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

Progress Report for 2013

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Section I

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

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Abstract

Warm Spring NFH spring Chinook juveniles have been PIT tagged as part of a juvenile monitoring program since brood year 2005 (migration year 2007). Migration year 2013 was the fourth year of PIT tag monitoring of both Warm Springs NFH and Round Butte stocks. A total of 14,979 Warm Springs NFH and 7,440 Round Butte hatchery brood year 2011 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 between two raceways, 20 and 23, which were volitionally released into the Warm Springs River from March 27 to April 4 of 2013. Round Butte juveniles were volitionally released into the Deschutes River between April 16 and May 31 of 2013. Median day of passage of PIT tagged juveniles over Bonneville Dam was April 26 for Round Butte juveniles and April 30 for Warm Springs NFH juveniles. Estimated survival from release to Bonneville Dam was similar for juveniles from each raceway at Warm Springs NFH, with a combined survival estimate of 58% (95% C.I. of 40%-74%). Due to hatchery release protocols, we were unable to monitor PIT tagged fish as they were released from the hatchery so the total number of PIT tagged fish released was estimated by subtracting the number of shed tags and on-hatchery mortalities from the known number of tagged fish that were placed into the raceways. Adult return rates at Warm Springs NFH have not necessarily tracked trends seen in juvenile survival. Estimated survival of Round Butte juveniles was 52% (95% C.I. of 31% to 71%). Due to a PIT monitoring equipment malfunction, the survival estimate for Round Butte was also made using tagged fish. This differed from previous years (brood years 2008-2010), when known releases were used. 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, released from the Pelton ladder as part of the Round Butte mitigation program, were PIT tagged starting with brood year 2008 (migration year 2010). Migration year 2013 was the fourth year of PIT tag monitoring of both Warm Springs NFH and Round Butte Hatchery stocks.

This report summarizes the PIT tagging and juvenile monitoring of brood year 2011 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

For brood year 2011, Warm Springs NFH reared and released two groups of spring Chinook salmon. One group was reared according to standard rearing protocols and was coded-wire tagged in May of 2012. A second, experimental, group of fish was reared at a slower early rearing growth rate (non-heated water) and was coded-wire tagged in October of 2012. The PIT tagging of brood year 2011 was designed to represent only the standard reared fish, that is none of the experimental fish were PIT tagged. Brood year 2011 juveniles from Warm Springs NFH were PIT tagged on February 5-6 2013. The goal of the PIT tagging effort was to tag approximately 7,500 juveniles from each of two standard reared raceways, raceway 20 and raceway 23. 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 brood year 2011 juveniles. Starting on March 27, 2013 all 19 raceways at Warm Springs NFH were opened up for volitional release. On April 4, the eleven standard reared raceways were drained and the remaining fish were forced out into the Warm Springs River. Due to the abbreviated nature of the volitional release, we were unable to monitor actual release times of PIT tagged fish. The large number of PIT tagged fish that remained in the raceway after the short volitional release period led to a high probability of tag "collisions" during PIT monitoring of the release. When two PIT tags are in an antenna field simultaneously, the tag reader is unable to differentiate the signals so neither tag can be detected. Hatchery staff collected and stored all known mortalities from the raceways from time of PIT tagging to release. Mortalities were then scanned for the presence of a PIT tag. After the hatchery release, the raceways were scanned for the presence of shed PIT tags by walking a large magnet through the empty ponds, and recovering any PIT tags that were attached to the magnet. For the survival analysis of brood year 2011 Warm Springs juveniles, the number of PIT tagged fish released from the hatchery was estimated as the total number of fish PIT tagged minus the number of known shed and pre-release mortalities.

Round Butte Hatchery

Brood Year 2011 juveniles from Round Butte hatchery were PIT tagged on October 23 and 24 2012. The goal was to PIT tag approximately 7,500 juveniles from the hatchery raceways that were to be released from cell one (Cell 1) 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. All juveniles tagged at Round Butte were progeny of Round Butte stock adults.

PIT tagged fish were moved from the hatchery raceways one week after tagging and were held in Cell 1 of the Pelton ladder until release in the spring of 2013. Round Butte juveniles were volitionally released starting on April 16, 2012 and ending on May 31, 2012. 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. Unfortunately, equipment malfunction led to no PIT tag detections during the release period at Round Butte. Due to the design of the rearing areas in the Pelton Ladder (Cell 1), it was not possible to estimate the number of pre-release mortalities or PIT tag shed rate. For the survival analysis (see below), survival for brood year 2011 Round Butte fish was estimated from time of marking to Bonneville Dam. This is in contrast to previous years, when survival of Round Butte fish was estimated from known release from Cell 1 (as determined by PIT antennas) to Bonneville Dam.

Downstream Migration

Detections of PIT tagged fish at Bonneville Dam (rkm 235; Figure 1) were downloaded from the PTAGIS database system on September 11, 2013. Due to the release strategy and poor release detection capability at Warm Springs NFH, records of all fish tagged were used for survival estimates. Mini-jacks, sexually mature age 1+ males, were identified as fish migrating upstream over Bonneville dam after May 31st. Mini-jack detections

were excluded from the downstream juvenile migration analysis, but were used to determine detection probability at Bonneville Dam (see description of juvenile survival analysis). Since time of emigration from the hatchery was not calculated for brood year 2011, we were not able to compare migration speed between fish from Warm Springs NFH and Round Butte. Median day of migration over Bonneville Dam was compared using a Mann-Whitney Rank Sum test. 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). Mortality recoveries from the bird colonies are typically uploaded into the PTAGIS database in December or January, and as such, they are not included in this Progress Report. This report will be updated in early 2014 to reflect the additional recoveries.

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

Not uploaded into PTAGIS at time of this report. Will be updated in early 2014.

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.

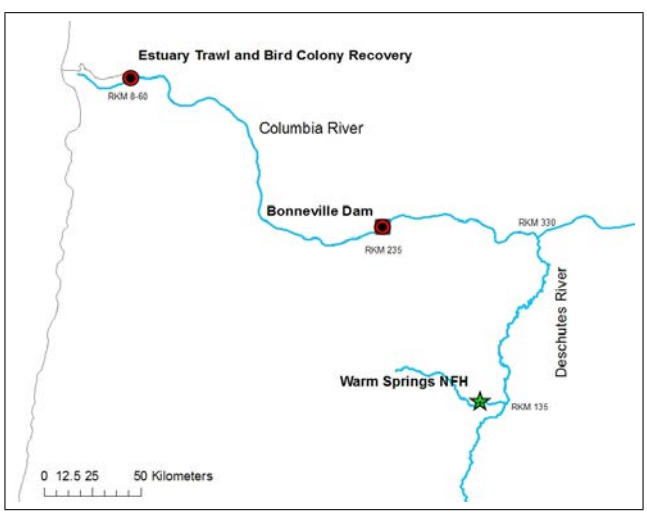

Figure 1: Location of Warm Springs NFH, and downstream PIT tag detection sites (red circles).

