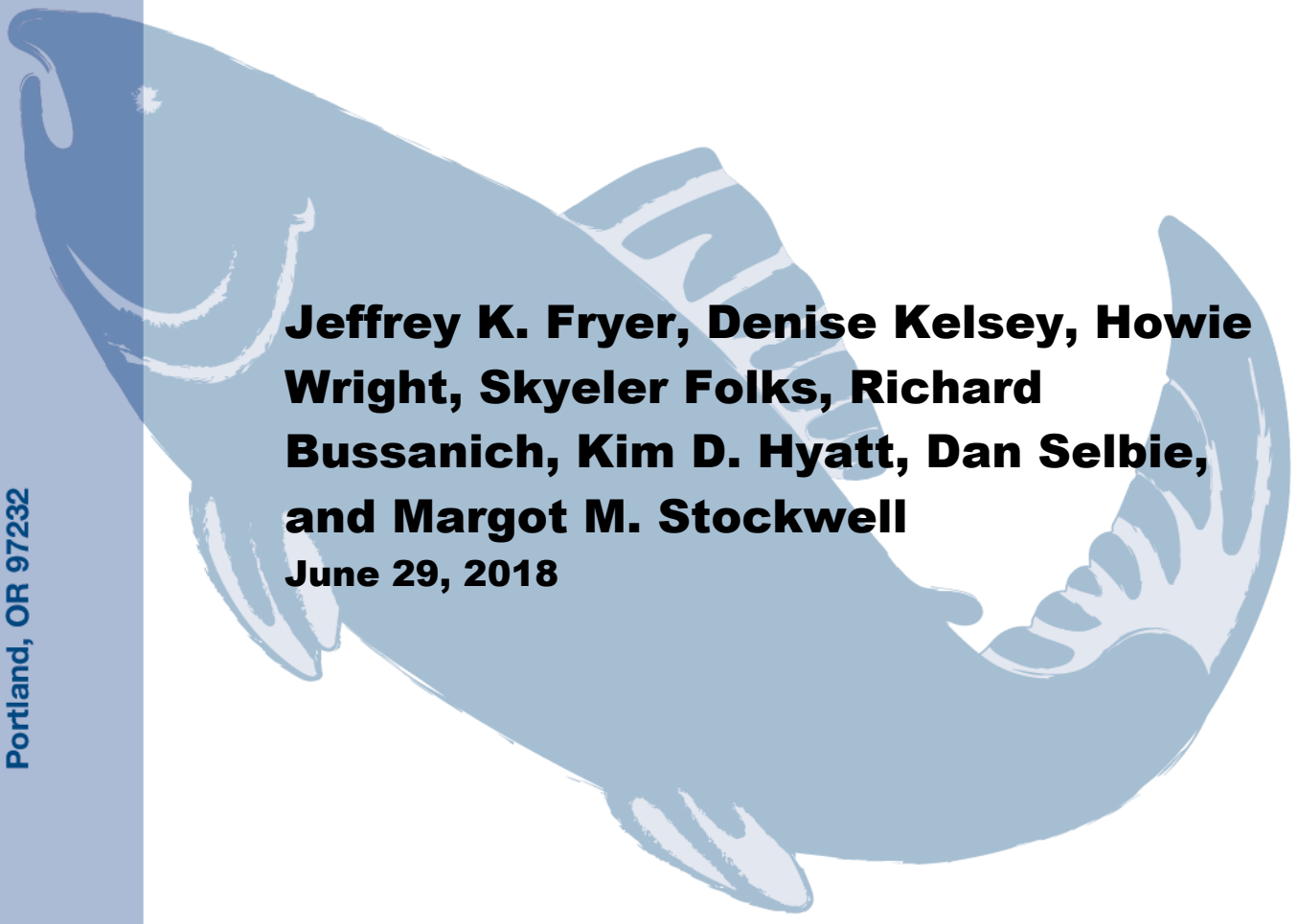
CRITFC
TECHNICAL REPORT 18-02

Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2016 and 2017



Jeffrey K. Fryer, Denise Kelsey, Howie Wright, Skyeler Folks, Richard Bussanich, Kim D. Hyatt, Dan Selbie, and Margot M. Stockwell

June 29, 2018

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

Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2016 and 2017

Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00, Contract 75801

Report date range: 1/16–12/17

Jeffrey K. Fryer and Denise Kelsey
Columbia River Inter-Tribal Fish Commission

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

Kim D. Hyatt, Dan Selbie, and Margot M. Stockwell
Department of Fisheries and Oceans, Canada

June 29, 2018

EXECUTIVE SUMMARY

A total of 1655 Sockeye Salmon, *Oncorhynchus nerka*, were sampled and PIT tagged at the Bonneville Dam Adult Fish Facility in 2016, while 1092 were PIT tagged in 2017. 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. Upstream detections of adult PIT tagged Sockeye Salmon tracked by this project resulted in an estimated survival in 2016 of 89.2% to McNary Dam and 81.2% to Rock Island Dam for 2016. In 2017, estimated survival to McNary was 81.7% and 70.8% to Rock Island Dam.

Genetic stock identification (GSI) was used to classify the stock of 1,706 Sockeye Salmon sampled at Bonneville Dam in 2016 and 1,093 in 2017. After excluding likely sample mix ups (four in 2016 and one in 2017), concurrence was 99.7% in 2016 and 99.8% in 2017. Stock composition at Bonneville Dam in 2016 was estimated as 70.1% Okanagan, 27.7% Wenatchee, 1.6% Yakima, 0.4% Deschutes, and 0.3% Snake River; in 2017 it was estimated as 59.2% Okanagan, 39.6% Wenatchee, 0.7% Yakima, 0.5% Snake, and 0.1% Deschutes.

Upstream detections of Sockeye Salmon PIT tagged by this project resulted in an estimated survival of in 2016 of 94.0% to The Dalles Dam, 89.2% to McNary Dam, and 81.6% to Rock Island Dam. In 2017, estimated survival was 89.3% to The Dalles Dam, 81.7% to McNary Dam, and 70.8% to Rock Island Dam. Survival to Rock Island Dam in 2016 was second highest since 2006 while in 2017 it was the second lowest since 2006.

The estimates from PIT tag data of adult Sockeye tagged at Bonneville Dam indicates minimum fallback rates at Columbia River mainstem dams that range from 0.1% at Bonneville Dam to 2.6% at Rocky Reach Dam in 2016 and from 0.1% at McNary Dam to 3.1% at Priest Rapids and The Dalles dams in 2017.

The median travel time of Sockeye Salmon between Bonneville and Rock Island dams in 2016 was 11.7 days and in 2017, 13.1 days. This resulted in a median migration rates of 41.8 km/d in 2016 and 37.5 km/d in 2017.

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, 2016 and December 31, 2016 at Zosel Dam a total of 26 Chinook, 28 steelhead, 1795 Sockeye and 1 White Sturgeon were detected, in 2016 7 Chinook, 9 steelhead, 164 Sockeye, 1 Coho and 2 White Sturgeon were detected. High flows in 2017 resulted in spillgates open sufficiently to allow salmon to swim upstream without being detected by fishway PIT tag antennas. As a result, an estimated 74.5% of passing PIT tagged sockeye were not detected.

At Wells Dam in 2016, 810 Sockeye Salmon were sampled and 808 PIT tagged Sockeye Salmon released. In 2017, a low run size resulted in only 334 Sockeye Salmon being sampled, tagged, and released.

Okanagan juvenile PIT tagging in 2016 resulted in 10,241 smolts being tagged between March 22 and April 29, 2016 from Sockeye Salmon captured at four sites, SKATAL (the tailrace downstream of Skaha Outlet Dam), SKAHAL (Skaha Lake), and OSOYOBR (downstream of the Highway 3 Bridge at the Osoyoos Narrows) and OSOYOL (Osoyoos Lake). Reliable estimates of survival from release to Rocky Reach Dam could be calculated for all four release groups with survival estimates to Rocky Reach Dam ranging from 0.468 (SE-0.030) at SKATAL to 0.747 (SE=0.048) at OSOYOL. 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 ranged from 11.2 days for the SKAHAL group to 23.9 days for the OSOYOL group.

Okanagan juvenile PIT tagging in 2017 resulted in 8,794 smolts being tagged between April 26 and May 3, 2017 from Sockeye Salmon captured at two sites, OSOYOBR (downstream of the Highway 3 Bridge at the Osoyoos Narrows) and OSOYOL (Osoyoos Lake). Estimated survival to Rocky Reach Dam was 0.804 (SE-0.076) for the OSOYBR site to 0.621 (SE=0.026) for the OSOYOL site. 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 12.8 days for the OSOYBR

This project is proposed to continue and evolve over the next several years as there are several priority areas to investigate. One area of continuing concern is adult survival between Wells Dam and Osoyoos Lake. We had thought we had a good understanding of mortality sites upstream of Wells Dam, thanks to PIT tag detection in Zosel fish ladders as well as acoustic tag results. However, in 2016, we dropped the acoustic tagging due to the large expense for the relatively small number of tags we could

deploy, and instead focused on PIT tags. We had good PIT tag detection at Zosel Dam in 2016, but in 2017 over 70% of the run passed through the spillways at Zosel Dam, and we predict that 2018 may be the same as flows are forecast to be high. Of the Sockeye Salmon passing Wells Dam in 2017, only 45.2% were detected at OKC. It is unknown what portion of this mortality may have been associated with migration conditions downstream of Zosel Dam or in Osoyoos Lake. We would like to improve PIT tag detection at, or near, Zosel Dam to improve our understanding of adult survival to this point at high flows when Sockeye Salmon do not use the fish ladders.

Lake Wenatchee acoustic trawl surveys (ATS) are expected to continue through along with limnological sampling to better estimate the annual production and future productive potential of Lake Wenatchee Sockeye Salmon. The ATS data from Skaha, Osoyoos, and Wenatchee lakes are also used in Columbia Basin run forecasting for Sockeye. 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.

An exciting development in recent years has been the colonization of Sockeye in Skaha Lake once passage was provided at McIntyre and Skaha dams. Spawning beds, funded by Grant and Chelan Public Utility District (PUD)s have been built to encourage Sockeye spawning in the Penticton Channel immediately downstream of Okanagan Lake. We plan to test the use of sidescan sonar in 2018 to map and assess the quality of the spawning gravels in this area and correlate the data with the actual distribution of redds. This also will serve as baseline data to evaluate how the quantity and quality of these spawning beds changes over time.

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 500,000 Sockeye Salmon have occurred with less than 5% of historical Columbia Basin habitat available (Fryer 1995), making historical estimates appear conservative. To further explore this question, we are working with the ONA, DFO, and Grant, Chelan, and Douglas PUDs 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. We expect at least one peer-reviewed journal article in the upcoming year as well as a Master's thesis to be published from this work.

ACKNOWLEDGMENTS

The following individuals assisted in this project: Steve Anglea and Brett Turley of Biomark, Maureen Kavanagh and Christine Peterson of Bonneville Power Administration, Joe Nowinski, Ryan Branstetter, Amber Cate, Crystal Chulik, Melissa Holland, David Graves, Doug Hatch, Jayson FiveCrows, Jon Hess, Aaron Ikemoto, and Agnes Strong of the Columbia River Inter-Tribal Fish Commission; John Arterburn, Casey Baldwin, and Sonya Schaller of the Confederated Tribes of the Colville Reservation; Ben Hausmann, Tammy Mackey, Jon Rerecich, and Casey Welch of the US Army Corps of Engineers; Dan Selbie of Canada Department of Fisheries and Oceans; Don McQueen; Ryan Benson, Jessica Hilton-McPherson, Sheena Hooley, Chelsea Mathieu, Amanda Stevens, Jamison Squakin, Cash Tonasket, Lynnea Wiens, and Nicholas Yaniw of the Okanagan Nation Alliance, Tom Scott of the Okanagan-Tonasket Irrigation District; Nicole Trancreto of the Pacific States Marine Fisheries Commission; Al Josephy of Washington Department of Ecology, Travis Maitland, Ben Truscott, and Andrew Murdoch of Washington Department of Fish and Wildlife; and Keely Murdoch, Corey Kampaus, Kraig Mott, Casey Heemsah, Clifford Smith, and Terri Benson of the Yakama Nation.

This report summarizes research funded by the Bonneville Power Administration under the Columbia Basin Fish Accords and the Pacific Salmon Commission.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **i**

ACKNOWLEDGMENTS ..... **v**

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

LIST OF FIGURES ..... **xv**

INTRODUCTION **18**

METHODS **22**

Adult PIT Tag Detection Infrastructure *22*
Zosel and OKC PIT tag arrays 22

Adult Sampling at Bonneville, Wells, and Priest Rapids dams *22*
Bonneville Dam Sampling 22
Wells Dam Sampling 23
Priest Rapids Dam Sampling (2016 only as part of Whooshh project) 24

Stock Identification and Classification *27*

Genetic Stock Identification (GSI) *27*
PIT Tag Stock Identification 28
Final Stock Classification Rules 29

Age Analysis *30*

Site Detection Efficiencies *30*

Escapement *30*

Upstream Survival/Conversion Rates *31*

Migration Timing and Passage Time *31*

Bonneville Stock Composition Estimates Using PIT Tag Recoveries *32*

Okanagan and Wenatchee Age and Length-at-age Composition *32*

Night Passage *33*

Fallback *33*

Acoustic Trawl Surveys for Juvenile Sockeye Abundance *34*

Juvenile PIT Tagging *35*
Rotary Screw Trap (RST) Operation at Skaha Lake Outlet-2016 35
Smolt Trapping at Osoyoos Lake Narrows-2016 36
Smolt Seining at Osoyoos and Skaha lakes-2016 and 2017 38

RESULTS **39**

Upstream Migration Analysis *39*
Mixed Stock Sample Size and Age Composition 39
Upstream Recoveries, Mortality, and Escapement: 43
Migration Rates and Passage Time 50
Night Passage 54

Fallback 54
2016 Stock Composition Estimates 58
2017 Stock Composition Estimates 62
Stock Specific Upstream Survival 66
Wells Dam Sampling Results *69*
2016 Priest Rapids Dam Sampling *71*
Okanagan and Wenatchee Age, and Length-at-Age Composition *72*
Stock Composition at Wells Dam *75*
Migration into Natal Areas-Okanagan River *76*
Migration into Natal Areas-Wenatchee River *86*
Upstream Survival Comparisons with Sockeye Tagged as Juveniles *88*
Lake Wenatchee Acoustic Trawl and Limnology Surveys *92*
Brood Year 2015 nerkids (Sockeye and Kokanee) 92
Brood Year 2016 nerkids (Sockeye and Kokanee) 92
2016 Juvenile PIT Tagging *94*
2017 Juvenile PIT Tagging *98*
DISCUSSION **102**
REFERENCES **111**
Appendix A **114**
2016 and 2017 Performance of Okanagan Basin PIT Tag Detection Infrastructure Funded by this Project. *114*
Accords-project Funded PIT Tag Antenna Performance in 2016 114
Accords-project Funded PIT Tag Antenna Performance in 2017 119
Appendix B **123**
Interrogation Sites in the Columbia Basin that have Detected Sockeye Salmon *123*
Appendix C **133**
ȻAWST'IKʷ [Okanagan River] Sockeye Smolt out of Basin Survival: PIT Tagging 2015 and 2016 ..... *133*
Appendix D **170**
Fish Passage Center Memoranda regarding 2016 and 2017 Okanagan Sockeye Smolt Survival *170*
Appendix E **191**
History of Okanagan Network of PIT Sites Funded by the Accords *191*

LIST OF TABLES

Table 1. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2016. 39

Table 2. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2017. 40

Table 3. Number and percentage of Bonneville Dam PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2016-17 compared to 2006-2015. Okanagan and Wenatchee in-stream antenna sites (LWE, UWE, OKL) are also included since 2014. 41

Table 4. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2016. (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)..... 42

Table 5. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2017. (Weighted by Statistical week). (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.) 42

Table 6. Survival of Sockeye PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams 2006-2017. 43

Table 7. Survival of Sockeye PIT, tagged as smolts at Rock Island Dam, on their adult upstream migration from Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams 2008-2017. 44

Table 8. Percentage of PIT tagged Sockeye Salmon detected at upstream dams subsequent to tagging at Bonneville Dam to upstream dams, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2016..... 45

Table 9. Percentage of PIT tagged Sockeye Salmon detected at upstream dams subsequent to tagging at Bonneville Dam to upstream dams, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2017..... 45

Table 10. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2016 and the p-value for a linear regression between weekly reach survival and statistical week. 48

Table 11. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2017 and the p-value for a linear regression between weekly reach survival and statistical week. 48

