Migration Timing and Survival of Juvenile Hatchery Spring Chinook Salmon Releases in the Deschutes Basin

Progress Report for 2012

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Section I

Migration Timing and Survival to Bonneville Dam of Hatchery Juvenile Spring Chinook Salmon in the Deschutes Basin

Summary

Migration year 2012 was the third year of PIT tag monitoring of Warm Springs and Round Butte stocks. A total of 14,937 Warm Springs NFH and 7,489 Round Butte hatchery brood year 2010 spring Chinook salmon juveniles were PIT tagged as part of a Deschutes basin spring Chinook salmon monitoring and evaluation program. At Warm Springs NFH, PIT tags were split into two raceways, raceway 11 which had a volitional release of juveniles between April 2 and April 26, and raceway 19 which had an abbreviated volitional release between April 2 and April 12 of 2012. Round Butte juveniles were volitionally released between April 17 and the first week of June 2012. The majority of Round Butte juveniles left their holding facility in the first three days of the volitional release, while the Warm Springs juveniles migrated out in a more variable pattern. Round Butte juveniles migrated downstream to Bonneville Dam the fastest, with a median migration time of 7 days, compared to 22 days for Warm Springs NFH juveniles. Median day of passage of PIT tagged juveniles over Bonneville Dam was April 25 for Round Butte juveniles and May 9 for Warm Springs NFH juveniles. Although fish from raceway 19 at Warm Springs NFH were forced out two weeks earlier than fish in raceway 11, passage timing over Bonneville Dam was similar.

Estimated survival from release to Bonneville Dam was similar for juveniles from each raceway at Warm Springs NFH, with a combined survival estimate of 45% (95% C.I. of 30%-62%). Adult return rates at Warm Springs NFH have not necessarily tracked trends seen in juvenile survival. Estimated survival of Round Butte juveniles was 65%, although confidence intervals were large (95% C.I. of 27% to 90%). Round Butte juveniles surviving to Bonneville Dam returned as mini-jacks at a rate approximately five times greater than Warm Springs NFH juveniles.

Introduction

Long term monitoring of spring Chinook salmon hatchery populations in the Deschutes basin has primarily been accomplished by monitoring adult returns through creel surveys, counts of adults at hatchery racks, and evaluating coded-wire tag recoveries from returning adult fish. Relatively little information on juvenile survival has been collected due to technical and logistical limitations. The general assumption has been that all juvenile Chinook salmon in the Deschutes basin experience similar environmental variables during their downstream migration and therefore likely have similar freshwater survival rates; however, Warm Springs National Fish Hatchery (NFH) and Round Butte hatchery manage their stocks in different manners. Warm Springs NFH has tried to maintain wild traits in the hatchery population while Round Butte has been managed strictly for production purposes. The rearing and release strategies at the two hatcheries are also quite different, and have changed over the years, although each hatchery has generally been successful in meeting their respective production goals. The effect of rearing and release strategies on juvenile migration behavior and survival is unknown. In addition, how juvenile migration and survival of the hatchery populations in the Deschutes Basin compares to wild populations is unknown. The expansion of PIT tag detection systems throughout the basin has led to an opportunity to collect baseline information on juvenile survival for both hatchery and wild stocks. Tagging of both Warm Springs NFH and Round Butte hatchery fish will allow for comparisons to be made between Deschutes River populations. Additionally, different release strategies at Warm Springs NFH (forced release versus spring volitional release) can be evaluated. Monitoring of juvenile releases at Warm Springs NFH using PIT tag technology began with a brood year 2005 (spring migration year 2007) evaluation of a fall/spring volitional release. Warm Spring NFH releases have been PIT tagged every year since. In order to compare hatchery stocks within the Deschutes Basin, Round Butte juveniles were PIT tagged starting with brood year 2008 (migration year 2010). Migration year 2012 was the third year of PIT tag monitoring of Warm Springs and Round Butte stocks.

This report summarizes the PIT tagging and juvenile monitoring of brood year 2010 spring Chinook juveniles at both Warm Springs NFH and Round Butte hatchery. The objectives addressed in this preliminary report are:

1) PIT tag representative numbers of juvenile fish at both Warm Springs NFH and Round Butte hatchery.
2) Monitor the release strategies at each hatchery.
3) Compare downstream migration speed and migration timing to Bonneville Dam.
4) Compare juvenile survival from release to Bonneville Dam.

Methods

Tagging and Release

Warm Springs NFH

Brood year (BY) 2010 juveniles from Warm Springs NFH were PIT tagged on January 31 and February 1 of 2012. PIT tagged juveniles represented the overall BY 2010 production, approximately 480,000 juveniles total, at Warm Springs NFH. Warm Springs NFH BY 2010 juveniles were reared in 16 raceways, raceways 7-22, at approximately 30,000 fish per raceway. The goal of the PIT tagging effort was to tag approximately 7,500 juveniles from each of two raceways, raceway 11 and raceway 19. All juveniles tagged at Warm Springs NFH were progeny of Warm Springs hatchery stock parents.

Warm Springs NFH planned a sequential release strategy for the spring volitional release of BY 2010 juveniles. Starting on April 2, 2012 all 16 raceways at Warm Springs NFH were opened up for volitional release. Three days later, two of the raceways were scheduled to be forced out, that is the remaining fish forced out of the raceway and the raceway drained of water. Subsequently, every three to six days, another two raceways were to be forced out, until all 16 raceways were empty. Raceway 19, which included PIT tagged juveniles, was forced out on April 12th, and raceway 11 was forced out on April 26th, the last raceway to be forced out.

Round Butte Hatchery

Brood Year 2010 juveniles from Round Butte hatchery were PIT tagged on October 24-26, 2011. The goal was to PIT tag approximately 7,500 juveniles from the hatchery raceways that were to be released from cell one (C1) in the Pelton fish ladder rearing area. The PIT tagged fish represented the entire Round Butte spring Chinook hatchery production release of approximately 260,000 juveniles into the Deschutes River downstream of Pelton Dam. The fish were to be moved from the hatchery raceways to the Pelton fish ladder rearing area one week after tagging. All juveniles tagged at Round Butte were progeny of Round Butte stock adults.

PIT tagged fish were held in Cell 1 of the Pelton ladder until release in the spring of 2012. Round Butte BY2010 juveniles were volitionally released starting on April 17, 2012 and ending the first week of June. Any fish that had not volitionally migrated out of the fish ladder by the end of the release period were sacrificed. Two square PIT antennas were placed in the fish ladder downstream of the holding cells to detect fish volitionally leaving the ladder. PIT tag codes were classified into the same categories as at Warm Springs NFH, with the exception being mortalities and sheds were not monitored at Round Butte. Only tags with known detection histories were used for analysis.

Downstream Migration

Detections of PIT tagged fish at Bonneville Dam (rkm 235; Figure 1) were downloaded from the PTAGIS database system on January 23, 2013. Data from the release detections were cross referenced with Bonneville Dam detections. Only tags with known release detections, either volitional or forced release, were used in the migration timing analyses at both hatcheries. For survival analyses, only fish with known release detections were used for Round Butte estimates. Due to the release strategy and poor release detection capability at Warm Springs NFH, records of all fish tagged were used for survival estimates (see Results section for explanation). Mini-jacks, sexually mature age 1+ fish, were also excluded from the downstream migration analysis. Mini-jacks were identified as fish migrating upstream over Bonneville dam after May 31st. The number of days from release to Bonneville Dam was calculated for each PIT tagged fish, along with the day of year that the fish was detected at Bonneville Dam. Median days were used for comparisons between groups of fish (raceway 11, raceway 19, and Round Butte) using Kruskal-Wallis Analysis of Variance (ANOVA). All statistical tests were performed using SigmaPlot 11.0.

Juvenile Survival

Fish swimming downstream to Bonneville Dam can take several different passage routes past the dam including the following: 1) passage through the power turbines, 2) through spillways when spill is occurring, 3) through the juvenile bypass system, 4) through the corner collector, 5) downstream through the adult ladder, and 6) through the shipping locks. PIT tagged fish can only be detected if they pass through the juvenile bypass, corner collector, or adult ladders. PIT tagged fish passing through any of the other routes will not be detected, therefore estimates must be made of the detection efficiency at Bonneville Dam in order to estimate the total number of PIT tagged fish that survived to Bonneville Dam. The precision of the survival estimates is a function of the number of fish PIT tagged, the number of fish detected moving downstream over Bonneville Dam, and the number of fish detected at points downstream of Bonneville Dam. Downstream detection points include both fish detected at an estuary trawl (river kilometer 60-80) and mortality recoveries of PIT tags from the Caspian tern and double-crested cormorant colonies in the lower river (Figure 1).

Detection histories for each tagged fish leaving the hatchery were created and were summarized into the following four categories: 1) tagged fish leaving the hatchery but not detected anywhere else, 2) tagged fish leaving the hatchery and detected at Bonneville Dam only, 3) tagged fish leaving the hatchery, not detected at Bonneville Dam, and subsequently detected either at the estuary trawl or on the bird colonies, and 4) fish leaving the hatchery, detected at Bonneville Dam, and subsequently detected at the estuary trawl or bird colonies. Summaries of detection histories were then entered into program MARK, which calculated Bonneville Dam detection efficiencies and survival estimates for fish leaving the hatchery to Bonneville Dam using a Cormack-Jolly-Seber model.

Bird Colony Recoveries

The National Marine Fisheries Service leads an annual PIT tag recovery effort from bird colonies in the Columbia River Basin (Sebring et al. 2010). Bird colony recoveries for the 2012 migration year were downloaded from PTAGIS on January 23rd 2013. Only recoveries from East Sand Island (rkm 8; Figure 1) were included in the downstream of Bonneville Dam data category.

Mini-jack Returns

Mini-jacks were identified by querying the PTAGIS database for detections of upstream migrating fish over Bonneville Dam. All Bonneville Dam adult ladder detections of Round Butte and Warm Springs PIT tagged fish after May 31st were considered mini-jacks. Mini-jack rate was calculated based on the estimated downstream survival to Bonneville and subsequent upstream detections. Fisher's exact test was used to compare mini-jack rates between Warm Springs NFH and Round Butte.

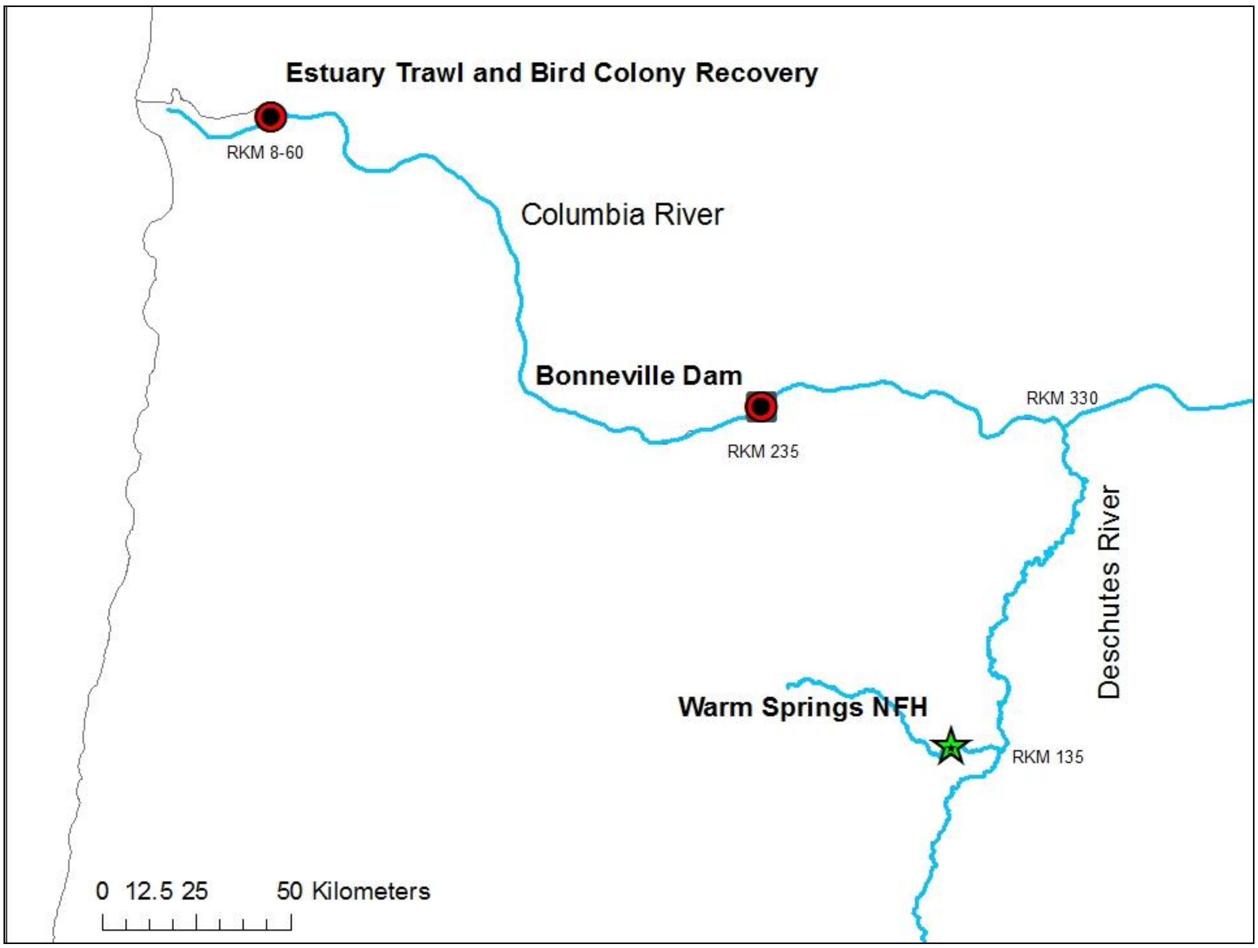


Figure 1. Location of PIT tag detection sites (red circles) used for juvenile survival analyses.

