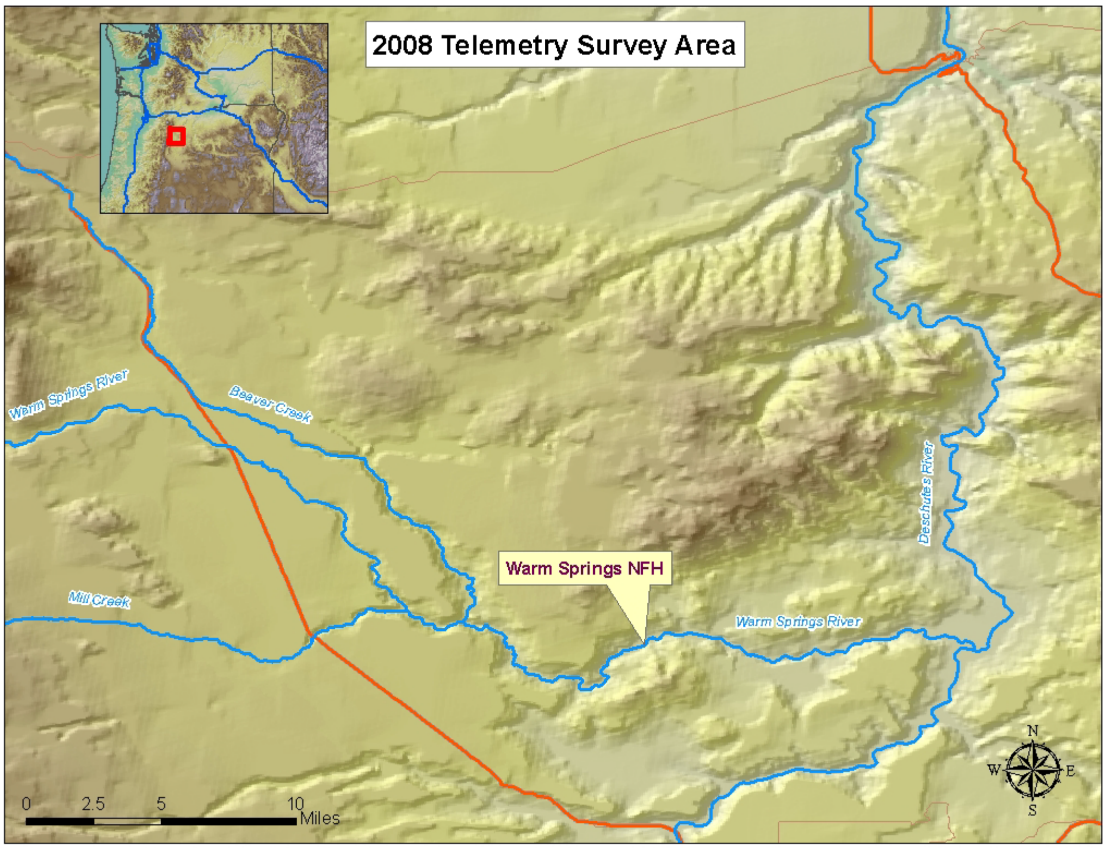
Distribution and Survival of Adult Hatchery Spring Chinook Salmon Radio-Tagged and Released Upstream of Warm Springs National Fish Hatchery in 2008
Progress Report



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Abstract

The Warm Springs River supports the largest population of wild spring Chinook salmon *Oncorhynchus tshawytscha* in the Deschutes River Basin. Located on the Warm Springs River in north-central Oregon, the Warm Springs National Fish Hatchery was constructed in 1978 and produces spring Chinook salmon for sport and tribal harvests. Current hatchery practices intend to minimize disturbance to upstream wild fish populations by limiting the number of hatchery fish passed upstream. Concerns over the low numbers of wild fish returns, increasing pre-spawning mortality, and significant reductions in wild genetic integration into hatchery broodstock have led to inquiry over the fate of spring Chinook salmon passed above Warm Springs National Fish Hatchery. Increasing the number of hatchery fish allowed upstream of the hatchery has been suggested as a potential management action to compensate for the low wild fish numbers. The ecological and genetic consequences of this potential management action are currently unknown. To gain further insight on these management concerns, 35 hatchery-origin spring Chinook salmon were radio-tagged during the spring and summer of 2008 and released upstream of the hatchery to study their movement patterns, identify potential holding areas, estimate survival, and approximate their contribution to spawning. During the duration of the study, 45% of the radio-tagged fish migrated downstream of the hatchery and seven fall-back fish were recovered at the hatchery; however the majority of downstream migrants remained downriver. Based on tag movements during the spawning period, an estimated 60% of the tagged fish survived to spawning. Additionally, an estimated 31% of the radio-tagged hatchery fish contributed to natural spawning based on tag movement distance and location on traditional spawning grounds during the spawning period. The distribution of hatchery fish during spawning differed from the natural distribution of redds both within year, and historically. This report summarizes the first year of a multiyear study conducted by the United States Fish and Wildlife Service and Confederated Tribes of the Warm Springs Reservation of Oregon to monitor the distribution and survival of adult hatchery spring Chinook salmon radio-tagged and released upstream of Warm Springs National Fish Hatchery.

Introduction

Warm Springs National Fish Hatchery (NFH) is located at river kilometer (rkm) 17 of the Warm Springs River within the Warm Springs Indian Reservation of Oregon. The Warm Springs River is a major tributary of the Deschutes River entering at rkm 134 in north-central Oregon. The facility is cooperatively managed by the United States Fish and Wildlife Service (USFWS) and the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) with the primary intent of producing spring Chinook salmon *Oncorhynchus tshawytscha*, for harvest opportunities in the Deschutes River and Reservation waters (Olson et al. 1995). The production goal of the hatchery is to provide 2,925 hatchery origin spring Chinook salmon to the mouth of the Deschutes River for harvest and broodstock needs (CTWSRO and USFWS 2007). The broodstock objective is to collect 630 adults each year for a maximum release of 750,000 adipose fin clipped and coded wire tagged (CWT) juvenile smolts (USFWS 2006). In addition to providing harvest opportunities for tribal and sport fisheries in the Deschutes River, Warm Springs NFH operates with the intent of promoting the preservation and enhancement of the wild fish stocks in the Warm Springs River.

Since full production began in 1978, Warm Springs NFH has maintained an adaptive management strategy to meet production goals and minimize risks to native fish populations. While artificial propagation can be successful at increasing salmon abundance and supporting harvest, hatcheries can also increase risks to native fish populations. If managed incorrectly, hatcheries can threaten native populations with ecological, genetic, and management risks (Kostow 2008). To minimize these types of risks, Warm Springs NFH has attempted to maintain the genetic and life-history characteristics of the wild stock in the hatchery population by implementing an integrated broodstock strategy. The hatchery's goal is to have, on a 10 year average, 10% of the broodstock be of wild fish origin (USFWS 2006). Incorporating wild fish into the broodstock helps to maintain phenotypic traits that represent the wild population, and minimizes artificial selection and domestication of the hatchery stock. Reducing or eliminating genetic divergence between hatchery fish and the natural spawning population works to lessen potential negative impacts on wild stocks caused by hatchery fish spawning in the wild (Olson et al. 2004).

Each year, the predicted number of wild returning adults is used to determine how many wild fish can be integrated into the hatcheries broodstock without negatively impacting the wild population's reproduction potential. Under the current operation plan, the escapement objective for wild spring Chinook salmon is a minimum 1,000 wild adults passed above the hatchery to spawn naturally (CTWSRO and USFWS 2007). The long term goal is to reach an annual spawning population of 2,800 wild adult Chinook salmon, which would be similar to wild runs in the system before the hatchery was constructed. A sliding scale, based on preseason wild fish run predictions, is used to determine the number of wild fish held at the hatchery for broodstock. If the wild run prediction is less than 1,000 fish, wild fish are not collected for broodstock. Due to a declining trend in wild fish runs (Fig. 1) and difficulties in predicting the true size of wild fish runs, there have recently been several years where wild fish have not been integrated into hatchery broodstock (Fig. 2). Wild fish contributed to 68% of the hatchery's broodstock between

1978 and 1987 (Olson et al. 2004). On average, only 3% of hatchery broodstock has consisted of wild fish from return years1990 to 2009.

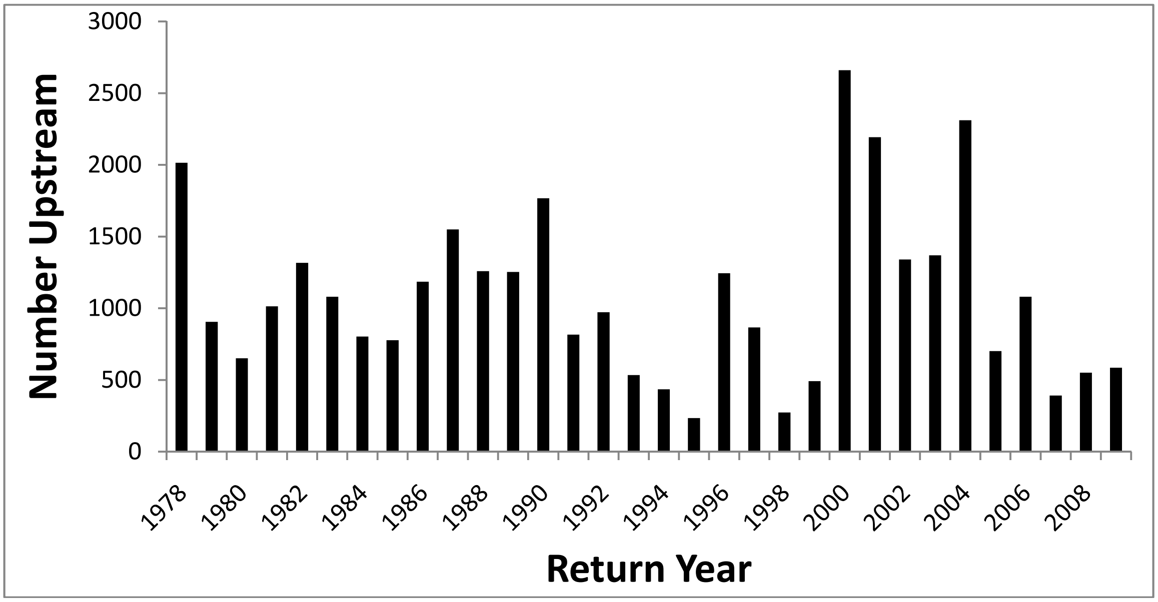

Figure 1. Number of wild (unmarked) spring Chinook salmon passed upstream of Warm Springs National Fish Hatchery 1978-2009. A small percentage (< 5%) of unmarked fish each year may be hatchery fish.

