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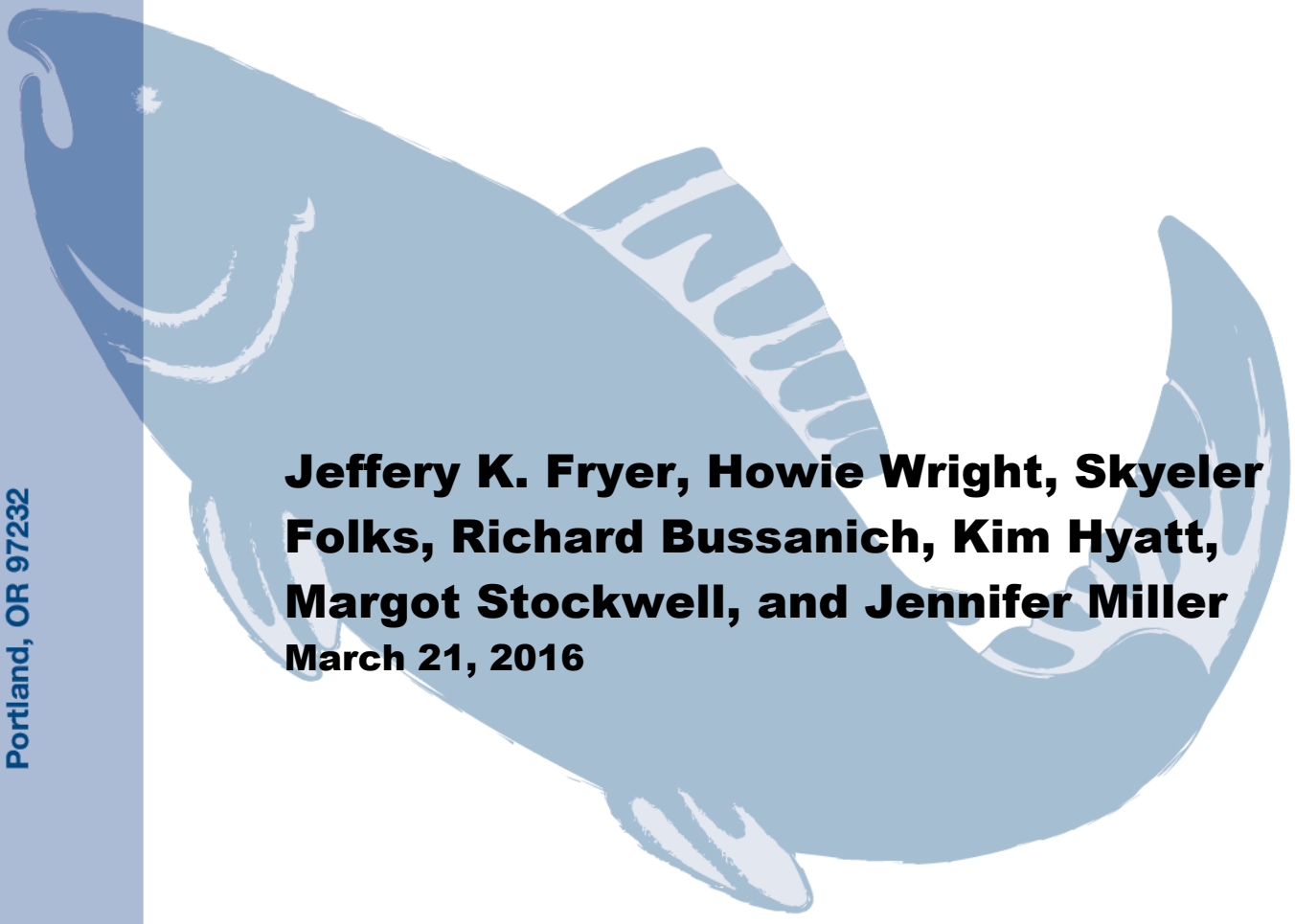
TECHNICAL REPORT 16-02

Limiting Factors of the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2014



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March 21, 2016

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Limiting Factors of the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2014

Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00

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EXECUTIVE SUMMARY

A total of 1414 Sockeye Salmon, *Oncorhynchus nerka*, were PIT tagged at the Bonneville Dam Adult Fish Facility in 2014. These fish, along with previously PIT tagged Sockeye Salmon also sampled, were tracked upstream using data from detection arrays at mainstem Columbia River dam fish ladders as well 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 81.1% Okanagan, 17.5% Wenatchee, 1.0% Snake, and 0.4% Yakima.

In 2014 genetic stock identification (GSI) was used to classify Sockeye Salmon by stock (Okanagan, Wenatchee or Snake) 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 79.6% Okanagan, 19.2% Wenatchee, 0.9% Snake River, and 0.3% Yakima. The estimated survival rate from Bonneville Dam to terminal areas was 81.3% for the Okanagan stock, 74.1% for the Wenatchee stock, and 66.2% for the Snake River stock.

Upstream detections of Sockeye Salmon PIT tagged by this project resulted in an estimated survival of 88.3% to McNary Dam. This was higher than three of the four groups of returning Sockeye Salmon tagged as juveniles at locations upstream of McNary Dam (range=61.7% to 93.2% with the lowest rate for returning Snake River Sockeye and the highest for natural origin Okanagan Sockeye juveniles).

PIT tag data from adult sockeye PIT-tagged at Bonneville Dam estimates fallback rates at Columbia River dams that range from 0.7% at McNary Dam to 3.6% at Priest Rapids Dam. Fallback rates at Snake River dams, based on eight or fewer sockeye were 0% at Ice Harbor and Lower Monumental, 14.3% at Little Goose Dam, and 16.7% at Lower Granite Dam. Fallback rates for returning adults tagged as juveniles were estimated to be over 12% at Bonneville, The Dalles, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams.

The median travel time of Sockeye Salmon between Bonneville and Rock Island dams was 12.2 days, resulting in a median migration rate of 40.5 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, 2014 and December 31, 2014 at Zosel Dam, 4 coho, 26 Chinook, 31 steelhead, and 1,359 Sockeye were detected, while at OKC 1 Chinook, 10 steelhead, and 291 Sockeye were detected. Unlike previous years when high flows made it possible for upstream migrating salmon to pass through Zosel Dam spillways undetected, in 2014 lower flows resulted in there being no salmon detected upstream that were not detected at Zosel Dam. However, a software coding error meant that an unknown number of PIT tagged fish with tag codes beginning with 3DD were missed prior October 22, 2014.

At Wells Dam, 776 Sockeye Salmon were sampled and 773 PIT tags and 99 acoustic tags deployed, with 3 Sockeye PIT tagged at Bonneville Dam included in the sample. In addition, 60 temperature tags were deployed at Wells Dam. All Sockeye sampled at Wells Dam were also Floy tagged. The weighted conversion rate to the Zosel Dam for fish PIT+Floy tagged at Wells Dam was 67.9% compared to 76.1% 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 1.8% higher conversion rate to Zosel Dam than those only tagged at Wells Dam with PIT tags only, while those PIT plus temperature tagged had a 33.9% lower conversion rate to Zosel. For those Sockeye passing, or tagged at, Wells Dam on or before July 23, 80.6% of both the Wells-tagged and 71.5% of Bonneville-tagged Sockeye were detected at Zosel. For those Sockeye passing or tagged at Wells Dam on or after July 24, 53.4% of Wells-tagged and 45.9% of Bonneville-tagged Sockeye were detected at Zosel Dam.

A total of 21 acoustic receivers were deployed between Wells Dam and Skaha Lake and 99 acoustic tagged Sockeye were released at Wells Dam. Survival was estimated at 93.2% to the Monse Bridge site on the Okanagan River just upstream of Wells Dam, 60.7% to the North Basin of Osoyoos Lake, and 11.8% 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 Lake Pateros. Of the 99 Sockeye acoustic tagged, 40 were estimated to be on the spawning grounds during the spawning period, 46 were missing on the upstream migration, and 13 were last detected just in the northern basin of Osoyoos Lake or at the mouth of the Okanagan River immediately upstream of Osoyoos Lake but not detected on the spawning grounds.

Okanagan juvenile PIT tagging resulted in 5,056 smolts being released during 19 tagging sessions between April 7 and May 5, 2014 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 0.34 (SE = 0.04) for the SKATAL release group, and 0.63 (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 17 days for the SKATAL release group, and 10 days for the OSOYOL release group. Overall travel time from release to Bonneville Dam was approximately 23 days for both groups combined.

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. 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 planning on testing the use of a DIDSON 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, and Skaha lakes.

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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 highs of over 500,000 Sockeye Salmon counted at Bonneville Dam in 2012, 2014, and 2015 (DART 2015, Fish Passage Center 2015). The Bonneville Dam count of Sockeye Salmon in 2014 was a record high of 614,179.

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).

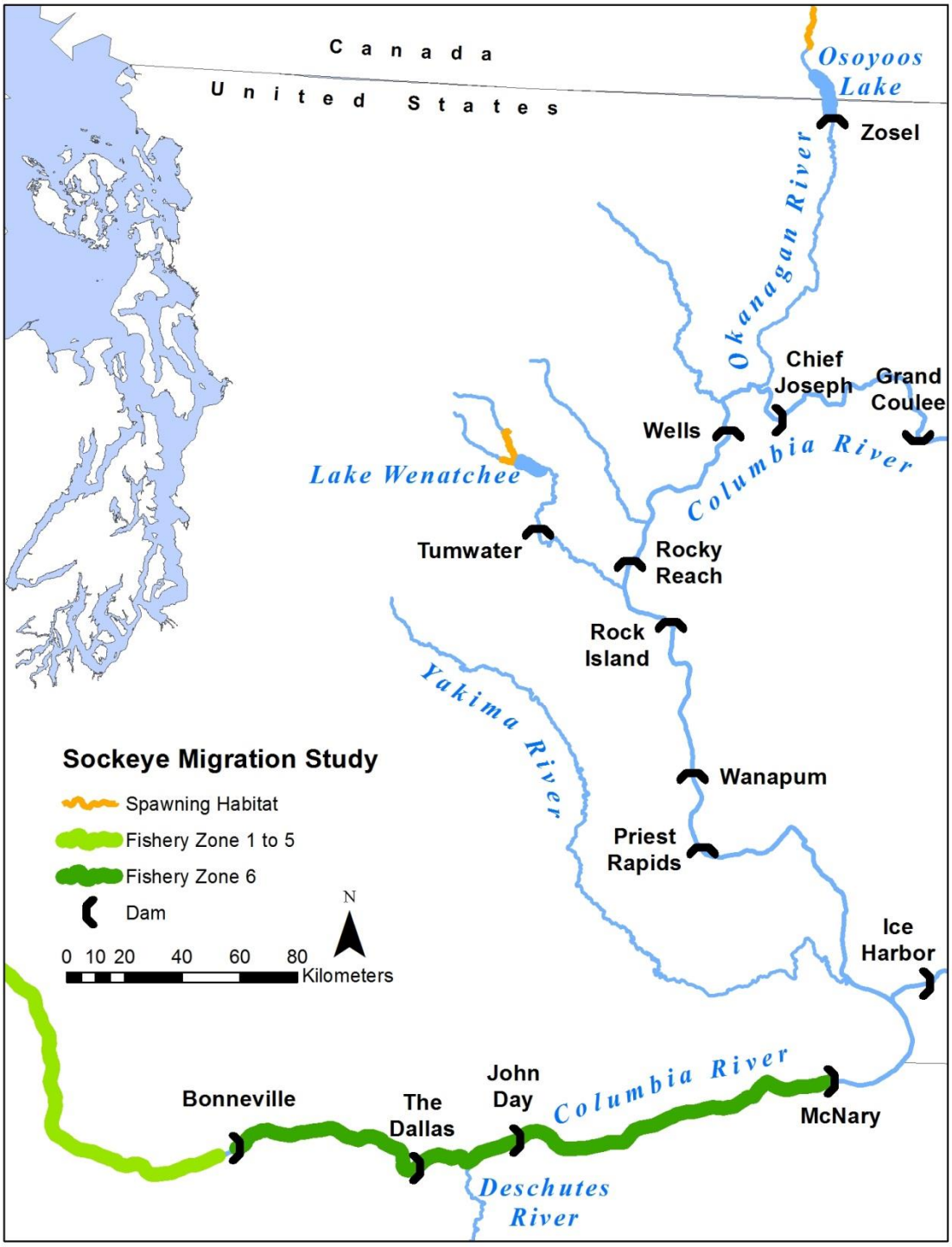

Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the two major Sockeye Salmon production areas and significant dams on their migration route.

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 2007, 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 tagging 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 Osoyoos Lake. 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 Receiver Network

An acoustic receiver 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 Sampling

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, tissue punched for later genetic analysis, 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 west 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 long chute leading to a hatchery raceway or returned them to the ladder upstream of the barrier gate. Fish were crowded in the raceway and netted 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 water and bubbled oxygen before being loaded into a 2800 liter tank on a transport truck, 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=60) or an internally implanted acoustic transmitters (N=99). The temperature tags were Alpha Mach Inc. iBCod 21 Z submersible temperature data loggers (max width of 44.4mm, height of 12.2mm, 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).

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 2014, 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, Okanagan smolt traps, 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. 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 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 and 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 (Sunday to Saturday) 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 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[2]. 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

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

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 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. 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). Methods for DNA extraction, DNA amplification, microfluidics, and genotyping of SNP assays are

available at (https://www.monitoringmethods.org/Protocol/Details/230). 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*). Sockeye salmon GSI analyses utilized the baseline described in Hess et al. (2013), and has previously been shown to accurately discriminate among the three major stocks in 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 Assigning individual samples using Individual Assignment (IA) genetic methods v1.0 (ID: 1334) (Published). We also used GSIsim for "Mixture modeling to estimate stock proportions v1.0" (ID: 1333).

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, as in 2013, in 2014 we did GSI only on Sockeye classified as unknown by PIT tags or those with unusual PIT tag detection histories.

Juvenile PIT Tagging

Rotary Screw Trap (RST) Operation at Skaha Lake Outlet

Two rotary screw traps (RST) with a cone size of 2.4 m in diameter at the opening were used to sample out-migrating Sockeye smolts during the spring of 2014. The traps were located in the Okanagan River in Canada at the outlet of Skaha Lake. As in previous years, an index RST was installed near the west bank of the river. In order to increase capture efficiency, a second RST was installed in the thalweg of the river, immediately adjacent to the index RST (Figure 2). The traps were held in place with 1.27 cm aircraft cable strung across the river and secured to a tree and a metal eyelet drilled into the bedrock. Warning signs were installed upstream to alert the public of the RST's presence.

Figure 2. Rotary screw traps used to trap juvenile sockeye salmon located downstream of Skaha Dam in 2014.

Both RSTs were installed April 25, 2014. The cones were first lowered on March 17 and fished 24 hours for the first night. Cones were raised for five days, then lowered and fished for 24 hour periods every other day until April 8 when daily catches exceeded 10 smolts in either trap. The thalweg RST was demobilized on May 3 due to damage to the main axle. Both RSTs were equipped with a hub odometer in order to calculate a CPUE (catch per unit effort) with effort measured in linear distance of water sampled. The hub odometer stops recording when the cone stops turning (e.g. debris jam) and allows for more accurately estimating adjustments to CPUE in lieu of non-operational periods. Trap boxes were checked each morning that traps were operational. Fish in the trap boxes were identified, enumerated, and then released downstream. A sub-sample was collected for bio-sampling at the OAE aging lab. Beginning April 14, most live smolt captures were transferred to kitoi boxes downstream of the RSTs for Passive Integrated Transponder (PIT) tagging. The Index trap was demobilized for the season by May 6 because of a scheduled increase in flows from Skaha Lake Outlet Dam.

Smolt Trapping at Osoyoos Lake Narrows

The floating trawl net with attached fyke nets was set at the Osoyoos Lake Narrows directly downstream of the Highway 3 Bridge in Osoyoos, using the bridge pilings as anchor points (Figures 3 and 4). The fyke net configuration consisted of a 28 m long beach seine, 4 m wide in the middle and tapering to 0.7 m on each end. The net panels were composed of 0.5 cm, 1 cm, and 2 cm stretched mesh. The central panel was made with the smallest mesh and progressed to larger mesh towards each end. A 2 m x 2 m floating trawl net was attached to the central panel and tapered down to a 10 cm diameter cod end. The trawl net was 5.5 m in length and was constructed of progressively smaller mesh sizes (4 cm, 2 cm, 1 cm, 0.5 cm) toward the cod end. The trawl net funneled into a 0.6 m x 0.35 m x 0.3 m aluminum trap box (Figure 3). The fyke net set-up was similar to previous year's studies (Appendix B).

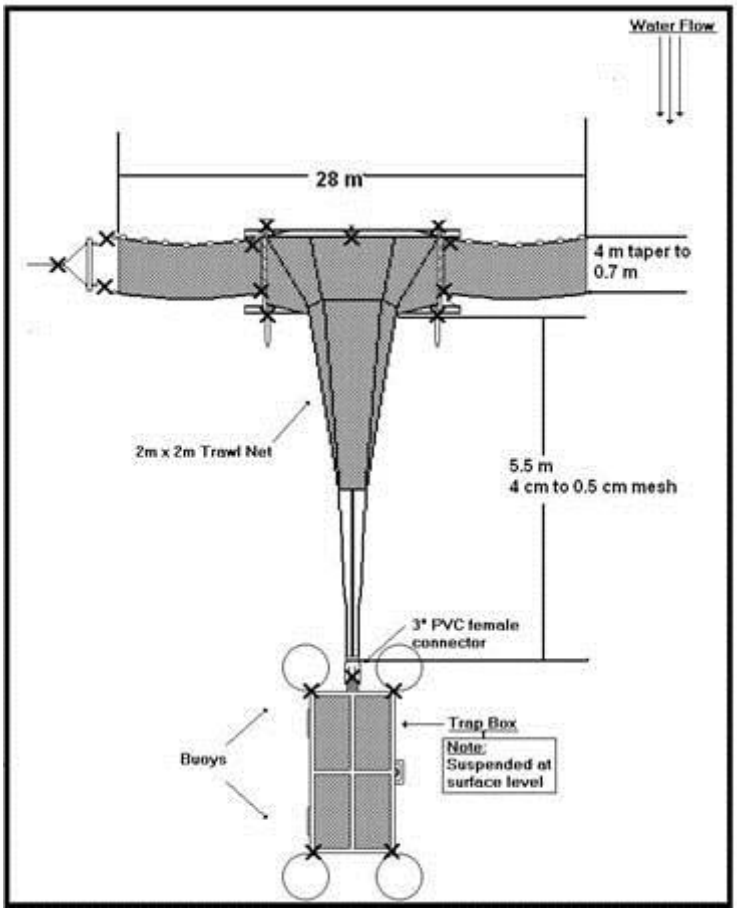

Figure 3. Schematic diagram of the fyke net used to trap sockeye located immediately downstream of the Highway 3 bridge in Osoyoos in 2015.

Figure 4. Fyke net used to trap juvenile sockeye salmon downstream of the Highway 3 bridge in Osoyoos.

Sampling was conducted every two to seven nights (with sampling frequency increased to every other night during peak migration) from April 2 to June 4, 2014, for a total of 27 sampling nights. The fyke net was typically deployed from 1900 to 2000 and checked once every hour. Smolts were enumerated and released directly downstream of the fyke net. A small sub-sample was collected for bio-sampling, and on certain nights a number of smolts were held in kitoi boxes for PIT tagging. The net was removed at 0200 each night.

Procedures developed by PTAGIS (2014) 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 1395 Sockeye, 31 steelhead, 26 Chinook, and 4 coho were detected passing Zosel Dam fish ladders (Table 1, Figure 5)[3]. Unlike the previous years since Zosel Dam fishway PIT tag detection installation in 2010, low flows meant spill gates were not opened sufficiently to allow summer migrating adults from migrating past Zosel Dam through the spillways undetected. Based on upstream detections of 291 Sockeye, 2 (or 0.7%) passed Zosel Dam undetected. Over 81% of sockeye detected passed between July 21 and July 29, 2015 when mean daily water temperatures dipped to a low of 22.2°C (Figure 6). Salmon tagged by CRITFC adult tagging projects (adult Wells Sockeye and adult Bonneville Sockeye, Chinook, and steelhead tagging) comprised 80.0% of PIT tagged fish detected at Zosel Dam (Table 1).

A total of 291 Sockeye, 10 steelhead and one sockeye were detected at the OKC PIT tag array between January 1, 2014 and December 31, 2014 (Table 2, Figure 7). The majority of Sockeye detected were either during a dip in water temperatures between July 21 and 26, 2014 or after Okanagan River temperatures dropped below 18°C after September 10, 2014 (Figure 8). No Sockeye were detected both in July 2014 and again in September or October 2014.

No Sockeye with PIT tags beginning with 3DD were detected at OKC until October 22, 2014 due to a software coding error. This was corrected as part of a site visit on November 14, 2014 at which time new software was installed. Tags still stored in the site's buffer at that time, which happened to include tags since October 22, were recovered as part of this site visit.

[3] While writing this report, gaps were noted in Zosel data uploaded to ptagis.org. Brett Turley of Biomark investigated and found technical problems had prevented upload of data from July 1 through July 6, 2014 and part of July 24-26 and uploaded data from 94 tagged fish passing Zosel Dam during these periods on October 30, 2015.

Table 1. Number of PIT Tagged Chinook, steelhead, and Sockeye detected at Zosel Dam ladders between January 1, 2014 and December 31, 2014 by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Coho	Steelhead	Sockeye	Total
Below Bonneville Dam	Adult	6	0	0	139	141
Bonneville Dam	Adult	10	0	1	648	636
Priest Rapids Dam	Adult	0	0	20	0	20
Wells Dam	Adult	3	0	3	506	487
Okanagan basin-Canada	Juvenile	0	0	0	41	39
Chelan Falls-Chief Joseph and tribs excluding Wells Dam	Juvenile	5	4	6	0	15
Rock Island Dam	Juvenile	1	0	1	61	59
Snake Basin	Juvenile	1	0	0	41	1
Total		**26**	**4**	**31**	**1395**	**1456**

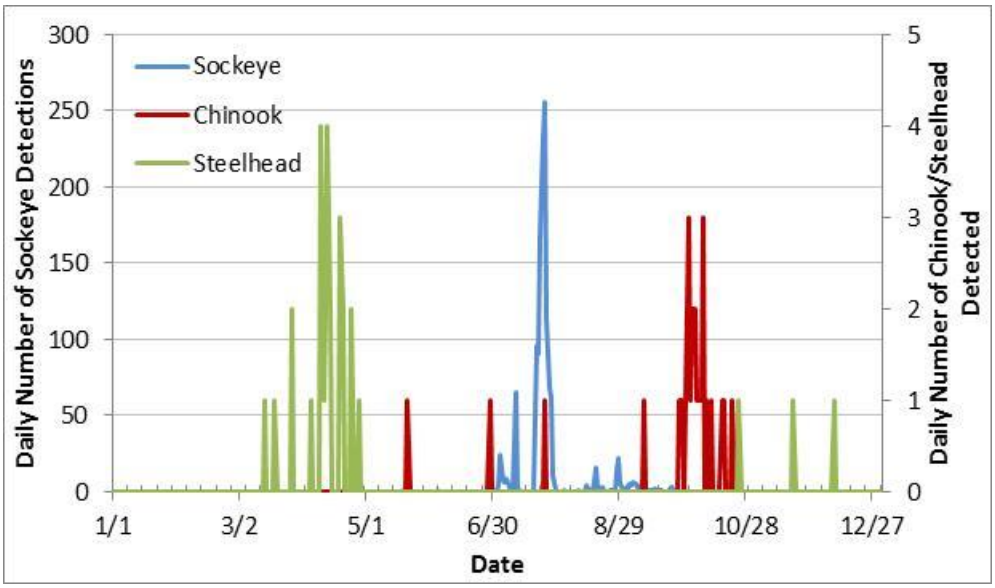

Figure 5. Number of PIT tagged Sockeye and Chinook Salmon and steelhead detected passing Zosel Dam fishways by date in 2014.

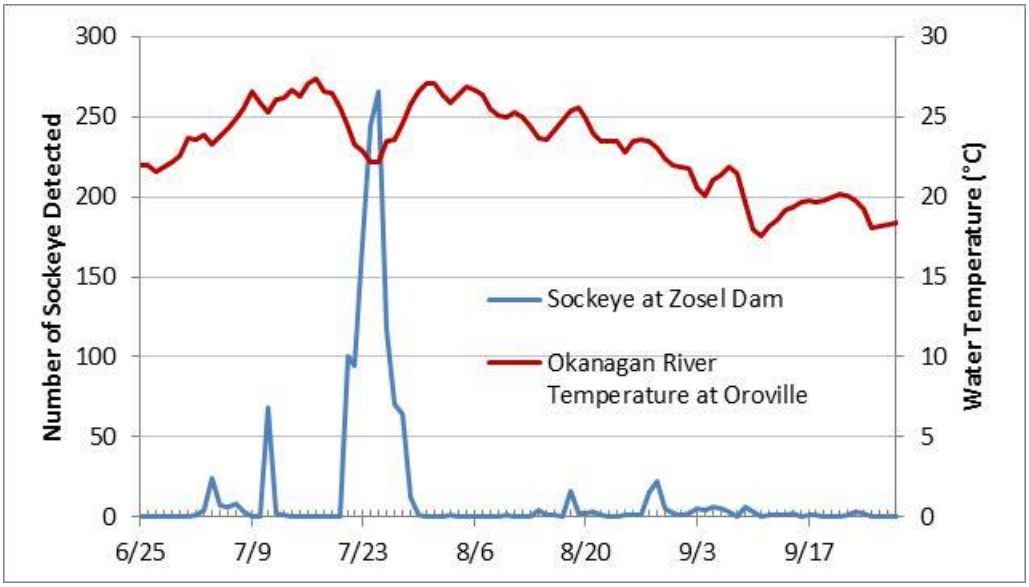

Figure 6. Number of PIT tagged Sockeye Salmon detected by date and mean daily temperature at Zosel Dam during Sockeye migration in 2014.

Table 2. Number of PIT Tagged Chinook, steelhead, and Sockeye Salmon detected at the Okanagan Channel (OKC) PIT tag array between January 1, 2014 and December 31, 2014 by release site and life stage at time of tagging. (Note that PIT tags beginning with 3DD, which included most of the tags deployed at both Bonneville and Wells Dam, were not detected prior to October 22, 2014).

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye	Total
Below Bonneville Dam	Adult	0	1	56	57
Bonneville Dam	Adult	1	0	104	106
Priest Rapids Dam	Adult	0	5	0	5
Wells Dam	Adult	0	3	80	83
Okanagan basin-Canada	Juvenile	0	0	14	14
Wells-Canadian Border	Juvenile	0	1	0	1
Rock Island Dam	Juvenile	0	0	37	37
Total		**1**	**10**	**291**	**302**

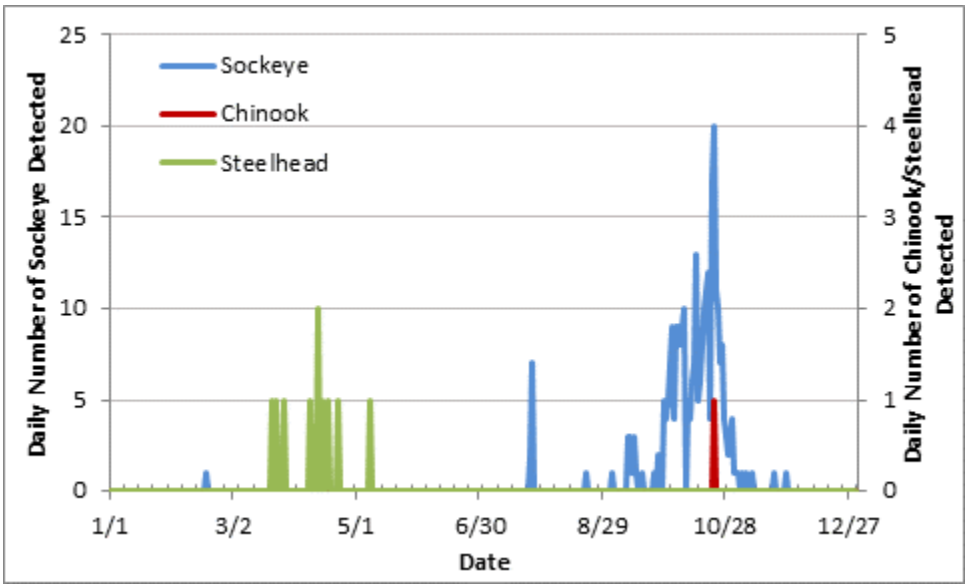

Figure 7. Number of PIT tagged Sockeye and Chinook Salmon and steelhead detected at the Okanagan Channel PIT tag array by date in 2014.

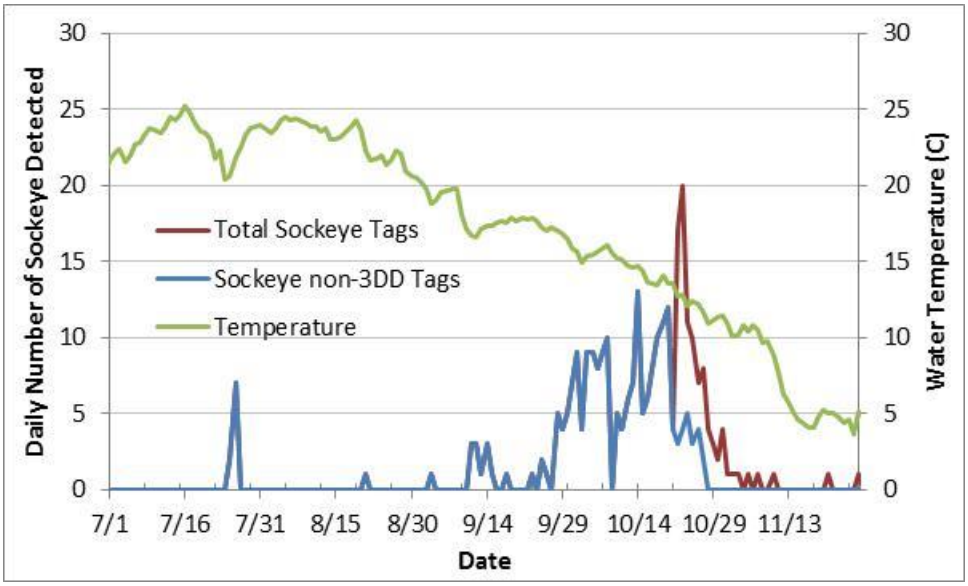

Figure 8. Number of PIT tagged Sockeye Salmon detected passing the Okanagan Channel PIT tag array (OKC) by date in 2014 compared with Okanagan River water temperatures recorded immediately upstream of OKC[4].

[4] Due to a software coding error, no PIT tags beginning with 3DD were detected prior to October 22, 2014.

Okanagan Acoustic Tag Network Installation and Monitoring

A total of 21 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 9). 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 2014. See Figure 9 for the map for this table.

