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2012 Spring Chinook Escapement to the Upper Basin of the Klickitat River Based on DIDSON Sonar Counts

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June 19, 2013

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EXECUTIVE SUMMARY

A Dual-Frequency Identification Sonar (DIDSON) sonar was deployed to observe passage of fish through the Castile Falls fishway on the Klickitat River, to obtain an estimate of 2012 spring Chinook *Oncorhynchus tshawytscha* escapement to the upper basin. The DIDSON was set up to continuously record sequential 1-hour files from July 2 until September 21. A total of 30 observations of medium to large-sized fish, presumed to be spring Chinook, were observed outside the fishway swimming from in an upstream direction. This estimate is similar in magnitude to the escapement estimates of 24 ± 4, 26 to 27, and 38 derived with the DIDSON in 2009, 2010 and 2011, respectively. Also similar to prior years, the 2012 estimate is substantially higher than the estimate of 15 at based on spawning ground surveys (5 redds observed X 3 fish/redd).

Unlike prior years, a similar set of observations were recorded with a video camera recently installed in a newly constructed monitoring facility. The video recordings, showed 45 fish passage events in the corresponding July-September period – 50% more than observed with the DIDSON. Also, the video images indicated that the majority of fish were steelhead (34 of 45; 76%), as opposed to spring Chinook (11 of 45; 24%). A video count of 11 spring Chinook is not dissimilar to the estimate of 15 based on expanded redd counts. Assuming that the species mix was similar across years, we readjusted our prior estimates of spring Chinook escapement for the years 2009 to 2011, making the new estimates to be only 6, 6, and 9 in 2009, 2010 and 2011, respectively. Similar to 2012, these lower estimates bring them closer in line with escapement estimates based on expanded redd counts for these years. However, these new estimates also indicate that spring Chinook are recolonizing the upper basin at a much lower rate than previously thought. Steelhead escapement in prior years was estimated as 18, 20 to 21 and 9 for 2009, 2010 and 2011, respectively.

INTRODUCTION

The Yakama Nation (YN) is actively involved in efforts to rebuild the spring Chinook *Oncorhynchus tshawytscha* population in the Klickitat River (YN 2008, and see www.ykfp.org/klickitat/). These efforts have included projects to renovate the Castile Falls fishway complex to facilitate recolonization of the upper basin. Castile Falls (rkm 103) is a series of 11 natural falls with a total vertical drop of 33 m over 1.0 km, located in the Klickitat River Gorge immediately upstream of the confluence with the West Fork of the Klickitat River – all within the boundaries of the YN reservation. Upstream of Castile Falls, the Klickitat and its tributary streams comprise 72 rkm, much of which would be prime spawning and juvenile rearing habitat for spring Chinook (YN 2008). The falls, however, created a near-total barrier to upstream migration of spring Chinook (and steelhead) into the upper basin of the Klickitat River (Figure 1).

In the early 1950s, the Washington Department of Fish and Wildlife (WDFW) signed a Memorandum of Agreement with the Yakama Nation (YN), the Bureau of Indian Affairs, and the US Fish and Wildlife Service to use Mitchell Act funds to finance a project to improve access for anadromous fish (spring Chinook and steelhead) to the upper Klickitat basin (YN 2008). The project involved construction between 1960 and 1962, of a fishway complex consisting of two tunnels - one 61 m in length which by-passes Falls #4 and #5, and a second 260 m in length which by-passes Falls #10 and #11 (the uppermost barrier). Additionally, dynamite blasting of Falls #1, #8 and #9 was performed to facilitate fish passage at these locations. The smaller Falls #2, #3 and #6 were not modified as they were not considered to be barriers. At the upstream end of the upper fishway tunnel, a 3-4 m high concrete dam was constructed to divert flow into the fishway (Figure 2A and 2B). Unfortunately, the design of the tunnels did not sufficiently preclude entry of rock and debris which is mobilized by the heavy flows that the river experiences each spring, and maintenance of the tunnels was inadequate. As a result, the tunnels became completely blocked within a few years of operation; and with the upstream dam creating an additional blockage for migration via the natural river channel, the upper basin became virtually inaccessible to spring Chinook (YN 2008).

YN projects to renovate the fishway complex began in 2002. Flow into the two tunnels was blocked, and the accumulated debris removed. The concrete stair-step fish ladder structure within each tunnel was demolished and replaced with a vertical slot design that would accumulate debris less readily, and maintain suitable entrance velocities and depth, head differences between pools, and maximum velocities at the weir slots. Trash racks were modified and a fore bay sluice gate installed in both tunnels to better preclude entry of debris and to facilitate its removal. In summer of 2005, renovation was complete and water flow through the fishway was reestablished. Later that same year, spring Chinook redds were observed during walking surveys of the river in the upper basin, presumably the result of fish successfully accessing the upper basin via the renovated fishway.