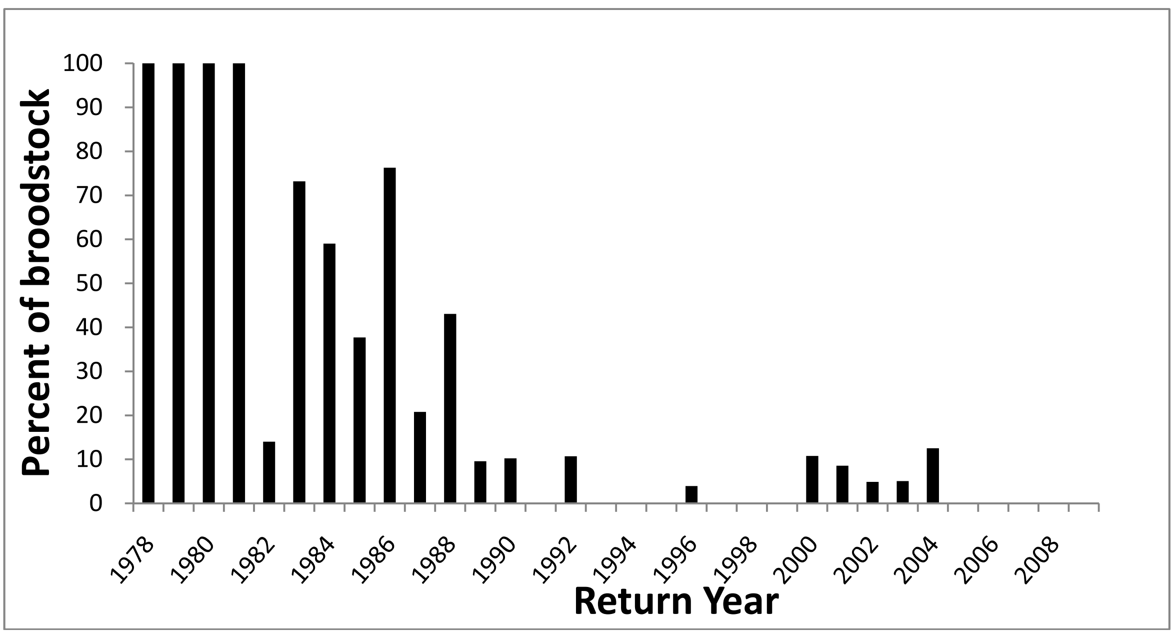

Figure 2. Percentage of hatchery broodstock consisting of wild spring Chinook salmon collected at Warm Springs National Fish Hatchery, for return years 1978-2009.

In addition, to declining numbers of returning wild adults, it appears that the pre-spawning mortality of wild adults upstream of the hatchery has increased in recent years; with an average of 5.1 fish per redd between 2000 and 2007 compared to 3.3 fish per redd between 1990 and 1999. It is unknown what is causing this observed shift in pre-spawning mortality, but it could be linked to changes in habitat, handling stress while passing upstream of Warm Springs NFH, increased predation, or fishing pressure upstream of the hatchery. The canyon area, between the hatchery and the mouth of Beaver Creek (rkm 31), is a 13.4 kilometer section of river containing deep pool habitats. This remote stretch of river is considered to be the primary pre-spawning holding area for spring Chinook salmon in the Warm Springs River (Cates 1992). An aerial radio-tracking study conducted in 1979 and 1980 indicated that 58 of 64 (90.6%) wild adult spring Chinook salmon tagged in the Deschutes River entered the Warm Springs River to spawn. Researchers reported most of the fish held until August in the Warm Springs River canyon within seven miles (11.2 rkm) upstream of the hatchery (Lindsay et al. 1989).

A man-made barrier dam spans the entire width of the Warm Springs River at the hatchery and directs all upstream migrating fish into a fish ladder adjacent to Warm Springs NFH. In order to continue upstream, all migrating fish must navigate the hatchery fish ladder and pass through an automated passage system or be selectively passed upstream by hatchery staff. Typically, the passage system separates wild and hatchery fish by detecting CWT's in the snout of the hatchery fish (Olson et al. 2004). If the system detects metal CWT's, it is designed to divert these fish into the hatchery catch ponds, allowing fish without CWT's to proceed upstream without being handled. Some hatchery fish may lose their CWT through improper placement during tagging operations. The goal of the hatchery is to have a minimum 97% coded-wire tag retention rate (CTWSRO & USFWS 2007). Manual marking at Warm Springs NFH for brood years 1993 to 2000, 2002, and 2003 produced an average annual tag-retention rate of 93% with a range of 85% to 97% (Fig. 3). For brood years 2001 and 2004, the automated marking trailer was used to mark and tag fish in an attempt to increase the tag-retention rate. The average tag-retention rate for these two brood years was 97% and 99%, respectively (Hand et al. 2007).

Tag loss in hatchery fish and the mechanical design of the bypass system results in a number of hatchery fish being allowed to pass upstream of the facility. Current program objectives require that no more than 10% of the total Chinook passed upstream should be of hatchery origin (USFWS 2006). Video surveillance footage is reviewed by hatchery staff to estimate the number of wild and hatchery fish passed upstream. If video data indicates that greater than 10% of the adult Chinook passed upstream are of hatchery origin, the automated passage system is deactivated, and all fish are sorted by hand. The automated passage can be reactivated once the upstream hatchery fish proportion falls below the 10% threshold.

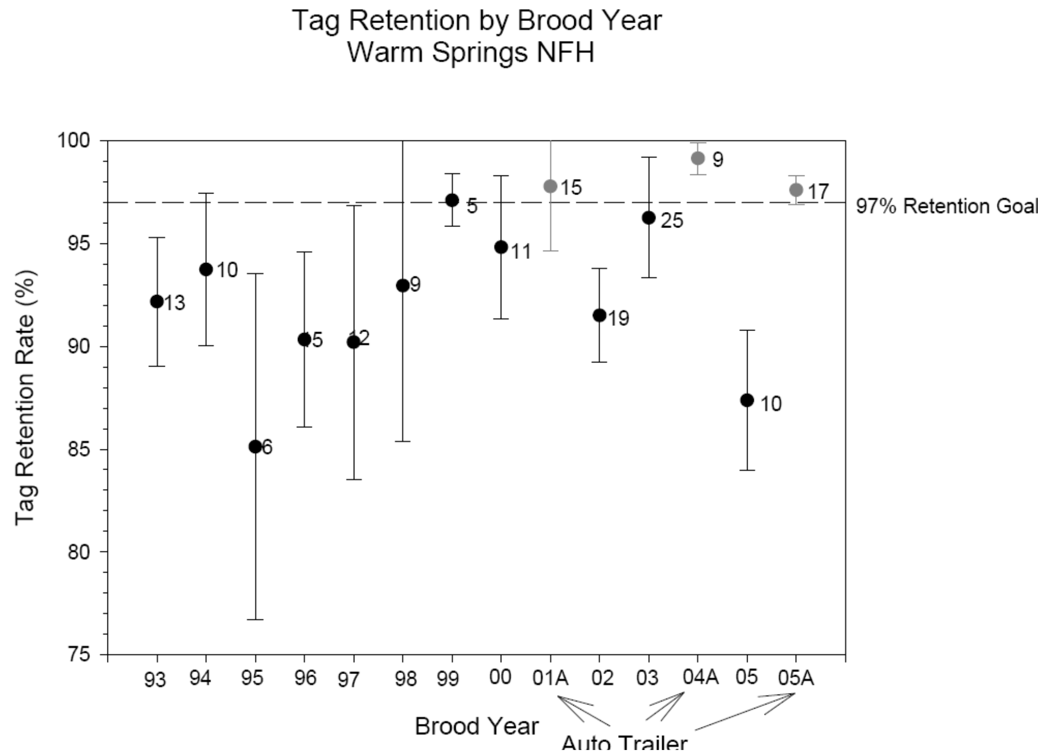

Figure 3. Coded Wire Tag retention rates for spring Chinook salmon marked and tagged at Warm Springs NFH, brood years 1993 to 2005. All brood years were tagged using a manual trailer except for brood years 2001, 2004, and part of 2005. The number of tag groups is given, error bars are 1 standard deviation (Hand et al. 2007).

The natural reproduction of hatchery origin spring Chinook salmon in the Warm Springs River was first examined by USFWS researchers in 1983 to determine if hatchery spring Chinook released above the barrier dam at Warm Springs NFH would enter the historical spawning areas and successfully spawn (Cates 1992). Researchers jaw tagged 192 adult, hatchery-origin, spring Chinook salmon and released them upstream of the hatchery. A fish that was released upstream, fell below the barrier dam, and subsequently reentered the hatchery was considered a fall-back. Fall-back behavior was observed 19 times (7.3%) and represented 14 individual fish. A total of 6.5% of the tagged fish were recovered as carcasses on traditional spawning grounds, all of which showed signs of having successfully spawned. Cates (1992) reported that the distribution of tagged carcasses on the spawning grounds was similar to the historical wild distribution, with 70% in the mainstem Warm Springs River, 25% in Beaver Creek, and 5% in Mill Creek. No abnormal mortalities prior to spawning or any significant distribution deviation from wild fish were found. The researchers concluded that “while some hatchery fish released above Warm Springs NFH will linger in the vicinity of the hatchery, most will enter historical spawning areas (Cates 1992).”

Concerns over the low numbers of wild fish returns, increasing pre-spawning mortality, and significant reductions in wild genetic integration into hatchery broodstock have led to questions about the fate of spring Chinook salmon passed above Warm Springs NFH. Additionally, the distribution and survival of hatchery origin adults bypassed upstream of the facility has not been monitored since 1983. Increasing the number of hatchery fish allowed upstream of the hatchery is one potential management action to compensate for the low wild fish numbers; however the genetic and demographic consequences of such an action are not known. Understanding the distribution and survival of hatchery fish released upstream of the hatchery will provide insight into upstream habitat and fish behavior that can help guide future management decisions.

This progress report summarizes a radio-telemetry study conducted in the spring and summer of 2008 by the USFWS Columbia River Fish Program Office (CRFPO) and the Fisheries Department of the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). Specific objectives for this radio-telemetry study were to: 1) document the spatial/temporal migration patterns including fall-back rates of adult hatchery spring Chinook salmon released upstream 2) estimate the release to spawning survival of hatchery fish released upstream 3) determine holding areas for adult spring Chinook salmon upstream, and 4) estimate the contribution of hatchery fish to the natural spawning population of spring Chinook salmon upstream of Warm Springs NFH.