Table 12. Survival of Sockeye groups PIT tagged as juveniles from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2016. 50

Table 13. Survival of Sockeye groups PIT tagged as juveniles from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2017. 50

Table 14. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2016. 51

Table 15. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2017. 51

Table 16. 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 2016. 52

Table 17. 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 2017. 52

Table 18. 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 2016. 53

Table 19. 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 2017. 53

Table 20. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2016. 54

Table 21. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2017. 54

Table 22. Estimated fallback rates for Sockeye Salmon at dams in 2016. (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.) 55

Table 23. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2016. 56

Table 24. Estimated dam fallback rates for Sockeye Salmon tagged at Bonneville Dam in 2017. (NA indicates Sockeye were not detected at a dam outside the range of the particular stock.) 57

Table 25. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2017. 57

Table 26. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2016. 58

Table 27. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2016 with a comparison to stock composition estimates estimated using visual dam counts as well as using only PIT tags and GSI. 59

Table 28. GSI classification of Sockeye last detected in non-terminal areas (downstream of OKL, LWE, and Ice Harbor Dam) in 2016. 61

Table 29. Type and number of fin clips by stock for Sockeye Salmon sampled at Bonneville Dam in 2016. 62

Table 30. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2017. 63

Table 31. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2017 and a comparison to stock composition estimates estimated using visual dam counts. 64

Table 32. GSI classification of Sockeye last detected in non-terminal areas (downstream of OKL, LWE, and Ice Harbor dams) in 2017. 65

Table 33. Type and number of fin clips by stock for Sockeye Salmon sampled at Bonneville Dam in 2017. 66

Table 34. Stock specific survival from Bonneville Dam weighted by weekly Bonneville Dam run size, as estimated by GSI and PIT tags in 2016. 67

Table 35. Stock specific survival from Bonneville weighted by weekly Bonneville Dam run size, as estimated by GSI and PIT tags in 2017. Survival to Zosel Dam could not be accurately estimated in 2017 due to high flows resulting in Sockeye bypassing fish ladders where PIT tag antennas are located. 68

Table 36. Number of Sockeye Salmon sampled and PIT tagged at Wells Dam by date and statistical week in 2016. 69

Table 37. Number of Sockeye Salmon sampled and PIT tagged at Wells Dam by date and statistical week in 2017. 69

Table 38. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2016. Sex was visually estimated when the fish were sampled. 70

Table 39. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2017. Sex was visually estimated when the fish were sampled. 70

Table 40. Summary of 2016 Priest Rapids Dam Sockeye sampling. 71

Table 41. Age composition of Sockeye Salmon sampled at Priest Rapids Dam in 2016. 72

Table 42. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2016. 72

Table 43. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2017. 73

Table 44. Length-at-age (fork length) 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 2016. 74

Table 45. Length-at-age (fork length) 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 2017. 74

Table 46. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI and PIT tags in 2016. (Wells Dam estimates are weighted by the weekly Wells Dam run size, Bonneville estimates are unweighted.) 75

Table 47. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI and PIT tags in 2017. (Wells Dam estimates are weighted by the weekly Wells Dam run size, Bonneville estimates are unweighted.) 76

Table 48. Number of Wells Dam sampled and tagged Sockeye released upstream at the Wells Dam East Bank Fish ladder in 2016 with the estimated percentage last detected by site (weighted by weekly run size at Wells Dam). Rates for Bonneville and Priest Rapids dams' tagged Sockeye Salmon detected at Wells Dam are shown for comparison. 78

Table 49. GSI stock classification by basin of last detection for Sockeye Salmon tagged at Wells Dam in 2016 which were not detected at, or upstream of, Zosel Dam. 79

Table 50. Number of Wells Dam sampled and tagged Sockeye released in the Wells Dam East Bank fish ladder in 2017 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..... 80

Table 51. GSI stock classification by basin of last detection for Sockeye Salmon tagged at Wells Dam in 2017..... 81

Table 52. Groups of PIT tagged Sockeye passing OKL and percent detected upstream at OKC by date at passing OKL in 2017. 85

Table 53. 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 2016. 87

Table 54. 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 2017. 87

Table 55. 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 2016. An asterisk (*) indicates Sockeye which strayed from the normal migration route for the stock of concern. Stock at Bonneville Dam was estimated using GSI. 88

Table 56. Distribution of Sockeye Salmon in the Wenatchee Basin in 2016 PIT tagged as both juveniles and adults. 90

Table 57. 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 2017. An asterisk (*) indicates Sockeye which strayed from the normal migration route for the stock of concern. Stock at Bonneville Dam was estimated using GSI. 91

Table 58. Distribution of Sockeye Salmon in the Wenatchee Basin in 2017 PIT tagged as both juveniles and adults. 91

Table 59. 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. 93

Table 60. Brood Year 2016 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. 93

Table 61. Summary of Okanagan Sockeye smolt PIT tagging effort, 2016. 95

Table 62. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2016. 95

Table 63. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2016. 96

Table 64. Mean travel time from release to downstream sites for Sockeye tagged in the Okanagan, Wenatchee, and Snake basins in 2016. 98

Table 65. Summary of Okanagan Sockeye smolt PIT tagging effort, 2017. 99

Table 66. Mean survival estimate for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2017. 99

Table 67. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2017. 100

Table 68. Mean travel time from release to downstream sites for Sockeye tagged in the Okanagan, Wenatchee, and Snake basins in 2017. 101

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. 19

Figure 2. Images from the 2016 Priest Rapids Sockeye migration study. Left: remaining ladder climb after sampling at OLAFT. Top Left: CRITFC and Yakama Nation crew sampling and PIT tagging Sockeye at OLAFT. Top Right: Hand feeding Sockeye into the WFTS. Right: Week 30 WFTS fish transporting to top of the dam. Bottom: Week 30 WFTS spanning the dam crest. 25

Figure 3. Rotary screw traps used to trap juvenile Sockeye Salmon located downstream of Skaha Dam. 36

Figure 4. Schematic diagram of the fyke net located immediately downstream of the Highway 3 bridge in Osoyoos used in 2016 to trap Sockeye. 37

Figure 5. Fyke net used to trap juvenile Sockeye Salmon downstream of the Highway 3 Bridge in Osoyoos. 38

Figure 6. 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 2016. 46

Figure 7. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2017. 47

Figure 8. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2017. 49

Figure 9. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2016. 49

Figure 10. Percentage of the Sockeye run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, Yakima, and Deschutes origin by week in 2016. 60

Figure 11. Percentage of the Sockeye run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, Yakima, and Deschutes origin by week in 2017 65

Figure 12. Number of Sockeye (PIT tagged at Bonneville, Priest Rapids, and Wells dams) detected at OKL by date in 2016 with daily Okanagan River temperatures. 81

Figure 13. Percentage of Sockeye Salmon tagged at Bonneville, Priest Rapids, and Wells dams passing OKL and detected at Zosel Dam in 2016 with daily Okanagan River temperatures. 82

Figure 14. Percentage of Sockeye tagged at Bonneville, Priest Rapids, and Wells Dam passing Wells Dam subsequently detected at Zosel Dam by date past Wells Dam in 2016. Okanagan River temperatures were recorded at the Malott and Oroville gaging station. (http://waterdata.usgs.gov/nwis)..... 82

Figure 15. Number of Sockeye Salmon tagged passing OKL by date and Okanagan River temperatures at Malott and Oroville in 2017..... 83

Figure 16. Number of PIT tagged adult Sockeye PIT detected by date at OKL with mean daily Okanagan River temperatures at the USGS Malott gauging station in 2017. 84

Figure 17. Number of Sockeye detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2016..... 85

Figure 18. Number of Sockeye detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2017..... 86

Figure 19. The Wenatchee Basin showing PIT tag interrogation sites and highlighting sites where Sockeye were detected in 2016 and 2017. Also displayed is the spawning area of Sockeye. Appendix B Table B1 has site information. 89

Figure 20. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam to McNary, John Day, and Bonneville dams with 95% confidence intervals in 2016. 97

Figure 22. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam to McNary, John Day, and Bonneville dams with 95% confidence intervals in 2017. 100

Figure 23. Mean daily water temperature at Bonneville Dam during the months of June-August in the years 2015-2017. 102

Figure 24. Mean daily flow at Bonneville Dam during the months of June-August in the years 2015-2017 with the mean 2006-2015 flow for comparison. 103

Figure 25. Lower Wenatchee River water temperatures 2015-2017. 104

Figure 26. Detections at avian colonies in 2016 and 2017of Sockeye Salmon PIT tagged by this project. 107

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 2018, FPC 2018). The Bonneville Dam sockeye count dropped to 342,498 in 2016 and 87,693 in 2017.

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. In recent years, there have also been efforts to reintroduce Sockeye Salmon to the Deschutes and Yakima basins.

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).

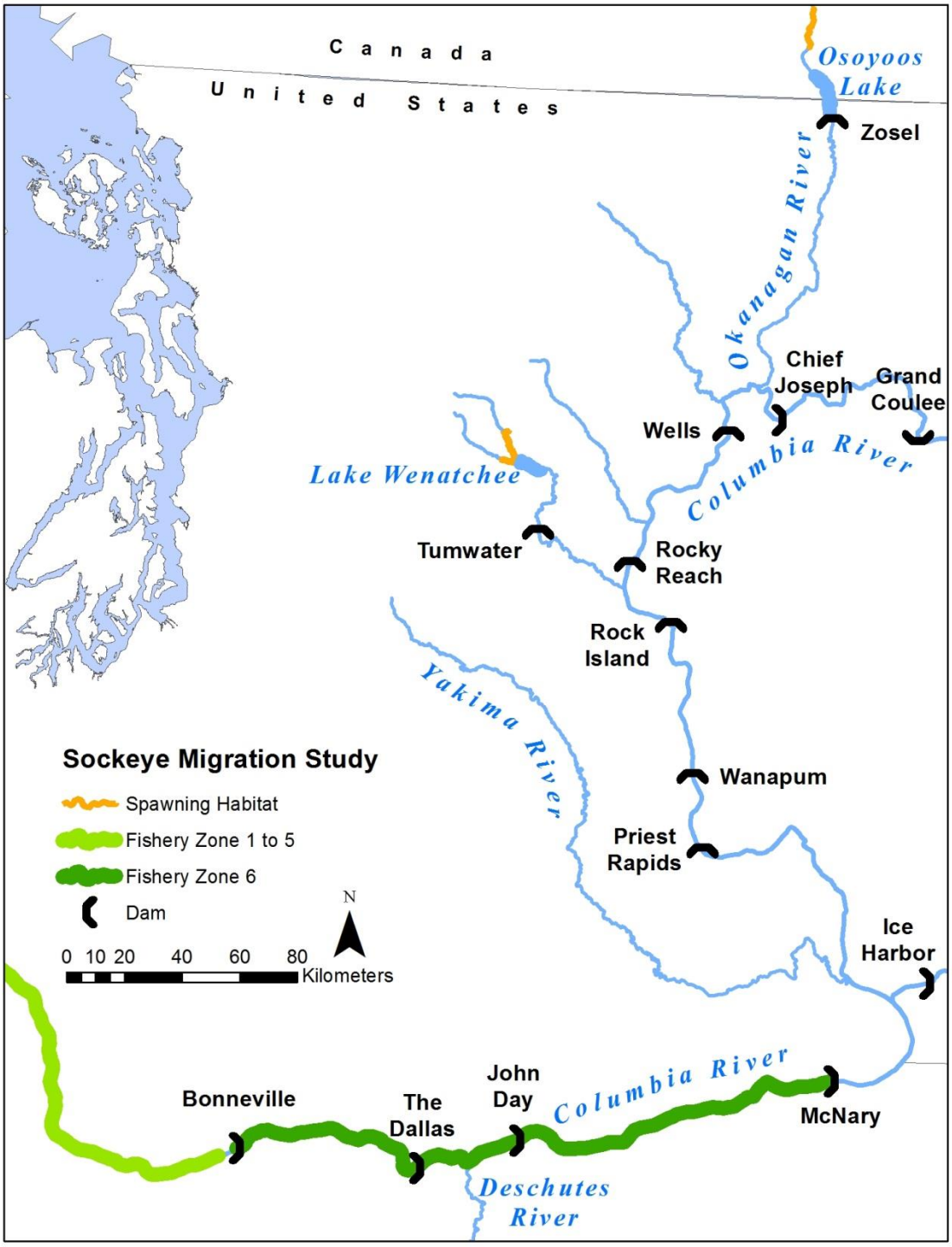


Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the two major Sockeye Salmon production areas and significant dams on their migration route.

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) and in 2010 funded installation of antennas at both Zosel Dam fishways (ZSL) in 2010, Skaha Dam fishway (SKA) in 2015, a second OKC antenna array in March, 2017, and an antenna across the Okanagan River at Penticton Channel (OKP) in November, 2017.

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 Tag Detection Infrastructure

Zosel and OKC PIT tag arrays

This project has installed five Okanagan River PIT tag detection sites to detect PIT tagged Sockeye Salmon as they ascend the Okanagan River. The first site (OKC at www.ptagis.org), 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. A second OKC channel-width array was added in 2017. The second site installed was at Zosel Dam (ZSL at www.ptagis.org) in September 2010, and consists of two antennas in each of the two fish ladders at Zosel Dam in Oroville, WA (Fryer et al. 2011). A floating antenna was added immediately upstream of one spillway at Zosel Dam in 2015 and a second spillway in 2016, although neither floating antenna was deployed in 2017. An experimental PIT tag antenna was added to one spillway at McIntyre Dam as well two antennas in Skaha Dam fish ladder (SKA at www.ptagis.org) in 2015. Finally, a channel-width PIT array was installed in the Penticton Channel downstream of Okanagan Lake (OKP) at rkm196 on November 29, 2017. PIT tag detection results for OKC, ZLS, and SKA in 2016 and 2017 are found in Appendix A while a history of OKC, OKP, SKA and Zosel is found in Appendix E.

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.

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 east 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. All sampled Sockeye were released back into the Wells Dam east bank ladder immediately upstream of the weir diverting Sockeye Salmon into the trap.

In 2015 we noted a relatively high percentage of late migrating Sockeye Salmon at Wells Dam and were interested in the success of a late migrating strategy[2]. Washington Department of Fish and Wildlife (WDFW), which was trapping Chinook broodstock at Wells Dam in August 2016, agreed to sample and PIT tag Sockeye Salmon after our sampling stopped. We did not have WDFW do any late season trapping in 2017.

Priest Rapids Dam Sampling (2016 only as part of Whooshh project)

Priest Rapids Dam Sockeye sampling was funded by Whooshh innovations to test the use of the Whooshh Fish Transport System (WTFS, www.whooshh.com) on migrating salmon (Fryer 2017). Sockeye Salmon were sampled weekly for the four weeks between June 29, 2016 and July 22, 2016, which, based on historical run timing, comprise the period when the bulk of the Sockeye migration pass Priest Rapids Dam. The goal was to tag between 700 and 900 Sockeye Salmon, half of which were to be transported to the recovery area by the WFTS with the other half being hand-carried to the recovery area (non-WFTS group). The sampling crew consisted of staff from CRITFC, the Yakama Nation, and Whooshh Innovations, LLC.

Sockeye Salmon trapped at the Priest Rapids Dam left bank ladder fish trap were diverted by a barrier gate into the Off Ladder Adult Fish Trap (OLAFT). An attraction flow of approximately 9 cfs 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 large holding area for sampling. Additional Sockeye passing up the steeppass were automatically diverted back to a channel returning them to the ladder upstream of the barrier gate. Sockeye Salmon in the holding tank were crowded and four or

[2] The 99th percentile of the 2015 run did not pass until August 14 compared to a mean date of August 6 in the years 2011-2014.

five netted at a time and placed into a 380-liter stock tank filled with 300 L of water and 24 mg Aqui-S/l. The fish were held in the Aqui-S solution until they lost equilibrium and their opercular rate was slow but regular. Sockeye were examined for existing tags, fin clips, wounds, and condition. Fork lengths were measured and four scales were removed and placed on scale cards for later age analysis. Caudal punches were collected for possible future genetics analysis. Sockeye were also scanned for PIT tags and, if none found, they were tagged in the body cavity.

At the OLAFT, Whooshh Innovations set up a WFTS near the sampling area with the tube running approximately 30.5 m in a sweeping curve with an incline of 1.5 m, exiting into the recovery area (see https://1drv.ms/v/s!Ak8mNDpAR2geinsYc-bdQ9EzyrPo). With the exception of the final day of sampling on July 22, Sockeye were sampled in groups of five. The five Sockeye were sequentially sampled, tagged and placed in a 380-liter stock tank with freshwater and allowed to recover from the Aqui-S anesthetic. Prior to transporting a group of fish via the WFTS, wet sponges were run through the WFTS to make sure the tube walls remained lubricated. This was followed by the five Sockeye run sequentially through the WFTS to a calm water area with a channel leading to the fish ladder upstream of the barrier gate. These comprised the WFTS treatment group (Figure 2).