Results and Discussion

Release

The number of fish PIT tagged, and the number of shed or known mortalities prior to release, are summarized in Table 1. Approximately 7,500 fish were tagged from each of Warm Springs NFH raceways (RW) 20 and 23, 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	Shed or Mort*	Total Released**
Warm Springs RW 20	7487	60	7427
Warm Springs RW 23	7492	42	7450
Warm Springs Total	14979	102	14877
Round Butte C1	7440	–	7440

*Known shed or inpond mortalities. For Round Butte, Pelton Ladder design precludes recoveries of sheds or mortalities.

**Estimated number of tagged releases (# tagged - #shed or mort). No PIT antenna detections during release in 2013. For Round Butte, an unknown number of fish did not volitionally migrate (mainly precocial males) and were sacrificed.

Downstream Migration

Since PIT detections at time of release were not monitored in 2013, no estimate of migration speed from release to Bonneville Dam was calculated. Timing of downstream passage over Bonneville Dam is shown in Figure 2. Median day of downstream passage was different for Warm Springs releases compared to Round Butte releases (Mann-Whitney Rank Sum test, $p < 0.001$), with a median date of April 30th for Warm Springs releases and April 26th for Round Butte releases.

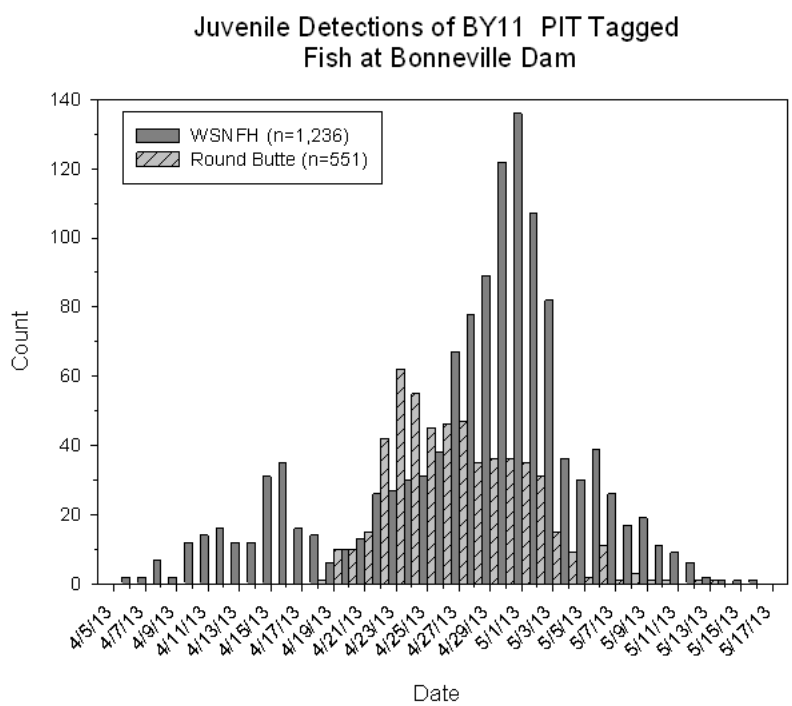

Figure 2: Downstream passage timing at Bonneville dam of brood year 2011 Warm Springs NFH and Round Butte hatchery PIT tagged juveniles in the spring of 2013.

Survival

Survival estimates for BY 2011, migration year 2013, Warm Springs NFH combined releases and Round Butte release are shown in Table 2. Warm Springs NFH had an estimated downstream survival from release to Bonneville Dam of 58% (95% C.I. of 40-74%). The estimated survival for Round Butte stock juveniles was 52% (95% C.I. of 31%-71%). Mini-jack rates were higher for Round Butte than for Warm Springs, consistent with previous years observations.

Estimated survival for the Warm Springs NFH spring releases for brood years 2005 to 2011 are shown in Figure 3, with estimated survival ranging from 34% to 58%. Adult returns rates have not necessarily tracked the trends seen with juvenile survival (Figure 4). Brood year 2008 had the highest estimated juvenile survival for spring released fish (58%) but the lowest adult return rate to Bonneville Dam (0.31%). Adult return rates will be monitored in future years to evaluate the effect of juvenile survival on overall adult return rates.

Table 2: Summary of 2013 PIT tag detections for brood year 2011 and estimated survival from release to Bonneville Dam. Estimated number to Bonneville and mini-jack rates for fish surviving to Bonneville are for a) estimated tagged releases (# tagged minus # of known sheds and pre-release mortalities) at Warm Springs NFH, and b) tagged fish (number of fish tagged, no shed or pre-release mortality estimate) for Round Butte. Data downloaded from PTAGIS on 9/11/13. Bird colony recoveries not reported to PTAGIS at time of download.

	Tagged	Bonneville Survival (95% C.I.)	Estimated Number to Bonneville (Observed)	Bird Colony	Mini-Jacks
WSNFH	14,979	58% (40% - 74%)	8,688 (1,236)	-	14 (0.16%)
Round Butte	7,440	52% (31% - 71%)	3,869 (551)	-	42 (1.09%)

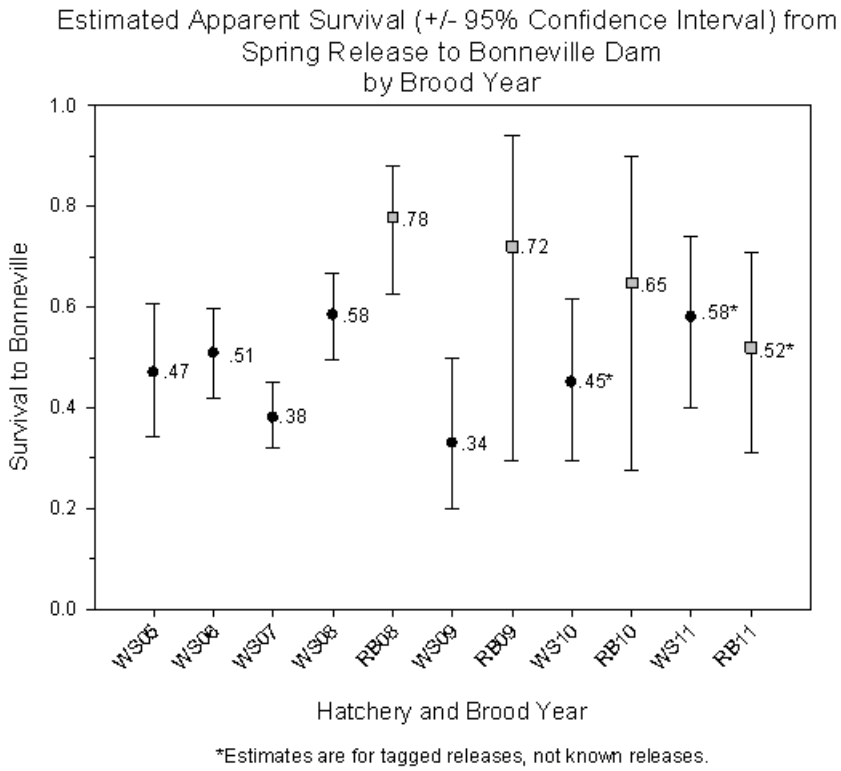

Figure 3: Estimated survival from release to Bonneville Dam for spring released PIT tagged fish at Warm Springs NFH and Round Butte hatchery. Estimates were calculated using known release from each hatchery, except for brood year 2010 and 2011 at Warm Springs NFH and 2011 at Round Butte where tagged 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.

