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Columbia River Inter-Tribal Fish Commission
700 NE Multnomah, Suite 1200
Portland, OR 97232
503.238.0667
www.critfc.org

Limiting Factors of the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2013

Jeffery K. Fryer, Howie Wright, Skyeler Folks, Richard Bussanich, Kim D. Hyatt, and Margot M. Stockwell

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Jeffrey K. Fryer
Columbia River Inter-Tribal Fish Commission

Howie Wright, Skyeler Folks, and Richard Bussanich
Okanagan Nation Alliance

Kim D. Hyatt and Margot M. Stockwell
Department of Fisheries and Oceans, Canada
March 1, 2015

EXECUTIVE SUMMARY

A total of 789 Sockeye Salmon, *Oncorhynchus nerka*, were PIT tagged at the Bonneville Dam Adult Fish Facility in 2013. These fish, along with previously PIT tagged Sockeye also sampled, were tracked upstream using data from detection arrays at mainstem Columbia River dam fish ladders as in-river arrays in the Wenatchee and Okanagan basins. Using data from PIT tags deployed at Bonneville Dam, the estimated stock composition of Sockeye Salmon was 70.0% Okanagan and 28.0% Wenatchee with 2.0% last detected in other potential terminal areas (Entiat 1.0%, Yakima 0.5%, and Deschutes 0.6%).

In 2013 genetic stock identification (GSI) was used to classify the stock of Sockeye Salmon that were not detected in terminal areas, precluding stock classification by PIT tag. Incorporating these classifications into the PIT tag stock classifications resulted in a stock composition estimate of 69.2% Okanagan, 28.5% Wenatchee, 0.9% Snake River, 0.6% Entiat, 0.4% Deschutes, and 0.3% Yakima. The estimated survival rate from Bonneville Dam to terminal areas was 72.1% for the Okanagan stock, 70.1% for the Wenatchee stock, and 0% (n=10) for the Snake River stock.

Sockeye Salmon tagged at Bonneville Dam had an estimated survival of 83.6% to McNary Dam. This was higher than four of the five groups of returning Sockeye Salmon tagged as juveniles at locations upstream of McNary Dam (range=57.1% to 100.0% with the highest rate based on 12 returning PIT-tagged natural origin Okanagan Sockeye juveniles).

PIT tag data from Bonneville tagged fish estimated fallback rates at mainstem dams that ranged from 1.0% at Bonneville Dam to 6.2% at McNary Dam. At Bonneville Dam, the fallback rate for Sockeye that, subsequent to tagging, ascended the Oregon short ladder was 13.3% (n=15) compared to 0.8% on the Washington side. Fallback rates for returning adults tagged as juveniles were estimated to be between 11.0 and 19.2% at Bonneville, The Dalles, Rocky Reach, Wells, and Ice Harbor dams and 54.9% at Lower Granite Dam.

The median travel time of Sockeye Salmon between Bonneville and Rock Island dams was 13.1 days, resulting in a median migration rate of 37.1 km per day. Fish

passing Bonneville Dam later in the migration traveled upstream faster than those earlier in the migration.

In the Okanagan Basin, PIT tag antennas installed and maintained by this project at Zosel Dam (ZSL) and the Okanagan Channel (OKC) were operational for the entire year. Between January 1, 2013 and December 31, 2013 at Zosel Dam, 31 Chinook, 39 steelhead, and 177 Sockeye were detected, while at OKC 6 Chinook, 5 steelhead, and 613 Sockeye were detected. Most Sockeye Salmon, as well as some Chinook Salmon, likely passed Zosel Dam during periods of high flow when it was possible to move upstream through the spillways, bypassing PIT tag detection in the fish ladders.

At Wells Dam, 665 Sockeye Salmon were sampled and 658 PIT tags and 61 acoustic tags deployed, with 7 Sockeye PIT tagged at Bonneville Dam included in the sample. In addition, 137 temperature tags were deployed at Wells Dam. All Sockeye sampled at Wells Dam were also Floy tagged. The weighted conversion rate to the Okanagan Channel PIT tag detection array (OKC) for fish PIT+Floy tagged at Wells Dam was 49.0% compared to 56.5% for Sockeye passing Wells Dam that were PIT tagged at Bonneville Dam. Sockeye tagged at Wells Dam with both PIT and acoustic tags had a 15.9% lower conversion rate to OKC than those only tagged at Wells Dam with PIT tags only while those PIT plus temperature tagged had a 93% lower conversion rate to OKC. However, temperature tags were mostly deployed late in the run when survival was low. For those Sockeye passing, or tagged at, Wells Dam on or before July 16, 61.9% of Wells-tagged and 71.5% of Bonneville-tagged Sockeye were detected at OKC. For those Sockeye passing, or tagged at, Wells Dam on or after July 17, 23.3% of Wells-tagged and 29.2% of Bonneville-tagged Sockeye were detected at OKC

A total of 18 acoustic receivers were deployed between Wells Dam and Okanagan Lake Dam and 61 acoustic tags implanted at Wells Dam. Survival was 85.6% to the Monse Bridge site on the Okanagan River just upstream of Wells Dam, 71.3% to the North Basin of Osoyoos Lake, and 18.6% to McIntyre Dam. Sockeye Salmon did not pass the Monse Bridge site when the Okanagan River temperature was above 23.0^{o}C, likely choosing to hold in in Lake Pateros. Of the 61 Sockeye acoustic tagged, 24 were estimated to be on the spawning grounds during the spawning period, 28 were missing on the upstream migration, 5 were captured and kept in fisheries and 1 was last detected just upstream of Osoyoos Lake but not detected on the spawning grounds.

Okanagan juvenile PIT tagging resulted in 4018 smolts being released during 11 tagging sessions between April 12 and May 7, 2013 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYOL, downstream of the Highway 3 bridge at the Osoyoos Narrows. Reliable estimates of survival from release to Rocky Reach Dam could be calculated for both release groups. Survival from release to Rocky Reach Dam was 0.45 (SE = 0.06) for the SKATAL release group, and 0.49 (SE = 0.04) for the OSOYOL release group. After Rocky Reach, error associated with survival estimates for both release groups, individually and combined, was large. Travel time from release to Rocky Reach Dam was approximately 20 days for the SKATAL release group, and 19 days for the OSOYOL release group. Travel time for individual reaches was similar between both release groups. Overall travel time from release to Bonneville Dam was approximately 29 days for both groups combined.

This project is proposed to continue and evolve through at least 2017. Past work has created the monitoring infrastructure through funding PIT tag antennas at OKC and Zosel Dam as well as acoustic arrays to better determine where losses of Okanagan Sockeye Salmon are occurring upstream of Wells Dam. However, low sample sizes of acoustic tagged Sockeye, possible acoustic tagging impacts, as well as the lack of any PIT tag detection between Wells Dam and Zosel Dam and OKC still leaves considerable uncertainty in quantifying mortality. A PIT tag array in the lower Okanagan River (OKL) installed in 2014 will assist in filling in this gap. We hope to work with the Colville Tribe in the future on expanding PIT tag detection in the Okanagan Basin downstream of Osoyoos Lake. In addition, we have been investigating possible PIT tag detection under the Highway 3 Bridge in Osoyoos between the north and central basins of Osoyoos Lake. It is hoped that better PIT tag detection at some of these sites could eliminate the need for acoustic tags, providing better data at lower cost.

Unlike in 2012, we noticed little stock specific difference in survival on the upstream migration to Rock Island Dam between the Okanagan (72.1%) and Wenatchee stock (70.1%). In 2012, the Wenatchee stock had a 64.3% survival rate to Rock Island Dam compared to 75.5% for the Okanagan. In both years, survival of Snake River Sockeye was 0%, though this was based on only eight fish in 2013 and two fish in 2012. The differential survival between Bonneville and terminal areas is something we will explore further in future years.

We also expect to continue with Wenatchee acoustic trawl surveys and limnological work to better estimate the production and productive potential of

Wenatchee Sockeye Salmon. Acoustic trawl survey data from both Lake Wenatchee and Osoyoos Lake are also being used in Columbia Basin run forecasting. There are several unanswered questions regarding Lake Wenatchee Sockeye that we hope to address as part of this project. A primary question is why Lake Wenatchee Sockeye have not increased in relative abundance as much as Okanagan Sockeye, or even Snake River Sockeye, in recent years. Our limnology and ATS work will help in answering this question, but it is also uncertain what the optimal spawning escapement goal is for this stock. An optimal escapement analysis is being compiled separate of this project for Osoyoos and Skaha Sockeye and we plan to consider this for the Wenatchee stock as part of this project.

Another unanswered question is how current production for both Osoyoos and Wenatchee Sockeye Salmon compares to historical production. Peak historical Columbia Basin Sockeye runs have been estimated at 2.6 million to 4.3 million (Chapman 1986, NPPC 1986, Fryer 1995); however the 2012 run of over 510,000 Sockeye Salmon with less than 5% of historical Columbia Basin habitat available makes those peak estimates appear conservative. To answer this question, we plan to work with the Okanagan Nation, Department of Fisheries and Oceans Canada, and Grant, Chelan, and Douglas Public Utility District to fund paleolimnological work in Wenatchee, Osoyoos, Skaha, and Okanagan lakes to provide relative historical Sockeye Salmon abundance.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Sockeye Salmon, *Oncorhynchus nerka,* is one of the species of Pacific salmon native to the Columbia River Basin. Prior to European settlement of the region, it is estimated the Columbia Basin supported an annual Sockeye Salmon run averaging over three million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, the Sockeye Salmon run has severely declined, reaching a low of fewer than 9,200 fish in 1995 before rebounding in recent years to a record highs of over 500,000 Sockeye Salmon counted at Bonneville Dam in both 2012 and 2014 (DART 2014, Fish Passage Center 2014). The Bonneville Dam count of Sockeye Salmon in 2013 was 185,505.

The Columbia Basin Sockeye Salmon run was once composed of at least eight principal stocks (Fulton 1970, Fryer 1995). Today, only two major stocks remain (Figure 1); the first originating in the Wenatchee River-Lake Wenatchee System (Wenatchee stock) and the second in the Okanagan[1] River-Osoyoos Lake System (Okanagan stock). A third remnant stock, comprising well under 0.1% of the run, returns to Snake River-Redfish Lake (Snake stock) and is listed under the Endangered Species Act.

Okanagan Sockeye Salmon spawn in the Canadian portion of the Okanagan River and then rear in Osoyoos Lake, through which runs the border between the United States and Canada. This run has persisted despite one of the longest, most difficult migrations of any salmon stock in the world. The stock migrates 986 km between the spawning grounds and the ocean through one dam and a series of irrigation control structures on the Okanagan River as well as nine mainstem Columbia River dams. The production of this run is believed to be limited by upstream and downstream migration survival as well as habitat factors in the spawning and rearing areas (Fryer 1995; Hyatt and Rankin 1999, Hyatt and Stockwell 2009).

[1] The Canadian spelling for Okanagan will be used throughout this document as opposed to the American spelling (Okanogan).

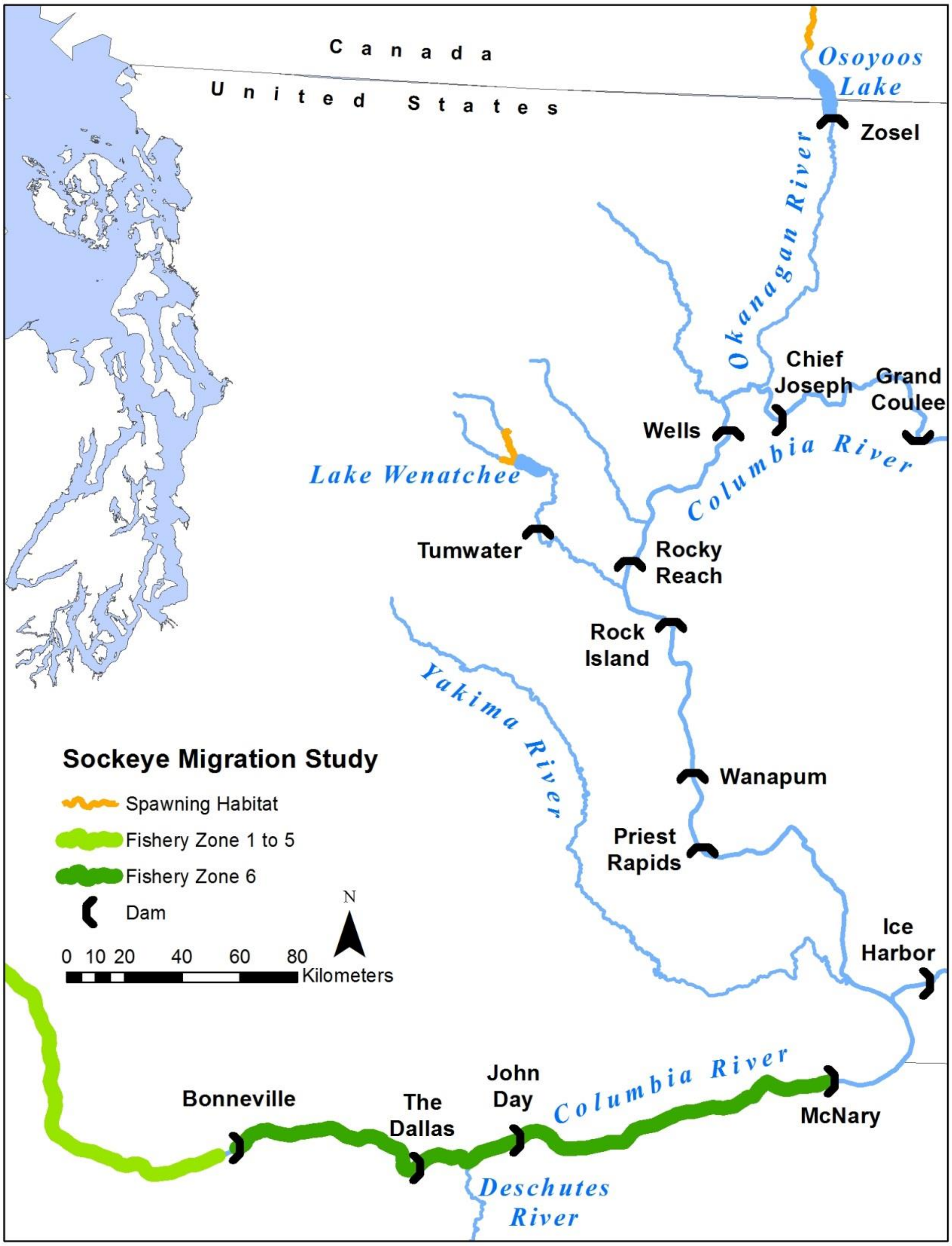

Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the two major Sockeye Salmon production areas and significant dams on their migration route.

The Wenatchee stock spawns in tributaries to Lake Wenatchee and rears in the lake. This stock migrates 842 km through two Wenatchee River dams and seven mainstem Columbia River dams. Since the spawning grounds and lake are relatively pristine, the production of this run is believed to be limited by upstream and downstream survival as well as the low productivity of the oligotrophic Lake Wenatchee (Fryer 1995).

This Columbia River Inter-Tribal Fish Commission (CRITFC) study, funded by the Columbia Basin Fish Accords, seeks to expand our knowledge of factors limiting production of Okanagan and Wenatchee Sockeye Salmon stocks. This study expands upon previous work, funded by the Pacific Salmon Commission from 2006-2008, to examine upstream survival and timing by inserting Passive Integrated Transponder (PIT) tags in Sockeye sampled at Bonneville Dam as part of the annual Pacific Salmon Commission (PSC)-funded Sockeye stock identification project. These PIT tagged fish can then be detected at several upstream dam fish ladders with detection capability (McNary, Priest, Rock Island, Rocky Reach, and Wells dams on the Columbia River, Ice Harbor and Lower Granite dams on the Snake River, Tumwater Dam on the Wenatchee River), and Zosel Dam on the Okanagan River as well as at in-stream tributary antennas.

The fact that there are only two significant Columbia Basin Sockeye Salmon stocks passing through multiple Columbia River dams with PIT tag detection makes the species ideal for a PIT tag study. Determination of migration timing and mortality for other salmon and steelhead species is difficult, since many tributaries are without detection facilities, or with detection facilities that only detect a fraction of fish passing, meaning that fish can escape undetected. The run timing of the adult Columbia Basin Sockeye Salmon migration is of particular interest because the migration timing has shifted to earlier in the year over the past 70 years (Fryer 1995, Quinn et al. 1997). A 1997 radio-tagging study also found high mortality of the latter portion of the run (Naughton et al. 2005) as well as no difference in stock-specific migration timing. The radio tag study was conducted in an unusually high flow year that may not be typical of other years. Results of PIT tagging studies between 2006 and 2010 (Fryer 2007b, 2009, Fryer et al. 2010, 2011) concurred with the 1997 radio-tagging results (Naughton et al. 2005) regarding higher mortality during the latter portion of the run.

In 2009, PIT tag detection antennas were installed by Washington Department of Fish and Wildlife (PTAGIS 2014) in natal streams in the Wenatchee Basin (Little Wenatchee and White rivers), making it possible to track Wenatchee Sockeye to the spawning grounds. No similar detection system was available in the Okanagan Basin; therefore in 2009 this project funded installation of a PIT tag antenna on the Okanagan River upstream of Osoyoos Lake (known at www.ptagis.org as OKC – see Appendix Table A4 for site information) and in 2010 funded installation of antennas at both Zosel Dam fishways (ZSL). In 2011, this project funded maintenance of these antennas. To further investigate the mortality rate of Okanagan Sockeye in the Okanagan Basin, since 2009 this project has funded an acoustic network in the Okanagan basin and acoustic tagged Sockeye Salmon at Wells Dam.

Since 2010 this project has funded a hydroacoustic survey of Lake Wenatchee to initiate standardized Sockeye Salmon smolt abundance estimation for the Wenatchee stock for comparison with similar estimates already available for Okanagan Sockeye in Lake Osoyoos. This estimate will be used to estimate juvenile survival and compared to Wenatchee River smolt trap smolt estimates. In 2012, the project began limnology surveys of Lake Wenatchee with the goal of estimating potential smolt capacity of the lake as well as PIT tagging Okanagan stock Sockeye Salmon to estimate downstream migration mortality.

METHODS

Adult PIT and acoustic tag detection infrastructure

Okanagan River (Canada) PIT tag detection

This project has installed two Okanagan River PIT tag detection sites. The first site (OKC), installed in November 2009 (Fryer et al. 2010), is a channel width array at river km 147, just downstream of Vertical Diversion Structure 3 near Oliver, BC. The second (ZSL), installed in September 2010, consists of two antennas in each of the two fish ladders at Zosel Dam in Oroville, WA (Fryer et al. 2011). These systems were designed to detect PIT-tagged adult Sockeye Salmon as they ascend the Okanagan River

Okanagan acoustic tag network

An acoustic tag network was deployed in the Okanagan Basin to monitor survival and timing of adult Sockeye acoustically tagged at Wells Dam. The system consisted of Vemco VR2W receivers deployed from Pateros, just upstream of Wells Dam through the Okanagan Basin to Penticton Channel between Skaha Lake and Okanagan Lake. The receivers in the U.S. portion of the basin were deployed and maintained by Confederated Tribes of the Colville Reservation staff, while the receivers in the Canadian portion of the basin were deployed and maintained by Okanagan Nation Alliance staff. Data from these receivers were used to estimate mortality and passage time upstream of Wells Dam.

Adult sampling at Bonneville and Wells dams

Bonneville Dam

Sockeye Salmon were sampled and tagged at the Adult Fish Facility located adjacent to the Second Powerhouse at Bonneville Dam (river km 235) in conjunction with the sampling of steelhead (*O. mykiss)* and summer Chinook Salmon (*O. tshawytscha)*. Sampling and tagging typically occurred between approximately 0800 and 1300 hours four to five days per week. A picket weir diverts fish ascending the Washington Shore fish ladder into the adult sampling facility collection pool. An attraction flow is used to draw fish through a false weir where they may be selected for sampling. Fish not selected and fish that have recovered from sampling then migrate back to the Washington Shore fish ladder

above the picket weir.

Sockeye selected for tagging were examined for tags (including scanning for existing PIT tags using a Biomark HPR reader), fin clips, wounds, and condition. They were measured for length, and four scales were removed for later age analysis. PIT tags were inserted into the body cavity (if not already present) of the Sockeye Salmon using standard techniques (CBFWA 1999) and the fish scanned again for PIT tags. If the PIT tag was not detected, no effort was made to implant another tag to eliminate the possibility of double tagging. Sockeye Salmon were allowed to recover prior to release. All PIT tag and sampling information was uploaded to the Columbia Basin PIT Tag Information System (PTAGIS) database (www.ptagis.org).

PIT tagged Sockeye Salmon were detected by existing detection arrays in adult fish ladders at Bonneville, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams on the Columbia River; Ice Harbor and Lower Granite dams on the Snake River; Zosel Dam on the Okanagan River, and Tumwater Dam on the Wenatchee River (array configurations are available at www.ptagis.org) as well as several in-stream detection arrays. PIT tag detection data from these arrays are automatically uploaded several times daily to the PTAGIS database where they are immediately accessible to users of the site. If a tag was not detected after the fish was released, we removed it from further analysis.

Wells Dam Sampling

Sockeye were trapped at the Wells East Bank ladder fish trap where they were blocked from ascending the ladder by a gate with bars spaced 5.4 cm apart. Fish were diverted up a steep pass Denil fishway where they accumulated in an upwell enclosure. An attraction flow into the enclosure encouraged fish to voluntarily swim down a sorting chute, where an operator either diverted them into a 2.3 cubic meter holding tank or returned them to the ladder upstream of the barrier gate. Fish were netted from the holding tank into a 380 liter stock tank and anesthetized in a bath of 40 mg MS-222/L until they lost equilibrium and their opercular rate was slow but regular. Fish were examined for existing tags, fin clips, wounds, and condition. Lengths were also measured and five scales were removed and placed on scale cards for later age analysis. All fish were tagged

externally with a numbered Floy tag below the dorsal fin and all previously unmarked fish were implanted with a PIT tag in the pelvic girdle, posterior to the pelvic fins. After sampling, fish were allowed to recover in a 380 liter stock tank with fresh oxygen-aerated water before being loaded into a 2800 liter tank on a transport truck. The truck tank was supplied with oxygen at a rate of 1-5 L/min, depending on fish densities.

A subsample of fish were selected to receive an externally attached archival temperature tag (N=135) or an internally implanted acoustic transmitters (N=61). The temperature tags were Alpha Mach Inc. iBCod 21 Z submersible temperature data loggers (max width of 44.4mm, height of 12.2mm, and weight in water 5.5 g) with a logging interval of 1.5h and were affixed below the dorsal fin with two 75mm nickel pins. The acoustic transmitters were Vemco© model V9 2H (29 x 9 mm, weight in water 2.9 g) with a projected battery life of 132 days. Transmitters were disinfected in ethanol and rinsed in water prior to insertion through a 20 mm incision made anterior to the pelvic girdle and placed directly on the ventral midline (Langford et al. 1997). The incision was closed with two simple interrupted sutures (Ethicon 3-0 Ethilon monofilament, FS-1 24mm 3/8 c reverse cutting).

At the request of Douglas County Public Utility District, which owns Wells Dam, all sampled Sockeye were placed into a tanker truck and hauled approximately four kilometers upstream of Wells Dam on the western side of the forebay and released (release site WELSBR at www.ptagis.org).

Upstream migration analysis

In 2013, we calculated some migratory characteristics of Sockeye Salmon PIT tagged as juveniles for comparison with Sockeye PIT tagged by this project. These Sockeye were from PIT tagging programs in the Snake River, the Wenatchee Eastbank Hatchery program, Wenatchee River smolt trap and mixed-stock juveniles moving through Rock Island and Wanapum dams.

Stock classification

Sockeye Salmon stock determinations (Wenatchee, Okanagan, Snake, or Unknown - mortalities) were made by the last detection point. Those individuals last observed at or upstream of Rocky Reach Dam were classified as being

Okanagan stock unless last detected in the Entiat River in which case it was classified as Entiat stock[2]. Individuals which were last observed at or upstream of Tumwater Dam were classified as Wenatchee stock. Sockeye which were last observed at or upstream of Ice Harbor or Lower Granite Dam were classified as being Snake River stock. All remaining Sockeye Salmon last observed downstream of the aforementioned sites were recorded as unknown stock using PIT tags, but genetics samples were used to classify these.

Escapement

Escapement to upstream sites dams was estimated as:

$$N = \sum_i \frac{B_i R_i}{T_i}$$

where N was the estimated escapement at a particular upstream site, B_i is the weekly visual count passing Bonneville Dam in week i (DART 2014, Fish Passage Center 2014), T_i is the number of fish PIT tagged at Bonneville Dam in week i, and R_i is the number of PIT tag detections at the dam where escapement is being estimated of those fish tagged in week i.

Upstream survival/conversion rates

Survival/conversion rates were calculated for Sockeye to upstream dams with PIT tag detection as:

$$S = \sum_i \frac{W_i D_i}{N_i}$$

where W_i is the proportion of the Sockeye run passing Bonneville Dam in week i, D_i is the number of Sockeye detected at or above the dam in question, and N_i is the number of tagged Sockeye Salmon detected subsequent to release at Bonneville Dam. Given that the percentage of PIT tagged fish missed passing upstream through dams is typically very small, this provides a good approximation of survival to upstream dams. However, at terminal in-stream antennas (such as OKC in the Okanagan and LWN and WTL in the Wenatchee) where the percentage of PIT tagged fish missed is much higher and there is no

[2] Small numbers of Sockeye Salmon are annually observed spawning in the Entiat River (Schmit et al. 2014)

or insufficient detection of PIT tagged fish upstream to estimate this percentage, estimation using these techniques cannot be considered a survival rate. The nomenclature in the Columbia Basin is to call this a conversion rate and this term will be used in this report when referring to the percentage of tagged fish being detected at an in-stream antenna.

Detection Rate

We used the record of detections of PIT tagged fish to determine the detection rate at the fish ladders at dams[3]. PIT tag antennas in fish ladders are placed such that all fish must go through them, although at Bonneville, McNary, Ice Harbor, and Lower Granite dams it is possible for fish to use the navigation locks. PIT tagged fish going through PIT tag antennas can still be missed due to rare antenna outages, possible faulty tags or tag orientation, tag collision from two tagged fish passing through antennas simultaneously, or problems with antennas. Since CRITFC began PIT tagging salmon at Bonneville Dam in 2006, we have been computing detection efficiency at upstream dams. There has been some variation in methodology over these years, but currently we are calculating detection efficiency as the ratio of the number of fish detected upstream missed at the site in question, divided by the total number of fish detected upstream. For example, the percentage missed at Rocky Island Dam was calculated as:

$$P = \frac{R_m}{R_d}$$

where R_m was the number of fish missed at Rocky Island Dam but detected at sites upstream of Rock Island Dam divided by R_d, the number of fish detected upstream of Rock Island Dam.

Compiled for placement in Appendix A (Table A1) of this report was the probability of detection at the different sites at dam fish ladders. PIT tag detection antennas in fish ladders are always located in close proximity in such a way that a PIT tagged fish must go through at least two antennas in sequence at each fish ladder. At some ladders, one antenna covers the entire fishway width at a given point, while at other ladders two antennas in parallel cover the fishway width. Therefore, if a fish is detected at one antenna, or a pair of antennas, it

[3] A similar approach was used to estimate the detection rate at acoustic receiver sites.

should also be detected at the rest of the antennas, or pairs of antennas, in that same ladder. Exceptions are lower sites in Bonneville and McNary fish ladders where only underwater orifices have antennas which fish can bypass. However, upper sites at these ladders have 2-4 antennas which fish must pass through. This allows a probability of detection at the individual antennas to be calculated by comparing it with other antennas in that same ladder. Detection probabilities were calculated as:

$$Pi = \frac{N_i}{Max(N_i)}$$

where N_i is the number of fish detected at a given antenna and $Max(N_i)$ is the total number of fish detected by any antenna in that ladder. An overall probability of detection was calculated as:

$$1 - \prod_i (1 - P_i)$$

Also calculated was the percentage of Sockeye Salmon using each ladder at dams with multiple ladders.

Migration timing and passage time

Run timing was estimated using the date and time of detection at the different dams. Migration rates were calculated between dam pairs as the time between the last detection at the lower dam and the first detection at the upper dam. The amount of time required to pass each dam was estimated as the difference between the first detection time at a dam and the last detection time at the same dam.

Bonneville stock composition estimates using PIT tag recoveries

The overall stock composition, P_i, for stock *i* (where *i* denotes the Wenatchee or Okanagan stock) at Bonneville Dam was estimated as:

$$P_i = \sum_j W_j * S_{ij}$$

where W_j is the proportion of the run passing Bonneville Dam in week *j*, and S_{ij} is the percentage of the run estimated in week *j* to belong to stock *i* based on upstream recoveries.

The stock composition estimated by PIT tag recoveries was compared with that estimated from two visual counts, the first estimating the Wenatchee

stock abundance as the difference between the Rock Island and Rocky Reach Dam counts and the second using Tumwater Dam visual counts to estimate the Wenatchee stock abundance.

Okanagan and Wenatchee age and length-at-age composition

The age composition for the Okanagan and Wenatchee stocks was estimated as:

$$T_{i,j} = \sum_k A_{i,j,k} * W_k$$

where $T_{i,j}$ was the estimate for stock *i and age gro*up *j,* $A_{i,j,k}$ was the percentage of Sockeye for stock *i* and age group *j* in week *k* and W_k was the percentage of the run that passed Bonneville Dam in week *k.*

The variance was estimated as

$$Var(T_{i,j}) = \sum_k Var(A_{i,j,k}) * W_k^{\ 2}$$

where

$$Var(A_{i,j}) = \frac{\sum_k A_{i,j,k}(1 - A_{i,j,k})}{n_{i,k}}$$

Night passage

Fish passing viewing windows at Columbia Basin dams are not always counted using the same time period. Fish passing Bonneville and McNary Dam fish viewing windows are counted by observers only from 0400 to 2000 hours Pacific Standard Time for 50 minutes of each hour and the counts expanded by a factor of 1.2. Video records of fish migration at Priest Rapids, Rock Island, Rocky Reach, and Wells dams are recorded 24 hours per day and subsequently reviewed to yield total counts of daily fish passage. In this study, night passage rates (where night is defined as 2000 to 0400 hours) were calculated by stock, for all dams passed, based on the last detection time for a given fish ladder. The last time at the uppermost antenna was used as an approximation for passage time as this antenna was closer to the fish counting window than the lowermost antenna (where the first detection would be made). This was the case at all sites except at BO4 near the fish counting facility on the Washington shore at Bonneville Dam, where the distance between the uppermost and lowermost antennas is only about 15 meters so the uppermost antenna was still used for

consistency.

Fallback

Three methods were used to estimate fallback, which is defined as a fish that ascends a fish ladder into the reservoir above the dam, then “falls back” to the downstream side of the dam either over the spillway, or through the navigation locks, juvenile bypass systems, or turbines. The first method was if a PIT tagged adult Sockeye Salmon was detected in the juvenile bypass system. However, on the Columbia River, only Bonneville, John Day, McNary, Rocky Reach dams have juvenile bypass system PIT detection capability while all four dams in the Snake River have juvenile detection. Furthermore, there is no detection at any dam for fish falling back over the spillway or through the navigation locks or turbines. Therefore, a second method of estimating fallback was to look at each dam for fish detected at the uppermost antenna followed by detection more than two hours later at an antenna located downstream in the same ladder (or another ladder for multiple ladder dams). Finally, a third method of defining fallback was ascertained by fish that passed an upstream PIT tag detector at a given dam, then were next observed at a site downstream of the dam in question. Thus if a fish was detected at the upper antenna at Wells Dam and then subsequently detected at Tumwater Dam, it would be considered a fallback at both Wells and Rocky Reach dams. Similarly, if a fish was last detected the Wells Dam upper antenna and then detected at the Rocky Reach juvenile bypass, it would be considered a fallback at Wells and Rocky Reach dams.

A list of possible fallbacks was compiled using each of these methods and duplicates eliminated. Each fallback PIT tag detection record was examined to determine whether it met the criteria above. If a fish fell back over a dam multiple times, each time was considered a separate fallback. Fallbacks were compiled by dam and a fallback rate calculated by dividing the number of fallbacks by the total number of PIT tagged fish passing the dam in question. The resulting estimated fallback is almost certainly biased low as it will not include fish that fall back over a dam and are not subsequently detected.

Acoustic trawl surveys for juvenile Sockeye abundance

Night-time juvenile Sockeye Salmon densities in Osoyoos Lake were estimated by executing specialized acoustics and trawl based survey (ATS) methods. Several whole-lake transects covering depth strata from the lake surface to bottom were traversed with hydro-acoustics gear (Simrad or Biosonics sounders operating at 70-200 kHz) deployed from a boat at night (Hyatt et al. 1984). Acoustic signal returns from juvenile Sockeye were digitally recorded for subsequent population estimates of the total number of targets comprising pelagic fish located between the lake's bottom and surface. Echo counting is frequently confounded by fish schooling behavior during short nights in May–July; therefore, the best estimates are normally obtained during ice-free periods in the fall to early spring. Fish density estimates, in combination with species composition and biological traits (length, weight, age) information from trawl catches, are used to determine numbers and biomass of juvenile Sockeye Salmon found in the lake. Data from multiple surveys may be used to estimate salmon mortality between consecutive seasonal intervals (fall-spring, spring-summer, summer-fall).

Fish bio-samples were collected using a small, mid-water trawl net (2 x 2m mouth opening, 7.5-m length). Haul depths were based on echo-sounding results that indicate depths at which juvenile Sockeye Salmon were most likely to be caught.

Immediately upon capture, pelagic fish destined for laboratory analysis (biological traits, stomach contents, etc.) were placed into a 90% solution of ethanol and then subsequently frozen. Random samples of up to 150 juvenile Sockeye and/or kokanee were normally retained from each survey date in 2013. Trawl segment duration was adjusted to shorter or longer times depending on catch success. Larger catches triggered short trawl sets (10-15 minutes) such that most fish remained in good condition upon trawl retrieval. Following random withdrawal of a sub-sample of fish from a large catch, all other trawl caught fish were released unharmed.

Genetic Stock Identification (GSI)

Tissue samples in the form of a caudal fin punch were collected for genetic analyses from all adult Sockeye Salmon sampled at Bonneville Dam. Tissue samples were stored using a dry Whatman paper medium (LaHood et al. 2008). Genomic DNA was extracted from digested tissue samples using a standard Qiagen DNeasy protocol. Prior to amplification of single-nucleotide polymorphism (SNP) loci using primer-probe sets (fluorescent tags), an initial polymerase chain reaction (PCR) "pre-amp" step was implemented using whole genomic DNA to jumpstart SNP amplification via increased copy number of target DNA regions. The cycling regime and PCR conditions for the pre-amp step were as follows: one initial cycle of 95C for 15 min, 14 cycles of 95C for 15 seconds, 60C for four minutes, and a final dissociation step. For each data collection run, each panel of 96 SNP loci were arrayed with 96 samples using a Fluidigm® microfluidic 96.96 chip (including one genotype indicator and one no-template control sample) to generate high throughput genotyping. Sample cocktails included: 3.4µl GTXpress Taqman (Applied Biosystems), 0.30µl GT load buffer (including taq polymerase), 0.30µl H2O and 2.0µl pre-amp DNA template. Single SNP assays were prepared in a 5.0µl reaction mix (per sample), containing the following reagents: 2.5µl DA load buffer, 0.25µl Rox 19 dye, 1µl H2O, and 1.25µl primer/probe. Microfluidic chips were loaded with assay cocktail dispensed at 4.5µl per well, and sample cocktail dispensed at 5.0µl per well. Chip loading was completed following standard manufacturers protocol on a Fluidigm IFC controller. Amplification conditions using a fast-cycling protocol were; 70C for 30 min, 25C for 10 minutes, and 95C for one minutes, followed by 50 cycles of 95C for 5 seconds, and 50C for 25 seconds, and a final cool down step of 25C for 10 minutes. Chips were imaged and scored on a Fluidigm EP1 imager using Fluidigm SNP Genotyping Analysis Software version 3.1.1. Carcass samples often provide poor quality and/or quantity of viable DNA relative to fresh tissue, and our final sample sizes were pared based on individual genotyping success. Successful genotyping for a given sample was defined proportionally as less than 10% missing data (i.e. fewer than ten missing SNP genotypes per individual for *O. nerka*).

For the *O. nerka* baseline data, methods for DNA extraction, DNA amplification, microfluidics, and genotyping of SNP assays are available at

Monitoring Methods (2012a). Sockeye Salmon GSI analyses utilized the baseline described in Hess at al. 2013, and has previously been shown to accurately discriminate among the three major stocks of the Columbia River: Wenatchee, Okanagan, and Snake River Sockeye Salmon. The program ONCOR was used to estimate the most likely population-of-origin for the Sockeye Salmon samples. Individuals were assigned using a "best estimate" approach (Monitoring Methods 2012b) and the program gsi_sim was used for estimating stock proportions (Monitoring Methods 2012c).

In 2012, GSI was in concurrence over 99% of the time with PIT stock classifications for those Sockeye that could be classified by terminal area PIT tag detections (Fryer et al. 2013). Given this concurrence, in 2013 we did GSI only on Sockeye classified as unknown by PIT tags or those with unusual PIT tag detection histories.

Juvenile PIT tagging

Sockeye smolts were captured downstream of Skaha Lake Outlet Dam during the smolt outmigration monitoring program (Appendix C). Two rotary screw traps (RSTs) were set for 12-hour periods on alternate nights from 26 March to 15 April, 2013, then 24-hour periods from 15 April to 5 May, 2013. Live wells were checked one or two times daily, depending on smolt abundance. During morning checks, a sub-sample of captured smolts were kept in perforated aluminum boxes positioned in the river downstream of the RSTs until tagging was complete. Procedures developed by PTAGIS (1999) and Biomark (2012) were used for PIT tagging smolts. Cormack/Jolly-Seber survival estimates and travel times were estimated using a set of on-line tools developed by the University of Washington School of Aquatic and Fishery Sciences Columbia Basin Research (http://www.cbr.washington.edu/dart/query/pit_sum_tagfiles).

RESULTS

Zosel Dam and Okanagan Channel PIT tag antenna operation

PIT tags from 177 Sockeye, 39 steelhead, and 31 Chinook were detected passing Zosel Dam fish ladders (Table 1, Figure 2). High flows resulted in most Sockeye passing Zosel Dam undetected through the spillway rather than through the fishway PIT tag antennas as Sockeye passage was negligible until flows dropped below 1,200 cfs (Figure 3).

Table 1. Number of PIT Tagged Chinook, steelhead, and Sockeye detected at Zosel Dam ladders between January 1, 2013 and December 31, 2013 by release site and life stage at time of tagging.

