

# **Radio-telemetry investigation to test closure assumptions underpinning escapement estimates for the Harrison stock (Fraser River Fall Run Aged 0.3 Chinook Aggregate).**

## **Final Report**

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## ABSTRACT

From 1982 to present, the late-run (Fraser Fall Stock Group) Chinook salmon (*Oncorhynchus tshawytscha*) escapement to the Harrison River has been estimated annually using high-precision, two event mark-recapture methods. In 2012, a telemetry study on Harrison River Chinook was conducted to investigate the behavior and distribution of the spawning population, and to determine whether this two-event mark recapture study met the assumption of closure.

Radio tags were applied in-river to holding male and female Chinook salmon. Movement was telemetrically monitored throughout the mark-recapture study period (in-river holding and spawning period through death) using fixed monitoring stations and a mobile tracking system. Most of the radio tagged Chinook salmon held upstream prior to spawning. However, a few radio tagged fish moved back downstream before returning upstream to spawn. All radio tagged fish were detected and remained within the mark-recapture study area. Therefore, this study did not invalidate the assumption of closure for the Harrison River Chinook salmon mark-recapture in 2012.

## INTRODUCTION

The Harrison River was designated an escapement indicator stock for Chinook salmon in 1984 as this stock comprised close to one-third of the Fraser River system Chinook escapement in the 1970s (Farwell *et al.* 1987). The Harrison River Chinook stock is part of a unique Fraser Chinook population identified as a white-fleshed, fall spawning stock with juveniles that migrate to sea immediately following emergence (Fraser *et al.* 1982). The Canadian Department of Fisheries and Oceans (CDFO), has been conducting a high-precision Chinook salmon mark-recapture study on the Harrison River annually since 1984 (Staley 1990; Farwell *et al.* 1990, 1991, 1992, 1996, 1998; Schubert *et al.* 1993, 1994).

Escapements to the Harrison River are estimated using a closed, two event Petersen mark-recapture. To produce asymptotically unbiased estimates, several key assumptions must be met including the assumption of closure. In order to meet the assumption of closure, all marked fish must remain in the study area throughout the spawning period. No fish should enter the study area after tagging has ceased (immigration) and no fish should leave the study area after tagging to spawn in another stream (emigration).

Telemetry has been used for investigating fish behavior since 1956 (Trefethen (1956) in Stasko and Pinock (1977) and was used to investigate closure of the Chilko River Chinook salmon mark-recapture in 2010. Radio telemetry was used to assess closure and investigate the behavior of Harrison Chinook salmon in the vicinity of the spawning grounds. Movement within the study area, and emigration beyond the upstream or downstream extents of the mark-recapture study area were monitored using fixed monitoring stations and a mobile tracking system. Radio tagged fish were detected past the lower extent of the study area; therefore, mobile tracking was conducted outside the study area to investigate whether these fish were moribund and drifted out or they emigrated. The Chilliwack River is an exploitation rate indicator stock used to represent the distribution of the Harrison Chinook stock. Chinook salmon spawning in the Chilliwack River in the late-fall are pre-dominantly Harrison River Chinook salmon that were raised at Chilliwack Hatchery. The Chilliwack River is within close proximity (3 km) to the Harrison River and Chinook tagged in the Harrison River during the mark-recapture project have been recovered in the Chilliwack River. Therefore, Chilliwack River was the most likely destination of Chinook salmon emigrating out of the Harrison River.

Mark-recapture data and field observations from the Harrison River have indicated that adult Chinook migrate into the upper portion of the spawning habitat to hold and then drop downstream to spawn.

In order to evaluate the assumption of closure in 2012, Chinook salmon were radio tagged during the tag application phase of the mark-recapture. The

upstream and downstream boundaries of the study area were monitored using fixed station receivers to count the number of tagged fish that emigrated from the study area. Mobile tracking was used to confirm the presence of the radio tagged Chinook salmon within the study area. In addition, movement patterns were determined for each fish by compiling the fixed station and mobile tracking data, and general behavioural patterns and distribution of the spawning population were then summarized.

## STUDY AREA

The Harrison River drains a mountainous coastal watershed in southern British Columbia (Figure 1). The river originates at Harrison Lake and flows south-west for 16.5 km, entering the Fraser River 116 km upstream from the Strait of Georgia. Measured at the outlet of the lake (hydrometric station ID 08MG013), the annual mean daily discharge between the years 1951 and 2011 was  $441 \text{ m}^3 \times \text{s}^{-1}$ . The annual mean daily maximum was  $1248 \text{ m}^3 \times \text{s}^{-1}$  and a minimum of  $128 \text{ m}^3 \times \text{s}^{-1}$ . During the study (October to December 2012), the mean daily discharge was  $370 \text{ m}^3 \times \text{s}^{-1}$  (unpublished data, pers. comm., T. Mitchell, Environment Canada). The water temperature ranged between 8 and 15 degrees Celsius with a mean of 11.

The Harrison River is 12 km in length and has limited spawning habitat. The majority of Chinook salmon spawning habitat is downstream of the mark-recapture tag site (**Error! Reference source not found.**). The study area was divided into the same eight sections (reaches) as those used in the mark-recapture study (Farwell *et al.*, 1999). The reaches were originally based on homogeneity of physical characteristics. The two major tributaries to the Harrison River are Chehalis River and Morris Creek; however, no evidence of fall spawning Chinook has been observed in either of these tributaries.



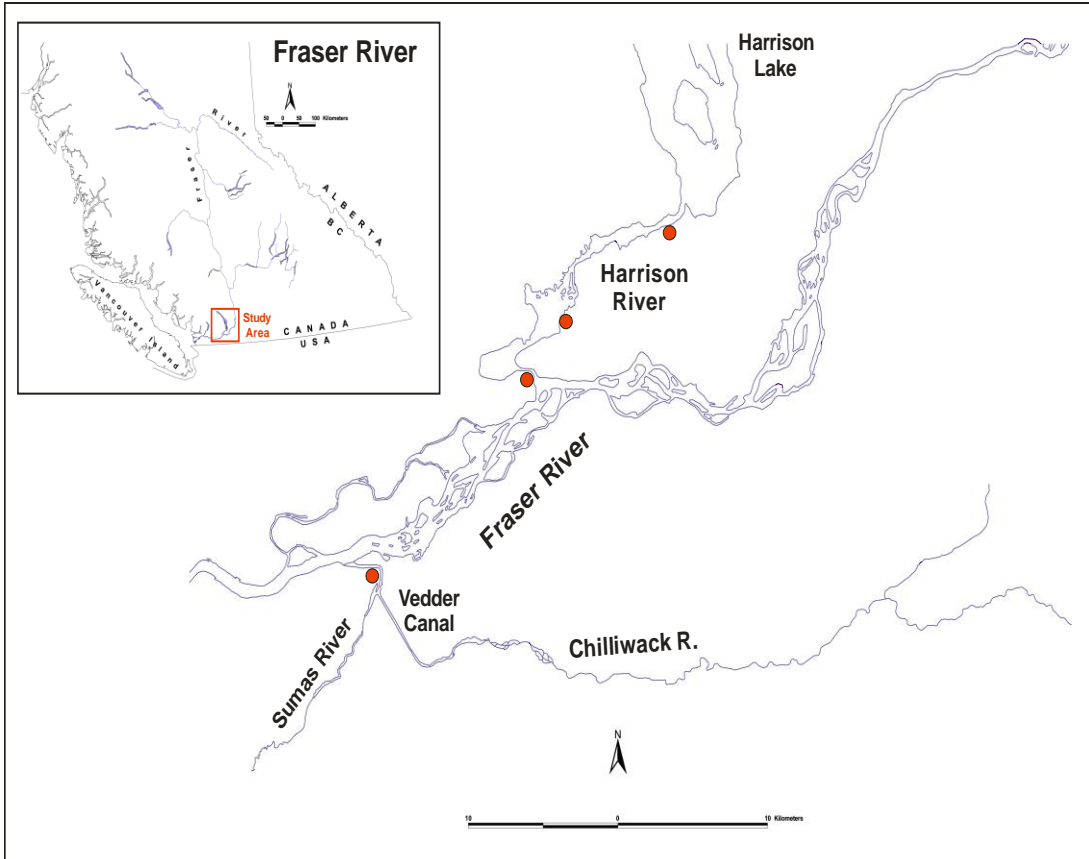


Figure 1. The locations of the radio telemetry fixed stations (red dots) in the Harrison River and at the mouths of the Harrison and Chilliwack rivers, 2012.