Methods

Hatchery origin spring Chinook salmon were radio-tagged at Warm Springs NFH while the hatchery was performing standard surplus, sorting, and spawning activities in the spring and summer of 2008. A total of 35 radio-tags were available for this study. Fish were tagged proportionately throughout the hatchery run based on historical run timing and broodstock collection. During normal hatchery operations, small groups (5-10) of returning hatchery fish were crowded into a holding basket and anesthetized with dissolved CO^2 in water prior to handling. Hatchery fish were randomly selected from the holding basket for radio-tagging, measured for fork length, and placed ventral side up in a tub of fresh water so the tag could be gastrically inserted. The radio-transmitters used during this study were Model MCFT-3A fish transmitters manufactured by Lotek Wireless, Inc., of Newmarket, Ontario, Canada. They were 16 mm in diameter, 46 mm long, and had a 460-mm-long antenna. Radio-tags were fitted with a 10 mm section of surgical tubing and treated with Argentine iodine prior to insertion. Radio-tags were gastrically inserted into the gullet just posterior to the pectoral fins with a ½ inch diameter polyvinyl chloride (PVC) pipe. After tagging, fish were passed down a sorting tube to the upstream end of the hatchery’s fish ladder. Once recovered from the anesthetic, fish could migrate volitionally upstream above the barrier dam and enter the upper Warm Springs River drainage.

Since the majority of the upper Warm Springs River drainage is remote and inaccessible by road, radio-tagged fish were primarily tracked with fixed-wing aerial surveys. Aerial surveys were conducted on a monthly basis from May until October. As described in Hockersmith (1997) and Roberts (2005), radio-transmitter locations were marked with a

Global Positional System (GPS) when the aircraft telemetry receiver received the strongest power signal from each transmitter. In addition to aerial tracking, a fixed site data logging radio-telemetry receiver was positioned approximately 400 meters downstream of Warm Springs NFH to detect fish movement below the hatchery. Both the aerial and fixed site stations used Lotek Model TRX400 receivers with 4-element Yagi antennas. The stationary system was tested with a test tag in the stream to determine gain settings, antenna direction, and to ensure all codes detected were downstream of the hatchery. Additional radio-tracking surveys via vehicle and kayak were also conducted along limited portions of the survey area. The CTWSRO conducted multiple-pass redd surveys in indexed spawning reaches in the Warm Springs River Drainage during August and September of 2008.

Data fields collected from all telemetry surveys used in this study included the following: unique radio-tag code, tag frequency, detection date, detection method, location description, GPS coordinates, number of detections (mark), power, and comments. All data was entered into an Excel file and imported into an ArcGIS database for quality control, analytical purposes, and map design. Data fields were combined with a Deschutes Basin stream layer, NAIP image layer, Oregon highway layer, and Elevation hill shade layer. With GPS points overlaid onto ArcGIS layers, river kilometers of each point location could be digitally calculated so distribution and migration patterns of each fish could be quantitatively analyzed.

Objective 1

<u>Document fall-back rates and spatial/temporal migration patterns and of adult hatchery spring Chinook salmon released upstream of Warm Springs NFH</u>

Consistent with the USFWS study conducted in 1983, as described in Cates (1992), a fall-back was defined as any fish that was tagged and released upstream of the hatchery and subsequently migrated downstream of the barrier dam and was captured again in the fish ladder by hatchery staff. To determine fall-back rates, the total number of individual fall-back fish (f) was divided by the total number of fish that were originally tagged and passed above the hatchery (n). If a fish fell back more than one time it was only counted as one fish. Fall-back counts from the 1983 jaw tagging study were compared to the 2008 telemetry fall-back counts with a 2x2 chi-square test. The percent of fall-backs is expressed by the following equation.

$$(f/n)*100\%$$

With the use of radio-tags, the proportion of fish that fell below the barrier dam but didn't reenter the hatchery could be quantified. In this study, downstream migrants that fell below the barrier dam, including those that returned to the hatchery and those that did not, is expressed as (d). The percent of downstream migrants is expressed by the following equation.

$$(d/n)*100\%$$

Spatial and temporal migration patterns were documented with the aid of ArcGIS mapping software. In order to document changes in tagged fish distribution over time, aerial detections for each month were overlaid onto ArcGIS maps. The number of fish tagged, and the date of aerial survey along with a brief summary of tag locations is provided with each map. There are a total of five aerial detection maps beginning in the month of June and ending with the final detections in October. This information is a broad overview and documentation of migration trends during this tagging year and was not statistically analyzed.

Tag detection efficiency of the downstream stationary receiver (R_1) was estimated as the percentage of fish detected that were estimated to have migrated within the survey range. For this, any tagged fish detected downstream by aerial survey (R_2) was assumed to have passed within range of the stationary receiver. For this calculation a variation of a Lincoln Peterson mark-recapture calculation described in Horton (2007) was used. The efficiency of the aerial flights could not be estimated due to the possibility that a tagged fish could pass within the survey area and then leave the survey area while flights were not occurring. The efficiency of the stationary receiver (EFF_{R1}) was estimated by calculating the number of individual tag codes detected by R_1 and detected on R_2 (Recap) and dividing this by the total number of individual codes detected on just the downstream aerial receiver. This ratio was then multiplied by 100%.

$$EFF_{R1} = 100\% \,((Recap)/ R_2)$$

<u>Estimate the release to spawning survival of hatchery fish released upstream of Warm Springs NFH.</u>

One of the most important considerations in the application of survival analysis to radio-telemetry data is the definition of a time origin (Pollock et al. 1989). Past research on the Warm Springs River has indicated that natural spawning of spring Chinook salmon typically starts around mid August (Cates 1992). Warm Springs NFH spawns fish from August through September, and redd counts are typically conducted in September on the Warm Springs River (CTWSRO & USFWS 2007). Based on this information, August 14^{th} was selected as the start date for the spawning period in this report. All telemetry detections on or after August 14th are considered spawning period detections.

It wasn't logistically feasible to confirm survival through visual detection in this study due to the size and remoteness of the study area. Instead, the distance a tag was detected from a previous known detection location was used to estimate survival. In this report, a tagged fish is assumed to have survived to the spawning period if the radio-tag is detected after August 14^{th} and then subsequently detected at a distance greater than 2 rkm from the previous detection. A tag detection distance of at least 2 rkm is a conservative estimate that indicates the radio-tag likely traveled some distance in a live fish, and that movement was not solely due to aerial detection errors or stream flow. Fish that did not meet these downstream and upstream migration criteria are described as having unknown survival to spawning, since non-detectable movement, or non-detection does not necessarily indicate mortality.

Survivorship (p) is the proportion of individuals surviving throughout a given time period (Bart et al. 1998). Survivorship is defined in this report as the ratio of fish that are assumed to have survived until the spawning period (x) to the number of fish known to be alive at tagging (n).

$$p = x/n$$

<u>Identify holding areas for adult spring Chinook salmon (wild and hatchery) upstream of Warm Springs NFH.</u>

To identify holding areas, spring and summer aerial survey detections were plotted on ArcGIS and mapped. To determine if radio-tagged hatchery fish prefer specific regions within the canyon area or distribute evenly upstream of the hatchery, the canyon holding area was subdivided into seven, equally-spaced, 2 rkm long reaches and the counts of the detections found in each reach were compared with a 7x2 chi-square contingency test. The null hypothesis of this statistical test is that radio-tagged hatchery fish distribute evenly prior to spawning in the canyon area.

<u>Estimate the contribution of hatchery fish to the natural spawning population of spring Chinook salmon upstream of Warm Springs NFH</u>

Contribution to natural spawning was estimated by determining the proportion of surviving radio-tagged fish that were detected in documented spawning habitat during the spawning period. Spawning ground surveys have been conducted on an annual basis in the Warm Springs basin since 1969 (Lindsay et al. 1989). The CTWSRO have been using a subsample of stream reaches, or “index areas’ for annual redd surveys since 1986. These index areas tend to be areas with the greatest concentration of suitable spawning habitat (Lovtang et al. 2008). In this report, a tagged fish was considered a contributor to spawning if it met the survival criteria, and if it was located on a spawning index reach sometime on or after the August 14th spawning start date. ArcGIS was used to construct a map that was overlaid with historical spawning boundaries and spawning period detections to determine the proportion of radio-tagged hatchery fish on spawning grounds. The locations of these detections were briefly described with 2008 Warm Springs redd counts conducted by CTWSRO. Spawning reach boundaries in this report are defined as follows: Culpus Bridge to Warm Springs NFH, Fawn Flats upstream on Beaver Creek to headwaters, from the mouth of Boulder Creek upstream on Mill Creek to headwaters, and from the mouth of Badger Creek upstream on the Warm Springs River to headwaters.

Results

Throughout the 2008 spring and summer adult spring Chinook migration period, 35 fish were successfully radio-tagged and released at Warm Springs NFH (Table 1). In an attempt to avoid run timing bias in the tagging sample, fish were tagged on five separate occasions, loosely following traditional broodstock collection timing (Fig. 4). No mortality, regurgitated tags, abnormal health conditions, or physical abnormalities in any of the tagged fish were observed during the tagging or recovery. All fish tagged in August were males, however due to the undeveloped secondary sexual characteristics in early returning spring Chinook salmon, sex was not determined on fish tagged prior to August. All tagged fish exited the fish ladder and entered the upper Warm Springs River within an hour of tagging. All fork lengths taken in this study were at least five centimeters greater than the Warm Springs NFH standard jack cutoff length of 60 cm, so it is unlikely that any fish used in this study were less than four years old.

