U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

Migration Timing and Survival of Warm Springs National Fish Hatchery Juvenile Spring Chinook Salmon in the Deschutes Basin

2012-2014 Final Report

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On the cover: *Fixed radio-telemetry detection station at river kilometer five on lower Deschutes River.*

Disclaimers

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Abstract – Passive integrated transponder (PIT) data dating back to 2007 have shown that Warm Springs National Fish Hatchery (WSNFH) reared juvenile Spring Chinook survival rates during their migration from WSNFH to Bonneville Dam have been low, ranging from 30 to 60 percent. In migration years 2012, 2013 and 2014 we used radio-telemetry technology to assess where the majority of these mortalities occur by comparing apparent survival estimates in the Warm Springs, Deschutes and Columbia rivers. We surgically implanted a total of 199 radio tags (41, 78 and 80, 2012-2014 respectively) into a representative sample of hatchery Spring Chinook and tracked downstream migration with fixed telemetry sites stationed along the Warm Springs and Deschutes rivers. Fixed telemetry station detection probability and apparent survival to these sites were estimated using the Cormack-Jolly-Seber model via Program MARK. All apparent survival estimates and migration times to Bonneville Dam were calculated using PIT tag data. Travel times through the Warm Springs and Deschutes rivers were fast with median travel times averaging at two days, compared to a 27 median travel time average from release to Bonneville Dam. Although travel times varied considerably between the Deschutes and Columbia basins, our results could not indicate any specific areas experiencing elevated mortality rates, rather we found mortalities to be fairly constant per river kilometer. Although confidence intervals were wide, survival estimates followed a similar annual trend at the Warm Springs River mouth, the Deschutes River mouth and Bonneville Dam with highest estimates occurring in 2013 and lowest in 2012.

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Introduction

Long term monitoring of Warm Springs National Fish Hatchery (NFH) Spring Chinook salmon populations has largely focused on adult returns and information gained from creel surveys, counts obtained from the hatchery adult-bypass system and coded-wire-tag recoveries. The expansion of passive integrated transponder (PIT) tag detection arrays in the lower Columbia Basin has provided an opportunity to monitor and collect information on juvenile hatchery outmigration as well. The Columbia River Fish and Wildlife Conservation Office began using PIT technology to monitor Warm Springs NFH juvenile Spring Chinook releases for brood year 2005 (migration year 2007). Since this time approximately 15,000 juveniles have been PIT tagged annually. Our annual PIT tagging objectives are to assess migration timing and survival to Bonneville Dam, evaluate hatchery rearing and release strategies (e.g., volitional vs force release; fall marking vs spring marking) and inform management questions or decisions (see Hand et al. 2014). Juvenile survival estimates from release at Warm Springs NFH to Bonneville Dam (migration year 2007-2014) have ranged from 30% to 60%, indicating that a substantial loss of hatchery production is occurring upstream of Bonneville Dam. Whether the apparent mortality of juveniles between hatchery release and Bonneville Dam is occurring within the Warm Springs/Deschutes River basins, the mainstem Columbia River, or both is unknown. PIT tag monitoring infrastructure in the Warm Springs and Deschutes rivers has been absent or insufficient for determining juvenile survival estimates at points upstream of Bonneville Dam. As an alternative, we used radio-telemetry technology to monitor the fine-scale movement and survival of juvenile hatchery releases in the Warm Springs and Deschutes Rivers. Survival estimates in the Deschutes basin from radio-tags compared with PIT tag survival estimates to Bonneville dam might help identify where fish loss may be occurring, allowing managers to modify rearing/release practices, or alter in-river management to benefit juvenile outmigration in the future.

We initiated a radio-telemetry study to monitor brood year 2010 (migration year 2012) juvenile releases of hatchery Spring Chinook salmon from Warm Springs NFH. Our objective was to estimate the survival of radio-tagged fish from hatchery release to the mouth of the Deschutes River (Hand et al. 2012). This study was replicated for migration year 2013 and 2014 juvenile releases of Spring Chinook salmon from Warm Springs NFH. This report summarizes the findings from our three year study, provides recommendations for future investigations and addresses three management questions:

1) Is freshwater mortality of hatchery releases predominantly due to mainstem Columbia River passage issues or is mortality concentrated in the Warm Springs and/or Deschutes River?
2) Can hatchery rearing/release practices be altered to minimize mortality upstream of Bonneville Dam?
3) Are there management actions in the Deschutes Basin that can be altered to benefit juvenile downstream migration?

Study Area

Warm Springs National Fish Hatchery is located at river kilometer (rkm) 16 of the Warm Springs River within the Warm Springs Indian Reservation in north central Oregon. The hatchery is operated by the USFWS in cooperation with the Confederated Tribes of the Warm Springs Reservation of Oregon to produce Spring Chinook salmon for tribal and sport harvest opportunities, and promote wild fish conservation. The Warm Springs River flow approximately 48 river kilometers from its headwaters before joining the Deschutes River at rkm 135. The Deschutes River continues north to its confluence with the Columbia River at rkm 330 (Figure 1.)

