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Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2015

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May 15, 2017

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

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May 15, 2017

EXECUTIVE SUMMARY

A total of 916 Sockeye Salmon, *Oncorhynchus nerka*, were PIT tagged at the Bonneville Dam Adult Fish Facility in 2015. High temperatures prevented sampling during two weeks and restricted sampling during two additional weeks. Sockeye PIT tagged by this project, 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 and detected in the system, the estimated stock composition of Sockeye Salmon was 78.4% Okanagan, 21.1% Wenatchee, and 0.5% Snake.

In 2015 genetic stock identification (GSI) was used to classify the stock of 803 Sockeye Salmon sampled at Bonneville Dam. This resulted in estimates of 62.8% Okanagan, 35.7% Wenatchee, and 1.4% Snake which differed considerably from the PIT tag estimates. This turned out to be due almost entirely to the high rate of straying of Wenatchee stock Sockeye Salmon past Rocky Reach Dam; when Sockeye Salmon last detected at Rocky Reach and Wells dams were omitted as potential strays, the PIT tag stock composition estimate was 62.5% Okanagan, 36.7% Wenatchee, and 0.9% Snake River.

Upstream detections of Sockeye Salmon PIT tagged by this project resulted in an estimated survival of 54.0% to McNary Dam compared to 59.2% for juveniles tagged in the Okanagan Basin, 61.8% for those tagged in the Wenatchee Basin, and 14.8% for those tagged in the Snake basin. Mortality between Bonneville and McNary Dams was 194.5% greater than the mean mortality for Sockeye tagged by this project for the years 2006-2014.

The estimates from PIT tag data of adult Sockeye tagged at Bonneville Dam indicates fallback rates at Columbia River mainstem dams that range from 0.7% at Bonneville Dam to 9.8% at Rocky Reach Dam and 5.9% at Wells Dam. The high fallback rates at Rocky Reach and Wells dams are likely attributable to Wenatchee stock Sockeye that bypassed the Wenatchee River due to high water temperatures, only to return after passing Rocky Reach and Wells dams. Fallback rates for Wenatchee stock Sockeye tagged as juveniles released into the Wenatchee Basin and juvenile mixed stock Sockeye tagged at Rock Island dam were also high at Rocky Reach and Wells dams. Sockeye tagged as juveniles in the Snake Basin had fallback

rates ranging from 9.1% at Little Goose Dam to 24.0% at Lower Monumental Dam in the Snake Basin in addition to 14.3% at Bonneville Dam and 34.3% at The Dalles Dam.

The median travel time of Sockeye Salmon between Bonneville and Rock Island dams was 11.5 days. This resulted in a median migration rate of 42.3 km per day.

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, 2015 and December 31, 2015 at Zosel Dam 18 Chinook, 54 steelhead, and 303 Sockeye were detected, while at OKC 3 Chinook, 15 steelhead, and 136 Sockeye were detected. Unlike many years when high flows made it possible for upstream migrating salmon to pass through Zosel Dam spillways undetected, in 2015 lower flows resulted in an estimated 100% detection rate for upstream migrating PIT tagged Sockeye Salmon.

At Wells Dam, 711 Sockeye Salmon were sampled and 704 PIT tags and 126 acoustic tags deployed, with four previously PIT tagged Sockeye included in the sample. 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 9.7%compared to 13.4% 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 higher conversion rate to Zosel Dam than those only tagged at Wells Dam with PIT tags only.

Low flows resulted in a much higher than normal high detection rate of 86.2% at the PIT tag antenna in the lower Okanagan River (OKL) allowing conversion rates to OKC to be calculated. After the earliest arrivals passed prior to 6/23, water temperatures of up to 27C formed a barrier at the Okanagan River mouth resulting in sockeye attempting to pass upstream on dips in temperature. Sockeye tagged at Bonneville Dam arriving prior to 6/23 during this period had a 36.4% conversion rate to OKC compared to 4.3% for the largest group passing on 7/17 and 7/18; 17.1% for those passing OKL between 7/27 and 7/29 and 27.3% for those passing from 8/22-8/29. The overall, unweighted, conversion rate from OKL to OKC was 16.8% for Sockeye Salmon tagged at Bonneville Dam compared to 27.8% for those tagged at Wells Dam.

A total of 31 acoustic receivers were deployed by this project between Wells Dam and Skaha Lake with tag data also provided by an additional 32 acoustic receivers

maintained by Chelan and Douglas PUDs in the Columbia River between Rocky Reach and Chief Joseph dams. A total of 126 acoustic tagged Sockeye were released at Wells Dam, 83 of which were V9 transmitters and 38 with larger V13TP temperature/depth sensor transmitters. Sockeye tagged with V13TP transmitters had significantly lower survival to Monse than those tabbed with V9 transmitters (p=0.02) so V13TP data was excluded from survival estimates. Using V0 transmitters, survival was estimated at 58.7% to the Monse Bridge site on the Okanagan River just upstream of Wells Dam, 13.5% to the North Basin of Osoyoos Lake, and 9.3% to McIntyre Dam. Sockeye Salmon did not pass the Monse Bridge site when the Okanagan River temperature was above 23.0C, likely choosing to hold in Lake Pateros. Of the 88 Sockeye acoustic tagged with V9 transmitters, three were considered tagging mortalities, 69 were missing on the upstream migration, and six 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, and 10 were estimated to be on the spawning grounds during the spawning period.

Okanagan juvenile PIT tagging resulted in 7,176 smolts being released between April 9 and May 6, 2015 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 0.40 (SE = 0.02) for the SKATAL release group, and 0.45 (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 14.2 days for the SKATAL release group, and 21.2 days for the OSOYOL release group. Overall travel time from release to Bonneville Dam was approximately 26 days for both groups combined.

This project is proposed to continue and evolve through at least 2018. Upcoming work will include investigating possible PIT tag detection as Sockeye pass under the Highway 3 Bridge in Osoyoos between the north and central basins of Osoyoos Lake. The north basin is the first cold water refuge that Sockeye Salmon encounter on their upstream migration. We are planning to test the use of a Dual frequency IDentification SONar, or DIDSON, to get images of Sockeye Salmon passing the area. These images will be used 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.

Lake Wenatchee acoustic trawl surveys are expected to continue through 2018 along with limnological sampling to better estimate the annual production and future productive potential of Lake Wenatchee Sockeye Salmon. Acoustic trawl survey (ATS) data in Skaha, Osoyoos, and Wenatchee lakes are also used in Columbia Basin run forecasting. There are several unanswered questions regarding Lake Wenatchee Sockeye that we hope to address during this project. A primary question is why Lake Wenatchee Sockeye, in recent years, have not increased in relative abundance as much as Okanagan Sockeye, or even Snake River Sockeye. Our limnology and ATS work should help to answer this question, but it is also uncertain what the optimal spawning escapement goal is for this stock. An optimal escapement analysis is being completed, using other funding, for Osoyoos and Skaha Sockeye and we are considering a similar analysis 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 several recent years with runs over 500000 Sockeye Salmon have occurred while less than 5% of historical Columbia Basin habitat is available (Fryer 1995), making historical estimates appear conservative. To answer this question, we are working with the ONA, DFO, and Grant, Chelan, and Douglas Public Utility District to fund paleolimnological analysis of lake core samples from Wenatchee, Osoyoos, and Skaha lakes to assess lake limnology and Sockeye Salmon production back several hundred years.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY .... **i**

ACKNOWLEDGMENTS .... **v**

LIST OF TABLES .... **viii**

LIST OF FIGURES .... **xiv**

INTRODUCTION **1**

METHODS **5**

Adult PIT and Acoustic Tag Detection Infrastructure *5*
Zosel and OKC PIT tag arrays 5
Okanagan Acoustic Receiver Network and Mobile Tracking 5

Adult Sampling at Bonneville, Wells, and Priest Rapids dams *6*
Bonneville Dam Sampling 6
Wells Dam Sampling 7
Priest Rapids Dam Sampling 8

Age Analysis *8*

Site Detection Efficiencies *9*
Stock Classification 9
Escapement 10
Upstream Survival/Conversion Rates 10
Migration Timing and Passage Time 10
Bonneville Stock Composition Estimates Using PIT Tag Recoveries 11
Okanagan and Wenatchee Age and Length-at-age Composition 11
Night Passage 11
Fallback 12

Genetic Stock Identification (GSI) *13*

Acoustic Trawl Surveys for Juvenile Sockeye Abundance *14*

Juvenile PIT Tagging *15*
Rotary Screw Trap (RST) Operation at Skaha Lake Outlet 15
Smolt Trapping at Osoyoos Lake Narrows 16

RESULTS **20**

Okanagan Basin Acoustic and PIT Tag Detection Infrastructure Funded by this Project *20*
Okanagan River Acoustic Receiver Network 20
Accords-project Funded PIT Tag Antenna Performance in 2015 25

Upstream Migration Analysis *29*
Mixed Stock Sample Size and Age Composition 29
Upstream Recoveries, Mortality, and Escapement: 33
Migration Rates and Passage Time 38
Night Passage 40
Fallback 41
Stock Composition Estimates Using PIT tags 42

Genetic Stock Identification (GSI) *44*
Wells Dam Sampling Results *48*
Priest Rapids Dam Sampling *49*
Okanagan and Wenatchee Age, and Length-at-Age Composition *51*
Stock Composition at Wells Dam *53*
Detections in Natal Areas *54*
Upstream Survival Comparisons with Sockeye Tagged as Juveniles *57*
Migration into Natal Streams-Wenatchee River *60*
Migration into Natal Streams-Okanagan River *63*
Adult Acoustic Tag Results *66*
Detections Downstream of Wells Dam 73
Acoustic Mobile Tracking 73
Lake Wenatchee Acoustic Trawl and Limnology Surveys *79*
Juvenile PIT Tagging *81*
DISCUSSION 85
REFERENCES 95
Appendix A 98
Appendix B 129
Appendix C 150
Appendix D 189

LIST OF TABLES

Table 1. Acoustic receivers deployed by Chelan and Douglas public utility districts deployed in 2015 upstream of Rock Island Dam deployed by Chelan Public Utility District (CPUD), Douglas Public Utility District (DPUD), the CCT and ONA in 2015. A map showing the location of each receiver can be found in Figure 5). 20

Table 2. Number of PIT tagged Chinook, steelhead, and Sockeye detected at Zosel Dam ladders between January 1, 2015 and December 31, 2015, by release site and life stage at time of tagging. 26

Table 3. Number of PIT Tagged Chinook, steelhead, and Sockeye Salmon detected at the Okanagan Channel (OKC) PIT tag array between January 1, 2015 and December 31, 2015 by release site and life stage at time of tagging. 28

Table 4. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2015. 30

Table 5. Number and percentage of PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2015 compared to 2006-2014. Tributary site data (LWE, UWE, OKL) is also included for 2015. 31

Table 6. Percentage of Sockeye detected at Rock Island Dam by date passing Priest Rapids Dam in 2015. (Median travel time from Priest Rapids to Rock Island Dam was 3.0 days.) 32

Table 7. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2015. (Weighted by Statistical week, ignoring Sockeye passing during weeks 28-29). 33

Table 8. Survival of Sockeye PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams 2006-2015. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report.). 34

Table 9. Rate of loss of Sockeye tagged at Bonneville Dam between mainstem Columbia Basin dams in 2015 compared to 2006-2014 rates as determined from data in Table 8. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report. The Dalles Dam PIT tag data is only available since 2013.) 35

Table 10. 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 2015. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report). 35

Table 11. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2015 and the p-value for a linear regression between weekly reach survival and statistical week. Since no tagging was permitted at Bonneville Dam for weeks 28 and 29, data from returning adult Sockeye tagged as juveniles was used (noted with orange shading). 37

Table 12. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2015. 38

Table 13. Adult Sockeye Salmon median travel 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 2015. 39

Table 14. 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 2015. 40

Table 15. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2015. 40

Table 16. Estimated fallback rates for Sockeye Salmon at dams in 2015. (An asterisk indicates a dam outside the range of the stock in question for which Sockeye were detected; a NA indicates Sockeye were not detected at a dam outside the range of the particular stock.) 41

Table 17. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2015. 42

Table 18. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags in 2015 and a comparison to stock composition estimates estimated using visual dam counts. Note no sampling was conducted Statistical Weeks 28 and 29 and too few Sockeye were sampled Statistical Week 30 to estimate stock composition in week 30. 43

Table 19. Last detection site of clipped Sockeye Salmon tagged at Bonneville Dam in 2015. 44

Table 20. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2015. 44

Table 21. GSI classification of Sockeye last detected in non-terminal areas (downstream of OKL, LWE, and Ice Harbor dams). 46

Table 22. Comparison classification by stock using GSI and PIT tags of Sockeye Salmon sampled at Bonneville Dam in 2015 for Statistical weeks 23-27 and 31. 46

Table 23. Comparison of stock classification of Sockeye sampled at Bonneville Dam using GSI and PIT tag detections in 2015. No data is available for Statistical Weeks 28 and 29 due to sampling restrictions at the Bonneville Dam trap. 47

Table 24. 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 2015. No data is available for Statistical Weeks 28 and 29 due to sampling restrictions at the Bonneville Dam trap. 48

Table 25. Number of Sockeye Salmon sampled and PIT and acoustic tagged at Wells Dam by date and statistical week in 2015. 49

Table 26. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2015. Sex was visually estimated when the fish were sampled. 49

Table 27. Summary of 2015 Priest Rapids Dam Sockeye sampling. 50

Table 28. Age composition of Sockeye Salmon sampled at Priest Rapids Dam between July 10 and 20, 2015. 50

Table 29. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2015. Standard errors are in parentheses. 52

Table 30. Length-at-age composition of Wenatchee and Okanagan Sockeye Salmon stocks estimated by detection of Sockeye Salmon previously PIT tagged at Bonneville and sampled at Wells dams in 2015. 53

Table 31. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI in 2015. (Wells Dam estimates are weighted by the weekly Wells Dam run size, Bonneville estimates are unweighted.) 53

Table 32. Number of tagged (PIT+floy, PIT+floy+acoustic) Sockeye released upstream of Wells Dam in 2015 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. 55

Table 33. GSI stock classification by basin of last detection for Sockeye Salmon tagged at Wells Dam in 2015. 55

Table 34. 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 2015. An asterisk (*) indicates Sockeye which strayed from the normal migration route for the stock of concern. Stock at Bonneville Dam was estimated using GSI. 57

Table 35. Distribution of Sockeye Salmon in the Wenatchee Basin in 2015 PIT tagged as both juveniles and adults. 58

Table 36. Median migration time in days between Columbia Basin PIT tag antenna sites for adult and juvenile Sockeye tagged migrating upstream in 2015. An asterisk (*) indicates any detected Sockeye would be staying from the normal migration route for the stock of concern. Appendix A Table A1 has site information. 60

Table 37. Survival of Sockeye Salmon from the Lower Wenatchee River (LWE) to Tumwater Dam and the spawning grounds as well as the percentage last detected in tributaries downstream of Tumwater Dam in 2015. 62

Table 38. Unweighted survival of Sockeye Salmon sampled and tagged at Bonneville Dam from the Lower Okanagan River (OKL) to Zosel Dam (ZSL) and OKC in 2015. 64

Table 39. Unweighted survival of Sockeye Salmon sampled and tagged at Wells Dam from the Lower Okanagan River (OKL) to Zosel Dam (ZSL) and OKC in 2015. 64

Table 40. Comparison of survival of V9 and V13TP acoustic tagged Sockeye to Monse in 2015. (Week 28-31 mean different using a comparison of proportions in independent samples for weeks 28-31 at p=0.02) 66

Table 41. Estimated survival 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 2015. 67

Table 42. Percentage of Sockeye Salmon acoustic tagged at Wells Dam passing upstream receivers in 2015 (V9 tags only). 68

Table 43. Detection rate at acoustic receiver sites and estimated survival rate to those sites for Sockeye Salmon PIT and acoustic tagged at Wells Dam in 2015. 69

Table 44. Migration time to upstream receiver sites for Sockeye acoustic tagged at Wells Dam by date in 2015. (Note only five fish passed the Highway 97 site.) 69

Table 45. Number of acoustic tagged Sockeye passing Monse, Pump Station, North Basin and OKC acoustic receivers by date first detected at Monse; river temperatures in 2015 also included. Dates with detections are shaded green. 71

Table 46. Survival of Sockeye PIT tagged at Wells Dam from Monse to the Osoyoos Lake North Basin by Okanagan River temperature at Malott in 2015. 72

Table 47. Number Sockeye acoustic tagged at Wells Dam in 2015, Number detected downstream, and their GSI classification. 73

Table 48. 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 2015. (Green text indicates the fish was likely on the spawning grounds during the spawning period. Red text indicates confirmed captured in fisheries, blue text indicates missing on upstream migration, black text indicates last detected in Osoyoos Lake or at the Okanagan River Mouth before September 15, 2015. Sockeye detected at the Okanagan River Mouth after September 15, 2015 were assumed to be on the spawning grounds.). 75

Table 49. Total limnetic fish estimates based on acoustic trawl surveys of Lake Wenatchee from 2010 to present. The majority of total limnetic fish are juvenile Sockeye Salmon. Note that the 95% CI does not represent a true level of confidence in an estimate, rather a measure of the variability in density among acoustic transects for a given survey date. 80

Table 50. Brood Year 2015 pre-smolt abundance and size summary for Lake Wenatchee, Osoyoos Lake, and Skaha Lake nerkids. Pre-smolt abundance estimates represent the average of two or three October-Winter surveys. 80

Table 51. Summary of Okanagan Sockeye smolt PIT tagging effort, 2015. 82

Table 52. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2015. 83

Table 53. Harmonic mean travel time in days for juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as Rock Island Dam in 2015. 84

Table 54. Comparison of different methods of estimating Okanagan and Wenatchee Sockeye stock composition in 2015. Methods A and B are from Table 22 and exclude Statistical weeks 28 and 29 due to sampling restrictions and week 30 because none of the 15 Sockeye Salmon tagged were detected above Rock Island Dam. 90

LIST OF FIGURES

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. 2

Figure 2. Rotary screw traps used to trap juvenile Sockeye Salmon located downstream of Skaha Dam in 2015. 16

Figure 3. Schematic diagram of the fyke net used to trap sockeye located immediately downstream of the Highway 3 bridge in Osoyoos in 2015. 18

Figure 4. Fyke net used to trap juvenile Sockeye Salmon downstream of the Highway 3 Bridge in Osoyoos. 19

Figure 5. Map A shows the 2015 location of acoustic receiver sites in the Columbia River and lower Okanagan Basin. Map B shows the 2015 location of acoustic receiver sites in the upper Okanagan Basin. Location numbers reference sites listed in Table 1. Mainstem Okanagan PIT tag detection sites funded by this project (ZSL, OKC, SKA, and McIntyre Dam) are also shown. 24

Figure 6. Number of PIT tagged Chinook, Steelhead, and Sockeye detected by date at Zosel Dam in 2015. Note no tags were detected prior to February 15 or after November 5, 2015. 26

Figure 7. Zosel Dam with number of PIT tagged juvenile Sockeye Salmon detected at the two fish ladders and the floating PIT tag array located immediately upstream of spillway 4 seen in photo at right. ... 27

Figure 8. Number of PIT tagged Sockeye Salmon detected by date and mean daily Okanagan River water temperature at Oroville, WA between June 1 and October 31, 2015. 27

Figure 9. Number of PIT tagged Sockeye and Chinook Salmon and steelhead detected at the Okanagan Channel PIT tag array by date in 2015. There were no detections prior to February 15 or after November 5, 2015. 28

Figure 10. Number of PIT tagged Sockeye Salmon detected passing the Okanagan Channel PIT tag array (OKC) by date in 2015 compared with Okanagan River water temperatures recorded immediately upstream of OKC. 29

Figure 11. 2015 daily Bonneville Dam forebay water temperature with 2014 and 2006-2015 temperatures for comparison. 34

Figure 12. 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 2015. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report). 36

Figure 13. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2015. Since no tagging was permitted at Bonneville Dam for weeks 28 and 29, data from returning adult sockeye tagged as juveniles was used. 37

Figure 14. Picture showing Sockeye Salmon with lesions sampled at Priest Rapids Dam, July 20, 2015. 51

Figure 15. Percentage of Sockeye tagged at Wells and Bonneville passing Wells Dam subsequently detected at OKC by date past Wells Dam in 2015. Okanagan River temperatures were recorded at the Malottat and Oroville gaging station. (http://waterdata.usgs.gov/nwis). 56

Figure 16. Number of Sockeye detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2015. 56

Figure 17. The Wenatchee Basin showing PIT tag interrogation sites and highlighting sites where Sockeye were detected in 2015. Also displayed is the spawning area of Sockeye. Appendix A Table A1 has site information. 59

Figure 18. Number of Sockeye Salmon detected at LWE, median days from first to last detection at LWE, and lower Wenatchee River water temperatures by date in 2015 61

Figure 19. Percentage of sockeye salmon detected in the Lower Wenatchee River at LWE surviving to Tumwater Dam by date at LWE in 2015 (3 day moving average, 3 fish minimum). 62

Figure 21. Unweighted survival of Sockeye PIT tagged at Wells Dam from OKL to ZSL and OKC by date at OKL with lower Okanogan River temperatures in 2015. 65

Figure 20. Unweighted survival of Sockeye PIT tagged at Bonneville Dam from OKL to ZSL and OKC by date at OKL with lower Okanogan River temperatures in 2015. 65

Figure 22. Okanagan River temperature at Malott and Osoyoos Lake outlet and survival of Sockeye acoustic tagged passing Monse Bridge acoustic receiver to Osoyoos Lake in 2015. 72

Figure 23. Lake Wenatchee zooplankton biomass (µg/L dry weight) from 2012-2016. 81

Figure 24. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins in addition to Rock Island Dam to McNary, John Day, and Bonneville dams with 95% confidence intervals in 2015. 84

Figure 25. Survival between The Dalles and McNary dams by date at The Dalles Dam as estimated from sockeye PIT tagged at Bonneville Dam in 2015 (3 day average, 4 fish minimum)............................ 86

Figure 26. Relationship between the travel time from The Dalles to McNary Dam in 2015 and percentage survival from McNary to Priest Rapids Dam for sockeye tagged at Bonneville Dam in 2015. 86

Figure 27. Percentage of Wenatchee stock Sockeye Salmon (as classified by GSI) detected at Rock Island Dam that were subsequently detected at Rocky Reach Dam by date past Rock Island Dam in 2015. Lower Wenatchee River temperatures are also shown. 87

Figure 28. Percentage of Wenatchee stock Sockeye Salmon (as classified by GSI) at Rocky Reach Dam by date in 2015. 88

Figure 29. Detections of Sockeye Salmon PIT tagged by this project detected at avian colonies in 2015. 92

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 9200 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 2017, FPC 2017). The Bonneville Dam count of Sockeye Salmon in 2015 of 510,706 fish was the third highest Sockeye Salmon count since the dam was constructed in 1938.

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 and Skaha 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. In recent years, the range of Okanagan Sockeye Salmon has been extended to Skaha Lake and a hatchery program operated by the Okanagan Nation Alliance (ONA) near Penticton, BC.

Okanagan Sockeye Salmon have 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).

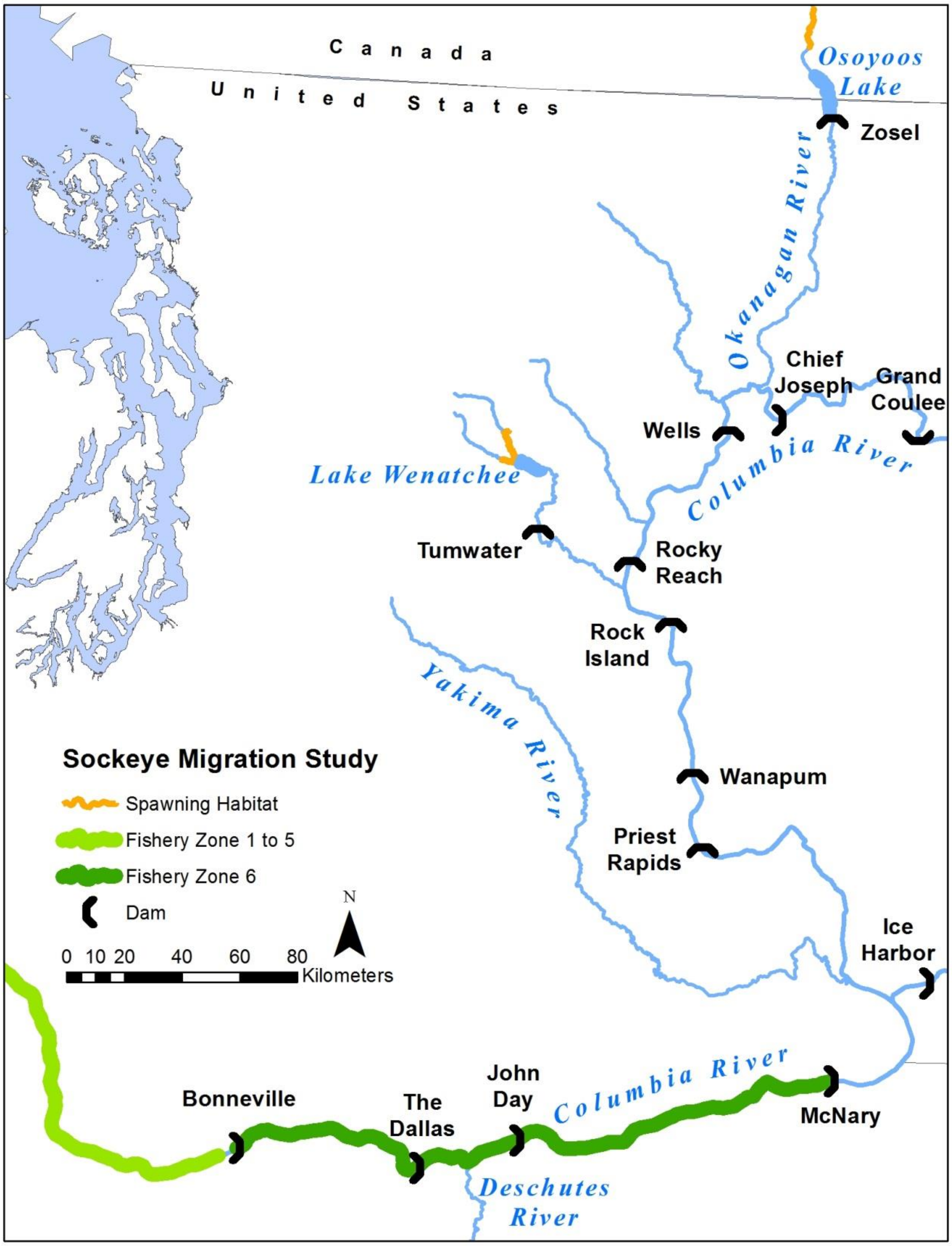


Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the two major Sockeye Salmon production areas and significant dams on their migration route.

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 earlier over the years in which Sockeye have been counted at Columbia River dams (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 A Table A1 for site information) and in 2010 funded installation of antennas at both Zosel Dam fishways (ZSL) with PIT tag detection funded at Skaha Dam fishway (SKA) in 2015. To further investigate the mortality rate of Okanagan Sockeye in the Okanagan Basin, from 2009 to 2015 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 data will be used to estimate juvenile survival and compared to Wenatchee River smolt trap smolt estimates. Since 2012, this project has also funded limnology surveys of Lake Wenatchee with the goal of estimating potential smolt capacity of the lake, as well as the PIT tagging of Okanagan stock Sockeye Salmon to estimate downstream migration mortality.

METHODS

Adult PIT and Acoustic Tag Detection Infrastructure

Zosel and OKC PIT tag arrays

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 and Mobile Tracking

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 ONA staff. Data from these receivers were used to estimate mortality and passage time upstream of Wells Dam. Data from additional receivers between Rock Island and Wells dams, deployed as part of other projects by Chelan and Douglas public utility districts, was made available and added to our detection database.

A Vemco© VR100 mobile tracker was used to identify final locations for acoustic tags which had either been expelled from fish or were located where the fish presumably died and ceased movement between Wells and Zosel dams. The mobile tracker was first used on October 13, 2015 on a jet boat in the mainstem Columbia River. The boat was launched in Brewster, WA and the hydrophone was attached to a heavy anchor and lowered over the side of the boat to an approximate depth of 5 m. The boat proceeded downstream at an approximate rate of 4 kph to the forebay of Wells Dam, a linear distance of 20km, and any detections were logged by the mobile tracker. The boat returned to the launch in Brewster, WA and mobile tracking commenced at an approximate rate of 4 kph upstream, with the boat covering a linear distance of 10 km.

Mobile tracking was performed opportunistically in the Okanagan and Similkameen rivers by the Confederated Colville Tribes during their Chinook spawning ground surveys from October through November, 2015. The hydrophone was attached to an anchor and lowered over the side of the raft to an approximate depth of 1 m and remained in the water as the survey crew floated downstream. Approximate linear distance covered was 124km on the Okanagan River and 10km on the Similkameen River.

Adult Sampling at Bonneville, Wells, and Priest Rapids 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 five days per week. A picket weir diverts fish ascending the Washington Shore fish ladder into the adult sampling facility collection pool. An attraction flow is used to draw fish through a false weir where they may be selected for sampling. Fish not selected and fish that have recovered from sampling then migrate back to the Washington Shore fish ladder above the picket weir.

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

PIT tagged Sockeye Salmon were detected by existing detection arrays in adult fish ladders at Bonneville, The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams on the Columbia River; Ice Harbor, Lower Monumental, Little Goose, 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.

In 2015, we also 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, Okanagan, and Wenatchee basins and mixed-stock juveniles tagged on their downstream migration at Rock Island Dam.

Wells Dam Sampling

Sockeye were trapped at the Wells west bank ladder fish trap where they were blocked from ascending the ladder by a picket weir 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 was selected to receive internally implanted acoustic transmitters (N=126). Eighty-eight of the acoustic transmitters were Vemco© model V9 2H (29 x 9 mm, weight in water 2.9 g) with a projected battery life of 242 days and 38 were V13TP transmitters (48 x 13 mm, weight in water 6.5 g), which were equipped with temperature and pressure sensors and had a projected battery life of 355 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).

Priest Rapids Dam Sampling

Priest Rapids Dam Sockeye sampling was not part of this project until high temperatures shut down sampling at Bonneville Dam for two weeks. This prevented us from obtaining age composition data that is important in run forecasting as well as providing any information on upstream survival of Sockeye migrating during the affected portion of the run. Therefore, we obtained approvals necessary to sample Sockeye Salmon at the Off Ladder Adult Fish Trap (OLAFT) located on the east shore fish ladder at Priest Rapids Dam.

Sampling at Priest Rapids Dam was similar to that at Wells Dam. Sockeye were diverted from the fish ladder by a picket gate. An attraction flow of approximately 3.1 CM/s was provided over the steeppass wherein the fish volitionally entered the steeppass and slid down a sorting chute. The trap operator regulating fish collection diverted a group of Sockeye into a holding tank. Additional Sockeye passing up the steeppass were automatically diverted back to a channel returning them to the ladder upstream of the barrier gate. As Sockeye were required for sampling, they were 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 initially placed into a recovery area where they could volitionally swim over a false weir back to the fish ladder. On our third day of sampling, we switched to hand carrying fish after sampling approximately 15 meters to a calm water site in the return fishway.

Age Analysis

Visual assessment of scale patterns was used to determine age composition through techniques developed for the Bonneville Stock Sampling project (Whiteaker and Fryer 2008, Kelsey et al. 2011). We used the European method for fish age description (Koo 1962) where the number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The

number following the period indicates the number of winters a fish spent in saltwater. Total age, therefore, is equal to one plus the sum of both numerals. If poor scale quality, particularly in the freshwater prevents age determination in all scales collected from a particular fish, no age is assigned.

Site Detection Efficiencies

Any fish detected at an upstream dam should have been detected at lower dams (with the exception of Bonneville, McNary, Ice Harbor, and Lower Granite dams where it is possible that a fish could use the navigation locks to pass the dam). The percentage of PIT tagged fish missed at each dam with PIT tag detection arrays was calculated by looking at the fish detected upstream of the site in question and estimating the percentage not detected at that site. For example, the percentage missed at Rocky Reach Dam was calculated as:

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

where R_m was the number of fish missed at Rocky Reach Dam but detected upstream of Rocky Reach Dam and R_d was the number of fish detected upstream of Rocky Reach Dam.

Stock Classification

In the years this project has been conducted, Sockeye Salmon stock determinations (Wenatchee, Okanagan, Snake, or Unknown) have been made by the last detection point. Those individuals last observed at or upstream of Rocky Reach Dam were classified as being Okanagan stock[2]. Individuals that were last observed at, or upstream of, Tumwater Dam, were classified as Wenatchee stock. Sockeye that were last observed at or upstream of Ice Harbor Dam were classified as being Snake River stock. In 2015, genetics samples were collected from all Sockeye sampled at Bonneville Dam, and most of these samples analyzed by 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.

[2] In 2015, genetic stock identification (GSI) indicated significant straying of Wenatchee stock Sockeye Salmon upstream of Rocky Reach and Wells dams. Therefore, in 2015, we also presented stock identification estimates where Sockeye had to be detected in the Okanagan River (either at the Okanagan Weir (OKL), ZSL, or OKC) to be considered Okanagan stock based on PIT tag detection. In this case, Sockeye last detected at Rocky Reach and Wells dams were considered unknown origin.

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 2015, Fish Passage Center 2015), 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.

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.

Genetic Stock Identification (GSI)

Tissue samples in the form of a caudal fin punch were collected for genetic analyses from all adult Sockeye Salmon sampled at Bonneville Dam. Tissue samples were stored using a dry Whatman paper medium (LaHood et al. 2008). Genomic DNA was extracted from digested tissue samples using a standard Qiagen DNeasy protocol. Prior to amplification of single-nucleotide polymorphism (SNP) loci using primer-probe sets (fluorescent tags), an initial polymerase chain reaction (PCR) "pre-amp" step was implemented using whole genomic DNA to jumpstart SNP amplification via increased copy number of target DNA regions. The cycling regime and PCR conditions for the pre-amp step were as follows: one initial cycle of 95C for 15 min, 14 cycles of 95C for 15 seconds, 60C for four minutes, and a final dissociation step. For each data collection run, each panel of 96 SNP loci were arrayed with 96 samples using a Fluidigm® microfluidic 96.96 chip (including one genotype indicator and one no-template control sample) to generate high throughput genotyping. Sample cocktails included: 3.4µl GTXpress Taqman (Applied Biosystems), 0.30µl GT load buffer (including taq polymerase), 0.30µl H2O and 2.0µl pre-amp DNA template. Single SNP assays were prepared in a 5.0µl reaction mix (per sample), containing the following reagents: 2.5µl DA load buffer, 0.25µl Rox 19 dye, 1µl H2O, and 1.25µl primer/probe. Microfluidic chips were loaded with assay cocktail dispensed at 4.5µl per well, and sample cocktail dispensed at 5.0µl per well. Chip loading was completed following standard manufacturers protocol on a Fluidigm IFC controller. Amplification conditions using a fast-cycling protocol were; 70° C for 30 min, 25C for 10 minutes, and 95C for one minutes, followed by 50 cycles of 95C for 5 seconds, and 50C for 25 seconds, and a final cool down step of 25C for 10 minutes. Chips were imaged and scored on a Fluidigm EP1 imager using Fluidigm SNP Genotyping Analysis Software version 3.1.1. Carcass samples often provide poor quality and/or quantity of viable DNA relative to fresh tissue, and our final sample sizes were pared based on individual genotyping success. Successful genotyping for a given sample was defined proportionally as less than 10% missing data (i.e. fewer than ten missing SNP genotypes per individual for *O. nerka*). 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, in both 2013 and 2014 we did GSI only on Sockeye classified as unknown by PIT tags or those with unusual PIT tag detection histories. However, in 2015, we did GSI on virtually all Sockeye sampled at Bonneville, Priest Rapids, and Wells dams as we were interested in evidence of straying due to the high water temperatures experienced by migrating Sockeye Salmon.

Acoustic Trawl Surveys for Juvenile Sockeye Abundance

Night-time juvenile Sockeye Salmon densities in Wenatchee, Osoyoos, and Skaha lakes[3] were estimated by executing specialized acoustics and trawl based survey (ATS) methods by ONA or DFO crews. 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

[3] Only Lake Wenatchee surveys were funded by this project. The other surveys were conducted by the ONA using other funding, but survey results are included in this report.

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.

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 2015. 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 2015.

Both RSTs were installed March 10, 2015. The cones were first lowered on 17 March and fished 24 hours the first night. Cones were raised for five days, then lowered and fished for 24 hour periods every other day until 8 April when daily catches exceeded 10 smolts in either trap. The thalweg RST was demobilized on 3 May due to damage to the main axle.

Smolt Trapping at Osoyoos Lake Narrows

A 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).

Sampling was conducted every two to seven nights (with sampling frequency increased to every other night during peak migration) from April 7 to May 5, 2015. 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.

Sockeye Smolts were PIT tagged using standard procedures (PTAGIS 2014, Biomark 2013). 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) were used to estimate Cormack-Jolly-Seber survival estimates as well as travel times.

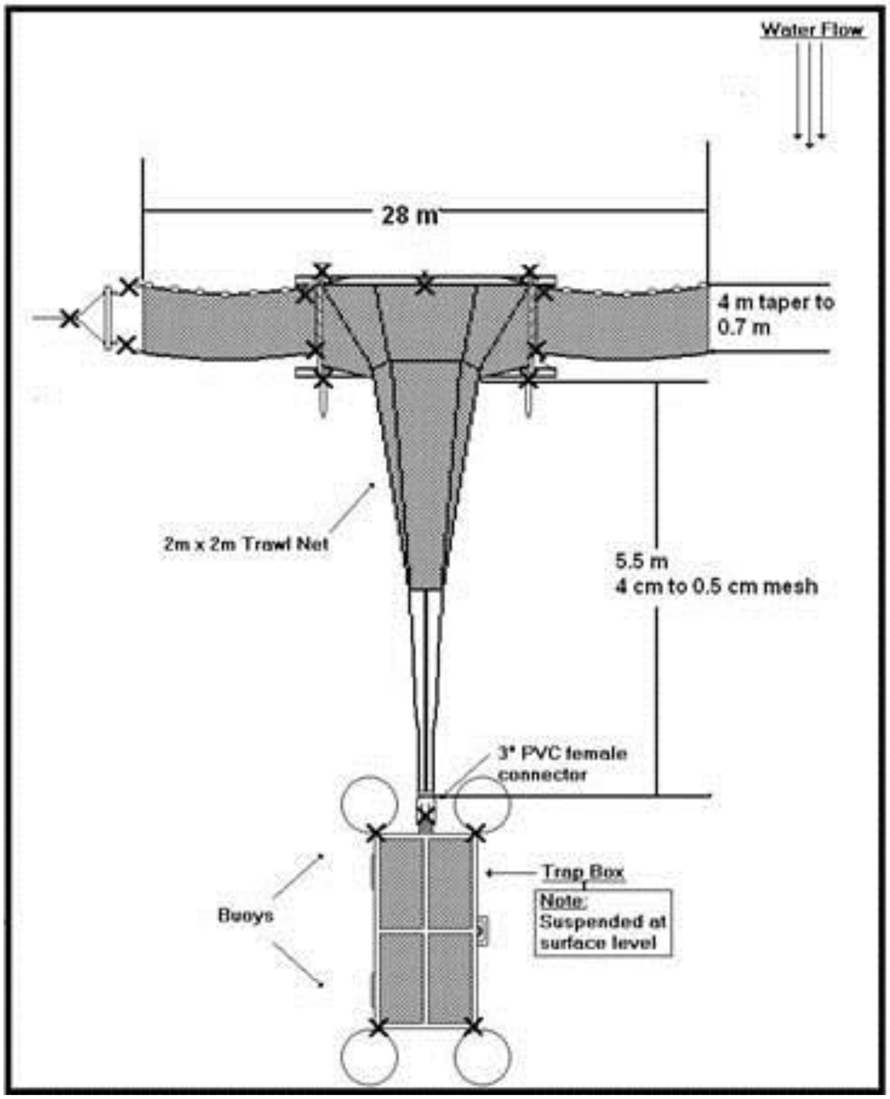


Figure 3. Schematic diagram of the fyke net used to trap sockeye located immediately downstream of the Highway 3 bridge in Osoyoos in 2015.

Figure 4. Fyke net used to trap juvenile Sockeye Salmon downstream of the Highway 3 Bridge in Osoyoos.

RESULTS

Okanagan Basin Acoustic and PIT Tag Detection Infrastructure Funded by this Project

Okanagan River Acoustic Receiver Network

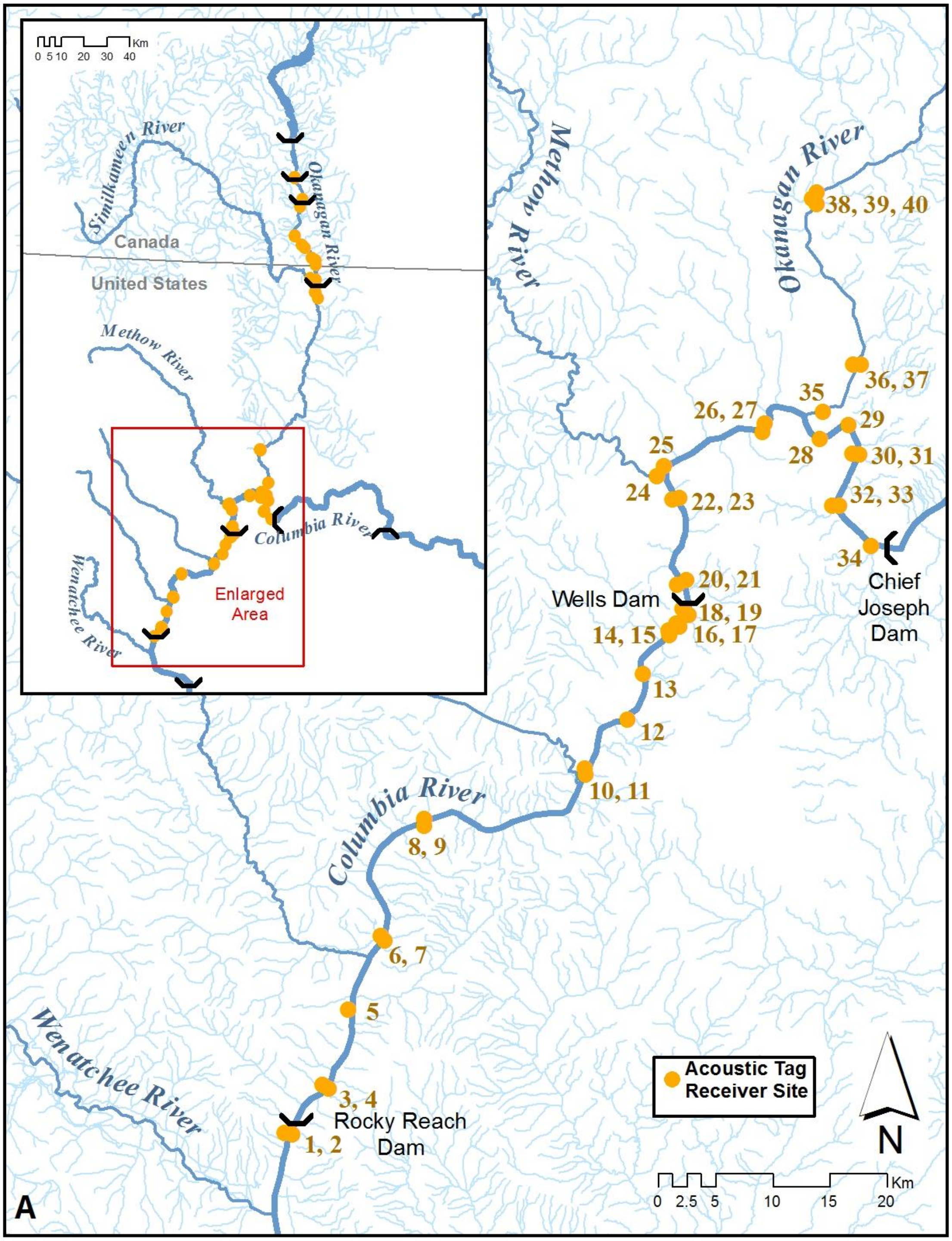
A total of 31 receivers were deployed by this project in the Okanagan Basin between Pateros, located 13 km upstream of Wells Dam on the Columbia River at rkm 843, and Skaha Lake at rkm 176 (Table 1 and Figure 5). All receivers were checked and downloaded at least once per month. In addition, Douglas and Chelan public utility districts (PUD) maintained a network of 32 receivers between rkm 761 downstream of Rocky Reach Dam and rkm 876 downstream of Chief Joseph Dam. The PUD network was developed for sturgeon monitoring, however detections of Sockeye acoustic tagged at Wells Dam were forwarded to us while we forwarded any sturgeon detections on our receivers to the Chelan and Douglas PUDs.

Table 1. Acoustic receivers deployed by Chelan and Douglas public utility districts deployed in 2015 upstream of Rock Island Dam deployed by Chelan Public Utility District (CPUD), Douglas Public Utility District (DPUD), the CCT and ONA in 2015. A map showing the location of each receiver can be found in Figure 5).

Map No.	Location Name	Agency	River	rkm	Latitude	Longitude	Date Deployed	Date Retrieved
1	Rocky Reach Tailrace 3	CPUD	Columbia	761	47.519040	-120.301714	5/8/12	n/a
2	Rocky Reach Tailrace 2	CPUD	Columbia	761	47.520076	-120.304633	5/9/12	n/a
3	Turtle Rock 2	CPUD	Columbia	766	47.556020	-120.259190	6/29/13	n/a
4	Turtle Rock 1	CPUD	Columbia	766	47.558900	-120.264660	6/29/13	11/3/15
5	Orondo 1	CPUD	Columbia	773	47.618764	-120.238572	11/3/15	n/a
6	Entiat 2	CPUD	Columbia	781	47.674250	-120.199569	5/9/12	11/3/15
7	Entiat 1	CPUD	Columbia	781	47.677565	-120.204115	5/9/12	n/a
8	Ducktail 2	CPUD	Columbia	794	47.766832	-120.158827	5/15/12	n/a
9	Ducktail 1	CPUD	Columbia	794	47.769610	-120.159130	5/15/12	11/4/15
10	Beebe 2	CPUD	Columbia	811	47.811970	-119.973400	5/7/12	11/4/15
11	Beebe 1	CPUD	Columbia	811	47.814229	-119.974555	5/15/12	n/a
12	Airport 2	CPUD	Columbia	818	47.854770	-119.926320	5/7/12	n/a
13	Long Draw 2	CPUD	Columbia	822	47.891117	-119.910798	11/4/15	n/a
14	R826_71	CPUD	Columbia	826	47.922370	-119.880950	4/8/15	n/a
15	R826_81	CPUD	Columbia	826	47.926130	-119.882540	4/8/15	n/a

16	V13 Wells Tailrace East	CPUD	Columbia	827	47.931746	-119.873620	4/17/15	7/23/15
17	V14 Wells Tailrace West	CPUD	Columbia	827	47.931640	-119.873440	4/17/15	n/a
18	R829_01	CPUD	Columbia	829	47.938650	-119.859890	4/8/15	n/a
19	V12 Wells Tailrace Hatchery Outfall	CPUD	Columbia	829	47.94361	-119.86691	4/17/15	n/a
20	V11 Wells Forebay West	DPUD	Columbia	832	47.9625	-119.87641	4/17/15	n/a
21	V10 Wells Forebay East	DPUD	Columbia	832	47.96579	-119.87136	4/17/15	n/a
22	V9 Starr Access	DPUD	Columbia	840	48.02933	-119.88328	5/2/15	n/a
23	V8 Starr Access	DPUD	Columbia	840	48.03082	-119.87912	5/2/15	n/a
24	V7 Methow River Mouth	DPUD	Methow	1	48.04958	-119.90301	5/2/15	12/4/15
25	Pateros Dock	CCT	Columbia	843	48.053960	-119.896957	4/13/15	12/31/15
26	V6 Brewster Hwy 173 Bridge	DPUD	Columbia	853	48.08606	-119.78139	4/16/15	n/a
27	Brewster Bridge Dock W	CCT	Columbia	853	48.090222	-119.778127	4/13/15	12/31/15
28	Brewster Dock SE	CCT	Columbia	861	48.081014	-119.713666	4/13/15	12/31/15
29	V0 Washburn Release	DPUD	Columbia	864	48.09224	-119.6799	5/21/15	n/a
30	V4 CJ State Park West	DPUD	Columbia	867	48.06971	-119.66782	4/16/15	n/a
31	V3 CJ State Park East	DPUD	Columbia	867	48.0698	-119.67234	4/16/15	n/a
32	V2 CJ Tailerace CCT resident Fish Hatchery	DPUD	Columbia	872	48.02909	-119.69154	4/16/15	n/a
33	V1 CJ Tailrace West	DPUD	Columbia	872	48.02847	-119.69437	4/16/15	n/a
34	V15 CJD Foster Creek Delta	DPUD	Columbia	876	47.99829	-119.64926	10/15/15	n/a
35	V5 Okanagan River Mouth, Hwy 97 Bridge	DPUD	Okanagan	2	48.10243	-119.71043	4/16/15	n/a
36	Monse Bridge, west	CCT	Okanagan	8	48.140200	-119.673783	6/15/15	11/05/15
37	Monse Bridge, east	CCT	Okanagan	8	48.140089	-119.673364	6/15/15	11/05/15
38	Weir Downstream	CCT	Okanagan	25	48.269463	-119.728737	6/15/15	Lost, 11/15/15
39	Weir Upstream Left Bank	CCT	Okanagan	25	48.267504	-119.726002	6/15/15	11/15/15
40	Weir Upstream	CCT	Okanagan	25	48.271653	-119.726431	6/15/15	11/15/15

	Right Bank							
41	Horseshoe Bend/Lake	CCT	Okanagan	113	48.872991	-119.416943	6/15/15	11/02/15
42	Similkameen Confluence	CCT	Similkameen	2	48.896315	-119.434316	6/15/15	11/02/15
43	Driscoll Pool	CCT	Similkameen	10	48.919777	-119.433126	6/15/15	11/02/15
44	Similkameen Canyon	CCT	Similkameen	11	48.949341	-119.465309	6/15/15	10/14/15
45	OKR Upstream of Similkameen Confluence	CCT	Okanagan	119	48.893882	-119.429752	6/15/15	11/02/15
46	Pump Intake, east bank	CCT	Okanagan	124	48.945815	-119.431925	6/15/15	11/6/15
47	Pump Intake, west bank	CCT	Okanagan	124	48.945967	-119.432043	6/15/15	11/6/15
48	Haynes Creek Mouth (RDOS Park)	ONA	Osoyoos Lk.	130	49.004084	-119.438172	6/15/15	11/6/15
49	South Basin Haynes Campground (Point West)	ONA	Osoyoos Lk.	132	49.018189	-119.442716	6/15/15	11/6/15
50	Haynes Point Nav Buoy	ONA	Osoyoos Lk.	132	49.020988	-119.438454	6/15/15	11/6/15
51	Hwy 3 Bridge (Narrows)	ONA	Osoyoos Lk.	134	49.028452	-119.459516	6/15/15	11/6/15
52	North Basin EC Buoy (Ink Creek)	ONA	Osoyoos Lk.	140	49.068838	-119.502163	6/15/15	11/6/15
53	OKR Mouth East	ONA	Okanagan	142	49.078728	-119.521149	6/15/15	11/6/15
54	OKR Mouth West	ONA	Okanagan	142	49.079104	-119.522222	6/15/15	11/6/15
55	OKR VDS 3 Downstream	ONA	Okanagan	147	49.113886	-119.565323	6/15/15	11/6/15
56	OKR VDS 3 Upstream	ONA	Okanagan	147	49.115547	-119.56727	6/15/15	11/6/15
57	OKR Hwy 97 Bridge	ONA	Okanagan	162	49.229845	-119.541784	6/15/15	11/6/15
58	McIntyre Dam Downstream	ONA	Okanagan	166	49.256824	-119.528131	6/15/15	11/6/15
59	McIntyre Dam Upstream	ONA	Okanagan	167	49.261211	-119.529447	6/15/15	11/6/15
60	Town of Okanagan Falls (RST Boulder)	ONA	Okanagan	174	49.342557	-119.580325	6/15/15	11/6/15
61	Skaha Dam downstream	ONA	Okanagan	175	49.344544	-119.580405	6/15/15	11/6/15
62	Skaha Dam Upstream	ONA	Okanagan	175	49.344713	-119.580330	6/15/15	11/6/15
63	Skaha Lake	ONA	Okanagan	176	49.345321	-119.579388	6/15/15	11/6/15



Km
0 5 10 20 30 40
Similkameen River
Okanagan River
Canada
United States
Methow River
Columbia River
Wenatchee River
Enlarged Area
Methow River
Okanagan River
38, 39, 40
36, 37
35
26, 27
29
25
28
30, 31
24
22, 23
32, 33
34
Chief Joseph Dam
20, 21
Wells Dam
18, 19
14, 15
16, 17
13
12
10, 11
Columbia River
8, 9
6, 7
5
Wenatchee River
3, 4
Rocky Reach Dam
1, 2
Acoustic Tag Receiver Site
N
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0 2.5 5 10 15 20
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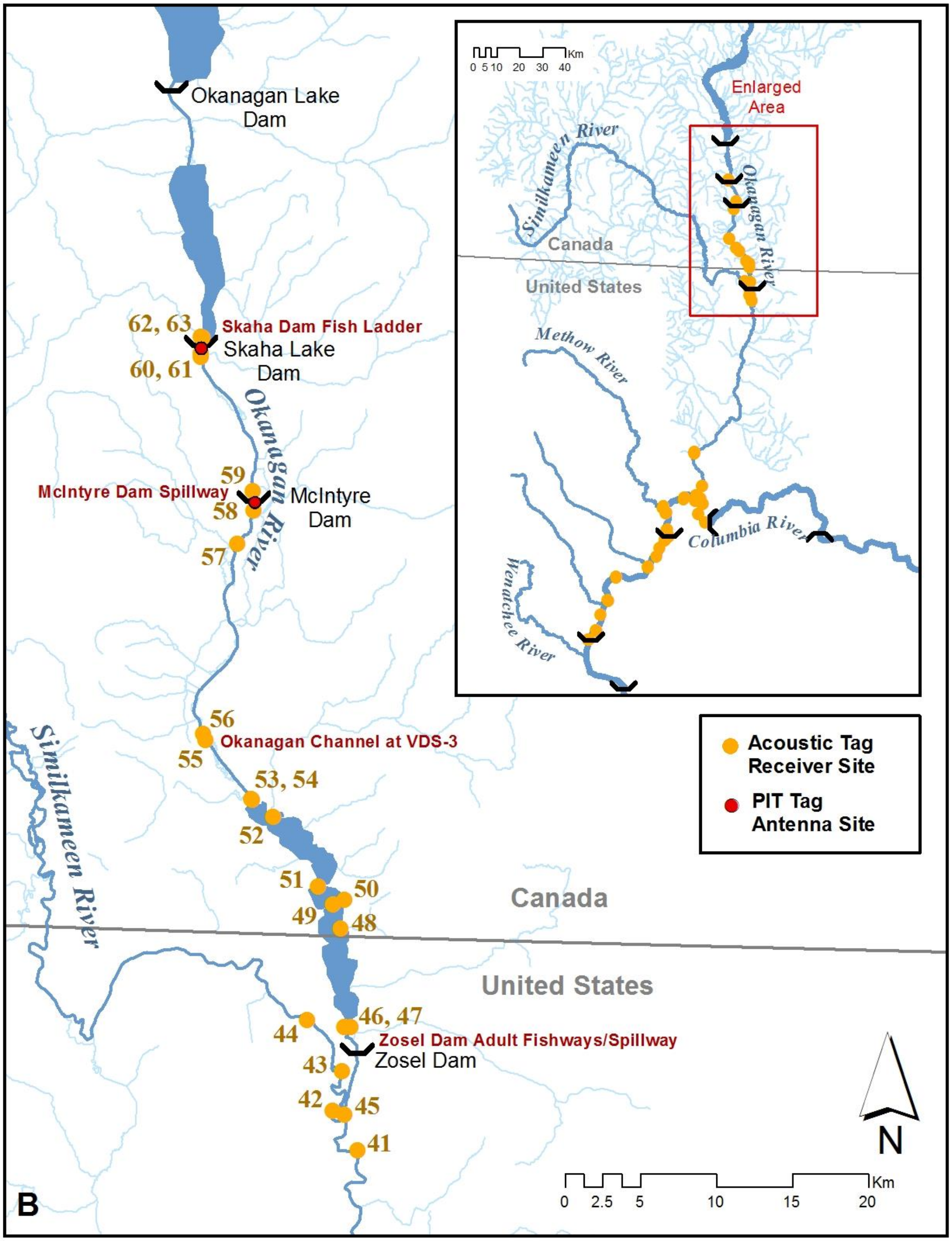

Figure 5. Map A shows the 2015 location of acoustic receiver sites in the Columbia River and lower Okanagan Basin. Map B shows the 2015 location of acoustic receiver sites in the upper Okanagan Basin. Location numbers reference sites listed in Table 1. Mainstem Okanagan PIT tag detection sites funded by this project (ZSL, OKC, SKA, and McIntyre Dam) are also shown.

Accords-project Funded PIT Tag Antenna Performance in 2015

This project has funded PIT tag antennas at Zosel (installed in 2010) and Skaha dam (2015) fish ladders as well at McIntyre Dam spillway (2015) and an in-channel array at OKC (2009), Figure 5B. At Zosel Dam, PIT tags from 303 Sockeye, 54 steelhead, and 18 Chinook were detected at Zosel Dam between January 1, 2015 and December 31, 2015 (Table 2 and Figure 6). Among the Sockeye detections were 63 juveniles detected between April 20 and May 20, 2015. Of these 63 juveniles detected at Zosel Dam, 32 were detected in Zosel fish ladders with the remaining 31 detected at a floating PIT tag antenna installed prior to the juvenile out-migration immediately upstream of the west-most spillway (Figure 7).

Among the adult Sockeye Salmon passing Zosel Dam, 43.3% passed between August 25 and September 3 after the mean daily water temperature dipped below 23C and an additional 35.0% passed Zosel Dam between July 29 and August 2, 2015 shortly after the mean daily water temperature briefly dipped to 23.7C (Figure 8). Salmon tagged by CRITFC adult tagging projects (adult Wells, Priest Rapids and Bonneville Dam Sockeye plus Bonneville adult Chinook and steelhead) Sockeye at Bonneville Sockeye, Chinook, and steelhead tagging) comprised 231 of the 376 salmonids, or 61.5%, of the PIT tagged salmonids detected at Zosel Dam (Table 2). Among the 130 adult Sockeye detected upstream of Zosel Dam at OKC, only one (0.8%) passed Zosel Dam undetected.

A total of 136 Sockeye, 15 steelhead and 3 Chinook were detected at the OKC PIT tag array between January 1, 2015 and December 31, 2015 (Table 3 and Figure 9). The majority of Sockeye detected after Okanagan River temperatures stayed below 18C on October 2, 2015 (Figures 8 and 10). Temperatures reached elevated levels very early in 2015, reaching 20C on June 6 and 22C on June 25, resulting in no adult Sockeye Salmon being detected at OKC prior to September 3, 2015.