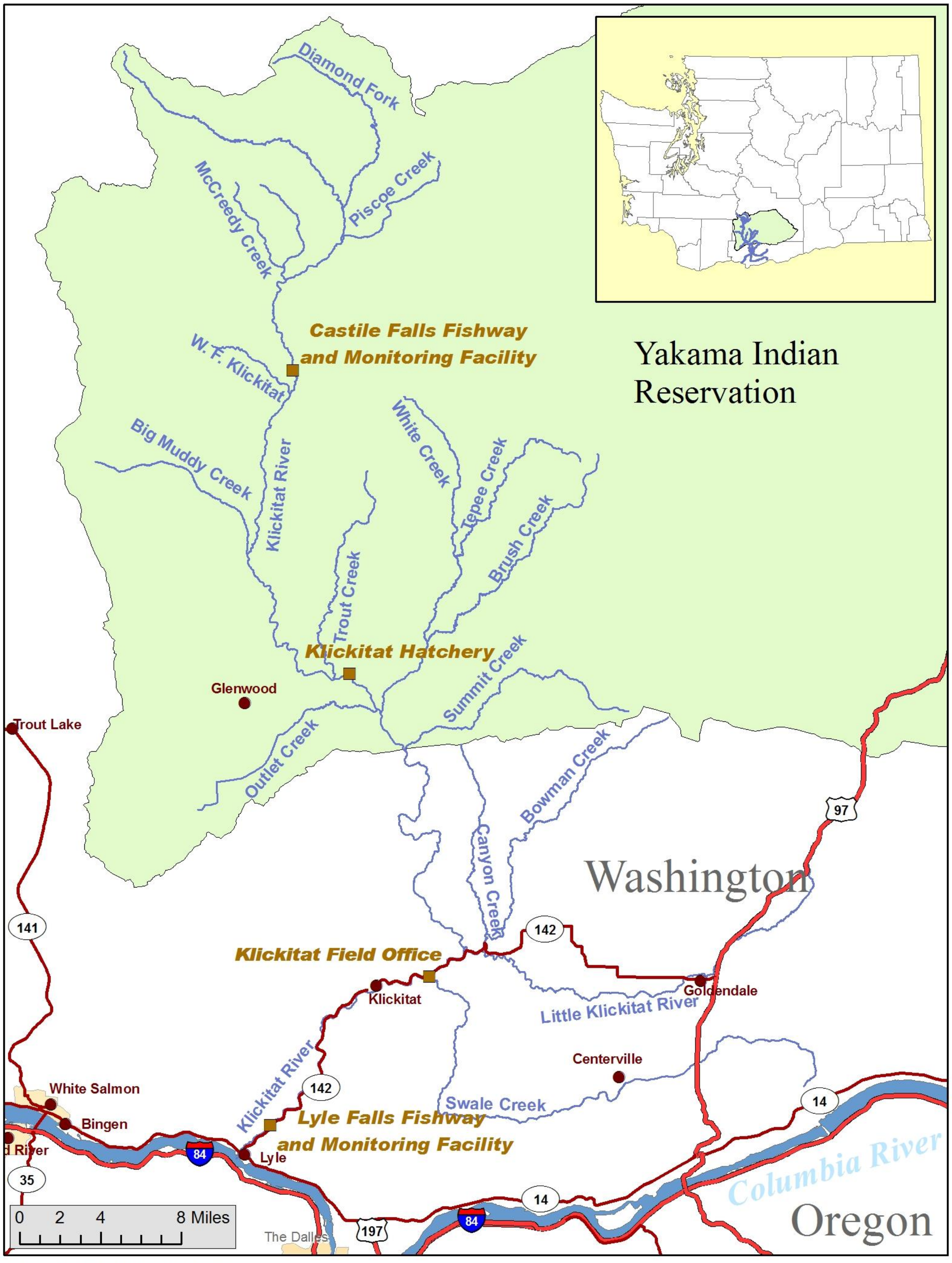

Figure 1. Location of Yakama Nation facilities for the Klickitat River Anadromous Fisheries Project (Figure 1-2, YN 2008).

For many years, WDFW operated a segregated spring Chinook program at the Klickitat Hatchery (rkm 68; Figure 1). Returns of fish from this program to the lower basin supported sport and tribal harvest, but the naturally spawning population has remained depressed. In December 2005, management of the hatchery was transferred to the YN, and operations are transitioning from a segregated to an integrated program, with the objective to supplement and rebuild the natural population (YN 2008). At present, the juvenile acclimation and release locations for the supplementation program will remain at locations in the river below Castile Falls. Prior to implementing any proposed artificial production and release of spring Chinook in the upper basin, the YN first wished to monitor the rate at which the fish might naturally re-colonize the upper basin via volitional upstream passage through the fishway.