Figure 2. Images from the 2016 Priest Rapids Sockeye migration study. Left: remaining ladder climb after sampling at OLAFT. Top Left: CRITFC and Yakama Nation crew sampling and PIT tagging Sockeye at OLAFT. Top Right: Hand feeding Sockeye into the WFTS. Right: Week 30 WFTS fish transporting to top of the dam. Bottom: Week 30 WFTS spanning the dam crest.

Sockeye that were not put through the WFTS, were, as with the WFTS fish, sampled in groups of five. After each fish was sampled, it was placed in a rubber boot and hand carried approximately 15 m and placed into the same calm water site to which the WFTS fish were transported. After recovery, these fish, as with the WFTS fish, could swim up the channel leading to the fish ladder upstream of the in-ladder barrier gate. These Sockeye comprised the non-WFTS treatment group.

On July 22 (the only sampling day in Week 30), there was the opportunity to use the WFTS to transport Sockeye over Priest Rapids Dam to the forebay above the dam rather than the calm water site leading to the fish ladder. The WFTS setup, use, and breakdown requirement presented several challenges. Recovery of sponges used to lubricate the tube prior to fish passage from the Priest Rapids forebay was difficult so the decision was made to continuously pass WFTS sockeye through the tube after an initial run through of wet sponges. To do so, rather than separating the subject Sockeye into groups of five, approximately two-thirds of the non-WFTS Sockeye were sampled while the WFTS was set up, followed by sampling the complete set of WFTS fish and then completing the day of sampling with the remaining one-third of the non-WFTS Sockeye sample set of the day. The WFTS fish were transported by WFTS 50.9 m up a 12.2 m (24%) incline into the Priest Rapids Dam headwater immediately above the OLAFT and near the Priest Rapids ladder exit.

Stock Identification and Classification

A primary goal of CRITFC's Sockeye sampling program, since the project began in 1985, has been to estimate the stock composition of Columbia Basin Sockeye Salmon at Bonneville Dam with the data used in fisheries management and run forecasting. Scale pattern analysis was first used, where scale growth was measured from Okanagan and Wenatchee known stock samples as well as Bonneville Dam mixed-stock samples (Fryer and Schwartzberg, 1988) and a linear discriminant analysis used to classify those mixed-stock samples. With the widespread deployment of PIT tag infrastructure at Columbia, in 2006, we began PIT tagging Sockeye Salmon at Bonneville Dam and tracking them through PIT tag antennas located in upstream dam fish ladders and in-stream arrays. In 2012, we began also collecting genetics samples from Sockeye sampled to classify Sockeye Salmon using Genetics Stock Identification.

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 H_2O 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 H_2O, 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. 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 2016 and 2017, Sockeye Salmon samples were classified to the three major stocks (Wenatchee, Okanagan, and Snake River) as well as to a Deschutes stock and a kokanee stock.

PIT Tag Stock Identification

Since antennas were installed at the Tumwater Dam fishways in 2008 (complementing existing antennas at Rocky Reach, Wells and Snake River dams), 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 have been classified as being Okanagan stock. 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. Sockeye Salmon last detected at sites downstream of Ice Harbor or Rocky Reach/Tumwater dams were classified as "Unknown".

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 Dam and estimated that 11.6% of Sockeye Salmon detected at Wells Dam were of Wenatchee origin. No Sockeye detected in the Okanagan River in 2015 were classified by GSI as Wenatchee stock. In 2016 and 2017 we again completed GSI analysis on virtually all Sockeye sampled at Bonneville Dam as well as Sockeye PIT tagged at Wells and Priest Rapids dams that were not detected in the Okanagan or Wenatchee rivers. In reviewing results, we found four Sockeye in 2016 and one in 2017 classified as Wenatchee stock by GSI that were last detected in the Okanagan River, something we have never seen before. Each of these cases was immediately preceded or followed by a Sockeye classified by GSI as an Okanagan Sockeye that was last detected in the Wenatchee River which is also extremely rare. Therefore, a mix-up in the genetic samples was assumed and the PIT tag stock classification used rather than the GSI classification for these 10 Sockeye.

Final Stock Classification Rules

In 2016 and 2017 we used a combination of GSI and PIT tag detections to classify Sockeye Salmon:

1.) We have no known Yakima stock in the GSI known stocks. Therefore, if the last PIT tag detection Sockeye is in the Yakima River, it is classified as Yakima unless the fish was detected at Priest Rapids Dam followed by Roza Dam in which case the fish was likely transported from Priest Rapids Dam to Cle Elum Dam as part of a reintroduction program and fell back downstream. In this case, we used the PIT tag stock classification.
2.) If GSI indicates Okanagan, Wenatchee, Snake or Deschutes, we used GSI classification except for those mix-ups identified in (4).
3.) If GSI classifies to kokanee, we used the PIT tag stock classification.
4.) If GSI is suspected to be in error compared to the PIT tag classification, assume a genetics sample mix-up and discard the GSI result. We had eight identified mix-ups in 2017 and two in 2016. In a stock where strays have been found to be extremely rare, in these mix-ups, Sockeye classified by GSI as Wenatchee last detected in Okanagan terminal areas (in the Okanagan Basin) were immediately preceded or proceeded by an Okanagan Sockeye (as classified by GSI) that was last detected in Wenatchee terminal areas (at or upstream of Tumwater Dam).

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 1955) 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.

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 2017, Fish Passage Center 2017), 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.

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 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

[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.

that indicate depths at which juvenile Sockeye Salmon were most likely to be caught.

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

Juvenile PIT Tagging

Rotary Screw Trap (RST) Operation at Skaha Lake Outlet-2016

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 2016[4]. 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 3). 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. Details on RST operation in 2016 can be found in Appendix C.

[4] High flows prevented RST deployment in 2017.

Figure 3. Rotary screw traps used to trap juvenile Sockeye Salmon located downstream of Skaha Dam.

Smolt Trapping at Osoyoos Lake Narrows-2016

In 2016, 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 4 and 5). The fyke net configuration consisted of a 28m 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 2m 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 4). The fyke net set-up was similar to previous year's studies (Appendix C). As with RST deployment at Skaha Lake Outlet in 2017, high flows prevented smolt trapping at Osoyoos Lake Narrows.

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.

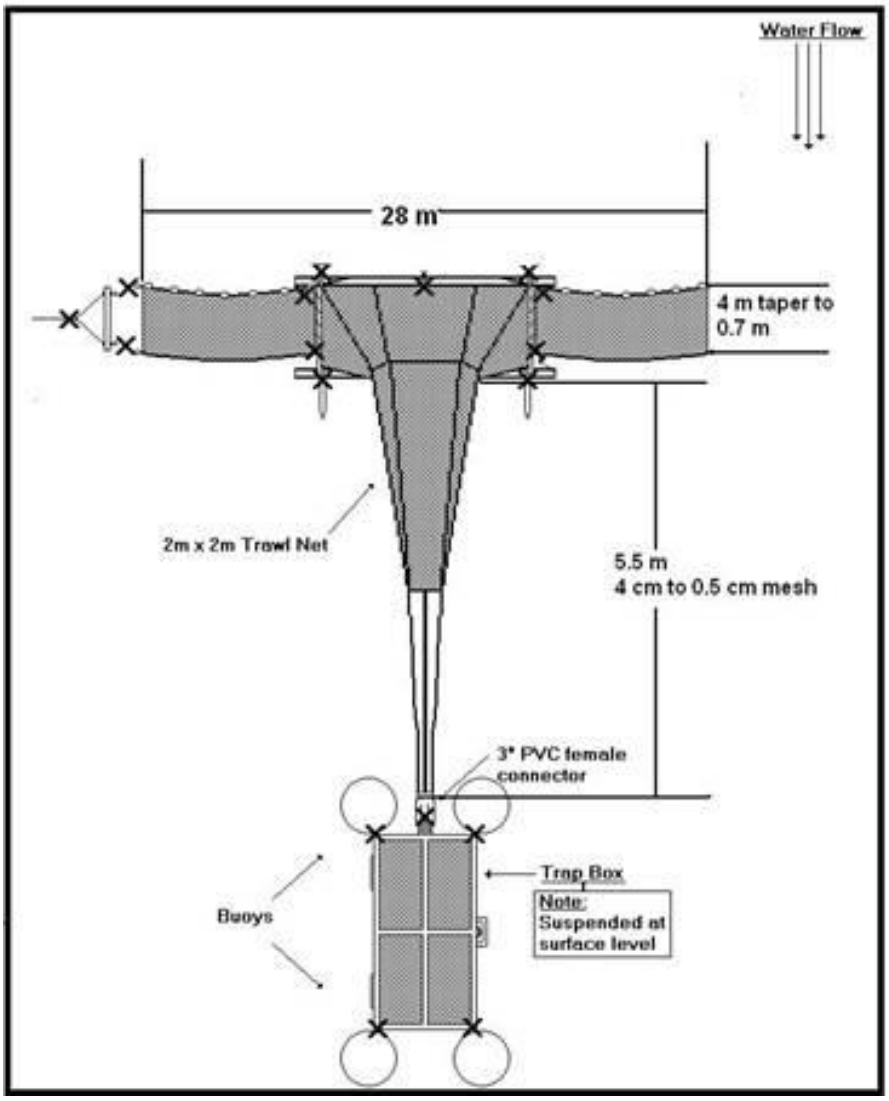


Figure 4. Schematic diagram of the fyke net located immediately downstream of the Highway 3 bridge in Osoyoos used in 2016 to trap Sockeye.

Figure 5. Fyke net used to trap juvenile Sockeye Salmon downstream of the Highway 3 Bridge in Osoyoos.

Smolt Seining at Osoyoos and Skaha lakes-2016 and 2017

Sockeye smolts were also captured using a purse seine net set one to five times per week (depending on boat availability) in both 2016 and 2017. The smolts were held in aluminum kitoi boxes and holding pens attached to the end of a privately-owned docks in the south basin of Skaha Lake and the North Basin of Osoyoos Lake.

RESULTS

Upstream Migration Analysis

Mixed Stock Sample Size and Age Composition

In 2016 a total of 1706 Sockeye Salmon were sampled for this project at the Bonneville Dam Adult Fish Facility between May 26 and August 18 (Table 1). Of these, 51 were not tagged[5], and 1 fish died prior to release. Three Sockeye were previously tagged and added to the remaining 1655 Sockeye tagged and released resulting in a total sample size of 1657 tagged Sockeye Salmon, 1653 of which were detected after release. In 2016, sampling restrictions resulting in raised picket leads affected this project on 40 sampling day, 24 due to high shad abundance as well as 16 days due to high water temperatures (21.1-22.2C, Table 1) [6]. Sampling was also curtailed for one day on three weeks by protocol during weeks with temperatures between 21.1 and 22.2C. All sampling days subject to temperature restrictions were in weeks 31-34 which were weeks in which only 1.9% of the Sockeye run passed Bonneville Dam (FPC 2017).

Table 1. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2016.

								Days Sampling Restrictions in Effect		
Sampling Dates	Statistical Week[7]	% of Run	Sampled (N)	Tagged	Mortalities	Previously Tagged	Detected After Tagging and Tracked	Reduced Sampling Temperature	Reduced Sampling Shad or Salmon Abundance	No Sampling Temperature
5/26,5/31-6/3	22-23	0.7	69	68	0	1	69	0	2	0
6/6-6/10	24	4.6	213	213	0	0	213	0	5	0
6/13-6/17	25	21.1	380	331	0	1	332	0	5	0
6/20-6/24	26	40.9	360	360	0	0	360	0	5	0
6/27-30,7/1	27	20.6	267	267	0	0	265	0	5	0
7/4,7/6-8	28	7.3	175	174	0	1	175	0	2	0
7/11-7/15	29	2.9	142	142	1	0	141	0	0	0
7/18-22	30	1.1	49	49	0	0	48	0	0	0
7/25-7/29	31	0.6	36	36	0	0	35	4	0	0
8/1-4	32	0.2	8	8	0	0	8	4	0	1
8/9,10,11,18	33-34	0.1	7	7	0	0	7	8	0	2
Total			**1706**	**1655**	**1**	**3**	**1653**	**16**	**24**	**3**

[5] Of the 51 Sockeye not tagged, 48 were on June 17 when our sampling crew ran out of PIT tags.
[6] Raising picket leads is required by trap regulations and decreases the number of fish going through the trap and can introduce trap biases (Fryer et al. 2011).
[7] 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 2016, for instance, Statistical Week 24 began on June 6 and ended on June 11.

In 2017 a total of 1095 Sockeye Salmon were sampled between June 2 and August 22 (Table 2). Of these, 3 were not tagged, and 2 fish died prior to release. One Sockeye was previously tagged and added to the remaining 1092 Sockeye tagged and released resulting in a total sample size of 1091 tagged Sockeye Salmon, 1079 of which were detected after release. Pickets were raised due to shad abundance on 8 days during Statistical Weeks 25 and 27; picket leads were never raised due to high water temperatures, in 2017.

Table 2. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2017.

							Days Sampling Restrictions in Effect[8]		
Sampling Dates	Statistical Week[9]	Sampled (N)	Tagged	Mortalities	Previously Tagged	Detected After Tagging and Tracked	Reduced Sampling-Temperature	Reduced Sampling-Shad or Salmon Abundance	No Sampling-Temperature
6/2,5-9	22-23	36	36	0	0	36	0	0	0
6/12-16	24	142	142	0	0	140	0	0	0
6/19-23	25	251	251	0	0	248	0	3	0
6/26-30	26	298	296	1	1	295	0	4	0
7/3,5-7	27	143	142	1	0	140	0	1	0
7/10-14	28	148	148	0	0	145	0	0	0
7/17-21	29	56	56	0	0	55	0	0	0
7/24-27 ,31,8/22	30-34	21	21	0	0	20	5	0	1
Total		**1095**	**1092**	**2**	**1**	**1079**	**5**	**8**	**1**

A total of 4 tagged Sockeye released by this study at Bonneville Dam in 2016, and 12 in 2017, 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 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 without being detected at PIT tag antennas. All other dams with

[8]For weeks 30-34, only days of sampling restrictions are summarized through July 31 only.
[9] 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 2017, for instance, Statistical Week 24 began on June 11 and ended on June 17.

PIT tag detection have antennas in fish ladders that Sockeye Salmon must pass, through data from 2006-2017 indicate that PIT tagged Sockeye are missed at fish ladder sites (Table 3).

Annual detection rates since Sockeye PIT tagging began are given in Table 3. The highest percentage missed in 2016-17 is in 2017 at Zosel Dam (74.5%) due to high flows resulting in Sockeye Salmon going through the Zosel Dam spillways rather than using the fish ladder. Rock Island Dam has had the lowest detection rate among Columbia River dams every year since 2013, likely due to electrical noise adversely affecting the ability of PIT tag antennas to detected PIT tags (Fryer et al. 2017). See also Appendix B for detection site information and maps showing sites Sockeye were detected.

Table 3. Number and percentage of Bonneville Dam PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2016-17 compared to 2006-2015. Okanagan and Wenatchee in-stream antenna sites (LWE, UWE, OKL) are also included since 2014[10].

	Percentage by Year and Mean of All Years												
Dam	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Mean
Bonneville	0.2	2.8	1.6	0.7	0.4	1.8	0.5	0.7	0.6	0.4	2.1	0.2	1.0
The Dalles	2.1	0.4	0.6	0.3	1.6	--	--	--	--	--	--	--	1.0
McNary	5.2	2.4	1.1	3.8	2.1	12.1	1.6	3.8	5.0	10.1	6.5	3.1	4.7
Priest Rapids	0.0	0.3	0.4	0.2	0.0	0.4	0.2	0.6	0.3	0.3	0.8	0.0	0.3
Rock Island	5.9	2.9	10.2	41.5	4.4	5.4	4.4	6.2	2.6	6.9	6.8	1.3	8.2
Rocky Reach	0.7	0.0	0.0	0.3	0.0	1.4	0.7	0.5	0.0	0.2	0.7	12.3	1.4
Wells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	--	--	--	0.0
Ice Harbor	0.0	0.0	0.0	12.5	--	0.0	--	0.0	20.0	0.0	--	--	4.1
Lower Monumental	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--	0.0
Little Goose	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--	0.0
Lower Granite	0.0	0.0	--	0.0	--	--	--	--	--	--	--	--	0.0
Tumwater	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	--	--	0.0
Zosel	74.5	1.6	0.0	0.9	87.3	83.0	98.6	--	--	--	--	--	49.4
LWE	49.6	54.7	17.9	48.0									42.5
UWE	9.3	9.7	24.6	52.7									24.1
OKL	47.4	59.4	13.8	68.9									47.4
OKC	NA	16.9	--	--	--	--	--	--	--	--	--	--	16.9

[10] No data indicates there were no detections upstream of the site in question for determining a percentage. PIT tag antennas were not installed at The Dalles Dam until the 2013 migration, at Zosel Dam until the 2011 migration.