Table 2. Number of PIT tagged Chinook, steelhead, and Sockeye detected at Zosel Dam ladders between January 1, 2015 and December 31, 2015, by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye Returning Adults	Sockeye Downstream Juveniles	Total
Bonneville Dam	Adult	5	1	58		64
Prosser Dam	Adult	0	1	0		1
Columbia River (rkm 661-960)	Juvenile	9	0	0		9
Priest Rapids	Adult	0	40	31		1
Rock Island	Juvenile	2	1	10		71
Wells Dam	Adult	2	2	136		13
Methow Basin	Juvenile	0	3	0		140
Okanagan Basin (U.S.)	Juvenile	0	4	0		3
Osoyoos Lake	Juvenile	0	0	3	22	26
Skaha Tailrace	Juvenile	0	0	2	41	44
No Site		0	2			2
Total		**18**	**54**	**240**	**63**	**376**

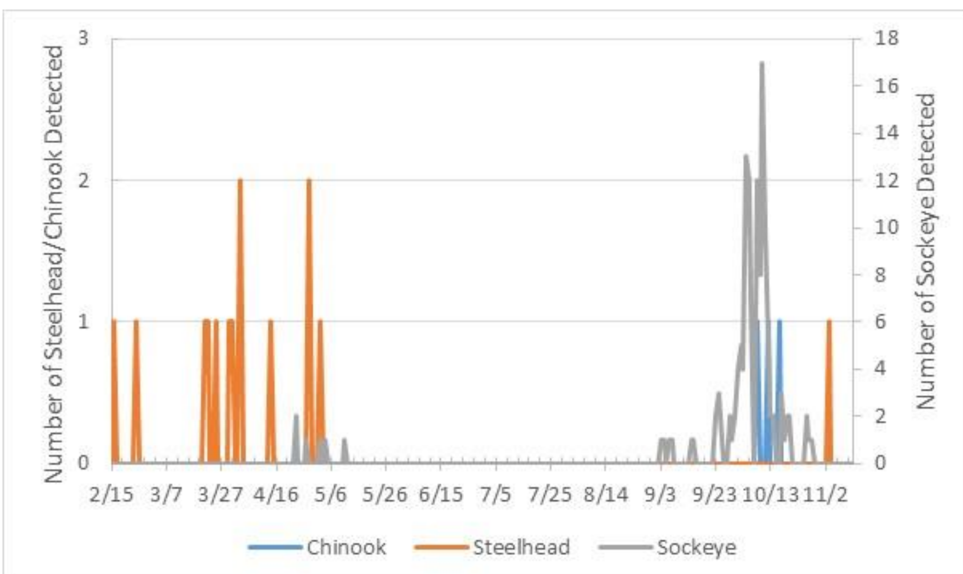

Figure 6. Number of PIT tagged Chinook, Steelhead, and Sockeye detected by date at Zosel Dam in 2015. Note no tags were detected prior to February 15 or after November 5, 2015.

Figure 7. Zosel Dam with number of PIT tagged juvenile Sockeye Salmon detected at the two fish ladders and the floating PIT tag array located immediately upstream of spillway 4 seen in photo at right.

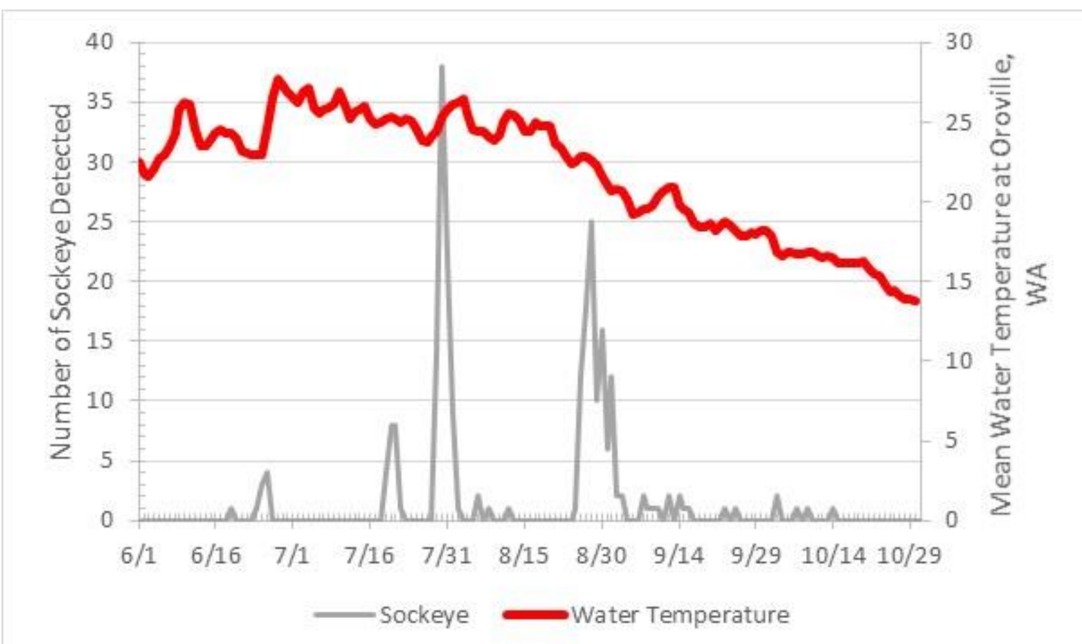

Figure 8. Number of PIT tagged Sockeye Salmon detected by date and mean daily Okanagan River water temperature at Oroville, WA between June 1 and October 31, 2015.

Table 3. Number of PIT Tagged Chinook, steelhead, and Sockeye Salmon detected at the Okanagan Channel (OKC) PIT tag array between January 1, 2015 and December 31, 2015 by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye Juveniles	Sockeye	Total
Bonneville Dam	Adult	1			24	25
Priest Rapids Dam	Adult		14		18	32
Wells Dam	Adult				77	77
Okanagan basin-Canada	Juvenile			6	5	11
Wells-Canadian Border	Juvenile	2	1			3
Rock Island Dam	Juvenile				6	6
Total		**3**	**15**	**6**	**130**	**154**

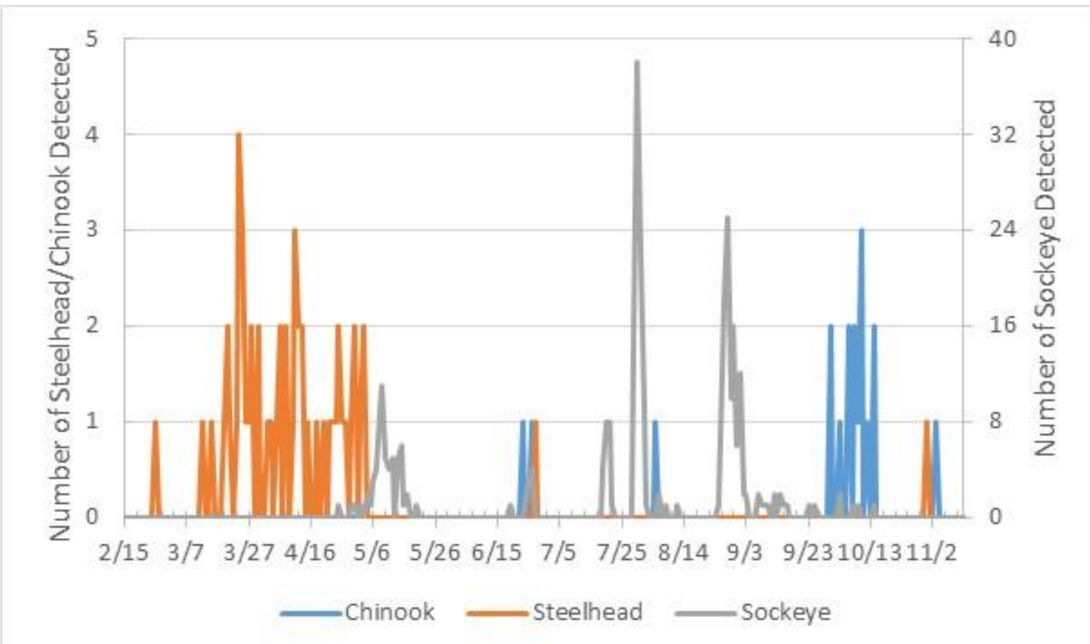

Figure 9. Number of PIT tagged Sockeye and Chinook Salmon and steelhead detected at the Okanagan Channel PIT tag array by date in 2015. There were no detections prior to February 15 or after November 5, 2015.

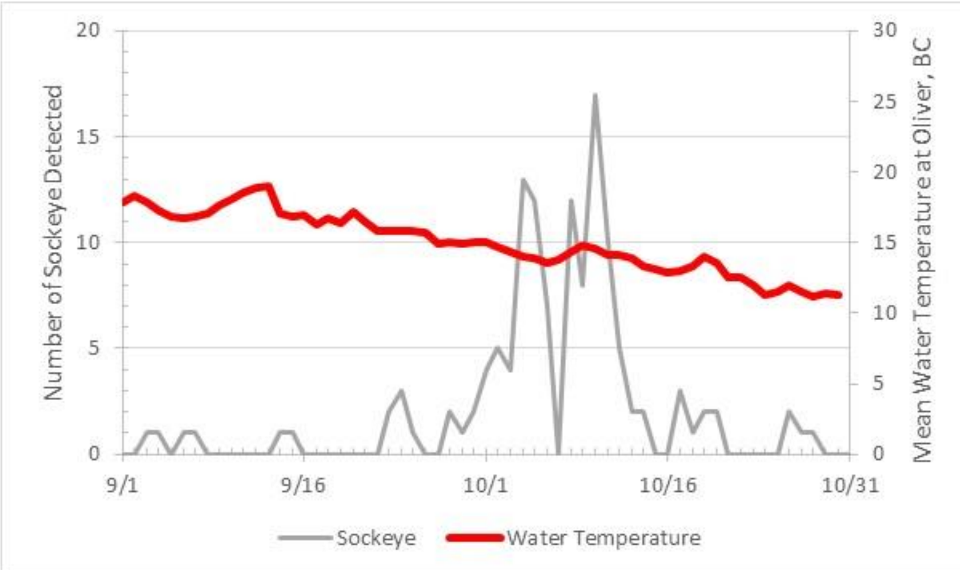

Figure 10. Number of PIT tagged Sockeye Salmon detected passing the Okanagan Channel PIT tag array (OKC) by date in 2015 compared with Okanagan River water temperatures recorded immediately upstream of OKC.

Our Skaha Dam fish ladder PIT tag antenna site (SKA) became operational on May 12, 2015. During the 2015 calendar year, there were only three detections due to low survival and suspected low detection efficiency. The first (tag 3DD.003B9B647E) was a juvenile Sockeye released in Skaha Tailrace (SKTAL) on April 26, 2013 that was detected at Bonneville Dam June 30, 2015, Wells Dam on July 7, 2015, Zosel at 7/30, OKC on 9/24 and SKA on 10/6. The other two were both tagged at Wells Dam, one on 6/24 (3DD.00778DBC9D) and the other on 7/6 (3DD.007781633F). Both Sockeye passed OKL and ZSL in late July (7/28 and 7/31 for the first fish, 7/27 and 7/30 for the second). Fish 3DD.00778DBC9D was detected at OKC on 10/9 and SKA on 10/19 while 3DD.007781633F was detected at OKC on 9/30 and SKA on 10/8 and 10/9.

Upstream Migration Analysis

Mixed Stock Sample Size and Age Composition

In 2015 a total of 917 Sockeye Salmon were sampled for this project at the Bonneville Dam Adult Fish Facility between May 27 and August 6 (Table 4). Of these, one was not tagged, and one fish died prior to release. One Sockeye was previously tagged and added to the remaining 915 Sockeye tagged and released resulting in a total sample size of 916 tagged Sockeye Salmon.

Table 4. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2015.

Sampling Dates	Statistical Week[4]	Mean Temp (C)	Sampled (N)	Tagged	Mortalities	Previously Tagged	Detected After Tagging and Tracked	Days of Reduced Sampling	Days of No Sampling
5/27-28,6/2-6/5	22-23	16.8	30	30	0	0	29	0	0
6/8-6/12	24	18.7	125	125	0	0	125	0	0
6/15-6/19	25	19.6	298	298	0	1	295	0	0
6/22-6/26	26	20.7	251	251	1	0	248	0	0
6/30,7/1-2	27	22.3	175	174	0	0	169	3	2
7/6-7/10	28	22.5	0	0	0	0	0	0	5
7/13-7/19	29	22.5	0	0	0	0	0	0	5
7/24	30	21.8	15	15	0	0	15	1	4
7/27-8/6	31-32	21.8	24	24	0	0	22	7	3
Total			**917**	**916**	**1**	**1**	**901**	**11**	**19**

Unprecedented early summer water temperatures resulted in the triggering of restrictions on our use of the Adult Fish Facility as outlined in Appendix G of the 2015 U.S. Army Corps of Engineers Fish Fish Passage Plan (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2015/final/FPP15_AppG.pdf). These restrictions resulted in a reduction in sampling hours between June 30 and July 2 (Table 4) when water temperatures were between 21.1 and 22.2C. Temperatures continued to climb above 22.2C, resulting in no sampling between July 3 and July 23 (Table 4), a period in which 22.2% of the run passed. Upon resumption of sampling, hours were restricted for the rest of the Sockeye migration due to high temperatures.

Of the 916 Sockeye included in this study, 15 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 a series of antennas at the upper end of both the Oregon and Washington shore fish ladders that detect very close to 100% of passing PIT tagged fish. 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 data from 2006-2015 indicate that PIT tagged Sockeye Salmon are missed at fish ladder sites (Table 5). No Sockeye PIT tagged by this project in 2015 were detected above Ice Harbor Dam making it impossible to estimate

[4] 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 2015, for instance, Statistical Week 24 began on June 7 and ended on June 13.

detection rates at Snake River dams. Low flows meant much higher than normal detection rates at detection arrays at the mouths of the Okanagan (OKL) and Wenatchee (LWE) rivers as well as at the UWE site on the Wenatchee River upstream of Tumwater Dam; therefore these sites are included in Table 5 in 2015.

Table 5. Number and percentage of PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2015 compared to 2006-2014. Tributary site data (LWE, UWE, OKL) is also included for 2015.

Dam	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
Bonneville	1.6%	0.7%	0.4%	1.8%	0.5%	0.7%	0.6%	0.4%	2.1%	0.2%
The Dalles	0.6%	0.3%	1.6%	--	--	--	--	--	--	--
McNary	1.1%	3.8%	2.1%	12.1%	1.6%	3.8%	5.0%	10.1%	6.5%	3.1%
Priest Rapids	0.4%	0.2%	0.0%	0.4%	0.2%	0.6%	0.3%	0.3%	0.8%	0.0%
Rock Island	10.2%	41.5%	4.4%	5.4%	4.4%	6.2%	2.6%	6.9%	6.8%	1.3%
Rocky Reach	0.0%	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%	0.0%	--	--	--	--
Ice Harbor	0.0%	12.5%	NA	0.0%	--	0.0%	20.0%	0.0%	--	--
Lower Monumental	0.0%									
Little Goose	0.0%									
Lower Granite	--	0.0%	--	--	--	--	--	--	--	--
Tumwater	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	--	--	--
LWE	17.9%									
UWE	24.6%									
OKL	13.8%									

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Rock Island Dam has stood out in both 2014 and 2015 for the high rate of PIT tagged Sockeye Salmon that missed detection (Table 6). New antennas were installed by Biomark during the winter of 2014-15, however, in mid-June we noticed that the percentage of missed Sockeye and Chinook was still high. We informed Biomark of this on June 16, 2015 and Biomark subsequently changed the operation of these antennas on June 24. Given a median travel time Sockeye Salmon travel time between Priest Rapids and Rock Island dams of 3.0 days this suggests detection rates of Sockeye passing Priest Rapids after approximately June 21 were affected by this change. The percentage of Sockeye passing Priest Rapids Dam between June 12 and 21 detected at Rock Island Dam was 80.1% compared to 92.3% for those between June 22 and July 9 (Table 6). Among Sockeye passing Priest Rapids Dam on or after June 28, all Sockeye passing Rock Island Dam were detected.

Table 6. Percentage of Sockeye detected at Rock Island Dam by date passing Priest Rapids Dam in 2015. (Median travel time from Priest Rapids to Rock Island Dam was 3.0 days.)

Date at Priest Rapids	Number at Priest Rapids Subsequently Detected Upstream of Rock Island	Number Detected at Rock Island	Percentage Detected at Rock Island
6/12/2015	7	5	71.4%
6/13/2015	8	4	50.0%
6/14/2015	4	3	75.0%
6/15/2015	8	7	87.5%
6/16/2015	5	2	40.0%
6/17/2015	7	6	85.7%
6/18/2015	24	17	70.8%
6/19/2015	28	25	89.3%
6/20/2015	19	18	94.7%
6/21/2015	11	10	90.9%
6/22/2015	19	14	73.7%
6/23/2015	27	21	77.8%
6/24/2015	35	31	88.6%
6/25/2015	36	30	83.3%
6/26/2015	45	42	93.3%
6/27/2015	32	31	96.9%
6/28/2015	16	16	100.0%
6/29/2015	15	15	100.0%
6/30/2015	31	31	100.0%
7/1/2015	22	22	100.0%
7/2/2015	18	18	100.0%
7/3/2015	24	24	100.0%
7/4/2015	15	15	100.0%
7/5/2015	11	11	100.0%
7/6/2015	2	2	100.0%
7/7/2015	1	1	100.0%
7/8/2015	4	4	100.0%
7/9/2015	3	3	100.0%

The predominant age group, of the 83.9% of the run that was sampled, was Age 1.2, followed by Age 1.3 (Table 7). The number of Age 1.1 Sockeye typically increases after the mid-point of the Sockeye run, which is the period when our sampling curtailed by temperature sampling restrictions.

Table 7. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2015. (Weighted by Statistical week, ignoring Sockeye passing during weeks 28-29).

Statistical Week	Percentage of Run	N Ageable	Age Class				
			1.1	1.2	2.1	1.3	2.2
22-23	0.6%	30	0.0%	96.7%	0.0%	3.3%	0.0%
24	4.3%	123	0.0%	92.7%	0.0%	7.3%	0.0%
25	16.5%	291	0.7%	94.8%	0.0%	4.1%	0.3%
26	35.6%	250	0.0%	94.8%	0.2%	4.4%	0.4%
27	24.1%	168	0.0%	91.7%	0.0%	7.7%	0.6%
28	11.5%	0	NA	NA	NA	NA	NA
29	4.6%	0	NA	NA	NA	NA	NA
30	1.9%	14	0.0%	92.9%	0.0%	7.1%	0.0%
31-32	0.9%	20	0.0%	90.0%	0.0%	10.0%	0.0%
Composite Weeks 22-27 30-32	**83.9%**	**896**	**0.1%**	**93.8%**	**0.1%**	**5.6%**	**0.4%**

Upstream Recoveries, Mortality, and Escapement:

Unprecedented Columbia River temperatures (Figure 11) adversely affected the Sockeye Salmon migration in 2015. The mean Bonneville Dam forebay temperature in June 2015 was 3.4C above the 10-year average and temperatures elsewhere in the basin were also at high levels. Survival, as estimated using PIT tags, to all upstream Columbia Basin dams was the lowest since CRITFC began PIT tagging Sockeye at Bonneville Dam in 2006 (Table 8). The increase in upstream migration mortality over the mean rate for previous years ranged from 97.7% between Bonneville and The Dalles to 358.8% between The Dalles and McNary dams (Table 9).

Estimated escapement based on upstream PIT tag detections were consistently less than the number of Sockeye counted at mainstem dams (Table 10, Figure 12). The sole exception was at Ice Harbor Dam where only three Sockeye Salmon from this study were detected.

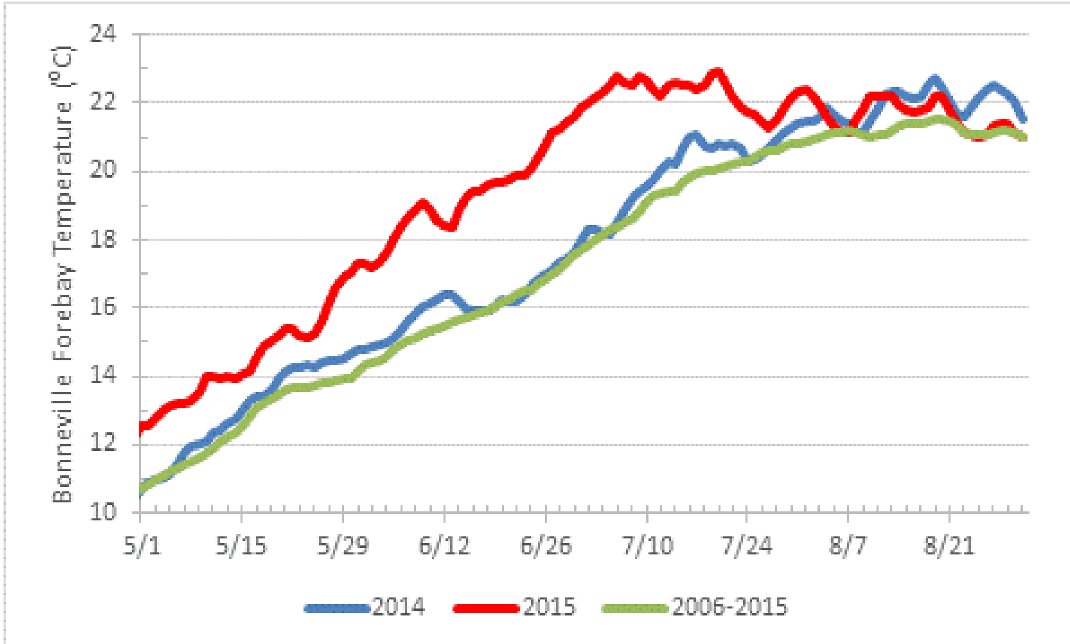

Figure 11. 2015 daily Bonneville Dam forebay water temperature with 2014 and 2006-2015 temperatures for comparison.

Table 8. Survival of Sockeye PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams 2006-2015. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report.).

Dam	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Mean 2006 to 2014
The Dalles	82.8	93.1	89.5								91.3
McNary	54.0	88.3	83.6	82.4	76.1	81.5	85.7	89.4	84.0	88.4	84.4
Priest Rapids	44.9	84.5	78.6	77.3	71.9	78.4	82.1	86.3	77.4	84.8	80.1
Rock Island	40.6	79.5	74.2	75.0	68.9	76.3	80.2	85.8	73.4	81.1	77.2
Rocky Reach	31.6	65.3	52.4	62.1	55.3	63.7	67.1	73.7	62.2	58.8	62.3
Wells	29.4	64.2	50.5	60.8	53.9	62.6	65.2	71.1	60.9	53.8	60.3
Tumwater	8.3	13.6	20.9	12.9	14.2	13.3	12.2	9.4	NA	NA	13.8
Bonn Pool Temperature 6/15-7/14	21.3	17.9	18.2	16.4	15.8	16.6	17.9	17.0	18.2	18.3	17.8

Table 9. Rate of loss of Sockeye tagged at Bonneville Dam between mainstem Columbia Basin dams in 2015 compared to 2006-2014 rates as determined from data in Table 8. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report. The Dalles Dam PIT tag data is only available since 2013.)

Dam Pairs	2015 loss	2013-2014 Mean Loss	2006-2014 Mean Loss	Increase in 2015 Mortality Over Base Mean Rate
Bonneville-The Dalles	17.2%	8.7%	NA	97.7%
The Dalles-McNary	34.8%	7.6%	NA	358.8%
Bonneville-McNary	46.0%	-	15.6%	194.5%
McNary-Priest Rapids	16.9%	-	5.0%	235.9%
Priest Rapids-Rock Island	9.6%	-	3.7%	156.8%

Table 10. 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 2015. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report).

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using Bonneville PIT Tagged Sockeye	Visual Dam Count	Difference Between Bonneville PIT Tag and Visual Estimate
Bonneville	--	--	510,077	--
The Dalles	82.8%	423,032	429,797	-1.6%
McNary	54.0%	275,889	279,744	-1.4%
Priest Rapids[5]	44.9%	229,078	301,272	-24.0%
Rock Island	40.6%	207,174	264,678	-21.7%
Rocky Reach	31.6%	161,493	216,389	-25.4%
Wells	29.4%	150,147	187,055	-19.7%
Zosel	4.9%	24,988	36,360	-25.1%
Tumwater	8.3%	42,586	59,939	-17.4%
Ice Harbor	0.3%	1,308	1,052	24.3%

[5] Thirty 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.

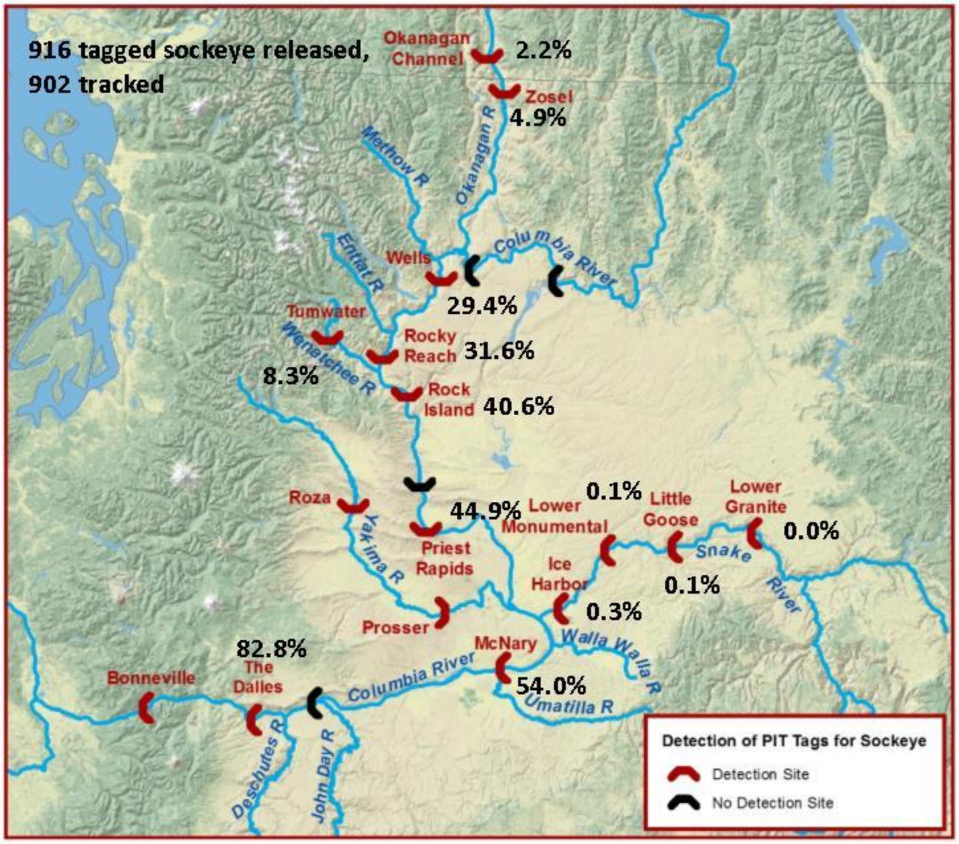

Figure 12. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2015. (Since no Sockeye were tagged during weeks 28 and 29, data from Sockeye tagged as juveniles was used for those weeks as described later in this report).

Computing weekly upstream survival for Bonneville Dam-tagged Sockeye Salmon during Statistical weeks 28 and 29 was not possible because no Sockeye were tagged during those weeks. As a substitute, the survival of all adult Sockeye PIT tagged as juveniles at Rock Island Dam and in the Wenatchee and Okanagan basins which passed Bonneville Dam during these weeks was used (shown in orange shading in Table 11). Using this data, as in most years of this study, survival from Bonneville to The Dalles, McNary, Priest Rapids, and Rock Island dams showed a significant linear decrease with week sampled and tagged at Bonneville Dam (Table 11, Figure 13) as did survival to Rock Island Dam of the three groups of returning juvenile Sockeye Salmon tagged originating from Wenatchee and Okanagan Sockeye. The percentage of Age 1.3 Sockeye surviving to Rock Island Dam (50.0%) was greater than that for Age 1.2 (42.7%) Sockeye Salmon.

Table 11. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2015 and the p-value for a linear regression between weekly reach survival and statistical week. Since no tagging was permitted at Bonneville Dam for weeks 28 and 29, data from returning adult Sockeye tagged as juveniles was used (noted with orange shading).

Statistical Week at Bonneville Dam	Adults Tagged at Bonneville Dam				Returning Juveniles		
					Wen Hat	Oka Wild	RIA Mixed
	Bonneville-The Dalles	Bonneville-McNary	Bonneville-Priest Rapids[6]	Bonn-RIS	Bonn-RIS	Bonn-RIS	Bonn-RIS
23	100.0%	96.6%	93.1%	93.1%	100.0%	NA	100.0%
24	95.2%	92.8%	89.6%	88.8%	75.0%	100.0%	87.5%
25	90.8%	82.7%	77.9%	70.4%	72.7%	66.7%	81.3%
26	91.1%	75.0%	64.9%	58.1%	54.7%	59.4%	60.7%
27	72.8%	23.1%	11.8%	9.5%	2.9%	16.0%	20.0%
28	64.5%	16.1%	9.7%	9.7%	15.4%	0.0%	7.7%
29	75.0%	12.5%	6.3%	6.3%	0.0%	0.0%	12.5%
30	86.7%	40.0%	0.0%	0.0%	NA	0.0%	0.0%
31	72.7%	40.9%	27.3%	27.3%	NA	0.0%	0.0%
Composite[7]	**82.8%**	**54.0%**	**44.9%**	**40.6%**	**47.0%**	**41.7%**	**47.7%**
p-value	**0.028**	**0.012**	**0.003**	**0.003**	**0.001**	**0.002**	**<0.001**

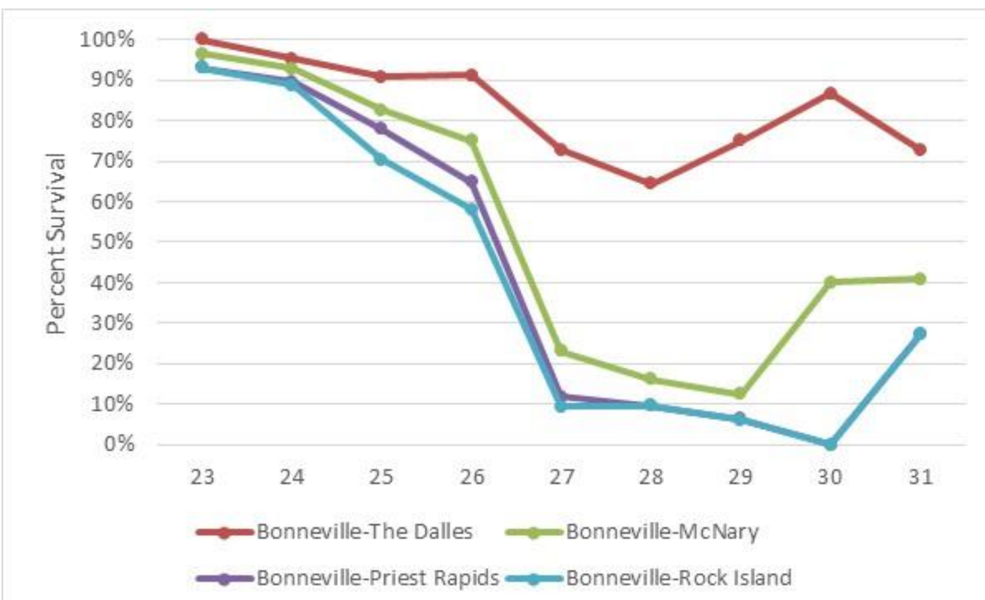

Figure 13. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2015. Since no tagging was permitted at Bonneville Dam for weeks 28 and 29, data from returning adult sockeye tagged as juveniles was used.

[6] Includes Sockeye Salmon only detected in the Priest Rapids Dam trap that likely were collected for the Cle Elum Sockeye reintroduction project.
[7] Composite estimates for Bonneville Dam-tagged Sockeye Salmon are weighted by Statistical Week, juvenile estimates are unweighted.

Migration Rates and Passage Time

Adult Sockeye Salmon travel quickly upstream with a median migration rates between mainstem dams ranging between 29.6 and 53.2 km/day for Sockeye tagged at Bonneville Dam (Table 12). 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 12).

Sockeye Salmon tagged at Bonneville Dam later in the migration travel upstream faster than those tagged earlier in the migration (Table 13). Unlike most previous years when later migrating Sockeye generally migrated between mainstem dams faster than earlier migrating Sockeye, there were no significant (α=0.05) linear relationships between statistical week passing Bonneville Dam and migration time from Bonneville Dam to upstream dams (Table 13). The median difference in travel time from Bonneville Dam to all upstream mainstem dams was 1.7 days or less between the two major stocks, and 1.5 days or less between the three main age groups (Table 13).

Table 12. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2015.

		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	1.5	47.1	1.4	51.4
The Dalles-McNary	162	3.0	53.2	3.2	50.1
McNary-Priest Rapids	167	3.4	50.1	3.2	52.0
Priest Rapids-Rock Island	89	3.0	30.2	3.0	30.8
Rock Island-Rocky Reach	33	1.1	29.6	1.0	30.9
Rocky Reach-Wells	65	1.6	41.6	3.0	34.0
Rock Island-Tumwater	73	15.2	4.6	4.0	17.4
Bonneville-McNary	231	4.7	49.5	4.7	49.4
Bonneville-Priest Rapids	329	8.0	41.1	7.9	50.9
Bonneville-Rock Island	487	11.5	42.3	10.9	45.0
Bonneville-Tumwater	560	27.1	20.7	28.3	19.8
Bonneville-Wells	585	13.9	42.6	13.3	42.6

Table 13. Adult Sockeye Salmon median travel 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 2015.

Statistical Week at Bonneville Dam	BON-TDA	BON-MCN	BON-PRA	BON-RIA	BON-TUM	BON-RRH	BON-WEL	BON-ZSL	WEL-ZSL	RIA-TUM
22	1.9	4.7	8.4	NA	NA	12.7	14.9	22.8	7.8	NA
23	1.7	4.7	9.2	12.5	25.3	14.1	16.5	20.9	6.5	NA
24	1.6	4.7	8.1	12.0	18.8	12.7	14.2	49.0	35.4	7.4
25	1.2	4.4	7.8	10.9	29.9	11.8	13.6	45.6	33.8	18.9
26	1.5	4.8	8.1	11.0	24.9	11.7	13.0	37.3	23.0	14.0
27	1.7	5.1	9.2	12.9	NA	15.1	17.2	30.3	13.3	NA
28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	1.2	4.2	NA	NA	NA	NA	NA	NA	NA	NA
31	1.8	5.5	9.1	12.6	NA	13.8	15.9	31.4	14.5	NA
p-value	**0.512**	**0.469**	**0.443**	**0.660**	**0.719**	**0.543**	**0.656**	**0.778**	**0.942**	**0.612**
Stock										
Okanagan	1.5	4.7	7.9	10.9	NA	12.0	13.9	41.9	28.0	NA
Wenatchee	1.5	4.7	8.1	12.1	27.1	13.7	14.0	NA	NA	15.0
Unknown[8]	1.5	4.4	7.9	11.7	NA	11.8	13.2	NA	NA	NA
Age										
1.1	1.6	4.6	8.0	10.1	NA	12.1	13.5	NA	NA	NA
1.2	1.5	4.7	8.0	11.6	27.0	12.1	13.9	41.7	27.8	15.4
1.3	1.4	4.7	8.0	10.9	29.0	12.5	13.1	71.3	58.2	19.1

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 six minutes (Table 14). Exceptions were Ice Harbor and Lower Monumental, where only three fish passed, and Bonneville Dam with an extensive array of antennas that include the lower ladders resulting in earlier detection than most other dams and thus a more complete record of passage times in the ladders. Median passage time for Sockeye tagged as juveniles was generally similar to those tagged as part of this project; however the percentage of juveniles-tagged adults taking more than 12 hours to pass was greater than that for adult Sockeye tagged by this study at 9 out of 12 dams (Table 14).

[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.

Table 14. 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 2015.

	Adults Tagged at Bonneville Dam		Previously Tagged as Juveniles	
Dam	**Median Passage (Minutes)**	**%>12 Hours**	**Median Passage (Minutes)**	**%>12 Hours**
Bonneville	10.2	0.3%	16.0	6.9%%
The Dalles	0.1	0.9%	0.2	16.2%
McNary	0.2	3.4%	0.2	4.3%
Priest Rapids	5.9	2.4%	5.8	3.1%
Rock Island	0.8	0.9%	1.4	1.1%
Rocky Reach	5.6	1.8%	6.4	3.4%
Wells	4.8	3.5%	7.2	11.4%
Zosel	2.3	10.3%	1.5	20.0%
Tumwater	5.2	1.9%	5.0	0.0%
Ice Harbor	9.0	0.0%	4.2	11.7%
Lower Monumental	796.8	50.0%	3.1	26.0%
Little Goose	0.0	0.0%	0.0	9.4%
Lower Granite			3.4	14.8%

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 7 out of 11 sites where Sockeye from both stocks were detected (Table 15). Okanagan stock Sockeye Salmon had among the highest night passage rates at Zosel Dam (93.1% compared to 46.7% for Sockeye tagged as juveniles). The Bonneville Dam Washington shore (site BO4) estimate of night passage is likely biased low because tagging occurred between about 0800 and 1300 hours, and with a median passage time of 10.2 minutes from tagging to final detection at Bonneville Dam (Table 14), fish would be expected to pass the counting window prior to 2000 hours.

Table 15. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2015.

	Adults Tagged at Bonneville Dam					Sockeye Tagged as Juveniles
Dam	**All Adults**	**Okanagan**	**Wenatchee**	**Snake**	**Unknown**	
Bonneville-OR shore	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%
Bonneville-WA shore	0.8%	0.6%	1.1%	10.0%	0.0%	2.5%
The Dalles-OR shore	10.4%	10.7%	11.3%	0.0%	0.0%	5.2%
The Dalles, WA shore	8.7%	9.7%	6.8%	0.0%	10.0%	7.2%
McNary-OR shore	7.8%	10.0%	3.1%	0.0%	13.3%	3.6%
McNary-WA shore	6.8%	8.3%	0.0%	0.0%	33.3%	4.9%
Priest Rapids	3.1%	4.0%	1.2%	NA	0.0%	0.9%
Rock Island	2.8%	4.2%	0.0%	NA	0.0%	5.5%
Rocky Reach	6.8%	6.7%	6.3%	NA	50.0%	6.8%
Wells	12.1%	11.5%	16.7%	NA	50.0%	13.8%
Tumwater	4.7%	NA	4.7%	NA	NA	5.0%
Zosel	93.1%	93.1%	NA	NA	NA	46.7%

Fallback

Fallback rates for adults tagged at Bonneville Dam ranged from 0.7% at Bonneville Dam to 19.6% at Zosel Dam for sites with 10 or more detections (Table 16). Fallback rates of Sockeye tagged as juveniles were generally higher than those tagged as adults, reaching a high of 34.5% at The Dalles Dam. Fallback rates for all four Snake River dams were 9.1% or more for Sockeye tagged as juveniles. Of the 86 Sockeye tagged by this project in 2015 which were estimated to fall back over at least one dam, 27 had multiple fallbacks (Table 17). Among Sockeye tagged as juveniles, the mean number of fallbacks events per Sockeye Salmon for Snake River Sockeye was 0.67 compared to 0.08 to 0.30 for the other juvenile groups and 0.16 for Sockeye in our Bonneville study.

Table 16. Estimated fallback rates for Sockeye Salmon at dams in 2015[9]. (An asterisk indicates a dam outside the range of the stock in question for which Sockeye were detected; a NA indicates Sockeye were not detected at a dam outside the range of the particular stock.)

		Tagged as Juveniles					
Dam	**Adults Tagged at Bonneville**	**Snake (n=671)**	**Yakima (n=13)**	**OKA (n=104)**	**Wenatchee (n=174)**	**RIS (n=132)**	**Total (n=1094)**
Bonneville	0.7%	23.0%	0.0%	1.0%	0.6%	0.0%	14.3%
The Dalles	1.4%	62.5%	0.0%	3.5%	0.7%	1.8%	34.3%
McNary	1.3%	6.1%	0.0%	0.0%	1.0%	0.0%	2.0%
Priest Rapids	2.3%	10.0%	0.0%*	2.1%	2.1%	0.0%	1.8%
Rock Island	1.0%	0.0%*	0.0%*	2.3%	1.2%	1.6%	1.5%
Rocky Reach	9.8%	0.0%*	100.0%*	2.3%	60.4%*	28.6%	30.4%
Wells	5.9%	0.0%*	NA	0.0%	55.2%*	22.7%	21.1%
Tumwater	0.9%	NA	NA	NA	NA	0.0%	0.0%
Zosel	19.6%	NA	NA	40.0%	NA	0.0%	13.3%
Ice Harbor	0.0%*	11.1%	NA	NA	NA	NA	11.1%
Lower Monumental	50.0%*	24.0%	NA	NA	NA	NA	24.0%
Little Goose	0.0%*	9.1%	NA	NA	NA	NA	9.1%
Lower Granite	NA	18.5%	NA	NA	NA	NA	18.5%

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

Table 17. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2015.

Fallback Events	Sockeye Tagged as Juveniles by Tagging Location					Adults Tagged at Bonneville
	Okanagan	Rock Island	Snake	Wenatchee	Yakima	
1	5	7	74	21	1	57
2	2	5	39	10	0	20
3	0	2	31	4	0	7
4	0	1	16	0	0	0
5	0	0	7	0	0	0
6	0	0	9	0	0	1
7	0	0	3	0	0	0
8	0	0	1	0	0	0
10	0	0	1	0	0	1
11	0	0	1	0	0	0
Number of Sockeye falling back at least once	7	15	182	35	1	86
% of Sockeye with at least one fallback event	6.7%	11.4%	27.1%	20.1%	7.7%	9.7%
Total fallback events	9	27	448	53	1	134
Number of Sockeye in study	104	132	671	174	13	915
Fallbacks events per Sockeye	0.09	0.20	0.67	0.30	0.08	0.16

Stock Composition Estimates Using PIT tags

An overall Sockeye stock composition estimate is not possible for 2015 as two entire weeks (weeks 28-29 comprising 22.2% of the run) and portions of two others (weeks 27 and 30, an additional 17.6% of the run) were missed due to Bonneville trap restrictions (Table 18). In Statistical Week 30, only 15 Sockeye were sampled and none of these fish made it upstream of McNary Dam and were, therefore, not possible to classify by stock based on PIT tag detections. For the portion of the run that was sampled, 78.4% of the run was estimated as Okanagan stock, 21.1% Wenatchee stock, and 0.5% Snake stock. No Sockeye tagged at Bonneville Dam were detected migrating upstream in the Yakima River.

Thirty-four Sockeye Salmon last detected in the Wenatchee River were previously detected at Rocky Reach Dam with 18 of these also detected at Wells Dam. There was only one Sockeye detected at Tumwater Dam that was subsequently detected anywhere downstream of Tumwater Dam. This Sockeye, with PIT tag 3DD.00775E08D4, was tagged at Bonneville on June 18, 2015, passed Wells Dam on July 3, but dropped downstream to pass LWE on July 8, Tumwater on July 18, and the Upper Wenatchee array on July 18 before being last detected at the ICL array on Icicle

Creek downstream of Tumwater Dam on July 31 and August 1, 2015. This was the only fallback observed at Tumwater Dam.

Among the three Sockeye detected at Ice Harbor Dam, two were last detected at Little Goose Dam with the third last detected at Ice Harbor Dam.

Table 18. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags in 2015 and a comparison to stock composition estimates estimated using visual dam counts. Note no sampling was conducted Statistical Weeks 28 and 29 and too few Sockeye were sampled Statistical Week 30 to estimate stock composition in week 30.

Statistical Week and Dates	Run Size from Bonneville Dam Visual Counts	PIT Tags Deployed at Bonneville	% Okanagan	% Wenatchee	% Snake
23 (May 16-June 6)	2,810	30	88.9%	11.1%	0.0%
24 (June 9-13)	21,918	125	64.8%	35.2%	0.0%
25 (June 16-20)	84,383	298	72.1%	26.9%	1.0%
26 (June 23-27)	181,971	251	67.6%	31.7%	0.7%
27 (June 30-July 3)	123,153	174	100.0%	0.0%	0.0%
28 (July 7-11)	58,543	0	NA	NA	NA
29 (July 14-18)	23,496	0	NA	NA	NA
30 (July 21-25)	9,927	15	NA	NA	NA
31-32 (July 28-Aug 1)	4,506	23	100.0%	0.0%	0.0%
Composite (weeks 23-27 and 31-32)	**418,741**	**916**	**78.4%**	**21.1%**	**0.5%**
Week 28-30	**91,965**	**NA**	**NA**	**NA**	**NA**
Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach counts to estimate proportion Wenatchee escapement; Rocky Reach to estimate Okanagan escapement)			81.7%	18.3%	
Visual Fish Counts at dams (Tumwater count to estimate the Wenatchee; Rocky Reach to estimate Okanagan)			80.8%	19.2%	

A total of 21 Sockeye Salmon PIT tagged at Bonneville Dam were adipose clipped[10] with 2 each left maxillary clipped, and 1 with both a right maxillary and adipose clip (Table 19). Of these Sockeye, eight were last detected in the Wenatchee Basin, one in the Okanagan Basin, two at Priest Rapids Dam, one in the Snake Basin, nine downstream of McNary Dam.

Table 19. Last detection site of clipped Sockeye Salmon tagged at Bonneville Dam in 2015.

Last Detection Site	Left Maxillary Clip	Right Maxillary Clip Plus Adipose Clip	Adipose Clip	All Clips
Bonneville Dam	0	0	2	2
The Dalles Dam	0	0	6	6
Deschutes River Mouth (DRM)	0	0	1	1
Priest Rapids Dam	1	0	1	2
Upper Wenatchee (UWE)	0	1	2	3
Wenatchee spawning grounds (WTL)	0	0	5	5
Wells Dam	0	0	2	2
Lower Methow River (LMR)	0	0	1	1
OKC	1	0	0	1
Little Goose Dam	0	0	1	1
Total	**2**	**1**	**21**	**24**

Genetic Stock Identification (GSI)

In 2015, genetics stock identification (GSI) was used to classify samples from 803 Sockeye Salmon sampled at Bonneville Dam (Table 20), 629 sampled at Wells dam, 243 at Priest Rapids Dam, and 12 collected from the Methow River.

Table 20. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2015.

Stock Estimated Using PIT Tags	Stock Estimated by GSI				
	Okanagan	Wenatchee	Snake	Unknown	Total
Okanagan	297	11	0	0	308
Wenatchee	0	129	0	1	130
Snake	0	0	3	0	3
Unknown	216	138	7	1	362
Total	**513**	**278**	**10**	**2**	**803**

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

Among Sockeye sampled at Bonneville Dam for which genetics samples were analyzed, 11 (2.5%) Sockeye out of the 440 that could be classified by stock using both PIT tags and GSI were classified differently (Table 20). These 11 Sockeye were all Wenatchee stock Sockeye last detected at Wells or Rocky Reach dams.

Three of the 10 Sockeye Salmon classified by GSI as being of Snake River origin (Table 20) were last detected in the Snake River, with 2 last detected at the Little Goose fishways (3DD.00775DDF06 and 3DD.00775DFBFF both on July 1, 2015) and 1 at Ice Harbor Dam fishways (3DD.00775E6895 on July 13, 2015). Among the seven Sockeye Salmon classified by GSI as being of Snake River origin that were last detected in the Columbia River, two were last detected at Bonneville Dam (6/15 and 7/2), five were last detected at The Dalles (one each on 6/29, 7/3, 7/4, 7/16, and 7/18).

GSI classified the two Sockeye last detected in the Yakima River as Okanagan stock (Table 21). Both Sockeye were detected in the fish trap at the Priest Rapids Dam east fish ladder before being detected at Roza Dam in the Yakima River (thereby missing Prosser Dam PIT tag antennas) and were likely transported from Priest Rapids Dam to Cle Elum Lake as part of a Sockeye restoration program only to migrate downstream to Roza Dam.

Among the three Sockeye last detected in the Deschutes, two were classified as Wenatchee stock and one of Okanagan stock (Table 21). Among the two Sockeye last detected in the Methow, one was classified as Wenatchee origin while no GSI was done on the other (Table 21). (An additional Sockeye detected in the Methow that also was not analyzed was subsequently recaptured at Chief Joseph Hatchery immediately downstream of Chief Joseph Dam.)

Stock composition estimates of Sockeye Salmon passing Bonneville Dam using PIT tags estimated 78.4% Okanagan origin compared to 64.3% estimated by GSI (Table 22). However, due to high mortality on the upstream migration, some weekly estimates were based on the survival of only a few Sockeye. For example, in week 27, only 15 (all Okanagan) out of 169 Sockeye PIT tagged survived to terminal areas. Also, in many weeks, there was considerable straying of Wenatchee origin Sockeye with Sockeye detected at Rocky Reach and Wells dams being subsequently detected in the Wenatchee River and classified using PIT tags as being Wenatchee stock. Many others, last detected at Rocky Reach and Wells dams, may have been Wenatchee stock Sockeye that did not return to the Wenatchee River. If only Sockeye detected in the Okanagan River (at OKL, ZSL, or OKC) are considered Okanagan Sockeye, the PIT

tag estimate for all three stocks is within one percentage point of the GSI estimate (Tables 23 and 24). Stock specific survival from Bonneville Dam to natal rivers (OKL, LWE, and IHA) was 20.3% for the Okanagan stock, 34.3% for the Wenatchee stock, and 11.2% for the Snake stock (Table 24). Survival to the spawning grounds was 2.6% for the Okanagan stock, 20.5% for the Wenatchee stock, and 0.0% to the Snake River.

Table 21. GSI classification of Sockeye last detected in non-terminal areas (downstream of OKL, LWE, and Ice Harbor dams).

Last Site Detected	Okanagan	Wenatchee	Snake	Total
Bonneville Dam (BO1, BO3, BO4, BCC)	65	31	3	99
Deschutes River mouth (DRM)	1	2	0	3
John Day Dam juvenile bypass	2	1	0	3
McNary Dam (MC1, MC2)	36	20	0	56
Methow River	0	1	0	1
Priest Rapids Dam	23	11	0	34
Priest Rapids Hatchery	1	3	0	4
Rock Island Dam	2	0	0	2
Roza Dam (ROZ), Yakima River	5	2	0	7
Rocky Reach Dam fish ladders	6	2	0	8
Rocky Reach Dam juvenile bypass	0	1	0	1
The Dalles Dam (TD1, TD2)	73	63	4	140
Tumwater Dam	0	10	0	10
Wells Dam	169	10	0	179
Not detected after tagging	8	3	0	11
Total	**391**	**160**	**7**	558

Table 22. Comparison classification by stock using GSI and PIT tags of Sockeye Salmon sampled at Bonneville Dam in 2015 for Statistical weeks 23-27 and 31.

	Stock Classification		
Classification Type	**Okanagan**	**Wenatchee**	**Snake**
Using PIT tags	78.4%	21.1%	0.5%
Using GSI	62.8%	35.7%	1.4%
PIT without classifying WEL/RRF fish	62.5%	36.7%	0.9%

Table 23. Comparison of stock classification of Sockeye sampled at Bonneville Dam using GSI and PIT tag detections in 2015. No data is available for Statistical Weeks 28 and 29 due to sampling restrictions at the Bonneville Dam trap.

Statistical Week	Run Proportion	Classification Using PIT Tags								Classification Using Genetics Only			
		Classifying as Described in Methods Using PIT Tags (last detection at WEA or RRF treated as Okanagan Stock)				Only Classifying Sockeye Detected in Okanagan, Wenatchee, and Snake Rivers				Stock Classification Using GSI			
		N	OKA	WEN	Snake	N	OKA	WEN	Snake	N	OKA	WEN	Snake
22-23	0.6%	27	88.9%	11.1%	0.0%	18	83.3%	16.7%	0.0%	27	85.2%	14.8%	0.0%
24	4.3%	108	64.8%	35.2%	0.0%	56	32.1%	67.9%	0.0%	110	62.7%	37.3%	0.0%
25	16.5%	205	71.7%	27.3%	1.0%	116	50.0%	48.3%	1.7%	254	64.6%	33.9%	1.6%
26	35.6%	142	67.6%	31.7%	0.7%	84	45.2%	53.6%	1.2%	225	58.7%	40.4%	0.9%
27	24.1%	15	100.0%	0.0%	0.0%	5	100.0%	0.0%	0.0%	154	66.2%	31.2%	2.6%
28	11.5%	0	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	NA
29	4.6%	0	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	NA
30	1.9%	0	NA	NA	NA	4	NA	NA	NA	13	69.2%	30.8%	0.0%
31-32	0.9%	4	100.0%	0.0%	0.0%	1	100.0%	0.0%	0.0%	18	77.8%	22.2%	0.0%
Weeks 23-27, 31-32		**501**	**78.3%**	**21.2%**	**0.5%**	**284**	**62.5%**	**36.7%**	**0.9%**	**801**	**62.8%**	**35.7%**	**1.4%**

Table 24. 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 2015. No data is available for Statistical Weeks 28 and 29 due to sampling restrictions at the Bonneville Dam trap.

	Okanagan River		Wenatchee		Snake River		
Statistical Week	Okanagan River	Okanagan Spawning	Wenatchee River	Wenatchee Spawning	Snake River	Snake Spawning	All Stocks Spawning
23	65.2%	9.1%	75.0%	0.0%	50.0%	0.0%	10.0%
24	20.3%	8.7%	75.6%	41.5%	50.0%	0.0%	18.4%
25	29.9%	2.4%	51.2%	37.2%	0.0%	0.0%	10.4%
26	27.3%	3.0%	46.7%	26.1%	NA	NA	10.0%
27	4.9%	1.0%	0.0%	0.0%	NA	NA	0.6%
28	NA	NA	NA	NA	NA	NA	NA
29	NA	NA	NA	NA	NA	NA	NA
30	0.0%	0.0%	0.0%	0.0%	NA	NA	0.0%
31	21.4%	7.1%	0.0%	0.0%	NA	NA	10.0%
Composite (Weeks 23-27, 30-31)	**20.5%**	**2.6%**	**34.3%**	**20.5%**	**11.2%**	**0.0%**	**7.6%**

Wells Dam Sampling Results

A total of 711 Sockeye were sampled at the Wells Dam west bank trap, of which 704 were PIT tagged with an additional four previously tagged fish added to our study group (Table 25). Of these 708 PIT tagged fish, 126 were also acoustic tagged. All sampled fish were transported by truck and released at the Starr Ramp approximately four km upstream of Wells Dam along the west shore of Lake Pateros (PTAGIS site WELSBR). A total of nine adipose clipped Sockeye were sampled at Wells Dam, all Age 1.2. Five of these were identified by GSI as being of Wenatchee origin, two of Okanagan origin, and one of Snake River origin with one not analyzed.

In all weeks, Age 1.2 was the predominant age class at Wells Dam (Table 26) with an overall estimate of 93.0%. Among those Sockeye visually identified as males, 89.9% were Age 1.2 and 9.9% 1.3 compared to 97.0% and 2.8% respectively for those identified as females (Table 26).

Table 25. Number of Sockeye Salmon sampled and PIT and acoustic tagged at Wells Dam by date and statistical week in 2015.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	Acoustic Tagged	Genetic Stock Classification Available
6/22-6/24	26	62	61	1	5	54
6/29-6/30	27	116	115	1	10	99
7/6-7/7	28	193	193		33	165
7/13-7/14	29	148	148		27	135
7/22	30	109	108	1	27	95
7/30	31	55	54	1	18	50
8/6	32	28	28		6	27
Total		**711**	**704**	**4**	**126**	**625**

Table 26. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2015. 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
26	6/22-6/24	19,665	62	61	0.0%	98.4%	1.6%	0.0%
27	6/29-6/30	65,214	116	113	0.0%	95.6%	4.4%	0.0%
28	7/6-7/7	68,854	193	187	0.0%	90.9%	9.1%	0.0%
29	7/13-7/14	18,735	148	146	0.0%	89.7%	9.6%	0.7%
30	7/22	4,961	109	106	0.9%	91.5%	7.5%	0.0%
31	7/30	2,703	55	53	0.0%	92.5%	7.5%	0.0%
32	8/6	3,328	28	27	3.7%	77.8%	14.8%	3.7%
Composite		**183460**	**711**	**693**	**0.1%**	**93.0%**	**6.7%**	**0.1%**
Std. Err.					**0.1%**	**1.1%**	**1.1%**	**0.1%**
Males (visual ID)			406	394	0.1%	89.9%	9.9%	0.1%
Females (visual ID)			303	299	0.1%	97.0%	2.8%	0.1%

Priest Rapids Dam Sampling

A total of 279 Sockeye were sampled at the Priest Rapids Dam OLAFT between July 10 and July 20, 2015, of which 276 were PIT tagged (Table 27). One sampled Sockeye was previously PIT tagged and there were three mortalities that did not recover after sampling. All three mortalities were found impinged on a grate at the recovery site. We moved the recovery site to the return fish ladder towards the end of sampling on 7/13 and had no additional mortalities.

The primary purpose of Priest Rapids Dam sampling was to assess the age composition for those Sockeye Salmon that likely passed Bonneville Dam during the period we were not allowed to sample. The percentage of predominant Age 1.2 Sockeye Salmon in our Priest Rapids Dam sample of 93.2% was very similar to the 93.8% estimated at Bonneville Dam (Table 7). The percentage of Age 1.1 Sockeye sampled at Priest Rapids Dam was higher (3.0% versus 0.1%) and the percentage of Age 1.3 Sockeye lower (3.0% versus 5.6%) than that observed at Bonneville Dam. However, the Priest Rapids sample targeted the end of the run which has traditionally had a higher percentage of one-ocean, and a lower percentage of three-ocean Sockeye than the run at large (Fryer et al. 2014).

Table 27. Summary of 2015 Priest Rapids Dam Sockeye sampling.

Statistical Week	Dates	Number Sampled	Number Tagged	Number Previously Tagged	Number of Mortalities	Detected Upstream
28	July 10	98	96	1	2	81
29	July 13, 15	128	128	0	1	95
30	July 20	53	52	0	0	37
Total		**279**	**276**	**1**	**3**	**213**

Table 28. Age composition of Sockeye Salmon sampled at Priest Rapids Dam between July 10 and 20, 2015.

Statistical Week	Age					
	N	1.1	1.2	2.1	1.3	2.2
28	94	3.2%	93.6%	1.1%	2.1%	0.0%
29	121	3.3%	94.2%	0.0%	1.7%	0.8%
30	51	2.0%	90.2%	0.0%	7.8%	0.0%
Total	266	3.0%	93.2%	0.4%	3.0%	0.4%
Bonneville Dam (from Table 7)		**0.1%**	**93.8%**	**0.1%**	**5.6%**	**0.4%**

Notable at Priest Rapids Dam sampling was the poor condition of the Sockeye Salmon, with 70.4% showing lesions similar to those in Figure 14 and 9.0% with fungus. What we described as lesions were often circular in nature and have been attributed to lamprey wounds, possibly inflicted in the estuary but exacerbated on the upstream migration by high water temperatures (E-mail from Richard Beamish, Department of Fisheries and Oceans, Canada to Jeff Fryer, October 12, 2015.) Similar wounds were observed on 41.6% of Sockeye Salmon sampled at Wells Dam in 2015. At Bonneville Dam, 20.4% of Sockeye Salmon sampled had similar, though smaller, wounds, with this peaking during the high temperature weeks of 27, and 30-32 at over 33%.

Figure 14. Picture showing Sockeye Salmon with lesions sampled at Priest Rapids Dam, July 20, 2015.

Okanagan and Wenatchee Age, and Length-at-Age Composition

Okanagan and Wenatchee age composition was estimated from Sockeye PIT tagged by this project at Bonneville Dam and subsequently detected in terminal areas (Table 29). The Wenatchee stock was estimated to be comprised primarily of Age 1.2 Sockeye (88.9%) with the remainder Age 1.3 and 2.2. The Okanagan stock was 97.0% Age 1.2 with 2.4% Age 1.3 and 0.2% for both Age 1.1 and 2.1.

Age composition estimates for Sockeye sampled at Bonneville, Priest Rapids and Wells dams by stock are presented in Table 29. Wenatchee stock Sockeye, as estimated using GSI, had a higher percentage of Age 1.3 and lower percentage of Age 1.2 Sockeye than do Okanagan or mixed-stock Sockeye Salmon in 2015 (Table 29).

Table 29. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2015. Standard errors are in parentheses.

Sampling Site	Stock	Methodology	Ageable Sample Size	Brood Year and Age Class				
				2012	2011		2010	
				1.1	1.2	2.1	1.3	2.2
Bonneville Dam	Mixed	Weighted by weekly visual count with weeks 28-29 not included	898	0.1	93.8	0.1	5.6	0.4
Priest Rapids Dam	Mixed	Priest Rapids Dam weeks 28-30 only	266	3.0	93.2	0.4	3.0	0.4
Bonneville Dam	Wenatchee	Based on GSI of Bonneville-sampled Sockeye (weeks 28-29 not included)	142	--	88.9 (0.5)	--	10.6 (0.5)	0.5 (0.0)
Bonneville Dam	Okanagan	Based on GSI of Bonneville-sampled Sockeye (weeks 28-29 not included)	143	0.2 (0.0)	97.0 (0.2)	0.2 (0.2)	2.4 (0.2)	--
Wells Dam	Okanagan	Wells Dam Sampling	692	0.1 (0.1)	93.0 (1.1)	--	6.7 (1.1)	0.1 (0.1)

Mean fork lengths estimated by measuring Sockeye Salmon at Wells Dam were greater than those estimated using Bonneville PIT tag data (Table 30) for the predominant 1.2 and 1.3 age groups. This was likely due to the 5.1 cm spacing of the bars on the gate diverting Sockeye Salmon into the Wells Dam east bank fish trap being sufficiently wide that smaller fish can slip through and avoid being trapped.