Results and Discussion

Release

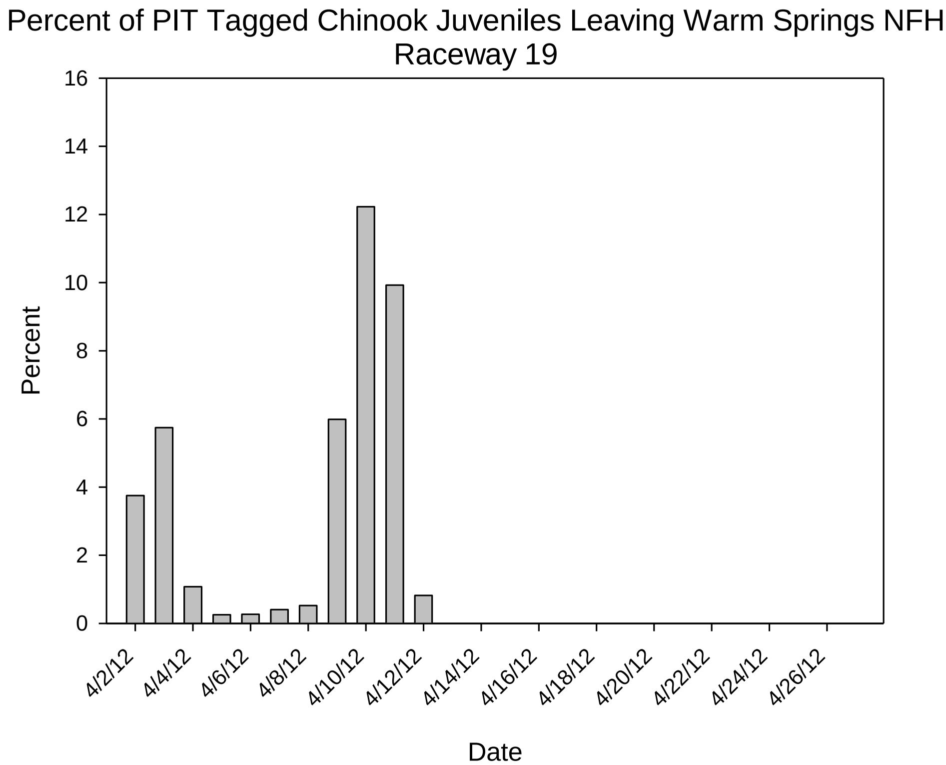
The number of fish PIT tagged and detected during release from each hatchery are summarized in Table 1. Approximately 7,500 fish were tagged from each of Warm Springs NFH raceways (RW) 11 and 19, as well as from Round Butte hatchery cell 1.

Table 1. Number of fish PIT tagged (excluding shed tags and mortalities prior to release), and detections of fish leaving the hatchery during the volitional release or forced release.

Group	Tagged	Volitional	Forced*	Total Detected	Unknown
Warm Springs RW 11	7,495	6,696	334	7,030	405
Warm Springs RW 19	7,442	3,047	-	3,047	4,388
Warm Springs Total	14,937	9,743	334	10,077	4,860
Round Butte C1	7,489	7,083	0	7,083	406

* Number of PIT tagged fish during forced release in RW 19 is unknown. Large numbers of PIT tagged fish remained in the raceway after the volitional release, complicating efforts to detect tagged fish. Most of the unknown tags in RW 19 are likely part of the forced release.

Detection efficiency during the volitional release period at Warm Springs NFH was high, with estimated antenna efficiencies greater than 90% for both raceways. The majority (>85%) of fish volitionally leaving the raceways did so during hours of darkness. The estimated percentages of fish leaving the raceway daily during the volitional release are shown in Figure 2. The sequential release strategy, where some raceways are on volitionally release for only a few days, greatly complicated PIT tag detection efforts in raceway 19. Raceway 19 was on a volitional release for 10 days, and approximately 40% of the PIT tagged fish left during that time. With the large number of PIT tagged fish that remained in the raceway, detection efforts of fish during the force release was impossible due to the high number of detection "collisions" in the PIT antenna field. It is likely that a large majority of the 4,388 PIT tags in the unknown category in raceway 19 were in fact released during the force release at the end of the volitional release period. In raceway 11, the longer volitional release period (April 2 to April 26) allowed the majority of fish to leave the hatchery volitionally (Figure 2).



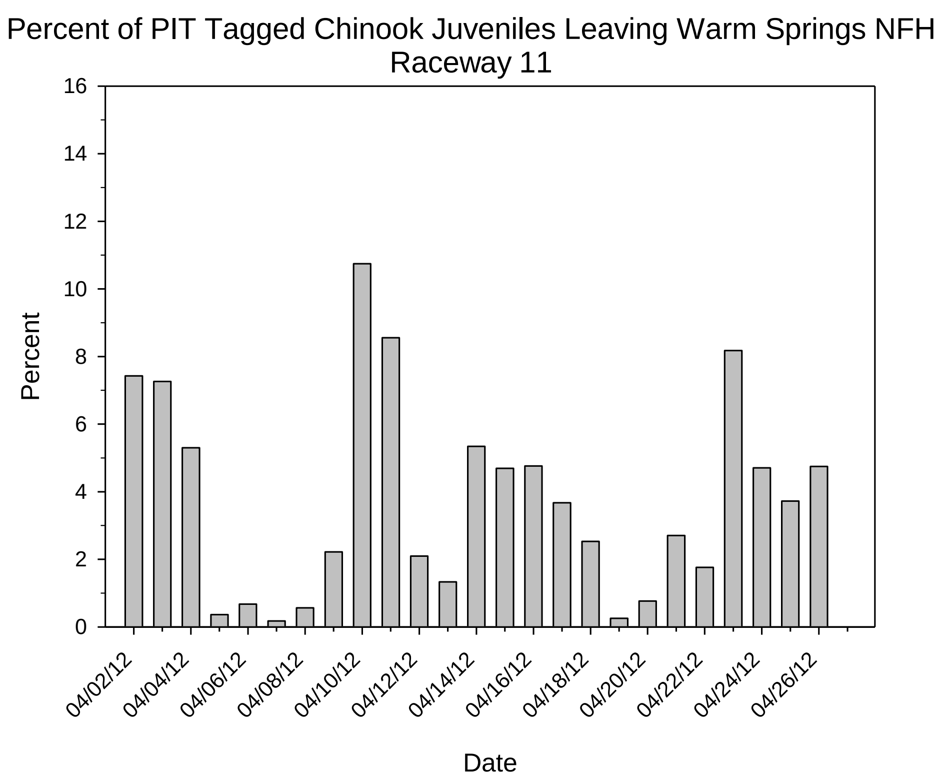


Figure 2. Percent of PIT tagged spring Chinook juveniles leaving Warm Springs NFH raceways 11 and 19 daily during the spring 2012 release. Volitional release was between April 2 and April 12 for raceway 19, and April 2 and April 26 for raceway 11. An estimated 57% of PIT tagged fish remained in raceway 19 after volitional release and were forced out on April 12, while less than 5% of raceway 11 remained after volitional release and were forced out on April 26.

At Round Butte hatchery, almost 90% of the PIT tagged fish left volitionally during the first two days of the release (Figure 3). In contrast to the nighttime migration pattern seen at Warm Springs NFH, fish began exiting the Pelton ladder holding cell as soon as the release started during the morning hours of April 17. Similar to observations in release years 2008 and 2009, it appears that some fish are able to escape from the Pelton Ladder holding Cell 1 prior to the start of the volitional release. One PIT tagged fish was detected passing downstream of Bonneville Dam on April 12, five days before the release started at Round Butte. How fish are exiting the holding cell prior to release is unknown.

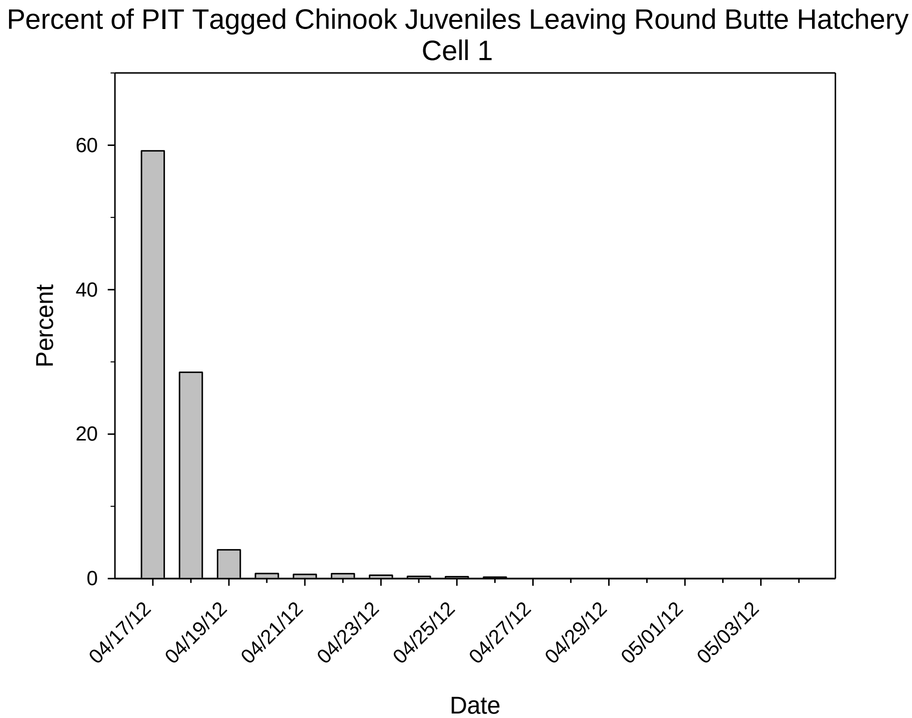


Figure 3. Percent of PIT tagged spring Chinook juveniles leaving Round Butte Cell 1 daily. Volitional release started on April 17 and ended on June 3. A total of 7,435 PIT tagged fish were in Cell 1. No PIT tagged fish were detected leaving after May 11.

<u>Downstream Migration</u>

Summary statistics for downstream migration can be found in Appendix A. Round Butte stock fish migrated quicker to Bonneville Dam than Warm Springs NFH stock fish (ANOVA on ranks, Dunn's method, $p<0.05$ for all comparisons). The median number of days from release to Bonneville Dam was seven days for Round Butte stock and 22 days for Warm Springs NFH stock. In addition, fish from Round Butte migrated downstream over Bonneville Dam over a more compressed time period than fish from Warm Springs NFH (Figure 4). Median day of passage over Bonneville Dam was different for Warm Springs NFH and Round Butte hatchery (ANOVA on ranks, Dunn's method, $p<0.05$ for all comparisons), with fish from Round Butte having the earliest median day of passage on April 25 compared to May 9 for Warm Springs NFH fish. Despite fish from raceway 11 at Warm Springs NFH being forced out two weeks earlier than fish in raceway 19, passage date over Bonneville Dam was the same. It appears that the fish that had not volitionally left raceway 19 prior to the force release on April 12, which was estimated to be over 50% of the fish in the raceway, moved slowly downstream and migrated downstream over Bonneville Dam at the same time as fish that were forced out of raceway 11 two weeks later. Whether these "slow" migrating fish remained in the Deschutes River or moved into the mainstem Columbia could not be determined from the PIT tag detections.

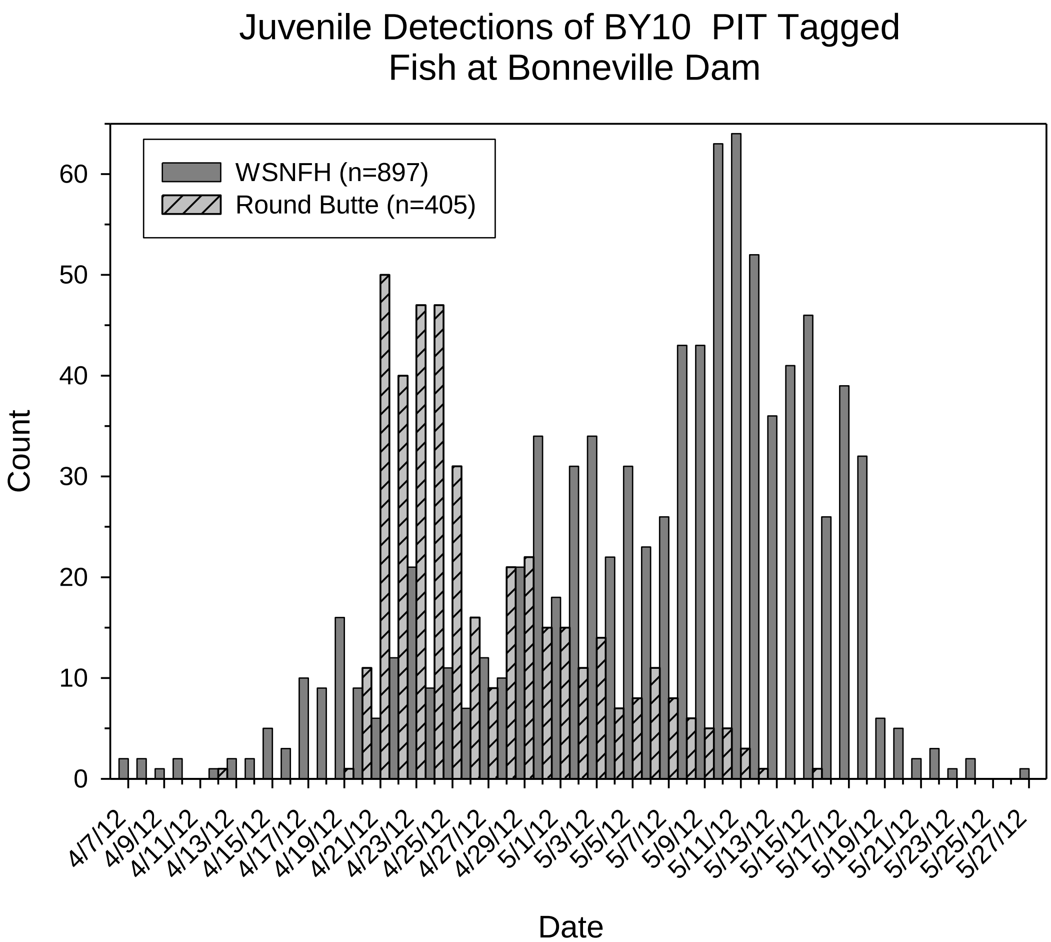


Figure 4. Downstream passage timing at Bonneville dam of brood year 2010 Warm Springs NFH and Round Butte hatchery PIT tagged juveniles in the spring of 2012.