The predominant age group in both 2016, at 88.1% of the run, and 2017, at 47.6% of the run was estimated to be Age 1.2 (Tables 4 and 5). Other age groups with over 10% of the run were Age 1.3 in 2016, and Age 1.3 and Age 1.1 in 2017. Among these major age groups, in 2016, the percentage of 1.2 Sockeye showed a significant linear increase as the run progressed ($p=0.004$) over the run, while the percentage of Age 1.3 Sockeye decreased ($p=0.017$). In 2017, the percentage of age 1.1 Sockeye increased ($p<0.001$), while the percentage of Age 1.2 Sockeye decreased ($p=0.003$) and the percentage of Age 1.3 Sockeye did not show a significant linear trend ($p=0.161$).

Table 4. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2016. (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)

Statistical Week	Percentage of Run	N Ageable	Age Class			
			1.1	1.2	1.3	2.2
22-23	0.7%	62	3.2%	85.5%	11.3%	0.0%
24	4.6%	211	0.5%	83.4%	16.1%	0.0%
25	21.1%	373	1.1%	85.3%	13.7%	0.0%
26	40.9%	354	0.6%	87.3%	11.6%	0.6%
27	20.6%	264	0.8%	92.0%	6.4%	0.8%
28	7.3%	169	0.6%	92.3%	5.9%	1.2%
29	2.9%	140	0.7%	87.1%	12.1%	0.0%
30	1.1%	48	0.0%	91.7%	4.2%	4.2%
31	0.6%	36	0.0%	91.7%	5.6%	2.8%
32-34	0.3%	15	0.0%	93.3%	6.7%	0.0%
Composite	**100%**	**1657**	**0.7%**	**88.1%**	**10.6%**	**0.5%**

Table 5. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2017. (Weighted by Statistical week). (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)

Statistical Week	Percentage of Run	N Ageable	Age Class					
			1.1	1.2	2.1	1.3	2.2	2.3
22-23	2.3%	35	2.9%	54.3%	0.0%	37.1%	5.7%	0.0%
24	11.9%	136	2.9%	62.5%	0.7%	33.8%	0.0%	0.0%
25	29.6%	239	5.0%	50.2%	0.8%	43.1%	0.8%	0.0%
26	30.4%	287	9.4%	50.5%	2.1%	34.8%	3.1%	0.0%
27	16.5%	135	25.9%	34.1%	4.4%	31.9%	2.2%	1.5%
28	6.4%	144	28.5%	37.5%	2.1%	30.6%	1.4%	0.0%
29	1.8%	55	23.6%	32.7%	12.7%	27.3%	3.6%	0.0%
30-34	1.0%	20	35.0%	5.0%	15.0%	35.0%	10.0%	0.0%
Composite	**100%**	**1051**	**11.7%**	**47.6%**	**2.2%**	**36.3%**	**2.0%**	**0.2%**

Upstream Recoveries, Mortality, and Escapement:

Survival rates to upstream dams, as estimated from detections of Sockeye PIT tagged by this study at Bonneville Dam, are compiled in Table 6. While 2016 had the highest estimated survival to The Dalles Dam (TDA) (94.0%), since detection at TDA began in 2013, 2017 had the lowest, with the exception of 2015 when high mortality resulted from record high water temperatures (Fryer et al. 2017). Again excluding 2015, survival to McNary dam in 2017 was second lowest to 2011, while 2016 was the highest since 2008.

For comparison with Sockeye Salmon tagged by this project as well as a predecessor project, survival rates to upstream dams were also tabulated for Rock Island smolt releases since 2008 (Table 7). The stock composition of this group, and therefore the expected geographic distribution on the upstream migration, would be expected to be similar to what this project tags at Bonneville Dam. However, sample sizes of returning adults from the Rock Island program were only 35 Sockeye in 2016 and 16 in 2017. Survival rates to The Dalles, McNary, Priest Rapids, and Rock Island dams were consistently higher for Sockeye tagged by this project compared to those tagged as juveniles at Rock Island Dam. In 2017, the difference was 0.4 to 5.8 percentage points, in 2016 it was 11.0 to 14.9 percentage points. Comparisons above Rock Island Dam are affected by even smaller sample sizes for juveniles as well as differences in stock composition so no similar analyses were conducted.

Table 6. Survival of Sockeye PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams 2006-2017.

	Percentage by Year and Mean of All Years												
Dam	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Mean
TDA	89.3	94.0	82.8	93.1	89.5								91.3
MCN	81.7	89.2	54.0	88.3	83.6	82.4	76.1	81.5	85.7	89.4	84.0	88.4	84.4
PRA	74.6	85.3	44.9	84.5	78.6	77.3	71.9	78.4	82.1	86.3	77.4	84.8	80.1
RIA	70.8	81.6	40.6	79.5	74.2	75.0	68.9	76.3	80.2	85.8	73.4	81.1	77.2
RRF	43.7	60.5	31.6	65.3	52.4	62.1	55.3	63.7	67.1	73.7	62.2	58.8	62.3
WEA	42.5	59.3	29.4	64.2	50.5	60.8	53.9	62.6	65.2	71.1	60.9	53.8	60.3
TUF	25.8	20.8	8.3	13.6	20.9	12.9	14.2	13.3	12.2	9.4	NA	NA	13.8
BON TEMP 6/15-7/14	18.1	18.8	21.3	17.9	18.2	16.4	15.8	16.6	17.9	17.0	18.2	18.3	17.8

Table 7. Survival of Sockeye PIT, tagged as smolts at Rock Island Dam, on their adult upstream migration from Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams 2008-2017[11].

	Percentage by Year and Mean of All Years										
Dam	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	Mean
N at BON	**16**	**35**	**128**	**155**	**66**	**121**	**125**	**130**	**33**	**38**	**85**
The Dalles	87.5	82.9	85.9	92.9	87.9						87.4
McNary	81.3	74.3	60.2	87.1	80.3	74.4	74.4	82.3	100.0	89.5	80.4
Priest Rapids	68.8	74.3	54.7	83.9	74.2	71.9	73.6	81.5	93.9	89.5	76.6
Rock Island	68.8	68.6	46.9	77.4	68.2	69.4	68.8	79.2	90.9	81.6	72.0
Rocky Reach	68.8	45.7	36.7	60.0	56.1	48.8	55.2	70.0	87.9	55.3	58.4
Wells	62.5	42.9	32.8	58.7	56.1	43.8	52.8	68.5	87.9	55.3	56.1
Zosel	18.8	37.1	7.0	39.4	3.0	0.8	1.6				15.4
Tumwater	6.3	22.9	13.3	16.1	10.6	23.1	14.4	10.0	3.0	26.3	14.6

In both 2016 and 2017, estimated escapement based on upstream PIT tag detections was greater than the number of Sockeye counted at The Dalles and McNary dams, but less than at Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams (Tables 8 and 9, Figures 6 and 7). Relatively large deviations between these estimates at Ice Harbor and Prosser dams are likely explained, at least in part, by the low number of Sockeye PIT tagged by this project passing these sites.

Sockeye Salmon show a significant linear decrease in survival over the period of the run to upstream dams in both 2016 and 2017 with the exception of Bonneville-The Dalles in 2016 (Tables 10 and 11, Figures 8 and 9). This exception is driven by the high survival rates in weeks 31 and 32-34 to The Dalles, however survival to points further upstream for Sockeye tagged in those weeks was much lower.

Among Sockeye groups tagged as juveniles on the downstream migration, there is not a significant linear relationship between survival to Rock Island Dam and statistical week as adults migrating upriver, with the exception of the group tagged as juveniles at Rock Island Dam that returned in 2016 (p=0.027) and the

[11] Years prior to 2008 were not included due to low sample sizes. From 2002-2007, the number of Sockeye PIT tagged as juveniles detected at Bonneville ranged between one and eight fish annually. 2011 was the first year with PIT tag detection at Zosel Dam, 2013 the first year for The Dalles Dam.

returns from juveniles tagged in the Okanagan Basin in 2017 (p=0.013). The sample sizes were low from these groups.

Table 8. Percentage of PIT tagged Sockeye Salmon detected at upstream dams subsequent to tagging at Bonneville Dam to upstream dams, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2016.

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using Bonneville PIT Tagged Sockeye	Visual Dam Count	Difference Between Bonneville PIT Tag and Visual Estimate
Bonneville	--	--	342,498	--
The Dalles	94.0%	322,000	288,401	11.7%
McNary	89.2%	305,472	261,696	16.7%
Priest Rapids	85.3%	292,317	311,072	-6.0%
Rock Island	81.6%	279,492	310,341	-9.9%
Rocky Reach	60.5%	207,363	235,925	-12.1%
Wells	59.3%	202,969	216,036	-6.0%
Zosel	53.0%	181,575	179,868	0.9%
Tumwater	20.8%	71,405	73,697	-3.1%
Ice Harbor	0.3%	758	898	-15.6%
Prosser	1.6%	5,546	3,742	48.2%

Table 9. Percentage of PIT tagged Sockeye Salmon detected at upstream dams subsequent to tagging at Bonneville Dam to upstream dams, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2017.

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using Bonneville PIT Tagged Sockeye	Visual Dam Count	Difference Between Bonneville PIT Tag and Visual Estimate
Bonneville	--	--	87,693	--
The Dalles	89.3%	78284	64058	22.2%
McNary	81.7%	71627	58022	23.4%
Priest Rapids	74.6%	65397	66670	-1.9%
Rock Island	70.8%	62058	73218	-15.2%
Rocky Reach	43.7%	38287	46701	-18.0%
Wells	42.5%	37284	42299	-11.9%
Zosel	21.6%	18906	NA	NA
Tumwater	25.8%	22605	23851	-5.2%
Ice Harbor	0.3%	271	392	-30.8%
Prosser	0.7%	622	372	67.1%

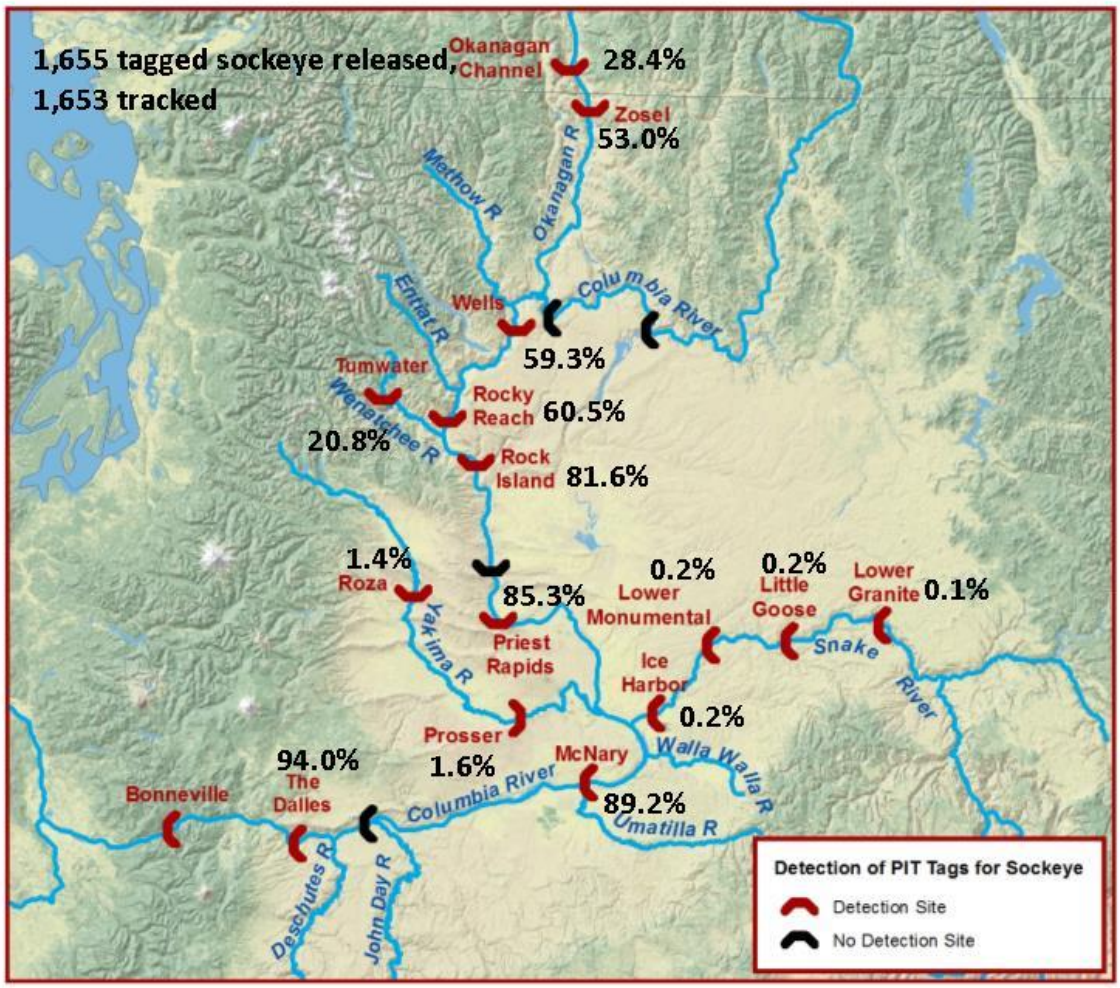


Figure 6. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2016.

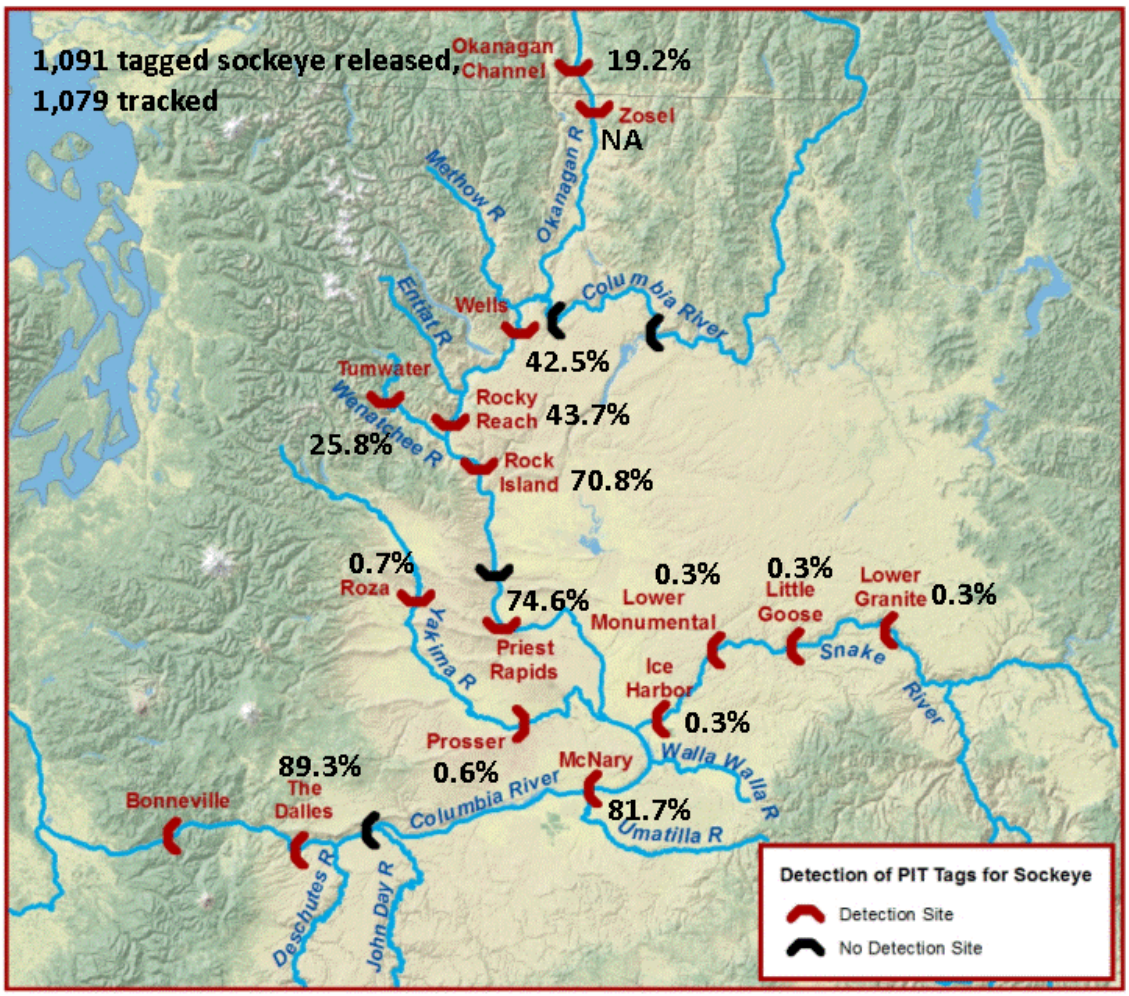


Figure 7. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2017.