Map No.	Location Name	rkm	Latitude	Longitude	Date Deployed	Date Retrieved
1	Pateros Dock (Columbia River)	843	48.054	-119.897	6/26/2014	10/10/2014
2	Brewster Bridge Dock W (Columbia River)	**853**	48.090	-119.778	6/26/2014	10/10/2014
3	Brewster Dock SE (Columbia River)	861	48.081	-119.714	6/26/2014	10/10/2014
4	Monse Bridge, west	8	48.140	-119.674	6/26/2014	10/10/2014
5	Monse Bridge, east	8	48.140	-119.673	6/26/2014	10/10/2014
6	Weir Downstream	25	48.269	-119.729	7/21/2014	10/10/2014
7	Weir Upstream Left Bank	25	48.268	-119.726	7/21/2014	10/10/2014
8	Weir Upstream Right Bank	25	48.272	-119.726	7/21/2014	10/10/2014
9	Driscoll Pool	10	48.919	-119.433	6/26/2014	10/20/2014
10	Similkameen Canyon	11	48.949	-119.465	6/26/2014	10/15/2014
11	Pump Intake, east bank	124	48.946	-119.432	6/26/2014	10/15/2014
12	Pump Intake, west bank	124	48.946	-119.432	6/26/2014	10/15/2014
13	South Basin Haynes Campground (Point West)	132	49.018	-119.443	6/27/2014	12/1/2014
14	Haynes Point Nav Buoy	132	49.021	-119.438	6/27/2014	12/1/2014
15	North Basin EC Buoy (Ink Creek)	140	49.069	-119.502	6/27/2014	12/1/2014
16	OKR Mouth East	141	49.079	-119.521	6/27/2014	12/1/2014
17	OKR Mouth West	141	49.079	-119.522	6/27/2014	12/1/2014
18	OKR Hwy 97 Bridge	162	49.230	-119.542	6/27/2014	12/1/2014
19	McIntyre Dam	165	49.257	-119.528	6/30/2014	12/1/2014
20	Skaha Dam downstream	175	49.342	-119.580	6/30/2014	12/1/2014
21	Skaha Lake	176	49.345	-119.580	6/30/2014	12/1/2014

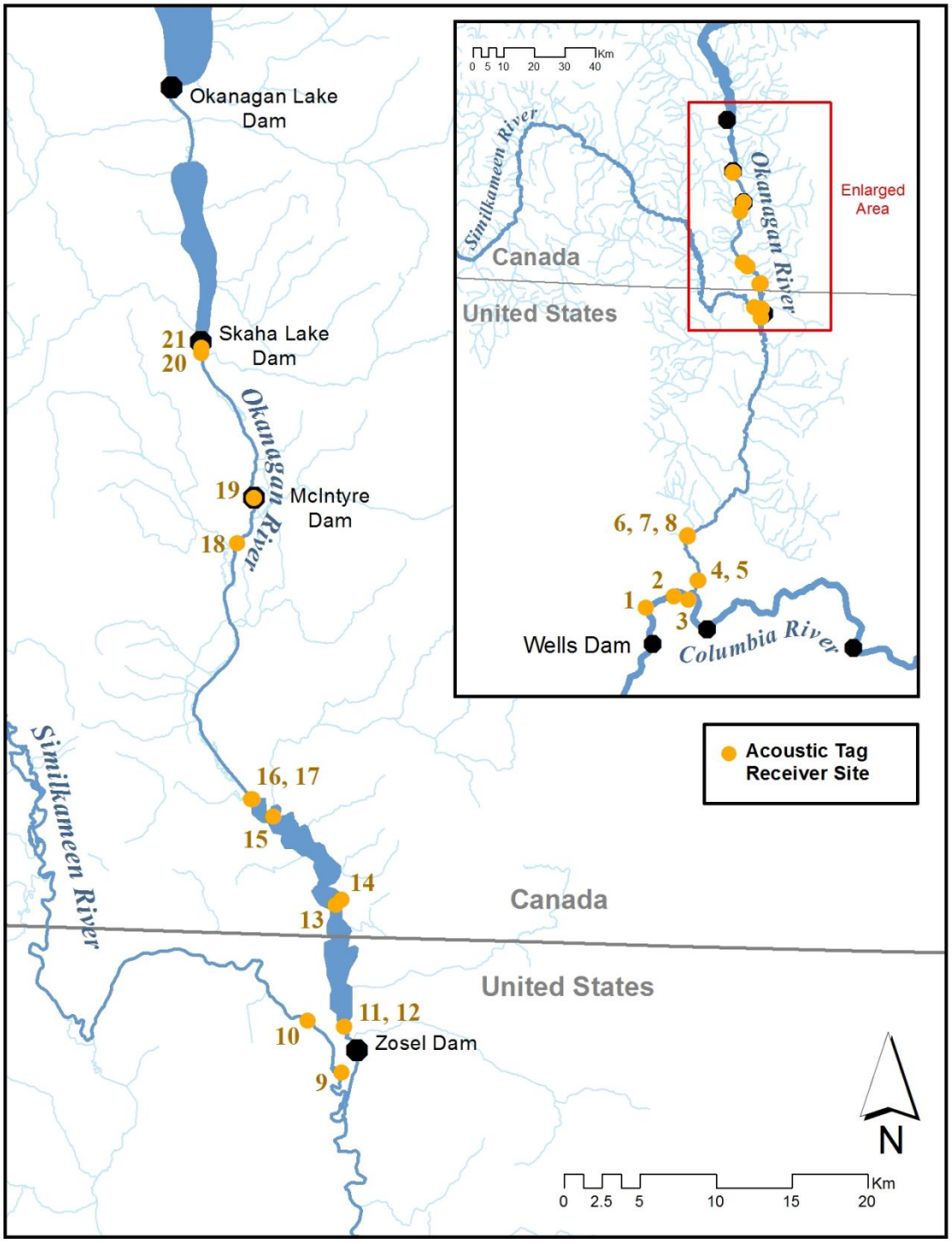

Figure 9. Okanagan Basin acoustic receiver sites in 2014. Location numbers reference sites listed in Table 3.

Upstream Migration Analysis

Mixed Stock Sample Size and Age Composition

In 2014 a total of 1420 Sockeye Salmon were sampled for this project at the Bonneville Dam Adult Fish Facility between May 16 and August 7, 2014 (Table 4). Of these, two were not tagged or the tags were unreadable, and four died prior to release. Four Sockeye were previously tagged and added to the 1410 Sockeye tagged and released.

Table 4. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2014.

Sampling Dates	Statistical Week[5]	Sampled (n)	Tagged	Mortalities	Previously Tagged	Detected after tagging and tracked
5/16,29,6/2,4-6	21-23	16	16	0	0	15
6/9-6/13	24	110	110	0	0	110
6/16-6/20	25	269	268	0	0	268
6/23-6/27	26	300	299	0	0	296
6/30,7/1-3	27	230	229	0	0	228
7/7-7/11	28	259	256	0	1	255
7/14-7/18	29	146	146	2	0	141
7/21-25	30	59	59	0	0	58
7/28-31, 8/1	31	22	22	1	2	21
8/5-7	32	9	9	1	1	8
Total		**1420**	**1414**	**4**	**4**	**1400**

Of these 1414 Sockeye included in this study, 14 were not detected after release. These fish may have shed their tags, had defective tags, or died. It is also possible that these 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 on the Washington shore ladder or three antennas on the Oregon shore ladder 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 2006-2014 indicate that PIT tagged Sockeye Salmon are missed, although the percentage is normally low (Table 5) with the exception of Rock

[5] Statistical weeks are sequentially numbered calendar-year weeks. Excepting the first and last week of most years, statistical weeks are seven days long beginning on Sunday and ending on Saturday. In 2014, for instance, Statistical Week 24 began on June 8 and ended on June 14.

Island Dam as noted in previous years. The percentage missed at Ice Harbor Dam was 12.5% but this is based on only eight Sockeye.

Table 5. Number and percentage of PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2014 compared to 2006-2013.

Dam	2014	2013	2012	2011	2010	2009	2008	2007	2006
Bonneville	0.7%	0.4%	1.8%	0.5%	0.7%	0.6%	0.4%	2.1%	0.2%
The Dalles	0.3%	1.6%	--	--	--	--	--	--	--
McNary	3.8%	2.1%	12.1%	1.6%	3.8%	5.0%	10.1%	6.5%	3.1%
Priest Rapids	0.2%	0.0%	0.4%	0.2%	0.6%	0.3%	0.3%	0.8%	0.0%
Rock Island	41.5%	4.4%	5.4%	4.4%	6.2%	2.6%	6.9%	6.8%	1.3%
Rocky Reach	0.3%	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%	0.0%	--	--	--	--
Ice Harbor	12.5%	NA	0.0%	--	0.0%	20.0%	0.0%	--	--
Lower Granite	0.0%	--	--	--	--	--	--	--	--
Tumwater	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	--	--	--

The predominant age group was Age 1.2, followed by Age 1.1 and 1.3 (Table 6). The percentage of 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 2014.

Statistical Week	N Ageable	Age Class				
		1.1	1.2	2.1	1.3	2.2
23	14	0.0%	85.7%	0.0%	14.3%	0.0%
24	107	4.7%	93.5%	0.0%	1.9%	0.0%
25	265	4.2%	91.7%	0.0%	2.3%	1.9%
26	295	10.2%	89.5%	0.0%	0.0%	0.3%
27	225	14.2%	84.0%	0.0%	0.4%	1.3%
28	255	23.5%	75.7%	0.4%	0.4%	0.0%
29	144	27.1%	72.2%	0.0%	0.7%	0.0%
30	58	25.9%	74.1%	0.0%	0.0%	0.0%
31	31	38.7%	58.1%	0.0%	3.2%	0.0%
Composite	**1394**	**14.2%**	**84.4%**	**0.1%**	**0.6%**	**0.7%**
Std. Dev.		**1.0%**	**1.1%**	**0.1%**	**0.2%**	**0.4%**

Upstream Recoveries, Mortality, and Escapement:

Based on PIT tag detections, an estimated 88.3% of Sockeye Salmon passing Bonneville Dam also passed McNary Dam (Figure 10). The Dalles Dam and McNary dams estimated by PIT tags deployed by this project were within 2.5% of visual counts at The Dalles (Table 7). However, at dams upstream of Priest Rapids Dam, PIT tag estimates of escapement were between 8.2% and 19.7% less than visual dam counts. We did estimate higher escapements than visual counts at Ice Harbor and Lower

Granite dams but sample sizes (seven and six PIT tagged Sockeye respectively) were very small.

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 2014.

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using Bonneville PIT Tagged Sockeye	Visual Dam Count	Difference Between Bonneville PIT Tag and Visual Estimate
Bonneville	--	614,179	614,179	--
The Dalles	93.1%	571,731	586,188	-2.5%
McNary	88.3%	542,199	546,012	-0.7%
Priest Rapids[6]	84.5%	519,258	608,142	-14.6%
Rock Island	79.5%	488,025	581,121	-16.0%
Rocky Reach	65.3%	401,259	492,892	-18.6%
Wells	64.2%	394,000	490,804	-19.7%
Zosel	48.6%	298,582	325,277	-8.2%
Tumwater	13.6%	83,564	99,899	-16.4%
Ice Harbor	0.7%	4,479	2,392	87.3%
Lower Granite	0.6%	3,571	2,786	28.2%

[6] Eleven tagged Sockeye were 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 trapped downstream of the fish ladder so would not be expected to be included in Priest Dam visual counts.

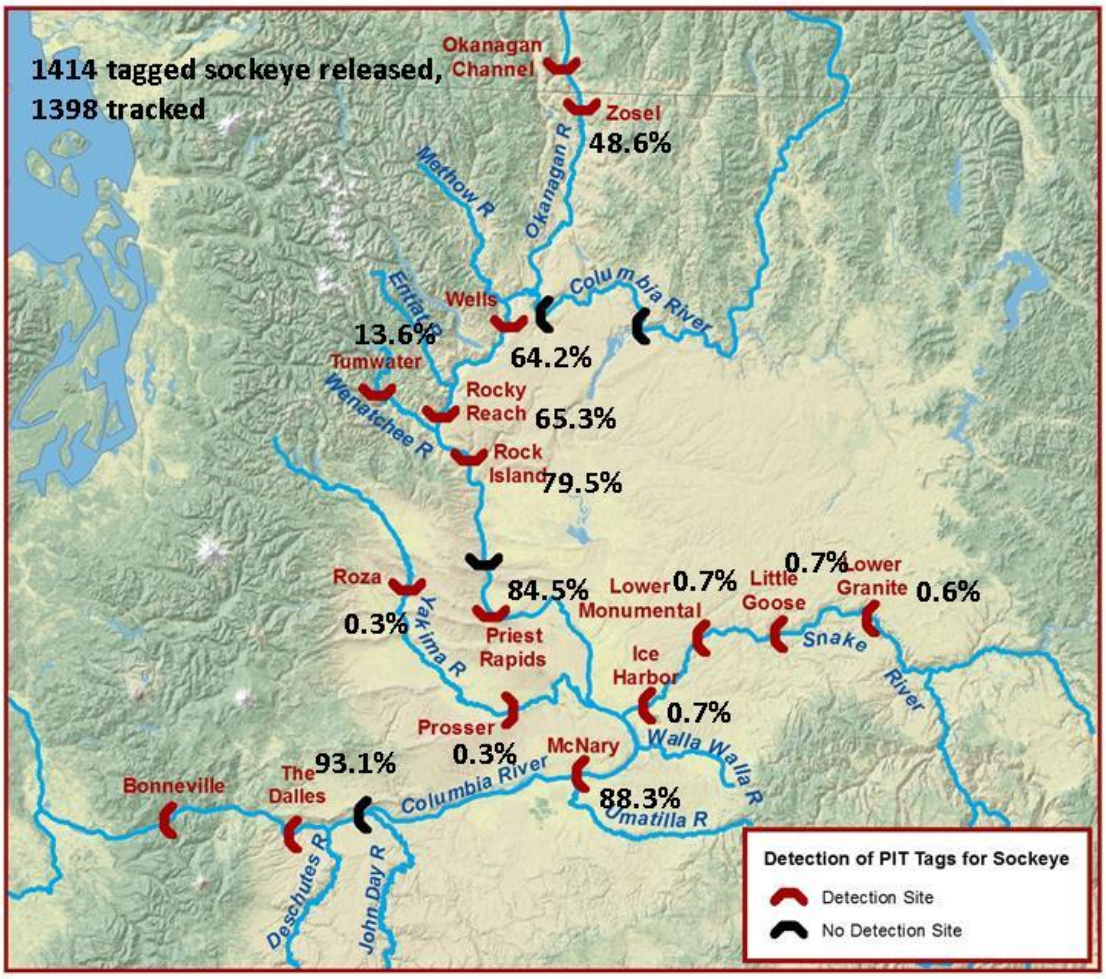

Figure 10. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2014.

As in most years of this study, and also true in 2014 survival from Bonneville to McNary, Priest Rapids, and Rock Island dams showed a significant linear decrease with week sampled and tagged at Bonneville Dam (Table 8, Figure 11). There was also a significant linear decrease for survival to The Dalles but survival from Rocky Reach to Wells dam was not significantly related to statistical week tagged at Bonneville Dam. The percentage of Age 1.1 Sockeye surviving to Rock Island Dam (81.3%) was greater than that for Age 1.2 (79.5%) Sockeye Salmon (Figure 12).

Table 8. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2014 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[7]	Bonneville-Rock Island	Rocky Reach-Wells
23	100.0%	87.5%	81.3%	81.3%	100.0%
24	95.5%	94.5%	92.7%	91.8%	98.8%
25	92.9%	90.3%	89.2%	82.5%	97.7%
26	95.6%	91.2%	87.8%	82.4%	98.4%
27	92.5%	89.4%	85.0%	79.7%	98.7%
28	95.7%	89.8%	86.7%	82.7%	97.3%
29	79.1%	64.7%	55.4%	51.1%	98.5%
30	75.9%	58.6%	55.2%	46.6%	96.0%
Composite	**93.1%**	**88.3%**	**84.5%**	**79.5%**	**98.2%**
P-value	**0.016**	**0.057**	**0.009**	**0.004**	**0.446**

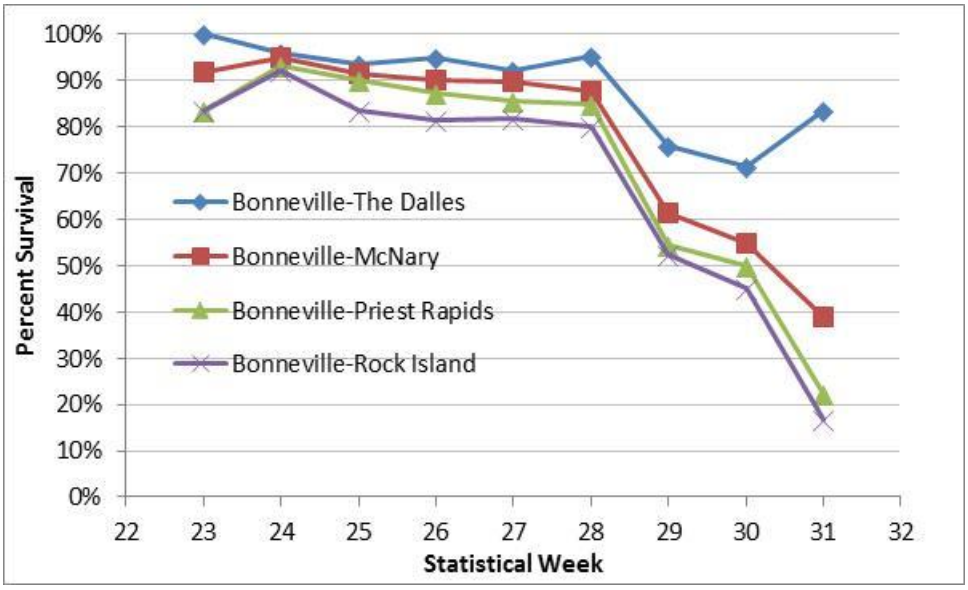

Figure 11. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2014.

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

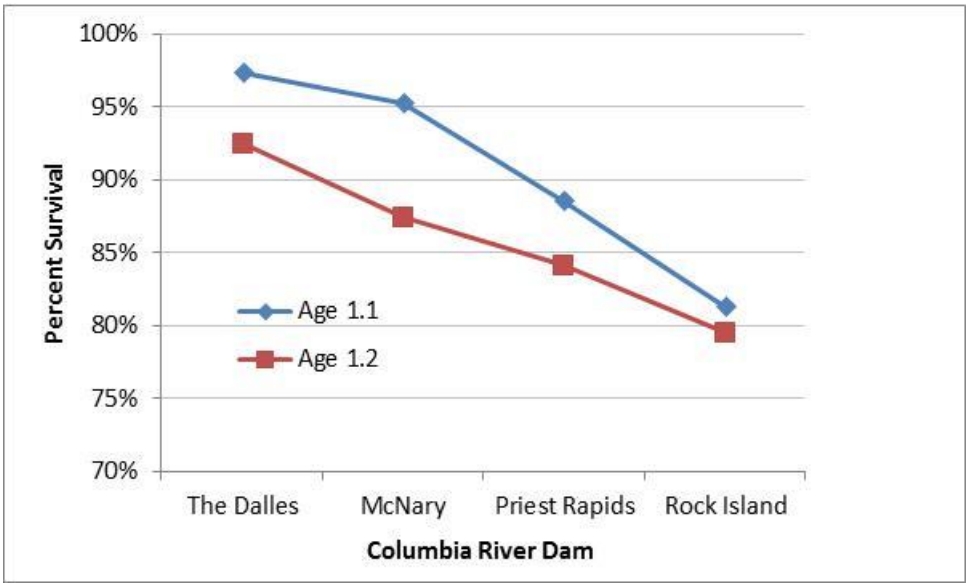

Figure 12. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams age group in 2014.

Migration Rates and Passage Time

Adult Sockeye Salmon travel quickly upstream with a median migration rates between mainstem dams ranging between 28.5 and 53.7 km/day for Sockeye tagged at Bonneville Dam (Table 9). Returning adults tagged as smolts generally have comparable migration rates, with their median migration rate from Bonneville to Rock Island Dam being 0.5 km per day greater than Sockeye tagged as adults (Table 9).

Table 9. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2014.

		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	1.8	41.6	1.7	43.7
The Dalles-McNary	162	3.0	53.7	3.1	51.6
McNary-Priest Rapids	167	3.8	44.0	3.8	44.4
Priest Rapids-Rock Island	89	3.1	28.5	3.1	28.3
Rock Island-Rocky Reach	33	1.0	31.6	0.9	35.3
Rocky Reach-Wells	65	1.8	36.1	1.7	39.3
Rock Island-Tumwater	73	9.4	7.8	10.2	7.2
Bonneville-McNary	231	4.8	47.7	4.9	47.1
Bonneville-Rock Island	487	12.2	40.0	12.0	40.5
Bonneville-Tumwater	560	22.9	24.4	22.2	25.2
Bonneville-Wells	585	14.9	39.4	14.0	41.7

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 Dam to all upstream dams in Table 10 except for Rock Island Dam where the low PIT tag detection rate likely resulted in a high travel time for those Sockeye tagged in week 31. The median difference in travel time from Bonneville Dam to all upstream mainstem dams except Rocky Reach Dam (where only four Sockeye classified as Wenatchee stock were detected) was one day or less between the two major stocks (Table 10). Age 1.1 Sockeye salmon traveled fastest upstream, followed by Age 1.2 and 1.3 Sockeye salmon.

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 2014.

Statistical Week at Bonneville Dam	BON-TDA	BON-MCN	BON-PRA	BON-RIA	BON-TUM	BON-RRH	BON-WEL	BON-ZSL	WEL-ZSL	RIA-TUF
23	2.0	6.7	12.6	19.2	39.7	20.2	22.7	44.8	20.9	NA
24	1.9	5.7	10.8	14.6	31.8	16.9	19.3	40.7	21.4	13.9
25	1.9	5.0	9.5	13.1	24.9	14.7	16.7	34.5	16.8	10.3
26	1.9	4.8	8.8	12.1	21.0	12.9	14.7	28.6	13.5	9.0
27	1.8	4.8	8.1	10.9	18.1	11.9	13.8	22.8	8.1	6.7
28	1.4	4.5	7.8	10.8	20.0	11.7	13.6	17.5	4.1	7.6
29	1.6	4.3	8.0	11.2	18.9	12.1	13.8	41.8	27.7	6.7
30	1.7	4.9	8.9	11.5	25.0	12.1	13.8	36.7	23.7	NA
31	1.4	4.9	8.9	19.9	NA	13.2	15.1	NA	NA	NA
P-value	**0.01**	**0.03**	**0.03**	**0.70**	**0.04**	**0.01**	**0.01**	**0.24**	**0.64**	**0.07**
Stock										
Okanagan	1.8	4.8	8.7	12.9	NA!	12.9	14.9	25.9	11.1	NA
Wenatchee	1.8	5.0	9.2	13.9	22.9	14.9	14.9	NA	NA	9.4
Unknown[8]	1.8	4.8	9.0	13.0	NA	20.8	23.1	NA	NA	NA
Age										
1.1	1.8	4.8	8.5	10.9	20.0	12.5	14.0	23.1	8.0	NA
1.2	1.8	4.9	8.8	13.2	22.6	13.0	15.0	27.0	11.7	9.1
1.3	2.2	6.0	11.0	15.2	28.6	17.1	19.9	31.5	13.3	10.1

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 smolts was generally under five minutes (Table 11). Exceptions were at dams with adult trapping which may delay upstream migration (Bonneville, Priest Rapids, Wells, Tumwater, and Lower Granite dams) and dams with PIT tag antennas distributed through a higher proportion of the length of the fish ladder (e.g. Bonneville, McNary, Priest Rapids, and Wells dams). For example, 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

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

dams and thus a more complete record of passage times in the ladders. Even with the tendency of sockeye salmon to use the unmonitored overflow orifices, they often hit at least one PIT tag monitored underwater orifice on their passage through fish ladders. Median passage time for Sockeye tagged as juveniles was generally similar to those tagged as part of this project. Exceptions were Bonneville Dam, where it is possible that impacts of our tagging delayed passage and the Snake River where sample sizes of adults tagged at Bonneville Dam were very small.

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 2014.

	Adults Tagged at Bonneville Dam		Previously Tagged as Juveniles	
Dam	Median Passage (Minutes)	%>12 Hours	Median Passage (Minutes)	%>12 Hours
Bonneville	63.57	4.4%	15.02	4.3%
The Dalles	0.10	2.2%	0.12	7.4%
McNary	0.13	0.8%	0.13	0.2%
Priest Rapids	7.10	3.6%	6.95	1.6%
Rock Island	2.10	0.6%	2.17	1.2%
Rocky Reach	4.67	1.6%	4.72	0.0%
Wells	11.19	3.9%	7.83	3.6%
Zosel	0.6	2.7%	0.40	1.2%
Tumwater	6.05	6.3%	6.53	8.1%
Ice Harbor	4.72	0.0%	5.15	9.1%
Lower Monumental	0.25	0.0%	0.19	12.3%
Little Goose	0.05	14.3%	90.58	8.8%
Lower Granite	69.31	33.3%	94.27	28.6%

Night Passage

Okanagan Sockeye Salmon stock tagged at Bonneville Dam passed PIT tag antennas at night (2000-0400 hours) at a higher rate than Wenatchee Sockeye Salmon stock at 8 out of 10 sites where Sockeye from both stocks were detected (Table 12). Okanagan stock Sockeye Salmon had among the highest night passage rates in natal areas (9.5% at Wells Dam, 23.5% at Zosel Dam, and 19.2% at the Okanagan Channel (OKC)). The Bonneville Dam Washington shore estimate of night passage is likely biased low because tagging occurred between about 0800 and 1300 hours, and with a median passage time of 64 minutes from tagging to final detection at Bonneville Dam (Table 12), fish would be expected to pass the counting window prior to 2000 hours.

Table 12. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2014.

Dam	Adults Tagged at Bonneville Dam				Sockeye Tagged as Juveniles
	Okanagan Stock	Wenatchee Stock	Unknown	All Adults	
Bonneville-OR shore	11.8%	0.0%	0.0%	8.0%	4.6%
Bonneville-WA shore	0.3%	0.0%	1.0%	0.4%	2.4%
The Dalles-OR shore	9.8%	2.3%	9.5%	8.7%	7.3%
The Dalles, WA shore	3.5%	0.0%	13.3%	6.1%	4.9%
McNary-OR shore	4.0%	7.0%	5.8%	4.5%	5.8%
McNary-WA shore	7.1%	7.3%	10.3%	7.5%	8.6%
Priest Rapids	4.1%	1.1%	1.5%	3.4%	1.6%
Rock Island	3.4%	0.0%	0.0%	2.9%	9.9%
Rocky Reach	4.4%	0.0%	0.0%	4.4%	2.8%
Wells	9.5%	0.0%	0.0%	9.5%	6.7%
Tumwater	NA	3.4%	NA	3.4%	4.3%
Zosel	23.5%	NA	NA	23.5%	24.7%
Okanagan Channel	19.2%	NA	NA	19.2%	33.3%

Fallback

Fallback rates for adults tagged at Bonneville Dam ranged from 0.0% at Ice Harbor and Lower Monumental dams to 16.7% at Lower Granite Dam (Table 13). Fallback rates of Sockeye tagged as juveniles were generally higher than those tagged as adults, reaching a high of 32.7% at Lower Granite Dam. Fallback rates for all four Snake River dams were greater than 12% for Sockeye tagged as juveniles. Of the 346 returning Sockeye, 154 (44.5%) fell back at least once, with two falling back 10 times (Table 14). The mean number of fallbacks per Sockeye Salmon for Snake River Sockeye was 1.05 compared to 0.09 to 0.12 for the other juvenile groups and 0.12 for Sockeye in our Bonneville study.

Table 13. Estimated fallback rates for Sockeye Salmon at dams in 2014[9].

Dam	Adults Tagged at Bonneville	Tagged as Juveniles
Bonneville	1.4%	15.0%
The Dalles	3.9%	19.1%
McNary	0.7%	0.6%
Priest Rapids	3.6%	2.6%
Rock Island	0.6%	3.7%
Rocky Reach	1.7%	5.6%
Wells	1.7%	3.6%
Tumwater	0.0%	0.0%
Zosel	2.7%	6.6%
Ice Harbor	0.0%	12.3%
Lower Monumental	0.0%	17.1%
Little Goose	14.3%	15.1%
Lower Granite	16.7%	32.7%

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

Table 14. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2014.

	Sockeye Tagged as Juveniles by Tagging Location				Adults Tagged
Fallback Events	**Okanagan**	**Rock Island**	**Snake**	**Wenatchee**	**at Bonneville**
1	7	12	73	3	109
2	0	1	32	1	15
3	0	0	15	1	4
4	0	0	16	0	1
5	0	0	5	0	0
6	0	0	5	0	0
7	0	0	6	0	0
10	0	0	2	0	1
Number of Sockeye falling back at least once	7	13	154	5	130
% of Sockeye with at least one fallback event	10.4%	8.4%	44.5%	5.7%	9.3%
Total fallback events	7	14	363	8	165
Number of Sockeye in study	67	155	346	87	1400
Fallbacks events per Sockeye	0.10	0.09	1.05	0.09	0.12

Stock Composition Estimates

The percentage of the run that was comprised of the Wenatchee Sockeye Salmon stock was highest during the middle of the run at Bonneville Dam when compared to the beginning and end of the run (Table 15). The overall stock composition estimate at Bonneville Dam was 17.5% Wenatchee, 81.1% Okanagan, 1.0% Snake River, and 0.4% Yakima. Removing the Snake River and Yakima components results in an estimate above Priest Rapids Dam of 82.3% Okanagan and 17.7% Wenatchee which is within 2.5 percentage points of estimates derived from visual counts (Table 15).

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). Among the seven Sockeye detected at Ice Harbor Dam, one (PIT Tag code 3DD.00773AB80D) passed upstream of Priest Rapids Dam before falling back over Priest Rapids and turning up the Snake River. This is the first time that this study has observed this behavior but our Snake River Sockeye Salmon sample size is always very small.

Table 15. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags in 2014 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	Percent Okanagan	Percent Wenatchee	% Snake	% Yakima[10]
23 (May 16-June 6)	1,528	16	92.3%	7.7%	0.0%	0.0%
24 (June 9-13)	17,986	110	85.0%	15.0%	0.0%	0.0%
25 (June 16-20)	67,754	269	79.2%	20.4%	0.0%	0.5%
26 (June 23-27)	181,833	300	77.2%	22.0%	0.8%	0.0%
27 (June 30-July 3)	189,166	230	80.5%	17.3%	1.6%	0.5%
28 (July 7-11)	110,316	259	86.3%	12.7%	0.5%	0.5%
29 (July 14-18)	33,124	146	87.7%	9.6%	1.4%	1.4%
30 (July 21-25)	9,465	59	88.9%	11.1%	0.0%	0.0%
31 (July 28-Aug 1)	2,123	31	83.3%	0.0%	16.7%	0.0%
Composite	**613,295**	**1,420**	**81.1%**	**17.5%**	**1.0%**	**0.4%**
Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach counts to estimate proportion Wenatchee)			84.8%	15.2%		
Visual Fish Counts at dams (Tumwater count to estimate the proportion Wenatchee)			82.2%	17.2%		

A total of 10 Sockeye Salmon PIT tagged at Bonneville Dam were adipose clipped[11] with with an additional four Sockeye Salmon maxillary clipped (Table 16). Of these Sockeye, six were last detected in the Wenatchee Basin, three in the Okanagan Basin, two in the Snake Basin, two at McNary Dam, and one at Priest Rapids Dam.

Table 16. Last detection site of clipped Sockeye Salmon tagged at Bonneville Dam in 2014.

Last Detection Site	Left Ventral Clip	Right Maxillary Clip	Adipose Clip
McNary Dam	1	0	1
Priest Rapids Dam	0	0	1
Upper Wenatchee River (UWE)	0	0	4
Wenatchee spawning grounds (WTL)	0	0	2
Zosel Dam	1	1	0
Okanagan spawning grounds (OKC)	0	1	0
Lower Granite Dam	0	0	1
Upper Salmon River (USE)	0	0	1
Total	**1**	**1**	**10**

[10] Excludes four sockeye that were transported from Priest Rapids Dam to Cle Elum Lake and were subsequently detected at Prosser or Roza dams.

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

Wells Dam Sampling

A total of 776 Sockeye were sampled at the Wells Dam west bank trap, of which 773 were PIT tagged with an additional 3 previously tagged fish added to our study group (Table 17). Of these 776 PIT tagged fish, 99 were also acoustic tagged and 58 were tagged with an external temperature tag. Two of the 58 temperature-tagged fish were harvested and the tags returned while sampling was still occurring, so we redeployed the tags to achieve a total of 60 temperature-tagged fish. All sampled fish were transported by truck and released approximately 4 km upstream of Wells Dam along the west shore of Lake Pateros (PTAGIS site WELSBR). Unlike previous years, in 2014 no adipose-clipped Sockeye salmon were sampled at Wells Dam.

Table 17. Number of Sockeye Salmon sampled and PIT and acoustic tagged at Wells Dam by date and statistical week in 2014.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	Acoustic Tagged	Temperature Tagged
6/30, 7/2	27	31	31	0	10	0
7/8-10	28	301	300	1	30	15
7/15-16	29	219	218	1	20	18
7/24	30	62	62	0	15	15
7/29-30	31	144	143	1	18	10
8/7	32	19	19	0	6	2
Total		**776**	**773**	**3**	**99**	**60**

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 Sockeye decreased (Table 18). A higher percentage of females were visually classified as being of Age 1.1 than were males.

