Assessment of the homing behaviour of 3 and 4 year old Puntledge summer Chinook adult returns from lake and river released juveniles

FWCP Project No. 14.Pun.04

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EXECUTIVE SUMMARY

An investigation on the homing behaviour of summer Chinook in the Puntledge River is being conducted to determine whether Chinook smolts that have been released in Comox Lake will imprint and successfully migrate to the lake as adults and in greater abundance than those that are released directly in the lower river. Results from past research and assessment projects on Puntledge River summer-run Chinook have clearly demonstrated that summer Chinook adults arriving before late June have the greatest success in reaching Comox Lake and surviving to spawn compared to later arrivals (i.e. >90% versus ≤50%). This report summarizes activities in year four of a multi-year study to assess the homing behaviour of the two groups of returning summer Chinook adults (from "lake released" and "river released" juveniles) in the Puntledge River.

Three and four year old summer Chinook adults from 2011 and 2012 juvenile releases returning to the Puntledge River were captured at the lower Puntledge Hatchery, implanted with PIT (Passive Integrated Transponder) tags and released back to the river to continue their migration. Their migration behaviour was passively monitored using Radio Frequency Identification (RFID) monitoring systems installed at both the Puntledge diversion dam and Comox impoundment dam fishways. A total of 44 "lake released" and 39 "river released" adults were PIT tagged at the Puntledge Hatchery in 2014. Of these fish, 17 "lake released" adults and 19 "river released" adults, were detected migrating past the diversion dam into the headpond (Reach B) and 14 "lake" and 14 "river" adults were detected migrating into Comox Lake. Additional 4 year old adult returns from both groups released as juveniles in 2012 will be PIT tagged in 2015 to ensure a representative number of adults from each year class (i.e. 2011 and 2012 juvenile CWT releases) are included in the study. Pooling the 3 years of PIT tags will increase the precision of the study results.

An underwater video camera located at the diversion dam and DIDSON sonar camera at the impoundment dam, were also used to determine the number of non-PIT tagged adults migrating into the upper river. A total of 232 and 165 Chinook, inclusive of PIT tagged adults, were observed migrating through the diversion and impoundment dam fishways, respectively. Data collected from two years of tagging suggests that point of release of Chinook fry has no impact on homing behaviour in the Puntledge River. Additional adults from both groups (i.e. lake and river releases) will be PIT tagged in 2015 to increase the overall sample size.

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1 INTRODUCTION

In 2011, a homing behaviour study on Puntledge summer Chinook was initiated with funding support from the Fish and Wildlife Compensation Program (FWCP). The study will extend over several years in order to determine if releases of summer Chinook smolts in Comox Lake imprint and successfully return to the lake as adults. Specifically, the study will determine whether lake released summer Chinook juveniles migrate back to the lake as adults in greater abundance than adults that were released as juveniles directly in the river below the diversion dam (Guimond 2012).

Activities in Year 1 (2011) and Year 2 (2012) of this project included the releases of coded wire tagged Chinook juveniles in the river below the diversion dam, and in Comox Lake, and the installation of equipment to monitor adult returns. These activities are summarized in separate reports (Guimond 2012 and 2013). Year 3 (2013) was the first year of monitoring 3-yr old summer Chinook adult returns from 2011 smolt releases (Guimond 2014). This report summarizes activities conducted in Year 4 of the project (2014) which includes PIT tagging 3 and 4 year old summer Chinook adult returns at the Puntledge River Hatchery from lake and river juvenile releases in 2011 and 2012, and monitoring migration past the Puntledge diversion and Comox impoundment dams.

1.1 Background

The recovery of summer Chinook in the Puntledge River is contingent on successful migration and access into Comox Lake where adults hold in deeper cool water during the summer before spawning in October. Past research and assessments have clearly demonstrated that this migration and holding behaviour results in a spawning survival rate greater than 95% compared to 30-50% for fish that hold in much higher water temperatures in the lower river (Guimond and Taylor 2009). Actions and efforts that improve adult access into Comox Lake are therefore viewed as a priority and critical to the recovery of the population. When the Puntledge summer Chinook enhancement program began in 1965 with the operation of the upper hatchery spawning channel, the majority of Puntledge hatchery summer Chinook smolts were released immediately downstream of the Puntledge diversion dam. Although poorly documented, support biologists and hatchery managers in the DFO SEP program observed a strong tendency for hatchery fish to return to the site of release. Following the installation of Eicher fish screens in the penstock in 1993, which purportedly reduced turbine mortality to below 10% on outmigrating smolts, summer Chinook were then outplanted in the upper watershed (Upper Puntledge and Cruickshank rivers). In 2005, the first time adult returns were enumerated at the diversion and Comox impoundment dam; video cameras in the fishways found that 76% of the adult returns in the headpond (i.e. 134 of 176) successfully migrated into Comox Lake (Guimond 2006). This event corresponds to the last brood year a large hatchery release was made upstream of the Comox impoundment dam. DFO could not confirm if the 2005 adults migrating through the fishway were originally imprinted to the upper watershed but since the last hatchery smolt releases above Comox Dam, very few fish have been counted through this fishway.

1.2 Goals and Objectives

The goal of this report is to determine whether juvenile summer Chinook that were released in Comox Lake migrated to the lake as adults in greater abundance than adults that originated from juveniles released in the river (below the diversion dam). The objectives of the 2013 project are as follows:

1. **Monitor 3 and 4-yr old adult returns -** The migration and homing behaviour of 3 and 4 year old adult returns originating from juveniles released in the river and Comox Lake in 2011 and 2012 will be monitored using antennas and RFID (Radio Frequency Identification) receivers installed at the Puntledge diversion and Comox Lake impoundment dam fishways.

2. **Monitor all summer Chinook access into Comox Lake -** operate a DIDSON (Dual-frequency IDentification SONar) acoustic camera and underwater video camera at the Comox impoundment dam, and a video camera at the diversion dam during the summer Chinook migration period to monitor all Chinook migration into Reach B (headpond) and Comox Lake. This will provide a greater understanding of migration behaviour and Chinook access into the upper watershed throughout the migration period.

2 STUDY AREA

The Puntledge River Watershed encompasses a 600 km^2 area west of the city of Courtenay (Figure 1). The lower Puntledge River flows from Comox Lake in a north-easterly direction for 14 km where it joins with the Tsolum River. From this point downstream the river is called the Courtenay River, and flows for another 2.9 km into the Strait of Georgia. The lower river below Comox Lake is divided into 3 major reaches (Bengeyfield and McLaren 1994).