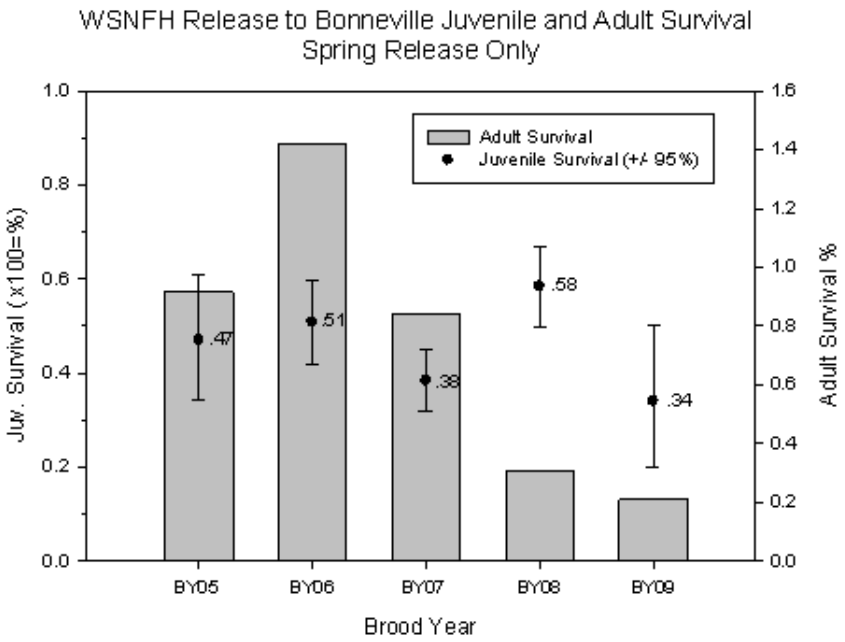

Figure 4: Estimated juvenile survival from release to Bonneville Dam for spring released PIT tagged fish at Warm Springs NFH, along with release to adult return survival rates to Bonneville Dam. Whiskers are ± 95% confidence intervals. BY09 adult survival is through 4-year old returns.

For Round Butte releases of BY2011 juveniles, the survival estimate was 52% with a confidence interval of 31% to 71% (Table 3, Figure 3). The estimated survival rate for Round Butte fish in migration year 2013 was the lowest estimated survival during the four years of Round Butte tagging (brood years 2008 to 2011). As noted previously, due to PIT monitoring equipment malfunction, the brood year 2011 survival estimate was made for tagged fish. In previous years, the Round Butte survival estimates were calculated based on known PIT tag detections of fish leaving the holding cells. Hatchery staff regularly encounter several hundred, if not more, non-migrant fish when they drain the water from the holding cells at the end of the volitional release period. All non-migrant fish are sacrificed at the end of the release year. PIT tagged non-migrants were not included in the downstream survival estimates in previous years, however they were included in brood year 2011. This likely had some, although probably small, impact on the lower survival estimate for Round Butte fish that was observed for brood year 2011.

Bird Colony Recoveries

Bird colony recoveries were not available from the PTAGIS database at the time of this report.

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 42 PIT tagged Round Butte mini-jacks and 14 Warm Springs NFH mini-jacks migrated upstream through the Bonneville Dam adult ladders. Mini-jacking rates were significantly different between hatcheries ($p < 0.001$). Round Butte stock produced mini-jacks at a rate approximately six 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

The U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and Confederated Tribes of the Warm Springs Reservation of Oregon all assisted in the tagging and monitoring of the PIT tagged fish. Jesse Rivera, Geoff Gribble, Dan Butler, James Archibald, Pat Kemper, Chuck Fuller, and Darren Gallion, were responsible for tagging the fish and maintaining tagging records. Staff at Warm Springs NFH, including Roger Sorensen, Mary Bayer, Joe Badoni, Kevin Blueback, and Randy Boise were extremely helpful and accommodating in the tagging and monitoring of the hatchery releases. We also would like to thank Jack Palmer, Shaun Montgomery, and all the staff at Round Butte hatchery for helping us tag and monitor the Round Butte releases. Additionally, Steven Haeseker from the Columbia River Fisheries Program Office provided much needed statistical support for the survival analyses.

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Section II

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

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Abstract

Radio-telemetry was used to estimate the survival of brood year 2011 (migration year 2013) juvenile spring Chinook salmon released from Warm Springs NFH to the mouth of the Deschutes River. A total of 78 juvenile spring Chinook were tagged with radio transmitters and PIT tags and released into the Warm Springs River. An additional 10 fish were tagged with dummy transmitters and PIT tags and held at the hatchery to monitor tag retention and post-surgery survival. Length and weights of tagged fish were representative of raceway populations, and tag burden was well below the 5% threshold for all fish. Upon release, radio telemetry tags were monitored by seven fixed stations along the Warm Springs and Deschutes rivers for the duration of the manufacturers guaranteed tag life (42 days). Detection efficiencies at fixed sites were generally high, ranging from 68% to 99%. A total of 65 radio-tagged fish were ultimately detected at the mouth of the Deschutes River, 54 of which were detected within five days of release. The survival estimate of radio-tagged fish from release to the mouth of the Warm Springs River was 96% (95% C.I. 89% to 99%), and the survival estimate of tagged fish from release to the mouth of the Deschutes River was 85% (95% C.I. 75% to 91%). Present results indicate low apparent mortality occurred within the Warm Springs and Deschutes rivers in 2013.

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. 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. Representative groups of hatchery releases are PIT tagged annually for long-term monitoring of trends in juvenile and adult survival and migration timing; however the current PIT tag monitoring infrastructure in the Warm Springs and Deschutes rivers is insufficient for determining juvenile survival estimates at points upstream of Bonneville Dam. Using radio-telemetry to monitor fine-scale fish movement within the Deschutes Basin may assist in identifying areas where loss may be occurring. Comparing estimates of juvenile survival derived from radio-telemetry and PIT tags will provide a more complete understanding of juvenile outmigration timing and survival in the freshwater environment and may allow managers to modify rearing/release practices, or alter in-river management to benefit juvenile outmigration.

In the spring of 2012, we initiated a radio-telemetry study 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 (Hand et al. 2013). This study was replicated in 2013 to monitor brood year 2011 juvenile releases of spring Chinook salmon from Warm Springs NFH. Work conducted in 2013 followed a similar study design with minor modifications to address recommendations identified in 2012 (see Hand et al. 2013). This report describes results of work conducted in spring 2013. 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 and/or Deschutes River?
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

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). To minimize potential tagging effects, two biologists with prior surgery experience undertook a series of practice sessions at the USGS Columbia River Research Lab in the two months prior to the study. All practice surgeries were conducted on live juvenile spring Chinook salmon comparable in size to Warm Springs NFH study fish. Practice fish were surgically implanted with radio-tags and held for a period of time in aerated holding tanks to observe any post-tagging mortality. Fish were ultimately sacrificed and a necropsy was performed to critique internal tag placement, suture integrity, and to identify any internal organ damage.

