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

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

FY 2014 Annual Report

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On the cover: *Warm Springs National Fish Hatchery*

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Section 1

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

2014 ANNUAL REPORT

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Abstract – Warm Spring NFH spring Chinook Salmon juveniles have been PIT tagged as part of a juvenile monitoring program since brood year 2005 (migration year 2007). In January of 2014, a total of 11,048 spring marked (coded-wire tagged and adipose fin clipped) and 3,963 fall marked brood year 2012 juveniles were PIT tagged. All PIT tagged fish were released from the hatchery on April 3, 2014. The number of migration days from the hatchery downstream to Bonneville Dam ranged from 3 to 52 days, with a median of 30 days. Migration speed averaged 8.2 river kilometers per day. No difference in migration speed was observed between fall marked and spring marked fish. Detection efficiency of PIT tagged juveniles passing Bonneville Dam was 14% (95% C.I. of 9% to 25%), and survival from hatchery release to Bonneville Dam for all PIT tagged fish was 52% (95% C. I. of 29% to 74%). A separate survival estimate for the fall marked fish was not calculated due to the small number of PIT tagged fall marked fish. Survival of PIT tagged Warm Springs NFH spring Chinook Salmon juveniles has ranged from 34% to 70% over the past 8 years (brood years 2005 to 2012), while release to adult return rates of PIT tagged fish have ranged from 0.22% to 1.42% for brood years 2005 to 2010.

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 has allowed for comparisons to be made between Deschutes River populations. Additionally, different release strategies at Warm Springs NFH (forced release versus spring volitional release; spring marked versus fall marked) 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 for four consecutive years, starting with brood year 2008 (migration year 2010). Due to funding constraints, tagging of Round Butte stocks has been discontinued. This report summarizes the PIT tagging and juvenile monitoring of brood year 2012 spring Chinook Salmon juveniles at Warm Springs NFH. The objectives addressed in this preliminary report are:

1) PIT tag representative numbers of juvenile fish at Warm Springs NFH
2) Monitor migration speed and migration timing to Bonneville Dam.
3) Estimate juvenile downstream survival from hatchery release to Bonneville Dam.
4) Estimate release to adult return rates of PIT tagged fish.

Methods

Tagging and Release

Warm Springs NFH

For brood year 2012, Warm Springs NFH reared and released two groups of spring Chinook salmon. One group was reared according to standard rearing protocols and was fin clipped and coded-wire tagged in May of 2013. A second, experimental, group of fish was reared at a slower early rearing growth rate (non-heated water) and was fin clipped and coded-wire tagged in October of 2013. In order to represent these two groups of fish in the PIT tagging effort, approximately 10,000 spring marked fish and 5,000 fall marked fish were to be PIT tagged. PIT tagging of both groups of fish occurred on January 27 and 28 of 2014. Approximately 5,000 fish per raceway were PIT tagged in raceways 16 (fall marked), 21 (spring marked), and 23 (spring marked). An additional 80 fish (40 in raceways 21 and 40 in raceway 23) were PIT tagged just prior to release as part of a radio-telemetry study (see Section II). Approximately 37,000 total fish were in raceway 16, while raceways 21 and 23 each had approximately 40,000 total fish per raceway. All juveniles tagged at Warm Springs NFH were progeny of Warm Springs hatchery stock parents.

After tagging, hatchery staff recovered and stored mortalities from each of the raceways. Recovered mortalities were scanned for the presence of a PIT tag by staff from the Columbia River Fisheries Program Office. After all fish were released from the hatchery, a large magnet was dragged through the raceways to recover shed PIT tags. Shed tags and tags from dead fish, were removed from the tagging data files. The hatchery forced released raceways 16, 21, and 23 on April 3, 2014. For the survival analysis of brood year 2012 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. An unknown number of unobserved mortalities (e.g. bird or otter predation) and shed tags that flushed out of the raceway were not included in the dataset, possibly negatively biasing release to Bonneville Dam survival estimates.

Round Butte Hatchery

Due to funding constraints, no brood year 2012 Round Butte Hatchery fish were PIT tagged. The Oregon Department of Fish and Wildlife, Portland General Electric, and the Confederated Tribes of the Warm Springs Reservation of Oregon are discussing the potential for future PIT tagging of Round Butte Hatchery spring Chinook Salmon releases in the Deschutes Basin.

Downstream Migration

Detections of PIT tagged fish at Bonneville Dam (rkm 235; Figure 1) were downloaded from the PTAGIS database system on June 27, 2013. 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). For

juvenile out-migrants detected at Bonneville Dam, the number of days for migration from the hatchery to the dam was calculated.

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 2015 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 2015.

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 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.