Reach B, the headpond reach, is located between the Comox impoundment dam at the outlet of Comox Lake, and the Puntledge diversion dam approximately 3.7 km downstream. Both of these structures have concrete fishways to provide fish access. Reach C, the diversion reach, extends downstream of the diversion dam for 6.3 km to the BC Hydro Puntledge Generating Station or "Powerhouse". Reach D encompasses the remaining 4 km of the Puntledge River from the Powerhouse to the Tsolum River confluence. Puntledge River Hatchery is located 400 m downstream of the Powerhouse. A barrier fence across the river directs migrating fish into a fishway where they may proceed further into concrete raceways in the facility, or continue their migration upstream in the river depending on the hatchery's broodstock collection requirements.

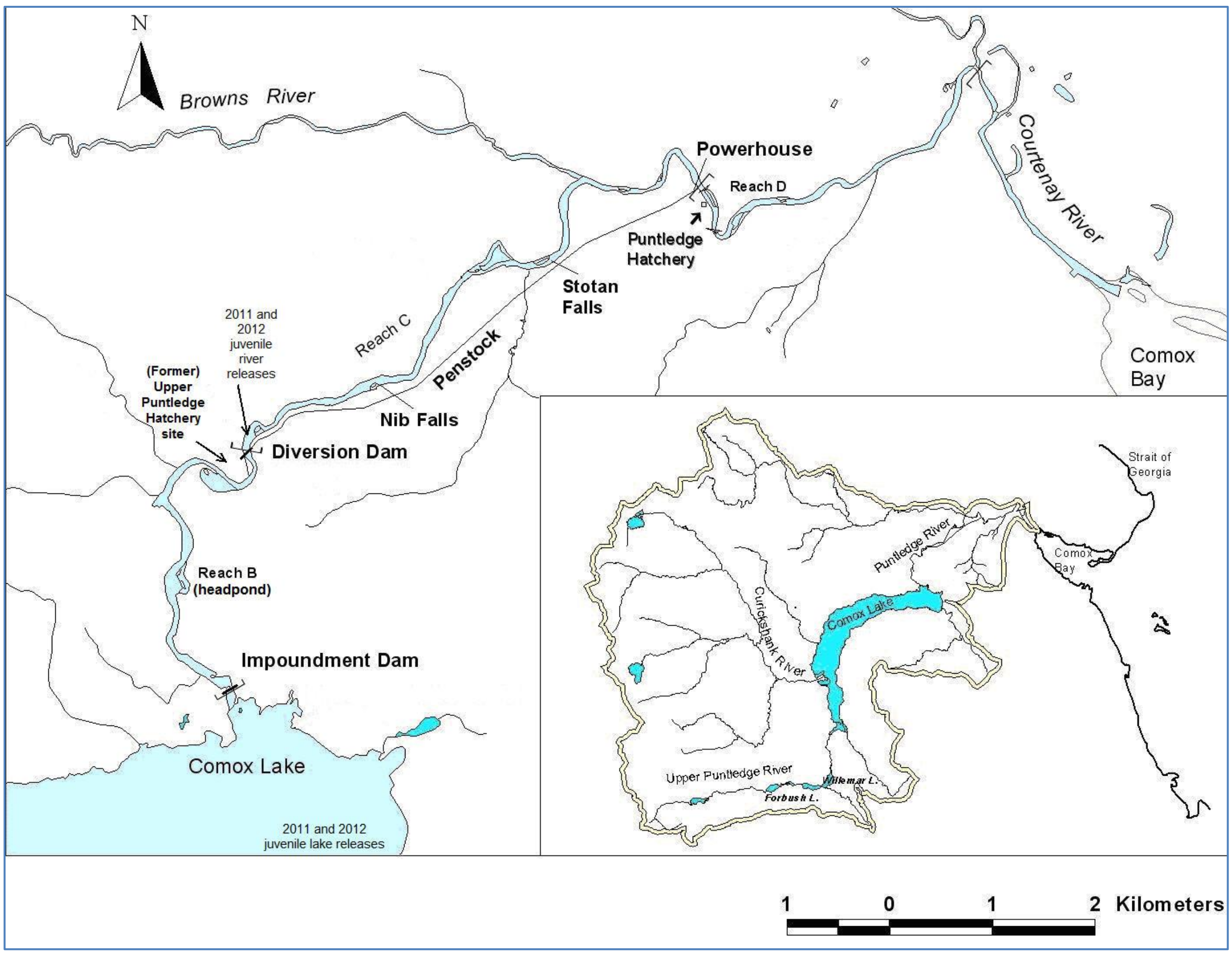

Figure 1. Location map of the Puntledge River watershed including lower river features and location of juvenile Chinook releases in 2011 and 2012.

3 METHODS

3.1 PIT tagging adults at Puntledge Hatchery

Summer Chinook adults migrating up the Puntledge River were diverted at the barrier fence into raceways at the lower Puntledge River Hatchery beginning in late May 2014. Every few days the adults were crowded for sorting and inspected for coded wire tags (CWTs). Fish were netted from the hatchery raceway and scanned with a handheld CWT Wand Detector (Northwest Marine Technology Inc. WA), in order to detect CWT'd adults with no adipose fin clip (lake release juveniles).

Coded wire tagged adults selected for PIT tagging were transferred to a sampling trough, and tagged with a uniquely coded 23 mm X 3.65 mm half duplex (HDX) PIT Tag (Oregon RFID, Portland, OR). The tag was injected subcutaneously into the dorsal cavity/sinus which surrounds the Pterygiophores (or interneural rays of the dorsal fin) using a 7-gauge hypodermic needle and metal injector[1]. PIT tag code numbers were recorded along with study group code ("Unmarked" or "Adipose Clipped" for lake and river releases respectively), sex, fork length and overall condition (scale loss, injury, etc.). A tissue sample (hole punch of the caudal fin) was also collected from each adult for DNA analysis. PIT tagged fish were then placed in a holding/recovery tank before release back to the river. All adults were tagged at the lower Puntledge Hatchery and released back to the river upstream of the hatchery barrier fence.

Summer Chinook that were not required for the homing study were either loaded into a transport truck and held at Rosewall Creek Hatchery for hatchery broodstock, or transported and released directly into Comox Lake where fish could safely hold and spawn naturally in October, in either the Lower Puntledge River or the Comox Lake tributaries.

3.2 Monitoring migration of PIT tagged summer Chinook adults

Radio-frequency identification (**RFID**) receivers and antenna arrays installed at the Puntledge diversion and Comox impoundment dam fishways were used to monitor the movement of the PIT tagged adults into the Puntledge River (headpond) and Comox Lake. Each fishway was equipped with two antennas - one at the downstream end

[1] PIT tags were injected as per methods described in http://www.biomark.com/Documents%20and%20Settings/67/Site%20Documents/PDFs/Fish%20Tagging%20Methods.pdf

(entrance), the other near the upstream end (exit). The two antennas at each fishway provided a backup if one antenna failed and information on rate of travel and migration success rate through the fishway. In addition, a multiplex HDX reader (Oregon RFID, Portland, OR) located at each site, automatically detected and recorded PIT tagged fish as they passed the antennas. The receivers were monitored and downloaded 3-4 times per week.