Survival

Due to the staggered release strategy at Warm Springs NFH, where less than half of the fish in raceway 19 were able to leave volitionally before the forced release, survival estimates for Warm Springs NFH known releases could not be split out among individual raceways (raceways 11 and 19). Using the number of fish tagged into each raceway, survival estimates for raceways 11 and 19 were calculated (see Table 2). No statistical difference in survival was detected between raceways, although confidence intervals for survival estimates for individual raceways were large and statistical power was low.

Table 2. Warm Springs NFH BY10 juvenile survival estimates to Bonneville Dam by raceway. Due to staggered release strategy, individual raceway estimates could only be made using tagging number and not known release numbers.

	Tagged	Detected at Release*	Bonneville Survival (95% C.I.)
RW11	7,495	*7,030*	43% (25%-62%)
RW19	7,442	*3,047*	49% (23%-77%)

*Due to low detections resulting from staggered release strategy, known releases were NOT used for survival estimates for individual raceways.

Survival estimates for BY 2010, migration year 2012, Warm Springs NFH combined releases and Round Butte release are shown in Table 3. Looking at Warm Springs NFH releases as a whole, using known releases, that is PIT tagged fish detected during release, resulted in a survival estimate to Bonneville Dam of 52% (95% C.I. of 29%-74%). Calculating a survival estimate using the number of fish tagged into the raceways at Warm Springs NFH produced a tighter confidence interval and a non-statistically different survival estimate than using known releases (45% survival and a 30%-62% confidence interval).

Table 3. Summary of 2012 PIT tag detections for brood year 2012 and estimated survival from release to Bonneville Dam. Estimated number to Bonneville and mini-jack rates for fish surviving to Bonneville are for known releases, except the WSNFH tagged release row. Data downloaded from PTAGIS on 1/23/13.

	Tagged	Detected at Release	Bonneville Survival (95% C.I.)	Estimated Number to Bonneville (observed)	Bird Colony	Mini-Jacks
WSNFH Known Releases	14,937	10,077	52% (29%-74%)	3,829 (618)	77	8 (0.21%)
WSNFH Tagged	14,937	-	45% (30%-62%)	4,929 (896)	108	8(0.16%)
Round Butte	7,489	7,083	65% (27%-90%)	5,241 (401)	62	43(0.82%)

Estimated survival for the Warm Springs spring releases for brood years 2005 to 2010 are shown in Figure 5, with estimated survival ranging from 34% to 58%. Adult returns rates have not necessarily tracked the trends seen with juvenile survival (Figure 6). Brood year 2008 had the highest estimated juvenile survival for spring released fish (58%) but the lowest adult return rate to Bonneville Dam through age-4 adult returns (0.29%). Adult return rates will be monitored in future years to evaluate the effect of juvenile survival on overall adult return rates.

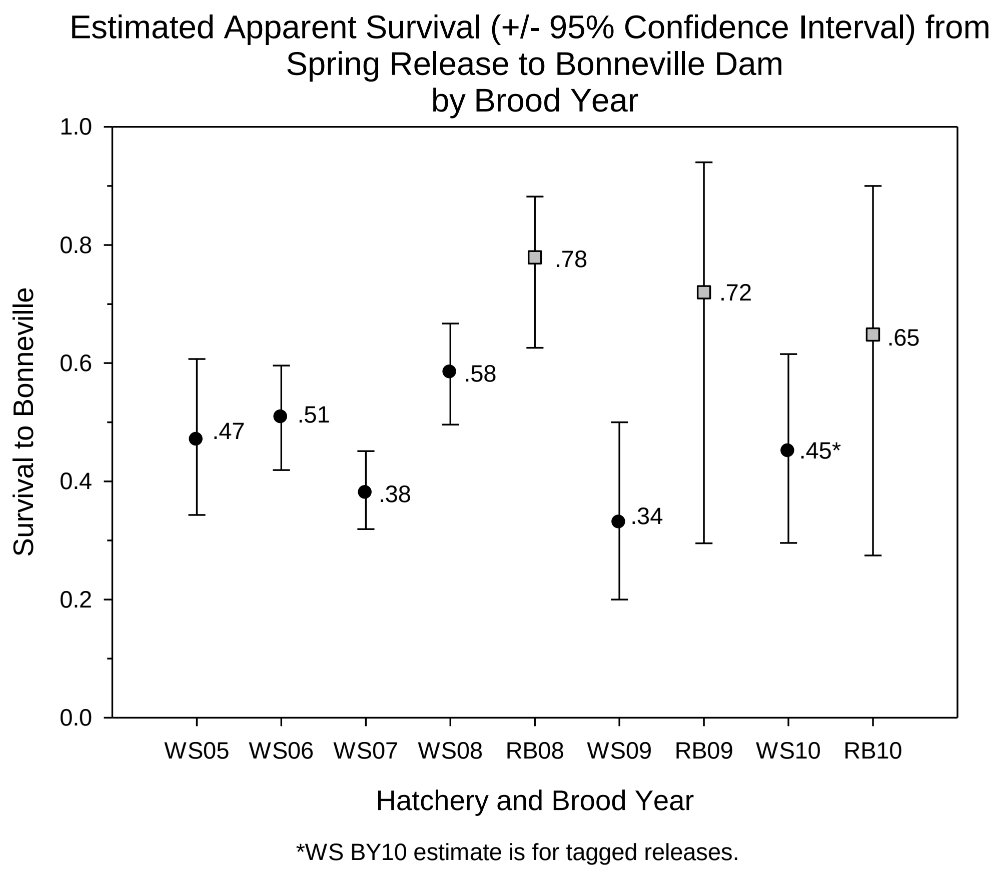


Figure 5. Estimated survival from release to Bonneville Dam for spring released PIT tagged fish at Warm Springs NFH and Round Butte hatchery. Estimates were calculated using known release from each hatchery, except for brood year 2010 at Warm Springs NFH where tagged releases were used. See text for details. For brood years 2005-2007 at Warm Springs NFH a fall/spring volitional release was employed. Estimates in this graph are for spring released fish only. Whiskers are +/- 95% confidence intervals.

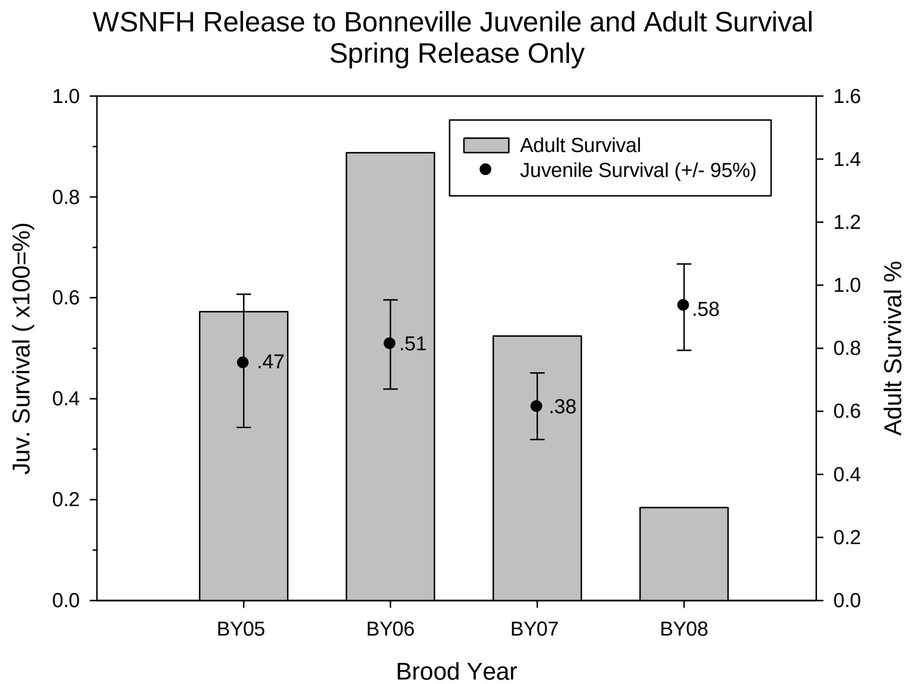


Figure 6. Estimated juvenile survival from release to Bonneville Dam for spring released PIT tagged fish at Warm Springs NFH, along with release to adult return survival rates to Bonneville Dam. Whiskers are +/- 95% confidence intervals. BY08 adult survival is through 4-year old returns.

For Round Butte releases of BY2010 juveniles, the survival estimate was 65% but the confidence interval ranged from 27% to 90% (Table 3, Figure 5). The large confidence interval for the Round Butte estimate was similar to that seen during the 2011 migration year. Several factors related to PIT tag detection probability could be contributing to the large confidence intervals for the Round Butte stock fish including the compressed timeframe for migration, lack of detections in the lower river estuary trawl, mini-jacks not migrating past all detection points, inadequate sample sizes, or other unknown factors. Precision of the survival estimates will likely improve as adult return detections are added to the dataset in subsequent years.

<u>Bird Colony recoveries</u>

Bird colony recoveries (i.e. mortalities) were downloaded from PTAGIS on January 23, 2013. All Warm Springs NFH and Round Butte hatchery recoveries were from East Sand Island, located in the lower Columbia River estuary. Recovery information from other bird colonies, for example Miller Rocks Island at the mouth of the Deschutes River or Foundation Island at the mouth of the Snake River, apparently had not been uploaded to PTAGIS at the time of this report. A total of 108 PIT tags from Warm Springs NFH and 62 PIT tags from Round Butte hatchery fish were recovered on East Sand Island.

Mini-Jack Returns

Mini-jacks, sexually mature males that return during the summer of the year of their downstream migration, were detected moving upstream through the adult ladders at Bonneville Dam on June 16 and continued through August 8th. A total of 43 PIT tagged Round Butte mini-jacks and 8 Warm Springs NFH mini-jacks migrated upstream through the Bonneville Dam adult ladders. Mini-jacking rates were significantly different between hatcheries ($p<0.001$). Using the estimated number of PIT tagged juveniles that survived to Bonneville Dam and the number of observed mini-jacks (Table 3), Round Butte stock produced mini-jacks at a rate approximately five times greater than the Warm Springs NFH stock.

Adult Returns

This report is primarily focused on reporting on the downstream migration of Warm Springs NFH and Round Butte hatchery juveniles. Adult returns will be monitored in subsequent years to gain a better understanding of the relationship between juvenile survival and adult return rates.

Acknowledgements

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Section II

Radio-Telemetry Monitoring of Warm Springs NFH Juveniles in the Deschutes Basin

Summary

Radio-telemetry was used to estimate survival from hatchery release to the mouth of the Deschutes River of brood year 2010 (migration year 2012) juvenile spring Chinook salmon from Warm Springs NFH. Fifty juveniles were radio-tagged and PIT tagged for release and another ten fish were radio-tagged with dummy transmitters and PIT tags, and held at the hatchery to monitor tag retention and post-surgery survival. Manufacturing issues with some of the radio-tags led to only forty-one fish being released with functional tags. Radio-tagged fish represented the length and weight of the hatchery population as a whole. Tagged fish were then monitored after release at seven fixed-telemetry stations located throughout the Warm Springs and Deschutes Rivers. Mobile tracking of radio tagged fish immediately after release indicated that most fish quickly migrated downstream of the hatchery location, and survival within the Warm Springs River appeared to be high. Ten of sixteen radio-tagged fish that were detected at the mouth of the Deschutes River (defined as a fixed-telemetry station at river kilometer four of the Deschutes River) were detected within two days after release from the hatchery. The overall survival estimate from release to the mouth of the Deschutes River for radio-tagged fish was 42%, with a 95% confidence interval of 28% to 58%. This compared to the overall estimated survival from release to Bonneville Dam for Warm Springs NFH juveniles, based on PIT tagging efforts, of 45% (95% C.I. of 30% to 62%). Our results indicate that a substantial amount of mortality of Warm Springs NFH juvenile spring Chinook salmon may be occurring within the Deschutes basin.

Introduction

Juvenile outmigration survival estimates, from release at Warm Springs NFH downstream to Bonneville Dam, have been estimated using PIT tag technology since brood year 2005 (see Section I for details). Survival estimates from hatchery release to Bonneville Dam have ranged from 30% to 60% over this time, indicating that a substantial loss of hatchery production is occurring upstream of Bonneville Dam. Representative groups of hatchery releases will continue to be PIT tagged to provide for long-term monitoring of trends in juvenile and adult survival and timing, however the current PIT tag monitoring infrastructure in the Warm Springs River and Deschutes River is insufficient for determining juvenile survival estimates for points upstream of Bonneville Dam. Whether the apparent mortality of juveniles between hatchery release and Bonneville Dam is occurring within the mainstem Columbia River, in the Deschutes/Warm Springs River, or both is unknown. Gathering more fine-scale information of juvenile mortality may allow managers to alter rearing/release practices, or alter in-river management to benefit juvenile outmigration.