Radio-tag Specifications and Tag Burden

The radio tags used in this study were Model NTQ-2 Nano Tags (Lotek Wireless, Inc.) with a minimum tag life of 42 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 (Figure 1). 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 (Figure 1). The combined weight of the radio tag and PIT tag was 0.402 grams. One week prior to surgery, radio tags were activated, submerged in water for 24 hours and individually scanned with a receiver to test tag functionality.

In an effort to minimize adverse effects associated with tag burden, defined as the transmitter-to-body weight ratio, we adhered to protocols established by the U.S. Geological Survey (USGS). In general, juvenile salmonid performance is not significantly compromised when the tag burden is less than 5% (see Liedtke et al. 2012 and references therein). Based on these guidelines, and given the combined tag weight of 0.402 grams, we estimated that fish greater than 8.0 grams could safely be tagged for the study.

Figure 1: Example of NTQ-2 radio transmitter and PIT tags implanted into juvenile spring Chinook salmon.

Tracking Systems

Radio-tagged juvenile Chinook salmon were monitored using a series of fixed stations along the Warm Springs and Deschutes rivers. Fixed sites used SRX400 receivers manufactured by Lotek Wireless, Inc., and 6-element or 4-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 single 12-volt battery which was connected to a solar panel for charging. Telemetry stations were operated from April 1 to May 17, 2013, and data was downloaded from receivers once per week. A total of seven fixed sites were established along the Warm Springs and Deschutes rivers (Figure 2, Table 1). Two fixed sites were located in the Warm Springs River: one at 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 Buck Hollow Creek (Site 3, rkm 69 of the Deschutes River), and three sites were located along the lower Deschutes River: one at river kilometer 20 (Site 4), one at river kilometer nine (Site 5), and two sites at river kilometer five (Site 6 and Site 7). Sites 6 and 7 were fastened to the same fence post with Site 6 positioned to detect radio tags upstream and Site 7 positioned to detect radio tags downstream. During pre-study testing, large amounts of radio-interference made it impossible to reliably detect tags near the confluence of the Deschutes and Columbia rivers. For the purposes of this study, the fixed sites at river kilometer five (Sites 6 and 7) were classified as the mouth of the Deschutes River.

A single mobile tracking survey was conducted by boat around Miller Rocks Island on May 2, 2013. Miller Rocks is a series of small rocky islets just upstream from Miller Island (rkm 327 of the Columbia River), which supports a large gull colony that is known to prey on out-migrating juvenile salmonids. During the survey, two SRX 400 receivers with hand-held three element antenna were oriented to the island while the boat slowly maneuvered around the rocks.

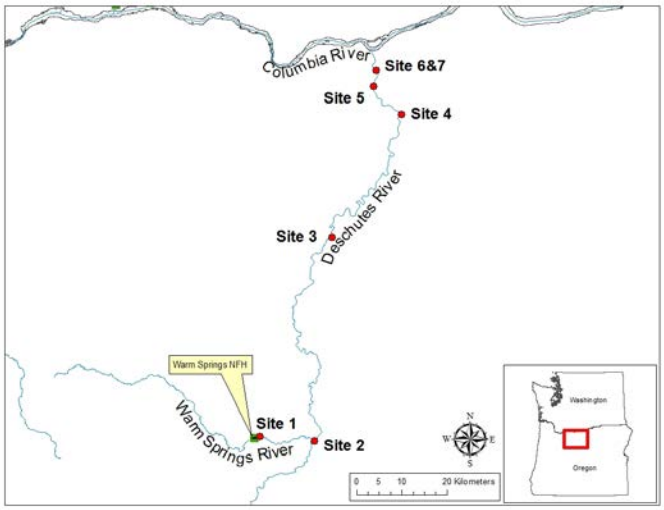

Figure 2: Location and distances, in river kilometers (rkm), of telemetry fixed site stations. Sites 6 and 7 were configured to scan for radio tags either upstream or downstream from the sites.

Table 1: Location and distances, in river kilometers (rkm), of telemetry fixed site stations. Sites 6 and 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	Buck Hollow	80	69
4	Deschutes	Lower Deschutes	129	20
5	Deschutes	Lower Deschutes	140	9
6	Deschutes	Lower Deschutes-up	149	5
7	Deschutes	Lower Deschutes-down	149	5
B2J	*Columbia River*	*Bonneville Dam (PIT)*	245	101

Pre-surgery collection

Fish collection, surgery, and release procedures generally followed USGS guidelines for implanting radio tags into juvenile salmonids (Liedtke et al., 2012). One day prior to the first surgery date, approximately 60 juvenile spring Chinook salmon were randomly dipped from two separate hatchery raceways (120 fish total). Fish were selected from the same raceways (#20 and #23) where a subsample (approximately 7,500 fish per raceway) had been previously PIT tagged as part of the survival monitoring to Bonneville Dam (see Section I). Selected fish were individually scanned for

PIT tags, checked for external injuries, and transported by aerated five gallon buckets into a covered indoor holding tank at the hatchery. Fish from different raceways were placed into two separate holding tanks. 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 from each raceway were measured and weighed for size comparison.

Surgical Procedures

Radio tag implantation surgeries were performed on a total of 89 juvenile spring Chinook salmon on April 2 and April 3, 2013. Seventy-nine fish were implanted with activated radio tags, and 10 fish were implanted with de-activated or "dummy" radio tags for laboratory holding and monitoring. PIT tags were inserted into all 89 test fish during the surgeries. Two surgeons performed approximately 45 tag implantations each. Surgeries were split evenly between the two raceways to reduce potential bias resulting from differences in technique between surgeons. 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 at a time were carefully netted from the holding tank and placed in an aerated 5 gallon holding bucket with lid. Fish were then 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). Once anesthetized, fish were 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 a covered indoor holding tank (separated by raceway) and held overnight.

An additional ten fish were implanted with dummy transmitters and PIT tags during the second tagging session (April 3) and held for 32 days in a covered indoor holding tank for delayed mortality and tag retention monitoring purposes. After 32 days, these fish were sacrificed, measured, weighed and a photograph was taken of the incision site and internal body cavity to document surgery technique and healing progress.

Post-surgery Monitoring and Release

On the morning of the scheduled release (April 4, 2013), researchers performed a visual inspection of the holding tanks to look for shed tags and to make sure fish were fully recovered from the surgery. Fish were then individually netted from the holding tank and placed in an aerated 5-gallon bucket. Once transmitter function was verified by using an SRX mobile receiver to scan the appropriate frequencies, 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 force-released, along with the rest of the raceway population, into the Warm Springs River. Force-release occurred in the early afternoon for both raceways.

Data Analysis

We used the Cormack-Jolly-Seber model in program MARK to estimate detection efficiencies and survival estimates. ArcGIS was used to create the fixed telemetry map. R was used for statistical comparisons and to create graphical displays.