Table 30. Length-at-age composition of Wenatchee and Okanagan Sockeye Salmon stocks estimated by detection of Sockeye Salmon previously PIT tagged at Bonneville and sampled at Wells dams in 2015.

Stock	Statistic	Brood Year and Age Class				
		2012	2011		2010	
		1.1	1.2	2.1	1.3	2.2
Bonneville Dam-Mixed Stock (Excluding weeks 28-29)	Mean Fork Length	41.5	49.9	40.5	54.3	52.2
	St. Dev.	0.7	2.3	-	2.1	1.8
	N	2	844	1	48	3
Priest Rapids Dam-Mixed Stock (Weeks 28-30 only)	Mean Fork Length	39.1	50.1	40.0	55.5	51.5
	St. Dev.	2.2	2.2	-	2.3	-
	N	8	248	1	8	1
Okanagan-based on GSI of Sockeye tagged at Bonneville Dam (Excluding weeks 28-29)	Mean	42.0	49.5		53.5	
	St. Dev.	-	2.2		0.9	
	N	1	139		3	
Okanagan-Wells Sampling	Mean	39.0	52.2		56.0	50.3
	St. Dev.	2.8	2.2		2.0	1.1
	N	2	635		53	2
Snake River-Bonneville PIT tags	Mean		53.2			
	St. Dev.		1.6			
	N		3			
Wenatchee based on GSI of Sockeye tagged at Bonneville Dam (Excluding weeks 28-29)	Mean		50.4		54.7	
	St. Dev.		2.1		1.5	
	N		127		13	

Stock Composition at Wells Dam

GSI estimated the weekly percentage of Sockeye Salmon of Wenatchee origin at Wells Dam ranged up to 44.0% for Statistical Week 31 based on Sockeye sampled at Wells Dam (Table 31). Over the entire run, based on Wells sampling, an estimated 15.2% of the run passing Wells Dam was of Wenatchee stock compared to 11.6% Wenatchee stock for Bonneville tagged Sockeye passing Wells Dam (Table 31). Sample sizes of Bonneville-tagged Sockeye passing Wells Dam were low after Statistical Week 29 due to low numbers of late-run Sockeye tagged at Bonneville Dam as well as high upstream mortality. Three Sockeye sampled at Wells Dam (an estimated 0.2% of the run) were classified by GSI as being of Snake River origin.

Table 31. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI in 2015. (Wells Dam estimates are weighted by the weekly Wells Dam run size, Bonneville estimates are unweighted.)

Week at	Wells Sampling	Bonneville Tagged

Wells Dam	N	Okanagan	Wenatchee	Snake	N	Okanagan	Wenatchee	Snake
26	55	92.6%	7.4%	0.0%	84[11]	97.6%	2.4%	0.0%
27	100	91.9%	8.1%	0.0%	137	90.5%	9.5%	0.0%
28	167	81.2%	18.8%	0.0%	82	85.4%	14.6%	0.0%
29	136	77.0%	21.5%	1.5%	6	83.3%	16.7%	0.0%
30	95	60.0%	38.9%	1.1%	6	83.3%	16.7%	0.0%
31	49	56.0%	44.0%	0.0%	1	100.0%	0.0%	0.0%
32	27	70.4%	29.6%	0.0%	4[12]	100.0%	0.0%	0.0%
Total	**629**	**84.7%**	**15.2%**	**0.2%**	**320**	**88.4%**	**11.6%**	**0.0%**

Detections in Natal Areas

Based on PIT tag detections, the estimated percentage of Sockeye surviving from Wells Dam to Zosel Dam was 10.0% for Sockeye tagged at Wells Dam (4.6% last detected at Zosel plus 5.4% last detected at OKC) compared to 7.3% for Sockeye tagged at Bonneville Dam (Table 32). Of the Sockeye Salmon tagged at Wells Dam, 2.5% were last detected downstream of Wells Dam (Wenatchee River or Rocky Reach juvenile bypass) compared to 6.5% of the Sockeye tagged at Bonneville Dam which passed Wells Dam and were last detected downstream of Wells Dam in the Wenatchee River or Rocky Reach Juvenile Bypass (Table 32).

Among the 33 Sockeye tagged at Wells Dam and last detected in the Wenatchee Basin for which GSI was conducted, all were classified as of Wenatchee stock (Table 33). Similarly, of the 244 Wells Dam-tagged Sockeye for which GSI was conducted that were last detected in the Okanagan Basin, all were classified as Okanagan stock (Table 33). Among the 13 last detected in the Methow Basin for which GSI was conducted, all were classified as Wenatchee stock. From the Methow Basin we also had samples from 12 Sockeye Salmon carcasses, five of which were classified as Wenatchee origin it not being possible to classify the remaining seven.

[11] Includes sockeye passing Wells Dam prior to Week 26

[12] No Bonneville tagged sockeye were detected passing Wells Dam in Week 32, however 4 passed between Weeks 33 and 37 and are reported here.

Table 32. Number of tagged (PIT+floy, PIT+floy+acoustic) Sockeye released upstream of Wells Dam in 2015 with the estimated percentage last detected by site (weighted by weekly run size at Wells Dam). Rates for Bonneville dam tagged Sockeye Salmon are shown for comparison.

Week	Wells Run %	N	Wenatchee River	Wells Dam	Methow River	OKL Array	Zosel Dam	OKC	Rocky Reach Juv Bypass	Not Detected
26	10.7%	62	1.6%	1.6%	0.0%	6.5%	1.6%	6.5%	0.0%	17.7%
27	35.5%	116	1.7%	0.0%	0.0%	8.6%	5.2%	5.2%	0.0%	20.7%
28	37.5%	193	2.6%	0.5%	1.6%	10.4%	3.6%	3.1%	0.0%	21.8%
29	10.2%	148	6.1%	0.0%	3.4%	20.9%	10.1%	12.2%	0.0%	52.7%
30	2.7%	109	4.6%	0.9%	6.4%	12.8%	6.4%	7.3%	0.0%	38.5%
31	1.5%	55	1.8%	5.5%	1.8%	3.6%	0.0%	14.5%	0.0%	27.3%
32	1.8%	28	0.0%	0.0%	0.0%	0.0%	3.6%	3.6%	0.0%	7.1%
Weighted Total		**711**	**2.5%**	**0.5%**	**1.1%**	**10.2%**	**4.6%**	**5.4%**	**0.0%**	**24.4%**
Bonneville Tagged Sockeye Detected at Wells		**874**	**5.9%**	**NA**	**1.5%**	**22.6%**	**7.3%**	**6.1%**	**0.6%**	**55.9%**

Table 33. GSI stock classification by basin of last detection for Sockeye Salmon tagged at Wells Dam in 2015.

	Classification Using Genetics Stock Identification (GSI)			
Basin of Last Detection	**Okanagan**	**Wenatchee**	**Not Classified**	**Total**
Methow[13]		13	4	17
Okanagan	244		33	277
Wenatchee		35	2	37
Total	**244**	**48**	**39**	**331**

Survival from Wells Dam to OKC for both Sockeye Salmon tagged at Wells Dam as well as Bonneville Dam-tagged Sockeye passing Wells Dam was generally under 15% through the migration occurred as Okanagan River temperatures remained above 22C (Figure 15).

No Sockeye Salmon were detected at OKC prior to September 3, 2015 with the number not surpassing four fish until water temperatures dropped below 15C on October 1, 2015 (Figure 16). The number passing peaked on October 10 at 17 fish detected with a mean water temperature of 14.6C.

[13] We also used GSI on 12 Sockeye Salmon found spawning in the Methow River in 2015. Of these 12 fish, 5 classified as Wenatchee stock with the remaining 7 not possible to classify.

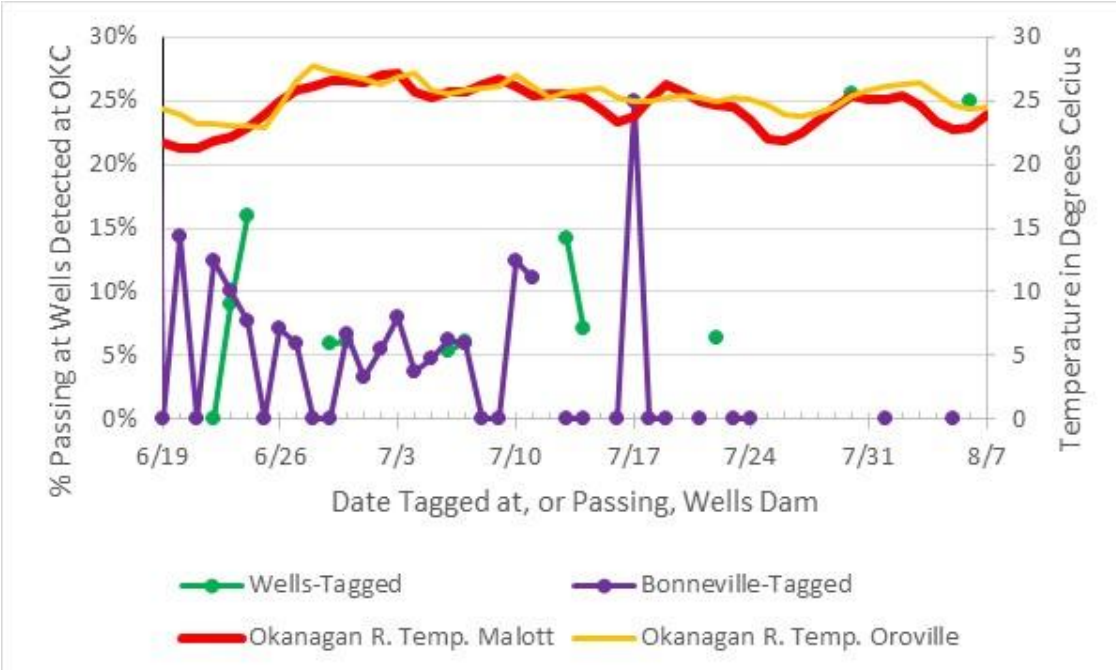

Figure 15. Percentage of Sockeye tagged at Wells and Bonneville passing Wells Dam subsequently detected at OKC by date past Wells Dam in 2015. Okanagan River temperatures were recorded at the Malottat and Oroville gaging station. (http://waterdata.usgs.gov/nwis).

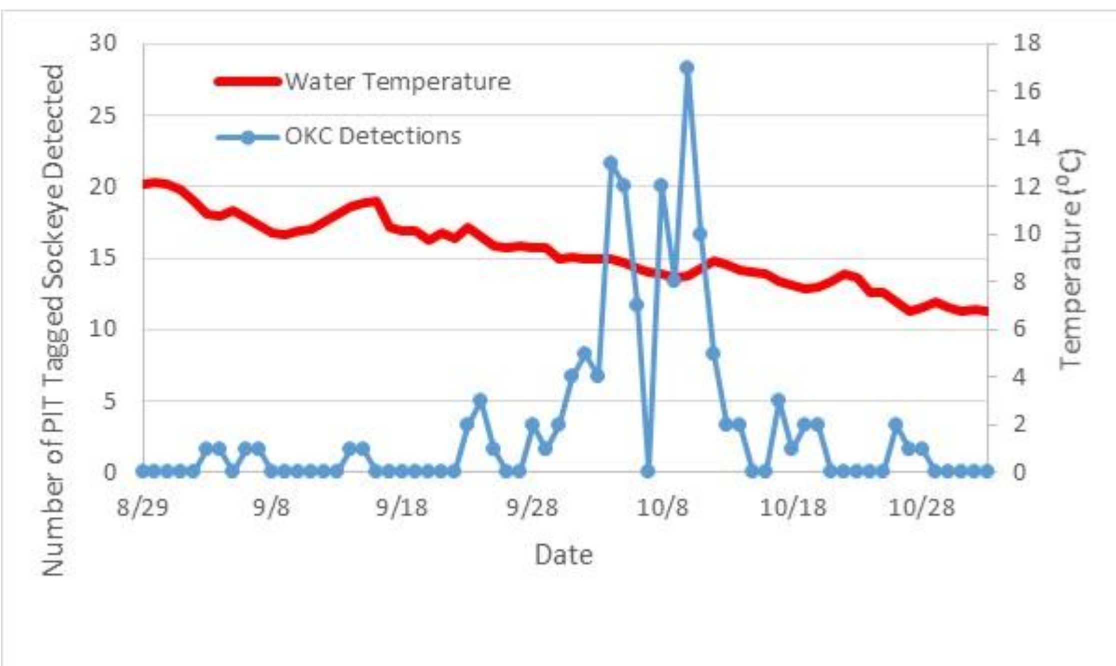

Figure 16. Number of Sockeye detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2015.

Upstream Survival Comparisons with Sockeye Tagged as Juveniles

Comparisons of upstream survival between adults tagged at Bonneville Dam and previously tagged juveniles were hampered by the lack of tagging at Bonneville Dam during weeks 28 and 29. As previously described, Week 28 and 29 survival rates for juveniles tagged at Rock Island Dam were used as a surrogate for Bonneville Dam survival rates for these weeks (Table 11). After incorporating these results into the Bonneville AFF group, survival rates from Bonneville to The Dalles were similar between all groups except for Sockeye tagged as juveniles in the Snake and Yakima basins (Table 34). The Yakima Basin estimates of upstream survival have low precision due to a small sample of only 12 Sockeye passing Bonneville. Sockeye tagged by this project had a lower survival rate to Priest Rapids and Rock Island Dam than did mixed-stock Sockeye tagged as juveniles at Rock Island Dam.

Table 34. 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 2015. An asterisk (*) indicates Sockeye which strayed from the normal migration route for the stock of concern. Stock at Bonneville Dam was estimated using GSI.

					% 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 Dam	Tumwater Dam
Eastbank Hatchery	Hatchery	Wenatchee	Juvenile	173	87.9	61.8	54.3	48.0	NA*	24.3
Okanagan River	Wild	Okanagan	Juvenile	103	83.5	59.2	47.6	41.7	4.9	NA*
Rock Island Dam	Mixed	Mixed	Juvenile	132	86.4	60.6	55.3	47.7	7.6	13.6
Snake River	Mixed	Snake	Juvenile	687	62.6	14.8	1.5*	1.3*	NA*	NA*
Yakima	Wild	Yakima	Juvenile	12	66.7	50.0	16.7*	8.3*	NA*	NA*
Bonneville AFF[14]	Mixed	Mixed	Adult	505	82.8	54.0	44.9	40.6	5.7	8.3
Bonneville AFF[14]	Mixed	Wenatchee	Adult	275	82.2	46.7	39.2	36.3	NA*	23.5
Bonneville AFF[14]	Mixed	Okanagan	Adult	902	82.1	58.0	48.3	44.0	8.5	NA*

[14] Since no Bonneville sampling was conducted in weeks 28 and 29, survival from sockeye tagged as juveniles at Rock Island Dam was used.

A higher percentage of Bonneville-tagged Sockeye passing Tumwater Dam were detected at spawning ground PIT arrays on the Little Wenatchee and White rivers than were Sockeye tagged as juveniles at Eastbank Hatchery (Wenatchee stock)and Rock Island Dam passing Tumwater Dam or as adults at Tumwater Dam (Table 35, Figure 17). All four groups of Sockeye Salmon showed a preference for the White River spawning grounds.

Table 35. Distribution of Sockeye Salmon in the Wenatchee Basin in 2015 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	42	9.5%	31.0%	40.5%
Rock Island	Mixed	Juvenile	18	0.0%	50.0%	50.0%
Bonneville AFF	Mixed	Adult	106	9.0%	51.9%	60.9%
Tumwater Dam	Mixed	Adult	961	6.6%	29.7%	36.3%

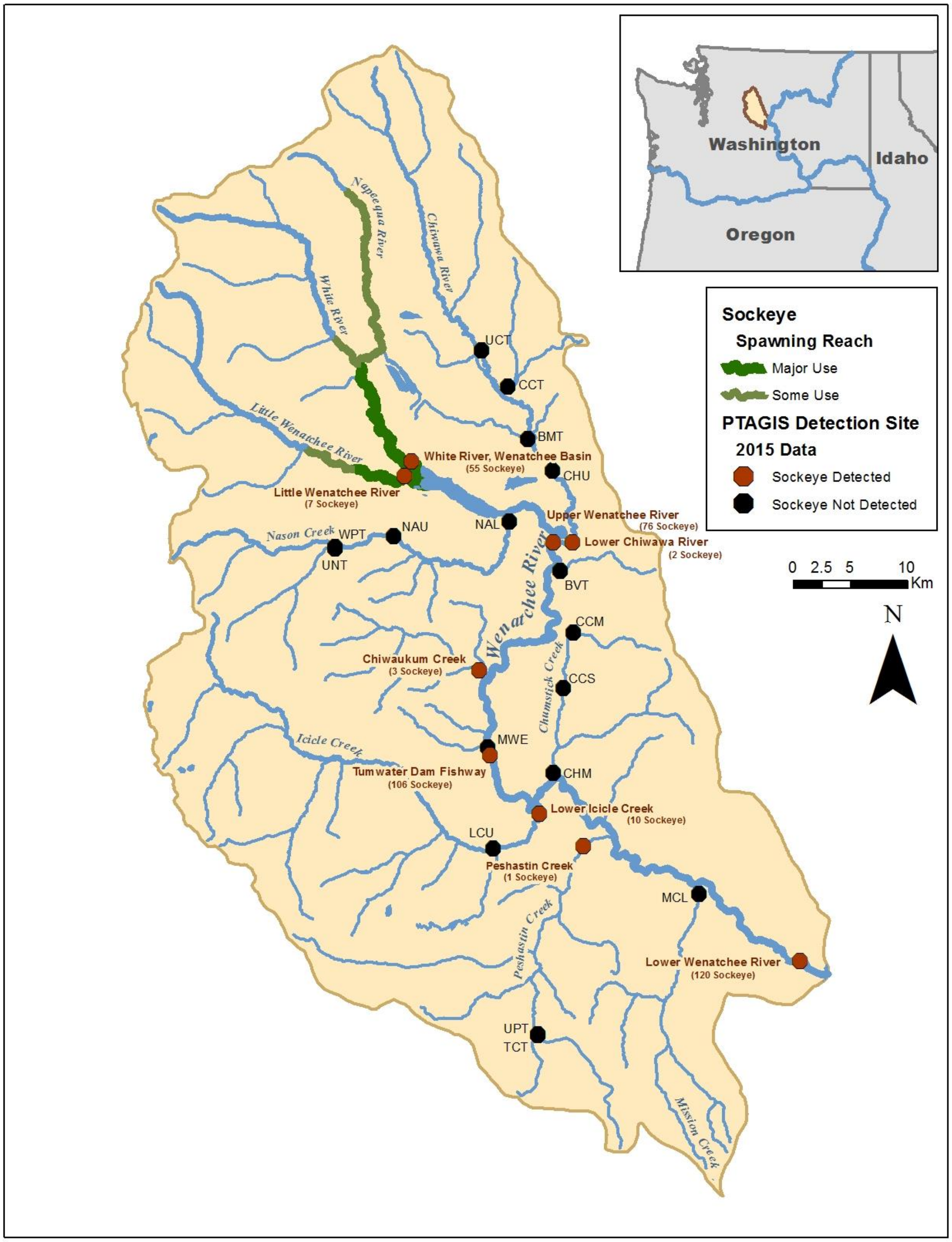

Figure 17. The Wenatchee Basin showing PIT tag interrogation sites and highlighting sites where Sockeye were detected in 2015. Also displayed is the spawning area of Sockeye. Appendix A Table A1 has site information.

With the exception of Sockeye tagged as juveniles in the Snake River, median migration times from Bonneville Dam to both The Dalles and McNary dams differed by 0.7 days or less between the PIT tag groups (Table 36). Snake and Yakima River Sockeye straying above Priest Rapids Dam had slower migration times than other Sockeye groups. Strays from Wenatchee stock Eastbank Hatchery program[15] 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 36. Median migration time in days between Columbia Basin PIT tag antenna sites for adult and juvenile Sockeye tagged migrating upstream in 2015. An asterisk (*) indicates any detected Sockeye would be staying from the normal migration route for the stock of concern. Appendix A Table A1 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
Okanagan River	Wild	Okanagan Juvenile	1.2	4.2	10.0	2.6	1.1	43.2	22.2	NA*	5.5
Rock Island Dam	Mixed	Mixed Wen/OKA Juvenile	1.2	4.4	11.0	3.1	1.0	44.1	34.2	17.1	5.7
Snake River	Mixed	Snake Juvenile	1.6	5.9	28.1*	3.6*	1.9*	27.2	NA*	NA*	7.2*
Wenatchee	Hatchery	Wenatchee Juvenile	1.3	4.7	11.3	2.9	1.0*	36.0	NA*	17.7	6.3*
Yakima	Wild	Yakima Juvenile	1.1	4.1	18.2*	9.0*	3.1*	NA*	NA*	NA*	NA*
Bonneville AFF	Mixed	Mixed Adult	1.8	4.8	12.2	3.1	1.0	1.8	11.1	11.6	6.1

Migration into Natal Streams-Wenatchee River

In previous years of this study Wenatchee River temperatures have not been a barrier to Sockeye Salmon migration unlike in the Okanagan River. In addition, LWE detection efficiency has been relatively low making it difficult to use the site to assess migration in the lower Wenatchee River. However, in 2015, Wenatchee River temperatures were high enough to affect the Sockeye migration and flows were low enough that the detection efficiency of LWE was estimated at 82.1% (Table 5). Sockeye detections at LWE were increasing in late June just as the mean daily temperature was climbing towards 23C (Figure 18) which was reached on June 29.

[15] Eastbank hatchery is located on the Columbia River adjacent to Rocky Reach Dam. The Eastbank Sockeye program trapped adults at Tumwater Dam, reared them at the hatchery, and released juveniles into Lake Wenatchee. The program has been discontinued but adults are still returning from it.

Temperatures remained at, or above 22.9C until July 8. During this period, 54 Sockeye were first detected at LWE with a median time between first and last detection at LWE of 9.0 days compared to the 68 Sockeye first detected before and after this period with a median time between first and last detections of less than one minute.

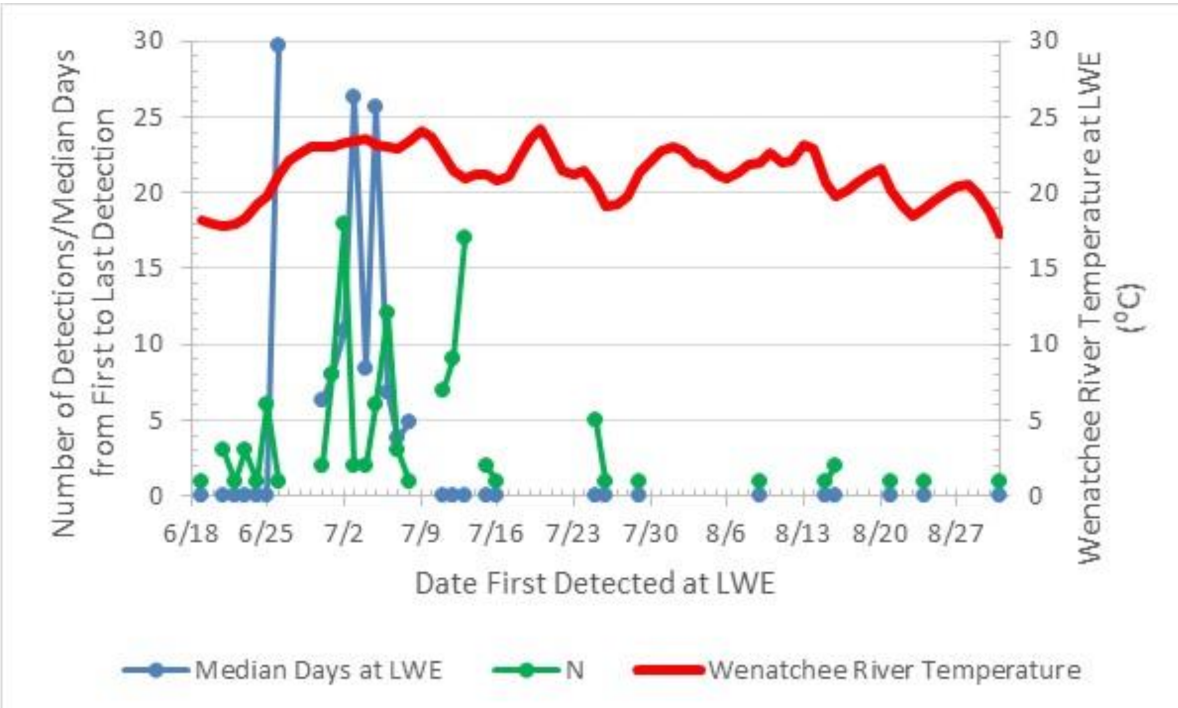

Figure 18. Number of Sockeye Salmon detected at LWE, median days from first to last detection at LWE, and lower Wenatchee River water temperatures by date in 2015

Sockeye last detected passing LWE that passed during lower temperatures had the best survival to Tumwater Dam (Table 37, Figure 19). The earliest group passing Tumwater Dam prior to July 2 as temperatures were climbing, had a survival from LWE to Tumwater Dam of 89.5% and a conversion rate to the spawning grounds from Tumwater Dam of 58.5%, The next group of Sockeye last detected at LWE between July 2 and 8 migrated up the Wenatchee River during the longest sustained period of high temperatures that summer and had a survival rate to Tumwater Dam of 42.9% (Table 37). The group passing between July 11 and 13 as temperatures were declining had the highest survival to Tumwater Dam of 93.5% and the highest conversion rate from Tumwater Dam to the spawning grounds (81.4%). This group also comprised the largest number of fish, at 46, compared to only 43 that passed later in the summer. The group of 23 Sockeye that waited until August 15 or later, after temperatures began to finally cool for the fall, had only a 34.8% survival to Tumwater Dam and only a 12.8% conversion rate to the spawning grounds. This group also had the highest percentage

(other than the 3 fish passing July 15 and 16) last detected at Icicle and Peshastin creeks and the longest median travel time to Tumwater Dam of 10.7 days, both suggestive that they may have run out of energy to complete the migration.

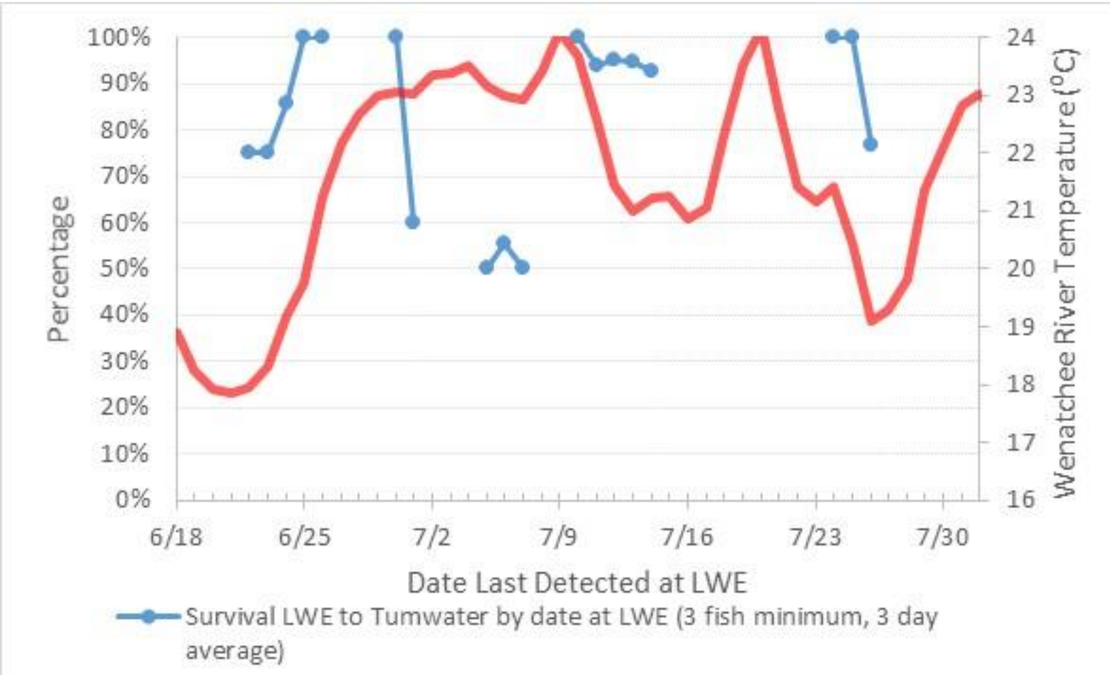

Figure 19. Percentage of sockeye salmon detected in the Lower Wenatchee River at LWE surviving to Tumwater Dam by date at LWE in 2015 (3 day moving average, 3 fish minimum).

Table 37. Survival of Sockeye Salmon from the Lower Wenatchee River (LWE) to Tumwater Dam and the spawning grounds as well as the percentage last detected in tributaries downstream of Tumwater Dam in 2015.

Date Last Detected at LWE	Number at LWE	% to Icicle or Peshastin Creeks	% Survival LWE to Tumwater Dam	Median Travel Time LWE to Tumwater Dam	% Conversion Tumwater-Spawning Grounds	Temperature at LWE (C)
6/19-7/1	19	0.0%	89.5%	6.0	58.8%	17.9-23.1
7/2-7/8	14	7.1%	42.9%	7.6	50.0%	22.9-23.4
7/11-7/13	46	2.2%	93.5%	5.2	81.4%	21.0-22.6
7/15-7/16	3	33.3%	33.3%	6.1	0.0%	20.9-21.2
7/25-8/9	17	11.8%	70.6%	5.4	33.3%	19.8-21.4
8/15-9/20	23	17.4%	34.8%	10.7	12.5%	Less than 20.8
Unweighted Total	**122**	**7.4%**	**71.3%**	**5.4**	**60.9%**	

Migration into Natal Streams-Okanagan River

As is often the case, Sockeye Salmon faced a significant temperature barrier in the Okanagan River with the mean daily temperature at the USGS gaging station in Monse remaining at or above 21.9 between June 23, 2015 and August 29, 2015 and peaking at 27.1C on July 2 and July 3, 2015. Given these high temperatures, Sockeye remained in Wells Pool after June 22, only moving upstream on temperature drops.

Unlike in the Wenatchee River, where the only large group of PIT tagged Sockeye Salmon we had moving upriver was those tagged at Bonneville Dam, in the Okanagan River, we also had the group tagged at Wells Dam. The first group of Bonneville-tagged Sockeye passed OKL June 16-22 (Figure 20), prior to the commencement of Sockeye sampling at Wells Dam. Sockeye reaching the Okanagan River found temperatures of 21.6 to 22.2C and quickly moved up the Okanagan River with a median travel time from Wells Dam to OKL of only 1.6 days and had the highest survival of any Bonneville-tagged group to OKC of 36.4% (Table 38). The next two groups of Sockeye past OKL attempted to go upstream on dips in temperature in mid- and late-July (Table 37) but temperatures quickly climbed after these dips resulting in only 4.3% and 17.1% survival to OKC. The final group waited (median time from Wells to OKL was 52.4 days) until after temperatures finally decreased in the fall and had a 27.3% survival rate to OKC.

The Wells Dam-tagged Sockeye showed a similar migration pattern except that Wells started tagging too late to hit the June migration window used by Bonneville-tagged Sockeye and that there was a small group of September migrants past OKL. Like the Bonneville Group, survival rates to OKC for the July migrants were very poor (2.2% and 16.5%) with the late August group having the best survival to OKC of 53.3% (Table 39 and Figure 21). The small September group (4 fish) had a 25.0% survival to OKC. Overall unweighted survival from OKL to OKC was 16.8% for Bonneville-tagged Sockeye and 27.3% for Wells-tagged Sockeye.

Table 38. Unweighted survival of Sockeye Salmon sampled and tagged at Bonneville Dam from the Lower Okanagan River (OKL) to Zosel Dam (ZSL) and OKC in 2015.

Date Last Detected at OKL	Number at OKL	% Survival OKL to ZSL	% Conversion ZSL-OKC	Median Travel Time WEA-OKL (Days)	Median Travel Time OKL to ZSL (Days)	% Conversion OKL-OKC	Temperature at OKL (C)
6/16-6/22	11	81.8%	44.4%	1.61	2.81	36.4%	21.6-22.2
7/17-7/18	46	15.2%	28.6%	16.78	2.77	4.3%	23.7-25.1
7/27-7/29	41	34.1%	50.0%	25.24	2.87	17.1%	22.5-24.5
8/22-8/29	33	60.6%	45.0%	52.37	4.42	27.3%	18.5-20.1
Unweighted Total	**131**	**38.2%**	**44.0%**	**21.16**	**3.55**	**16.8%**	

Table 39. Unweighted survival of Sockeye Salmon sampled and tagged at Wells Dam from the Lower Okanagan River (OKL) to Zosel Dam (ZSL) and OKC in 2015.

Date Last Detected at OKL	Number at OKL	% Survival OKL to ZSL	% Conversion ZSL-OKC	Median Travel Time WEA-OKL (Days)	Median Travel Time OKL to ZSL	% Conversion OKL-OKC	Temperature at OKL (C)
6/16-6/22	Sampling did not start until June 22, 2015 so no Sockeye were detected at OKL prior to 7/17						
7/17-7/21	46	8.9%	25.0%	12.54	2.59	2.2%	23.7-26.2
7/27-7/30	109	34.1%	50.0%	20.71	2.57	16.5%	22.5-25.3
8/22-8/29	90	72.2%	73.8%	42.78	4.33	53.3%	18.5-20.1
9/2-9/4	4	25.0%	100.0%	51.61	7.50	25.0%	17.5-17.7
Unweighted Total	**124**	**47.0%**	**58.1%**	**22.70**	**3.46**	**27.3%**	

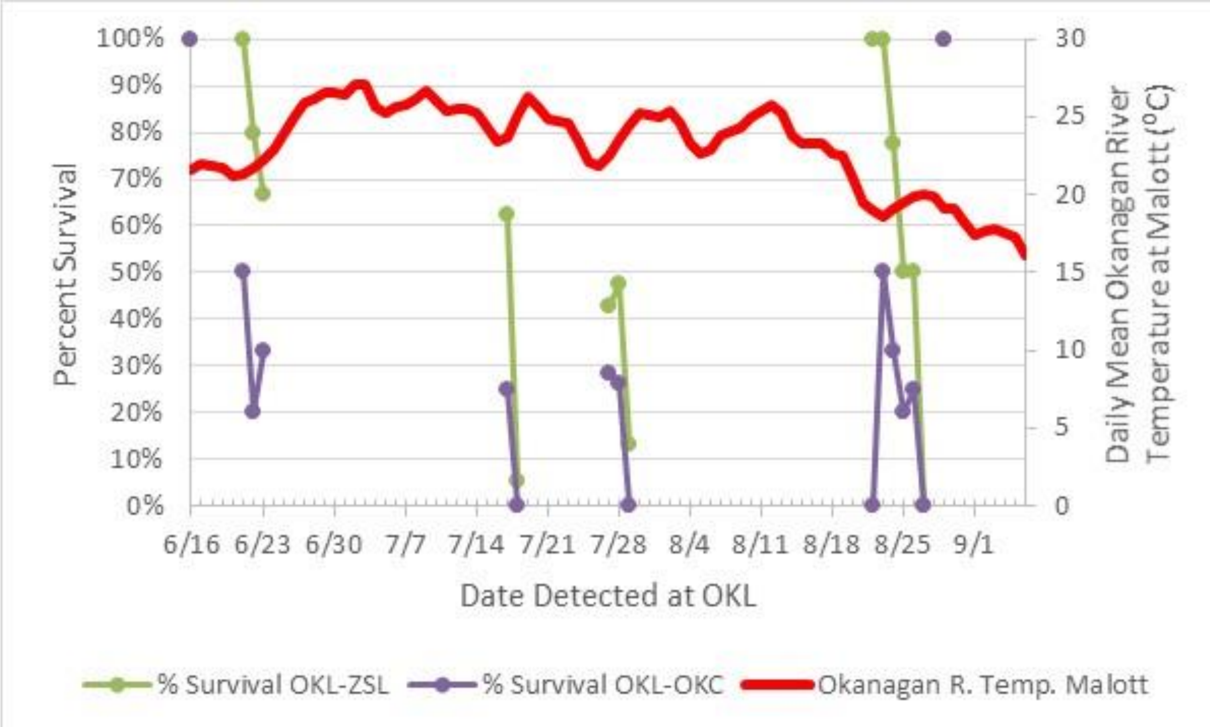

Figure 21. Unweighted survival of Sockeye PIT tagged at Bonneville Dam from OKL to ZSL and OKC by date at OKL with lower Okanogan River temperatures in 2015.

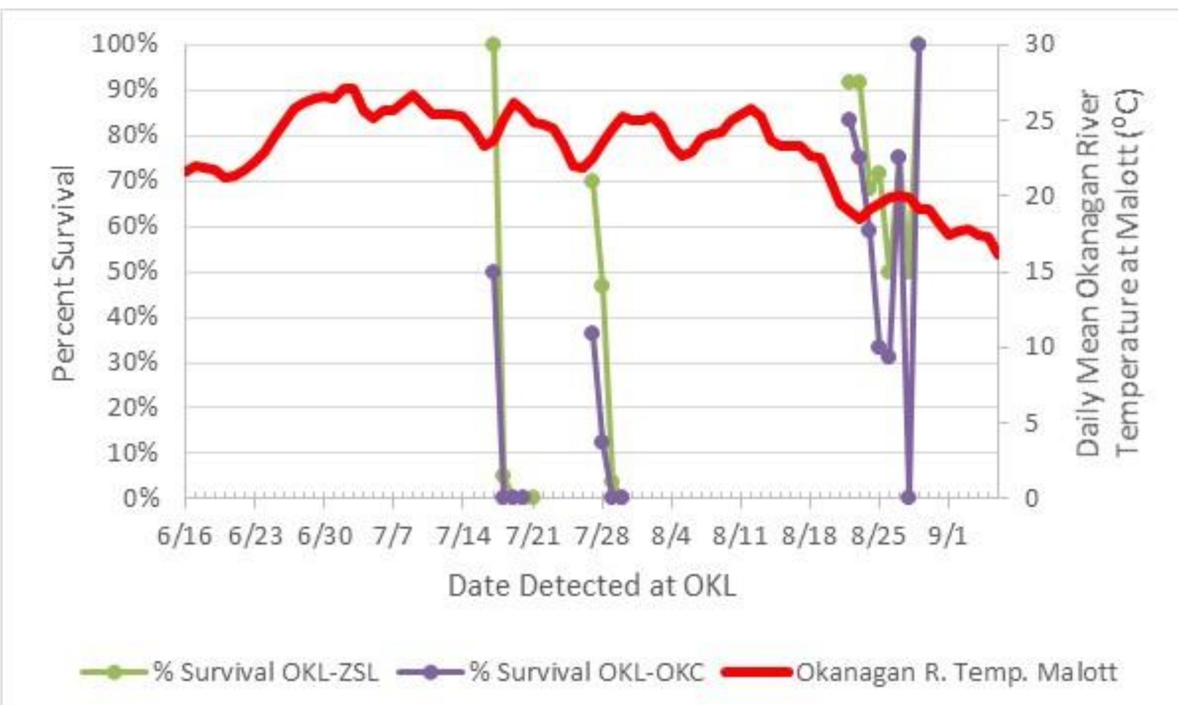

Figure 20. Unweighted survival of Sockeye PIT tagged at Wells Dam from OKL to ZSL and OKC by date at OKL with lower Okanogan River temperatures in 2015.

Adult Acoustic Tag Results

A total of 126 Sockeye Salmon were implanted with acoustic tags in addition to PIT and Floy tags at the Wells Dam west bank fish ladder between June 22 and August 6, 2015 (Statistical weeks 26-32, Table 40). The estimated survival to Monse, the first acoustic receiver site that Sockeye encounter when migrating up the Okanagan River, over the four weeks both tags were used (Statistical Weeks 28-31) was 56.2% for the smaller V9 tags and 34.4% for the larger V13 (includes temperature/depth sensor) tags. This difference was significant at $\alpha=0.05$ ($p=0.02$) so we removed the V13 tag data from subsequent survival estimates, but did include the data when examining fish behavior. Descriptions of the movement of individual fish tagged with V13 tags can be found in Appendix A.

After weighting by weekly run size at Wells Dam, survival to Zosel Dam as estimated by all acoustic (V9 only)+PIT+Floy-tagged Sockeye was 15.2% compared to 9.7% for those Sockeye PIT+Floy-tagged, but not acoustic tagged, at Wells Dam, 13.4% for those Sockeye PIT tagged at Bonneville Dam, and 18.6% for Sockeye Salmon tagged as juveniles in the Okanagan River (Table 41).

Table 40. Comparison of survival of V9 and V13TP acoustic tagged Sockeye to Monse in 2015. (Week 28-31 mean different using a comparison of proportions in independent samples for weeks 28-31 at p=0.02)

Week	V9	V13TP	% V9 to Monse	% V13 to Monse
26	5	0	40.0%	--
27	10	0	70.0%	--
28	20	13	60.0%	53.8%
29	20	7	75.0%	28.6%
30	20	7	50.0%	28.6%
31	13	5	30.8%	0.0%
32	0	6	--	0.0%
Total	**88**	**38**		
Weeks 28-31	**73**	**32**	**56.2%**	**34.4%**

Table 41. Estimated survival 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 2015.

			Sockeye Salmon Tagged at Wells Dam						Tagged at Bonneville Dam		Juveniles Tagged in Okanagan		All Returning Juveniles at WEA	
	Mean Weekly Temperature		PIT + Floy Tagged Only		PIT+Floy+V9 Acoustic Tagged		All Sockeye Tagged (Except V13)		PIT Tagged Only		PIT Tagged Only		PIT Tagged Only	
Week	**Wells**	**Okanagan River (Malott)**	**N**	**% at Zosel**	**N**	**% at Zosel**	**N**	**% at Zosel**	**N**	**% at Zosel**	**N**	**% at Zosel**	**N**	**% at Zosel**
<=25	15.2	21.1							1	100.0%	1	0.0%	2	0.0%
26	16.1	21.9	57	7.0%	5	20.0%	62	8.1%	13	53.8%	5	0.0%	15	6.7%
27	17.2	25.8	106	9.4%	10	20.0%	116	10.3%	78	12.8%	20	20.0%	45	15.6%
28	17.6	26.1	160	6.3%	20	10.0%	180	6.7%	163	12.3%	12	16.7%	39	10.3%
29	17.6	25.5	121	24.8%	20	10.0%	141	22.7%	86	15.1%	3	33.3%	10	10.0%
30	18.6	24.8	82	12.2%	20	25.0%	102	14.7%	10	10.0%	2	50.0%	5	0.0%
31	18.8	23.2	37	16.2%	13	15.4%	50	16.0%	6	0.0%	0	0	3	0.0%
>=32	19.3	24.5	22	9.1%	0	na	22	9.1%	1	0.0%	0	0	4	50.0%
Weighted			**585**	**9.7%**	**88**	**15.2%**	**673**	**10.2%**	**361**	**13.4%**	**43**	**18.6%**	**123**	**12.2%**

Survival of Sockeye Salmon from Wells Dam to the Monse site in the lower Okanagan River, as estimated using V9 acoustic tags, was 58.7%, 13.5% to the North Basin Osoyoos Lake receiver, and 9.3% to McIntyre Dam (Table 42). No acoustic tagged Sockeye were detected at Skaha Lake.

Table 42. Percentage of Sockeye Salmon acoustic tagged at Wells Dam passing upstream receivers in 2015 (V9 tags only).

Week	Tag Date	Sample Size	Monse Bridge	Similkameen River	Oroville Pump Station	Haynes Point	North Osoyoos Basin	McIntyre Dam	Skaha Lake	Estimated on Spawning Ground
26	June 22-24	5	40.0%	20.0%	20.0%	20.0%	20.0%	20.0%	0.0%	20.0%
27	June 29,30	10	70.0%	40.0%	20.0%	20.0%	20.0%	20.0%	0.0%	20.0%
28	July 6,7	20	60.0%	17.4%	10.0%	10.0%	5.0%	0.0%	0.0%	4.3%
29	July 13,14	20	75.0%	14.7%	15.0%	15.0%	10.0%	0.0%	0.0%	5.9%
30	July 22	20	50.0%	8.8%	30.0%	25.0%	20.0%	0.0%	0.0%	5.9%
31	July 30	13	30.8%	4.3%	23.1%	23.1%	23.1%	0.0%	0.0%	13.0%
32	August 6	0	NA	NA	NA	NA	NA	NA	NA	NA
Weighted by Weekly Wells Visual Count		**88**	**58.7%**	**27.1%**	**16.1%**	**16.0%**	**13.5%**	**9.3%**	**0.0%**	**11.8%**

Many of our receivers in the Okanagan Basin as well as just upstream of Wells Dam were deployed at confined channel locations on the migration corridor where we expected to be able to detect all, or nearly all, passing Sockeye Salmon. Twelve sites detected all acoustic tagged Sockeye, with remaining detection rates varying from 40.0% to 99.2%. (Table 43, Figure 5).

The time acoustic tagged Sockeye Salmon spent in Wells Pool and the Okanagan River downstream of Osoyoos Lake varied greatly by week (Table 44). Time to Monse Bridge varied from 11.6 days in Statistical Week 28, to 28.6 days in Statistical Week 27. Travel times beyond Monse are based on relatively few fish as only 18 acoustic tagged Sockeye were detected at Haynes Point, 14 at the North Basin, and 3 at McIntyre Dam.

Table 43. Detection rate at acoustic receiver sites and estimated survival rate to those sites for Sockeye Salmon PIT and acoustic tagged at Wells Dam in 2015.

Site	Number of Receivers	Estimated Detection Efficiency	Number Detected		Estimated % of run passing site based on V9 acoustic detections and accounting for detection efficiency
			Tagged with V9 Tags	Tagged with V13 Tags	
Pateros	1	100.0%	85	37	94.4%
Brewster Dock	1	99.2%	83	37	92.3%
RE Dock	1	100%	80	37	90.8%
Monse Bridge	2	100.0%	50	11	61.7%
Okanagan Weir Downstream	1	50.8%	31	5	58.3%
Okanagan Weir Upstream	2	100%	48	9	61.1%
Horseshoe Bend	1	100%	38	5	44.7%
Okanagan Confluence	1		6	1	6.7%
Similkameen Confluence	1	93.5%	23	2	33.7%
Driscoll, Similkameen River.	1	100.0%	18	2	27.1%
Upper Similkameen River	1	NA	16	1	36.8
Oroville Pumping Station	2	100.0%	17	2	16.1%
SB Haynes Point	1	40.0%	6	2	NA
SB Haynes Campground	1	100.0%	16	2	16.0
SB Haynes-buoy	1	45.0%	5	2	NA
Okanagan North Basin	1	100.0%	13	1	13.5%
Okanagan River Mouth	2	50.0%	12	1	11.6%
VDS3 DS	1	50.0%	4	1	NA
VDS3 US	1	100.0%	10	1	7.9%
Hwy 97 Bridge	1	100.0%	5	0	10.0%
McIntyre Dam	1	100.0%	3	0	9.3%
McIntyre Dam Upstream	1	NA	2	0	5.7%
Okanagan Falls	1	NA	0	0	0

Table 44. Migration time to upstream receiver sites for Sockeye acoustic tagged at Wells Dam by date in 2015. (Note only five fish passed the Highway 97 site.)

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
26	June 22-24	5	24.3	25.6	28.3	108.9	Oct 10
27	June 29,30	10	28.6	48.0	65.6	93.2	Sept 30
28	July 6,7	33	11.6	24.0	49.9	n/a	NA
29	July 13,14	27	13.4	30.9	48.8	86.2	Oct 8
30	July 22	27	19.9	37.5	44.0	n/a	NA
31	July 30	18	22.5	29.5	35.5	40.2	Sept 9
32	August 6	6	n/a	n/a	n/a	n/a	NA
All Dates		**126**	**15.2**	**35.5**	**46.5**	**87.2**	**Oct 7**

Acoustic tagged Sockeye Salmon passing the Monse acoustic site in 2015 can be separated into three groups (Tables 45 and 46, Figure 22. The first group consisted of 23 Sockeye Salmon migrating past Monse on July 17 and 18, 2015; which consisted of Sockeye tagged between June 23 and July 13. During this period, the minimum water temperature at Malott dipped to 22C on the July 17 and 21.9 on the 18th, although the mean temperature on those two dates was 23.4C and 23.7C respectively. However, temperatures quickly rebounded back above 25C on July 19 (minimum 23.2C) and the mean temperature at Oroville never dropped below 25C until July 25. Only one of the fish passing between July 17 and 18 (1601-34349), tagged June 23 and passing Monse on July 17, survived to Osoyoos Lake, reaching the pump station receiver on July 19, the North Basin on July 22, and ultimately being detected on the spawning grounds on October 8 (Table 48). Five Sockeye from this group were detected for no more than one day in the Similkameen between July 20 and July 31, none were subsequently detected.

A second group of 28 Sockeye passed Monse between July 27 and July 29 after the mean temperature dropped to 21.9C (Tables 45 and 46, Figure 22). This group of Sockeye consisted of fish that were tagged between June 29 and July 22. Only 10 of these 28 Sockeye were detected at the pump station, 5 in the North Basin, and 4 on the spawning grounds. Of 12 Sockeye detected in the Similkameen, 11 passed Monse on July 28 with 1 on July 27, with 7 first detected in the Similkameen on July 30 and 5 on July 31. Only two of the Sockeye detected in the Similkameen were subsequently detected, one spending 1.5 days in the Similkameen before being last detected at Zosel Dam and a second, after spending 12.8 days in the Similkameen, which was last detected in the North Basin of Osoyoos Lake.

A third group of 21 acoustic tagged Sockeye passed Monse between August 22 and August 26 (Tables 45 and 46, Figure 22). These Sockeye were tagged between June 29 and July 30. This group fared the best of the three groups described, with 10 making it to the pump station, 9 to the North Basin, and 7 to OKC. Only 5 Sockeye Salmon from this group were detected in the Similkameen, 4 of which were not subsequently detected with the fifth surviving to the spawning grounds.

There group of 12 acoustic tagged Sockeye tagged at Wells Dam on August 12, however none of these fish was subsequently detected at or upstream of Monse (Table 46).

Table 45. Number of acoustic tagged Sockeye passing Monse, Pump Station, North Basin and OKC acoustic receivers by date first detected at Monse; river temperatures in 2015 also included. Dates with detections are shaded green.

	Okanagan River Temperature								
Date First Detected at Monse	Mean at Monse	Min at Monse	Max at Monse	Mean at Oroville	# at Monse	# to Pump Station	# in Simlka-meen / Survive to North Basin	# to North Basin	# to OKC
7/15/2015	25.3	24.4	26.1	26.0					
7/16/2015	24.3	23.8	25.2	25.2					
7/17/2015	23.4	22.0	24.8	24.9	4	1		1	1
7/18/2015	23.7	21.9	25.7	25.0	19		3/0		
7/19/2015	25.1	23.2	27.2	25.3					
7/20/2015	26.2	24.6	28.2	25.3					
7/21/2015	25.7	24.3	26.9	25.2					
7/22/2015	24.9	23.3	26.4	25.0					
7/23/2015	24.7	23.0	26.3	25.2					
7/24/2015	24.5	23.3	25.6	25.1					
7/25/2015	23.4	22.1	24.7	24.6					
7/26/2015	22.1	21.0	23.4	23.9					
7/27/2015	21.9	20.5	23.3	23.7	9	6	2/0	2	
7/28/2015	22.5	20.5	24.5	24.1	13	3	10/1	2	
7/29/2015	23.5	21.7	25.5	24.5	6	1	0/0	1	1
7/30/2015	24.5	22.6	26.5	25.3					
7/31/2015	25.3	23.6	27.1	25.8					
No acoustic tagged Sockeye Salmon passed Monse between August 1 and 19									
8/20/2015	22.5	21.5	23.6	24.8					
8/21/2015	21.1	19.8	22.3	23.7					
8/22/2015	19.5	18.4	20.5	23.4	5	3	2/1	3	3
8/23/2015	19.0	18.1	19.9	22.9	5	2	0	2	2
8/24/2015	18.5	17.7	19.3	22.4	1	1	0	1	1
8/25/2015	19.2	18.0	20.5	22.5	8	3	2/0	2	0
8/26/2015	19.5	18.5	20.5	22.8	2	1	1/0	1	1
8/27/2015	19.9	18.9	20.9	22.8					
8/28/2015	20.1	19.4	20.7	22.6					
Total					**72**	**21**	**22/2**	**22**	**9**

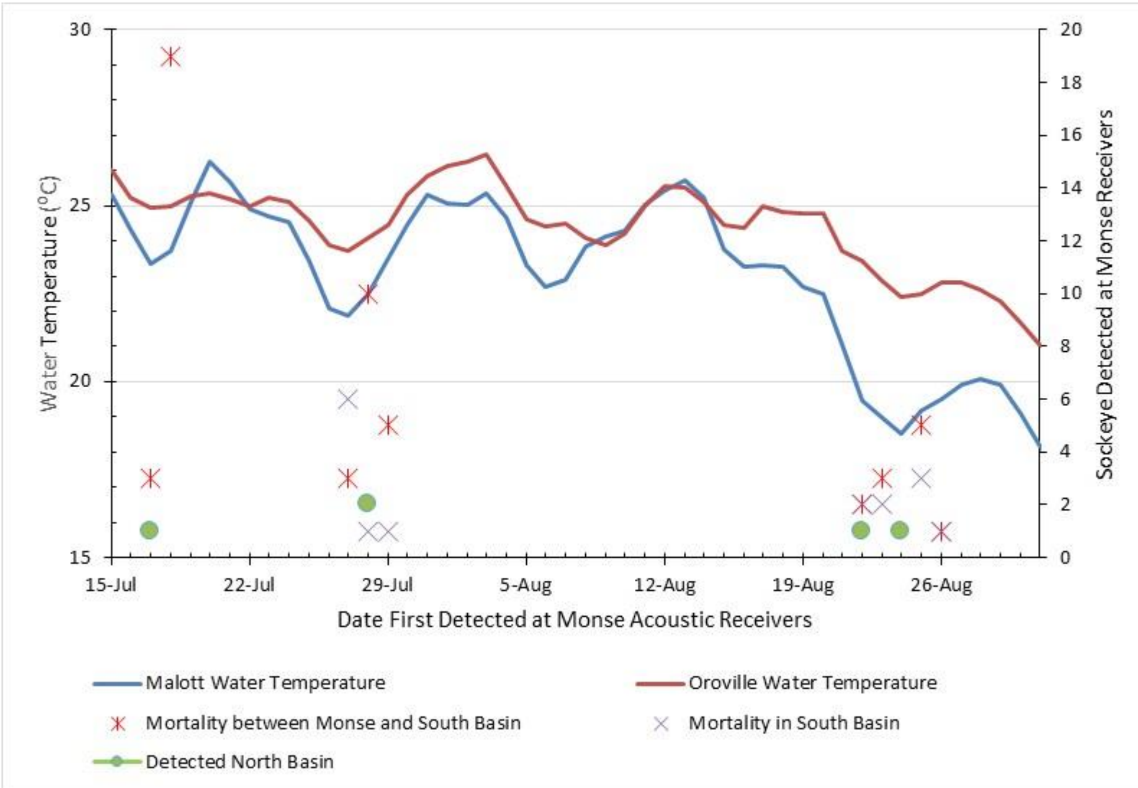

Figure 22. Okanagan River temperature at Malott and Osoyoos Lake outlet and survival of Sockeye acoustic tagged passing Monse Bridge acoustic receiver to Osoyoos Lake in 2015.

Table 46. Survival of Sockeye PIT tagged at Wells Dam from Monse to the Osoyoos Lake North Basin by Okanagan River temperature at Malott in 2015.

			Percent Survival			Sockeye Detected in Similkameen	
Group	N	Date Past Monse	Monse to South Basin (Pump Station)	South Basin to North Basin	North Basin to OKC	Detected	Subsequently Detected in North Basin
1	23	July 17-18	4.3%	100.0%	100.0%	5	0
2	28	July 27-29	35.7%	50.0%	80.0%	12	1
3	21	Aug 22-Aug 26	47.6%	90.0%	77.8%	5	1
4	12	None	NA	NA	NA	0	0

Detections Downstream of Wells Dam

A total of 19 acoustic tagged Sockeye Salmon were detected downstream of Wells Dam. Of these fish, GSI classified 12 as of Wenatchee origin and 6 of Okanagan origin (Table 47).

Table 47. Number Sockeye acoustic tagged at Wells Dam in 2015, Number detected downstream, and their GSI classification.

			GSI classification		
Week	Number Acoustic Tagged	Number Detected Downstream	Okanagan	Wenatchee	Not Classified
26	5	1	1	0	0
27	10	0	0	0	0
28	33	3	0	3	0
29	27	4	2	2	0
30	27	4	2	2	0
31	18	6	0	5	1
32	6	1	1	0	0
Total	**126**	**19**	**6**	**12**	**1**

Acoustic Mobile Tracking

A total of 12 acoustic tags were detected, 6 in the Columbia, 4 in the Okanagan, and 2 in the Similkameen rivers during mobile tracking by boat. Five of the fish were tagged with V13 temperature/depth sensor transmitters and the other 7 were V9 acoustic transmitters.

Both tags on the Similkameen were detected just upstream of Driscoll Island, with one being a sensor tag. The sensor tag was deployed July 6 and the fish passed the Monse Bridge July 28 and the Horseshoe Lake and Similkameen confluence receivers on July 30 at 25.6C and 25.1C respectively. It reached the Upper Similkameen July 31 and returned to the Driscoll Pool August 2 where it was last detected at Driscoll pool receiver at a temperature of 25.9C. The mobile tracker crew detected the tag from the presumed mortality just upstream of Driscoll Pool on October 24. Acoustic-tagged fish 36656 was released July 14 and passed the Monse Bridge on July 28. Over the next three days, it was detected subsequently at the Weir, Horseshoe Lake, Similkameen Confluence , and Driscoll Pool at the same time and temperatures as the sensor tagged fish, and the Upper Similkameen on August 1. It went between Driscoll Pool and the Upper Similkameen several times before it was last detected in the Upper Similkameen on August 17. It was then detected by the mobile tracker crew on October 22 in the Driscoll Pool and presumed dead.

Two of the four tags in the Okanagan were detected on the mobile tracker around Aeneas Creek, a cold, spring-fed creek where Sockeye were also documented holding at the confluence. One of those fish had passed the Monse Bridge and the weir on July 27-28 and was not subsequently detected on other receivers, indicating it may have held near Aeneas Creek until it died. The other fish detected at Aeneas Creek passed the Monse Bridge and the weir August 22-23 and was subsequently detected August 28 on the Horseshoe Lake receiver upstream, but it then went downstream to the Monse Bridge and then upstream again passed the weir on October 8-9. The third of the four tags in the Okanagan was a sensor-tagged fish and was detected at the town of Riverside; it had passed the Monse Bridge on July 18 when temperatures were 24C. On July 19, when the fish passed the weir, the sensor tag had a value of 25.4C and it was not subsequently detected at other receivers. The fourth tag was detected at Monse Bridge and the weir on August 25 and 26, respectively. It was not detected anywhere thereafter, until the mobile tracker detected it in October, presumably dead, 15km upstream of the weir in the town of Okanagan.

Two of the six tags in the Columbia were found near the mouth of the Okanagan, one of which was a sensor tag. The depth of this tag fluctuated from the day the tagged fish was released (July 22) until the day the depth remained steady four weeks later on August 13, suggesting the fish may have died. The other tagged fish found near the mouth of the Okanagan had been detected in the Chief Joseph tailrace the day after it was released. It appeared to stay in the tailrace for four weeks until it was detected moving downstream in the Columbia. It may have still been alive when it was detected by the mobile tracker in October, because it was subsequently detected on various receivers multiple times in November around the mouth of the Okanagan.

