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2011 Spring Chinook Escapement to the Upper Basin of the Klickitat River Based on DIDSON Sonar Counts

Peter F. Galbreath, Peter E. Barber, and Chris R. Fredericksen

February 17, 2012

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Peter F. Galbreath[1], Peter E. Barber[2] and Chris R. Frederiksen[2]

[1] Columbia River Inter-Tribal Fish Commission, Portland OR

[2] Yakima-Klickitat Fisheries Project, Yakima WA

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EXECUTIVE SUMMARY

A Dual-Frequency Identification Sonar (DIDSON) sonar was deployed to observe fish passage through the Castile Falls Fishway on the Klickitat River, to obtain an estimate of 2011 spring Chinook *Oncorhynchus tshawytscha* escapement to the upper basin. The DIDSON was set up with the intent to continuously record sequential 1-hour files from early July until mid-September. Technical problems occurred, however, and recordings were obtained for only 260 hours, 26% of the 1176 hours between August 3 (the date the Fishway was reopened following construction work, and the presumed beginning of the migration period) and September 20 (the estimated end of the migration period). An expansion of the observed count yields an estimate for total escapement of 38. No attempt was made to assign confidence limits to this estimate due to questions that exist regarding the non-random manner by which recorded files were obtained that compromises the statistical validity of the expansion. Nonetheless, the estimate is similar in magnitude the estimates of 24 ± 4 and of 26 to 27 derived with the DIDSON in 2009 and 2010, respectively. Also similar to the two prior years, the 2011 estimate contrasts substantially to that based on spawning ground surveys, which in fact was zero – no redds were observed during any of the surveys conducted in 2011. Whether pre-spawning mortality and/or unobserved redds accounts for the discrepancy is uncertain.

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 make for 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).