Results

Tagging and Release

The number of fish tagged and released by date are summarized in Table 2. Forty fish were tagged with active transmitters on April 2 and another thirty-nine fish were tagged with active transmitters on April 3, 2012. An additional ten fish were tagged with dummy transmitters on April 3, 2012. During post-surgery monitoring and tag verification, researchers identified a single tag that was not operational. This fish was sacrificed, and the tag was removed and sent back to the manufacturer for inspection. All other tags were verified as functional prior to release. Removing the non-functioning tag, a total of 78 active tags were released into the Warm Springs River (Table 2). During data analysis, we identified a single tag (code 34) with an unusual detection history. Following its detection at Site 3, the tag was detected 16 days later at the mouth (Site 7), then upstream 15 river kilometers at site 4, then back at the mouth with no additional detections between these sites. This abnormal detection history may indicate predation or technological malfunction. As a precaution, this tag was excluded from all analysis with no significant impact to the results.

Table 2: Number of fish radio-tagged and released, by date, in 2013

Surgery Date	Raceway	# Tagged	# Released*	Release Date
April 2nd	20	20	19	April 4th
April 2nd	23	31	31	April 4th
April 3rd	20	29**	19	April 4th
April 3rd	23	9	9	April 4th
Total	NA	89	78	NA

*Indicates the number of fish released with verified, functioning tags

**Number includes ten fish tagged with dummy transmitters

Individual tagging, surgery, and release data can be found in Appendix B. Size distribution of radio-tagged fish represented the overall hatchery population (Figure 3). Tag burden ranged from 0.8% to 3.3% for fish released, well below our pre-established maximum of 5%. Surgery 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 4.5 minutes.

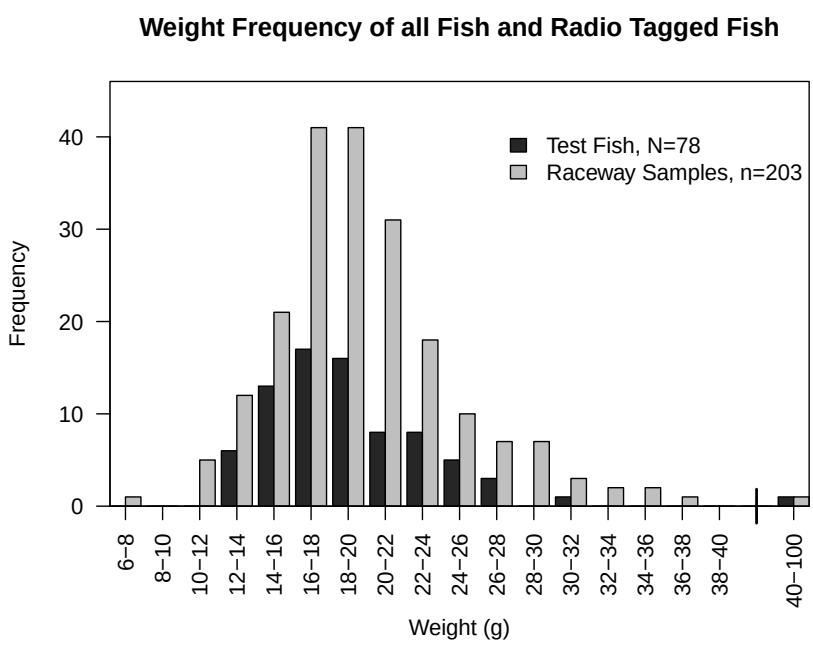

Figure 3: Weight frequencies of subsamples of fish from raceways 20 and 23 (grey bars) and radio-tagged fish (black bars).

Delayed Mortality and Tag Retentions (dummy tags)

Tag burden for dummy tagged fish ranged from 2.1% to 3.3%. Of the ten fish implanted with dummy radio tags, all survived until the end of the 32 day holding period, and radio-tags remained implanted within the fish. All dummy tagged fish increased in length (12.5 ± 2.3 mm [mean ± SD]) and weight (10.78 ± 3.0 g) during the holding period, suggesting normal feeding activity resumed following the surgery.

Downstream Migration Timing

Fixed telemetry data indicate fish move quickly out of the Warm Springs River into the Deschutes River. Out of 78 radio tagged fish, 73 were detected at the mouth of the Warm Springs River. These fish were detected between eight and 36 hours post-release (12.47 ± 3.14 hours [mean ± SD]). A total of 65 radio-tagged fish were detected at the mouth of the Deschutes River (Site 6, 7), 149 river kilometers downstream of Warm Springs NFH. Median travel time from release to the mouth of the Deschutes River was 2.5 days with 69% of all tagged fish arriving at the mouth within five days of release (Figure 4). The migration rate of tagged fish ranged from 4.9 to 95.5 river kilometers per day (median 58.8 rkm).

Four radio-tagged/PIT tagged fish were eventually detected at Bonneville Dam's juvenile bypass facility, 245 river kilometers downstream of Warm Springs NFH. Detections occurred 7, 10, 26, and 35 days after release from the hatchery. A single tagged fish was also detected by trawl in the Columbia River Estuary, 33 days after release from Warm Springs NFH.

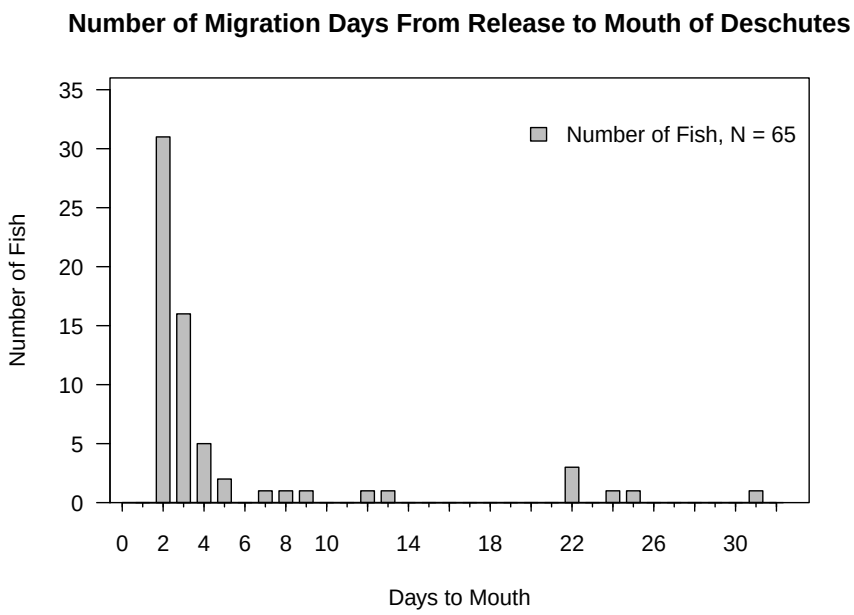

Figure 4: The number of days it took for radio-tagged juvenile spring Chinook to migrate from release at Warm Springs NFH to the mouth of the Deschutes River (rkm 5). Total distance between Warm Springs NFH and the mouth of the Deschutes River is 149 river kilometers. A total of 65 radio-tagged fish were detected at the mouth of the Deschutes.

Estimated detection efficiencies of fixed telemetry sites 1-6 ranged from 68% to 99% (Figure 5). This analysis does not include an additional site (North Junction, rkm 113) located between sites 2 and 3 that was omitted from this study due to an extremely low detection efficiency. The highest detection probabilities were observed at the mouth of the Warm Springs and Deschutes Rivers (defined as Site 6). With the exception of Site 1, all fixed sites had higher detection efficiencies in 2013 as compared to 2012, and 95% confidence intervals were significantly narrower for all sites.