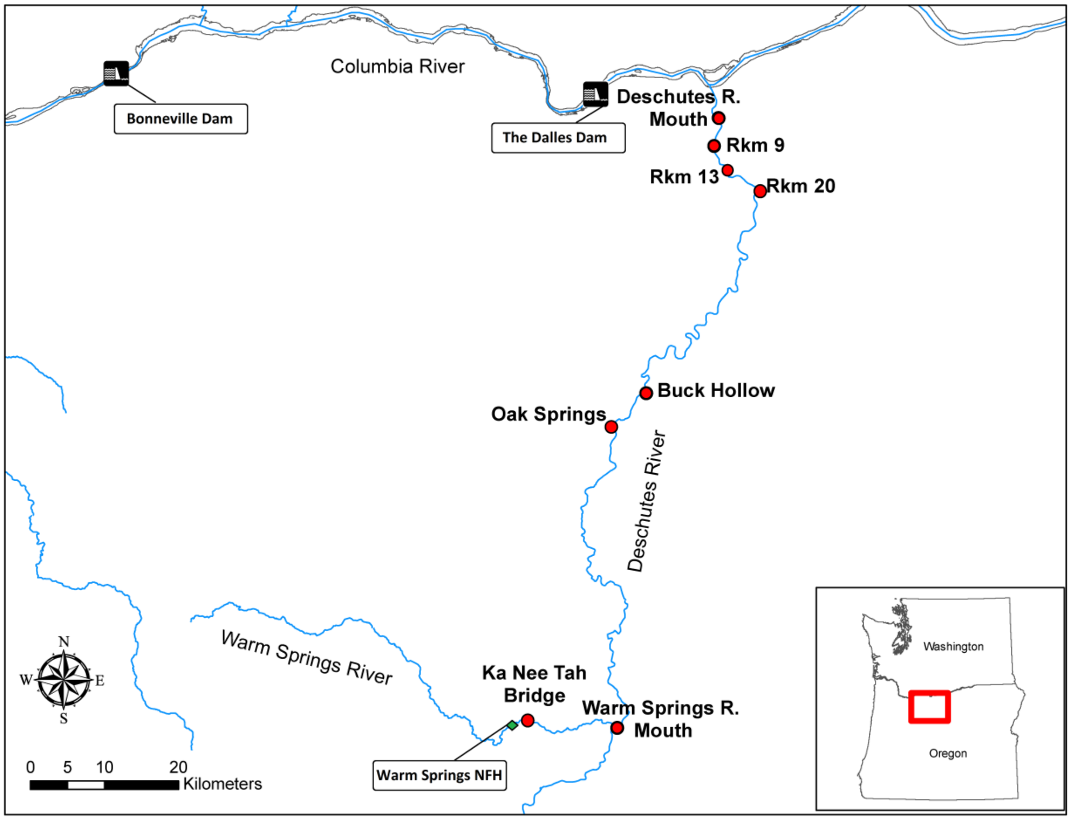

Figure 1. Location of Warm Springs NFH (green diamond), telemetry fixed-site locations (red dots, 2012-2014), The Dalles Dam, Bonneville Dam, and the Warm Springs, Deschutes and Columbia rivers.

Methods

Pre-Study Scoping

Prior to initiation of the radio-telemetry study in 2012, we simulated tagging and survival scenarios to determine whether radio-telemetry would provide reasonable estimates of juvenile survival within the Deschutes basin in order to meet our study objectives. We ran a series of simulations in program MARK to estimate the precision of survival estimates at various tagging sample sizes (25, 50, 75 and 100 radio tags), telemetry fixed station detection efficiencies (80% and 90%), and survival levels (70% to 90%) (see Hand et al. 2012). In a second exercise we calculated the percent reduction in 95% confidence intervals that would result from increasing the number of radio tags from 25 to 50 (30% reduction), 50 to 75 (19% reduction), and 75 to 100 (14% reduction). Based on these simulations, the effect of adding one telemetry fixed site was estimated to be the equivalent of adding 25 radio-tags. After comparing the results of these simulations, we concluded that 50 radio tags was the minimum required to provide a reasonable survival estimate with a confidence interval of around +/- 13%. We also elected to increase the number of fixed sites rather than spend money on additional tags as a way to increase the precision of our survival estimate.

Radio-tag Specifications

The radio tags used in this study were Model NTQ-2 Nano Tags (Lotek Wireless, Inc.) with a minimum tag life of 35 days (eight second burst rate). Tags transmitted on two frequencies at 10 different pulse intervals (8.0 to 8.9 seconds). Tag size was 5 mm wide by 3 mm high by 10 mm long, with an antenna length of 18 cm and weight of 0.31 g in air. Detection range of tags was approximately 100 to 150 meters when field tested along the lower Deschutes River. Each radio tagged fish was also implanted with a Passive Integrated Transponder (PIT) tag. PIT tags used in this study were 12.5 mm long by 2.1 mm high, with a weight of 0.10 g in air.