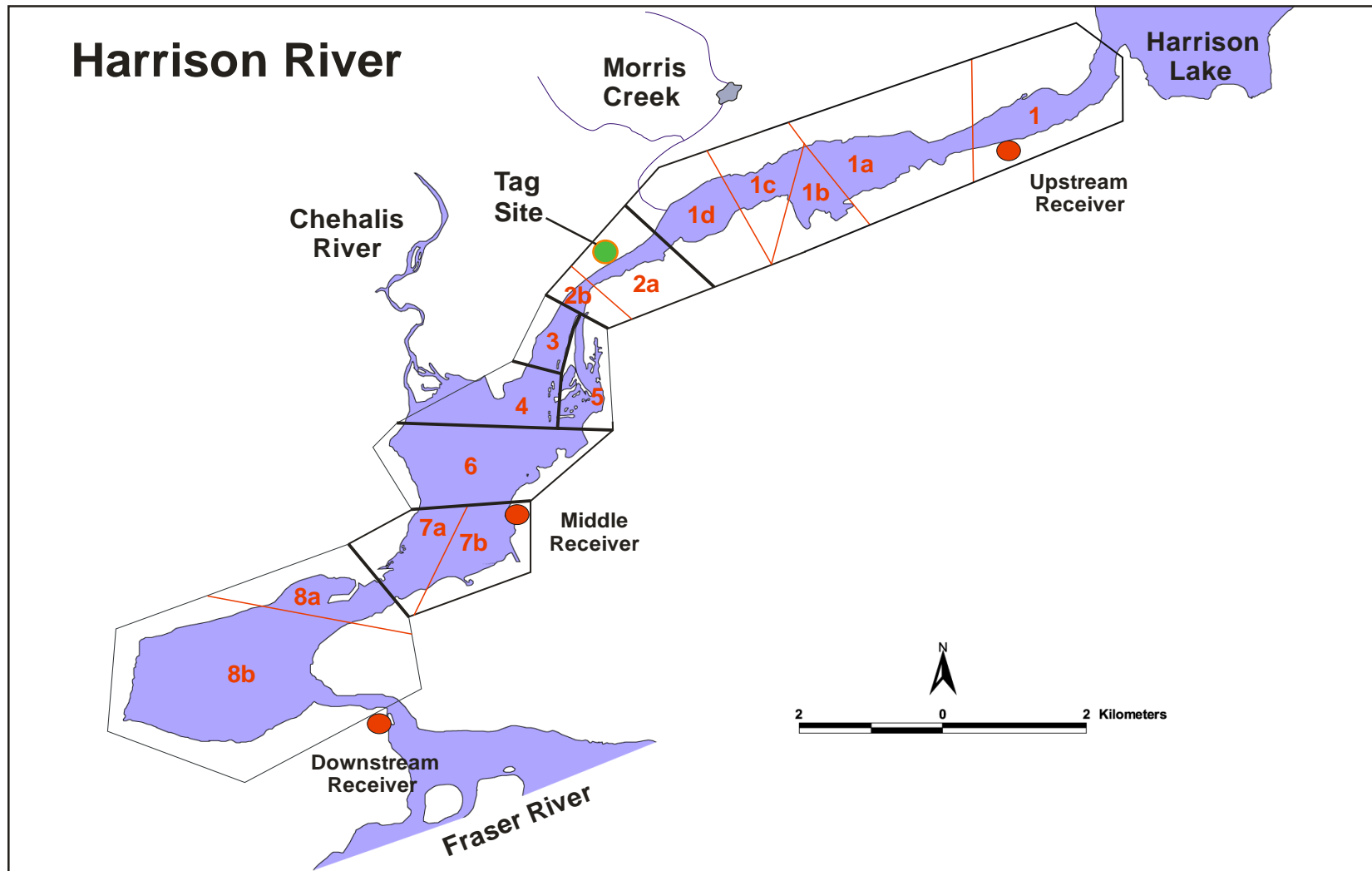


Figure 2. The mark-recapture reaches, telemetry sub areas, telemetry fixed stations (red dots) and tag application site (green dot) for the Harrison River Chinook salmon study in 2012.

## METHODS

### RADIO TAG APPLICATION

Harrison River Chinook salmon were captured for radio tag (transmitter) application during mark-recapture seining operations in Reach 2a (Figure 2) using a 250 X 30' seine net constructed with 3.5" mesh set by powerboat in a downstream crescent using a long upstream lead line and drawn from the river to enclose a portion of water along the riverbank. Once the seine and lead line (~50m) were set in an arc, they were withdrawn from the river until the net enclosed a small area of water along the shore. Captured salmon were held in the net in deep water until tag application (Farwell *et al.* 1999). Seining catch also included Sockeye, Chum, Coho and occasionally Sturgeon.

One to eight Chinook salmon were randomly selected for radio tag application daily. To activate the radio tag, the high power external magnet was removed and the tag was tapped on a hard surface. Pulse-coded Lotek MST-930-M radio tags with motion sensors were used (Lotek Wireless Inc., Newmarket Ontario). The tags are 7 mm wide x 28 mm in length and weigh 1.8 g underwater. A 225 mm long antenna, coated in a plastic sheath extruded from one end of the tag. The tags were applied externally and antennae were orientated to trail to the posterior of the fish. The radio tags were equipped with motion sensors, which changed the transmitted codes after 24 hours of inactivity. Inactive tags transmitted signal with a "1" preceding the original code. For example, a radio tag emitting a signal of code 15 change to 115. This would be considered a mortality code. The radio tags were programmed to stop emitting a signal after 90 days. Five external Lotek MCFT-3EM pulsing transmitters without mortality sensors were also used. Each radio tag had a unique channel and code combination for identification of individual fish. Frequency 150.720 was used predominately for males (codes 3-55) and 150.640 (codes 56-99) for females. Each radio tag was activated and tested with a receiver to ensure signal transmission in a controlled environment prior to release.

Upon capture, Chinook salmon were placed into a canvas sling in flowing water, and were quickly tagged, inspected for health, and released without being lifted from the water. The radio tags were applied using two 7.7 cm steel pins inserted through holes in the radio tag and into the dorsal musculature and pterygiophore bones approximately 1.5 cm below the dorsal fin with a Petersen disk tag (one orange and one transparent) on one side of the fish and a buffer Petersen disk tag on the other side. The radio tag and disks were held tightly against the fish by twisting each pin into a knot. Release time, radio tag channel (frequency) and code were recorded in addition to the regular data obtained during Peterson tagging. All other procedures implemented during regular Peterson disk tag

application were also conducted (Farwell *et al.*, 1999), except that sex-specific operculum punches were applied on the right operculum.

Radio tags were applied to 47 male and 47 female Chinook salmon. Various sized Chinook salmon were radio tagged throughout the run. Tags were applied from October 4 through November 8, when the majority of fish had moved onto the spawning grounds and very few fish were left holding. This allowed for tagging and monitoring fish that had arrived in the terminal area throughout the spawning period. Five of the radio tags released did not have motion sensors.

## TELEMETRIC MONITORING

A combination of fixed station and mobile tracking systems were used to locate Chinook salmon and monitor their movement, similar to the methods used for the Lower Shuswap River Chinook salmon radio-telemetry program from 2000-2002 (Trouton 2004) and the Chilko River in 2010 (Trouton *et al.* 2011).

### Fixed Stations

Fixed stations were installed along the bank where the river flow was confined to a single channel to ensure detection of radio tagged fish at three locations on the Harrison River and one on Chilliwack River (Figure 1 & 2). Fixed stations were equipped with a Lotek SRX 400A telemetry fixed receiver encased in waterproof, locked aluminum box and was powered by internal 13 to 18 hour batteries (Lotek Wireless Inc., Newmarket Ontario). A 12V RV battery and a solar panel were used to supplement and replenish receiver power. Two Yagi antennae (4-6 element) were installed at each station: one pointing upstream and the other pointing downstream.

Harrison River telemetry stations were installed at the upstream and downstream boundaries of the study area. The upstream station was located 2.04 km downstream of Harrison Lake and the downstream station was 0.41 km upstream of the Fraser River confluence. One additional station was located approximately in the middle of the study area, 5.79 km upstream of the confluence with Fraser River (Figure 2). All three sites were chosen at locations with minimal human presence and signal-noise interference. The Chilliwack station was located 2.43 km upstream the Fraser River confluence.

Fixed monitoring stations were calibrated and tested to ensure detection capability using a functioning tag prior to the start of application. Testing of receiver function was conducted by submerging an activated tag underwater at multiple depths and areas within the antennae ranges. To test the ability to detect moving tags, drifts using tags aboard jet boats at different speeds were

employed. Detection range limits were also tested, and an immobile tag was left in the range of each receiver station to test the motion (mortality) sensor function. Fixed stations on the Harrison River were visited every three or four days to download logged data and monitor battery life. Frequently but not always, a battery had to be exchanged, as the solar panels were not always producing enough power to charge the batteries. The Chilliwack River station was checked every 7 days.

## Mobile Tracking

A Lotek SRX 400A receiver was used for mobile tracking. A wooden case was constructed to secure the receiver during mobile tracking from the jet boat and to shield it from adverse weather conditions. The mobile receiver was equipped with a Yagi - 2 element antenna mounted on a 7' telescopic pole. A Yagi antenna was attached to the front on the helicopter for aerial tracking. The portable receiver was monitored and controlled by one person in the boat or helicopter while another crew member recorded tag detections. The time, location, channel, code, and signal power were recorded for each radio tag detected. The locations of individual radio tagged fish were interpreted as the location where the highest power level was identified and marked on a map.

Radio tagged Chinook salmon were mobile tracked out of the jet boat from Harrison Lake downstream to the confluence with the Fraser weekly between October 17<sup>th</sup> and November 27<sup>th</sup>. In addition, the Fraser River from the Harrison River outlet to the Chilliwack River fixed station was mobile tracked on November 16<sup>th</sup>. Finally, aerial (helicopter) mobile tracking was conducted on December 12<sup>th</sup>, the first suitable weather window after all Harrison River Chinook salmon completed spawning. Areas telemetrically surveyed from the air included: the Fraser River from the Agassiz Bridge to the confluence with Chilliwack River; the Harrison River from Harrison Lake to the confluence with the Fraser; and the downstream extremities of the Chehalis River and Morris Creek.

## RADIO TAG RECOVERY

Radio tagged Chinook carcasses were recovered during the mark-recapture spawning ground surveys. Observers collected the radio tags by snipping the pins and removing the tag. A magnet was placed on the radio tag immediately to end further radio signal transmission and the time was recorded. Sex, length, radio tag number (frequency and code), number of eyes remaining, recovery method, adipose fin presence, percent spawn (for females) and carcass condition were also recorded.

## DATA SUMMARY

A detailed history of each radio tagged Chinook salmon movement was compiled: from release through death or the end of the project. Each fish's history included date of release and fixed and mobile tracking information and when available the date of mortality and/or recovery (Appendix 1). Movement throughout the study area was tracked and used to determine if the fish remained within the study area.