Mobile tracking surveys were limited in 2013. All but two active tags were detected at fixed site locations downstream from the mouth of the Warm Springs River, so a more widespread survey effort was not deemed necessary. A single mobile tracking survey around Miller Rocks Island in the Columbia River did not result in any confirmed tag detections.

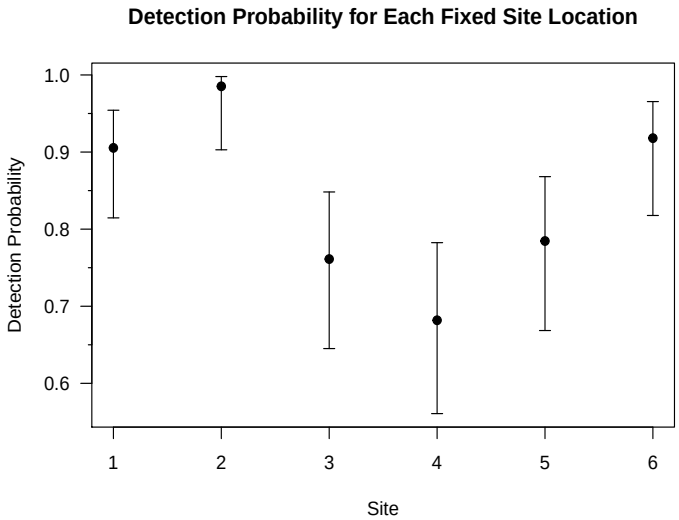

Figure 5: Detection probability at each telemetry fixed site location. Error bars are ± 95% confidence intervals. For a description of each fixed site location see Table 1.

Survival

Estimates of survival between fixed telemetry stations ranged from 92% to 99% (Figure 6). When these estimates are standardized for distance travelled (converting survival estimates between sites to: survival estimates per river kilometer), the results indicate apparent survival was fairly constant throughout the Warm Springs and Deschutes rivers (0.998 ± 0.001 survival/rkm [mean ± SD]). The overall survival estimate of radio-tagged fish from release to the mouth of the Warm Springs River was 96%, with a confidence interval of 89% to 99%. Estimated survival from release to the mouth of the Deschutes River, defined as Site 6, was 85%, with a 95% confidence interval of 75% to 91% (Figure 7).

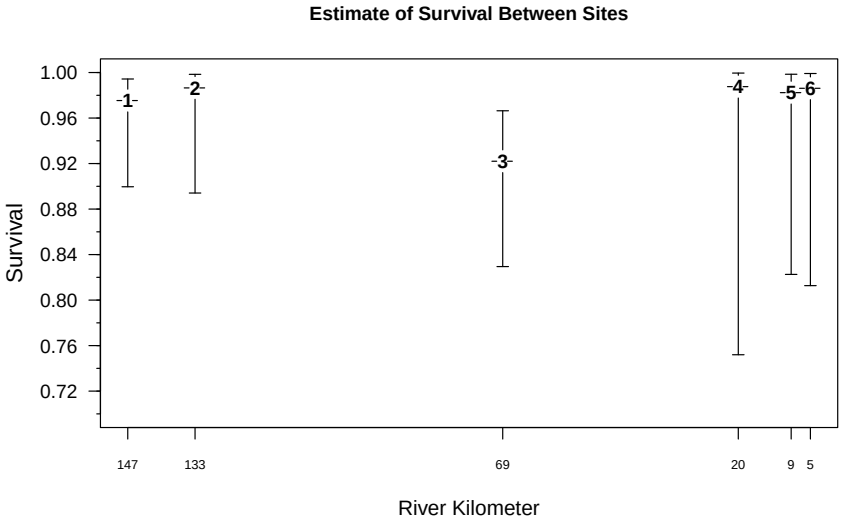

Figure 6: Survival estimates of radio-tagged juvenile spring Chinook migrating between telemetry fixed sites (1-6). Estimated survival from release to Site 1 was 98%, from Site 1 to Site 2 was 99%, etc. Error bars are ± 95% confidence intervals.

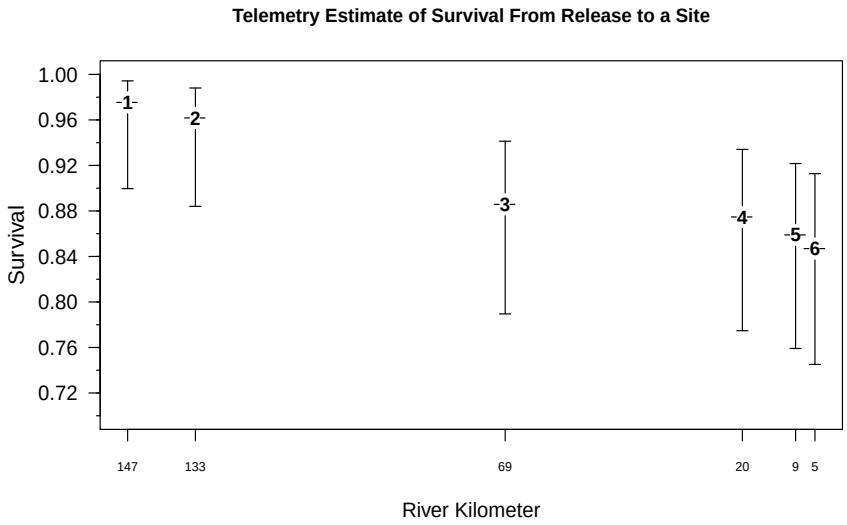

Figure 7: Survival estimates of radio-tagged juvenile spring Chinook from release at Warm Springs NFH to a particular telemetry site. Error bars are ± 95% confidence intervals. Site 6 is the mouth of the Deschutes River.

Discussion

The objective of this study was to estimate the survival of radio-tagged juvenile spring Chinook released from Warm Springs NFH to the mouth of the Deschutes River. Our results indicate high apparent survival of radio tagged fish in the Warm Springs (96% ± 5%) and Deschutes rivers (85% ± 8%) in 2013. The overall estimated survival from release to Bonneville Dam for PIT tagged juveniles of 58% ± 18% (see Section I), suggests that mortalities occurring within the mainstem Columbia River may have been higher than mortalities in the Deschutes and Warm Springs rivers in 2013. As a whole, survival estimates of juvenile spring Chinook released from Warm Springs NFH were higher in 2013 than in 2012, in all areas (Figure 8). Survival to the mouth of the Warm Springs River was 19% higher, survival to the mouth of the Deschutes River was 36% higher, and survival of PIT tagged fish to Bonneville Dam was 29% higher in 2013. Survival estimates between fixed telemetry stations were also high and consistent in 2013 (Figure 6), giving no clear indication as to where increased mortality may be occurring within the Deschutes River. Installing additional fixed sites above or below Site 3 where there are significant gaps between telemetry stations may improve our ability to recognize areas of high mortality within the basin.