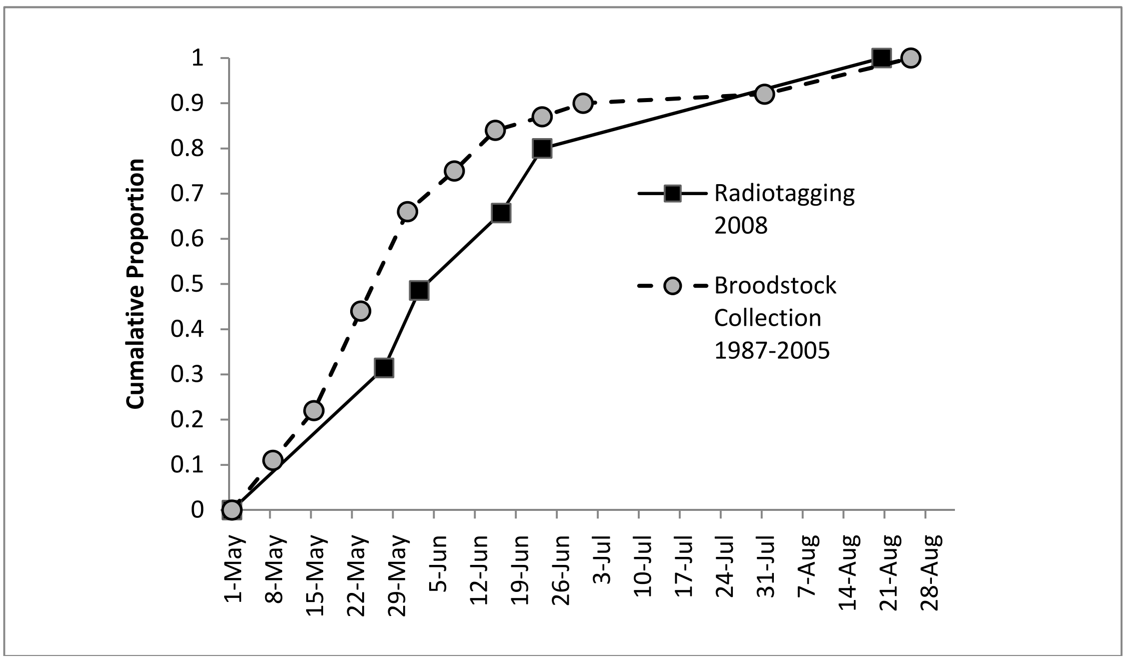

Figure 4. Cumulative radio-tagging of hatchery spring Chinook salmon in 2008 (n=35) and cumulative broodstock collection average from 1987-2005. Broodstock collection is based on an annual goal of 630 adults (CTWSRO and USFWS 2007).

Table 1. Tagging date, fork length, tag code, and sex of radio-tagged spring Chinook salmon at Warm Springs NFH in 2008.

Tag Date	Length (cm)	Tag Code	Sex
5/27/2008	74	10	Unknown
5/27/2008	75	11	Unknown
5/27/2008	72	12	Unknown
5/27/2008	75	13	Unknown
5/27/2008	76	14	Unknown
5/27/2008	73	15	Unknown
5/27/2008	72	16	Unknown
5/27/2008	67	17	Unknown
5/27/2008	68	18	Unknown
5/27/2008	80	19	Unknown
5/27/2008	69	20	Unknown
6/2/2008	68	21	Unknown
6/2/2008	77	22	Unknown
6/2/2008	71	23	Unknown
6/2/2008	71	25	Unknown
6/2/2008	73	26	Unknown
6/2/2008	73	24	Unknown
6/16/2008	73	28	Unknown
6/16/2008	74	29	Unknown
6/16/2008	72	31	Unknown
6/16/2008	67	27	Unknown
6/16/2008	69	30	Unknown
6/16/2008	79	32	Unknown
6/23/2008	82	34	Unknown
6/23/2008	78	33	Unknown
6/23/2008	75	35	Unknown
6/23/2008	80	36	Unknown
6/23/2008	72	37	Unknown
8/20/2008	72	38	Male
8/20/2008	75	39	Male
8/20/2008	77	40	Male
8/20/2008	78	41	Male
8/20/2008	78	42	Male
8/20/2008	74	43	Male
8/20/2008	75	44	Male

Document the spatial/temporal migration patterns and fall-back rates of adult hatchery spring Chinook salmon released upstream of Warm Springs NFH

Of the 35 fish that were radio-tagged and passed above the hatchery in 2008, the ratio of fish that migrated downstream of the hatchery during some portion of the study period (d) was 16/35 (45.7%). Only 19 (54.3%) fish remained upstream of the hatchery over the entire study period. The proportion of fall-backs (f), fish that returned to the hatchery after upstream release, was 7/35 (20%) (Table 2). There is a significant difference in the fall-back ratios between the 1983 jaw-tagging study and the fall-back ratio observed in this study (P = 0.017). The proportion of fish that migrated downstream of the hatchery but never returned to the hatchery was 9/35 (25.7%). Six of the seven fall-back fish were re-passed upstream of the hatchery after capture, and one fish was removed from the study. Of the six re-passed fall-backs, four remained upstream, and two returned to the hatchery again. These two fish were again passed upstream of the hatchery where one remained until spawning, and the other traveled downstream of the hatchery where it remained for the duration of the study.

Table 2. Adult hatchery Spring Chinook salmon fall-backs in 1983 (Cates 1992) and 2008 at Warm Springs National Fish Hatchery.

Year	Number tagged	Fallbacks	Percentage
1983	192	14	7.3%
2008	35	7	20%

Monthly Distribution

June

The June aerial telemetry survey was conducted on 6/23/2008. During this survey, there were a total of 23 adult hatchery spring Chinook tagged and released above the hatchery. The majority of fish detected during the month of June were located within five kilometers of the hatchery (Fig. 5). One fish (code 13), was located upstream of the Beaver Creek confluence, and one fish (code 26), was located in the Deschutes River (not on map). Aerial telemetry detected eight (34%) of the fish downstream of the hatchery and eleven (47%) upstream of the hatchery. Using all telemetry survey methods, thirteen (57%) of the twenty three tagged fish were detected downstream of the hatchery during the month of June.

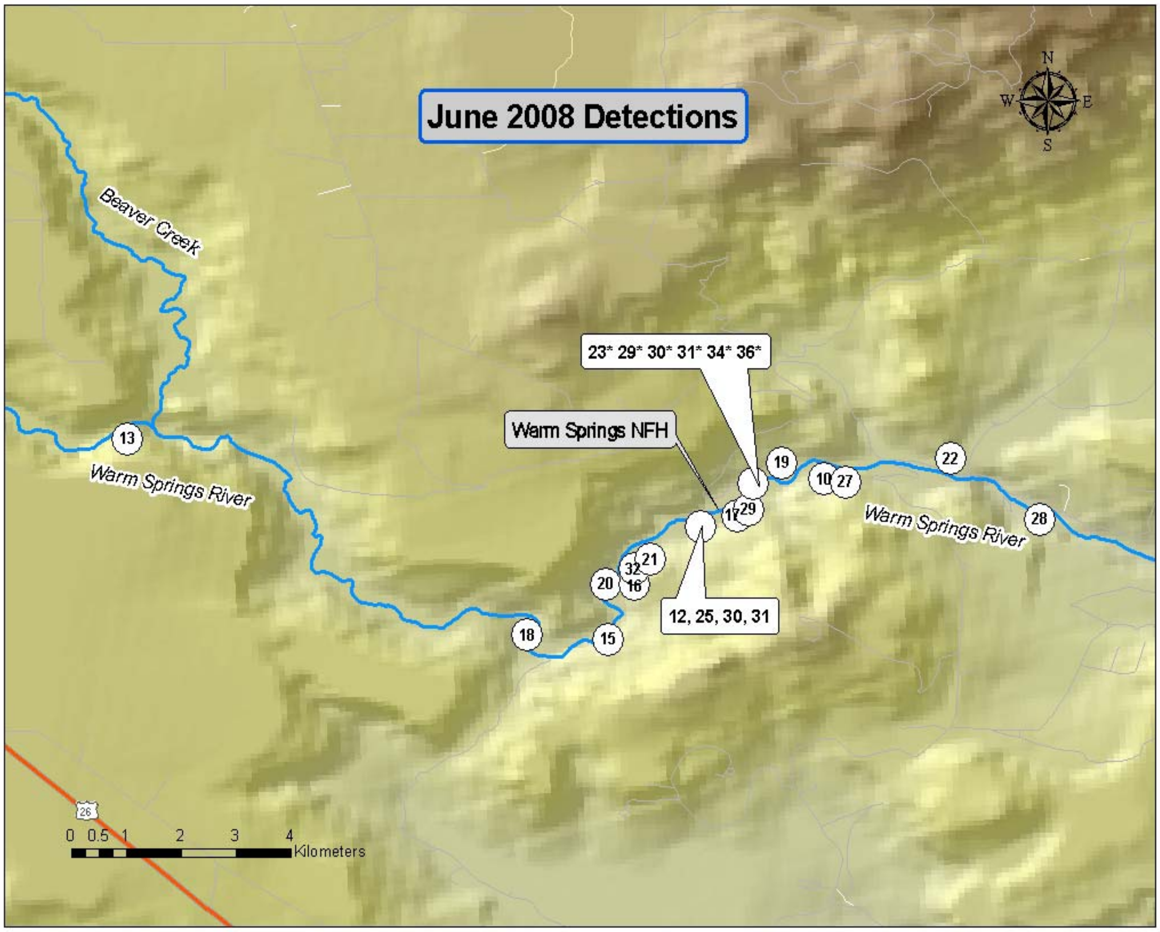

Figure 5. Aerial survey and stationary receiver detections of radio-tagged hatchery spring Chinook salmon (n=23) in June, 2008. Hatchery stationary detections are labeled with an asterisk*.

July

The July aerial telemetry survey was conducted during the summer holding period on 7/21/2008. During this survey, a total of 23 adult hatchery spring Chinook had been tagged and released above the hatchery. The majority of fish detected during the month of July were located either in the 14 kilometer canyon holding area or within 8 kilometers downstream of the hatchery (Fig. 6). Three fish (codes 24, 26, 27), were located in the Deschutes River (not on map). Aerial and stationary survey detected nine of the 23 tagged fish (39%) downstream of the hatchery, and 14 of the 23 tagged fish (61%) were detected upstream of the hatchery.