Since reopening the fishway in 2005, spawning escapement of spring Chinook to the upper basin has been estimated indirectly by expansion of an annual redd count. The YN performs three to four successive redd surveys during the spawning season each year (mid-August through late-September), spaced approximately 10 to 15 days apart. The surveys are presumed to cover essentially the totality of the known spawning area within the basin above Castile Falls. The total number of redds observed during these surveys are then multiplied by an expansion factor of 3 fish per redd (Zendt and Bosch 2009) to obtain an estimate of total escapement. While the method of estimating spawning abundance by expansion of annual redd counts is recognized to have substantial uncertainty (e.g., Mosey and Truscott 1999, Murdoch and Miller 1999, Dunham et al. 2001, Faurot and Kucera 2005, Gallagher et al. 2007), it was the only method available for use in the upper basin.

In 2008, the YN completed the Klickitat River Anadromous Fisheries Master Plan (YN 2008) which included a proposal to construct a fish monitoring facility at the upstream end of the fishway that would include a counting window and a motion-detection triggered optical video recording system. The resulting video clips would permit species-specific escapement information on a year-round basis. The facility would also have radio and PIT tag antennae and associated recording instruments, and satellite data transmission equipment. While awaiting completion of this facility, in 2009 the Columbia River Inter-Tribal Fish Commission (CRITFC) proposed to the YN, a collaborative project to use a Dual-Frequency Identification Sonar (DIDSON™; Sound Metrics Corporation, Seattle, Washington, www.soundmetrics.com) positioned at the upstream outlet of the fishway to obtain passage counts. Since that time, the DIDSON has been operated over the summer months each year to obtain annual escapement estimates of spring Chinook salmon.

A DIDSON is a multi-beam underwater acoustic video camera. It repetitively emits sets of sound beams and uses its unique patented lens to resolve the reflections of objects passing within its field of view into two-dimensional images. The standard model of the DIDSON emits an array of 96 beams at high frequency (HF; 1.8 MHz), or 48 beams at low frequency (LF; 1.1 MHz). The DIDSON has a functional range of 10-12 m when operated at HF, and a range of 24+ m when operated at LF - though the images are of reduced resolution relative to those obtained using the HF transducer. Placed in a body of water and oriented to transmit horizontally through the water column, it produces a top-down (“bird’s-eye”) view of the

conically-shaped ensonified field. Unlike optical cameras, the camera is able to “see” objects irrespective of light intensity, and in water with up to moderate levels of turbidity. Field testing for fisheries applications, including salmon escapement estimation, has shown the DIDSON to have some significant advantages relative to other sonar systems (Moursund et al. 2003, Johnson et al. 2004, Maxwell and Gove 2004, Faurot and Kucera 2005, Galbreath and Barber 2005, Xie et al. 2005, Kucera and Orme 2006, Burwen et al. 2007, Maxwell 2007, Faulkner and Maxwell 2008, Melegari and Osborne 2008).

Construction of the Castile Falls monitoring facility began in 2010 and it became operational in late 2011. Therefore, in addition to the escapement estimate obtained with the DIDSON in 2012, there was a comparable set of passage counts obtained from video recordings. These data sets were compared for concordance relative to time of the fish passage events, with the videos additionally providing species identification. To present, the DIDSON studies presumed that large fish observed migrating upstream in July, August and early September have been 100% spring Chinook.

METHODS

A standard model DIDSON was installed on July 2, 2012 at the upstream outlet of the Castile Falls fishway (Figure 2A). As in previous years (Galbreath et al. 2011 and 2012), weir frames were attached to the trash rack in five of the six 3.2 m long openings in the fishway outlet, such that passage of salmon would only occur in the sixth unblocked opening (Figure 2B and 2E). Each section of weir consisted of a 3.1 m x 0.8 m aluminum frame, with holes drilled along the lengths at 7 cm intervals, through which the pickets were passed. The pickets consisted of lengths (1.8 m for the downstream frames, and 1.2 m for the upstream frames) of 1.6 cm diameter aluminum conduit.

The DIDSON was attached to an H-frame stand (Figure 2C), and placed in the water immediately outside of the fishway, 4.0 m upstream of the unblocked section (Figure 2D). Sandbags were placed on the legs of the stand to stabilize the sonar against the force of the flowing water. The DIDSON was oriented in a downstream direction parallel to the fishway, and was readjusted over the course of the study to keep the lens at approximately 20 cm below the water surface.

Two heavy duty job site storage boxes were installed on top of the fishway outlet adjacent to the location of the sonar – one to house the electronic equipment (field computer, external hard drive, universal power supply, etc.) and the other for storage of tools and miscellaneous equipment (Figure 2E and 2F). The DIDSON and associated field computer were plugged into a nearby 120 v AC outlet, powered by the diesel generator installed as part of the new monitoring facility.