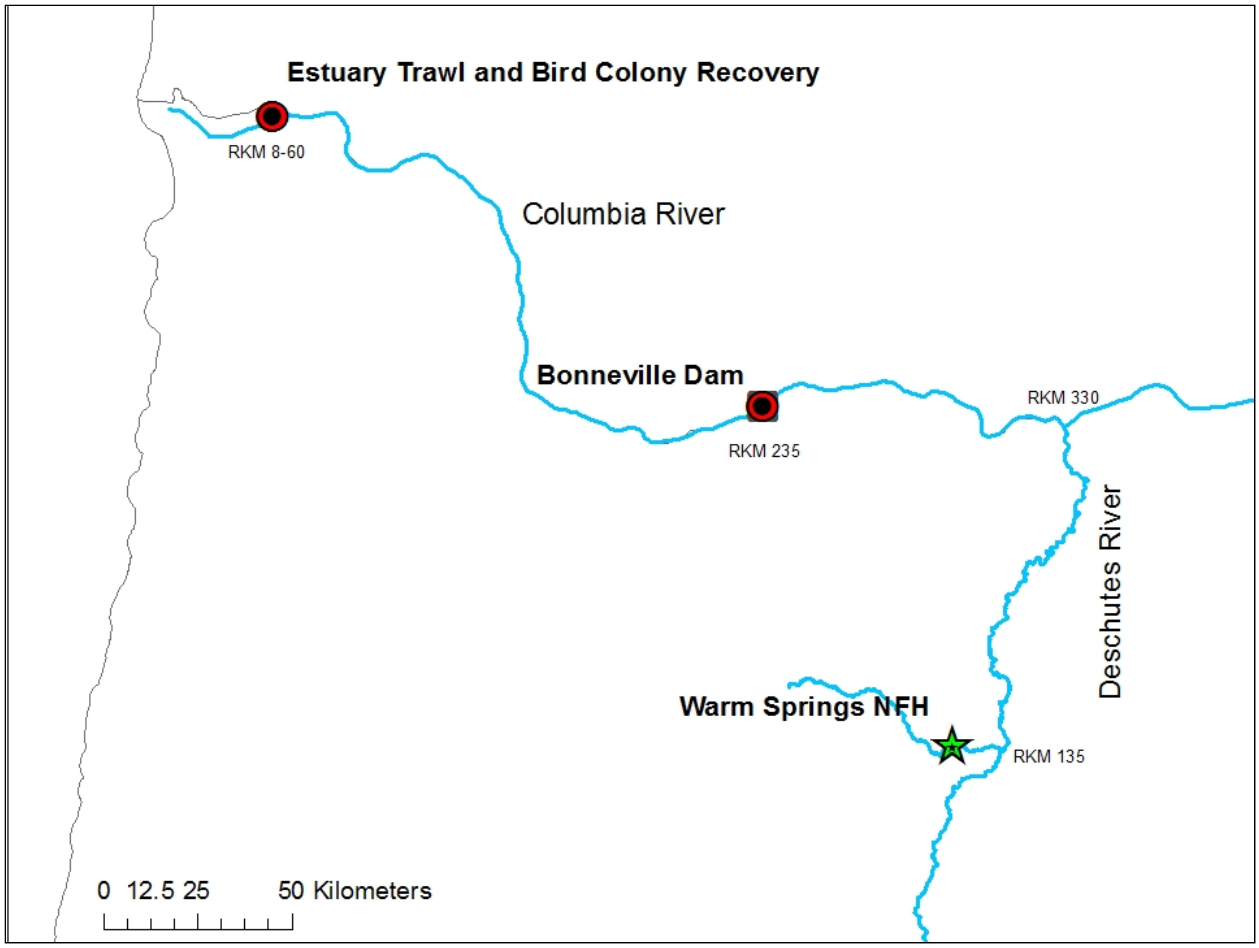

Figure 1. Location of Warm Springs NFH, and downstream PIT tag detection sites (red circles).

Results and Discussion

Release

The number of fish PIT tagged in each raceway (RW), and the number of shed or known mortalities prior to release, are summarized in Table 1.

Table 1. Number of fish PIT tagged, observed pre-release mortalities and shed tags, and estimated total release. Due to unobserved mortalities and unrecovered sheds, the total release is likely biased high.

Group	Tagged	Shed or Mort	Total Released
Warm Springs RW 16	3,963	53	3,910
Warm Springs RW 21	5,524	22	5,502
Warm Springs RW 23	5,524	42	5,486
Warm Springs Total	15,011	117	14,898

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. The number of days from hatchery release to detection at Bonneville Dam is shown in Table 2. There were no differences in migration speed between fish marked (coded-wire tagged and fin clipped) in the spring and fish marked in the fall. Mean migration speed for all PIT tagged fish was 8.2 rkm per day. The fastest downstream migration speed was 81.2 rkm per day, while the slowest speed was 4.7 rkm per day.

Table 2. Number of PIT tagged spring Chinook Salmon juveniles detected passing downstream through Bonneville Dam, and data on the number of days between release from Warm Springs NFH and detection at the dam, 245 river kilometers downstream of the hatchery.

	Number Observed	Median	Min	Max	Mean	Std. Dev
WSNFH RW 21	385	31	4	52	30	8.3
WSNFH RW 23	419	30	6	50	29	8.1
WSNFH RW 16	298	30	3	49	31	8.7
WSNFH All	1,102	30	3	52	30	8.4

All fish were released on April 3 2014. RW 21 and 23 were spring marked (adipose fin clip and coded wire tag) fish, RW 16 was marked in the fall. Data downloaded from PTAGIS on 6/27/14.

Survival

Data categories used for estimating apparent survival from release at the hatchery downstream to Bonneville Dam are shown in Table 3. The estimated detection efficiency of the PIT tag antennas at Bonneville Dam for Warm Springs NFH fish was 14% (95% C.I. of 9% to 25%), which is similar to the detection efficiencies observed over the last four years. Due to the relatively small number of fall marked PIT tagged fish releases (3,910), and subsequent small number of PIT tag detections at the lower river trawl site, no survival estimate was calculated for the fall marked fish. Spring marked fish had an estimated survival of 46% (95% C.I. of 25% to 68%), while the combined survival estimate (spring and fall marked) was 52% (95% C.I. of 29% to 74%).

Table 3. Data Categories for Program MARK Survival Estimates to Bonneville Dam for PIT tagged spring Chinook Salmon juveniles released from Warm Springs NFH in 2014. Data downloaded from PTAGIS on 6/27/14.

	PIT Tag Detections			
	Release Only	Release and Bonneville	Release and Trawl/Mini-jack	Release, Bonneville, and Trawl/Mini-jack
WSNFH-Spr Mrk	10,114	792	69	13
WSNFH-Fall Mrk	3,590	296	22	2
WSNFH-Total	13,704	1,088	91	15

Table 4. Summary of 2014 PIT tag detections for brood year 2012 releases, and estimated survival from release to Bonneville Dam for spring marked (coded-wire tagged and fin clipped) and combined spring and fall marked fish at Warm Springs NFH. Bird colony recoveries were not reported to PTAGIS at the time of download. Data downloaded from PTAGIS on 6/27/14.

	Released	Bonneville Survival (95% C.I.)	Estimated Number to Bonneville (observed)	Bird Colony	Mini-Jacks
WSNFH-Spr Mrk	10,988	46% (25%-68%)	5,055 (805)	-	3(0.03%)
WSNFH-Total	14,898	52% (29%-74%)	7,747 (1,103)	-	3(0.03%)

Estimated survival for Warm Springs NFH spring releases has ranged from 34% to 70% for brood years 2005 to 2012 (migration years 2007 to 2014; Figure 2). Release to adult return for spring released fish has ranged from 0.22% to 1.42% for brood years 2005 through 2010. Adult returns rates have not necessarily tracked the trends seen with juvenile survival (Figure 3); for example brood year 2008 had one of the higher (58%) estimated juvenile survival rates to Bonneville Dam but one of the lower (0.30%) adult return rates.