This was the second year evaluating the survival of Warm Springs NFH juvenile spring Chinook in the Warm Springs and Deschutes rivers. Our 2013 study design specifically addressed three recommendations outlined in the 2012 progress report (see Hand et al. 2013). These changes strengthened the 2013 study considerably. First, we increased the number of radio-telemetry tags implanted in juvenile fish from 50 to 79. This increased the precision of 2013 survival estimates and likely contributed to the narrowing of confidence intervals from ± 15% in 2012 to ± 8% in 2013. Second, we relocated three fixed telemetry stations with low detection efficiencies in 2012 (sites 2, 3, and 4), to areas with slower stream flow to better accommodate the shorter detection range and eight second signal burst rate of the radio tags. Detection efficiencies at the new locations were markedly improved over 2012 estimates. With the exception of Site 1, all fixed sites had higher detection efficiencies in 2013. The slight drop in detection efficiency at Site 1 (Kah-Nee-Ta bridge), may be due to signal collisions, as twice as many active tags were released into the Warm Springs River in 2013. Survival estimates suggest that the majority of juvenile spring Chinook released from Warm Springs NFH successfully migrated past the mouth of the Warm Springs River (Figure 8). In the future we may eliminate Site 1 from the study and install the equipment in the Deschutes River where there is more uncertainty regarding juvenile mortality. Third, radio-tag function was tested more thoroughly prior to implantation and release. Tags were tested for water intrusion for a minimum of 24 hours, and tag function of each individual tag was verified prior to the fish being returned to the raceway population. These activities led to the identification of a single non-functional tag that may have otherwise been treated as a mortality during data analysis.

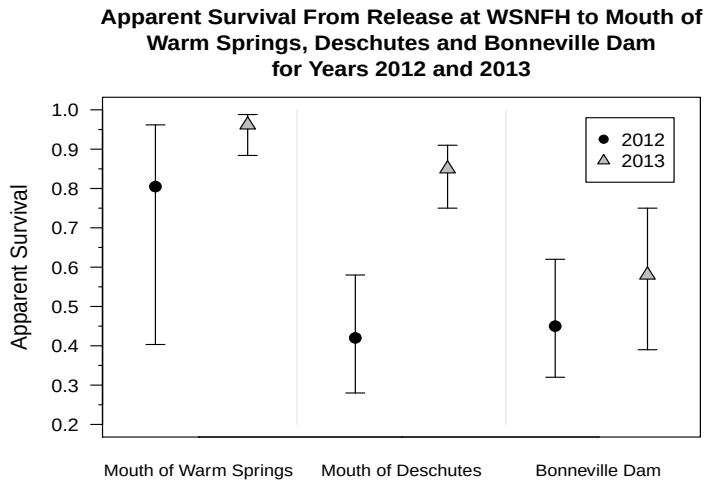

Figure 8: Survival estimates of radio-tagged and PIT tagged (Bonneville Dam) juvenile spring Chinook released from Warm Springs NFH to the mouth of the Warm Springs River, Deschutes River, and Bonneville Dam for years 2012 (black circles) and 2013 (grey triangles). Error bars are ± 95% confidence intervals.

The 2013 survival estimate of radio-tagged juvenile spring Chinook from release to the mouth of the Deschutes River was much higher than the 2012 estimate (85% and 42%). Differences between years may be attributed to uncertainty associated with the wide confidence intervals of 2012, a greater number of radio tags being released in 2013, modifications of hatchery rearing practices, fluctuating river conditions (e.g., discharge, temperature) or other biological/environmental factors. The conflicting results suggest a need for an additional year of study. A third year of evaluation would add clarity to existing results and further improve our understanding of the mechanisms influencing the survival of hatchery populations in the Deschutes River. The continuation of this study is also important because it serves as an example of how radio telemetry can be used as a surrogate for estimating freshwater survival in locations lacking robust PIT detection sites, or when large scale PIT evaluations are too cost prohibitive.

Acknowledgements

Through a Cooperative Agreement, Jens Lovtang and staff from the Confederated Tribes of the Warm Springs Reservation of Oregon provided valuable assistance with fish collection and tagging procedures, and took lead responsibility for the installation and operation of fixed telemetry stations along the Warm Springs River. We would like to thank Theresa "Marty" Liedtke, Lisa Gee and Ryan Tomka with the USGS Columbia River Research Lab in Cook WA, for granting us access to the lab and providing guidance regarding surgical procedures and techniques. Hatchery staff at Warm Springs NFH, including Mary Bayer, Kevin Blueback, Randy Boise, and Joe Badoni for helping with pre-surgery logistics and caring for dummy tagged fish. Rod French and Jason Seals with Oregon Department of Fish and Wildlife for providing suggestions for fixed site locations, and for heading up the mobile tracking survey around Miller Rocks Island, and Jim Anderson from the Oregon Parks Department, for permitting access to the lower Deschutes River.

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Appendix A: PIT Tag Data

Summary Statistics for BY 11 Migration to Bonneville Dam

Day of Year*: Passage Downstream Through Bonneville Dam

	Number Observed	Median	Min	Max	Mean	Std. Dev
WSNFH RW 20	599	120	94	134	118	7.27
WSNFH RW 23	633	120	96	136	118	7.01
WSNFH Combined	1,236	120	94	148	118	7.17
Round Butte	553	116	108	150	117	4.40

*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. Data downloaded from PTAGIS on 9/11/2013.

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
WSNFH	13,521	1,203	198	33
Round Butte	6,774	534	113	19

Brood year 2011 hatchery PIT tag data categories are for tagged fish released (estimated as number of tagged fish minus known sheds and pre-release mortalities). Bird colony recoveries in the lower Columbia River were not available, and are not included in this summary. Data downloaded from PTAGIS on 9/11/2013.