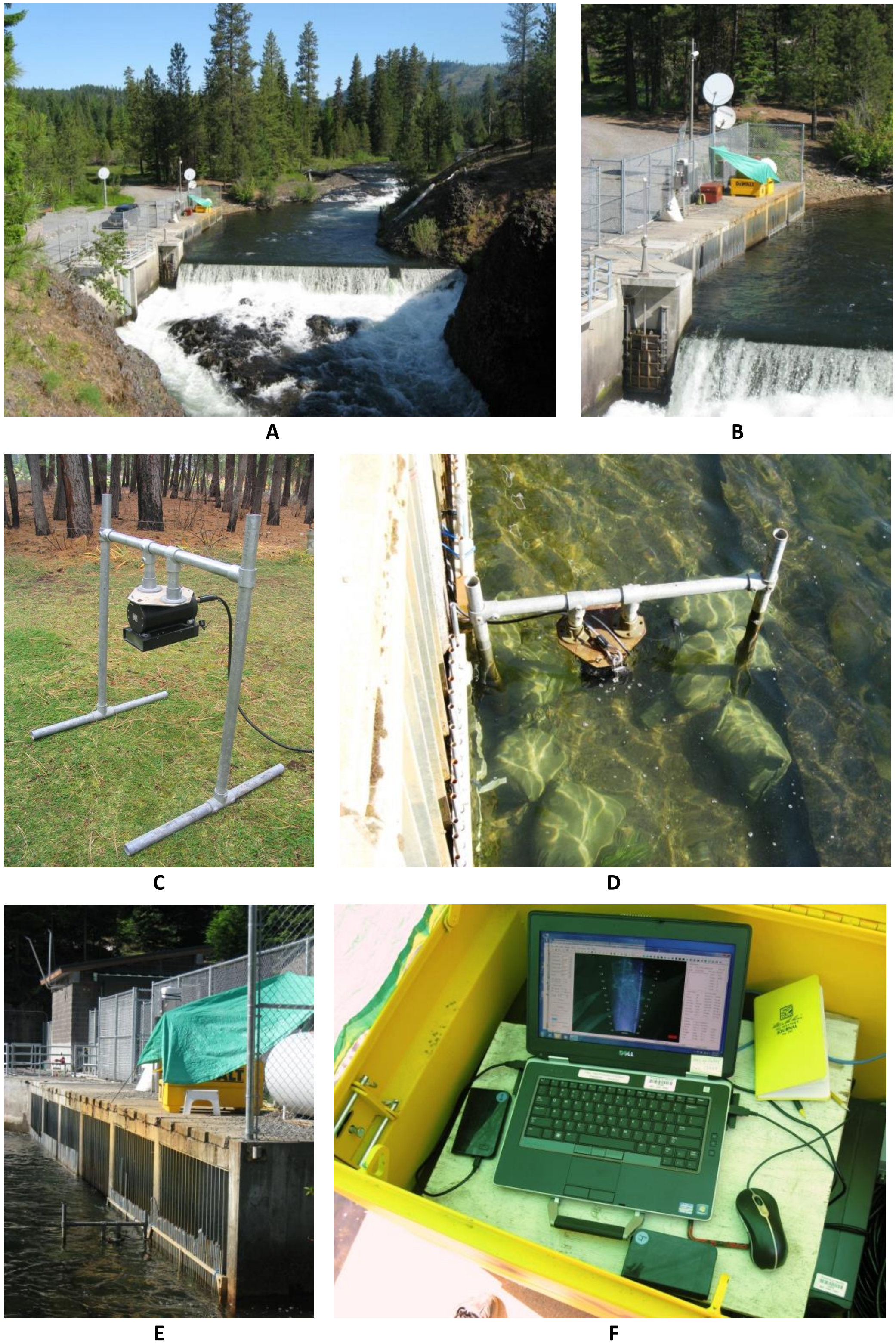

Figure 2. A) Dam and upstream outlet of Castile Falls upper fishway (July 2012), B) View from downstream of fishway outlet, C) DIDSON on H-frame stand, D) DIDSON deployed underwater adjacent to trash rack, E) View from upstream of fishway outlet showing the trash racks with weir frames attached, F) Field computer and external hard drive in job site storage box.

The DIDSON was programmed with a 3.3 m Start Length and a 5 m Window Length (Sound Metrics Corporation 2009). These settings permitted visualization of the entire water column just outside the unblocked section, through which upstream migrating salmon were obliged to pass (Figure 2E). The DIDSON was programmed to record sequential 1-hour files, at high frequency (1.8 MHz) and 10 frames per second. Operation of the DIDSON continued until September 21, 2012 (Figure 3), by which time migration, as well as spawning, is presumed to have ceased. The site was visited regularly over the summer to confirm proper operation of the sonar, and to “swap out” the 500 GB external portable hard drive to which the preceding week’s files had been stored. The recorded files were later copied to a pair of larger (2 TB) office-based hard drives – one drive used for processing and file reading, and the other as a back-up.