Tagging Site	Life Stage at Release	Chinook	Sockeye	Steelhead	Total
Bonneville Dam	Adult	19	74	0	93
Priest Rapids Dam	Adult			30	30
Wells Dam	Adult	2	99	3	104
Okanagan Basin	Juvenile	2	2	2	6
Methow Basin	Juvenile			3	3
Snake Basin	Juvenile	3			3
Columbia between Priest Rapids and Chief Joseph dams	Juvenile	5	2	1	8
Total		**31**	**177**	**39**	**247**

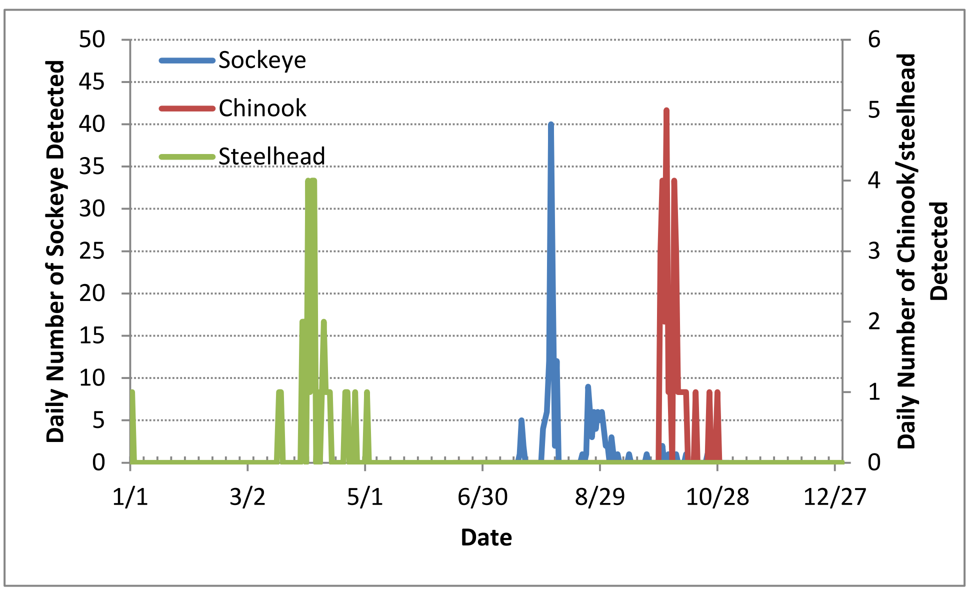

Figure 2. Number of PIT tagged Sockeye and Chinook Salmon and steelhead detected passing Zosel Dam fishways by date in 2013.

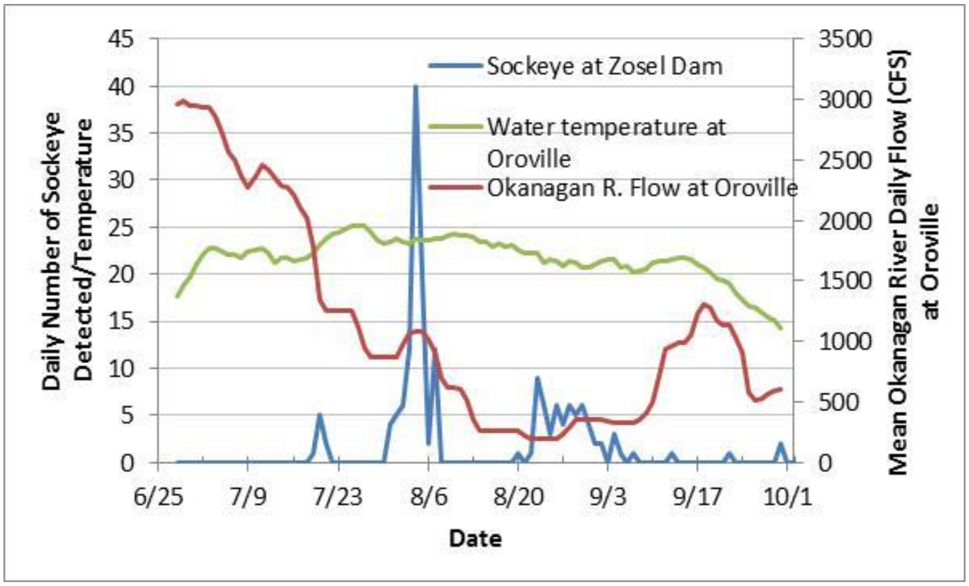

Figure 3. Number of PIT tagged Sockeye Salmon detected by date, mean daily flow, and mean daily temperature at Zosel Dam during Sockeye migration in 2013.

A total of 613 Sockeye, 6 Chinook, and 5 steelhead were detected at the OKC PIT tag array between January 1, 2013 and December 31, 2013 (Table 2, Figure 4). Two of these Sockeye, detected on April 18 and 22, were juveniles tagged at Skaha Lake earlier in April. There were an additional five tags detected between May 4 and June 29, 2013 from adult Sockeye tagged between 2002 and 2011 which were presumed to have been tags from past spawners that washed over the antenna during the high spring flows. These were omitted from further analyses. The majority of Sockeye detected were either during July or after Okanagan River temperatures dropped below 18C after September 23, 2013 (Figure 5). Three individual Sockeye were detected both in July 2013 and in October 2013.

Table 2. Number of PIT Tagged Chinook, steelhead, and Sockeye Salmon detected at the Okanagan Channel (OKC) PIT tag array between January 1, 2013 and December 31, 2013 by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Sockeye	Steelhead	Total
Bonneville Dam	Adult	2	348		350
Priest Rapids Dam	Adult			3	3
Wells Dam	Adult	2	231		233
Okanagan Basin	Juvenile		6		6
Methow Basin	Juvenile			1	1
Snake Basin	Juvenile	1		1	2
Columbia between Priest Rapids and Chief Joseph dams	Juvenile		28		28
Total		**6**	**613**	**5**	**623**

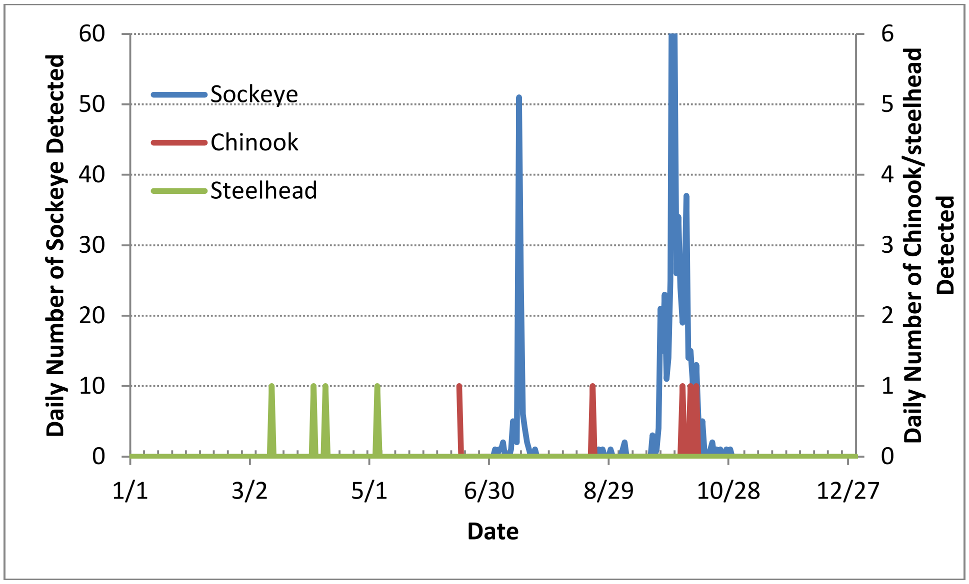

Figure 4. Number of PIT tagged Sockeye and Chinook Salmon and steelhead detected at the Okanagan Channel PIT tag array by date in 2013.

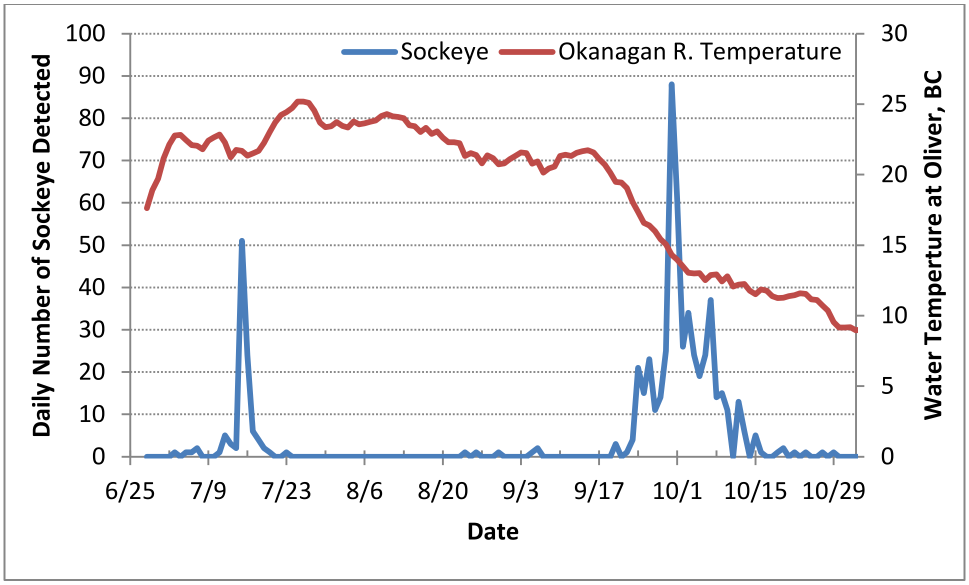

Figure 5. Number of PIT tagged Sockeye Salmon detected passing the Okanagan Channel PIT tag array (OKC) by date in 2013 compared with Okanagan River water temperatures recorded immediately upstream of OKC.

Okanagan acoustic tag network installation and monitoring

A total of 18 receivers were deployed in the Okanagan Basin between Pateros, located 13 km upstream of Wells Dam on the Columbia River, and Skaha Lake at rkm 176 (Table 3 and Figure 6). One receiver immediately downstream of Zosel Dam was lost shortly after deployment, likely due to vandalism. All receivers were checked and downloaded at least once per month.

Table 3. Acoustic receivers deployed in the Okanagan Basin, their location, and date of deployment in 2013. See Figure 6 for the map associated with this table.

Map No.	Location	rkm	Latitude	Longitude	Date Deployed	Date Retrieved
1	Pateros Dock (Columbia River)	843	48.054	-119.897	7/08/2013	11/13/2013
2	Brewster Bridge Dock W (Columbia River)		48.090	-119.778	7/08/2013	11/13/2013
3	Brewster Dock SE (Columbia River)		48.081	-119.714	7/08/2013	11/13/2013
4	Monse Bridge, west	6	48.140	-119.674	7/08/2013	11/13/2013
5	Monse Bridge, east	6	48.140	-119.673	7/08/2013	11/13/2013
6	West Channel Similkameen (Driscoll Pool)	5	48.911	-119.442	7/18/2013	11/18/2013
7	Similkameen Canyon	11	48.949	-119.465	7/10/2013	11/14/2013

8	Below Zosel Dam at railroad bridge		48.931	-119.420	7/10/2013	Went missing 7/17/2013
9	Pump Intake, east bank	124	48.946	-119.432	7/10/2013	11/14/2013
10	Pump Intake, west bank	124	48.946	-119.432	7/10/2013	11/14/2013
11	South Basin Haynes Campground (Point West)	132	49.018	-119.443	7/10/2013	11/14/2013
12	Haynes Point Nav Buoy	132	49.021	-119.438	7/10/2013	11/14/2013
13	North Basin EC Buoy (Ink Creek)	140	49.069	-119.502	7/10/2013	11/14/2013
14	OKR Mouth East	141	49.079	-119.521	7/10/2013	11/14/2013
15	OKR Mouth West	141	49.079	-119.522	7/10/2013	11/14/2013
16	OKR Hwy 97 Bridge	162	49.230	-119.542	7/10/2013	11/14/2013
17	McIntyre Dam	165	49.257	-119.528	7/10/2013	11/14/2013
18	Skaha Lake (Dam)	176	49.345	-119.580	7/10/2013	11/14/2013

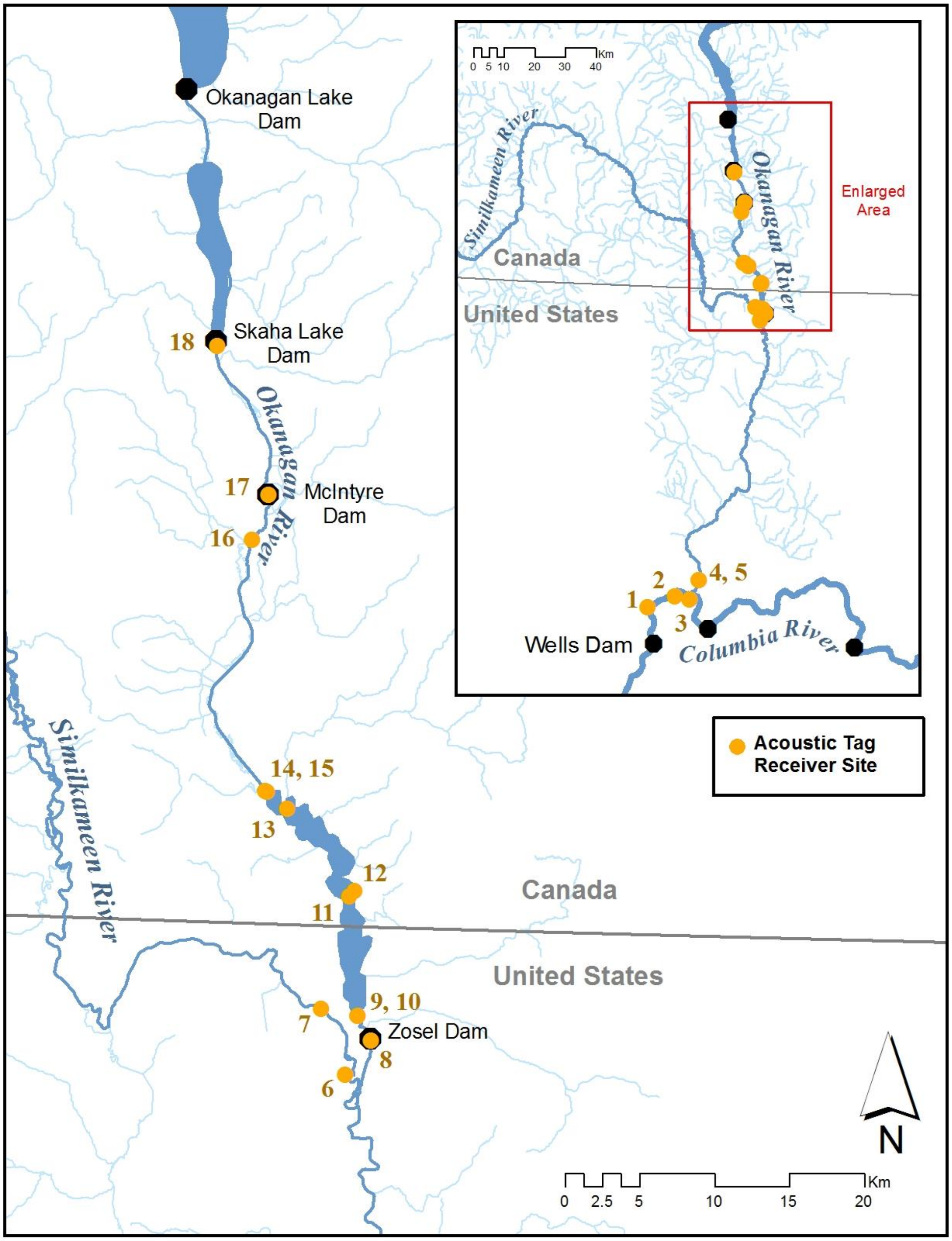

Figure 6. Okanagan Basin acoustic receiver sites in 2013. Location numbers reference sites listed in Table 3. Note that receiver 8 disappeared a week after deployment and was not replaced.

Upstream migration analysis

Mixed stock sample size and age composition

In 2013 a total of 799 Sockeye Salmon were sampled by this project at the Bonneville Dam Adult Fish Facility between June 5 and August 9, 2013 (Table 4). Of these, seven were not tagged or the tags were unreadable, and two died prior to release. One Sockeye was previously tagged and added to the 789 Sockeye tagged and released. Of the 790 Sockeye Salmon tracked, 18 were not detected after release. These fish may have shed their tags, had defective tags, or died. It was also possible that Sockeye Salmon passed downstream without being detected as Sockeye Salmon often pass over the top of weirs in the fish ladder rather than through the underwater slots where PIT tag antennas are located in the lower portions of Bonneville Dam fish ladders. It is unlikely that Sockeye Salmon pass upstream through fishways undetected as, at Bonneville Dam, they must pass through four PIT tag antennas near the fish counting window that detect very close to 100% of passing PIT tagged fish (Appendix A). However, at Bonneville Dam (as well as The Dalles, McNary, Ice Harbor, and Lower Granite dams) fish can pass upstream through the navigation locks. All other dams with PIT tag detection have antennas in fish ladders that Sockeye Salmon must pass through, however data from 2006-2013 indicates that PIT tagged Sockeye Salmon are missed, although the percentage is normally low (Table 5).

Table 4. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2013.

Sampling Dates	Statistical Week	Sampled (n)	Tagged	Previously Tagged	Detected after tagging and tracked
6/5-6/7	23	16	16	0	16
6/10-6/14	24	148	148	0	146
6/19-6/21	25	140	139	0	138
6/24-6/27	26	232	228	0	224
7/1-7/3	27	85	82	0	77
7/8-7/12	28	117	116	1	114
7/15-7/18	29	47	47	0	44
7/22,23,26;8/2,9	30-32	14	13	0	13
Total		**799**	**789**	**1**	**772**

Table 5. Number and percentage of PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2013 along with comparison data for 2006-2012.

Dam	2013 N	2013 %	2012	2011	2010	2009	2008	2007	2006
Bonneville	3	0.4%	1.8%	0.5%	0.7%	0.6%	0.4%	2.1%	0.2%
The Dalles	10	1.6%	--	--	--	--	--	--	--
McNary	13	2.1%	12.1%	1.6%	3.8%	5.0%	10.1%	6.5%	3.1%
Priest Rapids	0	0.0%	0.4%	0.2%	0.6%	0.3%	0.3%	0.8%	0.0%
Rock Island	25	4.4%	5.4%	4.4%	6.2%	2.6%	6.9%	6.8%	1.3%
Rocky Reach	0	0.0%	1.4%	0.7%	0.5%	0.0%	0.2%	0.7%	12.3%
Wells	0	0.0%	0.0%	0.0%	0.0%	--	--	--	--
Ice Harbor	--	--	0.0%	NA	0.0%	20.0%	0.0%	--	--
Tumwater	0	0.0%	0.0%	0.0%	0.0%	0.0%	--	--	--

The predominant age group was Age 1.2, flowed by Age 1.1 and 1.3 (Table 6.) Age 1.1 Sockeye increased as the run progressed while Age 1.2 and 1.3 Sockeye decreased.

Table 6. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2013.

Statistical Week	N Ageable	Age Class 1.1	1.2	2.1	1.3	2.2
23	16	0.0%	62.5%	0.0%	37.5%	0.0%
24	148	2.1%	67.9%	0.0%	25.0%	5.0%
25	140	0.7%	77.0%	0.0%	18.0%	4.3%
26	232	6.6%	72.1%	0.0%	12.7%	8.7%
27	85	22.2%	64.2%	1.2%	8.6%	3.7%
28	117	41.6%	40.7%	0.9%	8.0%	8.8%
29	47	70.2%	12.8%	2.1%	8.5%	6.4%
30	14	85.7%	14.3%	0.0%	0.0%	0.0%
Composite	**799**	**17.4%**	**62.7%**	**0.5%**	**13.4%**	**6.0%**
Std. Dev.		**1.3%**	**1.8%**	**0.3%**	**1.2%**	**0.9%**

Upstream recoveries, mortality, and escapement

As has been the case in previous years of this study, most of the Bonneville-tagged Sockeye Salmon that were not detected at Rock Island Dam in were lost prior to McNary Dam (Table 7, Figure 7). However, unlike previous years, PIT tagged fish were detected at The Dalles Dam fish ladders as antennas at that site became operational on February 7, 2013. Using detection data from these antennas, an estimated 10.5% of tagged Sockeye passing upstream of Bonneville Dam were not detected at The Dalles. Of those tagged Sockeye passing The Dalles, an estimated 6.6% were not detected at McNary Dam.

Sockeye escapement past The Dalles Dam estimated by PIT tags deployed by this project was within 2.5% of visual counts at The Dalles (Table 7). The estimated escapement at McNary Dam based on PIT tag detections was 15.6% greater than the McNary visual count; however the McNary visual count was much lower than visual counts at both The Dalles and Priest Rapids. At McNary Dam it is possible for fish to use navigation locks to bypass fish ladders, thus avoiding both PIT tag detection and visual detection; however we only estimated 2.1% of Sockeye were missed at McNary Dam (Table 5). Our PIT tag estimate ranged from 10.6% to 27.9% less than that of visual counts at Priest Rapids, Rock Island, Rocky Reach, and Wells dams. However, we estimate 40.1% more Sockeye than the Tumwater visual count.

Table 7. Percentage of PIT tagged Sockeye Salmon detected at upstream dams subsequent to tagging at upstream dams, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2013.

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using Bonneville PIT Tagged Sockeye	Visual Dam Count	Difference Between Bonneville PIT Tag and Visual Estimate
Bonneville	100.0%	--	185,505	--
The Dalles	89.5%	166,006	161,896	2.5%
McNary	83.6%	155,158	134,202	15.6%
Priest Rapids[4]	78.6%	145,717	163,079	-10.6%
Rock Island	74.2%	137,693	159,204	-13.5%
Rocky Reach	52.4%	97,178	131,660	-26.2%
Wells	50.5%	93,746	129,993	-27.9%
Tumwater	20.9%	38,862	27,738	40.1%
Ice Harbor	0.0%	0	895	--
Lower Granite	0.0%	0	757	--

[4] Eleven tagged Sockeye last detected at the Priest Rapids adult fish trap, and presumably among the 10,000 Sockeye collected for a Cle Elum Lake Sockeye reintroduction program, are not included. Trapped fish are also not included in Priest Dam visual counts.

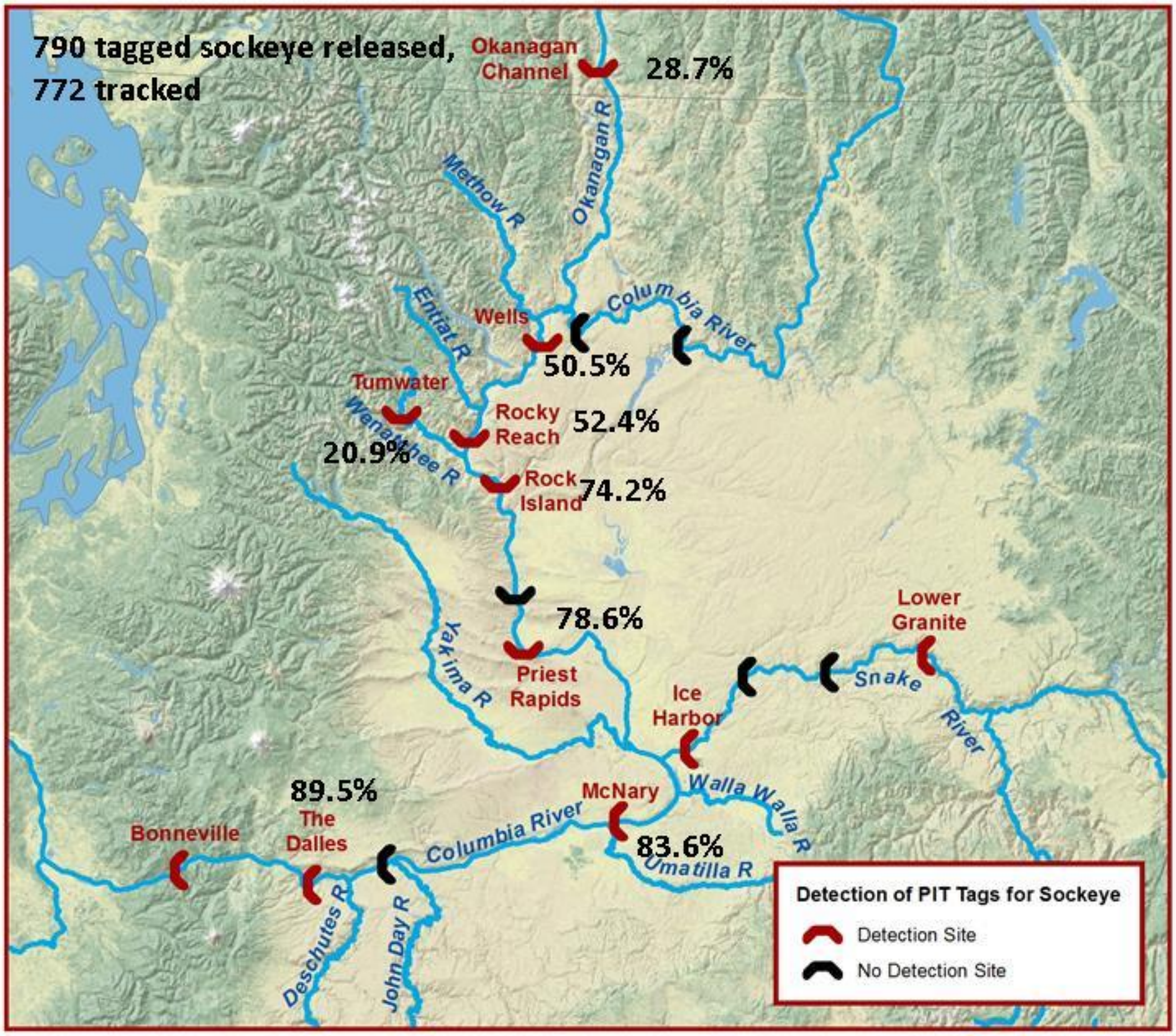

Figure 7. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, Ice Harbor, Lower Granite, and Tumwater dams and the Okanagan Channel in 2013.

As in most years of this study, and also true in 2013, survival from Bonneville to Priest Rapids and Rock Island dams showed a significant linear decrease with week tagged at Bonneville Dam (Table 8, Figure 8). The relationships for survival from Bonneville to McNary and Rock Island dams, as well as Rocky Reach to Wells Dam, were not significantly related to statistical week. The percentage of Age 1.2 Sockeye surviving to Rock Island Dam (79.3%) was greater than that for Age 1.3 (72.2%), Age 2.2 (74.5%) or Age 1.1 (68.0%) Sockeye Salmon (Figure 9).

Table 8. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2013 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Bonneville-The Dalles	Bonneville-McNary	Bonneville-Priest Rapids[5]	Bonneville-Rock Island	Rocky Reach-Wells
23	100.0%	87.5%	87.5%	87.5%	100.0%
24	93.8%	89.0%	87.6%	86.2%	96.7%
25	94.2%	92.0%	88.4%	82.6%	98.7%
26	85.3%	83.0%	79.5%	76.8%	97.1%
27	90.7%	81.3%	76.0%	69.3%	94.6%
28	86.0%	77.2%	72.8%	69.3%	93.0%
29	81.8%	65.9%	52.3%	47.7%	100.0%
30	100.0%	84.6%	38.5%	30.8%	100.0%
Composite	**89.5%**	**83.6%**	**78.6%**	**74.2%**	**96.6%**
p-value	**0.408**	**0.082**	**0.002**	**0.001**	**0.932**

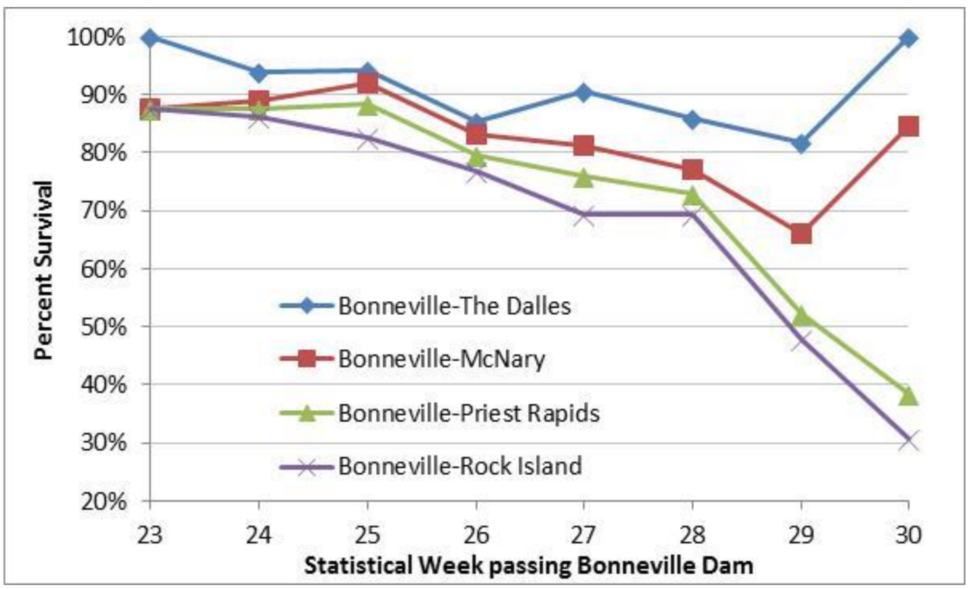

Figure 8. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2013.

[5] Includes Sockeye Salmon only detected in the Priest Rapids Dam trap that likely were collected for the Cle Elum Sockeye reintroduction project.

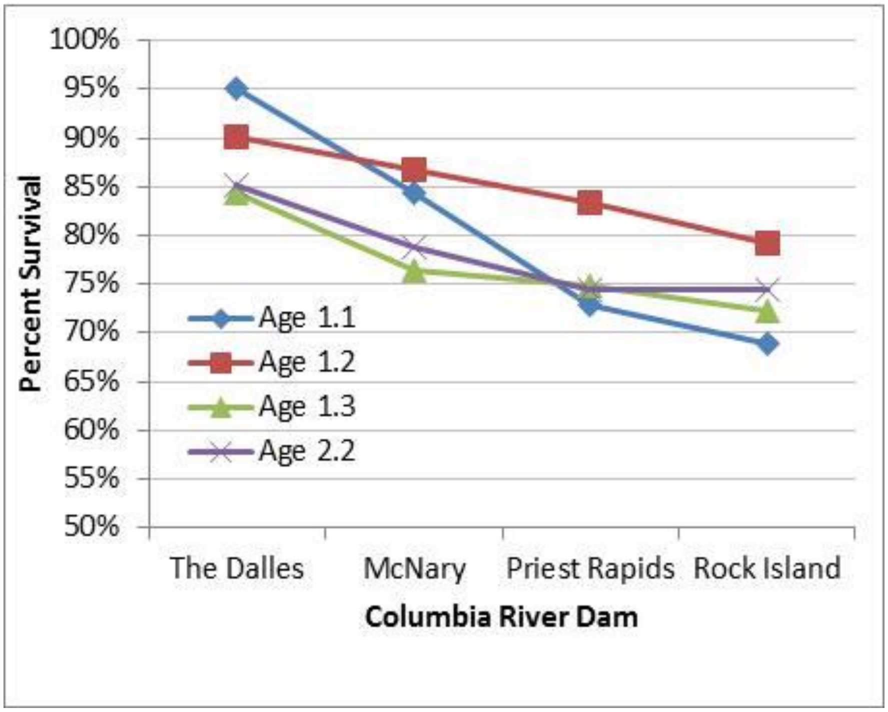

Figure 9. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams age group in 2013.

Migration rates and passage time

Adult Sockeye Salmon travel quickly upstream with a median migration rates between mainstem dams ranging between 21.7 and 52.7 km/day for Sockeye tagged at Bonneville Dam (Table 9). Returning adults tagged as smolts generally have slightly slower migration rates, with their median migration rate from Bonneville to Rock Island Dam being 1.3 km per day less than Sockeye tagged as adults (Table 9).

Sockeye Salmon tagged at Bonneville Dam later in the migration travel upstream faster than those earlier in the migration (Table 10). There is a significant (α=0.05) linear relationship between statistical week passing Bonneville Dam and migration time from Bonneville to Rock Island, Rocky Reach, Tumwater, and Wells dams as well as between McNary and Rock Island, Rock Island and Rocky Reach, and Rocky Reach and Wells dams. The median difference in travel time from Bonneville Dam to all upstream mainstem dams

except Wells Dam (where only four Sockeye classified as Wenatchee stock were detected) was one day or less between the two major stocks (Table 10).

Table 9. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2013.

		Tagged at Bonneville Dam		Adults Tagged as Juveniles	
Dam Pair	Distance (km)	Median Travel Time (days)	Median Migration Rate (km/day)	Median Travel Time (days)	Median Migration Rate (km/day)
Bonneville-The Dalles	74	1.9	39.9	1.7	44.0
The Dalles-McNary	162	3.1	52.7	3.3	49.4
McNary-Priest Rapids	167	4.8	34.6	5.0	33.7
Priest Rapids-Rock Island	89	2.9	30.5	2.9	30.5
Rock Island-Rocky Reach	33	1.1	30.8	1.0	32.3
Rocky Reach-Wells	65	1.8	35.3	1.9	34.6
Rock Island-Tumwater	73	11.6	6.3	12.1	6.0
Bonneville-McNary	231	5.0	46.2	5.1	45.7
Bonneville-Rock Island	487	13.1	37.1	13.6	35.8
Bonneville-Tumwater	560	25.8	21.7	26.8	20.9
Bonneville-Wells	585	16.0	36.6	16.6	35.2

Table 10. Adult Sockeye Salmon travel median time in days between dam pairs by statistical week tagged at Bonneville Dam, the p-value for a linear regression between travel time and statistical week, and mean travel time by stock as estimated using PIT tags in 2013.

Statistical Week at Bonneville Dam	BON-TDA	BON-MCN	BON-PRA	BON-RIA	BON-TUM	BON-RRH	BON-WEL	BON-OKC	WEL-OKC	RIA-TUF
23	2.2	6.0	12.3	16.8	38.3	18.8	21.9	115.1	93.1	20.3
24	2.0	5.2	13.0	17.9	34.2	19.3	21.5	108.8	86.2	15.4
25	1.9	5.1	10.7	13.7	27.0	14.8	16.7	101.9	85.8	12.2
26	1.9	5.1	9.8	12.8	24.6	13.7	15.8	96.0	81.1	10.9
27	1.7	4.8	9.0	11.8	21.0	12.5	15.0	88.5	75.5	7.6
28	1.7	4.6	8.7	10.8	19.8	11.7	13.1	86.1	72.3	8.2
29	1.7	4.8	8.1	10.7	--	11.6	13.6	80.2	67.1	--
30	1.9	5.0	10.6	12.3	--	13.3	15.9	75.9	60.1	--
P-value	**0.02**	**0.04**	**0.04**	**0.01**	**0.00**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**
Stock										
Okanagan	1.9	5.0	9.8	12.9	--	14.0	16.0	96.5	81.3	--
Wenatchee	1.9	5.1	10.2	13.9	25.8	13.9	23.7	--	--	11.6
Unknown[6]	1.8	5.1	9.9	13.0	--	--	--	--	--	--
Age										
1.1	1.7	4.8	8.7	10.9	--	12.0	13.8	85.4	72.1	--
1.2	1.9	5.0	10.1	13.2	25.3	14.7	16.6	99.2	82.6	11.8
1.3	1.9	5.1	10.9	15.2	28.1	17.6	19.6	95.2	77.4	11.6

[6] Unknown stock Sockeye Salmon are those that passed Bonneville but were not detected at Tumwater, Rocky Reach, Wells, Ice Harbor, or Lower Granite dams.

The median passage time at a dam (defined as the difference between the first and last detection at a dam) for Sockeye tagged at Bonneville Dam and those tagged as smolt was 7.4 minutes or less at all dams except for Bonneville Dam, and, in the case of juvenile-tagged fish, Wells and Lower Granite dams (Table 11). Bonneville Dam, unlike many dams which only have PIT tag antennas in the upper ladder, has an extensive array of antennas that include the lower ladders resulting in earlier detection than most other dams and thus a more complete record of passage times in the ladders.

Table 11. Sockeye Salmon median passage time from time of first detection at a dam to last detection at a dam and the percentage of Sockeye Salmon taking greater than 12 hours between first detection and last detection in 2013.

	Adults Tagged at Bonneville Dam		Previously Tagged as Juveniles	
Dam	**Median Passage (Minutes)**	**%>12 hours**	**Median Passage (Minutes)**	**%>12 hours**
Bonneville	64.9	6.7%	54.5	9.7%
The Dalles	0.1	2.1%	**0.1**	**10.6%**
McNary	0.1	0.8%	**0.2**	**2.5%**
Priest Rapids	6.2	2.1%	6.9	2.7%
Rock Island	3.7	1.3%	4.1	1.6%
Rocky Reach	1.3	2.7%	1.4	1.3%
Wells	7.4	3.5%	49.4	7.7%
Tumwater	6.6	4.3%	7.2	3.3%
Ice Harbor	--	--	7.1	17.4%
Lower Granite	--	--	130.9	29.7%

Night passage

Okanagan Sockeye Salmon stock tagged at Bonneville Dam generally passed PIT tag antennas at night (2000-0400 hours) at a higher rate than Wenatchee Sockeye Salmon stock (Table 12). As Okanagan Sockeye Salmon got closer to natal areas night migration increased, reaching 36.4% passing the Okanagan Channel PIT antenna during night hours. The Bonneville Dam estimate of night passage is likely biased low because tagging occurred between about 0800 and 1300 hours, and with a median passage time of 65 minutes from tagging to final detection at Bonneville Dam (Table 11), fish would be expected to pass the counting window prior to 2000 hours.

Table 12. Estimations for Sockeye Salmon stocks' nighttime passage (2000-0400 standard time) in 2013 at mainstem Columbia River dams as estimated by last PIT tag detection time.

Dam	Adults Tagged at Bonneville Dam				Sockeye Tagged as Juveniles
	Okanagan Stock	Wenatchee Stock	Unknown	All Adults	
Bonneville-OR shore	0.0%	0.0%	0.0%	0.0%	2.7%
Bonneville-WA shore	0.0%	0.6%	0.5%	0.3%	3.6%
The Dalles-OR shore	10.1%	5.1%	8.8%	7.7%	9.4%
The Dalles, WA shore	3.0%	10.7%	4.5%	5.6%	6.4%
McNary-OR shore	6.6%	2.2%	0.0%	4.0%	5.6%
McNary-WA shore	13.4%	4.1%	14.8%	9.7%	6.4%
Priest Rapids	5.2%	1.2%	2.6%	3.3%	2.0%
Rock Island	7.3%	1.9%	0.0%	4.5%	3.1%
Rocky Reach	12.0%	11.1%	NA	6.8%	3.8%
Wells	15.5%	0.0%	NA	8.5%	18.5%
Tumwater	NA	2.5%	NA	2.5%	3.3%
Okanagan Channel	36.4%	NA	NA	NA	15.9%

Fallback

Fallback rates for adults tagged at Bonneville Dam ranged from 1.0% at Bonneville Dam to 6.2% at McNary Dam (Table 13). Most tagged Sockeye passed on the Washington Shore. Visual counts suggested that 34.1% of Sockeye pass the Oregon shore ladder (DART 2014). Fallback rates of Sockeye tagged as juveniles were generally higher than those tagged as adults, reaching a high of 54.9% at Lower Granite Dam (50 out of 91 Sockeye passing).