Table 10. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2016 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Adults Tagged at Bonneville Dam				Sockeye tagged as Juveniles Bonneville-Rock Island Dam Survival by Tag Group		
	BON-TDA	BON-MCN	BON-PRD	BON-RIS	Wen Hat	Oka Wild	RIA Mixed
22-23	97.1%	94.2%	92.8%	91.3%	-	-	-
24	94.4%	93.0%	90.6%	90.1%	75.0%	75.0%	66.7%
25	97.6%	93.4%	91.6%	88.0%	72.7%	80.0%	81.8%
26	95.8%	92.8%	90.0%	86.1%	75.0%	95.2%	73.3%
27	91.1%	85.7%	78.0%	72.6%	81.8%	50.0%	50.0%
28	90.8%	83.3%	79.9%	78.7%	80.0%	100.0%	0.0%
29	77.3%	67.4%	59.6%	56.0%	100.0%	100.0%	-
30	75.0%	62.5%	54.2%	50.0%	0.0%	50.0%	-
31	91.4%	51.4%	42.9%	40.0%	-	100.0%	0.0%
32-34	92.9%	7.1%	7.1%	7.1%	-	0.0%	--
Composite[12]	**94.0%**	**89.2%**	**85.3%**	**81.6%**	**75.6%**	**79.4%**	**68.6%**
p-value	**0.115**	**0.001**	**<0.001**	**<0.001**	**0.373**	**0.138**	**0.027**

Table 11. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2017 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Adults Tagged at Bonneville Dam				Sockeye tagged as Juveniles Bonneville-Rock Island Dam Survival by Tag Group		
	BON-TDA	BON-MCN	BON-PRD	BON-RIS	Wen Hat	Oka Wild	RIA Mixed
23	94.4%	86.1%	83.3%	83.3%	100.0%	100.0%	50.0%
24	95.7%	91.4%	85.7%	84.3%	75.0%	83.3%	
25	91.1%	85.1%	80.6%	77.0%	84.6%	88.2%	57.1%
26	87.8%	83.7%	76.3%	73.9%	71.4%	77.8%	100.0%
27	87.9%	78.6%	66.4%	57.1%	50.0%	100.0%	50.0%
28	83.4%	65.5%	56.6%	53.8%	100.0%	33.3%	100.0%
29	81.8%	47.3%	36.4%	29.1%	100.0%		
30-31	65.0%	10.0%	10.0%	10.0%		0.0%	
Composite[13]	**89.3%**	**81.7%**	**74.6%**	**70.8%**	**78.9%**	**79.3%**	**68.8%**
p-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.893**	**0.013**	**0.319**

[12] Composite estimates for Bonneville Dam-tagged Sockeye Salmon are weighted by Statistical Week, juvenile estimates are unweighted.

[13] Composite estimates for Bonneville Dam-tagged Sockeye Salmon are weighted by Statistical Week, juvenile estimates are unweighted.

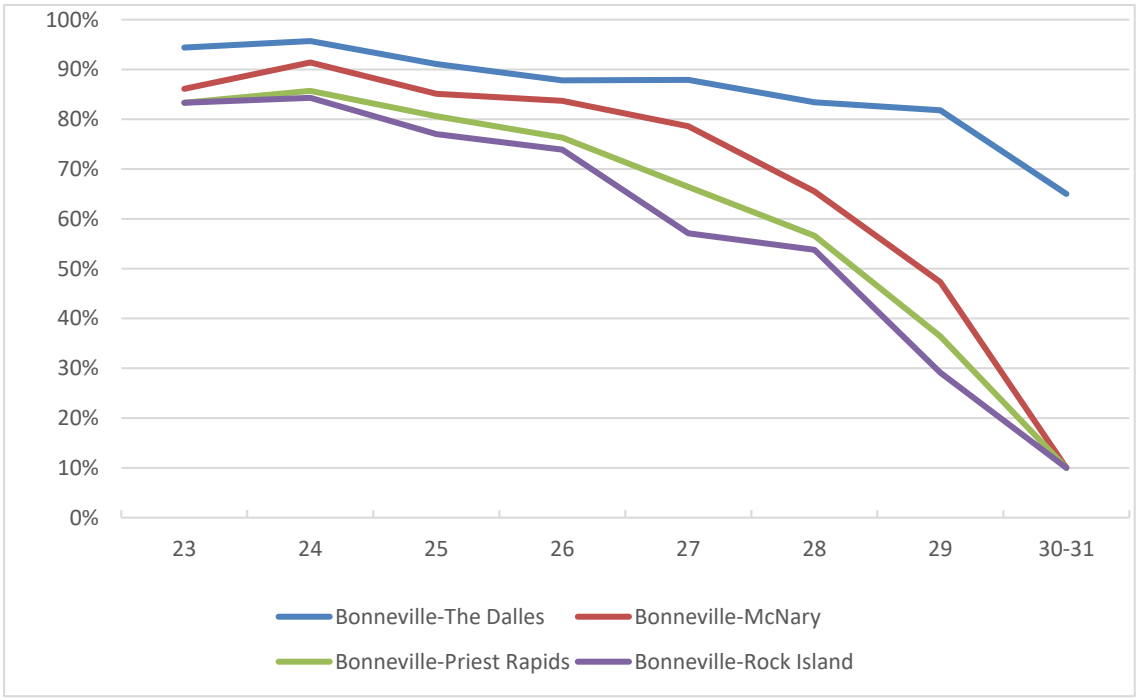


Figure 8. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2017.

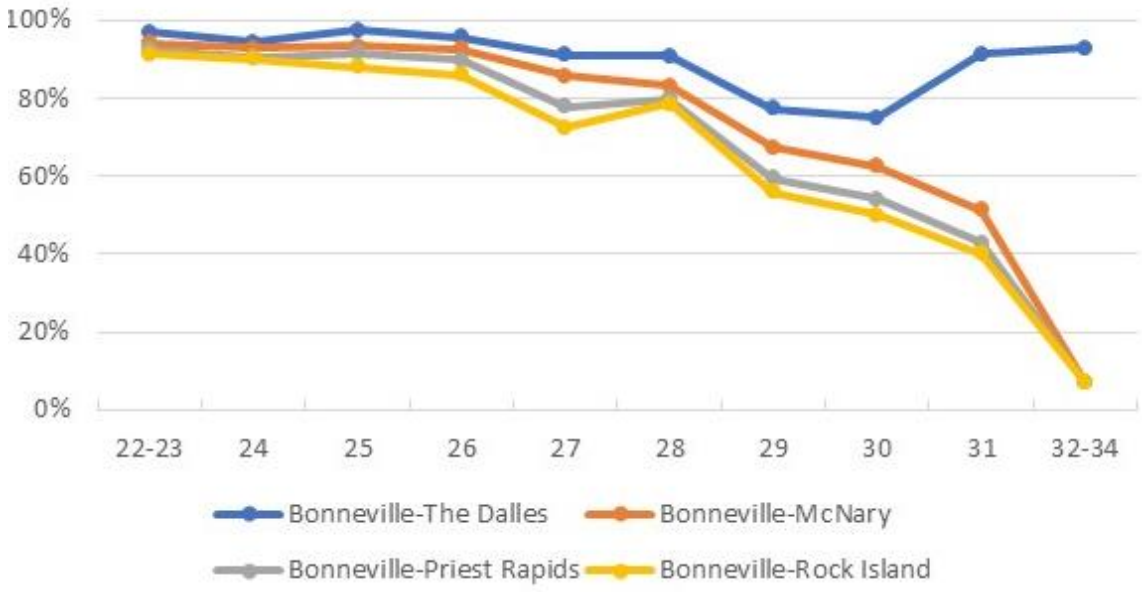


Figure 9. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2016.

Adult Sockeye tagged at Bonneville Dam in 2016 had a higher survival to McNary Dam (the last dam all groups pass on their way upstream) than any of the returning groups tagged as juveniles (Table 12). However, in 2017, Sockeye tagged at Bonneville Dam had a lower survival to McNary Dam than any other group with the exception of those Sockeye tagged as juveniles in the Snake Basin (Table 13). Similarly, Sockeye tagged at Bonneville Dam in 2016 had a higher survival to Rock Island Dam than the Okanagan, Wenatchee and Rock Island groups, however Bonneville tagged Sockeye had a lower survival than both the Okanagan and Wenatchee groups in 2017.

Table 12. Survival of Sockeye groups PIT tagged as juveniles from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2016.

		Percentage by Dam									
Tagging Location	N at BON	TDA	MCN	PRA	RIA	RRF	WEA	ZSL	OKC	TUF	IHA
Okanagan	68	94.1	88.2	85.3	79.4	75.0	75.0	72.1	38.2	0.0	0.0
Wenatchee	45	88.9	82.2	80.0	75.6	2.2	2.2	0.0	0.0	66.7	0.0
Rock Island	35	82.9	74.3	74.3	68.6	42.9	42.9	37.1	14.3	22.9	0.0
Snake	183	86.9	73.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	71.6
Bonneville	1653	94.0	89.2	85.3	81.6	60.5	59.3	53.0	28.4	20.8	0.3

Table 13. Survival of Sockeye groups PIT tagged as juveniles from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2017.

		Percentage by Dam									
Tagging Location	N at BON	TDA	MCN	PRA	RIA	RRF	WEA	ZSL	OKC	TUF	IHA
Okanagan	60	96.7	95.0	81.7	80.0	76.7	76.7	33.3	30.0	0.0	0.0
Wenatchee	38	94.7	89.5	86.8	78.9	0.0	0.0	0.0	0.0	73.7	0.0
Rock Island	16	87.5	81.3	68.8	68.8	68.8	62.5	25.0	25.0	6.3	0.0
Snake	77	76.6	62.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	59.7
Bonneville	1079	89.3	81.7	74.6	70.8	43.7	42.5	21.6	19.2	25.8	0.3

Migration Rates and Passage Time

Adult Sockeye Salmon travel quickly upstream with a median migration rates between mainstem dams ranging between 29.3 and 49.8 km/day in 2016 and 28.4 and 51.7 km/day in 2017 for Sockeye tagged at Bonneville Dam (Tables 14 and 15). From Bonneville Dam to Rock Island Dam, returning adults tagged as smolts have comparable migration times to Sockeye tagged by this study at

Bonneville Dam, with the times shown in Tables 14 and 15 differing by no more than 0.8 days with the exception of from Bonneville to Tumwater Dam in 2016 where it differed by 2.7 days.

Table 14. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2016.

		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	1.7	42.7	1.3	53.7
The Dalles-McNary	162	2.9	55.2	2.9	55.0
McNary-Priest Rapids	167	3.8	44.4	3.5	47.6
Priest Rapids-Rock Island	89	3.1	29.3	3.0	30.3
Rock Island-Rocky Reach	33	1.1	30.3	1.0	32.3
Rocky Reach-Wells	65	1.9	36.8	1.9	36.6
Rock Island-Tumwater	73	10.7	6.5	10.2	6.8
Bonneville-McNary	231	4.7	49.8	4.4	53.0
Bonneville-Priest Rapids	329	8.3	48.5	7.9	50.9
Bonneville-Rock Island	487	11.7	41.8	10.9	44.8
Bonneville-Tumwater	560	23.4	23.9	20.7	27.1
Bonneville-Wells	585	14.7	40.2	14.0	42.1

Table 15. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2017.

		Tagged at Bonneville Dam		Adults Tagged as Juveniles	
Dam Pair	Distance (km)	Median Travel Time (days)	Median Migration Rate (km/day)	Median Travel Time (days)	Median Migration Rate (km/day)
Bonneville-The Dalles	74	1.8	39.5	1.7	42.8
The Dalles-McNary	162	3.1	51.7	3.1	51.7
McNary-Priest Rapids	167	4.5	37.5	4.4	38.3
Priest Rapids-Rock Island	89	3.2	28.4	3.1	28.9
Rock Island-Rocky Reach	33	1.1	29.6	1.2	27.1
Rocky Reach-Wells	65	2.0	34.3	1.9	35.9
Rock Island-Tumwater	73	12.8	5.4	13.5	5.1
Bonneville-McNary	231	5.0	46.5	4.9	47.5
Bonneville-Priest Rapids	329	9.8	41.0	9.3	43.0
Bonneville-Rock Island	487	13.1	37.5	12.5	39.2
Bonneville-Tumwater	560	27.0	20.7	25.7	21.8
Bonneville-Wells	585	16.0	36.9	16.0	36.9

Sockeye Salmon tagged at Bonneville Dam later in the migration travel upstream faster than those tagged earlier in the migration (Tables 16 and 17). This relationship was significant from Bonneville to McNary, Priest rapids, Rock Island, Tumwater, and Zosel dams in 2017 but only from Bonneville to Rocky Reach, Wells, and Zosel dams in 2017.

Table 16. 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 2016.

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
22-23	1.7	4.7	8.1	11.5	23.6	12.8	15.1	20.5	4.68	11.9
24	1.7	4.7	8.5	11.8	25.1	12.8	14.8	20.8	5.06	11.3
25	1.7	4.7	8.7	12.0	25.9	12.9	14.9	21.0	4.97	11.9
26	1.7	4.7	8.6	11.8	25.1	12.3	14.4	19.8	4.75	11.9
27	1.6	4.3	8.0	11.3	21.8	12.3	13.9	21.2	6.54	8.9
28	1.5	4.6	8.0	11.0	20.9	12.0	14.2	18.8	4.97	8.3
29	1.5	4.5	8.0	11.7	20.9	12.6	14.1	18.7	4.42	8.6
31-32	1.2	3.9	7.4	10.8	20.0	12.0	13.9	17.6	3.64	9.0
p-value	**0.001**	**0.013**	**0.014**	**0.019**	**0.002**	**0.328**	**0.109**	**0.038**	**0.473**	**0.001**
Stock										
Okanagan	1.7	4.7	8.2	11.2	20.4	12.7	14.7	20.5	4.9	8.4[14]
Wenatchee	1.62	4.67	8.7	12.3	23.5	12.8	16.7	*NA*	*NA*	10.73
Age										
1.1	1.7	5.0	9.2	13.2	30.7	13,8	15.7	21.6	4.9	12.1
1.2	1.7	4.7	8.2	11.7	23.4	12.7	14.6	20.5	4.9	13.3
1.3	1.7	4.7	8.5	11.8	23.4	12.7	14.7	20.0	4.6	11.7

Table 17. 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 2017.

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
22-23	1.9	5.2	12.2	17.5	34.6	16.9	19.3	102.2	2.0	4.0
24	1.9	5.6	11.0	15.0	31.1	16.1	18.6	81.1	2.6	4.7
25	1.8	5.1	10.0	13.6	28.5	14.6	16.9	55.3	3.7	5.2
26	1.7	4.8	9.1	12.1	26.0	13.0	15.0	56.6	3.5	5.5
27	1.7	4.9	9.6	12.4	24.8	13.5	15.9	64.0	3.0	6.5
28	1.8	5.0	9.1	12.6	25.0	13.1	15.6	53.5	3.9	6.4
29	1.8	4.8	9.2	12.4	24.8	13.2	14.9			5.5
30-34	1.8	5.1	9.8	13.9	28.7	14.2	16.1	48.6	4.8	5.5
p-value	**0.138**	**0.144**	**0.036**	**0.077**	**0.054**	**0.033**	**0.019**	**0.027**	**0.008**	**0.069**
Stock										
Okanagan	1.8	5.0	9.7	12.7	32.9[15]	13.9	16.0	62.7	45.4	11.9
Wenatchee	1.8	5.1	9.9	14.0	27.0	14.0	19.7	63.9[16]	43.9	12.8
Age										
1.1	1.8	4.9	9.1	11.9	NA	15.0	13.1	47.2	32.4	NA
1.2	1.8	5.0	9.4	13.0	27.6	14.0	16.5	69.9	54.3	13.2
1.3	1.8	5.1	10.0	14.0	26.8	14.7	17.0	61.6	43.4	12.2

[14] Only four Okanagan stock Sockeye were detected at Tumwater Dam.
[15] Only one Okanagan stock Sockeye were detected at Tumwater Dam.
[16] Only one Wenatchee stock Sockeye were detected at Tumwater Dam.