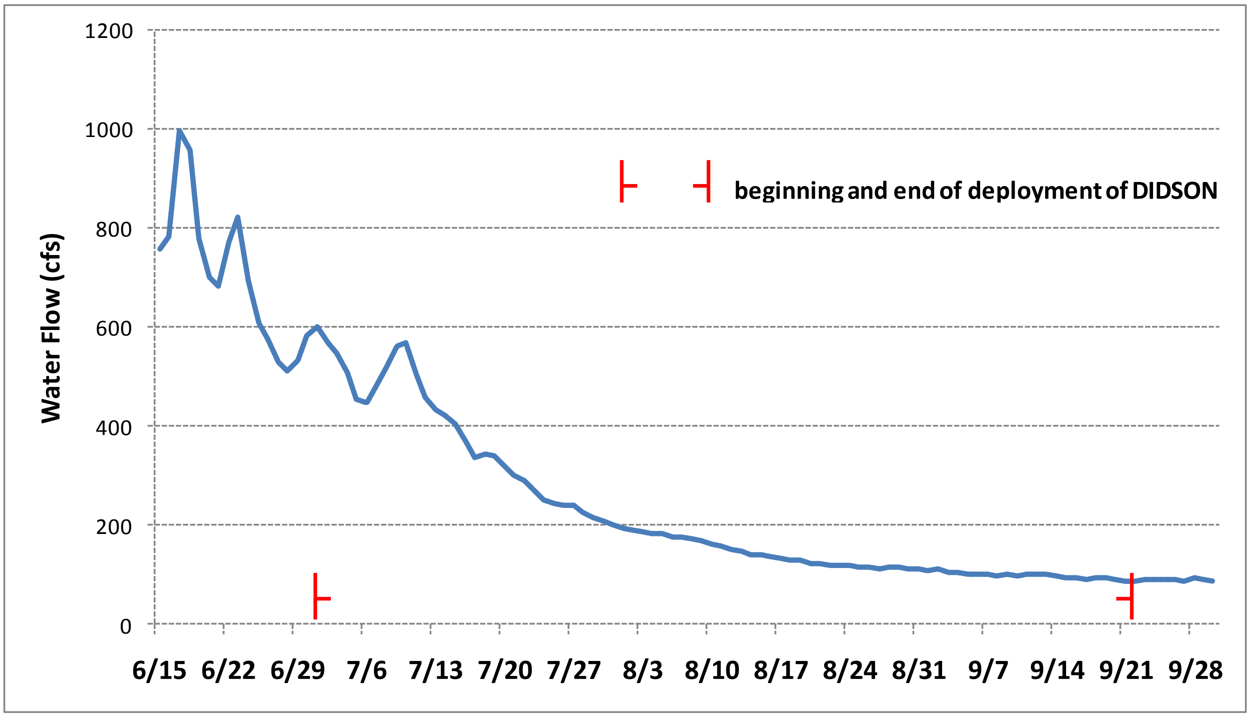

Figure 3. Water flow (cfs) recorded at the USGS stream flow gauge number 14107000 (Klickitat River above West Fork near Glenwood, WA), located 1 km upstream of the Castile Falls fishway Complex (rkm 103). (http://waterdata.usgs.gov/wa/nwis/uv?cb_00060=on&cb_00065=on&format=gif_default&period=60&site_no=14107000)

Processing and reading of the DIDSON video files began in November and finished in January 2013. Initially, an echogram was created for each DIDSON file. Processing parameters for the echograms included: Minimum Track Size = 12, Minimum cluster Area = 200 cm^2, and Maximum Cluster Area = 10,000 cm^2, and Minimum Threshold = 4.9 dB (Sound Metrics Corporation 2009). The echograms were reviewed by a single reader (Barber). When a “track” in an echogram was observed (indicative of possible fish passage events), a rectangle was drawn around the track to create a “tape loop” of the raw video. When the image in the video loop appeared to represent passage of a fish of medium to large size (suspected to be a salmon - as opposed to movement of a smaller sized fish, of floating debris, or of a cloud of air bubbles,

etc.), a note was made of the frame number and time, and of the relative size and direction of movement of the fish. After, all files were read, each noted passage event was re-reviewed in the presence of two additional readers (Frederiksen and Galbreath). Together, the readers reached a consensus as to which images were indeed those of upstream migrating spring Chinook, and the hour and date of the confirmed counts were recorded, and the data was entered into a spreadsheet (Appendix).

As the DIDSON operated without interruption, the sum of the separate fish passage events provided a direct estimate of total escapement. This estimate was compared to that derived from the year's redd count. The DIDSON counts were also analyzed for temporal trends – both within days (diurnal) and across dates. The DIDSON observations were also compared against those obtained from video files recorded over the same period, by the newly operational fish monitoring facility at Castile Falls.