As the motion sensor releases a mortality signal after 24 hours of inactivity, we assumed death took place at least 24 hours prior to the transmission of the mortality code. Some of the fish held and spawned close to a fixed station, which logged tag codes every minute. Therefore, when a radio tag signal being detected at a fixed station changed from a live code to a mortality code the time of death could be estimated within minutes. Mobile tracking detections of mortality signals could be linked to death occurring within the time between that detection and the previous survey (~3-5 days earlier).

## RESULTS

### RADIO TAG APPLICATION

A total of 94 radio tags were applied to Chinook salmon from October 4 to November 8, 2012 (Appendix 2). Forty-seven radio tags were applied to both males and females throughout the application phase of the mark-recapture project (Figure 3). Only six radio tags were recovered from carcasses (Appendix 1). Sex at application matched the recovery sex for all six recoveries of radio tagged carcasses; therefore, no sex identification correction for applied to radio tagged fish (Appendix 3).

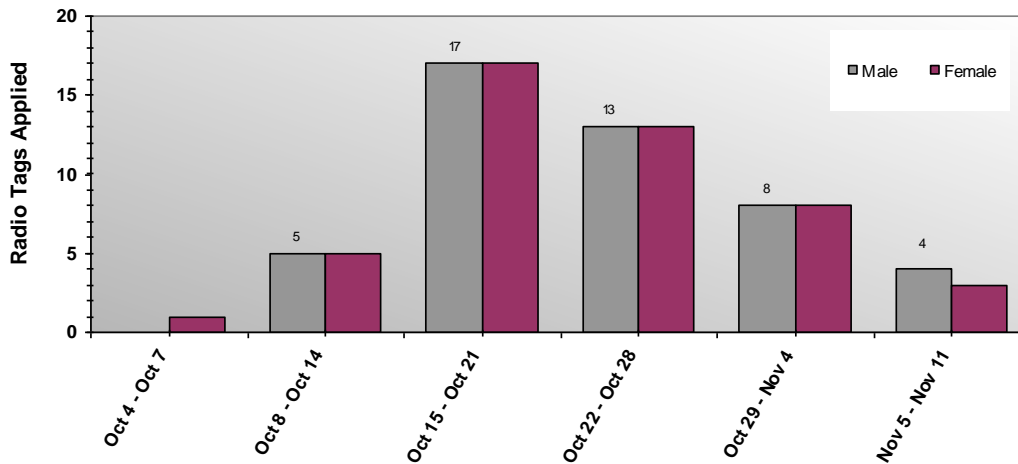


Figure 3. Radio tags applied to male and female Chinook salmon by week at the Harrison River in 2012.

## TELEMTRIC MONITORING

One of the 89 radio tagged fish with motion sensors was not subsequently detected; it was assumed that the radio tag battery died shortly after release or was not properly activated. Seventy three of 89 emitted mortality codes. Of the 15 that did not emit mortality codes: four were last recorded in the study area and 11 at the downstream station. These 11 passed the middle station shortly before the downstream station and had previously been mobile tracked on the spawning grounds during the spawning period; therefore, these fish were assumed moribund (Table 1). All five radio tagged fish without motion sensors remained within the study area.

Each radio tagged Chinook’s tracking history is described in **Error! Reference source not found.** It is unlikely that radio tags were missed leaving the study area, as all radio tags mobile tracked downstream of the study area were also detected as they passed the downstream receiver.

### Fixed Stations

Four individual fish were detected on the upstream fixed station receiver located at the top of the study area; however, these fish were all subsequently recorded within the study area (Appendix 1).

The downstream fixed station receiver recorded 29 individual codes, six of which were detected as mortalities and ten that were later detected during mobile

tracking as mortalities either within the study area or downstream in the Fraser River (Appendix 1). Of the 13 live radio tags, two were subsequently recorded upstream and 11 had shown evidence of spawning prior to moving downstream of the receiver and were most likely floating carcasses or moribund (Table 1 and **Error! Reference source not found.**).

Table 1. Time of death of moribund radio tagged Chinook salmon that exited the Harrison River.

Radio Tag	Date Released	Date of last recorded as live code	Total time of drift	Days Out <sup>a</sup>	Sex
15	16-Oct	5-Nov	0:04	21	M
21	16-Oct	31-Oct	0:21	16	M
24	31-Oct	7-Nov	0:10	8	M
30	23-Oct	5-Nov	0:08	14	M
45	3-Nov	10-Nov	0:03	8	M
55(4)	9-Oct	21-Oct	0:10	13	F
58	12-Oct	31-Oct	0:13	20	F
65 <sup>b</sup>	16-Oct	29-Oct	0:05	14	F
68 <sup>b</sup>	17-Oct	31-Oct	0:08	15	F
76	9-Oct	31-Oct	0:03	23	F
80	22-Oct	31-Oct	0:07	10	F
83 <sup>b</sup>	23-Oct	2-Nov	0:19	11	F
87	25-Oct	6-Nov	0:03	13	F
93	31-Oct	11-Nov	0:12	12	F
<b>Average</b>				<b>14.14</b>	

<sup>a</sup> Days Out is number of days between date of release to to date recorded at downstream as moribund plus 24hours.

<sup>b</sup> Radio tags recorded as mortalities downstream on Fraser River downstream of the confluence with Harrison River.

The middle fixed station receiver recorded 75 individual radio tag codes (Appendix 1). Twenty nine of these were mortality codes and 13 were a live code succeeded by a mortality code; therefore, date of death could be closely approximated.

No radio tag codes were detected at the Chilliwack fixed station.

### Mobile Tracking

Of the 94 radio tags released, 93 were mobile tracked (Table 2 and Appendix 2). The 1 radio tag not detected by mobile tracking was released and never subsequently tracked. Sixteen radio tag codes were only mobile tracked as they



remained in the area between the upper and middle fixed stations. The remaining radio tag codes were detected at the middle station.

Table 2. Daily total of radio tagged Chinook salmon recorded during mobile tracking by date and location.

Mobile Tracking Dates	Tracking Method	Number of radio tags recorded														Total Radio Tags
		Area 1				Area 2		Area 3	Area 4/5	Area 6	Area 7		Area 8		DS of Harrison	
		<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>4/5</i>	<i>a</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>Fraser</i>	
15-Oct	Boat	-	-	-	-	-	1	-	-	-	-	-	-	-	na	1
17-Oct	Boat	-	2	-	1	9	10	2	1	4	-	1	2	-	na	32
24-Oct	Boat	-	1	-	-	22	13	4	10	2	3	1	1	-	na	57
31-Oct	Boat	2	1	-	-	23	11	2	11	8	1	2	4	-	na	65
07-Nov	Boat	1	2	-	-	18	6	9	7	2	7	1	5	3	na	61
13-Nov	Boat	3	1	-	1	9	3	4	9	3	9	2	6	4	na	54
16-Nov	Boat	na	na	na	na	na	na	na	na	na	na	na	na	na	4	4
21-Nov	Boat	-	-	-	9	2	2	2	5	1	5	2	6	6	na	40
27-Nov	Boat	2	1	-	5	5	2	1	6	5	7	1	8	8	na	51
05-Dec	Boat	-	-	4	1	5	2	-	8	1	8	4	9	8	na	50
12-Dec	Aerial	2	2	2	1	5	2	3	2	11	3	1	8	9	2	51
Number of radio tags:		10	10	6	18	98	52	27	59	37	43	15	49	38	4	466

<sup>a</sup> Unique radio tags each mobile tracking day; duplicate recordings were removed

## DATE OF DEATH AND RECOVERY

Eight male and five female radio tagged fish that released a mortality code remained in the detectable area around the middle fixed station, these were assumed to have died one day prior to the timing of the first mortality code detection at the fixed station. The date of death was subtracted from the release date to calculate the number of days out (Table 3).

Table 3. Time of death of 13 radio tagged Chinook salmon based on middle fixed station data for the Harrison River in 2012.

Radio Tag	Date Released	Date of last recorded as live code	Time of last recorded as live code	Date of first recorded as mortality code	Time of first recorded as mortality code	Date of Death	Days Out	Sex
6	12-Oct	2-Nov	13:07	2-Nov	15:41	1-Nov	20	M
9	15-Oct	30-Oct	3:43	30-Oct	14:58	29-Oct	14	M
16	17-Oct	12-Nov	8:48	12-Nov	19:19	11-Nov	25	M
31	23-Oct	22-Nov	3:57	22-Nov	3:49	21-Nov	29	M
34	16-Oct	5-Nov	1:17	5-Nov	1:25	4-Nov	19	M
40	13-Oct	11-Nov	3:51	11-Nov	3:51	10-Nov	28	M
41	31-Oct	15-Nov	4:43	15-Nov	10:40	14-Nov	14	M
43	2-Nov	26-Nov	10:52	26-Nov	12:44	25-Nov	23	M
62	15-Oct	29-Oct	20:47	29-Oct	21:04	28-Oct	13	F
73	18-Oct	25-Oct	17:06	25-Oct	17:10	24-Oct	6	F
88	26-Oct	12-Nov	6:41	14-Nov	18:59	13-Nov	18	F
92	31-Oct	18-Nov	6:39	18-Nov	17:30	17-Nov	17	F
95	2-Nov	14-Nov	9:39	14-Nov	9:55	13-Nov	11	F
<b>Average</b>							<b>18.23</b>	

Six radio tags were recovered by the mark-recapture crew (Appendix 3) and all remained well attached to the fish carcasses. The plastic had delaminated from one of the tags; however, the tag was still functional. No delamination was observed in the other 5 tags recovered.

## DATA SUMMARY

### Closure

Most of the radio tagged Chinook salmon held upstream prior to spawning and some moved back downstream before returning upstream to spawn. However, no radio tags emigrated out of the Harrison River upstream to the Lake nor were any detected in the tributaries. All of the 18 radio tagged Chinook salmon that

exited the Harrison River study area past the downstream fixed station showed evidence of spawning for multiple days prior to leaving. Four of those were confirmed dead as they were releasing mortality codes and 14 were assumed to be drifting moribund or dead fish (Table 4). The remaining fish were assumed moribund or dead based on the drift time between the middle and the downstream receiver (Table 3). Some of those assumptions were confirmed as they were recovered as carcasses in the Fraser River (Table 1).