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, with the exception of at Snake River dams where sample sizes of AFF-tagged Sockeye were small (only four Sockeye passed up the Snake in both 2016 and 2017), was under 1 minute in 2016 and 1.2 minutes in 2017 (Tables 18 and 19). The percentage of juvenile-tagged adults taking more than 12 hours to pass was greater than that for adult Sockeye tagged by this study at 9 out of 13 dams in 2016, but only 4 out of 13 dams in 2017 (Tables 18 and 19).

Table 18. 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 2016.

	Adults Tagged at Bonneville Dam		Previously Tagged as Juveniles	
Dam	Median Passage (Minutes)	%>12 Hours	Median Passage (Minutes)	%>12 Hours
Bonneville	10.2	0.2%	9.3	4.7%
The Dalles	0.1	0.6%	0.1	9.3%
McNary	0.1	0.7%	0.2	0.8%
Priest Rapids	5.4	1.6%	5.4	3.3%
Rock Island	0.1	0.7%	0.1	0.0%
Rocky Reach	6.5	0.5%	5.7	1.4%
Wells	7.7	6.2%	6.9	11.9%
Zosel	0.4	0.9%	0.3	0.0%
Tumwater	6.9	5.3%	6.7	18.4%
Ice Harbor	122.7	33.3%	4.7	13.5%
Lower Monumental	9539.1	66.7%	0.8	14.3%
Little Goose	0.1	0.0%	0.0	6.4%
Lower Granite	420.4	0.0%	359.1	25.8%

Table 19. 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 2017.

	Adults Tagged at Bonneville Dam		Previously Tagged as Juveniles	
Dam	Median Passage (Minutes)	%>12 Hours	Median Passage (Minutes)	%>12 Hours
Bonneville	11.6	0.5%	10.4	0.0%
The Dalles	0.1	2.0%	0.1	1.2%
McNary	0.2	1.2%	0.2	1.3%
Priest Rapids	7.0	3.2%	6.5	4.3%
Rock Island	0.2	1.0%	0.2	1.2%
Rocky Reach	8.5	0.9%	7.4	0.0%
Wells	3.9	3.8%	3.1	1.8%
Zosel	0.7	1.3%	1.9	0.0%
Tumwater	41.5	11.9%	40.9	7.4%
Ice Harbor	1.8	0.0%	0.1	4.4%
Lower Monumental	1.3	0.0%	4.6	17.0%
Little Goose	0.1	0.0%	0.1	9.3%
Lower Granite	528.7	33.3%	381.3	23.8%

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 8 sites in 2016 but only 4 out of 9 sites in 2017 where Sockeye from both stocks were detected (Tables 20 and 21).

Table 20. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2016.

Dam	Adults Taggedat Bonneville Dam			Sockeye Tagged as Juveniles
	All Adults	Okanagan	Wenatchee	
Bonneville	0.8%	1.1%	0.2%	2.0%
The Dalles	8.2%	8.9%	6.7%	6.9%
McNary	7.4%	8.4%	4.2%	6.3%
Priest Rapids	3.6%	4.5%	1.1%	5.7%
Rock Island	5.4%	6.0%	3.7%	3.6%
Rocky Reach	8.3%	8.4%	4.2%	14.3%
Wells	13.0%	13.0%	12.5%	9.0%
Tumwater	3.6%	0.0%	3.6%	5.3%
Zosel	21.3%	21.3%	NA	17.2%

Table 21. Estimated Sockeye Salmon night passage (2000-0400) by stock at mainstem Columbia River dams in 2017.

Dam	Adults Tagged at Bonneville Dam			Sockeye Tagged as Juveniles
	All Adults	Okanagan	Wenatchee	
Bonneville	0.5%	0.5%	0.5%	1.8%
The Dalles	7.9%	7.8%	8.4%	7.3%
McNary	5.8%	6.4%	5.0%	22.8%
Priest Rapids	2.3%	3.4%	0.7%	1.1%
Rock Island	4.9%	5.3%	4.4%	2.4%
Rocky Reach	7.4%	7.3%	14.3%	3.4%
Wells	10.0%	10.0%	14.3%	7.0%
Tumwater	2.0%	0.0%	2.0%	3.7%
Zosel	17.1%	17.3%	0.0%	37.5%

Fallback

Fallback rates for adults tagged at Bonneville Dam in 2016 ranged from 0.0% at Skaha Dam to 2.6% at Rocky Reach Dam for sites with 10 or more detections (Table 22)[17]. Fallback rates of Sockeye tagged as juveniles were generally higher than those tagged as adults, reaching a high of 21.6% at The Dalles Dam. Sockeye tagged as juveniles in the Snake River had higher fallback rates at Bonneville, The Dalles, and McNary dams than did Sockeye tagged as juveniles in the Okanagan and Wenatchee basins or at Rock Island Dam. Fallback rates for all four Snake River dams were 7.3% or more for Sockeye tagged as

[17] Snake River dams are excluded as only 4 Bonneville-tagged Sockeye were detected in the Snake River.

juveniles. Of the 85 Sockeye tagged by this project in 2016, which were estimated to fall back over at least one dam, 16 had multiple fallbacks (Table 23). Among Sockeye tagged as juveniles, the mean number of fallbacks events per Sockeye Salmon for Snake River Sockeye was 0.84 compared to 0.03 to 0.07 for the other juvenile groups and 0.08 for Sockeye in our Bonneville study (Table 23).

Table 22. Estimated fallback rates for Sockeye Salmon at dams in 2016[18]. (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.)

		Sockeye Tagged as Juveniles by Tagging Location				
Dam	Adults Tagged at Bonneville	Okanagan Basin (n=68)	Rock Island Dam (n=35)	Snake Basin (n=183)	Wenatchee Basin (n=45)	Total (n=331)
Bonneville	0.1%	0.0%	0.0%	16.4%	0.0%	9.1%
The Dalles	1.1%	0.0%	0.0%	39.6%	0.0%	21.6%
McNary	0.3%	0.0%	0.0%	0.7%	0.0%	0.4%
Priest Rapids	1.5%	0.0%	0.0%	100.0%*	8.3%	4.1%
Rock Island	0.6%	1.9%	4.2%	NA	0.0%	1.8%
Rocky Reach	2.6%	5.9%	0.0%	NA	0.0%*	4.5%
Wells	2.0%	0.0%	0.0%	NA	0.0%*	0.0%
Zosel	0.4%	0.0%	0.0%	NA	NA	0.0%
Skaha	0.0%	12.5%	NA	NA	NA	12.5%
Tumwater	0.6%	NA	0.0%	NA	0.0%	0.0%
Ice Harbor	50.0%	NA	NA	16.8%	NA	16.8%
Lower Monumental	50.0%	NA	NA	12.4%	NA	12.4%
Little Goose	0.0%	NA	NA	7.9%	NA	7.9%
Lower Granite	NA	NA	NA	7.3%	NA	7.3%

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

Table 23. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2016.

Fallback Events	Sockeye Tagged as Juveniles by Tagging Location				Adults Tagged at Bonneville
	Okanagan Basin	Rock Island Dam	Snake Basin	Wenatchee Basin	
1	5	1	34	3	69
2	0	0	7	0	14
3	0	0	9	0	2
4	0	0	5	0	0
5	0	0	2	0	0
6	0	0	4	0	0
7	0	0	1	0	0
8	0	0	1	0	0
9	0	0	1	0	0
Number of Sockeye falling back at least once	5	1	64	3	85
% of Sockeye with at least one fallback event	8.3%	6.3%	83.1%	7.9%	5.2%
Total fallback events	5	1	153	3	103
Number of Sockeye in study	68	35	183	45	1635
Fallbacks events per Sockeye	0.07	0.03	0.84	0.07	0.06

Fallback rates for adults tagged at Bonneville Dam in 2017 ranged from 0.0% at Tumwater and Zosel dams to 3.1% at The Dalles and Priest Rapids dams for sites with 10 or more detections (Table 24).[19] Fallback rates of Sockeye tagged as juveniles were generally, but not always, higher than those tagged as adults, reaching 6.4% at Priest Rapids Dam and ranging from 9.5% to 19.6% at Snake River dams. Of the 81 Sockeye tagged by this project in 2017, which were estimated to fall back over at least one dam, 4 had multiple fallbacks (Table 25). Among Sockeye tagged as juveniles, the mean number of fallbacks events per Sockeye Salmon for Snake River Sockeye was 0.36 compared to 0.00 to 0.16 for the other juvenile groups and 0.08 for Sockeye in our Bonneville study.

[19] Snake River dams are excluded as only 3 Bonneville-tagged Sockeye were detected in the Snake River.

Table 24. Estimated dam fallback rates for Sockeye Salmon tagged at Bonneville Dam in 2017[20]. (NA indicates Sockeye were not detected at a dam outside the range of the particular stock.)

		Sockeye Tagged as Juveniles by Tagging Location				
Dam	Adults Tagged at Bonneville	Okanagan Basin (n=60)	Rock Island Dam (n=16)	Snake Basin (n=77)	Wenatchee Basin (n=38)	Total (n=191)
Bonneville	0.3%	0.0%	0.0%	0.0%	5.3%	1.0%
The Dalles	3.1%	1.7%	0.0%	3.4%	0.0%	1.8%
McNary	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Priest Rapids	3.1%	6.1%	0.0%	0.0%	9.1%	6.4%
Rock Island	1.3%	0.0%	0.0%	NA	0.0%	0.0%
Rocky Reach	2.6%	0.0%	0.0%	NA	NA	0.0%
Wells	2.2%	0.0%	0.0%	NA	NA	0.0%
Zosel	0.0%	0.0%	0.0%	NA	NA	0.0%
Tumwater	0.0%	NA	0.0%	NA	0.0%	0.0%
Ice Harbor	0.0%	NA	NA	19.6%	NA	19.6%
Lower Monumental	0.0%	NA	NA	13.0%	NA	13.0%
Little Goose	0.0%	NA	NA	15.9%	NA	15.9%
Lower Granite	0.0%	NA	NA	9.5%	NA	9.5%

Table 25. Number of fallback events by tag group for returning Sockeye tagged as juveniles and Sockeye included in our Bonneville adult tagging study in 2017.

	Sockeye Tagged as Juveniles by Tagging Location				
Fallback Events	Okanagan Basin	Rock Island Dam	Snake Basin	Wenatchee Basin	Adults Tagged at Bonneville
1	4	0	16	4	77
2	0	0	7	1	2
3	0	0	0	0	1
4	0	0	0	0	1
Number of Sockeye falling back at least once	4	0	22	5	81
% of Sockeye with at least one fallback event	6.7%	0.0%	28.6%	13.2%	7.5%
Total fallback events	4	0	28	6	88
Number of Sockeye in study	60	16	77	38	1079
Fallbacks events per Sockeye	0.38	0.10	0.13	0	0.08

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

2016 Stock Composition Estimates

In 2016, genetics stock identification (GSI) was used to classify samples from 1706 Sockeye Salmon collected at Bonneville Dam and the stock classification are compared by site of final PIT tag detection (Table 26). As discussed previously, the Wallowa kokanee classification was removed from further analysis and therefore PIT tag classification was used instead. This was also the case for eight Sockeye (four Wenatchee and four Okanagan) where a likely mix up of genetic samples occurred. After excluding the eight mix-ups, concurrence between Sockeye classified as Wenatchee stock by GSI and PIT tags was 100% (all 328 classified correctly) and was 99.5% (830 out of 834) for the Okanagan stock (Table 26) with an overall concurrence of 99.7% (1158 out of 1162).

Table 26. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2016.[21]

Stock Estimated Using PIT Tags	Stock Estimated by GSI						
	Okanagan	Wenatchee	Snake	Deschutes	Wallowa*	Unknown	Total
Okanagan	830				1	10	841
Wenatchee	4	328			1	5	338
Snake			4				4
Yakima	8	16					24
Unknown	324	152	3	14	2	4	499
Total	**1166**	**496**	**7**	**14**	**4**	**23**	**1706**

*Kokanee

When combining PIT and GSI stock determinations as described in the methods, this study estimated that the stock composition at Bonneville Dam in 2016 was 70.1% Okanagan, 27.7% Wenatchee, 1.6% Yakima, 0.4% Snake River, and 0.3% Deschutes River (Table 27). The percentage of Okanagan Sockeye declined as the run progressed, while the percentage of the other stocks generally increased (Table 27 and Figure 10). PIT tag and GSI estimates varied by less than a percentage point for the three stocks for which both methods could provide estimates. Using visual fish counts at dams to estimate Okanagan stock abundance relative to the Wenatchee yielded a higher percentage Okanagan (76.0 and 76.3%, Table 27) than did PIT and GSI estimates.

[21] As discussed in the methods, eight GSI classifications were considered genetic sample mix-ups and were moved to the unknowns.

Table 27. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2016 with a comparison to stock composition estimates estimated using visual dam counts as well as using only PIT tags and GSI.

Statistical Week and Dates	Bonneville Dam Visual Counts	% Okanagan	% Wenatchee	% Snake	% Yakima	% Deschutes	% Wallowa[22]
22-23 (May 26, 31-June 3	2,465	85.5%	13.0%	0.0%	1.4%	0.0%	NA
24 (June 6-10)	15,607	72.3%	25.8%	0.0%	1.9%	0.0%	NA
25 (June 13-17)	72,340	69.6%	29.4%	0.0%	1.1%	0.0%	NA
26 (June 20-24)	139,973	72.5%	26.4%	0.0%	1.1%	0.0%	NA
27 (June 27-July 1)	70,448	68.4%	26.7%	1.1%	3.8%	0.0%	NA
28 (July 4-8)	24,838	71.3%	26.4%	0.6%	0.0%	1.7%	NA
29 (July 11-15)	9,978	58.6%	36.4%	1.4%	0.7%	2.9%	NA
30 (July 18-22)	6,849	36.7%	55.1%	0.0%	0.0%	8.2%	NA
31 (July 25-July 29)	2,098	55.6%	41.7%	0.0%	0.0%	2.8%	NA
32 (Aug 1-4)	1,123	50.0%	37.5%	0.0%	0.0%	12.5%	NA
33-34 (Aug 8-18)	2,465	28.6%	42.9%	14.3%	0.0%	14.3%	NA
Combined PIT and GSI Estimate	**342,498**	**70.1%**	**27.7%**	**0.3%**	**1.6%**	**0.4%**	**NA**
PIT Tag Only Estimate		**69.7%**	**27.8%**	**0.4%**	**2.2%**	**NA**	**NA**
GSI Only Estimate		**70.3%**	**28.8%**	**0.3%**	**NA**	**0.4%**	**0.2%**
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)		76.0%	24.0%				
Visual Fish Counts at dams (Tumwater count to estimate the Wenatchee; Rocky Reach to estimate Okanagan)		76.3%	23.7%				

[22] As described in the methods, the four Sockeye classified by GSI as “Wallowa” were given final classifications based on their PIT tag destination.

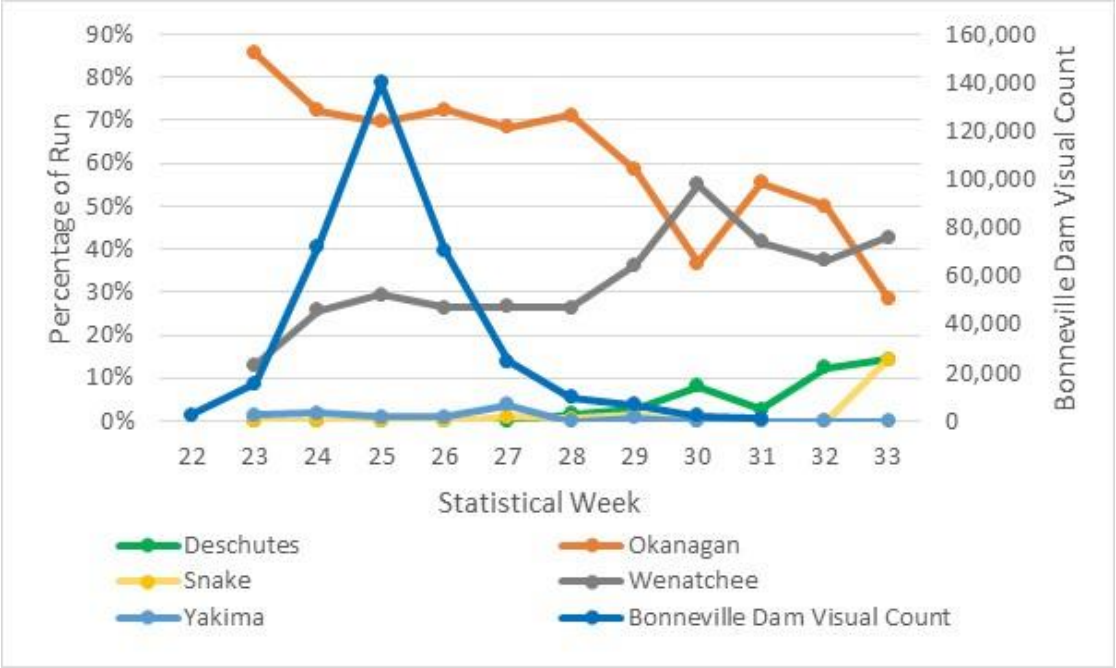


Figure 10. Percentage of the Sockeye run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, Yakima, and Deschutes origin by week in 2016.