Tracking Systems

Radio-tagged juvenile Chinook salmon were monitored using a series of fixed stations along the Warm Springs and Deschutes rivers (Figure 1, Table 1). Fixed sites used SRX400 receivers manufactured by Lotek Wireless, Incorporated. All receivers were programmed to scan each of the two tag frequencies at nine second intervals (18 second cycle). Antennas (6-element or 4-element Yagi) were attached to fence posts and oriented with the stream to optimize read range. Each fixed site was powered by a single 12-volt battery which was connected to a solar panel for charging. In the lower Deschutes River, two fixed sites were collocated at river kilometer 9 (2012 only) and the Deschutes River mouth (all years). Antennas for each receiver were fastened to the same fence post with one configured to detect radio tags upstream and one configured to detect radio tags downstream from the location. During pre-study testing, large amounts of radio-interference from overhead power lines made it impossible to reliably detect tags near the Deschutes River confluence with the Columbia River. For the purposes of this study, river kilometer five was classified as the mouth of the Deschutes River.

During the monitoring of migration year 2012, higher detection rates were observed at fixed telemetry sites located in stream sections that harbored slow current. Based on this observation two sites were relocated in 2013 in an effort to improve detection probabilities. In 2014 we removed the fixed site at Ka Nee Tah Bridge because we suspected a high rate of radio tag signal collisions likely due to the site's close proximity to the release area. We also justified the removal of this site because high apparent survival to the mouth of the Warm Springs River was seen in migration years 2012 and 2013. Fixed sites at the mouth of the Warm Springs River, river kilometer 9 (downstream) and the two sites at mouth of the Deschutes River remained consistent in all three years of the study (Table 1).

Table 1. Location and distances, in river kilometers (rkm) of all fixed site telemetry stations in Warm Springs River and Deschutes River 2012-2014.

Release Year	Site #	River	Location	Distance From WSNFH (rkm)	Distance From Mouth of Deschutes (rkm)
2012	1	Warm Springs	Ka Nee Tah Bridge	2	147
2012	2	Warm Springs	Mouth of Warm Springs	16	133
2012	3	Deschutes	Oak Springs	73	76
2012	4	Deschutes	Lower Deschutes-up	140	9
2012	5	Deschutes	Lower Deschutes-down	140	9
2012	6	Deschutes	Mouth of Deschutes-up	149	5
2012	7	Deschutes	Mouth of Deschutes-down	149	5
2013	1	Warm Springs	Ka Nee Tah Bridge	2	147
2013	2	Warm Springs	Mouth of Warm Springs	16	133
2013	3	Deschutes	Buck Hollow	80	69
2013	4	Deschutes	Lower Deschutes	129	20
2013	5	Deschutes	Lower Deschutes	140	9
2013	6	Deschutes	Mouth of Deschutes-up	149	5
2013	7	Deschutes	Mouth of Deschutes-down	149	5
2014	1	Warm Springs	Mouth of Warm Springs	16	133
2014	2	Deschutes	Buck Hollow	80	69
2014	3	Deschutes	Lower Deschutes	136	13
2014	4	Deschutes	Lower Deschutes	140	9
2014	5	Deschutes	Mouth of Deschutes-up	149	5
2014	6	Deschutes	Mouth of Deschutes-down	149	5

Pre-surgery Collection

Radio tags were surgically implanted into the study fish. One day prior to the surgery date, up to 60 juvenile Spring Chinook salmon were randomly dip-netted from the hatchery raceways where a subsample of fish (approximately 7,500 per raceway) had been previously PIT tagged as part of the survival monitoring to Bonneville Dam (see below). Selected fish were individually scanned for previously implanted PIT tags. If a fish already had a PIT tag in it, the fish was returned to the raceway. The fish were then visually inspected for external injuries and transported to an indoor holding tank at the hatchery. Fish were left undisturbed for a minimum of 12 hours before performing the tag implantation surgery to reduce stress from handling and transport. Approximately 100 additional fish from each sample raceway were measured and weighed to estimate the size distribution of fish in the raceways.

Surgical Procedures

In 2012, radio tag implantation surgeries were performed on a total of 60 juvenile Spring Chinook in two separate weeks. Twenty five fish from a single raceway were implanted with activated radio tags and PIT tags on April 10, and another 25 fish were tagged from a different raceway on April 24, 2012 (Table 2). An additional ten fish (five from each raceway) were implanted with de-activated or "dummy" radio tags comparable in size and weight to study tags. Fish tagged with dummy transmitters were held a minimum of 30 days in a covered indoor holding tank for delayed mortality and tag retention monitoring purposes. A single person performed all tag implantation surgeries during both tagging events in 2012. In 2013 and 2014, radio tag implantation surgeries were performed on a total of 89 and 90 fish respectively. On both occasions up to 80 fish were implanted with activated radio tags and PIT tags, and 10 fish were implanted with dummy radio tags for laboratory holding and monitoring. Two surgeons performed approximately 45 tag implantations each, pulling fish evenly from two different raceways in an effort to reduce bias that may occur from different surgery techniques. Surgeries were performed over a two day period during the first week of April (Table 2). Surgical techniques including incision placement, transmitter insertion, suture closure, and recovery procedures followed those described by Liedtke et al. (2012); see Hand et al. (2014) for details. At the completion of surgery, fish were returned to a covered indoor holding tank (separated by raceway) and held overnight.