No significant difference was noted ( $p > 0.09$ ; t-test) in the days out between true time of deaths recorded at the middle receiver (Table 3) and inferred time of death of the moribund Chinook recorded at the downstream receiver (Table 1). Male and female Chinook were pooled to increase sample size.

Table 4. Time of moribund and mortality radio tagged Chinook salmon that drifted past the downstream fixed telemetry receiver.

Radio Tag	Code designation	Date of drift	Start time of drift	End time of drift	Total Time of drift
129	mortality	18-Nov	0:30	0:38	0:08
136	mortality	16-Nov	17:19	17:23	0:04
142	mortality	15-Nov	6:43	6:46	0:03
188	mortality	14-Nov	18:59	19:20	0:21
15	live	5-Nov	10:53	10:58	0:04
21	live	31-Oct	15:48	16:09	0:21
24	live	7-Nov	19:45	19:55	0:10
30	live	5-Nov	8:37	8:46	0:08
45	live	10-Nov	15:02	15:05	0:03
55(4)	live	21-Oct	23:27	23:37	0:10
58	live	31-Oct	20:10	20:23	0:13
65	live	29-Oct	13:08	13:13	0:05
68	live	31-Oct	22:57	23:06	0:08
76	live	31-Oct	11:39	11:42	0:03
80	live	31-Oct	18:19	18:26	0:07
83	live	2-Nov	3:02	3:21	0:19
87	live	6-Nov	12:09	12:12	0:03
93	live	11-Nov	2:05	2:17	0:12

## Movement

Chinook salmon movement was categorized as remaining in the upper portion of the study area (areas 1-2) or the middle/lower portion of the river (areas 3-8). Of the 47 male Chinook radio tagged and released 72% (34) dropped downstream to spawn, 19% (9) remained in the upper areas and only 9% (4) showed movement between the middle reaches with spawning grounds and the downstream reach. Of the 47 female Chinook radio tagged and released 64% (30) dropped downstream to spawn, 25% (12) remained in the upper areas and 11% (5) showed movement within the study area (Table 45 and Appendix 1). The data recorded for each of the Chinook that moved between areas implies they only exhibited this behavior once and for a relatively short period of time. After exhibiting movement within the study area, 18 of the radio tagged Chinook (8 males and 10 females) left the study area and were not available to recover as a carcass sample.

Table 5. Male and female radio tagged Chinook salmon spawner movement and behaviour in the Harrison River in 2012.

Areas <sup>a</sup>	Male radio tags		Female radio tags		Total radio tags	
	No.	%	No.	%	No.	%
Upper	9	19%	12	25%	21	22%
Middle	34	72%	30	64%	64	68%
Movement pattern <sup>b</sup>	4	9%	5	11%	9	10%
Downstream Harrison <sup>c</sup>	(8)		(10)		(18)	(19)%
<b>Total</b>	<b>47</b>	<b>-</b>	<b>47</b>	<b>-</b>	<b>94</b>	<b>-</b>

<sup>a</sup> For the purpose of these categorized Chinook, the Upper areas are (1-2) and the Middle (3-8).

<sup>b</sup> Movement pattern relates to the recorded occurrences of Chinook that have moved from tag site and spawning grounds (upper and middle areas) to downstream areas (downstream fixed receiver area) and back to the middle of the river (Figure 2).

<sup>c</sup> Radio tags that drifted downstream of Harrison after movement in study area.

## DISCUSSION

This telemetry study failed to invalidate the assumption of closure for the Harrison River Chinook salmon mark-recapture study, as no emigration was detected. All radio tagged fish that passed the upstream receiver later moved back down into the mark-recapture study area to spawn. Fourteen (15%) radio tagged Chinook did exit downstream out of the mark-recapture study area, three of them were confirmed mortalities and evidence indicates that the other 11 were

moribund or dead - not emigrating out of the study area. Additionally, no radio tagged fish were detected at the Chilliwack station, where it is thought that Chinook tagged in the Harrison may opt to spawn due to its proximity, past observations, and genetic history of the Chilliwack late (fall) run population.

The one undetected radio tagged fish may have resulted from the radio tag not being activated, being removed from the river via fishers or predation (seals), or dying and floating to the bottom of a deep pool in which it could not be detected. Fifteen (16%) radio tagged fish with motion sensors did not stop moving for > 24 hours and therefore did not release mortality codes. This may have occurred due to the perpetual movement of carcasses or possibly carcasses being buried under sediment or at such a depth under the water (on the bottom) that the mortality signal could not be detected. There are many very deep pools that carcasses of all species collect within the Harrison River mark-recapture study area. Therefore, radio tagged Chinook carcasses may have been buried under multiple carcasses, potentially muting the radio tag signal.

During the mark-recapture study, Harrison Chinook have been observed migrating to the upper portion of the spawning grounds or above to hold, then dropping back downstream to spawn. During the mark-recapture study holding fish are captured in the upper area for tag application and it is assumed that these fish eventually move downstream to spawn. This behaviour was confirmed by the telemetric study and has been observed in the recovery portion for the mark-recapture. This behaviour has also been detected during the Lower Shuswap Chinook mark-recapture project (2000-2013) and the telemetry study (2000-2002). The Harrison River is relatively short (12 km) with limited effective spawning area. There may be little need for Chinook to move around as the radio tag histories suggest. Mobile tracking confirmed observed spawning areas near and downstream the tag site downstream to the middle fixed receiver. It also confirmed that during higher water conditions, Chinook can disperse into the Chehalis flood plain. As Chinook are not assessable for capture lower in the river, it is not possible to better determine this migration behavior.

There were three general patterns exhibited for both male and female Harrison Chinook: the majority dropped back and remained below the application site just above the middle fixed receiver; a few remained near the application site where there is a modest amount of spawning substrate; and a few dropped to the downstream extremity of the Harrison River and eventually returned upstream to spawn. This aligns with patterns observed during the mark recapture study. The telemetric study also confirmed that many carcasses are completely lost out of the study area downstream into the Fraser River; the timing of the recovery is appropriate; all potential recoverable carcass locations are surveyed; and that many in-river carcasses are not accessible for recovery.

The 2012 Harrison River Chinook salmon telemetry study was conducted during a year of relatively low escapement. It is recommended to repeat this study

during years of average and above average escapements as there may be more competition for redd sites and mates, thus potentially more displacement of spawning adults to other locations (emigration).

## **ACKNOWLEDGMENTS**

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# APPENDICES

Appendix 1. Radio tagged Chinook salmon histories including date, time, signal strength, location, behavior, final location, and sex.

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
3	9-Oct	-	-	-	2a	Application	study area	Male
	17-Oct	11:27	178	178	1b	Mortality		
4	11-Oct	-	-	-	2a	Application	mouth of Harrison	Male
	12-Oct	2:13 to 13:03	36	96	Mid Station	Spawning		
	14-Oct	18:54 to 20:10	33	152	Mid Station	Spawning		
	15-Oct	7:09 to 15:00	33	188	Mid Station	Spawning		
	17-Oct	10:35 to 17:47	36	213	Mid Station	Spawning		
	24-Nov	16:56	58	80	DS Station	Mortality		
5	11-Oct	-	-	-	2a	Application	study area	Male
	17-Oct	12:10 to 23:59	197	197	4/5	Spawning		
	17-Oct	23:52 to 0:47	50	113	Mid Station	Spawning		
	18-Oct	0:00 to 0:47	34	85	Mid Station	Spawning		
	24-Oct	10:50	160	160	2a	Mortality		
6	12-Oct	-	-	-	2a	Application	study area	Male
	14-Oct	8:05 to 8:29	39	119	Mid Station	Spawning		
	15-Oct	21:08 to 23:01	35	59	Mid Station	Spawning		
	16-Oct	0:27 to 23:59	31	212	Mid Station	Spawning		
	17-Oct	0:00 to 0:41	35	212	Mid Station	Spawning		
	17-Oct	11:42 to 11:50	118	118	2a	Spawning		
	27-Oct	6:44	23	23	Mid Station	Spawning		
	29-Oct	17:05	33	33	Mid Station	Spawning		
	30-Oct	8:15 to 14:19	15	84	Mid Station	Spawning		
	31-Oct	0:56	60	60	Mid Station	Spawning		
	1-Nov	08:41 to 08:42	67	59	Mid Station	Spawning		
	2-Nov	13:07 to 15:41	9	81	Mid Station	Spawning		
	5-Nov	11:42	151	151	Mid Station	Mortality		
	7	12-Oct	-	-	-	2a		
17-Oct		11:42	204	204	2a	Spawning		
24-Oct		10:50	142	142	2a	Mortality		
8	15-Oct	-	-	-	2a	Application	study area	Male
	17-Oct	12:10	113	113	3a	Spawning		
	21-Oct	12:45 to 23:59	12	212	Mid Station	Spawning		
	22-Oct	0:00 to 23:59	36	212	Mid Station	Spawning		
	23-Oct	0:00 to 5:44	35	111	Mid Station	Spawning		
	24-Oct	11:32	171	171	6a	Spawning		
	25-Oct	8:53	211	211	Mid Station	Spawning		
	31-Oct	10:50	154	154	2a	Spawning		
	7-Nov	10:54	173	173	3a	Mortality		
	9	15-Oct	-	-	-	2a		
17-Oct		11:42	173	173	1d	Spawning		
24-Oct		10:37	169	169	2a	Spawning		
27-Oct		9:55 to 23:59	27	207	Mid Station	Spawning		
28-Oct		0:00 to 12:47	33	227	Mid Station	Spawning		
29-Oct		12:47 to 23:59	14	213	Mid Station	Spawning		
30-Oct		0:00 to 14:58	130	2123	Mid Station	Spawning		
31-Oct		12:26	-	-	6a	Mortality		
10	15-Oct	-	-	-	2a	Application	study area	Male
	17-Oct	12:10	104	104	3a	Spawning		
	4-Dec	11:35	85	85	Mid Station	Mortality		
11	15-Oct	-	-	-	2a	Application	study area	Male
	17-Oct	11:50	-	-	2b	Spawning		
	24-Oct	10:37	-	-	2a	Spawning		
	31-Oct	10:50	-	-	2a	Spawning		
	2-Nov	10:24	63	63	Mid Station	Mortality		
12	16-Oct	-	-	-	2a	Application	study area	Male
	17-Oct	11:50	213	213	2b	Spawning		
	24-Oct	10:37	113	113	2a	Spawning		
	29-Oct	23:16	162	162	Mid Station	Spawning		
	31-Oct	10:50	188	188	2a	Spawning		
	7-Nov	10:28	120	120	2a	Spawning		
	9-Nov	12:02 to 12:36	48	119	Mid Station	Spawning		
	13-Nov	13:05	-	-	7a	Mortality		