Table 13. Estimated fallback rates for Sockeye Salmon at dams in 2013[7].

Dam	Adults Tagged at Bonneville	Tagged as Juveniles
Bonneville	1.0%	11.0%
The Dalles	2.8%	19.2%
McNary	6.2%	7.4%
Priest Rapids	3.6%	2.7%
Rock Island	2.2%	2.4%
Rocky Reach	4.6%	11.3%
Wells	1.3%	13.8%
Tumwater	1.8%	1.7%
Zosel	5.8%	0.0%
Ice Harbor	NA	16.5%
Lower Granite	NA	54.9%

[7] Does not include Sockeye Salmon that fell back over a dam and were not subsequently detected.

Stock composition estimates

The percentage of Wenatchee Sockeye Salmon stock was highest during the middle of the run at Bonneville Dam when compared to the beginning and end (Table 14). The overall stock composition estimate at Bonneville Dam was 28.0% Wenatchee, 70.0% Okanagan. A total of eight Sockeye were last detected in the Entiat, Yakima, and Deschutes rivers, resulting in stock composition estimates of 1.0% for the Entiat, 0.5% Yakima, and 0.6% Deschutes[8]. The percentage of the run at Bonneville Dam estimated to be of Okanogan origin (70.0%) was over 12 percentage points less than that estimated using visual fish counts (Table 14).

Table 14. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags in 2013 and a comparison to stock composition estimates estimated using visual dam counts

Statistical Week and Dates	Run Size from Bonneville Dam visual counts	PIT tags deployed at Bonneville	Okanagan	Wenatchee	Entiat	Yakima	Deschutes
23 (May 30-June 8)	2,331	16	85.7%	14.3%	0.0%	0.0%	0.0%
24 (June 11-14)	16,807	146	71.8%	28.2%	0.0%	0.0%	0.0%
25 (June 18-22)	40,879	138	65.5%	34.5%	0.0%	0.0%	0.0%
26 (June 25-29)	49,628	224	59.4%	40.0%	0.0%	0.6%	0.6%
27 (June 27-July 1)	37,818	77	68.0%	28.0%	4.0%	0.0%	2.0%
28 (July 5-8)	25,433	114	86.1%	10.1%	1.3%	2.5%	0.0%
29 (July 11-14)	9,214	44	100.0%	0.0%	0.0%	0.0%	0.0%
30 (July 18-19)	3,395	13	100.0%	0.0%	0.0%	0.0%	0.0%
Composite	**185,505**	**772**	**70.0%**	**28.0%**	**1.0%**	**0.5%**	**0.6%**
Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach counts to estimate proportion Wenatchee)			82.7%	17.3%			
Visual Fish Counts at dams (Tumwater count to estimate the proportion Wenatchee)			82.6%	17.4%			

[8] It is also possible that the two sockeye last detected in the Deschutes were harvested in the Zone 6 fishery or died by other means. The only other PIT tagged sockeye detected in the Deschutes were two Snake River sockeye that were also detected subsequent to the Deschutes River.

Table 15. Last detection site of clipped Sockeye Salmon tagged at Bonneville Dam in 2013.

Last Detection Site	Left Maxillary	Left Ventral	Right Maxillary Clip	Right Ventral Fin	Adipose Clipped
Bonneville Dam	0	0	0	0	1
McNary Dam	0	0	0	0	1
Wenatchee River	0	0	0	1	4
Wells Dam	1	0	0	0	3
OKC	0	1	1	0	0
Not Detected	0	0	0	0	1
Total	**1**	**1**	**1**	**1**	**10**

Nine Sockeye Salmon last detected in the Wenatchee River were previously detected at Rocky Reach Dam with one of these also detected at Wells Dam. There were no Sockeye detected at Tumwater Dam that were subsequently detected anywhere downstream of Tumwater Dam (including in the Columbia River upstream of the Wenatchee River).

A total of ten Sockeye Salmon PIT tagged[9] at Bonneville Dam were adipose clipped with one each recorded as right and left maxillary clipped and one each right and left ventral clipped (Table 15). Of these Sockeye, five were last detected in the Wenatchee Basin, two in the Okanagan Basin, four at Wells Dam, one at McNary Dam, and one at Bonneville Dam. One adipose-clipped fish was not detected after release following tagging at Bonneville Dam.

Wells Dam sampling

A total of 665 Sockeye were sampled at the Wells Dam Eastbank trap, of which 658 were PIT tagged with an additional 7 previously tagged fish added to our study group (Table 16). Of 665 Sockeye released with PIT tags, 61 were also acoustic tagged; one acoustic tag was used twice after being recovered from an angler-caught fish just upstream of Wells Dam. All sampled fish were transported by truck and released approximately 4 km upstream of Wells Dam along the west shore of Lake Pateros. The exception was 33 Sockeye Salmon sampled on July 30th, 29 of which were in the transport truck when it ran out of oxygen. This resulted in the death of 27 Sockeye Salmon. The two survivors from this event, as well as four Sockeye subsequently sampled, were released

[9] Juvenile Sockeye Salmon are adipose clipped in Snake River and Lake Wenatchee hatchery programs.

into the Eastbank fish ladder. The 27 mortalities as well as the two survivors, one of which was subsequently detected at Rocky Reach Dam with the other not detected, were excluded from all analyses of fish movement and survival.

Table 16. Number of Sockeye Salmon sampled and PIT and acoustic tagged at Wells Dam by date and statistical week in 2013. (Footnote 29 Sockeye lost on 7/30)

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	Acoustic tags deployed sample size	Temperature Tag
7/8,9	28	124	122	2	10	0
7/15,16,17	29	203	202	1	14	55
7/22,23,24	30	194	192	2	14	52
7/29,30,31; 8/1	31	109[10]	109	2	15	10
8/5,6,7,8	32	35	35	0	8	20
Total		**665**	**658**	**7**	**61**	**137**

Three fish sampled at Wells Dam were adipose clipped, suggesting they may have been Wenatchee stock since no Okanagan Sockeye are adipose clipped. Of these three Sockeye, one was detected at OKC, one was not subsequently detected, and the third was one of the aforementioned mortalities on July 30th, 2013.

Okanagan and Wenatchee age, and length-at-age composition

Okanagan and Wenatchee age composition was estimated from the age composition of Sockeye PIT tagged by this project at Bonneville Dam subsequently detected in terminal areas (Table 17). In both terminal areas, the majority of the run was Age 1.2. As has been observed in previous years, one-ocean Sockeye (ages 1.1 and 2.1) were only found in the Okanagan terminal area and none were detected in the Wenatchee terminal area. It has also been typical that five-year-olds (ages 1.3 and 2.2) are found in higher proportions in Wenatchee terminal areas compared to Okanagan terminal areas.

Sockeye sampled at Wells Dam had a much higher percentage of larger 1.3 fish and a lower percentage of Age 1.2 fish than the age composition estimated from Bonneville PIT tag detections at Wells would suggest. The tendency of the Wells Dam east ladder trap to select for larger fish has been

[10] Twenty-nine additional PIT tagged Sockeye Salmon were in a transport truck when it ran out of oxygen on July 30th, 2013 resulting in 27 mortalities. All 29 Sockeye were removed from subsequent analyses.

noted in previous years (Fryer et al 2013) and is likely a result of the 5.1 cm spacing of the bars on the diversion gate being sufficiently wide that smaller fish can slip through and avoid being trapped.

Table 17. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2013. Standard deviations are in parentheses.

Stock	Methodology	Ageable Sample Size	Brood Year and Age Class				
			2010	2009		2008	
			1.1	1.2	2.1	1.3	2.2
Bonneville Mixed	Bonneville Dam Sampling	799	17.4 (1.3)	62.7 (1.8)	0.5 (0.3)	13.4 (1.2)	6.0 (0.9)
Okanagan	Bonneville PIT tagged detected last detected at Rocky Reach or Wells or in the Okanagan River	395	24.3 (2.2)	61.6 4.3	--	8.7 (3.7)	5.4 (2.5)
	Wells Dam Sampling	694	25.8 (1.2)	44.5 (2.5)	0.3 (0.4)	27.9 (2.4)	1.4 (0.2)
Wenatchee	Bonneville PIT tagged last detected in Wenatchee River	161	--	67.8 (4.3)	--	24.5 (3.7)	7.6 (2.5)

Among Sockeye sampled at Wells Dam, the percentage of Age 1.1 Sockeye Salmon increased as the run progressed while the percentage of Age 1.2 and 1.3 Sockeye decreased (Table 18).

Table 18. Age composition by week for Sockeye Salmon sampled at Wells Dam in 2013.

Stat Week	Sampling Dates	Run Size	N	N Ageable	1.1	1.2	2.1	1.3	2.2
28	7/8,9	63,585	124	121	0.8%	56.2%	0.0%	43.0%	0.0%
29	7/15,16,17	34,812	203	197	33.5%	43.7%	0.5%	19.3%	3.0%
30	7/22,23,24	22,386	194	192	64.6%	23.4%	0.5%	8.9%	2.6%
31	7/31,8/1	6,372	138	136	77.2%	16.2%	1.5%	2.9%	2.2%
32	8/5,6,7,8	2,838	35	34	70.6%	23.5%	0.0%	2.9%	2.9%
Composite		**129,993**	**694**	**680**	**25.8%**	**44.5%**	**0.3%**	**27.9%**	**1.4%**
Std. Dev.					**1.2%**	**2.5%**	**0.4%**	**2.4%**	**0.2%**

Mean lengths estimated using fish sampled at Wells Dam were generally greater than those estimated using Bonneville PIT tag data (Table 19). The aforementioned trap selectivity at Wells likely contributed as did morphometric changes caused by fish maturation as well as differences in the way the Sockeye were measured. At Bonneville Dam, Sockeye were held up against a measuring stick mounted on top edge of the sampling tank while at and Wells dams, Sockeye were placed in a sling and a measuring tape used. In the former

approach, a fish not held straight would likely have its length underestimated while the latter approach may measure the curvature of the fish resulting in length being overestimated.

Table 19. Length-at-age composition of Wenatchee and Okanagan Sockeye Salmon stocks estimated by detection of Sockeye Salmon previously PIT tagged at Bonneville and Priest Rapids dams and sampling at Wells Dam in 2013.

		Brood Year and Age Class				
		2010	2009		2008	
Stock	Fork Length	1.1	1.2	2.1	1.3	2.2
Bonneville Dam-Mixed Stock	Mean (cm)	38.3	49.7	42.3	56.0	48.3
	St. Dev. (cm)	1.7	2.1	2.5	2.4	1.7
	N	129	481	3	115	129
Okanagan-Bonneville PIT tags	Mean	38.3	49.4	--	55.4	49.4
	St. Dev.	1.7	2.1	--	1.9	2.1
	N	83	250	--	39	22
Okanagan-Wells Sampling[11]	Mean	38.9	52.2	43.8	57.6	51.7
	St. Dev.	1.8	2.8	1.0	2.8	4.7
	N	320	229	4	112	15
Wenatchee-Bonneville PIT tags	Mean	--	50.1	--	56.2	51.7
	St. Dev.	--	2.0	--	2.0	1.5
	N	--	106	--	44	11

Detections in natal areas

Okanagan stock

The estimated conversion rate from Wells Dam to OKC based on Sockeye tagged at Wells Dam was 49.0% compared to 56.5% for Sockeye tagged at Bonneville Dam (Table 20). Of the Sockeye Salmon tagged at Wells Dam, 3.6% were last detected downstream of Wells Dam in the Entiat or Wenatchee rivers or at Rock Island or Rocky Reach dams, compared to 1.3% for Sockeye tagged at Bonneville Dam which passed Wells Dam (Table 20).

An estimated 3.2% of Wells dam tagged Sockeye entering Wells Pool were reported captured and released in the Colville purse seine fishery at the mouth of the Okanagan River (Table 21) with another 2.5% captured in the Osoyoos Lake fishery.

[11] The estimated Okanagan stock age composition determined from otoliths collected on the spawning ground (n=83) in 2013 was .1.1=16.9%, 1.2=56.6%, 2.1=1.2%, 1.3=13.3%, 2.2 =10.8%, 1.4=1.2% (Margot Stockwell, personal communication).

Table 20. Number of tagged (PIT+Floy, PIT+Floy+acoustic) Sockeye released upstream of Wells Dam in 2013 with the estimated percentage last detected by site (weighted by weekly run size at Wells Dam). Rates for Bonneville dam tagged Sockeye Salmon are shown for comparison.

Week	Wells Run %	N	Wenatchee River	RIS/ RRH	Entiat River	Wells Dam	Methow River	Omak Creek	Zosel Dam	OKC	Not Detected
28	48.9%	124	3.2%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	69.4%	26.6%
29	26.8%	203	2.5%	0.0%	1.0%	0.5%	1.0%	0.0%	3.9%	38.4%	52.7%
30	17.2%	194	2.1%	0.5%	1.5%	1.0%	1.5%	0.5%	9.3%	20.1%	63.4%
31	4.9%	109	0.0%	1.8%	3.7%	2.8%	1.8%	0.9%	9.2%	21.1%	58.7%
32	2.2%	35	0.0%	5.7%	0.0%	0.0%	5.7%	0.0%	2.9%	14.3%	71.4%
Weighted Total		**665**	**2.6%**	**0.3%**	**0.7%**	**0.4%**	**1.1%**	**0.1%**	**3.2%**	**49.0%**	**42.5%**
Bonneville tagged Sockeye detected at Wells		**400**	**0.2%**	**0.0%**	**1.1%**	**NA**	**0.0%**	**0.0%**	**6.0%**	**56.5%**	**35.5%**

Table 21. Percentage of Sockeye tagged at Wells Dam passing Wells Dam and reported harvested in Colville and Okanagan Nation Alliance fisheries in 2013.

Week Tagged	Colville Fishery			Osoyoos Lake Fishery	
	N	% of Sockeye Tagged	% Released	N	% of Sockeye Tagged
28	0	0	0	4	3.2%
29	14	6.9%	78.6%	4	2.0%
30	12	6.2%	75.0%	3	1.5%
31	3	2.8%	33.3%	2	1.8%
32	3	8.6%	100.0%	0	0.0%
Weighted by weekly Wells visual count	**32**	**3.2%**	**73.9%**	**13**	**2.5%**

Survival from Wells Dam to OKC decreased greatly for Sockeye Salmon passing Wells Dam later in the run (Table 20, Figure 10). For those Sockeye passing, or tagged at, Wells Dam on or before July 16, 61.9% of Wells-tagged and 71.5% of Bonneville-tagged Sockeye were detected at OKC. For those Sockeye passing, or tagged at, Wells Dam on or after July 17, 23.3% of Wells-tagged and 29.2% of Bonneville-tagged Sockeye were detected at OKC.

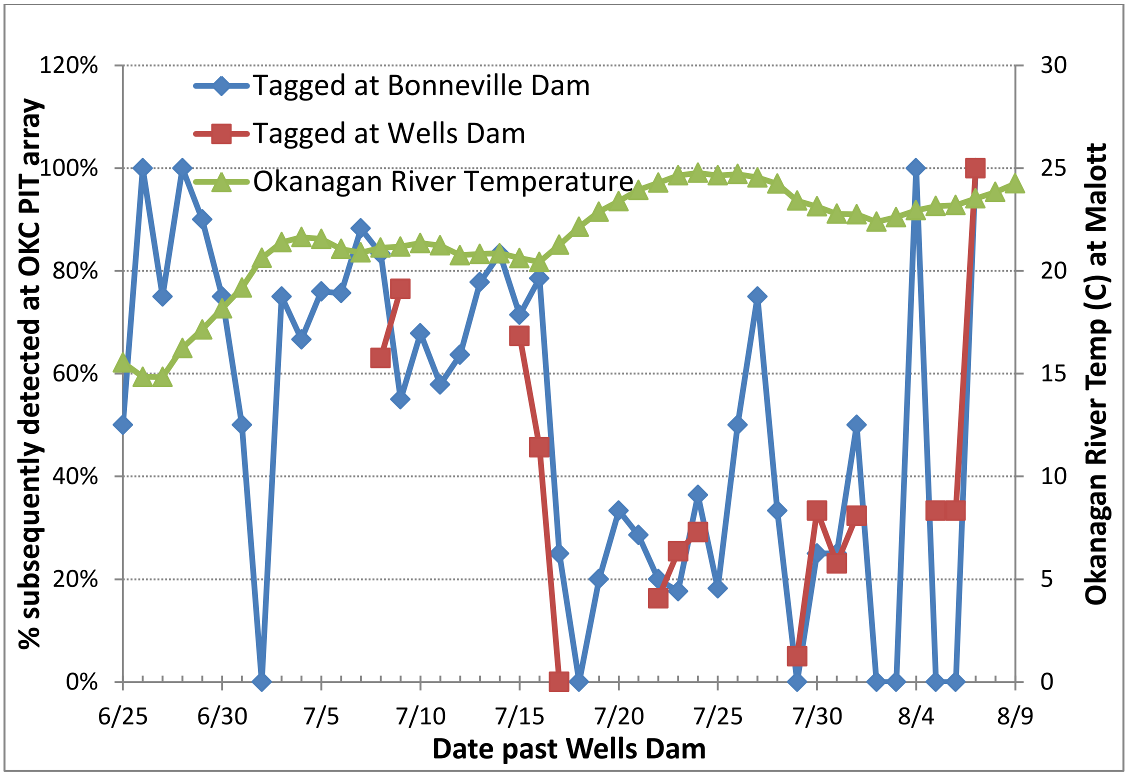

Figure 10**. Percentage of Sockeye tagged at Wells and Bonneville passing Wells Dam subsequently detected at OKC by date past Wells Dam in 2013. Okanagan River temperatures were recorded at the Malott gaging station (http://waterdata.usgs.gov/nwis/uv?site_no=12447200).**

In-basin detection of PIT tagged Okanagan Sockeye Salmon

As was noted earlier, high flows allowing salmon to migrate through the spillway rather than the fishways resulted in only 74 Bonneville-tagged, and 99 Wells-tagged Sockeye Salmon being detected at the Zosel Dam fish ladder PIT tag antennas (Table 1).

Upstream of Osoyoos Lake, early migrating Sockeye Salmon were detected at OKC in July prior to water temperatures climbing above 22C. Once temperatures climbed above 22C, significant numbers of Sockeye Salmon were not detected at OKC until water temperatures dropped from 15.1C on September 29, 2013 to 14.3C on September 29, 2013. This resulted in the number of Sockeye first detected at OKC increasing from 25 to 88 (Figure 11).

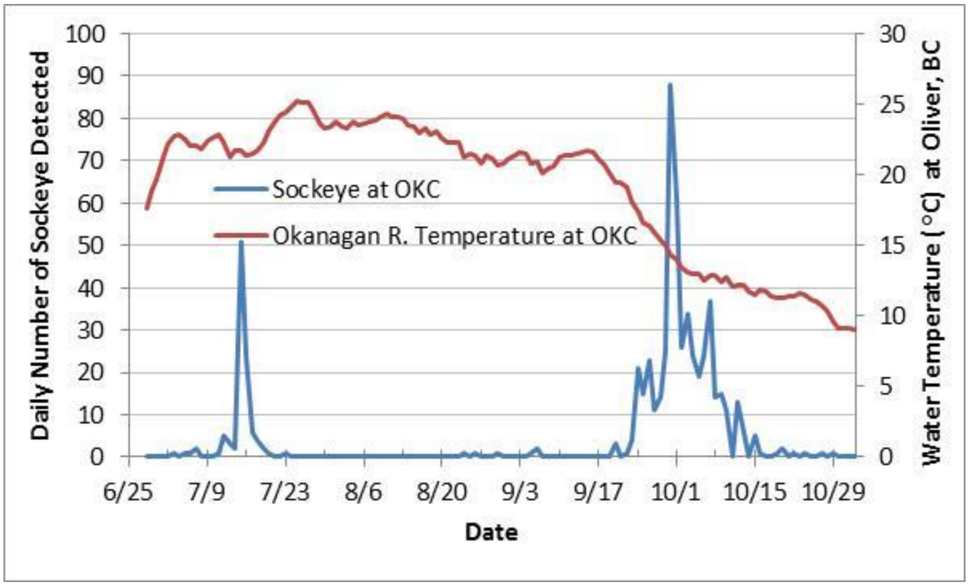

Figure 11. Number of PIT tagged Sockeye first detected at OKC and Okanagan River water temperatures by date in 2013.

Genetic Stock Identification (GSI)

In 2013, genetics stock identification (GSI) was used to classify samples from 248 Sockeye Salmon sampled at Bonneville Dam that could not be tracked to a terminal area. These consisted of 231 Sockeye which either were, not detected after tagging, last detected at mainstem Columbia River dams downstream of Wells Dam, or not PIT tagged. An additional 17 Sockeye were added to the analyses as their PIT tag detection history suggested some uncertainty in PIT tag stock classification. These included Sockeye last detected in tributaries (e.g. Entiat, Deschutes, and Yakima) other than the Okanagan and Wenatchee and Wenatchee River sites downstream of Tumwater Dam. Sockeye detected at Wells or Rocky Reach dam and subsequently detected in the Wenatchee River were also included. One Sockeye last detected at Wells Dam, and thus considered conclusively classified Okanagan stock, was inadvertently included.

Among Sockeye Salmon last detected in tributaries where spawning Sockeye have been observed, (Entiat, Yakima, Deschutes), both Sockeye last detected at the Deschutes River mouth were classified using GSI as Okanogan stock, while all three Sockeye last detected at Roza Dam in the Yakima River classified as Wenatchee stock (Table 22). In the Entiat River, two Sockeye

classified as Wenatchee and one as Okanagan. In all three cases, there was no known baseline data for these basins, so the possibility that these are Entiat/Yakima/Deschutes Sockeye cannot be dismissed; so, for purposes of further analyses and summaries, these classifications were used.

Table 22. GSI classification of Sockeye detected in both terminal areas, or last detected in terminal areas (at or above Wells or Tumwater dams), or detected in both terminal areas.

Last Site	Okanagan	Wenatchee	Snake
Bonneville Dam (BO1, BO3, BO4)	53	25	5
Deschutes River mouth (DRM)	2	0	0
Entiat Mouth (ENM)	1	1	0
Entiat Upstream (ENS)	0	1	0
Hood River mouth (HRM)	1	0	0
Icicle Creek (ICL)	0	1	0
Lower Wenatchee (LWE)	0	2	0
Little Wenatchee (LWN), also detected at Wells or Rocky Reach	0	2	0
McNary Dam (MC1, MC2)	30	3	0
Priest Rapids Dam	22	6	0
Rock Island Dam	5	5	0
Roza Dam (ROZ), Yakima River	0	3	0
Rocky Reach Dam	5	1	0
The Dalles Dam (TD1, TD2)	31	8	2
Upper Wenatchee (UWE), also detected at Wells or Rocky Reach	0	5	0
Wells Dam	1	0	0
Not detected after tagging	11	9	1
Not tagged	3	0	0
Mortalities	2	1	0
Total	**167**	**73**	**8**

All Sockeye detected at Wells and Rocky Reach dams subsequently detected in the Wenatchee River classified as Wenatchee stock as did one of six Sockeye last detected at Rocky Reach Dam.

When Sockeye placed in a category as unknowns, by last PIT tag detection, were classified by GSI, overall stock composition estimates changed by 1.3 percentage points or less (Table 23). The most notable change was that for ESA-listed Snake River Sockeye which increased from 0.0% to 0.9%, though this was based on only eight fish. Snake River Sockeye were more likely to be found later in the adult migration at Bonneville Dam, peaking at 2.6% in

Statistical Week 28 (Table 24). Stock specific survival to terminal areas was 72.1% for the Okanagan stock, 70.1% for the Wenatchee stock, and 0.0% for the Snake stock (Table 25).

Table 23. Comparison of classification by stock using GSI and PIT tags of Sockeye Salmon sampled at Bonneville Dam in 2013.

	Stock Classification					
Classification method	**Deschutes**	**Entiat**	**Okanagan**	**Snake**	**Wenatchee**	**Yakima**
Using PIT tags	0.6%	1.0%	70.0%	0.0%	28.0%	0.5%
Unknown Sockeye (based on PIT tags) classified using GSI	NA	NA	69.8%	3.1%	27.2%	NA
PIT + Genetics	0.4%	0.6%	69.2%	0.9%	28.5%	0.3%

Table 24. Comparison of stock classification of Sockeye sampled at Bonneville Dam using GSI and PIT tag detections in 2013.

	PIT Classification				Classification Using PIT Plus Genetics			
Statistical Week	**Okanagan**	**Wenatchee**	**Snake**	**Other**	**Okanagan**	**Wenatchee**	**Snake**	**Other**
23	85.7%	14.3%	0.0%	0.0%	87.5%	12.5%	0.0%	0.0%
24	71.8%	28.2%	0.0%	0.0%	72.3%	26.4%	1.4%	0.0%
25	65.5%	34.5%	0.0%	0.0%	67.1%	32.9%	0.0%	0.0%
26	59.1%	39.8%	0.0%	1.2%	59.5%	39.2%	0.4%	0.9%
27	66.7%	27.5%	0.0%	5.9%	65.9%	29.4%	1.2%	3.5%
28	86.1%	10.1%	0.0%	3.8%	82.9%	12.0%	2.6%	2.6%
29	100.0%	0.0%	0.0%	0.0%	85.1%	12.8%	2.1%	0.0%
30	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
Composite	**70.0%**	**28.0%**	**0.0%**	**2.0%**	**69.2%**	**28.5%**	**0.9%**	**1.3%**

Table 25. Stock specific survival from sampling at Bonneville Dam to terminal areas weighted by weekly Bonneville Dam run size, as estimated by GSI and PIT tags in 2013.

	Stock Classification Using PIT tags With GSI Used to Classify Unknowns			
Statistical Week	**Okanagan**	**Wenatchee**	**Snake**	**All Stocks**
23	85.7%	100.0%	--	87.5%
24	83.0%	92.0%	0.0%	84.8%
25	80.2%	84.6%	--	81.7%
26	74.1%	78.5%	0.0%	75.5%
27	64.4%	61.3%	0.0%	62.6%
28	71.0%	60.9%	0.0%	67.9%
29	52.4%	0.0%	0.0%	43.8%
30	29.2%	--	--	29.2%
Weighted Mean	**72.1%**	**70.1%**	**0.0%**	**71.7%**

Comparisons with Sockeye tagged as juveniles

Mixed and Okanagan stock Sockeye Salmon tagged as adults at Bonneville Dam generally had a higher survival from Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams than did returning Sockeye Salmon tagged as juveniles. The sole exception was juveniles tagged in the Okanagan Basin from which only 12 Sockeye returned (Table 26). The Wenatchee hatchery stock tagged at Eastbank Hatchery had the lowest survival to Rock Island Dam (after excluding Snake River-tagged Sockeye which would not be expected to be detected upstream of the Snake River.) Comparisons at dams above Rock Island are not possible due to the different stock compositions of the PIT tag groups.

Table 26. Survival of Sockeye Salmon PIT tagged adults at Bonneville Dam and as juveniles for other programs to McNary, Priest Rapids, and Rock Island dams in 2013.

					Estimated Survival from Bonneville Dam to:					
PIT Tagging Site	**Rearing**	**Stock**	**Life Stage at Tagging**	**Detected at or above Bonneville Dam**	**The Dalles Dam**	**McNary Dam**	**Priest Rapids Dam**	**Rock Island Dam**	**OKC**	**Tum-water**
Eastbank Hatchery	Hatchery	Wenatchee	Juvenile	77	83.3	79.5	78.2	71.8	0.0	50.0
Okanagan River	Mixed	Okanagan	Juvenile	12	100.0	100.0	100.0	83.3	50.0	0.0
Wenatche e River	Wild	Wenatchee	Juvenile	14	57.1	50.0	50.0	50.0	0.0	51.3
Rock Island Dam	Mixed	Mixed	Juvenile	66	88.4	78.3	75.4	62.3	39.1	11.6
Snake River	Mixed	Snake	Juvenile	207	83.7	67.8	5.3	4.3	0.0	0.0
Bonneville AFF	Mixed	Mixed	Adult	769	89.5	83.6	78.6	74.2	28.7	20.9
Bonneville AFF	Mixed	Wenatchee	Adult	213	82.1	76.8	75.1	71.7	0.0	66.7
Bonneville AFF	Mixed	Okanagan	Adult	541	90.7	84.7	78.5	73.9	41.4	0.0

Bonneville-tagged Sockeye had a lower combined detection rate at spawning ground PIT arrays on the Little Wenatchee and White rivers than did Eastbank and Wenatchee River-tagged fish (Table 27, Figure 12). However sample sizes were small for the juvenile-tagged groups (only 11 Sockeye combined detected at WTL and LWN) and there was an outage of the WTL site

from approximately 0900 on September 11th to 1300 on September 24th that may have missed many, if not most, of Sockeye spawning in the White River. Twelve out of 16 observations of Bonneville-tagged Sockeye at the White River array occurred in the 30 hours prior to the WTL site outage.

Table 27. Distribution of Sockeye Salmon in the Wenatchee Basin in 2013, PIT tagged as both juveniles and adults.

				Percent Detected at Antenna Arrays Upstream of Tumwater Dam			
PIT Tag Location	**Hatchery / Wild**	**Life Stage at Tagging**	**Number at Tumwater Dam**	**Little Wenatchee (LWN)**	**White River (WTL)**	**Nason Creek (NAL)**	**Total on spawning grounds (LWN and WTL)**
Eastbank	Hatchery	Juvenile	40	10.0%	7.5%	2.5%	17.5%
Wenatchee River	Wild	Juvenile	7	0.0%	14.3%	0.0%	14.3%
Rock Island	Mixed	Juvenile	8	0.0%	0.0%	0.0%	0.0%
Bonneville AFF	Mixed	Adult	162	5.6%	6.2%	0.0%	11.8%

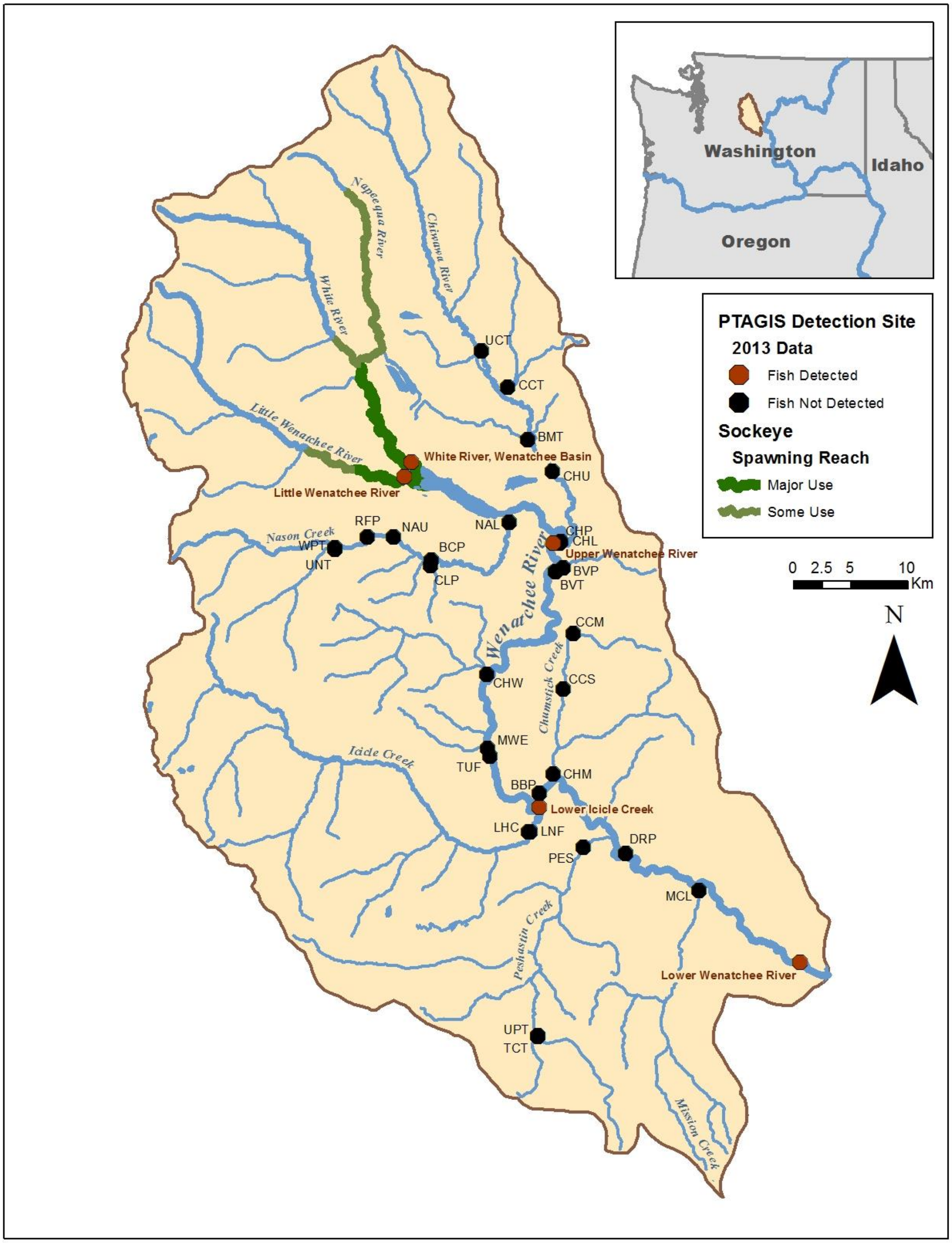

Figure 12. Portion of Wenatchee Basin with PIT detectors that could detect returning adult salmon or steelhead. Also displayed is the spawning area of Sockeye. Appendix Table A4 has site information.

Median migration times between Bonneville and The Dalles as well as between The Dalles and McNary Dam differed by 0.4 days or less between the PIT tag groups (Table 28). The Okanagan River PIT tag group had the fastest migration; however the sample size (12) was small.

Table 28. Median migration time in days between Columbia Basin PIT tag antenna sites for adult and juvenile Sockeye tagged migrating upstream in 2013. An asterisk (*) indicates Sockeye which strayed from the normal migration route for the stock of concern. Appendix table A4 has site information.

PIT Tagging Site	Rear Type	Stock and Life Stage at Tagging	BON-TDA	BON-MCN	PRD-RIS	RIS-RRH	RRH-WEA	WEA-OKC	RIS-TUF	PRD-WEA	PRD-TUF
Eastbank Hatchery	Hatchery	Wenatchee Juvenile	1.7	5.0	2.9	1.0*	3.1*	--	12.1	7.0	15.7
Okanagan River	Wild	Okanagan Juvenile	1.7	4.7	2.4	0.9	1.7	6.6	--	4.8	--
Wenatchee River	Wild	Wenatchee Juvenile	1.5	4.9	4.3	--	--	--	11.9	--	16.9
Rock Island Dam	Mixed	Mixed Juvenile	1.8	4.9	3.0	1.1	1.9	81.1	13.6	5.8	17.3
Snake River	Mixed	Snake	1.6	5.1	2.8*	1.0*	2.1*	--	--	5.0*	--
Bonneville AFF	Mixed	Mixed Adult	1.9	5.0	2.9	1.1	1.8	81.3	11.6	6.0	15.1

Acoustic data analysis

A total of 61 Sockeye Salmon were implanted with acoustic tags in addition to PIT tags at the Wells Dam East fish ladder between July 8 and August 8, 2013 (Statistical weeks 27-32, Table 29). One acoustic tag was used twice as a Sockeye tagged on July 23, 2013 was captured in an upstream fishery and the tag reapplied on July 30. After weighting by weekly run size at Wells Dam, the weighted conversion rate to OKC was 46.1% compared to 54.8% for those fish PIT but not acoustic-tagged at Wells Dam and 56.5% for those Sockeye PIT tagged at Bonneville Dam.

All 61 Sockeye acoustically tagged were detected upstream at our Pateros receiver (Table 30). Using the data from these acoustic tagged Sockeye, we estimated an 85.6% survival from Wells Dam to the Monse Bridge, 71.3% to our North Basin Osoyoos Lake receiver, and 18.6% to McIntyre Dam (Table 30).

Detections of Sockeye tagged at Wells Dam suggest a decrease in survival to upstream points as the run progressed. The survival to our Monse Bridge site

Table 29. Estimated conversion rate from Wells Dam to OKC for Sockeye Salmon tagged at Bonneville, and Wells dams by statistical week and weighted by the Wells Dam weekly run size in 2013.

			Tagging Site								
			Wells Dam							Bonneville Dam	
	Mean Weekly Temperature		PIT + Floy Tagged Only		PIT+ Floy+Acoustic Tagged		All PIT+ Floy tagged	PIT Plus temperature tag		PIT Tagged Only	
Week	Wells	Okanagan River (Malott)	N	% at OKC	N	% at OKC	% to OKC	N	% at OKC	N	% at OKC
<=27	15.8	20.5	--	--	--	--	--	--	--	123	72.4%
28	16.4	21.1	114	71.1%	10	50.0%	69.4%	--	--	135	69.6%
29	17.0	21.7	134	52.2%	14	42.9%	38.4%	55	3.6%	45	55.6%
30	18.1	24.5	130	23.1%	14[12]	50.0%	20.1%	50	5.8%	70	28.6%
31	18.2	23.0	84	23.3%	15	20.0%	20.7%	10	0.0%	22	27.3%
32	19.0	23.7	7	42.9%	8	25.0%	14.3%	20	0.0%	5	60.0%
Weighted			**694**	**54.8%**	**61**	**46.1%**	**49.0%**	**135**	**3.9%**	**400**	**56.5%**

Table 30. Detection rate at acoustic receiver sites and estimated survival rate to those sites for Sockeye Salmon PIT and acoustic tagged at Wells Dam in 2013.

Site	Number of Receivers	Estimated Detection Efficiency	Number Detected	Estimated % of run passing site based on acoustic detections and accounting for detection efficiency
Pateros	1	100.0%	61	100.0%
Brewster Dock	1	93.2%	59	100.0%
Monse Bridge	2	100.0%	46	85.6%
Driscoll, Similkameen R.	1	100.0%	5	8.9%
Oroville pumping station	2	100.0%	33	72.6%
Haynes Point	2	100.0%	32	71.3%
Okanagan North Basin	1	100.0%	32	71.3%
Okanagan River Mouth	2	100.0%	26	60.7%
Okanagan River-Hwy 97	1	84.6%	18	41.7%
McIntyre Dam	1	100.0%	10	18.6%
Okanagan Falls	1	NA	1	1.2%

[12] Two of these fish were also temperature tagged

dropped from 90% or greater in weeks 28 and 29, to 71.4-73.3% in weeks 29 and 30, to 37.5% in week 32. Sockeye Salmon tagged in week 31 had survival to Monse similar to that of those tagged in Week 30; however survival to Osoyoos Lake was more similar to the lower survival rate found in Week 32 (Table 31).