Two more of the six tags in the Columbia were found downstream of the mouth of the Methow River, and both of those were sensor tags. Fish with tag 1786 (Appendix A Figure A1 though A17) has other fish movement data on several fish) was detected multiple times going back and forth from the Wells Forebay to the Chief Joseph tailrace. Although it was last detected on receivers downstream of the mouth of the Methow, its depth values suggest it died near the mouth of the Okanagan approximately 5.5 weeks after it was released, and then it floated downstream on the surface to where it was last detected at the V8 (Starr Access) receivers at a depth of -0.6m (i.e. floating on the surface). It likely sank to the bottom of the river, because the mobile tracker crew detected the tag

in the vicinity of the V8 (Starr Access) receivers at a depth of 16.5m. The depth pattern of fish with tag 1769 showed a similar pattern of dying approximately 5 weeks after being released and staying at a steady depth of 10.5 m by the mouth of the Okanagan. It then appeared to float to the surface (steady depth of -0.6m) and was last detected on the V9 (Starr Access) receiver. It was detected by the mobile tracker crew, with a depth of 0.9 m, in the vicinity of the V9 (Starr Access) receivers. The last two of the six tags in the Columbia were detected just below the Starr Boat Launch release site. One fish, (tag 34360) appeared to be a tagging mortality because it was detected only at the V11 (Wells Forebay) receivers 3 days after release and this is also where the mobile tracker crew detected it in October. However, the other fish (tag 34367) was detected in the tailrace of Chief Joseph Dam and was detected multiple times going back and forth between the Wells Forebay and the mouth of the Okanagan. It is not clear from the acoustic detections when the fish may have died.

Last detection sites for all tags are found in Table 48. Six Sockeye Salmon were captured and released in the CCT seine fishery (Table 48). All were subsequently detected.

Table 48. 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 2015. (Green text indicates the fish was likely on the spawning grounds during the spawning period. Red text indicates confirmed captured in fisheries, blue text indicates missing on upstream migration, black text indicates last detected in Osoyoos Lake or at the Okanagan River Mouth before September 15, 2015. Sockeye detected at the Okanagan River Mouth after September 15, 2015 were assumed to be on the spawning grounds.).

Tag Code	Date Tagged	Furthest Upstream Detection		Last Detection		Capture and release date in CCT fishery	irst OKC Detectio	Mobile Track Dates
		Site	Date	Site	Date			
34346	6/22	Similkameen River	8/1	Similkameen River	8/1	7/2		
34347	6/24	Wells Pool	7/11	Wells Pool	7/11			
34348	6/23	Wells Pool	7/2	Wells Pool	7/2			
34349	6/23	McIntyre Dam upstream	10/11	McIntyre Dam upstream	10/1 1		10/8	
34350	6/23	Wells Pool	7/30	Beebe Downstream	8/3	6/25, 7/11		
34351	6/29	Wells Pool	7/22	Wells Pool	7/22			
34352	6/29	Similkameen River	8/1	Similkameen River	8/2			
34353	6/29	Wells Pool	8/25	Wells Pool	9/3			
34354	6/29	McIntyre Dam downstream	10/8	Hwy 97	10/1 9		10/4	

34355	6/29	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			
34356	6/29	McIntyre Dam upstream	9/26	McIntyre Dam upstream	9/26		9/23	
34357	6/29	Similkameen River	8/4	Similkameen River	8/4			
34358	6/29	Similkameen River	7/31	Similkameen River	7/31			
34359	6/30	Similkameen River	7/25	Horseshoe Bend	7/25			
34360	7/6	Wells Pool	7/6	Wells Pool	7/6			10/14
34361	7/6	Wells Pool	8/23	Wells Pool	8/23			
34362	7/6	South Basin at Haynes Point	8/16	South Basin at Haynes Point	8/16			
34363	7/6	Wells Pool	7/8	Wells Pool	7/8			
34364	7/6	North Basin	10/29	North Basin	10/29			
34365	7/6	Wells Pool	7/13	Wells Pool	7/13			
34366	6/29	Wells Pool	6/29	Wells Pool	6/29			
34367	7/7	Wells Pool	8/19	Wells Pool	8/29			10/14
34368	7/7	Wells Pool	7/10	WTL, Wenatchee Basin	9/6			
34369	7/7	Upper Okanagan Weir	7/19	Upper Okanagan Weir	7/19			
34370	7/6	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			
34371	7/6	Wells Pool	7/11	Wells Pool	7/15	7/9		
34372	7/6	Zosel Dam	8/1	Zosel Dam	8/1			
34373	7/6	Similkameen River	7/21	Similkameen River	7/21			
36629	7/7	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			
36630	7/7	Similkameen River	8/2	Similkameen River	8/2			
36631	7/7	Wells Pool	7/9	Wells Pool	7/9			
36632	7/7	Upper Okanagan Weir	7/19	Wells Pool	7/24			
36633	7/7	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			
36634	7/7	Upper Okanagan Weir	8/25	Upper Okanagan Weir	8/25			11/4
36635	7/7	Zosel Dam	9/2	Similkameen River	9/3			
36636	7/13	Hwy 97	10/19	Hwy 97	10/19		10/4	
36637	7/13	Wells Pool	7/13	Wells Pool	7/13			
36638	7/13	Monse Bridge	7/17	Wells Pool	7/24			
36639	7/30	Wells Pool	8/24	Wells Pool 8/29, Entiat 9/22	8/29			
36640	7/13	Wells Pool	7/16	Wells Pool	7/16			
36641	7/13	Upper Okanagan Weir	7/28	Upper Okanagan Weir	7/28			10/21
36642	7/13	Horseshoe Bend	7/20	Horseshoe Bend	7/20			
36643	7/13	South Basin at Haynes Point	8/1	Oroville Pump Station	8/3	7/23		
36644	7/13	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			

36645	7/13	Wells Pool	7/14	WTL, Wenatchee River	9/20			
36646	7/13	Horseshoe Bend	8/1	Horseshoe Bend	8/1			
36647	7/14	Upper Okanagan Weir	7/29	Upper Okanagan Weir	7/29			
36648	7/14	Zosel Dam	8/1	Zosel Dam	8/1			
36649	7/14	Similkameen River	8/3	Similkameen River	8/3			
36650	7/14	VDS3 Upstream	9/30	North Basin	10/29		9/28	
36651	7/14	Wells Pool	7/15	Wells Pool	7/15			
36652	7/14	Horseshoe Bend	7/31	Horseshoe Bend	7/31			
36653	7/22	Wells Pool	8/14	Orondo Downstream	11/3			
36654	7/22	Monse Bridge	8/24	Monse Bridge	8/24			
36655	7/14	Wells Pool	7/16	Turtle Rock	7/20			
36656	7/14	Similkameen River	8/16	Similkameen River	8/16			10/22
36657	7/14	Similkameen River	8/3	Similkameen River	8/3			
36658	7/14	Similkameen River	8/3	Similkameen River	8/3			
36659	7/22	South Basin at Haynes Point	7/31	Oroville Pump Station	8/8			
36660	7/22	Wells Pool	7/24	Wells Pool	7/24			
36661	7/22	Wells Pool	10/2	Wells Pool	10/2			10/14
36662	7/22	Similkameen River	8/1	Similkameen River	8/1			
36663	7/22	Wells Pool	9/4	Wells Pool (one detection at Wells DS on 1/18/16)	9/4			
36664	7/22	Okanagan Mouth (Canada)	9/13	North Basin	10/2			
36665	7/22	Wells Pool	7/22	Wells Pool	7/22			
36666	7/22	Similkameen River	7/31	Horseshoe Bend	8/2			
36667	7/22	Okanagan Mouth (Canada)	9/25	North Basin	9/27			
36668	7/22	Similkameen River	8/28	Similkameen River	8/28			
36669	7/22	Wells Pool	8/30	Wells Pool	9/2			
36670	7/22	Wells Pool	7/24	Wells Pool	7/24			
36671	7/22	VDS3 Upstream	10/26	North Basin	10/29		9/14	
36672	7/22	Wells Pool	7/24	Wells Pool	7/24			
36673	7/22	Oroville Pump Station	9/7	Horseshoe Bend	9/8			
36674	7/22	Wells Pool	8/29	Wells Pool	8/29			
36675	7/22	Wells Pool	7/25	Wells Pool	7/25			
36676	7/22	VDS3 Upstream	10/5	VDS3 Upstream	10/5		10/5*	
36677	7/30	Wells Pool	8/11	LWE	8/15			
36678	7/30	VDS3 Upstream	11/1	Okanagan Mouth (Canada)	11/2		10/17	
36679	7/30	Wells Pool	7/31	Wells Pool	7/31			
36680	7/30	Horseshoe Bend	10/3	Upper Okanagan Weir	10/9			10/6

36681	7/30	Wells Pool	8/15	Wells Pool	8/15			
36682	7/30	VDS3 Upstream	10/5	VDS3 Upstream	10/5		10/5	
36683	7/30	Wells Pool	8/13	Turtle Rock Downstream	8/19			
36684	7/30	Wells Pool	8/7	Longdraw downstream (detected 8/10 at Wells)	11/5			
36685	7/30	Hwy 97	9/9	Hwy 97	9/9		9/6	
36686	7/30	Wells Pool	8/4	Entiat	8/10			
36687	7/30	Wells Pool	7/31	Wells Pool	7/31			
36688	7/30	Wells Pool	8/4	Wells Pool	8/4	7/2		
1734	7/22	Horseshoe Bend	7/31	Horseshoe Bend	7/31			
1736	8/6	Wells Pool	8/12	Entiat	8/13			
1738	7/22	Wells Pool	7/22	Wells Pool	7/22			
1740	7/22	Wells Pool	8/11	Wells Pool	8/11			
1742	7/22	Wells Pool	7/31	Duck Tail	8/1			
1744	7/30	Wells Pool	8/6	Wells Pool	8/6			
1746	7/22	Upper Okanagan Weir	9/28	Monse Bridge	9/28			
1748	7/22	Wells Pool	11/8	Wells Pool	11/8			10/14
1750	7/13	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			11/3
1752	7/13	Wells Pool	7/21	Wells Pool	7/21			
1754	7/14	South Basin at Haynes Point	8/5	Oroville Pump Station	8/18			
1756	7/14	Wells Pool	7/16	Wells Pool	7/16			
1758	7/7	Wells Pool	7/15	Wells Pool	7/15			
1760	7/13	Wells Pool	8/13	Rocky Reach Tailrace	8/16			
1762	7/13	Wells Pool	7/22	Wells Pool	7/23			
1764	7/13	Wells Pool	7/21	Rocky Reach Tailrace	7/24			
1766	7/6	Upper Okanagan Weir	7/18	Upper Okanagan Weir	7/18			
1768	7/7	Monse Bridge	7/19	Wells Pool	8/14			
1770	7/7	Wells Pool	8/14	Wells Pool	8/15			10/14
1772	7/7	Zosel Dam	8/30	Similkameen River	9/7			
1774	7/6	Wells Pool	8/10	Rocky Reach Tailrace	8/13			
1776	7/6	Similkameen River	8/2	Similkameen River	8/2			10/24
1778	7/7	VDS3 Upstream	10/12	VDS3 Upstream	10/12		10/12*	
1780	7/6	Upper Okanagan Weir	8/26	Lower Okanagan Weir	8/26	8/17		
1782	7/6	Wells Pool	7/8	Wells Pool	7/8			
1784	7/6	Wells Pool	7/16	Turtle Rock Downstream	7/23			
1786	7/6	Wells Pool	8/12	Wells Pool	8/16			10/14

1788	7/7	Monse Bridge	7/21	Monse Bridge	7/21			
1790	7/30	Wells Pool	8/23	Rocky Reach Tailrace	8/12			
1792	8/6	Wells Pool	8/10	Wells Pool	8/10			
1794	8/6	Wells Pool	8/8	Wells Pool	8/8			
1796	8/6	Wells Pool	8/12	Wells Pool	8/12			
1798	7/30	Wells Pool	8/20	Wells Pool	8/20			
1800	7/30	Wells Pool	8/2	Wells Pool	8/2			
1802	8/6	Wells Pool	8/8	Wells Pool	8/8			
1804	8/6	Wells Pool	8/8	Wells Pool	8/8			
1806	7/30	Wells Pool	8/3	Wells Pool	8/3			
1808	7/22	Wells Pool	7/25	Entiat Downstream	7/31			

Lake Wenatchee Acoustic Trawl and Limnology Surveys

The following sampling was conducted on Lake Wenatchee during the in-lake rearing of brood year 2014 juvenile nerkids (see Appendix C for methods and additional details and results), which reared in the lake during 2015:

- Acoustic trawl surveys and biological sampling of nerkids on September 21, 2015 (fall survey) and March 11, 2016 (late winter survey),
- Zooplankton on six dates between June and September, 2015,
- Phytoplankton on four dates between June and September, 2015, and
- Temperature, dissolved oxygen, and transparency on six dates between June and September, 2015.

Total limnetic fish abundance was estimated to be 2,451,535 on September 21, 2015 and 2,226,019 on March 11, 2016. (Table 49) These values are above average but within the range observed since 2010 when acoustic trawl surveys began (Table 49). On both survey dates, age-0 nerkids were the only fish caught in the trawls (n=89 for the fall survey and n=102 for the late winter survey).

The average length and weight of brood year 2014 Lake Wenatchee nerkids in early March, 2015 was 72 mm and 3.7 g, respectively (Table 50). This is larger than Osoyoos Lake pre-smolts but smaller than Skaha Lake pre-smolts; both of which are sampled in acoustic trawl surveys conducted by the ONA using funding from other sources. This may possibly be a result of very successful

rearing in Osoyoos Lake which were estimated to be >15000 per ha in June 2015.

Table 49. Total limnetic fish estimates based on acoustic trawl surveys of Lake Wenatchee from 2010 to present. The majority of total limnetic fish are juvenile Sockeye Salmon. Note that the 95% CI does not represent a true level of confidence in an estimate, rather a measure of the variability in density among acoustic transects for a given survey date.

Brood Year	Survey Date	Total Limnetic Fish	Density (per ha)	95% CI	95% CI (as %)
2009	21-Sep-10	1,637,000	1,600	425,620	26%
2010	20-Sep-11	2,330,336	2,321	679,666	29%
2010	1-Nov-11	1,971,117	1,963	448,863	23%
2011	25-Jun-12	1,731,250	1,724	440,828	25%
2011	18-Sep-12	2,847,909	2,837	723,858	25%
2012	10-Jul-13	2,778,381	2,767	1,054,993	38%
2012	23-Sep-13	2,650,400	2,640	1,656,534	63%
2013	27-Oct-14	1,774,238	1,767	329,795	19%
2013	23-Feb-15	1,815,407	1,808	490,563	27%
2014	21-Sep-15	2,451,535	2,442	448,495	18%
2014	11-Mar-16	2,226,019	2,217	534,244	24%

Table 50. Brood Year 2015 pre-smolt abundance and size summary for Lake Wenatchee, Osoyoos Lake, and Skaha Lake nerkids. Pre-smolt abundance estimates represent the average of two or three October-Winter surveys.

Lake	Pre-Smolt Abundance (No.)	Pre-Smolt Density (No. per Ha)	Mean Weight in Early March 2016 (g)	Mean Length in Early March 2016 (mm)
Wenatchee	2,300,000	2,300	3.7	72
Osoyoos	5,500,000	5,900	2.7	66
Skaha (Wild Sockeye)	1,000,000	536	6.1	85
Skaha (Stocked Sockeye)	500,000	234	6.9	90

Lake Wenatchee typically has a well-oxygenated, cold, hypolimnion and stratifies in late July or August; however, in 2015 the lake stratified in early July and epilimnetic water temperatures >17C likely prevented juvenile nerkids from spending much time in the epilimnion. Almost all available phytoplankton in Lake Wenatchee are edible by zooplankton in contrast to Osoyoos Lake where many species are large and/or gelatinous and inedible by zooplankton. The average June-September total biovolume of phytoplankton was 50% lower in 2015 than in 2012-2014. This could be due in part to (1) higher rates of river discharge and flushing in 2015 and (2) higher rates of predation by the 2015 zooplankton

population. Zooplankton biomass was exceptionally high in 2015, especially *Daphnia sp.* biomass which was almost an order of magnitude higher than in 2012-2016 (Figure 23). It is possible that because epilimnion depth was deeper than in any of the other years and stratification lasted longer, juvenile nerkids were excluded from the epilimnion and consumption of *Daphnia sp.* was reduced. *Hesperodiaptomus kenai*, the very large copepod that makes excellent prey for nerkids, was abundant in all years (Figure 23).

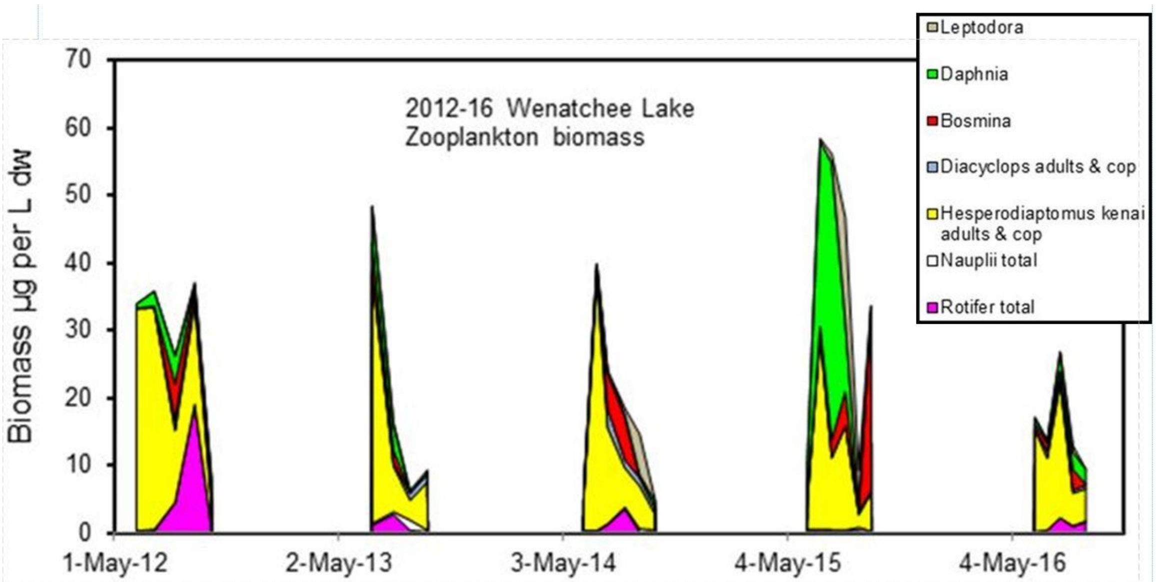

Figure 23. Lake Wenatchee zooplankton biomass (µg/L dry weight) from 2012-2016.

Juvenile PIT Tagging

In total, 7176 Sockeye smolts were PIT tagged and release between April 9 and May 6, 2015 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 51. The mean fork lengths of Sockeye PIT tagged at SKATAL was 105 mm compared to 82 mm at OSOYOL.

Downstream survival estimates were calculated for both release groups in addition to other groups of PIT tagged Columbia Basin Sockeye Salmon that out-migrated in 2015. These included a group of 7957 juvenile Wenatchee Sockeye Salmon tagged at a RST in the Wenatchee River, 1689 out-migrating Sockeye Salmon juveniles trapped at Rock Island Dam that consisted of mixed Okanagan

and Wenatchee stock origin Sockeye Salmon, and 103,455 juvenile Snake River Sockeye Salmon tagged at traps and hatcheries. Survival from release to Rocky Reach Dam was 0.40 (SE = 0.02) for the SKATAL release group, and 0.45 (SE = 0.04) for the OSOYOL release group (Table 52). Survival from release to John Day Dam was also similar, varying by only four percentage points (0.22 for OSOYOL and 0.26 for SKATAL). Low precision of OSOYOL survival estimates, a consequence in part of low sample sizes, resulted in high confidence intervals making comparisons of OSOYOL and SKATAL survival to other sites not possible.

Table 51. Summary of Okanagan Sockeye smolt PIT tagging effort, 2015.

	Number of PIT Tagged Sockeye Released		
Date	Osoyoos Bridge (OSOYBR)	Below Skaha Dam (SKATAL))	Total
9-Apr	125		125
13-Apr	163		163
14-Apr		92	92
15-Apr	271	88	359
16-Apr		75	75
17-Apr	152	130	282
20-Apr		65	65
21-Apr	140	317	457
22-Apr		313	313
23-Apr	307	236	543
24-Apr		188	188
25-Apr		244	244
27-Apr	243	543	786
28-Apr		1222	1222
29-Apr	305	620	925
30-Apr		234	234
1-May	35	82	117
2-May		576	576
3-May		282	282
5-May		105	105
6-May		23	23
Grand Total	**1741**	**5435**	**7176**

The survival of the Snake River group was consistently lower from release to McNary, John Day, and Bonneville dams than the other groups (Table 52 and Figure 24). However large confidence intervals for the Okanagan, Wenatchee, and Rock Island groups Snake River estimates to McNary Dam make

comparisons difficult. The only significant differences (α=0.05) were in comparison of survival to McNary Dam for Okanagan vs Wenatchee (p=0.03), Okanagan vs Snake (p=0.04) and Wenatchee vs Snake River (p=0.04) and in comparison of survival to Bonneville Dam for Okanagan vs. Snake (p=0.04).

Table 52. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2015[16].

	Release Group											
	Skaha and Osoyoos Combined		Osoyoos Lake (OSOYOL)		Below Skaha Dam (SKATAL)		Wenatchee (WENA4T)		Rock Island Dam (RI2BYP)		Snake Basin (multiple)	
Period	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Release to Rocky Reach	0.42	0.02	0.45	0.04	0.40	0.02	NA	NA	NA	NA		
Rocky Reach to McNary	0.80	0.13	1.20	0.50	0.70	0.12	NA	NA	NA	NA		
McNary to John Day	0.72	0.18	0.42	0.23	0.90	0.26	1.16	0.34	0.52	0.18	0.70	0.01
John Day to Bonneville	1.79	0.66	5.92	6.16	1.28	0.50	0.40	0.15	0.75	0.31	0.96	0.09
Release to McNary	0.33	0.05	0.54	0.22	0.29	0.05	0.44	0.05	0.78	0.17	0.22	0.01
Release to John Day	0.25	0.05	0.22	0.08	0.26	0.06	0.52	0.14	0.40	0.11	0.23	0.01
Release to Bonneville	0.44	0.14	1.33	1.30	0.33	0.11	0.20	0.05	0.30	0.09	0.15	0.01

Sockeye tagged at SKATAL migrated more rapidly to downstream dams than did Sockeye tagged at OSOYOL (Table 53), with a mean travel times of between 5.8 and 8.2 days less to downstream Columbia River dams with juvenile PIT tag detection. Okanagan Sockeye Salmon had a greater travel time to McNary, John Day, and Bonneville dams than all other groups in Table 53.

[16] Estimates were compiled February 2, 2017 using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

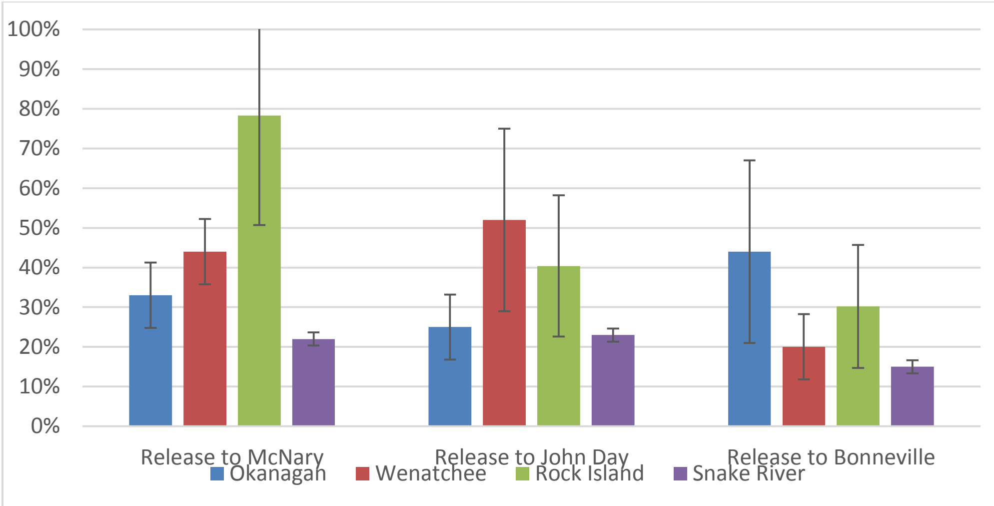

Figure 24. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins in addition to Rock Island Dam to McNary, John Day, and Bonneville dams with 95% confidence intervals in 2015.

Table 53. Harmonic mean travel time in days for juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as Rock Island Dam in 2015.

	Release Group											
	Skaha and Osoyoos Combined		Osoyoos Lake (OSOYOL)		Below Skaha Dam (SKATAL)		Wenatchee (WENA4T)		Rock Island Dam (RI2BYP)		Snake Basin (multiple)	
Period	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Release to Rocky Reach	15.40	0.14	21.22	0.48	14.22	0.12						
Release to McNary	22.35	0.46	28.12	1.04	20.94	0.43	18.97	0.48	9.35	0.49	15.76	0.05
Release to John Day	25.27	0.83	33.47	2.91	23.57	0.71	33.36	0.81	12.92	1.12	18.10	0.08
Release to Bonneville	25.99	0.31	32.83	0.61	24.37	0.28	35.42	0.63	12.28	0.40	18.04	0.03
Rocky Reach to McNary	5.79	0.14	5.99	0.35	5.74	0.16						
McNary to John Day	2.71	0.27	3.03	NA	2.64	0.33	7.16	1.38	5.11	1.53	3.55	0.16
John Day to Bonneville	1.66	0.04	1.79	0.05	1.63	0.05	1.88	0.11	1.62	0.07	1.48	0.02

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 found in Appendix D.

DISCUSSION

This completes the seventh year of this study, a year marked by unusually high water temperatures that resulted in high mortality of Sockeye Salmon on their upstream migration. For several weeks in late July, the plight of Columbia Basin Sockeye Salmon was widely covered in the media[17] and videos such as that produced by the U.S. Geological Survey[18] showed Sockeye badly infected with *Saprolegniasis* or Cotton Wool Disease (e-mail from Dr. Kyle Garver, DFO to Dr. Kim Hyatt, DFO dated August 14, 2015).

Although our Bonneville Dam sampling was shut down by high temperatures for two entire weeks just after the peak of the run along with portions of three other weeks, it is possible to summarize data that was collected by this project and draw some inferences on upstream survival. The greatest decrease in survival in 2015 over past years on the upstream migration through the mainstem Columbia River was between The Dalles and McNary dams (Table 9). Survival dropped precipitously between these two dams when water temperatures (as measured at the John Day Dam tailrace) increased past 20.5C on June 28, 2015 (Figure 25). Bonneville Dam tagging was halted on July 3, 2015 and only 8 tagged Sockeye were detected at The Dalles Dam between July 6, 2015 and July 24, 2015, with the spike on July 7 of 60% survival between The Dalles and McNary dams based on only 5 fish detected at The Dalles Dam (Figure 25). Survival from McNary to Priest Rapids Dam may have been adversely affected by longer migration times between The Dalles and McNary dams (Figure 26).

[17] http://wabc-afs.org/w/wp-content/uploads/2016/05/01.-Jeff-Fryer.pdf
[18] https://www.youtube.com/watch?v=g7N7aKQEvj4

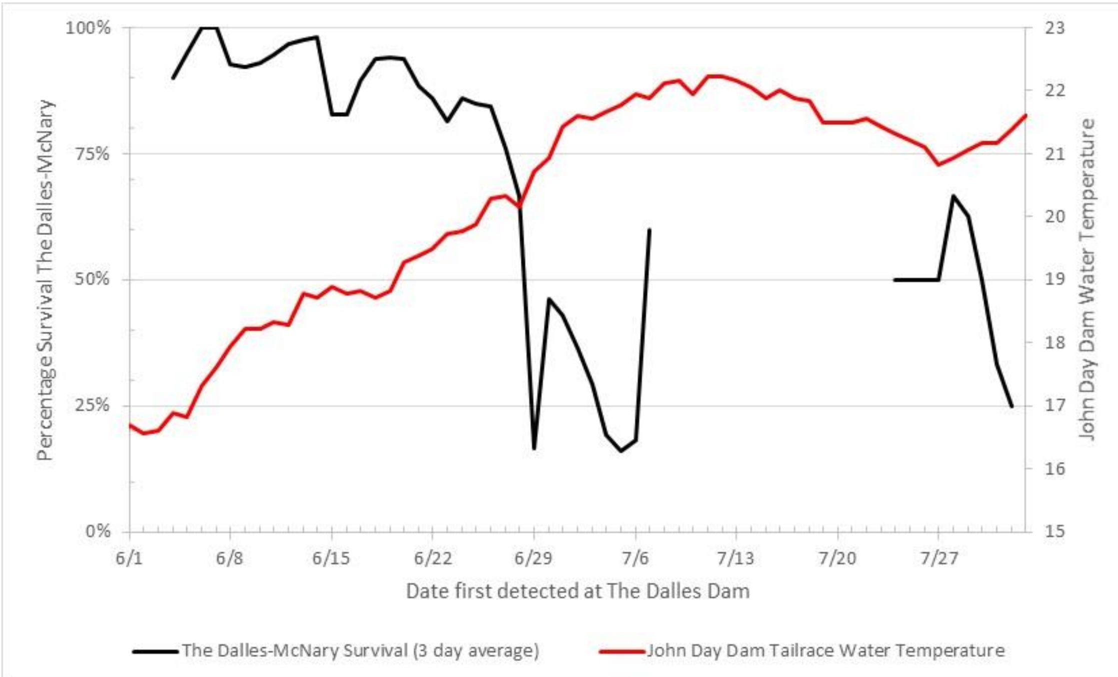

Figure 25. Survival between The Dalles and McNary dams by date at The Dalles Dam as estimated from sockeye PIT tagged at Bonneville Dam in 2015 (3 day average, 4 fish minimum).

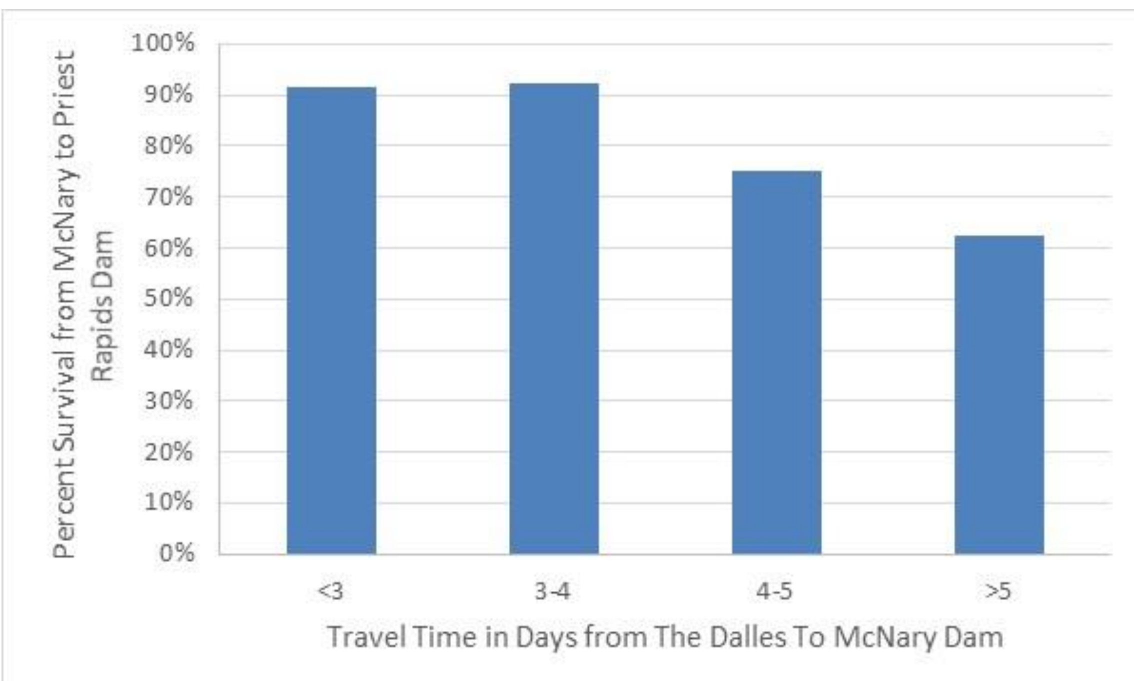

Figure 26. Relationship between the travel time from The Dalles to McNary Dam in 2015 and percentage survival from McNary to Priest Rapids Dam for sockeye tagged at Bonneville Dam in 2015.

Further upstream, high temperatures may have contributed to straying of Wenatchee stock Sockeye Salmon upstream of the Wenatchee River confluence to Rocky Reach and Wells dams (as determined by GSI). The percentage of Wenatchee stock, estimated as a three-day moving average, that passed Rock Island Dam (downstream of the Wenatchee River confluence) that were then detected at Rocky Reach Dam increased as Wenatchee River temperatures increased, although it then dropped as temperatures leveled off before returning to rates approaching 25% (Figure 27).

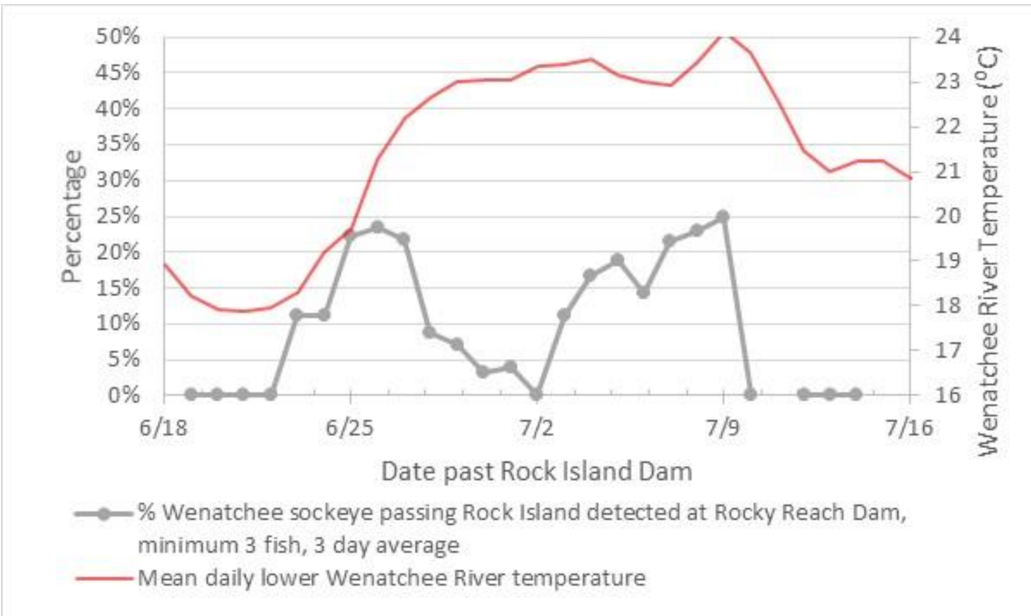

Figure 27. Percentage of Wenatchee stock Sockeye Salmon (as classified by GSI) detected at Rock Island Dam that were subsequently detected at Rocky Reach Dam by date past Rock Island Dam in 2015. Lower Wenatchee River temperatures are also shown.

A total of 122 Sockeye Salmon tracked by this study from the Bonneville Dam Adult Fish Facility that were detected at the Lower Wenatchee River (LWE) PIT array (Figure 17), 32 (26.2%) were previously detected at Rocky Reach Dam with 18 (13.6%) of these 32 also detected at Wells Dam. Two of the 32 Sockeye Salmon ((3DD.00775EA18F and 3DD.00775E4636) were detected at LWE before and after making a trip to Rocky Reach Dam where they were also detected. These fish “dipped in” to the Wenatchee River before temporarily straying up the Columbia River. An additional Sockeye Salmon (3DD.00775DC4C2) was detected at Rocky Reach Dam and subsequently detected at Tumwater Dam but not detected at LWE, which it would have passed on its migration upstream to Tumwater Dam.

All 58 PIT tagged Sockeye migrating past and detected at Rocky Reach Dam through June 24 were classified using GSI as Okanagan stock with none classified as Wenatchee stock (Figure 28). On and after the date of June 25, when the Wenatchee River temperature recorded at LWE reached 19.7C, 44 out of 234 (15.8%) of GSI-classified Sockeye Salmon passing Rocky Reach Dam were estimated to be of Wenatchee stock. Weighting weekly stock proportions of Sockeye by weekly run sizes at Rocky Reach and Wells dams resulted in estimates of 17.0% of fish at Rocky Reach and 11.1% of fish at Wells Dam being of Wenatchee origin in 2015. This results estimates of 36,800 Sockeye (out of 216,389 counted) at Rocky Reach Dam and 20,700 (out of 186,857 counted) at Wells Dam that were of Wenatchee origin.

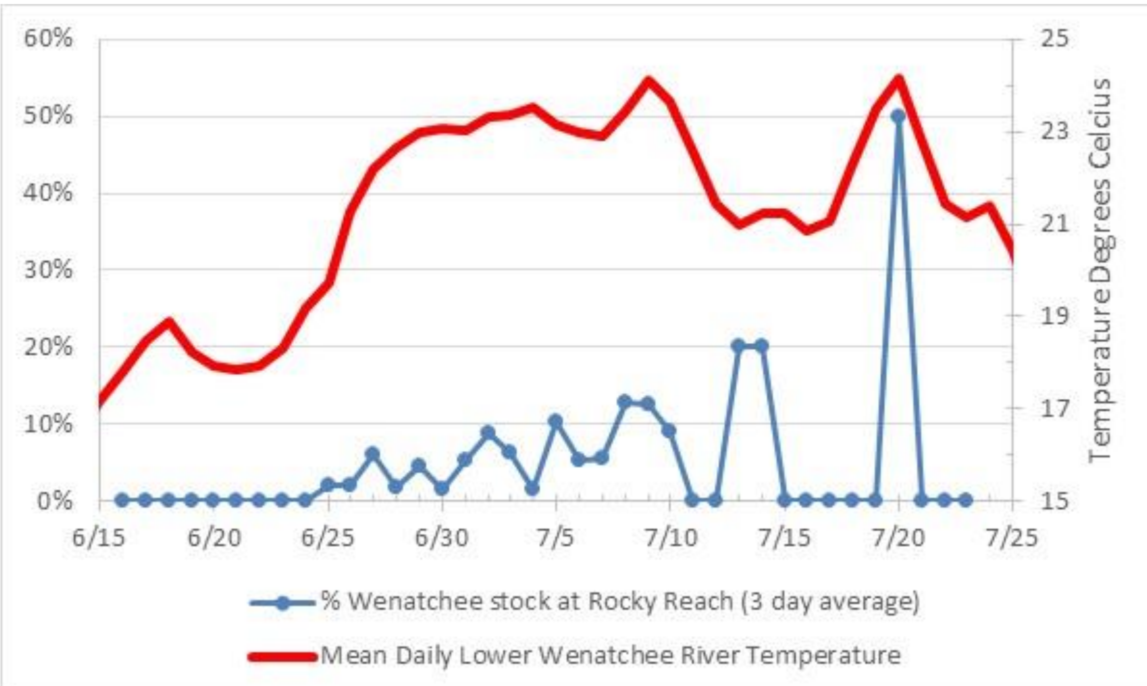

Figure 28. Percentage of Wenatchee stock Sockeye Salmon (as classified by GSI) at Rocky Reach Dam by date in 2015.

Sockeye Salmon sampling at Wells Dam continued throughout the Sockeye run. Survival to the Okanagan Sockeye Spawning grounds was only 5.4% compared to 6.1% for Bonneville-tagged Sockeye Salmon passing Wells Dam. Based on GSI of Sockeye sampled at Wells Dam, 15.6% of the Sockeye passing Wells Dam were of Wenatchee origin and an estimated 3.4% of the run passed Tumwater Dam (compared to 5.4% on the Okanagan River spawning grounds).

The PIT tag antenna infrastructure performance at OKC and ZSL, both funded by this project, was the best since these antennas were installed in 2009 and 2010 with high detection rates resulting from low flows and no software or hardware problems. Low flows meant that Zosel spillway gates were not open wide enough to allow adult fish to pass upstream through the spillways, and fish instead passed through the PIT tag antennas located in the fish ladders. All adult Sockeye Salmon detected upstream at OKC were also detected at Zosel Dam resulting in a detection efficiency of 100% for Zosel Dam. The low flows also benefited detection of juveniles at Zosel Dam. Without high spillway flows, juveniles were attracted to flows through the Zosel Dam fish ladders where they could be detected. In 2014 under high flow conditions, there were only 2 juvenile Sockeye detected out-migrating through Zosel Dam fish ladders. This compares to 63 juvenile Sockeye detections at Zosel Dam in 2015; 31 of which were detected in the two fish ladders with the remaining 32 detected by a new floating antenna located just upstream of the western spillway that was installed immediately prior to the juvenile out-migration. Low flows also meant higher than normal detection rates of PIT tagged Sockeye detected at instream arrays in the Wenatchee River (LWE) and the Okanagan River (OKL). The overall detection rate at OKL for Sockeye tagged by this project at Wells Dam was 85.4% and 86.3% for Sockeye tagged at Bonneville Dam while at LWE it was 82.1% for Sockeye tagged at Bonneville Dam. By comparison, in 2014 for Sockeye tagged at Bonneville Dam, only 38.1% were detected at OKL and 10.5% at LWE.

In past years, this study has used PIT tag data estimates of abundance, fallback, and night passage to provide and adjusted estimate escapement at dams and compare this estimate with visual counts (Fryer et al., 2016). However, in 2015 we did not do this as our sample was much less representative than in past years because we could not sample at Bonneville Dam during a period of 22 continuous days (July 3-July 23) when 22.2% of the run passed.

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 and then normally migrate into the Wenatchee River before 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. These estimates are similar to those derived from this study using PIT tags (albeit with no data for Sockeye passing Bonneville Dam in weeks 28-30), but differ when GSI is incorporated (Table 54).

Table 54. Comparison of different methods of estimating Okanagan and Wenatchee Sockeye stock composition in 2015. Methods A and B are from Table 22 and exclude Statistical weeks 28 and 29 due to sampling restrictions and week 30 because none of the 15 Sockeye Salmon tagged were detected above Rock Island Dam.

	Method	% Okanagan	% Wenatchee	Other	Source Table
A	PIT tags deployed at Bonneville Dam detected at Rocky Reach and Tumwater Dams	78.4%	21.1%	0.5%	22
B	PIT tags deployed at Bonneville Dam only using Okanagan and Wenatchee river detections as terminal areas	62.8%	35.7%	1.4%	22
B	GSI + PIT on Bonneville samples (weighted by Bonneville visual counts)	62.5%	36.7%	0.9%	22
C	Visual dam counts taking the Rock Island-Rocky Reach difference as Wenatchee	81.7%	18.3%	NA	18
D	Visual dam counts taking Tumwater as Wenatchee	80.8%	19.2%	NA	18

The PIT tag and GSI data both suggest that straying Wenatchee stock Sockeye Salmon inflated the Rocky Reach visual count. An estimated 15.1% of the Bonneville PIT tagged Sockeye Salmon detected at Rocky Reach Dam were of Wenatchee origin (with some returning to the Wenatchee River and thus being correctly classified). The PIT tag results also indicate that 27.9% of the Sockeye detected at the LWE array at the mouth of the Wenatchee River did not survive to Tumwater Dam. Both of these factors will tend to overestimate the proportion of the Sockeye run of Okanagan origin when using dam counts.

A total of 28 Sockeye Salmon tagged at Bonneville Dam were last detected at the Priest Rapids fish trap and likely ended up in the Cle Elum Sockeye reintroduction program. An additional 2 Sockeye Salmon were detected at the Priest Rapids fish trap followed by Roza Dam on the Yakima River so were presumed to have been transported to Cle Elum Lake and then fell back over Cle Elum Dam to Roza Dam.

The PIT tags from 12 adult tagged by this study at Bonneville Dam were found at the Badger Island pelican colony (Figure 29). Of these, 7 were last detected at The Dalles Dam, 4 at McNary Dam, and 1 at Priest Rapids Dam. The PIT tags from 93 juvenile Sockeye tagged, with funding provided in part from this project, at Skaha and Osoyoos lakes in 2015, were detected at five different avian colonies from Rock Island Dam forebay island to East Sand Island in the estuary (Figure 29). An additional 2 adult Sockeye PIT tagged at Bonneville Dam were recovered in tribal fisheries in the Bonneville Pool.

In past years, we have compared the survival from Wells to OKC or Zosel Dam for Sockeye PIT tagged at Bonneville and Wells dams to provide insights on the effect of different tagging regimes on Sockeye Salmon. However, in 2015, low survival rates from Wells to Zosel and OKC in addition to potential biases introduced by a lack of sampling at Bonneville Dam during a significant portion of the run make such comparisons questionable. For instance, in 2015, the estimated survival from Wells to Zosel was 9.7% for PIT tagged Sockeye, but 15.2% for PIT plus acoustic tagged Sockeye suggesting a 56.7% survival benefit with acoustic tagging. This survival rate was higher than that from Wells to Zosel for Bonneville-tagged Sockeye (13.4%) or for Sockeye tagged as juveniles detected at Wells Dam in 2015 (12.2%). In all other years of this study, acoustic tagged Sockeye had a lower survival than PIT tagged Sockeye and we would have expected an even bigger survival disadvantage in 2015 due to surgically implanting acoustic tags at high water temperatures.

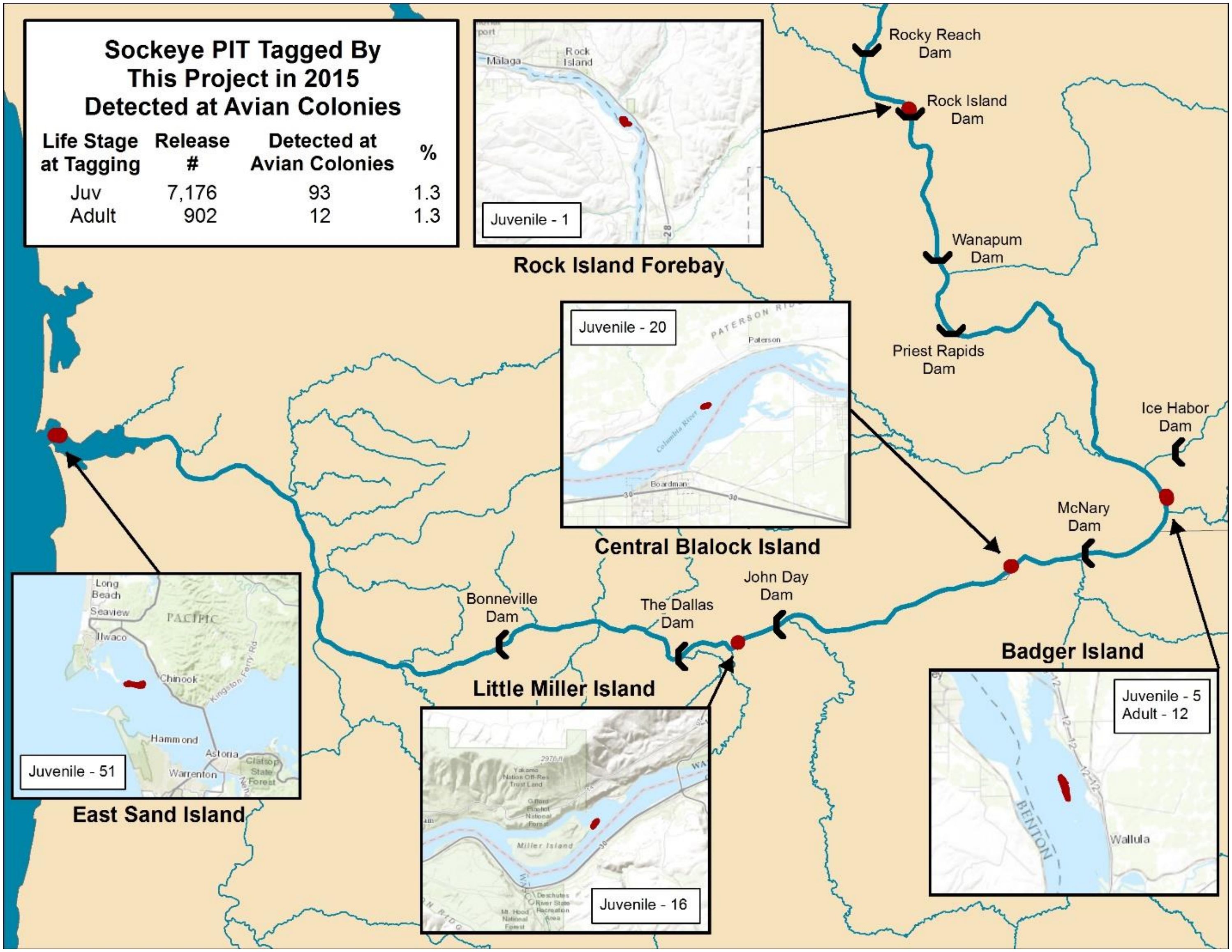

Figure 29. Detections of Sockeye Salmon PIT tagged by this project detected at avian colonies in 2015.

As has been the case since 2008, there was not a significant linear relationship between run timing at Bonneville Dam and stock composition (Table 18). The 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 0.5% or less for all dams but Bonneville, McNary and Rock Island dams in 2015 (Table 5). At McNary and Bonneville dams, it is possible that Sockeye are using the navigation locks. 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. These antennas were upgraded over the winter of 2014/15 but we reported to Biomark in June, 2015 that detection rates were still low. Biomark subsequently mad adjustments to these antennas and detection rates increased for the end of the Sockeye run.

Fallback rates at mainstem dams (Table 16) in 2015 through Rock Island Dam ranged from 0.7% at Bonneville Dam to 2.3% at Priest Rapids Dam but were considerably higher upstream at Rocky Reach (9.8%), Wells (5.9%) and Zosel (19.6%) dams. In 2014, no dam had a fallback rate higher than 3.9%. Most of the 2015 fallbacks at Rocky Reach and Wells dams are attributable to Wenatchee stock Sockeye Salmon that overshot the Wenatchee River, likely a result of high temperatures in the Wenatchee River. Mixed stock Sockeye tagged as juveniles at Rock Island Dam also had high fallback rates at Rocky Reach (28.6%) and Wells (22.7%) dams, again possibly attributable to high temperatures in the Wenatchee River. Sockeye tagged as juveniles in the Snake Basin had high fallback rates at Bonneville (23.0%) and The Dalles dams (62.5%).

This project is proposed to continue and evolve through at least 2018. Upcoming work will include investigating possible PIT tag detection as Sockeye pass under the Highway 3 Bridge in Osoyoos between the north and central basins of Osoyoos Lake. The north basin is the first cold water refuge that

Sockeye Salmon encounter on their upstream migration. We are planning to test the use of a Dual frequency IDentification SONar, or DIDSON, to get images of Sockeye Salmon passing the area. These images will be used 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.

Lake Wenatchee acoustic trawl surveys are expected to continue through 2018 along with limnological sampling to better estimate the annual production and future productive potential of Lake Wenatchee Sockeye Salmon. Acoustic trawl survey (ATS) data in Skaha, Osoyoos, and Wenatchee lakes are also used in Columbia Basin run forecasting. There are several unanswered questions regarding Lake Wenatchee Sockeye that we hope to address during this project. A primary question is why Lake Wenatchee Sockeye, in recent years, have not increased in relative abundance as much as Okanagan Sockeye, or even Snake River Sockeye. Our limnology and ATS work should help to answer this question, but it is also uncertain what the optimal spawning escapement goal is for this stock. An optimal escapement analysis is being completed, using other funding, for Osoyoos and Skaha Sockeye and we are considering a similar analysis 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 several recent years with runs over 500000 Sockeye Salmon have occurred while less than 5% of historical Columbia Basin habitat is available (Fryer 1995), making historical estimates appear conservative. To answer this question, we are working with the ONA, DFO, and Grant, Chelan, and Douglas Public Utility District to fund paleolimnological analysis of lake core samples from Wenatchee, Osoyoos, and Skaha lakes to assess lake limnology and Sockeye Salmon production back several hundred years.

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APPENDIX A

Table A1. 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.
15D	Fifteenmile Ck at Dry Ck	At the confluence of Dry 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.
BHC	Bohannon Creek Lemhi R Basin	The array is located in Bohannon Creek, 40 m upstream of the confluence with the Lemhi River.
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.
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).
CAL	Carson NFH Adult Return Ladder	Hatchery adult spring Chinook return ladder from the Wind River to Carson NFH.
CCW	Catherine Creek Ladder/Weir	Instream detection array located in the adult return fish ladder at the Catherine Creek weir.
CHL	Lower Chiwawa River	Chiwawa River rkm 1, located between the Chiwawa smolt trap and the Chiwawa Acclimation Ponds.
CHU	Upper Chiwawa River	Chiwawa River rkm 12, located above the Forest Road 62 bridge and below Alder Creek.
CHW	Chiwaukum Creek	Located at rkm 0.4 on Chiwaukum Creek, a tributary of Wenatchee River, near Tumwater Campground.
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.
CMP	Camp Creek - Imnaha	Located on Camp Creek in the Imnaha River Basin, 2.0 rkm from the mouth of the creek.
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 Decschutes River.
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
ESS	EFSF Salmon River at Parks Cr	East Fk South Fk Salmon River (rkm 21) near Parks Creek.
FDD	Feed Diversion Dam	Feed Diversion Dam, at Umatilla River rkm 47.
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.
HRM	Hood River Mouth	Located at the mouth of the Hood River against the west side jetty just inside the bar where the Hood River
HST	Touchet River at Harvey Shaw	Located at rkm 50 on the Touchet River.
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.
ICL	Lower Icicle Instream Array	Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA.
ICM	Middle Icicle Instream Array	Located at rkm 7 on Icicle Creek.
IML	Imnaha River Weir Adult Ladder	Located in the adult return fish ladder at the Imnaha River weir. Site is on public land.
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).
JD1	John Day River, McDonald Ferry	John Day River in-stream detection, near McDonald Ferry at RM 20.

Table A1. Continued.

Site Code	Site Name	Site Description
JDJ	John Day Dam Juvenile	John Day Dam Juvenile Fish Bypass and Sampling Facility.
JDM	Upper John Day Array	Located on the Upper Mainstem John Day River approximately 7 miles upstream of Dayville, Oregon.
JOC	Joseph Creek ISA at km 3	Joseph Creek, Grande Ronde basin at river km 3 (N 46.030016, W -117.016042).
JOH	Johnson Creek	Johnson Creek enters the Okanogan River at RKM 65.3, in the town of Riverside, WA. The site is located approximately 0.25 KM upstream from the confluence of the Okanogan River.
KHS	Big Bear Creek at Kendrick High School	Located near the mouth of Big Bear Creek (in the Potlatch River Basin) adjacent to the high school in the town of Kendricks, ID.
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.
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.
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.
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.
MDR	McDonald Road Bridge	Middle Walla Walla River at McDonald Road Bridge.
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.
MRC	Methow River at Carlton	Located in the mainstem Methow River near the town of Carlton at rkm 45.
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.
MTD	Mill Creek at The Dalles	Located approximately 2.5 km upstream of the mouth of Mill Creek and the confluence with the Columbia River. Site is on private land.
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.
MVF	Moving Falls Fish Ladder	Located in the fish ladder at a site known as Moving Falls on the West Fork of the Hood River.
MWC	Maxwell Canal	Maxwell Canal is located at rkm 24 on the Umatilla River.
NAL	Lower Nason Creek	Nason Creek rkm 1, located within Lake Wenatchee State Park.
NAU	Upper Nason Creek	Nason Creek rkm 19 (Wenatchee River Basin).
NBA	Nursery Bridge Adult	Nursery Bridge Dam Fishways (both), Walla Walla River at Milton-Freewater, OR.
NFS	North Fork Salmon River	Located on the North Fork Salmon River approximately 0.5 km above the confluence with the Salmon River.
NMC	Ninemile Creek Instream Array	Ninemile enters the east side of Lake Osoyoos at Okanogan River rkm 129.5, north of the town of Oroville, WA. The site is 0.78 km upstream from the confluence with Lake Osoyoos.
NSB	North Santiam at Upper Bennett Dam	Located on the North Santiam River, a tributary to the Wilammette River. The array is in the fish ladder at Upper Bennet Dam near the town of Stayton.
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.
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.
PEU	Upper Peshastin Creek	Located at rkm 17 on Peshastin Creek.
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.

Table A1. Continued.

Site Code	Site Name	Site Description
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.
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.
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).
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.
SUN	Sunnyside Instream Array	Located 600 M below Sunnyside Dam on the Yakima River.
SWC	Swale Creek Array	Located in Swale Creek, a tributary to the Klickitat River, Klickitat County, Washington. The site is approximately 100 m upstream from the confluence with the Klickitat River.
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.
TNK	Tunk Creek Instream Array	Tunk Creek enters the Okanogan River at rkm 72.4. The site is approximately 0.2 KM upstream from the confluence of the Okanogan River.
TON	Tonasket Creek	Tonasket Creek enters the Okanogan River in Lake Osoyoos at rkm 129.4, in the town of Oroville, WA. The site is approximately 0.40 KM upstream from the confluence of Lake Osoyoos.
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.
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).
WEB	Webb Creek	Located approximately 1.0 kilometers upstream from the mouth of Webb Creek.
WFF	Willamette Falls Fishway	Willamette Falls Adult Fishway
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.
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

Acoustic and Temperature/Depth Tagged Sockeye – Information on Behavior

Mean daily Similkameen temperatures (as recorded at the USGS Nighthawk station) during July averaged 5.7C lower than those recorded at the USGS Oroville station (Figure A1).

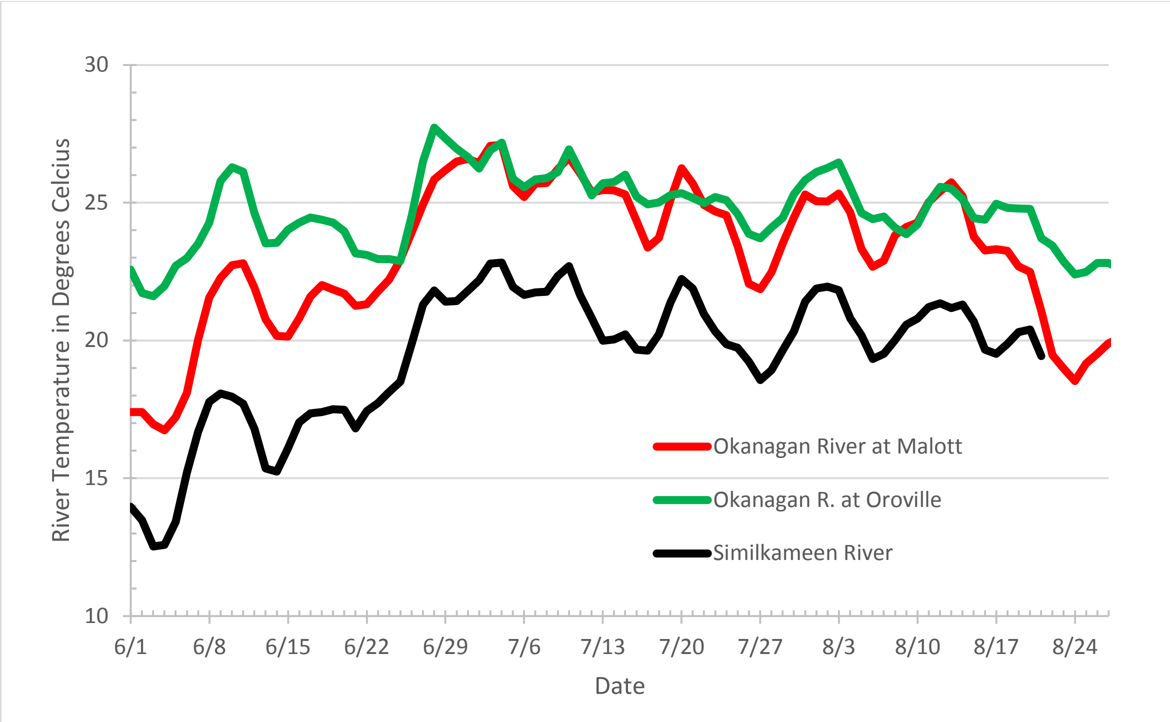

Figure A1. Mean daily temperature of the Okanagan River at Oliver and Monse, WA and the Similkameen River at Nighthawk, WA between June 1 and August 31, 2015.