PIT tagging

Approximately 15,000 juvenile Spring Chinook were PIT tagged during each year of the radio telemetry study to monitor migration timing and survival to Bonneville Dam (see Hand et al. 2014). The goal was to tag 7,500 fish from two different raceways, representing overall production numbers and rearing strategies. In most years (including 2012 and 2013), the tagging represents fish reared using standard rearing protocols (i.e., fish are fin clipped and coded-wire tagged in May – or spring marked). In 2014, PIT tagging also included an experimental group of fish that were reared at a slower early growth rate and fin clipped and coded-wire tagged five months later in October – or fall marked. In 2014, approximately 10,000 spring marked fish were tagged in two raceways, and 5,000 fall marked fish were tagged in a third raceway. Fall marked fish were not radio-tagged.

Post-surgery Monitoring and Release

Total numbers of fish tagged and released by date and year are summarized in Table 2. Size distribution of radio tagged fish represented the overall hatchery population in all three years (see Hand et al. 2012; Hand et al. 2013; Hand et al. 2014). Mean fork lengths were also similar for all three years of the study (118 ± 13.4 [mean ± SD], 121 ± 10.4 and 116 ± 10.4).

On the morning of the scheduled release, researchers performed a visual inspection of the holding tanks to look for shed tags and to ensure fish were fully recovered from the surgery. Once transmitter function was verified, each fish was released back into its respective raceway. Surgery fish were given a minimum of one hour to mix with the raceway population before being released with the rest of the raceway population, into the Warm Springs River. Hatchery release strategies varied in the three years of the study. In 2012, all 16 hatchery raceways were opened for volitional release beginning April 2, 2012. After three days, pairs of raceways were forced released (i.e., remaining fish forced out and raceway drained of water) every three to six days. The first group of radio tagged fish was forced released on April 12 while the second group of radio tagged fish was force released on April 26, 2012. The forced releases occurred during the early evening hours on both release dates. In 2013 the hatchery implemented an abbreviated volitional release. All 19 hatchery raceways were opened for volitional release on March 27, 2013. On April 4, fish remaining in 11 standard reared raceways (including PIT and radio tagged fish) were released sequentially into the Warm Springs River. In 2014 there was no volitional release period. Three raceways representing all PIT tagged groups (including radio tagged fish) were forced released into the Warm Springs River on April 3, 2014. Forced releases occurred in the early afternoon for all raceways in 2013 and 2014.

Table 2. Number of Spring Chinook radio-tagged and released in 2012, 2013 and 2014.

Year	Surgery Date	Raceway	Total Tagged	Total Released*	Release Date
2012	April 10	19	35**	20	April 12
2012	April 24	11	25	21	April 26
Total		-	*50*	***41***	-
2013	April 2	20	20	19	April 4
2013	April 2	23	31	31	April 4
2013	April 3	20	29**	19	April 4
2013	April 3	23	9	9	April 4
Total		-	*89*	***78***	-
2014	April 1	21	40	40	April 3
2014	April 1	23	20	20	April 3
2014	April 2	21	5**	-	April 3
2014	April 2	23	25**	20	April 3
Total		-	*90*	***80***	-

**Number includes fish tagged with dummy transmitters.

The volitional releases in 2012 were monitored by two PIT antennas at each raceway outflow. Detection efficiencies of PIT antennas during the volitional release period were high, with estimated antenna efficiency greater than 90% for both raceways (Hand et al. 2012). Raceway 19 was on volitional release a total of 10 days prior to collecting fish to radio tag. At this point, approximately 50% of PIT tagged fish remained in the raceway prior to the force release. Raceway 11 was on volitional release a total of 21 days prior to collecting fish to radio tag and approximately 20% of PIT tagged fish remained in the raceway prior to the force release. More than 85% of PIT tagged juvenile Spring Chinook volitionally exited raceways during hours of darkness (Hand et al. 2012). PIT antennas were also used to monitor the volitional release of fish into the Warm Springs River in 2013, but due to the shortened volitional release, the majority of PIT tagged fish remained in their respective raceways during this period. This resulted in high tag "collision" rate when the remaining population was forced out into the Warm Springs River. Collisions occur when two or more tags are within an antenna's field at the same time, rendering the PIT reader unable to detect any of them. Due to this phenomenon we were unable to obtain accurate counts of PIT tagged fish leaving the raceways in 2013 (Hand et al. 2013). Warm Springs NFH did not release their fish volitionally in 2014, so all juvenile Spring Chinook were present in raceways during radio tag sampling and release into the Warm Springs River.