Table 31. Percentage of Sockeye Salmon acoustic tagged at Wells Dam passing upstream receivers in 2013.

Week	Tag Date	N	Monse Bridge	Oroville Pump Station	Haynes Point	North Osoyoos Basin	OKC Array[13]	McIntyre Dam
28	July 8-9	10	90.0%	90.0%	90.0%	90.0%	50.0%	30.0%
29	July 15-16	14	92.9%	57.1%	57.1%	57.1%	42.9%	0.0%
30	July 22-23	14	71.4%	64.3%	57.1%	57.1%	50.0%	21.4%
31	July 29-30	15	73.3%	33.3%	33.3%	33.3%	20.0%	0.0%
32	August 5-6	8	37.5%	25.0%	25.0%	25.0%	25.0%	12.5%
Weighted by Weekly Wells Run		**61**	**85.6%**	**72.6**	**71.3**	**71.3**	**46.1%**	**18.6%**

The percentage of acoustic tagged Sockeye Salmon subsequently detected at or above OKC was approached 50% during the early portion of the run (tagged at Wells Dam during weeks 28-32) compared to 20.0-25.0% during the later portion of the run (tagged at Wells Dam during weeks 31-32, Table 31). Sockeye tagged on or after July 22 were more than twice as likely as earlier tagged fish to be last detected in Wells Pool or the North Basin. Acoustic tagged Age 1.3 Sockeye Salmon had higher survival to the OKC array (75.0%) than Age 1.2 (38.1%) or Age 1.1 (32.1%).

Many of our receivers were deployed at confined locations on the migration corridor where we expected to be able to detect all, or nearly all, passing Sockeye Salmon. The detection rates for passing acoustic tagged Sockeye Salmon were 93.2% or better at all acoustic receiver sites except the Highway 97 bridge site upstream of Lake Osoyoos (Table 30, Figure 6).

Acoustic tag detections upstream of OKC for PIT plus acoustic tagged Sockeye can be used to estimate detection efficiency at the OKC PIT tag

[13] Includes two Sockeye not detected by the OKC array, but with acoustic tags detected upstream.

antenna. Of the 18 fish both acoustic and PIT tagged that were detected upstream of OKC, PIT tags were detected at OKC for 16, resulting in an estimated detection efficiency for the OKC PIT antenna of 88.9%.

The amount of time that acoustic tagged Sockeye Salmon spent in the Wells Pool and the Okanagan River, downstream of Osoyoos Lake, varied greatly by week (Table 32). Sockeye tagged in weeks 28 and 29 which were subsequently detected in the North Basin had a median migration time of less than one week. On the other hand, Sockeye tagged in weeks 30-32 had a median migration time ranging from 28.0 to 33.0 days to the North Basin. The Sockeye Salmon which passed Monse and were not detected in the North Basin all passed Monse during periods of rising water temperatures between July 16-18 (five mortalities) and July 31-August 4 (eight mortalities) (Figure 13). Eight of these 13 mortalities were detected in the Similkameen River. For six of these, this was their last detection with the remaining two moving downstream with one being last detected at our Brewster antenna and the other at Monse. No Sockeye detected in the Similkameen in 2013 was detected any further upstream in the Okanagan River. Survival from Monse to the North Basin of Osoyoos lake was lowest for Sockeye passing Monse when temperatures recorded just upstream at Malott were between 22 and 23C (Table 33, Figure 13).

Table 32. Migration time to upstream receiver sites for Sockeye acoustic tagged at Wells Dam by date in 2013.

Week	Tag Date	Median Days to Monse Bridge	Median Days to Haynes Point	Median Days to North Basin	Median Days to OKC	Median OKC Passage Date
28	July 8-9	3.8	6.4	6.7	83.8	10/1
29	July 15-16	0.9	3.8	6.7	77.3	10/1
30	July 22-23	12.1	24.5	33.0	67.9	9/29
31	July 29-30	3.6	23.7	28.0	65.7	10/3
32	August 5-6	17.7	25.0	28.3	54.6	9/30
Overall		**3.8**	**6.7**	**11.5**	**74.0**	**10/1**

Table 33. Survival of Sockeye PIT tagged at Wells Dam from Monse to the Osoyoos Lake North Basin by Okanagan River temperature at Malott in 2013.

Temperature range (°C)	Detected at Monse and subsequently detected at Osoyoos Lake north basin	Detected at Monse and not detected at north basin	% Survival from Monse to North Basin
20 to 21	12	2	85.7%
>21 to 22	10	2	83.3%
>22 to 23	10	10	50.0%

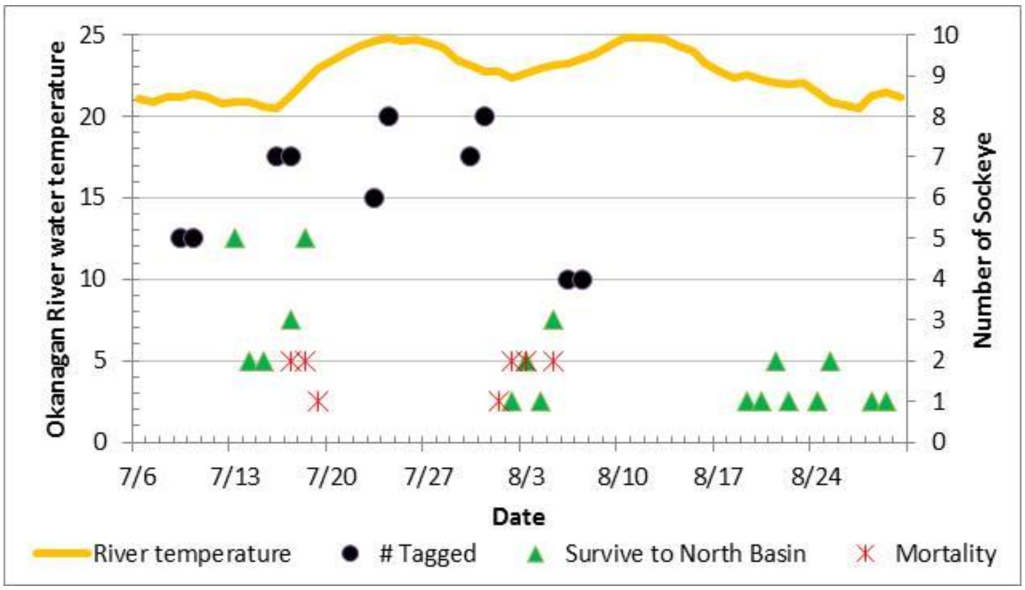

Figure 13. Okanagan River temperature at Malott and survival of Sockeye acoustic tagged passing Monse Bridge acoustic receiver to Osoyoos Lake in 2013. Black circles indicate date of tagging at Wells Dam, green triangles indicate the date passing Monse for fish that survived to Osoyoos Lake, while red starts indicate date passing Monse for fish that did not reach Osoyoos Lake.

Acoustic tagged Sockeye Salmon passing the Monse acoustic site can be divided into four groups (Table 34). The first group consisted of nine Sockeye Salmon tagged between July 8 and 10 that migrated past Monse between July 12 and 14. These fish had a median time from Wells to Monse of 3.8 days. Temperatures in the Okanagan River were under 21C and these fish then took 3.1 days to travel from Monse to the North Basin and had 100% survival from Monse to the North Basin.

Table 34. Survival of Sockeye PIT tagged at Wells Dam from Monse to the Osoyoos Lake North Basin by Okanagan River temperature at Malott in 2013.

Group	N	Date Past Monse	Weeks Tagged at Wells	Monse to North Basin	% North Basin to OKC	Overall % Monse-OKC	Median Time Wells to Monse	Median Days Monse-North Basin
1	9	July 12-14	28	100.0%	77.8%	77.8%	3.8	3.1
2	13	July 16-18	29	61.5%	75.0%	46.2%	0.9	5.7
3	14	July 31-Aug 4	30, 31	42.9%	66.7%	28.6%	5.8	4.9
4	10	Aug 8-18	30-32	90.0%	88.9%	80.0%	21.6	9.7

The second group was tagged from July 16-18 and had a median migration time from Wells Dam to Monse of only 0.9 days; possibly responding to increasing water temperatures by moving past Monse more quickly. These 13 fish passed Monse between July 16 and July 18 when water temperatures were rising from 20.5 to 22.2C on their way to a peak of 24.8C on July 24. These fish had a survival rate from Monse to the North Basin of 61.5% and a median time of 5.7 days.

The third group consisted of 14 of the Sockeye tagged between July 22 and 29 and passed Monse between July 31 and August 4. Between July 24 and August 4, temperatures ranged from 22.4 to 23 degrees and then climbed to a peak of 24.8C on August 11. Survival to the North Basin was 42.9% and these fish had the lowest overall survival to OKC of 28.6%.

The final group consisted of the remainder of Sockeye tagged at Wells between July 22 and July 29 plus all of those tagged on August 5 and 6. These ten fish held in Wells Pool and then passed Monse between August 18 and 28 when temperatures ranged between 21.2 and 22.6 and were generally declining. These Sockeye had the slowest migration from Monse to the North Basin with a median travel time of 9.7 days but had a 90% survival from Monse to the North Basin and the best overall survival to OKC. This survival was likely enhanced by their arriving at the North Basin after the bulk of Osoyoos Lake fisheries had been conducted.

Four acoustic tagged Sockeye were last detected downstream of Wells Dam where Chelan PUD has a network of acoustic receivers in both Rocky

Reach and Rock Island pools. Sockeye #11460, tagged July 9, went upstream to Brewster then downstream and was last detected at a PIT tag array (UWE) just downstream of Lake Wenatchee (Table 35 and maps in Appendix D). Sockeye #11479 was tagged at Wells Dam on July 22, had numerous detections in Wells Pool through July 31 then migrated downstream and was last detected at an acoustic receiver at the mouth of the Entiat River on August 1. Sockeye #11510 was tagged on August 5 and had numerous detections in Wells Pool until August 20 then moved downstream and was last detected at the mouth of the Entiat River on August 22. Sockeye #11507 was tagged on August 5 and had numerous detections in Wells Pool through August 20 before moving downstream and was last detected on August 20 at the Beebe Bridge. Maps showing movement of these and other acoustic tagged Sockeye can be found in Appendix D.

Twenty-four of the 61 fish tagged were estimated to be on the spawning grounds during the spawning period (Table 35), 28 were missing on the upstream migration (3 of which were caught and released in Wells pool fisheries), 5 were captured and kept by fisheries, and one was last detected at the Okanagan River mouth just upstream of Osoyoos Lake but not detected further upstream in spawning areas.

Table 35. Tagging data, last detection and date, and first PIT tag detection at OKC PIT tag array for Sockeye Salmon acoustic tagged at Wells Dam in 2013. (Green text indicates the fish was on the spawning grounds during the spawning period. Red text indicates confirmed captured in fisheries, blue text indicates missing on upstream migration, black text indicates last detected in Osoyoos Lake or at the Okanagan River Mouth).

Tag Code	Date Tagged	Furthest Upstream Detection		Last Detection		First OKC Detection	Mobile Track Dates	Comments
		Site	Date	Site	Date			
11455	7/8	Hwy 97	10/15	Hwy 97	10/15	10/4	10/7, 10/15, 11/4	
11456	7/8	McIntyre Dam	7/16	Hwy 97	10/13	Missed site	10/7	
11457	7/8	OKC PIT array	9/29	OKC PIT array	9/30	9/29	9/16, 10/7, 10/18, 10/25	
11458	7/8	North Basin	7/15	North Basin	8/13			Osoyoos Fishery 1928
11459	7/8	Okanagan Mouth (Canada)	7/15	Okanagan Mouth (Canada)	7/15			
11460	7/9	Wells Pool	7/10	Upper Wenatchee PIT array (UWE)	7/26			
11461	7/9	McIntyre Dam	7/18	McIntyre Dam	10/9	7/15		
11462	7/9	Hwy 97	10/9	Hwy 97	10/9	10/2	10/7, 10/25, 11/4	
11463	7/9	Hwy 97	10/22	North Basin	11/6	10/1		
11464	7/9	McIntyre Dam	7/18	McIntyre Dam	10/18	Missed Site		
11465	7/15	Similkameen River	7/19	Wells Pool	7/22			
11466	7/15	Monse Bridge	7/16	Monse Bridge	7/16			
11467	7/15	Wells Pool	7/17	Wells Pool	9/4			Released by CCT 7/23 4020
11468	7/15	OKC PIT array	10/4	OKC PIT array	10/4	10/4	9/16	
11469	7/15	Hwy 97	10/4	Hwy 97	10/18	9/30	9/16, 10/7, 10/15, 10/18, 10/25, 11/4	
11470	7/15	OKC PIT array	10/1	OKC PIT array	10/1	10/1		
11471	7/16	Similkameen River	7/22	Similkameen River	7/26			

11472	7/16	North Basin	8/15	North Basin	8/17		9/16	
11473	7/16	Similkameen River	7/20	Similkameen River	7/21			
11474	7/16	Hwy 97	10/5	OKC PIT array	10/20	9/30	10/15	
11475	7/16	North Basin	7/26	North Basin	8/8			
11476	7/16	Similkameen River	7/20	Monse Bridge	7/23			
11477	7/16	OKC PIT array	10/3	OKC PIT array	10/3	10/3	10/7, 10/18	
11478	7/16	Hwy 97	10/24	Hwy 97	10/24	9/30	10/15, 10/18, 10/25	
11479	7/22	Wells Pool	7/27	Rocky Reach Pool	8/1			
11480	7/22	Wells Pool	7/24	Wells Pool	7/24			
11481	7/22	OKC PIT array	9/28	OKC PIT array	9/30	9/28		
11482	7/22	OKC PIT array	10/2	OKC PIT array	10/2	10/2	9/16	
11483a	7/23	Wells Pool	7/23	Wells Pool	7/24			Wells Pool sport fishery
11483b	7/30	Similkameen River	8/5	Similkameen River	8/6			
11484	7/22	Okanagan Falls	9/27	North Basin	10/14	9/25		
11485	7/22	Wells Pool	7/24	Wells Pool	7/27			
11486	7/23	McIntyre Dam	9/1	McIntyre Dam	9/5	8/30		Okanagan Falls, 9/30
11487	7/23	North Basin	8/24	North Basin	8/31			9/3 Osoyoos lake
11488	7/23	Monse Bridge	8/2	Monse Bridge	8/3			
11489	7/23	Hwy 97	9/27	Hwy 97	10/12	9/24	10/15, 10/18, 10/25, 11/4	
11490	7/23	McIntyre Dam	10/3	McIntyre Dam	10/3	9/29	10/25	
11491	7/23	OKC PIT array	10/10	OKC PIT array	10/10	10/10	10/15, 10/18, 10/25, 11/4	
11492	7/23	Oroville pump station	8/4	Oroville pump station	8/4			
11493	7/29	Wells Pool	7/30	Wells Pool	8/5			
11494	7/29	Wells Pool	7/30	Wells Pool	8/7			
11495	7/29	Wells Pool	8/3	Wells Pool	8/8			

11496	7/29	Similkameen River	8/6	Similkameen River	8/6			
11497	7/29	OKC PIT array	10/3	OKC PIT array	10/3	10/3	9/16, 10/15, 10/18,	
11498	7/29	Monse Bridge	7/31	Monse Bridge	7/31			
11499	7/29	Similkameen River	8/7	Similkameen River	8/8			
11500	7/30	Hwy 97	10/20	North Basin	10/31	10/13	10/25	
11501	7/30	North Basin	8/6	North Basin	8/21			Osoyoos 9/3 4482
11502	7/30	OKC PIT array	9/30	OKC PIT array	9/30	9/30	9/16, 10/7, 10/15	
11503	7/30	North Basin	8/10	North Basin	10/2			
11504	7/30	Monse Bridge	8/1	Monse Bridge	8/1			
11505	7/30	Monse Bridge	8/4	Monse Bridge	8/4			
11506	7/30	Wells Pool	8/1	Wells Pool	8/15			
11507	8/5	Wells Pool	8/15	Wells Pool	8/20			
11508	8/5	Wells Pool	8/8	Wells Pool	8/18			Released CCT 4547 8/14
11509	8/5	Similkameen River	8/24	Similkameen River	8/24			Released CCT 4548 8/16
11510	8/5	Wells Pool	8/7	Wells Pool	8/20			
11511	8/5	OKC PIT array	10/5	OKC PIT array	10/5	10/5	10/7, 10/15, 10/18	
11512	8/5	Wells Pool	8/8	Wells Pool	8/29			
11513	8/5	Wells Pool	8/7	Wells Pool	8/8			
11514	8/5	McIntyre Dam	9/26	Hwy 97	10/24	9/24	10/25, 11/4	

Acoustic trawl and limnology surveys

Lake Wenatchee acoustic trawl surveys (ATS) were conducted on July 10, and September 23, 2013 to estimate juvenile Sockeye abundance for comparison with six Osoyoos Lake surveys conducted between June 6, 2013 and March 18, 2014 (Table 36). No species other than juvenile *O. nerkids* were captured in the trawl surveys. Based on a comparison of the mean for the September 5 and October 13 Osoyoos Lake and September 23 Lake Wenatchee surveys, based on density/ha Lake Wenatchee was estimated to be 43% as productive as Osoyoos Lake. By comparison, Lake Wenatchee was 63% as productive in 2012.

Table 36. Estimates of juvenile Sockeye Salmon abundance from Lake Wenatchee and Osoyoos Lake acoustic trawl surveys between June 2013 and February 2014.

Lake	Survey Date	Juvenile nerkids Abundance per Lake	Density (per ha)	Mean Length (cm)	Mean Weight (g)
Osoyoos	6-Jun-13	8,765,535	9395	3.7	0.4
Osoyoos	9-Jul-13	6,042,108	6476	4.5	1.0
Osoyoos	3-Aug-13	6,944,319	7443	5.1	1.4
Osoyoos	5-Sep-13	6,359,328	6816	5.5	1.7
Osoyoos	10-Oct-13	5,093,247	5459	6.0	2.4
Osoyoos	6-Nov-13	4,555,839	4883	6.5	2.9
Osoyoos	18-Mar-14	5,357,286	5742	7.4	4.1
Wenatchee	10-Jul-13	2,778,381	2,767	3.1	0.27
Wenatchee	23-Sep-13	2,650,400	2,640	5.6	1.89

Limnological surveys suggested that almost all available phytoplankton in Lake Wenatchee were edible by zooplankton in contrast to Osoyoos Lake where many species are large and/or gelatinous and could not be consumed by zooplankton. The Lake Wenatchee zooplankton biomass was less than that of 2012, with the most likely explanations being:

1.) Low food (algae) availability in 2013,
2.) High 2013 through-lake flow rates causing high rates of zooplankton loss due to washout.
3.) High spring 2013 rates of predation by juvenile Sockeye resulting in density dependent reductions in zooplankton biomass and reduced rates of Sockeye growth during the fall and winter.

Further details on the acoustic trawl and limnology surveys are found in Appendix C.

2013 Juvenile PIT tagging

In total, 4018 smolts were released during 11 tagging sessions between April 12 and May 7, 2013 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYOL, downstream of the Highway 3 bridge at the Osoyoos Narrows. Tagging effort is summarized in Table 37.

Table 37. Summary of Okanagan Sockeye smolt PIT tagging effort, 2013.

Date	Site	Number Released
12-Apr-13	SKATAL	82
16-Apr-13	SKATAL	317
17-Apr-13	OSOYOL	247
18-Apr-13	SKATAL	475
19-Apr-13	OSOYOL	389
25-Apr-13	OSOYOL	158
26-Apr-13	SKATAL	304
	OSOYOL	229
30-Apr-13	OSOYOL	425
1-May-13	OSOYOL	446
2-May-13	OSOYOL	889
7-May-13	OSOYOL	57
Total		**4018**

Reliable estimates of survival from release to Rocky Reach Dam were able to be calculated for both release groups. Survival from release to Rocky Reach Dam was 0.45 (SE = 0.06) for the SKATAL release group, and 0.49 (SE = 0.04) for the OSOYOL release group. After Rocky Reach, error associated with survival estimates for both release groups, individually and combined, was large. Survival could not be estimated for the SKATAL release group past McNary Dam due to insufficient sample size. Survival estimates for both release groups combined is presented in Table 38 and Figure 14.

Table 38. Mean survival for PIT tagged Okanagan River Sockeye smolts (SKATAL and OSOYOL combined), 2013.

Period	Survival	SE
Release to Rocky Reach	0.4830	0.0345
Rocky Reach to McNary	1.1379	0.2635
McNary to John Day	1.2454	0.6583
John Day to Bonneville	0.6962	0.5815
Release to Bonneville	0.4766	0.3256

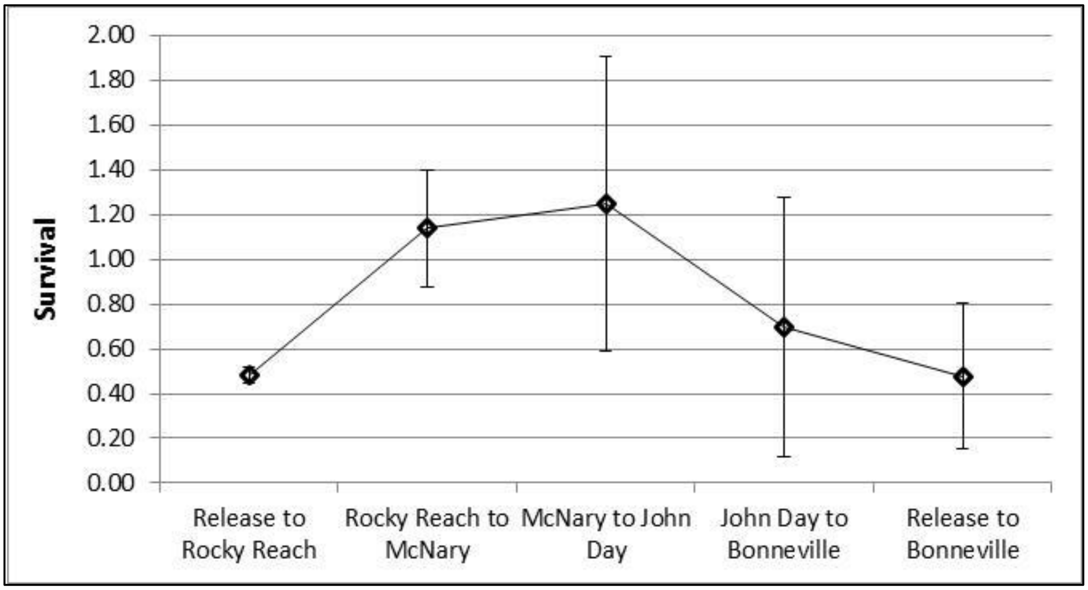

Figure 14. Mean survival and travel time for PIT tagged Okanagan River Sockeye smolts (SKATAL and OSOYOL combined), 2013.

Travel time from release to Rocky Reach Dam was approximately 20 days for the SKATAL release group, and 19 days for the OSOYOL release group. Travel time for individual reaches was similar between both release groups. Overall travel time from release to Bonneville Dam was approximately 29 days for both groups combined (Table 39).

Table 39. Mean travel time for PIT tagged Sockeye smolts, 2013; Standard Errors of mean presented in brackets.

Period	SKATAL Travel Time (d)	OSOYOL Travel Time (d)	SKATAL and OSOYOL Combined Travel Time (d)
Release to Rocky Reach	20.13 (0.30)	18.95 (0.33)	19.30 (0.25)
Rocky Reach to McNary	4.35 (0.24)	4.45 (0.17)	4.41 (0.14)
McNary to John Day	3.15 (0.00)	2.17 (0.18)	2.32 (0.22)
John Day to Bonneville	--	1.53 (0.15)	1.53 (0.15)
Release to Bonneville	--	28.44 (0.94)	29.02 (0.74)

No comparisons between Okanagan and Wenatchee juvenile Sockeye Salmon survival to McNary Dam are possible in 2013 as very few juvenile Wenatchee Sockeye were PIT tagged. A report detailing Okanagan Sockeye juvenile PIT tagging can be found in Appendix B.

DISCUSSION

This completes the fifth year of this study. The year 2013 was the third full year in which we had fully operational PIT tag detection sites at Zosel Dam (ZSL) and OKC in the Okanagan River near Oliver, BC, both of which were funded by this project. The OKC site worked well during the Sockeye migration, with a detection rate of 88.9% based on the percentage of both PIT and acoustic tagged fish detected upstream of the OKC PIT antenna. This compares to 88.9% in 2012, 87.5% in 2011 and 90.0% in 2010.

In contrast to OKC, PIT tag detection at ZSL was again low (13.3%), due to Sockeye bypassing the fish ladder and ascending the spillway made passable by high flows. Adding detection to one or more spillways is recommended, particularly if it could also detect smolts tagged above Zosel Dam that migrate downstream through the spillways.

PIT tag data were used in this report to estimate escapement at dams and compare this estimate with visual counts (Table 7). Visual counts are also affected by fallback and, at those dams so equipped, migration through navigation locks. Fallback means that viewing window counts will result in an inflated estimate of fish that ultimately pass, and stay upstream as an individual fish is counted more than once; or a fish with a single passage ends up falling back downstream and stays downstream. Conversely, navigation lock passage results in Sockeye not being counted at fish viewing windows. Using PIT tag data provided by this project, it is possible to adjust the visual counts given in Table 7 (and publicly available at DART 2014 and FPC 2014) by accounting for fallback (Table 13) and, for Bonneville and McNary dams, passage at night (Table 12). Bonneville and McNary estimates were also increased by the percentage of Sockeye missing the counting window PIT arrays (Table 5) as at these dams the most likely reason a Sockeye would not be detected is passage through the navigation locks. On the other hand, Priest Rapids, Rock Island, and Rocky Reach dams have no navigation locks for Sockeye to bypass detection (or counting at viewing windows), but also generally have fewer PIT antennas with often lower detection rates for individual antennas (Appendix A Table A1) making it more likely that a tagged fish would pass undetected. Table 40 presents adjusted fish counting estimates by expanding the estimated navigation lock passage at Bonneville and McNary, while subtracting fallbacks at all dams. Since the PIT tag passage estimate is based on the Bonneville visual counts, adjusted PIT tag estimates are also presented for passage at each dam along with the OKC array.

Table 40. Estimated Sockeye passage at mainstem dams using visual and PIT counts and counts adjusted to account for night passage, navigation lock passage and fallback in 2013.

Site	Visual Count	PIT Tag Estimate	Missed	Fall-back	Night Passage	Adjusted Visual Count	Adjusted PIT Tag Estimate	% Differenc e Between Adjusted Counts
Bonneville	185,505	--	0.4%	5.0%	3.3%	182,750	182,750	--
The Dalles	161,896	166,006	1.6%	2.8%	7.3%	171,368	163,561	-4.6%
McNary	134,202	155,158	2.1%	6.2%	6.4%	136,581	152,779	11.9%
Priest Rapids	163,079	145,717	0.0%	3.6%		157,208	143,642	-8.6%
Rock Island	159,204	137,693	4.4%	2.2%		155,702	135,601	-12.9%
Rocky Reach	131,660	97,178	0.0%	4.6%		125,604	95,761	-23.8%
Wells	129,993	93,746	0.0%	1.3%		128,303	92,289	-28.1%
Tumwater	27,738	38,862	0.0%	0.5%		27,599	38,195	38.4%
OKC array		53,240	--	--	--	--	52,449	--

Fish managers have long used visual counts at dams to estimate escapement. The completion of Rocky Reach Dam in 1961 provided fish counts, in combination with Rock Island Dam completed in 1933, which allowed the calculation of the relative abundance of Okanagan and Wenatchee stock Sockeye Salmon. Since Wenatchee Sockeye pass Rock Island dam, but not Rocky Reach Dam, the ratio of the Rocky Reach count to the Rock Island count is an approximate estimate of the Okanagan proportion at Rock Island Dam and the difference is that of the Wenatchee proportion. In recent years, counts at Tumwater Dam have provided another estimate of Wenatchee escapement which can be compared to Rocky Reach counts to provide another Okanagan to Wenatchee stock composition estimate.

In 2013, based on the ratio of Rocky Reach to Rock Island counts, 82.7% of the run at Rock Island was Okanagan stock compared to 82.6% if Tumwater Sockeye counts are used to estimate Wenatchee (Tables 14, 41). Unlike 2012, different fallback rates at Rock Island, Rocky Reach, and Tumwater dams have a relatively small effect on stock composition estimates, increasing the percentage Wenatchee stock to 19.3% using the ratio Method C (Rocky Reach to Rock Island ratio) and 18.0% using Tumwater counts (Method D). Also unlike 2012, GSI estimate differ little from PIT tag estimates (Table 41).

Table 41. Comparison of different methods of estimating Okanagan and Wenatchee Sockeye stock composition at Rock Island Dam in 2013.

Method		% Okanagan	% Wenatchee	Other	Source Table
A	PIT tags deployed at Bonneville Dam detected at Rocky Reach and Tumwater Dams	70.7%	28.3%	1.0%	15
B	GSI + PIT on Bonneville samples (weighted by Bonneville visual counts)	70.3%	29.0%	0.7%	26
C	Visual dam counts taking the Rock Island-Rocky Reach difference as Wenatchee	82.7%	17.3%	NA	15
D	Visual dam counts taking Tumwater as Wenatchee	82.6%	17.4%	NA	15
E	Method C using adjusted visual counts in Table 40	80.7%	19.3%	NA	38
F	Method D using adjusted visual counts in Table 40	82.0%	18.0%	NA	38

The Sockeye Salmon PIT tagged at Bonneville Dam were not classified by stock based on PIT tags unless they were subsequently detected in terminal areas (Snake, Wenatchee, Entiat, or Deschutes rivers or the Columbia River at or above Rocky Reach Dam). Using these criteria, the stock could not be identified for 215 Sockeye so these were subsequently identified by stock using GSI. All but 10 of these 215 Sockeye were lost in reaches between Bonneville and Rock Island dams (Table 42). PIT tags from four of these Sockeye were found upstream of McNary Dam on Badger Island, site of a pelican colony. Of these four fish, two Sockeye 38 and 46 cm in length were last detected passing McNary Dam while the other two, both 50 cm in length, were last detected passing Priest Rapids Dam.

Table 42. Genetic stock classification of Sockeye PIT tagged at Bonneville Dam last detected at Bonneville, McNary, Priest Rapids, and Rock Island dams in 2013

Reach PIT Tagged Fish Lost Between	N	Okanagan	Wenatchee	Snake River
Not detected after release	17	47.1%	47.1%	5.9%
Below Bonneville	3	100.0%	0.0%	0.0%
Bonneville-The Dalles	83	62.7%	31.3%	6.0%
The Dalles-McNary	41	75.6%	19.5%	4.9%
McNary-Priest Rapids	33	90.9%	9.1%	0.0%
Priest Rapids-Rock Island	28	78.6%	21.4%	0.0%
Rock Island-Rocky Reach/Tumwater	10	50.0%	50.0%	0.0%
Total	**215**	**71.2%**	**25.4%**	**3.4%**

Hess et al (2014) reported data from genetics analysis of Sockeye captured in 2014 tribal fisheries between Bonneville and McNary Dam (Table 43, Figure 15). These estimates show a higher percentage of Wenatchee and Snake River origin Sockeye ion

the harvest than this study estimates at Bonneville Dam. However, the fisheries sampled by Hess et al. (2014) only accounted for 8,033 of the approximately 30,000 Sockeye estimated by this project as missing between Bonneville Dam and McNary Dam.

Table 43. Zone 6 Harvest allocation by week (from Hess et al. 2014)

Week	Fishery Dates	Harvest	N	Okanagan	Snake	Wenatchee
25	June 17 to 21	2,109	308	52.3%	0.6%	47.1%
26	June 24 to 27	2,119	313	55.9%	1.3%	42.8%
27	July 1 to 3	1,814	264	50.4%	1.5%	48.1%
28	July 8 to 11	1,332	196	59.2%	3.6%	37.2%
29	July 15 to 18	485	60	73.3%	0.0%	26.7%
30	July 22 to 25	173	23	69.6%	8.7%	21.7%
Total		**8,033**	**1,164**	**55.6%**	**1.6%**	**42.8%**

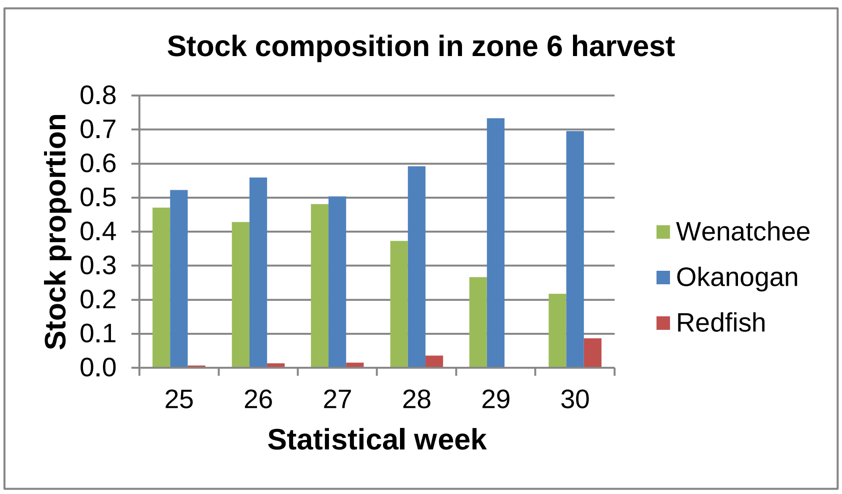

Figure 15. Stock composition of the Zone 6 Sockeye harvested in 2013.

A total of 11 Sockeye Salmon tagged at Bonneville Dam were last detected at the Priest Rapids trap and likely ended up in the Cle Elum Sockeye reintroduction program.

Our tagging at both Wells and Bonneville dams, in addition to acoustic and temperature tagging at Wells Dam combined with PIT and acoustic detection at OKC offered the opportunity to provide insights on the effect of different tagging regimes on Sockeye Salmon (Table 44). In 2013, this suggests sampling and PIT tagging at Wells Dam decreased survival to OKC by 3.8%, while PIT and acoustic tagging decreased

survival by 15.9%. Temperature tags decreased survival by 93%, however this is no doubt an overestimate of the impact of temperature tagging on fish as temperature tagging was not conducted in Statistical Week 28 when survival to OKC was high.

As in past years, Sockeye tagged at Wells Dam likely benefited in comparison to the Bonneville-tagged fish by the Sockeye fisheries in Lake Pateros upstream of Wells Dam. These fisheries were required to release Floy tagged Sockeye Salmon. However, Sockeye PIT tagged at Bonneville Dam were not Floy tagged and would presumably would have been kept, if captured in Lake Pateros fisheries. Sport fishery compliance with this directive is unknown, as is the survival of Sockeye that are caught and released.

The impact of sampling Sockeye Salmon at Wells Dam may be greater than at Bonneville dams. Water temperatures at Wells are higher than at Bonneville and sampling facilities not as good as at Bonneville Dam. At Wells Dam, Sockeye are transferred by net from capture to holding tank to anesthetic tank and then to transport truck where they are transported upstream. In addition, air temperatures at Wells Dam are commonly over 35C when Sockeye are being sampled. This compares to the Bonneville Dam facility where the air temperature rarely exceeds 25C and there is no need to net Sockeye Salmon.

Table 44. Conversion rates from Wells Dam to OKC between weeks 28 and 32 for Sockeye tagged at Bonneville and Wells dams and the percent deviation from that of Bonneville-tagged Sockeye Salmon in 2013.

Tagging Location	Tagging Regime	Wells-OKC Conversion Rate	Deviation from Bonneville-tagged Conversion Rate
Bonneville Dam	PIT tag	57.0%	--
Wells Dam	PIT plus Floy-tag	54.8%	-3.8%
Wells Dam	PIT plus acoustic plus Floy Tag	46.1%	-15.9%
Wells Dam	PIT plus temperature plus Floy	3.9%	-93.0%

The conversion rate from Wells Dam to OKC for Bonneville and Wells tagged Sockeye was similar for one and two ocean Sockeye tagged at both locations (Table 45). Three ocean (designated as Age x.3 in Table 45) Sockeye tagged at Bonneville Dam had a much higher conversion rate to OKC than did Wells Dam-tagged Sockeye, though sample sizes were small (Table 45).

Table 45. Conversion rates by saltwater age for Sockeye PIT tagged at Bonneville and Wells dams from Wells Dam to OKC by week in 2013. Totals are weighted by Wells Dam visual Sockeye counts.

	Bonneville-tagged Sockeye				Wells-tagged Sockeye			
Week	Weight	% x.1	% x.2	% x.3	Weight	% x.1	% x.2	% x.3
25-26	2.6%	–	86.7%	–	--	--	--	--
27	16.6%	0.0%	70.6%	66.7%	--	--	--	--
28	29.7%	78.6%	72.0%	80.0%	48.9%	100.0%	72.7%	65.9%
29	26.8%	69.2%	44.8%	46.2%	26.8%	66.7%	48.1%	18.8%
30	17.2%	31.4%	31.0%	100.0%	17.2%	26.7%	19.2%	8.3%
31	4.9%	26.7%	33.3%	0.0%	4.9%	28.1%	11.1%	0.0%
32	1.5%	75.0%	0.0%	0.0%	2.2%	75.0%	0.0%	
Weighted Conversion Rate		**51.4%**	**54.7%**	**66.6%**		**49.8%**[14]	**52.3%**	**39.6%**

One ocean (Age x.1) acoustic tagged Sockeye had a lower conversion rate from Wells to OKC than Age x.2 and x.3 (Table 46). Age x.1 comprised 45.9% (28 of 61) of acoustic tagged Sockeye compared to 26.1% for all Sockeye tagged at Wells Dam (Table 18). This may have resulted in the estimated effect of acoustic tagging Sockeye being overestimated Table 44.

Table 46. Conversion rates by saltwater age for Wells acoustic tagged Sockeye from Wells Dam to OKC by week in 2013. Totals are weighted by Wells Dam visual Sockeye counts.