Fish 1734 (Figure A2 for temperature depth information and Figure A3a and b for maps of fish movement) was detected several times at the mouth of the Okanagan on the Highway 97 receiver at transmitter temperatures of 19.1-20.2C from July 23-28 before it was detected on July 29 migrating upstream of Highway 97 at a temperature of 19.2C, Monse at 22.5C, the Okanagan Weir at 24.3C and Horseshoe Lake at 24.3C where it was last detected. The minimum, mean, and maximum transmitter temperature for this fish was 18.2C, 20.8C, and 25.9C respectively.

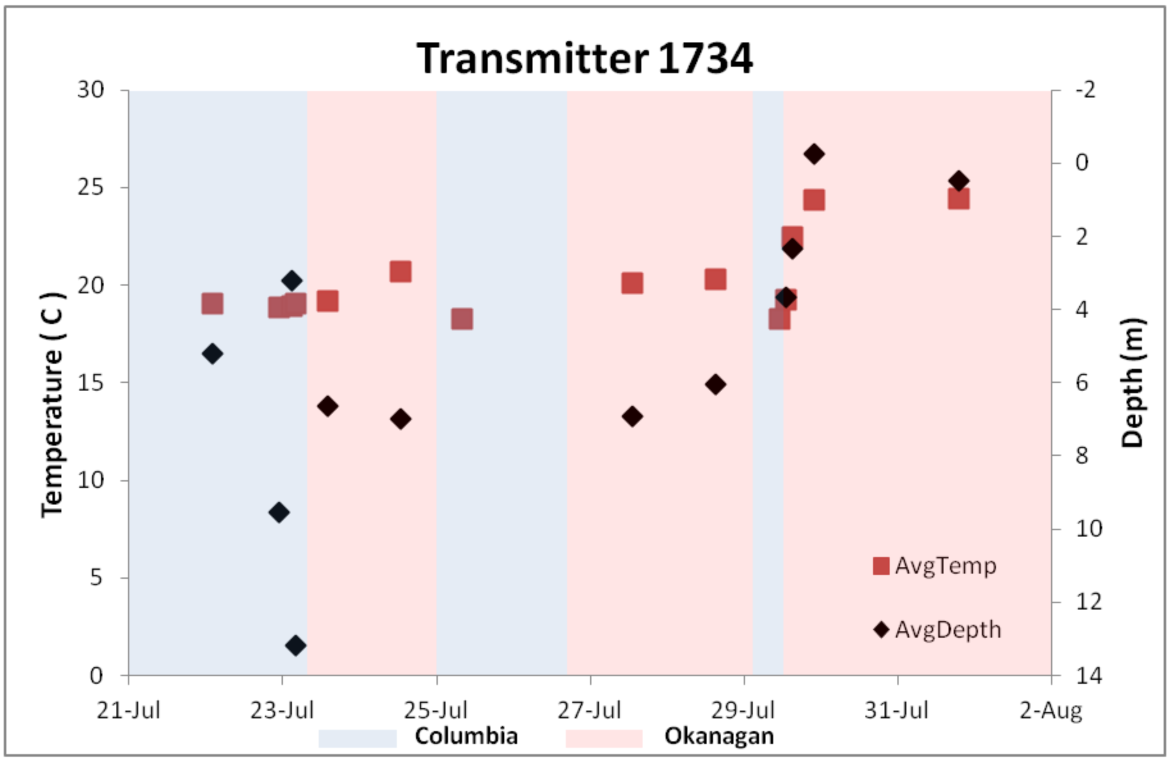

Figure A2. Temperature and depth data from transmitter 1734 in the Columbia and Okanagan rivers.

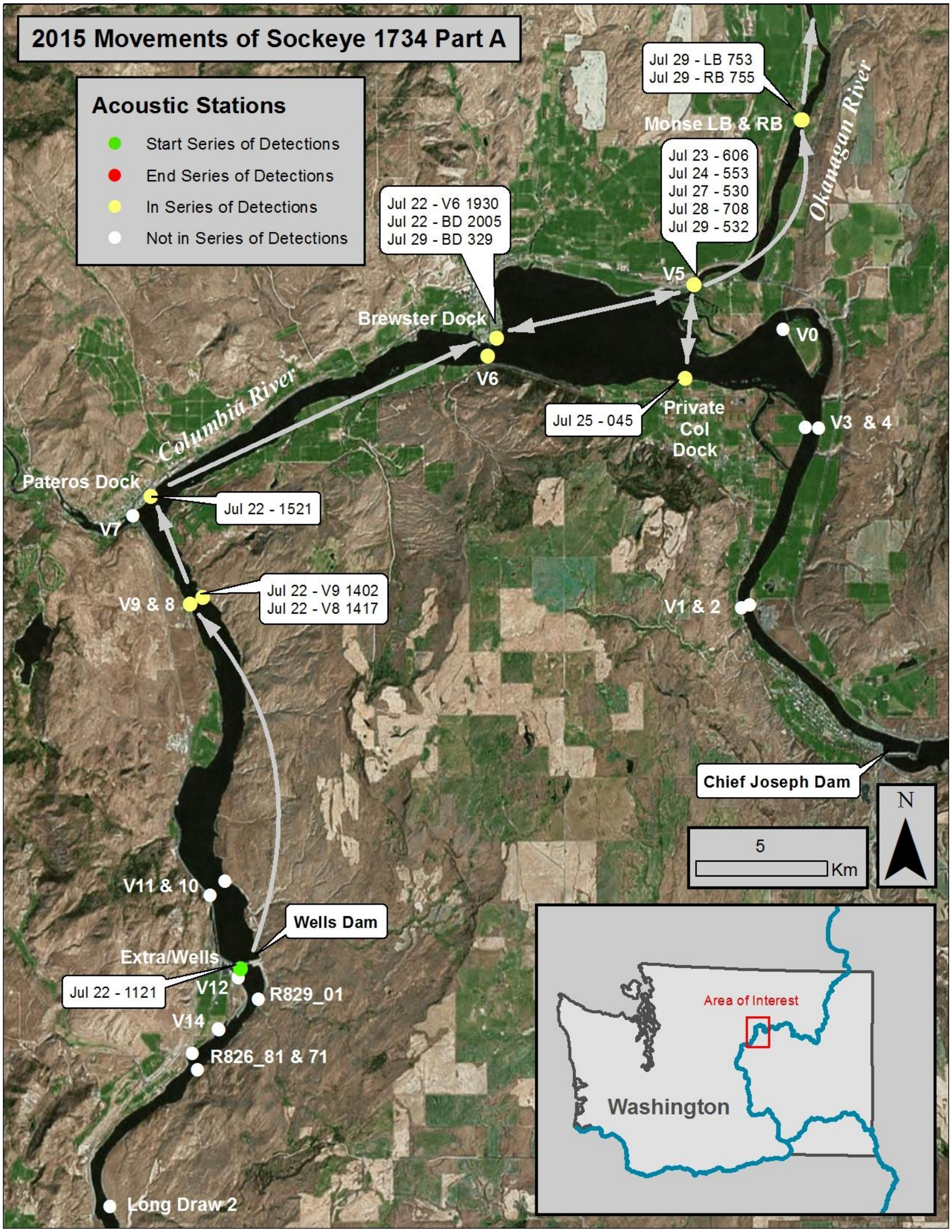

Figure A3a. Movements of fish with transmitter 1734 in the Columbia and Okanagan rivers.

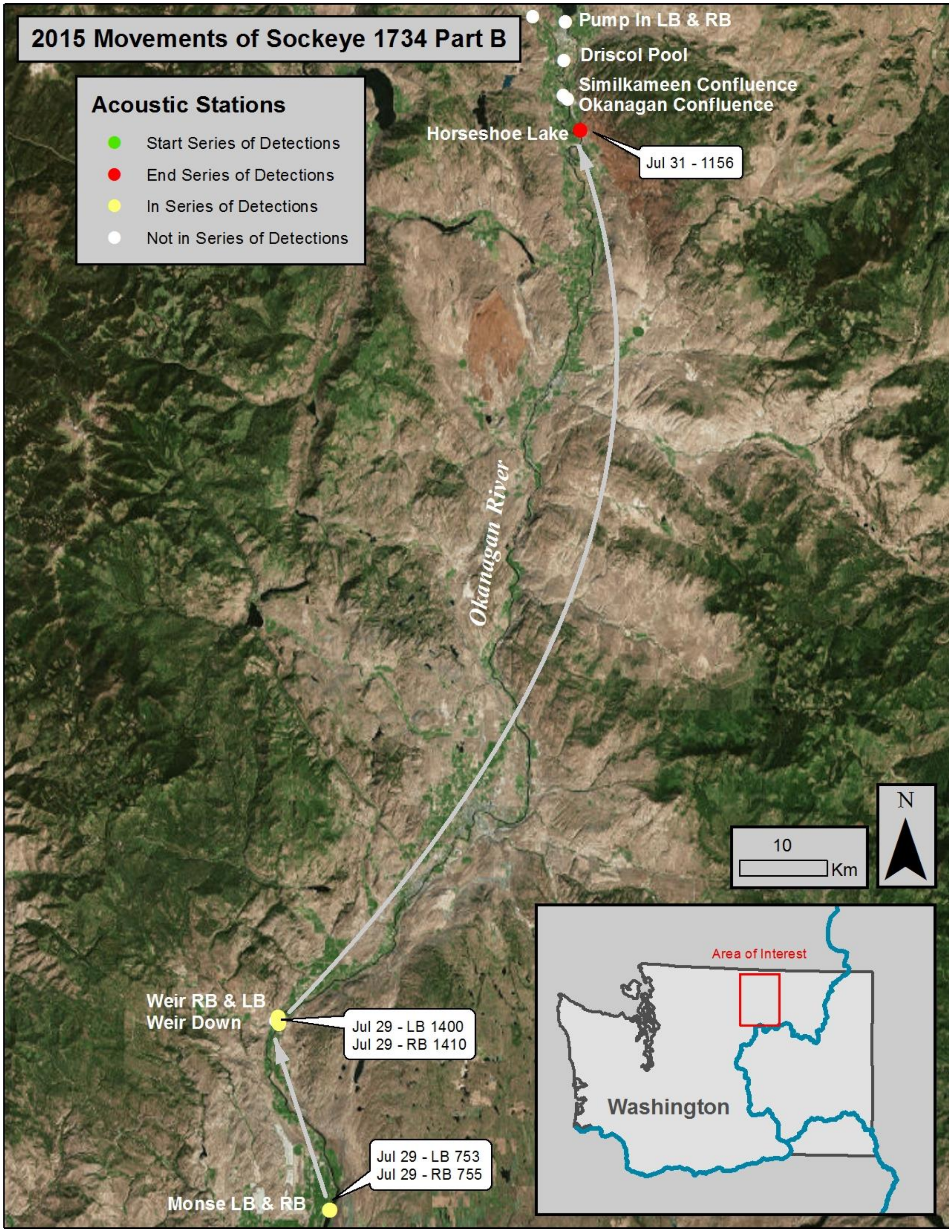

Figure A3b. Movements of fish with transmitter 1734 in the Okanagan River.

Fish 1754 (Figure A4 for temperature depth information and Figure A5a, b, and c for maps of fish movement) was detected on the Highway 97 receiver on July 24 at a transmitter temperature of 21.6C and again on July 27 at a temperature of 20.6C, Monse at 22.5C, the Weir at 23.1C, Horseshoe Lake at 23.6C, the Pump Station at 23.8C, and finally in the South Basin on July 30 at a temperature of 21.5C. It held at a range of 20.4-22.8C from July 30 through August 18, where it was last detected in the South Basin of Osoyoos Lake. The minimum, mean, and maximum transmitter temperature for this fish was 17.0C, 20.0C, and 23.9C respectively.

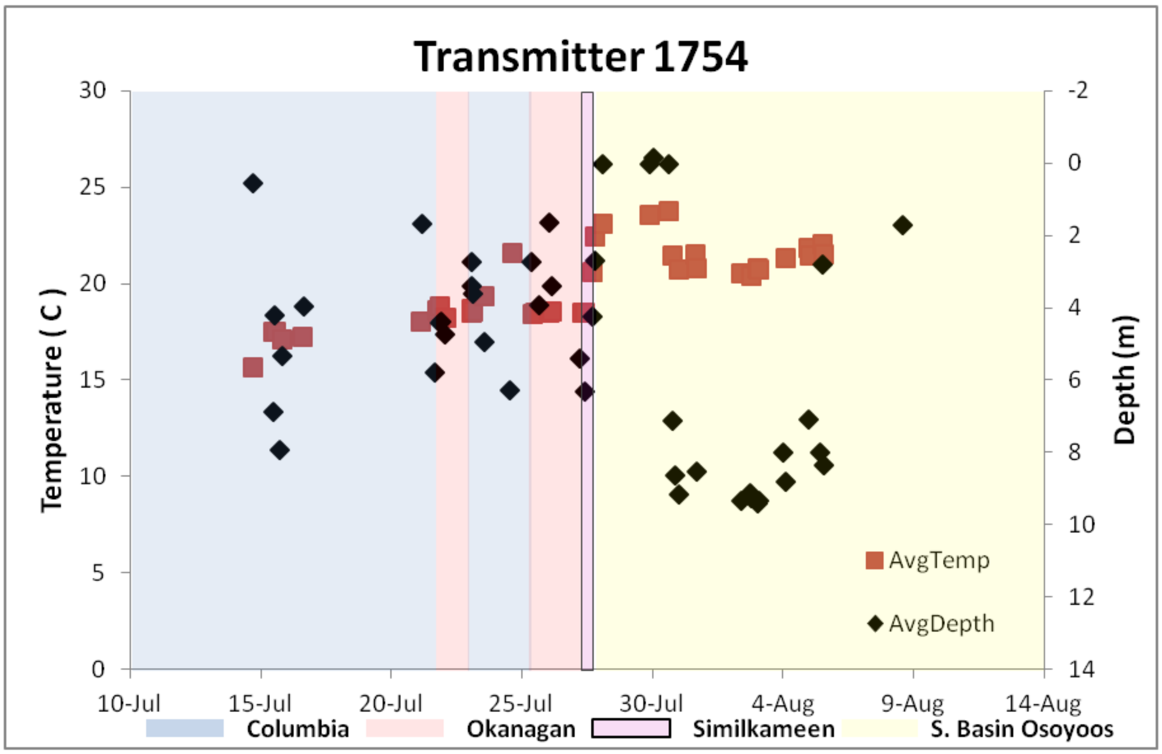

Figure A4. Temperature and depth data from transmitter 1754 in the Columbia and Okanagan rivers.

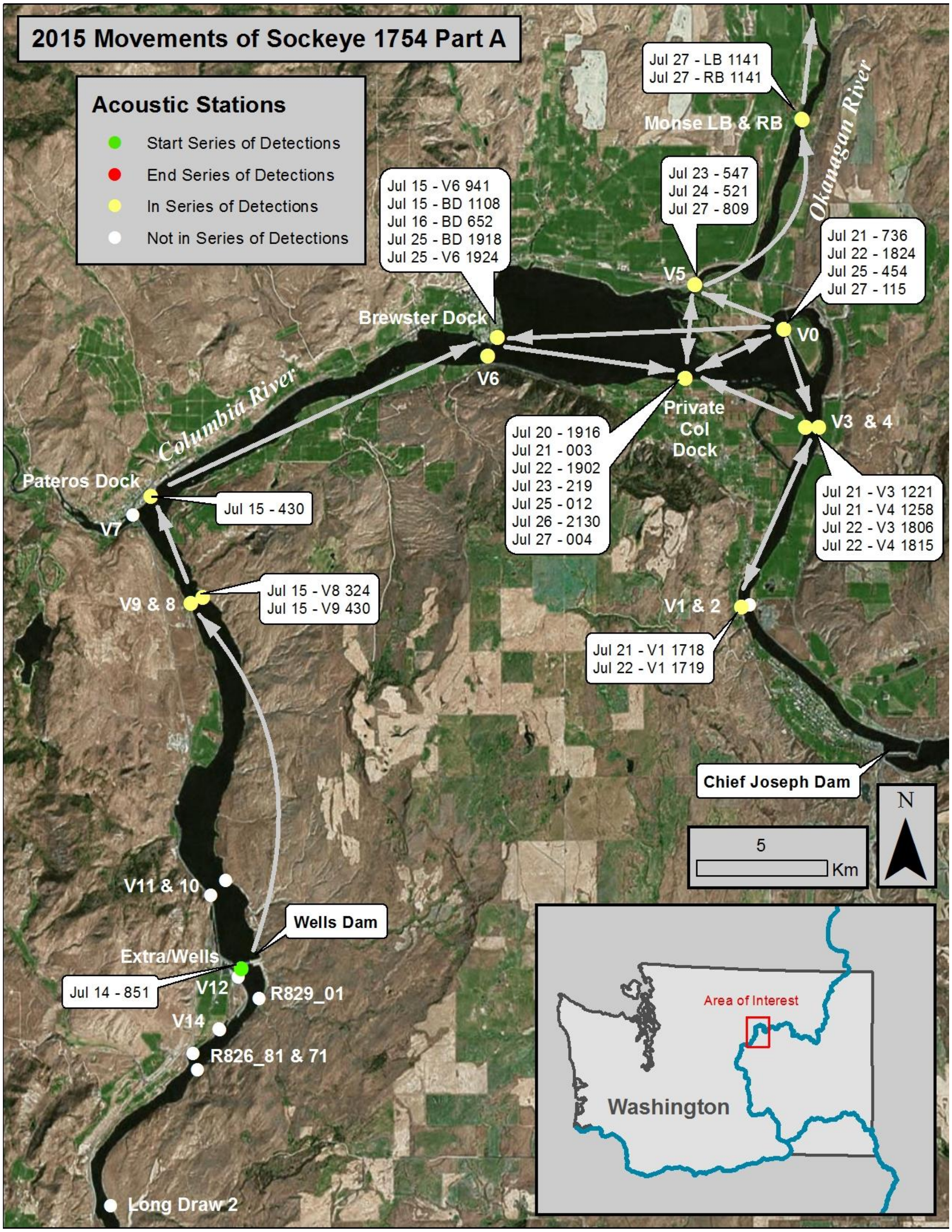

Figure A5a. Movements of fish with transmitter 1754 in the Columbia and Okanagan rivers.

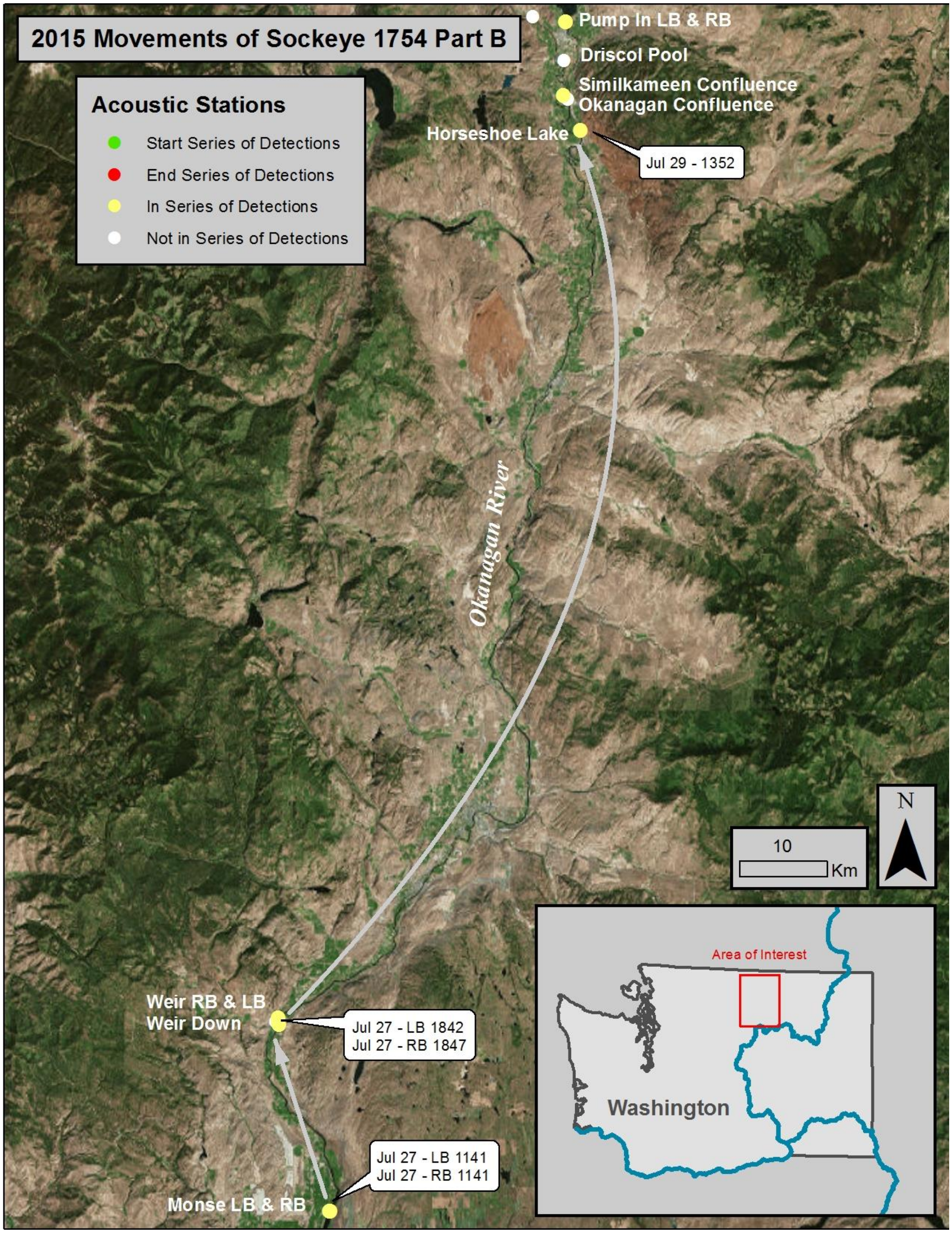

Figure A5b. Movements of fish with transmitter 1754 in the Okanagan River.

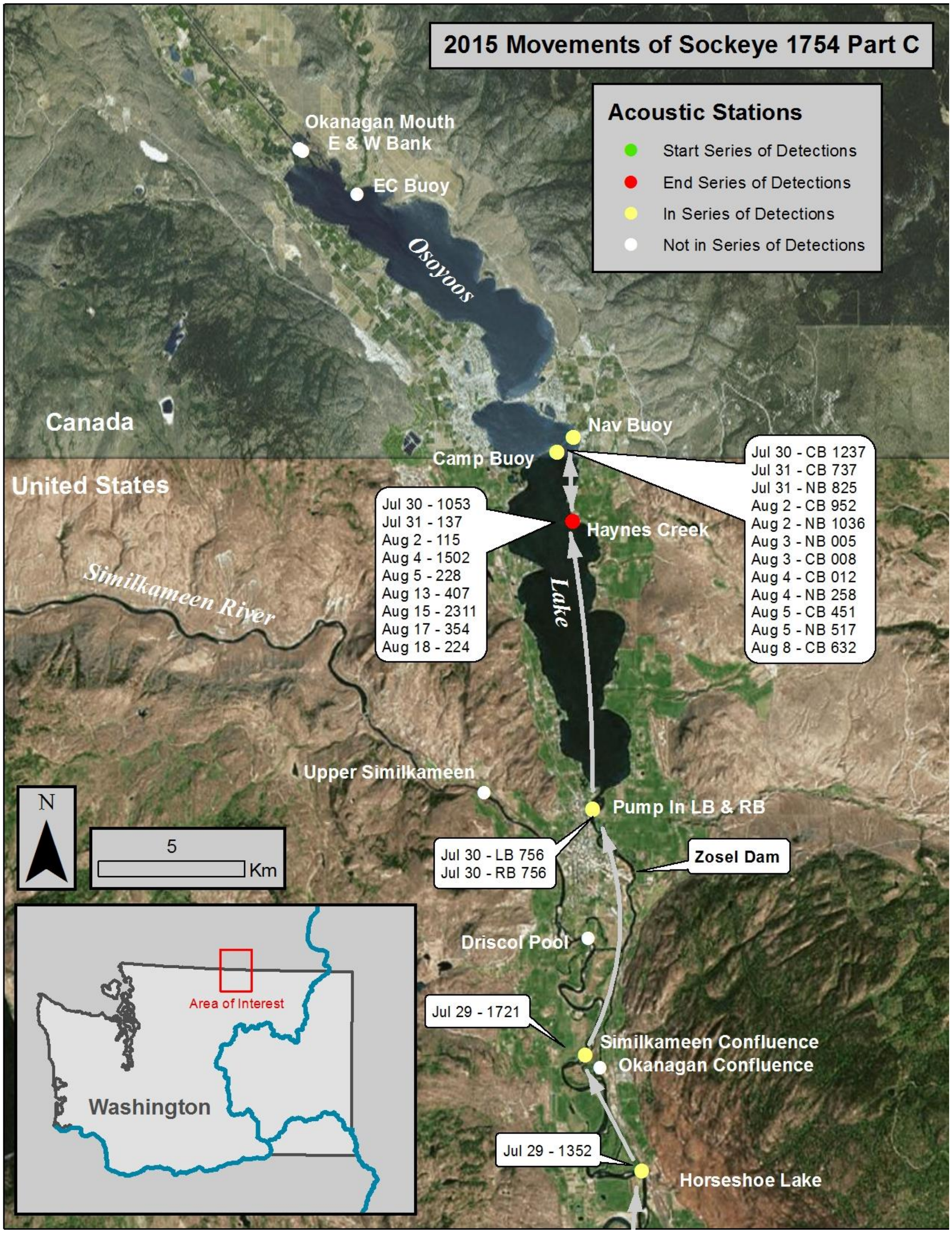

Figure A5c. Movements of fish with transmitter 1754 in the Okanagan River.

Fish 1772 (Figure A6 for temperature depth information and Figure A7a, b, and c for maps of fish movement) was detected on the Highway 97 receiver at the mouth of the Okanagan 8 different times before it proceeded to migrate upstream where it was last detected in the Similkameen. It was first detected on July 9 at a transmitter temperature of 18.0C and it began migrating upstream on August 25 where it was detected at Highway 97 at a temperature of 20C. It was then detected at Monse at 19.6C, the Weir at 19.9C, Horseshoe Lake at 19.6C on August 29, and then multiple times in the Similkameen/Okanagan Confluence area until it was last detected on September 7 in Driscoll Pool at 14.3C. The minimum, mean, and maximum transmitter temperature for this fish was 13.7C, 19.1C, and 22.3C respectively.

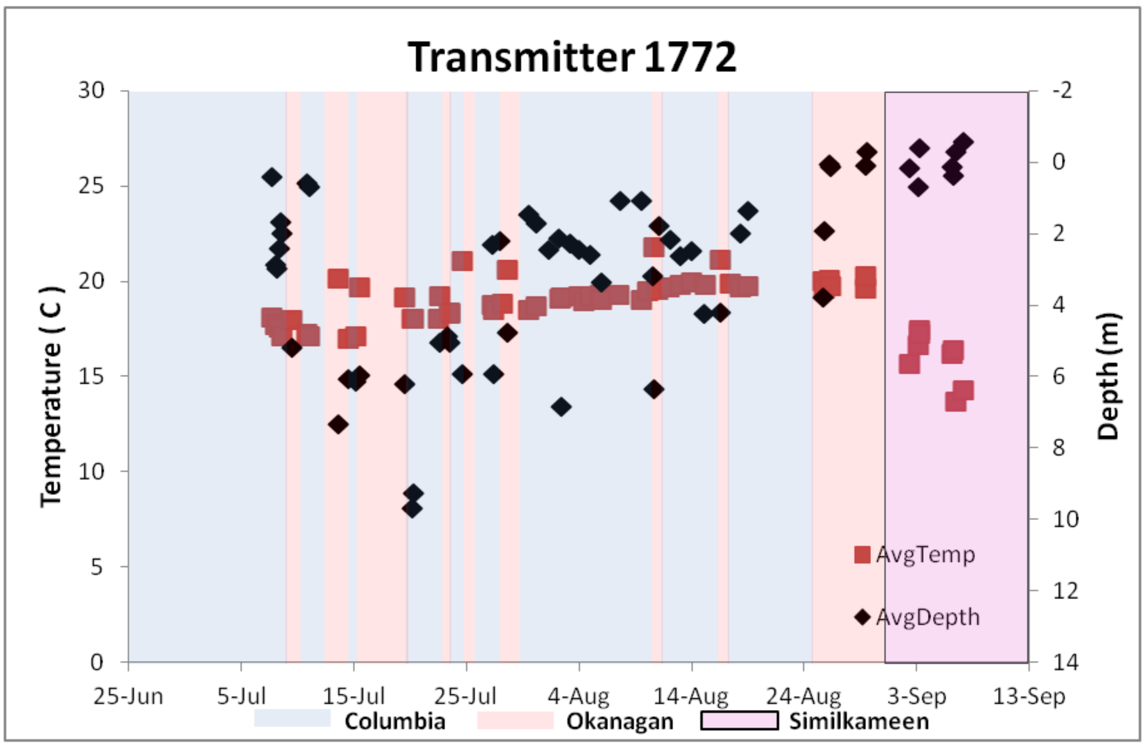

Figure A6. Temperature and depth data from transmitter 1772 in the Columbia and Okanagan rivers.

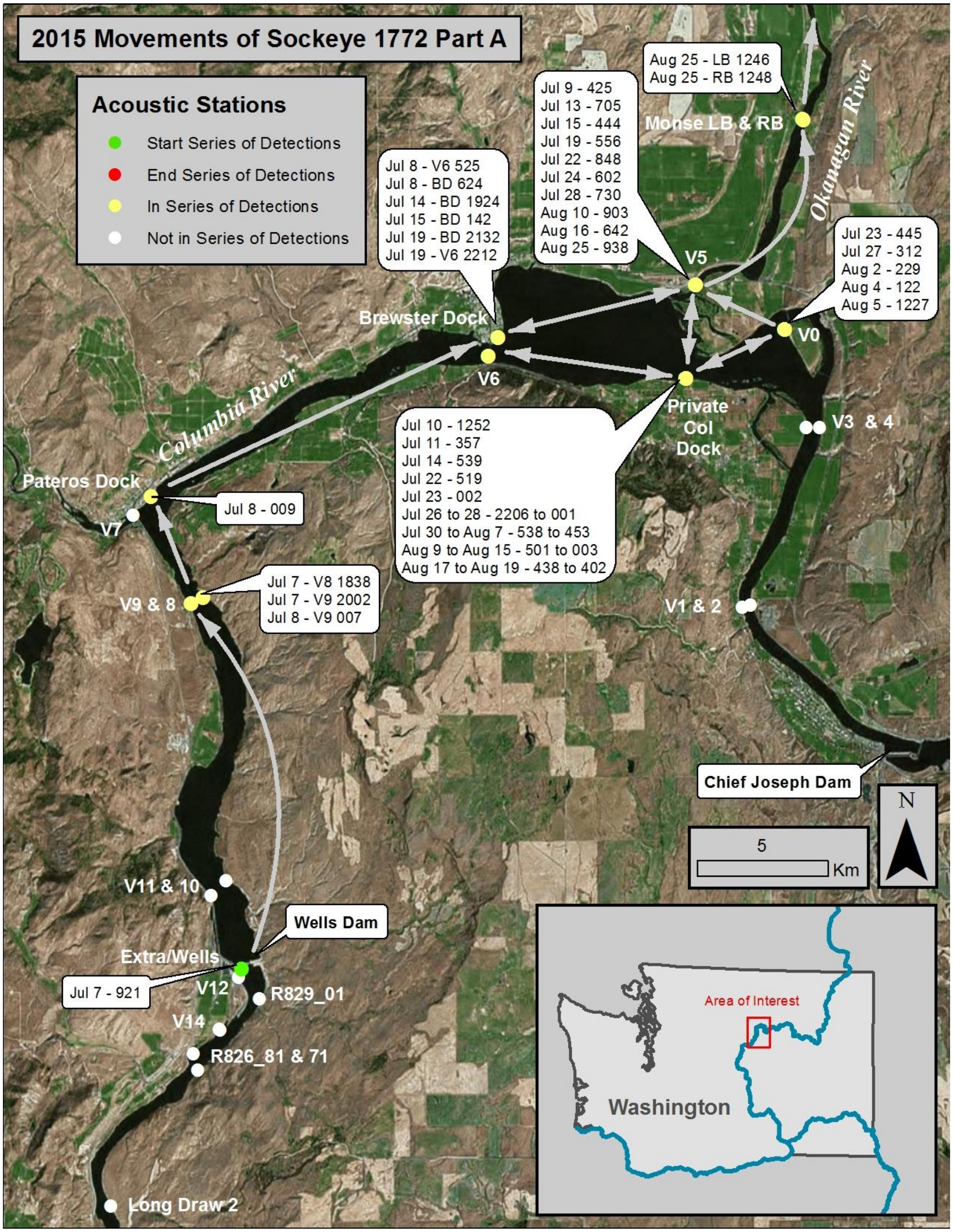

Figure A7a. Movements of fish with transmitter 1772 in the Columbia and Okanagan rivers.

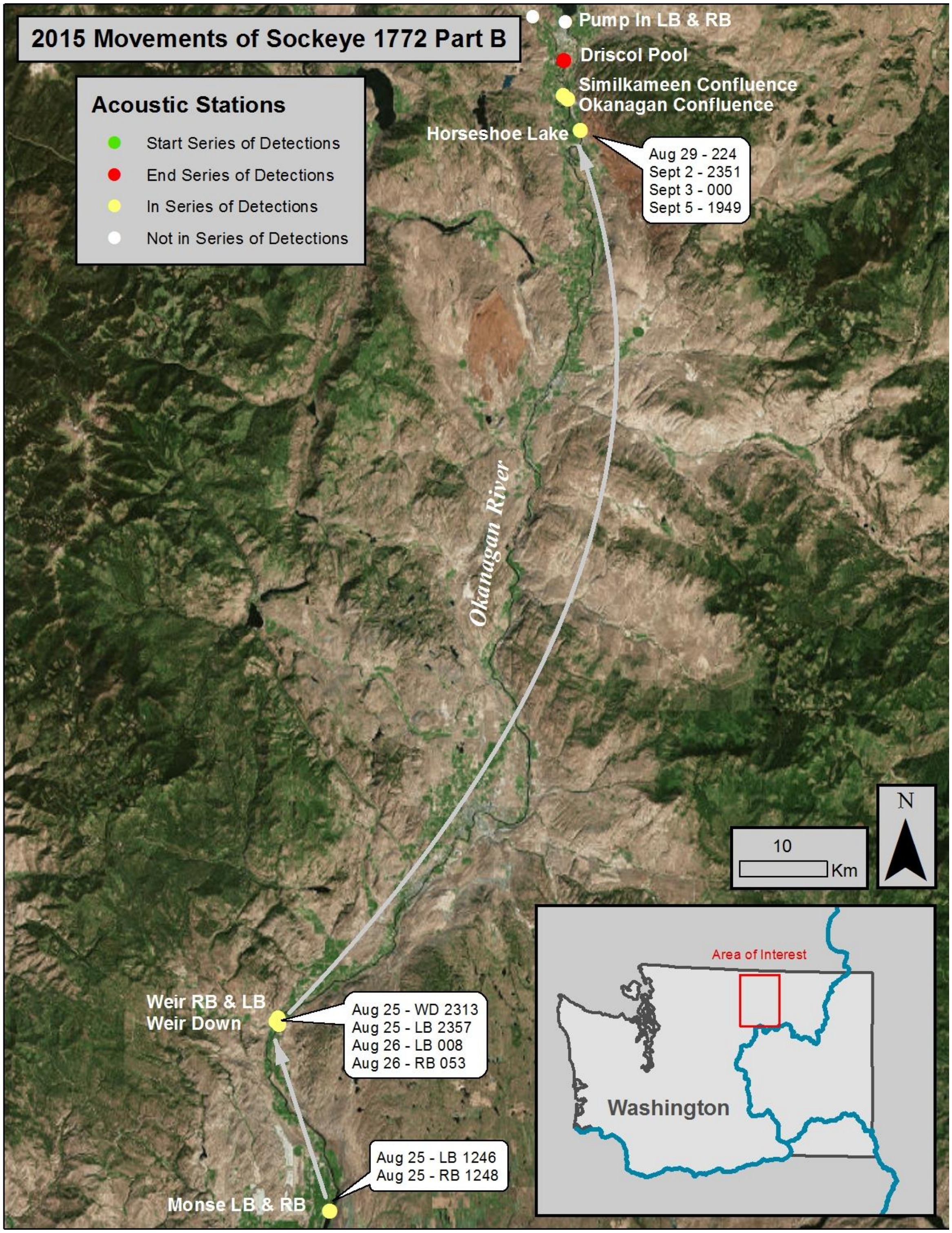

Figure A7b. Movements of fish with transmitter 1772 in the Okanagan River.

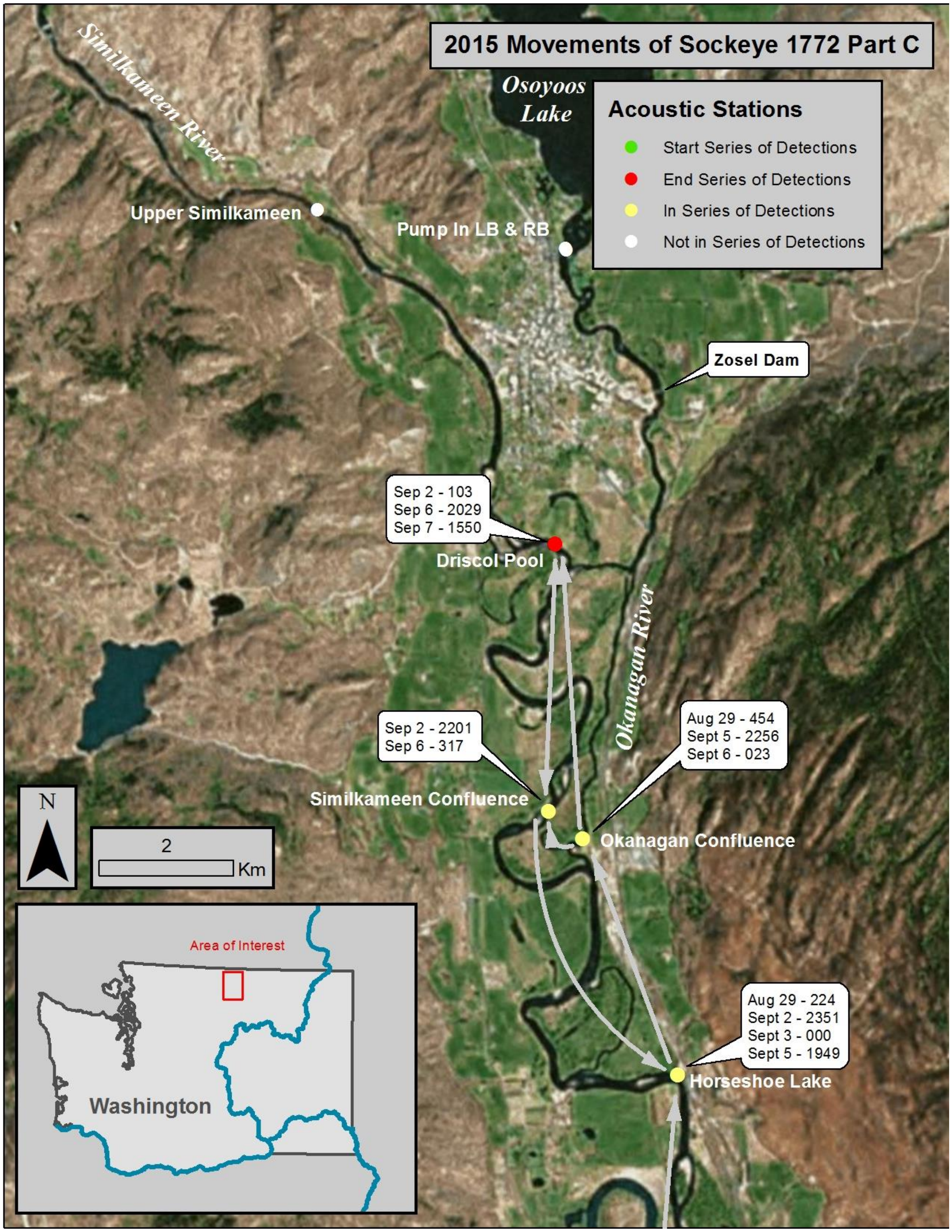

Figure A7c. Movements of fish with transmitter 1772 in the Okanagan River.

Fish 1776 (Figure A8 for temperature depth information and Figure A9a, b, and c for maps of fish movement) was detected on the Highway 97 receiver on July 10, 13, 17, 23-25, and 28 at temperatures ranging from 18.4-22.1C. It continued migrating past Monse on July 28 at 22.1C, the Weir at 24.3C, Horseshoe Lake at 25.6C, and then in the Similkameen from July 31 through August 2 at temperatures from 21.6-25.1C where it was last detected in the Upper Similkameen on August 2 at 22.8C. The minimum, mean, and maximum transmitter temperature for this fish was 16.8C, 19.1C, and 25.9C respectively.

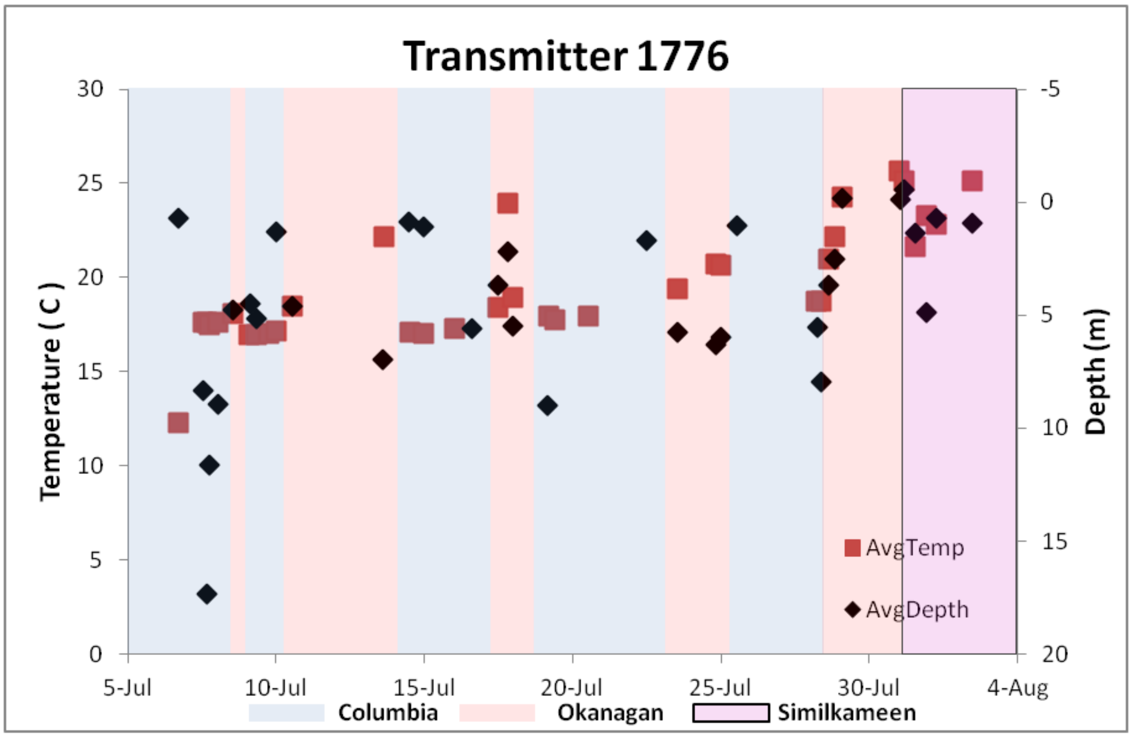

Figure A8. Temperature and depth data from transmitter 1776 in the Columbia and Okanagan rivers.

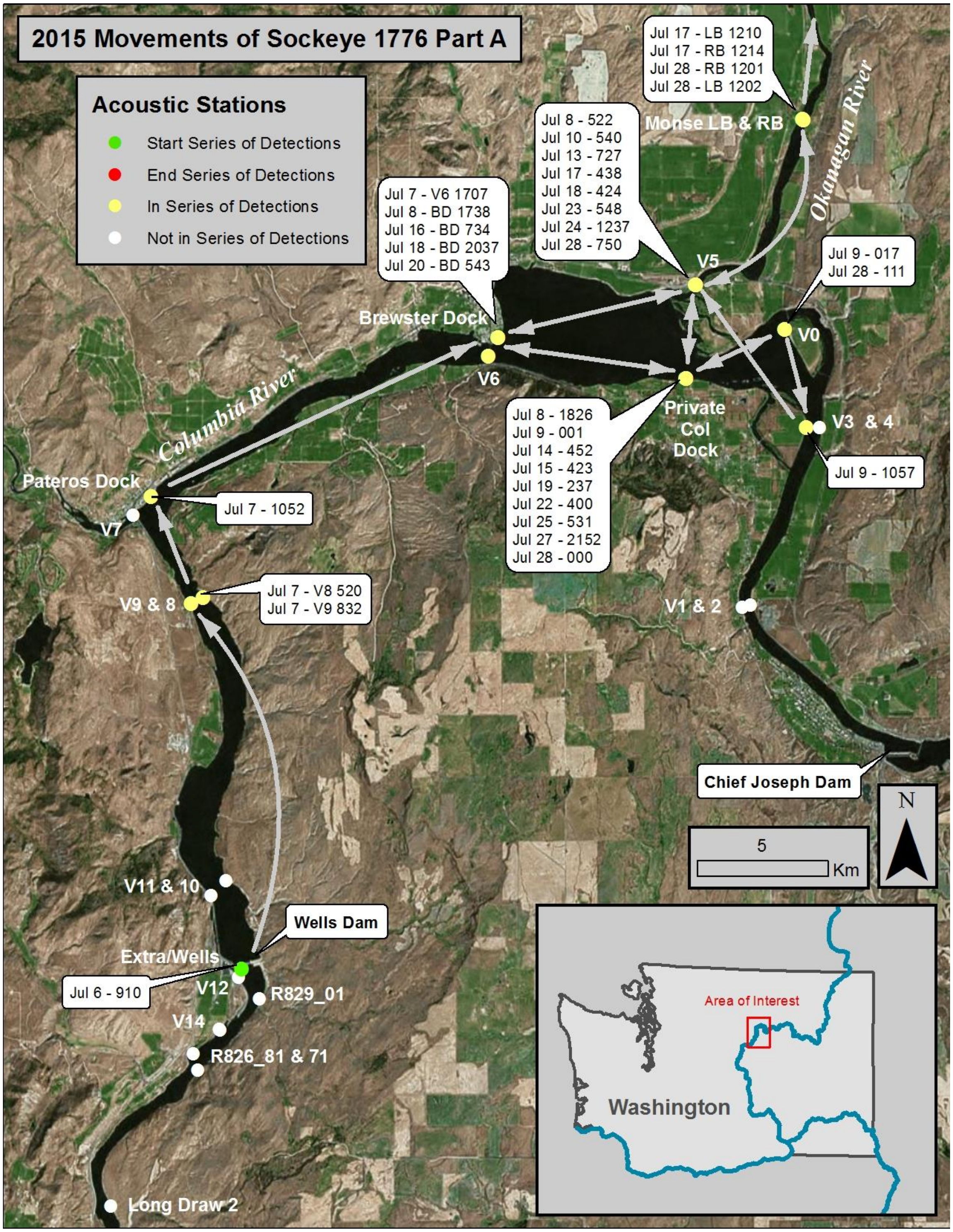

Figure A9a. Movements of fish with transmitter 1776 in the Columbia and Okanagan rivers.

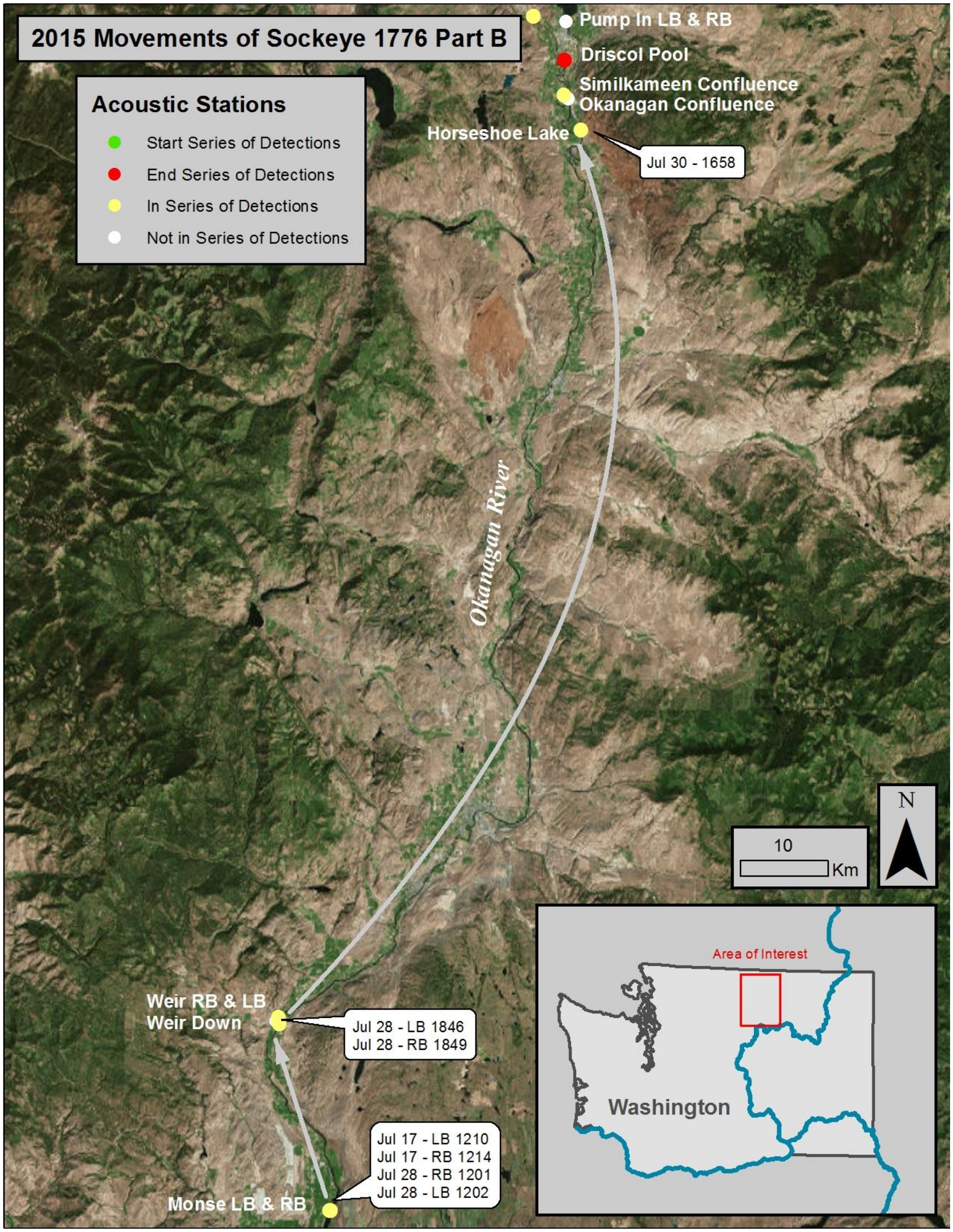

Figure A9b. Movements of fish with transmitter 1776 in the Okanagan River.

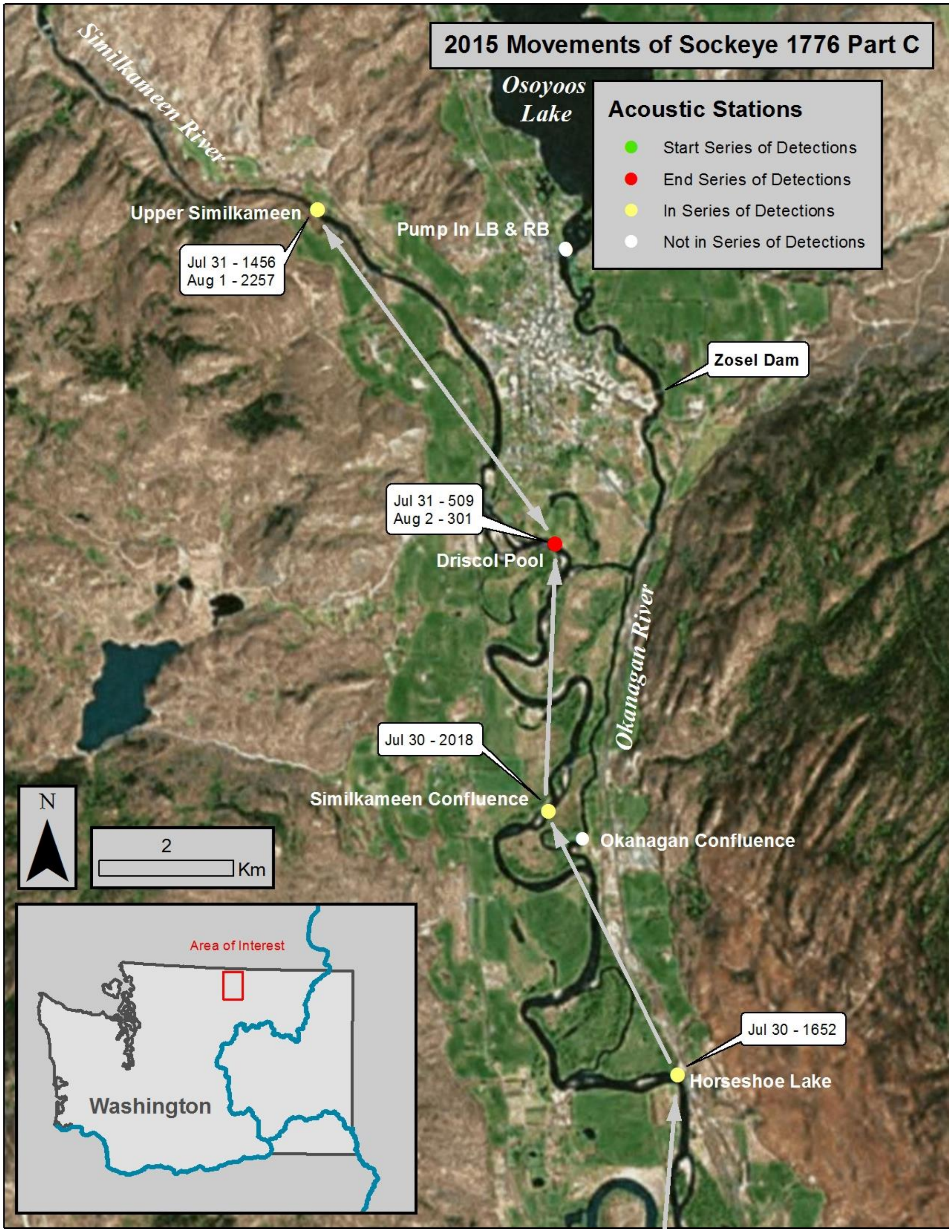

Figure A9c. Movements of fish with transmitter 1776 in the Okanagan River.

Fish 1778 (Figure A10 for temperature depth information and Figure A11a, b, and c for maps of fish movement) was detected twice at Highway 97 at transmitter temperatures of 20.7C on July 18 and 19.9C on July 23 before it was detected at the Highway 97 on July 27 at 19.7C, Monse at 22.3C, the Weir at 23.1C, Horseshoe Lake at 23.7C, and the Pump Station at 23.9C on July 30. It was detected in the South Basin from July 30 through August 24 at a temperature range of 19.6-23.1C and then in the North Basin from August 27 through October 11 at a temperature range of 9.6-16.1C. The minimum, mean, and maximum transmitter temperature for this fish was 9.0C, 15.0C, and 23.9C respectively.

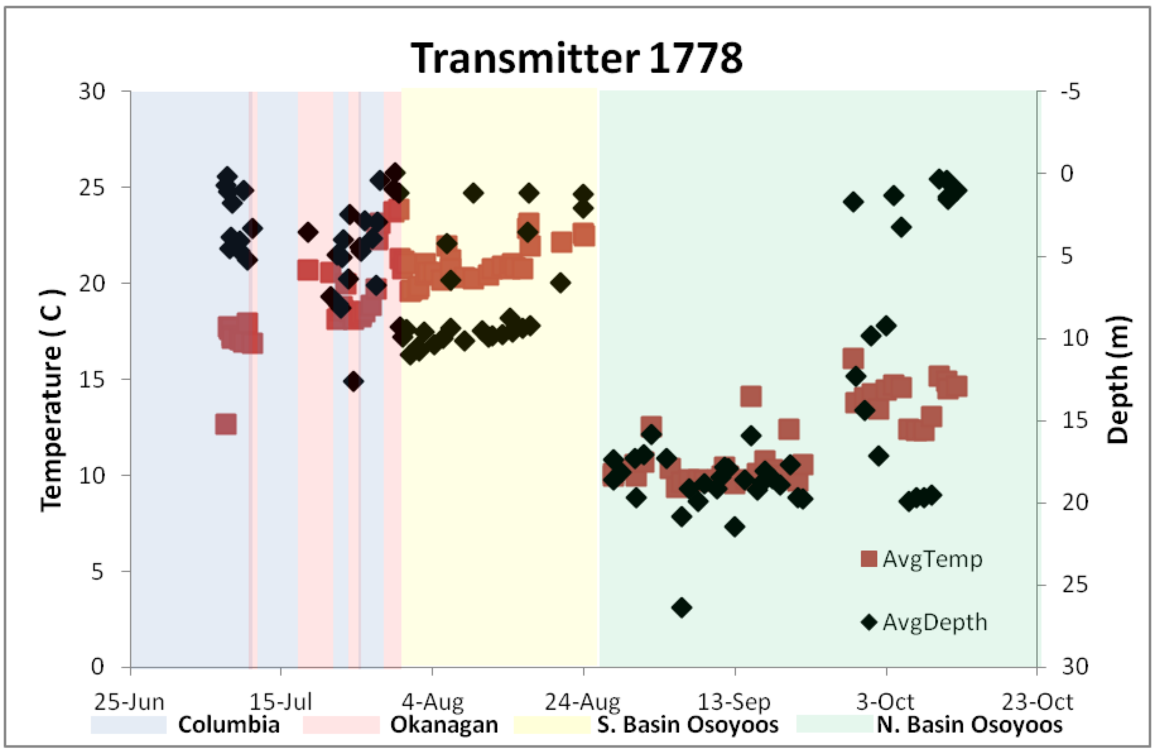

Figure A10. Temperature and depth data from transmitter 1778 in the Columbia and Okanagan rivers.