3.3 Monitoring migration of all summer Chinook adults into the headpond and Comox Lake

Puntledge Hatchery has monitored migration at the diversion dam fishway since 2005 with an underwater colour video camera (SplashCam Deep Blue) and digital video recorder (Duplex 1600/800 manufactured by Silent Witness®) referred to as a Digital Video Monitoring System (DVMS) in this report. The data from this installation verified the RFID detections and provides an overall estimate of summer Chinook adults that accessed habitat above the diversion dam.

A short-range **DIDSON (Dual-frequency IDentification SONar)** acoustic camera (Sound Metrics Corp., Bellevue, WA) was deployed at the Comox dam in early June and operated until the end of September. The DIDSON camera was connected to a laptop which was housed in a secure weather-proof metal storage cabinet at the dam. Video files from the camera were saved onto a removable hard drive that was swapped twice weekly, and reviewed in the office.

Following the 2013 homing behaviour study, it was recommended that a secondary surveillance system (DVMS) be installed at the impoundment dam and operate in tandem with the DIDSON sonar camera. The higher quality images from video recordings were used to corroborate recorded DIDSON sonar images of fish migration that were more difficult to interpret. An underwater colour video camera (SplashCam Deep Blue), connected to a digital video recorder (Duplex 1600/800 manufactured by Silent Witness®) was also housed in the weather-proof metal cabinet and operated simultaneously with the DIDSON. The camera was mounted on a pole in the fishway so that it could easily be positioned, readjusted or removed for cleaning. An underwater light was added later to capture night movement. This DVMS installation could only collect time lapse video footage. Motion event recordings could not be captured due to the amount of camera vibration in the fishway.

4 RESULTS AND DISCUSSION

4.1 Environmental Conditions

Mean hourly discharge and reservoir elevation data for the Puntledge River and Comox Lake during the summer Chinook migration period was obtained from BC Hydro Power Records and is illustrated in Figure 2. Data includes flows in Reach C recorded at BC Hydro Gauge 6 below the diversion dam (WSC Gauge No. 08HB084), Comox impoundment dam sluice gate releases (Reach B discharge), penstock discharge, and Comox Lake reservoir elevation. The Puntledge Generating Station was shut down for maintenance from June 12 - 25, 2014, and was not returned to service until late October due to low inflows and BC Hydro's need to conserve water during the summer to meet downstream fish flow requirements. As a result, discharge in Reach C remained higher than normal for the entire summer Chinook migration period (i.e. 13.5 m^3/s vs 5.7 m^3/s) and was slightly above the prescribed summer migration pulse flow (12 m^3/s) as per the Puntledge Water Use Plan, (PUN WUP).

Mean daily river temperature during the summer Chinook migration period, collected from a water level logger (Levelogger Model 3001; Solinst Canada Ltd., ON) located downstream of the diversion dam, is illustrated in Figure 3.

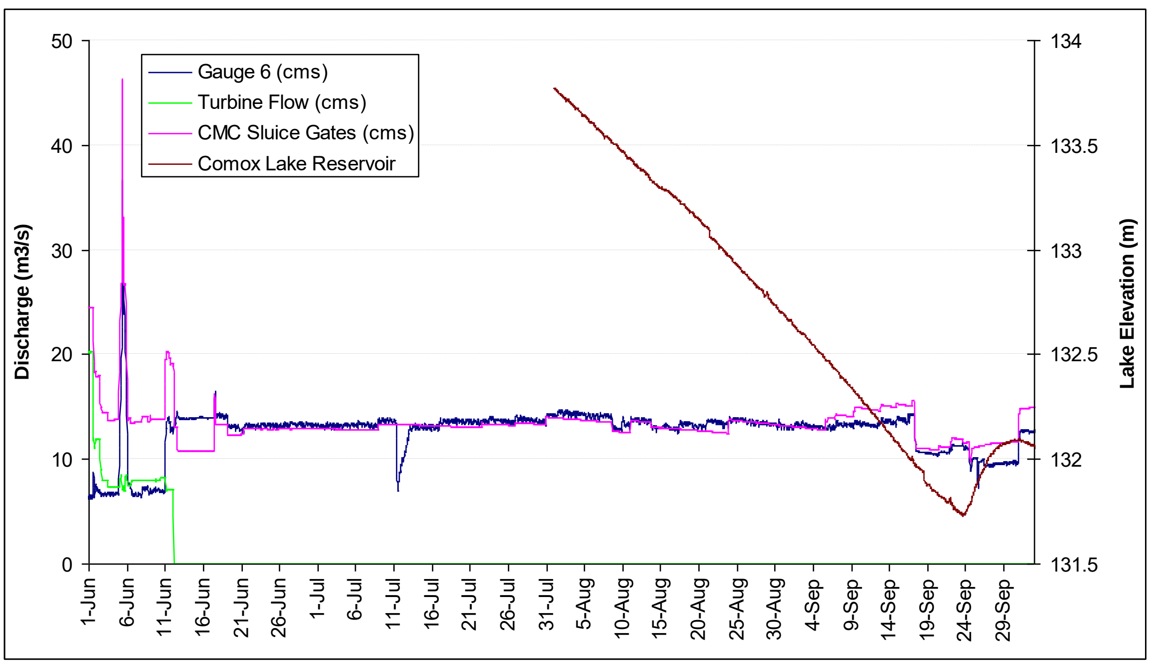

Figure 2. Puntledge River mean hourly discharge for Gauge 6 below the diversion dam (WSC Gauge No. 08HB084), Reach B (Comox dam sluice gate discharge), and penstock discharge, and Comox lake reservoir elevations during the summer Chinook migration period (June-October).