Appendix B: Radio Tag Data

Summary surgery and detection data for radio tagged fish released from Raceway 20 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 3 DR BuckHollow	Site 4 DR RKM 20	Site 5 DR RKM 9	Site 6 DR RKM 5 upstream	Site 7 RKM 5 downstream	Bonneville Dam*
166.360	10	118	17.7	1:30	4-Apr-13	4-Apr-13	5-Apr-13	12-Apr-13	29-Apr-13	29-Apr-13	29-Apr-13	29-Apr-13	
166.360	31	132	24.1	0:00	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	5-Apr-13		6-Apr-13	6-Apr-13	
166.360	32	112	15.2	2:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	
166.360	33	106	12.1	2:00	4-Apr-13	4-Apr-13	5-Apr-13			6-Apr-13	7-Apr-13	7-Apr-13	
166.360	34	114	16.1	4:00	4-Apr-13	4-Apr-13	4-Apr-13	6-Apr-13	27-Apr-13	28-Apr-13	28-Apr-13	22-Apr-13	
166.360	35	103	12.1	1:45	4-Apr-13								
166.360	36	113	15.9	0:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13		7-Apr-13		
166.360	37	114	15.2	0:30	4-Apr-13		4-Apr-13		8-Apr-13				
166.360	38	120	18.1	0:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	
166.360	39	116	15.8	0:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13					
166.360	40	136	26.6	2:30	4-Apr-13	4-Apr-13	4-Apr-13	6-Apr-13	6-Apr-13		7-Apr-13	7-Apr-13	
166.360	41	113	15.5	1:30	4-Apr-13	4-Apr-13	5-Apr-13						
166.360	42	107	12.5	1:50	4-Apr-13	4-Apr-13	4-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	11-Apr-13
166.360	43	121	19.1	3:45	4-Apr-13	4-Apr-13	4-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	
166.360	44	125	22	0:30	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	
166.360	45	127	22.4	0:00	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13		6-Apr-13	6-Apr-13	
166.360	46	107	13	2:00	4-Apr-13	4-Apr-13	4-Apr-13			7-Apr-13	8-Apr-13	8-Apr-13	
166.360	47	117	17	3:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13		7-Apr-13	7-Apr-13	7-Apr-13	
166.360	48	124	20.8	2:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13	
166.360	49	111	15	2:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	
166.380	71	132	23.6	1:00	4-Apr-13		4-Apr-13	5-Apr-13		6-Apr-13		6-Apr-13	
166.380	72	117	18.4	2:30	4-Apr-13	4-Apr-13	5-Apr-13	24-Apr-13	25-Apr-13	26-Apr-13	26-Apr-13	26-Apr-13	
166.380	73	119	17.9	0:30	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	
166.380	74	112	14.7	2:00	4-Apr-13		4-Apr-13	5-Apr-13	7-Apr-13	12-Apr-13	12-Apr-13	12-Apr-13	
166.380	75	126	20.1	3:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	
166.380	76	110	14.4	3:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	26-Apr-13		26-Apr-13	26-Apr-13	
166.380	77	113	14.8	2:00	4-Apr-13	4-Apr-13	5-Apr-13						
166.380	78	109	13.8	1:00	4-Apr-13	4-Apr-13	5-Apr-13		4-May-13	5-May-13	5-May-13	5-May-13	
166.380	79	117	17.3	1:30	4-Apr-13	4-Apr-13	5-Apr-13		7-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	30-Apr-13
166.380	81	122	18.2	0:30	4-Apr-13	4-Apr-13	5-Apr-13						
166.360	82	120	17.4	0:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13		6-Apr-13	8-Apr-13	8-Apr-13	
166.360	83	123	20.4	0:30	4-Apr-13	4-Apr-13	4-Apr-13	6-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13	
166.360	84	132	26.5	0:00	4-Apr-13	4-Apr-13							
166.360	85	128	22.6	3:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	
166.360	86	114	14.5	2:30	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	
166.360	87	129	20.3	2:30	4-Apr-13	4-Apr-13	4-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	
166.360	88	123	19.3	1:00	4-Apr-13	4-Apr-13	5-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	
166.360	89	132	23.6	1:30	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	

Summary surgery and detection data for radio tagged fish released from Raceway 23 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 3 DR BuckHollow	Site 4 DR RKM 20	Site 5 DR RKM 9	Site 6 DR RKM 5 upstream	Site 7 RKM 5 downstream	Bonneville Dam*	Trawl
166.360	12	135	24.2	0:30	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13		
166.360	13	129	22.7	1:15	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13			8-Apr-13	8-Apr-13		
166.360	14	120	18.8	3:00	4-Apr-13		4-Apr-13		6-Apr-13		6-Apr-13	6-Apr-13		
166.360	15	121	18.7	1:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13		
166.360	16	126	18.9	2:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	9-Apr-13	11-Apr-13	11-Apr-13		
166.360	17	133	24.3	2:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13		
166.360	18	117	17	0:00	4-Apr-13									
166.360	19	118	18.2	0:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	7-Apr-13	8-Apr-13	8-Apr-13	8-Apr-13		
166.360	20	116	16.3	1:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	13-Apr-13	13-Apr-13	13-Apr-13		
166.360	21	123	19.8	0:00	4-Apr-13		4-Apr-13	5-Apr-13		6-Apr-13	6-Apr-13			
166.360	22	130	22.7	1:00	4-Apr-13	4-Apr-13	5-Apr-13		6-Apr-13		6-Apr-13	6-Apr-13		
166.360	23	136	25	0:20	4-Apr-13	4-Apr-13	4-Apr-13							
166.360	24	119	16.8	0:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13		
166.360	25	116	15.6	3:00	4-Apr-13	5-Apr-13	5-Apr-13	7-Apr-13	8-Apr-13	9-Apr-13		9-Apr-13		
166.360	26	115	16.1	0:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	9-May-13	
166.360	27	132	24.6	0:00	4-Apr-13	4-Apr-13	5-Apr-13		28-Apr-13	28-Apr-13	28-Apr-13	28-Apr-13		
166.360	28	127	21.7	0:20	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13				
166.360	29	120	17.9	0:30	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13			9-Apr-13	9-Apr-13		
166.360	30	146	31.2	3:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13		
166.380	50	120	17.8	0:30	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13			6-Apr-13	6-Apr-13		
166.380	51	116	16.7	1:00	4-Apr-13	5-Apr-13			7-Apr-13			7-Apr-13		
166.380	52	116	16.9	0:30	4-Apr-13	4-Apr-13	5-Apr-13			6-Apr-13	6-Apr-13	6-Apr-13		
166.380	53	109	13.8	1:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13			
166.380	54	118	18.3	0:30	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	7-Apr-13	7-Apr-13	7-Apr-13		
166.380	56	116	16.8	1:00	4-Apr-13	4-Apr-13	4-Apr-13			6-Apr-13	6-Apr-13	6-Apr-13	14-Apr-13	
166.380	57	125	19.4	0:30	4-Apr-13	4-Apr-13	4-Apr-13	6-Apr-13			17-Apr-13	17-Apr-13		
166.380	58	161	49.1	3:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13		
166.380	59	117	17.6	3:30	4-Apr-13	4-Apr-13	5-Apr-13			6-Apr-13	6-Apr-13	6-Apr-13		
166.380	60	132	23.8	0:00	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13		6-Apr-13	6-Apr-13		
166.380	61	113	15.2	0:00	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13		
166.380	62	120	18.8	1:00	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13		
166.380	63	126	21.9	2:00	4-Apr-13	4-Apr-13	4-Apr-13							
166.380	64	134	26.7	2:00	4-Apr-13	4-Apr-13	4-Apr-13							
166.380	65	119	17.6	4:30	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13		8-Apr-13	8-Apr-13	8-Apr-13		7-May-13
166.380	66	131	23.9	0:00	4-Apr-13		4-Apr-13	5-Apr-13		6-Apr-13		6-Apr-13		
166.380	67	122	19.4	1:00	4-Apr-13		4-Apr-13		6-Apr-13	6-Apr-13	6-Apr-13			
166.380	68	125	21.1	0:30	4-Apr-13	4-Apr-13	5-Apr-13			16-Apr-13	16-Apr-13	16-Apr-13		
166.380	69	120	18.9	3:00	4-Apr-13	4-Apr-13	4-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13	6-Apr-13		
166.380	70	117	15.8	2:00	4-Apr-13	4-Apr-13	5-Apr-13	5-Apr-13	6-Apr-13	6-Apr-13	26-Apr-13	26-Apr-13		

* Includes the Bonneville Dam corner collector and juvenile bypass facility.