We designed an evaluation using radio-telemetry to monitor the 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. Radio tag survival estimates could then be combined with PIT tag survival estimates to Bonneville Dam (see Section I) to provide a more complete understanding of juvenile outmigration survival in the freshwater environment. The data from this evaluation were intended to help inform several 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/Deschutes rivers?
2) Can hatchery rearing/release practices be altered to minimize mortality upstream of Bonneville dam?
3) Are there management issues in the Deschutes Basin that can be altered to benefit juvenile downstream migration?

Methods

<u>*Pre-Study Scoping*</u>

Survival Estimates

Prior to initiation of the radio-telemetry study, we simulated a variety of tagging, release, and survival scenarios to determine whether radio-telemetry would provide reasonable estimates of juvenile survival within the Deschutes basin and meet our study objectives. Based on past PIT tagging evaluations (see Section I), apparent mortality from release to Bonneville Dam for Warm Springs NFH juveniles ranges from 40%-70%. Assuming an average mortality of 50% from release to Bonneville Dam, we wanted to know if radio-telemetry could estimate whether the majority of the mortality upstream of Bonneville Dam was occurring within the Deschutes basin or in the mainstem Columbia River. We ran through a series of simulations to estimate the precision of survival estimates at various tagging sample sizes, telemetry fix-station detection efficiencies, and survival levels.

We used the Cormack-Jolly-Seber (CJS) model in Program MARK to estimate survival. For all pre-study scoping analyses, the assumption was that radio-tagged fish were migrating downstream to Bonneville Dam. Any fish that did not migrate would be considered a mortality according to the CJS model. Survival estimates for fish migrating past fixed detection locations in the CJS model can be calculated for each detection location except for the last, or farthest downstream, location. In our pre-study scoping, we modeled the use of three detection (fixed-telemetry) sites. Figure 1 shows the proposed telemetry detection locations used in the initial scoping analysis. Site A would be located near the mouth of the Warm Springs River, Site B located near the mouth of the Deschutes River, and Site C located just downstream from Site B. The "simulation" function in Program MARK was used to construct hypothetical detection histories at varying tagging, detection, and survival rates. From these simulated detection histories, the CJS Live Recapture Analysis in Program MARK was used to calculate 95% confidence intervals around the various hypothetical survival estimates. Confidence intervals were evaluated to determine the precision of survival estimates that might be estimated at various tagging levels and over various survival conditions.

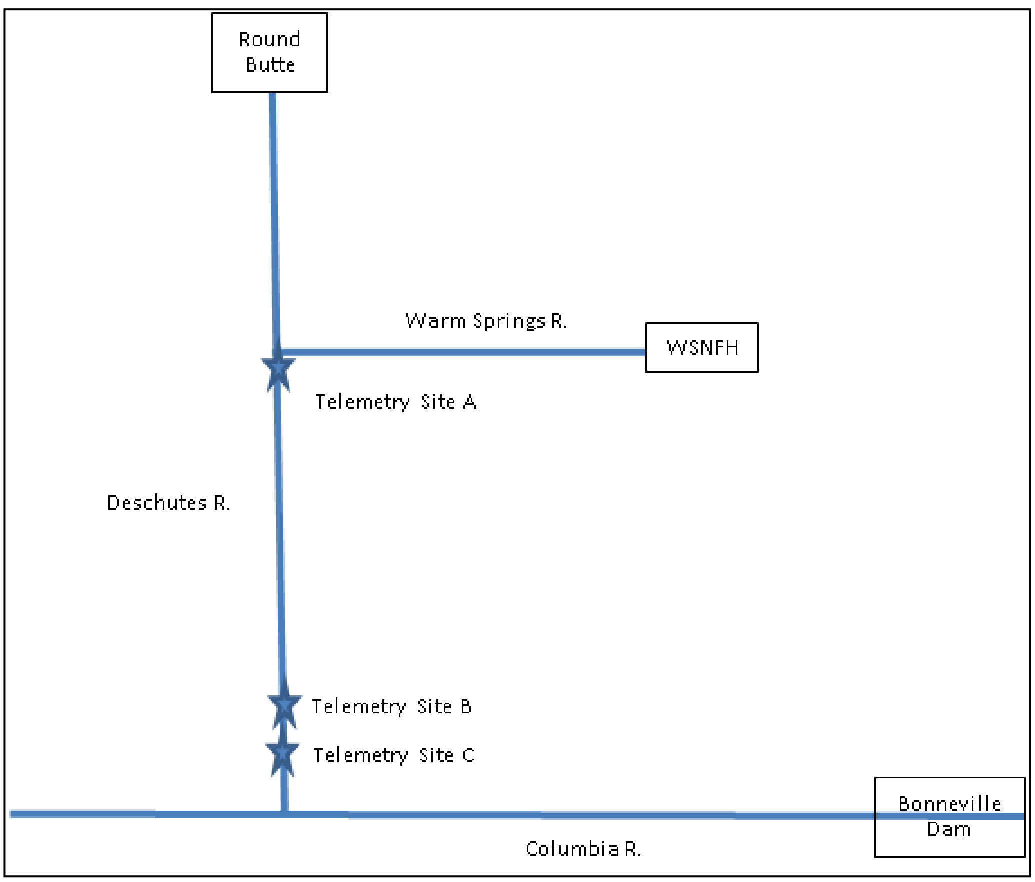

Figure 1. Proposed telemetry fixed-sites used for survival simulations.

For planning purposes, simulated tagging numbers ranged from 25 to 100 radio tags. Precision plots (precision defined as ½ of the 95% confidence interval calculated for each tag group size) were constructed for various survival and detection probability conditions. Based on previous work in the Deschutes Basin, and reviewing other telemetry studies reported in the literature, simulations were run using two fixed-site detection probabilities, 90% and 80%. These detection probabilities were used at all three sites (A, B, and C). Based on previous PIT tag estimates of survival to Bonneville Dam, we made the assumption that overall survival from release to Bonneville Dam was 50%, and we wanted to know whether more than half of that mortality was occurring within the Deschutes Basin. For the telemetry simulation, overall survival from release to the mouth of the Deschutes River was modeled at 70% and 80%. We also assumed that survival from release to telemetry Site A, the mouth of the Warm Springs River, was 90% in all cases. Using these assumptions, and running simulations through Program Mark, Figure 2 was created showing the estimated increase in precision, that is the reduction in the ½ 95% confidence intervals, for our various scenarios.

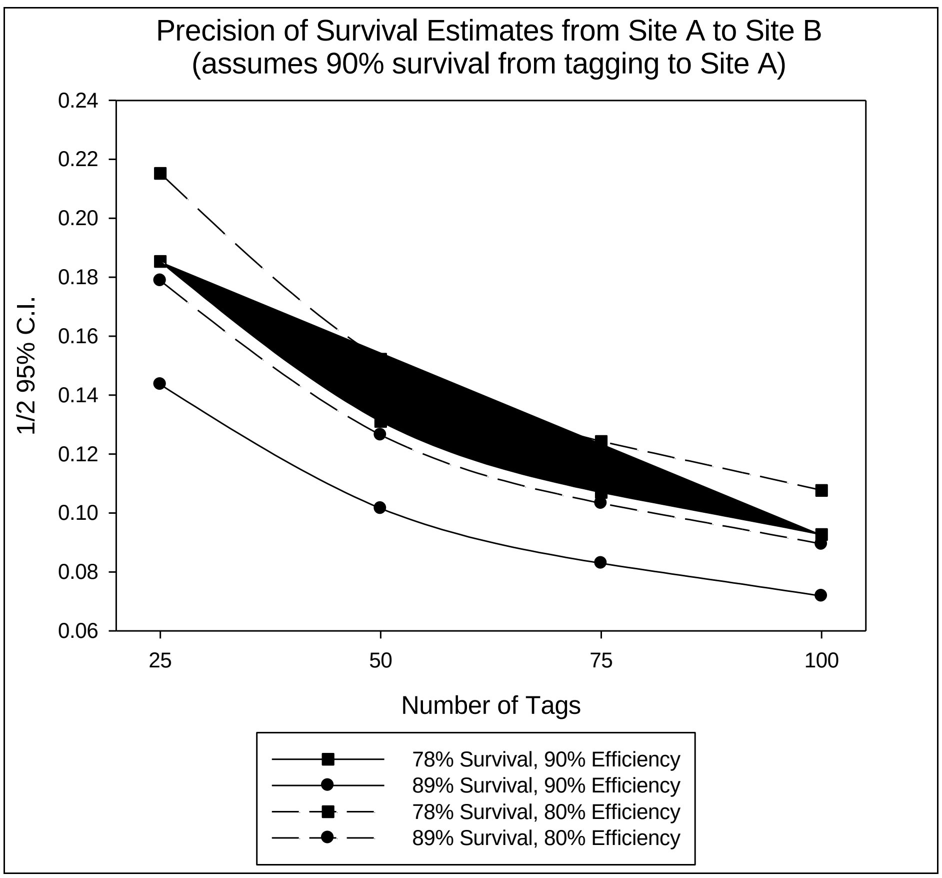

Figure 2. Estimated precision, defined as ½ of the 95% confidence interval, for various tag group sizes and survival from proposed telemetry Site A to Site B, assumes three fixed telemetry sites. Site B would be located near mouth of Deschutes River.

A second plot was then calculated, showing the percent reduction in confidence intervals that would result from increasing the number of radio tags from 25 to 50, 50 to 75, and 75 to 100

(Figure 3). Going from 25 to 50 tags resulted in a 30% reduction in confidence intervals, from 50 to 75 tags a 19% reduction, and 75 to 100 tags a 14% reduction. Additionally, the effect of adding more telemetry fixed sites was simulated (data not shown). Based on this simulation, adding one telemetry fixed site was estimated to be the equivalent of adding 25 radio-tags. After comparing the results of these simulations, we decided that 50 radio tags was the minimum required to provide a reasonable survival estimate, that is a confidence interval of around +/- 13%. Since surplus telemetry fixed site equipment was available at no cost for this evaluation, we also decided to increase the number of fixed sites rather than spend money on additional tags as a way to increase the precision of our survival estimates. For our evaluation, we were able to operate seven fixed site stations.

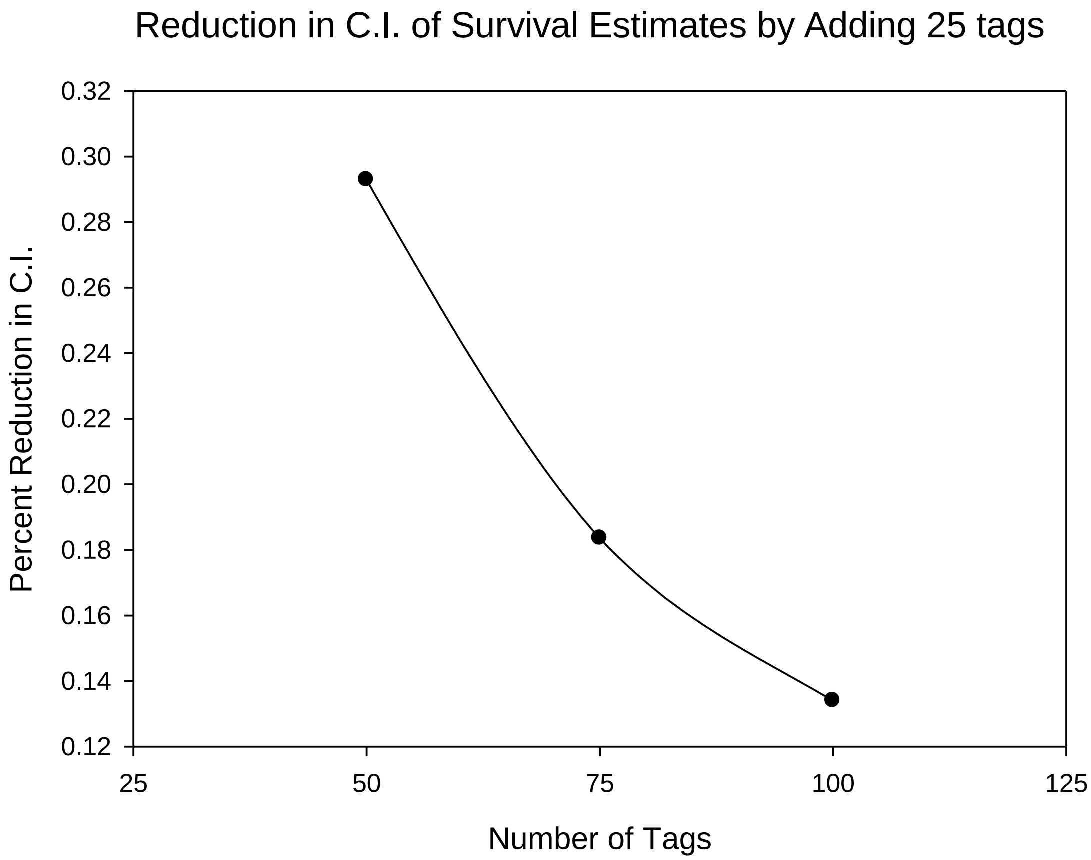

Figure 3. Estimated percent reduction in 95% confidence intervals of survival estimates by increasing the number of radio tagged fish released. For example, going from 50 radio-tags to 75 radio-tags would reduce the confidence interval by 19%.

Radio-tag burden and fish size

The size of fish that can be radio tagged depends on the size of the radio tag being used. In general, a reduction in radio-tag size leads to a reduction in the tag's battery life expectancy. For this evaluation, we selected the smallest radio tag that would have a battery life of at least 30 days. Based on the experiences of the USGS Columbia River Research Lab, juvenile salmonid performance is not significantly compromised when the tag burden, defined as the transmitter-to-body weight ratio, is less than 5% (Liedtke et al. 2012). Based on these guidelines, we estimated the size range of fish that we would be able to tag given a radio tag and PIT tag combined weight of 0.402 grams. We then sampled the raceways at Warm Springs NFH on January 31, 2012 to estimate the proportion of fish in the raceway that we would be able to tag (Figure 4). Based on these samples, we anticipated being able to tag over 90% of the fish at Warm Springs NFH.