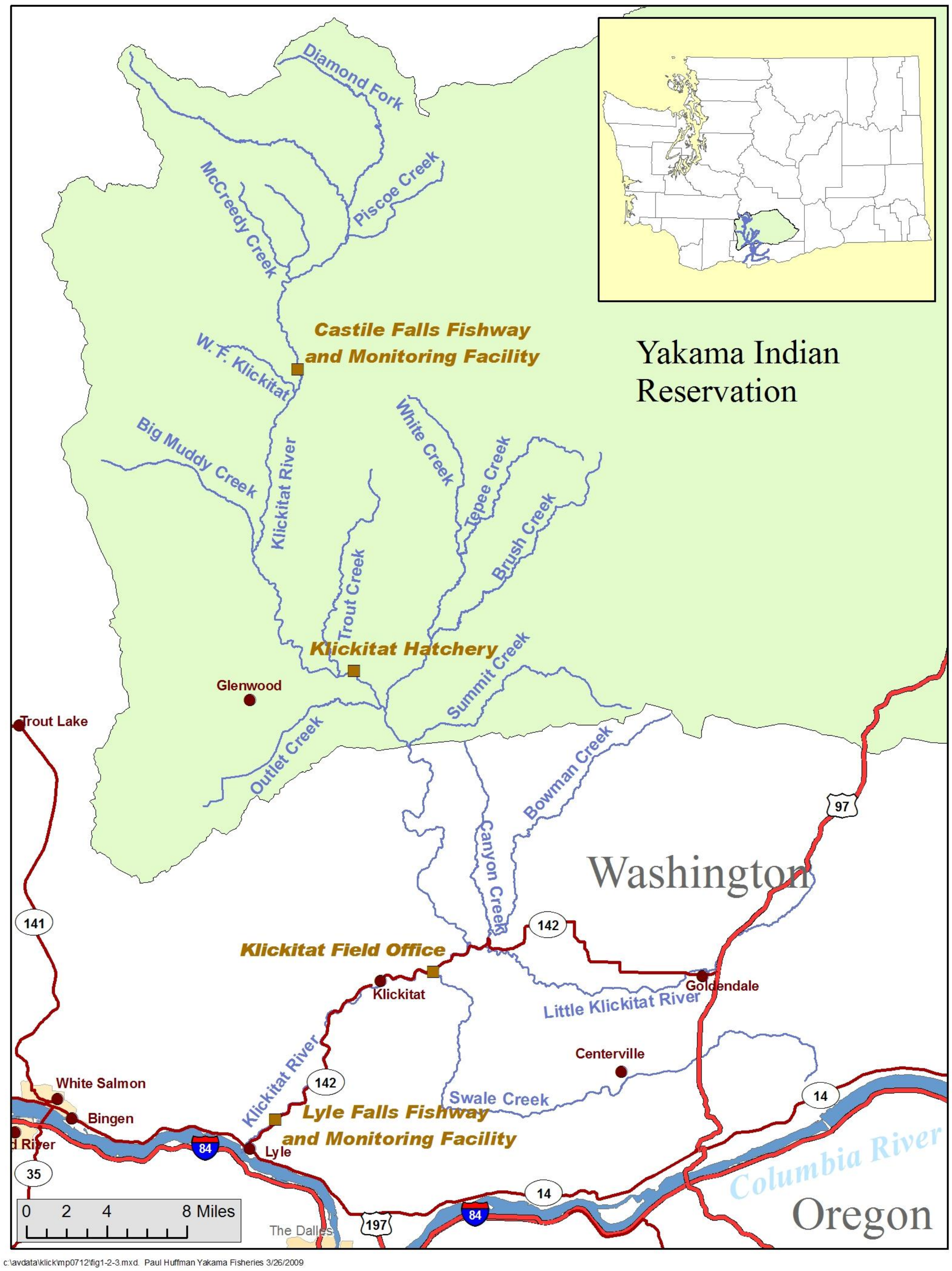

Figure 1. Location of Yakama Nation facilities for the Klickitat River Anadromous Fisheries Project (Figure 1-2, YN 2008).

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 construction project to improve access for anadromous fish (spring Chinook and steelhead) to the upper Klickitat basin (YN 2008). Constructed between 1960 and 1962, the Fishway Complex consists 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, blasting of Falls #1, #8 and #9 was performed to facilitate fish passage. The smaller Falls #2, #3 and #6 were not modified as they were not considered to be barriers. At the upstream end of the second Fishway, a 3-4 m high concrete dam was constructed to divert flow into the tunnel (Figure 2A and 2B). Unfortunately, the design of the Fishway 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, as well as 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 into the tunnels, and to facilitate its removal. In summer of 2005, renovation was complete and water flow reestablished through the Fishway. Later that same year, spring Chinook redds were observed during walking surveys of the river in the upper basin.

For many years, the Washington Department of Fish and Wildlife 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 additional 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 strategies targeting spring Chinook re-colonization of the upper basin, the YN is monitoring the natural re-colonization rate via redd counts and use of the DIDSON Sonar. If monitoring data indicates that fish are not finding and populating the new habitat, the YN will proceed with adult and/or juvenile out-planting. Accurate measures of annual escapement during this interim period will be essential to informing this management decision.

Figure 2. A) Dam and upstream outlet of Castile Falls upper Fishway at high water (May 2010), B) At low water (August 2011), C) DIDSON on stand, D) DIDSON deployed underwater adjacent to trash rack, E) Thermoelectric generator (TEG), F) Fishway outlet from downstream showing the trash racks, job site storage boxes and propane tank, G) Fishway outlet at water level from upstream - showing the section of the trash rack left unblocked with picket weirs, and the DIDSON stand positioned just upstream, H) Field computer and external hard drive in job site storage box.

Since reopening the Fishway, 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 the 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 has been the only method feasible for use in the upper basin. However, fish that access the upper basin are concentrated within the Fishway as they migrate upstream, which facilitates their enumeration. The recently completed Klickitat River Anadromous Fisheries Master Plan (YN 2008) includes a proposal to construct a fish monitoring facility within the upstream Fishway. This facility will include an optical video fish counting system, radio and PIT tag antennae and recording instruments, and satellite data transmission equipment. Construction of this facility began in the summer of 2010, and continued through 2011. While awaiting completion of the monitoring facility, we proposed use of an alternative technology for direct counting of fish passing through the Fishway - a Dual-Frequency Identification Sonar (DIDSON™; Sound Metrics Corporation, Seattle, Washington, www.soundmetrics.com).

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).

In both 2009 and 2010, we deployed a DIDSON at the upstream outlet of the Castile Falls upper Fishway, and operated the sonar over the summer. Recordings in each year were reviewed, and an estimate of spring Chinook escapement was calculated based on the counts of fish passage events (Galbreath et al. 2010 and 2011). In 2011, we again operated the DIDSON, following protocols very similar to those used in 2010.