RESULTS

DIDSON Escapement Estimation

The date and time of each upstream fish passage observation obtained with the DIDSON in 2012 is provided in Table 1. The total number of observations was 30. The DIDSON operated without interruption through the summer, and there is no error associated with the estimate. This estimate of spring Chinook escapement fish is twice that derived from the year's spawning surveys. A total of 5 redds were observed in 2012, which expanded by a presumed 3 fish/redd yields a total spawning escapement estimate of 15.

In 2012, fish were observed moving upstream through the fishway within the first week following deployment of the sonar on July 2. The highest weekly count was in week #2 (July 9-16; n=11), after which only one to three fish were observed weekly through the end of August (Figure 4A). The largest proportion of counts were observed from mid-afternoon through the evening (within a few hours either side of nightfall), with possibly another smaller peak in early morning (within a few hours either side of day-break). Few observations were recorded during the night and mid-day (Figure 4B).

Table 1. Observations of upstream fish passage at the Castile Falls fish recorded with the DIDSON sonar and with the new video camera from late June to mid-September 2012.

	Video				DIDSON		
	Date	Time	Species	Length	Date	Time	Time Diff.
	28-Jun	17:03	steelhead	53			
	28-Jun	18:49	steelhead	62			
#	begin DIDSON						
1					2-Jul	21:22	
2					4-Jul	21:32	
3					8-Jul	20:21	
4					8-Jul	20:56	
5					8-Jul	21:11	
6					9-Jul	5:00	
7	9-Jul	15:03	steelhead	49			
8	9-Jul	15:24	steelhead	49	9-Jul	15:37	0:13
9	9-Jul	16:58	steelhead	50	9-Jul	17:44	0:46
10	9-Jul	17:16	steelhead	55	9-Jul	17:51	0:35
11	9-Jul	21:56	steelhead	65	9-Jul	22:22	0:26
12	10-Jul	16:11	steelhead	54	10-Jul	21:32	5:21
13	11-Jul	17:13	steelhead	54	11-Jul	17:49	0:36
14	11-Jul	17:38	steelhead	57	11-Jul	20:39	3:01
15					12-Jul	17:32	
16	14-Jul	13:11	steelhead	51	14-Jul	13:29	0:18
17	14-Jul	14:33	steelhead	58			
18	14-Jul	20:04	spring Chinook	68			
19	15-Jul	15:49	spring Chinook	77			
20	15-Jul	15:50	steelhead	50			
21	15-Jul	16:01	steelhead	52			
22	15-Jul	16:58	spring Chinook	76	15-Jul	17:03	0:05
23	16-Jul	16:20	steelhead	52			
24	16-Jul	17:25	steelhead	57			
25	18-Jul	9:31	steelhead	52			
26	18-Jul	16:21	spring Chinook	79	18-Jul	17:29	1:08
27	19-Jul	14:10	spring Chinook	72			
28	19-Jul	16:33	steelhead	54			
29	20-Jul	9:07	spring Chinook	63			
30	20-Jul	14:43	spring Chinook	61			
31	20-Jul	16:19	spring Chinook	66			
32	21-Jul	13:15	spring Chinook	67.5	21-Jul	13:37	0:22
33					22-Jul	9:19	
34	24-Jul	12:25	steelhead	48	24-Jul	12:48	0:23
35					26-Jul	4:47	
36	26-Jul	16:28	steelhead	51	26-Jul	16:54	0:26
37	27-Jul	21:09	steelhead	54			
38	29-Jul	15:32	steelhead	55			
39	29-Jul	15:56	steelhead	47			
40	30-Jul	14:11	steelhead	55	30-Jul	14:17	0:06
41	1-Aug	11:32	steelhead	50			
42	7-Aug	17:36	spring Chinook	86	7-Aug	17:50	0:14
43					12-Aug	12:26	
44	14-Aug	21:56	steelhead	50			
45					15-Aug	5:44	
46	16-Aug	13:34	steelhead	46			
47	16-Aug	13:48	steelhead	55			
48	17-Aug	15:12	steelhead	51	17-Aug	15:26	0:14
49	18-Aug	2:25	spring Chinook	59			
50	19-Aug	14:48	steelhead	49			
51	19-Aug	18:52	steelhead	58	19-Aug	19:00	0:08
52	20-Aug	7:24	steelhead	53	20-Aug	7:54	0:30
53	22-Aug	19:20	steelhead	57	22-Aug	19:38	0:18
54	23-Aug	17:27	steelhead	57			
55	25-Aug	15:03	steelhead	55			
56	10-Sep	18:59	steelhead	55			