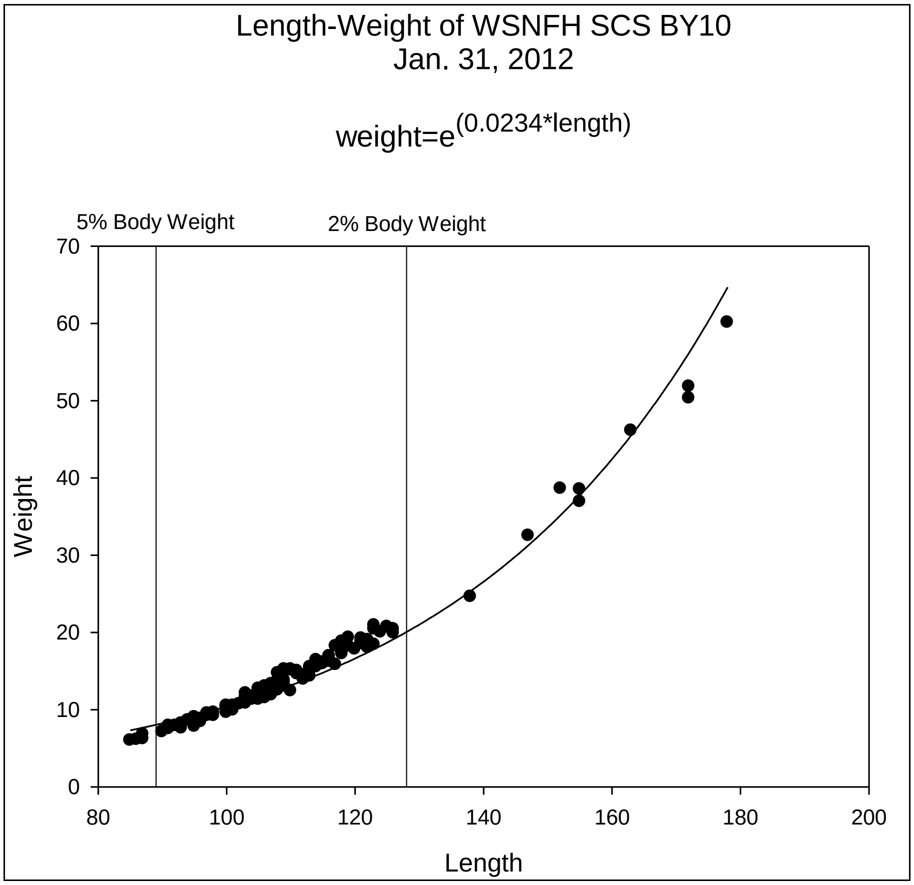

Figure 4. Length weight relationship of Warm Springs NFH SCS from Raceway 11 Jan. 31 2012. One hundred and twenty three fish were sampled. Regression line fitted using the "exp growth function" in Sigmaplot. Drop lines are estimated length (based on regression) of fish for tagging at 2% (20.1 g) and 5% (8.0 g) tag-to-body weight. Radio tag and PIT tag have combined weight of 0.402 grams.

Surgery Training

For the results of the radio-tagging evaluation to be applicable to the hatchery population as a whole, the capture, handling, and tagging of the study fish should have minimal effect on their behavior and performance (Liedtke et al. 2012). In an attempt to minimize any tagging effects, we undertook a series of surgery training and practice to become proficient in surgical procedures prior to the initiation of our study. Experienced staff from the USGS Columbia River Research Lab provided us with several days of training in the proper techniques for handling and tagging juvenile salmonids. In the month prior to our study, we also practiced surgery on juvenile spring Chinook salmon of similar size to our study fish. Fish were surgically implanted with radio-tags, held for a period of time in holding tanks to observe any post-tagging mortality, and then fish were sacrificed and examined to critique tag placement, suture integrity, and identify any internal organ damage.

Tagging

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 five different pulse intervals (8.0-8.4s). Tag size was 5 mm wide by 3 mm high by 10 mm long, with an antenna length of 18 cm and weight of 0.30 g in air. Dummy tags, which were implanted in control fish to monitor the effect of tagging and handling on fish survival, were comparable in size and weight to study tags. 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. The combined weight of the radio tag and PIT tag was 0.402 grams. One week prior to surgery, radio tags were activated, briefly submerged in water and scanned with a receiver to test tag functionality.

Tracking Systems

Radio-tagged juvenile Chinook salmon were monitored using fixed telemetry sites and mobile tracking. Fixed sites used SRX400 and 600 receivers manufactured by Lotek Wireless, Inc., and 6-element Yagi antennas. Antennas were attached to fence posts and oriented with the stream to optimize read range. Each fixed site was powered by a 12-volt battery which was connected to solar panels for charging. Telemetry stations were operated from April 12 to May 31, 2012, and data was downloaded one to two times per week. A total of seven fixed sites were established along the Warm Springs and Deschutes Rivers (Figure 5, Table 1). Two fixed sites were located in the Warm Springs River: one at the Kah-Nee-Ta Bridge (Site 1, rkm 14 of Warm Springs River) and one at the mouth of Warm Springs River (Site 2, rkm 0 of Warm Springs River). A single site was located in the middle Deschutes River, near Oak Springs hatchery (Site 3, rkm 76 of the Deschutes River). In the lower Deschutes River, two sites were located at river kilometer nine. At theese lower river sites, one site (Site 4) was configured to detect radio tags upstream and one site (Site 5) configured to detect radio tags downstream from the location. At river kilometer four, another two sites were located, with Site 6 detecting upstream and Site 7 detecting downstream. Telemetry detection capabilities were tested at a location near where the Deschutes River flowed into the Columbia River, however high-voltage power-lines produced large amounts of radio-interference that made it impossible to reliably detect tags passing that location. For the purposes of this study, the fixed sites at river kilometer four (Sites 6 and 7) were classified as the mouth of the Deschutes River.

Mobile tracking was conducted by vehicle and kayak to detect tags between fixed stations, or to confirm the final destination of tags that were not detected at fixed stations. Vehicle surveys were performed along a 14 river kilometer stretch of the Warm Springs River and along the lower 18 river kilometers of the Deschutes River. During the mobile surveys, an antenna was mounted to the roof of the vehicle, or a 6-element Yagi was held out the window while slowly driving along the river. A kayak survey of the Warm Springs river, from the hatchery downstream to the confluence with the Deschutes River, was conducted on May 10, 2012. During the kayak survey, a hand-held three element antenna was mounted to a tripod in front of kayak and SRX400 placed in dry bag. Receivers were set to log because river volume made it difficult to hear detections. Data was downloaded from the receivers after the survey.

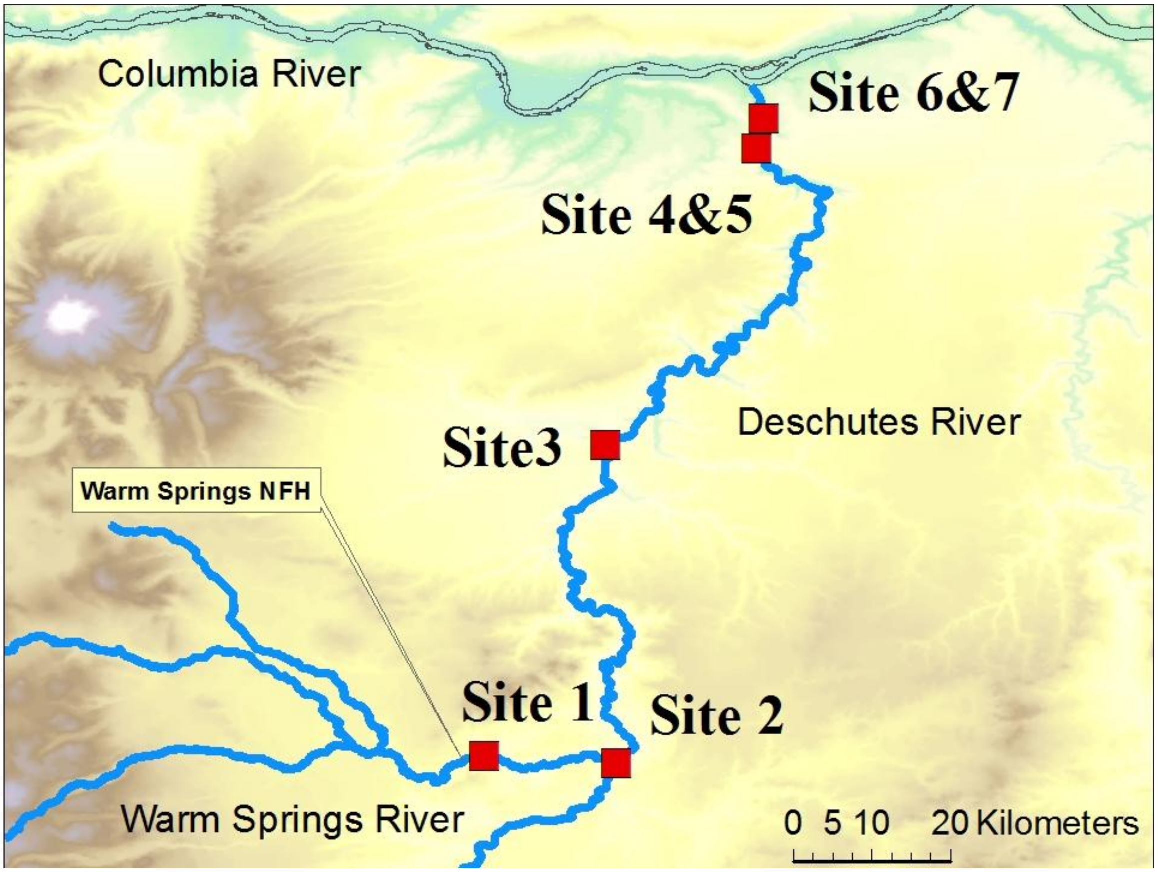

Figure 5. Telemetry fixed-site locations.

Table 1. Location and distances, in river kilometers (rkm), of telemetry fixed site stations. Sites 4 to 7 were configured to scan for radio tags either upstream or downstream from the sites. Bonneville Dam was a PIT tag detection site 101 rkm downstream from Site 7.

Site #	River	Location	Distance From WSNFH (rkm)	Distance From Mouth of Deschutes (rkm)
1	Warm Springs	Ka Nee Tah Bridge	2	147
2	Warm Springs	Mouth of Warm Springs	16	133
3	Deschutes	Oak Springs	73	76
4	Deschutes	Lower Deschutes-up	140	9
5	Deschutes	Lower Deschutes-down	140	9
6	Deschutes	Mouth of Deschutes-up	144	5
7	Deschutes	Mouth of Deschutes-down	144	5
B2J	*Columbia River*	*Bonneville Dam (PIT)*	*245*	*101*

Pre-surgery Collection Procedures

Fish collection, surgery, and release procedures generally followed USGS guidelines for implanting ratio tags into juvenile salmonids (Liedtke et al., 2012). One day prior to each surgery date, approximately 60 juvenile spring Chinook salmon were randomly dipped from the hatchery raceway, scanned for the presence of previously implanted PIT tags, checked for external injuries, and transported by aerated five-gallon bucket to an indoor holding tank at the hatchery. Once in the holding tank, fish were left undisturbed a minimum of 12 hours before surgery to reduce stress associated with handling and transport. An additional 100 fish collected from the same raceway were measured and weighed for size comparison.

Surgical Procedures

Surgeries were performed on a total of 60 juvenile spring Chinook salmon on April 10 and April 24, 2012. Fifty fish were implanted with activated radio tags, and PIT tags, and another ten fish were implanted with de-activated or “dummy” radio tags, and PIT tags, for laboratory holding and monitoring. For activated tags, radio tag frequencies and pulse intervals were split evenly between the two tagging sessions to reduce signal collision at fixed telemetry stations. A single surgeon performed all surgeries to minimize bias resulting from differences in surgery technique. Before and between each surgery, transmitters, PIT tags, surgical tools and suture materials were disinfected by immersion in a 30 mg/l solution of Nolvasan for a minimum of ten minutes and rinsed in deionized water before use. Total anesthesia time, surgery time and recovery time were closely monitored for each fish and recorded on a data sheet. Disinfectant trays, rinsing trays, anesthetic, sedation and freshwater containers were rinsed and refilled after the completion of every 5-6 surgeries.

On the day of surgery, fish were lightly crowded in the holding tank to minimize chasing and netting stress. Five to seven fish were carefully netted from the holding tank and placed in an aerated 5-gallon holding bucket with lid. Fish were individually anesthetized in a bath containing 60 mg/l MS-222, 60 mg/l sodium bicarbonate and 10 mg/l water conditioner (i.e. Stress Coat) until complete loss of equilibrium was observed (2-4 minutes). Fish were then visually inspected for signs of wounds or disease, weighed, measured, and placed ventral side up on a foam cradle coated with Stress Coat. A reduced dose of MS-222 (20 mg/l) was gravity fed through a soft silicone tube into the mouth of the fish during surgery to maintain sedation. Surgical procedures including incision placement, transmitter insertion, and suture closure followed those described by Liedtke et al. (2012). A small incision was made 3 mm anterior to the pelvic girdle, approximately 3mm off of and parallel, to the mid-ventral line. Both a radio tag and PIT tag were implanted in the body cavity of the fish using a shielded needle technique (described by Ross and Kleiner, 1982), and the incision was closed using two simple interrupted sutures secured with reinforced surgeon’s knots. On the second suture, sedation flow was replaced with freshwater to begin the recovery process. At the completion of surgery, fish were transferred to a recovery bucket supersaturated with oxygen (120-150%), and held for a minimum of 10 minutes. After full recovery, fish were returned to an indoor holding tank and held overnight with other tagged fish.

