., ½-hour). In addition to this document the calculations described below are demonstrated for hypothetical data in Microsoft Excel spreadsheet ('Video Monitoring Escapement Example.xlsx').

1. One trained observer views each video segment and records the number of total fish passing upstream. Fish passing downstream are subtracted from the total passing upstream. These are referred to as the original counts. The example spreadsheet contains hypothetical counts from 100 video segments.

2. At least three trained observers view each video segment with an original count >5 and come to a consensus on the true total count. The example spreadsheet contains 10 such video segments. Let the sum of these total counts based on consensus be v_1 .

3. The remaining video segments have original counts that are $\leq$ 5. Obviously, there is bound to be some error in these counts as well, so an adjustment factor needs to be estimated. Because the total error in original counts of 0 fish is expected to be extremely small and represent less than 1% of the total escapement, we will estimate an adjustment factor for video segments with original and imputed counts between 1 and 5 fish. To do this, draw a systematic sample of video segments with counts between 1 and 5 fish. Prior to sampling, the video segments with counts of 1 to 5 fish are listed in sequential order (i.e., sorted by date and time). A systematic sample of these video segments is then taken from the sequential list. For example, if there are 1,000 video segments with counts between 1 and 5 fish, and a desired sample size is 100, then every 10th video segment is selected for the sample. The minimum sample size recommended is 75, but obviously more is better. Let t represent the realized sample size.

4. At least three trained observers view each sampled video segment from Step 3 and reach a consensus on the true total count for each segment. Let the sum of these total counts

based on consensus be v_2. An adjustment factor is then estimated for video segments with original counts between 1 and 5 fish. This adjustment factor ($\hat{p}$) is calculated as

$$\hat{p} = \frac{\sum_{i=1}^{t} Original_i}{\sum_{i=1}^{t} Consensus_i}.$$

Where $Original_i$ and $Consensus_i$ are the original and true counts for sampled video segment *i*, respectively. If $\hat{p} < 1.0$ the variance estimate for this adjustment factor is calculated as

$$\widehat{var}(\hat{p}) = \frac{\hat{p}(1-\hat{p})}{t-1}.$$

However, if $\hat{p} > 1.0$ substitute $(\hat{p}-1)$ for $\hat{p}$ in above equation.

5. Any missing video segments when the unit was not operational or the water was too murky to rely on the video taken should be corrected at this time. One option for imputing missing data is to use a Generalized Additive Model (GAM; *see* Chapter 2 of Bergman et al. 2012). However, use of the GAM after correcting original counts by the adjustment factor in Step 4 requires a complicated bootstrap procedure for estimating precision (confidence interval) for total escapement. A simpler alternative is to use expert judgment and/or the average of the previous and subsequent adjusted video count for the missing count, and not account for the lack of precision in the imputation.

6. The remaining (not sampled) counts from video segments with original and imputed counts between 0 and 5 are then adjusted by dividing the original count by $\hat{p}$. Let k be the total number of these video segments. The sum of the adjusted count, $\hat{A}$, is calculated as

$$\hat{A} = \sum \frac{n_i}{\hat{p}} = \frac{\sum_{i=1}^{k} n_i}{\hat{p}} = \frac{n}{\hat{p}}.$$

7. The final total escapement estimate is then calculated using

$$\hat{E} = v_1 + v_2 + \hat{A}.$$

8. Using the Delta Method (Seber 2002) and assuming p and n are independent, the variance for this escapement estimate can be approximated by

$$\widehat{var}(\hat{E}) = \hat{A}^2\left(\frac{\widehat{var}(n)}{n^2} + \frac{\widehat{var}(\hat{p})}{\hat{p}^2}\right).$$

where

$$\widehat{var}(n) = \frac{k\sum_{i=1}^{k}\left(n_i - \left(\frac{n}{k}\right)\right)^2}{k-1}.$$

It is important to recognized that calculation of $\widehat{var}(n)$ includes the original and imputed counts (n_i) from video segments with original counts = 0.0 and all video segments with counts between 1 and 5 that were not sampled in Step 3, but it does not include video segments with 'true' counts reached by consensus (Steps 2 and 4).

9. A confidence interval (CI) for total escapement can then be calculated using

$$\hat{E} \pm Z_{1-\alpha/2}\left(\sqrt{\widehat{var}\left(\hat{E}\right)}\right).$$

Thus, a 90% CI would use $Z_{0.05} = 1.645.$

The methods described above provide a defensible means of reducing variance in the escapement estimate by developing 'true' counts in fish passage for a subset of the video segments, developing an adjustment factor for the remaining video segments only viewed by one observer, and estimating a measure of precision (confidence interval) for the escapement estimate. If expert judgment and/or the average of the previous and subsequent adjusted video counts is used to impute missing data (Step 5) during a few occasions when the video equipment was not operational and the methods described above are used, the variance of the imputation process is not included in the total variance estimate (Step 8). However, the imputation process is likely to be minor compared to the variability in the adjustment factor (Step 4) and the adjusted counts (Step 8). Obviously, we cannot account for fish passage before and after camera operations.

LITERATURE CITED

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Seber, G. A. F. 2002. Estimation of Animal Abundance. Second edition. The Blackburn Press.