Table 18. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2014. Sex was visually estimated when the fish were sampled.

					Age			
Stat Week	Sampling Dates	Run Size	N	N Ageable	1.1	1.2	1.3	2.2
27	6/30, 7/2	48,522	31	31	3.2%	93.5%	3.2%	0.0%
28	7/8-10	150,434	300	289	4.2%	91.3%	4.5%	0.0%
29	7/15-16	171,074	219	209	6.7%	91.9%	1.4%	0.0%
30	7/24	80,823	61	60	10.0%	81.7%	8.3%	0.0%
31	7/29-30	28,771	144	138	18.1%	79.0%	2.2%	0.7%
32	8/7	10,985	19	18	22.2%	77.8%	0.0%	0.0%
Composite		**490,609**	**774**	**745**	**7.1%**	**89.1%**	**3.7%**	**0.0%**
Std. Dev.					**1.0%**	**1.3%**	**0.8%**	**0.0%**
Males			404	391	5.0%	89.9%	5.1%	0.1%
Females			370	354	9.2%	88.1%	2.7%	0.0%

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 and subsequently detected in terminal areas (Table 19). The Wenatchee stock was estimated to be comprised almost entirely of Age 1.2 Sockeye (96.6%) with the remainder Age 1.3, 2.2 and 1.1. The Okanagan stock was 81.9% Age 1.2 with 17.5% Age 1.1 and the remaining 0.6% is comprised of Age 2.1, 1.3, and 2.2.

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 (Table 19). This same tendency has been noted for Wells Dam east ladder trapping in previous years (Fryer et al. 2014). In both ladders, this 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 19. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2014. Standard deviations are in parentheses.

Stock	Methodology	Ageable Sample Size	Brood Year and Age Class				
			2011	2010		2009	
			1.1	1.2	2.1	1.3	2.2
Bonneville Mixed	Bonneville Dam Sampling	1394	14.2 (1.0)	84.4 (1.1)	0.1 (0.1)	0.6 (0.2)	0.7 (0.3)
Wenatchee	Bonneville PIT tagged last detected in Wenatchee River	161	1.0 (1.0)	96.6 (1.4)	--	1.4 (0.6)	1.0 (p0.7)
Okanagan	Bonneville PIT tagged detected last detected at Rocky Reach or Wells or in the Okanagan River	859	17.5 (1.4)	81.9 (1.4)	0.1 (0.1)	0.1 (0.1)	0.4 (0.2)
	Wells Dam Sampling	774	7.1 (1.0)	89.1 (1.1)	--	3.7 (1.9)	0.0 (0.3)

Mean lengths estimated using Wells Dam measurements were generally greater than those estimated using Bonneville PIT tag data (Table 20). 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 the top edge of the sampling tank while at Wells Dam, 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 20. 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 dams in 2014.

Stock	Statistic	Brood Year and Age Class				
		2011	2010		2009	
		1.1	1.2	2.1	1.3	2.2
Bonneville Dam-Mixed Stock	Mean	40.1	48.2	42.5	55.8	49.6
	St. Dev.	1.5	2.3	--	3.0	2.6
	N	204	1166	1	14	9
Okanagan-Bonneville PIT tags	Mean	40.1	47.7	42.5	53.3	50.5
	St. Dev.	1.4	2.2	--	3.3	2.5
	N	140	722	1	3	4
Okanagan-Wells Sampling	Mean	41.1	50.0		54.6	52.0
	St. Dev.	2.0	2.4		2.7	--
	N	62	657		25	1
Snake River-Bonneville PIT tags	Mean	39.5	52.8			
	St. Dev.	--	1.5			
	N	1	7			
Wenatchee (Bonneville Tags)	Mean	40.0	49.1		57.4	47.8
	St. Dev.	--	2.0		1.9	0.4
	N	1	174		6	2
Yakima-Bonneville PIT tags	Mean		49.3			
	St. Dev.		1.8			
	N		7			

Detections in Natal Areas

Okanagan Stock

The estimated conversion rate from Wells Dam to Zosel Dam was 56.6% for Sockeye tagged at Wells Dam compared to 63.3% for Sockeye tagged at Bonneville Dam (Table 21). Of the Sockeye Salmon tagged at Wells Dam, 0.5% were last detected downstream of Wells Dam compared to none of the Sockeye tagged at Bonneville Dam which passed Wells Dam (Table 21).

Table 21. Number of tagged (PIT+floy, PIT+floy+acoustic) Sockeye released upstream of Wells Dam in 2014 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	Tumwater Dam	Entiat River	Wells Dam	Met-how River	OKL array	Zosel Dam	OKC	Not Detected
27	9.9%	31	0.0%	0.0%	0.0%	0.0%	6.5%	41.9%	22.6%	29.0%
28	30.7%	301	0.3%	0.0%	0.7%	0.0%	3.3%	60.8%	16.9%	17.9%
29	34.9%	219	0.0%	0.0%	0.5%	0.0%	5.5%	69.4%	5.9%	18.7%
30	16.5%	62	1.6%	0.0%	1.6%	0.0%	29.0%	38.7%	4.8%	24.2%
31	5.9%	144	0.0%	1.4%	1.4%	0.7%	13.2%	32.6%	3.5%	47.2%
32	2.3%	19	0.0%	0.0%	0.0%	0.0%	10.5%	42.1%	5.3%	42.1%
Weighted Total		**776**	**0.4%**	**0.1%**	**0.7%**	**0.0%**	**9.4%**	**56.2%**	**10.6%**	**22.6%**
Bonneville Tagged Sockeye Detected at Wells		**874**	**0.0%**	**0.0%**	**NA**	**0.0%**	**5.3%**	**63.3%**	**9.3%**	**22.0%**

An estimated 3.8% of Wells Dam tagged Sockeye entering Wells Pool were reported captured in the Colville purse seine fishery at the mouth of the Okanagan River (Table 22) with another 1.7% captured in the Osoyoos Lake fishery.

Table 22. Percentage of Sockeye tagged at Wells Dam passing Wells Dam and reported harvested in Colville and Okanagan Nation Alliance fisheries in 2014. (Excludes four fish captured for which a Floy tag was noted but no tag number recovered.)

Week Tagged	Colville Fishery				Fisheries Upstream of Zosel Dam	
	N	% of Sockeye Tagged	% Released	% of Released Fish Detected at ZSL	N	% of Sockeye Tagged
28	26	8.3%	100.0%	80.8%	9	3.0%
29	3	1.4%	50.0	50.0%	3	1.4%
30	0	0%	NA	NA	1	1.6%
31	17	11.8%	50.0%	50.0%	0	0%
Weighted Total	**46**	**3.8%**			**13**	**1.7%**

Survival from Wells Dam to Zosel Dam decreased for both Wells- and Bonneville-tagged Sockeye Salmon as the run progressed (Table 21, Figure 13). For those Sockeye passing or tagged at Wells Dam on or before July 23, 80.6% of both the Wells-tagged and Bonneville-tagged Sockeye were detected at Zosel Dam. For those Sockeye passing or tagged at Wells Dam on or after July 24, 53.3% of Wells-tagged and 46.0% of Bonneville-tagged Sockeye were detected at Zosel Dam.

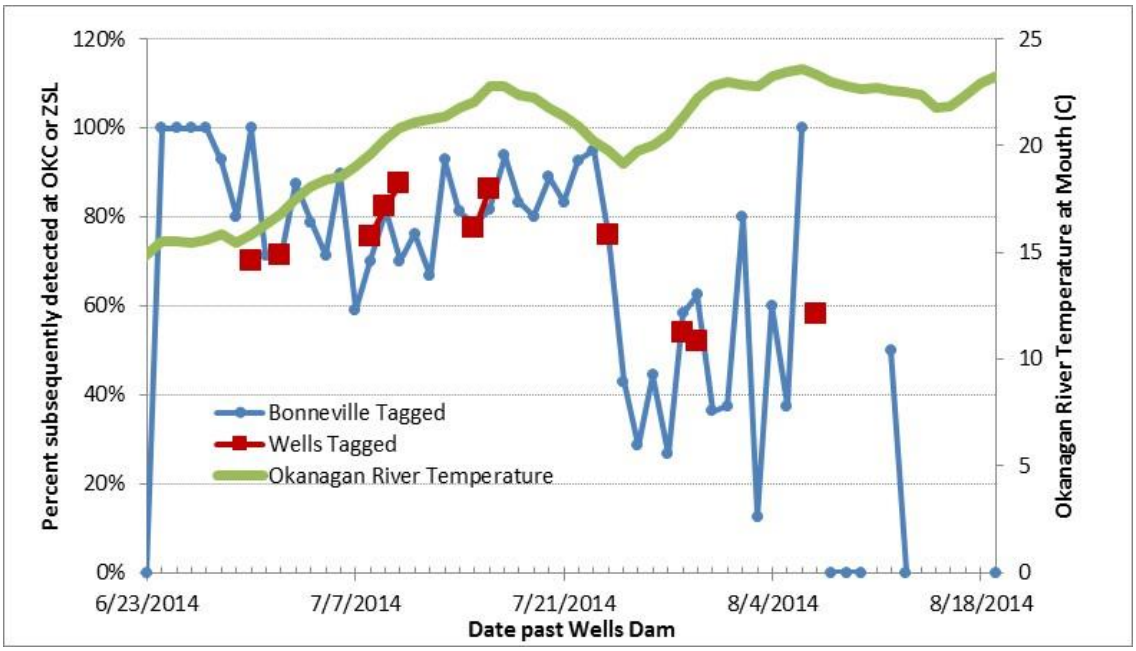

Figure 13. Percentage of Sockeye tagged at Wells and Bonneville passing Wells Dam subsequently detected at Zosel Dam by date past Wells Dam in 2014. Okanagan River temperatures were recorded at the Malott gaging station. (http://waterdata.usgs.gov/nwis/uv?site_no=12447200)

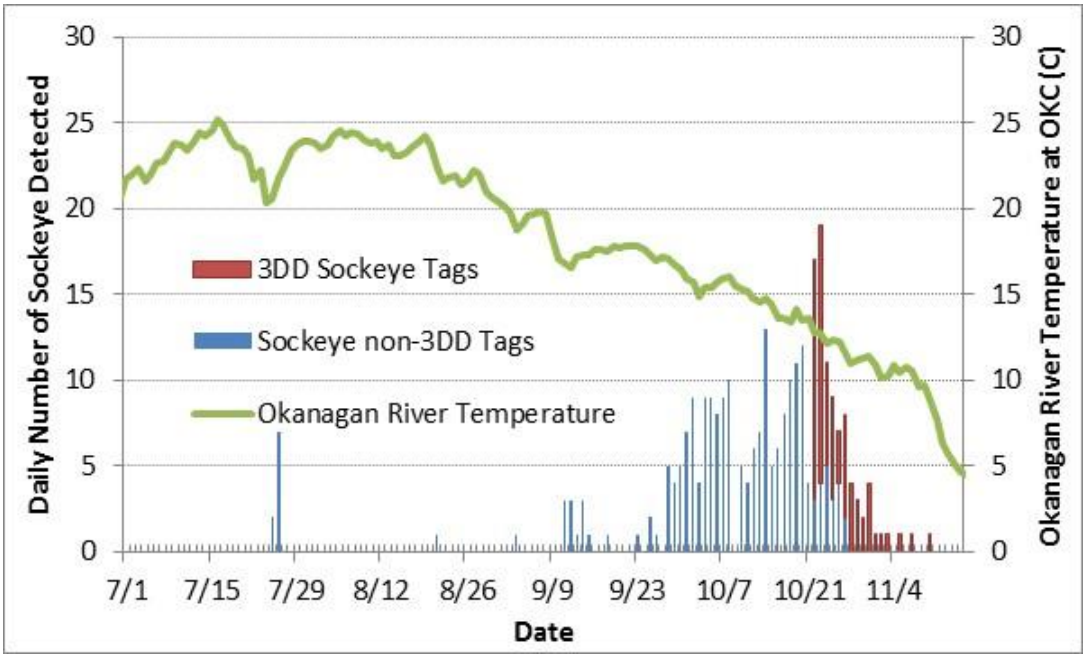

Figure 14. Number of 3DD and non-3DD PIT tagged Sockeye first detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2014.

Analysis of movement of PIT tagged Sockeye into the Okanagan River upstream of Osoyoos Lake past OKC was hampered by the fact that PIT tags with a code starting with 3DD passing OKC prior to October 22, 2014 were lost prior to uploading to PTAGIS due to an error in the software collecting the PIT tag data at OKC. In 2014, among Sockeye tagged by this project, 85.6% of Wells tagged Sockeye and 83.1% of Bonneville tagged Sockeye were tagged with 3DD tags. Among all adult Sockeye detected passing Zosel Dam in 2014, 24.5% were tagged with 3DD tags suggesting that the large majority of detections prior to October 22 were missed.

Among Sockeye that were detected at OKC, the overwhelming majority did not pass until water temperatures dropped below 17.0°C on September 29, with numbers of non-3DD tags peaking when they declined to 14.8°C on October 14 (Figure 14). The largest number of detections occurred on the first date 3DD tags were recorded, October 22, 2014, when 13 3DD tags and 3 non-3DD tags were detected and the water temperature was 12.8°C.

Genetic Stock Identification (GSI)

In 2014, genetics stock identification (GSI) was used to classify samples from 385 Sockeye Salmon sampled at Bonneville Dam and 9 Sockeye Salmon sampled at Wells Dam. These consisted of:

1.) 330 Sockeye sampled at Bonneville Dam which either were not tagged, not detected after tagging, or last detected at mainstem Columbia River dams downstream of Wells Dam.
2.) 12 Sockeye with a PIT tag detection history suggesting some uncertainty in PIT tag stock classification. These included Sockeye last detected in tributaries other than the Okanagan and Wenatchee, and sockeye detected at Wells or Rocky Reach that were subsequently detected at Tumwater Dam.
3.) 8 Sockeye last detected in the Snake River.
4.) 35 Sockeye last detected in the Okanagan or Wenatchee basin were included as a check on whether to compare the results of the two stock identification methods.

An additional 9 Sockeye sampled at Wells Dam were also analyzed. These included 5 Sockeye which fell back over Wells Dam and were last detected at Wells fish ladders, 2 fish last detected in the Entiat River, 1 fish last detected at Tumwater Dam, and 1 last detected in the Methow River.

There was concurrence between Sockeye Salmon stocks that were classified by both final PIT tag detection site and GSI, with 20 Okanagan Sockeye and 15 Wenatchee Sockeye classified similarly. Among the 8 Sockeye with PIT tags last detected in the Snake Basin, GSI classified 7 to the Snake River stock but one to the Wenatchee. This fish (PIT tag 3DD.00773AB80D) was the only Sockeye Salmon to be detected at Priest Rapids Dam prior to migrating up the Snake River. An additional 10 Sockeye that could not be classified by PIT tag detections were also classified using GSI as Snake River Sockeye (Table 23). Among these fish, 6 were last detected at Bonneville (with two being detected at The Dalles Dam and two in the Deschutes River prior to falling back over The Dalles and Bonneville dams) and 4 were last detected at The Dalles Dam.

Among the eight Sockeye last detected in the Yakima River, GSI classified four each as Wenatchee and Okanogan stock. Four of these eight Sockeye were detected in the trap at the Priest Rapids Dam east fish ladder before being detected in the Yakima River (one at Prosser Dam and three at Roza Dam) and were likely transported.

Among the four Sockeye detected in the Yakima River that likely migrated on their own volition, all were classified using GSI as Wenatchee stock (all last detected at Roza Dam, one falling back twice over Priest Rapids Dam before migrating up the Yakima River). Among the four Sockeye likely transported to Cle Elum Lake, all were classified by GSI as Okanagan stock with three last detected at Roza and one at Prosser.

Table 23. GSI classification of Sockeye last detected in non-terminal areas between Bonneville Dam and Rock Island Pool in 2014.

Last Site	Okanagan	Wenatchee	Snake
Bonneville Dam (BO1, BO3, BO4)	86	34	6
Deschutes River mouth (DRM)	2	0	0
John Day Dam juvenile bypass	1	0	0
McNary Dam (MC1, MC2)	40	6	0
Okanogan River	20	0	0
Priest Rapids Dam	54	9	0
Prosser Dam, Yakima River	1	0	0
Rock Island Dam	2	0	0
Roza Dam (ROZ), Yakima River	3	4	0
Rocky Reach Dam juvenile bypass	1	0	0
Snake River	7	1	0
The Dalles Dam (TD1, TD2)	55	14	4
Tumwater Dam	0	15	0
Tumwater Dam after being detected at Wells Dam	0	2	0
Not detected after tagging	6	3	0
Not tagged	7	0	0
Mortalities	2	0	0
Total	**260**	**70**	**10**

The two Sockeye last detected in the Deschutes were both classified as Okanagan stock.

GSI classification for Wells-tagged Sockeye classified both Sockeye last detected in the Entiat and the one Sockeye last detected in the Methow and at Tumwater Dam as Wenatchee stock. Among the five Sockeye falling back over Wells Dam and last detected in the Wells Dam fish ladders, all classified as Okanagan stock.

When Sockeye classified as unknowns by last PIT tag detection were classified by GSI, overall stock composition estimates changed by 1.6 percentage points or less (Table 24 and 25) with the percentage of ESA-listed Snake River Sockeye only changing from 1.0% to 0.9%. Stock specific survival to terminal areas was 81.3% for the Okanagan stock, 74.1% for the Wenatchee stock, and 66.2% for the Snake stock (Table 26).

Table 24. Comparison classification by stock using GSI and PIT tags of Sockeye Salmon sampled at Bonneville Dam in 2014.

	Stock Classification			
Classification Type	**Okanagan**	**Wenatchee**	**Snake**	**Yakima**
Using PIT tags	81.4%	17.6%	1.0%	0.4%
Unknown Sockeye (based on PIT tags) classified using GSI	74.6%	24.6%	0.8%	NA
PIT + Genetics	79.6%	19.2%	0.9%	0.3%

Table 25. Comparison of stock classification of Sockeye sampled at Bonneville Dam using GSI and PIT tag detections in 2014.

	Classification Using PIT Tags				Classification Using PIT Tags Plus Genetics			
Statistical Week	**OKA**	**WEN**	**Snake**	**Yakima**	**OKA**	**WEN**	**Snake**	**Yakima**
23	92.3%	7.7%	0.0%	0.0%	93.8%	6.2%	0.0%	0.0%
24	85.0%	15.0%	0.0%	0.0%	85.5%	14.5%	0.0%	0.0%
25	79.2%	20.4%	0.0%	0.5%	78.9%	20.7%	0.0%	0.4%
26	77.2%	22.0%	0.8%	0.0%	76.3%	23.0%	0.7%	0.0%
27	80.5%	17.3%	1.6%	0.5%	78.8%	19.9%	0.9%	0.4%
28	86.3%	12.7%	0.5%	0.5%	84.6%	14.2%	0.8%	0.4%
29	87.7%	9.6%	1.4%	1.4%	83.7%	12.2%	3.4%	0.7%
30	88.9%	11.1%	0.0%	0.0%	79.7%	16.9%	3.4%	0.0%
31	83.3%	0.0%	16.7%	0.0%	80.6%	6.5%	12.9%	0.0%
Composite	**81.1%**	**17.5%**	**1.0%**	**0.4%**	**79.6%**	**19.2%**	**0.9%**	**0.3%**

Table 26. 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 2014.

	Stock Classification Using PIT tags with GSI used to classify unknowns			
Statistical Week	**Okanagan**	**Wenatchee**	**Snake**	**All Stocks**
23	80.0%	100.0%		80.0%
24	90.4%	93.8%		90.4%
25	82.5%	80.7%		82.5%
26	84.1%	79.3%	100.0%	84.1%
27	82.6%	70.2%	100.0%	82.6%
28	84.5%	74.1%	50.8%	84.5%
29	53.9%	40.3%	20.7%	53.9%
30	51.9%	30.5%	0.0%	51.9%
31	21.4%	0.0%	26.7%	21.4%
Composite	**81.3%**	**74.1%**	**66.2%**	**81.3%**

Comparisons with Sockeye Tagged as Juveniles

Okanagan Sockeye Salmon stock tagged both as juveniles and as adults at Bonneville Dam had higher survival from Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams than did mixed stock, Wenatchee, or Snake River

Sockeye (Table 27). Snake River Sockeye tagged as juveniles had only 61.7% survival to McNary Dam which was 18.1 to 21.5 percentage points lower than the other groups. Comparisons at dams above Rock Island are not possible due to the different stock compositions of the PIT tag groups.

Table 27. 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 2014. An asterisk (*) indicates Sockeye which strayed from the normal migration route for the stock of concern.

					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	Zosel	Tumwater
Eastbank Hatchery	Hatchery	Wenatchee	Juvenile	83	90.5%	79.8%	76.2%	75.0%	0.0%*	73.5%
Okanagan River	Wild	Okanagan	Juvenile	74	95.9%	93.2%	87.8%	77.0%	51.4%	0.0%
Rock Island Dam	Mixed	Mixed	Juvenile	155	92.3%	83.2%	83.2%	76.8%	37.4%	16.1%
Snake River	Mixed	Snake	Juvenile	343	83.6%	61.7%	1.7%*	0.6%*	0.0%*	0.0%*
Bonneville AFF	Mixed	Mixed	Adult	1384	93.1%	88.4%	84.5%	79.5%	46.2%	13.6%
Bonneville AFF	Mixed	Wenatchee	Adult	253	85.6%	80.8%	78.3%	74.0%	0.0%*	70.3%
Bonneville AFF	Mixed	Okanagan	Adult	1131	94.6%	90.1%	86.8%	81.5%	60.8%	0.0%*

Bonneville-tagged Sockeye had a lower detection rate at spawning ground PIT arrays on the Little Wenatchee and White rivers than did Eastbank and Wenatchee River-tagged fish (Table 28, Figure 15).

Table 28. Distribution of Sockeye Salmon in the Wenatchee Basin in 2014, PIT tagged as both juveniles and adults.

				Percent of Sockeye Detected at Tumwater Dam Detected Upstream		
PIT Tag Location	Hatchery/ Wild	Life Stage at Tagging	Number at Tumwater Dam	Little Wenatchee (LWN)	White River (WTL)	Total on Spawning Grounds (LWN and WTL)
Eastbank	Hatchery	Juvenile	61	9.8%	52.5%	62.3%
Rock Island	Mixed	Juvenile	25	8.0%	52.0%	60.0%
Bonneville AFF	Mixed	Adult	175	5.7%	42.9%	48.6%

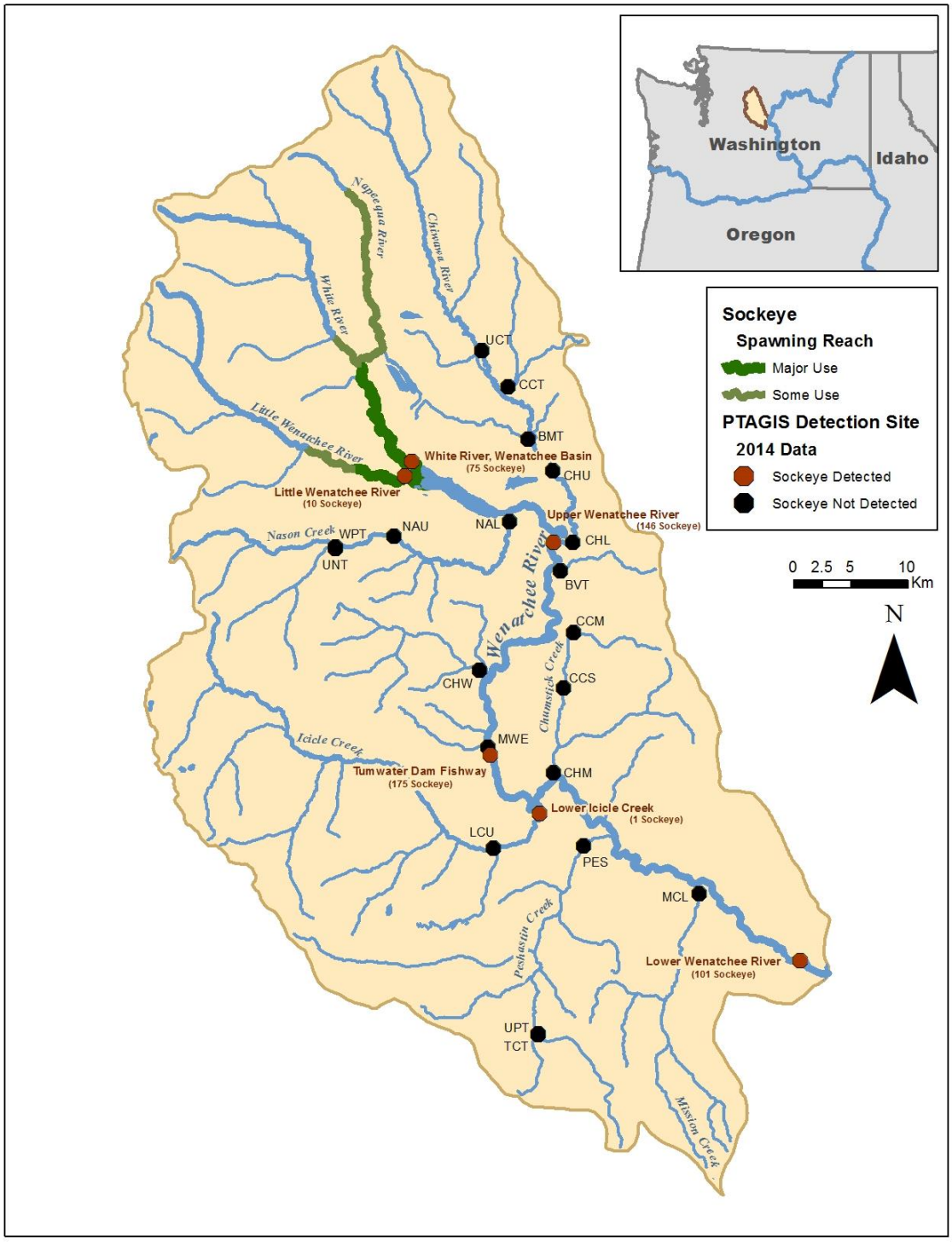

Figure 15. The Wenatchee Basin showing PIT tag interrogation sites and highlighting sites where sockeye were detected in 2014. Also displayed is the spawning area of Sockeye. Appendix Table A4 has site information.

Median migration times from Bonneville Dam to both The Dalles and McNary dams differed by 0.4 days or less between the PIT tag groups (Table 29). Sockeye tagged at Eastbank Hatchery had longer migration times from Priest Rapids to Rock Island Dam than did Okanagan River-tagged sockeye. Strays from Eastbank Hatchery and the Snake River migrated to Wells Dam but not to Zosel Dam; conversely there were no Okanagan River-tagged strays to Tumwater Dam.

Table 29. Median migration time in days between Columbia Basin PIT tag antenna sites for adult and juvenile Sockeye tagged migrating upstream in 2014. An asterisk (*) indicates any detected Sockeye would be staying 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	BON-RIA	PRD-RIS	RIS-RRH	RRH-WEA	WEA-ZSL	RIS-TUF	PRD-WEA
Eastbank Hatchery	Hatchery	Wenatchee juvenile	1.7	4.9	13.3	3.7	0.9*	3.0*	NA*	10.1	6.1*
Okanagan River	Wild	Okanagan juvenile	1.5	4.6	11.2	2.4	0.9	1.5	9.1	NA*	5.6
Rock Island Dam	Mixed	Mixed Wen/OKA Juvenile	1.5	4.7	11.9	3.2	0.9	1.7	10.2	11.8	5.9
Snake River	Mixed	Snake juvenile	1.5	5.0	12.7*	2.6*	1.2*	1.6*	NA*	NA*	7.4*
Bonneville AFF	Mixed	Mixed adult	1.8	4.8	12.2	3.1	1.0	1.8	11.1	11.6	6.1

Acoustic Data Analysis

A total of 99 Sockeye Salmon were implanted with acoustic tags in addition to PIT and Floy tags at the Wells Dam west bank fish ladder between June 30 and August 7, 2014 (Statistical weeks 27-32, Table 30). After weighting by weekly run size at Wells Dam, survival to Zosel Dam as estimated by all acoustic+PIT+Floy-tagged sockeye was 69.1% compared to 67.9% for those Sockeye PIT+Floy-tagged, but not acoustic or temperature-tagged, at Wells Dam and 76.1% for those Sockeye PIT tagged at Bonneville Dam.

Survival of Sockeye Salmon from Wells Dam to the Monse site in the lower Okanagan River was 93.2%, 60.7% to our North Basin Osoyoos Lake receiver, and 11.8% to McIntyre Dam (Table 31). Survival to Monse Bridge was relatively high at 83.3-100% for all weeks except week 31 when it was 55.6% (Tables 31 and 32). However, survival upstream to the North Basin decreased as the run progressed from 60-80% in weeks 27-29 to 22.2%-33.3% in weeks 30-32. A total of 80% of Sockeye Salmon acoustic-tagged in week 27 and 66.7% of fish tagged in week 30 were detected

in the Similkameen, but only 11.1% or fewer fish tagged in weeks 28-29 and 31-32 were detected in the Similkameen.

Table 30. Estimated conversion rate from Wells Dam to Zosel Dam for Sockeye Salmon tagged at Bonneville, and Wells dams by statistical week and weighted by the Wells Dam weekly run size in 2014.

			Sockeye Salmon Tagged at Wells Dam								Tagged at Bonneville Dam	
	Mean Weekly Temperature		PIT + Floy Tagged Only		PIT+Floy+ Acoustic Tagged		PIT+Floy+ Temperature Tag		All Sockeye tagged		PIT Tagged Only	
Week	Wells	Okanagan River (Malott)	N	% at Zosel	N	% at Zosel	N	% at ZSL	N	% at Zosel	N	% at Zosel
25-26	14.2	14.1	0	NA	0	NA	0	NA	0	NA	24	95.8%
27	14.6	15.3	21	61.9%	10	70.0%	0		31	64.5%	178	78.7%
28	15.2	16.9	256	76.6%	30	80.0%	15	46.7%	301	75.4%	229	73.8%
29	15.9	20.1	181	81.2%	20	75.0%	18	55.6%	219	78.5%	178	83.7%
30	16.5	22.2	32	40.6%	15	53.3%	15	40.0%	62	43.5%	153	77.8%
31	17.0	20.4	116	40.5%	18	27.8%	10	0.0%	144	36.1%	77	45.5%
32	18.3	21.8	11	54.5%	6	50.0%	2	0.0%	19	47.4%	35	37.1%
Weighted			**617**	**67.9%**	**99**	**69.1%**	**60**	**44.9%**	**786**	**67.0%**	**874**	**67.0%**

Table 31. Detection rate at acoustic receiver sites and estimated survival rate to those sites for Sockeye Salmon PIT and acoustic tagged at Wells Dam in 2014[12].

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%	99	100.0%
Brewster Dock	1	97.7%	97	100.0%
Monse Bridge	2	100.0%	87	93.2%
Okanagan Weir downstream	1	NA	67	NA
Okanagan Weir Upstream	2	NA	67	NA
Driscoll, Similkameen R.	1	100.0%	24	25.1%
Oroville Pumping Station	2	90.2%	55	69.1%
Haynes Point	2	100.0%	61	68.3%
Okanagan North Basin	1	100.0%	54	60.7%
Okanagan River Mouth	2	50.0%	41	55.9%
Okanagan River, Hwy 97	1	100.0%	24	26.2%
McIntyre Dam	1	100.0%	12	11.8%
Skaha Downstream	1	20.0%	1	5.9%
Okanagan Falls	1	NA	5	5.9%

[12] Receivers at the Okanagan Weir were not installed until after the many acoustic-tagged sockeye had already passed, making it impossible to estimate a detection efficiency.

Table 32. Percentage of Sockeye Salmon acoustic tagged at Wells Dam passing upstream receivers in 2014.