An additional ten fish were implanted with dummy transmitters and PIT tags during the first tag session (April 10) and held for 30 days in a separate indoor holding tank for delayed mortality and tag retention purposes. After 30 days, tag retention fish were individually anesthetized, measured, weighed and a photograph was taken of the incision site. Upon recovery, fish were transported by aerated 5 gallon bucket to the Warm Springs River and released in a quiet back-eddy.

Post-surgery Monitoring and Release

On the morning following surgery, researchers performed a visual check of tagged fish to look for shed tags and to make sure fish were fully recovered from the surgery. Tagged fish were then held in the indoor tanks for an additional night before being released back into the outdoor hatchery raceways. On the morning of the scheduled raceway release, (minimum of 60 hours after surgery), researchers again performed a visual check of tagged fish to look for shed tags and to make sure fish were fully recovered from the surgery before returning them to the raceway population. Fish were then individually netted from the holding tank and placed in an aerated 5-gallon bucket. Once transmitter function was verified the fish was released back into the raceway. Surgery fish were given approximately 6-8 hours to mix with the raceway population before being forced-released, along with the rest of the raceways population, into the Warm Springs River. The force-release occurred during the early evening hours. Tagged fish were monitored throughout the day prior to release with a mobile telemetry receiver to monitor tag function as well as during the forced release to verify that all radio tagged fish left the raceway.

Results and Discussion

Tagging and Release

The number of fish tagged and released are summarized in Table 2. Twenty five fish were tagged with activated tags, and ten fish tagged with dummy tags, on April 10 and another twenty five fish were tagged with activated tags on April 24, 2012. During post-surgery monitoring it became apparent that several of the activated radio tags had ceased functioning. Tag function was not verified for five tags from the April 10 tagging event and three tags from the April 24 tagging event. In addition, one fish tagged on April 24 was later found to have jumped out of the holding container and died within the hatchery building. Two of the non-functioning tags were recovered and sent back to the manufacturer for inspection. It was determined that tag failure likely resulted from improper coating during the manufacturing process and/or improper antenna attachment. Based on conversations with the manufacturer, tag malfunction likely occurred within 1-12 hrs after surgery. During pre-release tag verification, which was conducted 24-48 hrs after surgery, one tag was only detected two times, compared with upwards of 50 to 100 times for all other tags. It is possible that this one tag did not function properly post-release, however for our evaluation purposes we classified it as a functioning tag because it was functioning just prior to release and we have no other data that would warrant its exclusion from our study. We are confident that all of the other tags that were verified to be functioning prior to release continued to function during the duration of the study. Removing the non-functioning tags and on-hatchery mortality from our study, a total of 41 functional tags were released (Table 2).

Table 2. Number of fish radio-tagged and released, by date, in 2012.

Surgery Date/Group	Tagged	Released*	Release Date
April 10 RW 19	25	20	April 12
April 24 RW 11	25	21	April 26
Total	50	41	-

*Released indicates the number of fish released with verified, functioning tags

Individual tagging, surgery, and release data can be found in Appendix B. In general, fish that were radio-tagged represented the size distribution of the overall hatchery population (Figure 6). Tag burden ranged from 1.1% to 3.5% for fish released, well below our pre-established maximum of 5%. Recovery time, defined as the amount of time after sutures were closed to the time a fish was observed to have regained equilibrium in the recovery buckets, ranged from 0s, indicating instant recovery, to six minutes.

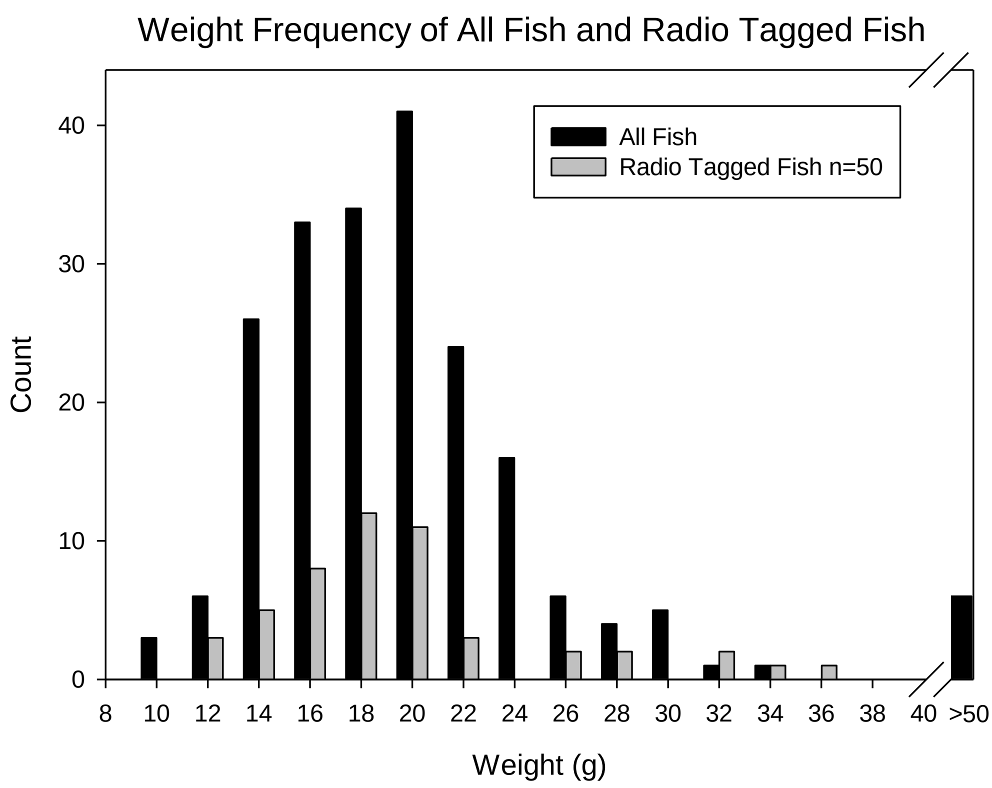

Figure 6. Weight frequency of fish in raceways 11 and 19 (black bars) and weight frequency of radio-tagged fish (grey bars). The largest fish sampled in a raceway was 68 grams.

Delayed mortality and tag retentions (dummy tags)

Tag burden for dummy tagged fish ranged from 2.0% to 4.4%. Of the ten fish implanted with dummy radio tags on April 10th and held in a hatchery tank, nine survived until the end of the 30 day holding period. One fish died on May 1, twenty-one days post tagging. The cause of death is unknown, however hatchery staff commented that the fish did not appear to have eaten during the holding period. All dummy radio-tags remained implanted in the fish during the 30 day holding period.

Downstream Migration Timing

Mobile tracking of radio tagged fish immediately after release indicated that most fish quickly migrated downstream of the hatchery location. No fish were detected remaining in the immediate area around the hatchery (within ~ 1 river kilometer) after approximately 20 minutes. All of the fish that were detected at Site 1, at the Ka Nee Tah bridge 2 river kilometers downstream of the hatchery, were detected within 2-6 hours after release. The number of days it took each tagged fish to migrate downstream to the mouth of the Deschutes, at river kilometer 4, is shown in Figure 7. Ten of the sixteen tagged fish detected at the mouth were detected within two days of release, translating into a migration speed of 74.5 river kilometers per day. The slowest migrating tagged fish (three fish total) were detected at the mouth 20 to 22 days after release, which translates to a migration speed of 6.8 to 7.5 river kilometers per day. Two radio-tagged/PIT tagged fish were eventually detected at the PIT antenna array at Bonneville Dam's juvenile bypass facility. Both fish were released from the hatchery on April 26, with one detected at Bonneville Dam on May 8 and the other detected on May 12.

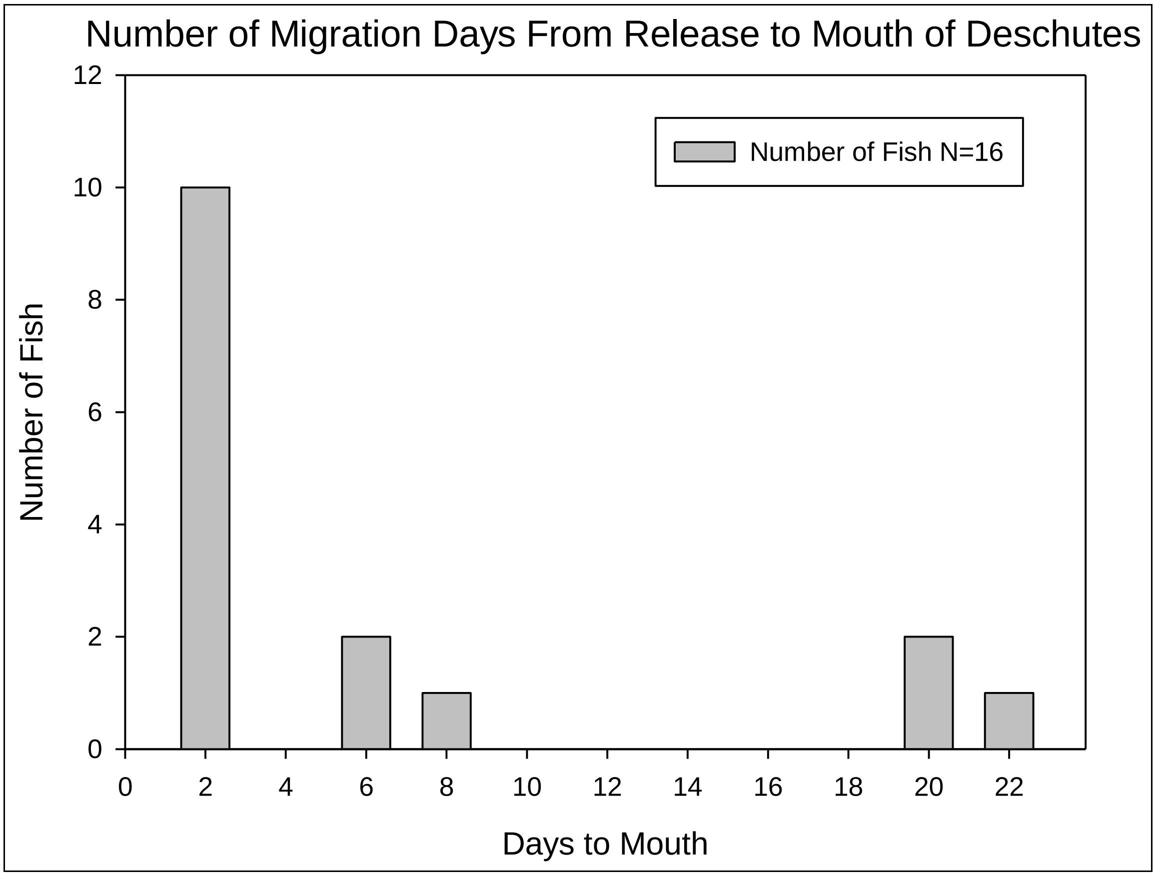

Figure 7. The number of days it took for radio-tagged juvenile spring Chinook to migrate from release at Warm Springs NFH to the mouth of the Deschutes River (rkm 4). Total distance between Warm Springs NFH and the mouth of the Deschutes River is 149 river kilometers. A total of 16 radio-tagged fish were detected at the mouth of the Deschutes.

Estimated fixed-site detection efficiency ranged from 34% to 100% (Figure 8). Detection efficiencies were generally lower than the values we used in the pre-study scoping simulations (see previous). The small size of the radio-tags we used, while allowing us to tag the size ranges of fish in the hatchery, limited the distance from which tags could be detected. During pre-study testing we found that the radio-tags could be detected at a maximum distance of approximately 100-150 meters. At some fixed-site locations, such as Site 2 at the mouth of the Warm Springs River and Site 3 at Oak Springs on the Deschutes River, river width and velocity were such that radio-tagged fish were likely in the detection range of the fixed-site telemetry antennas for a limited amount of time. Given that the signal burst from the radio-tags was set at around eight seconds, the low detection efficiencies at some sites was likely due to fish passing the detection range without sending a signal burst. In future studies, fixed-site locations where antennas can scan slow-moving river sections will likely have higher detection efficiencies.

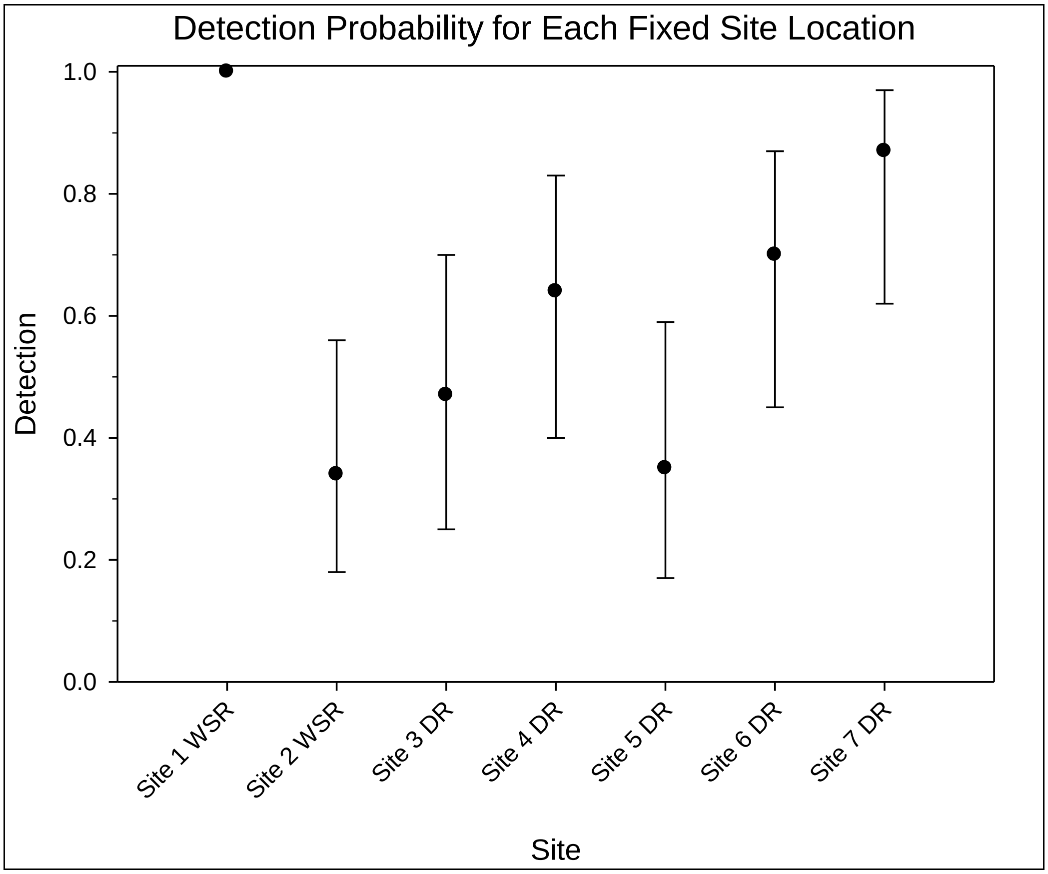

Figure 8. Detection probability at each telemetry fixed-site location. Error bars are +/- 95% confidence intervals. WSR denotes sites in Warm Springs River, DR denotes sites in Deschutes River. For a description of each fixed site location see Figure 4 and Table 1.