During post-surgery monitoring in 2012 and 2013, it became apparent that several of the activated radio tags had ceased functioning as a result of insufficient tag surface coating and/or improper antenna attachment. As a result, a total of eight tags were removed from the study in 2012 and a single tag was removed in 2013. In addition, one fish tagged in 2012 was found to have jumped out of the holding container and died within the hatchery building. A total of 41 functional tags were released into the Warm Springs River in 2012, 78 tags were released in 2013, and 80 active tags were released into the Warm Springs River in 2014 (Table 2).

River Discharge

Warm Springs River and Deschutes River discharge data were obtained from the United States Geological Survey (USGS), National Water Information System webpage. Daily discharge (cubic feet per second) data during years 2012-2014, from April 1 through May 31 were retrieved from the Warm Springs River gauge near Ka Nee Ta Hot Springs (USGS gauge #14097100), the Deschutes River gauge at Moody near Biggs, Oregon (USGS gauge #1410300) and the Columbia River gauge at The Dalles, Oregon (USGS gauge #14105700).

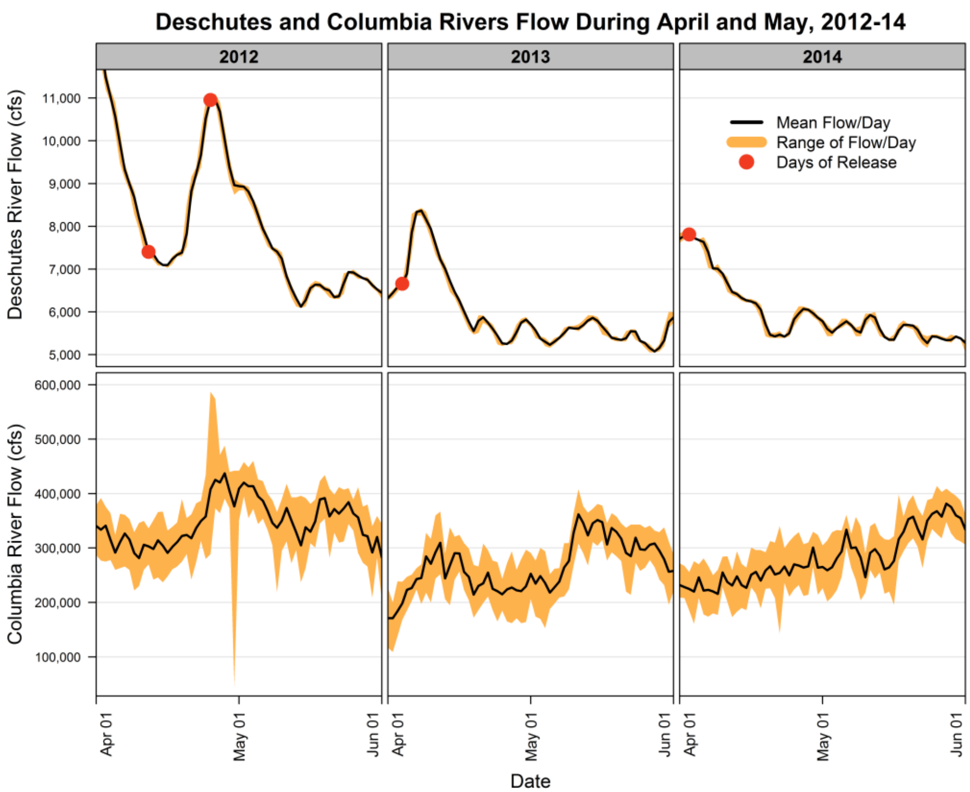

Figure 2. Warm Springs NFH juvenile Spring Chinook release dates (red dots), Deschutes River discharge at Moody (rkm 1.6) and Columbia River discharge (1.9 kilometers downstream of The Dalles Dam) during hatchery migration months (April and May), years 2012-14.

Discharge in the Warm Springs and Deschutes Rivers were relatively high in 2012 with releases of radio tagged fish occurring just prior to and during a peak flow event. Discharge in the Warm Springs and Deschutes Rivers were lower during juvenile releases in 2013 and 2014 (Figure 2). The magnitude of discharge in the Warm Springs and Deschutes Rivers differed, but followed similar trends with medians highest in 2012 (754 cfs and 7410 cfs respectively) and lowest in 2013 (476 cfs and 5658 cfs).

Results

Downstream Migration and Timing

Of all radio tagged fish released into the Warm Springs River for the duration of the study, 185 tags out of 199 tagged fish (93.0%) were detected at least once at a fixed telemetry site, 73.9% were detected at the mouth of the Warm Springs River and 67.3% were detected on at least one of the two telemetry sites stationed at the mouth of the Deschutes River. Migrational travel time through the Warm Springs and Deschutes rivers was rapid for all three years of the study. Average travel time from release to the mouth of the Warm Springs River was 0.30 days (radio tags, years 2012-14), from release to the mouth of the Deschutes River was 2 days and average travel time to Bonneville Dam was 27 days (PIT tags) (see Table 3). Of the tags detected at the Deschutes River mouth (N = 134, years 2012-14), 79% arrived within four days of release (Figure 3). These fish exhibited a diel migration pattern with 66% of detections occurring during the hours of darkness (median = 04:32 am).