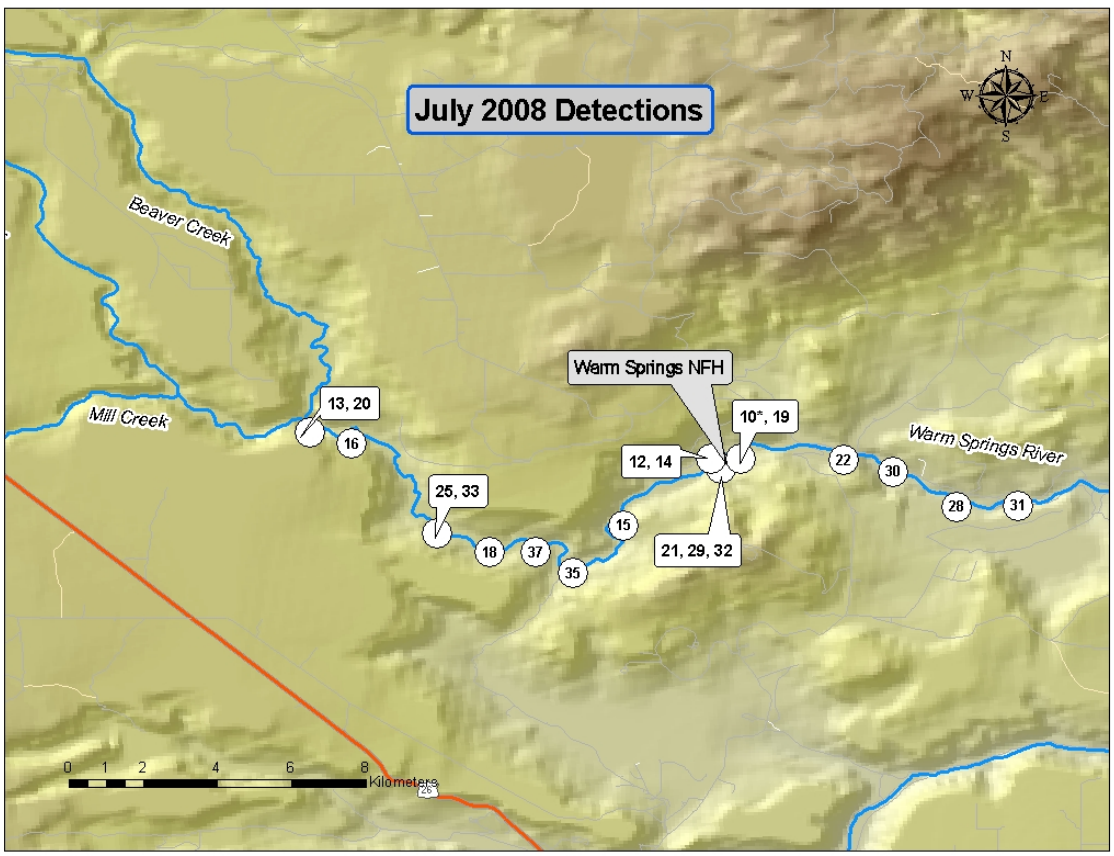

Figure 6. Aerial survey and stationary receiver detections of radio-tagged hatchery spring Chinook salmon (n=23) in July, 2008. Hatchery stationary detections are labeled with an asterisk*.

August Detections by Kayak

Kayak telemetry surveys were conducted on the 14th of August during the beginning of the spring Chinook spawning period. The one-day survey began on Beaver Creek, approximately 1 kilometer upstream of the Beaver Creek confluence, and ended at the hatchery. Kayak surveys provided precise coordinates on nine individual fish locations in the canyon area (Fig. 7). No significant abnormal habitat conditions or fishing activity were observed during the survey. Attempts to observe tagged fish through snorkeling were not feasible due to moderate turbidity and low (<1 meter) underwater visibility.

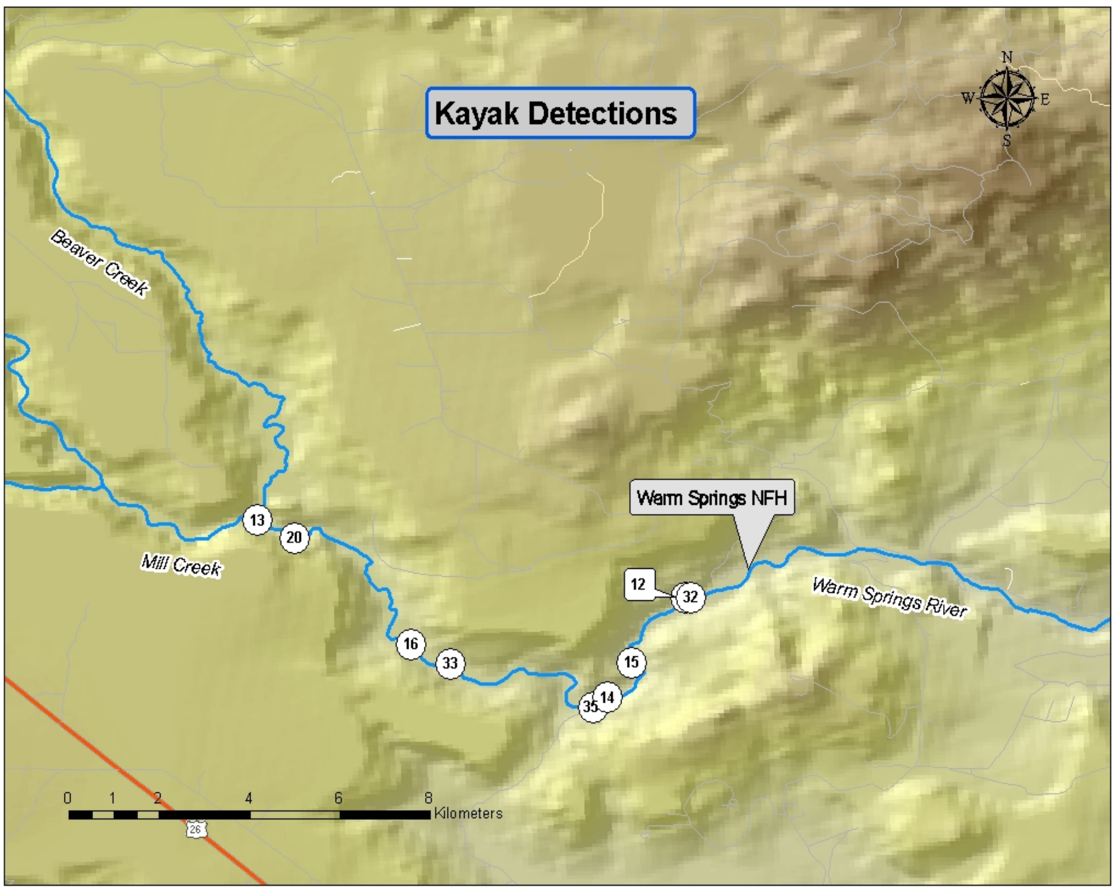

Figure 7. Kayak survey detections of radio-tagged hatchery spring Chinook salmon (n=35) on August 14th, 2008. The survey began on Beaver Creek, approximately 1 kilometer upstream of the Beaver Creek confluence, and ended at Warm Springs NFH.

August

The August aerial telemetry survey was conducted during the spring Chinook spawning period on 8/27/2008. During this survey, all 35 adult hatchery spring Chinook had been tagged and released above the hatchery. The majority of fish detected during the month of August were located in the canyon area (Fig. 8) The August aerial survey detected two fish (codes 23, 24) in the Deschutes River (not on map). Code 23 was located over 60 kilometers downstream of the hatchery tagging point. Aerial survey detected five fish (16%) downstream of the hatchery. Aerial survey detections upstream of the hatchery totaled 19 (54%). Although spawning was underway, relatively few hatchery fish were detected in upper spawning reaches.

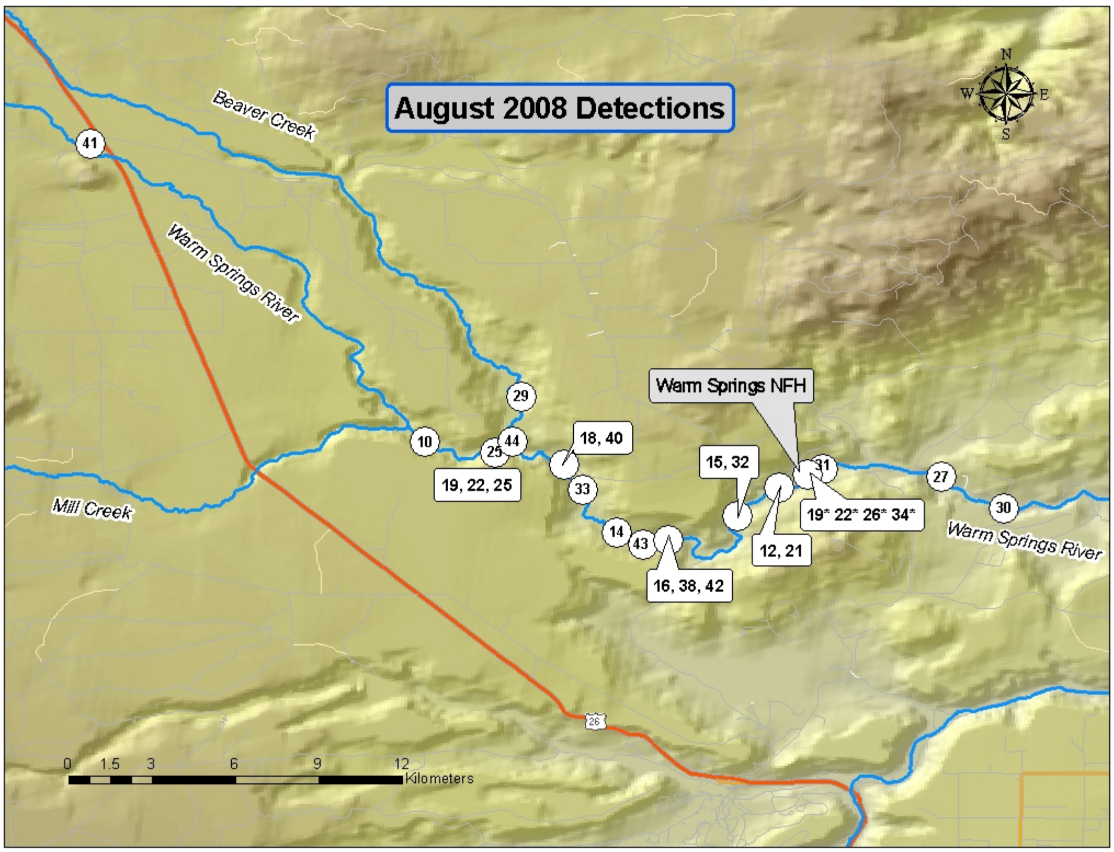

Figure 8. Aerial survey and stationary receiver detections of radio-tagged hatchery spring Chinook salmon (n=35) in August, 2008. Hatchery stationary detections are labeled with an asterisk*.

September

The September aerial telemetry survey was conducted on 9/22/2008, when the majority of spring Chinook spawning was thought to have ended. The individual fish detections in September were less concentrated in the canyon area with more fish detected in traditional spawning areas than previous months (Fig. 9). Of the 21 (60%) fish detected upstream of the hatchery, 13 of them were detected upstream of the Beaver Creek confluence, and eight of them remained in the canyon holding area. Of the ten (29%) fish detected downstream of the hatchery, two fish (codes 23, 28) were detected in the Deschutes River (not on map).