Mobile telemetry tracking in the Warm Springs and Deschutes River by car did not result in any confirmed tag detections. The limited detection range of the tags used in our study, combined with the large distances of river where a tagged fish could be residing, limited the utility of mobile tracking in our study. During the kayak survey of the Warm Springs River on May 10, two tags were detected in the stretch of river between Site 1 and Site 2. Whether these tags were in live fish that had failed to migrate, were in fish that had died, or had fallen out of the fish is unknown; although based on our tag retention data it is likely that the tag remained in the fish.

Survival

Three of the forty-one fish released with functioning radio-tags were not detected after release, including the one tag detected only two times during pre-release verification. All 38 of the remaining tagged fish were detected at the Site 1 telemetry fixed station located at the Ka Nee Tah bridge, approximately 2 river kilometers downstream from Warm Springs NFH. The estimated survival from release to Site 1 was 93% (95% C.I. of 79% to 98). Estimated survival between telemetry fixed sites ranged from 57% to 100% (Figure 9). The large confidence intervals associated with survival estimates between Sites 1 to 4 are the result of lower detection efficiencies (see above). The estimated 100% survival rates in the lower section of the Deschutes River are not surprising given the minimal distance between the telemetry sites, with only five river kilometers separating Sites 4 and 7.

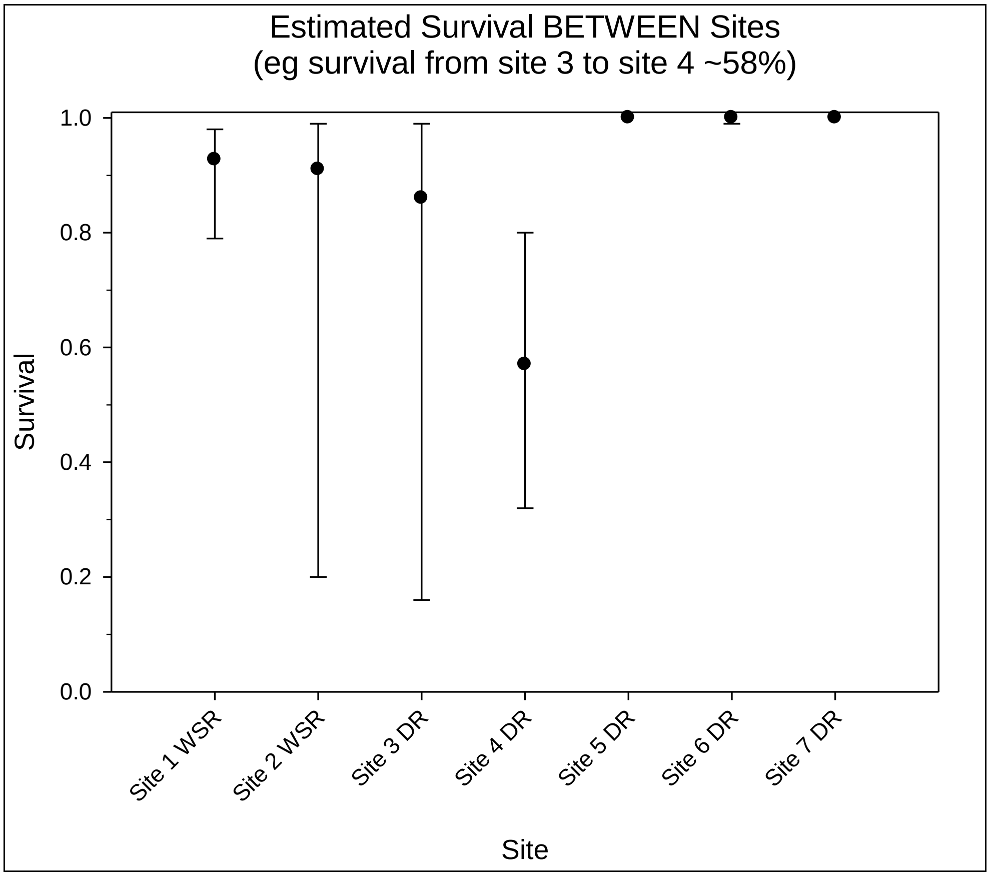

Figure 9. Estimated survival of radio-tagged juvenile spring Chinook migrating between telemetry fixed sites. Estimated survival from release to Site 1 was 93%, from Site 1 to Site 2 was 91%, etc. Error bars are +/- 95% confidence intervals. For a description of each fixed site location see Figure 5 and Table 1.

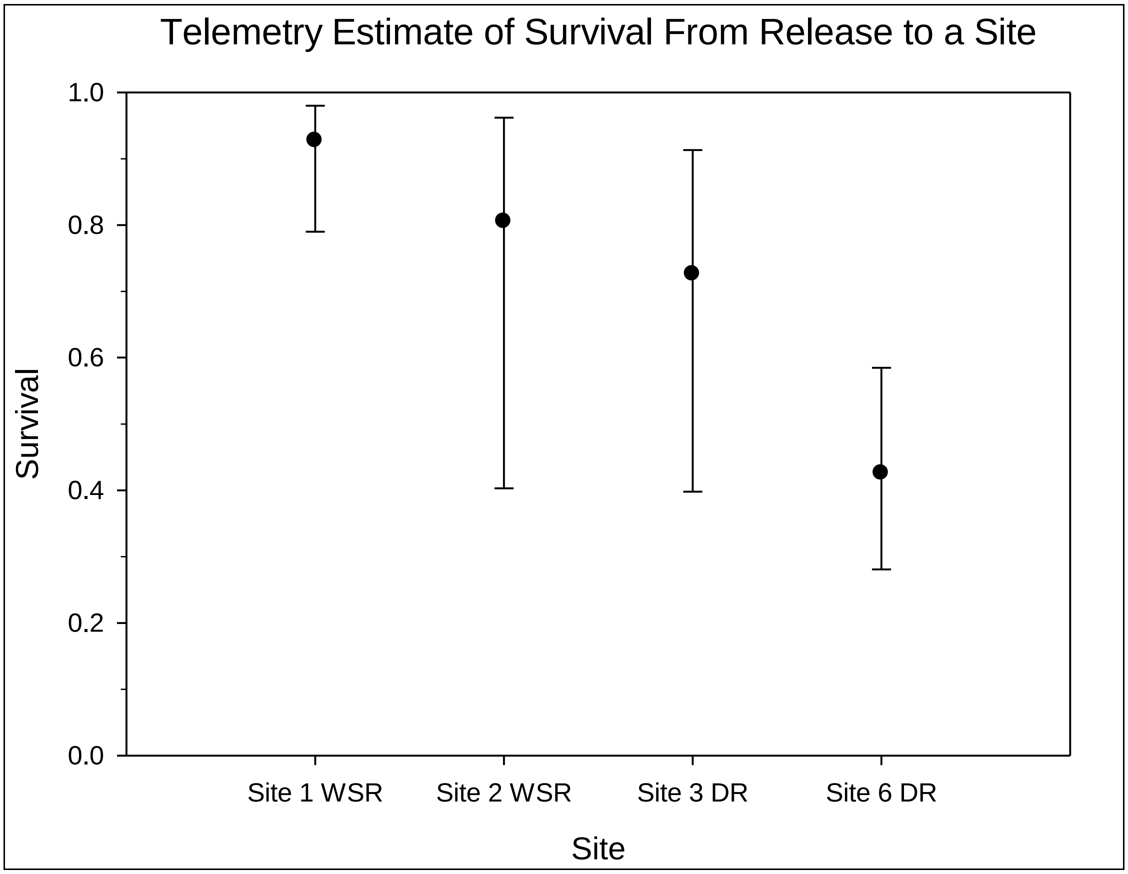

Figure 10. Estimated survival of radio-tagged juvenile spring Chinook from release at Warm Springs NFH to a particular telemetry site. Error bars are +/- 95% confidence intervals. Site 6 is the mouth of the Deschutes River. For a description of each fixed site location see Figure 5 and Table 1.

Survival from release at Warm Springs NFH to a particular telemetry site is shown in Figure 10. Although site to site estimates of survival within the Deschutes basin had wide confidence intervals, combining detection histories from all sites still provided a reasonable estimate of overall survival from release downstream to the mouth of the Deschutes River, which was the main objective of our study. The overall survival estimate from release to the mouth of the Deschutes River, defined as Site 6 at river kilometer 4 of the Deschutes River, for radio-tagged fish was 42%, with a 95% confidence interval of 28% to 58% (Figure 10). This compared to the overall estimated survival from release to Bonneville Dam for Warm Springs NFH juveniles, based on PIT tagging efforts, of 45% (95% C.I. of 30% to 62%; Figure 11). Bonneville Dam is approximately 101 river kilometers downstream from the Site 6 telemetry location. Our results indicate that a substantial amount of mortality of Warm Springs NFH juvenile spring Chinook salmon may be occurring within the Deschutes River.

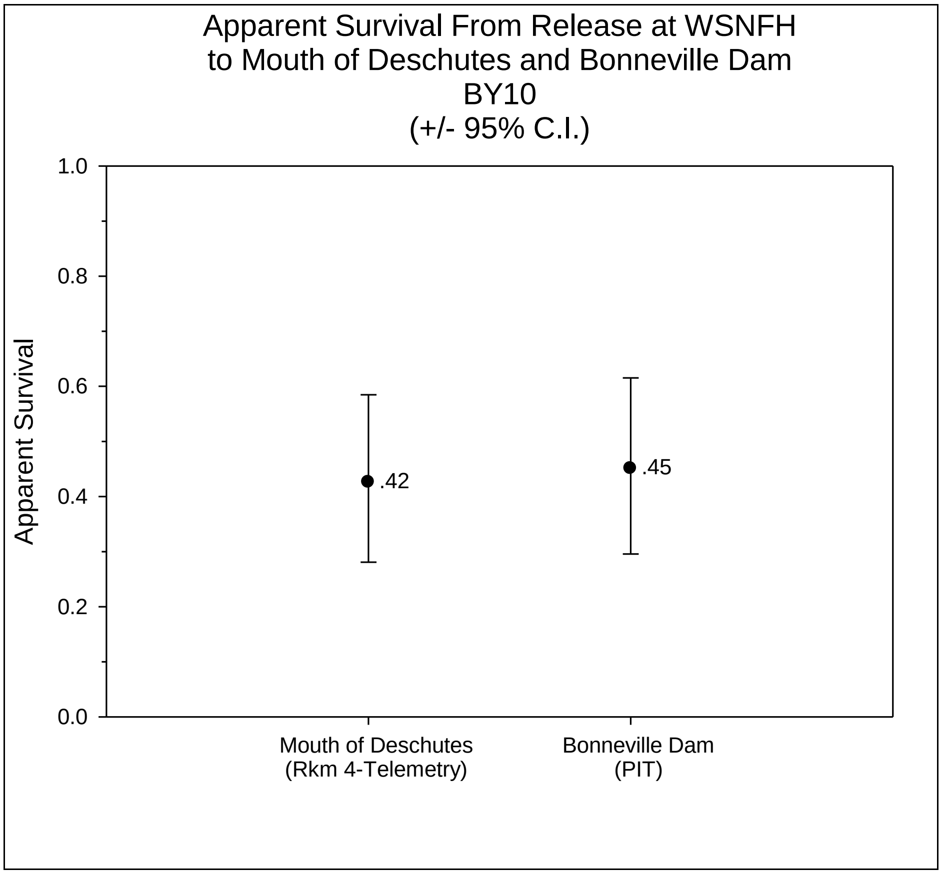

Figure 11. Survival from release to mouth of the Deschutes River (telemetry estimate) and release to Bonneville Dam (PIT estimate) for brood year 2010 Warm Springs NFH releases. Mouth of Deschutes is defined as river kilometer 4 of the Deschutes River. Error bars are +/- 95% confidence intervals.

As defined by our protocols and the CJS model used to estimate survival, for our study a mortality could have been a fish that:

1) Died as a result of tagging and handling
2) Migrated downstream to the mouth of the Deschutes River but lost its tag or the tag malfunctioned
3) Did not migrate downstream past the telemetry stations at the mouth of the Deschutes River during our study period
4) Died of cause not related to our study

Mortality due to categories 1 to 3 could affect the interpretation of the results of our study. We took several steps to try to minimize the effect of tagging and handling procedures on the behavior and survival of the study fish. The smallest radio tag model that could meet the minimum battery life requirements for this study was selected. Fish handling and tagging protocols followed USGS recommendations for implanting radio transmitters in juvenile salmonids (Liedtke et al. 2012). In addition, extensive surgical training and practice at the USGS Columbia River Research Lab was undertaken in the months prior to the study. Despite these efforts, it is still possible that some fish mortality did result from tagging and handling.