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex			
13	16-Oct	-	-	-	2a	Application	study area	Male			
	17-Oct	8:44 to 8:48	48	183	Mid Station	Spawning					
	17-Oct	10:35 to 15:31	41	193	DS Station	Spawning					
	19-Oct	9:29 to 23:59	35	212	Mid Station	Spawning					
	20-Oct	0:00 to 23:59	20	212	Mid Station	Spawning					
	21-Oct	0:0 to 16:06	21	212	Mid Station	Spawning					
	24-Oct	10:37	102	102	2a	Spawning					
	31-Oct	10:50	120	120	2a	Spawning					
	1-Nov	12:12 to 13:23	41	213	Mid Station	Spawning					
7-Nov	11:30	101	101	7a	Mortality						
14	16-Oct	-	-	-	2a	Application	study area	Male			
15	16-Oct	-	-	-	2a	Application	exit to Fraser				
	17-Oct	11:50	214	215	2b	Spawning					
	22-Oct	1:05 to 19:21	47	212	Mid Station	Spawning					
	23-Oct	2:20 to 7:18	33	212	Mid Station	Spawning					
	24-Oct	11:32	121	121	4/5	Spawning					
	25-Oct	18:22 to 18:49	40	211	Mid Station	Spawning					
	26-Oct	2:49 to 3:26	51	210	DS Station	Spawning					
	26-Oct	8:22 to 23:59	54	212	Mid Station	Spawning					
	27-Oct	0:31 to 23:50	17	212	Mid Station	Spawning					
	28-Oct	0:38 to 12:47	50	252	Mid Station	Spawning					
	29-Oct	12:48 to 23:59	38	212	Mid Station	Spawning					
	30-Oct	0:00 to 23:59	37	213	Mid Station	Spawning					
	31-Oct	0:00 to 23:59	35	212	Mid Station	Spawning					
	31-Oct	12:26	147	147	6a	Spawning					
	4-Nov	0:00 to 23:59	47	211	Mid Station	Spawning					
	5-Nov	0:00 to 8:43	43	199	Mid Station	Spawning					
	5-Nov	10:53 to 10:58	57	202	DS Station	Moribund					
	16	17-Oct	-	-	-	2a			Application	study area	Male
		17-Oct	11:56	203	203	2b			Spawning		
22-Oct		2:06	55	55	Mid Station	Spawning					
24-Oct		10:37	233	233	2a	Spawning					
25-Oct		2:29 to 2:31	105	109	Mid Station	Spawning					
3-Nov		0:31	129	129	Mid Station	Spawning					
6-Nov		22:28	73	73	Mid Station	Spawning					
7-Nov		11:54	42	42	Mid Station	Spawning					
10-Nov		15:36	135	150	Mid Station	Spawning					
11-Nov		5:15	108	141	Mid Station	Spawning					
12-Nov		8:48 to 22:52	42	182	Mid Station	Spawning					
13-Nov		4:37 to 23:59	35	131	Mid Station	Spawning					
14-Nov		0:00 to 23:54	33	78	Mid Station	Spawning					
15-Nov		0:26 to 23:43	26	80	Mid Station	Spawning					
16-Nov		0:55 to 23:59	34	73	Mid Station	Spawning					
17-Nov		0:04 to 0:20	43	67	Mid Station	Spawning					
21-Nov		11:12	173	173	7b	Mortality					
17	17-Oct	-	-	-	2a	Application	study area	Male			
	17-Oct	11:42 to 11:50	203	203	2a	Spawning					
	24-Oct	10:37	200	200	2a	Spawning					
	31-Oct	10:50	117	117	2a	Spawning					
	7-Nov	10:25	210	210	2a	Mortality					
18	17-Oct	-	-	-	2a	Application	study area	Male			
	17-Oct	13:00	183	184	2a	Spawning					
	31-Oct	1:46 to 1:48	97	196	Mid Station	Spawning					
	20-Nov	21:46	20	20	Mid Station	Spawning					
	25-Nov	13:49	14	14	Mid Station	Spawning					
	27-Nov	11:48	14	14	Mid Station	Spawning					
	12-Dec	-	-	-	1d	Mortality					
19	18-Oct	-	-	-	2a	Application	study area	Male			
	24-Oct	10:37	214	214	2a	Spawning					
	7-Nov	10:22	135	135	1b	Mortality					
20	18-Oct	-	-	-	2a	Application	study area	Male			
	23-Oct	17:43 to 18:22	34	212	Mid Station	Spawning					
	24-Oct	11:32	234	234	6a	Spawning					
	31-Oct	12:37	144	144	6a	Mortality					

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
30	23-Oct	-	-	-	2a	Application	exit to Fraser	Male
	24-Oct	5:30 to 10:07	37	212	Mid Station	Spawning		
	24-Oct	10:50	191	191	2a	Spawning		
	26-Oct	9:53 to 14:20	44	212	Mid Station	Spawning		
	28-Oct	0:11 to 0:12	132	174	Mid Station	Spawning		
	31-Oct	12:18	171	171	4/5	Spawning		
	4-Nov	10:42 to 20:35	45	212	Mid Station	Spawning		
	5-Nov	6:08 to 6:26	42	212	Mid Station	Spawning		
	5-Nov	8:37 to 8:46	59	210	DS Station	Moribund		
31	23-Oct	-	-	-	2a	Application	study area	Male
	24-Oct	10:50	135	136	2a	Spawning		
	27-Oct	8:26:00 to 16:40:43	42	212	Mid Station	Spawning		
	31-Oct	11:55	117	117	2b	Spawning		
	31-Oct	14:59:00 to 22:49:22	34	212	Mid Station	Spawning		
	1-Nov	9:11:45 to 9:29:58	50	179	DS Station	Spawning		
	2-Nov	4:03:32 to 17:45:19	31	213	Mid Station	Spawning		
	2-Nov	19:16 to 19:58	50	169	DS Station	Spawning		
	3-Nov	1:58	59	61	DS Station	Spawning		
	5-Nov	9:18 to 9:28	49	116	DS Station	Spawning		
	7-Nov	10:48	-	-	2a	Spawning		
	9-Nov	11:53 to 17:45	42	189	Mid Station	Spawning		
	13-Nov	10:50	159	159	4/5	Spawning		
	18-Nov	4:05 to 23:58	43	173	Mid Station	Spawning		
	19-Nov	0:04 to 22:27	42	212	Mid Station	Spawning		
	20-Nov	0:09 to 23:56	34	179	Mid Station	Spawning		
	21-Nov	0:03 to 23:59	41	182	Mid Station	Spawning		
	22-Nov	0:00 to 4:39	48	148	Mid Station	Spawning		
	23-Nov	12:57 to 13:34	45	73	Mid Station	Spawning		
	27-Nov	5:30 to 5:38	52	73	Mid Station	Mortality		
32	24-Oct	-	-	-	2a	Application	study area	Male
	24-Oct	10:50	137	137	2a	Spawning		
	31-Oct	10:50	158	158	2a	Mortality		
33	24-Oct	-	-	-	2a	Application	study area	Male
	29-Oct	18:27 to 19:34	53	200	US Station	Spawning		
	31-Oct	10:28	186	186	1a	Spawning		
	7-Nov	10:00	122	153	1a	Mortality		
34	25-Oct	-	-	-	2a	Application	study area	Male
	29-Oct	22:26	-	-	Mid Station	Spawning		
	31-Oct	10:50	128	128	2a	Spawning		
	4-Nov	0:20 to 23:40	37	179	Mid Station	Spawning		
	5-Nov	0:10 to 1:17	29	125	Mid Station	Spawning		
	5-Nov	1:25 to 23:59	37	116	Mid Station	Mortality		
35	25-Oct	-	-	-	2a	Application	study area	Male
	31-Oct	12:18	-	-	4/5	Spawning		
	10-Nov	14:56	97	97	Mid Station	Spawning		
	11-Nov	4:35	80	91	Mid Station	Spawning		
	12-Nov	21:57 to 22:10	59	72	Mid Station	Spawning		
	13-Nov	11:48	61	61	Mid Station	Spawning		
	27-Nov	11:40	-	-	6a	Mortality		
	36	26-Oct	-	-	-	2a		
31-Oct		10:50	98	99	2a	Spawning		
6-Nov		9:31 to 23:57	30	131	Mid Station	Spawning		
7-Nov		0:00 to 13:32	44	104	Mid Station	Spawning		
7-Nov		12:46	162	162	7a	Spawning		
13-Nov		12:50	124	124	7a	Mortality		
37	26-Oct	-	-	-	2a	Application	study area	Male
	31-Oct	10:33	159	159	1a	Mortality		
38	29-Oct	-	-	-	2a	Application	study area	Male
	31-Oct	11:02	162	163	2a	Spawning		
	7-Nov	8:45 to 9:33	73	130	Mid Station	Spawning		
	7-Nov	11:53	190	190	8b	Spawning		
	11-Nov	4:00 to 5:05	84	98	Mid Station	Mortality		
39	30-Oct	-	-	-	2a	Application	study area	Male
	31-Oct	11:02:00 to 10:30:00	26	176	2a	Spawning		
	7-Nov	14:07	176	-	2a	Spawning		
	13-Nov	10:30	140	-	2a	Spawning		
	21-Nov	10:37	129	-	3a	Spawning		
	27-Nov	11:22	203	-	4/5	Spawning		
	21-Nov	10:37	129	129	3a	Mortality		