There was a group of tags that took an exceptionally long time to reach the mouth of the Deschutes River (see Figure 3); of these outliers (i.e., values greater than 1.5 times the third quartile [5 to 34 days], N = 25), only one of the PIT tags (4.0%) was subsequently detected at Bonneville Dam or elsewhere. This tag had reached the mouth of the Deschutes River in 5.5 days and was detected 20 days later at the Bonneville Dam Corner Collector. Of the remaining fish that were detected at the mouth of the Deschutes River (N = 109) within five days of release, eight of them (7.3%) were subsequently detected downstream at either Bonneville Dam (N = 5), the Estuary trawl (N = 1), as a mortality on East Sand Island (N = 1) or as a returning adult (N = 1). To date only one radio-tagged fish out of 199 radio-tags has returned as an adult. This fish was released on April 3, 2014 (brood year 2012) and was detected at a Warm Springs National Fish Hatchery PIT antenna on May 10, 2016. This fish was also detected returning as an adult at Bonneville Dam, The Dalles Dam, the Warm Springs River PIT array (located at the mouth of Warm Springs) and its radio tag was recovered at a spawning event on August 18, 2016.

Table 3. Number of days from release at WSNFH to the Deschutes River mouth (radio-tags) and Bonneville Dam (PIT tags).

	Mouth of Warm Springs			Mouth of Deschutes			Bonneville Dam		
Year	Median	Min	Max	Median	Min	Max	Median	Min	Max
2012	0.28	0.21	0.40	1.67	1.25	21.52	22	4	27
2013	0.47	0.32	1.42	2.51	1.52	30.49	29*	3*	45*
2014	0.42	0.29	9.44	1.71	1.28	33.48	30	3	52

*Migration times to Bonneville Dam in 2013 may be underestimated due to PIT tagged fish having the option to exit ponds volitionally eight days before being forced into the Warm Springs River. In 2012, data collected from volitional release tube PIT antennas show that 28.8% left after eight days. Known “forced” release date was used to determine migration timing in 2013.

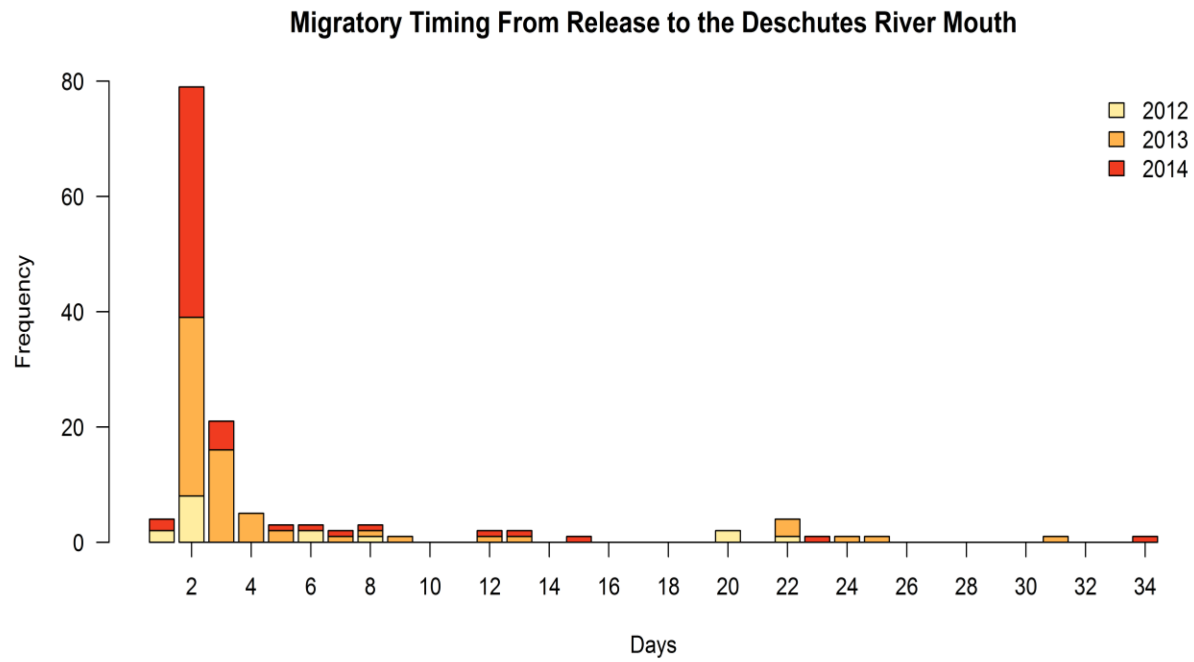

Figure 3 Migratory timing from release to the mouth of the Deschutes River for radio-tagged fish in 2012 (light bars), 2013 (medium bars), and 2014 (Dark bars)

Survival

Estimated fixed site detection efficiencies were generally lower than the values used in the pre-study scoping exercise (80% and 90%); in 2012, fixed telemetry site detection efficiencies ranged from 34% to 100% (Hand et al. 2012) . Low telemetry site detection efficiencies could in part be explained by the limited signal strength of the radio telemetry tag and by sites located in areas with fast water velocity or wide stream width. Sites harboring these attributes were relocated in 2013 and we observed an overall increase in detection efficiencies ranging from 68% to 99% (Hand et al. 2013). In 2014 we discarded detection probabilities and apparent survival estimates associated with three telemetry sites (sites 1, 3 and 4) due to technical malfunction and operator errors that resulted in data loss and/or poor detection. Of the 2014 telemetry encounter histories used for analyses (mouth of Warm Springs and Deschutes), detection efficiencies ranged from 45% to 70%.