METHODS

Data obtained in 2009 and 2010 indicated that spring Chinook migration through the Fishway begins in early to mid July, and end in early September. Our plan in 2011 was therefore to operate the sonar from early July through mid September.

In early July, preparations were made to deploy a standard model DIDSON at the upstream outlet of the Castile Falls Fishway. The outlet canal of the Fishway consists of six 3.2 m long openings. Each opening is faced with a heavy metal trash rack. The 15 cm spacing between the vertical bars of the trash rack grates permits exit of upstream migrating salmon and steelhead from within the Fishway to the upper basin of the Klickitat River, but blocks entry of most large woody debris. To the outside face of five of the six trash rack openings (the upper two and the lower three) we attached sections of picket weir fencing, so as to restrict passage of fish out of the Fishway to the single unobstructed opening (Figure 2G). Each section of weir fencing 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.

On July 7, the DIDSON was attached to an H-frame stand (Figure 2C). A silt exclusion box was not used in 2011, as it was initially in 2010, as water flow and turbidity had already diminished considerably. The DIDSON was 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 a depth approximately 20 cm below the water surface (Figure 2F and 2G).

A 1900 l propane tank, transported to the site in 2009, was refilled and used to fuel a Global Thermoelectric (Calgary, Alberta, Canada) Model 5120™ thermoelectric generator (TEG), which optimally produces a continuous 24 volts DC current of approximately 108 watts (Figure 2E). The DIDSON was powered directly from the TEG, whereas power to the field computer was first passed through a 24 to 12 v DC transformer. Two heavy duty job site storage boxes were installed on top of the Fishway outlet – one to house the electronic equipment - field computer, external hard drive, transformer, etc. – and the other for storage of tools and miscellaneous equipment (Figure 2H).

The DIDSON was programmed with a 3.3 m Start Length and a 5 m Window Length (Sound Metrics Corporation 2009), such that the entire water column just outside the unblocked section, through which upstream migrating salmon were obliged to pass, was within the field of view of the sonar (Figure 2C). The DIDSON was programmed to record sequential 1-hour files, at high frequency (1.8 MHz) and 10 frames per second. The site was visited regularly to confirm proper operation of the sonar, and to “swap out” the 500 GB external portable hard drive to which the previous week’s files had been stored with a new one. 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.