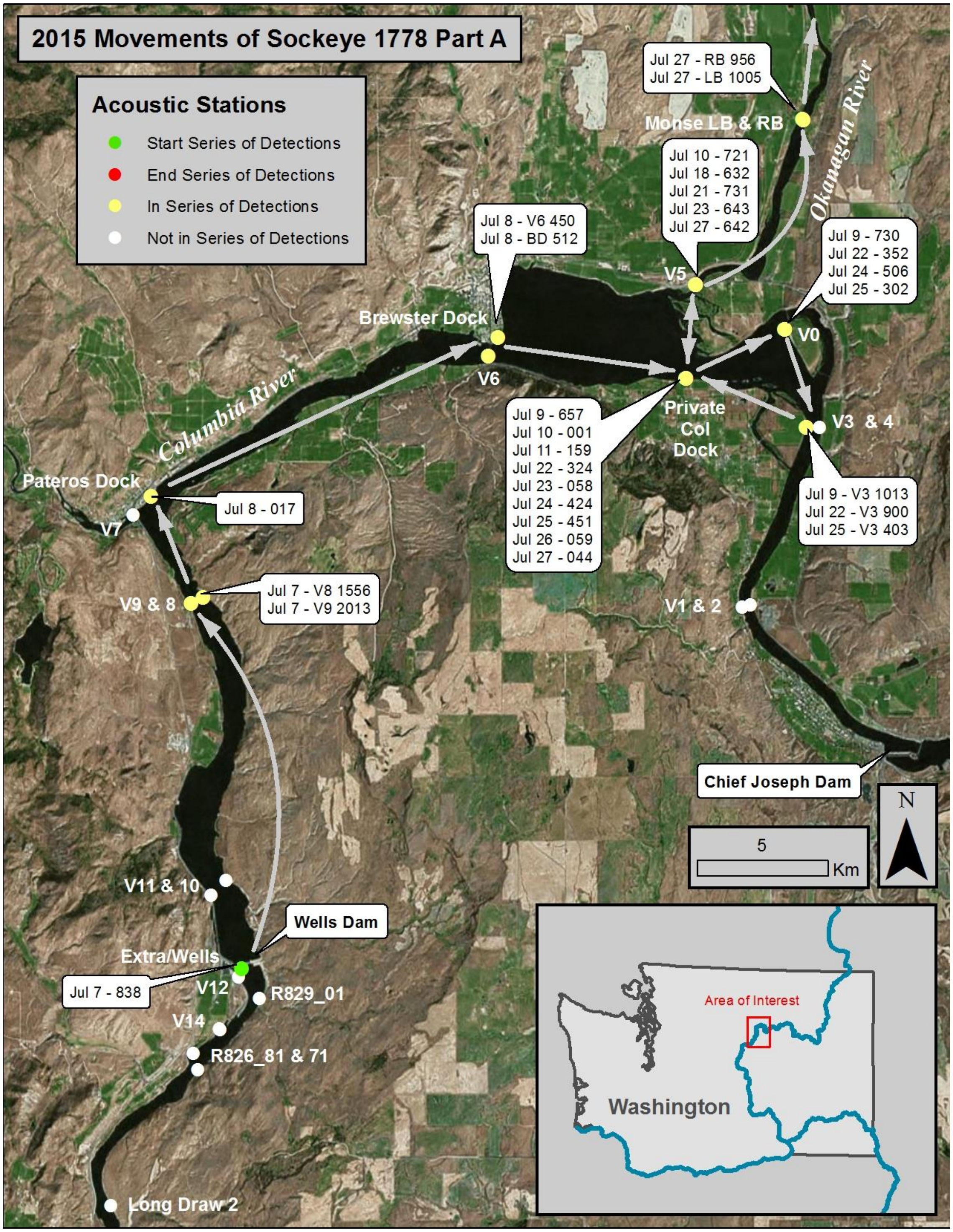

Figure A11a. Movements of fish with transmitter 1778 in the Columbia and Okanagan rivers.

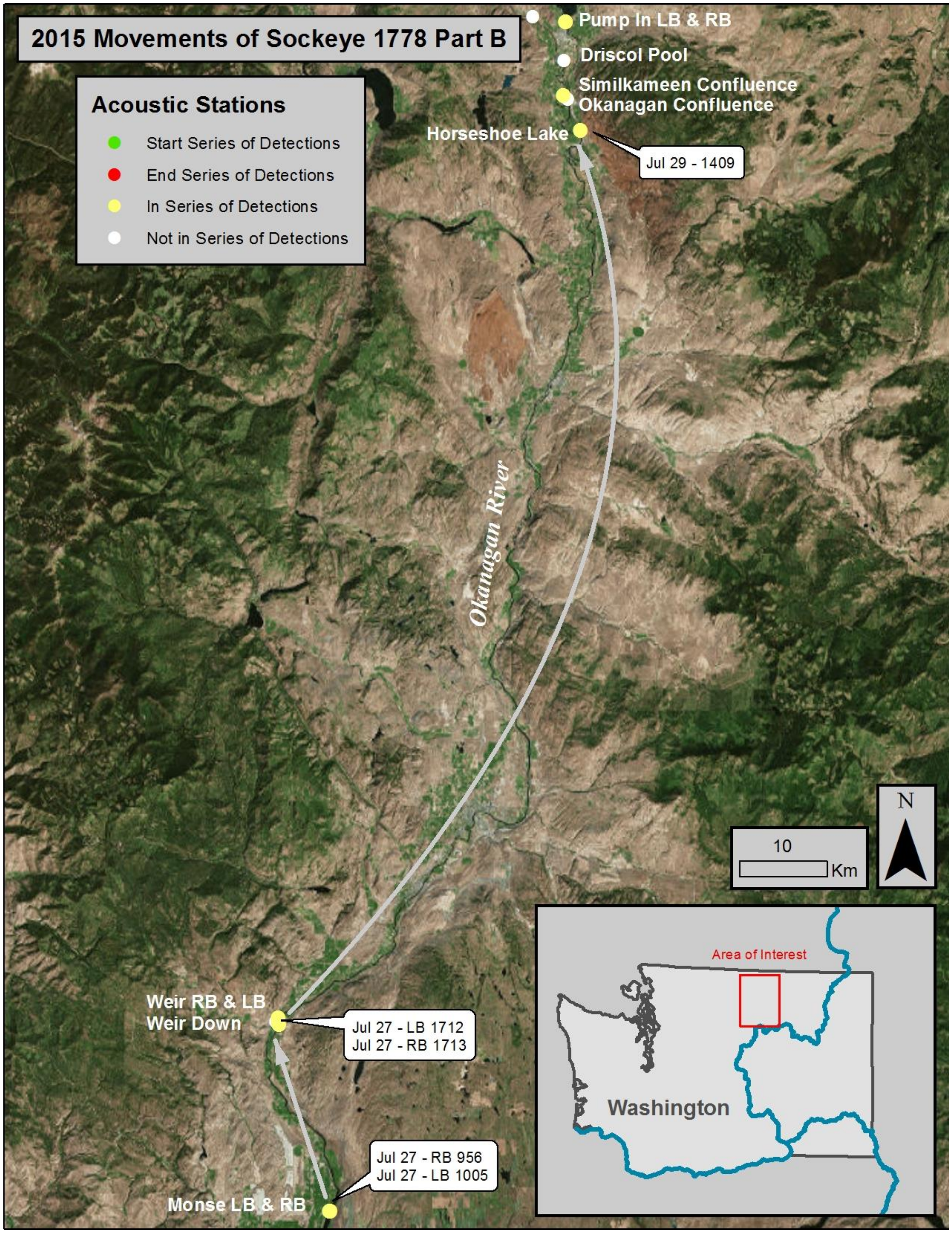

Figure A11b. Movements of fish with transmitter 1778 in the Okanagan River.

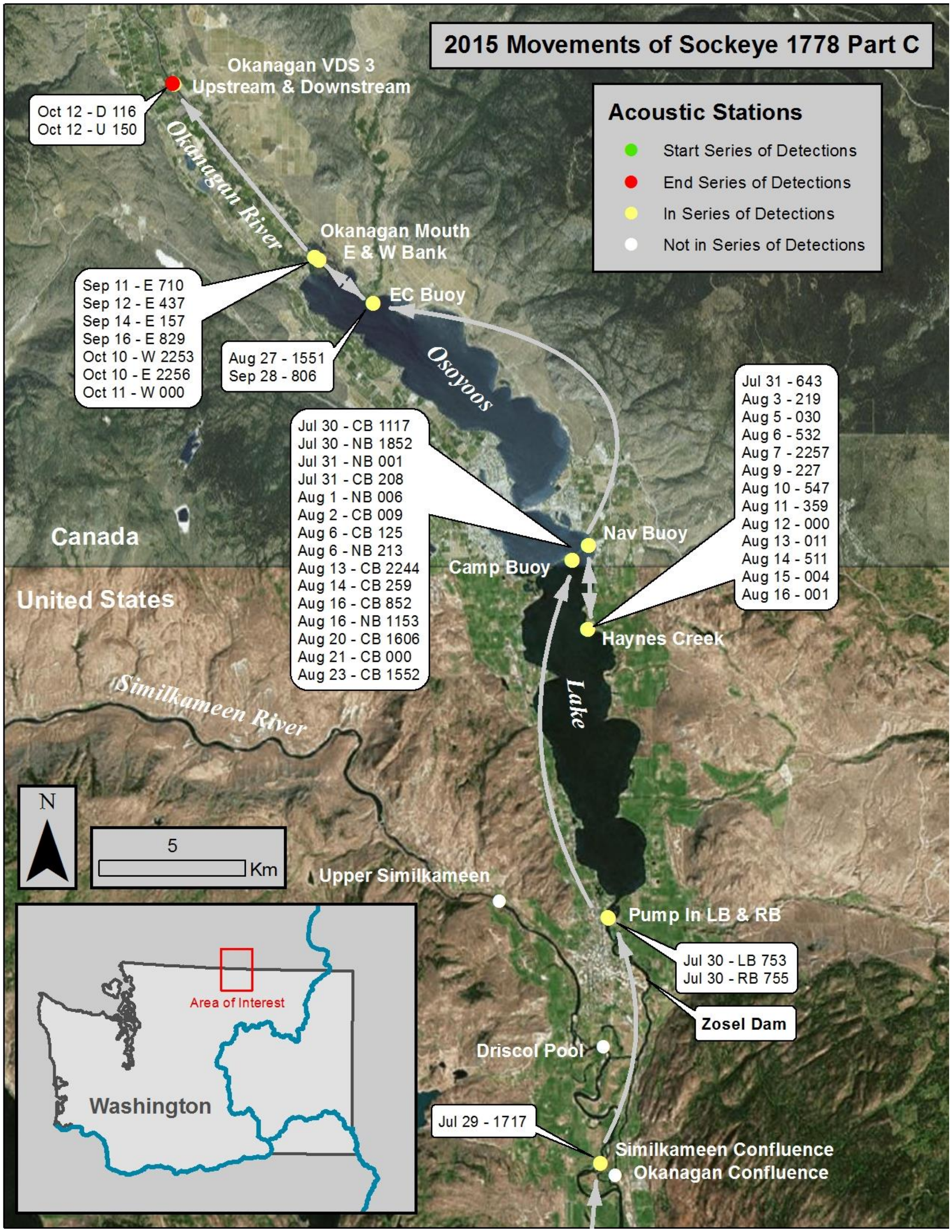

Figure A11c. Movements of fish with transmitter 1778 in the Okanagan River.

Fish with transmitter numbers 1790 (Figure A12 for temperature depth information and Figure A13a, b, and c for maps of fish movement), 1796 (Figure A14 for temperature depth information and Figure A15 for maps of fish movement), and 1798 (Figure A16 for temperature depth information and Figure A17 for maps of fish movement) were typical of fish that were not detected upstream of the mouth of the Okanagan River and were last detected in the Columbia River. These three fish held at average depths of 5.4 m, with a range of 0.9 to 13.2 m and average temperatures of 19.3C with a range of 18.5 to 21.3C.

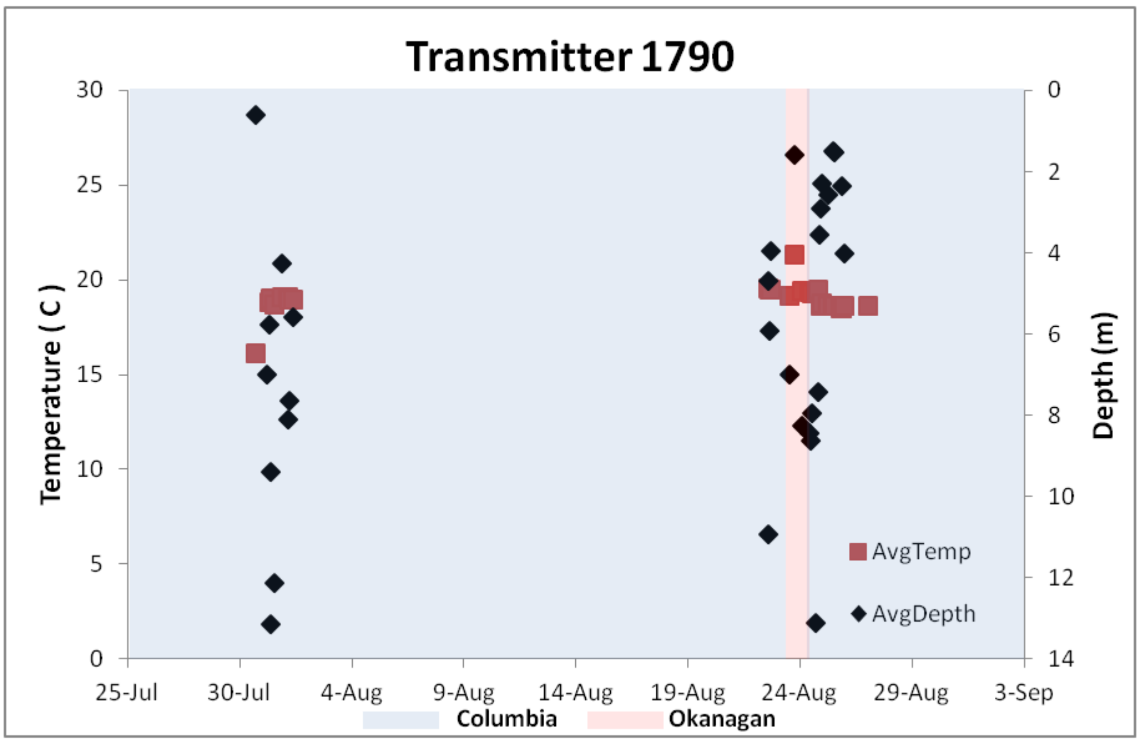

Figure A12. Temperature and depth data from transmitter 1790 in the Columbia and Okanagan rivers.

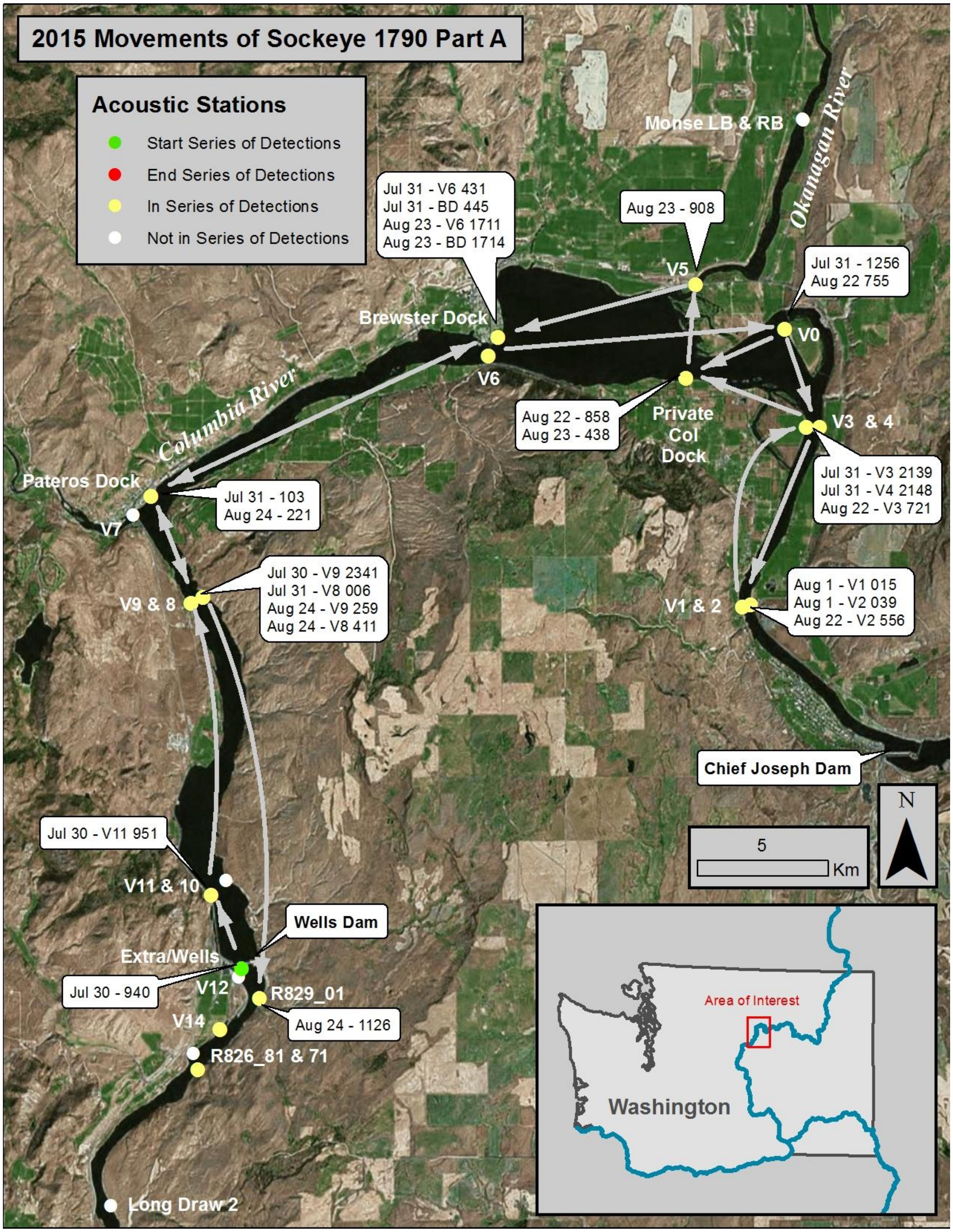

Figure A13a. Movements of fish with transmitter 1790 in the Columbia and Okanagan rivers.

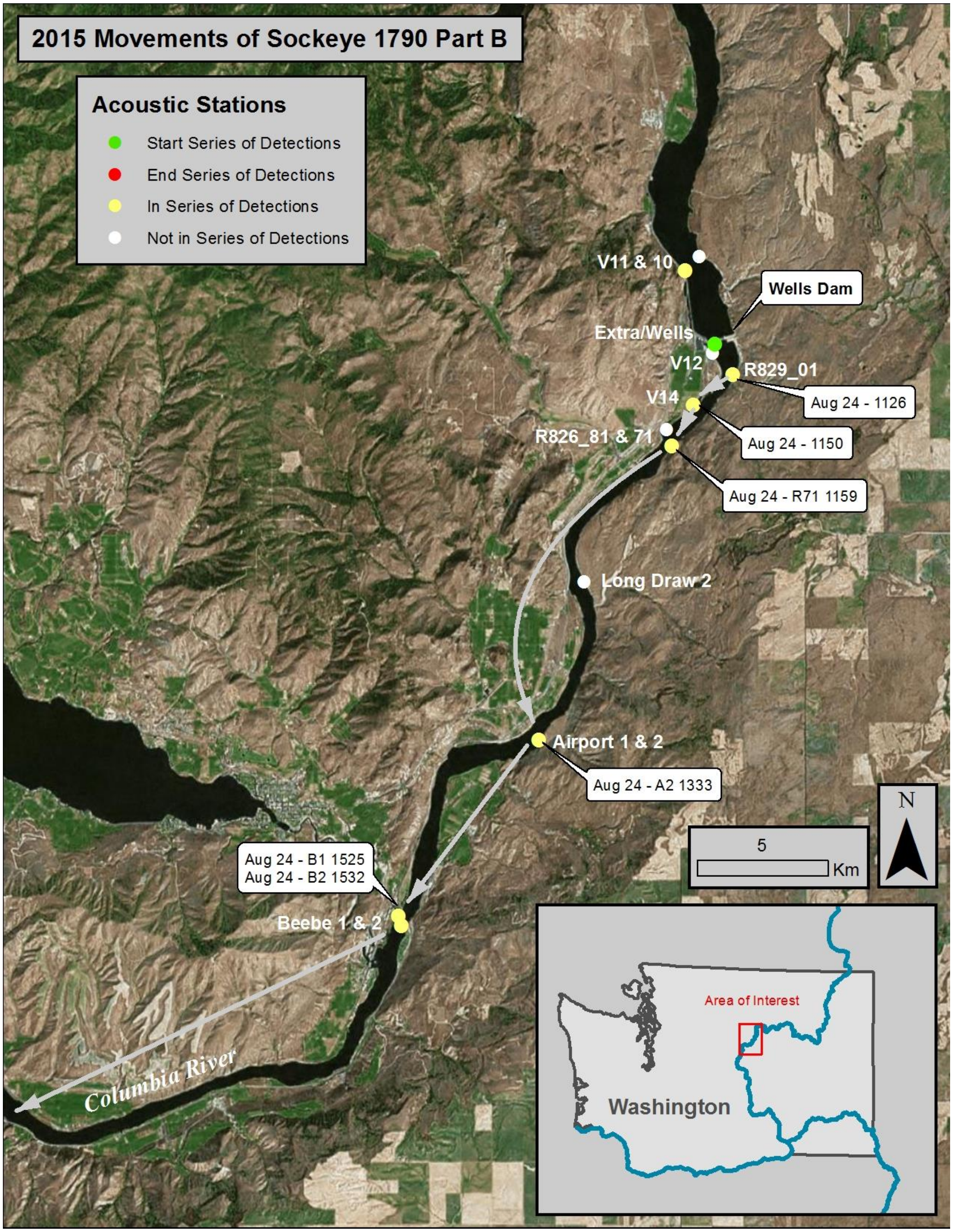

Figure A13b. Movements of fish with transmitter 1790 in the Columbia River.

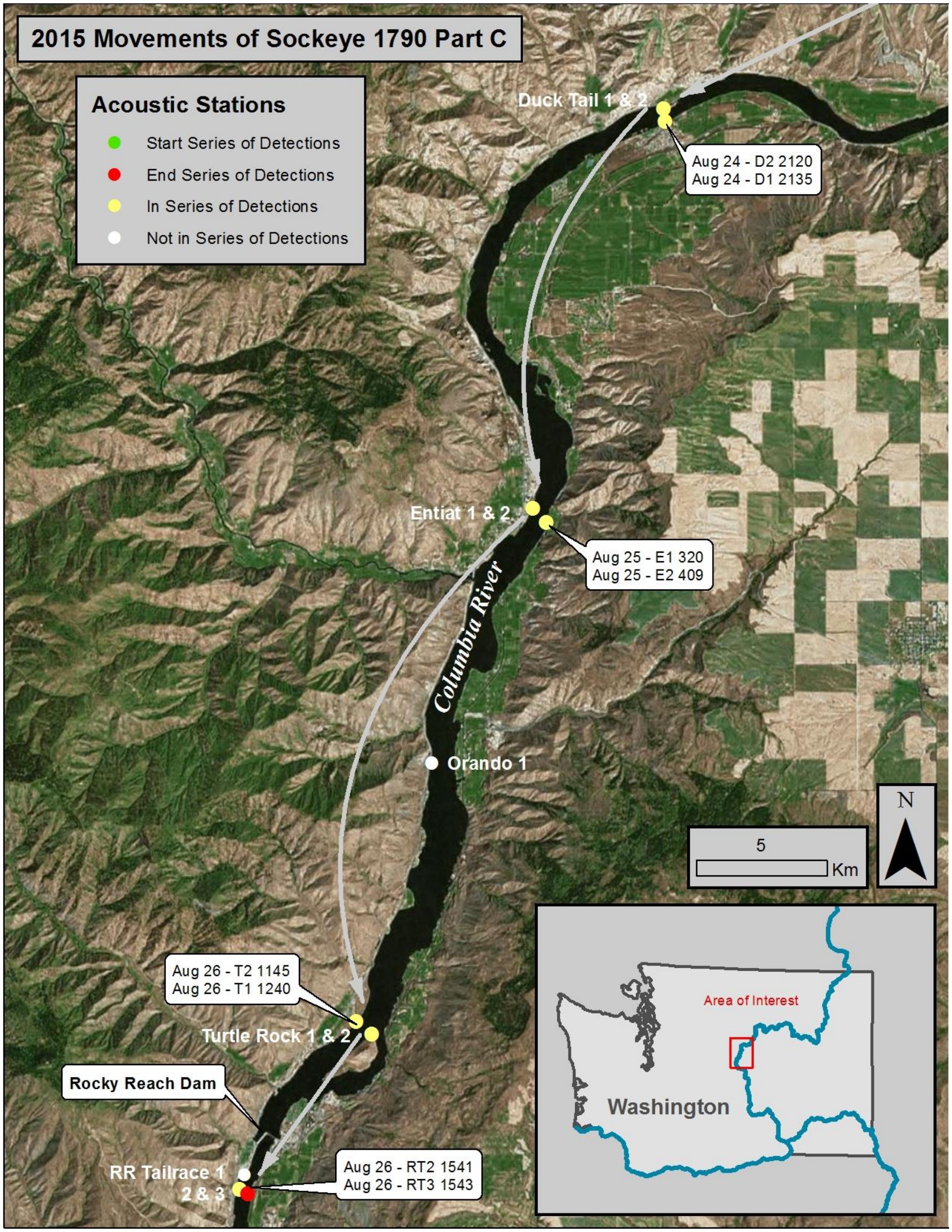

Figure A13c. Movements of fish with transmitter 1790 in the Columbia River.

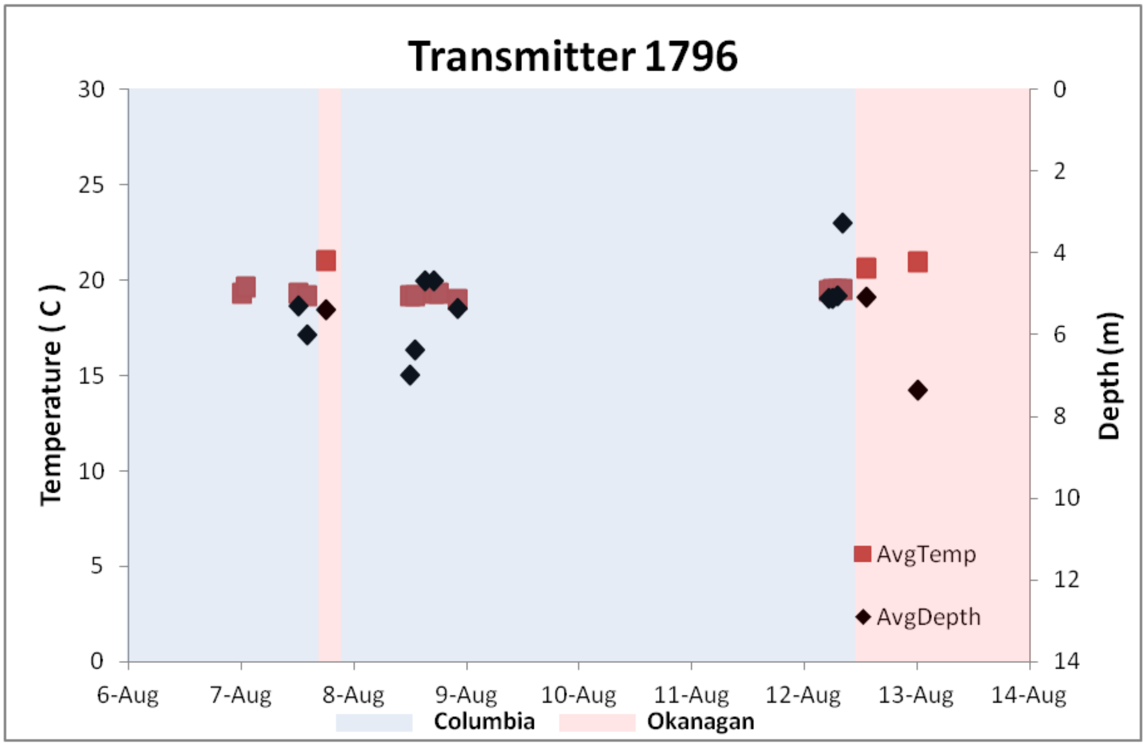

Figure A14. Temperature and depth data from transmitter 1796 in the Columbia and Okanagan rivers.

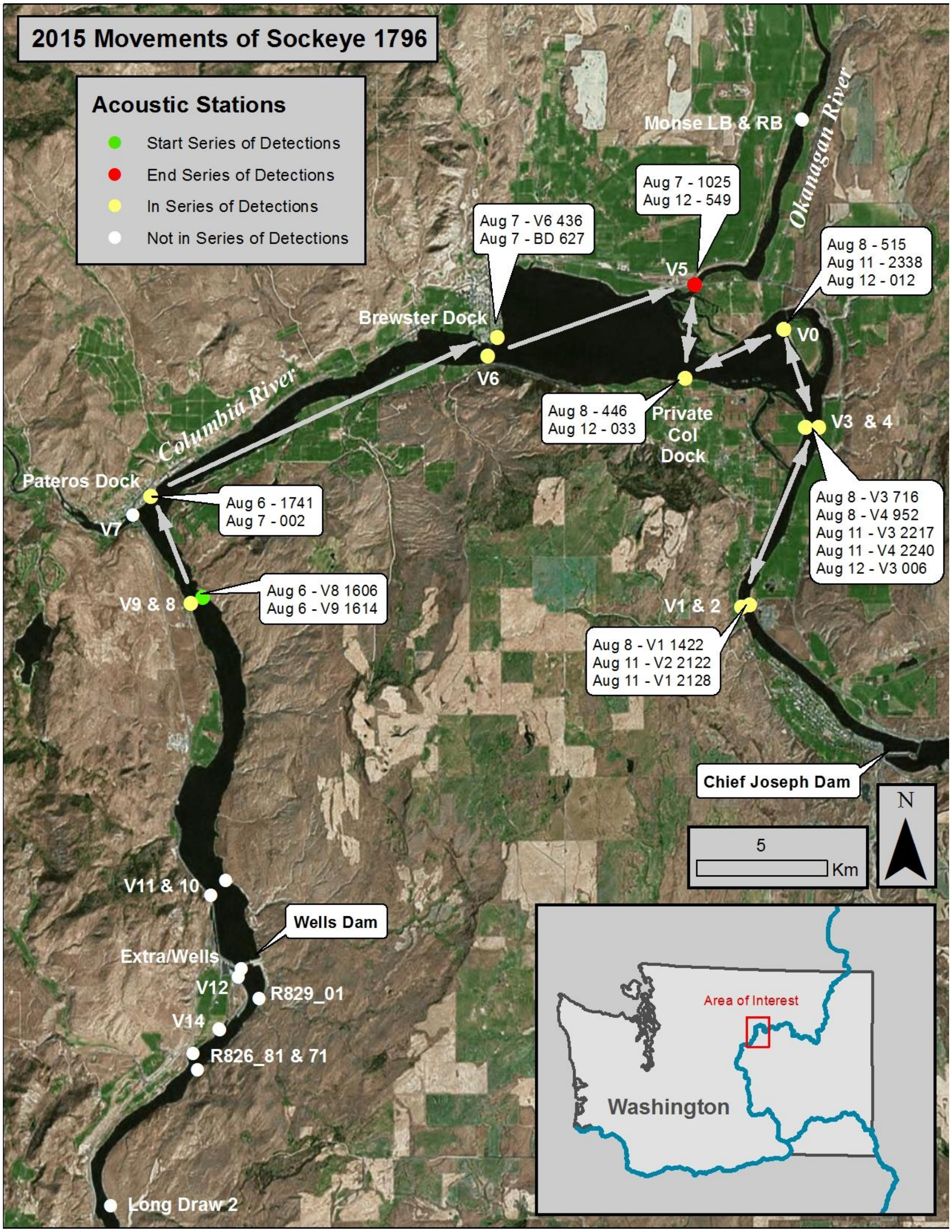

Figure A15. Movements of fish with transmitter 1796 in the Columbia and Okanagan rivers.

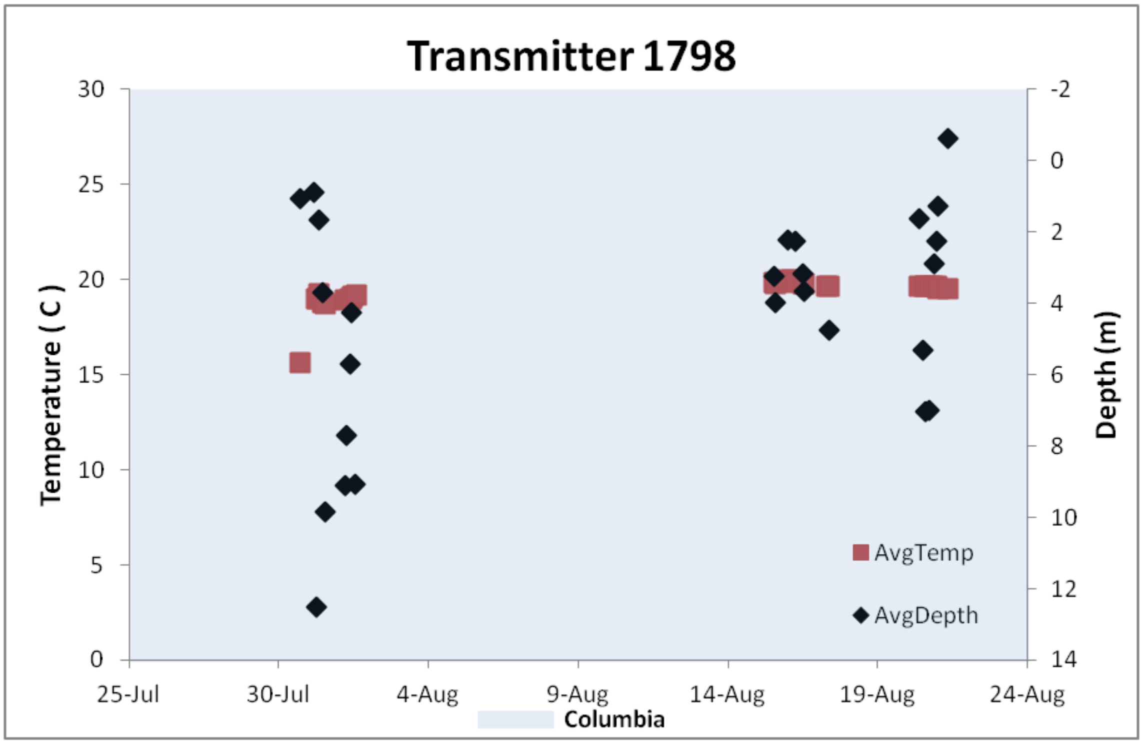

Figure A16. Temperature and depth data from transmitter 1798 in the Columbia and Okanagan rivers.

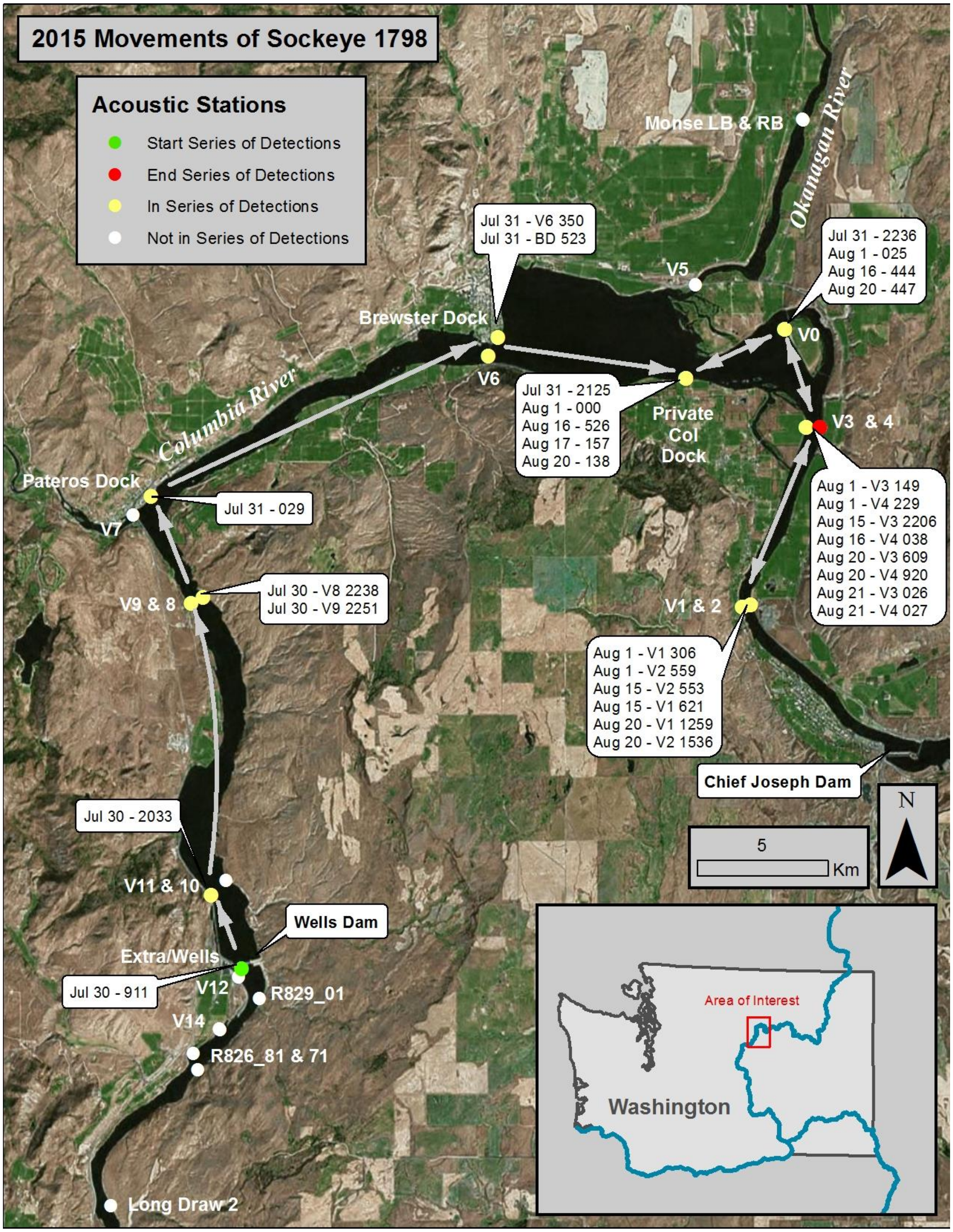

Figure A17. Movements of fish with transmitter 1798 in the Columbia and Okanagan rivers.

APPENDIX B

Q̓AWST'IK^{w} [OKANAGAN RIVER] SOCKEYE SMOLT OUT OF BASIN SURVIVAL: PIT TAGGING 2014 & 2015

q̓awsitkʷ (Okanagan River) Sockeye Smolt Out of Basin Survival: PIT Tagging 2014 & 2015

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2016

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Executive Summary

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

Following recommendations from the 2012 pilot study and the 2013 sampling season, 2014 and 2015 study objectives were to:

1. PIT tag up to 5,000 hatchery- and natural-origin smolts as they migrate from q'awst'ik'ʷt and suwiw̓s.
2. Monitor PIT tagged smolt survival and travel rates to the nx̌ʷəntkʷitkʷ estuary.
3. Synthesize an efficient study design and data management protocol that will address out of basin survival.

In 2014, 5054 smolts were released during 14 tagging sessions between April 7 and May 5, 2014 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYBR, downstream of the Highway 3 bridge at the Osoyoos Narrows. While in 2015, 7176 smolts were released during 21 tagging sessions between April 9 and May 6, 2015 at the same sites as 2014. Reliable estimates of survival from release to Rocky Reach Dam were possible for both 2014 and 2015 and were determined to be 0.57 (SE=0.768), and 0.42 (SE = 0.018), respectively. After Rocky Reach, error associated with survival estimates vary depending on year and release group. In 2014 only a combined population estimate was possible to lower Dams (survival to Bonneville; 0.028, SE = 0.0844). While in 2015, beyond Rocky Reach estimates were possible for SKATAL (survival to Bonneville; 0.32, SE = 0.10), while for OSOYOL the error was large.

The 2014 Travel time from release to Rocky Reach Dam (RRD) was approximately 10.4 days for the SKATAL release group, and 17.4 days for the OSOYBR release group. While 2015 travel time from release to RRD 14.9 days for the SKATAL release group, and 22.2 days for the OSOYBR release group. Travel time between reaches for both populations, and years were similar.

Recommendations from the 2014 and 2015 sampling years are to continue to develop the logistics and capacity to enable PIT tagging a minimum of 5,000 Okanagan Sockeye smolts from each lake population; q̓awst'ik'ʷt and suwiw̓s (Osoyoos Lake).

Acknowledgements

Okanagan Nation Aquatic Enterprises would like to thank the following people for their continued support:

Grant and Chelan Public Utility Districts (GCPUD and CCPUD), the Columbia River Inter Tribal Fisheries Commission (CRITFC) and the Bonneville Power Administration through the Columbia Basin Accords provided funding for this project. Jennifer Miller of the Colville Confederated Tribes provided audit support of our tagging operations, set up, and training. Also the Fish Passage Center was able to provide PIT tags to support our efforts.

Our ever valuable ONA staff that make this one the ground work possible; Sheena Hooley, Jessica Hilton – McPherson, Hannah Sungaila, Alexis Friesen, Dave Tom, Andrew Clark, Chelsea Mathieu, Casimir Tonasket, Saul Squakin

Table of Contents

Executive Summary ..... **i**

Acknowledgements ..... **ii**

Table of Contents ..... **iii**

List of Tables ..... **iii**

List of Figures ..... **iv**

List of Okanagan Place Names ..... **iv**

Okanagan Place Names (Okanagan-English Translation) ..... **iv**

1.0 INTRODUCTION **1**

1.1 Project Background 1
1.2 Study Area 2
1.3 Project Objectives 4

2.0 METHODS **5**

PIT Tagging Procedures 5

3.0 RESULTS **6**

PIT Tagging Results 6
2014 6
2015 9

4.0 DISCUSSION AND RECOMMENDATIONS **12**

PIT Tagging 12

5.0 REFERENCES **14**

List of Tables

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2014. 6

Table 2. Mean survival for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKATAL and OSOYBR combined), 2014. 7

Table 3. Mean travel time for PIT tagged q'awsitk^{w} Sockeye smolts, 2014; Standard Errors of mean presented in brackets. 8

Table 4. Summary of Okanagan Sockeye smolt PIT effort, 2015. 9

Table 3. Mean travel time for PIT tagged q'awsitk^{w} Sockeye smolts, 2015; Standard Errors of mean presented in brackets. 11

List of Figures

Figure 1. q’awsitkw juvenile PIT tagging locations in both 2014 and 2015. 3

Figure 2 Mean survival for PIT tagged q’awsitkw (Okanagan River) Sockeye smolts (SKATAL and OSOYBR combined), 2014. 7

Figure 3. Mean travel time for PIT tagged q’awsitkʷ (Okanagan River) Sockeye smolts (SKATAL and OSOYBR combined), 2014. 8

Figure 4 Mean survival for PIT tagged q’awsitkw (Okanagan River) Sockeye smolts (SKATAL and OSOYBR), 2015. 10

Figure 5 Mean travel time for PIT tagged q’awsitkw (Okanagan River) Sockeye smolts (SKATAL and OSOYBR), 2015. 11

Figure 6. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam. 12

List of Okanagan Place Names

Okanagan Place Names	English Translation
nx̆ʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
suwiw̓s	Osoyoos Lake
q̓awst’ik’ʷt, also known as t̓iwcən	Skaha Lake
akspaqmix	Vaseux Lake
nʕaylintən	McIntyre Dam
sx̌wəx̌wnikw	Okanagan Falls

1.0 INTRODUCTION

1.1 Project Background

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

As a means to determine freshwater outmigration survival, Passive Integrated Transponder (PIT) tag technology has been used as a tool by researchers and fisheries managers in nx̌ʷəntkʷitkʷ Basin to mark and track anadromous fish since 1987. Currently, a comprehensive network of PIT arrays, tagging programs, and a data repository is operational in the Basin. The system is managed by the Pacific States Marine Fisheries Commission and funded by Bonneville Power Administration (BPA) (PTAGIS 1999). In 2009, CRITFC and ONA installed a PIT antenna in q'awsitkʷ upstream of suwiw̓s in order to track adults tagged at Wells Dam to the spawning grounds (Fryer et al. 2012). The existing PIT network allows us to track tagged smolt survival rates and travel times during outmigration.

In 2012 ONA commenced with a trial PIT tagging program, releasing 534 tags. A number of logistical and operational recommendations were made and were followed by 4018 tags released in 2013. From 2013 it was further recommended to move forward for the PIT component to increase the sample size to a minimum of 5,000 tagged smolts and to expand the scope of tagging to include suwiw̓s (Osyoos Lake) smolts.

In this report, we cover the tagging programs from both the 2014 and 2015 tagging seasons. In both years we were able to increase the number of deployed PIT tags in an effort to refine survival estimates to Lower nx̌ʷəntkʷitkʷ PIT detection sites.

1.2 Study Area

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

For the 2012 brood year, hatchery-reared fry were released into suwiw̓s, while no hatchery fry were released for the 2013 brood year. Therefore smolts outmigrating from q̓awst'ik'ʷt in 2014 and 2015 were of natural origin. While smolts outmigrating from suwiw̓s in 2014 were of mixed natural and hatchery origin and in 2015 were of natural origin.

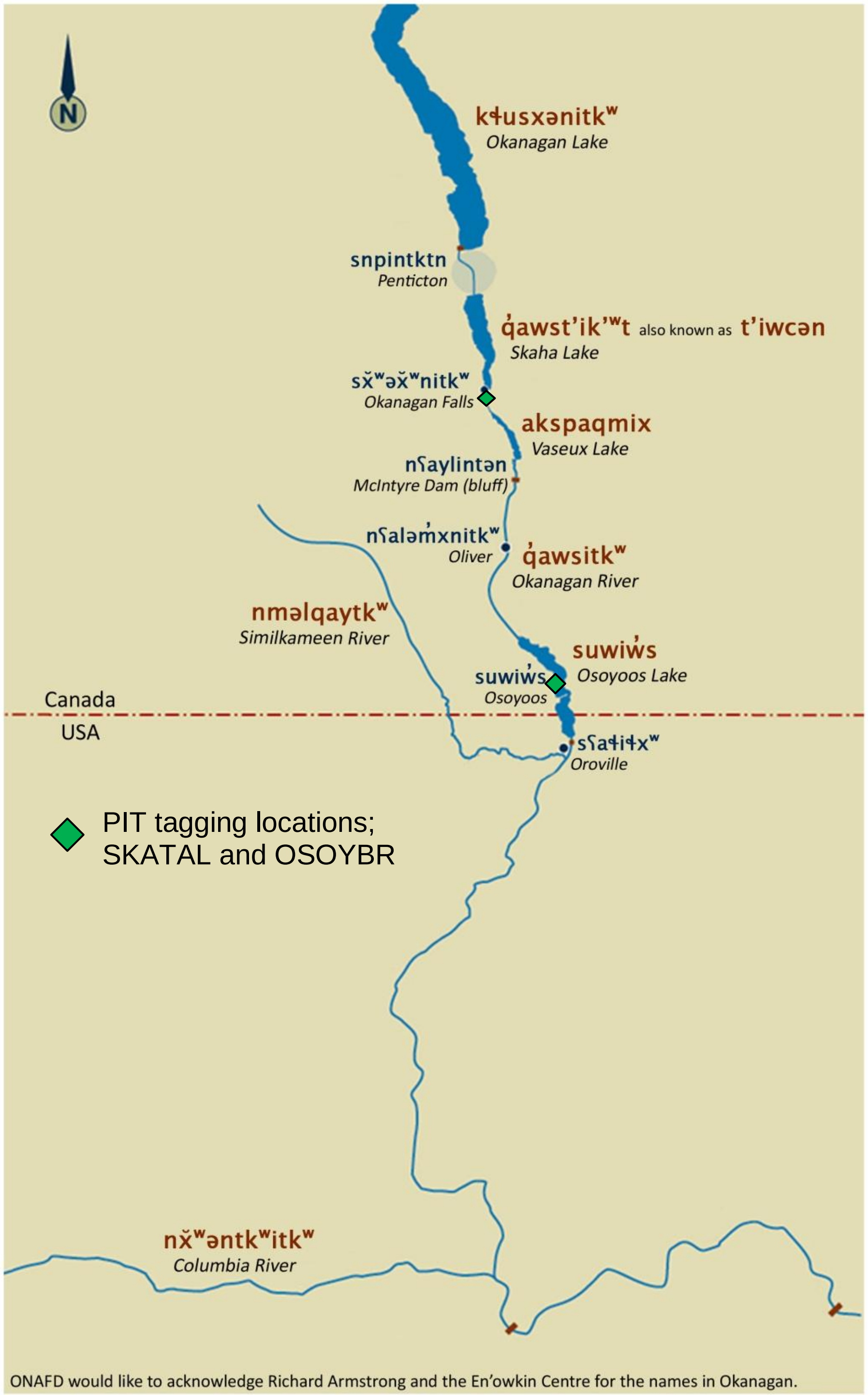

Figure 1. q'awsitkw juvenile PIT tagging locations in both 2014 and 2015.

1.3 Project Objectives

The main objective was to PIT tag a minimum of 5000 smolts from both q̓awst'ik'ʷt and suwiw̓s as a means to determine Sockeye smolt out of basin survival and travel time. Current objectives have been refined from the 2012 pilot study (Benson et al. 2013). Specific objectives included:

1. PIT tag up to 5,000 hatchery- and natural-origin smolts as they migrate from q'awst'ik'ʷt and suwiw̓s.

2. Monitor PIT tagged smolt survival and travel rates to the nx̌ʷəntkʷitkʷ estuary.

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

2.0 METHODS

PIT Tagging Procedures

q'awst'ik'ʷt smolts were captured downstream of Skaha Lake Outlet Dam and at Osoyoos Lake Narrows at the Highway 3 Bridge during the smolt outmigration monitoring program (Benson and Stevens 2013).

In 2014: two (2) Rotary Screw Traps (RSTs) were installed 25 March, 2014 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.

suwiw̓s smolts were captured using a floating fyke net set every 2 – 3 nights from 2 April to 4 June, 2014, and held in aluminum kitoi boxes placed in the shallows of Osoyoos Narrows for tagging the following day.

In 2015: Both RSTs were installed 10 March, 2015. The cones were first lowered on 17 March 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 8 April when daily catches exceeded 10 smolts in either trap. The thalweg RST was demobilized on 3 May due to damage to the main axle.

suwiw̓s smolts were captured using a floating fyke net set every 2 – 3 nights from 25 March to 28 May, 2015, and held in aluminum kitoi boxes placed in the shallows of Osoyoos Narrows for tagging the following day.

Common to both 2014 and 2015 we checked live wells once or twice per day depending on peak outmigration. During morning checks, a sub-sample of captured smolts were held in aluminum kitoi boxes positioned in the river downstream of the RSTs until for tagging later that day.

We used procedures outlined by PTAGIS (1999) and Biomark (2012) for marking smolts. We deployed BIOMARK HPT 12 PIT tags (134.2 kHz) measuring 12.5 mm in length. The MK-25 Rapid Implant Gun along with HPT9 pre-loaded sterile needles manufactured by Biomark® was used for implanting tags. Fish were removed from kitoi boxes and placed in a 19-L (5-gal) pail containing a 40 mg/l solution of tricaine methanesulfonate (MS 222). Fish were kept in the solution until they lost equilibrium. Smolts were then transferred to a weaker solution (20 mg/l MS 222) until processed for tagging. Each smolt was measured for fork length (cm) and weight (g) in 2014, while in 2015 each smolt was measured only for fork length, and general body condition/descaling percentage was recorded. The tagging needle was inserted on the left side between the dorsal fin and lateral line, then the trigger was depressed until the tag was inserted into the incision hole. The tagged smolt was scanned and logged using an HPR Plus reader (Biomark®). The system was connected to a laptop computer, which logged each number in an Excel spreadsheet. This configuration allowed taggers to enter bio-data and tagging comments directly into the tagging file without the need for post-season data entry. Following processing,

each tagged fish was placed in a bucket of aerated water until fully recovered. All tagged smolts were returned to the kitoi boxes and released back into river the same day, typically between 22:00 and 24:00 to reduce predation. Fish were released either downstream of the Skaha Lake Outlet Dam (SKATAL) or downstream of the Highway 3 bridge on suwiw̓s (OSOYBR)

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

3.0 RESULTS

PIT Tagging Results

2014

In total, 5054 smolts were released during 14 tagging days, between April 7 and May 5, 2014 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYBR, downstream of the Highway 3 bridge at the Osoyoos Narrows. Five of the tagging days saw simultaneous tagging teams at both SKATAL and OSOYBR. Tagging effort is summarized in Table 2.

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2014.

	SITE	
Date	**SKATAL**	**OSOYBR**
07-Apr-14		27
11-Apr-14		62
15-Apr-14		93
17-Apr-14		98
22-Apr-14		239
23-Apr-14		215
24-Apr-14		272
25-Apr-14	175	302
28-Apr-14	195	330
29-Apr-14	294	442
30-Apr-14	306	417
02-May-14	378	843
05-May-15		366
TOTAL	**1348**	**3706**

Reliable estimates of survival from release to Rocky Reach Dam were able to be calculated for both release groups. Survival from release to Rocky Reach Dam was 0.41 (SE = 0.07) for the SKATAL release group, and 0.63 (SE = 0.04) for the OSOYBR release group. After Rocky Reach, error associated with survival estimates for both release groups, individually and

combined, was large. Survival was not able to be estimated at all for the SKATAL release group past McNary Dam due to insufficient sample size. Survival estimates for both release groups combined is calculated as 0.57 (SE = 0.0768) and is presented in Table 2 and Figure 2.

Table 2. Mean survival for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKATAL and OSOYBR combined), 2014.

Period	Survival	SE
Release to Rocky Reach	0.57	0.0768
Rocky Reach to McNary	0.68	0.4376
McNary to John Day	2.8	0.6464
John Day to Bonneville	0.26	0.2360
Overall	0.028	0.0844

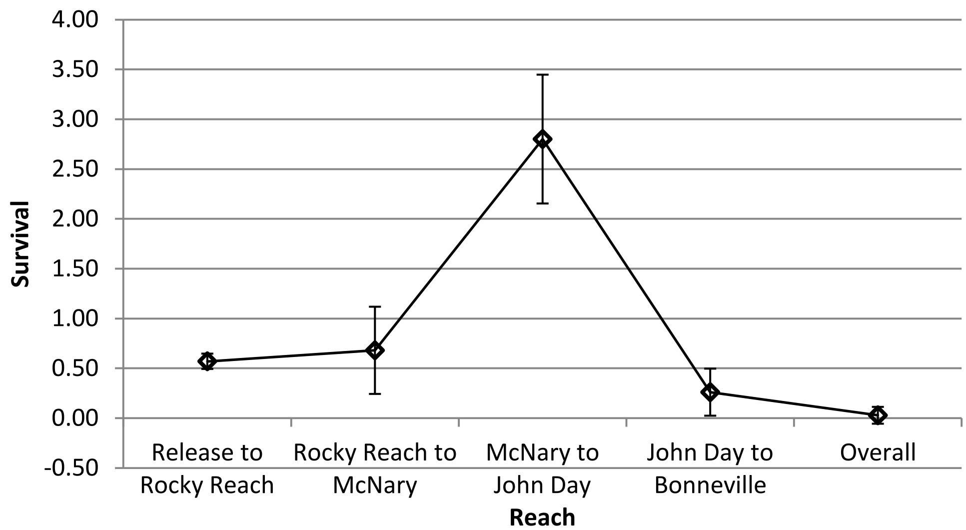

Figure 2 Mean survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (SKATAL and OSOYBR combined), 2014.

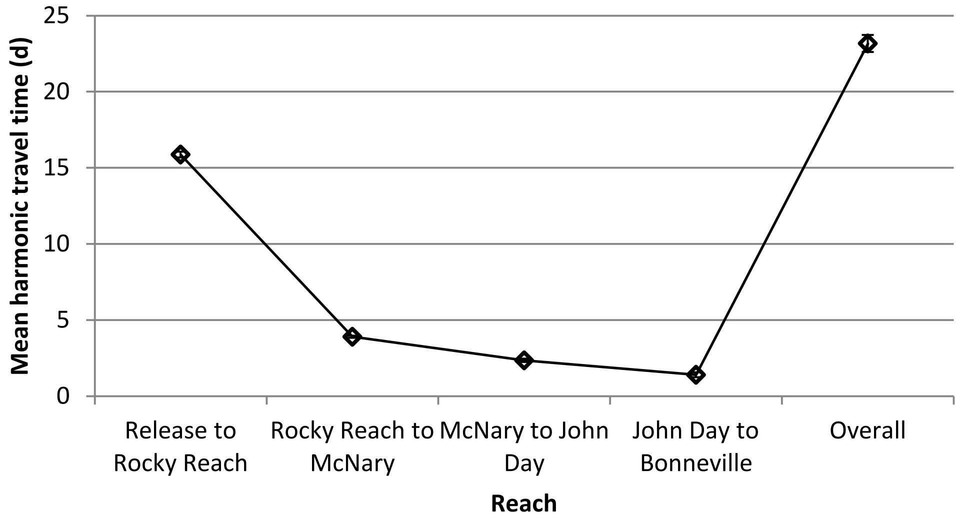

Figure 3. Mean travel time for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKATAL and OSOYBR combined), 2014.

Travel time from release to Rocky Reach Dam was approximately 10.4 days for the SKATAL release group, and 17.4 days for the OSOYBR release group. Travel time for individual reaches was similar between both release groups. Overall travel time from release to Bonneville Dam was approximately 23 days for both groups combined (Figure 3 and Table 3).

Table 3. Mean travel time for PIT tagged q'awsitk^{w} Sockeye smolts, 2014; Standard Errors of mean presented in brackets.

Period	SKATAL Travel time (d)	OSOYBR Travel Time (d)	SKATAL AND OSOYBR Combined Travel Time (d)
Release to Rocky Reach	10.42 (0.18)	17.4 (0.19)	15.872 (0.19)
Rocky Reach to McNary	3.65 (0.95)	3.96 (0.08)	3.9 (0.07)
McNary to John Day	2.24 (0.42)	2.64 (0.12)	2.35 (0.11)
John Day to Bonneville	-	1.40 (0.16)	1.4 (0.16)
Overall	-	25.06 (0.65)	23.17 (0.56)

2015

In total, 7176 smolts were released during 21 tagging days, between April 9 and May 6, 2015 at two sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, and OSOYBR, downstream of the Highway 3 bridge at the Osoyoos Narrows. Tagging effort is summarized in Table 4.

Table 4. Summary of Okanagan Sockeye smolt PIT effort, 2015.

	SITE	
Date	**SKATAL**	**OSOYBR**
09-Apr-15		125
13-Apr-15		163
14-Apr-15	92	
15-Apr-15	88	271
16-Apr-15	75	
17-Apr-15	130	152
20-Apr-15	65	
21-Apr-15	317	140
22-Apr-15	313	
23-Apr-15	236	307
24-Apr-15	188	
25-Apr-15	244	
27-Apr-15	543	243
28-Apr-15	1222	
29-Apr-15	620	305
30-Apr-15	234	
01-May-15	82	35
02-May-15	576	
03-May-15	282	
05-May-15	105	
06-May-15	23	
TOTAL	**5435**	**1741**

Reliable estimates of survival from release to Rocky Reach Dam were able to be calculated for both release groups. Survival from release to Rocky Reach Dam was 0.41 (SE = 0.02) for the SKATAL release group, and 0.45 (SE = 0.04) for the OSOYBR release group. Based on smaller sample sizes from 2014 and earlier, a larger tagging effort was allocated to the SKATAL release group. For 2015 it was possible to determine survival to lower nx̌ʷəntkʷitkʷ dams for the SKATAL release group. While the OSOYBR release group, estimates beyond John Day are not reliable. Survival estimates for both release groups, individually and combined is presented in Table 4 and Figure 4.

Table 4. Mean survival for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKATAL and OSOYBR), 2015.