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
40	31-Oct	-	-	-	2a	Application	study area	Male
	31-Oct	11:02	128	129	2b			
	3-Nov	11:57 to 18:17	44	213	Mid Station	Spawning		
	4-Nov	12:01 to 18:29	90	198	Mid Station	Spawning		
	4-Nov	20:02 to 20:09	48	211	DS Station	Spawning		
	5-Nov	2:07 to 13:23	48	197	Mid Station	Spawning		
	5-Nov	5:28 to 5:44	52	71	DS Station	Spawning		
	6-Nov	13:09	115	115	Mid Station	Spawning		
	7-Nov	10:47	199	199	2a	Spawning		
	10-Nov	3:21 to 23:59	40	170	Mid Station	Spawning		
	11-Nov	0:00 to 3:51	83	163	Mid Station	Spawning		
11-Nov	3:51	104	104	7a	Mortality			
41	31-Oct	-	-	-	2a	Application	study area	Male
	4-Nov	17:23 to 17:45	46	213	Mid Station	Spawning		
	5-Nov	2:46 to 3:18	37	213	Mid Station	Spawning		
	7-Nov	14:00			2a	Spawning		
	8-Nov	10:20			DS Station	Spawning		
	13-Nov	10:53			4/5	Spawning		
	14-Nov	9:13 to 21:37	39	168	Mid Station	Spawning		
	15-Nov	1:43 to 4:56	22	68	Mid Station			
	15-Nov	10:40	43	43	Mid Station	Mortality		
	42	31-Oct	-	-	-	2a		
1-Nov		11:00	-	-	Mid Station	Spawning		
1-Nov		11:00	-	-	Mid Station	Mortality		
43	2-Nov	-	-	-	2a	Application	study area	Male
	4-Nov	11:43:34 to 8:17:41	11	213	Mid Station	Spawning		
	5-Nov				Mid Station	Spawning		
	6-Nov				Mid Station	Spawning		
	7-Nov				Mid Station	Spawning		
	7-Nov	11:15	170	170	4/5	Spawning		
	12-Nov	3:44:51 to 23:56:35	31	212	Mid Station	Spawning		
	13-Nov				Mid Station	Spawning		
	13-Nov	12:50	120	120	6a	Spawning		
	14-Nov	00:00:16 to 20:01:50	18	212	Mid Station	Spawning		
	15-Nov					Spawning		
	16-Nov					Spawning		
	17-Nov					Spawning		
	18-Nov					Spawning		
	19-Nov					Spawning		
20-Nov					Spawning			
21-Nov	10:45	103	103	4/5	Spawning			
25-Nov	4:08 to 5:11	46	212	Mid Station	Spawning			
25-Nov	9:55:44 to 12:44:33	44	190	DS Station	Spawning			
26-Nov	1:06 to 12:43	49	88	DS Station	Spawning			
27-Nov	14:14	102	192	8b	Mortality			
44	2-Nov	-	-	-	2a	Application	study area	Male
	7-Nov	10:38	112	112	2a	Spawning		
	10-Nov	15:14	89	89	Mid Station	Spawning		
	13-Nov	10:38	215	215	2a	Spawning		
	14-Nov	7:24 to 7:36	52	209	Mid Station	Spawning		
	21-Nov	11:57	172	172	8b	Mortality		
45	3-Nov	-	-	-	2a	Application	exit to Fraser	Male
	7-Nov	11:07	151	152	4/5	Spawning		
	10-Nov	5:20 to 20:45	39	200	Mid Station	Spawning		
	10-Nov	15:02	81	210	DS Station	Moribund		
52 old	7-Nov	-	-	-	2a	Application	study area	Male
	7-Nov	10:35	119	119	2a	Spawning		
	7-Nov	10:45	61	61	Mid Station	Spawning		
	10-Nov	15:28 to 18:08	75	113	Mid Station	Spawning		
	11-Nov	5:07 to 19:05	72	115	Mid Station	Spawning		
	12-Nov	8:40 to 23:39	61	129	Mid Station	Spawning		
	13-Nov	0:47 to 15:26	56	59	Mid Station	Spawning		
	13-Nov	10:51	133	133	4/5	Spawning		
	13-Nov	15:26	59	59	Mid Station	Spawning		

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
55 (640)	9-Oct	-	-	-	2a	Application	exit to Fraser	Female
	13-Oct	16:24 to 16:30	44	177	Mid Station	Spawning		
	14-Oct	12:26 to 12:36	38	134	Mid Station	Spawning		
	15-Oct	8:28 to 8:46	43	133	Mid Station	Spawning		
	16-Oct	8:16 to 23:59	30	150	Mid Station	Spawning		
	17-Oct	0:00 to 0:52	35	115	Mid Station	Spawning		
	17-Oct	12:29	209	209	6a	Spawning		
	19-Oct	00:58 to 3:10	38	196	Mid Station	Spawning		
	20-Oct	21:38 to 23:59	52	108	US Station	Spawning		
	21-Oct	0:00 to 0:01	55	80	US Station	Spawning		
	21-Oct	18:23 to 20:51	34	212	Mid Station	Spawning		
	21-Oct	23:27 to 23:37	56	174	DS Station	Moribund		
	55 (720)	5-Nov	-	-	-	2a		
7-Nov		10:30	173	173	2a	Spawning		
10-Nov		9:08 to 23:59	41	160	Mid Station	Spawning		
11-Nov		0:00 to 23:58	17	163	Mid Station	Spawning		
12-Nov		0:00 to 23:59	11	135	Mid Station	Spawning		
13-Nov		0:00 to 15:17	46	96	Mid Station	Spawning		
13-Nov		13:02	102	102	7a	Spawning		
14-Nov		3:38 to 18:22	40	79	Mid Station	Spawning		
15-Nov		8:10 to 14:41	38	101	Mid Station	Spawning		
16-Nov		10:31 to 13:12	44	57	Mid Station	Spawning		
21-Nov		11:45	124	124	8b	Spawning		
27-Nov		14:00	199	199	8a	Spawning		
5-Dec		11:45	196	196	8b	Spawning		
12-Dec		-	-	-	8b	Spawning		
56	11-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:42	202	202	2a	Spawning		
	24-Oct	11:21	148	148	4/5	Spawning		
	31-Oct	13:00	98	98	4/5	Mortality		
57 (640)	11-Oct	-	-	-	2a	Application		Female
	16-Oct	10:21 to 10:21	41	62	Mid Station	Mortality		
57 (720) <sup>a</sup>	8-Nov	-	-	-	2a	Application	study area (old tag mortality)	Female
	13-Nov	10:36	185	186	2a	Spawning		
	15-Nov	22:24 to 22:53	59	211	Mid Station	Spawning		
	29-Nov	11:53 to 23:58	16	69	Mid Station	Spawning		
	30-Nov	0:02 to 12:28	15	64	Mid Station	Spawning		
	12-Dec	-	199	199	8b	Spawning		
58	12-Oct	-	-	-	2a	Application	exit to Fraser	Female
	16-Oct	15:01 to 18:32	36	203	Mid Station	Spawning		
	17-Oct	13:00	215	215	6a	Spawning		
	24-Oct	11:32	232	232	4/5	Spawning		
	31-Oct	12:26	88	88	6a	Spawning		
	31-Oct	13:20 to 18:16	33	213	Mid Station	Spawning		
	31-Oct	20:10 to 20:23	60	139	DS Station	Moribund		
59	12-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:42	220	220	2a	Spawning		
	24-Oct	10:37	105	105	2a	Spawning		
	31-Oct	8:34 to 8:41	51	129	Mid Station	Mortality		
60	15-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	12:10	92	92	2b	Spawning		
	24-Oct	10:37	189	189	1b	Mortality		
61	15-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:50:00	178	178	2b	Spawning		
	24-Oct	10:37:00	155	155	2a	Spawning		
	31-Oct	5:27:56 to 23:43:56	35	105	Mid Station	Spawning		
	31-Oct	12:26:00	178	178	6a	Spawning		
	1-Nov	1:02 to 12:32	35	92	Mid Station	Spawning		
	3-Nov	3:53 to 11:52	55	76	Mid Station	Spawning		
	7-Nov	11:42	113	113	8a	Mortality		