Among the 310 Sockeye Salmon classified as Wenatchee stock that were last detected in the Wenatchee River, 15 (4.8%) were previously detected at Rocky Reach Dam and 8 (2.6%) at Wells Dam. Additional Wenatchee stock Sockeye Salmon that were last detected upstream of the Wenatchee River were two at Rocky Reach Dam, two at Wells Dam fish ladders, and three in the Methow River (Table 28). One Sockeye classified as Wenatchee stock was last detected at Priest Rapids Hatchery.

One out of 1166 Sockeye Salmon classified as Okanagan stock was last detected in the Wenatchee River, at Tumwater Dam. The size (56.5 cm) and age (1.3) of this Sockeye suggests that the GSI stock classification of this Sockeye may be in error[23]. No other Okanagan Sockeye Salmon were detected straying into the Wenatchee River on their upstream migration.

[23] To be presented later in this report, based on GSI of Bonneville-sampled Sockeye, an estimated 32.0% of Wenatchee stock Sockeye and only 2.4% of Okanagan Sockeye were estimated to be Age 1.3.

Table 28. GSI classification of Sockeye last detected in non-terminal areas (downstream of OKL, LWE, and Ice Harbor Dam) in 2016.

Last Site Detected	Okanagan	Wenatchee	Snake	Deschutes	Total
Bonneville Dam (BO1, BO3, BO4, BCC)	75	49	3	4	131
Deschutes River mouth (DRM)	1	1		4	7
Eastbank Hatchery	1				1
Entiat River (ENL, ENS)		2			2
McNary Dam (MC1, MC2)	20	15			35
Methow River (CRW)	1	3			4
Priest Rapids Dam	32	19			51
Priest Rapids Hatchery		1			1
Prosser Dam	2	2			4
Ringold Springs Hatchery	1				1
Rock Island Dam	9	10			19
Rocky Reach Dam	13	2			15
Roza Dam	7	14			21
Shitike Creek, Deschutes River				1	1
The Dalles Dam (TD1, TD2)	59	30		5	94
Wells Dam	73	2			

Among the seven Sockeye classified as Snake River origin, three were last detected exiting the Bonneville Dam Washington shore fish ladder (although 3DD.00778A4B33 tagged August 8, 2016 passed upstream on August 9, but then fell back over Bonneville Dam and was last detected again exiting the Washington Shore fish ladder on August 20, 2016). Another three Snake River Sockeye were last detected at Lower Granite Dam. The seventh Sockeye (3DD.00779784BC) tagged on July 1 was detected at IR1 at Imnaha River km 7 on August 25, reaching as far upstream as the Imnaha River weir at rkm 84 September 30-October 6 before being last detected at IR1 on October 19.

Among the 14 Sockeye classified as Deschutes origin, 4 were last detected at Bonneville Dam, 5 at The Dalles Dam, 4 at the Deschutes River mouth site (DRM), and one at Shitike Creek (SHK) at Deschutes River rkm 155 (Table 28).

A total of 25 Sockeye were detected at Prosser Dam with 21 subsequently detected at Roza Dam (Table 28). One of these sockeye, 3DD.00775E35E4, was detected only at Roza Dam and was presumed to have been translocated by the Cle Elum Sockeye reintroduction program to Cle Elum Lake and subsequently migrated downstream where it was detected at Roza Dam. Among the remaining 24 Sockeye, 16 were classified using GSI as of Wenatchee origin and 8 Okanagan. It is presumed that these may have been offspring of Sockeye translocated in

previous years to Cle Elum Lake so these Sockeye were considered of Yakima origin. (Table 28).

A total of 20 Sockeye sampled by this project at Bonneville Dam were fin or maxillary clipped, including all 7 of the Snake River Sockeye (Table 29). Among the fin clipped Okanagan Sockeye, 3 each were last detected at OKC and Zosel Dam, 2 at Wells Dam and 1 at The Dalles. Among the clipped Wenatchee Sockeye, there was one Sockeye last detected at The Dalles, Priest Rapids, and Wells dams as well as the WTL PIT tag array in the White River. Juvenile Sockeye are tagged in the Snake River but it is unknown what Sockeye project is clipping Okanagan or Wenatchee Sockeye Salmon.

Table 29. Type and number of fin clips by stock for Sockeye Salmon sampled at Bonneville Dam in 2016.

	Clip Type					
Stock	**Adipose**	**Left Maxillary**	**Left Ventral**	**Right Maxillary**	**Right Ventral**	**Total**
Okanagan	4	2	2	1		9
Snake	7					7
Wenatchee	2			1	1	4
Total	**13**	**2**	**2**	**2**	**1**	**20**

2017 Stock Composition Estimates

In 2017, genetics stock identification (GSI) was used to classify samples from 1095 Sockeye Salmon sampled at Bonneville Dam (Table 30). Among the sampled, it appeared that there were two Sockeye (one Wenatchee and one Okanagan) where a generic sample mix-up occurred. After excluding these mix ups, concurrence between Sockeye classified as Okanagan stock by GSI and PIT tag was 100% (272 out of 272) and 99.6% among the Wenatchee stock (258 out of 259, Table 30) with an overall concurrence of 99.8% (530 out of 531).

Table 30. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2017.[24]

Stock Estimated Using PIT Tags	Stock Estimated by GSI					
	Okanagan	Wenatchee	Snake	Deschutes	Unknown	Total
Okanagan	272	1			4	277
Wenatchee		258			3	261
Snake			3			3
Yakima	3	4				7
Unknown	378	151	3	2	11	545
Total	**739**	**415**	**6**	**2**	**20**	**1093**

When combining PIT and GSI stock determinations as described in the methods, this study estimated that the stock composition at Bonneville Dam in 2017 was 59.2% Okanagan, 39.6% Wenatchee, 0.7% Yakima, 0.5% Snake River, and 0.1% Deschutes (Table 31). The percentage of Okanagan Sockeye was highest early and late in the run while the percentage of the Wenatchee stock was highest at the peak of the run (Figure 11). PIT tag and GSI estimates varied by 10.6 percentage points for the Okanagan stock and 9.9 percentage points for the Wenatchee stock. The combined PIT/GSI and GSI estimates agreed more closely with visual fish count stock composition estimates presented in Table 31 than did the PIT Tag only estimate.

Among the 251 Sockeye Salmon classified as Wenatchee stock that were last detected in the Wenatchee River, 8 (3.2%) were previously detected at Rocky Reach Dam and 2 (0.8%) at Wells Dam (Table 32). One Wenatchee stock Sockeye was last detected in the Entiat River and a second in the Methow. One Sockeye, 3DD.00778B7281, identified using GSI as Wenatchee stock spent just over 4 hours ascending and then descending the Tumwater Dam fish ladder on July 31 and was last detected in the Rocky Reach ladder fish trap on August 9. Sockeye traveling from Tumwater Dam to Rocky Reach Dam has been rarely observed in the 9 years of this study. There was also a single Wenatchee stock Sockeye (3DD.0077BAA94B) last detected at Zosel Dam which is the first time we have observed an apparent Wenatchee-stock Sockeye detected in the Okanogan Basin.

[24] As discussed on page 29, two GSI classifications were considered genetic sample mix-ups and were moved to the unknowns.

Table 31. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2017 and a comparison to stock composition estimates estimated using visual dam counts.

Statistical Week and Dates	Run Size from Bonneville Dam Visual Counts	Sockeye Sampled at Bonneville Classified	% Okanagan	% Wenatchee	% Snake	% Yakima	% Deschutes
22-23 (5/28-6/10)	1,987	36	75.0%	22.2%	0.0%	2.8%	0.0%
24 (6/11-6/17)	10,475	140	64.2%	35.0%	0.0%	0.7%	0.0%
25 (6/18-6/24)	25,975	248	50.8%	49.2%	0.0%	0.0%	0.0%
26 (6/25-7/1)	26,669	295	60.3%	37.7%	1.3%	0.7%	0.0%
27 (7/2-7/8)	14,499	140	63.6%	34.3%	0.0%	2.1%	0.0%
28 (7/9-7/15)	5,646	145	63.3%	36.1%	0.7%	0.0%	0.0%
29 (7/16-7/22)	1,539	55	69.1%	30.9%	0.0%	0.0%	0.7%
30-34 (7/23-8/22)	903	20	65.0%	30.0%	5.0%	0.0%	1.8%
Combined PIT and GSI Estimate	**87,693**	**1079**	**59.2%**	**39.6%**	**0.5%**	**0.7%**	**0.1%**
PIT Tag Only Estimate			**48.7%**	**49.4%**	**0.5%**	**1.4%**	**NA**
GSI Only Estimate			**59.5%**	**39.9%**	**0.5%**	**NA**	**0.1%**
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)			63.8%	36.2%			
Visual Fish Counts at dams (Tumwater count to estimate the Wenatchee; Rocky Reach to estimate Okanagan)			62.2%	33.8%			

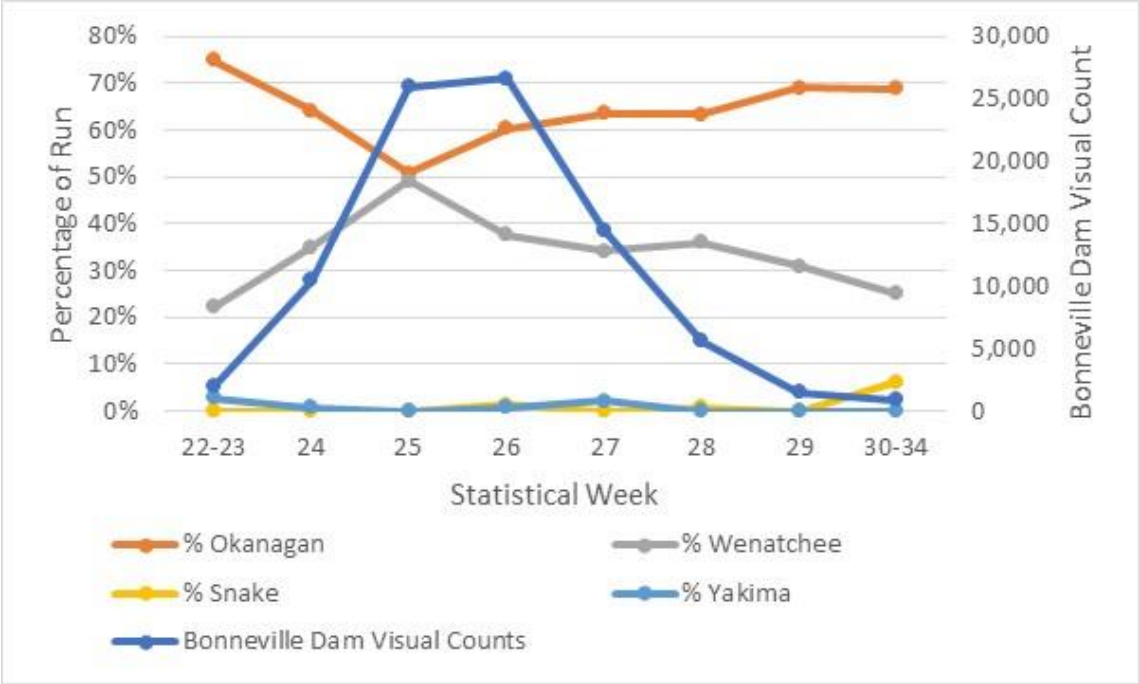


Figure 11. Percentage of the Sockeye run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, Yakima, and Deschutes origin by week in 2017

Table 32. GSI classification of Sockeye last detected in non-terminal areas (downstream of OKL, LWE, and Ice Harbor dams) in 2017.

Last Site Detected	Okanagan	Wenatchee	Snake	Deschutes	Total
Bonneville Dam (BO1, BO3, BO4, BCC)	69	51	3	1	124
Deschutes River mouth (DRM)	2				2
Entiat River (ENL, ENS)	1	1			2
McNary Dam (MC1, MC2)	51	14			65
Methow River (CRW)		1			1
Priest Rapids Dam	22	17			39
Prosser Dam		1			
Ringold Springs Hatchery	1				1
Rock Island Dam	4	12			16
Roza Dam (ROZ), Yakima River	3	3			6
Rocky Reach Dam fish ladders	5	2			7
The Dalles Dam (TD1, TD2)	51	49		1	101
Wells Dam	163	1			164
Not detected after tagging	11	5			16
Total	**383**	**157**	**3**	**2**	**545**

None of the 739 Sockeye classified using GSI as Okanagan stock (Table 30) were last detected in the Wenatchee River. One was last detected in the Entiat River and one at Ringold Springs hatchery upstream of Richland, WA. Two others

were last detected in the Deschutes River mouth; all others were last detected in the migratory corridor between Bonneville Dam and the Okanagan River (Table 32).

Among the six Sockeye classified as Snake River origin, three were last detected at Bonneville Dam, one at Lower Granite Dam, and two in the Stanley Basin, ID (one at the Sawtooth Hatchery Trap (STL) and the other at Valley Creek (VC1)).

Among the two Sockeye classified as being of Deschutes origin, one was last detected at Bonneville Dam and the other at The Dalles Dam (Table 32).

A total of seven sockeye were detected at Prosser Dam with six subsequently detected at Roza Dam. Among these seven Sockeye, four were classified using GSI as of Wenatchee origin and three Okanagan. It is presumed that these may have been offspring of sockeye translocated in previous years to Cle Elum Lake so these Sockeye were considered of Yakima origin (Table 32).

A total of six Sockeye Salmon included in this study in 2017 were previously adipose clipped and two were left ventral, one right ventral, and one left maxillary clipped (Table 33). Of three Okanagan stock clipped Sockeye, one each was last detected at OKL, ZSL, and TD1. The Wenatchee clipped Sockeye were last detected at Priest Rapids Dam and WTL, and the Snake River Sockeye last detected at Bonneville Dam (one in the Washington shore fish ladder and the other in the corner collector, BCC) and one each at Lower Granite Dam, Valley Creek (VC2) and at the Sawtooth Hatchery trap (STL).

Table 33. Type and number of fin clips by stock for Sockeye Salmon sampled at Bonneville Dam in 2017.

	Clip Type				
Stock	**Adipose**	**Left Maxillary**	**Left Ventral**	**Right Ventral**	**Total**
Okanagan		1	1	1	3
Snake	5				5
Wenatchee	1		1		2
Total	**6**	**1**	**2**	**1**	**10**

Stock Specific Upstream Survival

Upstream survival of Okanagan Sockeye Salmon was lower in 2017 than in 2016 (72.1% vs 85.8% to Rock Island, 32.3% vs 40.7% to OKC, Tables 34 and

35). Upstream survival of Wenatchee Sockeye stock was also lower to Rock Island in 2017 compared to 2016 (69.6% vs 78.1%) but higher the spawning grounds (56.6% vs 44.5%).

Table 34. Stock specific survival from Bonneville Dam weighted by weekly Bonneville Dam run size, as estimated by GSI and PIT tags in 2016.

	Estimated survival from Bonneville Dam by stock (%)								
	Okanagan (n=1123)			Wenatchee (=469)			Snake River (n=7)		Okanagan, Wenatchee, Snake combined (n=1599)
Statistical Week	Rock Island Dam	Zosel Dam	Okanagan Spawning (OKC)	Rock Island Dam	Tumwater Dam	Wenatchee Spawning (LWE or WTL)	Snake River	Snake Spawning[25]	Snake, OKA, WEN Spawning
22-23	91.5	84.7	42.4	100.0	100.0	44.4	NA	NA	42.6
24	95.5	90.9	47.4	81.8	76.4	47.3	NA	NA	47.4
25	89.5	85.2	48.5	88.8	85.7	42.9	NA	NA	46.8
26	89.7	84.3	40.2	80.0	76.8	46.3	NA	NA	42.1
27	78.7	63.8	40.2	71.8	66.2	43.7	66.7	0.0	40.7
28	82.9	52.0	32.5	73.9	67.4	52.2	100.0	0.0	37.6
29	53.1	27.2	13.6	70.6	66.7	43.1	50.0	0.0	25.4
30	58.8	29.4	17.6	51.9	40.7	33.3	NA	NA	29.5
31	50.0	20.0	10.0	28.6	14.3	14.3	NA	NA	11.8
32-34	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0
2016	**85.8**	**76.0**	**40.7**	**78.1**	**73.8**	**44.5**	**57.1**	**0.0**	**41.8**

[25] Detected in upper Salmon River upstream of Stanley, ID.