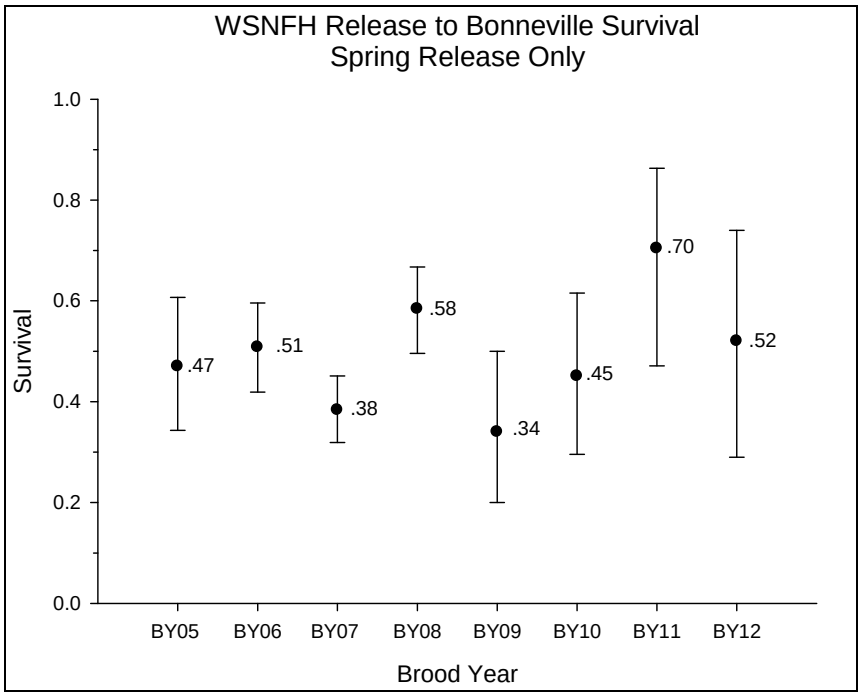

Figure 2. Estimated survival from release to Bonneville Dam for spring released PIT tagged fish at Warm Springs NFH. Estimates were calculated using known PIT tagged releases for brood years 2005 to 2009, and estimated tagged releases (# tagged minus sheds/mortalities) for brood years 2010 on.

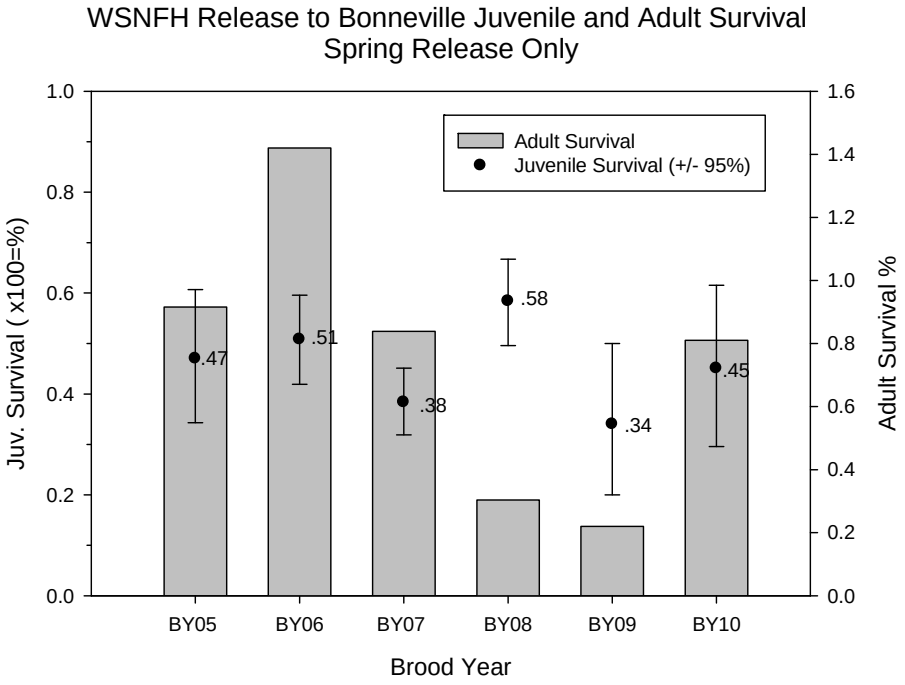

Figure 3. Estimated juvenile survival from release to Bonneville Dam for spring released PIT tagged fish at Warm Springs NFH, along with release to adult return survival rates to Bonneville Dam. Whiskers are +/- 95% confidence intervals. BY10 adult survival is through 4-year old returns.

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, helped tagging the fish and maintaining tagging records. Staff at Warm Springs NFH, including Mary Bayer, Joe Badoni, and Kevin Blueback were extremely helpful and accommodating in the tagging and monitoring of the hatchery 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 2

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

2014 ANNUAL REPORT

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Abstract – Radio telemetry was used to estimate the survival of brood year 2012 (migration year 2014) juvenile spring Chinook salmon released from Warm Springs NFH to the mouth of the Deschutes River. A total of 80 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. Upon release, radio telemetry tags were monitored by six fixed stations along the Warm Springs and Deschutes rivers for the duration of the manufacturers guaranteed tag life (36 days). A total of 56 radio-tagged fish were detected at the mouth of the Deschutes River, 47 of which were detected within three days of release. Detection efficiency at the mouth (Site 5) was 45%, and the survival estimate of radio-tagged fish from release to the mouth of the Deschutes River was 78% (95% C.I. 61% to 88%).

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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 70% 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. 2012). This study was replicated in 2013 and 2014 to monitor brood year 2011 and 2012 juvenile releases of spring Chinook salmon from Warm Springs NFH. This report describes results of work conducted in spring 2014. 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?