Estimated survival of radio-tagged juvenile Spring Chinook to the mouth of the Warm Springs River was high in 2012 and 2013 (see Table 4). We were unable to calculate the point estimate to the Warm Springs mouth in 2014, but survival to Buck Hollow approximately 64 km downstream of the Warm Springs mouth was 91%, 95% CI [76, 97]. Survival estimates to the mouth of the Deschutes River were relatively low in 2012 at 43% (95% C.I. [28,59]) compared to 2013 (85%, C.I. [75,91]) and 2014 (78%, C.I. [62,88]) (Table 4, Figure 4). Survival between fixed sites was variable between years (see Hand et al. 2012; Hand et al. 2013), but when estimates were standardized for distance traveled (converting survival estimates between sites to survival per kilometer), our results indicate that apparent survival was fairly constant throughout the Warm Springs and Deschutes Rivers.

Apparent survival estimates for all three years of the study (outmigration, 2012 -2014) were recalculated (data were downloaded from www.ptagis.org on August 29, 2016) to incorporate new data from bird colony mortalities and adult return detections. The updated estimates did not affect telemetry results (only one radio-tagged fish was detected returning as an adult), but PIT tag based survival estimates to Bonneville Dam have differed since previous reports. The additional data decreased detection probability estimates at Bonneville Dam, shifted survival estimates higher and narrowed confidence intervals.

All survival estimates to the mouth of the Warm Springs and Deschutes rivers obtained from radio-tags and to Bonneville Dam obtained from PIT tags followed the same annual trends (i.e. lowest survival in 2012, highest in 2013). Apparent survival and detection probability estimates were obtained using the Cormack-Jolly-Seber model in Program MARK (Cooch and White 2006).

Table 4. Apparent survival estimates (phi), detection probability estimates (p), standard error and 95% confidence intervals, to fixed telemetry sites at the mouth of the Warm Springs and Deschutes rivers, 2013-14.

Location	Year	Estimate		Standard Error	Lower C.I.	Upper C.I.
Warm Springs River Mouth	2012	*phi*	0.805	0.145	0.403	0.962
		p	0.364	0.103	0.193	0.577
	2013	*phi*	0.986	0.015	0.894	0.998
		p	0.985	0.015	0.903	0.998
	2014	*phi*	0.908[*]	0.049[*]	0.759[*]	0.969[*]
		p	0.702[*]	0.061[*]	0.572[*]	0.806[*]
Deschutes River Mouth	2012	*phi*	0.426	0.080	0.281	0.585
		p	0.688	0.116	0.433	0.864
	2013	*phi*	0.849	0.042	0.748	0.914
		p	0.918	0.035	0.818	0.965
	2014	*phi*	0.776	0.069	0.615	0.883
		p	0.450	0.070	0.321	0.588
Bonneville Dam[**]	2012	*phi*	0.521	0.070	0.386	0.652
		p	0.115	0.016	0.088	0.150
	2013	*phi*	0.713	0.078	0.540	0.840
		p	0.116	0.013	0.093	0.114
	2014	*phi*	0.626	0.073	0.477	0.754
		p	0.118	0.014	0.093	0.149

[*]Due to technical difficulties in 2014, detection probability and apparent survival estimates to the mouth of Warm Springs were estimated at Buck Hollow (64 km downstream).
[**]Apparent survival and detection probability estimates to Bonneville Dam were calculated using PIT tag data (N = 44790) whereas estimates to the Warm Springs and Deschutes mouths were obtained via radio tags (N = 199).

Discussion

Despite varying environmental conditions (e.g., discharge), biological characteristics (e.g., fish health) and management practices (e.g., release strategies), all three years of radio telemetry data suggest that hatchery Spring Chinook salmon mortality rates in the Warm Springs River are minimal. These data also suggest that mortality rates are generally constant per kilometer within the Warm Springs and Deschutes rivers, giving no indication there are any troublesome areas (i.e., areas with disproportionately high mortality). We could also not detect any significant differences in mortality rates per kilometer when comparing telemetry survival estimates to the mouth of the Deschutes with PIT tag survival estimates to Bonneville Dam. Although burdened by wide confidence intervals, our estimates suggest an average of about one mortality per eight kilometers, with the exception of migration year 2012 between the Deschutes's mouth and Bonneville dam; in migration year 2012 our results suggest very few to zero mortalities within the 96 river kilometers between the mouth of the Deschutes and Bonneville Dam. When viewed from a temporal standpoint it could be argued that our test fish survived at a higher rate in the Columbia River compared to the Deschutes River, as the average travel speed slowed drastically between the Deschutes River and Bonneville Dam. Median travel time from Warm Springs NFH to Bonneville Dam was 27 days compared to a two day travel time to the mouth of the Deschutes, suggesting that rate of travel drastically slows on average from 70 rkm/day to 3.5 rkm/day when fish enter the Columbia River.