Week	Tag Date	Statis-tical Week	Monse Bridge	In Similka meen	Oroville Pump Station	Haynes Point	North Osoyoos Basin	McIntyre Dam	Skaha Lake	Estimated on Spawning Grounds
27	June 30	10	100.0%	80.0%	60.0%	60.0%	60.0%	10.0%	0.0%	40.0%
28	July 8-10	30	93.3%	6.7%	80.0%	86.7%	80.0%	16.7%	6.7%	70.0%
29	July 15-16	20	95.0%	10.0%	75.0%	80.0%	65.0%	10.0%	10.0%	40.0%
30	July 24	15	100.0%	66.7%	20.0%	33.3%	33.3%	6.7%	0.0%	20.0%
31	July 29-30	18	55.6%	11.1%	27.8%	27.8%	22.2%	5.6%	0.0%	5.6%
32	August 7	6	83.3%	0.0%	33.3%	33.3%	33.3%	33.3%	16.7%	33.3%
	Weighted by Weekly Wells Visual Count	**99**	**93.2%**	**25.1%**	**62.3%**	**68.3%**	**60.7%**	**11.8%**	**5.9%**	**43.7%**

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 90.2% or better at all acoustic receiver sites except the Okanagan River mouth upstream of Osoyoos Lake and just downstream of Skaha Dam (Table 31, Figure 9).

The time that acoustic tagged Sockeye salmon spent in Wells Pool and the Okanagan River downstream of Osoyoos Lake varied greatly by week (Table 33). Sockeye tagged in Week 27 had a median time to the Monse Bridge of 1.4 days but it was 12.2 days to Haynes Point and 24.8 days to the North Basin indicating an extended migration and holding time in the Okanagan River. Sockeye tagged in Week 28 held in Wells Pool for a median of 13.2 days but were at Haynes Point only 2.8 days later and the North Basin 6.0 days later. Sockeye tagged in weeks 29 and 30 (July 15, 16, and 24) had the shortest time to Haynes Point as they migrated during the dip in temperatures that occurred shortly thereafter (Figure 16). Sockeye tagged in weeks 31 and 32 (July 29, 30, and August 5) had the longest migration to Monse and Haynes Point as they waited for temperatures to dip in late August (Figure 16).

Table 33. Migration time to upstream receiver sites for Sockeye acoustic tagged at Wells Dam by date in 2014.

Week	Tag Date	Number of Acoustic Tags	Median Days to Monse Bridge	Median Days to Haynes Point	Median Days to North Basin	Median Days to Hwy 97	Median Hwy 97 Passage Date
27	June 30	10	1.4	12.2	24.8	107.0	10/15
28	July 9-10	15	13.2	16.0	19.2	88.9	10/5
29	July 15-16	18	6.9	9.1	10.0	82.4	10/6
30	July 24	15	0.8	6.2	39.8	99.1	10/31
31	July 29-30	10	28.0	33.0	37.0	76.6	10/14
32	August 7	2	17.9	23.0	29.0	32.5	9/8
Overall		**99**	**8.0**	**14.0**	**24.8**	**86.7**	**10/6**

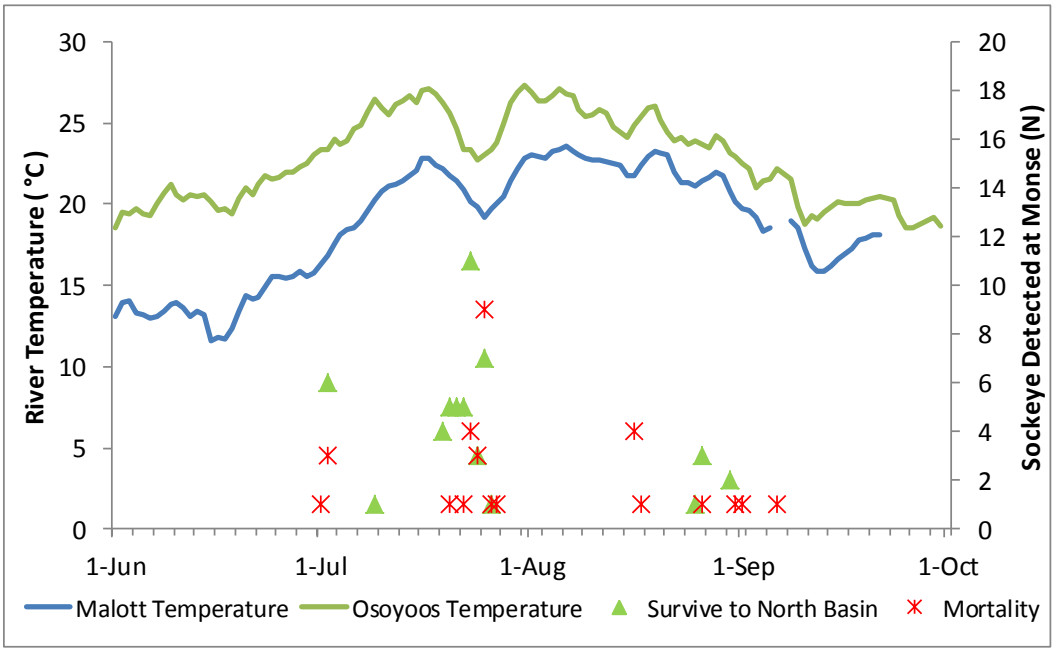

Figure 16. Okanagan River temperature at Malott and Osoyoos Lake outlet and survival of Sockeye acoustic tagged passing Monse Bridge acoustic receiver to Osoyoos Lake in 2014. Green triangles indicate the date passing Monse for fish that survived to Osoyoos Lake, while red stars indicate date passing Monse for fish that did not reach Osoyoos Lake.

Thirty-three acoustic-tagged Sockeye Salmon passed Monse but did not make it to the North Basin, and 20 of these fish passed Monse when water temperatures were less than 20°C (Table 34). Of these 33 fish, four passed Monse in early July when water temperatures were rising and had already exceeded 22°C in Osoyoos Lake, 20 passed Monse when temperatures fell over the period of one week in late July but still exceeded 22°C in Osoyoos Lake, and 9 were detected in mid-August through September when temperatures were less than 22°C at Monse but still greater than 22°C in Osoyoos Lake (Figure 16). Of the 33 fish detected at Monse but not in the North

Basin, 16 were last detected in the Similkameen, 14 were last detected between Monse and the North Basin receivers, and 3 were last detected in Wells Pool downstream of Monse.

Table 34. Survival of acoustic tagged at Wells Dam from Monse to the Osoyoos Lake North Basin by Okanagan River temperature at Malott at the time these fish passed Monse in 2014.

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	15	20	42.9%
20 to 21	19	6	76.0%
>21 to 22	16	6	72.7%
>22 to 23	4	1	80.0%
All Temperatures	54	33	62.9%

Acoustic-tagged Sockeye Salmon passing the Monse acoustic site in 2014 can be divided into three groups (Table 35). The first group consisted of 10 Sockeye Salmon tagged on June 30th that migrated past Monse between July 1 and 2. These fish had a median time from Wells to Monse of 0.6 days. Although temperatures in the Okanagan River were under 20°C, the median time from Monse to the North Basin was 23.3 days (compared to a minimum time of approximately 3 days documented in other years) and survival was 60%. Eight out of 10 of these Sockeye Salmon were detected in the Similkameen and it is likely that these fish delayed migration by holding in the Similkameen River until temperatures in the Okanagan River upstream of its confluence with the Similkameen dropped.

Table 35. Survival of Sockeye PIT tagged at Wells Dam from Monse to the Osoyoos Lake North Basin by Okanagan River temperature at Malott in 2014.

Group	N	Date Past Monse	Monse to North Basin	Median Time Wells To Monse	Median Days Monse-North Basin
1	10	July 1-2	60.0%	0.6	23.3
2	62	July 9-27	67.7%	8.1	7.3
3	15	Aug 16-Sep 6	40.0%	27.6	8.2

The second group was tagged between July 8-24 and had a median migration time from Wells Dam to Monse of 8.1 days. All but one of these 62 fish passed Monse between July 19 and July 26 when water temperatures fell steadily over a week-long period, from 22.8°C on July 17 to 19.7°C on July 25. These fish had a survival rate from Monse to the North Basin of 67.7% and a median time of 7.3 days. Forty two fish from this group survived to the North Basin, with only one detected in the Similkameen as

compared to the 20 fish that did not survive to the North Basin, where 13 were also detected in the Similkameen".

The third group consisted of 15 of the Sockeye tagged between July 29 and August 7 and passed Monse between Aug 16 and September 9. Temperature was declining overall during this time period, from 21.8C to 18.5C and survival to the North Basin was 40.0%. The 6 fish that survived to the North Basin were not detected in the Similkameen, and of the 9 fish that did not survive to the North Basin, six were last detected at the weir site in the lower Okanagan River, two were in the Similkameen River and one was at the Pump Intake receiver.

Forty of the 99 fish acoustic tagged were estimated to be on the spawning grounds during the spawning period (Table 36), 46 were missing on the upstream migration prior to entering the North Basin of Osoyoos Lake, and 13 were last detected in the northern basin of Osoyoos Lake or at the Okanagan River mouth just upstream of Osoyoos Lake prior to September 15, 2014 and not detected further upstream in spawning areas. No Sockeye were reported as fishery mortalities although one Sockeye (tag number 18411) was captured and released in the CCT fishery on August 7 and last detected on the spawning grounds.

Table 36. 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 2014. (Green text indicates the fish was likely on the spawning grounds during the spawning period. Blue text indicates missing on upstream migration, black text indicates last detected in Osoyoos Lake or at the Okanagan River Mouth before September 15, 2014. Sockeye detected at the Okanagan River Mouth after September 15, 2014 were assumed to be on the spawning grounds.).

Tag Code	Date Tagged	Furthest Upstream Detection		Last Detection		First OKC Detection	Mobile Track Dates
		Site	Date	Site	Date		
16164	6/30	Hwy 97	10/28	Hwy 97	10/28	10/24	X
16165	6/30	South Basin at Haynes Point	7/26	South Basin at Haynes Point	10/22		
16166	6/30	North Basin	8/02	North Basin	8/20		X
16167	6/30	Similkameen River	7/12	Similkameen River	7/12		
16168	6/30	McIntyre Dam	10/4	McIntyre Dam	10/6	10/1	X
16169	6/30	North Basin	7/25	North Basin	11/28		X
16170	7/9	Similkameen River	7/16	Similkameen River	7/25		
16171	6/30	Okanagan Mouth (Canada)	8/4	Okanagan Mouth (Canada)	10/2	10/2	X
16172	6/30	Okanagan Mouth (Canada)	10/4	Okanagan Mouth (Canada)	10/5		X
16173	6/30	Similkameen River	7/9	Similkameen River	8/3		
16174	7/8	Skaha Dam	10/15	Skaha Dam	10/15		X
16175	7/8	South Basin at Haynes Point	7/31	Oroville pump station	8/25		
16176	7/8	Okanagan Mouth (Canada)	8/30	Okanagan Mouth (Canada)	9/28		X
16177	7/8	Okanagan Mouth (Canada)	9/19	North Basin	10/20	10/4	X
16178	7/8	HWY 97	10/5	HWY 97	10/8	10/2	X
16179	7/8	Okanagan Mouth (Canada)	10/8	Okanagan Mouth (Canada)	10/8	10/8	
16180	7/8	Lower Okanagan Weir	7/25	Lower Okanagan Weir	7/25		
16181	7/8	Wells Pool	7/10	Wells Pool	7/13		
16182	7/8	Okanagan Mouth (Canada)	8/29	North Basin	10/15	10/16	X
16183	7/8	North Basin	8/24	North Basin	8/26		X
16184	7/9	McIntyre Dam	10/19	McIntyre Dam	11/2		
16185	7/9	HWY 97	9/16	HWY 97	10/18		X
16186	7/9	Okanagan Mouth (Canada)	7/30	North Basin	10/13	10/31	X
16187	7/9	North Basin	8/16	North Basin	8/16		
16188	7/9	HWY 97	10/31	HWY 97	11/2		X
16189	7/9	Okanagan Mouth (Canada)	10/5	Okanagan Mouth (Canada)	10/6		
16190	7/9	HWY 97	10/12	HWY 97	10/13		
16191	7/9	HWY 97	10/19	North Basin	10/27		X
16192	7/9	McIntyre Dam	10/5	HWY 97	10/7		X
16193	7/9	Okanagan Mouth (Canada)	10/1	North Basin	10/11		X
16194	7/10	Skaha Dam	10/2	Skaha Dam	10/2		X
16195	7/10	HWY 97	10/6	HWY 97	12/1		
16196	7/10	Okanagan Mouth (Canada)	9/23	North Basin	10/21	10/23	X

16197	7/10	Similkameen River	7/30	Similkameen River	9/28		
16198	7/10	Wells Pool	7/12	Wells Pool	7/16		
16199	7/10	McIntyre Dam	10/5	HWY 97	10/20		X
16200	7/10	North Basin	7/25	North Basin	8/18		X
16201	7/10	Okanagan Mouth (Canada)	8/4	Okanagan Mouth (Canada)	10/6		X
16202	7/10	Okanagan Mouth (Canada)	9/20	Okanagan Mouth (Canada)	10/5		X
18366	7/10	South Basin at Haynes Point	7/26	South Basin at Haynes Point	8/7		
18367	7/15	Similkameen River	7/25	Similkameen River	8/2		
18368	7/15	South Basin at Haynes Point	7/25	South Basin at Haynes Point	8/26		
18369	7/15	Skaha Dam	10/8	Skaha Dam	10/8		X
18370	7/15	Wells Pool	7/20	Wells Pool	7/20		
18371	7/15	HWY 97	10/6	HWY 97	10/6		X
18372	7/15	Okanagan Mouth (Canada)	9/8	North Basin	10/10		X
18373	7/15	Okanagan Mouth (Canada)	9/13	North Basin	10/22		X
18374	7/15	South Basin at Haynes Point	7/26	South Basin at Haynes Point	10/5		
18375	7/15	North Basin	7/25	North Basin	8/15		X
18376	7/15	South Basin at Haynes Point	7/25	South Basin at Haynes Point	8/22		
18377	7/16	Lower Okanagan Weir	7/25	Wells Pool	7/28		
18378	7/16	Similkameen River	7/29	Wells Pool	8/5		
18379	7/16	Okanagan Mouth (Canada)	7/29	North Basin	8/4		
18380	7/16	Skaha Dam	9/7	Skaha Dam	9/8		
18381	7/16	HWY 97	10/20	HWY 97	10/20		X
18382	7/16	HWY 97	10/6	HWY 97	10/6		X
18383	7/16	North Basin	12/1	North Basin	12/1		
18384	7/16	Okanagan Mouth (Canada)	10/4	North Basin	10/15		X
18385	7/16	HWY 97	11/2	HWY 97	11/2	10/23	X
18386	7/16	North Basin	7/25	North Basin	8/29		X
18387	7/24	North Basin	8/17	North Basin	8/21		X
18388	7/24	Similkameen River	7/28	Similkameen River	7/29		
18389	7/24	Similkameen River	7/31	Similkameen River	8/8		
18390	7/24	Similkameen River	7/31	Similkameen River	8/2		
18391	7/24	Similkameen River	7/28	Similkameen River	7/30		
18392	7/24	Okanagan Mouth (Canada)	9/4	North Basin	10/16		X
18393	7/24	Similkameen River	7/28	Similkameen River	7/29		
18394	7/24	Similkameen River	7/28	Similkameen River	8/13		
18395	7/24	Okanagan Mouth (Canada)	9/26	North Basin	10/24	10/29	X
18396	7/24	Similkameen River	7/31	Similkameen River	8/29		
18397	7/24	Similkameen River	7/29	Similkameen River	8/10		
18398	7/24	Similkameen River	7/30	Similkameen River	7/31		
18399	7/24	Similkameen River	7/30	Wells Pool	9/3		
18400	7/24	Okanagan Mouth (Canada)	9/12	North Basin	9/13		X
18401	7/24	McIntyre Dam	10/9	HWY 97	10/31		

18402	7/29	North Basin	9/2	North Basin	9/3		
18403	7/29	Similkameen River	8/20	Similkameen River	9/21		
18404	7/29	Similkameen River	8/20	Similkameen River	8/22		
18405	7/29	Lower Okanagan Weir	9/7	Lower Okanagan Weir	9/7		
18406	7/29	South Basin at Haynes Point	8/30	Oroville pump station	9/2		
18407	7/29	Lower Okanagan Weir	9/1	Lower Okanagan Weir	9/1		
18408	7/29	McIntyre Dam	10/7	HWY 97	10/8		
18409	7/29	Lower Okanagan Weir	8/16	Lower Okanagan Weir	8/16		
18410	7/30	Wells Pool	8/1	Wells Pool	8/4		
18411	7/30	HWY 97	10/21	HWY 97	10/21		
18412	7/30	Wells Pool	7/31	Wells Pool	8/1		
18413	7/30	Okanagan Mouth (Canada)	9/21	South Basin at Haynes Point	10/29		
18414	7/30	Wells Pool	8/1	Wells Pool	8/7		
18415	7/30	Wells Pool	8/1	Wells Pool	10/2		
18416	7/30	Wells Pool	7/31	Wells Pool	7/31		
18417	7/30	Wells Pool	7/31	Wells Pool	8/29		
18418	7/30	Wells Pool	8/1	Wells Pool	10/10		
18419	7/30	Wells Pool	7/31	Wells Pool	8/2		
18420	8/7	Wells Pool	8/8	Wells Pool	8/10		
18421	8/7	Lower Okanagan Weir	9/2	Lower Okanagan Weir	9/2		
18422	8/7	Lower Okanagan Weir	8/16	Lower Okanagan Weir	8/16		
18423	8/7	McIntyre Dam	9/7	McIntyre Dam	9/9		
18424	8/7	Skaha Dam	9/15	Skaha Dam	9/15		
18425	8/7	Lower Okanagan Weir	8/16	Lower Okanagan Weir	8/16		

Archival Temperature Tags

The first 10 archival temperature tags deployed were inadvertently set to collect data at one minute intervals rather than 1.5 hour intervals. Two of these tags were recovered by the Colville Tribes' harvest purse seine at the mouth of the Okanagan and redeployed in other Sockeye. The data from the two fish are shown in Figure 17 and show these two Sockeye Salmon migrating through Wells Pool at temperatures of 15.5-16C and attempting to enter the Okanagan River on July 10 when the mean daily temperature of the river at Malott was 21.5°C. Fish 1 appears to have nosed in and out of the warmer water before remaining in the Columbia at the mouth of the Okanagan, where it was harvested. Fish 2 appears to have nosed in and out of the warmer water where it remained at approximately 20.5°C for 45 minutes before returning to the cooler Columbia at the mouth of the Okanogan, where it was harvested. These data suggest that temperatures of 21.5°C hinder migration of Sockeye

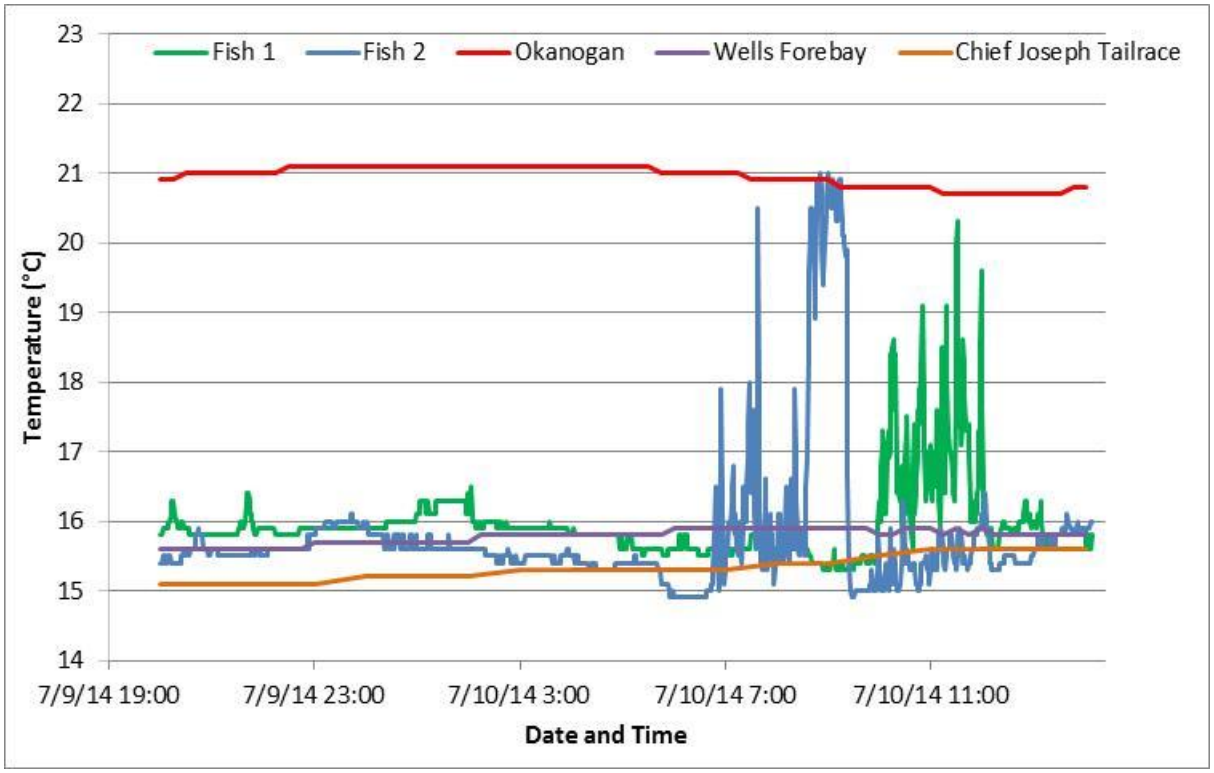

Figure 17. Temperature record of two sockeye salmon released on July 9 and captured in fisheries on July 10 with Wells Pool and Okanagan River Temperatures.

Acoustic Trawl and Limnology Surveys

Osoyoos Lake and Skaha Lake acoustic trawl surveys (ATS) were conducted on seven occasions between May 2014 and February 2015 to monitor the Brood Year 2013 cohort of juvenile Sockeye Salmon (Table 37). Acoustic trawl surveys of Lake Wenatchee were conducted on October 27, 2014 and February 23, 2015. In Osoyoos Lake and Lake Wenatchee, no species other than juvenile *O. nerkids* (Sockeye) were captured in the October 2014 and February 2015 trawl surveys. Based on a comparison of the mean densities for the October 2014 and February 2015 surveys, Lake Wenatchee was estimated to be 74% as productive as Osoyoos Lake. By comparison, Lake Wenatchee was 63% as productive in 2012 and 43% as productive in 2013. Analysis of 2014 phytoplankton and zooplankton abundance and composition is in progress.

Table 37. Estimates of juvenile Sockeye Salmon abundance from Skaha Lake, Osoyoos Lake, and Lake Wenatchee acoustic trawl surveys.

Lake	Survey Date	N	Std. Dev.	Density (per ha)
Skaha	26-May-14	1,736,874	166,324	892
Skaha	23-Jun-14	1,776,945	148,599	913
Skaha	22-Jul-14	2,474,323	290,930	1,271
Skaha	25-Aug-14	1,548,408	121,758	795
Skaha	22-Sep-14	1,715,429	72,935	881
Skaha	21-Oct-14	1,423,332	70,315	731
Skaha	25-Feb-15	953,457	32,705	490
Skaha	26-May-14	1,736,874	166,324	892
Osoyoos	29-May-14	3,425,445	259,085	3,671
Osoyoos	25-Jun-14	3,282,501	398,107	3,518
Osoyoos	24-Jul-14	3,671,420	270,058	3,935
Osoyoos	27-Aug-14	4,268,351	259,150	4,575
Osoyoos	24-Sep-14	3,695,438	474,566	3,961
Osoyoos	23-Oct-14	2,733,271	178,374	2,930
Osoyoos	27-Feb-15	1,800,794	95,094	1,930
Wenatchee	21-Sep-10	1,637,000	217,153	1,600
Wenatchee	20-Sep-11	2,330,336	346,768	2,321
Wenatchee	1-Nov-11	1,971,117	229,012	1,963
Wenatchee	25-Jun-12	1,731,250	224,912	1,724
Wenatchee	18-Sep-12	2,847,909	369,315	2,837
Wenatchee	10-Jul-13	2,778,381	538,262	2,767
Wenatchee	23-Sep-13	2,650,400	845,170	2,640
Wenatchee	27-Oct-14	1,774,238	168,263	1,767
Wenatchee	23-Feb-15	1,815,407	250,287	1,808
Wenatchee	21-Sep-15	2,451,535	228,824	2,442

2014 Juvenile PIT Tagging

In total, 5,056 Sockeye smolts were PIT tagged and release between April 7 and May 5, 2014 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYOL, downstream of the Highway 3 bridge at the Osoyoos Narrows in Osoyoos Lake. Tagging effort is summarized in Table 38. The mean fork lengths of Sockeye PIT tagged at SKATAL was 105 mm compared to 82 mm at OSOYOL.

Table 38. Summary of Okanagan Sockeye smolt PIT tagging effort, 2014.

	Number of PIT Tag Releases		
Date	Below Skaha Dam (SKATAL)	Osoyoos Lake (OSOYOL)	Total
7-Apr-14		27	27
11-Apr-14		62	62
15-Apr-14		93	93
17-Apr-14		98	98
22-Apr-14		238	238
23-Apr-14		215	215
24-Apr-14		272	272
25-Apr-14	176	302	478
28-Apr-14	196	330	526
29-Apr-14	294	441	735
30-Apr-14	305	417	722
1-May-14	378	444	822
2-May-14		403	403
5-May-14		365	365
Grand Total	**1349**	**3707**	**5056**

Reliable estimates of survival from release to Rocky Reach Dam were calculated for both release groups (Table 39). Survival from release to Rocky Reach Dam was 0.41 (SE = 0.06) for the SKATAL release group, and 0.63 (SE = 0.04) for the OSOYOL release group, suggesting a differential mortality of 34.9% between the two groups. Survival from Rocky Reach to McNary was 70.0% for the OSOYOL group compared to 60.0% for the SKATAL group, a difference of 16.7%. Overall survival to McNary was 39.0% for the combined Okanagan group compared to 43.0% for Wenatchee sockeye smolt tagged as part of another program. After McNary Dam, 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.

Table 39. Mean survival juvenile sockeye PIT tagged in the Okanagan and Wenatchee basins in 2014.

	Release Group							
	Skaha and Osoyoos Combined		Osoyoos Lake (OSOYOL)		Below Skaha Dam (SKATAL)		Wenatchee	
Period	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Release to Rocky Reach	0.57	0.03	0.63	0.04	0.41	0.06	NA	NA
Rocky Reach to McNary	0.68	0.08	0.70	0.09	0.60	0.17	NA	NA
Release to McNary	0.39	0.09	0.44	0.05	0.25	0.06	0.43	0.05
McNary to John Day	2.80	1.39	2.46	1.22	NA	NA	1.72	0.87
John Day to Bonneville	0.26	0.19	0.23	0.17	NA	NA	0.38	0.31
Release to Bonneville	0.28	0.15	0.24	0.13	NA	NA	NA	NA

Sockeye tagged at SKATAL migrated more rapidly to Rocky Reach and McNary dams than did sockeye tagged downstream at OSOYOL (Table 40), likely due to their larger size. Travel times from McNary to John Day dam were varied by only 0.2 days between the two groups, with Wenatchee-tagged sockeye taking twice as long to migrate this stretch. Overall migration ties from release to Bonneville dam were 18.0 days for the SKATAL release group, 25.1 days for the OSOYOL group, and 36.6 days for the Wenatchee group.

Table 40. Harmonic mean travel time for juvenile sockeye PIT tagged in the Okanagan and Wenatchee basins in 2014.

	Release Group							
	Skaha and Osoyoos combined		Osoyoos Lake		Below Skaha Dam		Wenatchee	
Period	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Release to Rocky Reach	15.9	0.19	17.4	0.19	10.4	0.18	NA	NA
Rocky Reach to McNary	3.9	0.07	3.9	0.08	3.7	0.07	NA	NA
Release to McNary	18.4	0.26	20.5	0.28	13.3	0.2	18.8	0.53
McNary to John Day	2.4	0.11	2.4	0.12	2.2	0.11	4.8	0.74
John Day to Bonneville	1.4	0.16	1.4	0.16	NA	NA	1.4	0.05
Release to Bonneville	23.2	0.56	25.1	0.65	18.0	0.39	36.6	1.48

A report detailing Okanagan Sockeye juvenile PIT tagging can be found in Appendix B and a Fish Passage Center memo reviewing survival and migration times in both 2014 and 2015 round in Appendix C.

DISCUSSION

This completes the sixth year of this study. The year 2014 was the fourth full year in which we had a PIT tag detection site at Zosel Dam (ZSL), but the first year in which flows were low enough that upstream migrating Sockeye Salmon were forced to use the fish ladder rather than swim through an open spillway. The site performed well during much of the year, but in preparing this report in October, 2015, a gap was found in the data in early July when numerous Sockeye were detected at both OKL downstream and OKC upstream but were not detected at ZSL. Biomark, who maintains this site for this project, was contacted and they found and corrected a problem with files uploaded for July 1 through July 6 and another affecting part of July 24 and 25. After corrections were made, over 99% of Sockeye detected at OKC upstream were also detected at Zosel Dam.

We also had problems with our OKC site in the Okanagan River near Oliver, BC, which we discovered was not programmed to upload to PTAGIS PIT tags with codes beginning with 3DD. These tags were introduced to the Columbia Basin in 2014. A low detection rate at OKC was identified during summer 2014 but the cause of the problem was not identified until early November 2014, at which time only the 3DD tags stored in the on-site data buffer at OKC since October 22, 2014 could be recovered.

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). Table 41 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.

Table 41. 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 2014.

Site	Visual Count	PIT Tag Estimate	Fall-back	Night Passage	Adjusted Visual Count	Adjusted PIT Tag Estimate	% Difference Between Adjusted Counts
Bonneville	614,179	614,179	1.4%	2.6%	621,326	NA	NA
The Dalles	586,188	571,731	3.9%	8.4%	610,646	578,384	-5.3%
McNary	546,012	542,199	0.7%	6.2%	575,806	548,508	-4.7%
Priest Rapids[13]	608,142	519,258	3.6%		586,249	525,300	-10.4%
Rock Island[13]	581,121	488,025	0.6%		577,634	493,704	-14.5%
Rocky Reach[13]	492,892	401,259	1.7%		484,513	405,928	-16.2%
Wells[13]	490,804	394,000	1.7%		482,460	398,585	-17.4%
Tumwater[13]	99,899	83,564	0.0%		99,899	84,536	-15.4%
Zosel[13]	325,277	284,015	2.7%	--	316,495	287,320	-9.2%

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 2014, based on the ratio of Rocky Reach to Rock Island counts, 82.1% of the run at Rock Island was Okanagan stock compared to 79.7% if Tumwater Sockeye counts are used to estimate the Wenatchee stock proportion (Table 42). Different fallback rates at Rock Island, Rocky Reach, and Tumwater dams have a relatively small effect on stock composition estimates, decreasing the percentage of Okanagan stock to 80.8% using the ratio Method C (Rocky Reach to Rock Island ratio) and 79.4% using Tumwater counts (Method D, Table 42). Also unlike 2013, GSI estimates differ little from PIT tag estimates (Table 42).

[13] Night passage is included in reported visual counts.

Table 42. Comparison of different methods of estimating Okanagan and Wenatchee Sockeye stock composition in 2014.

Method		% Okanagan	% Wenatchee	Other	Source Table
A	PIT tags deployed at Bonneville Dam detected at Rocky Reach and Tumwater Dams	80.7%	17.5%	1.8%	15
B	GSI + PIT on Bonneville samples (weighted by Bonneville visual counts)	79.9%	19.2%	0.9%	25
C	Visual dam counts taking the Rock Island-Rocky Reach difference as Wenatchee	82.1%	17.9%	NA	15
D	Visual dam counts taking Tumwater as Wenatchee	79.7%	20.3%	NA	15
E	Method C using adjusted visual counts in Table 41	80.8%	19.2%	NA	41
F	Method D using adjusted visual counts in Table 41	79.4%	20.6%	NA	41

Sockeye Salmon PIT tagged at Bonneville Dam were not classified by stock based on PIT tags unless they were subsequently detected in terminal areas (the Snake or Wenatchee basins or the Columbia River at or above Rocky Reach Dam). Using these criteria, the stock could not be identified for 331 PIT-tagged Sockeye Salmon in 2014 so these were subsequently identified by stock using GSI (Table 43).

Table 43. Genetic stock classification of Sockeye PIT tagged at Bonneville Dam last detected at Bonneville, McNary, Priest Rapids, and Rock Island dams and those not detected after release in 2014.