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
62	15-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:42	-	-	1b	Spawning		
	24-Oct	11:21	234	235	4/5	Spawning		
	26-Oct	14:45 to 16:24	29	212	Mid Station	Spawning		
	27-Oct	12:38 to 13:00	62	62	Mid Station	Spawning		
	29-Oct	12:50 to 22:09	30	79	Mid Station	Spawning		
	30-Oct	5:37 to 11:34	33	63	Mid Station	Spawning		
	31-Oct	12:35	108	108	6a	Mortality		
63	15-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:56	108	180	2b	Spawning		
	24-Oct	10:50	108	108	2b	Spawning		
	31-Oct	11:02	105	105	2a	Spawning		
	31-Oct	11:02	130	130	2b	Spawning		
	31-Oct	20:44 to 20:45	71	215	US Station	Spawning		
	5-Oct	15:03 to 15:06	57	186	US Station	Spawning		
	13-Nov	10:11	100	100	1a	Mortality		
64	16-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:50	131	132	2b	Spawning		
	21-Oct	22:30 to 22:33	67	102	Mid Station	Spawning		
	22-Oct	0:12 to 4:19	34	69	Mid Station	Spawning		
	24-Oct	10:50	214	214	2b	Spawning		
	31-Oct	12:03	90	90	4/5	Mortality		
	65	16-Oct	-	-	-	2a		
17-Oct		11:56	106	106	2b	Spawning		
21-Oct		11:00 to 16:53	36	212	Mid Station	Spawning		
22-Oct		8:05 to 11:46	43	212	Mid Station	Spawning		
24-Oct		10:50	98	98	2a	Spawning		
29-Oct		13:08 to 13:13	45	194	DS Station	Moribund		
66 (640)	16-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:42	153	153	2a	Spawning		
	19-Oct	9:50 to 12:27	59	137	US Station	Spawning		
	24-Oct	10:37	93	93	2a	Spawning		
	31-Oct	10:50	224	224	2a	Spawning		
	1-Nov	12:25 to 12:58	44	213	Mid Station	Spawning		
	7-Nov	11:40	-	-	8a	Mortality		
66 (720) <sup>a</sup>	7-Nov	-	-	-	2a	Application	study area (old tag mortality)	Male
	7-Nov	10:35	133	133	2a	Spawning		
	10-Nov	22:39 to 23:14	74	103	US Station	Spawning		
	21-Nov	10:19	105	105	1d	Spawning		
	27-Nov	11:52	150	150	1d	Spawning		
	5-Dec	10:05	100	100	2a	Spawning		
	12-Dec	-	-	-	2a	Spawning		
67	16-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	12:29	160	160	6a	Spawning		
	17-Oct	18:16 to 21:07	36	212	Mid Station	Spawning		
	19-Oct	9:44 to 23:54	32	124	Mid Station	Spawning		
	20-Oct	0:08 to 7:59	41	128	Mid Station	Spawning		
	24-Oct	11:55	226	226	7a	Spawning		
	25-Oct	10:54 to 23:54	31	212	Mid Station	Spawning		
	26-Oct	0:00 to 1:57	51	193	Mid Station	Spawning		
	31-Oct	12:40	140	140	8a	Spawning		
	7-Nov	11:44	147	147	8a	Mortality		
	68	17-Oct	-	-	-	2a		
17-Oct		11:50	199	199	2b	Spawning		
24-Oct		10:50	128	128	2a	Spawning		
31-Oct		10:50	156	156	2a	Spawning		
31-Oct		19:57 to 20:45	44	186	Mid Station	Spawning		
31-Oct		22:55 to 23:06	50	192	DS Station	Moribund		
69 (640)	17-Oct	-	-	-	2a	Application	study area	Female
	17-Oct	11:42	187	187	2a	Spawning		
	17-Oct	11:50	187	187	2a	Spawning		
	20-Oct	18:47 to 19:58	44	212	Mid Station	Spawning		
	20-Oct	23:23 to 23:48	48	166	DS Station	Spawning		
	21-Oct	1:13 to 7:40	49	164	DS Station	Spawning		
	22-Oct	4:02 to 4:38	45	212	Mid Station	Spawning		
	24-Oct	10:50	147	147	2b	Spawning		
	7-Nov	10:39	128	128	2a	Spawning		
	27-Nov	14:09	-	-	8b	Mortality		



Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
69 (720) <sup>a</sup>	7-Nov	-	-	-	2a	Application	study area (old tag mortality)	Male
	13-Nov	9:26 to 9:46	52	212	Mid Station	Spawning		
	13-Nov	13:30	133	133	8b	Spawning		
	5-Dec	11:45	126	126	8b	Spawning		
	12-Dec	-	-	129	8b	Spawning		
70	17-Oct	-	-	-	2a	Application	study area	Female
	24-Oct	10:50	152	152	2a	Spawning		
	31-Oct	11:02	108	108	2a	Mortality		
71 (640)	18-Oct	-	-	-	2a	Application	study area	Female
	23-Oct	2:22 to 23:59	34	212	Mid Station	Spawning		
	24-Oct	0:00 to 11:46	34	215	Mid Station	Spawning		
	24-Oct	11:46	215	215	6a	Spawning		
	6-Nov	6:10 to 23:59	41	166	Mid Station	Spawning		
	7-Nov	0:00 to 14:28	39	155	Mid Station	Spawning		
	7-Nov	12:58	101	101	2b	Spawning		
	12-Nov	12:17	65	65	Mid Station	Mortality		
71 (720) <sup>a</sup>	4-Oct	-	-	-	2a	Application	study area (old tag mortality)	Female
	6-Oct	12:15 to 12:21	60	63	US Station	Spawning		
	15-Oct	11:40	233	233	4/5	Spawning		
	15-Oct	13:42	188	188	2b	Spawning		
	17-Oct	11:42	168	168	2a	Spawning		
	17-Oct	12:29	131	131	6a	Spawning		
	24-Oct	11:25:00	143	143	4/5	Spawning		
	31-Oct	12:18:00	209	209	4/6	Spawning		
	4-Nov	18:30 to 19:16	49	212	Mid Station	Spawning		
	07-Nov	11:27	185	185	7a	Spawning		
	13-Nov	13:08	192	192	7a	Spawning		
	21-Nov	11:22	233	233	7a	Spawning		
	27-Nov	13:53	155	155	7a	Spawning		
	5-Dec	11:45	200	200	8a	Spawning		
	12-Dec	-	-	-	8a	Mortality		
72	18-Oct	-	-	-	2a	Application	study area	Female
	24-Oct	10:50	114	114	2b	Spawning		
	31-Oct	10:50	90	90	2a	Spawning		
	16-Nov	4:38 to 4:52	91	99	Mid Station	Spawning		
73	18-Oct	-	-	-	2a	Application	study area	Female
	24-Oct	6:51 to 23:59	25	101	Mid Station	Spawning		
	25-Oct	0:00 to 23:59	30	93	Mid Station	Spawning		
	24-Oct	11:32	232	232	4/5	Spawning		
	25-Oct	7:10 to 23:59	30	93	Mid Station	Mortality		
74	19-Oct	-	-	-	2a	Application	study area	Female
	24-Oct	10:50	234	234	2b	Spawning		
	31-Oct	11:02	121	121	2b	Spawning		
	3-Nov	9:06 to 16:15	45	213	Mid Station	Spawning		
	7-Nov	11:38	n/a	n/a	8a	Mortality		
75	19-Oct	-	-	-	2a	Application	study area	Female
	21-Oct	7:47 to 23:59	35	212	Mid Station	Spawning		
	22-Oct	12:32 to 8:22	30	212	Mid Station	Spawning		
	25-Oct	9:40 to 10:13	42	212	Mid Station	Spawning		
	26-Oct	7:24 to 18:19	30	212	Mid Station	Spawning		
	13-Nov	16:38	142	142	Mid Station	Spawning		
	15-Nov	16:05	20	20	Mid Station	Spawning		
	20-Nov	6:35	116	116	Mid Station	Spawning		
	21-Oct	18:34 to 20:22	48	211	DS Station	Spawning		
	24-Oct	11:32	168	168	4/5	Spawning		
	31-Oct	10:50	117	117	2a	Spawning		
	7-Nov	10:36	135	135	2a	Spawning		
76	19-Oct	-	-	-	2a	Application	exit to Fraser	Female
	24-Oct	10:37	214	214	2a	Spawning		
	30-Oct	2:26 to 15:43	39	213	Mid Station	Spawning		
	31-Oct	11:39 to 11:42	61	184	DS Station	Moribund		
77	22-Oct	-	-	-	2a	Application	study area	Female
	22-Oct	20:43 to 23:59	30	122	Mid Station	Spawning		
	23-Oct	0:00 to 10:59	11	211	Mid Station	Spawning		
	24-Oct	11:32	141	141	4/5	Spawning		
	31-Oct	12:03	119	119	2b	Spawning		
	21-Nov	11:36	188	118	8a	Mortality		
78	22-Oct	-	-	-	2a	Application	study area	Female
	21-Oct	18:06 to 23:59	39	212	Mid Station	Spawning		
	22-Oct	0:00 to 23:57	35	212	Mid Station	Spawning		
	23-Oct	0:06 to 7:40	33	148	Mid Station	Spawning		
	24-Oct	11:55	134	134	8a	Spawning		
	31-Oct	12:40	90	90	8a	Mortality		