Week	% x.1 (n=28)	% x.2 (n=21)	% x.3 (N=12)
28	–	100.0%	62.5%
29	33.3%	37.5%	66.7%
30	57.1%	33.3%	100.0%
31	16.7%	33.3%	–
32	33.3%	0.0%	–
Weighted Conversion Rate	**39.8%**	**66.3%**	**66.7%**

As has been the case since 2008, there was not a significant linear relationship between run timing at Bonneville Dam and stock composition. PIT tag studies in 2006 and 2007, as well as several scale pattern studies in past years (e.g. Fryer 1995, 2006); found a significant relationship between run timing and stock composition. These pre-2008 results suggested a higher percentage of the Wenatchee stock migrated in the early portion of the run and a higher percentage of the Okanagan stock migrated in the

[14] Statistical week 28 was omitted in this calculation as the 100% survival for that week was based on only one fish which, with weighting, represents 48.9% of the run. Including statistical week 28 increases the conversion rate to 74.4%.

latter portion of the run. In recent years, the proportion of Okanagan stock Sockeye relative to the Wenatchee has increased early in the run.

The 2013 mean rate of Sockeye missing detection at mainstem dams with data for all years since 2006 (Bonneville, McNary, Priest Rapids, Rock Island, and Rocky Reach) of 1.15% was the lowest since we started PIT tagging Sockeye in 2006 (Table 5). As is typically the case, Rock Island (4.4%) and McNary (2.1%) had the highest rates but these were low compared to past years. At McNary Dam it is possible that Sockeye are using the navigation locks, which are located on the north side of the dam just downstream from the Snake River (which enters the Columbia River from the south side). Rock Island Dam is known for having lower rates of detection than other mainstem dams due to electrical interference (Fryer et al. 2011) at the antennas.

Fallback rates (Table 13) in 2013 ranged from 1.0% at Bonneville to 6.2% at McNary Dam. Fallback rates for Sockeye tagged as juveniles returning in 2013 were generally higher, reaching a peak of 19.2% at The Dalles. It is unknown how representative these results are of the run as the majority of Sockeye PIT tagged as juveniles are from the Snake River. Even Sockeye tagged as juveniles in the Upper Columbia were not representative of the run upstream of Priest Rapids Dam as the bulk of these Sockeye are mostly hatchery-origin Wenatchee stock while the majority of the Sockeye run is Okanagan stock. The preponderance of Wenatchee hatchery Sockeye likely explains the high percentage of returning tagged juveniles that pass Rocky Reach and Wells dams before returning to the Wenatchee River, contributing to high Rocky Reach and Wells dam fallback rates for previously tagged Sockeye.

In 2013, four PIT tags from Bonneville tagged Sockeye were detected on Badger Island, located in McNary Pool just downstream of the Snake River. This island is site of a colony of pelicans. Two of these Sockeye genetically classified as Okanagan Sockeye and were last detected at McNary Dam on June 25 and 26, 2013. One was 38 cm in length and the other 46 cm in length. The other two, both 50 cm in length, were last detected at Priest Rapids Dam on July 7 and 15, 2013, with the earlier fish Wenatchee stock and the later Okanagan stock.

This project is proposed to continue and evolve through at least 2017. Past work has created the infrastructure through funding PIT tag antennas at OKC and Zosel Dam as well as acoustic arrays to better determine where losses of Okanagan Sockeye Salmon are occurring upstream of Wells Dam. However, low sample sizes of acoustic tagged Sockeye, possible acoustic tagging impacts, as well as the lack of any PIT tag

detection between Wells Dam and Zosel Dam and OKC still leaves considerable uncertainty in quantifying mortality. This gap began to be filled in 2014 when the Colville Tribe implemented a PIT tag array in the lower Okanagan River and will be described in our 2014 report. We hope to work with the Colville Tribe to continue to expand PIT tag detection in the Okanagan Basin. In addition, we have been investigating possible PIT tag detection as Sockeye pass under the Highway 3 bridge in Osoyoos between the north and central basins of Osoyoos Lake. We are tentatively planning on testing the use of a DIDSON in 2015 to determine where Sockeye migrate relative to the lake bottom and bridge abutments with the goal of using this data to design an antenna system for this site. It is hoped that better PIT tag detection at some of these sites could eliminate the need for acoustic tags providing considerable savings which could be better applied elsewhere.

We also expect to continue with Wenatchee acoustic trawl surveys and limnological work to better estimate the production and productive potential of Wenatchee Sockeye Salmon. Acoustic trawl survey data in both Lake Wenatchee and Osoyoos Lake are also being used in Columbia Basin run forecasting. There are several unanswered questions regarding Lake Wenatchee Sockeye that we hope to address for this project. A primary question is why Lake Wenatchee Sockeye have not increased in relative abundance as much as Okanagan Sockeye, or even Snake River Sockeye, in recent years. Our limnology and ATS work will help in answering this question, but it is also uncertain what the optimal spawning escapement goal is for this stock. An optimal escapement analysis is being done, using other funding, for Osoyoos and Skaha Sockeye and we plan to consider this for the Wenatchee stock.

Another unanswered question is how current production for both Osoyoos and Wenatchee Sockeye Salmon compares to historical production. Peak historical Columbia Basin Sockeye runs have been estimated at 2.6 million to 4.3 million (Chapman 1986, NPPC 1986, Fryer 1995); however the 2012 run of over 510,000 Sockeye Salmon with less than 5% of historical Columbia Basin habitat available (Fryer 1995) makes those peak estimates appear conservative. To answer this question, we are working with the Okanagan Nation, Department of Fisheries and Oceans Canada, and Grant, Chelan, and Douglas Public Utility District to fund paleolimnological work in Wenatchee, Osoyoos, Skaha, and Okanagan lakes.

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APPENDIX A

Table A1. Probability of detection at PIT tag detectors by antenna at mainstem Columbia Basin fish ladders and the overall probability of detection, for Sockeye Salmon in 2013.

Dam, Site, Tag Type, and Number		Antenna and Probability of Detection at Antenna				Overall Detection Probability
Bonneville	**N**	**1**	**2**	**3**	**4**	
BO1	15	100.0	93.3	93.3	100.0	100.0
BO4	755	98.9	98.8	99.6	99.1	100.0
The Dalles	**N**	**1**	**2**			
TD1 (Oregon)	574	99.7	99.5			100.0
TD2 (Washington)	108	100.0	100.0			100.0
McNary	**N**	**1**	**2**	**3**		
MC1 (Oregon)	371	97.8	97.6			100.0
MC2 (Washington)	165	92.1	100.0	92.1		100.0
Priest Rapids	**N**	**Upper**	**Lower**			
West	34	100.0	97.1			100.0
East	567	99.8	100.0			100.0
Rock Island	**N**	**Upper**	**Lower**			
Left	131	100.0	100.0			100.0
Middle	110	97.3	100.0			100.0
Right	317	90.2	86.4			98.7
Rocky Reach	**N**	**Upper**	**Lower**			
Right	414	100.0	99.0			100.0
Wells	**N**	**Upper**	**Lower**			
Left	320	99.5	100.0			100.0
Right	187	100.0	100.0			100.0
Tumwater	**N**	**Upper**	**Lower**			
Left	162	99.4	100.0			100.0

Right or left is determined by looking downstream at the dams, thus the right bank at Wells Dam would be the west bank.

Table A2. Distribution of Sockeye Salmon by fish ladder for dams with multiple fish ladders as estimated by PIT tag detections of Sockeye tagged at Bonneville Dam in 2013.

Dam	Left Bank	Right Bank	Center
Bonneville	2.0%	98.0%	
The Dalles	15.8%	84.2%	
McNary	58.2%	41.8%	
Priest Rapids	5.7%	94.3%	
Rock Island	23.4%	56.5%	20.1%
Wells	94.4%	5.6%	

Right or left is determined by looking downstream at the dams, thus the right bank at Wells Dam would be the west bank, at McNary it would be the Washington shore.

Table A3. Harvest by fishery for Columbia Basin Sockeye Salmon in 2013.

Location	Fishery Type	Source	Totals
Zone 1-5	Commercial	TAC	119
Zone 6	Commercial, Ceremonial and Subsistence	TAC	8,046
Priest Rapids Tailrace	Wanapum Ceremonial and Subsistence	TAC	92
Lake Wenatchee	Sport	WDFW	12,107
Washington State Recreational	Estuary-Priest Rapids	WDFW	502
	Priest Rapids to Rocky Reach	WDFW	473
	Rocky Reach to Wells	WDFW	648
	Above Wells Dam	WDFW	5,197
Colville Harvest (Lake Pateros and Okanogan River)	Colville (all fisheries)	CCT	4,705
Canada Okanagan Basin	Okanagan Nation Alliance Communal	ONA	2,731
	Okanagan Nation Alliance Economic Demo	ONA	295
	Recreational	DFO	2,249
Priest Rapids Dam	Yakama Broodstock Removals[15]	YN	3,996

[15] Although not a true "harvest", the Yakima Nation collect live, adult Sockeye Salmon at Priest Rapids Dam each year and place them in Cle Elum and Cooper Lakes to spawn. This Sockeye reintroduction project was initiated in 2009.

Table A4. Information on interrogation sites for detection of PIT tags in the Columbia Basin.

Site Code	Site Name	Site Description
ACB	Asotin Cr. at Cloverland Brdg.	Mainstem of Asotin Creek above the George Creek confluence, underneath the Cloverland Bridge, 4.6 km upstream from the mouth of Asotin Creek.
ACM	Asotin Creek near mouth	Near the mouth of Asotin Creek 50 m upstream of the Highway 129 bridge spanning the mainstem of Asotin Creek in two serial sets of two antennas.
B2J	Bonneville PH2 Juvenile	Bonneville Dam PH2 Juvenile Bypass and Sampling Facility
BBT	Touchet River at Bolles Bridge	The Bolles Bridge site is located about 200 feet above the State HWY 124 bridge on the Touchet River, near Bolles Road, at River Kilometer 65.2.
BCC	BON PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel
BGM	Burlingame Dam and Canal	Burlingame Diversion Dam is located on the lower Walla Walla River.
BHL	Adult Fishway at BONH	In-stream detection system located in Bonneville Hatchery Ladder.
BO1	Bonneville Bradford Is. Ladder	Bradford Island Adult Fishway at Bonneville Dam
BO2	Bonneville Cascades Is. Ladder	Cascades Island Adult Fishway at Bonneville Dam
BO3	Bonneville WA Shore Ladder/AFF	Washington Shore Adult Fishway and AFF at Bonneville Dam; replaces B2A and BWL
BO4	Bonneville WA Ladder Slots	Washington Shore Fishway Vertical Slots at Bonneville Dam
BSC	Big Sheep Creek ISA at km 6	In-stream detection system located in Big Sheep Creek at river km 6 (N 45.50649, W -116.85067).
CAL	Carson NFH Adult Return Ladder	Hatchery adult spring Chinook return ladder from the Wind River to Carson NFH.
CHL	Lower Chiwawa River	Chiwawa River rkm 1, located between the Chiwawa smolt trap and the Chiwawa Acclimation Ponds.
CHU	Upper Chiwawa River	Chiwawa River rkm 12, located above the Forest Road 62 bridge and below Alder Creek.
CRT	Crooked River Satellite Fac.	Ladder of the Crooked River Satellite Facility. The Crooked River is a tributary to the South Fork Clearwater River. The array consists of two overflow antennas.
CRW	Chewuch River above Winthrop	Chewuch River at river km 1, above Winthrop, WA.
DRM	Deschutes River mouth	Mouth of the Deschutes River in the west channel at Moody Island (rkm 0.46).
DWL	Dworshak NFH adult trap	Located at the terminus of the Dworshak National Hatchery adult fish ladder in the North Fork Clearwater River.
ENA	Upper Entiat River at rkm 17.1	The site is located approximately 400 meters above the mouth of the Mad River near the township of Ardenvoir at river kilometer 17.1
ENF	Upper Entiat River at rkm 40.6	The site is located approximately 600 meters below the beginning of Forest Service Property within the upper portion of the Entiat River at rkm 40.6.
ENL	Lower Entiat River	Entiat River rkm 2, located immediately upstream of Entiat, WA.
ENM	Middle Entiat River	Entiat River rkm 26, below the McKenzie Diversion Dam.
ENS	Upper Entiat River at rkm 35.7	The site is located approximately 4.3 km above Stormy Creek at river kilometer 35.7 and near the entrance of the Riverwood subdivision.
ESJ	Easton Acc. Pond	Easton Acclimation Pond Outfall
ESS	EFSF Salmon River at Parks Cr.	East Fk South Fk Salmon River (rkm 21) near Parks Creek.
FDD	Feed Diversion Dam	Feed Diversion Dam, at Umatilla River rkm 47.
GLC	Gold Creek, Methow River	Gold Creek, Methow River Basin
GOJ	Little Goose Dam Juvenile	Little Goose Dam Juvenile Fish Bypass/Transportation Facility
GRA	Lower Granite Dam Adult	Lower Granite Dam Adult Fishway and Fish Trap
GRJ	Lower Granite Dam Juvenile	Lower Granite Dam Juvenile Fish Bypass/Transportation Facility
HRM	Hood River Mouth	Mouth of the Hood River against the west side jetty just inside the bar where the Hood River meets the Columbia River.
HYC	Hayden Creek In-stream Array	Lower section of Hayden Creek, in the Lemhi River Basin.
ICH	Ice Harbor Dam (Combined)	Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass
ICL	Lower Icicle Instream Array	Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA.
IR1	Lower Imnaha River ISA @ km 7	Lower Imnaha River at river km 7 (N 45.761162, W -116.750658).
IR2	Lower Imnaha River ISA @ km 10	Lower Imnaha River at river km 10 (N 45.742839 W -116.764563).
IR3	Upper Imnaha River ISA @ km 41	Upper Imnaha River at river km 41 (N 45.49004 W 116.80393).
JD1	John Day River, McDonald Ferry	John Day River in-stream detection, near McDonald Ferry at RM 20
JDJ	John Day Dam Juvenile	John Day Dam Juvenile Fish Bypass and Sampling Facility
JOC	Joseph Creek ISA @ km 3	Joseph Creek, Grande Ronde basin at river km 3 (N 46.030016, W -117.016042).
KRS	SF Salmon River at Krassel Cr.	Krassel Creek at rkm 65 on the South Fork Salmon River.
LC1	Lower Lolo Creek at rkm 21	Lolo Creek, a tributary to the Clearwater River located at river km 522.224.087.021 (N 46.294434 W -115.976119).
LC2	Upper Lolo Creek at rkm 25	Lolo Creek, a tributary to the Clearwater River located at river km 522.224.087.025 (N 46.290562 W -115.934153.
LFF	Lyle Falls Fishway	The Lyle Falls Fishway in Klickitat River
LLC	Loup Loup Creek Instream Array	Loup Loup Creek trib of the Okanogan River at RKM 27.2, within the city of Malott, WA. The LLC site is located 0.42 km from the confluence with the Okanogan River.
LLR	Lower Lemhi River	Lower Lemhi River in Salmon, ID.
LMJ	Lower Monumental Dam Juvenile	Lower Monumental Dam Juvenile Fish Bypass/Transportation Facility
LMR	Lower Methow River at Pateros	Lower Methow River near the WDFW 'Miller Hole' access site on the lower Methow River immediately upstream of Pateros, WA.
LNF	Leavenworth NFH Adult Ladder	Located in the Leavenworth National Fish Hatcheries adult ladder and holding pond.
LRW	Lemhi River Weir	Lemhi River above the mouth of Hayden Creek and below the IDFG weir.
LTR	Lower Tucannon River	Near the mouth of the Tucannon River. The upstream array group was located at an abandoned railroad bridge abutment upstream of Hwy 261 on the Tucannon River downstream from Starbuck. The CO in-stream array was relocated below the Hwy 261 bridge on Sept. 29, 2010.
LWD	Lowden Diversion Dam	At the entrance to the fish ladder at Lowden Diversion Dam. Lowden Dam is located at rkm 51 on the Walla Walla River.
LWE	Lower Wenatchee River	Wenatchee River rkm 2.
LWL	Ltl. White Salmon NFH returns	Adult fish ladder allowing passage from the Little White Salmon River into the adult holding ponds at Little White Salmon NFH.
LWN	Little Wenatchee River	Little Wenatchee River rkm 4, located at the old fish weir site.
MAD	Mad River, Entiat River Basin	Mad River rkm 1, located at Ardenvoir, WA.
MC1	McNary Oregon Shore Ladder	Oregon Shore Adult Fishway at McNary Dam
MC2	McNary Washington Shore Ladder	Washington Shore Adult Fishway at McNary Dam
MCD	Mill Creek Diversion Project	Fish bypass and passage facilities at the (Bennington) Diversion Dam and the first Division Works in the Mill Creek Diversion Project in the Walla Walla Basin.

Table A4. Table A4 continued.

Site Code	Site Name	Site Description
MCJ	McNary Dam Juvenile	McNary Dam Juvenile Fish Bypass/Transportation Facility
MCL	Lower Mission Creek Instream	Located at rkm 0.7 on Mission Creek (Wenatchee River Basin), near Cashmere, WA.
MRT	Methow River at Twisp	Methow River at river km 67, above the Twisp River.
MRW	Methow River at Winthrop	Methow River. During 2009 and early 2010, the array was located at river km 81, above Winthrop, WA near Winthrop National Fish Hatchery. In Sept. 2010 it was moved upstream to its new location below Wolf Creek on the mainstem Methow River, at river km 85.
MSH	Methow Fish Hatchery Outfall	Outlet of the Washington Department of Fish and Wildlifes (WDFW) Methow Hatchery located on the Methow River at Rk 82.3 from the confluence with the Columbia River.
MTR	Middle Tucannon River	The Middle Tucannon River site is located about 250 feet above the River Ranch Ln bridge on the Tucannon River, at River Kilometer 19.5.
MWC	Maxwell Canal	Maxwell Canal is located at rkm 24 on the Umatilla River.
MWE	Middle Wenatchee River	Wenatchee River rkm 50 above Tumwater Dam, consisting of a single antenna array floated off the bottom spanning the river.
NAL	Lower Nason Creek	Nason Creek rkm 1, located within Lake Wenatchee State Park.
NAU	Upper Nason Creek	Nason Creek rkm 19 (Wenatchee River Basin).
NBA	Nursery Bridge Adult	Nursery Bridge Dam Fishways (both), Walla Walla River at Milton-Freewater, OR.
NFW	North Fork Walla Walla River	North Fork Walla Walla River approximately 267 meters upstream from the confluence with the South Fork Walla Walla River.
OKC	Okanagan Channel at VDS-3	The OKC site is located in the Okanagan (Canadian spelling) Channel at 310th Avenue/Road 18 upstream from Osoyoos Lake.
OMK	Omak Creek Instream Array	Omak Creek enters the Okanogan River at RKM 51.5, approximately 1 km upstream from the city of Omak, WA. The OMK site is located on Omak Creek, 0.24 km from the confluence with the Okanogan River.
ORB	Oasis Road Bridge	In-stream arrays at Oasis Road Bridge, lower Walla Walla River
PRA	Priest Rapids Adult	Priest Rapids Dam Adult Fishways (both)
PRH	Priest Rapids Hatchery Outfall	Priest Rapids Hatchery outfall channel. The site is located just upstream of the typical point of inundation in the channel.
PRO	Prosser Diversion Dam Combined	Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam
PRV	Walla Walla R at Pierce RV Prk	Lower Walla Walla River at Pierce Green Valley RV Park.
RCL	Rock Creek (WA) at rkm 5	Rock Creek (WA) at rkm 5 near the Yakama Nation Longhouse.
RCS	Rock Creek (WA) at rkm 14	Rock Creek (WA) at rkm 14 at the confluence of Rock and Squaw Creeks.
RIA	Rock Island Adult	Rock Island Dam Adult Fishways (all three)
ROZ	Roza Diversion Dam (Combined)	Roza Dam Smolt Bypass.
RPJ	Rapid River Hatchery Pond	Rapid River Hatchery (IDFG) outfall
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway
RRJ	Rocky Reach Dam Juvenile	Juvenile Fish Bypass Surface Collector.
RRT	Red River Satellite Facility	Ladder of the Red River Satellite Facility. The Red River is a tributary to the South Fork Clearwater River.
SC1	Lower SF Clearwater R at rkm 1	Lower South Fork Clearwater River at river km 0.9 (N 46.13685 W -115.98091).
SC2	Lower SF Clearwater R at rkm 2	Lower South Fork Clearwater River at river km 2 (N 46.12749 W -115.97730).
SCL	Spring Creek NFH Adult Ladder	Fish ladder allowing passage from the Columbia River into the adult holding ponds at Spring Creek NFH.
SCP	Spring Creek Acclimation Pond	Juvenile releases from and adults returning to Winthrop National Fish Hatchery.
SFG	SF Salmon at Guard Station Br.	Located at rkm 30 near the lower South Fork Salmon River Guard Station on the South Fork Salmon River.
STL	Sawtooth Hatchery Adult Trap	Ladder of the Sawtooth Hatchery adult fish trap.
STR	SF Salmon Satellite Facility	Ladder of the South Fork Salmon River adult fish trap.
SWK	Lower Swauk Creek	Located at rkm 0.5 on lower Swauk creek, just above the highway 10 bridge.
TAY	Big Creek at Taylor Ranch	Centered around the bridge at Taylor Ranch, Big Creek, ID.
TD1	The Dalles East Fish Ladder	East Fish Ladder at The Dalles Dam
TD2	The Dalles North Fish Ladder	North Fish Ladder at The Dalles Dam
TMF	Three Mile Falls Dam Combined	Adult Fishway and Juvenile Bypass/subsampling facility at Three Mile Falls Dam
TRC	Trout Creek, Wind River	Trout Creek located at river km 2 on Trout Creek, in the Wind River (WA.) Basin above Hemlock Lake.
TUF	Tumwater Dam Adult Fishway	Adult Fishway at Tumwater Dam
TWR	Lwr Twisp Rvr near MSRF Ponds	Lower Twisp River adjacent to the Methow Salmon Recovery Foundation Ponds.
TWX	Estuary Towed Array (Exp.)	The TWX experimental trawl detector is typically deployed in the Columbia River estuary, at and above Jones Beach (rkm 75).
UGR	Upper Grande Ronde at rkm 155	Grand Ronde River located at river km 522.271.155 (45. 593338, -117.903124).
USE	Upper Salmon River at rkm 437	Located in the Salmon River at river km 522.303.437 (N45.028939 W-113.915892).
USI	Upper Salmon River at rkm 460	Located in the mainstem Salmon River at river km 522.303.460 (N44.890380 W-113.962575).
UTR	Upper Tucannon River	The Upper Tucannon River site is located about 200 yards above Don Howards House on the Tucannon River, at River Kilometer 53.2.
UWE	Upper Wenatchee River	Located at rkm 81.2 on the Wenatchee River, near Plain, WA.
VC1	Valley Creek, Upstream Site	Located on Valley Creek at Stanley, ID., in the Upper Salmon River.
VC2	Valley Creek, Downstream Site	Located on Valley Creek below Stanley, ID., in the Upper Salmon River.
WEA	Wells Dam, DCPUD Adult Ladders	Wells Dam Adult Fishways (both)
WFC	Wolf Creek, Methow River	Wolf Creek, Methow River Basin
WHC	Lwr White Creek, Klickitat Bsn	White Creek (Klickitat River Basin) approximately 150 meters upstream from the mouth.
WSH	Warm Springs Hatchery	Adult Fishway at Warm Springs NFH
WTL	White River, Wenatchee Basin	White River rkm 4, located at the old fish weir site.
WW1	Harris Bridge S F Walla Walla	Harris County Park Bridge, South Fork Walla Walla River
WW2	SF Walla Walla at Bear Creek	Bear Creek, South Fork Walla Walla River
YFK	Yankee Fork Salmon River	The site is located 3.14 river kilometers upstream from the confluence with the Salmon River at an elevation of 1855m.
ZEN	Secesh River at Zena Cr. Ranch	Near the Zena Creek Ranch
ZSL	Zosel Dam Adult Fishways	Zosel Dam is located at Okanogan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos in the town of Oroville, Washington.

APPENDIX B

Wenatchee Lake
Sockeye salmon and limnology status report
BY2011 (in-lake 2012) and
BY2012 (in-lake 2013):

Don McQueen

Summary

Based on data assembled in 2012 and 2013, Wenatchee Lake has a well oxygenated, cold water hypolimnion, low (oligotrophic) concentrations of total phosphorus, nitrogen and chlorophyll, and low to intermediate (oligotrophic-mesotrophic) biomasses of algae. In addition, most of the algal species found in Wenatchee Lake have sizes, shapes and digestibility that make them excellent food sources for freshwater zooplankton. Finally all of the abundant zooplankton species found in Wenatchee Lake are known to be good food sources for juvenile sockeye and the species having the highest biomass (*Hesperodiaptomus kenai*) is very large allowing Wenatchee Lake sockeye to hunt with high efficiency (energy return per feeding strike was higher). All of these characteristics suggest that the lake should provide excellent habitat for juvenile sockeye.

During 2012, Wenatchee Lake fish density averaged 2250 age-0 plus age-1 juvenile sockeye per ha which was about ½ the 2012 summer density found in Osoyoos Lake. Wenatchee Lake September sockeye weights averaged 1.9 g compared to 2.3 g in Osoyoos Lake. Wenatchee Lake smolts weights averaged 7.4 g which compares favorably with Osoyoos Lake February trawl weights of 4.1g. Given that Wenatchee Lake 2012 zooplankton biomasses were only 1/3rd the comparable Osoyoos Lake biomasses, the Wenatchee Lake 2012 juvenile sockeye growth rates were excellent.

However during 2013 Wenatchee Lake juvenile sockeye growth rates were much lower than they were in 2012. Year 2013 Wenatchee Lake fish density averaged 2700 per ha which was again about ½ the 2013 summer density found in Osoyoos Lake. Wenatchee Lake September sockeye weights were unavailable, but smolt weights averaged only 3.7 g compared to Osoyoos Lake March trawl weights of 4.6 g. In

addition, 2013 zooplankton community began the summer with densities and biomasses that were very similar to those observed in 2012, but by the end of the summer, Wenatchee Lake zooplankton biomass had fallen to low levels and zooplankton production had almost ceased.

The most likely explanations for these patterns in zooplankton and sockeye were (i) low food (algae) availability in 2013, (ii) high 2013 through-lake flow rates causing high rates of zooplankton loss due to washout, and (iii) high spring 2013 rates of predation by juvenile sockeye resulting in density dependent reductions in zooplankton biomass and reduced rates of sockeye growth during the fall and winter. We found the following.

(i) Phytoplankton: Between-year differences in phytoplankton biomass could not account for differences in zooplankton biomass and sockeye growth rates. There were no significant differences in the biomasses of total and edible phytoplankton recorded during 2012 and 2013. During both years, edible zooplankton comprised an exceptionally high proportion of total phytoplankton biomass suggesting that the Wenatchee Lake food web is very “efficient” and has the capacity to support a disproportionately high density of zooplankton and therefore juvenile sockeye.

(ii) Zooplankton loss due to washout: Between-year differences in discharge could not account for differences in zooplankton biomass and sockeye growth rates. During both 2012 and 2013, rates of discharge in the Wenatchee River at Plane Washington were similar suggesting that differences in lake-turnover and subsequent zooplankton washout did not account for differences in zooplankton biomass. It should be noted however (Stockwell pers. com.), that during August 2013 there were several forest fires in the area including a large fire near Leavenworth. Although there is no clear link, it may be worth investigating the hypothesis that smoke, ash and fire retardant chemicals had an impact on zooplankton reproduction.

(iii) Density dependent predation: Sockeye densities were not high enough to reduce zooplankton biomass. During spring-summer 2013, zooplankton biomass was in decline and zooplankton production fell to almost zero. Through this period, age 0 sockeye consumed only 0.5% of prey biomass per day and 11.9% of daily prey production and therefore could not have caused significant losses in zooplankton. However, during the August-September period when zooplankton biomass was very low and production almost zero, juvenile sockeye consumed 1.1% of the zooplankton standing stock per day and 328% of the daily zooplankton production. From this we conclude that density-dependent predation by fish on zooplankton could not explain the loss of zooplankton biomass observed between June and August 2013, but that low late summer-fall zooplankton biomasses very likely accounted for the low juvenile sockeye growth rates observed during 2013.

The unanswered question is why 2013 zooplankton biomass declined during the summer. As noted above, the side effects of the August forest fire near Leavenworth

may have had negative effects on zooplankton production. Perhaps more importantly, Wenatchee Lake calcium concentrations are low. During 2012, June Ca was 2.5 µg/L and during July 2013, Ca concentrations were only 1.7 µg/L. Low alkalinity and low concentrations of calcium have been shown to inhibit chitin formation in *Daphnia*. Lower limits for calcium limitation are thought to range from 1-3 mg Ca L^{-1}. During 2013, Wenatchee Lake may have drifted below this critical limit resulting in exoskeleton inhibition. This bottom-up effect may also explain the very low sockeye growth rates observed in other years (BY2001, BY2002, BY2005, BY 2008) and deserves further study. Wenatchee Lake and may be a candidate for both calcium and nutrient additions.

Wenatchee Lake 2012-13 sampling schedule:

Table 1: Samples collected at Wenatchee Lake during in-lake 2013. Black x indicate that the samples were collected, processed, analyzed and included in this report. Red x means that the trip report has not been received from the field crew. The * symbol indicates that the fish sample was destroyed and that length-weight data could not be obtained. The ? symbol indicates that the exact sampling date has not been confirmed by the field crew (i.e. field report missing).

Date Surveyed	Water chemistry average 1,3,5 and 25 m	Temperature and Oxygen	Secchi Depth	Phytoplankton average 1,3,5 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling
04-Jun-12		x	x	x	x		
25-Jun-12	x	x	x	x		x	x
05-Jul-12		x	x	x	x		
08-Aug-12		x	x	x	x		
10-Sep-12				x	x		
18-Sep-12		x	x	x		x	x
06-Oct-12	x	x	x	x	x		

Date Surveyed	Water chemistry average 1,3,5 and 25 m	VIU chemistry	Temperature and Oxygen	Secchi Depth	Phytoplankton average 1,3,5 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish Lengths	Fish Weights	Fish Stomachs	Other trip report
25-Jun-13			x	x	x	x					x
10-Jul-13	?	x					x	x	x	x	
30-Jul-13			x	x	x	x					x
26-Aug-13			x	x	x	x					x
23-Sep-13	?		x	x	x	x	x	x	*	*	x

Wenatchee Lake 2012-13 water temperature and oxygen concentrations:

Water temperatures during 2013 were slightly warmer than during 2012 and 2013 Secchi depths were slightly deeper (Table 2). Oxygen concentrations were slightly higher in 2012 (Table 3). Despite these minor differences, rearing conditions for juvenile sockeye were excellent in both years.

Table 2: Wenatchee Lake 2012-13 water temperatures and Secchi depths

	2012				2013			
Water depth (m)	04-Jun-12	05-Jul-12	09-Aug-12	06-Oct-12	25-Jun-13	30-Jul-13	26-Aug-13	23-Sep-13
1	8	11	14	14	11	18	19	16
2	8	10	14	14	11	18	18	16
3	8	10	14	14	10	17	18	16
4	7	9	14	14	10	17	18	16
5	7	9	14	14	10	17	18	16
6	7	9	14	14	10	17	18	16
7	7	9	14	14	10	17	18	16
8	7	9	14	14	10	16	18	16
9	7	9	14	14	10	16	18	16
10	7	9	14	14	10	16	18	16
11	7	9	14	14	10	16	18	16
12	7	9	13	14	10	16	18	16
13	7	8	13	14	9	16	17	16
14	7	8	13	14	9	15	17	16
15	7	8	13	14	9	15	17	16
16	7	8	13	14	9	13	16	15
17	7	8	13	14	9	13	16	15
18	7	8	13	14	9	11	15	15
19	7	8	13	14	9	11	14	14
20	7	8	12	13	9	11	13	13
24	7	7	10	13	8	10	11	11
28	6	7	10	11	8	10	10	10
32	6	7	9	9	8	9	9	9
36	6	7	8	8	8	8	9	8
40	6	7	8	8	8	8	8	8
44	6	7	8	7	7	8	8	8
48	6	7	7	7	7	7	8	8
52	6	7	7	7	7	7	7	7
Mean 0-15 m	7	9	14	14	10	16	18	16
Secchi depth	5.8	5.9	4.3	7.2	5.6	5.4	6.6	6.9

Table 3: Wenatchee Lake 2012-13 oxygen concentrations

Water depth (m)	2012				2013			
	04-Jun-12	05-Jul-12	09-Aug-12	06-Oct-12	25-Jun-13	30-Jul-13	26-Aug-13	23-Sep-13
1	10	13	10	10	11	9	9	9
2	10	13	10	10	11	9	9	9
3	10	13	10	10	11	9	9	9
4	10	13	10	10	11	9	9	9
5	10	13	10	10	11	9	9	9
6	10	13	10	10	11	9	9	9
7	10	13	10	10	11	9	9	9
8	10	13	10	10	11	9	9	9
9	10	13	10	10	11	9	9	9
10	10	14	10	10	11	9	9	9
11	10	14	10	10	11	9	9	9
12	10	14	10	10	11	9	9	9
13	9	14	10	10	11	9	9	9
14	10	13	10	10	11	9	9	9
15	10	14	10	10	11	9	9	9
16	10	14	10	10	11	9	9	9
17	10	14	10	10	11	9	9	9
18	10	14	10	10	11	10	9	9
19	10	14	10	10	11	10	9	8
20	10	14	10	9	11	10	9	9
24	6	14	10	9	11	10	9	9
28	7	14	10	10	11	10	9	9
32	7	14	10	10	11	10	9	9
36	7	14	10	10	11	10	9	9
40	7	14	10	10	11	9	9	9
44	7	14	10	10	10	9	9	9
48	7	14	10	10	10	9	9	9
52	7	14	10	10	10	9	9	9

Wenatchee Lake 2012-13 water chemistry:

During 2012, nitrate concentrations declined through the summer to near zero. This suggests that algal productivity was high. Year 2012 phosphorus (TP) and chlorophyll concentrations were about average for moderately oligotrophic lakes. Water chemistry data were not available for 2013.

During 2012-13 total alkalinity and calcium concentrations were very low (about ½ the concentrations found in oligotrophic coastal sockeye lakes). Low alkalinity and low concentrations of calcium have been shown to inhibit chitin formation in *Daphnia*. Lower limits for calcium limitation range from 1-3 mg Ca L^{-1}. As we shall see in the zooplankton section of this report, *Daphnia* were found in Wenatchee Lake, but rates of production were very low. This lake might benefit from artificial calcium additions.

Table 4: Wenatchee Lake 2012 water chemistry collected in both the epilimnion and hypolimnion. Water chemistry was not collected during 2013.

Date	Stations	Depth	Nitrate µg/L	TP µg/L	Chl a µg/L	Depth	Nitrate µg/L	TP µg/L
25-Jun-12	1	1,3,5	68.9	6.5	0.9	25	71.3	7.4
18-Sep-12	Mean 1,2	1,3,5	0.4	5.2	1.2	25	20.3	7.5

Table 5: Wenatchee Lake 2012-13 alkalinity and trace elements.

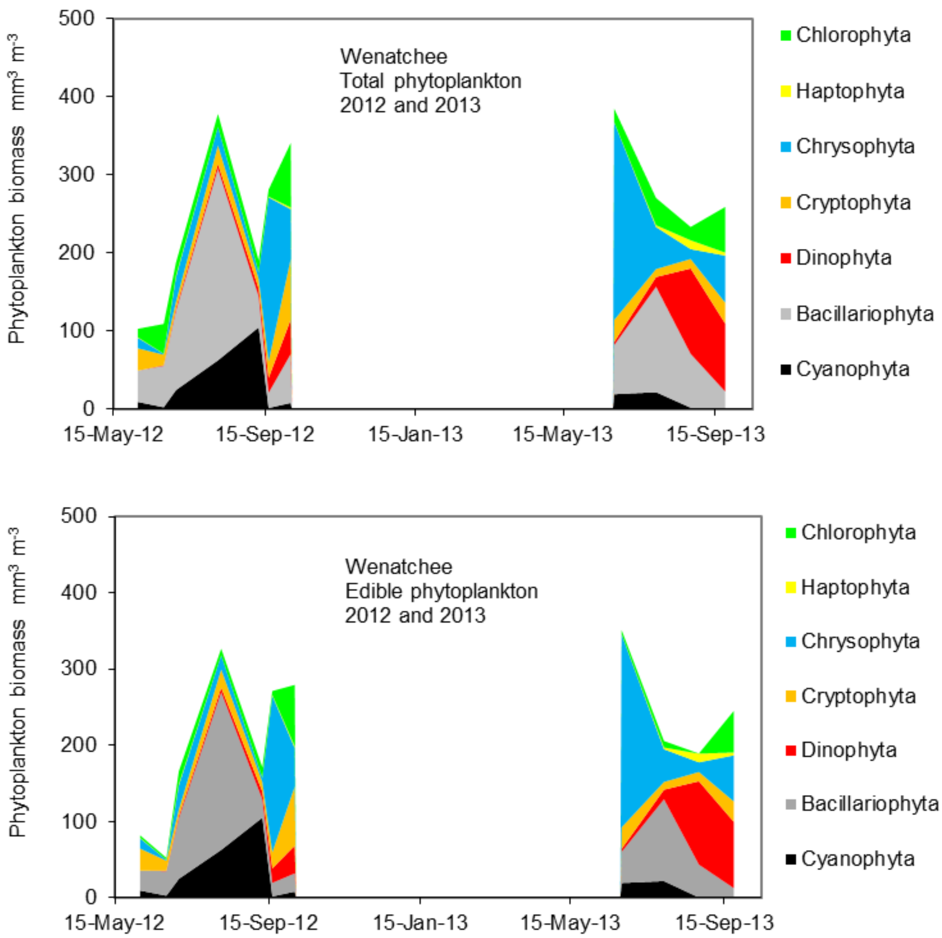
Date	Stations	Depth	Total alkalinity µg/L	Na µg/L	Mg µg/L	Calcium µg/L
25-Jun-12	1	1,3,5	12.84	0.81	0.62	2.52
25-Jun-13	Mean 1,2	1,3,5	6.27	0.50	0.33	1.78

Wenatchee Lake 2012-13 phytoplankton:

Phytoplankton were collected on 5 dates during 2012 and on four dates during 2013 (Figure 1). Biomasses were recorded from samples taken at 1,3,5m (combined). Densities, cell sizes, cell shapes and biovolumes were recorded. One of the objectives of the phytoplankton counting procedure was to assess the relative availabilities of edible (grazable) and non-edible (non-grazable) algae. We quantified "edibility" based on size, toxicity and digestibility. Single cells or colonies < 30 µm width or length were considered edible unless they were classified as being either "toxic" or "digestion-resistant". *Microcystis* was always classified as being "toxic". Other genera were assumed to be non-toxic. Algae with thick gelatinous sheaths can pass through *Daphnia* guts undigested and were considered to be digestion-resistant, independent of size.