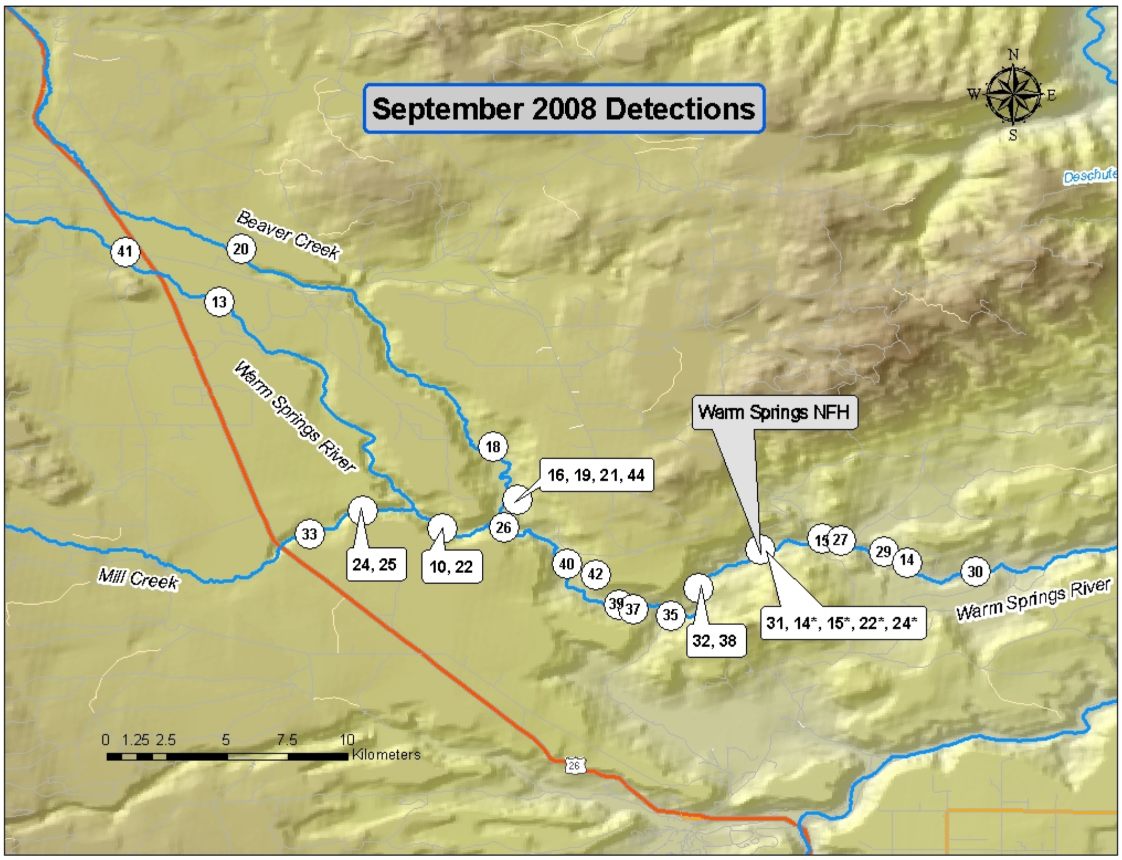

Figure 9. Aerial survey and stationary receiver detections of radio-tagged hatchery spring Chinook salmon (n=35) in September, 2008. Hatchery stationary detections are labeled with an asterisk*.

October

The final 2008 aerial telemetry survey was conducted on October 14th to determine post spawning locations of radio-tagged fish for spawning success and survival estimates. The majority (55%) of the fish detected upstream of the hatchery were located in the canyon holding area. Of the nine tagged fish detected upstream of the Beaver Creek confluence, only four (44%) were located on traditional spawning index reaches. Six (17%) of the 35 tagged fish were detected downstream of the hatchery during the month of October. Aerial surveys were not conducted on the Deschutes River for the month of October. Of the five fish detected in the Deschutes River in previous months, codes 24 and 26 were detected upstream of the hatchery, and code 27 was detected 4 km downstream of the hatchery in October.

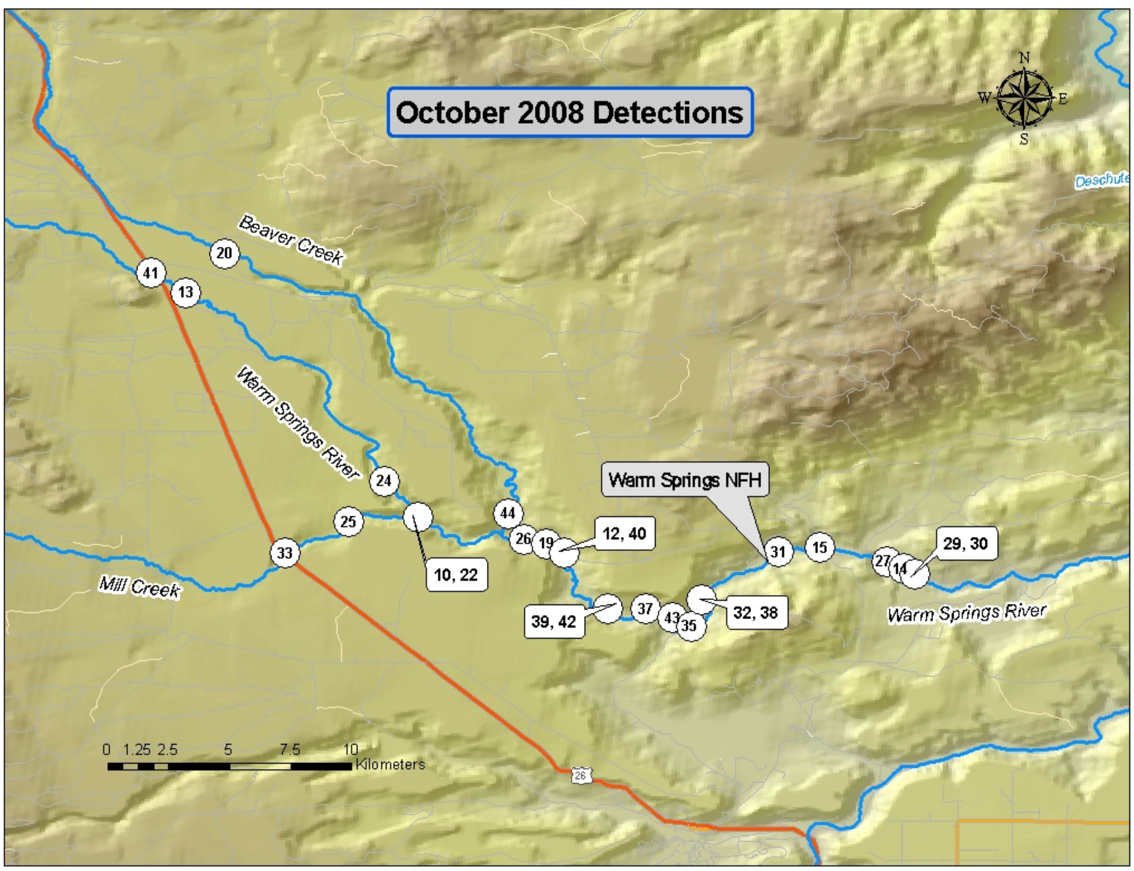

Figure 10. Final post spawning aerial survey detections of radio-tagged hatchery spring Chinook salmon in October, 2008.

Receiver Efficiency

Together, the stationary receiver and the downstream aerial surveys detected 15 unique tag codes, 11 of which were detected by the both receivers. The downstream aerial survey detected a total of 13 unique codes, and the stationary receiver detected a total of 13 unique codes. Each receiver detected two codes that were not detected on the other receiver. The downstream stationary receiver had an estimated efficiency of 84.6%.

<u>Estimate the release to spawning survival of hatchery fish released upstream of Warm Springs NFH.</u>

In 2008 the number of fish alive at tagging (n) was 35. The number of fish estimated to have survived to spawning (x) was 21. Survivorship (p) of the radio-tagged hatchery fish released upstream of Warm Springs NFH, estimated as $p = x/n$, was 21/35 (60.0%). The radio-tags in these 21 fish were detected on or after August 14th and were subsequently detected at a distance greater than 2 rkm from the previous detection (Fig. 11). The remaining 14 of the 35 (40%) radio-tagged fish had insufficient migration distance or non-detection (Table 4). A fall-back fish, (code 17 recovered and surplussed at the hatchery on June 16th), was the only confirmed mortality in the study.

Table 3. Upstream and downstream radio-tag movement distance beginning on August 14th and ending during the fall spawning period between August 14th and October 14th 2008. Fish with movements greater than 2 rkm during this period were considered survivors.

Movement		Number of Fish
Upstream	< 2 rkm	7
Upstream	> 2 rkm	17
Downstream	< 2 rkm	2
Downstream	> 2 rkm	4
Not Detected At Spawning		5
		Total = 35

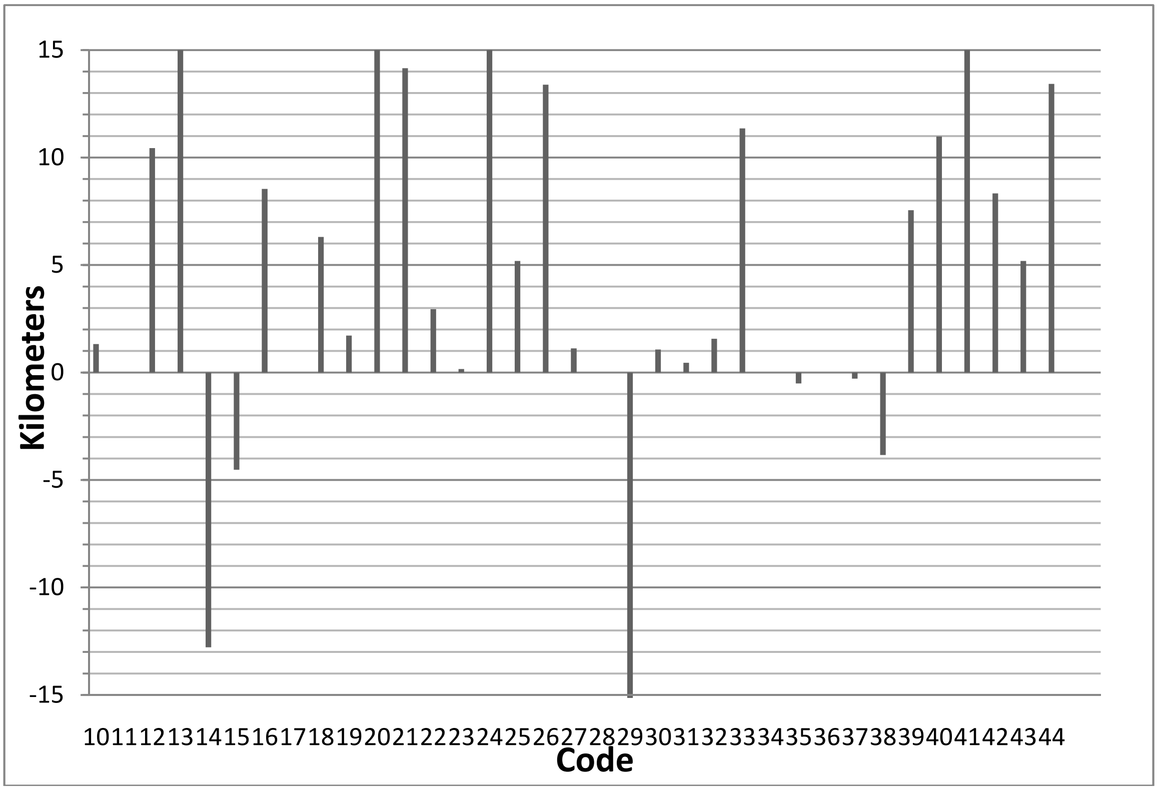

Figure 11. Individual tag movement in rkm during the spring Chinook spawning period. The Y-axis is scaled to a maximum limit of fifteen kilometers although some tags moved greater than fifteen kilometers during the spawning period.