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex				
79	22-Oct	-	-	-	2a	Application	study area	Female				
	24-Oct	11:13	-	-	2b	Spawning						
	31-Oct	12:03	114	114	4/5	Mortality						
80	22-Oct	-	-	-	2a	Application	exit to Fraser	Female				
	22-Oct	7:54 to 8:25	35	212	Mid Station	Spawning						
	24-Oct	11:55	94	94	7a							
	24-Oct	12:33 to 13:56	46	210	DS Station							
	25-Oct	0:35 to 2:32	36	212	Mid Station							
	26-Oct	7:36 to 9:38	37	212	Mid Station							
	27-Oct	19:20 to 23:59	25	212	Mid Station							
	28-Oct	0:00 to 7:53	23	212	Mid Station							
	29-Oct	12:51 to 23:54	29	73	Mid Station							
	30-Oct	0:00 to 23:40	34	104	Mid Station							
	31-Oct	0:23 to 14:21	34	152	Mid Station							
	31-Oct	12:26	148	148	6a							
	31-Oct	18:19 to 18:26	52	211	DS Station				Moribund			
81	23-Oct	-	-	-	2a		Application	study area	Female			
	24-Oct	10:50	157	157	2b	Spawning						
	31-Oct	12:20	226	226	4/5							
	6-Nov	7:30 to 8:09	50	95	Mid Station							
	7-Nov	8:14 to 11:41	45	135	Mid Station							
	15-Nov	16:09 23:01	37	79	Mid Station							
	21-Nov	11:28	117	117	8a		Mortality					
82	23-Oct	-	-	-	2a		Application	study area	Female			
	24-Oct	11:32	216	216	4/5	Spawning						
	25-Oct	18:20 to 23:59	30	212	Mid Station							
	26-Oct	0:00 to 0:20	46	71	Mid Station							
	30-Oct	2:47 to 2:53	42	190	Mid Station							
	12-Dec	-	105	105	8b		Mortality					
	83	23-Oct	-	-	-		2a			Application	exit to Fraser (Mortality)	Female
24-Oct		10:50	107	107	2a		Spawning					
31-Oct		11:02	133	133	2a							
2-Nov		00:45 to 00:48	53	183	Mid Station							
2-Nov		3:02 to 3:21	51	148	DS Station	Moribund						
84	24-Oct	-	-	-	2a	Application		study area	Female			
	24-Oct	10:50	139	139	2a	Spawning						
	31-Oct	12:18	200	200	4/5							
	7-Nov	11:14	131	131	4/5							
	13-Nov	10:53	97	97	4/5							
	21-Nov	10:51	108	108	4/5							
	27-Nov	11:29	119	119	4/5							
	5-Dec	10:35	78	78	4/5							
	12-Dec	-	150	150	6a		Mortality					
	85	24-Oct	-	-	-		2a			Application	study area	Female
		24-Oct	13:30	172	173		2a			Spawning		
31-Oct		12:10	122	123	4/5							
7-Nov		3:04 to 3:46	46	191	Mid Station							
7-Nov		11:44	113	113	8a							
12-Dec		-	130	130	8b	Mortality						
86	25-Oct	-	-	-	2a	Application	study area	Female				
	31-Oct	10:50	104	104	2a	Spawning						
	31-Oct	11:55	-	-	2a							
	2-Nov	18:38	144	144	Mid Station							
	6-Nov	15:40	56	56	Mid Station							
	7-Nov	11:31	122	122	7a							
	13-Nov	20:43 to 20:45	53	56	Mid Station							
	18-Nov	21:02	88	88	Mid Station				Mortality			
	87	25-Oct	-	-	-				2a	Application	exit to Fraser	Female
26-Oct		19:23 to 23:59	15	212	Mid Station		Spawning					
27-Oct		0:00 to 1:27	34	211	Mid Station							
31-Oct		12:30	226	226	6a							
6-Nov		7:23	53	53	Mid Station							
6-Nov		12:09 to 12:12	54	157	DS Station	Moribund						
88	26-Oct	-	-	-	2a	Application		exit to Fraser as mortality	Female			
	31-Oct	11:02	114	114	2a	Spawning						
	7-Nov	10:38	111	111	2a							
	12-Nov	6:41	171	171	Mid Station							
	14-Nov	18:59 to 19:20	50	147	DS Station		Mortality					

Radio Tag Code	Date Tracked	Time Tracked	Signal strength (min)	Signal strength (max)	Area	Behaviour <sup>a</sup>	Final destination <sup>b</sup>	Sex
89	26-Oct	-	-	-	2a	Application	study area	Female
	31-Oct	10:50	162	162	2a	Spawning		
	10-Nov	23:34	131	131	Mid Station	Spawning		
	13-Nov	10:53	185	185	4/5	Mortality		
90	29-Oct	-	-	-	2a	Application	study area	Female
	29-Oct	18:38 to 11:37	29	213	Mid Station	Spawning		
	31-Oct	12:18	200	200	4/5	Spawning		
	7-Nov	8:30 to 18:34	36	160	Mid Station	Spawning		
	26-Nov	10:24	61	61	Mid Station	Spawning		
	5-Dec	11:35	-	-	8a	Mortality		
91	30-Oct	-	-	-	2a	Application	study area	Female
	31-Oct	13:00	104	104	2a	Spawning		
	7-Nov	10:34	182	182	2a	Spawning		
	13-Nov	10:30	176	176	2a	Spawning		
	21-Nov	10:19	124	124	1d	Mortality		
	31-Oct	-	-	-	2a	Application		
92	31-Oct	11:02	184	184	2b	Application	study area	Female
	3-Nov	9:14	105	105	Mid Station	Spawning		
	7-Nov	11:02	108	108	4/5	Spawning		
	13-Nov	10:45	172	172	4/6	Spawning		
	15-Nov	8:27 to 23:59	41	179	Mid Station	Spawning		
	16-Nov	0:00 to 23:59	46	171	Mid Station	Spawning		
	17-Nov	0:00 to 23:59	40	150	Mid Station	Spawning		
	18-Nov	0:00 to 17:29	42	140	Mid Station	Spawning		
	18-Nov	17:30 to 23:59	52	155	Mid Station	Mortality		
	31-Oct	-	-	-	2a	Application		
	7-Nov	14:09	106	107	2a	Application		
10-Nov	13:46	12	12	DS Station	Moribund			
10-Nov	23:25 to 23:36	54	212	Mid Station	Moribund			
11-Nov	2:05 to 2:17	57	209	DS Station	Moribund			
94	31-Oct	-	-	-	2a	Application	study area	Female
	7-Nov	11:04	109	109	4/5	Spawning		
	13-Nov	10:36	124	124	2a	Spawning		
	14-Nov	12:33 to 5:12	40	171	Mid Station	Spawning		
	5-Dec	11:35	132	132	8a	Mortality		
	31-Oct	-	-	-	2a	Application		
95	2-Nov	-	-	-	2a	Application	study area	Female
	2-Nov	18:23 to 23:59	47	213	Mid Station	Spawning		
	3-Nov	0:00 to 23:04	41	213	Mid Station	Spawning		
	4-Nov	0:04 to 18:06	43	213	Mid Station	Spawning		
	5-Nov	2:20 to 3:29	42	208	Mid Station	Spawning		
	6-Nov	15:36 to 16:03	47	113	Mid Station	Spawning		
	7-Nov	4:15 to 5:52	41	212	Mid Station	Spawning		
	7-Nov	10:54	215	215	3a	Spawning		
	12-Nov	21:14 to 23:59	42	165	Mid Station	Spawning		
	13-Nov	0:00 to 23:40	14	147	Mid Station	Spawning		
	14-Nov	0:42 to 9:39	32	59	Mid Station	Spawning		
	14-Nov	9:55 to 22:34	35	68	Mid Station	Mortality		
	6-Nov	-	-	-	2a	Application		
	7-Nov	10:51	n/a	n/a	2b	Application		
13-Nov	10:47	128	129	4/5	Spawning			
18-Nov	23:16 to 23:39	46	212	Mid Station	Spawning			
21-Nov	11:29	124	124	7a	Mortality			
97	5-Nov	-	-	-	2a	Application	study area	Female
	7-Nov	10:42	167	167	2a	Spawning		
	13-Nov	10:35	153	153	2a	Spawning		
	21-Nov	10:19	106	106	1d	Spawning		
	27-Nov	10:53	105	105	1d	Mortality		
	3-Nov	-	-	-	2a	Application		
98	7-Nov	14:07	135	136	2a	Spawning	study area	Female
	9-Nov	1:48 to 5:13	40	97	Mid Station	Spawning		
	13-Nov	10:47	137	137	4/5	Spawning		
	17-Nov	5:37 to 21:19	42	157	Mid Station	Spawning		
	2-Nov	-	-	-	2a	Application		
	7-Nov	11:02	179	179	4/5	Spawning		
99	13-Nov	10:47	180	180	4/5	Spawning	study area	Female
	5-Dec	10:35	156	156	4/5	Mortality		

<sup>a</sup> Behaviour is a general description of the Chinooks activities. There is no direct confirmation of spawning success.

<sup>b</sup> Refer to Figures 1 and 2 for study area locations.

Appendix 2. Daily number of Petersen disk tags and radio tags applied to male and female Chinook salmon in the Harrison River.

Date	Petersen tags applied			Radio tags applied		
	Male	Female	Total	Male	Female	Total
4-Oct	1	1	3	0	1	1
5-Oct	6	2	12	0	0	0
9-Oct	30	28	96	1	1	2
10-Oct	71	44	143	0	0	0
11-Oct	11	2	20	2	2	4
12-Oct	12	12	32	2	2	4
15-Oct	98	59	199	4	4	8
16-Oct	64	58	176	4	4	8
17-Oct	53	60	146	3	3	6
18-Oct	65	74	189	3	3	6
19-Oct	25	32	77	3	3	6
22-Oct	21	17	57	4	4	8
23-Oct	48	34	100	3	3	6
24-Oct	40	33	84	2	2	4
25-Oct	38	34	87	2	2	4
26-Oct	54	66	135	2	2	4
29-Oct	59	115	197	1	1	2
30-Oct	41	95	154	1	1	2
31-Oct	29	36	72	1	1	2
1-Nov	20	35	61	2	2	4
2-Nov	1	1	4	2	2	4
3-Nov	0	1	1	1	1	2
5-Nov	4	6	11	1	1	2
6-Nov	0	0	1	0	1	1
7-Nov	1	1	3	3	0	3
8-Nov	2	2	4	0	1	1
9-Nov	0	1	1	0	0	0
Total	794	849	2065	47	47	94

Appendix 3. Recovered Radio Tags, by tag number, date and location of recovery, sex, spawning success, carcass condition.

Tag Number	Application Date	Days Out <sup>a</sup>	Recovery Date	Motion sensor activation	Recovery area	Sex	Spawning Success	Carcass Condition
70	17-Oct	29	15-Nov	yes	5	F	not known	skin and bones
92	31-Oct	20	20-Nov	yes	6	F	100	tainted
8	15-Oct	23	7-Nov	yes	5	M	-	fresh
9	15-Oct	19	3-Nov	yes	7	M	-	rotten
13	16-Oct	25	10-Nov	yes	7	M	-	rotten
52	7-Nov	6	13-Nov	na	4	M	-	tainted

<sup>a</sup> Days out in this recovery sample refers to the number of days between release and recovery of the carcass