Reach PIT Tagged Fish Lost Between	N	Okanagan	Wenatchee	Snake River
Not detected after release	9	66.7%	33.3%	0.0%
Bonneville-The Dalles	128	68.8%	26.6%	4.7%
The Dalles-McNary	74	75.7%	18.9%	5.4%
McNary-Priest Rapids	54	81.5%	18.5%	0.0%
Priest Rapids-Rock Island	63	85.7%	14.3%	0.0%
Rock Island-Rocky Reach/Tumwater	3	100.0%	0.0%	0.0%
Total	**331**	**75.8%**	**21.1%**	**3.0%**

Hess et al (2015) reported data from genetics analysis of Sockeye captured in 2014 tribal fisheries between Bonneville and McNary Dam (Table 44, Figure 18). These estimates show a higher percentage of Wenatchee Sockeye, and lower percentage of Okanagan Sockeye in the harvest than this study estimated at Bonneville Dam (Tables 15 and 44). There was one sockeye captured in Statistical Week 21 that was classified using GSI as being of Whatcom Lake origin (near Bellingham, WA). With Sockeye only recently being re-introduced to the Yakima Basin, no baseline GSI sample exists for a

Yakima Sockeye stock so GSI could not identify any Sockeye as being of Yakima origin[14].

Table 44. 2014 Zone 6 Harvest allocation by week as classified using genetics stock identification techniques (from Hess et al. 2015).

Week	Fishery Dates	Harvest	N	Okanagan	Snake	Wenatchee	Whatcom	Yakima
<=23	Through June 16	451	4	100.0%	0.0%	0.0%	0.0%	NA
24	June 16 to 19	1,346	24	87.5%	0.0%	12.5%	0.0%	NA
25	June 23 to 26	6,356	129	70.5%	0.0%	29.5%	0.0%	NA
26	June 30 to July 3	5,473	354	58.8%	1.1%	40.1%	0.0%	NA
27	July 7 to 11	10,313	301	69.1%	1.0%	29.9%	0.0%	NA
28	July 14 to 18	5,374	519	74.0%	1.9%	24.1%	0.0%	NA
29	July 21 to 25	1,338	270	72.6%	4.4%	23.0%	0.0%	NA
30	July 28 to 31	311	296	80.4%	1.7%	17.6%	0.3%	NA
>=31	August	90	66	81.8%	3.0%	15.2%	0.0%	NA
Weighted by Weekly Harvest		**31,052**	**1,963**	**70.0%**	**1.1%**	**28.9%**	**<0.1%**	NA
Estimated Stock Composition at Bonneville Dam from Table 15				**81.1%**	**1.0%**	**17.5%**	**0.0%**	**0.4%**

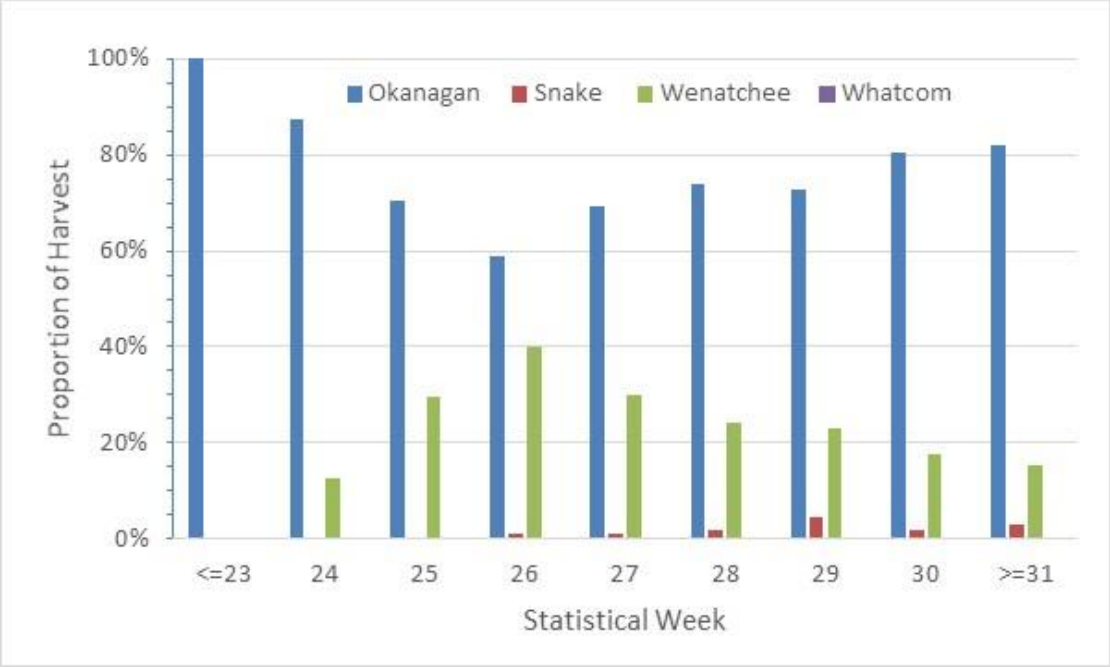

Figure 18. Weekly stock composition of the zone 6 Sockeye harvest in 2014

[14] Sockeye in the Yakima Basin reintroduction represent both the Okanagan and Wenatchee stocks, and so far there is evidence that these two genetic stocks have remained "pure" and have exhibited spatially and temporally stratified spawning in the Yakima Basin (A Matala, CRITFC, personal communication).

A total of 10 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.

PIT tags from 9 sockeye PIT tagged at Bonneville Dam were found at bird colonies. Eight were found upstream of McNary Dam at a pelican colony at Badger Island. Five of these Sockeye were last detected at McNary Dam, two at Priest Rapids, and one at The Dalles. The ninth Sockeye tag was found on a bird colony was at Little Miller Island, site of a gull colony upstream of The Dalles Dam, and was last detected at The Dalles Dam. Four Sockeye were detected in the Zone 6 harvest between Bonneville and McNary dams. Three of these Sockeye were last detected at The Dalles Dam while the fourth was last detected at Bonneville Dam.

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 Zosel offered the opportunity to provide insights on the effect of different tagging regimes on Sockeye Salmon (Table 45). In 2014, this suggests sampling and PIT tagging at Wells Dam decreased survival to Zosel by 10.7%, while PIT and acoustic tagging decreased survival by 9.2%. Temperature plus PIT tagging at Wells Dam decreased survival by 41.0%.

Table 45. Conversion rates from Wells Dam to Zosel 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 2014.

Tagging Location	Tagging Regime	Wells-Zosel Conversion Rate	Deviation from Bonneville-tagged Conversion Rate
Bonneville Dam	PIT tag	76.1%	--
Wells Dam	PIT plus Floy-tag	67.9%	-10.7%
Wells Dam	PIT plus acoustic plus Floy Tag	69.1%	-9.2%
Wells Dam	PIT plus temperature plus Floy	44.9%	-41.0%

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 is likely greater than at Bonneville Dam. Water temperatures at Wells are higher than at Bonneville, sampling facilities are poorer, and fish condition is worse after such a long migration. At Wells Dam, Sockeye are diverted into a large holding area fed by well water that can be several degrees cooler than river water. They are then transferred by net from the holding area to the anesthetic tank to a recovery tank and then to transport truck, all of which are supplied with well water although both the holding tank and anesthetic tank are small and warm up quickly if water is not regularly exchanged. After tagging, the fish are transported upstream to a boat ramp (PTAGIS release site WELSBR) to be released in shallow, warm waters. Air temperatures at Wells Dam are commonly over 35°C. In comparison, at the Bonneville Dam facility, the air temperature rarely exceeds 25°C, water temperatures in anesthetic and recovery tanks are similar to that in the river, there is no need to net Sockeye Salmon, and fish are released directly into the river.

When conversion rates are calculated by age, weighted conversion from Wells Dam to Zosel Dam are similar for one (x.1) and two (x.2) ocean Sockeye Salmon, varying by 0.2 and 4.2 percentage points for Wells- and Bonneville-tagged Sockeye Salmon (Table 46). Among Bonneville-tagged three ocean (x.3) Sockeye, only 3 out of 14 survived to Wells Dam but three of these were subsequently detected at Zosel Dam while the survival of Wells-tagged Age x.3 Sockeye was similar of those of x.1 and x.2 Sockeye.

Table 46. Conversion rates by age for Sockeye PIT tagged at Bonneville and Wells dams from Wells Dam to Zosel Dam by week in 2014 Totals are weighted by Wells Dam visual Sockeye counts. Sample sizes (n) are the total number of sockeye of each age class tagged at, or passing, Wells Dam.

	Bonneville-tagged Sockeye				Wells-tagged Sockeye			
Week	**Weight**	**% x.1 (n=139)**	**% x.2 (n=711)**	**% x.3 (n=3)**	**Weight**	**% x.1 (n=62)**	**% x.2 (n=657)**	**% x.3 (n=25)**
25&26	1.0%	-	94.1%	100.0%	-	-	-	-
27	8.9%	100.0%	80.1%	100.0%	9.9%	100.0%	65.5%	0.0%
28	30.7%	40.0%	74.1%	100.0%	30.7%	66.7%	76.1%	76.9%
29	34.9%	74.2%	84.3%	0.0%	34.9%	64.3%	79.7%	100.0%
30	16.5%	78.3%	75.7%	0.0%	16.5%	66.7%	42.9%	20.0%
31	5.9%	86.7%	48.1%	0.0%	5.9%	44.0%	34.9%	33.3%
32	2.2%	40.9%	36.4%	0.0%	2.2%	75.0%	42.9%	0.0%
Weighted Conversion Rate		**72.1%**	**76.3%**	**100.0%**		**67.3%**	**67.5%**	**64.5%**

As has been the case since 2008, there was not a significant linear relationship between run timing at Bonneville Dam and stock composition (Table 15). 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 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 percentage of Sockeye missing PIT tag detection at mainstem dams was 0.7% or less for all dams, except Ice Harbor, McNary and Rock Island dams in 2014 (Table 5). The Ice Harbor estimate of 12.5% is based on one of only eight Sockeye Salmon missing detection. Among dams with more detections, as is typically the case, Rock Island (41.5%) and McNary (3.8%) had the highest rates. 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 and an upgrade was scheduled for those PIT tag antennas in the winter of 2014/15.

Fallback rates at mainstem dams (Table 13) in 2014 ranged from 0.0% at Bonneville to over 14% at Little Goose and Lower Granite, though sample sizes were very small in the Snake River. Fallback rates were less than 4% at all Columbia River dams in 2014. Fallback rates for Sockeye tagged as juveniles returning in 2014 were generally higher, reaching a peak of 32.7% at Lower Granite Dam and 19.1% 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 there were more returning PIT tagged hatchery-origin Wenatchee Sockeye Salmon than PIT tagged Okanagan stock Sockeye Salmon 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 higher Rocky Reach and Wells dam fallback rates for previously tagged Sockeye.

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. 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 planning on testing the use of a DIDSON 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.

REFERENCES

Biomark (2012) Fish tagging methods. Retrieved online November 2013: http://www.biomark.com/Documents%20and%20Settings/67/Site%20Documents/PDFs/Fish%20Tagging%20Methods.pdf

Benson, R. and A. Warman. 2012. Okanagan Sockeye smolt migration from suwiẁs [Osoyoos Lake] and q̓awst̓ikʷt [Skaha Lake] 2010 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 28 pp.

CBFWA (Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee. 1999. PIT tag marking procedures manual. CBFWA. Portland. 26 pp.

Chapman, D.W. 1986. Salmon and steelhead abundance in the Columbia River in the 19th century. Transactions of the American Fisheries Society 115:662-670.

DART (Columbia River Data Access in Real Time). 2014 and 2015. Online at: http://www.cbr.washington.edu/dart/dart.html

FPC (Fish Passage Center). 2014 and 2015. Adult fish counts online at: http://www.fpc.org.

Fryer, J.K. 1995. Columbia Basin Sockeye Salmon: causes of their past decline, factors contributing to their present low abundance, and the future outlook. PhD dissertation. University of Washington, Seattle. 272 pp.

Fryer, J.K. 2006. Identification of Columbia Basin Sockeye Salmon stocks in 2005. Columbia River Inter-Tribal Fish Commission Technical Report 06-04. Portland.

Fryer, J.K. 2007. Use of PIT tags to determine upstream migratory timing and survival of Columbia Basin Sockeye Salmon in 2007. Columbia River Inter-Tribal Fish Commission Technical Report. Portland.

Fryer, J.K. 2009. Use of PIT tags to determine upstream migratory timing and survival of Columbia Basin Sockeye Salmon in 2008. Columbia River Inter-Tribal Fish Commission Technical Report. Portland.

Fryer, J.K.., H. Wright, S. Folks, and K. Hyatt. 2010. Studies into factors limiting the abundance of Okanagan and Wenatchee Sockeye Salmon. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00.

Fryer, J.K.., H. Wright, S. Folks, and K. Hyatt. 2011. Studies into factors limiting the abundance of Okanagan and Wenatchee Sockeye Salmon in 2010. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00.

Fryer, J.K.., H. Wright, S. Folks, and K. Hyatt. 2013. Studies into factors limiting the abundance of Okanagan and Wenatchee Sockeye Salmon in 2012. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00.

Fryer, J.K.., H. Wright, S. Folks, and K. Hyatt. 2014. Studies into factors limiting the abundance of Okanagan and Wenatchee Sockeye Salmon in 2013. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00.

Fulton, L.A. 1970. Spawning areas and abundance of steelhead trout and coho, Sockeye, and chum Salmon in the Columbia River Basin-past and present. National Marine Fisheries Service Special Scientific Report (Fisheries) 618.

Hess, J.E., N.R. Campbell, A.P. Matala, S.R. Narum. 2013. 2012 Annual Report: Genetic Assessment of Columbia River Stocks. U.S. Dept. of Energy Bonneville Power Administration Report Project #2008-907-00.

Hess, J.E., R. Nathan, A. P. Campbell,.D.J. Matala, J. Hasselman and S.R. Narum, 2015. Genetic Assessment of Columbia River Stocks, 4/1/2014 - 3/31/2015 Annual Report, 2008-907-00

Hyatt, K. D., D.J. Rutherford, T. Gjernes, D.P. Rankin, and T. Cone. 1984. Lake Enrichment Program: juvenile Sockeye unit survey guidelines. Can. Ms. Rep. Fish. Aquat. Sci. No. 1796.

Hyatt, K., Machin, D., Stockwell, M., Wright, H., Wiens, L., and Askey, P. (In prep.). Okanagan Fish and Water Management Tools Project Assessments: Brood Year 2014 Salmon (*Oncorhynchus nerka*) Abundance and Biological Traits. Report to file: JSIDS-SRe01-16. Salmon in Regional Ecosystems Program, Fisheries and Oceans Canada, Nanaimo, B.C. V9T 6N7

Hyatt, K. D. and D. P. Rankin. 1999. A habitat based evaluation of Okanagan Sockeye Salmon escapement objectives. Canadian Stock Assessment Secretariat Research Document. 99/191. 59p. Available from www.dfo-mpo.gc.ca/csas/CSAS/English/Research_Years/1999/

Hyatt, K. D. and M. M. Stockwell. 2009. Okanagan fish and water management tool project assessments: Record of management strategy and decisions for the 2006-2007 fish-and-water year. Can. Ms. Rep. Fish. Aquat. Sci. No. 2913, 65p.

LaHood, E.S., J.J. Miller, C. Apland, and M.J. Ford. 2008. A rapid, ethanol-free Tissue Collection Method for Molecular Genetic Analyses. Transactions of the American Fisheries Society 137:1104-1107.

Langford, T.E., J.M. Fleming and N.P.James, 1997. The tracking of Salmonids in the Afon Seiont River System, using ultrasonic tagging techniques. Central Electricity Research Laboratories, Lab. Note RD/L/N51/77, 16 p.

Luikart, G., P. R. England, D. Tallmon, S. Jordan and P. Taberlet. 2003. The power and promise of population genomics: from genotyping to genome typing. Nature Reviews. Genetics 4(12):981-994.

Naughton, G.P., C.C. Caudill, M. L. Keefer, T.C. Bjornn, C. A. Peery, and L.C. Stuehrenberg. 2005. Late-season mortality during migration of radio-tagged adult Sockeye Salmon (*Oncorhynchus nerka*) in the Columbia River. Canadian Journal of Fisheries and Aquatic Science. 62: 30-47.

Northwest Power Planning Council (NPPC). 1986. Council staff compilation of information on Salmon and steelhead losses in the Columbia River Basin. Portland.

PTAGIS (Columbia Basin PIT Tag Information System). 2014. PIT tag marking procedures manual. Online at http://www.ptagis.org.

Quinn, T.P., Hodson, S. and Peven, C. 1997. Temperature, flow, and the migration of adult Sockeye Salmon (*Oncorhynchus nerka*) in the Columbia River. Canadian Journal of Fisheries and Aquatic Science. 54: 1349-1360.

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 2014

Dam, Site, Tag Type, and Number		Antenna and Probability of Detection at Antenna				Overall Detection Probability
Bonneville	**N**	**1**	**2**	**3**	**4**	
BO1 (Oregon)	25	96.0	100.0	100.0	100.0	100.0
BO4 (Washington)	1369	99.3	99.1	99.1	100.0	100.0
The Dalles						
TD1 (Oregon)	1162	100.0	100.0			100.0
TD2 (Washington)	131	100.0	98.5			100.0
McNary	**N**	**1**	**2**	**3**		
MC1 (Oregon)	511	99.4	100.0			100.0
MC2 (Washington)	649	100.0	99.8	95.5		100.0
Priest Rapids	**N**	**Upper**	**Lower**			
West	361	100.0	97.1			100.0
East	771	69.2	99.7			100.0
Rock Island	**N**	**Upper**	**Lower**			
Left	270	77.0	98.2			99.6
Middle	114	81.6	94.7			99.0
Right	39	79.5	59.0			91.6
Rocky Reach	**N**	**160**	**Upper**	**Lower**		
Right	888	99.4	99.8	98.8		100.0
Wells	**N**	**Upper**	**Lower**			
Left-	383	100.0	100.0			100.0
Right	492	99.8	99.8			100.0
Tumwater	**N**	**Upper**	**Lower**			
Left	175	100.0	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 2014.

Dam	Left Bank	Right Bank	Center
Bonneville	0.8%	99.2%	
The Dalles	89.9%	10.1%	
McNary	43.5%	56.5%	
Priest Rapids	68.1%	31.9%	
Rock Island	63.8%	9.2%	27.0%
Wells	43.8%	56.2%	

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 2014 (Hyatt et al., in preparation).

Location	Fishery Type	Totals
Zone 1-5	Commercial	306
Zone 6	Commercial, Ceremonial and Subsistence	31,055
Priest Rapids Tailrace	Wanapum Ceremonial and Subsistence	814
Lake Wenatchee	Sport	16,255
Washington State Recreational	Estuary-Priest Rapids	1,775
	Priest Rapids to Rocky Reach	4,118
	Rocky Reach to above Wells Dam	25,765
Colville Harvest (Lake Pateros and Okanogan River)	Colville (all fisheries)	20,000
Canada Okanagan Basin	Okanagan Nation Alliance Communal	10,102
	Okanagan Nation Alliance Economic Demo	25,986
	Recreational	8,004
Priest Rapids Dam	Yakama Broodstock Removals[15]	10,000

[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
158	Fifteenmile Ck at Eightmile Cr	At the confluence of Eightmile and Fifteenmile Creeks. Site is on private land.
ACB	Asotin Cr at Cloverland Bridge	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.
AFC	Asotin Creek ISA at North/South fk junction	Instream detectors on Asotin Creek at the junction of the North and South forks.
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 consisting of a tandem array 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.
BPC	Bonaparte Creek Instream Array	On Bonaparte Creek, which enters the Okanogan River at RKM 91.2, within the city of Tonasket, WA. Located 0.08 km from the confluence with the Okanogan River.
BR0	Bridge Creek Gauge	Located near the USGS flow gauge site on Bridge Creek.
BR1	Bridge Creek Kiosk	Located at the John Day Fossil Beds National Monument on Bridge Creek.
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).
BVC	Beaver Creek, Methow River	In-stream arrays on Beaver Creek, Methow River Basin.
CAL	Carson NFH Adult Return Ladder	Hatchery adult spring Chinook return ladder from the Wind River to Carson NFH.
CCP	Catherine Creek Acc. Pond	Catherine Creek Acclimation Pond
CCW	Catherine Creek Ladder/Weir	Instream detection array located in the adult return fish ladder at the Catherine Creek weir.
CFF	Castile Falls Fishway	Castile Falls Fishway.
CFJ	Clark Flat Acclimation Ponds	Clark Flat Acclimation Pond outfall.
CHL	Lower Chiwawa River	Chiwawa River rkm 1, located between the Chiwawa smolt trap and the Chiwawa Acclimation Ponds.
CHP	Chiwawa Acc. Pond	Chiwawa Acclimation Pond, Wenatchee River Basin
CHU	Upper Chiwawa River	Chiwawa River rkm 12, located above the Forest Road 62 bridge and below Alder Creek.
CLC	Clear Creek near Kooskia NFH	Instream detection array located in lower Clear Creek, a tributary to the Clearwater River, just downstream of Kooskia National Fish Hatchery.
COC	Cow Creek ISA at stream mouth	Instream detectors on Cow Creek at river km 0.5.
CRU	Upper Chewuch Instream Array	Instream PIT tag interrogation site at RKM 28.35 on the Chewuch River.
CRW	Chewuch River above Winthrop	Chewuch River at river km 1, above Winthrop, WA.
DBH	Buck Hollow Ck Deschutes Trib	Instream detection array in Buck Hollow Creek, a tributary to the Decshutes River.
DBO	Bakeoven Cr Deschutes Trib	The site is approximately 1/4 mile from the mouth of Bakeoven Creek. Site is on private land.
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.
EHL	Entiat NFH Adult Ladder	This adult interrogation site is located in the Entiat National Fish Hatchery adult ladder.
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.
EWC	Early Winters Creek rkm 0.36	This site is located at rkm 0.36 on Early Winters Creek (Methow River Basin), located near Early Winters Campground.
FDC	Feed Canal	Feed Canal, on the Umatilla River at rkm 47.
FDD	Feed Diversion Dam	Feed Diversion Dam, at Umatilla River rkm 47.
GOA	Little Goose Fish Ladder	Adult Fishway at Little Goose Dam.
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.
HLM	Potlatch River near Helmer	Potlatch River near Helmer.
HYC	Hayden Creek Instream 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.

Table A4 continued.

Site Code	Site Name	Site Description
ICL	Lower Icicle Instream Array	Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA.
IR1	Lower Imnaha River ISA at km 7	Lower Imnaha River at river km 7 (N 45.761162, W -116.750658).
IR2	Lower Imnaha River ISA at km 10	Lower Imnaha River at river km 10 (N 45.742839 W -116.764563).
IR3	Upper Imnaha River ISA at km 41	Upper Imnaha River at river km 41 (N 45.49004 W 116.80393).
JCJ	Jack Creek Acclimation Pond	Jack Creek Acclimation Pond outfall.
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 at 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.
LAP	Lapwai Creek, near its mouth	In-stream detection system consisting of three arrays located in Lapwai Creek.
LBT	Little Bridge Creek (Twisp R.)	The site is on Little Bridge Creek, just upstream (200m) from its confluence with the Twisp 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.
LMA	Lower Monumental Adult Ladders	This interrogation site is in both ladders at Lower Monumental Dam.
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.
LMT	Lower Mainstem Teanaway River	Instream array at km 0.4 on the Teanaway River, upper Yakima River Basin.
LNF	Leavenworth NFH Adult Ladder	Located in the Leavenworth National Fish Hatcheries adult ladder and holding pond.
LOR	Lost River at rkm 0.81	A permanent instream PIT tag detection system located at rkm 0.81 on the Lost River (Methow River Basin), located near the Lost River Airport.
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.
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.
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.
MDR	McDonald Road Bridge	Middle Walla Walla River at McDonald Road Bridge.
MIS	Mission Creek	This is an instream interrogation system approximately 0.1 kilometers upstream from the mouth of Mission Creek.
MJ1	Middle Fork John Day Array	The Middle Fork John Day Array is near the current confluence with Mosquito Creek on Malheur National Forest Service Land.
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	On the outlet of the Washington Department of Fish and Wildlife (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.
MWF	Whitefish SC in Methow River	Site is at the entrance and exit of Whitefish Island side channel (rkm 76).
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.
NFT	North Fork Teanaway River	Located at rkm 0.2 on North Fork Teanaway river near Cle Elum, WA.
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.
OKL	Lower Okanogan Instream Array	Site at RKM 24.9 on the mainstem Okanogan River, upstream of Chiliwist area in Okanogan County.
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.

Table A4 continued.

Site Code	Site Name	Site Description
PES	Peshastin Creek	Instream interrogation system at rkm 3 on the Peshastin River (Wenatchee River Basin), located just below the bridge at Smithson's property.
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.
SA1	Salmon Creek Instream Array	Salmon Creek, 2.9 km upstream of the confluence with the Okanogan River.
SAT	Lower Satus Creek	On Satus Creek approximately 1700 meters upstream from the confluence of Satus Creek with the Yakima River at rkm 112, based on 2011 aerial photography.
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.
SHK	Shitike Creek PIT Array	he array is located across the tailout of a pool created by a bridge (known as the Scale Bridge) that is used by logging truck to deliver lumber to the Warm Springs Mill.
SJ1	SF John Day (Mid)	Located on the South Fork John Day River south of Dayville on the PW Schneider Wildlife Management Area (ODFW).
SJ2	SF John Day (Murderer's)	Located on the South Fork John Day River south of Dayville. This site is on property split between the PW Schneider Wildlife Management Area (ODFW) and Bureau of Land Management at the confluence of the South Fork John Day River and Murderers Creek.
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.
SWT	Sweetwater Cr. near its mouth	Approximately 0.1 kilometers upstream from the mouth of Sweetwater Creek.
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.
TFH	Tucannon Fish Hatchery	The Tucannon Fish Hatchery site is located about 200 feet above the Tucannon Fish Hatchery Adult Trap and Water Intake System on the Tucannon River, at River Kilometer 59.4.
TMF	Three Mile Falls Dam Combined	Adult Fishway and Juvenile Bypass/subsampling facility at Three Mile Falls Dam.
TOP	Lower Toppenish Creek	On Toppenish Creek located approximately 1700 meters upstream from the confluence of Toppenish Creek with the Yakima River at rkm 130, based on 2011 aerial photography.
TR1	Lower Trout Cr - Deschutes	Lower Trout Creek is located at RKM 0.7 upstream from the confluence with the Deschutes River on privately owned land.
TR2	Trout/Antelope Cr - Deschutes	Trout and Antelope Creek array is located at RKM 20.7 upstream from the confluence with the Deschutes River on privately owned land.
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	Lwr White Creek, Klickitat Bsn	This is an instream interrogation system in White Creek (Klickitat River Basin) approximately 150 meters upstream from the mouth.
WR1	Wallowa River at river km 14	Instream array located in the Wallowa River, Oregon rkm 522.271.131.014 (N 45.633769 ° W -117.73369°).
WRU	Upper Wind River (WA) rkm 30	At rkm 30 of the Wind River, WA. The site is at the FR3065 bridge over the Wind River.
WSH	Warm Springs Hatchery	Adult Fishway at Warm Springs NFH.
WSR	Warm Springs River PIT Array	The Warm Springs River PIT tag array is installed end-to-end across the entire river channel.
WTL	White River, Wenatchee Basin	A permanent instream PIT tag interrogation site at RKM 2.88 on the White River.
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.
YHC	Yellowhawk Creek	Yellowhawk Creek in-stream detection site, between Mill Creek and Walla Walla R.
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

Okanagan Sockeye Smolt Migration from suwiẃs [OsoyoosLake] and q̓awst'ik'ʷt [Skaha Lake] – Brood Year 2012

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Prepared for:
Skaha Lake Sockeye Salmon Re-introduction Program
Brood-year 2012
Grant and Chelan County Public Utility district

December 2014

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Executive Summary

Okanagan Nation Aquatic Enterprises (OAE) conducted sampling to determine run timing and size at age of out migrating Sockeye (*Oncorhynchus nerka*) smolts as they leave q̓awst'ik'ʷt[16] [Skaha Lake] and move through suwiẁs [Osoyoos Lake]. In 2012, approximately 8,200 adult Sockeye were able to enter q̓awst'ik'ʷt and spawn in Penticton Channel. The population of Sockeye smolts in q̓awst'ik'ʷt was comprised entirely of naturally produced juveniles. q̓awst'ik'ʷt out-migrating smolts were monitored with two rotary screw traps (RSTs) located approximately 300m downstream of the Skaha Lake Outlet Dam. suwiẁs and q̓awst'ik'ʷt out-migrating smolts were monitored using a floating fyke net set off of the Highway 3 Bridge located in a narrow passage between the North Basin and Central Basin of suwiẁs.

Smolt out-migration timing was determined for both q̓awst'ik'ʷt and suwiẁs. Observed peak migration for q̓awst'ik'ʷt smolts occurred on 25 April, 2014; however, it is uncertain whether peak migration was captured during the sampling window as sampling was terminated on 02 May due to high flows. Peak migration for suwiẁs smolts occurred on 05 May, 2014. Skaha smolts (n = 2,825) were primarily aged 1.0 with a mean length and weight of 10.5 cm (± 0.01) and 12.4 g (± 0.04), respectively. suwiẁs smolts (n = 4,377) had a mean length of 10.5 cm (± 0.05) and a mean weight of 5.6 g (± 0.13) Expected run size of out-migrating smolts from q̓awst'ik'ʷt was the lowest since the re-introduction program began, however, the smolt run was from wild parental stock.

[16] Throughout this report the proper Okanagan name written in N'Syilxcen will be used to identify locations

Acknowledgements

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List of Okanagan Place Names

Okanagan Place Names	(Okanagan-English Translation)
nxˇʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
suwiẁs	Osoyoos Lake
q̓awst'ikʷt, also known as t̓iwcən	Skaha Lake
akspaqmix	Vaseux Lake
nʕaylintən	McIntyre Dam
sxˇʷəxˇʷnitkʷ	Town of Okanagan Falls
Kłusxənitkʷ	Okanagan Lake
akłxʷminaʔ	Shingle Creek

1.0 INTRODUCTION

The 2012 brood year is the ninth year of the Okanagan Nation Aquatic Enterprises (OAE) 12-year Skaha Lake Experimental Sockeye Re-introduction Program. During the 2012 spawning run, approximately 8,000 Sockeye spawners (*Oncorhynchus nerka*) swam over the Skaha Lake Outlet Dam and were able to spawn in Penticton Channel (Benson 2014). As a result, hatchery-raised Sockeye fry were not released into q̓awst'ik'ʷt [Skaha Lake], as in past years. In June 2013, 837,800 hatchery fry were released into suwiẁs [Osoyoos Lake]. Approximately 8.5 million wild sockeye fry entered the lake in May-June 2012 (McQueen et al. 2014). Roughly 3.6 million survived to become pre-smolts (2.7 % egg-to-presmolt survival). Juvenile Sockeye spend one year in q̓awst'ik'ʷt and suwiẁs [Osoyoos Lake] before migrating to the ocean. The migration typically begins in early spring. Understanding migration patterns and biological traits of Sockeye smolts from both lakes is crucial to monitoring and evaluating the reintroduction program.

Specific objectives of the smolt migration program are as follows:

- To determine the migration timing, size, and age structure of Sockeye smolts leaving q̓awst'ik'ʷt, and
- To determine the migration timing, size, and age structure of wild and hatchery-origin Sockeye smolts as they migrate through suwiẁs.
- To capture q̓awst'ik'ʷt and suwiẁs smolts for Passive Integrated Transponder (PIT) tagging as part of a juvenile out of basin survival study.
- To pilot test a second RST site on Penticton Channel to assess the logistics of installing and maintaining the RST, and to test the trap efficiency for capturing emerging nerkid fry in the Channel.

Pilot studies were conducted 2010 – 2012 to assess the efficacy of gears used to monitor smolt populations at Osoyoos Lake Narrows. The objective of the pilot study is validation of methodology and to correct for possible uncertainties associated with gear selectively (Bussanich et al. 2010; Benson et al. 2011; Benson and Warman 2012).