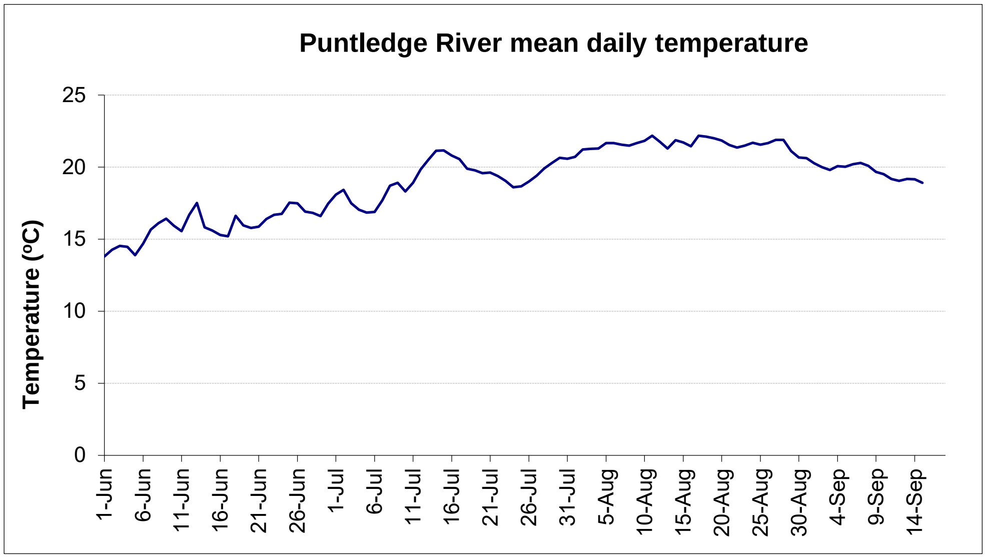

Figure 3. Mean daily river temperature from data collected at the Puntledge diversion dam Eicher assessment facility, June 1 – September 15, 2014.

4.2 Monitoring Adult Returns

The total number of summer Chinook adult returns that were PIT tagged in 2014 is summarized in Table 1. Of the 83 Chinook PIT tagged, 44 were from lake released juveniles, and 39 were from river released juveniles. The 2014 Puntledge River summer Chinook escapement was 1,176, much higher than the previous two years, but still significantly lower than the target level (3,500). Approximately 7% of the total escapement was PIT tagged for the 2014 study.

The fishway at the diversion dam was opened for Chinook migration beginning July 7, 2014 and remained opened until August 15 (the fishway was closed August 15 to prevent fall Chinook from accessing Reach B or headpond and cross-breeding with summer Chinook). A total of 37 PIT tagged Chinook were detected by either one or both of the antennas in the diversion dam fishway, and 36 successfully entered the headpond (Table 2).

Table 1. PIT tagging summary of summer Chinook adult returns to Puntledge Hatchery in 2014.

Application Date	No. Chinook PIT tagged: Unclipped (Lake releases)	No. Chinook PIT tagged: Adipose Clipped (River releases)	Water Temp (ºC)	Total No. Inspected	% PIT tagged
2-Jun	1	1	13	5	40.0
10-Jun	0	1	15	12	8.3
18-Jun	1	1	16.5	7	28.6
23-Jun	1	0	17	18	5.6
25-Jun	5	3	17.5	72	11.1
26-Jun	6	5	17.5	51	21.6
27-Jun	1	5	17.5	36	16.7
30-Jun	1	0	18	61	1.6
2-Jul	7	0	18	80	8.8
3-Jul	2	5	18.5	39	17.9
4-Jul	3	0	18	17	17.6
7-Jul	1	0	18	25	4.0
8-Jul	2	2	19	18	22.2
9-Jul	0	3	19	15	20.0
10-Jul	1	0	19	36	2.8
11-Jul	5	4	19	25	36.0
14-Jul	3	4	21	50	14.0
15-Jul	2	2	21	28	14.3
16-Jul	0	3	21	22	13.6
17-Jul	2	0	21	10	20.0
Total	**44**	**39**		**627**	**13.2**

Table 2. PIT tagged summer Chinook detected at the Puntledge diversion and the Comox impoundment dam fishways between 7 July and 7 August 2014.

				Diversion Dam					Comox Dam				
PIT tag #	Tagging Date	Group	Sex	Antenna 2 (Lower)		Antenna 1 (Upper)		Time to Pass	Antenna 2 (Lower)		Antenna 1 (Upper)		Time to Pass
690	2-Jun	Ad Clip	M	7-Jul	14:51:13	7-Jul	15:09:40	0:18:27					
685	2-Jun	Nmk	M	13-Jul	5:37:58	13-Jul	5:55:41	0:17:43	15-Jul	5:52:06	15-Jul	6:17:36	0:25:30
687	18-Jun	Ad Clip	M	n/d	n/d	7-Jul	14:27:42	-	15-Jul	6:13:51	15-Jul	6:34:56	0:21:05
691	25-Jun	Nmk	F	n/d	n/d	11-Jul[1]	n/d	-	17-Jul	22:46:35	17-Jul	23:52:38	1:06:03
697	25-Jun	Nmk	M	n/d	n/d	11-Jul[1]	n/d	-	14-Jul	8:41:08	14-Jul	9:09:01	0:27:53
704	25-Jun	Ad Clip	M	n/d	n/d	11-Jul[1]	n/d	-	15-Jul	9:18:52	15-Jul	9:42:36	0:23:44
695	25-Jun	Ad Clip	M	7-Jul	14:46:35	7-Jul	15:04:09	0:17:34	18-Jul	14:48:09	18-Jul	15:02:57	0:14:48
703	26-Jun	Nmk	M	10-Jul	4:11:51	10-Jul	4:41:52	0:30:01	18-Jul	18:19:10	18-Jul	18:36:30	0:17:20
698	26-Jun	Ad Clip	M	16-Jul	20:33:00	16-Jul	20:45:40	0:12:40					
900	26-Jun	Ad Clip	M	13-Jul	3:05:36	13-Jul	3:27:39	0:22:03	15-Jul	6:02:40	15-Jul	7:31:13	1:28:33
903	26-Jun	Nmk	M	9-Jul	14:25:50	9-Jul	14:42:09	0:16:19	13-Jul	7:54:41	13-Jul	8:04:03	0:09:22
911	27-Jun	Ad Clip	M	13-Jul	4:10:11	13-Jul	4:38:54	0:28:43					
909	27-Jun	Ad Clip	F	13-Jul[2]	0:24:56	n/d	n/d						
912	27-Jun	Ad Clip	M	10-Jul	4:58:34	10-Jul	5:44:23	0:45:49	15-Jul[2]	6:33:03	n/d	n/d	
907	27-Jun	Ad Clip	M	13-Jul	2:14:02	13-Jul	2:47:56	0:33:54	31-Jul	2:31:34	31-Jul	3:56:54	1:25:20
914	2-Jul	Nmk	M	n/d	n/d	10-Jul	5:20:43						
924	2-Jul	Nmk	M	20-Jul	1:00:16	20-Jul	1:49:03	0:48:47	10-Aug	6:41:34	10-Aug	7:03:47	0:22:13
920	2-Jul	Nmk	M	7-Aug	4:27:05	7-Aug	4:29:30	0:02:25					
918	3-Jul	Nmk	M	17-Jul	21:22:39	17-Jul	21:24:42	0:02:03	2-Aug	7:40:01	2-Aug	8:00:17	0:20:16
915	3-Jul	Ad Clip	M	16-Jul	20:07:41	16-Jul	20:09:39	0:01:58	18-Jul	17:52:58	18-Jul	18:05:09	0:12:11
913	3-Jul	Ad Clip	M	22-Jul	19:16:48	22-Jul	19:29:23	0:12:35	3-Aug	5:45:32	3-Aug	5:50:39	0:05:06