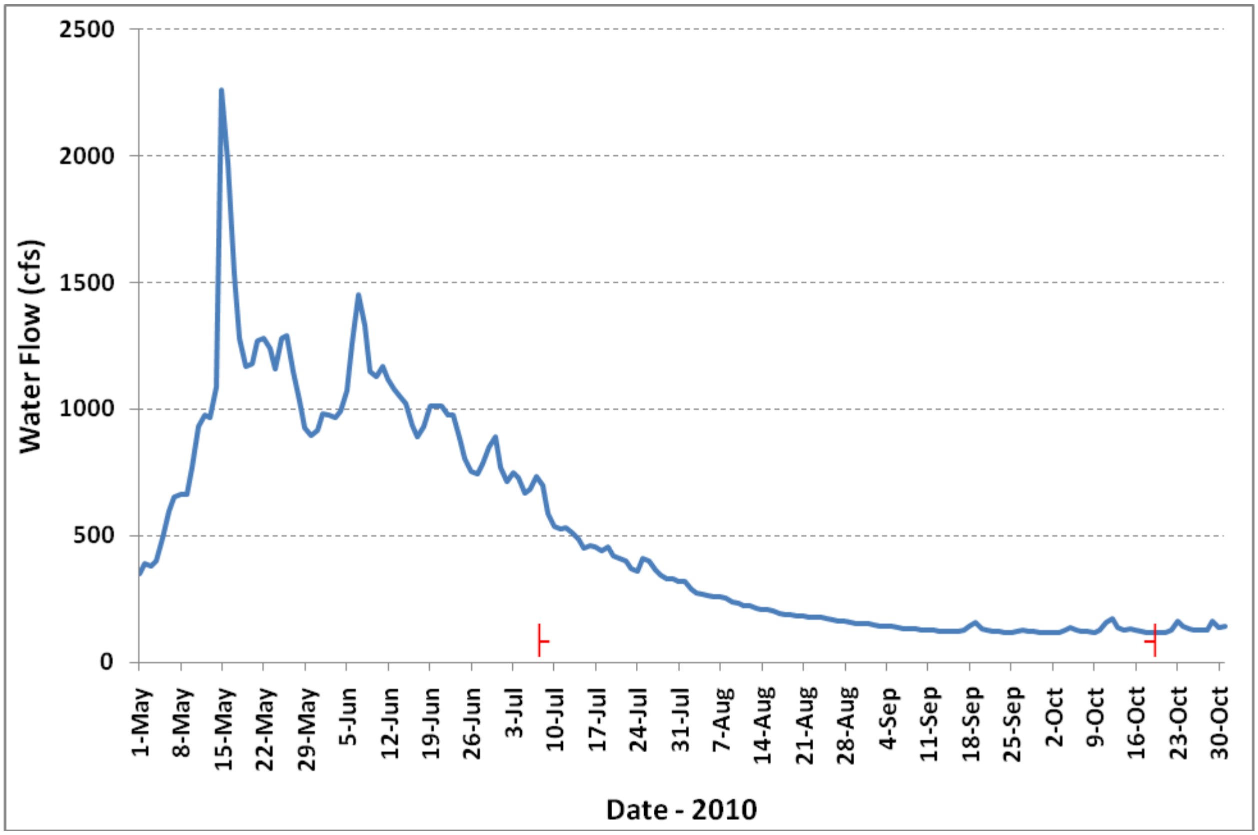

Figure 3. Water flow (cfs) recorded at the USGS stream flow gauge number 14107000 (Klickitat River above West Fork near Glenwood, WA), located 1 km upstream of the Castile Falls Fishway Complex (rkm 103). (http://waterdata.usgs.gov/nwis/dv?cb_00060=on&cb_00065=on&format=html&begin_date=2011-05-01&end_date=2011-31-15&site_no=14107000&referred_module=sw)

Unfortunately, a series of power supply problems occurred, resulting in erratic functioning of the sonar and recordings were obtained for only about 26% of the season. These issues were finally resolved in late September, and to confirm proper functioning of the sonar, we prolonged its operation until October 17 (see Discussion).

Processing and reading of the DIDSON video files began in October and finished in January 2012. 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 “tracks” in the echograms occurred (indicative of possible fish passage events), a rectangle around the track was drawn 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 in a spreadsheet (Appendix).

Our intent was to analyze the data for temporal trends – both within days (diurnal) and across dates – then to derive an estimate of total escapement – the total of the number of upstream passage events that had occurred for a period during the observed migration period – which was to be compared to the year's redd count. However, because files were successfully recorded for only a portion of the migration season, and in a non-random manner, we were unable to make these assessments for migration within and across days, and expansion of the observed count to estimate total escapement was also highly compromised (see Results).

RESULTS

DIDSON Operation

A series of technical problems occurred that precluded proper operation of the DIDSON until very late in the migration season. Initially, the problems were found to involve computer software parameter settings that were then corrected. Subsequently, however, the sonar was repeatedly found to have ceased operation within a few hours after having been restarted upon our arrival for the 1 to 2 site visits we made per week. Initially we believed the problem lay with a "glitch" in the DIDSON software, and was not until mid-August that we deduced that the problem might instead be associated with fluctuations in the power output of the TEG. In response, we placed "in line", two 12 volt deep cycle batteries to buffer against such fluctuations, and for a week (Aug 21-28) the sonar functioned normally. But then, the sonar again ceased recording. Our suspicions then switched from fluctuations to inadequacy in the power output – we suspected that the output had dropped below that specified by the manufacturer under proper operating conditions, and to a level insufficient to keep the batteries charged. A call was then made to colleagues with the USGS (owners of the TEG; who are operating it in collaboration with the YN to power a radio receiver), to have the TEG checked and serviced. It was not until Sept. 30, following receipt of a replacement fuel filter that had to be ordered, that the USGS technician was able to make a site visit to service the TEG. He confirmed that the sonar was indeed operating well below specifications – no doubt associated with the very dirty fuel filter. He changed the fuel filter and recalibrated the power output, and we restarted the DIDSON. We continued operation of the sonar until October 17, not in the expectation of observing fish passage events (as migration of spring Chinook had already ceased), but as a test of proper operation of the sonar.