One of the ten fish implanted with a dummy radio tag and held at the hatchery during the duration of the study died 21 days after surgery. Whether this fish died as a result of the tagging or from the holding conditions at the hatchery is not known. We also documented several manufacturing quality control issues with the radio tags we used that led to tag malfunctions 1-12 hrs post-surgery, and these tags were removed from our analyses (see section on tagging and release). It is possible that tags malfunctioned after release, but based on conversations with the tag manufacturer we think this was unlikely. Additionally, if a fish migrated downstream to the mouth of the Deschutes River after our study period, which ended on May 31 thirty-five days after the last release of radio-tagged fish, or after the radio-tag had ceased operating, it would have been considered a mortality in our analyses. We consider either of these two scenarios to be unlikely. The last detection of a PIT tagged fish from Warm Springs NFH at Bonneville Dam in 2012 was on May 27 (see Section I). Similar patterns of Bonneville Dam detections have been seen in previous years. In addition, the last known detection of a radio-tagged fish at the mouth of the Deschutes River was 22 days after release. According to the manufacturer, the minimum tag battery life for our tags was 35 days.

The small sample size in our study did not allow us to determine where, within the Deschutes basin, the majority of the mortality was occurring. We also were not able to determine whether there was differential survival of radio-tagged fish released at different times. Despite the caveats regarding potential study effects and limitations due to sample size, we feel that valuable information was gained from this evaluation. The purpose of the study was to estimate the number of Warm Springs NFH juvenile releases that successfully migrated out of the Deschutes River. Based on the limited results of this study, a substantial mortality of juvenile fish may be occurring within the Deschutes River basin. The cause of the mortality is not known. One possible cause of mortality is avian predation. During our mobile telemetry efforts and our site visits to download data from the fixed-telemetry stations, we observed gull populations at many of the pools and tail-outs in the lower Deschutes River. Staff at Oak Springs Hatchery, located near our Site 3 fixed-station, commented that they annually see bird populations congregate near a large pool in the Deschutes River near the hatchery during the spring juvenile outmigration period. Staff remarked that the birds would usually start showing up once Round Butte state hatchery and Warm Springs NFH started their spring release of spring Chinook salmon juveniles. In additions, a large gull colony is located on Miller Rocks Island, located in the Columbia River, near the mouth of the Deschutes River. Mortality may also be occurring due to disease, piscivorous predation, inability to adapt to a natural environment, or other causes. Additional studies are needed to determine potential causes of mortality.

Our 2012 study provided some initial information on survival and mortality rates of Warm Springs NFH juvenile spring Chinook salmon in the Deschutes Basin. Additional years of study would allow for verification of the 2012 results. Based on our experiences in 2012, future studies could be strengthened by:

1) Increasing the number of fish tagged. The number of fish we tagged in 2012 (50 tagged, 41 functional tags released), along with the number of fixed-telemetry sites we monitored, allowed for a survival estimate with a confidence interval of approximately +/- 15%. This precision was comparable to the precision of the Bonneville Dam survival estimates based on 15,000 PIT tags released. Increasing the number of fish radio-tagged would not only increase the precision of overall survival

estimates, but could also allow for comparisons of survival between release groups and/or comparisons of survival between locations within the Deschutes River.

2) Testing radio-tag functionality in a more comprehensive manner prior to surgery. In 2012, we tested each radio-tag by placing it in a bucket of water for 3 to 20 minutes and then verifying tag function. In future studies, we recommend soaking tags in water for 6-12 hours before verifying functionality. Also, verifying tag functionality after implantation but before release is critical. If we had not verified tag function after surgery we would not have known that several of the tagged fish we thought we were releasing did not have functional tags.
3) Locating fixed-telemetry sites in areas of slow-moving water where radio-tagged fish would remain in the antenna detection field for a longer period of time.
4) Think about ways to determine location(s) where mortality may be occurring. Increasing the number of fixed-site locations might allow for a more fine-scale analysis of survival patterns. Mobile tracking by vehicle was not a feasible way to determine locations of fish. While not a specific purpose of our study, the kayak trip in the Warm Springs River did provide verification that two of the radio-tags were located in the Warm Springs River at the conclusion of our study. Additional kayak surveys could be used to supplement fixed-station monitoring. A survey of Miller Rocks Island at the mouth of the Deschutes River could provide useful information on whether mortality in the lower Deschutes River is due to gull predation.

Acknowledgements

Through a Cooperative Agreement, Jens Lovtang and staff from the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) provided valuable assistance in study design and implementation. The CTWSRO took lead responsibility for radio-tag monitoring in the Warm Springs River. Theresa "Marty" Liedtke, Lisa Gee, and others at the USGS Columbia River Research Lab in Cook, WA were extremely helpful in describing techniques for surgical implantation of radio-transmitters, training us in proper surgical procedures, and providing a sounding board for us to bounce ideas off of. Hatchery staff at Warm Springs NFH, including Roger Sorsensen, Mary Bayer, Kevin Blueback, Randy Boise, and Joe Badoni went out of their way ensure our study was a success. Steven Haeseker, from the USFWS-Columbia River Fisheries Program Office, provided statistical support for the pre-scoping and survival analyses We also would like to thank Rod French and Jason Seals from Oregon Department of Fish and Wildlife, and Jim Anderson from the Oregon Parks Department, for help in designing, establishing, and running our telemetry sites in the Deschutes River.

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Appendix A
PIT Tag Data

Summary Statistics for BY 10 Migration to Bonneville Dam

Migration Days: Release to Bonneville Dam

	Number Observed[A]	Median	Min	Max	Mean	Std. Dev
WSNFH RW 11	464	21	4	47	21.4	9.60
WSNFH RW 19	154	28	5	44	25.7	10.12
WSNFH Combined	618	22	4	47	22.5	9.91
Round Butte	401	7	2	27	9.2	5.35

[A]Only fish with known detection times at release were used for migration day analysis

Day of Year[B]: Passage Downstream Through Bonneville Dam

	Number Observed	Median	Min	Max	Mean	Std. Dev
WSNFH RW 11	486	129	98	145	128	8.40
WSNFH RW 19	411	130	98	148	127	9.32
WSNFH Combined	897	130	98	148	127	8.84
Round Butte	406	116	103	136	118	5.47

[B]Day of year is julian day of year. For example, May 1st is day 122 of the year. All tagged releases were used for this analysis.

Number of brood year 2008 fish PIT tagged, and downstream detections of Warm Springs NFH and Round Butte hatchery spring Chinook juveniles in 2010. Data downloaded from PTAGIS on 10/15/12.

			Detections Downstream[A]			
	Tagged	Detected at Release	Bonneville	Estuary Trawl	Bird Colony[B]	Mini-jacks
WSNFH	14,937	10,077	617	42	-	8
Round Butte	7,489	7,083	401	22	-	43

[A]Detections downstream **only** include fish that were also detected at release.
[B]2012 bird colony recoveries were not uploaded into PTAGIS at the time of this report.

Data Categories for Program MARK Survival Estimates to Bonneville Dam

		PIT Tag Detections			
		Release Only	Release and Bonneville	Release and Trawl/Mini-jack/Bird	Release, Bonneville, and Trawl/Mini-jack/Bird
Known Releases	WSNFH Total	9,347	603	112	15
Tagged	WSNFH RW11	6,925	471	84	15
	WSNFH RW19	6,959	402	72	9
	WSNFH Total	13,884	873	156	24
Known Releases	Round Butte	6,567	390	115	11

Know release detections using tagged fish detected during release by PIT antennas in release tubes. For WSNFH tagged release, estimates were derived from tagging files (not adjusted for shed or in-pond mortality) and categories refer to fish tagged and detected downstream. Mini-jacks, defined as Bonneville Dam adult ladder detections after 6/15/2012, are categorized with other “downstream of Bonneville” detections (ie trawl detections). Bird colony recoveries, that is mortalities, from East Sand Island in the lower Columbia River were included in the “downstream of Bonneville” group, that trawl/min-jack/bird recoveries were treated as one. Data downloaded from PTAGIS 1/23/2013.

Appendix B
Radio-Tag Data

Summary surgery and detection data for radio tagged fish released from Raceway 19 of Warm Springs NFH.

Frequency	Code	Length mm	Weight g	Recovery Time (MM:SS)	Release Date	Site 1 WSR KBridge	Site 2 WSR Mouth	Site 4 DR upstream	Site 5 DR downstream	Site 6 DR Mouth upstream	Site 7 DR Mouth Downstream	Site 99 WSR River Mobile[A]	Bonneville Dam[B]
166.380	6	102	12.9	4:30	12-Apr-12								
166.380	16	124	19	1:30	12-Apr-12								
166.360	13	140	31.5	3:00	12-Apr-12	12-Apr-12		14-Apr-12		14-Apr-12	14-Apr-12		
166.360	14	120	19.4	3:30	12-Apr-12	12-Apr-12	13-Apr-12	13-Apr-12	13-Apr-12	14-Apr-12	13-Apr-12		
166.360	15	110	13.5	6:00	12-Apr-12	26-Apr-12					02-May-12		
166.360	18	120	19.3	5:30	12-Apr-12	12-Apr-12	13-Apr-12					10-May-12	
166.360	19	110	14.5	2:45	12-Apr-12	12-Apr-12	12-Apr-12						
166.360	23	110	15.2	6:00	12-Apr-12	12-Apr-12		14-Apr-12	14-Apr-12	14-Apr-12	14-Apr-12		
166.360	24	110	13.9	0:30	12-Apr-12	12-Apr-12	12-Apr-12				02-May-12		
166.360	3	119	19.2	0:30	12-Apr-12	12-Apr-12							
166.360	4	107	14.3	0:30	12-Apr-12	12-Apr-12							
166.360	8	111	15.3	0:30	12-Apr-12	12-Apr-12	13-Apr-12	14-Apr-12		14-Apr-12	14-Apr-12		
166.360	9	127	24.2	0:10	12-Apr-12	12-Apr-12							
166.380	11	114	16	4:00	12-Apr-12	12-Apr-12							
166.380	17	119	17.5	0:30	12-Apr-12	12-Apr-12		14-Apr-12	14-Apr-12	14-Apr-12			
166.380	21	109	14	0:15	12-Apr-12	12-Apr-12	12-Apr-12						
166.380	22	116	16.4	0:15	12-Apr-12	12-Apr-12	12-Apr-12						
166.380	26	118	17.5	0:30	12-Apr-12	12-Apr-12							
166.380	27	122	21.5	1:00	12-Apr-12	12-Apr-12		14-Apr-12		14-Apr-12	14-Apr-12		
166.380	7	142	30.6	1:30	12-Apr-12	12-Apr-12				14-Apr-12	14-Apr-12		

[A]Site 99 detections were from a kayak survey of the Warm Springs River conducted on May 10, 2012.
[B]Bonneville dam detections were PIT detections at the Bonneville Dam juvenile bypass facility

Summary surgery and detection data for radio tagged fish released from Raceway 11 of Warm Springs NFH.

Frequency	Code	Length mm	Weight g	Recovery Time (MM:SS)	Release Date	Site 1 WSR KBridge	Site 2 WSR Mouth	Site 4 DR upstream	Site 5 DR downstream	Site 6 DR Mouth upstream	Site 7 DR Mouth Downstream	Site 99 WSR River Mobile[A]	Bonneville Dam[B]
166.380	14	121	17.7	0:45	26-Apr-12								
166.360	12	125	20.5	5:00	26-Apr-12	26-Apr-12							
166.360	16	122	18.2	0:15	26-Apr-12	26-Apr-12		28-Apr-12	28-Apr-12	28-Apr-12	28-Apr-12		
166.360	17	126	20	2:15	26-Apr-12	26-Apr-12							
166.360	20	124	20.1	1:45	26-Apr-12	26-Apr-12							
166.360	21	135	26.3	0:00	26-Apr-12	26-Apr-12		28-Apr-12	28-Apr-12		28-Apr-12		
166.360	22	119	17.7	1:30	26-Apr-12	26-Apr-12							
166.360	25	121	17.3	2:45	26-Apr-12	26-Apr-12	26-Apr-12						
166.360	26	118	17.9	1:30	26-Apr-12	26-Apr-12			28-Apr-12	28-Apr-12	28-Apr-12		
166.360	27	107	12	0:45	26-Apr-12	26-Apr-12	26-Apr-12						
166.360	6	124	18.4	3:00	26-Apr-12	26-Apr-12		02-May-12		02-May-12	02-May-12		08-May-12
166.360	7	118	17	1:30	26-Apr-12	26-Apr-12	26-Apr-12				02-May-12		
166.380	10	116	17.2	4:45	26-Apr-12	27-Apr-12							12-May-12
166.380	15	124	19.4	3:30	26-Apr-12	26-Apr-12		03-May-12		04-May-12	04-May-12		
166.380	19	121	17.6	4:30	26-Apr-12	26-Apr-12							
166.380	23	122	18.2	0:00	26-Apr-12	26-Apr-12						10-May-12	
166.380	3	135	27	2:00	26-Apr-12	26-Apr-12	27-Apr-12						
166.380	4	111	14.1	2:00	26-Apr-12	26-Apr-12							
166.380	5	119	17.3	2:30	26-Apr-12	26-Apr-12	27-Apr-12						
166.380	8	119	17.5	0:30	26-Apr-12	12-Apr-12		18-May-12		18-May-12	18-May-12		
166.380	9	115	14.8	1:45	26-Apr-12	26-Apr-12							

[A]Site 99 detections were from a kayak survey of the Warm Springs River conducted on May 10, 2012.
[B]Bonneville dam detections were PIT detections at the Bonneville Dam juvenile bypass facility