Table 2. Cont'd

				Diversion Dam					Comox Dam				
PIT tag #	**Tagging Date**	**Group**	**Sex**	**Antenna 2 (Lower)**		**Antenna 1 (Upper)**		**Time to Pass**	**Antenna 2 (Lower)**		**Antenna 1 (Upper)**		**Time to Pass**
919	3-Jul	Ad Clip	M	30-Jul	1:39:06	30-Jul	1:54:19	0:15:13	5-Aug	8:33:01	5-Aug	8:50:09	0:17:08
930	3-Jul	Nmk	F	16-Jul	19:25:53	16-Jul	19:52:48	0:26:55	30-Jul	0:58:28	30-Jul	2:32:08	1:33:40
928	3-Jul	Ad Clip	M	13-Jul	0:29:39	13-Jul	1:23:35	0:53:56	2-Aug	7:22:02	2-Aug	7:36:19	0:14:17
931	4-Jul	Nmk	M	15-Jul	16:28:35	15-Jul	16:33:16	0:04:41					
927	4-Jul	Nmk	M	14-Jul	2:26:33	14-Jul	3:06:14	0:39:41	6-Aug	8:19:00	6-Aug	8:45:42	0:26:42
938	8-Jul	Nmk	M	29-Jul	23:48:12	30-Jul	11:58:24	11:49:48			8-Aug	8:04:11	
933	8-Jul	Ad Clip	M	1-Aug	13:10:28	1-Aug	13:19:26	0:08:58	5-Aug	7:51:45	5-Aug	8:07:34	0:15:49
935	9-Jul	Ad Clip	M	27-Jul	19:46:20	27-Jul	20:35:26	0:49:06	30-Jul	2:07:40	30-Jul	4:27:28	2:19:48
940	11-Jul	Ad Clip	F	26-Jul	15:08:43	26-Jul	15:26:25	0:17:42	5-Aug	7:29:58	5-Aug	7:45:30	0:15:32
942	11-Jul	Nmk	F	1-Aug	5:11:44	1-Aug	5:24:34	0:12:50	5-Aug	8:03:15	5-Aug	8:16:44	0:13:29
950	11-Jul	Ad Clip	M	5-Aug	10:02:23	5-Aug	10:39:08	0:36:45	8-Aug	7:31:06	8-Aug	8:24:12	0:53:06
958	14-Jul	Nmk	F	5-Aug	0:39:46	5-Aug	1:30:18	0:50:32	12-Aug	7:34:29	12-Aug	8:03:34	0:29:05
954	14-Jul	Ad Clip	M	2-Aug	10:40:43	2-Aug	10:57:06	0:16:23					
952	15-Jul	Nmk	M	5-Aug	1:35:34	5-Aug	1:57:03	0:21:29	11-Aug	7:50:24	11-Aug	8:07:18	0:16:54
967	16-Jul	Ad Clip	M	5-Aug	12:47:41	5-Aug	58:31.4	0:10:50	12-Aug	9:06:58	12-Aug	9:13:43	0:06:45
963	17-Jul	Nmk	M	22-Jul	12:02:45	22-Jul	12:07:44	0:04:59	30-Jul	6:12:27	30-Jul	6:32:53	0:20:26
							Total Nmk (Lake)	**17**					**14**
							Total Ad Clip (River)	**19**					**14**
							Passage uncertain	**1**					**1**
							TOTAL	**37**					**29**
							Average time to pass through fishway	**22:42***				**Average time to pass through fishway**	**32:25**

n/d = not detected; Ad Clip = CWT and adipose clipped "river" released juvenile; Nmk = CWT and unmarked "lake" released juvenile.

1 - suspected passage, but undetected due to antenna tuning issue on 11 July; 2 – successful passage unknown

* - outlier from PIT tag #938 removed.

A total of 232 summer Chinook, including the PIT tagged adults, were counted by the underwater video camera in the diversion dam with the greatest daily migration occurring on the first day the fishway was opened (Figure 4). While reviewing migration video files during the first week, it was discovered that the motion event recordings failed to detect every fish moving past the camera in the fishway, possibly due to incorrect sensitivity zone settings, pixel area trigger size and/or direction settings on the recorder. This reduced the equipment's effectiveness to detect every fish. The digital DVMS recorders allow simultaneous time-lapse and motion event recording which were stored as separate files. We were able to identify the missing fish after reviewing the time-lapse video files.

The average time for Chinook to pass through the diversion dam fishway, a distance of ~25 m between antennas, was 22:42 minutes (range = 0:01:58 to 0:53:56) if one outlier of 11:49:48 is removed from the calculation. It is interesting to note that some adults displayed considerable movement upstream and downstream between the lower and upper antennas before their final passage into the headpond.

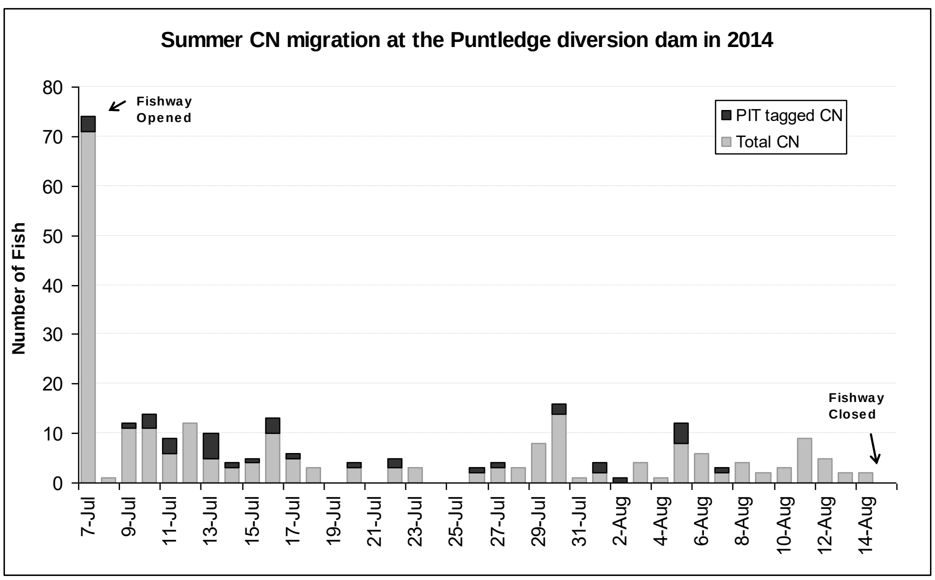

Figure 4. Movement of summer Chinook salmon (including PIT tagged adults) through the diversion dam fishway as recorded by underwater video surveillance, July 7 - August 15, 2014.