Period	Survival Combined SKATAL and OSOYBR	SE	Survival Combined SKATAL	SE	Survival OSOYBR	SE
Release to Rocky Reach	0.42	0.02	0.41	0.02	0.45	0.04
Rocky Reach to McNary	0.8	0.13	0.72	0.13	1.2	0.50
McNary to John Day	0.72	0.18	0.85	0.25	0.39	0.22
John Day to Bonneville	1.79	0.66	1.28	0.51	6.29	6.54
Overall	0.44	0.14	0.32	0.10	1.33	1.29

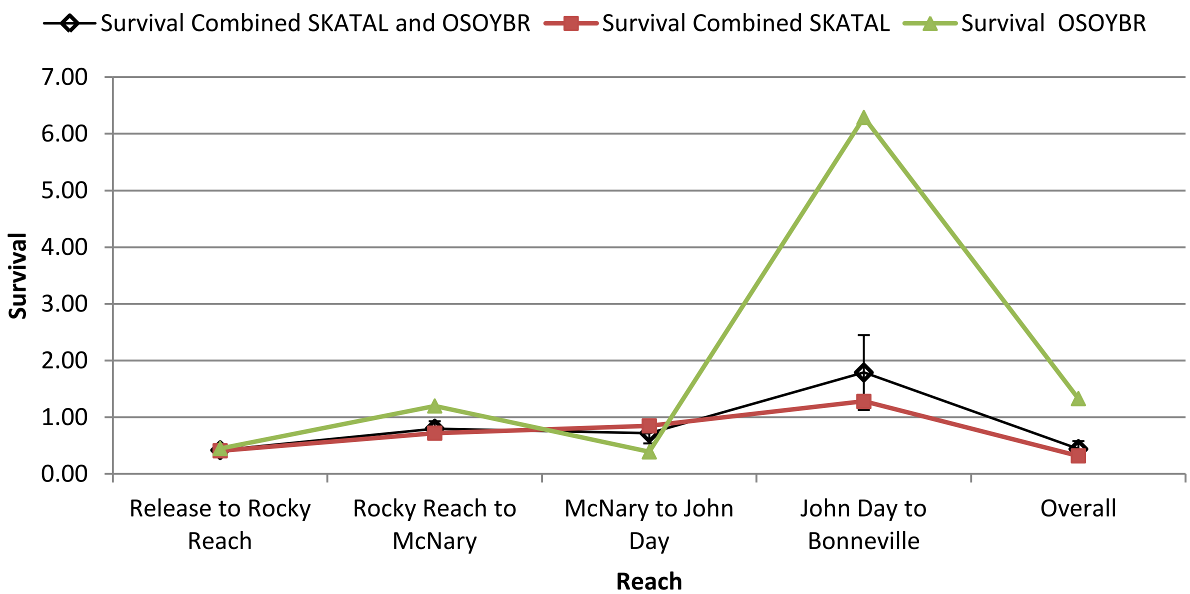

Figure 4 Mean survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (SKATAL and OSOYBR), 2015.

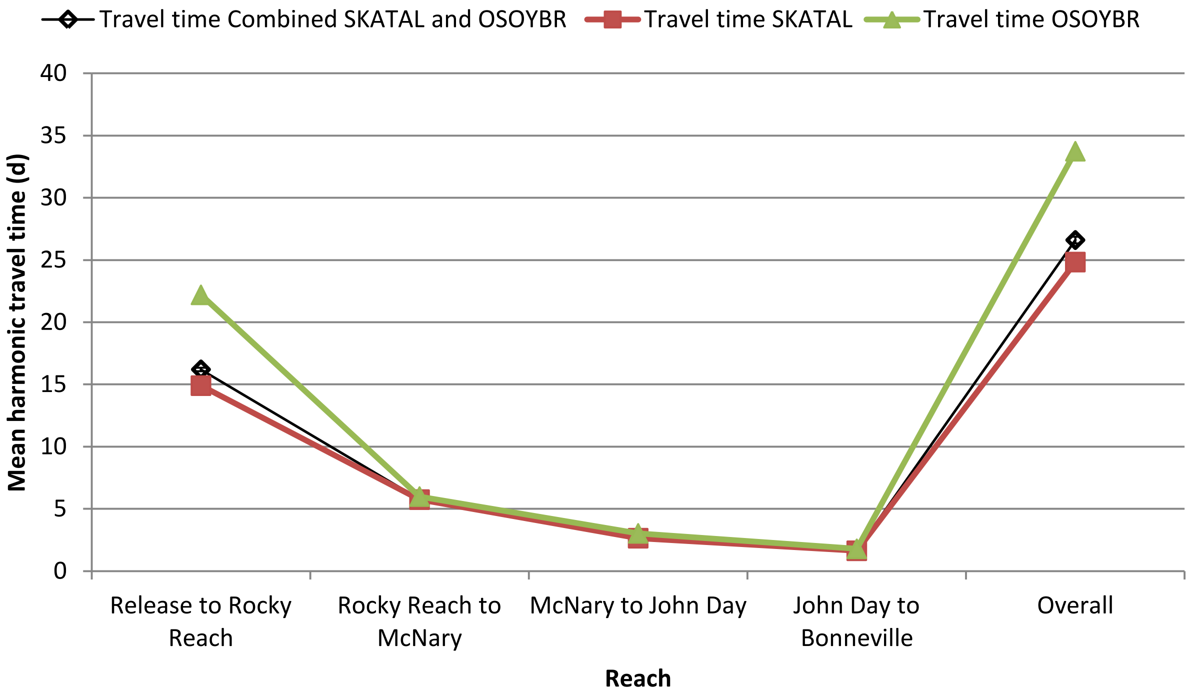

Figure 5 Mean travel time for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (SKATAL and OSOYBR), 2015.

Travel time from release to Rocky Reach Dam was approximately 15 days for the SKATAL release group, and 22 days for the OSOYBR release group. Travel time for individual reaches was similar between both release groups. Overall travel time from release to Bonneville Dam was approximately 26.6 days for both groups combined (Figure 3 and Table 3).

Table 5. Mean travel time for PIT tagged q'awsitk^{w} Sockeye smolts, 2015; Standard Errors of mean presented in brackets.

Period	SKATAL Travel time (d)	OSOYBR Travel Time (d)	SKATAL AND OSOYBR Combined Travel Time (d)
Release to Rocky Reach	14.9 (0.11)	22.2 (0.47)	16.2 (0.14)
Rocky Reach to McNary	5.74 (0.16)	5.99 (0.35)	5.79 (0.14)
McNary to John Day	2.64 (0.33)	3.03 (0.00)	2.71 (0.28)
John Day to Bonneville	1.63 (0.05)	1.79 (0.052)	1.66 (0.05)
Overall	24.8 (0.21)	33.74 (0.61)	26.6 (0.27)

4.0 DISCUSSION AND RECOMMENDATIONS

PIT Tagging

The program *SampleSize* (Columbia Basin Research, School of Aquatic & Fishery Sciences, University of Washington) was used to develop confidence intervals for a single-release survival estimates of juvenile Sockeye Salmon through the Columbia River Basin (Figure 6). Estimates require an assumed survival and detection probability at downstream locations. Lake Wenatchee-origin sockeye smolts were used to generate capture probabilities at McNary, John Day, and Bonneville; spring Chinook smolts released above Wells Dam were used to generate detection probabilities at Rocky Reach Dam. Survival probabilities were generated from spring Chinook releases above Wells Dam. Average values from these observations were used as assumptions in the program. Based on the sample size analysis, a minimum of 5,000 PIT tags would be optimal for estimating survival (Figure 6).

In 2014, 1348 were tagged from q̓awst'ik'ʷt and 3706 were tagged from suwiw̓s. While it was possible to determine survival for the combined population (>5000) it was not possible for the lesser sampled q̓awst'ik'ʷt population. Inversely in 2015, 5435 were tagged from q̓awst'ik'ʷt and 1741 were tagged from suwiw̓s. In 2015 it was possible to determine survival for q̓awst'ik'ʷt and for suwiw̓s as far as Rocky Reach.

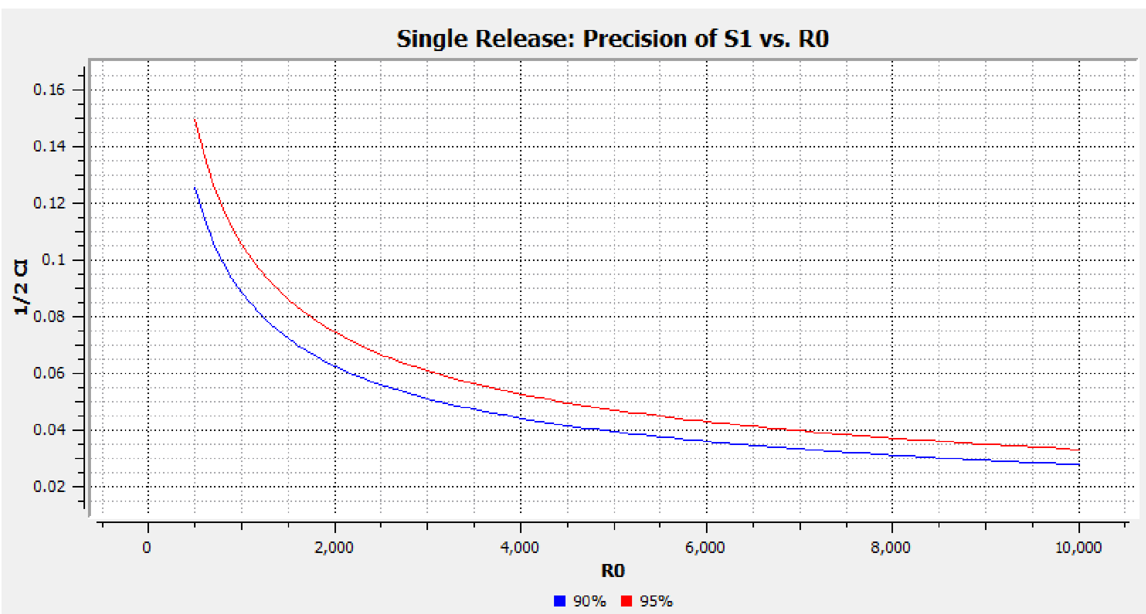

Figure 6. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam.

We suggest a minimum tagging of 5000 per release group (by lake) to build both survival estimates combined, and also to refine survival rates, by lake population.

We propose the following recommendations for future studies:

- Continue to develop representative sampling for PIT tagging a minimum of 5,000 Okanagan Sockeye smolts, by lake (i.e. late-winter purse seining (early March),
- Continue to refine capture methods and holding techniques to improve on tagging efficiencies.
- Work to improve detection efficiencies between q̓awst'ik'ʷt and suwiw̓s to further refine survival rates by lake.

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APPENDIX C

Lake Wenatchee Juvenile Sockeye Salmon and Limnology Status Report
Brood Years 2011-2015

LAKE WENATCHEE
JUVENILE SOCKEYE SALMON AND LIMNOLOGY STATUS REPORT
BROOD YEARS 2011-2015

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April 2017

SUMMARY

Preface: Sockeye Salmon from BY2011-15 were sampled in-lake during 2012-16. Because these and associated limnological data were recorded during the summer following egg deposition (for example BY2012 is followed by in-lake 2013) this document reports data in terms of in-lake years. Following each section in this summary, we offer suggestions for future improvements in the sampling protocol.

River discharge and Lake-turnover: During 2012-16, rates of river discharge and lake-turnover were recorded during the spring and early summer (01 May – 01 August). Mean spring-summer lake turnover times ranged from 40-129 days. The lowest turnover time (i.e. highest rate of river discharge) was recorded in 2012 and the longest turnover time (i.e. lowest rate of river discharge) was recorded in 2015. Rates of river discharge during the late summer-fall (August-October) were much lower and rates of lake-turnover were much longer.

Temperature and oxygen: During 2012-16 Lake Wenatchee had a well oxygenated, cold water hypolimnion. During most years the lake stratified relatively late in the summer (late-July, August) and for most of the spring-summer, Sockeye Salmon were able to feed throughout the water column. However during 2015, the lake stratified in early July and epilimnetic water temperatures increased to >17^{O}C. It is likely that this prevented Sockeye Salmon from spending much time in the epilimnion. The current oxygen-temperature sampling protocol is well executed and meets all of the needs of this research program.

Water chemistry: Nutrient chemistry was measured only during 2012 and Lake Wenatchee was found to have low concentrations of total phosphorus, nitrogen and chlorophyll. Total alkalinity and calcium were measured in 2012 and 2013 and Lake Wenatchee had very low (1.8-2.5 mg/L) calcium concentrations that might have prevented the growth of calcium sensitive taxa such as some species of *Daphnia*. Going forward, calcium concentration should be monitored 3 times during May-October.

Phytoplankton: During 2012-16, Lake Wenatchee total phytoplankton biovolume averaged 250 $mm^3\ m^{-3}$ and the edible biovolume averaged 182 $mm^3\ m^{-3}$. During most months, the ratio of edible to total phytoplankton was exceptionally high suggesting that most of the algal species found in Lake Wenatchee had sizes, shapes and digestibility that make them excellent food sources for freshwater zooplankton. In future years, phytoplankton should be sampled 3 times during the summer-fall (late-May, July, late-September).

Zooplankton: Lake Wenatchee zooplankton were monitored during 2012-16. The community comprised two dominant copepods (*Diacyclops thomasi, Hesperodiaptomus kena*i) and very occasional occurrences of the copepod *Epischura nevadensis*. The community also included two small bodied cladocerans (*Bosmina longirostris, Eubosmina coregoni*) and two large bodied cladocerans (*Daphnia thorata, Leptodora kindtii).*

***Hesperodiaptomus kenai*:** is a very large species that should provide an excellent food source for juvenile Sockeye Salmon. To date, only one stomach sample (10 July 2013) has been collected from Lake Wenatchee Sockeye Salmon. That sample (n = 30 stomachs) showed that *Hesperodiaptomus* comprised 82% of the prey items found in the stomachs and that they accounted for 93% of prey biomass. *Daphnia* were the next most important prey accounting for 13% of the prey items and 7% of the prey biomass.

An exceptional year 2015: During 2015, phytoplankton biomasses were 50% lower than they were in other years, and the *Daphnia* population was almost an order of magnitude higher than it was in any of the other years. Several factors may have been at

work. Rates of river discharge in 2015 were the lowest recorded and lake-turnover was the longest recorded. During 2015, epilimnion depth was deeper than in any of the other years and stratification lasted longer. During this period of stratification, Sockeye Salmon were likely excluded from the epilimnion and consumption of *Daphnia* was reduced. High *Daphnia* biomasses resulted in higher grazing rates and lower algal biomasses. However, this is all speculation because we do not know where the *Daphnia* were in the water column. In order to make this case we would require periodic night-time measures of zooplankton depth distributions. In the future, the current very well-executed zooplankton sampling program should be continued and in addition a series of Schindler Trap samples should be taken during (i) late-June, (ii) late July and (iii) early-September.

Sockeye Salmon: Juvenile Sockeye Salmon densities recorded in the fall of each sample year were higher in 2011, 2012, 2013, and 2015 (average 2456 juveniles ha^{-1}) than they were in 2010, 2013, 2016 (average 1545 juveniles ha^{-1}). We investigated several hypotheses to explain these trends. (1) The first working hypothesis is that there is a negative relationship between Sockeye fall weight and Sockeye density. Based on 6 years of data we did not find a significant relationship between Sockeye density and fall weight ($n = 6$, $R^2 = 0.27$, $p = 0.28$). (2) Our second working hypothesis was that higher biomasses of zooplankton should produce larger juvenile Sockeye Salmon. Based on 4 years with appropriate length-weight data there was no relationship and we failed to find support for this hypothesis. (3) Our third working hypothesis was that higher densities of Sockeye Salmon should be able to consume more zooplankton and reduce zooplankton biomasses. Based on 6 years of appropriate data we failed to find support for this hypothesis. In the future there are several issues for consideration. The first is that fish lengths and weights should be collected and processed for each acoustic sampling date. The second is that whenever possible, biosampled fish should be processed for scale ages and stomach content. Finally, sample frequency should be considered. A basic monitoring program will require 3 Sockeye samples (September, November, winter). A program designed for bioenergetics analysis should include at least 5 Sockeye salmon samples (August, September, October, November, winter).

Lake Wenatchee Physical Characteristics

Lake Wenatchee physical characteristics are summarized in Table 1. Based on volume and annual estimates of water flowing into Lake Wenatchee (Dion et al. 1976), Lake Wenatchee turns over once every 450 days. However, based on May-July rates of river flow measured at Plain WA, which is located downriver from Lake Wenatchee, lake-turnover can vary from 30-90 days. In part the discrepancy between the two estimates derives from (1) the Dion estimates are for annual water flow into the lake including low winter flows and (2) the Plain WA, USGS estimates measure flow down-stream from the lake during high flow periods (May-July, 2012-16). In addition the Plain WA estimates include contributions from the Chiwawa River which flows into the Wenatchee River between the Lake and Plain WA. To account for this extra contribution we have subtracted the Chiwawa flow from the flow recorded at Plain WA (Table 2).

Table 1: Lake Wenatchee physical characteristics. The data source for the first 8 rows of Table 1 is: *Dion, N.P., G.C. Bortleson, J.B. McConnell, and J.K. Innes. 1976. Data on selected lakes in Washington, Part 5. Water-Supply Bulletin 42, Part 5. State of WA, Dept. of Ecology*. The data source for rows 9-21 is the USGS monitoring site 12457000 Wenatchee River at Plain, WA.

		Units USA		Units metric	
1	Location 47.823°N, 120.778°W				
2	Elevation	1,872	ft	570	m
3	Area	2,500	acre	1,011	ha
4	Volume	360,000	acre feet	444,052,800	cubic m
5	Average depth	150	feet	45	m
6	Maximum depth	244	feet	74	m
7	Average flow into lake	800	cubic ft per second	23	cubic m per second
8	Average turnover time based on annual flow into lake	450	days		
9	Average 2012-16 (May-July) flow out of lake (Plain Washington)	4,390	cubic ft per second	124	cubic m per second
10	Flow (May-July) at Plain Washington				
11	Year 2012	6,141	cubic ft per second	174	cubic m per second
12	Year 2013	4,972	cubic ft per second	141	cubic m per second
13	Year 2014	5,244	cubic ft per second	149	cubic m per second
14	Year 2015	2,014	cubic ft per second	57	cubic m per second
15	Year 2016	3,580	cubic ft per second	101	cubic m per second
16	Average turnover time based on summer flow out of lake at Plain Washington				
17	Year 2012	30	days		
18	Year 2013	37	days		
19	Year 2014	35	days		
20	Year 2015	90	days		
21	Year 2016	51	days		

Table 2: May-July estimates of rates of water flow in the Wenatchee River exiting Lake Wenatchee. These estimates are based on the flow measured at Plain WA minus the flow form the Chiwawa River.

Year	Flow (May-July) Wenatchee River at Plain Washington cubic feet per second	Flow (May-July) Chiwawa River cubic feet per second	Net flow cubic feet per second	Net flow cubic meters per second	Net flow per day cubic meters	May-July Lake Wenatchee turnover time days
2012	6,141	1,614	4,527	128	11,077,375	40
2013	4,972	1,247	3,725	105	9,114,606	49
2014	5,244	1,301	3,943	112	9,647,943	46
2015	2,014	604	1,410	40	3,449,164	129
2016	3,580	1,128	2,452	69	6,000,302	74

It should be noted that the net estimates (Table 2) and resultant turnover times do not account for inputs from Nason Creek which also flows into the Wenatchee River south of the lake and upstream from the USGS gauge at Plain WA. The implication is that net flow rates recorded in Table 2 should be less than shown and that lake turnover times should be greater. At this time, because Nason and other smaller creeks are not gauged our current estimates are likely to be the best available. They show that over a similar time period (01 May – 01 August 2012 and 2013), Lake Wenatchee turnover times (average 37 days) were slightly shorter than comparable turnover times (49 days) recorded for Osoyoos Lake. In Osoyoos Lake there was a positive relationship between lake turnover time (days) and both phytoplankton and zooplankton biomass. We will investigate this potential relationship in the sections of this report that deal with phytoplankton and zooplankton.

Lake Wenatchee Sampling and Data Processing Methods

Two sampling sites (**Limno 1**: N 47^{O}49.394 W 120^{O}47.170) (**Limno 2**: N 47^{O}48.590 W 120^{O} 45.190) were used for water chemistry, phytoplankton and zooplankton and seven transects were used for juvenile Sockeye Salmon acoustic and trawl sampling (Figures 1, 2). Details regarding sample timing and frequency are summarized in Table 3.

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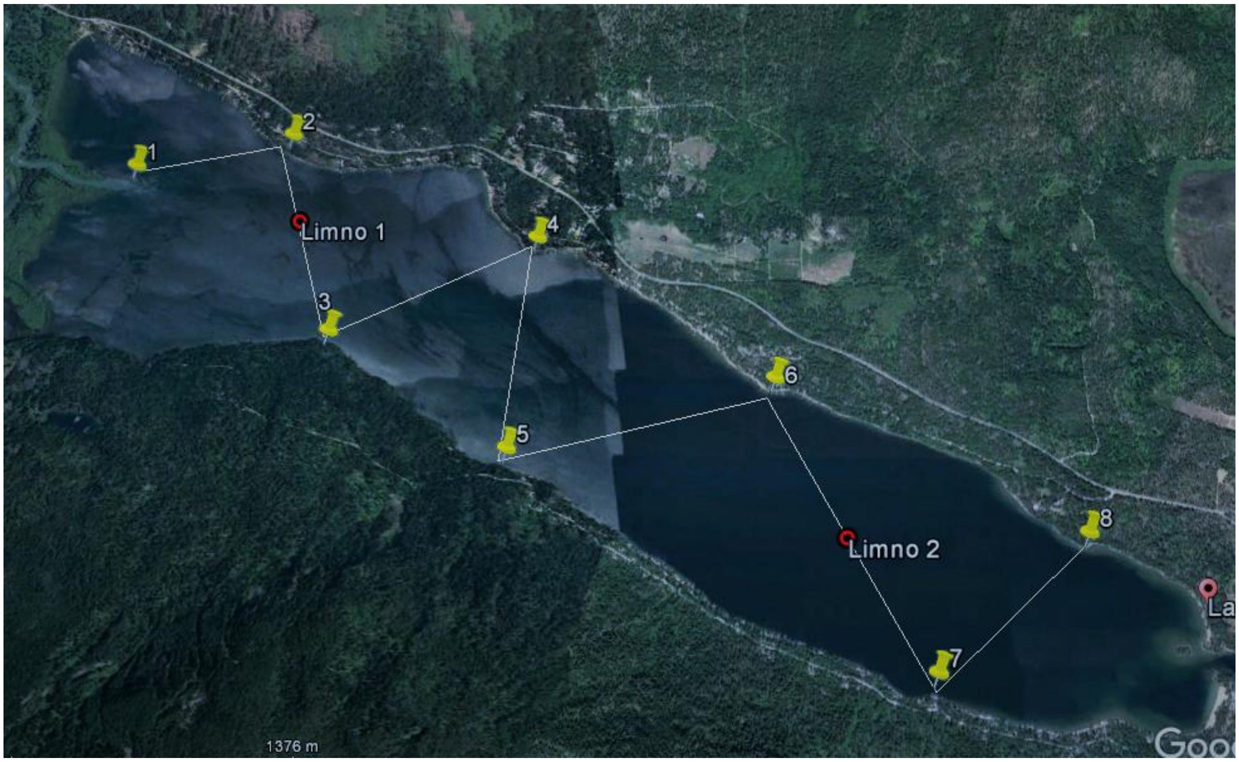


Figure 1: Seven Lake Wenatchee acoustic and trawl transects were used for sampling juvenile Sockeye Salmon. Two sampling stations (Limno 1 and Limno 2) were used to sample oxygen, temperature, Secchi depths, water chemistry, phytoplankton and zooplankton.

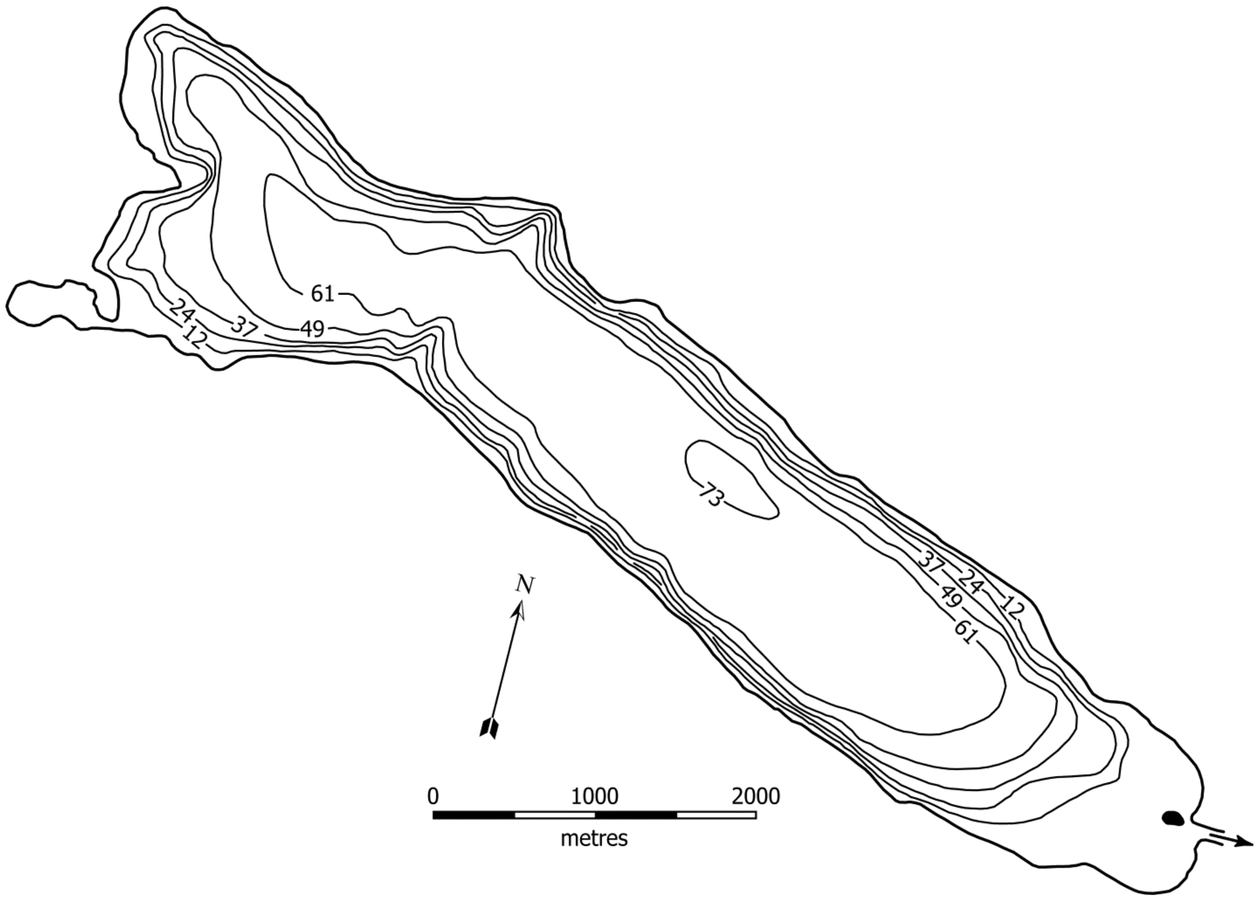


Figure 2: Bathymetric map of Lake Wenatchee, WA. Depths are in metres (original map in feet). Adapted from: Dion, N.P., G.C. Bortleson, J.B. McConnell, and J.K. Innes. 1976. Data on selected lakes in Washington, Part 5. Water-Supply Bulletin 42, Part 5. State of WA, Dept. of Ecology.

Oxygen and temperature were recorded at 1 meter intervals (1-20 m) and at 4 meter intervals (24-52 m) thereafter.

Limnological samples were collected at 1, 5, and 10 m (epilimnion) and 25 m (hypolimnion). During 2012-13, total phosphorus (TP) samples were stored in screw-cap test-tubes in the dark until analysis. $NO_{3\,+}\,NO_2$ samples were passed through an acrodisk filter, placed in screw-cap plastic bottles, and frozen until analysis. Chlorophyll a samples were filtered (47 mm Millipore) and frozen until analysis. Samples were analyzed at the Cultus Lake laboratory, Fisheries and Oceans Canada. Additional samples were sent to Vancouver Island University where they were analyzed for Na, Mg, and Ca (ppm) and for $CaCO_3$ alkalinity (ppm).

Phytoplankton biomasses were recorded from samples taken at 1, 5, and 10m (combined). In the laboratory the samples were settled and densities, cell sizes, cell shapes, and biovolumes were recorded. One of the objectives of the phytoplankton counting procedure was to assess the relative availabilities of edible (grazable) and non-edible (non-grazable) algae. We quantified "edibility" based on size, toxicity, and digestibility. Single cells or colonies ≤ 30 µm width or length were considered edible (Cyr 1998; Cottingham 1999) unless they were classified as being either "toxic" or "digestion-resistant". *Microcystis* was always classified as

being "toxic". Other genera were assumed to be non-toxic. Algae with thick gelatinous sheaths can pass through *Daphnia* guts undigested (Stutzman 1995) and were considered to be digestion-resistant, independent of size. Additional detail with respect to methods is available in Hyatt et al. (2005) and McQueen et al. (2007).

Zooplankton were sampled at night at two stations (Figure 1) using a vertical haul net (Rigosha meter, 100 µm mesh, 0.5 m net diameter, net length 3 m). Samples were collected approximately every 4 weeks (see sample schedule Table 3). Each sample was washed out of the plankton net using water saturated with carbon dioxide and were then preserved in 5.5% buffered and sugared formalin and returned to the laboratory. In the laboratory, individual samples from each of 2 stations were combined to produce one volume-weighted "combined" sample for each sampling date (McQueen et al. 2007). Because each of the samples had different sampling efficiencies (measured with a Rigosha flow meter), each station sample was suspended in water so that each one mL of sample contained water from 10 L of lake water. For each station, 10 mL (containing plankton from 100 L of lake water) from each sample jar was then added to a "combined" sample jar. Since there were 2 stations the combined sample jar contained 20 mL of sample representing the zooplankton found in 200 L of lake water. The original samples were then re-filtered to remove excess water, re-suspended in 5.5 % formalin and relabelled to record the loss of a certain percentage of the sample. During counting, Cladocera and copepods (adults and copepodids) were identified to species. Nauplii were identified as either *Diacyclops thomasi* or *Hesperodiaptomus keni.* Edmondson (1959) was the principal taxonomic reference, but also Dussart and Fernando (1990) for Cyclopoida, and Lieder (1983) for bosminids. Eggs per female were counted for all species. To calculate biomass, body lengths of all animals were measured using a semi-automated counting and measuring system (Allen et al. 1994). Animal weights were estimated using length-weight regressions summarized in Girard and Reid (1990). If preserved animals were used to develop these regressions, a 39% correction for weight loss in formalin was applied (Giguère et al. 1989).

Juvenile Sockeye Salmon (*Oncorhynchus nerka*) densities were assessed 1-2 times per year (depending on the lake-year; sample schedules in the results) using a Biosonics DT-X echosounder (200 kHz sounder, pulse width at 0.4 ms and a 6.6° transducer). More details are available in (MacLellan and Simmons 1992, Hyatt et al 2011). The acoustics transducer was towed at night over 7 transects (Figure 1). During each sampling trip, samples of pelagic fish were collected using a 3m x 7m mid-water trawl designed by Enzenhofer and Hume (1989). When the fish samples were collected by Fisheries and Oceans Canada, juvenile Sockeye were preserved in 95% ethanol. Fish samples were then transported to the laboratory, where the preservative was changed twice over six weeks. They were then removed from the preservative, blotted dry, measured (total length), and weighed. Weights were corrected for the effects of ethanol using the expression (fresh weight = preserved weight/0.868429; P. Rankin, Pacific Biological Station, unpublished data). When samples were collected by the Okanagan Nation Alliance, they were kept on ice and transported back to the laboratory where fresh lengths and weights were recorded.

Lake Wenatchee 2012-16 Inventory of Samples Collected:

Table 3: Samples collected at Lake Wenatchee during in-lake 2012-16. Black x indicate that the samples were collected, processed, analyzed and included in this report. nd = no data available.

In-Lake 2012

Date Surveyed	Discharge from Wenatchee River at Plain Washington	Water chemistry average 1,5,10 and 25 m	Temperature and Oxygen	Secchi Depth (with Oxy-temp)	Phytoplankton average 1,5,10 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling	Fish lengths	Fish weights	Fish Ages	Fish stomachs
May-July	x											
4-Jun-12			x	x	x	x						
25-Jun-12		x	x	x	x		x	x	x	x	nd	nd
5-Jul-12			x	x	x	x						
8-Aug-12			x	x	x	x						
10-Sep-12					x	x						
18-Sep-12			x	x	x		x	x	x	x	nd	nd
6-Oct-12		x	x	x	x	x						

In-Lake 2013

Date Surveyed	Discharge from Wenatchee River at Plain Washington	Water chemistry average 1,5,10 and 25 m	VIU chemistry	Temperature and Oxygen	Secchi Depth (with Oxy-temp)	Phytoplankton average 1,5,10 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling	Fish Lengths	Fish Weights	Fish Ages	Fish stomachs
May-September	x												
25-Jun-13				x	x	x	x						
10-Jul-13			x					x	x	x	x	nd	x
30-Jul-13				x	x		x						
26-Aug-13				x	x		x						
23-Sep-13				x	x		x	x	x	x	nd	nd	nd

In-Lake 2014

Date Surveyed	Discharge from Wenatchee River at Plain Washington	Water chemistry average 1,5,10 and 25 m	VIU chemistry	Temperature and Oxygen	Secchi Depth	Phytoplankton average 1,5,10 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling	Fish lengths	Fish weights	Fish Ages	Fish stomachs
May-September	x												
5-Jun-2014		nd	nd	x	x	x	x						
23-Jun-2014				x	x								
26-Jun-2014		nd	nd				x						
14-Jul-2014		nd	nd	x	x	x	x						
11-Aug-2014		nd	nd	x	x		x						
4-Sep-2014		nd	nd	x	x	x	x						
29-Sep-2014		nd	nd			x	x						
8-Oct-2014				x	x								
27-Oct-2014								x	x	x	x	nd	nd
23-Feb-2015								x	x	x	x	nd	nd

In-Lake 2015

Date Surveyed	Discharge from Wenatchee River at Plain Washington	Water chemistry average 1,5,10 and 25 m	VIU chemistry	Temperature and Oxygen	Secchi Depth (with Oxy-temp)	Phytoplankton average 1,5,10 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling	Fish lengths	Fish weights	Fish Ages	Fish stomachs
May-September	x												
1-Jun-15				x		x							
4-Jun-2015		nd	nd		x		x						
25-Jun-2015		nd	nd	x			x						
14-Jul-2015		nd	nd	x	x	x	x						
5-Aug-2015		nd	nd	x			x						
25-Aug-2015					x	x							
27-Aug-2015		nd	nd	x			x						
16-Sep-2015		nd	nd	x	x	x	x						
21-Sep-2015								x	x	x	x	nd	nd
11-Mar-2016								x	x	x	x	x	nd

In-Lake 2016

Date Surveyed	Discharge from Wenatchee River at Plain Washington	Water chemistry average 1,5,10 and 25 m	VIU chemistry	Temperature and Oxygen	Secchi Depth	Phytoplankton average 1,5,10 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling	Fish lengths	Fish weights	Fish Ages	Fish stomachs
May-September	x												
08-Jun-16				x	x								
09-Jun-16		nd	nd			x	x						
29-Jun-16		nd	nd	x			x						
20-Jul-16		nd	nd	x	x	x	x						
10-Aug-16		nd	nd	x			x						
31-Aug-16		nd	nd	x	x	x	x						
01-Sep-16								x	x	x	x	x	nd
29-Sep-16				x	x								
02-Nov-16								x	x	x	x	x	nd
April 2017				TBD				TBD	TBD	TBD	TBD	TBD	TBD

Lake Wenatchee 2012-16 Water Temperature and Oxygen Concentrations:

Shaded areas represent water temperatures (i.e. >17^{O} C) that are typically avoided by juvenile Sockeye Salmon. Year 2015 stands out as a year when juvenile Sockeye were restricted to the hypolimnion during the two summer months.

Table 4: Lake Wenatchee 2012-16 water temperatures.

Water depth (m)	2012				2013				2014						2015						2016					
	4-Jun-12	5-Jul-12	9-Aug-12	6-Oct-12	25-Jun-13	30-Jul-13	26-Aug-13	23-Sep-13	5-Jun-14	23-Jun-14	14-Jul-14	11-Aug-14	4-Sep-14	8-Oct-14	1-Jun-15	25-Jun-15	14-Jul-15	5-Aug-15	28-Aug-15	16-Sep-15	8-Jun-16	29-Jun-16	20-Jul-16	10-Aug-16	31-Aug-16	29-Sep-16
1	8	11	14	14	11	18	19	16	9	12	15	19	18	16	13	17	19	19	18	17	12	13	16	17	19	16
2	8	10	14	14	11	18	18	16	9	12	15	19	18	15	13	17	19	19	18	16	12	13	16	17	19	15
3	8	10	14	14	10	17	18	16	9	11	15	18	17	15	13	17	19	19	18	16	12	13	16	17	18	15
4	7	9	14	14	10	17	18	16	9	11	15	18	17	15	13	16	19	19	18	16	11	13	16	17	18	15
5	7	9	14	14	10	17	18	16	9	11	15	18	17	15	12	16	19	18	18	16	11	13	16	17	18	15
6	7	9	14	14	10	17	18	16	9	11	14	17	17	15	12	16	19	18	18	16	11	13	15	17	18	15
7	7	9	14	14	10	17	18	16	9	11	14	17	17	15	11	15	19	18	18	16	11	13	15	17	18	15
8	7	9	14	14	10	16	18	16	9	11	14	17	17	15	11	15	19	18	18	16	11	13	15	17	18	15
9	7	9	14	14	10	16	18	16	9	11	14	16	17	15	11	15	18	18	18	16	10	13	15	17	18	15
10	7	9	14	14	10	16	18	16	9	10	14	16	17	15	11	15	18	18	18	16	10	13	15	17	18	15
11	7	9	14	14	10	16	18	16	9	10	14	16	17	15	10	14	18	18	18	16	10	13	15	17	18	15
12	7	9	13	14	10	16	18	16	9	10	13	16	16	15	10	14	17	18	18	16	10	12	14	17	18	15
13	7	8	13	14	9	16	17	16	9	10	13	16	16	15	10	14	16	18	18	16	10	12	14	17	18	15
14	7	8	13	14	9	15	17	16	9	10	12	15	16	15	10	14	15	18	18	16	10	12	14	17	18	15
15	7	8	13	14	9	15	17	16	8	10	12	15	16	15	10	13	14	18	18	16	9	12	14	16	17	15
16	7	8	13	14	9	13	16	15	8	9	12	15	15	15	10	13	14	18	18	16	9	12	14	16	17	15
17	7	8	13	14	9	13	16	15	8	9	12	14	14	15	10	13	13	18	18	16	9	12	13	16	17	15
18	7	8	13	14	9	11	15	15	8	9	11	13	14	15	10	12	12	18	18	16	9	12	13	16	16	15
19	7	8	13	14	9	11	14	14	8	9	11	12	13	14	9	12	12	16	18	16	9	12	13	16	16	15
20	7	8	12	13	9	11	13	13	8	9	11	12	13	14	9	12	12	15	17	16	9	12	13	16	15	15
24	7	7	10	13	8	10	11	11	8	9	10	11	12	13	9	11	10	11	13	15	9	11	11	13	13	14
28	6	7	10	11	8	10	10	10	8	9	10	10	11	11	9	10	10	10	10	10	8	10	10	12	11	11
32	6	7	9	9	8	9	9	9	8	8	9	9	10	10	8	9	9	9	9	9	8	9	9	10	10	10
36	6	7	8	8	8	8	9	8	8	8	9	9	9	9	8	8	8	8	8	8	8	8	9	9	9	9
40	6	7	8	8	8	8	8	8	7	8	9	8	9	9	7	8	8	8	8	8	8	8	8	9	8	8
44	6	7	8	7	7	8	8	8	7	8	8	8	8	8	7	7	7	8	8	7	7	8	8	8	8	8
48	6	7	7	7	7	7	8	8	7	8	8	8	8	8	7	7	7	7	7	7	7	8	8	8	8	8
52	6	7	7	7	7	7	7	7	7	7	8	8	8	8	6	7	7	7	7	7	7	8	7	8	8	8

In all years, at all water depths, oxygen concentrations were high enough to support juvenile Sockeye Salmon.

Table 5: Lake Wenatchee 2012-16 oxygen concentrations (ppm).

	2012				2013				2014						2015						2016					
Water depth (m)	4-Jun-12	5-Jul-12	9-Aug-12	6-Oct-12	25-Jun-13	30-Jul-13	26-Aug-13	23-Sep-13	5-Jun-14	23-Jun-14	14-Jul-14	11-Aug-14	4-Sep-14	8-Oct-14	1-Jun-15	25-Jun-15	14-Jul-15	5-Aug-15	28-Aug-15	16-Sep-15	8-Jun-16	29-Jun-16	20-Jul-16	10-Aug-16	31-Aug-16	29-Sep-16
1	10	13	10	10	11	9	9	9	11	10	10	9	9	9	10	10	9	9	9	9	11	10	10	9	9	9
2	10	13	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
3	10	13	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
4	10	13	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	10	9	11	10	10	9	9	9
5	10	13	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
6	10	13	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
7	10	13	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
8	10	13	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
9	10	13	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
10	10	14	10	10	11	9	9	9	11	11	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
11	10	14	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
12	10	14	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
13	9	14	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
14	10	13	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
15	10	14	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
16	10	14	10	10	11	9	9	9	11	10	10	9	9	9	11	10	9	9	9	9	11	10	10	9	9	9
17	10	14	10	10	11	9	9	9	11	10	10	9	9	9	10	10	9	9	9	9	11	10	10	9	9	9
18	10	14	10	10	11	10	9	9	11	10	10	9	9	9	10	10	9	9	9	9	11	10	10	9	9	9
19	10	14	10	10	11	10	9	8	11	10	10	9	9	9	10	10	9	9	9	9	11	10	10	9	8	9
20	10	14	10	9	11	10	9	9	11	10	10	9	9	9	10	10	9	9	9	9	11	10	10	9	8	9
24	6	14	10	9	11	10	9	9	11	10	10	9	9	9	10	10	9	9	8	9	11	10	10	9	8	9
28	7	14	10	10	11	10	9	9	11	10	10	9	9	8	10	10	9	9	8	8	11	10	10	9	9	8
32	7	14	10	10	11	10	9	9	11	10	10	9	9	8	10	10	9	9	9	8	11	10	10	9	9	8
36	7	14	10	10	11	10	9	9	11	10	10	9	9	9	10	10	10	9	9	8	10	10	10	9	9	8
40	7	14	10	10	11	9	9	9	10	10	10	9	9	9	10	10	10	9	9	8	10	10	10	9	9	9
44	7	14	10	10	10	9	9	9	10	10	10	9	9	9	10	10	10	9	9	8	10	10	10	9	9	8
48	7	14	10	10	10	9	9	9	10	10	10	9	9	9	10	10	10	9	9	8	10	10	9	9	9	8
52	7	14	10	10	10	9	9	9	10	10	10	9	9	9	10	10	10	9	9	8	10	10	9	9	9	8

Lake Wenatchee 2012-16 Secchi Depths

In all years Secchi depths were typically greater than 5 m suggesting oligotrophic water quality conditions suitable for juvenile Sockeye Salmon.

Table 6: Lake Wenatchee 2012-16 Secchi Depths.

		Secchi Depths (m)
2012	4-Jun-12	5.8
	5-Jul-12	5.9
	9-Aug-12	4.3
	6-Oct-12	7.2
2013	25-Jun-13	5.6
	30-Jul-13	5.4
	26-Aug-13	6.6
	23-Sep-13	6.9
2014	5-Jun-14	7.5
	23-Jun-14	7.7
	14-Jul-14	5.3
	11-Aug-14	nd
	4-Sep-14	8.0
	8-Oct-14	9.2
2015	1-Jun-15	5.7
	25-Jun-15	nd
	14-Jul-15	7.8
	5-Aug-15	nd
	28-Aug-15	7.9
	16-Sep-15	7.0
2016	8-Jun-16	5.5
	29-Jun-16	nd
	20-Jul-16	4.9
	10-Aug-16	nd
	31-Aug-16	7.1
	29-Sep-16	10.5

Lake Wenatchee 2012-16 Water Chemistry

Lake Wenatchee alkalinity and trace elements were collected during 2012-13. Nutrient chemistry was recorded only during 2012.

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

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

This lake might benefit from artificial calcium additions.

Table 7: Lake Wenatchee 2012 water chemistry collected in both the epilimnion and hypolimnion. Water chemistry was not collected during 2013. Mean 1,2 refers to the average from stations 1 and 2.

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

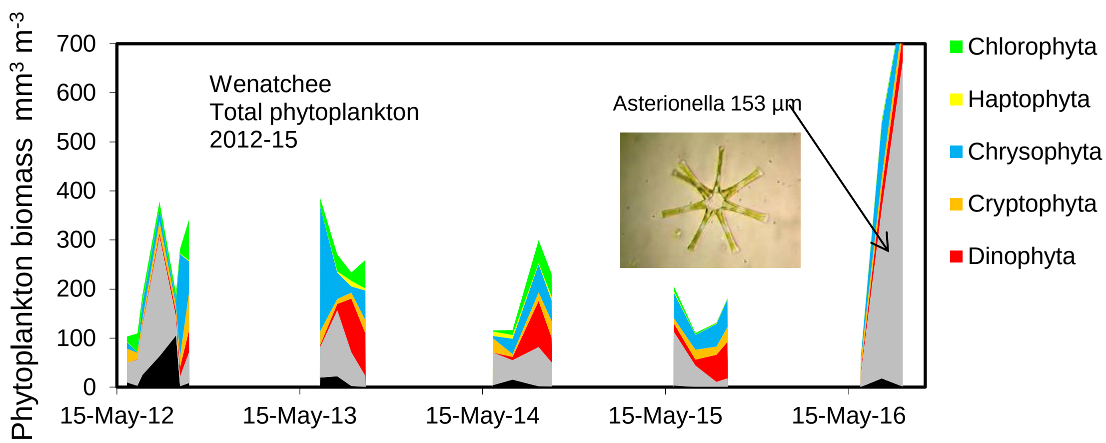
Table 8: Lake Wenatchee 2012-13 alkalinity and trace elements.

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

Lake Wenatchee 2012-16 phytoplankton:

Phytoplankton were collected on seven dates during 2012, four dates during 2013-15 and on three dates during 2016 (Figure 3, Table 9). Biomasses were recorded from samples taken at 1,5,10 m (combined). Densities, cell sizes, cell shapes and biovolumes were recorded. One of the objectives of the phytoplankton counting procedure was to assess the relative availabilities of edible (grazable) and non-edible (non-grazable) algae. We quantified "edibility" based on size, toxicity and digestibility (see Methods for details).

In Lake Wenatchee during all years, total phytoplankton biovolume averaged 250 $mm^3 m^{-3}$ and the edible biovolume averaged 182 $mm^3 m^{-3}$. As a point of reference, Osoyoos Lake 2005-13 total phytoplankton biovolume averaged 1120 $mm^3 m^{-3}$ and the edible biovolume averaged 322 $mm^3 m^{-3}$. Although the total biovolume in Lake Wenatchee was lower than in Osoyoos Lake, the percentage that was edible was much higher (Wenatchee 73%, Osoyoos 28%). Detailed count data are provided in Tables 9 and 10.



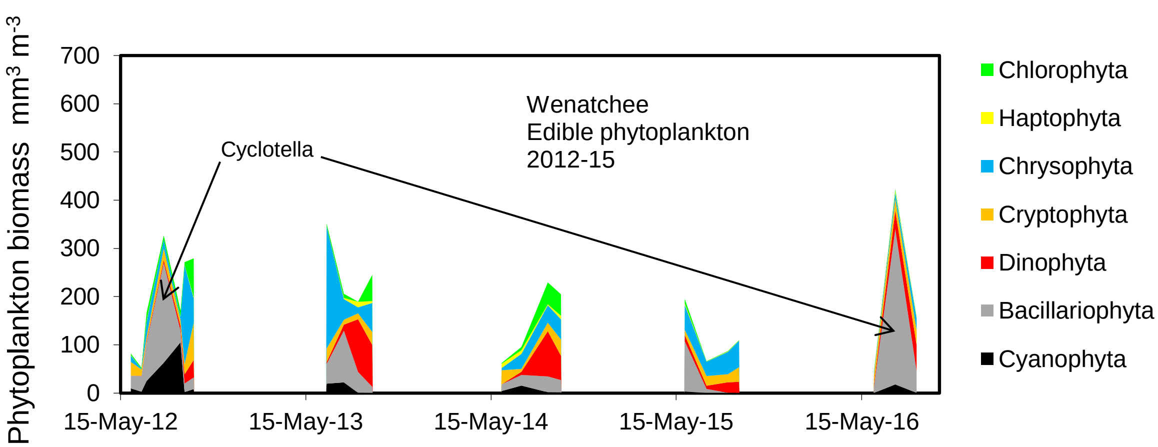


Figure 3: Lake Wenatchee 2012-16, total and edible phytoplankton biomass as $mm^3 m^{-3}$ which approximates $\mu g \bullet L^{-1}$ wet weight.

Through 2012-16 (Figure 3, Table 9) there was considerable year to year variability. During 2012 there was a bloom of *Cyclotella* a small disk-shaped diatom that is thought to be a good food source for zooplankton. *Cyclotella* also appeared in the edible fraction of the phytoplankton sampled in 2016. During that year there was also a very large bloom of *Asterionella* a star-shaped diatom colony (see figure 3) that is too large for consumption by zooplankton. Neither the presence of *Cyclotella* or *Asterionella* was obviously correlated with changes in zooplankton biomass (Figures 4, 5 Table 11).

During 2015, phytoplankton biovolumes, especially edible phytoplankton biovolumes, were lower than in the other 4 years. The most likely correlates could be (1) higher rates of river flow into Lake Wenatchee and therefore higher rates of phytoplankton washout during 2015 and (2) higher rates of predation by the 2015 zooplankton population. From Table 3 we see that 2015 rates of river flow were the lowest recorded suggesting that 2015 phytoplankton washout should have been minimal. From Figures 4,5 Table 11, we see that during 2015, zooplankton biomasses were the highest recorded and that *Daphnia* biomasses were exceptionally high suggesting that 2015 grazing rates may have been higher than normal accounting for lower than normal 2015 phytoplankton biomasses. But a word of caution – given only 5 years of biomass data and no data for algal production or consumption by zooplankton, this observation is very tentative. It is however, interesting.

Table 9: Lake Wenatchee 2012-16, total phytoplankton biomass as $mm^3 m^{-3}$ which approximates $\mu g L^{-1}$ wet weight.

Date	Cyanophyta	Dinophyta	Cryptophyta	Euglenophyta	Chrysophyta	Haptophyta	Tribophyta	Chlorophyta	Raphidophyta	Bacillariophyta	TOTAL
4-Jun-12	9.6	0.0	28.6	0.0	13.4	0.8	0.0	10.8	0.0	40.1	**103.3**
25-Jun-12	2.8	0.8	13.4	0.0	1.2	0.1	0.0	38.2	0.0	53.1	**109.5**
5-Jul-12	24.9	3.5	8.2	0.0	31.9	1.8	0.0	16.4	0.0	101.4	**188.2**
8-Aug-12	63.0	5.9	24.1	0.0	23.9	0.0	0.0	16.4	0.0	245.3	**378.5**
10-Sep-12	105.2	10.2	12.5	0.0	8.4	0.1	0.0	15.0	0.0	39.4	**190.9**
18-Sep-12	1.8	19.0	21.2	0.0	210.0	1.0	0.0	9.0	0.0	19.6	**281.6**
6-Oct-12	8.4	44.0	77.8	0.0	63.4	2.4	0.0	82.8	0.0	62.8	**341.6**
25-Jun-13	19.5	4.0	28.2	0.0	253.5	0.3	0.0	17.1	0.0	62.8	**385.3**
29-Jul-13	22.1	12.5	10.2	0.0	53.9	2.4	0.0	34.8	0.0	135.0	**270.8**
26-Aug-13	2.3	109.3	12.2	0.0	12.6	11.4	1.1	17.0	0.0	69.0	**234.8**
23-Sep-13	0.0	86.9	26.8	0.0	60.3	4.0	0.0	58.4	0.0	23.0	**259.3**
5-Jun-14	4.1	0.0	29.1	0.0	4.8	8.8	0.0	2.5	0.0	66.4	**115.7**
14-Jul-14	15.4	6.6	5.9	0.0	31.3	7.6	0.0	9.9	0.0	39.5	**116.2**
4-Sep-14	1.7	93.7	17.7	0.0	57.3	2.1	0.0	47.1	0.0	80.1	**299.8**
30-Sep-14	1.3	50.3	33.8	0.0	42.4	7.5	0.9	46.0	0.0	49.1	**231.4**
1-Jun-15	3.2	16.9	10.7	0.0	52.2	3.1	0.0	9.8	0.0	109.7	**205.5**
14-Jul-15	0.0	12.1	20.1	0.0	30.2	0.4	0.0	3.4	0.0	44.1	**110.3**
25-Aug-15	0.0	55.2	16.8	0.0	46.3	1.0	0.0	1.4	0.0	10.7	**131.3**
16-Sep-15	0.0	74.3	30.5	0.0	56.3	0.5	0.0	1.5	0.0	17.9	**181.1**
8-Jun-16	0.3	4.5	20.1	0.0	6.3	1.8	0.0	0.7	0.0	26.4	**60.1**
20-Jul-16	17.9	38.6	24.1	0.0	110.2	4.2	0.0	3.2	0.0	346.9	**545.0**
31-Aug-16	1.1	53.9	30.8	0.0	25.7	0.8	0.0	3.9	0.0	664.2	**780.4**

Table 10: Lake Wenatchee 2012-16, edible phytoplankton biomass as $mm^3\ m^{-3}$ which approximates $\mu g\ L^{-1}$ wet weight.

Date	Cyanophyta	Dinophyta	Cryptophyta	Euglenophyta	Chrysophyta	Haptophyta	Tribophyta	Chlorophyta	Raphidophyta	Bacillariophyta	TOTAL
4-Jun-12	9.6	0.0	28.6	0.0	13.4	0.8	0.0	3.2	0.0	26.4	**82.0**
25-Jun-12	2.8	0.8	13.0	0.0	1.2	0.1	0.0	2.5	0.0	32.2	**52.5**
5-Jul-12	24.9	3.5	8.2	0.0	31.9	1.8	0.0	16.4	0.0	79.4	**166.1**
8-Aug-12	63.0	5.9	24.1	0.0	18.6	0.0	0.0	8.6	0.0	206.8	**326.9**
10-Sep-12	105.2	10.2	12.5	0.0	5.7	0.1	0.0	13.4	0.0	24.0	**171.1**
18-Sep-12	1.8	19.0	21.2	0.0	205.2	1.0	0.0	5.3	0.0	17.9	**271.4**
6-Oct-12	8.3	36.3	77.8	0.0	50.1	2.4	0.0	80.6	0.0	24.0	**279.4**
24-Jun-13											
25-Jun-13	19.5	4.0	28.2	0.0	253.5	0.3	0.0	5.3	0.0	40.8	**351.4**
29-Jul-13	22.1	12.5	10.2	0.0	42.9	2.4	0.0	8.5	0.0	107.3	**205.8**
26-Aug-13	0.5	109.3	12.2	0.0	12.6	11.4	1.1	0.3	0.0	43.2	**190.5**
23-Sep-13	0.0	86.9	26.8	0.0	60.3	4.0	0.0	54.4	0.0	12.8	**245.3**
5-Jun-14	4.1	0.0	29.1	0.0	4.8	8.8	0.0	1.5	0.0	13.9	**62.3**
14-Jul-14	15.4	6.6	5.9	0.0	31.3	7.6	0.0	6.7	0.0	22.1	**95.6**
4-Sep-14	1.7	93.7	17.7	0.0	36.1	2.1	0.0	45.3	0.0	32.7	**229.4**
30-Sep-14	1.3	50.3	33.8	0.0	41.8	7.5	0.9	44.5	0.0	25.5	**205.7**
1-Jun-15	3.1	13.2	10.7	0.0	51.8	3.1	0.0	9.1	0.0	104.1	**195.1**
14-Jul-15	0.0	6.7	20.1	0.0	29.7	0.4	0.0	0.8	0.0	8.4	**66.1**
25-Aug-15	0.0	21.6	16.8	0.0	46.3	1.0	0.0	0.9	0.0	0.6	**87.3**
16-Sep-15	0.0	23.1	30.5	0.0	55.0	0.5	0.0	0.7	0.0	0.0	**109.8**
8-Jun-16	0.3	4.5	20.1	0.0	5.1	1.8	0.0	0.7	0.0	13.6	**46.0**
20-Jul-16	17.9	38.6	24.1	0.0	12.9	4.2	0.0	3.1	0.0	322.0	**422.7**
31-Aug-16	0.4	53.9	30.8	0.0	24.4	0.8	0.0	1.8	0.0	45.3	**157.4**

Lake Wenatchee 2012-16 zooplankton:

The Lake Wenatchee zooplankton community comprises a very small number of species. There are two dominant copepods (*Diacyclops thomasi, Hesperodiaptomus kenai*) and very occasional occurrences of the copepod *Epischura nevadensis*. There are two bosminids (*Bosmina longirostris, Eubosmina coregoni*) counted separately but grouped together in this report (Figures 4,5 Table 11). The remaining cladocerans are *Daphnia thorata and Leptodora kindtii.* Most of these species are typical of those found in the Okanagan lakes. The exception is *Hesperodiaptomus kenai* which is extremely large, typically brightly coloured and an excellent food source of juvenile Sockeye Salmon.

Through 2012-16, there was considerable variation in zooplankton biomass (Figure 4). During 2012, the rotifer *Kellicottia* was abundant (Figure 5) and accounted for the unusually high zooplankton biomasses recorded in the fall. During 2013 and 2014, there was a decline in total zooplankton from August through to the end of sample collection in October (Table 11). During 2015, there was an unusually large *Daphnia* population which persisted through the summer until early September (Figure 5, Table 11). During spring-summer 2016, zooplankton biomasses were lower than normal and all species appeared to be equally affected, but during the fall *Daphnia* and *Bosmina* biomasses increased.

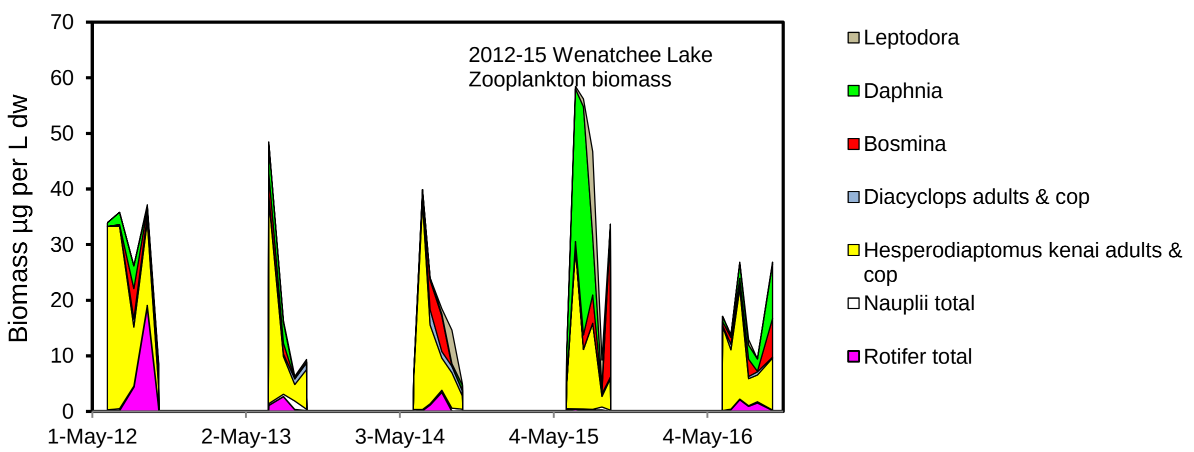


Figure 4: Year 2012-16 zooplankton biomass (µg L^{-1} dry weight).