1.1 Study Area

q̓awst'ik'ʷt smolts leave the lake and pass through Skaha Lake Outlet Dam, then migrate down q̓awsitkʷ [Okanagan River] through akspaqmix [Vaseux Lake], nʕaylintən [McIntyre Dam], and suwiẁs (Figure 1). Sockeye that rear in the North Basin of suwiẁs begin outmigration at similar times as q̓awst'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. The

smolts continue their journey downstream in q̓awsitkʷ, which flows into the main-stem of nxˇʷəntkʷitkʷ [Columbia River]. Smolts must migrate through nine hydroelectric dams to reach the Pacific Ocean.

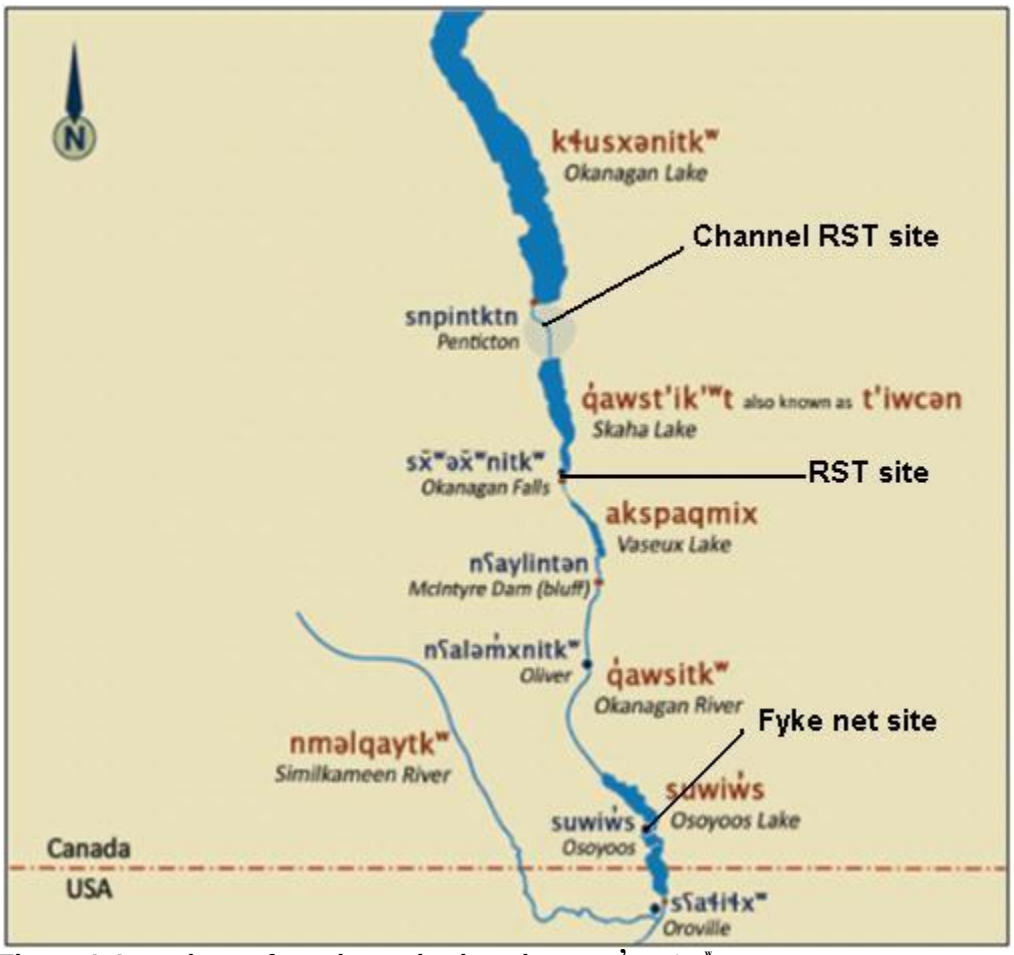


Figure 1. Locations of smolt monitoring sites on q̓awsitkʷ.

The Rotary Screw trap (RST) site is located approximately 300 m downstream of the Skaha Lake Outlet Dam in sxˇʷəxˇʷnitkʷ [Town of Okanagan Falls]. The suwiẁs study site is located at the Highway 3 Bridge which crosses the Osoyoos Lake Narrows downstream of the natural spawning grounds below nʕaylintən. The monitoring program is similar to that in previous years (Tonasket et al. 2005; Walsh et al. 2006; Benson and Wiens, 2007; Long et al. 2008; Folks and Wiens, 2009; Bussanich et al. 2010; Benson et al. 2011; Benson and Warman 2012; Benson and Stevens 2014).

The second RST site was located in Penticton Channel, between Kłusxənitkʷ (Okanagan Lake) and q̓awst'ikʷt (Figure 1). The RST was anchored to the Fairview Bridge, slightly downstream of the confluence with akłxwminaʔ (Shingle Creek).

2.0 METHODS

2.1 Smolt Capture and Migration Timing

Typically, the timing of smolt migration in Sockeye rearing lakes range from April to early July (Burgner 1991). However, for most southern lakes free of ice, migration generally starts in the early part of that period and is typically over by the time temperatures reach 10° C. Given the warm temperatures in the Okanagan Valley lakes, sampling commenced 25 March, 2014.

2.2 Skaha Lake Sockeye Smolts

2.2.1 Rotary Screw Trap (RST) Operation

Two RSTs (cone size = 2.4 m in diameter at the opening) were used to sample out-migrating q̓awst'ik'ʷt smolts during the spring of 2014. As in previous years, an index RST was installed near the west bank of the river. In order to increase capture efficiency, a second RST was installed in the thalweg of the river, immediately adjacent to the index RST (Photo 1). The traps were held in place with ½" aircraft cable strung across the river and secured to a tree and a metal eyelet drilled into the bedrock. Warning signs were installed upstream to alert the public of the RST's presence.

Photo 1. Rotary screw traps (RSTs) set up at the outlet of ʔqawst'ik'ʷt during the spring of 2014.

Both RSTs were installed 25 March, 2013 and fished 24 hours for the first night. Cones were raised for five days, then lowered and fished for 24 hour periods every other day until 21 April when daily catches exceeded 100 smolts in either trap. The thalweg RST was demobilized on 24 April due to damage to the main axle. Both RSTs were equipped with a hub odometer in order to calculate a CPUE (catch per unit effort) with effort measured in linear distance of water sampled. The hub odometer stops recording when the cone stops turning (e.g. debris jam) and allows for more accurately estimating adjustments to CPUE in lieu of non-operational periods. Trap boxes were checked each morning that traps were operational. Fishes in the trap boxes were identified, enumerated, and then released downstream. A sub-sample was collected for bio-sampling at the OAE aging lab. On several nights, an additional sub-sample of smolts was kept in kitoi boxes downstream of the RSTs for Passive Integrated Transponder (PIT) tagging (see Folkes et al., in prep). The Index trap was demobilized for the season by 2 May because extremely high flows and the likely damage to the trap.

The Penticton Channel RST (cone size = 2.4 m in diameter) was tested to capture and sample emerging nerkid fry. The trap was situated 30 m downstream of Fairview Bridge closest to the

east bank. Aircraft cable (3/8" diameter) was wrapped around the east and centre bridge pilings to create anchor loops around each piling. A third cable was strung across and attached to the two anchor points. The RST was then attached to the third cable using a custom made cable bridle. When operational, the RST was situated approximately 7 m from the east bank (Photo 2). Warning signs were installed upstream to alert the public of the RST's presence.

Photo 2. Penticton Channel RST set up downstream of Fairview Bridge during the spring of 2014.

2.3 suwiẃs Sockeye Smolts

The fyke net configuration consisted of a 28 m long beach seine, 4 m wide in the middle and tapering to 0.7 m on each end. The net panels were composed of 0.5 cm, 1 cm, and 2 cm stretched mesh. The central panel was made with the smallest mesh and progressed to larger mesh towards each end. A 2 m x 2 m floating trawl net was attached to the central panel and tapered down to a 10 cm diameter cod end. The trawl net was 5.5 m in length and was constructed of progressively smaller mesh sizes (4 cm, 2 cm, 1 cm, 0.5 cm) toward the cod end. The trawl net funneled into a 0.6 m x 0.35 m x 0.3 m aluminum trap box (Figure 2). The floating trawl net was set at the Osoyoos Lake Narrows directly downstream of the Highway 3 Bridge in

Osoyoos, using the bridge pilings as anchor points (Photo 2). The fyke net set-up was similar to previous year's studies (Benson and Wiens 2007; Long et al. 2008; Folks and Wiens 2009; Bussanich et al. 2010; Benson et al. 2011; Benson and Warman 2012; Benson and Stevens 2014).

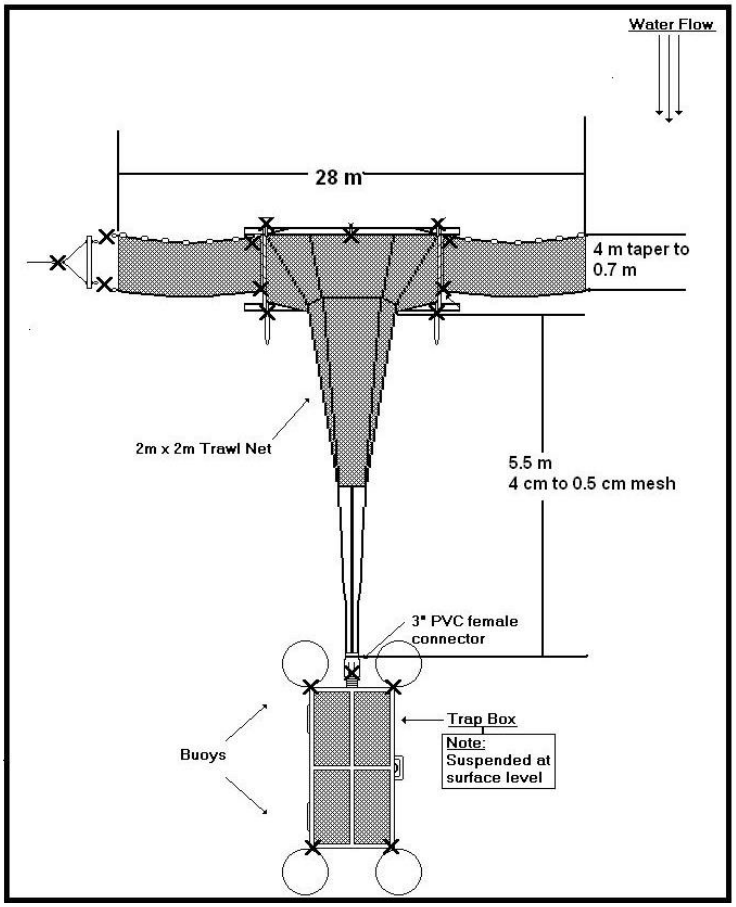


Figure 2. suwiẁs fyke net schematic diagram.

Photo 3. suwiẇs (Osoyoos Lake) study site and fyke net configuration.

Sampling was conducted every two to seven nights (with sampling frequency increased to every other night during peak migration) from 02 April to 04 June, 2014, for a total of 27 sampling nights. The fyke net was typically deployed from 19:00 to 20:00 and checked once every hour. Smolts were enumerated and released directly downstream of the fyke net. A small sub-sample was collected for bio-sampling, and on certain nights a number of smolts were held in kitoi boxes for PIT tagging (see Benson et al. 2014; Folks et al., in prep). The net was removed at 02:00 each night. It was estimated that approximately 3,676,900 wild and hatchery Sockeye smolts would be migrating out of suwiẇs (McQueen et al. 2014).

2.4 Smolt Biological Sampling

2.4.1 Lethal Sampling

We derived a minimum of 4,000 Sockeye smolts to be sampled representatively from q̓awst'ik'ʷt. Lethal samples were collected daily from the RSTs and transported to the lab for sampling. The smolts were sampled for presence of marks, fork length, weight, scales, and a sub-sample for otolith collection, preserved individually in ethanol (95%) and stored in a fridge. Based on the predicted number of out-migrant smolts, we derived a minimum of 4,000 Sockeye smolts to be sampled representatively from suwiẁs.

Typically, fork length and otoliths analysis of thermal marks are two methods used to distinguish between hatchery and wild smolts (Benson and Wiens 2007; Long et al. 2008; Folks and Wiens 2009; Bussanich et al. 2010; Benson et al. 2011; Benson and Warman 2012; Benson and Stevens 2014). Hatchery smolts are usually larger than wild smolts, and it is usually possible to use length-frequency distribution to differentiate between these two populations. Hatchery fry are marked with thermal bands on otoliths (Benson et al. 2014), and it is necessary to check for otolith thermal marks to differentiate the two populations when length ranges overlap.

The sagittae otoliths were removed from the smolts and cleaned of tissue using water. The otoliths were dried and glued sulcus-side-up to a microscope slide using Crystalbond™ 509 clear, thermoplastic cement. Mounted otoliths were polished using medium grain sandpaper or a Dremmel Tool and checked for thermal marks. Scale samples were processed by OAE lab personnel.

3.0 RESULTS

3.1 Migration Timing and Testing of Monitoring Methods

3.1.1 ʔawst'ikʷt Sockeye Smolts

On 24 April, field personnel discovered the thalweg RST had experienced severe damage to the main axle supporting the cone. This RST was inoperable due to the damage, and the trap was removed for the season. On 02 May, the index RST was removed due to anticipated flow increases from Skaha Lake Outlet Dam and increased risk of damage to the trap. The early termination of the sampling program resulted in an incomplete assessment of smolt run timing.

The first smolt capture occurred on 01 April, 2014. Observed peak migration occurred on 25 April at the Index RST, with a total CPUE of 39.4 smolts per hour (Figure 3). The peak catch at the Thalweg RST occurred 23 April with a CPUE of 11.1 smolts per hour. A total of 5,564 smolts were captured in the RSTs during the spring of 2014. The first major catch of smolts was one week later than in 2013 (Benson and Stevens 2014). Total catch was significantly lower this year; peak catch from the Index RST was 887 versus a peak catch of 3,356 in 2013. Total catch in 2013 was 81,297. Other fish captured in the RSTs this year included 12 Redside Shiner (*Richardsonius balteatus*), six Kokanee, six Black Bullheads (*Ameiurus melas*), five Bass (*Micropterus spp.*), three Northern Pikeminnow (*Ptychocheilus oregonensis*), three Yellow Perch (*Perca flavescens*), one Pumpkinseed (*Lepomis gibbosus*), one sculpin (*Cottus spp.*), and one Rainbow Trout (*Oncorhynchus mykiss*).

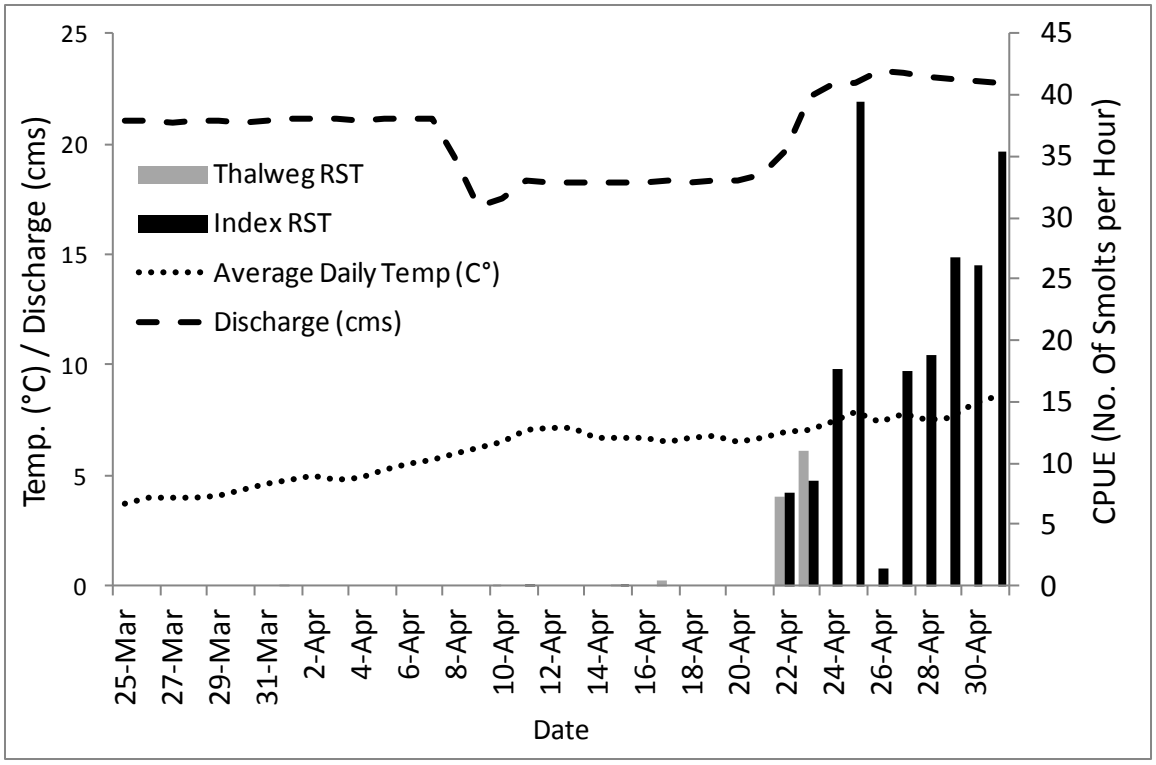


Figure 3. CPUEs for Index and Thalweg RSTs plotted with temperature and discharge of the ḳawsitkʷ at sxˇʷəxˇʷnitkʷ during the smolt out-migration of 2014.

3.1.2 Penticton Channel Nerkid Fry

The Penticton Channel RST was operational 31 March to 01 May, 2014. The RST was operational four days per week until significant numbers were captured. From 22 April to 1 May, the RST fished continuously. Increased water release from Okanagan Lake Dam resulted in flows exceeding 32 cms on 02 May. The high flows and excessive debris in the trap reduced capture efficiency and increased the risk for crews checking the trap. We raised the RST cone on 03 May for the duration of the season.

The first nerkid fry was captured 08 April. The first significant catch occurred on 25 April (approximately 1,000 caught). Peak CPUE occurred 29 April, with a catch of 29.6 fry per hour (Figure 4). Catch rates appeared to be independent of stream flow.

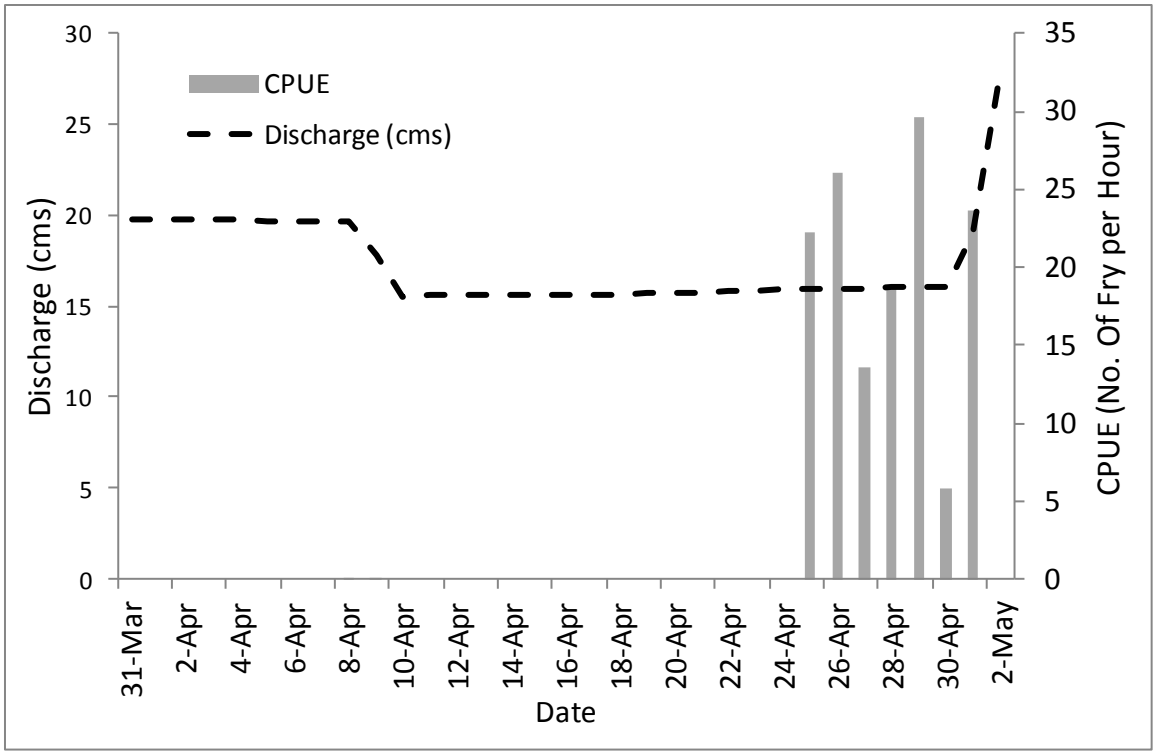


Figure 4. CPUE for the Penticton Channel RST plotted with discharge during nerkid fry emergence, 2014.

3.1.3 suwiẇs Sockeye Smolts

suwiẇs fyke net sampled a total of 27 nights from 02 April to 04 June 2014. In total, 50,762 Sockeye smolts were enumerated. The smolt counts represent a mixture of q̓awst'ik'^{w}t and suwiẇs fish with the majority being suwiẇs smolts. A large number of smolts (305) were captured the first night of sampling when water temperature was over 6°C (Figure 5). The migrating population exhibited variable high and low captures, with at least three smaller peaks before peak migration, occurring 05 May with a CPUE of 1,469 smolts per hour (total catch: 10,535) (Figure 5, Appendix 2a). Water temperatures consistently remained above 10°C after 01 May. Peak timing is likely a function of lake temperatures rather than discharge upstream in the q̓awsitk^{w}. Other fish captured in the fyke net included 68 Yellow Perch (*Perca flavescens*), 28 Bass (*Micropterus spp.*), five Black Bullhead (*Ameiurus melas*), five Northern Pikeminnow (*Ptychocheilus oregonensis*), two Rainbow Trout (*Oncorhynchus mykiss*), and two Pumpkinseed (*Lepomis gibbosus*).

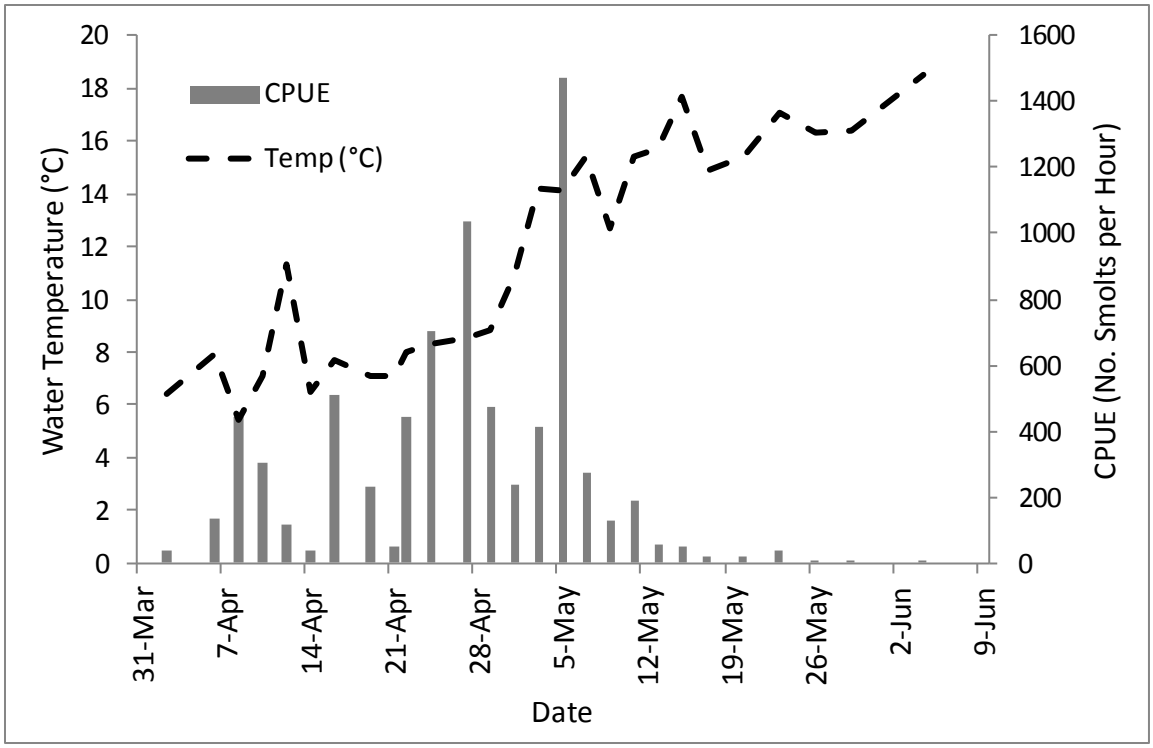


Figure 5. Fyke net CPUE and lake temperature for Sockeye smolts in suwiẁs, 2014.

3.2 Smolt Biological Sampling

3.2.1 q̓awst̓ik̓ʷt Sockeye Smolts

A total of 2,853 q̓awst̓ik̓ʷt smolts were lethally sampled out of the 5,564 smolts captured by the RST sampling. Of the lethal samples, 28 (1.0% of the sub-sample aged) were age-2 or age-3, for an adjusted lethal sample of 2,825 (Table 1). The average fork-length was 105 mm (± 0.1). The average weight was 102.4 g (± 0.04). The length-frequency histogram shows a single mode in the 105 mm length bin (Figure 6).

Table 1. q̓awst'ik'ʷt RST/ suwiẃs fyke smolt sample summary, 2014.

Area of Capture	Gear Type	Total Captured	Smolt Origin	Number of lethal samples	Mean Length (mm)	95% Confidence Interval	Mean Weight (g)	95% Confidence Interval
q̓awst'ik'ʷt	RST	5,564	Wild	2,825	105	± 0.1	12.4	± 0.04
suwiẃs	Fyke	50,762	Wild	1,874	82	± 0.2	5.7	± 0.04
			Hatchery	60	88	± 1.2	7.1	± 0.32
			Unknown	2,443	81	± 0.1	5.5	± 0.02

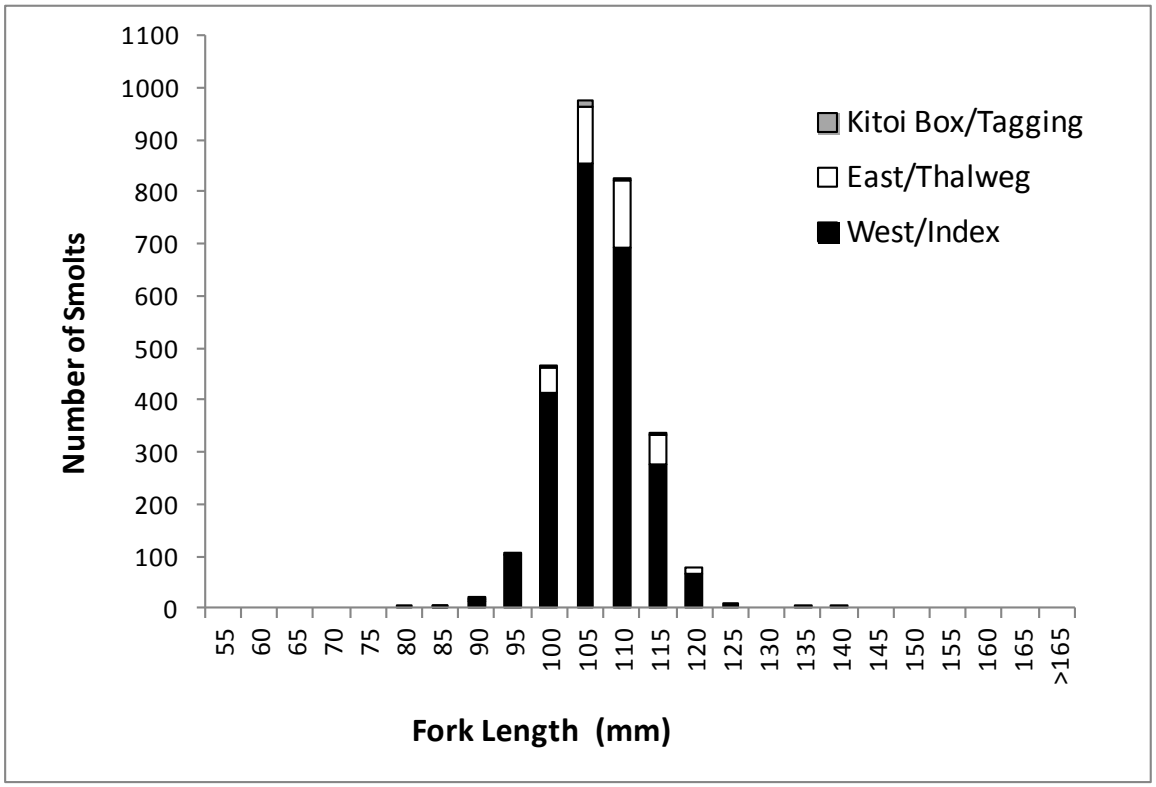


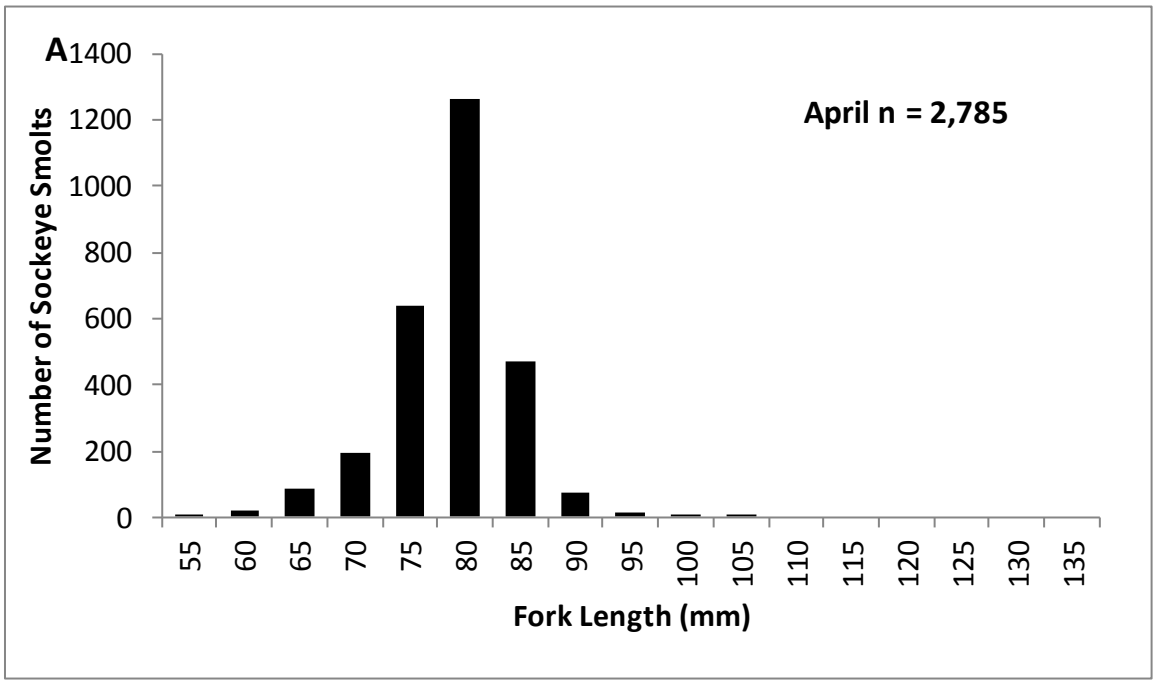
Figure 6. Length-frequency distributions of smolts captured in the RSTs at the outlet of q̓awst'ik'ʷt in 2014.

3.2.2 suwiẇs Sockeye Smolts

At the suwiẇs fyke net, a total of 50,762 smolts were captured, of which 4,420 were lethally sampled. A sub-sample (44%) of otoliths was checked for thermal marks. All fish less than 5.0 cm were classified as fry. We aged a sub-sample of fish less than 10.0 cm, and aged all fish greater than 10.0 cm to exclude age-2 fish and (presumably) Kokanee. After the fry, Kokanee, and smolts age-2 and older were filtered out of the catch, the adjusted smolt sample size was 4,377. The suwiẇs catch is separated into wild, hatchery, and unknown origin based on thermal marks. Mean length and weight for population of origin and gear type have been summarized (Table 1). The pooled mean length was 81 mm (± 0.18), and mean weight was 5.6 g (± 0.04).