<u>Identify holding areas for adult spring Chinook salmon (wild and hatchery) upstream of Warm Springs NFH.</u>

The majority of surviving radio-tagged hatchery fish held in the Warm Springs River canyon within 13.4 rkm upstream of the hatchery. The majority of downstream migrants held within 2 rkm downstream of the hatchery, however three tagged fish (24, 26, and 27) migrated over 17 rkm to successfully hold during the summer months in the Deschutes River and returned to the hatchery during spawning. Two tagged fish (23 and 28) migrated to the Deschutes River but never returned to the hatchery. The highest counts of aerial detections during the holding period were observed upstream of the hatchery in the canyon area at rkms 18, 20, 25, 26, and 31 (Fig. 12). There is statistical evidence that radio-tagged hatchery spring Chinook do not distribute evenly prior to spawning within the canyon area ($P = 0.028$).

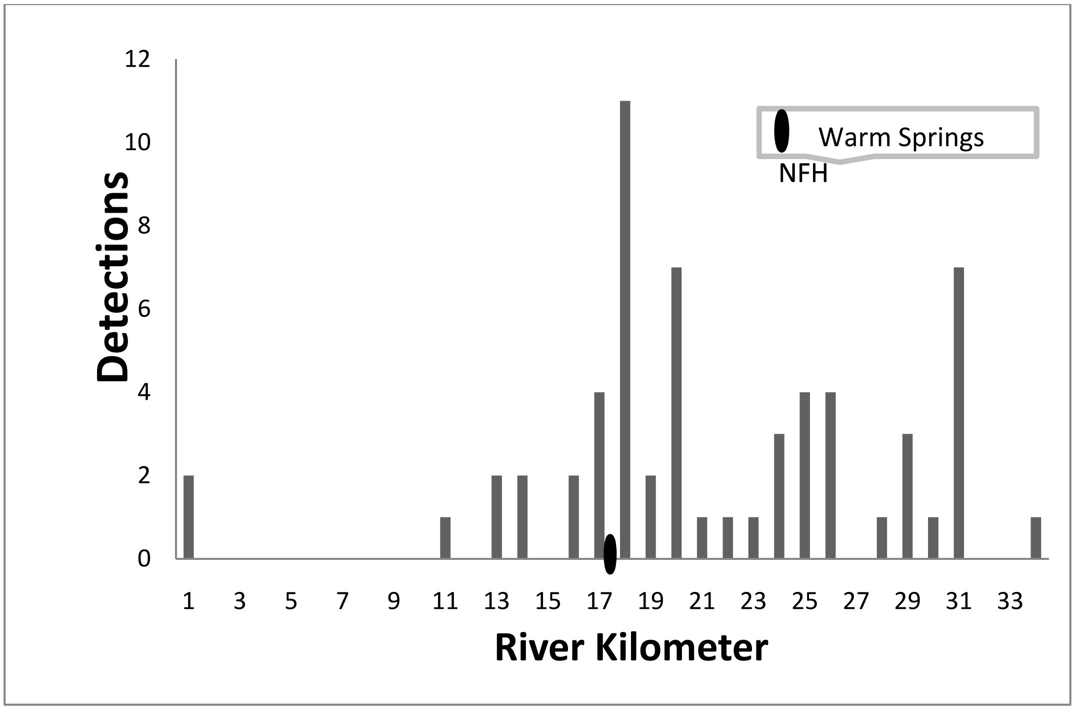

Figure 12. Number of surviving fish detections per river kilometer using aerial radio-telemetry survey on the Warm Springs River during the spring Chinook holding period May 1st through August 14th 2008.

<u>Estimate the contribution of hatchery fish to the natural spawning population of spring Chinook salmon upstream of Warm Springs NFH</u>

Radio-tagged fish that met the survival criteria and were detected in spawning index reaches during the spawning period, were plotted in ArcGIS. The results were mapped along with labels indicating spawning reach boundaries. An estimated 11 of 35 (31%) radio-tagged spring Chinook salmon contributed to spawning in index reaches during 2008 (Fig 13). Two radio-tagged fish were detected upstream of Badger Creek on the Warm Springs River, which based on historical redd counts, is the most productive spring Chinook spawning area in the Warm Springs drainage. A large percentage of redds are typically found upstream of the Badger Creek spawning boundary, and this area represented 61.7% of the 107 redds counted in 2008. Seven surviving fish were detected upstream of the Fawn Flats spawning boundary on Beaver Creek. Historically, these reaches are moderately productive, and accounted for 24.3% of the redds documented in 2008. No fish were detected on Mill Creek upstream of the Boulder Creek spawning boundary. The Mill Creek spawning area accounted for 14.0% of redds counted in 2008. Two surviving fish were detected in between the Warm Springs NFH and Culpus Bridge spawning boundaries during the spawning period. Redd counts were not conducted by CTWSRO downstream of Warm Springs NFH in 2008, however historical redd count data indicates this reach averages 2.1% of the total redd counts for the Warm Springs drainage (Table 4).

Table 4. Distribution of surviving radio-tagged adult hatchery spring Chinook salmon and spring Chinook salmon redds within spawning index reaches in the Warm Springs River Drainage. Historic redd survey data from 1986-2004. *Redd surveys were not conducted downstream of the hatchery in 2008.

Method	Badger Creek WSR	Mill Creek	Beaver Creek	Hatchery D/S
2008 Telemetry	18%	0%	63%	18%
2008 Redd Survey	62%	14%	24%	0%*
Historical Redd Survey	66%	9%	23%	2%

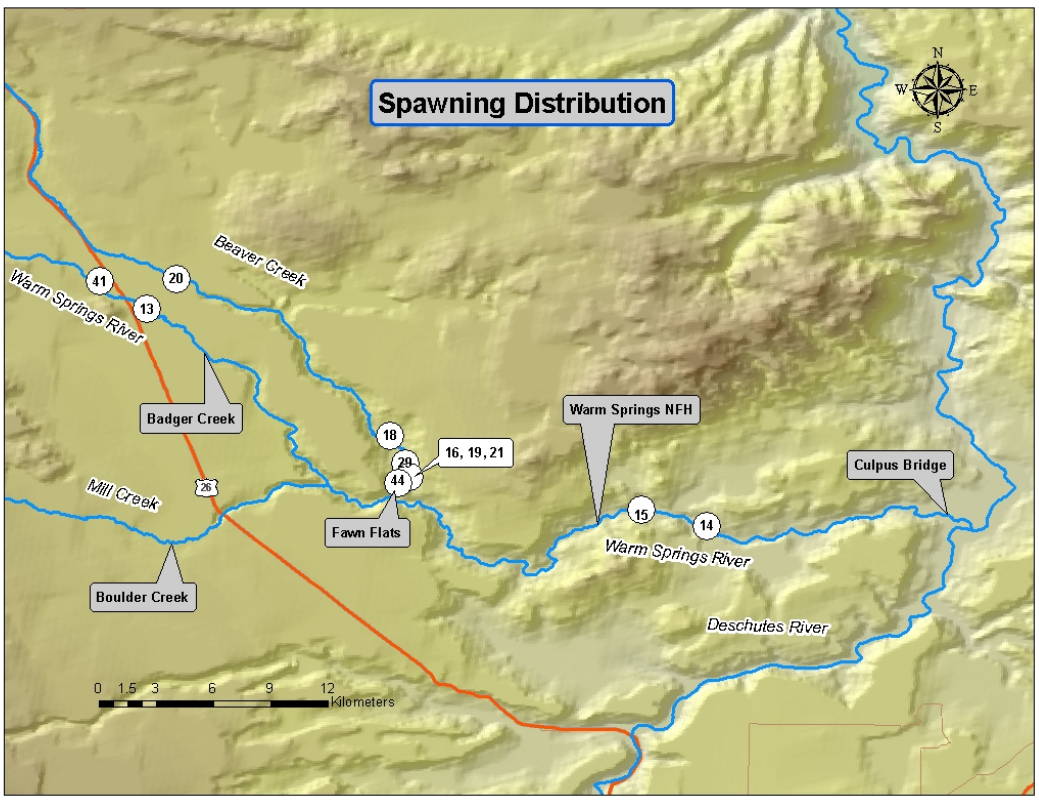

Figure 13. Aerial survey detections of surviving radio-tagged hatchery Chinook salmon on traditional spawning ground survey reaches during the spawning period. Spawning reach boundaries are labeled with callouts as follows: Culpus Bridge to Warm Springs NFH, Fawn flats upstream on Beaver Creek, Boulder Creek upstream on Mill Creek, Badger Creek upstream on Warm Springs River.

Discussion

The use of fixed-wing surveys allows transmitter-implanted fish to be tracked over long distances and in remote areas. However, the accuracy of aerially determined tag locations can limit the types of conclusions one can draw about fish habitat use, and movement patterns. This study uses conservative survival criteria, requiring that a tagged fish be detected at a distance greater than 2 rkm from the previous detection to be considered alive. In a literature review reported in Roberts (2005), mean location errors of aerially acquired tag locations averaged 158 meters in a synthesis of 415 telemetry studies. Additionally, using a blind study with aerial detections of known tag locations, these researchers found that errors ranged from 22 to 426 m and had a mean of 178 m. Based on aerial telemetry accuracy data provided in (Roberts 2005), and a review of the tag movement data provided in (Fig. 11), we feel this criterion will more likely underestimate the true number of survivors rather than overestimate it. However, had we used a lesser detection distance in the survival criteria, we feel it would have greatly increased the probability that we would incorrectly label any potential mortalities and shed tags as survivors.