Study Area

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

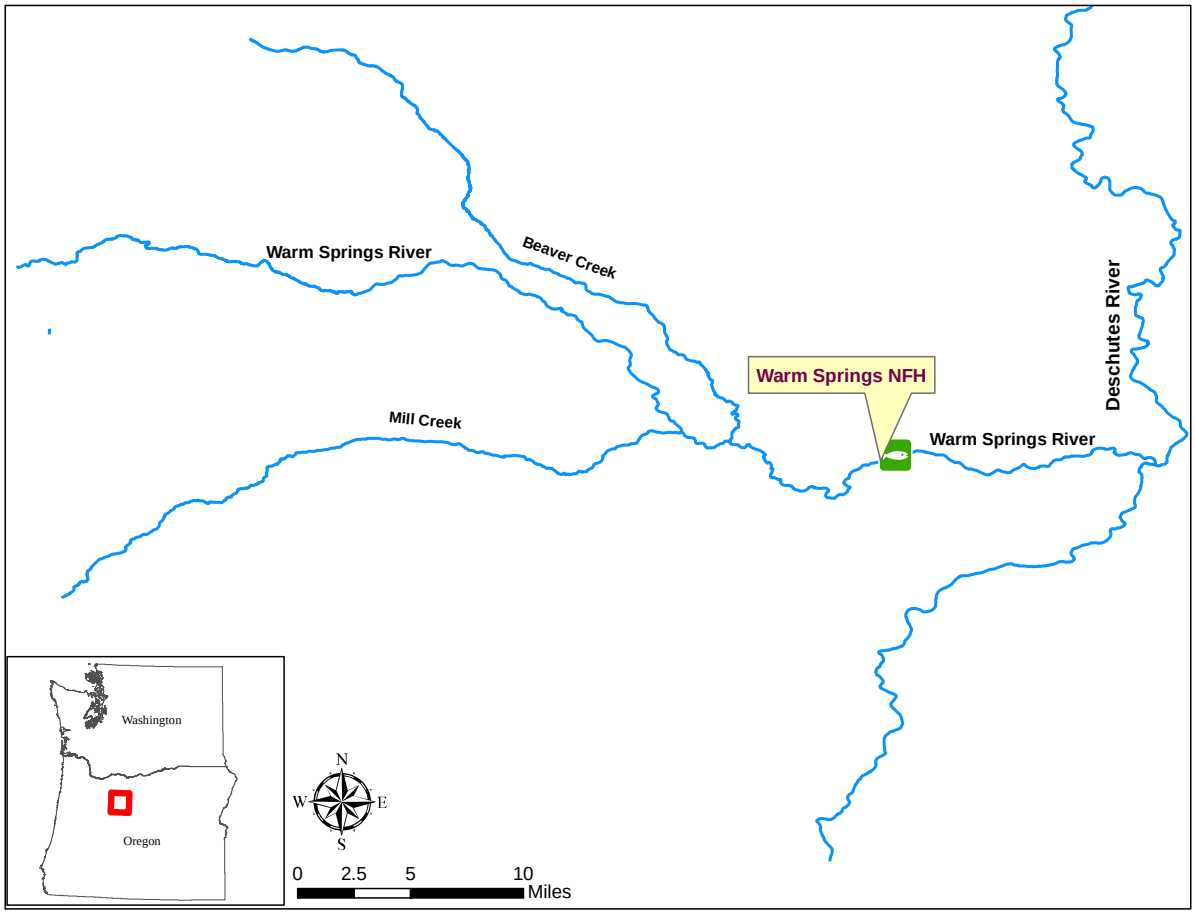

Figure 1. Location of Warm Springs NFH, Warm Springs and Deschutes Rivers.

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, sacrificed and necropsied 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 36 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 2). 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 2). 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 2. 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, Incorporated. All receivers were programmed to scan each of the two tag frequencies at nine second intervals (18 second cycle). Antennas (6-element or 4-element Yagi) were attached to fence posts and oriented with the stream to optimize read range. Each fixed site was powered by a single 12-volt battery which was connected to a solar panel for charging. Telemetry stations were operated from April 1 to May 15, 2014, and data was downloaded from receivers once per week. A total of six fixed sites were established along the Warm Springs and Deschutes rivers (Figure 3, Table 1). A single site was located at the mouth of Warm Springs River (Site 1, rkm 0 of Warm Springs River), a single site was located in the middle Deschutes River, near Buck Hollow Creek (Site 2, rkm 69 of the Deschutes River), and three sites were located along the lower Deschutes River: one at river kilometer 13 (Site 3), one at river kilometer nine (Site 4), and two sites at river kilometer five (Site 5 and Site 6). Sites 5 and 6 were fastened to the same fence post with Site 5 positioned to detect radio tags upstream and Site 6 positioned to detect radio tags downstream. During pre-study testing, large amounts of radio-interference made it impossible to reliably detect tags downstream of Site 6. For the purposes of this study, the fixed sites at river kilometer five (Sites 5 and 6) were classified as the mouth of the Deschutes River.

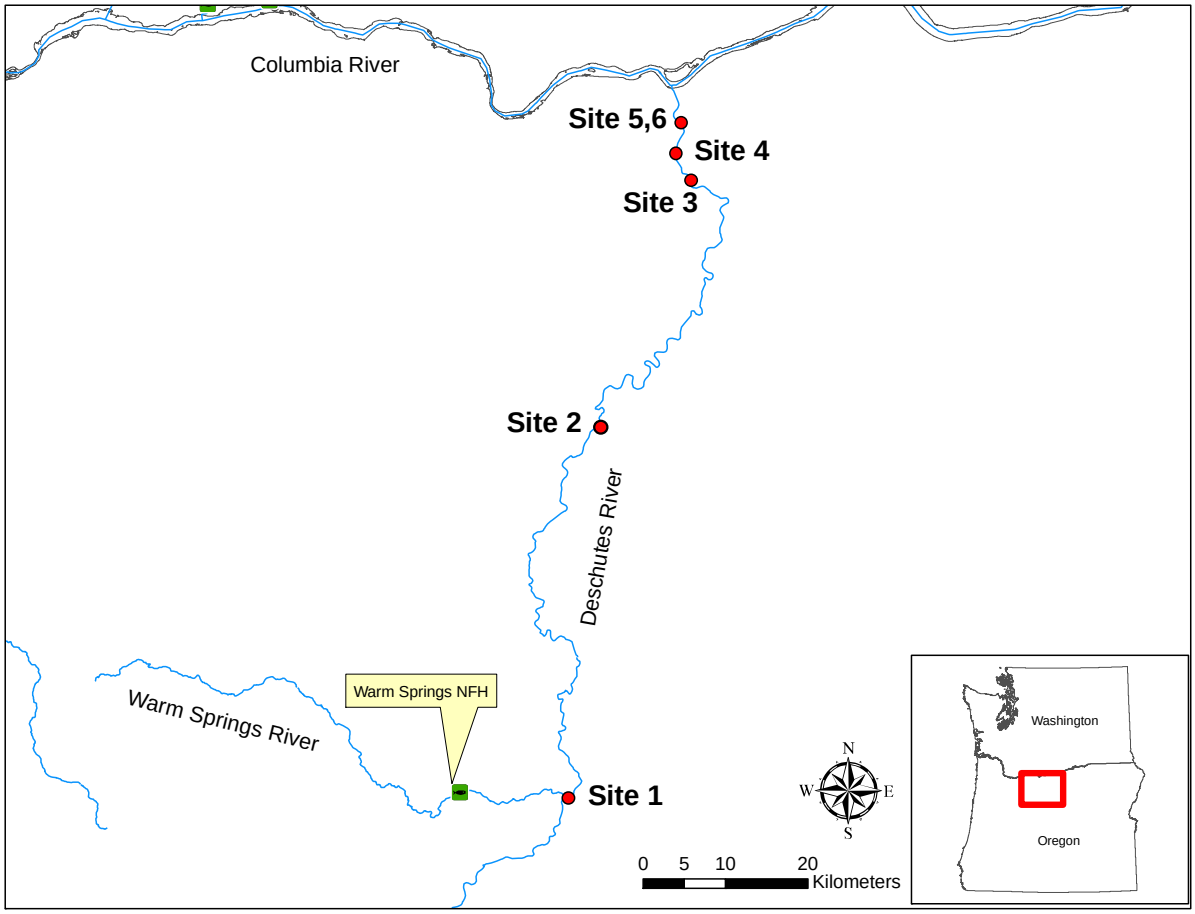

Figure 3. Telemetry fixed-site locations.

Table 2. Location and distances, in river kilometers (rkm), of telemetry fixed site stations. Sites 5 and 6 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 6.

Site #	River	Location	Distance From WSNFH (rkm)	Distance From Deschutes Mouth - Sites 5 and 6 (rkm)
1	Warm Springs	Mouth of Warm Springs	16	133
2	Deschutes	Buck Hollow	80	69
3	Deschutes	Lower Deschutes	136	13
4	Deschutes	Lower Deschutes	140	9
5	Deschutes	Lower Deschutes - up	149	5
6	Deschutes	Lower Deschutes - down	149	5
B2J	*Columbia River*	*Bonnevillle 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 (#21 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 previously implanted PIT tags, and untagged fish were 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 for 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 to estimate the size distribution of fish in the raceways.