Of the successfully checked otolith thermal marks, 3.1% were determined to be of hatchery origin. Typically, hatchery smolts originate in q̓awst'ik'ʷt; however, in 2013 all hatchery fry were released into suwiẇs (Benson et al. 2014). The wild smolts captured in suwiẇs represent a mix of q̓awst'ik'ʷt and suwiẇs stocks. There is currently no practical method to separate these two stocks.

We separated catches by time (early vs. late timing) and compared length-frequency histograms for each sampling method (Figure 7A and B). There does not appear to be a difference in length distribution between early and late timing.



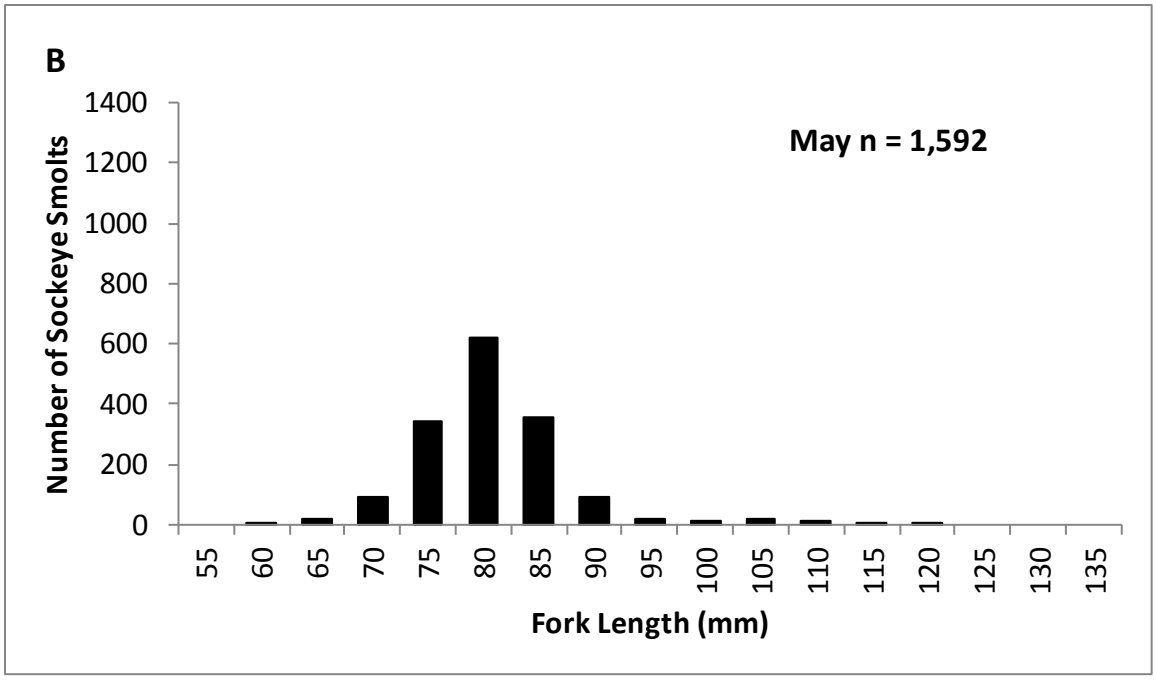


Figure 7. Length-frequency histogram of Sockeye for two time periods (A: April, B: May) in suwiẃs.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Okanagan Sockeye Smolt Migration Trends

This year, Sockeye pre-smolt numbers were the lowest in q'awst'ik'^{w}t since 2004 (Table 1) (McQueen et al. 2014). As with the 2013 smolt run, all q'awst'ik'^{w}t smolts were natural origin, being the progeny of Sockeye spawning in Penticton Channel. It is significant that, while no hatchery fry were planted in the lake in both 2013 and 2014, these brood years produced the highest and lowest number of smolts since the Re-Introduction Program started in 2004 (Table 1). Sockeye smolt out-migrant sampling conducted at the outlet of q̓awst'ik'^{w}t and in suwiẃs allowed us to determine the peak timing of migration. The peak timing for smolts in q̓awst'ik'^{w}t and suwiẃs was 25 April (observed) and 05 May, respectively.

Although the observed peak of q̓awst'ik'^{w}t outmigration was 25 April, we adjusted the peak to 30 April based on the mean run-time percentile from previous years (BY2006 – BY2008, 3 years in which sampling occurred consistently throughout duration of run). This was the fourth year (2011 – 2014) that RST sampling was terminated prematurely due to scheduled increased flows from Skaha Dam. Although RST sampling commenced 25 March, significant catches did not occur until 22 April, one week later than in 2013 (Benson and Stevens 2014). Index RST

capture rate was still high when sampling stopped on 02 May (Figure 3). Given the low total catch, delayed migration start, and early suspension of sampling, it is likely that this year's run timing only represents a fraction of the total smolt run.

The peak suwiẁs outmigration in 2013 was within the range of the previous six years (ranged from 17 April to 08 May) (Table 3). Peak timing for suwiẁs smolts was slightly later than in 2013 (24 April and 02 May) (Benson and Stevens 2014).

Table 2. Summary of q̓awst'ik'ʷt Sockeye smolt sampling, migration timing, biological traits, abundance, and origin.

Brood Year	Smolt Year	Sampling Date Start	Sampling Date End	Samples (days)	Run Timing Percentile* 25%	Run Timing Percentile* 50%	Run Timing Percentile* 75%	Total Biosample Size No.	Expected Run Size No.	Mean FL (mm)	Mean Weight (g)	Expected % of total smolts %
2002	2004	.	.	.	.	.	.	.	.	.	.	.
2003	2005	6-Apr	27-May	16	.	.	.	4	159,000	118	19.2	20
2004	2006	3-Apr	9-May	31	22-Apr	26-Apr	5-May	36	171,000	111	14.2	9
2005	2007	10-Apr	30-May	45	27-Apr	2-May	5-May	106	142,000	110	13.3	9
2006	2008	7-Apr	20-May	44	27-Apr	29-Apr	3-May	181	198,000	113	14.8	9
2007	2009	31-Mar	5-Jun	67	3-May	7-May	12-May	93	170,000	119	19.4	15
2008	2010	16-Mar	3-Jun	71	23-Apr	1-May	9-May	226	350,000	106	13.1	4
2009	2011	25-Mar	9-May	46	29-Apr	4-May	5-May	356	56,000	115	16.0	7
2010	2012	29-Mar	2-May	20	29-Apr	4-May	5-May	470	485,600	104	12.4	6
2011	2013	26-Mar	5-May	27	29-Apr	4-Apr	5-May	2,449	508,879**	100	10.2	16
2012	2014	25-Mar	2-May	19	29-Apr	4-Apr	5-May	2,825	47,163**	105	12.4	1

***Brood Year 2009 - 2012 run timing estimated using mean daily cumulative proportions, between 2006 and 2008**

**** Average of late fall and winter acoustic-trawl assessments**

Table 3. Summary of suwiẁs Sockeye smolt sampling, migration timing, biological traits, abundance, and origin.

		Sampling Date			Run Timing Percentile			Total Biosample Size	Expected Run Size	Mean FL	Mean Weight	Expected % of total smolts
Brood Year	Smolt Year	Start	End	Samples	25%	50%	75%	No.	No.	(mm)	(g)	%
2002	2004	15-Apr	11-May	6	23-Apr	23-Apr	23-Apr	343	822,000	86	5.6	.
2003	2005	7-Apr	23-May	12	20-Apr	22-Apr	26-Apr	16	620,000	88	7.3	80
2004	2006	3-Apr	23-May	34	17-Apr	23-Apr	27-Apr	1,297	1,663,000	86	6.1	91
2005	2007	19-Apr	2-Jun	15	3-May	6-May	7-May	892	1,359,000	90	7.7	91
2006	2008	2-Apr	4-Jun	44	29-Apr	1-May	10-May	871	1,999,000	82	5.9	91
2007	2009	27-Mar	7-Jun	33	21-Apr	25-Apr	5-May	210	1,000,000	100	10.3	85
2008	2010	23-Mar	2-Jun	24	18-Apr	26-Apr	2-May	2,024	7,700,000	79	4.8	96
2009	2011	23-Mar	2-Jun	27	3-May	8-May	16-May	2,800	707,000*	103	11.9	93
2010	2012	29-Mar	5-Jun	22	24-Apr	26-Apr	30-Apr	4,783	4,310,500	82	6.0	94
2011	2013	4-Apr	27-May	24	23-Apr	1-May	3-May	3,788	2,707,566**	89	7.6	84
2012	2014	2-Apr	4-Jun	27	21-Apr	27-Apr	4-May	4,377	3,676,953***	81	5.6	99

*** includes both wild (624,800) and hatchery (82,100) stock**
**** includes both wild (2,464,053) and hatchery (243,513) stock**
***** includes both wild (3,614,442) and hatchery (62,511) stock**

4.2 Monitor Run Timing, and Biological Metrics

Based on pilot studies to assess the efficacy of sampling gears in suwiẇs, the beach seine targets larger fish, while the fyke targets smaller fish disproportionately (Bussanich et al. 2010; Benson et al. 2011; Benson and Warman 2012). This effect is more pronounced at higher fish densities. However, it is likely that the statistically significant difference in length distribution between methods represents a negligible biologically significant difference. Furthermore, it will be difficult to account and correct for the size bias between gears. It is recommended that future monitoring effort be focused only on standardized fyke netting to add to time series data.

The peak smolt migration was later than in 2013 (05 May 2014 vs. 24 April/02 May, 2013). The temperature and discharge profile in q̓awsitkʷ upstream of suwiẇs was similar for 2014 and 2013 (Figures 8 and 9). Generally, peak catches seem to occur after water temperatures reach 10-12°C.

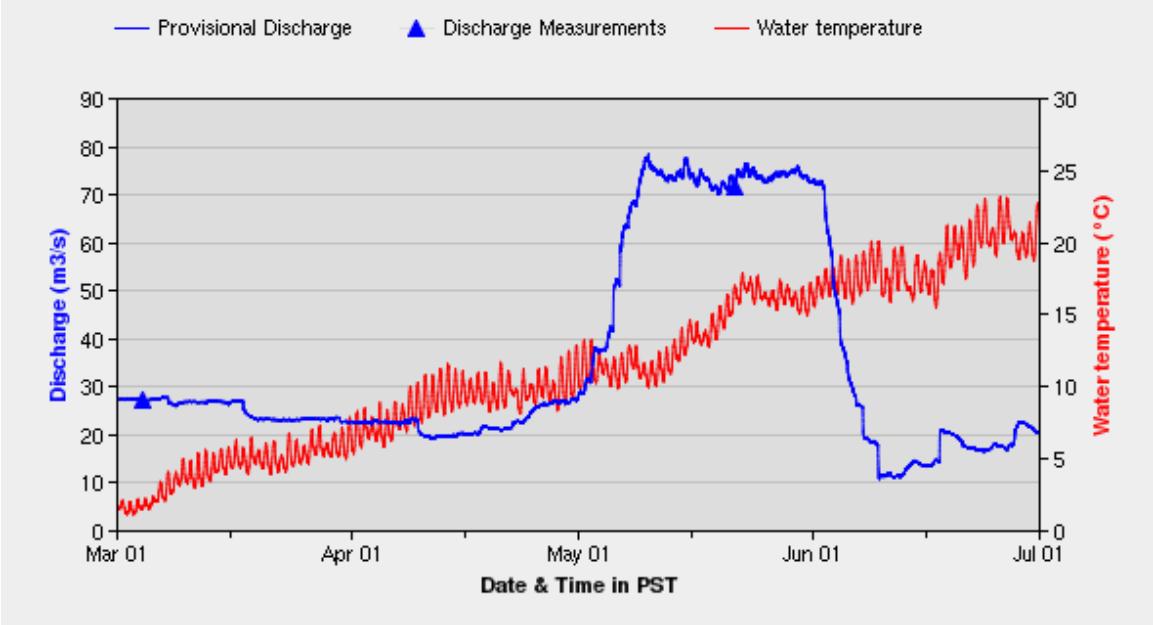


Figure 8. q̓awsitkʷ temperature and discharge upstream of suwiẇs, 2014 (WSC station # 08NM085).

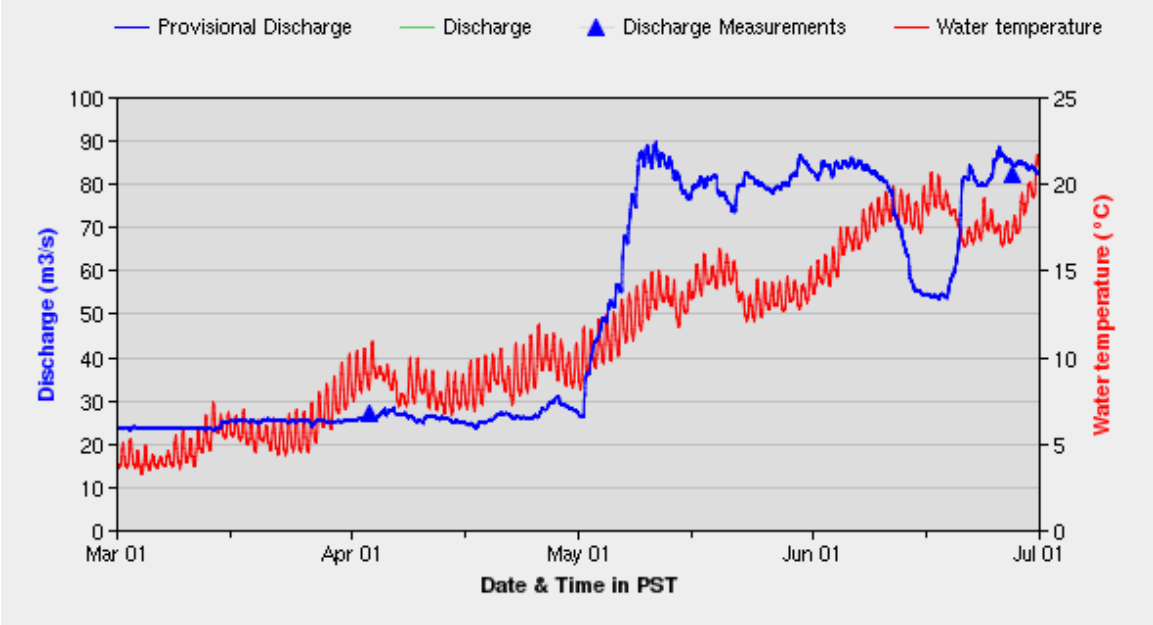


Figure 9. q̓awsitkʷ temperature and discharge upstream of suwiẇs, 2013 (WSC station # 08NM085).

We were able to successfully sample nerkid fry in the Penticton Channel RST. Attempts to sample fry with an RST in the Channel were largely unsuccessful in the past (Benson 2008; Mathieu and Kozlova 2008). Possible reasons for the unsuccessful sampling program include fry potentially escaping from the RST trap box mesh and the RST not placed in the ideal location. This year we deployed a new RST with smaller mesh, in a location downstream of known Sockeye/Kokanee spawning areas (downstream of the akɬxwminaʔ confluence).

4.5 Recommendations for 2015

Based on the results above and the lessons learned thus far, the following are recommended improvements for the 2013 program:

1. Continue to use the RSTs and fyke net as a capture platform for PIT tagging sockeye smolts for on-going out of basin survival studies.

2. Conduct Fyke net sampling at Osoyoos Narrows, taking into account the size selectivity for this sampling gear.

3. Continue to operate a second trap at sx̌ʷəx̌ʷnitkʷ to guarantee the minimum biological sample size required to characterize biological attributes (distribution, run timing, PIT tagging) of the q̓awst'ik'ʷt smolt population in 2014

4. Future studies, including mark-recapture studies using genetic markers will provide an opportunity to assess smolt migration behavior trends.

5. Due to damage cause to the RSTs during high flow, monitor the discharge daily and lift the cones and/ or remove the traps when flow nears 20 cms.

5.0 REFERENCES

Benson, R. 2008. Skaha Lake kokanee fry emergence enumeration 2007. Prepared for the Skaha Lake Sockeye Salmon Re-introduction Program - Broodyear 2006. Okanagan Nation Alliance Fisheries Department, Westbank, BC.

Benson, R. 2014. q'awst'ik'^{w}t (Skaha Lake) Kokanee Spawner Enumeration and Biological Sampling 2012. Prepared as part of the Skaha Lake Sockeye Salmon Re-introduction Monitoring and Evaluation Program: Brood Year 2012. Okanagan Nation Aquatic Enterprises Ltd. Westbank, BC. 31 pp.

Benson, R., and L. Wiens. 2007. Okanagan Sockeye smolt migration from Osoyoos and Skaha lakes, 2005 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC.

Benson, R., and A. Warman. 2012. Okanagan Sockeye smolt migration from suwiẇs [Osoyoos Lake] and q̓awst'ik'^{w}t [Skaha Lake] 2010 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 28 pp.

Benson, R., and A. Stevens. 2014. Okanagan Sockeye smolt migration from suwiẇs [Osoyoos Lake] and q̓awst'ik'^{w}t [Skaha Lake] 2011 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 24 pp.

Benson, R., A. Warman, A, and R. Bussanich. 2011. Okanagan Sockeye smolt migration from suwiẇs (Osoyoos Lake) and q'awst'ik'^{w}t (Skaha Lake) 2009 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 36 pp.

Benson, R., R. Bussanich, and A. Stevens. 2013. q̓awst'ik'^{w}t (Skaha Lake) Kokanee Spawner Enumeration and Biological Sampling 2011. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2011. Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC.

Benson, R., A. Stevens, S. Wolski, and K. Garver. 2014. Collection and Rearing of Okanagan Sockeye Salmon for the Skaha Re-introduction Program: Brood Year 2012. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2012. Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 48 pp.

Bussanich, R., R. Benson, and C. Davis. (2010). Okanagan Sockeye smolt migration from Osoyoos and Skaha lakes, 2008 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 38 pp.

Burgner, R. L. (1991). Life History of Sockeye Salmon (Oncorhynchus nerka).In C. Groot and L. Margolis (Eds.), *Pacific Salmon Life Histories*, (pp. 3-117). Vancouver: UBC Press.

Folks, S., and L. Wiens. (2009). Okanagan Sockeye smolt migration from Osoyoos and Skaha lakes, 2007 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 18 pp.

Benson, R., Folks, S., A. Stevens, and R. Bussanich. 2014. Brood Year 2012 – Sockeye smolt out of basin survival pilot study in q'awsitk^{w} (Okanagan River) – Year II. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC.

Folks, S., R. Benson, and A. Stevens. In prep. Brood Year 2013 – Sockeye smolt PIT tag out of basin survival monitoring in q'awsitk^{w} (Okanagan River). Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC.

Long, K., L. Wiens, N. Audy, and J. Pooley. (2008). Okanagan Sockeye smolt migration from Osoyoos and Skaha lakes, 2006 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC.

Mathieu, C. and T. Kozlova. 2008. Skaha Lake Kokanee Fry Emergence Enumeration 2008. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program. Broodyear 2007. Okanagan Nation Alliance, Fisheries Department, Westbank, BC.

McQueen, D., K.D. Hyatt, R. Bussanich, A. Stevens, H. Wright, D.P. Rankin, S. Lawrence, C. Mathieu, L. Wiens and R. Ferguson. Annual Report for year 2013 (2012 brood year): Evaluation of the experimental re-introduction of sockeye salmon (*Oncorhynchus nerka*) into Skaha Lake and assessment of the Osoyoos Lake pelagic food web with emphasis on juvenile sockeye. Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 107 pp

Tonasket, E., K. Long, and R.H. Wright. (2005). Okanagan Sockeye smolt migration from Osoyoos and Skaha lakes, 2003 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC.

Walsh, M., R.H. Wright., and L. Wiens. (2006). Okanagan Sockeye smolt migration from Osoyoos and Skaha lakes, 2004 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 22 pp.

APPENDIX A: ʔawstʼikʷt [Skaha Lake] Outlet RST Sockeye Smolt Capture Summary, March to May 2014.

Date	Event	Time of Event	RST	HUB Odometer	% Cone Lowered	LIVE SK - Released	LIVE SK - Held for Tagging	LIVE SK - Collected for Biosampling	DEAD SK - Collected for Biosampling	Total Catch	Comments
25-Mar-14	Lower Cone	am	West		3/4 down	0	0	0	0	0	
25-Mar-14	Lower Cone	am	East		All the way	0	0	0	0	0	
26-Mar-14	Check and Raise Cone	10:00	West	3312		0	0	0	0	0	
26-Mar-14	Check and Raise Cone	10:05	East	906		0	0	0	0	0	
31-Mar-14	Lower Cone	am	West		3/4 down	0	0	0	0	0	
31-Mar-14	Lower Cone	am	East		All the way	0	0	0	0	0	
1-Apr-14	Check and Raise Cone	9:50	West	3349		0	0	0	0	0	
1-Apr-14	Check and Raise Cone	9:50	East	933		0	0	1	0	1	
3-Apr-14	Lower Cone	11:12	West		3/4 down	0	0	0	0	0	
3-Apr-14	Lower Cone	11:12	East		All the way	0	0	0	0	0	
4-Apr-14	Check and Raise Cone	9:55	West	33822		0	0	0	0	0	
4-Apr-14	Check and Raise Cone	9:58	East	9571		0	0	0	0	0	
7-Apr-14	Lower Cone	13:43	West		3/4 down	0	0	0	0	0	axel loose from track, difficulty lowering

Date	Event	Time of Event	RST	HUB Odometer	% Cone Lowered	LIVE SK - Released	LIVE SK - Held for Tagging	LIVE SK - Collected for Biosampling	DEAD SK - Collected for Biosampling	Total Catch	Comments
7-Apr-14	Lower Cone	14:15	East		All the way	0	0	0	0	0	
8-Apr-14	Check and Raise Cone	9:35	West			0	0	0	0	0	
8-Apr-14	Check and Raise Cone	9:28	East			0	0	0	0	0	
9-Apr-14	Lower Cone	10:04	West	3410	3/4 down	0	0	0	0	0	
9-Apr-14	Lower Cone	10:04	East	977.7	All the way	0	0	0	0	0	
10-Apr-14	Check and Raise Cone	am	West	3441.7		0	0	0	0	0	no time noted for OKF RST check
10-Apr-14	Check and Raise Cone	am	East	999.2		0	0	1	0	1	no time noted for OKF RST check
11-Apr-14	Check and Raise Cone	10:40	West	3473.5		0	0	1	0	1	
11-Apr-14	Check and Raise Cone	10:50	East	1020.2		0	0	0	0	0	
14-Apr-14	Lower Cone	9:45	West			0	0	0	0	0	
14-Apr-14	Lower Cone	9:45	East			0	0	0	0	0	

Date	Event	Time of Event	RST	HUB Odometer	% Cone Lowered	LIVE SK - Released	LIVE SK - Held for Tagging	LIVE SK - Collected for Biosampling	DEAD SK - Collected for Biosampling	Total Catch	Comments
15-Apr-14	Check and Raise Cone	am	West	3496		1	0	0	0	1	*miscommunication (smolts released "b/c cone raised"???)/no check time noted
15-Apr-14	Check and Raise Cone	am	East	1042		2	0	0	0	2	*miscommunication (smolts released "b/c cone raised"???)/no check time noted
16-Apr-14	De-mobe	10:25	West			0	0	0	0	0	west cone up, hub slipping out and damaging trap
16-Apr-14	Lower Cone	10:25	East	1042.1	All the way	0	0	0	0	0	
17-Apr-14	De-mobe		West			0	0	0	0	0	
17-Apr-14	Check and Raise Cone	10:32	East	1063.5		2	0	8	0	10	
21-Apr-14	Lower Cone	17:59	West	3496	3/4	0	0	0	0	0	
21-Apr-14	Lower Cone	17:59	East	1063.7	All the way	0	0	0	0	0	
22-Apr-14	Check and Keep Fishing	12:25	West	3521		1	0	135	0	136	

Date	Event	Time of Event	RST	HUB Odometer	% Cone Lowered	LIVE SK - Released	LIVE SK - Held for Tagging	LIVE SK - Collected for Biosampling	DEAD SK - Collected for Biosampling	Total Catch	Comments
22-Apr-14	Check and Keep Fishing	11:40	EAst	1080		0	0	130	0	130	
23-Apr-14	Check and Keep Fishing	13:40	West	3556		0	105	112	0	217	
23-Apr-14	Check and Keep Fishing	13:20	East	1103		0	45	237	0	282	
24-Apr-14	Check and Keep Fishing	11:30	West	3592		167	120	101	0	388	
24-Apr-14	De-mobe		East							0	East RST had pull out, shaft broke
25-Apr-14	Check and Keep Fishing	10:05	West	3621		687	50	150	0	887	
26-Apr-14	Check and Keep Fishing	9:30	West	3655		0	0	33	0	33	water seems to be getting higher
27-Apr-14	Check and Keep Fishing	9:50	West	3691.4		119	200	100	1	420	
28-Apr-14	Check and Keep Fishing	10:00	West	3727		0	300	151	0	451	
29-Apr-14	Check and Keep Fishing	9:30	West	3762		27	300	300	0	627	
30-Apr-14	Check and Keep Fishing	12:01	West	3801.5		249	300	140	2	691	
1-May-14	Check and Keep Fishing	11:05	West	3835.9		0	100	715	0	815	

Date	Event	Time of Event	RST	HUB Odometer	% Cone Lowered	LIVE SK - Released	LIVE SK - Held for Tagging	LIVE SK - Collected for Biosampling	DEAD SK - Collected for Biosampling	Total Catch	Comments
2-May-14	De-mobe	9:55	West	3870.1		0	0	471	0	471	de-mobe for season

APPENDIX B: Osoyoos Lake Narrows Fyke Net Smolt Summary, April to June, 2014.

Date	Effort (hr)	No. Smolts	CPUE	Cum. CPUE	% Cum. CPUE	kept for PIT	Comments
2-Apr-14	7.30	305	41.8	41.8	0.6%		fry in every check
6-Apr-14	6.50	894	137.5	179.3	2.4%		
8-Apr-14	6.50	2900	446.2	625.5	8.4%		
10-Apr-14	6.50	1977	304.2	929.6	12.5%	182	smolts started to move when wind picked up
12-Apr-14	7.25	839	115.7	1045.4	14.0%		
14-Apr-14	6.75	274	40.6	1085.9	14.6%	151	calm night, no signs of schools
16-Apr-14	6.25	3182	509.1	1595.1	21.4%	202	
19-Apr-14	6.75	1575	233.3	1828.4	24.5%		
21-Apr-14	6.50	315	48.5	1876.9	25.2%	300	~ 25% run outmigration
22-Apr-14	6.50	2871	441.7	2318.6	31.1%	369	
24-Apr-14	7.00	4929	704.1	3022.7	40.6%	365	
27-Apr-14	7.00	7251	1035.9	4058.6	54.5%	400	~ 50% run outmigration
29-Apr-14	6.00	2860	476.7	4535.2	60.9%	500	
1-May-14	7.25	1709	235.7	4770.9	64.0%	502	
3-May-14	6.66	2738	411.1	5182.1	69.5%	0	
5-May-14	7.17	10535	1469.3	6651.4	89.2%		~ 75% run outmigration; approx 700 on w. wing of net
7-May-14	7.00	1905	272.1	6923.5	92.9%		water levels increased, debris increasing a bit
9-May-14	6.50	853	131.2	7054.7	94.7%		
11-May-14	7.17	1376	191.9	7246.7	97.2%		flows increased, debris in wings
13-May-14	7.00	415	59.3	7305.9	98.0%		
15-May-14	7.33	364	49.7	7355.6	98.7%		large woody debris in fyke at end, no damage
17-May-14	6.75	127	18.8	7374.4	98.9%		mostly Skaha smolts
20-May-14	7.25	145	20.0	7394.4	99.2%		lot's of fishermen
23-May-14	7.17	279	38.9	7433.3	99.7%		lot's of debris
26-May-14	7.50	66	8.8	7442.1	99.9%		filling up with lot's of debris by 2nd check
29-May-14	7.25	76	10.5	7452.6	100.0%		
4-Jun-14	6.83	2	0.3	7452.9	100.0%		
Grand	185.63	50762	7452.9				
Mean	6.88	1880	276.0				
Minimum	6.00	2	0.3				
Maximum	7.50	10535	1469.3				

APPENDIX C

Fish Passage Center Memo "Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, 2013-2015

FISH PASSAGE CENTER

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MEMORANDUM

To: Jeff Fryer, CRITFC

From: Michele DeHart

Date: November 12, 2015

Re: Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, 2013–2015.

In 2013, the CSS Oversight Committee was approached with a request to explore the feasibility of adding a long-term monitoring group for sockeye trapped and released from the Okanogan River. Upon the request from the Okanogan Nation Alliance (ONA) and the Columbia River Inter-Tribal Fish Commission (CRITFC), the CSS Oversight Committee transferred 3,000 PIT tags in 2013, 2,500 tags in 2014, and 4,000 tags in 2015 to the ONA to supplement PIT-tagging efforts at Osoyoos Lake in the spring. Similar to previous years, below are results from these exploratory efforts, followed by more specific details. Also, in response to your specific request this year, we provide an analysis of the expected improvement in the precision of estimated survival from Release to Zosal Dam and from Zosal Dam to Rocky Reach Dam

under several scenarios of improvements in the detection capabilities of the floating antenna in the Zosal Dam forebay.

- With each successive year of tagging, the total number of tags released in the Okanogan River basin has increased from 4,018 in 2013, to 5,055 in 2014, and 7,176 in 2015.
- Survival from release to Rocky Reach Dam was 0.49 in 2013, 0.57 in 2014, and 0.42 in 2015.

- Estimates of survival beyond Rocky Reach Dam were unreliable in 2013. This was partially due to the low survival from release to Rocky Reach Dam which contributed to a low number of detections of PIT-tagged fish at and below McNary Dam.
- The larger sample sizes in 2014 and 2015 allowed for the estimation of survival from Release to McNary Dam, which was 0.39 (95% CI: 0.31–0.47) in 2014 and 0.32 (95% CI: 0.22–0.42) in 2015.
- The estimated smolt-to-adult return (SAR) for 2013 was 7.96% (95% CI: 6.72–9.18%) for juveniles at Rocky Reach Dam to adults at Bonneville Dam. Given the uncertainty in the juvenile survival estimate below Rocky Reach in 2013, the SAR estimate for juveniles at McNary to adults at Bonneville in 2013 of 7.37% (95% CI: 5.27–9.46%) is likely an underestimate and should be interpreted with caution.
- Increasing the detection probability at Zosal Dam resulted in decreases in the standard errors of each of the reach survival estimates (e.g., Release-Zosal and Zosal-Rocky Reach). However, it appears there may be a point of diminishing returns as the Zosal detection probability increases. Increasing detection probability at Zosal had a larger impact on the standard error of the Release-Zosal survival estimate and lesser impact on the Release-Rocky Reach survival estimate.
- Results from 2013–2015 indicate that estimating survival from release to McNary Dam is possible with approximately 5,000 tags.
- Given that estimating SARs from RRH-BOA was possible for 2013 and that juvenile survival estimates for 2014 and 2015 were more reliable with larger total PIT-tag releases, we believe that incorporating this group into the CSS is warranted. The CSS Oversight Committee will discuss incorporating analyses for this group into the 2016 Annual Report.

Methods

Timing and Travel Time

Juvenile passage timing and fish travel times were estimated for 2013–2015 out-migrants based on PIT-tag detections at various dams within the Rocky Reach to Bonneville Dam reach. For each year, we estimated cumulative juvenile passage timing based on PIT-tag detections at Rocky Reach (RRH), McNary (MCN), John Day (JDA), and Bonneville (BON) dams. Daily PIT-Tag detections at each of these projects were summed and adjusted based on the average proportion of flows that passed through the powerhouse. In 2015, a new floating PIT-tag antenna was installed in the forebay at Zosal Dam (ZSL). Therefore, we also estimated juvenile timing and travel times for fish detected at ZSL in 2015. However we did not adjust daily PITtag detections by powerhouse flows at this site, as the fish that are detected at ZSL do not pass through the powerhouse. Minimum, median, and maximum fish travel times were estimated from release to detection at each dam in the reach with detection capabilities.