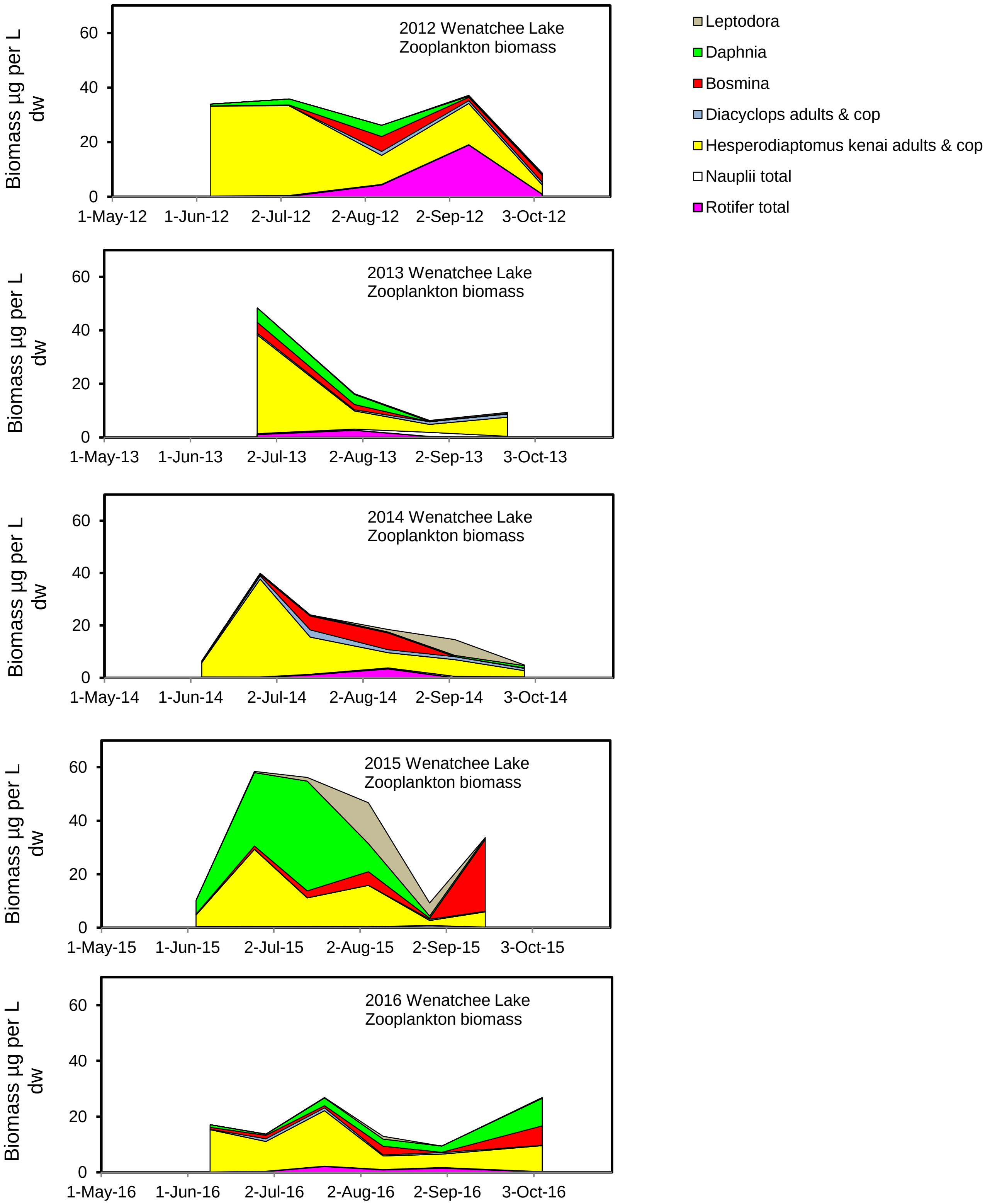


Figure 5: Year 2012-2016 zooplankton biomass (µg L^{-1} dw).

Table 11: 2012-16 Lake Wenatchee zooplankton biomasses (µg L^{-1} dry weight).

Date	Rotifer total	Nauplii total	Diacyclops adults & cop	Hesperodiaptomus kenai adults & cop	Epischura	Bosmina	Daphnia	Diaphanosoma	Leptodora	Other	Total
6/6/2012	0.14	0.13	0.04	32.97	0.00	0.00	0.65	0.00	0.00	0.00	33.93
7/5/2012	0.18	0.30	0.06	32.84	0.00	0.23	2.20	0.00	0.00	0.00	35.82
8/8/2012	4.40	0.15	1.45	10.61	0.00	5.46	4.11	0.00	0.00	0.00	26.17
9/9/2012	19.00	0.09	1.05	15.07	0.00	1.24	0.34	0.00	0.36	0.00	37.15
10/6/2012	0.97	0.03	1.00	3.32	0.00	2.65	0.18	0.00	0.57	0.00	8.71
6/24/2013											
6/25/2013	1.09	0.30	0.64	36.93	0.00	4.07	5.38	0.00	0.04	0.00	48.45
7/30/2013	2.68	0.40	0.46	6.78	0.00	1.96	3.76	0.00	0.27	0.00	16.30
8/26/2013	0.34	1.52	1.02	2.96	0.00	0.00	0.07	0.00	0.39	0.00	6.30
9/23/2013	0.15	0.23	1.21	7.14	0.00	0.00	0.17	0.00	0.42	0.00	9.32
6/5/2014	0.07	0.26	0.38	5.43	0.00	0.08	0.23	0.00	0.00	0.00	6.45
6/26/2014	0.15	0.17	1.26	37.35	0.00	0.45	0.49	0.00	0.00	0.00	39.88
7/14/2014	1.17	0.18	2.78	14.19	0.00	5.29	0.39	0.00	0.01	0.00	24.01
8/11/2014	3.47	0.34	1.17	5.79	0.00	6.39	0.34	0.00	0.97	0.00	18.46
9/4/2014	0.07	0.49	1.16	6.38	0.00	0.04	0.43	0.00	6.04	0.00	14.60
9/29/2014	0.10	0.29	0.89	2.34	0.00	0.16	0.88	0.00	0.24	0.00	4.91
6/4/2015	0.22	0.26	0.12	4.20	0.00	0.26	5.13	0.00	0.00	0.00	10.18
6/25/2015	0.41	0.04	0.13	28.80	0.00	1.17	27.46	0.00	0.44	0.00	58.46
7/14/2015	0.20	0.24	0.08	10.68	0.00	2.57	41.05	0.00	1.39	0.00	56.19
8/5/2015	0.26	0.11	0.07	15.44	0.00	5.07	10.49	0.00	15.29	0.00	46.73
8/27/2015	0.26	0.52	0.49	1.88	0.00	0.39	0.81	0.00	4.86	0.00	9.21
9/16/2015	0.03	0.19	0.25	5.67	0.00	26.84	0.70	0.00	0.00	0.00	33.67
6/9/2016	0.12	0.03	0.15	15.16	0.13	0.70	0.95	0.00	0.00	0.00	17.24
6/29/2016	0.35	0.05	1.00	10.67	0.00	1.23	0.38	0.00	0.08	0.00	13.74
7/20/2016	2.14	0.08	1.04	19.91	0.00	0.76	2.76	0.00	0.18	0.00	26.85
8/10/2016	0.93	0.08	0.40	4.86	0.00	3.11	2.55	0.00	1.00	0.00	12.92
8/31/2016	1.55	0.18	0.57	4.81	0.00	0.10	2.22	0.00	0.00	0.00	9.42
10/6/2016	0.19	0.05	0.17	9.34	0.00	6.96	9.86	0.00	0.30	0.00	26.86

The importance of *Hesperodiaptomus*: In the 2012 report we noted that Osoyoos Lake zooplankton biomasses (average 76 µg L^{-1}) were more than twice as high as the Lake Wenatchee biomasses (average 28 µg L^{-1}). Among the cladocerans, both lakes had *Daphnia* and *Bosmina* but *Diaphanosoma* was found only in Osoyoos Lake. Among the copepods, both lakes had *Diacyclops bicuspidatus*, but Osoyoos Lake had *Leptodiaptomus ashlandi* while Lake Wenatchee had *Hesperodiaptomus kenai*. This single species substitution (*Hesperodiaptomus* vs *Leptodiaptomus*) represents a major difference in the availability of zooplankton for fish. On average, *Leptodiaptomus* copepodids and adults weigh 2.5 µg dry weight and measure less than 1 mm in body length. The average weight for *Hesperodiaptomus* is >30 µg dry weight and the average body length is about 2 mm. This makes *Hesperodiaptomus* an important target for juvenile sockeye. In general, lower Lake Wenatchee total zooplankton biomasses suggest that Lake Wenatchee sockeye should have grown at about half the rate of Osoyoos Lake juvenile sockeye. However, the presence of *Hesperodiaptomus* likely allowed Lake Wenatchee sockeye to hunt with greater efficiency (energy return per feeding strike was higher), resulting in a smaller than expected difference in sockeye growth rates. In fact during 2012, 2013 and 2014, both Wenatchee and Osoyoos Juvenile Sockeye had similar lengths and weights (Table 12).

Table 12: Comparisons of Lake Wenatchee and Osoyoos Lake age-0 sockeye lengths and weighs.

Lake Wenatchee			Osoyoos Lake		
Date	Length (mm)	Weight (g)	Date	Length (mm)	Weight (g)
18-Sep-12	56	1.9	11-Sep-12	61	2.3
23-Sep-13	60	nd	10-Oct-13	74	4.1
23-Feb-14	74	4.2	27-Feb-14	75	4.5

Warm water during 2015: During 2015 spring-summer *Daphnia* biomasses were exceptionally high and fall *Eubosmina* egg production was the highest recorded. The explanation for both likely relates to water temperatures. During that summer, epilimnetic water temperatures were unusually warm (Table 4). During Late June - early July 2015, the epilimnion warmed to >17^{O}C and these warm conditions persisted through to late August - early September. Because juvenile Sockeye Salmon are known to avoid water temperatures >17^{O}C, it seems likely that the warm epilimnetic water acted as a refuge for *Daphnia* and stimulated unusually high egg production in *Eubosmina*. These trends in zooplankton biomass, combined with data reported in the section dealing with phytoplankton (Figure 3, Table 9) suggest that during 2015, high grazing rates by *Daphnia* may have had an unusually large top-down effect on phytoplankton biomass.

Between-year differences in zooplankton biomass: During 2013, 2014 and 2016 (Figure 5, Table 11), Lake Wenatchee zooplankton biomasses were lower than during 2012 and 2015. Three explanations for this general pattern are: (i) decreasing food (algae) availability, (ii) increasing spring to fall through-lake flow rates and high rates of zooplankton loss due to washout, or (iii) high rates of zooplankton consumption by juvenile Sockeye Salmon.

(i) Phytoplankton abundance hypothesis: From the preceding phytoplankton section, we see that phytoplankton biomasses were about the same in 2012 and 2013, and slightly lower in 2014 (Figure 3, Table 9). Zooplankton biomasses were higher in 2012 and declined through the summers in 2013 and 2014. None of these data suggest a significant bottom-up correlation between algal biomass and zooplankton biomass. It is important to note

however, that this conclusion is tentative because our data do not include estimates of phytoplankton production or zooplankton consumption.

(ii) **River flow hypothesis**: During 2012-16, rates of discharge in the Wenatchee River at Plain Washington were recorded by the Washington Department of Ecology (Table 2, Figure 7). These data show that during 2013-16, flow rates declined from early July through late September. The implication is that flow alone could not account for the observed 2013, 2014 reductions in zooplankton biomass. In addition, the flow decline in 2012 was later than in the other years and yet 2012 late summer-fall zooplankton biomasses were the highest recorded.

However, 2015 was an interesting exception. During 2015, river flow rates were the lowest recorded (Table 2, Figure 7) and as noted above, zooplankton biomasses; especially *Daphnia* biomasses, were the highest recorded. It seems that during 2015, the combined effects of low turnover time plus warm epilimnetic temperatures stimulated *Daphnia* production and in turn the *Daphnia* consumed more algae.

(iii) **Density dependent growth hypothesis**: This will be investigated in the following section.

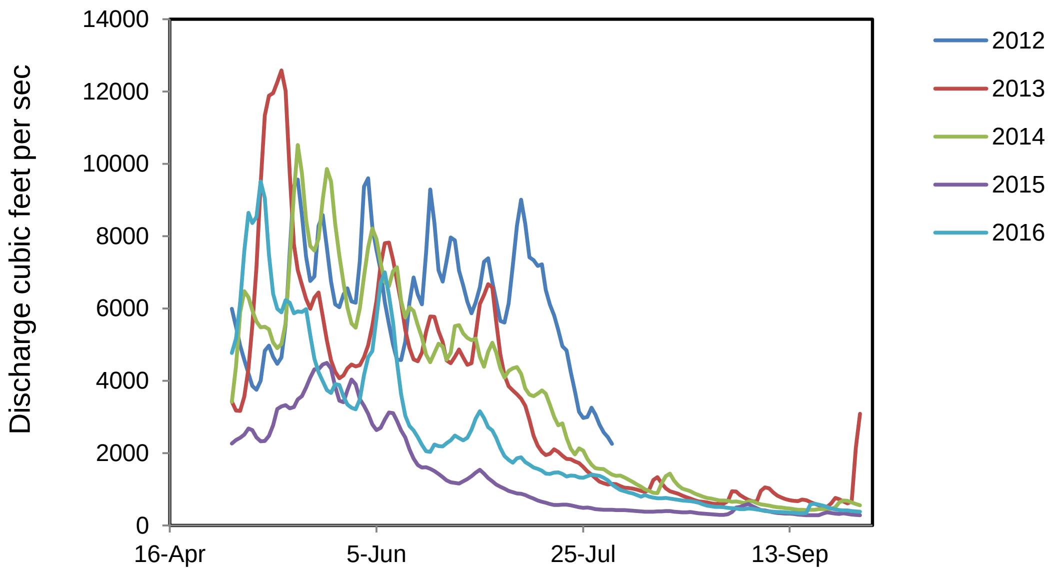


Figure 7: Rates of discharge (cubic feet per second) measured at Plain WA. See the Methods section for a full discussion of the data.

Lake Wenatchee 2012-16 juvenile Sockeye Salmon:

Table 13: Year 2012-16 Lake Wenatchee juvenile sockeye numbers (lake area 1004 ha), densities, lengths and weights. Dates highlighted in red represent fall samples. Data for in-lake 2010 and 2011 are from Hyatt (pers. com.).

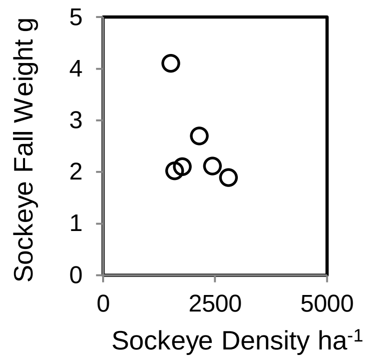
Brood year	In-Lake year	Sample date	Number per lake	Mean density per ha	95% CI measuring between-transect variability	Length mm	Weight g
2009	**2010**	21-Sep-10	1,600,000	1600	nd		2.02
2010	**2011**	1-Nov-11	2,150,000	2150	nd		2.69
2011	**2012**	25-Jun-12	1,700,000	1700	25%	31	0.27
2011	**2012**	18-Sep-12	2,800,000	2800	25%	56	1.89
2012	**2013**	10-Jul-13	2,778,381	2767	38%	38	0.66
2012	**2013**	23-Sep-13	2,650,400	2640	63%	60	nd
2013	**2014**	27-Oct-14	1,774,238	1767	19%	58	2.10
2013	**2014**	23-Feb-15	1,520,056	1514	19%	74	4.15
2014	**2015**	21-Sep-15	2,451,535	2442	18%	59	2.11
2014	**2015**	11-Mar-16	2,225,868	2217	24%	72	3.67
2015	**2016**	1-Sep-16	1,515,036	1509	49%	67	4.11
2015	**2016**	3-Nov-16	1,205,804	1201	20%	75	4.73

Juvenile Sockeye Salmon densities recorded in the fall of each sample year were higher in 2011, 2012, 2013, and 2015 (average 2456 juveniles h^{-1}) than they were in 2010, 2013, 2016 (average 1545 juveniles h^{-1}) (Table 13).

The questions of interest are (i) whether fall weights of juvenile Sockeye Salmon are correlated with in-lake densities of juvenile Sockeye Salmon, (ii) whether Sockeye Salmon fall weights are correlated with zooplankton density and (iii) whether zooplankton biomasses are correlated with fall densities of juvenile Sockeye Salmon. (iv) We would also like to know whether the high *Daphnia* biomasses observed in 2015 (Figure 5) could have influenced juvenile Sockeye Salmon fall weight (Table 13).

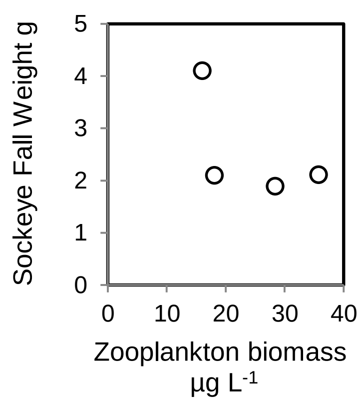
(i) Sockeye density and fall weights: The working hypothesis is that there is a negative relationship between Sockeye fall weight and Sockeye density. i.e. density-dependence. Data for Sockeye fall weights vs Sockeye densities were available for all years except 2012 and a scatter plot (Figure 8) suggests that higher densities were weakly associated with lower fall weights. However, the sample size is small and the relationship is not significant (Correlation, n= 6, R^2 = 0.27, p = 0.28).

Figure 8: Juvenile Sockeye Salmon fall weights (g) with respect to juvenile Sockeye fall density ha^{-1}



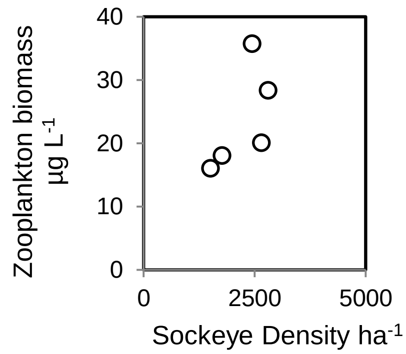
(ii) Sockeye fall weight with respect to zooplankton biomass: The working hypothesis is that higher biomasses of zooplankton should produce larger juvenile Sockeye Salmon. Data were available only for 2012, 2014, 2015 and 2016 (Figure 9). The relationship is opposite to what would be expected and there is insufficient data to test the hypothesis.

Figure 9: Juvenile Sockeye Salmon fall weights (g) with respect to zooplankton biomass (µg L^{-1} dw)



(iii) Zooplankton biomass with respect to the density of juvenile Sockeye Salmon. The working hypothesis is that higher densities of sockeye salmon should be able to consume more zooplankton and reduce zooplankton biomasses. The corollary is that growth rates of juvenile Sockeye Salmon are density dependent. i.e. higher densities of Sockeye → consume more zooplankton → zooplankton biomasses are reduced → sockeye growth rates decline. Data were available for 2012, 2013, 2014, 2015 and 2016 (Figure 10). There was no relationship between Sockeye density and zooplankton biomass.

Figure 10: Zooplankton biomass (µg L^{-1} dw) with respect to Sockeye density ha^{-1}



(iv) Special case of 2015. Did the high *Daphnia* biomasses observed in 2015 have a positive effect on juvenile Sockeye Salmon fall weight? To date, only one stomach sample (10 July 2013 – Appendix 1) has been collected from Lake Wenatchee Sockeye Salmon. That sample (n = 30 stomachs) showed that *Hesperodiaptomus* comprised 82% of the prey items found in the stomachs and that they accounted for 93% of prey biomass. *Daphnia* were the next most important prey accounting for 13% of the prey items and 7% of the prey biomass. Cyclopoids and bosminids accounted for <1% of prey biomass. These data would suggest that there should be a positive relationship between *Hesperodiaptomus* and *Daphnia* biomass and Sockeye Salmon weight. This was not the case.

Hesperodiaptomus was especially abundant in 2012 (Figure 5, Table 11), but Sockeye Salmon weights during the fall of that year were no greater than they were in 2009, 2010 and 2016. (other years with appropriate length-weight data were available Table 12).

Similarly, *Daphnia* were very abundant in 2015 (Figure 5, Table 11), and Sockeye Salmon weights during the winter of that year were no greater than they were in 2014 (the only other year when appropriate length-weight data was available Table 12).

These results do not detract from the importance of *Hesperodiaptomus* and *Daphnia* as food sources; they simply suggest that even though the Sockeye were feeding at high rates, they were unable to have negative impacts on prey availability. That is, rates of prey production were greater than rates of prey consumption.

This leads to the conclusion that Lake Wenatchee has excess rearing capacity for Sockeye Salmon.

Juvenile sockeye ages

The echogram from 25 June 2012, listed 10% of the Sockeye Salmon population as age-1. Age-1 sockeye were not identified in the September echogram from the same year (2012) and we have been unable to locate accompanying biosamples and ageing data. We are therefore unsure of the basis upon which June 2012 determinations were made and we have not included these data in this report.

Juveniles from BY2014 (inlake 2015) were sampled in March 2016 (Table 14). Four percent of the population was age-1 and 96% was age-0. Juveniles from BY2015 (inlake 2016) were sampled during September and November 2016 (Table 14). Only fish >10 cm were aged.

The September biosample comprised 137 juvenile sockeye, 18 of which were >10 cm in length and all were age-1. However, examination of weights suggested that an additional 3 juveniles should have been included as age-1s making a total of 21 age-1 juveniles (15% of the sample). For the November biosample, age determinations based on both lengths and weights were in agreement. In November 2016, 6% of the juvenile population was age-1 and 94% was age-0. In future years, ageing should be continued to assist bioenergetics modeling and to assess potential relationships between population density and percent holdovers.

Table 14: Age, lengths and weights for brood year 2014 juvenile Sockeye were sampled during March 2016. Brood year 2015 juvenile Sockeye were sampled during September and November 2016.

Brood year	Sample date	Scale age	Number in sample	Percent	Mean length (cm)	Mean weight (g)
BY2014	11-Mar-16	age 0	102	96	7.0	3.3
		age 1	4	4	11.7	13.9
BY2015	1-Sep-16	age 0	116	85	6.1	2.4
		age 1	21	15	10.5	13.3
BY2015	2-Nov-16	age 0	106	94	7.3	4.2
		age 1	7	6	10.9	13.4

Smolt lengths and weights

The following table (Table 15) appeared in the 2014 Lake Wenatchee Report. Since that date, additional data have been unavailable.

Table 15: Smolt lengths and weights taken at the lower Wenatchee smolt trap from in-lake years 2012 and 2013 along with data from previous years. In-lake year 2013 is highlighted in bold print. These data include combined age-0 and age-1smolts. Data provided by Keeley Murdoch (Yakima Nation).

Collection year	In-lake year	Brood year	Average length (mm)	Samples size	Average weight (g)	Sample size
2014	**2013**	**2012**	**76**	**5650**	**3.68**	**4300**
2013	2012	2011	86	705	7.37	682
2012	2011	2010				
2011	2010	2009				

2010	2009	2008	84	727	5.28	706
2009	2008	2007	105	277	10.26	274
2008	2007	2006	112	156	12.39	141
2007	2006	2005	80	627	4.58	615
2006	2005	2004	88	421	6.65	420
2005	2004	2003	95	193	7.15	193
2004	2003	2002	74	426	3.53	421
2003	2002	2001	84	742	5.07	732
2002	2001	2000	80	310	4.60	195
2001	2000	1999	99	21	9.14	21
2000	1999	1998	94	123	7.12	21

Smolt lengths and weights were much lower for the 2013 in-lake juveniles (smolts sampled in 2014) than they were for the 2012 in-lake juveniles (smolts sampled in the spring of 2013). In fact the 2013 fish were among the smallest on record (Table 14).

Note that the data in table 14 are not segregated with respect to age, suggesting that the 2012 smolt weights might be biased higher than the 2013 weights.

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Appendix 1

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

Samples appropriate for bioenergetics analysis were collected only during 2012 and 2013. What follows is a copy of what was included in the 2013 report. The intent is to include all of the available Lake Wenatchee Sockeye Salmon results in this 2016 report.

In-lake 2012

During 2012, Lake Wenatchee sockeye were sampled on 25 June and 18 September 2012. Fish weight data were available for both dates and the growth portion of the bioenergetics model was fit to these data (Figure 11). Fish depth distributions and densities were available for two dates (Table 15). Fish water temperatures were estimated for four dates (Table 16).

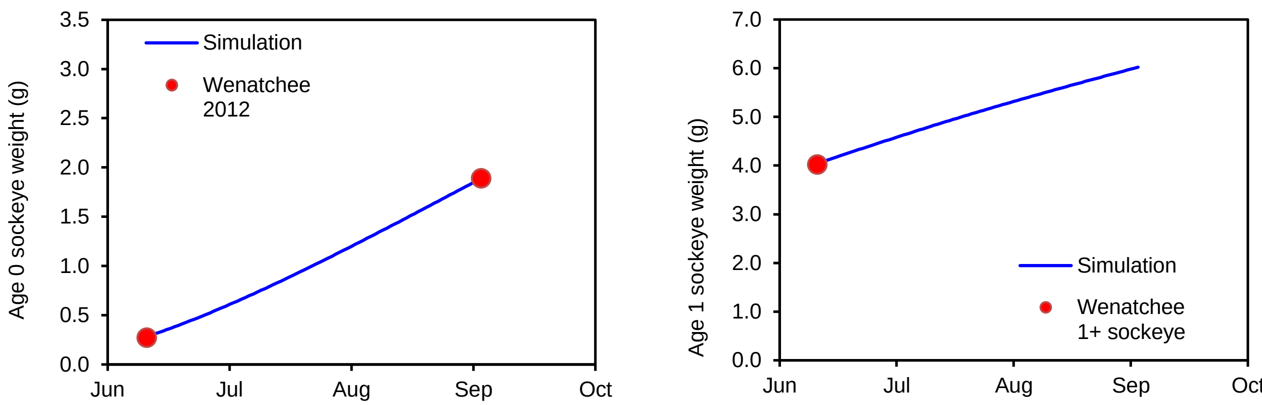

Figure 1: 2012 Lake Wenatchee age-0 and age-1 juvenile sockeye growth through the season showing the field data (red symbols) and the growth pattern simulated by the model (blue Line). The age-1 fish were not found in the September, and growth was estimated based on the rates shown by the age-0 fish.

Table 1: 2012 Lake Wenatchee sockeye depth distributions recorded on 2 dates. The shaded area includes >90% of the observations.

	25-Jun-12	18-Sep-13
2-5	0.00	0.00
5-10	0.25	0.03
10-15	0.30	0.05
15-20	0.24	0.02
20-30	0.16	0.51
30-40	0.04	0.36
40-50	0.01	0.03
50-60		0.00

Table 2: 2012 Lake Wenatchee temperatures occupied by fish when they were feeding at night. The yellow area is defined by the fish distributions shown above, and the average “fish” temperatures are shown at the bottom of the table. These temperatures were used as input for the bioenergetics simulation.

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

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

Table 3: Lake Wenatchee fish diet data.

Date	Number stomachs	Cyclopoid	Calanoid	Daphnia	Bosmina
Average number of prey per fish					
13-Jul-13	30	0.61	57.27	10.91	1.52
Seasonal average mean weight of each prey type µg dw		1.81	22.76	8.44	2.82
Average prey weight per individual fish stomach (µg dw)		1.10	1303.73	92.12	4.27
Proportion by weight		0.0008	0.9304	0.0657	0.0030

Bioenergetics simulations were run from 25 June – 18 September 2012. Fish weights (Table 13) diets (Table 17) and temperature (Table 16) were inputs. Species specific consumption outputs were recorded as µg dry weight consumed per day.

In the following figure (Figure 12), the top panel shows total zooplankton biomass during the 4 sampling periods. (2) The second panel shows zooplankton production. (3) The third panel shows consumption of zooplankton by fish. All units are µg L^{-1} dw and consumption and production are µg L^{-1} d^{-1} dw. It is immediately clear that the fish consumed only a small portion of biomass produced on each day by the zooplankton community.

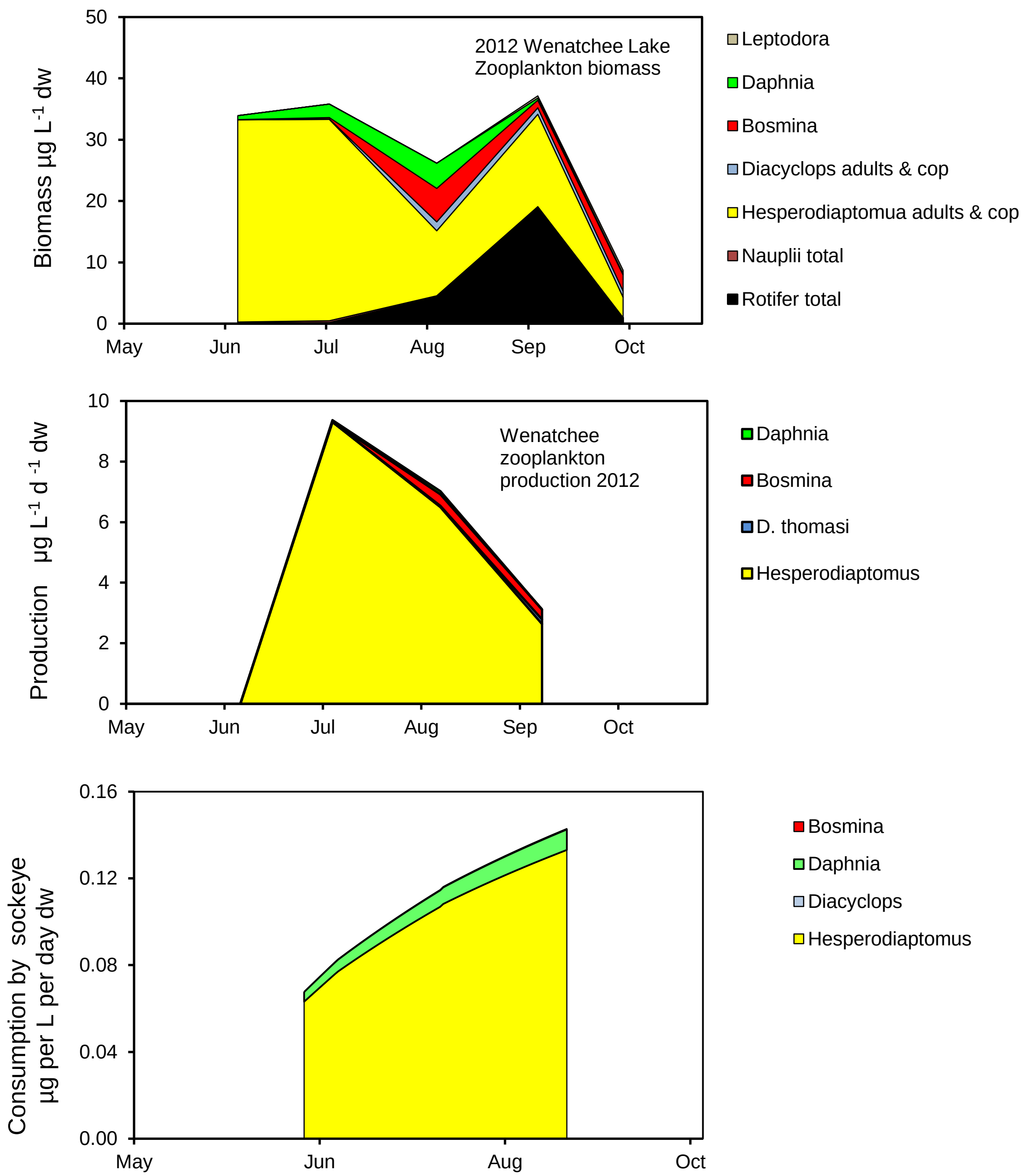

Figure 2: Wenatchee 2012 **-** Top panel = biomass of total zooplankton (µg L^{-1} dry weight), Second panel = production of the zooplankton species that were consumed by age-0 and age-1 fish (µg L^{-1} d^{-1} dry weight), bottom panel = biomass of zooplankton consumed each day by age-0 plus age-1 fish (µg L^{-1} d^{-1} dry weight).

For Lake Wenatchee 2012, the seasonal averages are summarized in Table 18. Through the summer-fall, age-0 plus age-1 fish consumed about 0.5% of prey biomass per day and 2.1% of prey production. It should be noted that the model output assumes that the fish feed on zooplankton in the top 30 m of lake water.

Table 4: Summary of Lake Wenatchee 2012 bioenergetics model input and output data.

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

In-lake 2013

During 2013, Lake Wenatchee sockeye were sampled on 10 July and 23 September 2013. Fish weight data were available only for 10 July. Mean weight for 23 September was assumed to be the same as it was in 2012 (Figure 11, Figure 13). There is no acceptable way to assess the consequences of this assumption, but as we will see the simulation is robust and even a very large difference (i.e 100 % or 200%) in growth rate would have no effect on the conclusions that will be drawn from the 2013 data. Fish depth distributions and densities were available for two dates (Table 19). Fish water temperatures were estimated for four dates (Table 20).

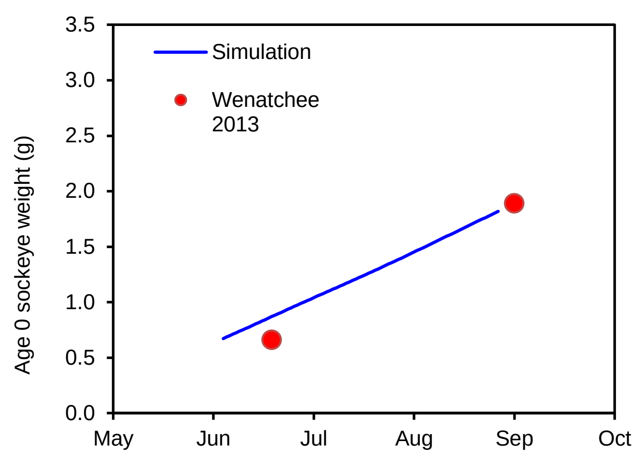

Figure 3: 2013 Lake Wenatchee fish age-0 juvenile sockeye growth through the season showing the field data (red symbols) and the growth pattern simulated by the model (blue Line).

Table 5: 2013 Lake Wenatchee sockeye depth distributions recorded on 2 dates. The shaded area includes >90% of the observations.

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

Table 6: 2013 Lake Wenatchee temperatures occupied by fish when they were feeding at night. The shaded area is defined by the fish distributions shown above, and the depth-weighted average temperatures are shown at the bottom of the table.

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

During 2012 and 2013, Lake Wenatchee juvenile sockeye diet data were collected only on one date (13 July 2013). These data are shown in table 17 above.

Bioenergetics simulations were run from 25 June – 23 September 2013. Fish weights (Table 13), diets (Table 17) and temperature (Table 20) were inputs. Species specific consumption outputs were recorded as µg dry weight consumed per day.

In the following figure (Figure 14), the top panel shows total zooplankton biomass during the 4 sampling periods. (2) The second panel shows zooplankton production. (3) The third panel shows consumption of zooplankton by fish. All units are µg L^{-1} dw and consumption and production are µg L^{-1} d^{-1} dw. It is immediately clear that during the first half of the summer, the fish consumed only a small portion of biomass produced on each day by the zooplankton community, but during the second half of the summer-fall the fish consumed more biomass than the zooplankton community could produce on each day.

For Lake Wenatchee 2013, the June-September averages are summarized in Table 21. Through this period, age-0 fish consumed about 0.5% of prey biomass per day and 11.9% of daily prey production. However, during the August-September period (Table 22), juvenile sockeye consumed 1.1% of the zooplankton standing stock per day and 328% of the daily zooplankton production. From this we conclude that density-dependent predation by fish on zooplankton could not explain the loss of zooplankton biomass observed during 2013, but that low late summer-fall zooplankton biomasses may have influenced juvenile Sockeye growth rates during the fall of 2013. Regrettably fall weights were not available in that year.

Table 6: Summary of Lake Wenatchee the June-September 2013 bioenergetics model input and output data.

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

Table 7: Summary of Lake Wenatchee the August-September 2013 bioenergetics model input and output data.

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

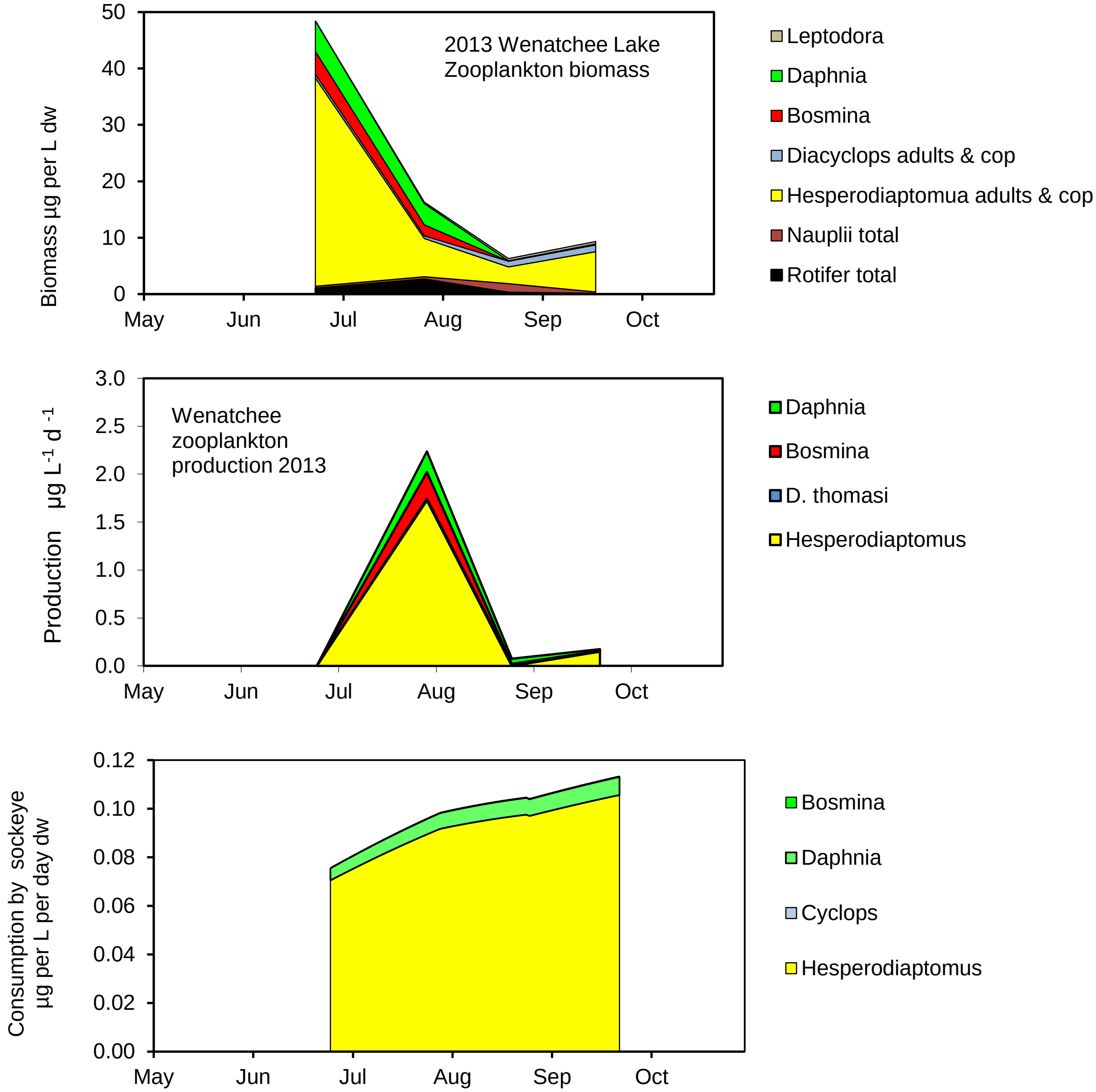

Figure 4: Wenatchee 2013. Top panel = biomass of total zooplankton (µg•L^{-1} dry weight), Second panel = production of the zooplankton species that were consumed by age-0 and age-1 fish (µg•L^{-1}•d^{-1} dry weight), Bottom panel = biomass of zooplankton consumed each day by age-0 fish (µg•L^{-1}•d^{-1} dry weight).

APPENDIX D

Fish Passage Center Letter

FISH PASSAGE CENTER

847 NE 19th Avenue, #250, Portland, OR 97232
Phone: (503) 833-3900 Fax: (503) 232-1259
www.fpc.org/
e-mail us at fpcstaff@fpc.org

MEMORANDUM

To: Jeff Fryer, CRITFC

From: Michele DeHart

Date: October 14, 2016

Re: Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, migration years 2013-2016.

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 surplus PIT tags to the ONA in 2013, 2014, 2015, and 2016 to supplement PIT-tagging efforts at Skaha and Osoyoos lakes in the spring. Based on the results from 2013 and 2014, the CSS Oversight Committee decided to include estimates of overall SARs from these two out-migration years in the 2016 Draft CSS Annual Report (McCann et al. 2016). In response to your request, we have updated analyses from previous years data requests to include estimates of juvenile survival, timing, and travel time for the 2016 PIT-tagged sockeye smolts. In addition, we provide updated estimates of overall SARs from the 2013 and 2014 out-migrations, with adults detected at Bonneville Dam through September 16, 2016. Below are results from these updated analyses, followed by more specific details.

- With each successive year of tagging, the total number of PIT-tagged sockeye smolts released in the Okanogan River basin has increased from 4,018 in 2013 to 10,238 in 2016.
- In all years of tagging (2013-2016), reliable estimates of juvenile survival from Release to Rocky Reach Dam were possible. Juvenile survivals from Release to Rocky Reach

Dam (all release sites combined) have ranged from 0.42 (95% CI: 0.38-0.45) in 2015 to 0.57 (95% CI: 0.51-0.64) in 2014.

- Reliable estimates of juvenile sockeye survival beyond Rocky Reach Dam were not always possible and, therefore, it was not always possible to estimate survival from Release to McNary Dam. When estimable, survival from Release-MCN was 0.39 (95% CI: 0.31–0.47) in 2014, 0.32 (95% CI: 0.22-0.42) in 2015, and 0.45 (95% CI: 0.28-0.62) in 2016.
- Smolt-to-Adult Return (SAR) estimates for Rocky Reach-to-Bonneville (RRE-to-BOA) were estimated for both the 2013 and 2014 out-migrations while a McNary-to-Bonneville (MCN-to-BOA) SAR was only possible for the 2014 out-migration. The RRE-to-BOA SARs for 2013 and 2014 were 8.13% (CI: 6.96-9.45%) and 2.05% (CI: 1.61-2.52%), respectively. The MCN-to-BOA SAR for 2014 was 2.82% (CI: 2.14-3.54%).

Methods

Timing and Travel Time

Juvenile passage timing and fish travel times were estimated for 2013-2016 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 (RRE), 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. Minimum, median, and maximum fish travel times were estimated from release to detection at each dam in the reach with detection capabilities. Due to a high number of PIT-tag detections in 2015, we also include estimates of travel time and passage timing to Zosel Dam on the Okanogan River.

Juvenile Survival

In April of 2016, many of the historic (MY 2013-2015) PIT-tag input files from the Okanogan River Basin wild sockeye marking program were modified with new release sites. Therefore, release site-specific estimates of survival from previous FPC analyses of Okanogan Basin wild sockeye (November 12, 2015, December 18, 2014, and March 6, 2014) are out-of-date. For this analysis, we have re-analyzed PIT-tag data for these migration years (2013-2015) to estimate juvenile survival for each release site, based on these updates to the PTAGIS database. In addition, we provide estimates for the 2016 out-migration.

For each migration year, we attempted to estimate smolt survival and associated variance estimates for all PIT-tagged juvenile sockeye from their release in the Okanogan Basin to MCN. We relied on juvenile detections at RRE, 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-RRE and RRE-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).

Over the years, PIT-tagged wild Okanogan Basin sockeye have been PIT-tagged and released from various sites, including: Osoyoos Lake Narrows Highway 3 Bridge (OSOYBR), Osoyoos Lake (OSOYOL), Skaha Dam or just below (up to 0.5 km) (SKA or SKATAL), and Skaha Lake (SKAHAL). Using the same methodologies outlined above, we attempted to estimate individual (e.g., Release-RRE and RRE-MCN) and combined reach survivals (Release-MCN) for each of these release sites, by migration year.

Smolt to Adult Survival (SARs)

With the complete return of adults from the 2013 out-migration and the nearly complete return from the 2014 out-migration, we were able to estimate Smolt-to-Adult Returns (SARs). Given the juvenile detection capabilities at RRE, we estimated SARs for two different reaches: 1) juveniles at RRE to adult return to BON (RRE-to-BOA) and 2) juveniles at MCN to adult return to BON (MCN-to-BOA). To estimate SARs we relied on the same methodology used in Chapter 4 of the Draft 2016 CSS Annual Report (McCann et al., 2016) for Chinook at steelhead from the Methow and Entiat rivers.

Results

To put out-migration conditions into context, Table 1 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 2013-2016.

Table 1. 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 (RRE), and Wells (WEL) dams in 2013-2016.

Migration Year	PRD Flow Volume (Kcfs)	Spill Proportion				
		WAN	PRD	RIS	RRE	WEL
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
2016	156.2	0.19	0.27	0.17	0.08	0.11

Travel Time and Timing

Over the last four years, PIT-tagging of juvenile sockeye in the Okanogan River Basin has occurred from early to late March through early May. Tagging efforts in 2013, 2014, 2015, and 2016 resulted in 4,018, 5,055, 7,176, and 10,238 PIT-tagged juvenile sockeye each year,

respectively. Estimates of minimum, median, and maximum travel times from release to RRE, MCN, JDA, and BON dams are provided below (Table 2). Due to a high number of PIT-tag detections in 2015, travel times to Zosel Dam (ZSL) are also provided. These travel times are based on fish that were detected at each of the sites in their respective year of out-migration. Also provided are estimates of the 95% confidence limits around the estimated median travel time.

Table 2. Travel times from release to juvenile detection site of PIT-tagged Okanogan River Basin sockeye smolts from migration years 2013 to 2016. PIT-tag detection sites include: Zosel (ZSL), Rock Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams.

Migration Year	Project	Release to Project Travel Time (days)			95% Confidence Limits	
		Min	**Med**	**Max**	**Lower**	**Upper**
2013	RRE	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	RRE	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
	RRE	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
2016	RRE	3.8	16.7	49.5	16.4	17.4
	MCN	8.0	21.4	51.5	20.6	22.3
	JDA	11.2	22.0	71.1	21.0	23.0
	BON	12.4	23.7	58.9	23.3	24.6

Overall, PIT-tagged sockeye smolts from the Okanogan River Basin passed through RRE from early to mid-May and Mid-Columbia Projects (MCN, JDA, and BON) in mid-May to early June (Table 3, Figure 1). In 2015, PIT-tagged sockeye smolts generally passed through Zosel Dam in late April to early May. The passage timing in 2016 appears to be slightly earlier than the previous three years. However, this could be due to the fact that 2016 tagging began in late March, which is about 2-3 weeks earlier than the previous three years.

Table 3. Migration timing of PIT-tagged Okanogan River Basin sockeye smolts detected at Zosel (ZSL), Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013 to 2016.

Migration Year	Project	Estimated Passage Date		
		10%	50%	90%
2013	RRE	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	2-Jun
2014	RRE	10-May	14-May	22-May
	MCN	12-May	19-May	24-May
	JDA	16-May	22-May	28-May
	BON	16-May	21-May	28-May
2015	ZSL	30-Apr	4-May	9-May
	RRE	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
2016	RRE	24-Apr	5-May	10-May
	MCN	27-Apr	10-May	18-May
	JDA	29-Apr	10-May	20-May
	BON	1-May	12-May	20-May

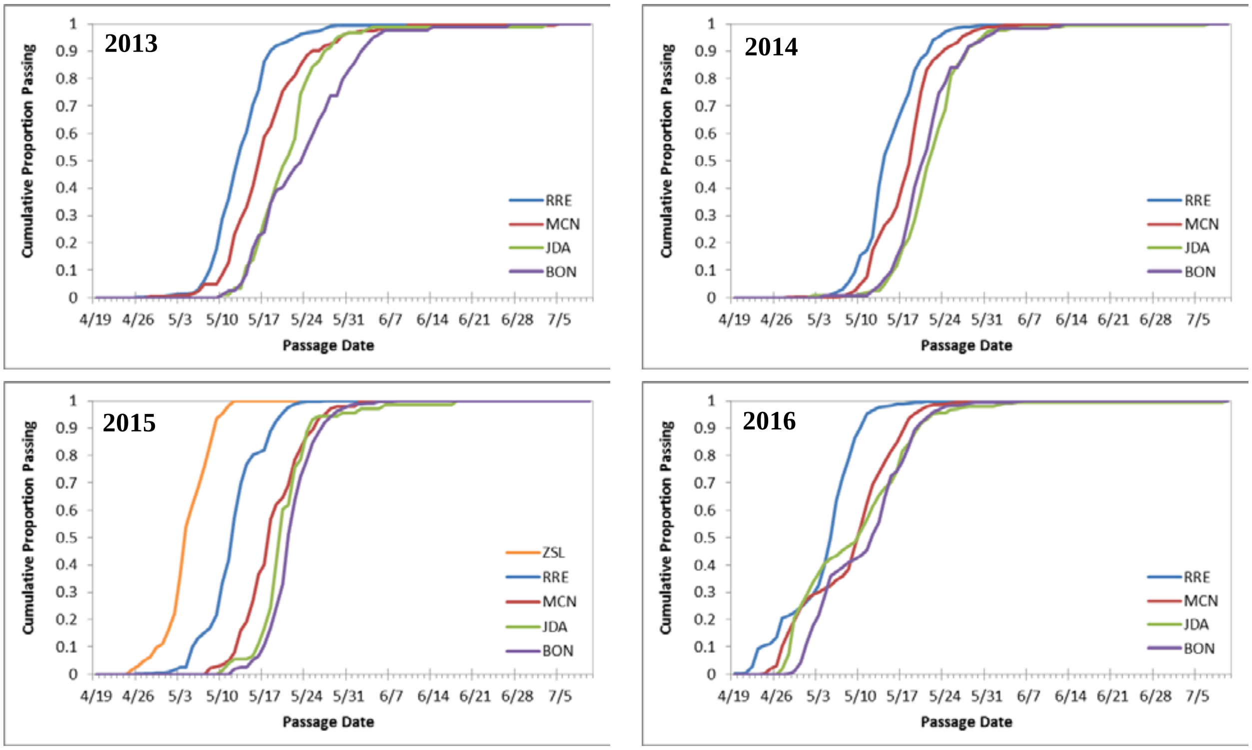

Figure 1. Cumulative passage timing of PIT-tagged wild Okanogan River basin sockeye smolts at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013, 2014, 2015, and 2016. Cumulative passage timing to Zosel Dam (ZSL) is provided for MY 2015.

Juvenile Survival

All Release Sites Combined

Estimates of individual reach survival (Release-RRE and RRE-MCN) and combined survival (Release-MCN) for each migration year (all release sites combined) are provided in Table 4. For 2013, we are only able to provide reliable estimates of survival from Release-RRE (0.49, 95% CI: 0.42-0.56). The total tags released in 2013 (4,018) was not sufficient to get reliable estimates of survival below RRE. 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 RRE-MCN that was greater than 1.0 with a high standard error. Given the anomalous estimate of survival from RRE-MCN, we were also not able to estimate survival from Release-MCN for 2013.

Migration years 2014 through 2016 had much higher total release numbers (5,055 in 2014, 7,176 in 2015, and 10,238 in 2016), which allowed for the estimation of not only individual reach survivals but also a combined (Release-MCN) reach survival for each year (Table 3). These Release-MCN survivals were: 0.39 (95% CI: 0.31-0.47) in 2014, 0.32 (95% CI: 0.22-0.42) in 2015, and 0.45 (95% CI: 0.28-0.62) in 2016.

Table 4. Survival of PIT-tagged sockeye juveniles tagged and released into the Okanogan River Basin in 2013-2016.

Migration Year	Number Tagged	Release-RRE (95% CI)	RRE-MCN (95% CI)	Release-MCN (95% CI)
2013	4,018	0.49 (0.42-0.56)	N/A	N/A
2014	5,055	0.57 (0.51-0.64)	0.68 (0.52-0.84)	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)
2016	10,238	0.56 (0.53-0.59)	0.80 (0.65-0.94)	0.45 (0.28-0.62)

Survival by Release Site

Of the 4,018 total wild sockeye that were tagged and released in 2013, 1,178 were tagged and released from Skaha Dam or just below (SKA or SKATAL), 2,783 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR), and 57 were tagged and released from Osoyoos Lake (OSOYOL). Too few tags were released from OSOYOL to estimate survivals for this release location. Due to the relatively low release totals for the SKA-SKATAL and OSOYBR release sites, we were only able to obtain reliable estimates of survival for the Release-RRE reach, which were 0.46 (95% CI: 0.36-0.57) for fish released at SKA-SKATAL and 0.50 (95% CI 0.41-0.58) for fish released at OSOYBR (Table 5). Estimates of survival for the RRE-MCN reach were unreliable for both release sites and, therefore, are not reported in Table 5.

In 2014, a total of 5,055 PIT-tagged sockeye were released in the Okanogan Basin. Of these, 1,348 were tagged and released from Skaha Dam or just below (SKA or SKATAL) and 3,707 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR). For 2014, we were able to generate estimates of both individual reach survival (Release-RRE and RRE-MCN) and combined reach survival (Release-MCN) for each of the two release sites (Table 5). Fish tagged and released from SKA-SKATAL had a Release-MCN survival of 0.25 (95% CI: 0.13-0.36) whereas those from OSOYBR had a Release-MCN survival of 0.44 (95% CI: 0.34-0.54).

In 2015, 7,176 total sockeye smolts were PIT-tagged and released into the Okanogan River Basin. Of these, 5,435 were tagged and released just below Skaha Dam (SKATAL) and 1,741 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR). We were able generate estimates of Release-RRE for both release sites (Table 5). However, we were only able to generate a reliable estimate of RRE-MCN survival for the SKATAL release site, which was 0.70 (95% CI: 0.46-0.95). The estimate of RRE-MCN survival for the OSOYBR release site was greater than 1.0 and, therefore, deemed unreliable. Similar to 2013, this was due to the lower release total for this group and the low number of detections at and below MCN. Of the 35 OSOYBR fish that were detected at MCN in 2015, only five were subsequently detected downstream of MCN. Because the RRE-MCN survival estimate was unreliable for the OSOYBR release site, we could not estimate survival from Release-MCN for this group. However, we were able to estimate Release-MCN survival for the SKATAL release site, which was 0.28 (95% CI: 0.19-0.38).

In 2016, 10,238 total sockeye smolts were PIT-tagged and released from four different release sites in the Okanogan River Basin. Of these, 2,338 were tagged and released at Skaha Lake (SKAHAL), 3,102 were tagged and released just below Skaha Dam (SKATAL), 1,754

were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR), and 3,044 were tagged and released from Osoyoos Lake (OSOYOL). We were able generate estimates of individual reach survival (i.e, Release-RRE and RRE-MCN) for all four release sites (Table 5). In addition, we were able to estimate Release-MCN survival for all four release sites. These Release-MCN survivals were: 0.38 (95% CI: 0.23-0.53) for the SKAHAL release site, 0.39 (95% CI: 0.19-0.59) for the SKATAL release site, 0.53 (95% CI: 0.31-0.75) for the OSOYBR release site, and 0.51 (95% CI: 0.31-0.75) for the OSOYOL release site. Although the point estimates of Release-MCN survival appear to be lower for the two Skaha release sites (SKAHAL and SKATAL) compared to the two Osoyoos release sites (OSOYBR and OSOYOL), the confidence intervals for all four of these release sites overlap (Figure 2). This indicates that these differences in survival are likely not significant.

It is also worth noting that the different release sites utilized for Okanogan River Basin sockeye marking over the years have relied on three different capture methods: screw trap, purse seines, and fyke nets (Table 5). Unfortunately, it is not possible to isolate the effects of capture method on estimates of survival, as each release site relied on a single capture method each year and, therefore, capture method effects would be confounded with the effects of release site.

Table 5. 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	Capture Method	Release-RRE (95% CI)	RRE-MCN (95% CI)	Release-MCN (95% CI)
2013	SKA-SKATAL	1,178	ST	0.46 (0.36-0.57)	N/A	N/A
	OSOYOL	57	FN	N/A	N/A	N/A
	OSOYBR	2,783	FN	0.50 (0.42-0.59)	N/A	N/A
2014	SKA-SKATAL	1,348	ST	0.41 (0.29-0.54)	0.60 (0.27-0.92)	0.25 (0.13-0.36)
	OSOYBR	3,707	FN	0.63 (0.56-0.71)	0.69 (0.52-0.87)	0.44 (0.34-0.54)
2015	SKATAL	5,435	ST	0.41 (0.37-0.45)	0.70 (0.46-0.95)	0.29 (0.19-0.38)
	OSOYBR	1,741	FN	0.44 (0.36-0.52)	N/A)	N/A
2016	SKAHAL	2,338	PS	0.48 (0.44-0.53)	0.79 (0.47-1.11)	0.38 (0.23-0.53)
	SKATAL	3,102	ST	0.47 (0.41-0.53)	0.84 (0.59-1.09)	0.39 (0.19-0.59)
	OSOYBR	1,754	FN	0.74 (0.65-0.84)	0.71 (0.41-1.02)	0.53 (0.31-0.75)
	OSOYOL	3,044	PS	0.56 (0.51-0.62)	0.91 (0.57-1.24)	0.51 (0.31-0.75)

Capture Methods: ST = Screw Trap, FN = Fyke Net, and PS = Purse Seine

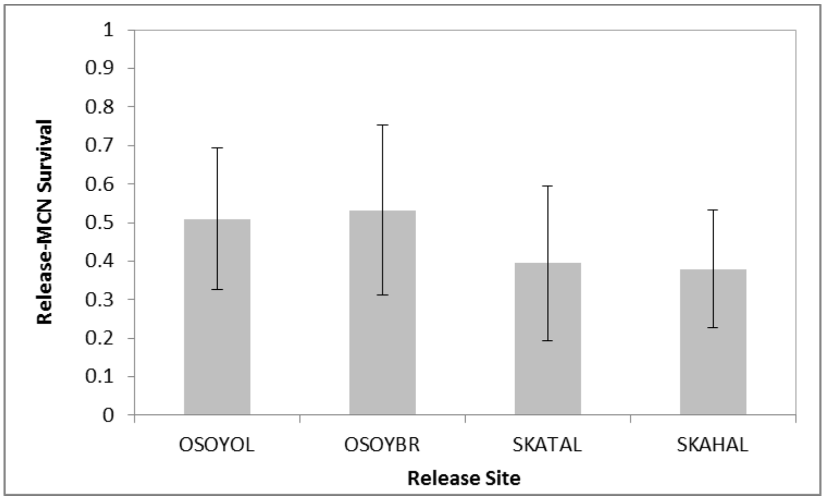

Figure 2. Estimated Release-MCN survivals (95% confidence intervals in parentheses) of PIT-tagged wild Okanogan River wild sockeye from each of four release sites used in 2016.

Smolt to Adult Survival (SARs)

As of September 16, 2016, 162 of the juveniles that were PIT-tagged and released in 2013 have been detected as adults at Bonneville Dam (BOA). Of these 162 adults, 59 returned in 2014, 99 returned in 2015, and 4 returned in 2016. For the PIT-tagged smolts that were released in 2014, 60 have been detected at BOA as adults (through September 16, 2016). Of these, 3 returned in 2015 and 57 returned in 2016.

Both Rocky Reach-to-Bonneville (RRE-to-BOA) and McNary-to-Bonneville (MCN-to-BOA) SARs are provided below (Table 6). Due to an unreliable estimate of juvenile survival for the RRH-MCN reach in 2013 (Table 4), the MCN-to-BOA SAR for 2013 is not provided.

Table 6. Overall McNary-to-Bonneville (MCN-to-BOA) and Rocky Reach-to-Bonneville (RRE-to-BOA) SARs for Okanogan River wild sockekeye, 2013-2014.

Juvenile migration year	Smolts arriving MCN[A]	MCN-to-BOA			Smolts arriving RRE[B]	RRE-to-BOA		
		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL		%SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2013[C]	--	--	--	--	1,993	8.13	6.96	9.45
2014[D]	2,126	2.82	2.14	3.54	2,930	2.05	1.61	2.52

[A] Estimated population of tagged study fish alive to MCN tailrace (included fish detected at the dam and those estimated to pass undetected). CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

[B] CJS estimation of S1 uses both the detector and recaptures at Rocky Reach Dam, as well as PIT-tags detected on bird colonies in the Columbia River estuary and adult detections to augment the NOAA Trawl detections below BON.

[C] Juvenile survival estimate for RRE-MCN reach was greater than 100%, resulting in an overestimate of the juvenile population at MCN. Therefore, $SAR_{MCN\text{-}to\text{-}BOA}$ was not estimated for this year.

[D] Incomplete, 2-salt returns through Sept. 16, 2016

Conclusions

The CSS Oversight Committee continues to believe that a long-term monitoring group for wild sockeye from the Okanogan Basin would be valuable if enough PIT-tagged individuals could be released annually. Results from the last four years of tagging indicate that approximately 5,000 PIT-tagged individuals are needed to obtain reliable estimates of juvenile survival from release to MCN. With reliable estimates of juvenile survival, it also appears that estimates of SARs (RRE-to-BOA and MCN-to-BOA) are also possible. The CSS Oversight Committee hopes to continue to incorporate results from this group into future annual reports.

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