Of the 36 PIT tagged Chinook that were confirmed in Reach B (headpond), twenty-eight (28) successfully migrated into Comox Lake between 15 July and 8 August (Table 2). These fish took on average 32:25 minutes (range = 0:5:06 to 2:19:48 minutes) to pass through the fishway, a distance of ~50 m. Unlike the diversion dam where some fish displayed significant upstream and downstream movement in the fishway, PIT tagged adults were detected only briefly at each antenna, likely a result of the different fishway type/configuration (submerged orifice at the Comox dam versus pool weir at the diversion dam).

A total of 165 summer Chinook, including the PIT tagged adults (28), were detected by the DIDSON and video camera at the impoundment dam fishway between July 9 and August 18, 2014 (Figure 5). Although both systems operated until the end of September, based on the infrequent observations in the latter half of August, the sonar and video files were only reviewed to September 4th.

Reservoir levels and total discharge were low in August 2014. There is a strong possibility that migration into Comox Lake could have occurred directly under the sluice gates rather than the fishway. It is assumed that Chinook could potentially swim through the sluice gates at the Comox dam when velocity through the gates is < 6.83 m/s (22.4 ft/s), which is the burst speed of Chinook salmon (Bjornn and Reiser 1991). Using records of lake level, discharge and height of the sluice gates in 2006, the velocity through each gate was calculated and results indicated that Chinook salmon may have been capable of passing through the gates at the dam as early as August 1st 2006 (Figure 6; Guimond 2007). Assuming the discharge was evenly split between the two sluice gates in 2014 as it was in 2006, Chinook access likely occurred through both gates (Figure 6). Passage through the fishway in late-August and September 2014 was also likely affected by low reservoir levels and lower attraction flow at the fishway entrance caused by progressively decreasing flows through the fishway as the lake level dropped throughout the summer.

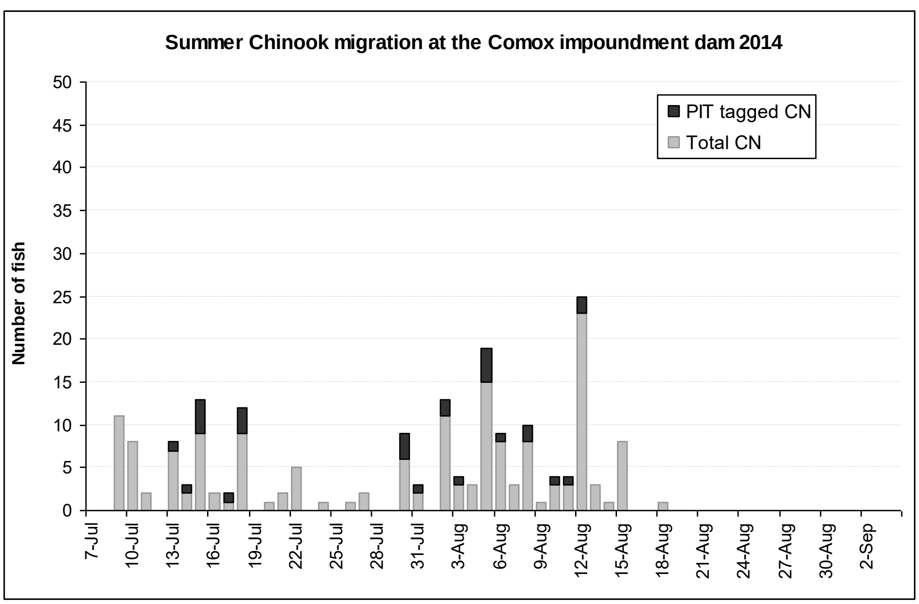

Figure 5. Movement of summer Chinook salmon (including PIT tagged adults) through the Comox impoundment dam fishway as recorded by a DIDSON sonar and video cameras, July 7 – September 4, 2014.

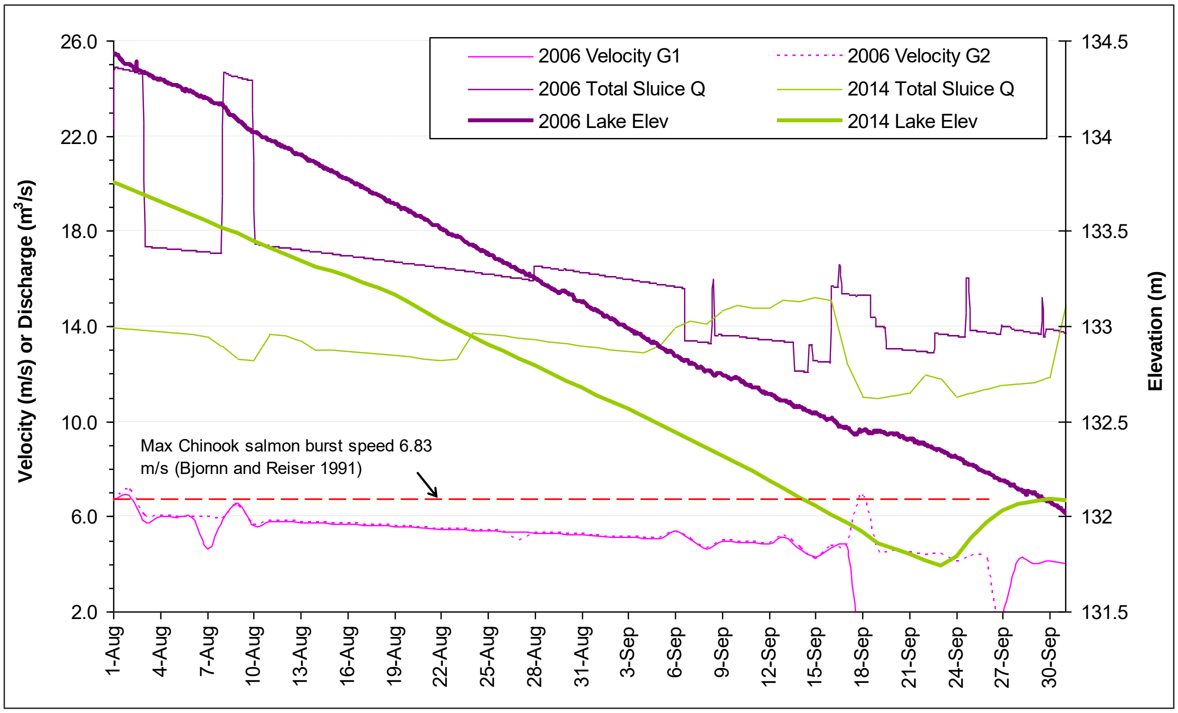

Figure 6. Comox Lake reservoir elevation (thick lines) and sluice gate discharge (thin lines) in 2014 (green) compared to 2006 (purple) elevation and discharge. The associated sluice gate velocity for each gate opening (G1 and G2) is provided for 2006 only to illustrate the opportunity for Chinook access under the gate based on Chinook burst speed.