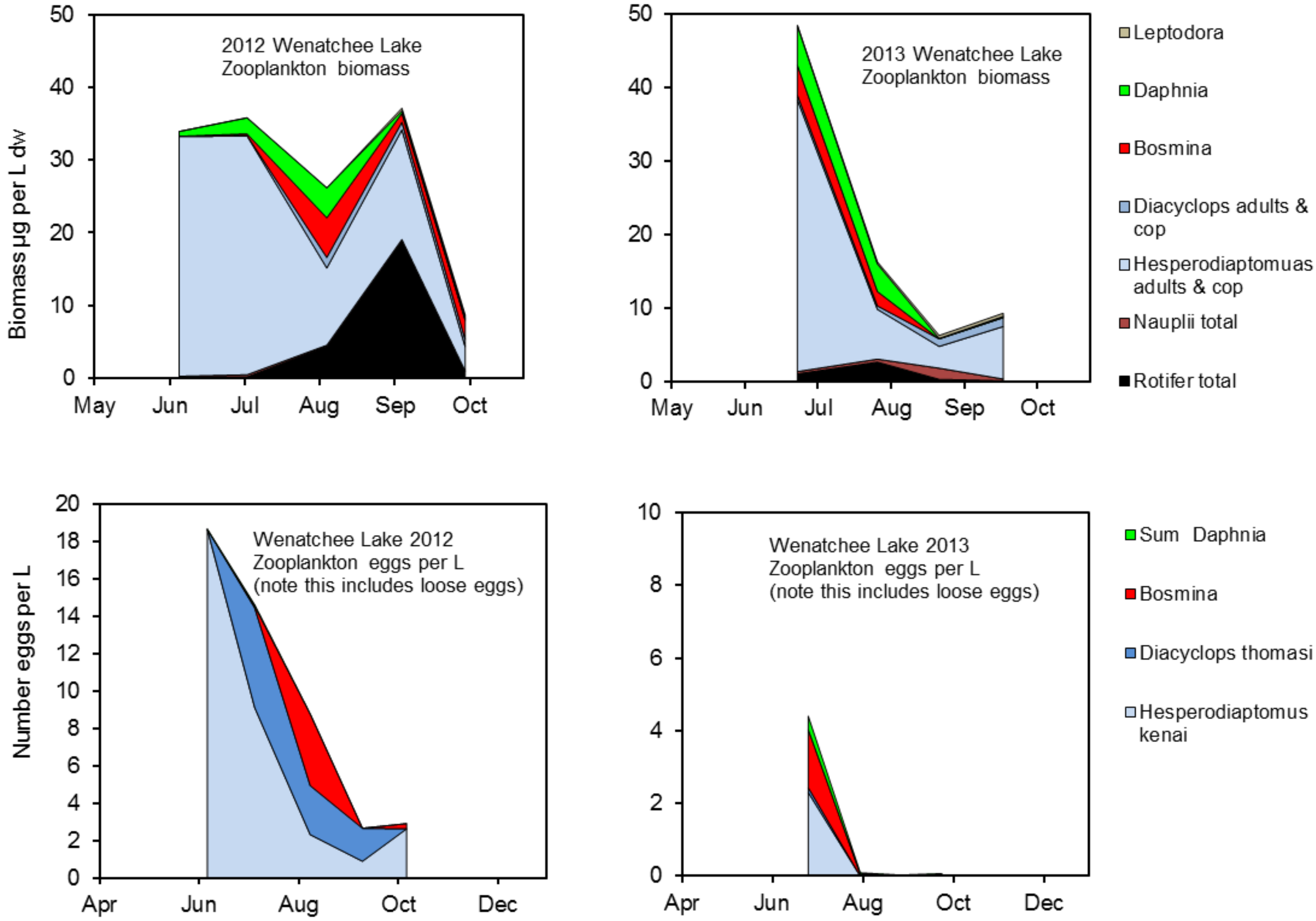
In Wenatchee Lake during both years, almost all of the “total” phytoplankton were edible. Given that Wenatchee Lake total phosphorus concentrations were much lower than comparable Osoyoos Lake concentrations, Wenatchee Lake had an unexpectedly high abundance of phytoplankton suitable for consumption by zooplankton.

Figure 1: Total and edible phytoplankton biomass as mm^3 m^{-3} which approximates µg L^{-1} wet weight.



Wenatchee Lake 2012-13 zooplankton:

Figure 2: Year 2012 (left) and 2013 (right) zooplankton biomass (top) and eggs per L (bottom).



In the 2012 in-lake report we noted that Osoyoos Lake zooplankton biomasses were more than twice as high as the Wenatchee Lake biomasses. Among the cladocerans, both lakes had *Daphnia* and *Bosmina* but *Diaphanosoma* was found only in Osoyoos Lake. Among the copepods, both lakes had *Diacyclops bicuspidatus*, but Osoyoos Lake had *Leptodiaptomus ashlandi* while Wenatchee Lake had

Hesperodiaptomus kenai. This single species substitution represents a major difference in the availability of zooplankton for fish. On average, *Leptodiaptomus* copepodids and adults weigh 2.5 µg dry weight and measure less than 1 mm in body length. The average weight for *Hesperodiaptomus* is >30 µg dry weight and the average body length is about 2 mm. This makes *Hesperodiaptomus* and important target for juvenile sockeye. In general, lower Wenatchee Lake total zooplankton biomasses suggest that Wenatchee sockeye should have grown at about half the rate of Osoyoos Lake juvenile sockeye. However, the presence of *Hesperodiaptomus* likely allowed Wenatchee Lake sockeye to hunt with greater efficiency (energy return per feeding strike was higher), resulting in a smaller than expected difference in sockeye growth rates. In fact during 2012, both Wenatchee and Osoyoos sockeye had similar lengths and weights in June and by September, Wenatchee Lake sockeye were only 20% smaller than Osoyoos Lake sockeye.

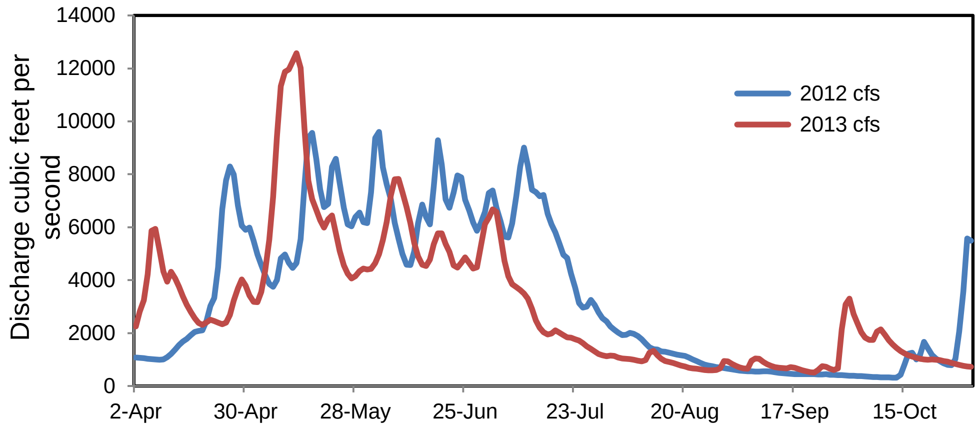
During 2013 (Figure 2), the Wenatchee Lake zooplankton community began the summer with biomasses that were similar to those recorded in 2012. However during 2013, egg production was much lower and all of the zooplankton species declined rapidly reaching very low levels in September 2013. The most likely explanations for this pattern would be (i) low food (algae) availability in 2013, (ii) high 2013 through-lake flow rates and high rates of zooplankton loss due to washout, or (iii) high 2013 rates of predation by fish including juvenile sockeye.

(i) Phytoplankton abundance hypothesis: From the preceding section dealing with total and edible phytoplankton biomass we see that there were no significant differences between 2012 and 2013. During both years, edible zooplankton (i.e. phytoplankton that were good food sources for zooplankton), comprised an exceptionally high proportion of total phytoplankton biomass suggesting that the Wenatchee Lake food web is very "efficient" and has the capacity to support a disproportionately high density of zooplankton and therefore juvenile sockeye.

(ii) River flow hypothesis: During both 2012 and 2013, rates of discharge in the Wenatchee River at Plane Washington were recorded by the Washington Department of Ecology (Figure 3). In both years, flow rates and patterns were similar suggesting that between-year differences in rates of lake-turnover cannot account for differences in zooplankton biomass. It should be noted however (Stockwell pers. com.), that during August 2013 there were several forest fires in the area including a large fire near Leavenworth. Although there is no clear link, it may be worth investigating the hypothesis that smoke, ash and fire retardant chemicals had an impact on zooplankton reproduction.

(iii) Density dependent predation by juvenile hypothesis: This will be investigated in the following section.

Figure 3: Year 2012 and 2013 Wenatchee River discharge rates recorded at Plane Washington. This figure is based on records posted by the Washington State Department of Ecology.



Wenatchee Lake 2012-13 juvenile sockeye:

In-lake juvenile sockeye densities were higher during 2013 than they were in 2012 and the 2013 confidence intervals were larger (Table 6). It appears that early summer weights were higher during 2013, but caution is advised because the 2012 and 2013 samples were taken 2 weeks out of phase. Between-year comparison of September biosamples was not possible due to a laboratory accident that resulted in total sample loss.

Smolt lengths and weights were much lower for the 2013 in-lake juveniles (smolts sampled in 2014) than they were for the 2012 in-lake juveniles (smolts sampled in the spring of 2013). In fact the 2013 fish were among the smallest on record (Table 7).

Table 6: Year 2012 and 2013 Wenatchee Lake juvenile sockeye numbers (lake area 1004 ha), densities, lengths and weights (bold print). In 2012, both age 0 and age 1 were captured (shown in lighter blue text). In 2013 only age 0 fish were captured. The September 2013 biosample was lost due to an accident on the laboratory.

		Date	Number per lake	Density per ha	95% CI from transects	Length mm	Weight g
2012		**25-Jun-12**	**1,700,000**	**1700**	**425**	**31**	**0.27**
		18-Sep-12	**2,800,000**	**2800**	**700**	**56**	**1.89**
	Age 0	25-Jun-12		1552			0.27
		18-Sep-12		2837			1.89
	Age 1	25-Jun-12		172			4.02
		18-Sep-12		0			nd
2013	**Age 0**	**10-Jul-13**	**2,778,381**	**2767**	**1051**	**38**	**0.66**
		23-Sep-13	**2,650,400**	**2640**	**1650**		

Table 7: Smolt lengths and weights taken at the lower Wenatchee smolt trap from in-lake years 2012 and 2013 along with data from previous years. In-lake year 2013 is highlighted in bold print. These data include combined age-0 and age-1smolts. Data provided by Keeley Murdoch.

Collection year	In-lake year	Brood year	Average length (mm)	Samples size	Average weight (g)	Sample size
2014	**2013**	**2012**	**76**	**5650**	**3.68**	**4300**
2013	2012	2011	86	705	7.37	682
2012	2011	2010				
2011	2010	2009				
2010	2009	2008	84	727	5.28	706
2009	2008	2007	105	277	10.26	274
2008	2007	2006	112	156	12.39	141
2007	2006	2005	80	627	4.58	615
2006	2005	2004	88	421	6.65	420
2005	2004	2003	95	193	7.15	193
2004	2003	2002	74	426	3.53	421
2003	2002	2001	84	742	5.07	732
2002	2001	2000	80	310	4.60	195
2001	2000	1999	99	21	9.14	21
2000	1999	1998	94	123	7.12	21

In-lake juvenile sockeye densities were higher during 2013 than they were in 2012 and the 2013 confidence intervals were larger (Table 6). It appears that early summer weights were higher during 2013, but caution is advised because the 2012 and 2013 samples were taken 2 weeks out of phase. Between-year comparison of September biosamples was not possible due to a laboratory accident that resulted in total sample loss.

Smolt lengths and weights were much lower for the 2013 in-lake juveniles (smolts sampled in 2014) than they were for the 2012 in-lake juveniles (smolts sampled in the spring of 2013). In fact the 2013 fish were among the smallest on record (Table 7).

Note that the data in table 7 are not segregated with respect to age, suggesting that the 2012 smolt weights might be biased higher than the 2013 weights. During 2012, about 10% of the spring population comprised age-1 fish. These were not observed in the fall, either because they had left the lake or because they were large enough to avoid the in-lake biosampling gear. During 2013, age-1 fish we not captured in the spring survey.

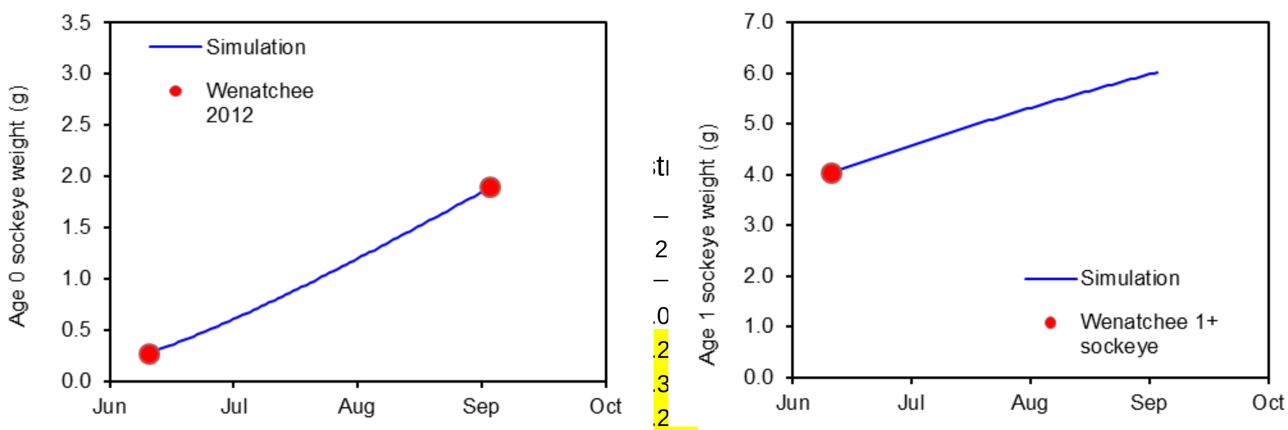
The questions of interest are (a) whether the slightly higher densities of juvenile sockeye observed in-lake 2013, could have consumed enough zooplankton in the spring and summer to account for the observed declines in 2013 zooplankton biomass (Figure 2) and (b) whether the low zooplankton biomasses observed in the fall could have caused food shortages for fall-winter sockeye thus accounting for very low smolt weights. Together these questions comprise (iii) the density dependent predation by juvenile hypothesis noted above.

Year 2012 and 2013 bioenergetics-based comparison of consumption by fish and production by zooplankton

In-lake 2012

During 2012, Wenatchee Lake sockeye were sampled on 25 June and 18 September 2012. Fish weight data were available for both dates and the growth portion of the bioenergetics model was fit to these data (Figure 4). Fish depth distributions and densities were available for two dates (Table 8). Fish water temperatures were estimated for four dates (Table 9).

Figure 4: 2012 Wenatchee Lake age-0 and age 1 juvenile sockeye growth through the season showing the field data (red symbols) and the growth pattern simulated by the model (blue Line). The age 1 fish were not found in the September, and growth was estimated based on the rates shown by the age 0 fish.



20-30	0.16	0.51
30-40	0.04	0.36
40-50	0.01	0.03
50-60		0.00

Table 9: 2012 Wenatchee Lake temperatures occupied by fish when they were feeding at night. The yellow area is defined by the fish distributions shown above, and the average “fish” temperatures are shown at the bottom of the table. These temperatures were used as input for the bioenergetics simulation.

Water depth (m)	04-Jun-12	05-Jul-12	09-Aug-12	06-Oct-12
1	8.1	10.6	14.2	13.8
2	7.7	10.2	14.2	13.8
3	7.6	10.0	14.2	13.7
4	7.5	9.5	14.2	13.7
5	7.3	9.3	14.2	13.7
6	7.3	9.2	14.2	13.7
7	7.2	9.1	14.0	13.7
8	7.2	9.0	13.9	13.6
9	7.2	8.8	13.7	13.6
10	7.1	8.6	13.6	13.6
11	7.1	8.6	13.5	13.6
12	7.1	8.5	13.5	13.6
13	7.0	8.4	13.4	13.6
14	6.9	8.4	13.4	13.6
15	6.9	8.3	13.3	13.6
16	6.8	8.2	12.9	13.6
17	6.8	8.0	12.8	13.6
18	6.7	7.9	12.8	13.6
19	6.7	7.8	12.7	13.5
20	6.7	7.8	12.3	13.4
24	6.5	7.5	10.5	13.2
28	6.4	7.4	9.5	11.1
32	6.3	7.2	8.9	8.6
36	6.3	7.1	8.5	7.9
40	6.2	7.0	7.9	7.5
44	6.1	6.9	7.6	7.4
48	6.1	6.8	7.3	7.2
52	6.0	6.7	7.1	7.1
	6.8	8.1	9.6	10.3

During 2012 and 2013, Wenatchee Lake juvenile sockeye diet data were collected only on one date (13 July 2013). For most lakes having only one diet sample would present very serious problems for the application of bioenergetics-based food consumption models. However in Wenatchee Lake, the zooplankton community is dominated by *Hesperodiaptomus kenai* with much smaller biomasses of *Bosmina* and *Daphnia*. During both years, these were the only prey types available and the only prey that were consumed during July 2013. The July 2013 diet data were used to estimate food consumption in both years.

Table 10: Wenatchee Lake fish diet data.

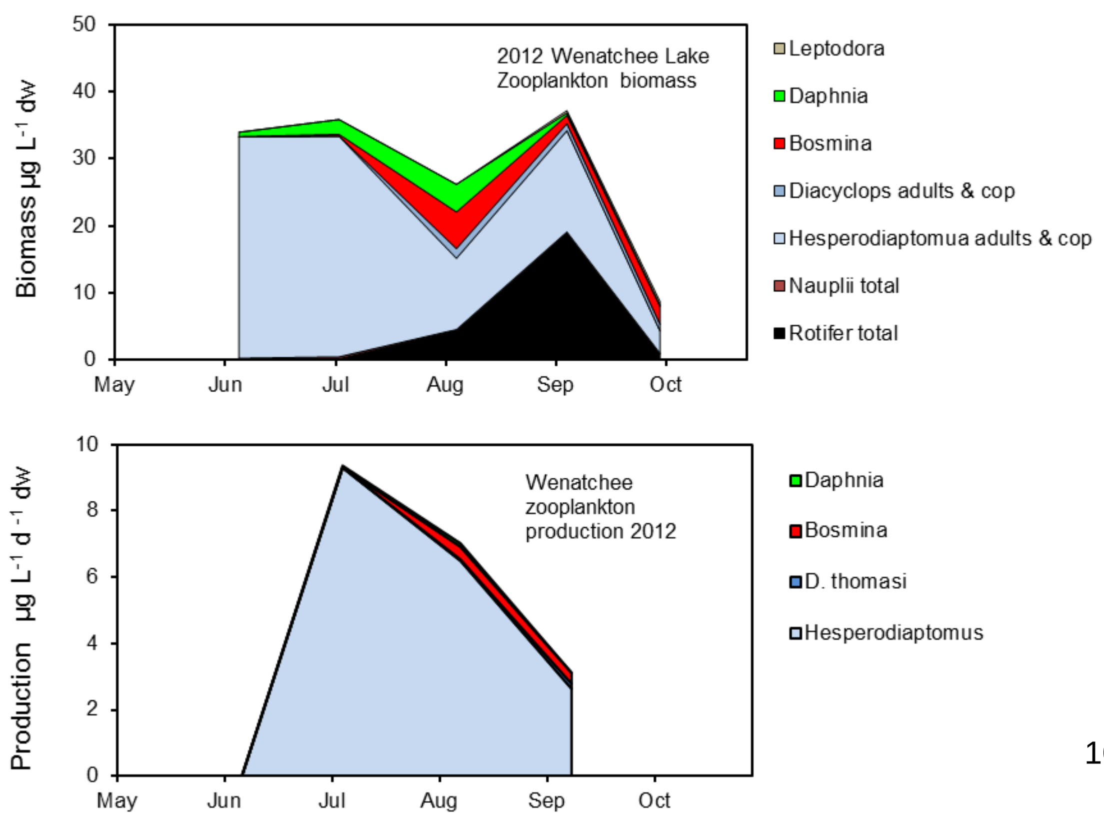
	Date	Number stomachs	Cyclopoid	Calanoid	Daphnia	Bosmina
Average number of prey per fish						
	13-Jul-13	30	0.61	57.27	10.91	1.52

Seasonal average mean weight of each prey type µg dw	1.81	22.76	8.44	2.82
Average prey weight per individual fish stomach (µg dw)	1.10	1303.73	92.12	4.27
Proportion by weight	**0.0008**	**0.9304**	**0.0657**	**0.0030**

Bioenergetics simulations were run from 25 June – 18 September 2012. Fish weights (Table 6), diets (Table 10) and temperature (Table 9) were inputs. Species specific consumption outputs were recorded as µg dry weight consumed per day.

In the following figure (Figure 5), the top panel shows total zooplankton biomass during the 4 sampling periods. (2) The second panel shows zooplankton production. (3) The third panel shows consumption of zooplankton by fish. All units are µg L^{-1} dw and consumption and production are µg L^{-1} d^{-1} dw. It is immediately clear that the fish consumed only a small portion of biomass produced on each day by the zooplankton community.

Figure 5: Wenatchee 2012 **-** Top panel = biomass of tot al zooplankton (µg L^{-1} dry weight), Second panel = production of the zooplankton species that were consumed by age 0 and age 1fish (µg L^{-1} d^{-1} dry weight), bottom panel = biomass of zooplankton consumed each day by age-0 plus age-1 fish (µg L^{-1} d^{-1} dry weight).



For Wenatchee Lake 2012, the seasonal averages are summarized in Table 11. Through the summer-fall, age 0 plus age 1 fish consumed about 0.5% of prey biomass per day and 2.1% of prey production. It should be noted the model output assumes that the fish feed on zooplankton in the top 30 m of lake water.

Table 11: Summary of Wenatchee Lake 2012 bioenergetics model input and output data.

Average density age 0	2194	per ha
Average density age 1	86	per ha
Average zooplankton biomass	23.1	µg per L dw
Average zooplankton production	5.26	µg per L per day dw
Average consumption by fish	0.11	µg per L per day dw
% biomass consumed per day	0.5	%
% production consumed per day	2.1	%

In-lake 2013

During 2013, Wenatchee Lake sockeye were sampled on 10 July and 23 September 2013. Fish weight data were available only for 10 July. Mean weight for 23 September was assumed to be the same as it was in 2012 (Figure 6). There is no acceptable way to assess the consequences of this assumption, but as we will see the simulation is robust and even a very large difference (i.e 100 % or 200%) in growth rate would have no effect on the conclusions that will be drawn from the 2013 data. Fish depth distributions and densities were available for two dates (Table 12). Fish water temperatures were estimated for four dates (Table 13).

Figure 6: 2013 Wenatchee Lake fish age-0 juvenile sockeye growth through the season showing the field data (red symbols) and the growth pattern simulated by the model (blue Line).

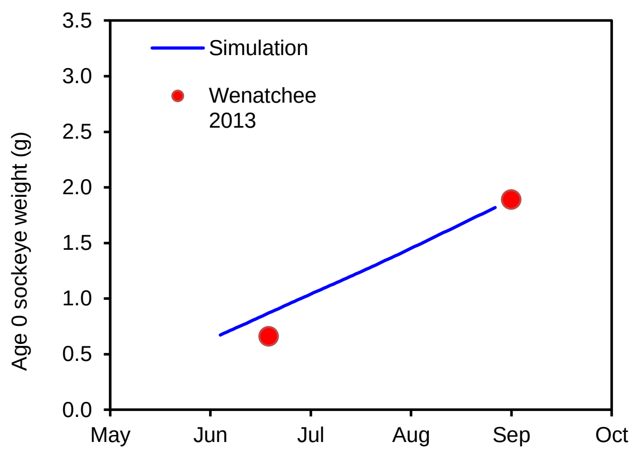


Table 12: 2013 Wenatchee Lake sockeye depth distributions recorded on 2 dates. The yellow area includes >90% of the observations.

	25-Jun-12	18-Sep-13
2-5	0.00	0.00
5-10	32.07	0.37
10-15	34.73	0.21
15-20	26.08	1.76
20-30	5.90	27.22
30-40	0.48	56.79
40-50	0.73	13.65
50-60		0.00

Table 13: 2013 Wenatchee Lake temperatures occupied by fish when they were feeding at night. The yellow area is defined by the fish distributions shown above, and the depth-weighted average temperatures are shown at the bottom of the table.

Water depth (m)	25-Jun-13	30-Jul-13	26-Aug-13	23-Sep-13
1	11.2	18.0	18.6	16.1
2	10.5	17.5	18.4	16.2
3	10.5	17.2	18.1	16.2
4	10.4	17.0	18.0	16.2
5	10.3	16.9	18.0	16.2
6	10.3	16.7	17.8	16.3
7	10.2	16.6	17.8	16.3
8	10.2	16.5	17.7	16.3
9	10.1	16.2	17.7	16.3
10	10.0	16.1	17.7	16.3
11	9.9	16.1	17.6	16.3
12	10.0	15.9	17.5	16.3
13	9.4	15.7	17.3	16.3
14	9.2	15.4	17.0	16.3
15	9.1	14.9	17.3	15.8
16	8.9	13.3	16.5	15.5
17	8.8	12.7	15.5	14.9
18	8.7	11.4	14.9	14.6
19	8.6	11.1	14.0	13.6
20	8.5	11.0	13.3	12.6
24	8.4	10.5	10.7	10.6
28	8.2	9.7	9.9	9.5
32	8.1	8.9	9.0	8.8
36	7.9	8.4	8.6	8.4
40	7.6	8.0	8.2	8.0
44	7.4	7.6	7.8	7.7
48	7.2	7.4	7.5	7.5
52	7.0	7.2	7.3	7.3
	9.5	11.5	9.4	9.1

During 2012 and 2013, Wenatchee Lake juvenile sockeye diet data were collected only on one date (13 July 2013). These data are shown in table 10 above.

Bioenergetics simulations were run from 25 June – 23 September 2013. Fish weights (Table 6), diets (Table 10) and temperature (Table 13) were inputs. Species specific consumption outputs were recorded as µg dry weight consumed per day.

In the following figure (Figure 7), the top panel shows total zooplankton biomass during the 4 sampling periods. (2) The second panel shows zooplankton production. (3) The third panel shows consumption of zooplankton by fish. All units are µg L^{-1} dw and consumption and production are µg L^{-1} d^{-1} dw. It is immediately clear that during the first half of the summer, the fish consumed only a small portion of biomass produced on each day by the zooplankton community, but during the second half of the summer-fall the fish consumed more biomass than the zooplankton community could produce on each day.

For Wenatchee Lake 2013, the June-September averages are summarized in Table 14. Through this period, age 0 fish consumed about 0.5% of prey biomass per day and 11.9% of daily prey production. However, during the August-September period (Table 15), juvenile sockeye consumed 1.1% of the zooplankton standing stock per day and 328% of the daily zooplankton production. From this we conclude that density-dependent predation by fish on zooplankton could not explain the loss of zooplankton biomass observed during 2013, but that low late summer-fall zooplankton biomasses very likely accounted for the low juvenile sockeye growth rates observed during 2013.

Table 14: Summary of Wenatchee Lake the June-September 2013 bioenergetics model input and output data.

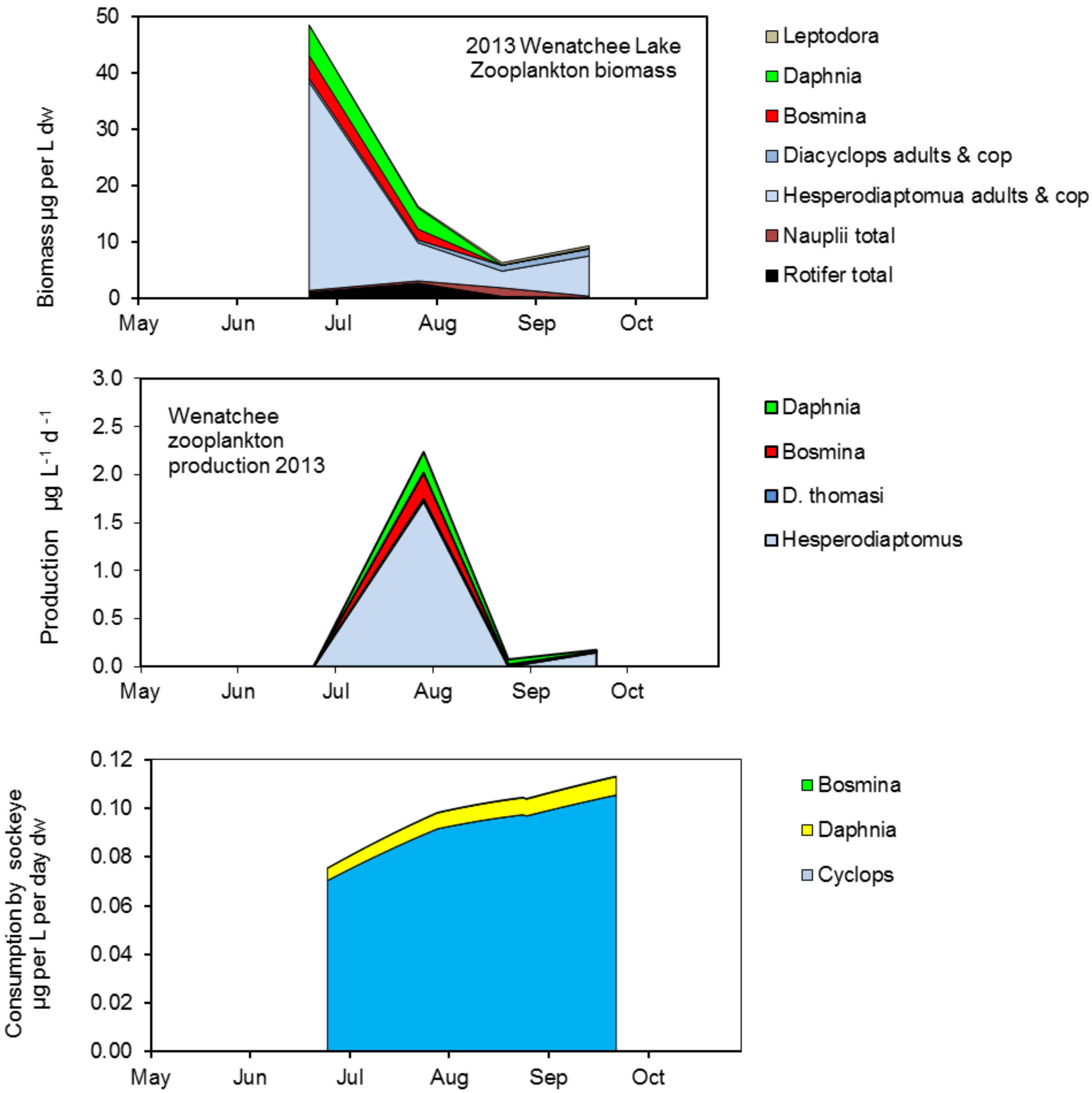
Average density age 0	2704	per ha
Average density age 1	0	per ha
Average zooplankton biomass	20.09	µg per L dw
Average zooplankton production	0.83	µg per L per day dw
Average consumption by fish	0.099	µg per L per day dw
% biomass consumed per day	0.5	%
% production consumed per day	11.9	%

Table 15: Summary of Wenatchee Lake the August-September 2013 bioenergetics model input and output data.

Average density age 0	2704	per ha
Average density age 1	0	per ha
Average zooplankton biomass	9.32	µg per L dw
Average zooplankton production	0.03	µg per L per day dw
Average consumption by fish	0.099	µg per L per day dw
% biomass consumed per day	1.1	%
% production consumed per	328.7	%

day

Figure 7: Wenatchee 2013 **-** Top panel = biomass of tot al zooplankton (µg L^{-1} dry weight), Second panel = production of the zooplankton species that were consumed by age 0 and age 1fish (µg L^{-1} d^{-1} dry weight), bottom panel = biomass of zooplankton consumed each day by age-0 fish (µg L^{-1} d^{-1} dry weight).



APPENDIX C

q̓awsitkʷ (Okanagan River) Sockeye Smolt Out of Basin Survival: PIT and Acoustic Tagging 2013

Authors:
Ryan Benson, M.Sc., RPBio
Skyeler Folks, B.Sc.
Amanda Stevens, B.Sc.
Richard Bussanich, M.Sc., RPBio
Okanagan Nation Alliance Aquatic Enterprises Ltd.

Prepared for:
Grant County Public Utility District, Chelan County Public Utility District, and Columbia River Inter-Tribal Fisheries Commission

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Okanagan Nation Aquatic Enterprises Ltd.
101-3535 Old Okanagan Highway
Westbank, BC, V4T 3L7

Phone: (250) 707-0095 **Fax: (250) 707-0166**

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EXECUTIVE SUMMARY

The q̓awsitkʷ (Okanagan River) Sockeye Salmon (*Oncorhynchus nerka*) population is one of the last few remaining viable Sockeye Salmon stocks in the Columbia River Basin. Since 2003, the Okanagan Nation Alliance has conducted an experimental re-introduction of hatchery-reared Sockeye Salmon into q̓awst'ik'ʷt (Skaha Lake). Out of basin survival of both hatchery and natural Okanagan Sockeye smolts remains an important unanswered question. In 2012, The Okanagan Basin Technical Working Group (COBTWG) conducted a pilot study to evaluate Juvenile Salmonid Acoustic Telemetry System (JSATS) and Passive Integrated Transponder (PIT) technology to test the methodology, effectiveness, and survival and travel time of smolts as the migrate out of the Okanagan River basin.

Following recommendations from the 2012 pilot study, the 2013 study objectives included:

1. Configure two receiver stations using Lotek JSATS receivers at akspaqmix (Vaseux Lake) and suwiẇs (Osoyoos Lake), and test the range and efficiency of each location to determine reliability of the system;
2. PIT tag up to 5,000 hatchery-origin and natural-origin smolts as they migrate from q'awst'ik'ʷt; and,
3. Monitor PIT tagged smolt survival and travel rates to the nx̌ʷəntkʷitkʷ (Columbia River) estuary.

Efficiency for all JSATS receivers tested ranged from 8.2% to 24.6%. Mean efficiencies for the two JSATS receiver sites tested were 21.9% (suwiẇs) and 16.4% (akspaqmix). Although reception efficiency is site dependent (substrate composition, water depth, noise, and turbulence), the maximum range appears to be less than 50 m. Similar maximum range was observed in 2012.

In total, 4018 smolts were released during 11 tagging sessions between April 12 and May 7, 2013 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYOL, downstream of the Highway 3 bridge at the Osoyoos Narrows. Reliable estimates of survival from release to Rocky Reach Dam could be calculated for both release groups. Survival from release to Rocky Reach Dam was 0.45 (SE = 0.06) for the SKATAL release group, and 0.49 (SE = 0.04) for the OSOYOL release group. After Rocky Reach, error associated with survival estimates for both release groups, individually and combined, was large. Travel time from release to Rocky Reach Dam was approximately 20 days for the SKATAL release group, and 19 days for the OSOYOL release group. Travel time for individual reaches was similar between both release groups. Overall travel time from release to Bonneville Dam was approximately 29 days for both groups combined.

Recommendations for future studies include waiting for JSATS technology to evolve to enable programmable tags with time delay activation to conserve battery life before continuing to conduct JSATS studies, and continuing to develop the logistics and capacity to enable PIT tagging a minimum of 5,000 Okanagan Sockeye smolts.

ACKNOWLEDGEMENTS

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Grant and Chelan Public Utility Districts (GCPUD and CCPUD), the Columbia River Inter Tribal Fisheries Commission (CRITFC) and the Bonneville Power Administration through the Columbia Basin Accords provided funding for this project. Todd West, Dave Beardsley, Brad Buchsieb, and Chris Vanwey (CCPUD) contributed instrumental logistical and personnel support to the PIT tagging efforts at Osoyoos Lake. Josh Murauskas (CCPUD) assisted with PIT queries and analysis of PIT results. Mark Timko, Audrey Thompson, and Michael Meagher (Blue Leaf Environmental) provided valuable JSATS technical training and database support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOT PLATES

LIST OF OKANAGAN PLACE NAMES

Okanagan Place Names (Okanagan-English Translation)	
nx˘ʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
suwiẁs	Osoyoos Lake
q̓awst’ik’ʷt, also known as ṫ̓iwcən	Skaha Lake
akspaqmix	Vaseux Lake
nʕaylintən	McIntyre Dam
sx̌wəx̌wnikw	Okanagan Falls

1.0 INTRODUCTION
1.1 Project Background

The q̓awsitkʷ (Okanagan River) Sockeye Salmon (*Oncorhynchus nerka*) population is one of the last few remaining viable Sockeye Salmon stocks in the Columbia River Basin. In response to concerns over declining stocks in the Okanagan Basin, the Okanagan Nation Alliance (ONA) commenced Sockeye Salmon re-introduction into q'awst'ik'ʷt (Skaha Lake) beginning in 2003 (Wright and Smith 2003). Sockeye eggs collected from q'awsitkʷ broodstock are hatchery reared then released into q'awst'ik'ʷt and/or suwiw̓s (Osoyoos Lake), where they rear for one year before migrating to nx̌ʷəntkʷitkʷ (Columbia River) and the Pacific Ocean as smolts (Benson et al. 2011a; 2011b). One main unanswered question is out of basin survival of both hatchery and natural Okanagan smolts. The tri-partite research group comprised of the Columbia River Inter-Tribal Fish Commission (CRITFC), ONA, and the Canadian Department of Fisheries and Oceans (DFO) are mutually interested in determining the limiting factors affecting the abundance of Okanagan Sockeye. Broadly, the factors of concern are the freshwater outmigration, marine survival, and freshwater migratory return.

The Okanagan Basin Technical Working Group (COBTWG), consisting of DFO, ONA, and the Ministry of Forests, Lands, and Natural Resource Operations proposed a pilot study to evaluate Juvenile Salmonid Acoustic Telemetry System (JSATS) technology to test the methodology, efficiency of the system, and survival and travel time of smolts as the migrate out of basin. Concurrently, a Passive Integrated Transponder (PIT) tagging pilot study was conducted to assess methods for a larger scale PIT study. As a result of this preliminary pilot study, recommendations for a second year were proposed. The main recommendation for the PIT component was to increase the sample size to a minimum of 5,000 tagged smolts and to expand the scope of tagging to include suwiw̓s (Osyoos Lake) smolts. For the JSATS component, the main recommendations were the following: 1) to eliminate the shallower river sites; 2) conduct range and efficiency tests at akspaqmix (Vaseux Lake) as well as at suwiw̓s; and 3) eliminate test tagging of live fish and focus on the range and efficiency tests (Benson et al. 2013).