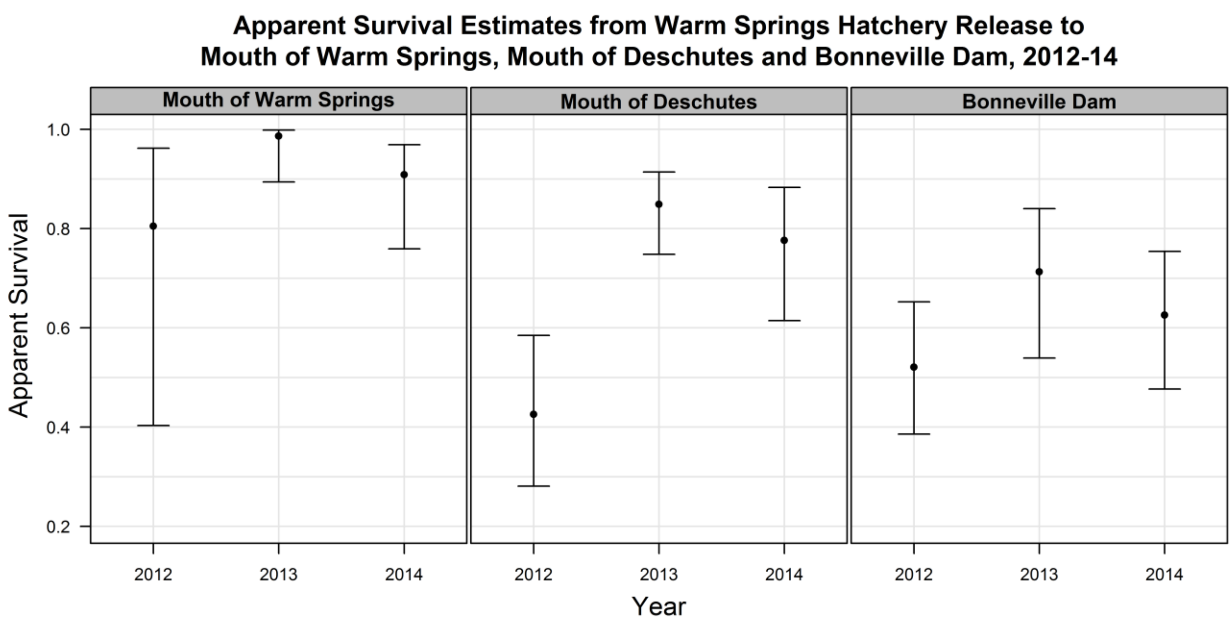

Figure 4 Apparent survival estimates of radio-tagged (Mouth of Warm Springs and Mouth of Deschutes) and PIT tagged (Bonneville Dam) juvenile Spring Chinook released from Warm Springs NFH for years 2012, 2013, and 2014. Error bars are ± 95% confidence intervals. In 2014 we experiences telemetry technical problems at the mouth of the Warm Springs so our apparent survival estimate to Buck Hollow (64 km downstream of Warm Springs) was used instead.

Annual apparent survival estimates of outmigrating juvenile Spring Chinook to the mouth of the Warm Springs River, the mouth of the Deschutes River and to Bonneville Dam all followed the same trend with lowest survival estimates occurring in 2012 and highest occurring in 2013. This trend was also observed looking at the percent of PIT tagged fish returning as adults (age-3 and 4) to the Columbia River (detected at Bonneville and The Dalles dams); 0.75% of PIT tagged fish were detected as adults from outmigration year 2012, 1.26% from 2013 and 0.90% from 2014. The fact that we were able to capture adult return trends within days of release is evidence that it may be possible to quantify a cohort's propensity to survive soon after if not before a hatchery release. In other words, smolt release survival and/or hatchery raceway survival rates might be useful indicators for predicting ocean survival and subsequent adult returns to the hatchery. Hatchery release strategies and other hatchery management practices varied annually during the three year study, which likely influenced survival rates.

Objectives for this study included determining where hatchery Spring Chinook mortalities were occurring between WSNFH and Bonneville Dam, and identifying management practices in either the hatchery or the Deschutes basin that could potentially reduce mortality risks. Given that this study offers no indication that mortality rates are elevated in a specific area between WSNFH and Bonneville Dam, we have no immediate recommendations concerning hatchery or Deschutes management practices. We do recommend working with the hatchery staff to launch a study that systematically incorporates hatchery management practices into the study design of any future monitoring of Deschutes basin outmigrant survival of hatchery Spring Chinook salmon. Understanding how different management practices affect survival (e.g., different release strategies [volitional vs. forced, midday vs. dusk, etc.]) could impart valuable information and guide future practices.

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