Surgical Procedures

Radio tag implantation surgeries were performed on a total of 90 juvenile spring Chinook salmon on April 1 and April 2, 2014. Eighty fish were implanted with activated radio tags, and 10 fish were implanted with de-activated dummy radio tags. Two surgeons performed 45 tag implantations each, pulling fish evenly from both raceways in an effort to reduce bias that may occur from different surgery techniques. 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 (3-4 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 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 2) and held for 33 days in a covered indoor holding tank for delayed mortality and tag retention monitoring purposes. After 33 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 3, 2014), 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

Total numbers of fish tagged and released by date are summarized in Table 2. Sixty fish were tagged with active transmitters on April 1 followed by another twenty fish on April 2, 2014. An additional ten fish were tagged with dummy transmitters on April 2, 2014. All tags were verified as functional prior to release. A total of 80 active tags were released into the Warm Springs River (Table 2).

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

Surgery Date	Raceway	# Tagged	Release Date
April 1	21	40	April 3
April 1	23	20	April 3
April 2	23	20	April 3
April 2	21	5*	N/A
April 2	23	5*	N/A

*Indicates the use of inoperable tags “dummy tags” in order to detect potential tagging effects.

Individual tagging, surgery, and release data can be found in Appendix B. Size distribution of radio-tagged fish represented the overall hatchery population (Figure 4). Tag burden ranged from 1.0% to 5.2% (2.4% ± 0.7% [mean ± SD]). For a single fish, combined PIT and radio tag weight exceeded our pre-established tag burden threshold by 0.22 percentage points, a fact that was not discovered until the surgery was completed. The arrival of this fish at the mouth of the Deschutes River two days after its release from Warm Springs NFH suggests no immediate effect on survival.

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 7.5 minutes (3.0 minutes ± 1.5 minutes).

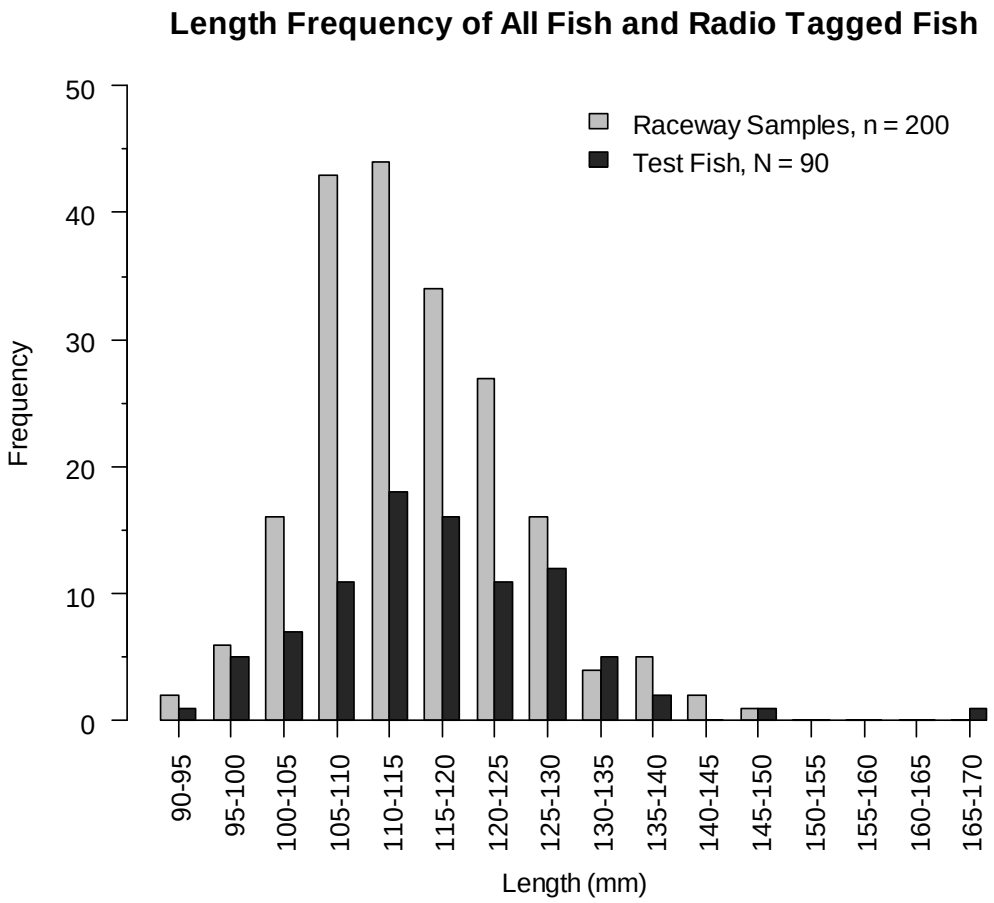

Figure 4. Length frequencies of subsamples of fish from raceways 21 and 23 (grey bars) and radio-tagged fish (black bars).

Delayed Mortality and Tag Retentions (dummy tags)

Tag burden for dummy tagged fish ranged from 1.8% to 3.9%. Of the ten fish implanted with dummy radio tags, all survived until the end of the 33 day holding period, and radio-tags remained implanted within the fish. All dummy tagged fish increased in length (18.6± 3.2mm) and weight (15.0 ± 6.2g) during the holding period, suggesting normal feeding activity resumed following the surgery.

Downstream Migration Timing

A total of 70% of radio tags were detected by at least one of the two fixed telemetry sites stationed at the mouth of the Deschutes River (Site 5, 6). Median travel time from release at Warm Springs NFH to the mouth of the Deschutes River was 1.8 days with 84% of all tagged fish arriving at the mouth within three days of release (Figure 5). The migration rate of tagged fish ranged from 4.4 to 113.0 river kilometers per day (median 85.0 rkm).

Travel time for fish originating from raceway 21 ranged from 1.31 to 5.08 days (median = 1.73, n = 29), whereas fish from raceway 23 ranged from 1.55 to 33.52 days (median = 2.15, n = 27) (Figure 5). A Wilcoxon rank-sum test for travel time between both raceways returns a P-value of 0.071, suggesting that raceway environment may have imparted an effect on migration and timing to the Deschutes mouth.

In addition to the Deschutes River mouth, a single radio-tagged fish was also detected at Bonneville Dam's juvenile bypass facility approximately nine days after its release from Warm Springs NFH.