Recent advances in technology have resulted in smaller acoustic transmitters and supported an increase in the use of acoustic telemetry to study juvenile salmonids. Based on the limitations of the existing technology in 2001, the Portland District of the U.S. Army Corps of Engineers (USACE) began development of a new acoustic telemetry system that would use an active transmitter small enough for implantation in the majority of the size distribution of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) emigrating through the Columbia Estuary. JSATS consists of microacoustic transmitters, receiving systems, and data management and processing applications (McMichael et al. 2010)

PIT tag technology has been used as a tool by researchers and fisheries managers in nx̌ʷəntkʷitkʷ Basin to mark and track anadromous fish since 1987. Currently, a comprehensive network of PIT arrays, tagging programs, and a data repository is operational in the Basin. The system is managed by the Pacific States Marine Fisheries

Commission and funded by Bonneville Power Administration (BPA) (PTAGIS 1999). In 2009, CRITFC and ONA installed a PIT antenna in q’awsitkʷ upstream of suwiw̓s in order to track adults tagged at Wells Dam to the spawning grounds (Fryer et al. 2012). The existing PIT network allows us to track tagged smolt survival rates and travel times during outmigration.

1.2 Study Area

q’awsitkʷ is a major tributary to nx̌ʷəntkʷitkʷ and has an approximate length of 185 km (37 km Canadian portion, 148 km US portion). q’awst’ik’ʷt smolts leave the lake and pass through Skaha Lake Outlet Dam located at sx̌wəx̌wnikw (Town of Okanagan Falls), then migrate down q’awsitkʷ through akspaqmix, nʕaylintən (McIntyre Dam), and suwiw̓s (Figure 1). Sockeye that rear in the North Basin of suwiw̓s begin outmigration at similar times as q’awst’ik’ʷt sockeye smolts. Both travel downstream and pass through the Osoyoos Lake Narrows, a part of the lake that connects the Central and North Basin of the lake. From suwiw̓s the q’awsitkʷ flows south through the Okanogan County, past the towns of Okanogan and Omak. q’awsitkʷ enters nx̌ʷəntkʷitkʷ from the north, 8 km east of Brewster, between the Wells Dam (downstream) and the Chief Joseph Dam (upstream). The reservoir behind Wells Dam, into which q’awsitkʷ empties, is called Lake Pateros. Smolts must migrate through nine hydroelectric dams to reach the Pacific Ocean.

For the 2011 Brood Year, hatchery-reared fry were released into suwiw̓s; therefore, smolts outmigrating from q’awst’ik’ʷt in 2013 were of natural origin. Smolts outmigrating from suwiw̓s were of both hatchery and natural origin.

Figure 1. q'awsitkw juvenile out of basin study area showing receiver locations for 2013.

1.3 Project Objectives

The main objective was to test the feasibility of JSATS and PIT tagging as methods to determine Sockeye smolt out of basin survival and travel time. The ultimate goal was to

conduct a small scale study and assess methods in order to expand on a larger scale study in the future. Current objectives have been refined from the 2012 pilot study (Benson et al. 2013). Specific objectives included:

4. PIT tag up to 5,000 hatchery- and natural-origin smolts as they migrate from q’awst’ik’^{w}t.

5. Monitor PIT tagged smolt survival and travel rates to the nx̌^{w}əntk^{w}itk^{w} estuary.

6. Configure two receiver stations using Lotek JSATS receivers at akspaqmix and suwiw̓s. Test the range and efficiency of each location to determine reliability of the system.

7. Synthesize an efficient study design and data management protocol that will address out of basin survival.

2.0 METHODS
2.1 JSATS Receiver Equipment, Site Selection, and Range Testing

We used four Lotek Wireless® JSATS compatible WHS 4000 autonomous data logging acoustic node receivers (Photo Plate 1). The WHS 4000 is a compact, lightweight, submersible data logging receiver that operates for 100 days with two D-cell lithium batteries and allows researchers to use the smallest acoustic tags available (0.25 g). The WHS 4000 is Lotek's beta version JSATS node. Due to budgetary constraints and the experimental nature of the pilot study, the WHS 4000 was chosen as an appropriate system to field test.

Photo Plate 1. JSATS receiver.

We chose two station locations based on geography, stream/lake morphology, and recommendations from 2012. Beginning upstream, the site locations are the following (Figure 1):

1. akspaqmix near the outlet, 2 km upstream of nʕaylintən,
2. Osoyoos Lake Narrows, at the Highway 3 Bridge.

We used two methods to deploy receivers. The first method employed a custom made aluminum frame (1 m X 1 m base, 1.3 height) with the receiver attached at the top (Photo Plate 2). The frame was weighted with four pieces of angle iron. This anchor system was deployed at the suwiw̓s site. The second method was used at the akspaqmix site. Two ten-pound mushroom anchors were attached to one end of a rope (Photo Plate 3), and a buoy was attached to the other end. The receiver was then attached slightly below

the buoy using zap-straps (Photo Plate 3). Once deployed the receiver hydrophone was within 0.5 m of the water surface.

Photo Plate 2. Aluminum frame receiver configuration.

Photo Plate 3. Anchor line receiver configuration.

A general approach for range testing was conducted at both sites. We launched two receivers in a gate configuration, with a 45 m maximum distance between receivers. The two receivers were positioned in areas that would maximize detection of migrating smolts, taking into account depth, thalweg, and distance from shore. An active tag was attached to a rope with an anchor and buoy, then placed at a specific distance from the two receivers for a set amount of time, approximately three weeks for each site. A second phase of the range test involved attaching an active tag to a weighted rope, then randomly traversing the vicinity of the node in a kayak or pontoon boat with the tag just below the water surface for a set time period. Following the field test, we would estimate a maximum number of tag pings (tag ping rate X total time tag was in water = max tag pings). The number of detections from each receiver was then divided by the maximum number of pings to estimate efficiency at each node location.

2.4 PIT Tagging Procedures

q'awst'ik'ʷt smolts were captured downstream of Skaha Lake Outlet Dam and at Osoyoos Lake Narrows at the Highway 3 Bridge during the smolt outmigration monitoring program (Benson and Stevens 2013). Two rotary screw traps (RSTs) were set for 12-hour periods on alternate nights from 26 March to 15 April, 2013, then 24-hour periods from 15 April to 5 May, 2013. We checked live wells once or twice per day depending on peak outmigration. During morning checks, a sub-sample of captured smolts were held in aluminum kitoi boxes positioned in the river downstream of the RSTs until for tagging later that day. suwiẇs smolts were captured using a floating fyke net set every 2 – 3 nights from 4 April to 27 May, 2013 and held in aluminum kitoi boxes placed in the shallows of Osoyoos Narrows for tagging the following day.

We used procedures outlined by PTAGIS (1999) and Biomark (2012) for marking smolts. We deployed BIOMARK HPT 12 PIT tags (134.2 kHz) measuring 12.5 mm in length. The MK-25 Rapid Implant Gun along with HPT9 pre-loaded sterile needles manufactured by Biomark® was used for implanting tags. Fish were removed from kitoi boxes and placed in a 19-L (5-gal) pail containing a 40 mg/l solution of tricaine methanesulfonate (MS 222). Fish were kept in the solution until they lost equilibrium. Smolts were then transferred to a weaker solution (20 mg/l MS 222) until processed for tagging. Each smolt was measured for fork length (cm) and weight (g), and general body condition/descaling percentage was recorded. The tagging needle was inserted on the left side between the dorsal fin and lateral line, then the trigger was depressed until the tag was inserted into the incision hole. The tagged smolt was scanned and logged using an HPR Plus reader (Biomark®). The system was connected to a laptop computer, which logged each number in an Excel spreadsheet. This configuration allowed taggers to enter bio-data and tagging comments directly into the tagging file without the need for post-season data entry. Following processing, each tagged fish was placed in a bucket of aerated water until fully recovered. All tagged smolts were returned to the kitoi boxes and released back into river the same day, typically between 22:00 and 24:00 to reduce predation. Fish were released either downstream of the Skaha Lake Outlet Dam or downstream of the Highway 3 bridge on suwiw̓s.

Survival and travel time calculations were determined by tagging and observation queries through the PTAGIS database and subsequently run through version 4.19.8 of PITPro.

3.0 RESULTS

3.1 Site Selection and Range Testing

Site maps and channel cross sections for JSATS range tests are presented (Figures 2-5). The depth data label indicates the approximate location of receiver deployment. Note that the scale differs for each figure.

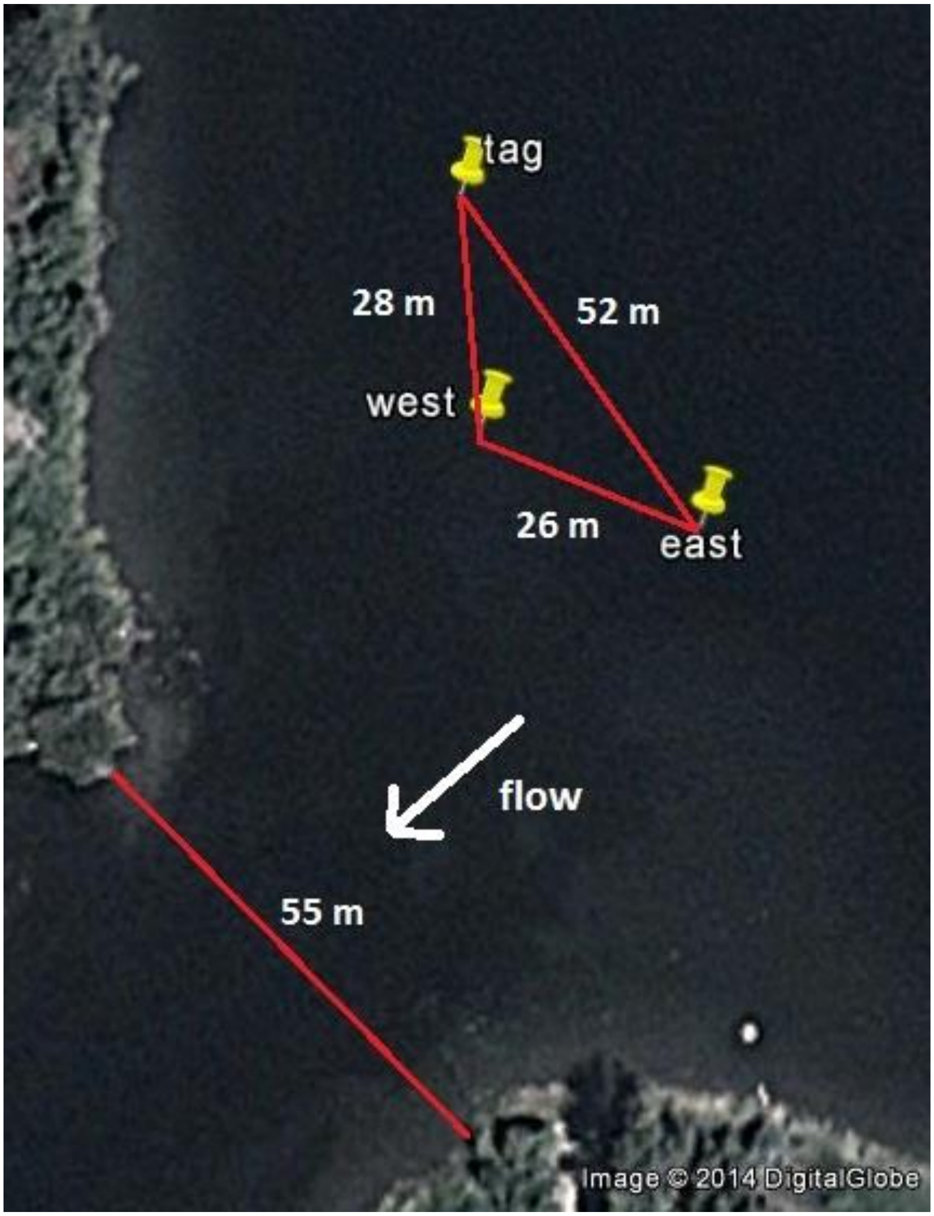

Figure 2. Map of akspaqmix (Vaseux Lake) JSATS receivers and test tag.

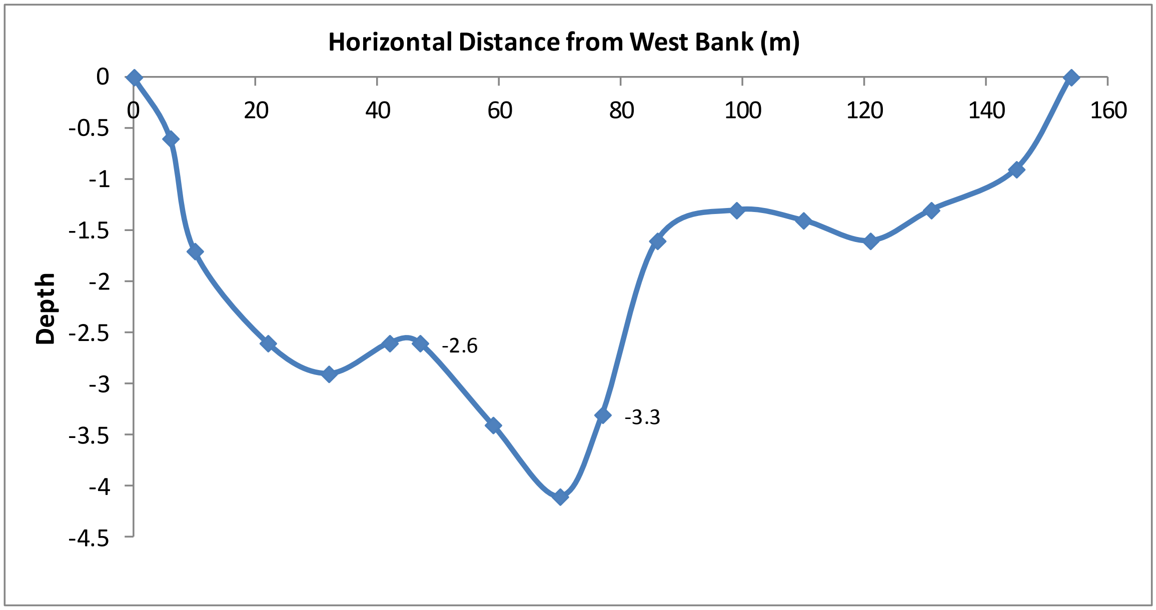

Figure 3. Cross-sectional profile of akspaqmix (Vaseux Lake) site.

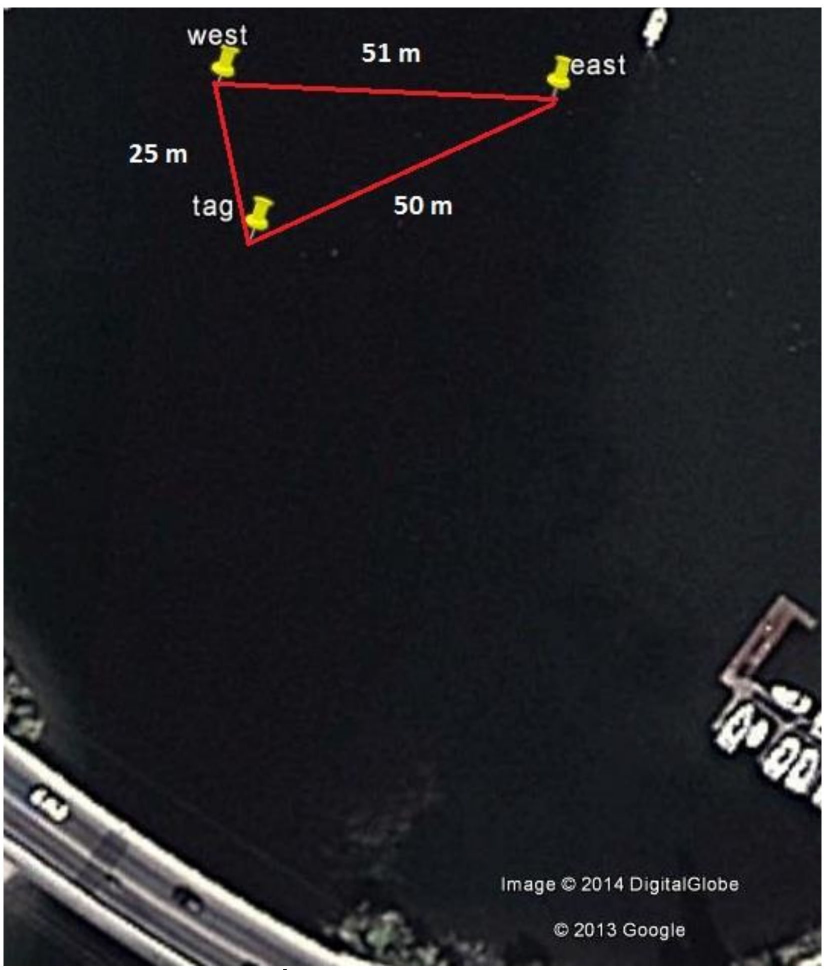

Figure 4. Map of suwiw̓s (Osoyoos Lake) JSATS receivers and test tag.

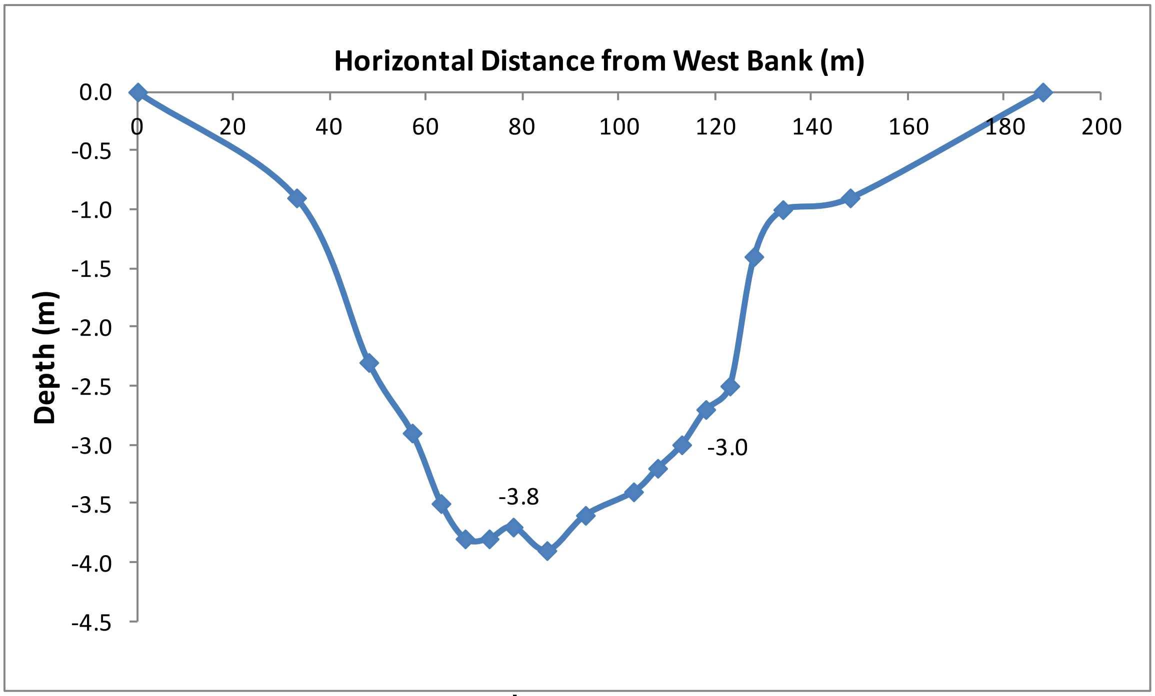

Figure 5. Cross-sectional profile of suwiw̓s (Osoyoos Lake) site at Osoyoos Narrows.

We successfully range tested one location at akspaqmix and suwiw̓s. Range tests were conducted on 23 April – 14 May (suwiw̓s) and 15 May – 2 July (akspaqmix). Results of range tests are summarized (Table 1).

Table 1. Summary of akspaqmix (Vaseux Lake) and suwiw̓s (Osoyoos Lake) JSATS range testing, 2013.

Site Name	Distance Between Nodes (m)	Distance to Test Tag (m)	Test Efficiency (%)	Lake Width (m)
suwiw̓s east	51	50	22.1	181
suwiw̓s west		25	21.7	
akspaqmix east	26	52	8.2	67
akspaqmix west		28	24.6	

Based on results from 2012 (Benson et al. 2013), the 15-second filter reduced the false signals, sometimes by up to three orders of magnitude. More importantly, the filter increased the efficiency of detections, possibly by significantly reducing background noise. Efficiency for all receivers ranged from 8.2% to 24.6%. Mean site efficiencies were 21.9% (suwiw̓s) and 16.4% (akspaqmix). Although reception efficiency is site dependent (substrate composition, water depth, noise and turbulence), the maximum effective range appears to be less than 50 m. We observed a similar maximum range in 2012 (Benson et al. 2013).

3.2 PIT Tagging Results

In total, 4018 smolts were released during 11 tagging sessions between April 12 and May 7, 2013 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYOL, downstream of the Highway 3 bridge at the Osoyoos Narrows. Tagging effort is summarized in Table 2.

Table 2. Summary of Okanagan Sockeye smolt PIT tagging effort, 2013.

Date	Site	Number Released
12-Apr-13	SKATAL	82
16-Apr-13	SKATAL	317
17-Apr-13	OSOYOL	247
18-Apr-13	SKATAL	475
19-Apr-13	OSOYOL	389
25-Apr-13	OSOYOL	158
26-Apr-13	SKATAL	304
	OSOYOL	229
30-Apr-13	OSOYOL	425
1-May-13	OSOYOL	446
2-May-13	OSOYOL	889
7-May-13	OSOYOL	57
Total		**4018**

Reliable estimates of survival from release to Rocky Reach Dam were able to be calculated for both release groups. Survival from release to Rocky Reach Dam was 0.45 (SE = 0.06) for the SKATAL release group, and 0.49 (SE = 0.04) for the OSOYOL release group. After Rocky Reach, error associated with survival estimates for both release groups, individually and combined, was large. Survival was not able to be estimated at all for the SKATAL release group past McNary Dam due to insufficient sample size. Survival estimates for both release groups combined is presented in Table 3 and Figure 6.

Table 3. Mean survival for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKATAL and OSOYOL combined), 2013.

Period	Survival	SE
Release to Rocky Reach	0.4830	0.0345
Rocky Reach to McNary	1.1379	0.2635
McNary to John Day	1.2454	0.6583
John Day to Bonneville	0.6962	0.5815
Release to Bonneville	0.4766	0.3256

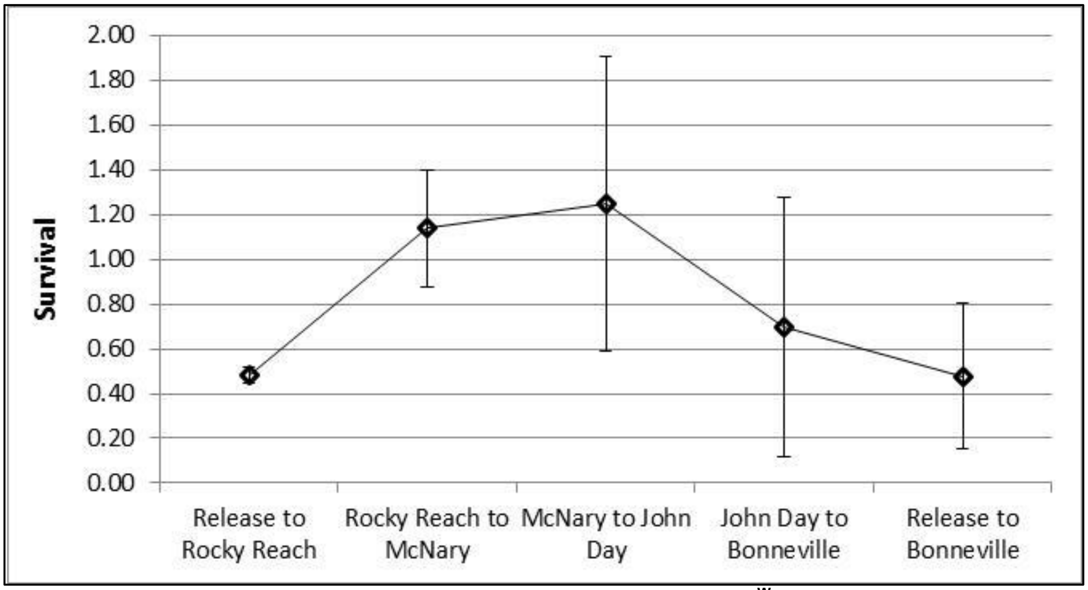

Figure 6. Mean survival and travel time for PIT tagged q'awsitk^w (Okanagan River) Sockeye smolts (SKATAL and OSOYOL combined), 2013.

Travel time from release to Rocky Reach Dam was approximately 20 days for the SKATAL release group, and 19 days for the OSOYOL release group. Travel time for individual reaches was similar between both release groups. Overall travel time from release to Bonneville Dam was approximately 29 days for both groups combined (Table 4).

Table 4. Mean travel time for PIT tagged q'awsitk^w Sockeye smolts, 2013; Standard Errors of mean presented in brackets.

Period	SKATAL Travel Time (d)	OSOYOL Travel Time (d)	SKATAL and OSOYOL Combined Travel Time (d)
Release to Rocky Reach	20.13 (0.30)	18.95 (0.33)	19.30 (0.25)
Rocky Reach to McNary	4.35 (0.24)	4.45 (0.17)	4.41 (0.14)
McNary to John Day	3.15 (0.00)	2.17 (0.18)	2.32 (0.22)
John Day to Bonneville	-	1.53 (0.15)	1.53 (0.15)
Release to Bonneville	-	28.44 (0.94)	29.02 (0.74)

4.0 Discussion and Recommendations
4.1 JSATS

Based on range and efficiency results from 2012 (Benson et al. 2013) and from this year, the maximum detection range seems approximately 50 m. Efficiency for all sites (excluding distances greater than 50 m) ranged from 0 – 82%. Typically, the WHS 4000 receivers work best in deep water (A. Thompson, Blue Leaf Environmental Inc., *pers. comm*.). Following the 2012 pilot study, we discontinued the shallow sites with poor performance and focused on deeper sites with potentially better detection efficiency. Even when these sites were eliminated, the efficiency was not greater than 25%. The JSATS system was originally designed for use in the Columbia River mainstem (McMichael et al. 2010). It's highly likely these mainstem sites are better suited for JSATS than the Okanagan, particularly the Canadian portion, where deep sites with minimal back ground noise (e.g. turbulent flow, boat activity) are limited.
In addition to the poor receiver performance, the 2012 pilot study documented generally low survival for tagged smolts. Groups with the lowest survival tended to be pre-smolts collected during trawl net sampling in suwiw̓s and q'awst'ik'ʷt. Smolts captured in RSTs had significantly higher survival rates (Benson et al. 2013). The difference in survival is likely due to increased stress from the trawl net. One potential issue of JSATS transmitter tags was the 30-day battery life, which may artificially inflate mortality rates (i.e. tag batteries expire before smolts are detected by receivers). Current JSATS technology limitations do not allow for programmable transmitters with time-delay activation. This type of feature would allow implantation, QA/QC to ensure tags are transmitting, then temporary deactivation. After a set amount of time, tags would activate before smolts leave the system and allow for tracking as they outmigrate. This configuration will conserve battery life and allow for longer tracking. COBTWG recommended waiting until JSATS technology can develop time-delay activation tags (Benson et al. 2013).

Finally, we encountered numerous "glitches" with the JSATS receiver and hardware. The LOTEK JSATS system was a beta version at the time of purchase, and it appears that many engineering issues still need to be sorted out. For example, acoustic tags that were de-activated after a short period of active pinging would re-activate automatically.

4.2 PIT Tagging

The program *SampleSize* (Columbia Basin Research, School of Aquatic & Fishery Sciences, University of Washington) was used to develop confidence intervals for a single-release survival estimates of juvenile Sockeye Salmon through the Columbia River Basin (Figure 9). Estimates require an assumed survival and detection probability at downstream locations. Lake Wenatchee-origin sockeye smolts were used to generate capture probabilities at McNary, John Day, and Bonneville; spring Chinook smolts released above Wells Dam were used to generate detection probabilities at Rocky Reach Dam. Survival probabilities were generated from spring Chinook releases above Wells Dam. Average values from these observations were used as assumptions in the program.

Based on the sample size analysis, a minimum of 5,000 PIT tags would be optimal for estimating survival (Figure 7). Although 4,018 smolts were released in 2013, sample size was still too small to be able to reliably estimate survival through the Columbia River Basin.

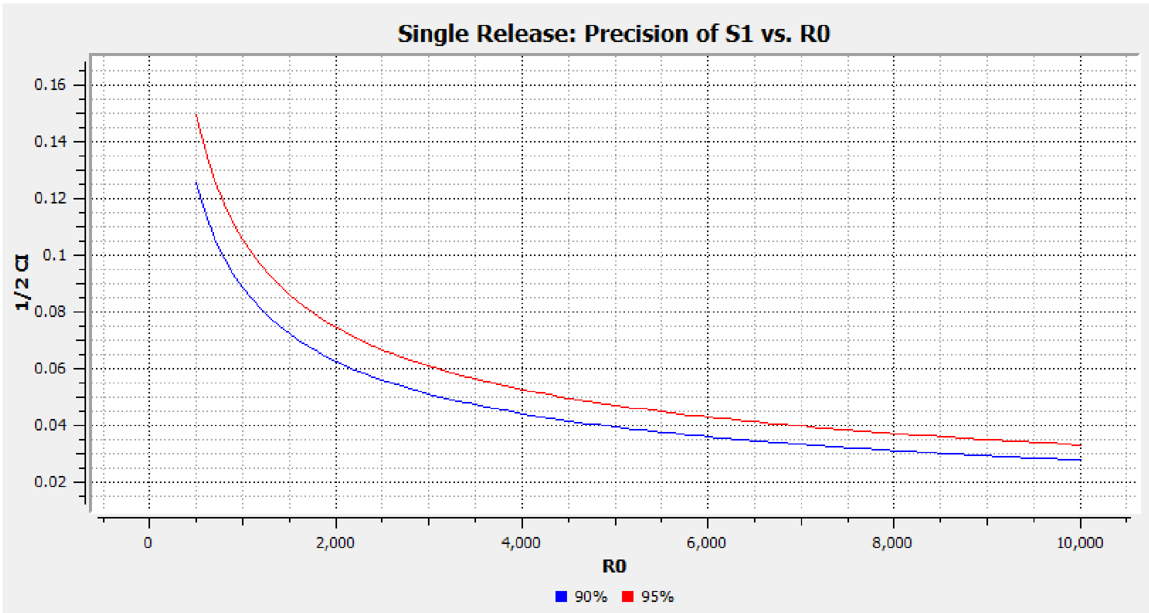

Figure 7. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam.

We propose the following recommendations for future studies:

- Wait for JSATS technology to evolve to enable programmable tags with time delay activation to conserve battery life before continuing to conduct JSATS studies;
- Continue to develop the logistics and capacity to enable PIT tagging a minimum of 5,000 Okanagan Sockeye smolts.

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APPENDIX D

Movement of select Sockeye Salmon acoustic tagged at Wells Dam in 2013

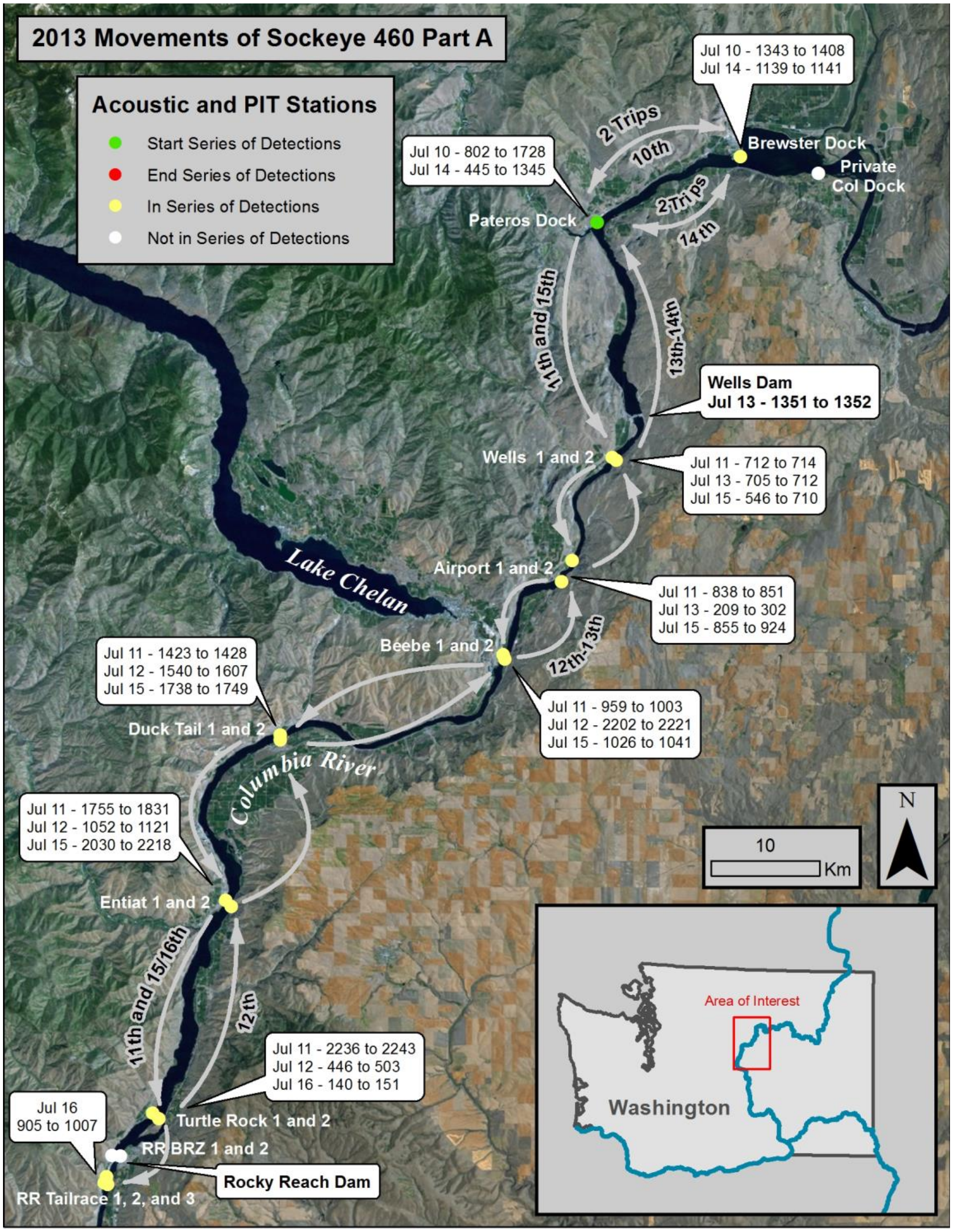

Figure D1 Movements of Sockeye tagged at Wells Dam on 7/9/13 which was last detected at PIT tag site UWE on 7/26/13 (See Figure A-2).

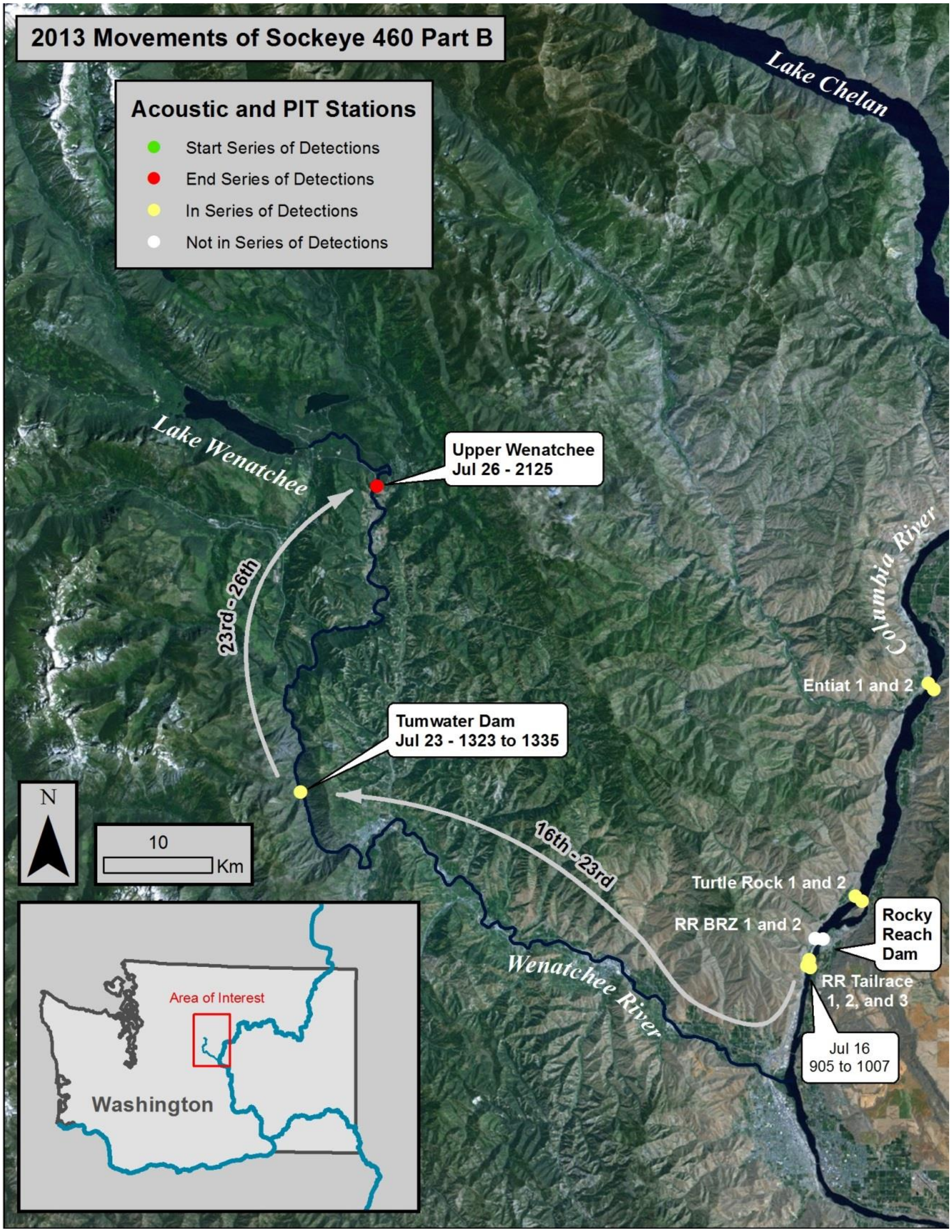

Figure D2. Movements of Sockeye tagged at Wells Dam on 7/9/13 (See Figure A-2) which was last detected at PIT tag site UWE on 7/26/13.