Escapement Estimation

Observations in sonar files recorded in 2009 and 2010 (Galbreath et al. 2010 and 2011), indicated that the spring Chinook migration through the Castile Falls Fishway began in early to mid-July, and ended by early September. In 2011, cool spring weather delayed spring migration generally in the Columbia basin, with return of hatchery-origin fish to the Klickitat Hatchery (rkm) downstream of Castile Falls, delayed by approximately a week. Additionally, the inlet gate to the Fishway was closed on July 26 to permit work within the Fishway associated with construction of the new video/PIT monitoring facility. Presuming that few if any fish had migrated through the Fishway prior to the closure, the 2011 migration would therefore have begun upon reopening of the Fishway on August 3. The end of the migration season we initially presumed would be early to mid September. However, as we observed 3 passage events in files that were recorded in mid September, we have made the presumption that the migration season may not have ended until approximately September 20. During this 49 day period from August 3 to September 20, we obtained 306 hour-long recordings – 26% of the 1176 total hours for the period. In these recordings, a total of 10 upstream fish passage events were noted (see Appendix). If these recordings can be considered as representative, an expansion of the count (to account for unavailable files) yields an estimate of 38 fish for the total 2011 spring Chinook escapement.

As described in Methods, the TEG was serviced on September 30 and the DIDSON was restarted, to see if it would function normally. Indeed, the sonar worked as programmed, successfully recording successive hourly files until October 17, at which time it was dismantled. Out of curiosity, as the spring Chinook migration had already ended, these files were also processed and read. It was thought that we might observe passage of a few summer steelhead. However, zero salmon/steelhead-sized fish were observed (see Appendix).

DISCUSSION

In 2009 and 2010, the beginning and end of the migration period was determined to be the time of passage of the first and the last observed fish, respectively. For 2011, we are unable to determine the migration period in this manner. As explained above, in light of the general delay of the 2011 spring Chinook run into the Klickitat, the August 3 date of reopening of the Fishway after its closure for a 10 day period appears reasonable as a start date for the 2011 migration at Castile Falls. And, because we observed 3 fish on September 10, 13 and 16, from a relatively limited number of files recorded during this period, we feel that September 20 is a reasonable estimate for the end date of the migration. Spawning ground surveys conducted above Castile Falls by the Yakama Nation in prior years indicate that spring Chinook spawning begins in late August already, and finishes my mid-September.

Expanding the count of 10 fish from those recordings that were obtained during the August 3 to September 20 period yielded a total escapement estimate of 38 spring Chinook for 2011. However, this estimate is based on several presumptions that are recognized to be of

questionable statistical validity. The files were obtained in a non-random manner, which compromises the extent to which they can be considered as representative. In fact, over half of the available recordings were obtained during the single week of August 21 and 28 – the only period this season when the sonar operated continuously over several days. However, in light of the data obtained in 2009 and 2010 that did not provide strong evidence for significant trends, either within or across days during the migration period, a bias related to the non-random collection of files in 2011 may be reduced. Additionally, the estimate of 38 fish is similar in magnitude to escapement estimates of 24 ± 4 and of 26 to 27 derived with the DIDSON in 2009 and 2010, respectively. Nonetheless, we made no attempt to calculate confidence limits for the 38 fish estimate.

Also similar to observations made in 2009 and 2010, our estimate of 38 for 2011 contrasts substantially to the lack of evidence for any escapement whatsoever to the upper basin, based on observation of zero redds during the spawning ground surveys conducted in 2011. As before, the difference is likely related to pre-spawning mortality and/or spawning that occurred in the survey areas for which the redds were unobserved, or spawning that occurs outside of the survey areas.

An additional 404 hours were recorded between September 30 and October 17, and these files were read believing that we might detect passage of a few in-migrating summer steelhead. However, no passage events were observed.

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Appendix – Hourly counts of upstream spring Chinook passage through the Castile Falls Fishway as observed in 2011 DIDSON recordings. (blank cells indicate that no file was recorded during that day/hour)

Month	Day \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Σ*
August	3																									
	4										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	0	0	0	0	0	0															
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	21															0	0	0	0	0	0	0	2	0	0	2
	22	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	24	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		1
	29																									
	30													0	0	0	0	0	1	0	0	0	0	0		1
	31																									
September	1																									
	2											0	0	0	0	0	0	0	0	0	0	0	0	0	0	
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	8																									
	9															0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	11	0																								
	12																									
	13											0	0	0	0	0	1	0	0							1
	14																									
	15																									
	16														0	0	1	0	0	0	0	0	0	0	0	1
	17	0																								
	18																									
	19																									
	20																									

												October																
Hour	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
0												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
11												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
13												0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
14										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
15										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
17										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
18										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
19										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
21										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
23										0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Σ*																												