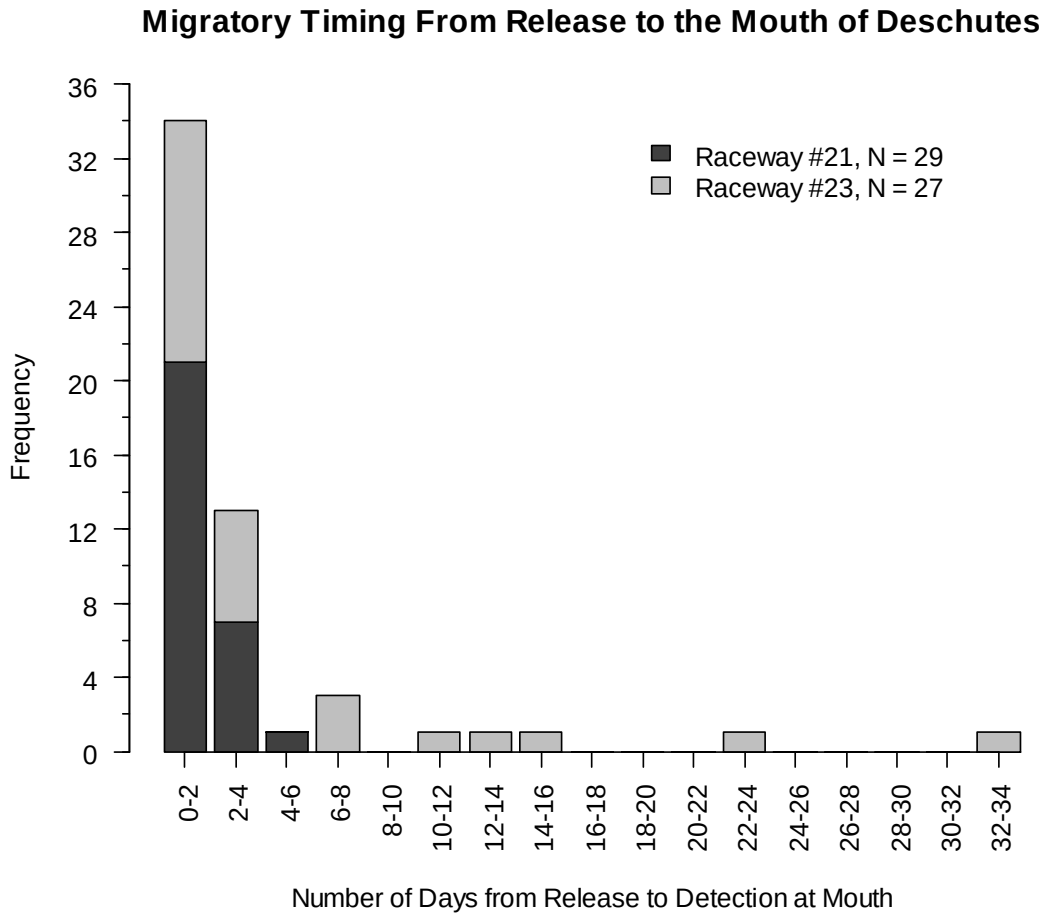

Figure 5. Migratory timing from release to the mouth of the Deschutes River for radio-tagged fish originating from raceway 21 (black bars) and raceway 23 (grey bars).

Survival

All but eight active tags were detected at fixed site locations downstream from Warm Springs NFH. Apparent mortalities were split evenly between surgeons and surgery recovery times were within acceptable ranges.

Survival estimates to select fixed telemetry sites (sites 1 – 4) within the Warm Springs and Deschutes Rivers are not reported due to low fixed site detection probability (Site 3, 4) and/or high antenna sensitivity creating substantial records of spurious data (Site 1). Buck Hollow (Site 2) lost power for 22 hours approximately six days after fish were released from Warm Springs NFH. There were no tag detections in the 38 hours prior to or one month following the outage, so it is likely most radio-tagged fish passed through the area before the brief outage. Detection probability at Site 2 was 70% and estimated survival from release to Site 2 was 91% with a 95% confidence interval of 76% to 97%.

Site efficiency at the Deschutes River mouth (Site 5) was 45% and apparent survival of radio-tagged fish to the Deschutes River mouth was 78% with a 95% confidence interval of 61% to 88% (Figure 6). There was no significant difference in survival between radio-tagged juveniles originating from raceway 21 and raceway 23.

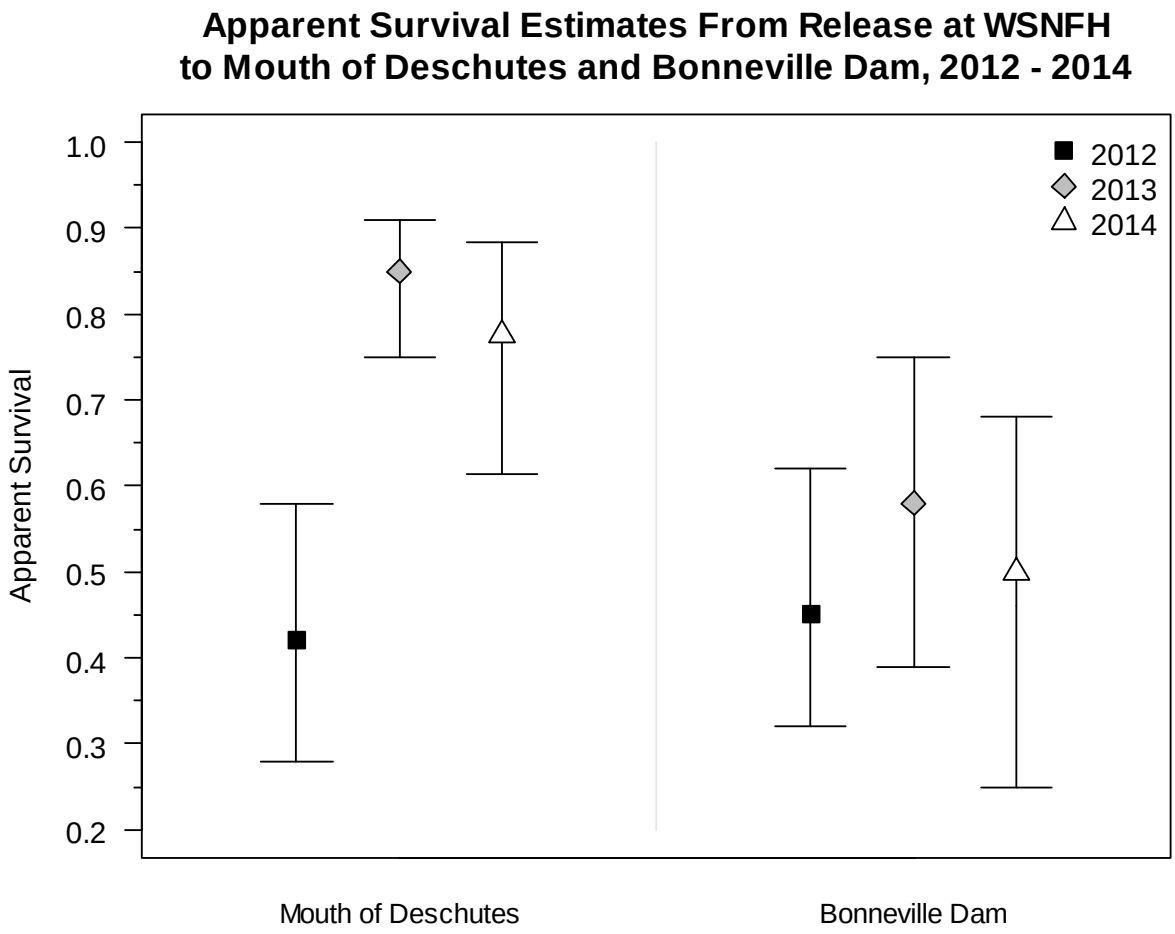

Figure 6. Survival estimates of radio-tagged and PIT tagged (Bonneville Dam) juvenile spring Chinook released from Warm Springs NFH to the mouth of the Deschutes River and Bonneville Dam for years 2012 (black squares), 2013 (grey diamonds) and 2014 (white triangles). Error bars are ± 95% confidence intervals.