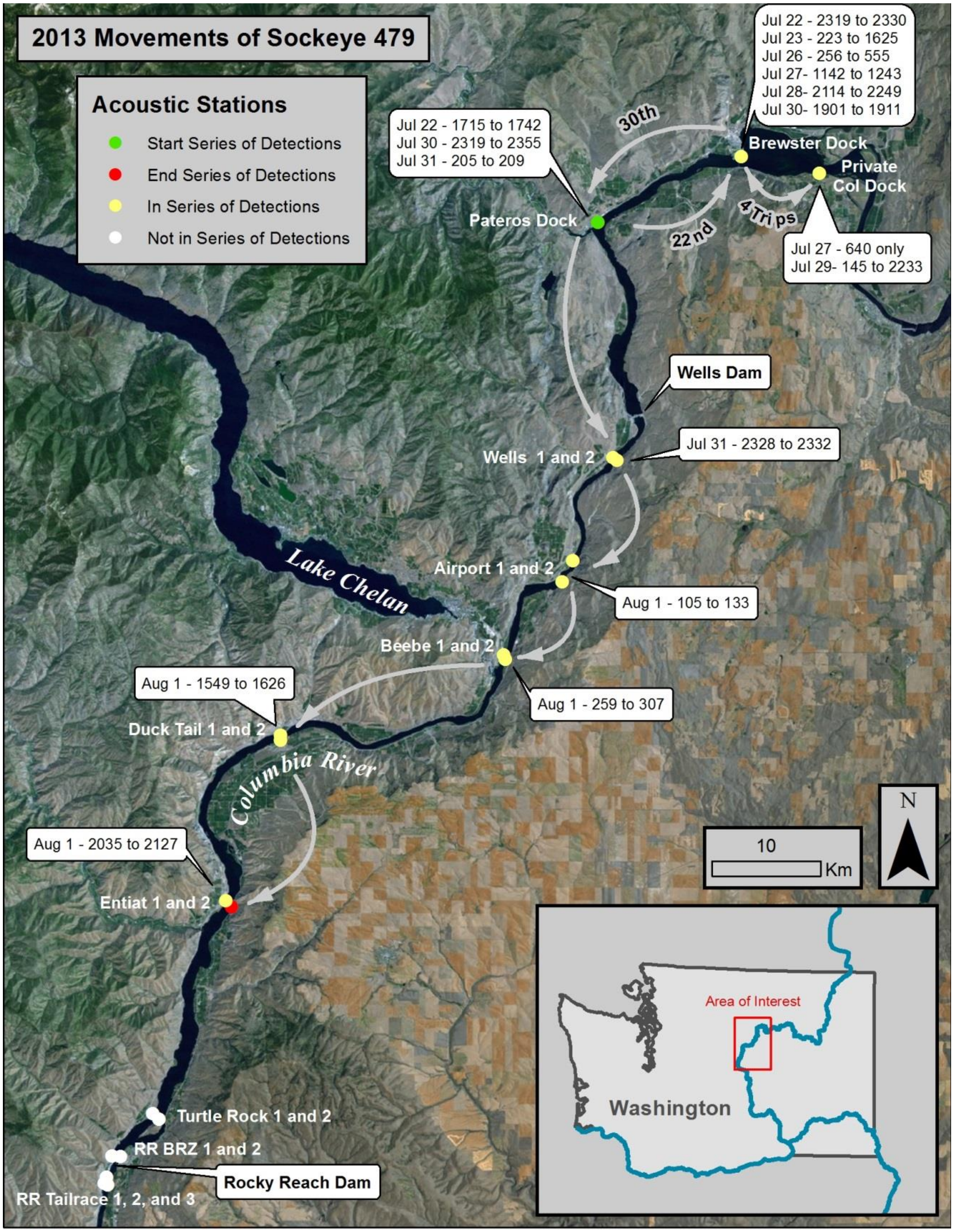

Figure D3. Movements of Sockeye tagged at Wells Dam on 7/9/13 (See Figure A-2) which was last detected at PIT tag site UWE on 7/26/13.

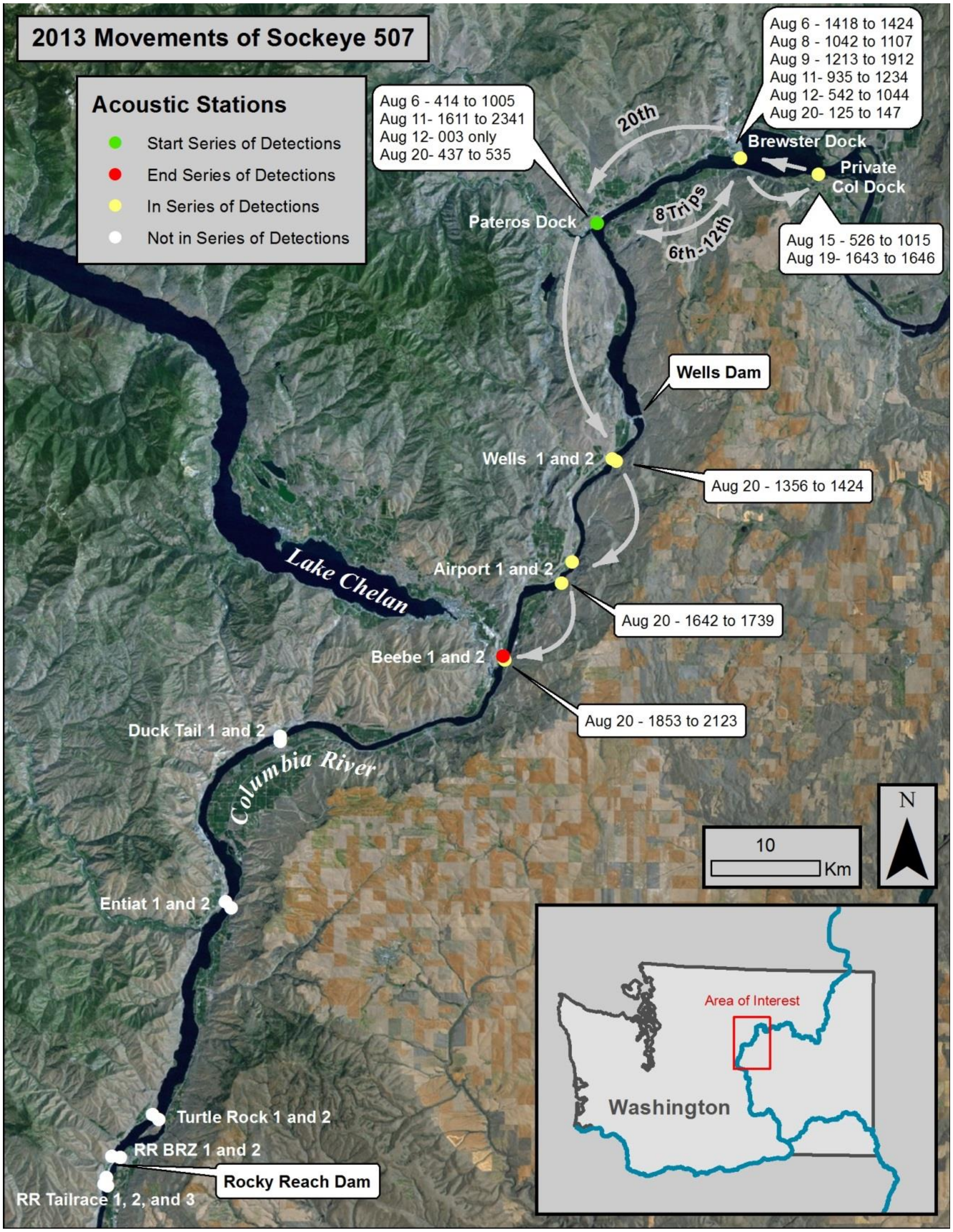

Figure D4. Movements of Sockeye tagged at Wells Dam on 8/5/13 which was last detected in Wells Pool on 8/20/13.

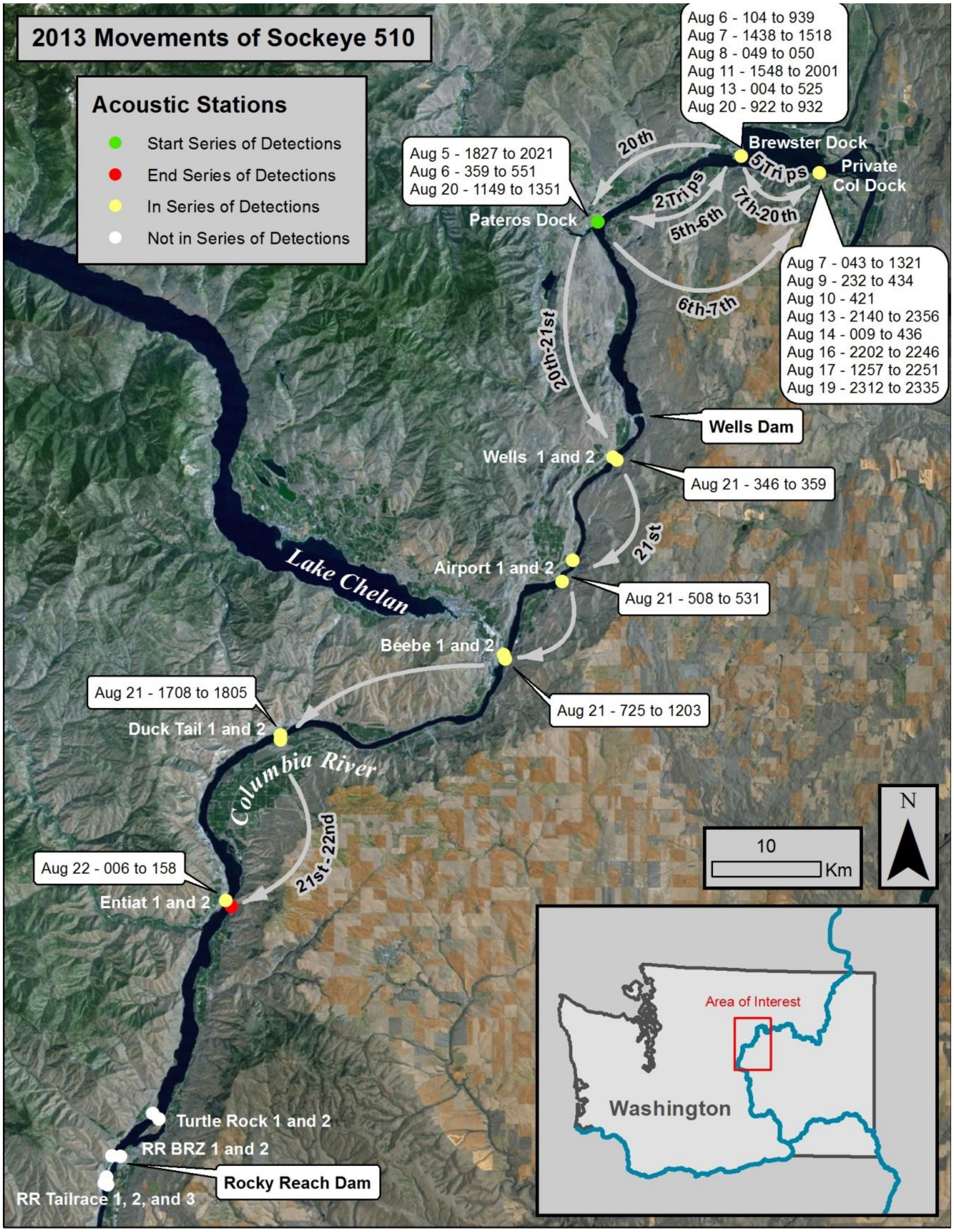

Figure D5. Movements of Sockeye tagged at Wells Dam on 8/57/13 which was last detected in Wells Pool on 8/20/13.

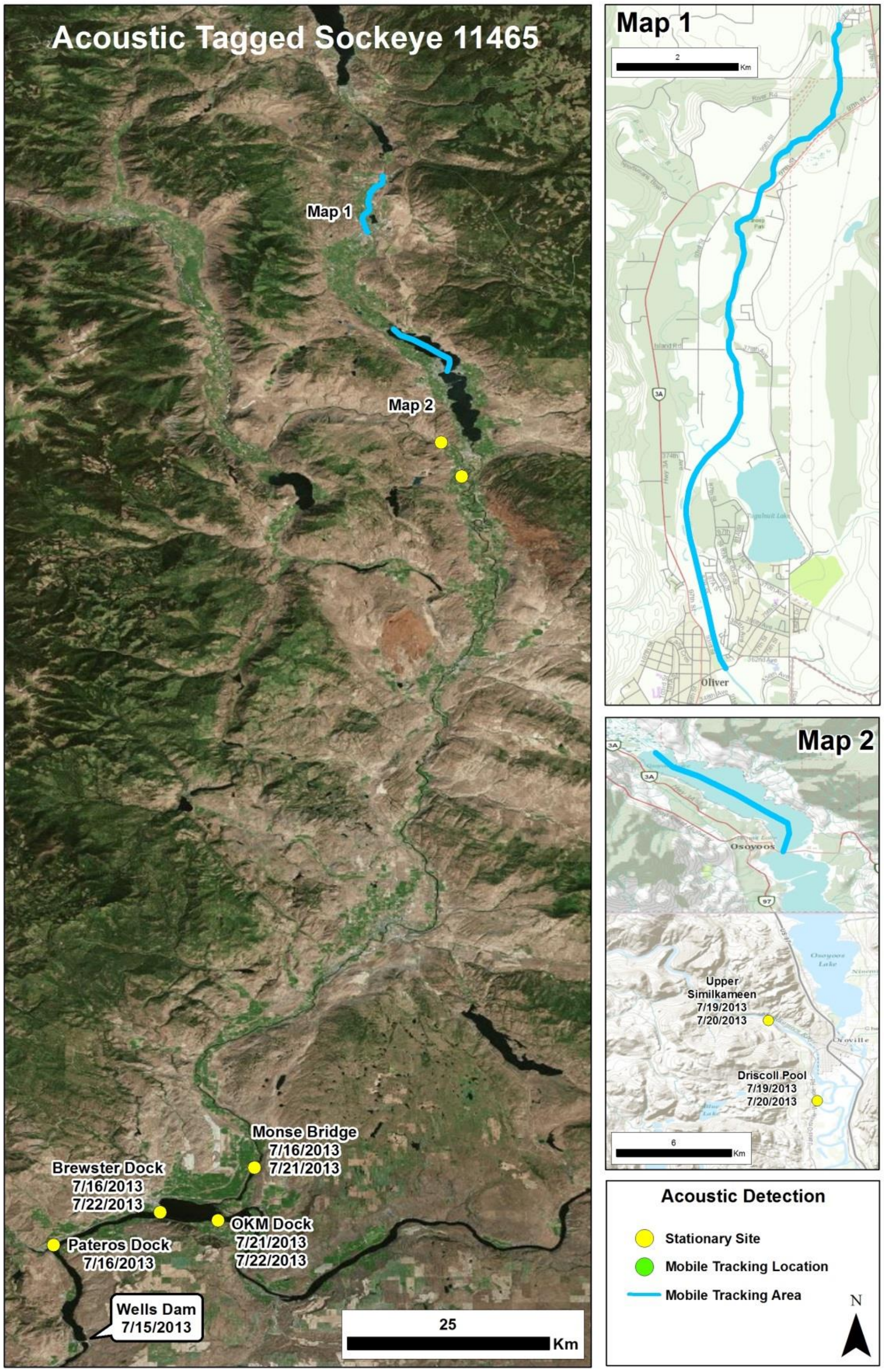

Figure D6. Movements of Sockeye tagged at Wells Dam on 7/15/13 which was detected in the Similkameen River 7/19 but last detected in Wells Pool on 8/20/13.

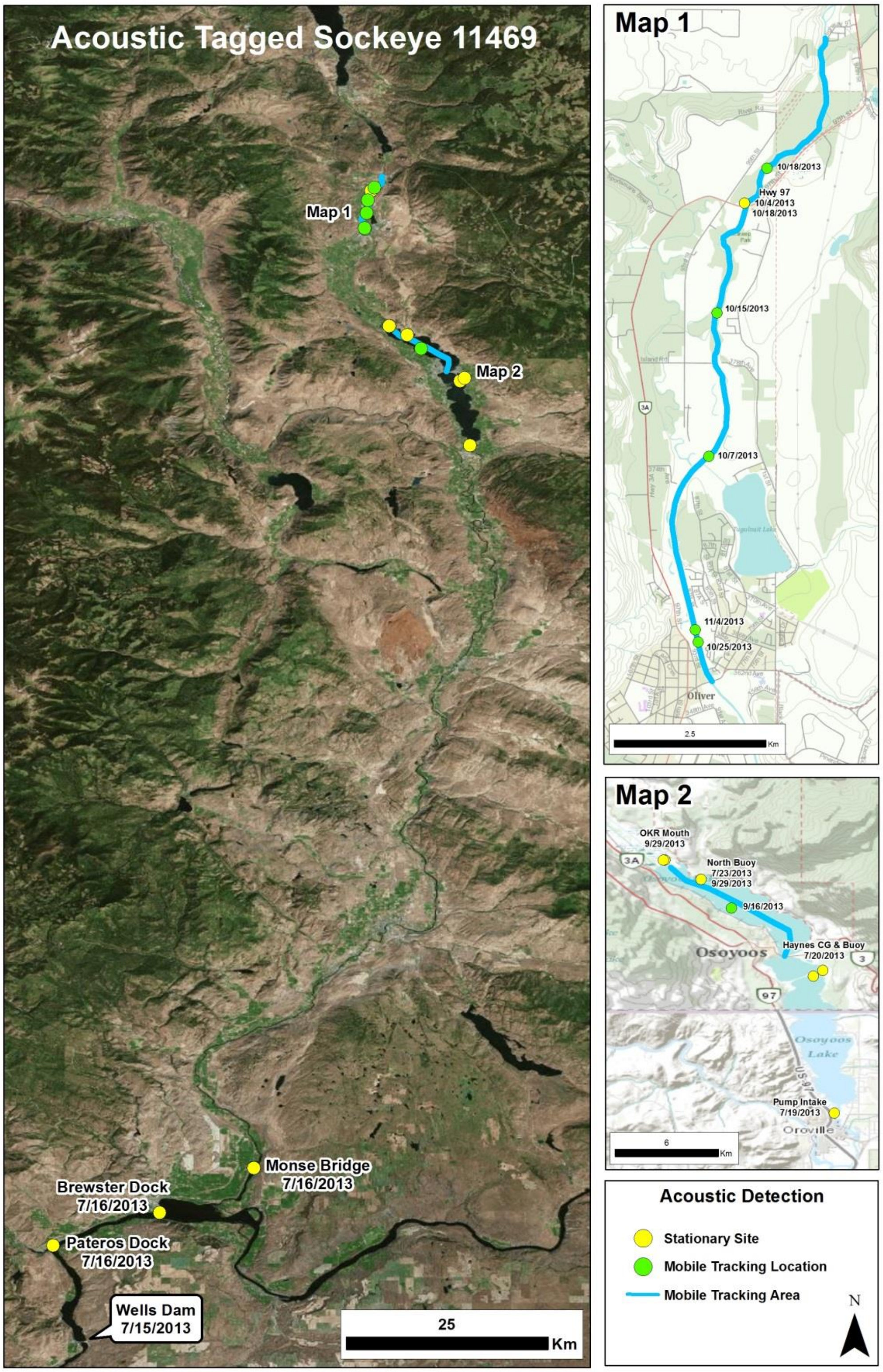

Figure D7. Movements of Sockeye tagged at Wells Dam on 7/15/13 which was last detected on the Okanagan spawning grounds on 10/4/13.

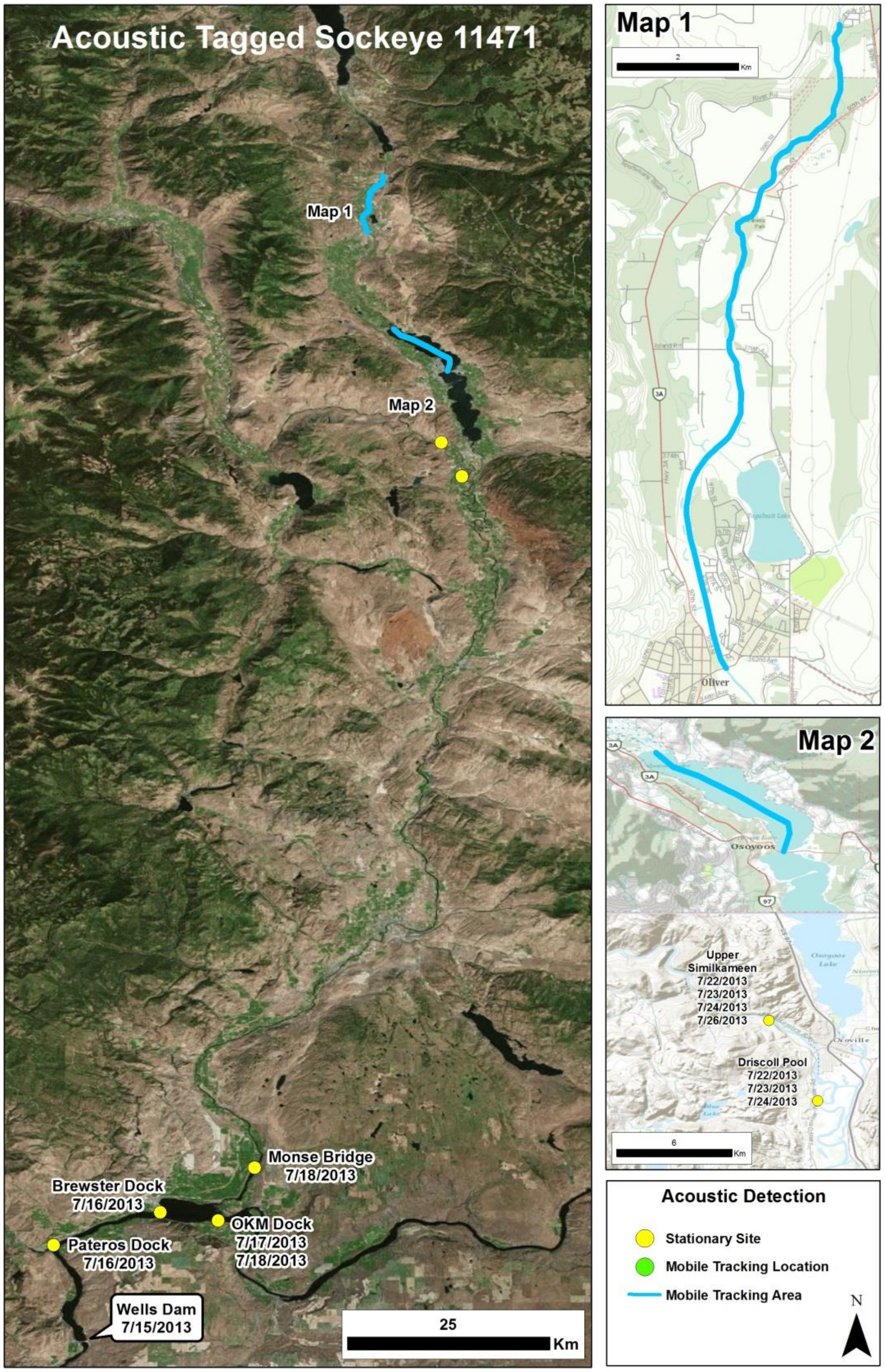

Figure D8. Movements of Sockeye tagged at Wells Dam on 7/16/13 which was last detected in the Similkameen River on 7/26/13.

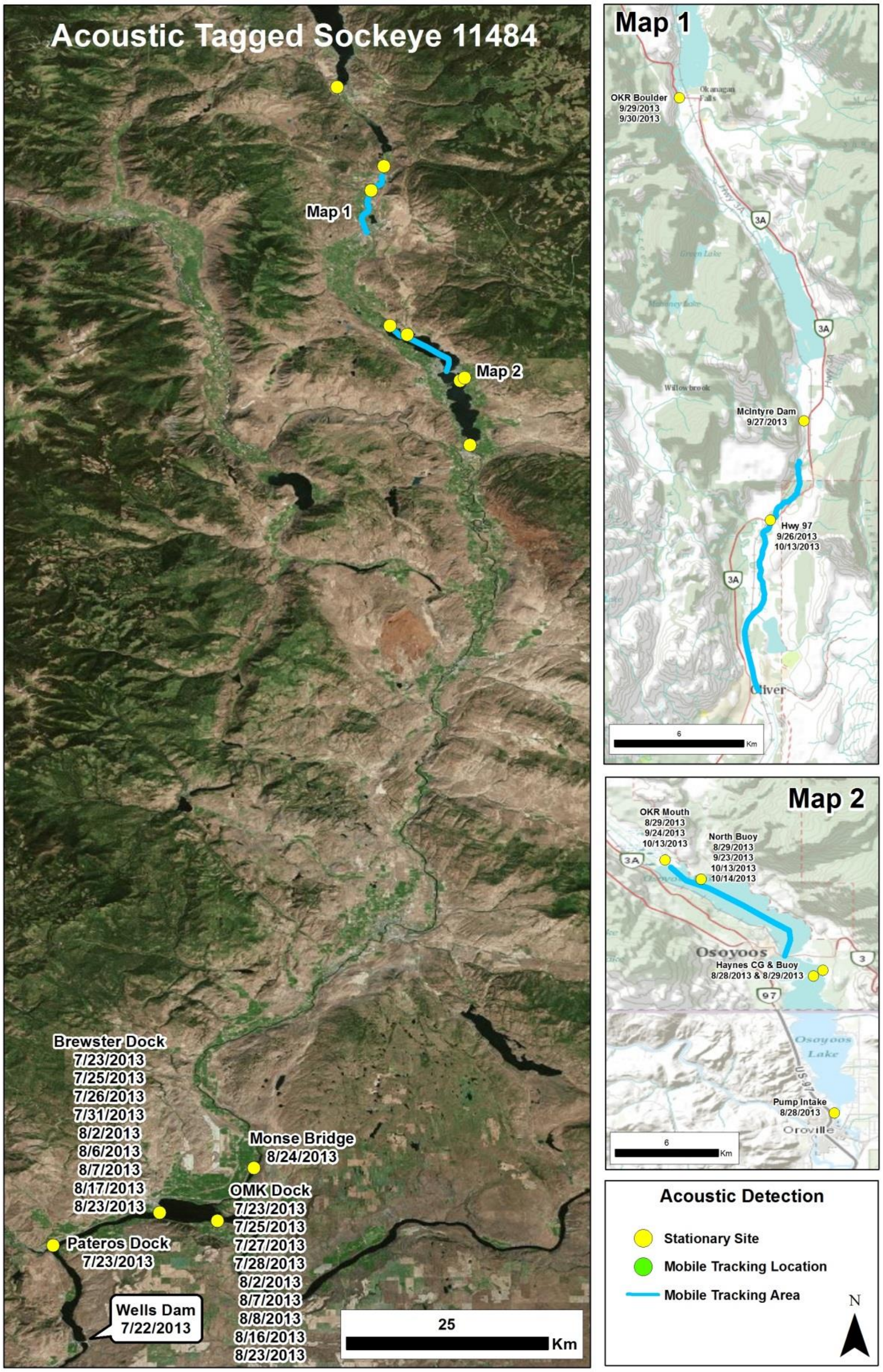

Figure D9. Movements of Sockeye tagged at Wells Dam on 7/22/13 held in Wells Pool until 8/24/13 and made it to Okanagan Falls on 9/27/13 and was last detected the Osoyoos Lake north basin on 10/14/13.

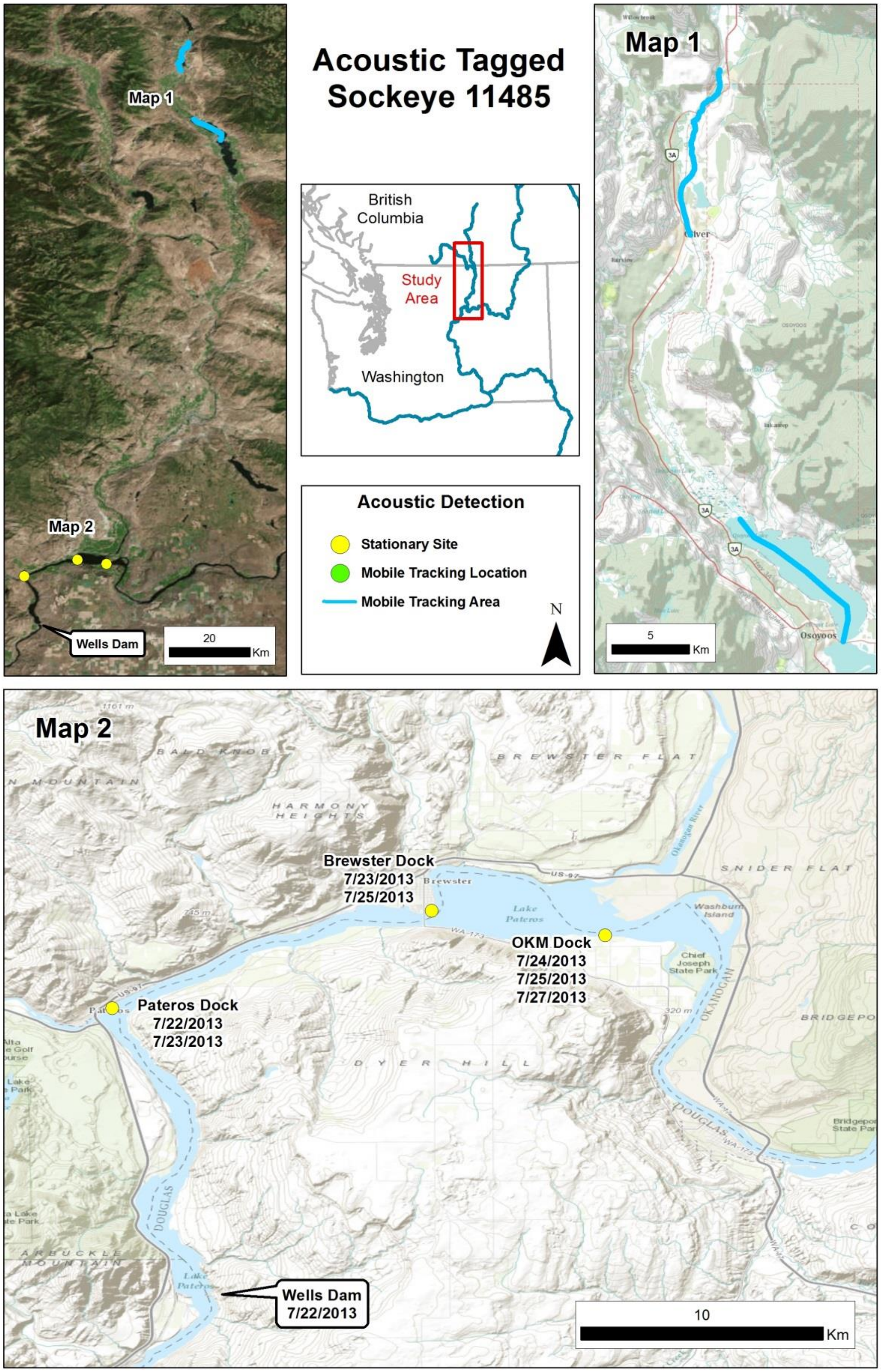

Figure D10. Movements of Sockeye tagged at Wells Dam on 7/22/13 which was last detected in Wells Pool on 7/27/13.

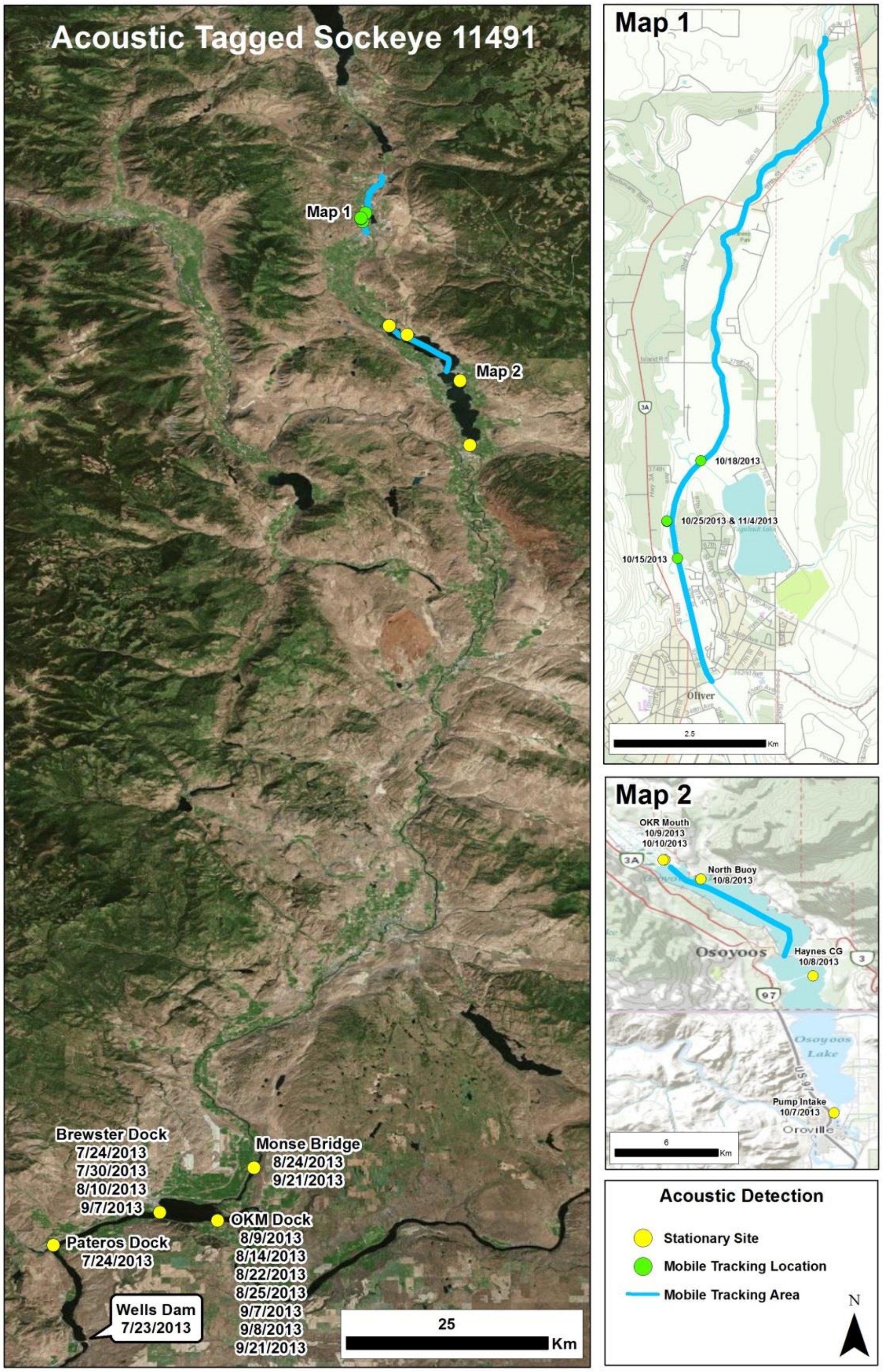

Figure D11. Movements of Sockeye tagged at Wells Dam on 7/23/13 which was last detected at by the mobile acoustic tracker on 11/4/13.

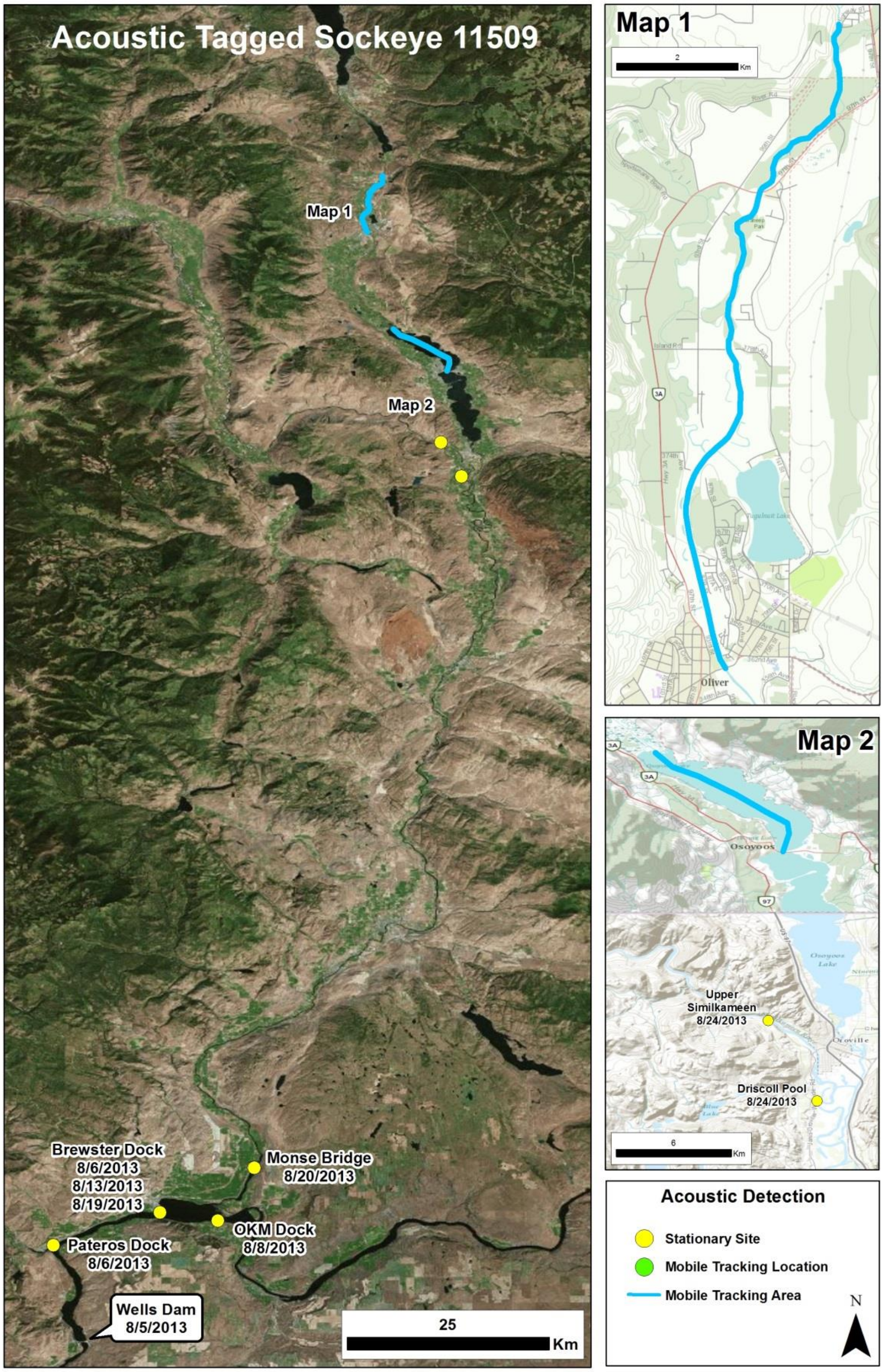

Figure D12. Movements of Sockeye tagged at Wells Dam on 8/5/13 which was last detected in the Similkameen River on 8/24/13. This fish was also captured by the Colville trawl fishery in Wells Pool and released on 8/16/13.