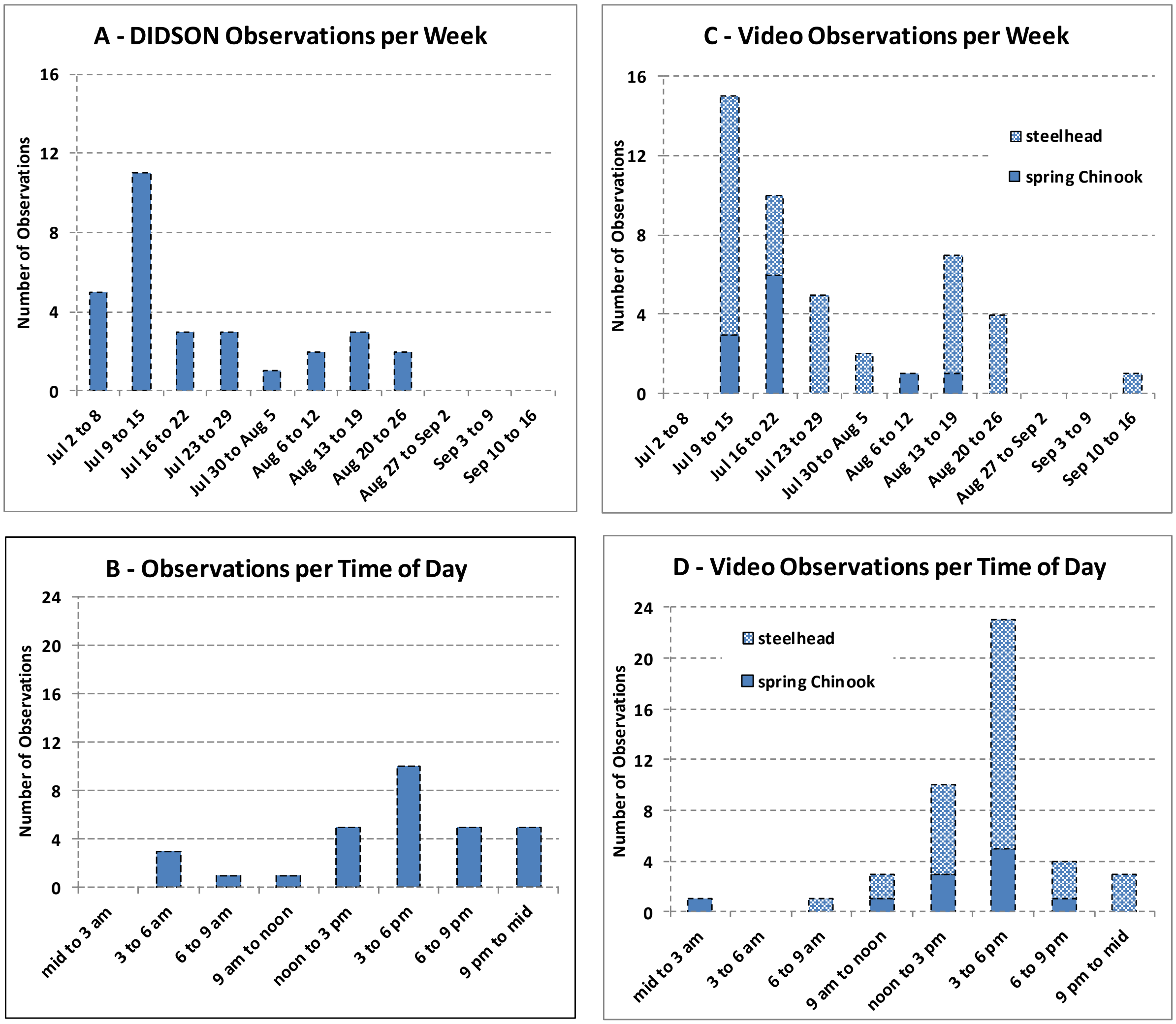

Figure 4. Frequency of fish passage observations per week and per time of day recorded with the DIDSON (A and B) and with the video camera (C and D). The video observations are indicated separately for spring Chinook and for steelhead.

DIDSON versus Video Observations

Late in 2011, construction of a fish counting facility was completed at Castile Falls, which included antennae for PIT tags and radio tags, and an observation window in the fishway with a motion-detection triggered video recording system. Video recordings of fish passage were therefore available for the same July-September period that the DIDSON was operated in 2012. The video files permitted identification of fish to species as well as estimation of fish length. Of the total of 45 video observations, 34 (76%) were of steelhead and 11 (24%) were of spring Chinook. A summary of the individual video observations are provided in Table 1. Within the table, the DIDSON and video observations were aligned when passage dates and times appeared to concord with the same fish.

DISCUSSION

Escapement Estimation

The DIDSON escapement estimate of 30 fish for 2012 was similar in magnitude to estimates in 2009 (n=24 ± 4), 2010 (n=26 to 27), and 2011 (n=38). Also similar to prior years, the DIDSON estimate was substantially greater than the estimate derived from the year's spawning surveys. Over the four years the DIDSON has been deployed at Castile Falls, we had assumed that all passage events observed with the DIDSON during this summer period were of spring Chinook, and that the discrepancy between the DIDSON escapement estimate and the corresponding, and much lower, estimate derived with expanded redd counts was attributable to pre-spawning mortality and/or to incomplete coverage of the spawning surveys. Observations acquired with the new video recording system in the fishway demonstrated this assumption to be erroneous.