Conclusion

Findings

- Our results indicate moderately high apparent survival of radio-tagged juvenile spring Chinook salmon from release at Warm Springs NFH to the mouth of the Deschutes River (78% ± 13.5%).
- Survival point estimates from release to Bonneville Dam for PIT juveniles in Raceways 21 and 23 (46% ± 21%) suggest that mortality rates in 2014 may have been higher in the

Columbia River when compared to the Deschutes River. Due to wide confidence intervals there is weak evidence to support this claim.

- Survival estimates of radio-tagged juvenile spring Chinook to the mouth of the Deschutes River have varied over the last three years as compared to Bonneville Dam PIT estimates (Figure 6). Differences within the Deschutes River may be attributed to large confidence intervals, hatchery rearing practices, fluctuating river conditions (e.g., discharge, temperature) or other biological/environmental factors.
- Detection efficiency at the Deschutes River mouth (Site 5) was significantly lower in 2014. This was likely due to a low gain setting on the receiver that was not realized until after the fish were released.
- Fixed telemetry data indicate radio-tagged fish move very quickly from release to the mouth of the Deschutes River. Total travel time ranged from 1.3 to 33.5 days (median=1.75, n=56).
- Radio-tagged fish originating from raceway 21 migrated to the mouth more quickly than fish from raceway 23 (p=.071), suggesting a possible raceway effect.
- In 2014 we were unable to calculate survival and detection probabilities for three telemetry sites (1, 3, and 4) due to technical malfunction.
- All hatchery fish except those from raceways 21 and 23 were released in the morning; raceways 21 and 23 were released around noon. This may weaken inferences made from this study to the 2014 outmigrating cohorts and strengthen comparisons to the 2013 study (also a noon release).

Acknowledgements

Through a Cooperative Agreement, Jens Lovtang and staff from the Confederated Tribes of the Warm Springs Reservation of Oregon provided equipment, assistance with fish collection, and took lead responsibility for the installation and operation of the fixed telemetry station at the mouth of the Warm Springs River. We would like to thank Theresa "Marty" Liedtke, Lisa Gee, Ryan Tomka and Joe Warren 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, 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, 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 12 Migration to Bonneville Dam

Number of days, release at WSNFH to Bonneville Dam.

	Number Observed	Median	Min	Max	Mean	Std. Dev
WSNFH RW 21	385	31	4	52	30	8.3
WSNFH RW 23	419	30	6	50	29	8.1
WSNFH RW 16	298	30	3	49	31	8.7
WSNFH All	1,102	30	3	52	30	8.4

All fish were released on April 3 2014. RW 21 and 23 were spring marked (adipose fin clip and coded wire tag) fish, RW 16 was marked in the fall. Data downloaded from PTAGIS on 6/27/14.

Data Categories for Program MARK Survival Estimates to Bonneville Dam for BY12

	PIT Tag Detections			
	Release Only	Release and Bonneville	Release and Trawl/Mini-jack	Release, Bonneville, and Trawl/Mini-jack
WSNFH-Spr Mrk	10,114	792	69	13
WSNFH-Fall Mrk	3,590	296	22	2
WSNFH-Total	13,704	1,088	91	15

Brood year 2012 hatchery PIT tag data categories are for tagged fish released (estimated as number of tagged fish minus known sheds and pre-release mortalities). A portion of BY12 production was fall marked (adipose fin clipped and coded wire tagged), while the majority were marked in the spring. Bird colony recoveries in the lower Columbia River were not available at the time of this report, and are not included in this summary. No BY12 Round Butte fish were tagged. Data downloaded from PTAGIS on 6/27/1

Appendix B: Radio Tag Data

Summary surgery and detection data for radio tagged fish released from Raceway 21 of Warm Springs NFH.

Frequency	Code	Length mm	Weight g	Recovery Time (MM:SS)	Release Date	Site 1 WSR Mouth	Site 2 DR Buck Hollow	Site 3 DR RKM 13	Site 4 DR RKM 9	Site 5 DR RKM 5 upstream	Site 6 DR RKM 5 downstream	Deschutes River Mouth RKM 0	Bonneville Dam
166.380	10	108	13.3	03:30	03-Apr-14		04-Apr-14				26-Mar-14		
166.300	136	112	16.4	03:30	03-Apr-14		04-Apr-14						
166.300	137	135	25.3	04:50	03-Apr-14		04-Apr-14						
166.300	138	112	16.1	04:00	03-Apr-14		04-Apr-14						
166.300	139	132	24.3	00:30	03-Apr-14								
166.300	140	104	13.0	03:00	03-Apr-14		04-Apr-14				06-Apr-14		
166.300	141	115	16.8	03:20	03-Apr-14	05-Apr-14	05-Apr-14				06-Apr-14		12-Apr-14
166.300	142	106	12.2	01:40	03-Apr-14				10-Apr-14				
166.300	143	108	13.3	05:10	03-Apr-14	03-Apr-14	04-Apr-14				05-Apr-14		
166.300	144	126	19.0	03:30	03-Apr-14	03-Apr-14				05-Apr-14	05-Apr-14		
166.300	145	100	10.9	07:30	03-Apr-14	03-Apr-14	04-Apr-14			05-Apr-14	05-Apr-14		
166.300	146	118	18.3	02:15	03-Apr-14	03-Apr-14	04-Apr-14			05-Apr-14			
166.300	147	119	18.8	02:20	03-Apr-14	04-Apr-14	04-Apr-14			05-Apr-14	05-Apr-14		
166.300	148	90	7.7	03:20	03-Apr-14	03-Apr-14	04-Apr-14				05-Apr-14		
166.300	149	128	22.5	01:30	03-Apr-14		04-Apr-14			05-Apr-14	05-Apr-14		
166.300	150	98	10.0	02:00	03-Apr-14	03-Apr-14	04-Apr-14				05-Apr-14		
166.300	151	166	42.0	04:50	03-Apr-14	03-Apr-14				05-Apr-14	05-Apr-14		
166.300	152	117	16.8	02:10	03-Apr-14	03-Apr-14	04-Apr-14			04-Apr-14			
166.300	153	102	11.9	00:40	03-Apr-14		07-Apr-14						
166.300	154	100	10.3	03:00	03-Apr-14		05-Apr-14						
166.300	155	110	13.1	03:07	03-Apr-14	03-Apr-14	04-Apr-14						
166.300	156	101	11.8	04:18	03-Apr-14		05-Apr-14			05-Apr-14	05-Apr-14		
166.300	157	131	25.5	03:58	03-Apr-14	03-Apr-14	04-Apr-14		08-Apr-14		08-Apr-14		
166.300	158	104	11.8	01:32	03-Apr-14	03-Apr-14					05-Apr-14		