With our current criteria, and based on tag movements observed in this study, we estimated that 60% of our tagged fish survived to spawning. Past redd count data has shown a trend towards increasing fish per redd ratios over time indicating a reduction in wild fish survival as well. More research is necessary to develop further understanding into the causes of this low observed survival rate and develop more precise estimates of wild fish survival. In order gain a better perspective of our aerial telemetry error distance, we plan to incorporate the use of additional test tags in future studies. We will also use a more advanced Lotek telemetry receiver with GPS capability so detections are automatically marked thereby reducing variances in the data. With these steps we hope to gain a finer resolution on the survivorship of radio-tagged fish.

In this study, the proportion of radio-tagged hatchery fish migrating downstream after tagging and those returning to the hatchery (fall-backs) were documented and compared to past data. Some adult downstream migration was expected due to homing on olfaction cues imprinted from the hatchery as smolts. Since salmon homing can be very precise, smolts released in a section of river are more likely to return to that section than to elsewhere in the river (Donaldson 1958). During a jaw-tagging study conducted in 1983, Cates (1992) expected some hatchery fall-backs since the adult fish were occasionally observed falling back over the barrier dam after upstream release. The fall-back rates observed in this study were significantly higher than the rates observed in the 1983 jaw tagging study. However, the sample size in our study was small (n=35), so more research is needed to determine if this difference is due to biological change, hatchery practices, tagging effects, or random variation.

A high percentage (45.7%) of the tagged fish migrated downstream of the hatchery at some time over the duration of the study. We found that the majority of these fish did not return to the hatchery. The higher than expected downstream migrant rates that we observed in this study suggests that the number of hatchery fish upstream of the hatchery is likely lower than the number of hatchery fish counted on the passage system video. With additional replication, a downstream migrant ratio could be calculated and applied to video counts to provide a better estimate of the hatchery fish population upstream of the hatchery. The downstream migrant rates observed in this study should not be applied directly to wild runs in the Warm Springs River. Significant differences in rearing locations between the study group and natural origin fish will likely lead to a divergence in homing and fall-back rates.

High quality summer holding habitats are directly related to spring Chinook salmon survival and ultimately spawning success (McHugh et al. 2004). These habitats typically contain deep, cool, slow flowing pools that help to reduce energy demand on the fish as they hold until spawning. In this study we identified several of these important habitats in the Warm Springs River. Although many hatchery fish were detected attempting to hold below the hatchery, few of these fish survived to spawning. Additionally, a high proportion of these downstream migrants did not meet the survival criteria to spawning indicating less than optimum holding habitat downstream of the hatchery. Some fish were observed migrating downstream to the Deschutes River during the holding period possibly in search of more suitable holding habitat. The majority of fish that survived to spawning were primarily detected in the canyon holding area during summer months, indicating this area contains important holding habitat that is essential for survival. This is consistent with the holding areas described by Lindsay et al. (1989). In addition, during our study, fish did not distribute evenly in the canyon area during holding and congregations of fish tended to favor certain areas within the canyon. With accurate identification of these holding habitats, it may be possible to focus habitat restoration and protection efforts in ways that further benefit wild spring Chinook runs during the summer holding period.

We observed low numbers of hatchery spring Chinook salmon on the historical wild spawning grounds. Only 31% of the tagged fish were considered contributors to spawning by both meeting the survival and spawning distribution criteria. Of twelve carcasses (6.5%) discovered on spawning grounds in the 1983 jaw tagging study, Cates (1992) reported that the distribution did not deviate from those of wild fish. In our study, we found that the distribution of radio-tagged hatchery spawners on historic spawning grounds did deviate from current and past redd count data. Explanations for these deviations are speculative, but since these hatchery fish did not originate from these upper spawning reaches, it is likely difficult for them to cue in on the most suitable spawning habitats, resulting in migration patterns that differ from wild fish.

In this study we used a strict spawning contribution criteria based on survival and presence or absence in traditional spawning index reaches. It is possible that more of these hatchery fish contributed to spawning, just not in traditional spawning index reaches. The spawning index reaches used for redd surveys were originally selected because of well known spawning activity and accessibility. Spawning does occur throughout the Warm Springs basin outside of spawning index reaches (Lovtang 2008). In this study, we estimated that 60% of tagged fish survived, but only 31% contributed to spawning by our definition because many were not detected in traditional spawning index reaches. It is possible that these hatchery fish are attempting to spawn in these undefined spawning habitats, but it is currently unknown why, or whether this is a successful spawning strategy. The researchers conducting the 1983 jaw tagging study concluded that "… while some hatchery fish released above Warm Springs NFH will linger in the vicinity of the hatchery, most will enter historical spawning areas (Cates 1992)." This same conclusion cannot be drawn from this current study, and it appears from our results that the majority of hatchery Chinook passed upstream of the hatchery do not enter the historical wild spawning areas in the Warm Springs basin.

Radio-telemetry can be a useful method for examining movement patterns of fishes. Data from radio-tagged Chinook salmon can be extrapolated to the rest of the population if the implantation and presence of the radio-tag have no significant effect on the survival or behavior of the fish. While some studies indicate there is potential for negative tagging effects and modified behavior due tag presence (Ross 1981), other studies directed at quantifying radio-tagging effects found no impact on survival, or behavior in adult salmon (Matter and Sanford 2003; Ramstad and Woody 2003). Information on the potential tagging effects of radio-tagging on adult spring Chinook in the Warm Springs basin are currently lacking. Because the effects of tagging are not yet fully understood, we feel a conservative approach should be used while interpreting the information in this report. Additionally, we stress that the hatchery fish tagged in this study should not be considered surrogates in predicting wild fish behavior since life history differences between the two populations are likely to influence fish behavior (i.e. homing, fall-backs,). However, with these major caveats in mind, the information gathered in this study can be useful in answering specific questions and guiding management decisions now and into the future.

Acknowledgments

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References

Cates, B.C. 1992. Warm Springs National Fish Hatchery evaluation and anadromous fish studyon the Warm Springs Indian Reservation, 1975-1989. Progress Report by the U.S. Fish and Wildlife Service, Vancouver, Washington.

Confederated Tribes of the Warm Springs of Oregon and United States Fish and Wildlife Service. 2007. Warm Springs national Fish Hatchery Operational Plan and Implementation Plan 2007-2011.

Gauvin, M. and D. Olson. 2001. Spring chinook salmon in the Deschutes River: Wild and hatchery 1975 to 2000 returns and 2001 run size prediction. Confederated Tribes of the Warm Springs Reservation of Oregon, Warm Springs, Oregon and U.S. Fish and Wildlife Service, Vancouver, Washington.

Donaldson, L. R. and G. H. Allen. 1958. Return of silver salmon *Oncorhynchus kisutch* (Walbaum) to point of release. Transactions of the American Fisheries Society 87:13–22.

Hand, D., W. R. Brignon, J. Rivera, and D. Olson. 2007. Comparative tag retention, clip quality, and injuries of juvenile spring Chinook salmon marked by an automated marking trailer and manual marking trailer at Warm Springs NFH.

Hockersmith, E. E. and B. W. Peterson. 1997. Use of the Global Positioning System for Locating Radio-Tagged Fish from Aircraft. North American Journal of Fisheries Management 17:2, 457-460

Kostow, K. 2008. Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Reviews in Fish Biology and Fisheries 19:1, 9-31

Lindsay, R.B., B.C. Jonasson, R.K. Schroeder, and B.C. Cates. 1989. Spring Chinook salmon in the Deschutes River, Oregon. Oregon Department of Fish and Wildlife Information Report 89-4, Portland, Oregon.

Lovtang , J., L. Hewlett-Dubisar, A. Mitchell, A. Scott, M. Meninick, 2008. Confederated Tribes of the Warm Springs Reservation of Oregon Fish Production Program 2008 Annual report.

Matter, A. L. and B. P. Sandford. 2003. A Comparison of Migration Rates of Radio- and PIT-Tagged Adult Snake River Chinook Salmon through the Columbia River Hydropower System. North American Journal of Fisheries Management 23:3, 967-973

McHugh, P., P. Budy, and H. Schaller. 2004. A Model-Based Assessment of the Potential Response of Snake River Spring–Summer Chinook Salmon to Habitat Improvements. Transactions of the American Fisheries Society 133:3, 622-638

Olson, D.E., B.C. Cates, and D.H. Diggs. 1995. Use of a National Fish Hatchery to complement natural production of spring Chinook salmon and summer steelhead in an Oregon stream. American Fisheries Society Symposium 15:317-328.

Olson, D.E., 1997. Investigation of rearing and release strategies affecting adult production of spring Chinook salmon. Proceedings of the 48th Annual Pacific Northwest Fish Culture Conference, RZ Smith (Chair), National Marine Fisheries Service:161-171.

Olson, D.E., and S.M. Pastor. 1998 (Draft). An account of summer steelhead returns and strays in the Warm Springs River. U.S. Fish and Wildlife Service, Vancouver, Washington.

Olson, D. E., B. Spateholts, M. Paiya, D. E. Campton. 2004. Salmon Hatcheries for the 21st Century: A Model at Warm Springs National Fish Hatchery. American Fisheries Society Symposium 44:581-598.

Pastor, S.M. 1992. Columbia River information System (CRiS). U.S. Fish and Wildlife Service, Vancouver, Washington.

Pollock, K. H. and S.R. Winterstein. Estimation and Analysis of Survival Distributions for Radio-Tagged Animals. Biometrics, Vol. 45, No. 1 (Mar., 1989), pp. 99-109 Published by: International Biometric Society

Ramstad, K. M. and C. A. Woody, 2003. Radio-tag Retention and Tag-Related Mortality among Adult Sockeye Salmon. North American Journal of Fisheries Management 23:3, 978-982

Roberts, J. and F. Rahel, 2005. Accuracy of Aerial Telemetry in Fisheries Studies North American Journal of Fisheries Management 25:2, 660-666

Ross, M. J. and H. McCormick, 1981. Effects of External Radio-transmitters on Fish The Progressive Fish-Culturist 43:2, 67-72

Spateholts, B. and D. Olson. 2001. Cultural significance and natural production of spring chinook salmon on the Warm Springs Indian Reservation. Confederated Tribes of the Warm Springs Reservation of Oregon, Warm Springs, Oregon and U.S. Fish and Wildlife Service, Vancouver, Washington.

U.S. Fish and Wildlife Service. 2004. Hatchery and genetic management plan for Warm Springs National Fish Hatchery, Oregon. Columbia River Fisheries Program Office, Vancouver, Washington.

U.S. Fish and Wildlife Service. 2006. Columbia River Basin, Columbia Plateau Province, Deschutes River Watershed, Warm Springs National Fish Hatchery Assessments and Recommendations Final Report. Hatchery Review Team. Pacific Region. USFWS, Portland Oregon. <http://www.fws.gov/pacific/ fisheries/Hatcheryreview/ team.html>.