The total number of Chinook observed may be under or over-estimated due to several sources of error: observer errors detecting and counting fish or mis-identifying fish, fish migrating outside the sonar beam, missed detection of fish within the sonar beam, and fish by-passing the DIDSON camera and accessing Comox Lake through the sluice gates.

Of the 83 PIT tagged Chinook released back to the river for the study, 46 Chinook, or 55%, were not detected at the lower diversion dam fishway. This figure seems to agree with the results from 2013, and from earlier radio telemetry studies (2002 – 2007) on summer Chinook migration in the Puntledge River Reach C (Guimond and Taylor 2009) which found overall, only ~50% of radio-tagged fish released at the lower Puntledge Hatchery successfully reached the diversion dam pool. However, as in previous years, the absence of additional detections at the fishway does not necessarily confirm a failure of fish to reach the diversion dam pool (i.e. immediately downstream of the diversion dam fishway), since further passage is restricted due to closure of the fishway in mid-August.

4.3 Monitoring summer Chinook migration into Comox Lake

Many of the issues with the DIDSON sonar employed in 2013 (Guimond 2014) were resolved in 2014. We started recording with DIDSON and Digital Video Monitoring System (DVMS) equipment simultaneously on 7 July. The DIDSON camera, installed upstream of the fishway and video recording camera, installed downstream of the existing camera tunnel in the fishway, provided continuous recording for the project between 10 July and 4 Sept except for a few brief interruptions when one of the two systems failed.

For each hour that the DIDSON was operational, 1 hour of video was recorded by the DIDSON software at 5 frames per second (fps) and each hour was saved automatically as a separate file (~900 Mb each) to an external hard drive. These files were reviewed at up to 20x speed (minimum of 3 min/hr of footage) using DIDSON software on a PC at the office.

For each hour that the DVMS was operational, 1 hour of video from the submerged camera was recorded by the DVMS software at 5 frames per second (fps) and each hour was saved automatically as a separate file (~500 Mb each) to one of the removable hard drives. These files were reviewed at up to 10x speed (minimum of 6 min/hr of footage). All DVMS files for the study period were reviewed to verify DIDSON recordings or to fill in gaps where DIDSON footage was not available.

In some cases, the fast speed of travel, and faint or obscured images of salmon exiting the fishway often necessitated a review of up to several minutes of video frames to confirm a DIDSON observation. The presence of actively feeding trout, which could be confused with smaller salmon, also increased reviewing time. Every hour of DIDSON sonar reviewed required between 3 and 8 minutes of observer time, depending on the level of fish activity. All DIDSON data recorded between 10 July and 4 Sept was reviewed. If a fish was detected, the corresponding DVMS footage was reviewed for up to ½ hr before and ½ hr after the recorded DIDSON event. (Review of the DVMS data between 7 July and 4 Aug was limited to only the footage recorded during daylight hours due to the absence of nighttime lighting capability). On 4 Aug a submersible LED light was installed with the video camera to provide light to the tunnel area which allowed reviewing of the entire 24hr period that the DIDSON was operating, improving our ability to verify migration data during low light conditions. However, the greatest number of migration events was detected between the hours of 8:00 and 12:00.

For the first 4 days of monitoring, there were no difficulties with either setup. Recording ceased on the DIDSON on 11 July around midnight, but technicians doing a maintenance check at 8 am reset the system back to recording mode. Other subsequent failures of the DIDSON recording occurred as follows:

- 17 July @ 0:00 – 18 Jul @ 11:00
- 22 Jul @ 13:00 – 23 Jul @ 8:30
- 29 Jul @ 15:00 – 30 Jul @ 8:00
- 18 Aug @ 9:00 – 20 Aug @ 15:00

The DVMS was also not operational on 18 Aug @ 9:00 to 20 Aug @ 15:00. No additional migrating fish were detected after 18 Aug.

Although the DIDSON sonar could operate under any light condition or water visibility and required minimal maintenance during the period of operation, it did require substantially more staff time than motion detection video to review and analyse recordings. For this study, using DVMS time lapse recordings to verify events detected by the DIDSON, significantly increased the total amount of review time required. The video camera/digital video recorder installation used in previous years effectively captured motion event recordings and only required analyses of the motion triggered video clips. This significantly reduced the time required to review video files. Unfortunately, the camera lens, which couldn't be accessed during the summer, required cleaning to maintain acceptable imagery. Modifications to the camera in 2014 allowed crew to access and clean the camera lens and maintain image quality but restricted video footage to time lapse only. Finding a balance between equipment performance and staff time requirements needs further improvement if monitoring adult migration into Comox Lake becomes a priority and long term objective.

4.4 Analysis of 2013 and 2014 migration into Comox Lake

The two years of "study group" juvenile releases in 2011 and 2012 (i.e. 90,000 smolts released into Comox Lake with a CWT and adipose fin; and 180,000 CWT-adipose clipped smolts into the river) will provide a 3 year period where the adult returns can be PIT tagged and their migration behaviour monitored at the dams. This ensures that a sufficient sample size can be examined. Multi-year assessment also reduces the bias a poor river escapement year (due to low marine survival, higher pre-spawn mortality from predation, warm water conditions, etc.) can have on the study results. The majority of summer Chinook females return at 4 years old (range 3-5 yrs) while the greatest proportion of males are 3 and 4 years old (range 2-5 yrs; Trites et al. 1996). Pooling homing results over the three years of study will increase the sample size in each group, improve the statistical power of the study design and average out the physical and biological conditions that can vary year-to-year.

Over the two tagging years, 2013 and 2014, totals of 55 adipose clipped Chinook (River group) and 57 un-clipped fish (Lake group) were tagged. These totals included 2 jacks in the river study group and 5 jacks in the lake group, all of which were tagged in 2013 (Table 3).

Table 3. Total number of Chinook tagged by study group and sex, over the first two years of the study.

	2013				2014			Two Yrs Combined			
Study Group	Sex			Total	Sex		Total	Sex			Total over 2 Yrs
	M	F	J		M	F		M	F	J	
River (Ad clip)	9	5	2	**16**	32	7	**39**	41	12	2	**55**
Lake (No mark)	5	3	5	**13**	31	13	**44**	36	16	5	**57**

In 2014, the average time from release at the lower Puntledge hatchery to detection at the Diversion Dam array was 18 days, with an additional 8 days, on average, for fish to reach the upper antenna at Comox Dam. Travel time of 21 days from the same release location to the diversion dam in 2013 was not significantly different ($t = 1.81$ $p = 0.359$): although the range of the 2013 data (range 13 to 35 days, variance 61.6) was narrower than that in 2014 (range 5 to 41 days, variance 57.5) the variance was similar. Similarly, 26 days including a period of residence in the headpond, were needed to reach Comox Dam in both 2013 and 2014 ($t = 1.78$ $p = 0.807$).