166.300	159	112	15.9	01:24	03-Apr-14		04-Apr-14			05-Apr-14	05-Apr-14		
166.300	160	109	14.6	01:45	03-Apr-14		04-Apr-14			05-Apr-14	05-Apr-14	06-Apr-14	
166.300	161	126	19.2	00:49	03-Apr-14	03-Apr-14	04-Apr-14				05-Apr-14		
166.300	162	150	36.2	02:30	03-Apr-14		04-Apr-14				05-Apr-14		
166.300	163	121	19.5	00:47	03-Apr-14		04-Apr-14				04-Apr-14		
166.300	164	103	13.2	03:43	03-Apr-14		04-Apr-14			05-Apr-14	05-Apr-14		
166.300	165	132	24.6	01:22	03-Apr-14	03-Apr-14	04-Apr-14						
166.300	166	127	23.0	02:22	03-Apr-14	03-Apr-14					05-Apr-14		
166.300	167	118	19.1	02:38	03-Apr-14	04-Apr-14				05-Apr-14	05-Apr-14		
166.300	168	125	22.0	02:13	03-Apr-14		04-Apr-14	05-Apr-14			05-Apr-14		
166.300	169	115	17.3	03:30	03-Apr-14		04-Apr-14						
166.300	170	133	25.0	03:55	03-Apr-14								
166.300	171	111	15.2	03:31	03-Apr-14	03-Apr-14	05-Apr-14			06-Apr-14	06-Apr-14		
166.300	172	112	15.2	03:23	03-Apr-14	04-Apr-14	05-Apr-14				05-Apr-14		
166.300	173	126	24.6	01:01	03-Apr-14		04-Apr-14				05-Apr-14		
166.300	175	110	13.5	05:04	03-Apr-14	03-Apr-14					06-Apr-14		

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 Mouth	Site 2 DR Buck Hollow	Site 3 DR RKM 13	Site 4 DR RKM 9	Site 5 DR RKM 5 upstream	Site 6 DR RKM 5 downstream	Deschutes River Mouth RKM 0	Bonneville Dam
166.380	8	113	16.1	02:23	03-Apr-14	03-Apr-14	05-Apr-14				10-Apr-14		
166.380	9	114	16.0		03-Apr-14	04-Apr-14							
166.300	174	126	20.5	02:40	03-Apr-14	04-Apr-14	05-Apr-14			05-Apr-14	05-Apr-14		
166.380	176	124	19.9	03:00	03-Apr-14					05-Apr-14			
166.380	177	115	17.3	02:20	03-Apr-14								
166.380	178	102	11.0	03:15	03-Apr-14						05-Apr-14		
166.380	179	130	25.2	06:00	03-Apr-14		04-Apr-14				05-Apr-14		
166.380	180	115	17.0	03:30	03-Apr-14				11-Apr-14	11-Apr-14			
166.380	181	120	18.4	04:10	03-Apr-14	03-Apr-14	04-Apr-14			05-Apr-14	05-Apr-14		

166.380	182	123	20.3	02:45	03-Apr-14								
166.380	183	113	16.4	06:00	03-Apr-14		06-Apr-14		06-May-14	07-May-14	07-May-14		
166.380	184	140	29.0	04:20	03-Apr-14		05-Apr-14			06-Apr-14	06-Apr-14		
166.380	185	128	24.4	04:15	03-Apr-14	03-Apr-14	04-Apr-14			05-Apr-14	05-Apr-14		
166.380	186	124	21.6	05:15	03-Apr-14		05-Apr-14		08-Apr-14		09-Apr-14		
166.380	187	106	12.2	02:40	03-Apr-14		05-Apr-14						
166.380	188	118	19.0	00:00	03-Apr-14		04-Apr-14	05-Apr-14			05-Apr-14		
166.380	189	116	17.1	04:40	03-Apr-14								
166.380	190	104	11.3	03:20	03-Apr-14								
166.380	191	99	10.2	02:55	03-Apr-14	03-Apr-14	16-Apr-14		18-Apr-14	18-Apr-14	18-Apr-14		
166.380	192	114	15.6	06:20	03-Apr-14		04-Apr-14						
166.380	193	110	13.7	03:00	03-Apr-14				25-Apr-14		26-Apr-14		
166.380	194	118	18.1	03:00	03-Apr-14	04-Apr-14							
166.380	195	118	17.7	04:58	03-Apr-14								
166.380	196	113	17.4	01:58	03-Apr-14	03-Apr-14				05-Apr-14	05-Apr-14		
166.380	197	139	28.9	03:01	03-Apr-14		04-Apr-14				05-Apr-14		
166.380	198	118	18.0	02:33	03-Apr-14	03-Apr-14							
166.380	199	120	17.8	04:43	03-Apr-14	04-Apr-14	04-Apr-14	05-Apr-14		05-Apr-14			
166.380	200	116	16.0	04:49	03-Apr-14	03-Apr-14				05-Apr-14	05-Apr-14		
166.380	201	123	19.5	04:36	03-Apr-14	04-Apr-14				05-Apr-14	05-Apr-14		
166.380	202	122	18.4	02:23	03-Apr-14	12-Apr-14	14-Apr-14		15-Apr-14		15-Apr-14		
166.380	203	125	20.7	04:07	03-Apr-14	03-Apr-14	04-Apr-14				05-Apr-14		
166.380	204	115	15.5	03:56	03-Apr-14		04-Apr-14				05-Apr-14		
166.380	205	111	14.9	00:13	03-Apr-14	03-Apr-14	04-Apr-14				05-Apr-14		
166.380	206	129	23.6	00:24	03-Apr-14	03-Apr-14					05-Apr-14		
166.380	207	113	16.5	05:17	03-Apr-14								
166.380	208	121	19.4	04:07	03-Apr-14	04-Apr-14	05-Apr-14			16-Apr-14	16-Apr-14		
166.380	209	106	12.6	02:28	03-Apr-14	05-Apr-14							
166.380	210	116	18.6	01:47	03-Apr-14					05-Apr-14	05-Apr-14		
166.380	211	117	17.4	03:34	03-Apr-14	03-Apr-14				05-Apr-14	05-Apr-14		
166.380	212	108	13.9	05:49	03-Apr-14		05-Apr-14						

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