Presuming that the species mix of 76% steelhead and 24% spring Chinook has been similar across years, we readjusted downward our DIDSON estimates of spring Chinook escapement for the years 2009 to 2012 (Table 2). These lower estimates bring them much closer to escapement estimates based on expanded redd counts. On the other hand, the lowered estimates also indicate that spring Chinook are recolonizing the upper basin at a much lower rate than previously thought.

Table 2. Updated estimates for annual escapement of spring Chinook to the upper basin of the Klickitat River – corrected with an estimate of spring Chinook as comprising only 24% of the original count of large fish migrating upstream, previously presumed to be 100% spring Chinook.

	Video escapement counts		Prior DIDSON spring Chinook estimate	Corrected (x 0.24) DIDSON spring Chinook estimate		Expanded redd count spring Chinook estimate	
Year	spring Chinook	steelhead		spring Chinook	steelhead	Redd count	Escapement estimate
2009	na	na	24 ± 4	6	18	4	12
2010	na	na	26 to 27	6	20 to 21	3	9
2011	na	na	38	9	29	0	0
2012	11	34	30	8	22	5	15

The total of 46 observations recorded with the video camera exceeds the 30 observations with the DIDSON by approximately 50%. With two exceptions, the DIDSON observations could be aligned with a video observation by virtue of a time of observation with the DIDSON that was within approximately an hour of the video record (average = 24 min). This difference represents the time the fish held within the sheltered upper portion of the fishway before exiting into the open river. The two exceptions are for fish that apparently remained within the fishway for 3 and 5 hours before exiting.

Migration Timing

Based on DIDSON observations from prior years (Galbreath et al. 2010, 2011 and 2012), migration of fish through the Castile Falls fishway was expected to begin in mid-July, to peak in late-July to early August, and to end by early September. In 2012, however, the run appeared much earlier. Fish were observed moving upstream through the fishway immediately following deployment of the sonar, and the first two weeks accounted for 50% of the passage counts (Figure 4A). Information from the video recordings, showed a similar distribution for spring Chinook and steelhead combined (Figure 4C). However, all of the earliest viewed fish (late June to mid-July) were steelhead. Among the 11 spring Chinook observed in the video recordings, 9 migrated through the fishway in mid-July, with the remaining 2 in early to mid-August.

Time of day that fish were observed was generally similar to that for previous years, with the majority of passage events occurring from mid-afternoon through the evening (Figures B and D). This may indicate that after the fish migrate through the dark fishway, they prefer to move out into the open river at times of lower light intensity, generally avoiding times of high light intensity, but also avoiding movement during the night.

DIDSON Versus Video Observations

The 45 video observations of fish passage through the fishway is 50% greater than the 30 events counted with the DIDSON. Some of the undercount with the DIDSON is likely due to a particularity of the location. The DIDSON is positioned just outside the trash rack at the upper end of the fishway, within a 1.4 m wide clean-out canal bordered on the opposing side with an underwater concrete wall (Figure 2D). When the fish initially exits through the trash rack of the fishway, they are perpendicular to the sounds waves emitted by the DIDSON, in a more readily observed orientation. However, with the concrete wall immediately in front of them, many fish quickly turn up or downstream within the canal. When they do so, the reflected image is much smaller and less easily observed in the DIDSON recordings. If undercounting with the DIDSON was of the same magnitude across years, the actual spring Chinook and steelhead escapement DIDSON estimates for 2009, 2010 and 2011 are possibly 50% greater than the “corrected” estimates in Table 2.

However, undercounting by the DIDSON due to unobserved fish, accounts for only a portion of the discrepancies between the DIDSON and video counts. Of the 30 DIDSON observations, only 2/3 (n=19) appear to concord with a video observation. There were 11 DIDSON counts for which no corresponding video observation was noted. The corresponding recordings for these 11 DIDSON counts were re-reviewed. It is possible that a few of them could involve double-counting of a fish that had already passed through the fishway – involving a fish that had circled back into the clean-out canal some time later, and was erroneously observed to be a new fish exiting the fishway. It is also possible that a few of these observations were of fish that had passed the video counting window, but then held within the fishway for more than a day, and were not deemed to concord with the preceding video observation. Others of these 11 DIDSON

observations, however, likely represent fish that passed through the fishway but for whatever reason (technical, or reader error) were not observed in the video recordings.

A final possible source of error for both the video and DIDSON counts is passage of fish upstream through the river (avoiding the fishway), that then jump up and over the dam constructed to divert water into the fishway. A few reports have been made over the past years of fish observed jumping, or attempting to jump, the fishway dam. However, as the summer months progress, water flows and levels diminish dramatically, progressively reducing the likelihood that fish could successfully jump over the dam. We feel strongly that undercounting due to fish that bypass the fishway is negligible.

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