The number of Chinook in each study group that reached the diversion dam and the Comox dam tracking sites, are listed in Table 4. In 2014, 3 Chinook were detected by the antennas at the Comox dam, but not by the antennas at the diversion dam 3.7 kms downstream. These were likely fish that passed through the diversion fishway RFID antennas during a brief period when the antennas' sensitivity required readjustment. Since other PIT tagged Chinook may have passed through the fishway during this time, but did not proceed into Comox Lake, these fish are not included in Table 4. Therefore, there is a degree of error associated with detection rates and unfortunately this error cannot be quantified from our data, as explained below.

Table 4. Number of Chinook recorded at the Diversion and Comox dams by year and study group. P1 and P2 identify the proportions of releases that migrated to the respective areas.

		Diversion Dam	Comox Dam	P1	P2
	2013	7	6	43.8%	37.5%
River	2014	18	14	46.2%	35.9%
	2013	6	5	46.2%	38.5%
Lake	2014	15	14	34.1%	31.8%
Total River		25	20	45.5%	36.4%
Total Lake		21	19	36.8%	33.3%

The overall success rate of tagged fish that migrated to the detection array at the diversion dam was 45.5% for the River group and 36.8% for the Lake group. The equivalent proportions that were detected at the Comox Lake array were 36.8% and 33.3%, respectively. The first hypothesis to be tested, H_1, states that more of the Lake release group would likely migrate to Comox dam, given their release in the upper system. The alternative hypotheses, H_0 states that the probabilities are equal and neither group shows a preference for a specific migration destination. Comparing the overall probabilities for these groups, there is no significant difference between them ($z = 0.337$ $p = 0.736$). Similarly, we can test the assumption that more River fish were attracted to the diversion dam. Again there was no significant difference between the probabilities ($Z = 0.927$ $p = 0.354$). Finally, we examined the possibility that, of the fish reaching the diversion dam, Chinook in the Lake group would be more likely to continue to Comox dam. These probabilities derived from the differences in counts from the first array to the second upstream, and P1 is 0.80, while P2 is 0.905. Once more, there was no significant difference between the proportions in each study group that continued upstream ($Z = -1.013$ $p = 0.267$).

Connolly (2010) discusses factors that affect passive integrated transponder (PIT) tag detection in terms of array orientation and antenna placement. These are both biological and physical and include tag orientation as well as lateral and vertical coverage by the array. Using more than one antenna allows for the estimation of detection efficiency which is useful where differential detection of the PIT tags is encountered. However, this method is applicable to studies of unidirectional movement, where it is assumed the subjects will continue to move past both arrays.

Unfortunately, in our study, there is the expectation that some fish will not continue their migration due to imprinting on a release location. Therefore, the probability of re-sighting a fish at the second array cannot be assessed. The movement of Chinook to the second array while undetected at the first suggests that the number of fish moving to the diversion dam is underestimated. This creates uncertainty in the detection rates, but may apply equally to both arrays. We have no ability to check on undetected movement past the Comox dam array. However, the error from this factor is likely to be small and in terms of underestimation of diversion dam fish it would tend to reduce the difference between the study groups, resulting in lower statistical significance for the comparison. Consequently, we can confirm that the data collected from two years of tagging suggests that point of release of Chinook fry has no impact on homing behaviour in the Puntledge River.

Based on previous study design calculations, a total of 60 adults from each release group were needed to be PIT tagged for a precision of ±20%. Extending the project over multiple years increases the opportunity for acquiring sufficient adults to tag. The adult release numbers do not have to be the same in each year, since the total recoveries can be pooled, providing additional safeguards in the event that tag releases in any one year are lower than anticipated.

Given the close agreement in the data to date, we have low power in the analysis that is unlikely to be significantly elevated by anything other than a very large sample size in 2015 combined with an equally large disparity in homing behaviour. Therefore we will endeavor to tag as many adults from each group as feasible, with little concern for equal numbers of each type (lake or river) since the analysis can accommodate different sample sizes for the 2 groups.

5 RECOMMENDATIONS

Monitoring of adult Chinook (and coho) migration into Comox Lake has been identified as an important long term management activity within the DFO SEP program. This will require efficient and effective surveillance methods to ensure quality data is captured throughout the migration periods, and that the installation can be easily monitored and maintained. The two years of monitoring with DIDSON, and combined DIDSON/video camera has shown that the location has limitations for optimum use of the DIDSON. However a DVMS and video camera system deployed in a suitable location in the fishway that would allow motion event recording, while still being easily accessible for maintenance, may be the most cost effective option at this time, and should be further explored for the 2015 summer Chinook migration period.

Following the closure and decommissioning of the Upper Hatchery site in 2012, all summer Chinook production was moved to the lower Puntledge Hatchery site and the smolts were to be transported and released into Comox Lake. Unfortunately, results from an assessment of Eicher screen performance in 2013 indicated that Chinook juvenile survival may be compromised and it was decided to release smolts from the lower hatchery. Although a follow-up assessment in 2014 verified that screen mortality varied with fish size and was found to be much higher on juveniles less than 50 mm in length, as a precaution, hatchery summer Chinook smolts, which are typically 65 mm have been released from the lower Puntledge hatchery since brood year 2012. This is approximately 6.5 kms further downstream from the river release site in the homing study. Although this lower river release strategy may reduce smolt downstream migration mortality and result in higher overall adult survival and returns, the returning adults may be less inclined to migrate past the lower hatchery. Hatchery adults must be capable of successfully re-integrating into the wild spawning population. A key behavioural component to achieving this goal is the need for the returning adults (hatchery and wild) to migrate into Comox Lake, hold in the cooler depths during the summer and successfully spawn in October.

In order to assess the future success of hatchery adults and the rebuilding of the overall summer Chinook population, continued adult enumeration at the lower Puntledge Hatchery, diversion dam and impoundment dam, differential marking of hatchery smolt releases, parentage-based (DNA) tagging, assessment of the Eicher screen performance and monitoring of new hatchery strategies will need to continue.

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APPENDICES

APPENDIX A - Confirmation of FWCP Recognition

Project Watershed participated in several outdoor events, including the Puntledge Hatchery Open House, October 2014, providing information on the Summer Chinook Homing Behaviour Study, and other FWCP projects, past and present. The following 24” x 36” poster was displayed at the event.