Juvenile Survival

For each migration year, we attempted to estimate smolt survival and associated variance estimates for PIT-tagged juvenile sockeye from their release in the Okanogan River Basin to MCN. We relied on juvenile detections at RRH, MCN, JDA, and BON dams, as well as downstream of Bonneville Dam using specialized trawl equipment for PIT-tag detection. Using recapture data from fish detected at these sites, single-release mark-recapture survival estimates were generated using the Cormack-Jolly-Seber (CJS) methodology as described by Burnham et al. (1987) with the Mark program (software available free from Colorado State University; White and Burnham 1999). In addition to estimating individual reach survivals (e.g., Release-RRH and RRH-MCN) we also attempted to estimate combined reach survival (i.e., Release-MCN) by multiplying individual reach estimates and determining the approximate variance using the delta method (Burnham et al. 1987).

The majority of wild sockeye were PIT-tagged in the Okanogan River Basin in 2013–2015 were tagged and released at two sites, Osoyoos Lake (OSOYOL) and Lake Skaha (SKATAL). Using the same methodologies outlined above, we attempted to estimate both individual and combined reach survivals for each of these two release sites, by migration year.

Smolt-to-Adult Survival (SARs)

With the nearly complete return of adults from the 2013 out-migration, we are able to estimate Smolt-to-Adult returns (SARs). Given the juvenile detection capabilities at RRH, we estimated SARs for two different reaches: (1) juveniles at RRH to adult return to BON (RRHBOA), and (2) juveniles at MCN to adult return to BON (MCN-BOA). To estimate SARs we relied on the same methodology used in Chapter 4 of the 2014 CSS Annual Report (McCann et al., 2014) for Chinook at steelhead from the Methow and Entiat rivers.

Potential Improvements in Survival Estimation from Increasing Detection Capabilities of the Floating Antenna in the Zosal Dam Forebay

For migration year 2015, we incorporated PIT-tag detections at Zosal Dam (ZSL) to estimate juvenile sockeye survival from release to ZSL. In 2015, there were three possible locations where PIT-tagged juvenile sockeye could be detected at ZSL, each of the two adult ladders and the floating antenna above the spillway. Per your request, we relied on 2015 detection data at all three of these sites to investigate the potential change in the precision of survival estimates, pending an increase in the overall detection probability at the ZSL detection sites. To do this, we incorporated ZSL detections to estimate survival from Release-ZSL, ZSLRRH, and Release-RRH using the methodology outlined above. We then simulated examined changes in the standard errors around these survival estimates, under a series of different assumed detection probabilities at ZSL. To estimate how sensitive these standard errors were to the number of tags that were released, we separately report estimates for release sizes of 7,176 tags (as seen in 2015) and 5,000 tags. We were able to examine how increases in detection probability (or equivalently more detections of individuals alive at Zosal Dam) by working the closed-form variance estimates of CJS survival provided in Skalski et al. (1998).

Results

Travel Time and Timing

Over the last three years, PIT-tagging of juvenile sockeye in the Okanogan River Basin has occurred from early to mid-April through early May. Tagging efforts in 2013, 2014, and 2015 resulted in 4,018, 5,055, and 7,176 PIT-tagged juvenile sockeye each year, respectively. Estimates of minimum, median, and maximum travel times from release to RRH, MCN, JDA, and BON dams are provided below (Table 1). These travel times are based on fish that were detected at each of the sites in their respective year of out-migration year. Also provided are estimates of the 95% confidence limits around the estimated median travel time.

Table 1. Travel times from release to juvenile detection site of juvenile sockeye PIT-tagged and released into the Okanogan River from 2013 to 2015.

Migration Year	Project	Release to Project Travel Time (days)			95% Confidence Limits	
		Min	Med	Max	Lower	Upper
2013	RRH	5.6	19.4	56.3	18.7	19.9
	MCN	10.0	23.7	63.7	22.1	24.7
	JDA	12.0	25.5	62.3	24.0	27.2
	BON	16.3	28.2	57.3	26.6	29.0
2014	RRH	4.4	16.7	40.6	16.4	17.4
	MCN	8.1	19.4	54.8	18.8	20.0
	JDA	13.0	23.0	67.5	22.1	24.0
	BON	11.8	22.7	59.0	20.8	24.6
2015	ZSL	4.7	14.2	31.0	12.0	16.0
	RRH	5.9	15.7	39.4	15.4	16.1
	MCN	14.0	23.2	43.0	21.6	24.0
	JDA	17.0	24.5	49.5	23.0	25.7
	BON	16.9	25.9	48.2	24.9	26.4

Overall, PIT-tagged sockeye juveniles from these tagging efforts passed through the Upper and Middle Columbia River from mid-May to early June (Table 2, Figures 1–3).

Table 2. Migration timing of PIT-tagged juvenile sockeye from Osoyoos Lake detected at ZSL, RRH, MCN, JDA, and BON dams from 2013 to 2015.

Migration Year	Project	Estimated Passage Date		
		10%	50%	90%
2013	RRH	8-May	13-May	18-May
	MCN	11-May	17-May	25-May
	JDA	14-May	21-May	27-May
	BON	15-May	24-May	1-Jun
2014	RRH	10-May	14-May	22-May
	MCN	12-May	19-May	24-May
	JDA	15-May	21-May	27-May
	BON	16-May	21-May	27-May
2015	ZSL	30-Apr	4-May	9-May
	RRH	6-May	12-May	19-May
	MCN	13-May	18-May	26-May
	JDA	16-May	20-May	25-May
	BON	17-May	21-May	27-May

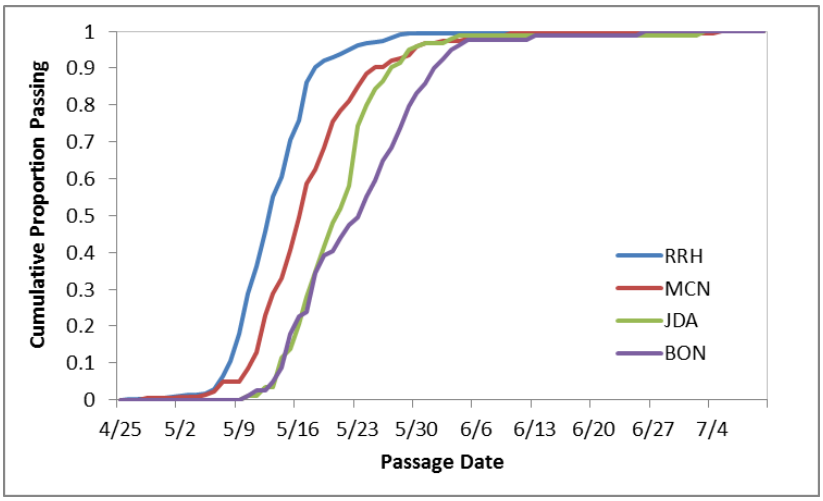

Figure 1. Cumulative passage timing at RRH, MCN, JDA, and BON dams of juvenile sockeye PIT-tagged and released into the Okanogan River by ONA in 2013.

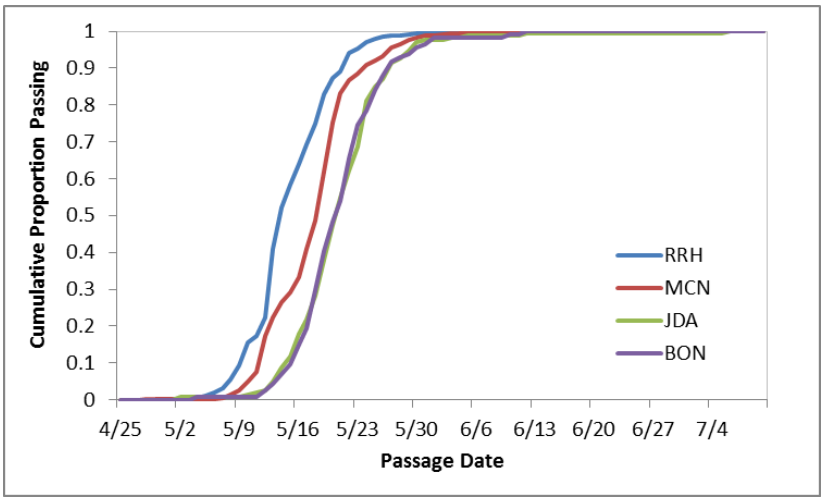

Figure 2. Cumulative passage timing at RRH, MCN, JDA, and BON dams of juvenile sockeye PIT-tagged and released into the Okanogan River by ONA in 2014.

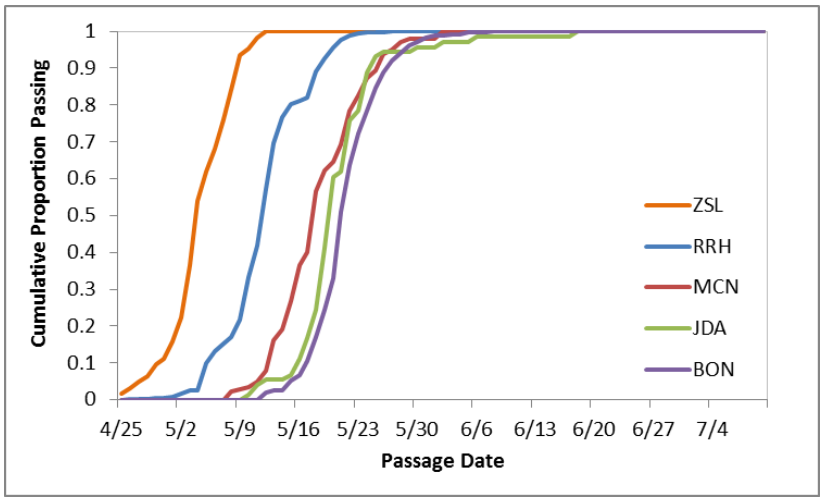

Figure 3. Cumulative passage timing at ZSL, RRH, MCN, JDA, and BON dams of juvenile sockeye PIT-tagged and released into the Okanogan River by ONA in 2015.

Juvenile Survival

Estimates of individual reach survival and combined survival for each migration year are provided in Table 3. For 2013, we were able to estimate survival from Release-RRH (0.49, 95% CI: 0.42–0.56). However, the total tags released in 2013 (4,018) was not sufficient to get reliable estimates of survival below RRH. This is largely due to low numbers of subsequent downstream detections. For example, of the 183 PIT-tagged sockeye smolts that were detected at MCN, only 19 were subsequently detected downstream of MCN. This low number of downstream detections led to an anomalous estimate of survival from RRH-MCN of 1.07 (95% CI: 0.61–1.52). Given the anomalous estimate of survival

from RRH-MCN, we do not report an estimate of survival from Release-MCN for 2013.

Migration years 2014 and 2015 had much higher release numbers (5,055 in 2014 and 7,176 in 2015), which allowed for the estimation of not only individual reach survivals but also a combined reach survival for each year (Table 3). Combined reach survivals in these years were 0.39 (95% CI: 0.31–0.47) for 2014 and 0.32 (95% CI: 0.22–0.42) for 2015.

Table 3. Survival of PIT-tagged sockeye juveniles tagged and released into the Okanogan River in 2013–2015.

Migration Year	Number Tagged	Release-RRH (95% CI)	RRH-MCN (95% CI)	Release-MCN (95% CI)
2013	4,018	0.49 (0.42-0.56)	1.07 (0.61-1.52)	N/A
2014	5,055	0.57 (0.51-0.64)	0.68 (0.52-0.82)	0.39 (0.31-0.47)
2015	7,176	0.42 (0.38-0.45)	0.78 (0.53-1.03)	0.32 (0.22-0.42)

The lower release total in 2013 also meant that estimating survival for each of the two release sites (OSOYOL and SKATAL) was only possible for the Release-RRH reach (Table 4). Survivals from Release-RRH were 0.50 (95% CI 0.42–0.59) for fish released at OSOYOL and 0.46 (95% CI: 0.36–0.57) for fish released at SKATAL. Estimates of survivals for the RRH-MCN reach were unreliable and, therefore, we did not estimate Release-MCN survival for 2013.

With the higher release total in 2014, we were able to generate estimates for both individual reach and combined reach survivals for each of the two release sites (Table 4). Fish tagged and released from OSOYOL had a Release-MCN survival of 0.44 (95% CI: 0.34–0.54) whereas those from SKATAL had a survival of 0.19 (95% CI: 0.08–0.31).

For 2015, we were able generate estimates of the individual reach survival for the Release-RRH reach for both release sites (Table 4). However, we were only able to generate a reliable estimate of survival in the RRH-MCN reach for the SKATAL release site, which was 0.70 (95% CI: 0.46–0.95). The estimate of survival for the RRH-MCN reach for the OSOYOL release site was greater than 1.0 and, therefore, deemed unreliable. This was due to the lower release total for this group and the low number of detections at MCN and downstream of MCN. Of the 35 OSOYOL fish that were detected at MCN in 2015, only five were subsequently detected downstream of MCN. Because the RRH-MCN survival estimate was unreliable for the OSOYOL release site, we do not report an estimate of survival from Release-MCN for this group in 2015.

Table 4. Survival of PIT-tagged sockeye juveniles, by release site, tagged and released into the Okanogan River in 2013–2015.

Migration Year	Release Site	Number Tagged	Release-RRH (95% CI)	RRH-MCN (95% CI)	Release-MCN (95% CI)
2013	OSOYOL	2,840	0.50 (0.42-0.59)	1.09 (0.52-1.65)	N/A
	SKATAL	1,178	0.46 (0.36-0.57)	0.99 (0.25-1.74)	N/A
2014	OSOYOL	3,707	0.63 (0.56-0.71)	0.69 (0.52-0.87)	0.44 (0.34-0.54)
	SKATAL	978	0.34 (0.22-0.47)	0.56 (0.17-0.95)	0.19 (0.08-0.31)
2015	OSOYOL	1,741	0.44 (0.36-0.52)	1.15 (0.22-2.09)	N/A
	SKATAL	5,435	0.41 (0.37-0.45)	0.70 (0.46-0.95)	0.28 (0.19-0.38)

Smolt-to-Adult Survival (SARs)

To date, 158 of the juveniles that were PIT-tagged and released in 2013 have been detected as adults at Bonneville Dam (BOA). Of these 158 adults, 59 (37%) were detected at BOA in 2014 and 99 (63%) were detected in 2015. The SAR estimate for juveniles at RRH to adults at BOA ($SAR_{RRH-BOA}$) was 7.96% (95% CI: 6.72–9.18%). The anomalous estimate of juvenile survival in the RRH-MCN reach (Table 3) resulted in an overestimate in the juvenile population at MCN. Therefore, the SAR estimate for juveniles at MCN to adults at BOA
($SAR_{MCN-BOA}$) of 7.37% (95% CI: 5.27–9.46%) is likely an underestimate and should be interpreted with caution.

Estimating Potential Improvements in Survival Estimation from Increasing Detection Capabilities of the Floating Antenna in the Zosal Dam Forebay

Of the 7,175 wild sockeye juveniles that were PIT-tagged and released in the Okanogan River Basin in 2015, 63 were detected at the three PIT-tag detection sites at ZSL. These detections, and subsequent downstream detections, equated to a detection probability of approximately 0.015 (95% CI: 0.009–0.021) at ZSL. Survival from Release-ZSL and ZSL-RRH was 0.59 (95% CI: 0.41–0.76) and 0.71 (95% CI: 0.49–0.94), respectively (Table 5, Figure 4). When including ZSL detects in the estimation of survival from Release-RRH, survival for this reach was 0.42 (95% CI: 0.38-0.45) (Table 6, Figure 4).

As expected, increasing the detection probability at ZSL resulted in decreases in the standard errors of each of the reach survival estimates (Tables 5 and 6, Figure 4). The largest impacts were for the individual reach survivals (e.g., Release-ZSL and ZSL-RRH). From these simulations, it appears there may be a point of diminishing returns as the ZSL detection probability increases. For the Release-ZSL reach, this point of diminishing returns appears to occur at detection probabilities of 0.08 or greater, which would equate to a 5-fold

increase in detection probability over what was seen in 2015. For example, at the 2015 detection probability of 0.015, the standard error for the Release-ZSL survival estimate was 0.090. Increasing detection probability to 0.08 resulted in a standard error of 0.038. However, when the detection probability increased even more to 0.15, the estimated standard error only decreased to 0.027.

Finally, increasing the detection probability at ZSL had less of an impact on the standard error of the combined survival estimate (Release-RRH) (Table 6, Figure 4C). The point of diminishing returns for this reach appears to occur at detection probabilities of 0.05 or greater. For example, at the 2015 detection probability of 0.015, the standard error for the Release-RRH survival estimate was 0.018. At a detection probability of 0.06, the estimated standard error only decreased to 0.011.

Table 5. Estimated standard errors and associated 95% confidence interval for estimates of survival from release to Zosal Dam and Zosal Dam to Rocky Reach Dam under different scenarios of detection probability at Zosal Dam detection sites, assuming a total of 7,176 tags released above the antenna. Row in bold-italics indicates estimated detection probability and associated standard error and confidence intervals observed in 2015. Data presented in this table are a subset of the scenarios presented in Figure 4.

Assumed Zosal Detection Probability.	Release to Zosal				Zosal to Rocky Reach			
			95% Conf. Int.				95% Conf. Int.	
	Survival.	Standard Error	Lower Limit	Upper Limit	Survival	Standard Error	Lower Limit	Upper Limit
0.01	0.59	0.111	0.368	0.803	0.71	0.140	0.438	0.987
0.015	***0.59***	***0.090***	***0.408***	***0.763***	***0.71***	***0.114***	***0.490***	***0.936***
0.02	0.59	0.078	0.433	0.739	0.71	0.102	0.513	0.913
0.03	0.59	0.064	0.461	0.710	0.71	0.086	0.545	0.881
0.04	0.59	0.055	0.478	0.693	0.71	0.076	0.564	0.862
0.05	0.59	0.049	0.490	0.682	0.71	0.070	0.576	0.849
0.06	0.59	0.044	0.499	0.673	0.71	0.065	0.586	0.840
0.07	0.59	0.041	0.505	0.666	0.71	0.061	0.593	0.833
0.08	0.59	0.038	0.511	0.661	0.71	0.058	0.598	0.828
0.09	0.59	0.036	0.515	0.656	0.71	0.056	0.603	0.823
0.10	0.59	0.034	0.519	0.652	0.71	0.054	0.607	0.819
0.11	0.59	0.032	0.523	0.649	0.71	0.052	0.610	0.816
0.12	0.59	0.031	0.526	0.646	0.71	0.051	0.613	0.813
0.13	0.59	0.029	0.528	0.643	0.71	0.050	0.616	0.810
0.14	0.59	0.028	0.530	0.641	0.71	0.049	0.618	0.808
0.15	0.59	0.027	0.533	0.639	0.71	0.047	0.620	0.806

Table 6. Estimated standard error and associated 95% confidence interval for estimates of survival from Release-Rocky Reach Dam under different scenarios of detection probability at Zosal Dam detection sites, assuming a total of 7,176 tags released above the antenna. Row in bold-italics indicates estimated detection probability and associated standard error and confidence intervals observed in 2015. Data presented in this table are a subset of the scenarios presented in Figure 4.

Assumed Zosal Detection Probability	Survival (Rel. to RRH)	Standard Error	95% Confidence Interval	
			Lower Limit	Upper Limit
0.01	0.42	0.022	0.374	0.461
0.015	***0.42***	***0.018***	***0.382***	***0.453***
0.02	0.42	0.016	0.386	0.449
0.03	0.42	0.014	0.391	0.445
0.04	0.42	0.013	0.393	0.442
0.05	0.42	0.012	0.394	0.441
0.06	0.42	0.011	0.395	0.440
0.07	0.42	0.011	0.396	0.439
0.08	0.42	0.011	0.396	0.439
0.09	0.42	0.011	0.397	0.439
0.10	0.42	0.011	0.397	0.438
0.11	0.42	0.011	0.397	0.438
0.12	0.42	0.011	0.397	0.438
0.13	0.42	0.011	0.397	0.438
0.14	0.42	0.011	0.397	0.438
0.15	0.42	0.011	0.397	0.438

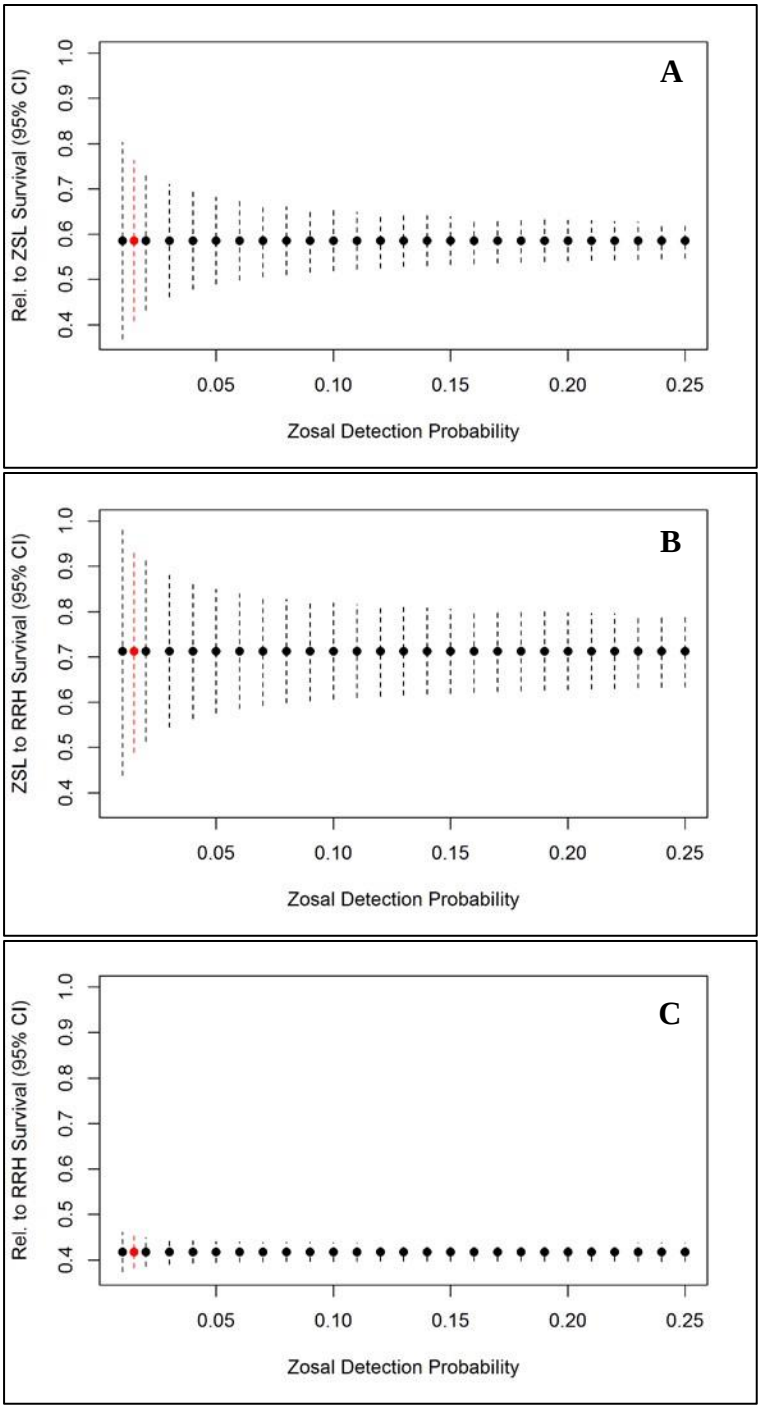

Figure 4. Estimated 95% confidence intervals for survival from Release to Zosal (A), Zosal to Rocky Reach (B), and Release to Rocky Reach (C) under different scenarios of detection probability at Zosal Dam detection sites, assuming a total of 7,176 tags released above the antenna. Red data point is actual detection probability and associated survival (and confidence interval) observed in 2015.

At any given estimate of detection probability, reducing the total number of tags released to 5,000 resulted in higher standard errors than did a release total of 7,176 (Tables 5–8, Figures 4 and 5). For example, at a detection probability of 0.03, the release total of 7,176 tags resulted in an estimated standard error of 0.064 for the Release-ZSL survival (Table 5), whereas that for a release total of 5,000 tags was 0.076 (Table 7).

Table 7. Estimated standard errors and associated 95% confidence interval for estimates of survival from release to Zosal Dam and Zosal Dam to Rocky Reach Dam under different scenarios of detection probability at Zosal Dam detection sites, assuming a total of 5,000 tags released above the antenna. Data presented in this table are a subset of the scenarios presented in Figure 5.

Assumed Zosal Detection Probability.	Release to Zosal				Zosal to Rocky Reach			
			95% Conf. Int.				95% Conf. Int.	
	Survival.	Standard Error	Lower Limit	Upper Limit	Survival	Standard Error	Lower Limit	Upper Limit
0.01	0.59	0.133	0.325	0.846	0.71	0.168	0.384	1.042
0.02	0.59	0.094	0.402	0.769	0.71	0.122	0.473	0.952
0.03	0.59	0.076	0.436	0.735	0.71	0.103	0.512	0.914
0.04	0.59	0.066	0.457	0.715	0.71	0.091	0.534	0.891
0.05	0.59	0.059	0.471	0.701	0.71	0.083	0.549	0.876
0.06	0.59	0.053	0.481	0.690	0.71	0.078	0.560	0.865
0.07	0.59	0.049	0.489	0.682	0.71	0.073	0.569	0.857
0.08	0.59	0.046	0.496	0.675	0.71	0.070	0.576	0.850
0.09	0.59	0.043	0.501	0.670	0.71	0.067	0.581	0.845
0.10	0.59	0.041	0.506	0.665	0.71	0.065	0.586	0.840
0.11	0.59	0.039	0.510	0.661	0.71	0.063	0.590	0.836
0.12	0.59	0.037	0.514	0.658	0.71	0.061	0.593	0.833
0.13	0.59	0.035	0.517	0.655	0.71	0.060	0.596	0.830
0.14	0.59	0.034	0.520	0.652	0.71	0.058	0.599	0.827
0.15	0.59	0.033	0.522	0.649	0.71	0.057	0.601	0.824

Table 8. Estimated standard error and associated 95% confidence interval for estimates of survival from Release-Rocky Reach Dam under different scenarios of detection probability at Zosal Dam detection sites, assuming a total of 5,000 tags released above the antenna. Data presented in this table are a subset of the scenarios presented in Figure 5.

Assumed Zosal Detection Probability	Survival (Rel. to RRH)	Standard Error	95% Confidence Interval	
			Lower Limit	Upper Limit
0.01	0.42	0.026	0.366	0.469
0.02	0.42	0.019	0.380	0.456
0.03	0.42	0.017	0.385	0.450
0.04	0.42	0.015	0.388	0.447
0.05	0.42	0.014	0.390	0.445
0.06	0.42	0.014	0.391	0.444
0.07	0.42	0.013	0.392	0.444
0.08	0.42	0.013	0.392	0.443
0.09	0.42	0.013	0.392	0.443
0.10	0.42	0.013	0.393	0.443
0.11	0.42	0.013	0.393	0.442

0.12	0.42	0.013	0.393	0.442
0.13	0.42	0.013	0.393	0.442
0.14	0.42	0.013	0.393	0.442
0.15	0.42	0.013	0.393	0.442

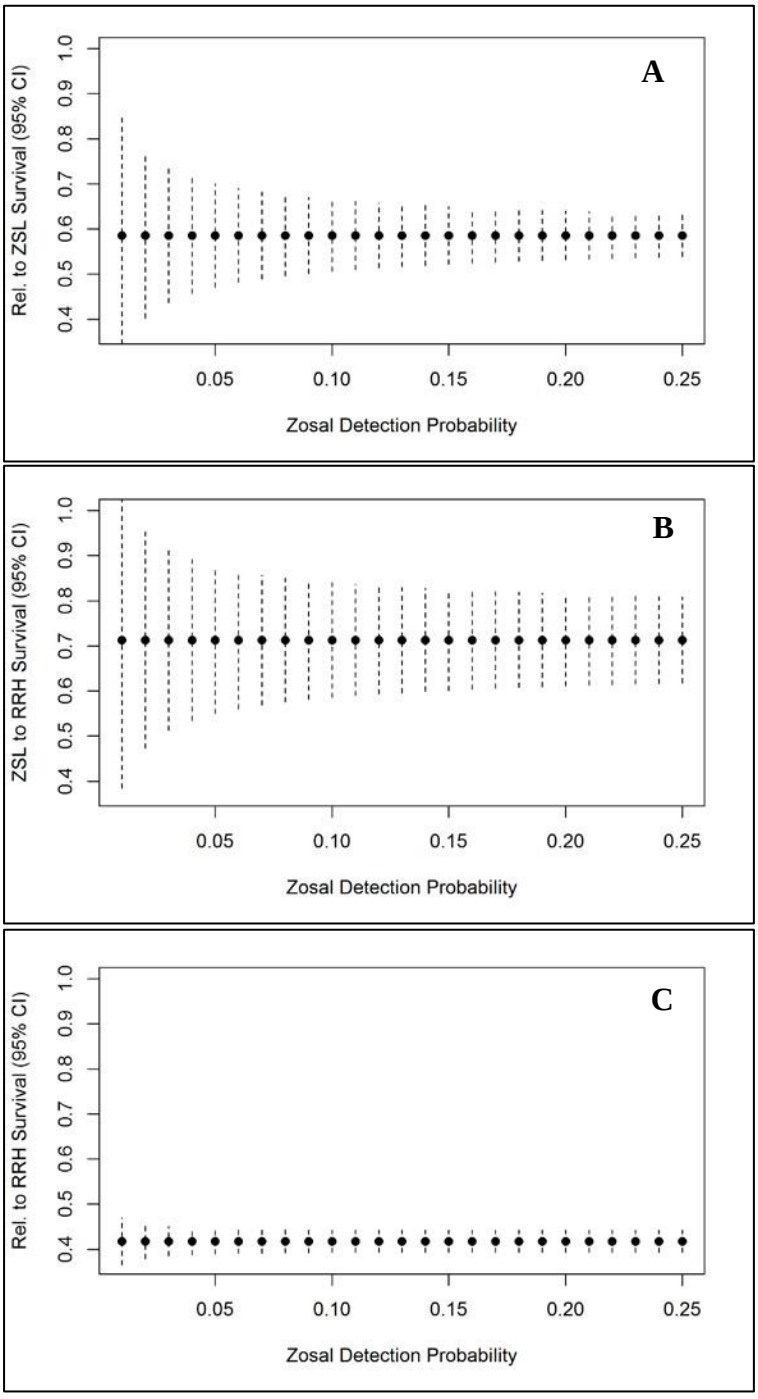

Figure 5. Estimated 95% confidence intervals for survival from Release to Zosal (A), Zosal to Rocky Reach (B), and Release to Rocky Reach (C) under different scenarios of detection

probability at Zosal Dam detection sites, assuming a total of 5,000 tags released above the antenna.

Finally, to put out-migration conditions into context, Table 9 provides the average spring flow volumes (April 15–June 30) for the Upper Columbia River (as measured at Priest Rapids Dam), along with the average spring spill proportions at each of Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids dams in 2013–2015.

Table 9. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wanapum (WAN), Priest Rapids (PRD), Rock Island (RIS), Rocky Reach (RRH), and Wells (WEL) dams in 2013–2015.

Migration Year	PRD Flow Volume (Kcfs)	Spill Proportion				
		WAN	PRD	RIS	RRH	WELL
2013	186.6	0.26	0.29	0.15	0.10	0.11
2014	189.4	0.31	0.35	0.21	0.10	0.13
2015	114.3	0.15	0.23	0.14	0.04	0.08

Conclusions

Based on these preliminary analyses, we feel a long-term monitoring group for wild sockeye from the Okanogan River Basin would be valuable to the CSS if enough PIT-tagged individuals could be released annually. Results from 2013–2015 indicate that approximately 5,000 PIT-tagged individuals are needed to obtain reliable estimates of juvenile survival from release to MCN. Based on the data from the 2013 out-migration, it appears that estimating SARs from RRH-BOA is possible for this group and, with larger sample sizes in future years, estimating SARs from MCN-BOA will also be possible. Given these points, the CSS Oversight Committee will discuss incorporating analyses from this group into the 2016 Annual Report.

References

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5. Bethesda, MD. 437 pp.

McCann, J., B Chockley, E. Cooper, H. Schaller, S. Haeseker, R. Lessard, C. Petrosky, E. Tinus,
E. VanDyke, and R. Ehlke. 2014. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye: 2014 Annual Report. BPA Contract #19960200.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Columbia and Snake rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:1484–1493.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120–138.