Table 35. Stock specific survival from Bonneville weighted by weekly Bonneville Dam run size, as estimated by GSI and PIT tags in 2017. Survival to Zosel Dam could not be accurately estimated in 2017 due to high flows resulting in Sockeye bypassing fish ladders where PIT tag antennas are located.

	Estimated survival from Bonneville Dam by stock (%)								
	Okanagan (n=642)			Wenatchee (n=409)			Snake River (n=6)		Okanagan, Wenatchee, Snake combined (n=1077)
Statistical Week	Rock Island Dam	Zosel Dam	Okanagan Spawning (OKC)	Rock Island Dam	Tumwater Dam	Wenatchee Spawning (LWE or WTL)	Snake River	Snake Spawning[26]	Snake, OKA, WEN Spawning
23	85.2	NA	46.4	87.5	75.0	50.0	NA	NA	50.0
24	87.2	NA	31.0	80.4	71.7	69.6	NA	NA	47.4
25	75.8	NA	34.1	77.9	74.6	68.0	NA	NA	51.4
26	79.8	NA	36.0	68.5	62.2	55.9	75.0	0.0	43.9
27	55.1	NA	26.7	62.0	56.0	48.0	NA	NA	36.4
28	56.5	NA	28.3	51.0	39.2	31.4	0.0	0.0	29.0
29	35.1	NA	13.5	17.6	5.9	5.9	NA	NA	10.9
30	10.0	NA	0.0	25.0	0.0	0.0	0.0	0.0	0.0
2017	**72.1**	**NA**	**32.3**	**69.6**	**63.2**	**56.6**	**16.7**	**0.0**	**44.9**
2016	**85.8**	**76.0**	**40.7**	**78.1**	**73.8**	**44.5**	**57.1**	**0.0**	**41.8**

[26] Detected in upper Salmon River upstream of Stanley, ID.

Wells Dam Sampling Results

A total of 810 Sockeye Salmon were sampled at the Wells Dam east bank fish ladder in 2016 and 334 in 2017 (Tables 36 and 37). After adding in previously tagged Sockeye (6 in 2016 and 7 in 2017), and subtracting mortalities (2 in 2016, none in 2017) a total number of tagged Sockeye released was 808 in 2016 and 334 in 2017. In August 2016, WDFW trapped and PIT tagged 27 additional Sockeye for us. Sample size was reduced in 2017 due to the lower number of Sockeye passing Wells Dam (42,299 compared to 216,036 in 2016) making sampling more difficult.

Table 36. Number of Sockeye Salmon sampled and PIT tagged at Wells Dam by date and statistical week in 2016.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	Mortalities	Tagged Sockeye Released
6/27-6/29	27	132	132	0	0	132
7/5-7/7	28	218	218	0	2	216
7/11-7/13	29	241	237	4	0	241
7/18-19	30	100	99	1	0	100
7/25-7/27	31	119	118	1	0	119
Total		**810**	**804**	**6**	**2**	**808**
Additional Sockeye Sampling and Tagging Conducted by WDFW						
8/8-8/10	33	13	13	**0**	0	13
8/15-8/17	34	12	12	**0**	1	11
8/23-8/24	35	2	2	**0**	0	2
Total		**27**	**27**	**0**	**0**	**27**

Table 37. Number of Sockeye Salmon sampled and PIT tagged at Wells Dam by date and statistical week in 2017.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	Mortalities	Tagged Sockeye Released
6/28-29	27	25	25	0	0	25
7/5-7/6	28	67	65	2	0	67
7/10-7/11	29	118	117	1	0	118
7/17-19	30	96	92	4	0	96
7/24-7/25	31	28	28	0	0	28
Total		**334**	**327**	**7**	**0**	**334**

In all weeks in 2016, Age 1.2 was the predominant age class at Wells Dam (Table 38) comprising an estimated 81.4% to 89.6% of the weekly run for weeks

27-31, and up to 100.0% in weeks 33 and 35. Age 1.3 was the second most abundant age class comprising 9.6% to 15.5% of the weekly run. Among those Sockeye visually identified as males, 80.2% were Age 1.2 and 18.4% 1.3 compared to 93.4% and 5.4% respectively for those identified as females (Table 38).

Table 38. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2016. Sex was visually estimated when the fish were sampled.

					Age			
Stat Week	**Sampling Dates**	**Percentage of Run**	**N**	**N Ageable**	**1.1**	**1.2**	**1.3**	**2.2**
27	6/27-6/29	30.1%	132	125	0.0%	89.6%	9.6%	0.8%
28	7/5-7/8	39.9%	218	213	0.0%	88.3%	11.7%	0.0%
29	7/11-7/13	17.9%	241	229	0.0%	88.2%	10.9%	0.9%
30	7/18-7/19	7.3%	100	97	1.0%	81.4%	15.5%	2.1%
31	7/25,27,28	4.8%	119	117	0.9%	86.3%	10.3%	2.6%
Composite			**810**	**781**	**0.1%**	**88.1%**	**11.1%**	**0.7%**
Males (visual ID)			373	358	0.6%	80.2%	18.4%	0.8%
Females (visual ID)			436	423	0.0%	93.4%	5.4%	1.2%
Additional Sockeye Sampling Tagging Conducted by WDFW During Chinook Broodstock Collection								
33	8/8-8/10		10	9	0.0%	100.0%	0.0%	0.0%
34	8/15-8/17		12	12	0.0%	83.3%	16.7%	0.0%
35	8/23-8/24		2	2	0.0%	100.0%	0.0%	0.0%
Total			**21**	**12**	**0.0%**	**91.3%**	**8.7%**	**0.0%**
Males			9	8	0.0%	86.7%	13.3%	0.0%
Females			15	15	0.0%	100.0%	0.0%	0.0%

In 2017, Age 1.2 was the predominant age class at Wells Dam (Table 39) in three out of five weeks, second to Age 1.3 in one week, and the two ages were tied in Week 26. Age 1.1 Sockeye generally increased as the run progressed and, in the Week 30, Age classes 1.1, 1.2, and 1.3 each comprised roughly one third of the run. Among those Sockeye visually identified as males, 39.9% were Age 1.2 and 52.3% were Age 1.3 compared to 64.2% and 23.3% respectively for those identified as females (Table 39).

Table 39. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2017. Sex was visually estimated when the fish were sampled.

				Age				
Stat Week	**Percentage of Run**	**N**	**N Ageable**	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**
26	5.4%	25	25	4.0%	48.0%	0.0%	48.0%	0.0%
27	27.1%	67	65	1.5%	46.2%	4.6%	44.6%	3.1%
28	37.1%	118	113	2.7%	61.1%	0.0%	36.3%	0.0%
29	19.2%	96	94	7.4%	47.9%	2.1%	38.3%	4.3%
30	11.3%	28	27	29.6%	33.3%	0.0%	37.0%	0.0%
Composite		**334**	**324**	**6.4%**	**50.7%**	**1.7%**	**39.6%**	**1.6%**
Males (visual ID)		185	177	6.0%	39.9%	0.7%	52.3%	1.1%
Females (visual ID)		149	147	7.1%	64.2%	3.1%	23.3%	2.3%

2016 Priest Rapids Dam Sampling

In 2016, we were funded by Whooshh Innovations to conduct a study at Priest Rapids dam that tested the impact Whooshh Fish Transport System (WFTS, www.whooshh.com) had on Sockeye Salmon at Priest Rapids Dam (Fryer, 2017). Similar to sampling at Wells and Bonneville dams, Sockeye Salmon were sampled for biological information, scales and genetics sample taken, and they were PIT tagged, and released and tracked upstream. Prior to release, half of the Sockeye were transported by the WFTS back to the fishway or over the dam and the other half were immediately released. Results pertaining to the impact of WFTS on Sockeye Salmon will not be discussed in this report; the only results used will be to provide another migrating adult group of Sockeye for analysis, which could be compared to those tagged at Wells Dam.

A total of 906 Sockeye were sampled at the Priest Rapids Dam OLAFT between June 29 and July 22, 2016, of which 897 were tagged (Table 40). This number, combined with 5 Sockeye previously tagged, resulted in a tagged group of 902. On the final day of sampling, there were five mortalities that were likely the result of being left too long in the anesthetic when WFTS logistical issues pulled the project lead away from the sampling area. Subtracting these five mortalities resulted in a total tagging and tracking group size of 897 (Table 40). Age composition estimates were similar to those estimated at Bonneville Dam, with a slightly higher percentage of Age 1.2 Sockeye and a correspondingly lower percentage of Age 1.3 Sockeye at Priest Rapids when compared to Bonneville Dam (Table 41).

Table 40. Summary of 2016 Priest Rapids Dam Sockeye sampling.

Statistical Week	Dates	Number Sampled	Number Tagged	Number Previously Tagged	Number of Mortalities	Tags Released
27	June 29-30, July 1	300	298	0	0	298
28	July 6-7	340	337	3	0	340
29	July 12	150	149	0	0	149
30	July 22	116	113	2	5	110
Total		**906**	**897**	**5**	**5**	**897**

Table 41. Age composition of Sockeye Salmon sampled at Priest Rapids Dam in 2016.

			Age		
Statistical Week	Percentage of Run	N Ageable	1.1	1.2	1.3
27	65.5%	291	1.4%	93.1%	5.5%
28	22.2%	331	0.9%	90.6%	8.5%
29	8.5%	148	0.7%	91.9%	7.4%
30	3.8%	105	0.0%	89.5%	10.5%
Total		**875**	**1.2%**	**92.3%**	**6.5%**
Bonneville Dam (from Table 4)		**1657**	**0.7%**	**88.1%**	**10.6%**

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

In 2016 age composition estimates for Sockeye sampled at Bonneville, Priest Rapids and Wells dams are presented in Table 42 as well as those estimated by stock from GSI of Sockeye sampled at Bonneville Dam. The latter estimates that Wenatchee Sockeye Salmon had much higher percentage of older Age 1.3, and lower percentage of Age 1.2 Sockeye than Okanagan Sockeye Salmon. Sockeye sampled at Wells Dam also had a higher percentage of Age 1.3 Sockeye than what was estimated from Bonneville Dam samples. This is likely attributable to a trap bias as the Wells Dam trap tends to select for larger, and therefore, older Sockeye Salmon due to the 5.1 cm spacing of the bars on the weir fish into the trap. This is sufficiently wide that smaller fish can slip through and avoid the trap.

Table 42. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2016.

		Ageable Sample Size	Brood Year and Age Class				
			2013	2012		2011	
Sampling Site	Stock		1.1	1.2	2.1	1.3	2.2
Bonneville Dam	Mixed	1672	0.7%	88.1%		10.6%	0.5%
Priest Rapids Dam	Mixed	875	1.2%	92.3%	0.4%	6.5%	
Bonneville Dam	Wenatchee: Stock determined as described on pages 29-30 of this report	478	0.0%	68.0%		32.0%	0.0%
Bonneville Dam	Okanagan: Stock determined as described on pages 29-30 of this report	1142	0.9%	95.9%		2.4%	0.7%
Wells Dam	Okanagan	781	0.1%	88.1%		11.1%	0.7%

In 2017, both the Wenatchee and Okanagan stocks had lower percentages of Age 1.2 Sockeye than in 2016 (Table 43). The majority of the Wenatchee stock was Age 1.3, compared to 2016, when the majority was Age 1.2. For the Okanagan stock also had a much high percentage of Age 1.3 Sockeye, then in 2016.

Table 43. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2017.

Sampling Site	Stock Methodology	Ageable Sample Size	Brood Year and Age Class					
			2014	2013		2012		2011
			1.1	1.2	2.1	1.3	2.2	2.3
Bonneville Dam	Mixed	1051	11.7%	47.6%	2.2%	36.3%	2.0%	0.2%
Bonneville Dam	Wenatchee: Stock determined as described on pages 29-30 of this report	396	0.0%	41.2%		57.2%	1.6%	
Bonneville Dam	Okanagan: Stock determined as described on pages 29-30 of this report	631	19.0%	52.7%	3.6%	22.1%	2.2%	0.4%
Wells Dam	Okanagan	324	6.4%	50.7%	1.7%	39.6%		1.6%

Mean fork lengths estimated by measuring Sockeye Salmon at Wells Dam were greater than those estimated at for the Okanagan stock using data collected at Bonneville Dam (Table 44 for 2016 and Table 45 for 2017) for the larger-sized fish age groups (1.2, 1.3, 2.2), likely due to the aforementioned spacing on the weir diverting fish into the trap. The same trend is also evident in 2017 (Table 45).

Table 44. Length-at-age (fork length) 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 2016.

Stock	Statistic	Brood Year and Age Class			
		2013	2012	2011	
		1.1	1.2	1.3	2.2
Bonneville Dam-Mixed Stock (Excluding weeks 28-29)	Mean Length	39.7	48.6	55.4	48.7
	St. Dev.	1.8	2.3	2	3.7
	N	13	1468	182	9
Priest Rapids Dam-Mixed Stock (Weeks 28-30 only)	Mean Length	42.1	49.6	56.7	
	St. Dev.	2.1	2.6	2.1	
	N	8	801	66	
Okanagan-based on GSI of Sockeye tagged at Bonneville Dam	Mean Length	39.3	48.2	54.2	48.8
	St. Dev.	1.8	2.2	2.0	4.0
	N	11	1089	34	8
Okanagan-Wells Sampling	Mean Length	39.0	50.8	57.1	52.1
	St. Dev.	2.8	2.7	2.1	1.0
	N	2	682	89	8
Snake River-Bonneville PIT tags	Mean Length		52.9		
	St. Dev.		1.6		
	N		7		
Wenatchee based on GSI of Sockeye tagged at Bonneville Dam	Mean Length		49.9	55.7	
	St. Dev.		2.0	1.8	
	N		334	144	

Table 45. Length-at-age (fork length) 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 2017.

Stock	Statistic	Brood Year and Age Class					
		2014	2013		2012		2011
		1.1	1.2	2.1	1.3	2.2	2.3
Bonneville Dam-Mixed Stock	Mean Length	37.3	49.8	39.7	54.6	50.8	52.8
	St. Dev.	1.8	2.3	1.9	2.2	2.1	3.2
	N	140	488	28	370	22	2
Okanagan-based on GSI of Sockeye tagged at Bonneville Dam	Mean Length	37.3	49.7	39.8	53.8	50.3	52.8
	St. Dev.	1.8	2.4	1.8	2.4	1.6	3.2
	N	138	319	27	134	14	2
Okanagan-Wells Sampling	Mean Length	37.9	51.8	42.2	55.3	53.5	
	St. Dev.	1.6	2.6	2.5	2.4	2.7	
	N	20	165	5	128	6	
Snake River-Bonneville PIT tags	Mean Length		50.0		56.0		
	St. Dev.		--		--		
	N		1		1		
Wenatchee based on GSI of Sockeye tagged at Bonneville Dam	Mean Length	38.0	49.9		55.0		
	St. Dev.	--	2.2		2.0		
	N	1	161		230		

Stock Composition at Wells Dam

In 2016 and 2017, we had insufficient funds to conduct GSI on all Sockeye sampled at Wells Dam, thus we assumed that all Sockeye detected in the Okanagan River were Okanagan origin and completed GSI on the remaining fish that migrated over Wells Dam to estimate stock composition at Wells Dam, but were not detected in the Okanagan or were detected at other sites. Using this method, in 2016, based on Wells sampling, we estimated that 10.3% of fish passing Wells were Wenatchee origin compared to 1.8% if estimated using Sockeye tagged at Bonneville Dam and detected passing Wells Dam (Table 46). No reason could be found for this disparity in stock composition estimates at Wells Dam. One Sockeye (3DD.00779BF30C) tagged and last detected at Wells Dam was estimated using GSI to be of Snake River origin.

Table 46. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI and PIT tags in 2016. (Wells Dam estimates are weighted by the weekly Wells Dam run size, Bonneville estimates are unweighted.)

Week at Wells Dam	Bonneville Tagged			Wells Tagged			
	N	Okanagan	Wenatchee	N	Okanagan	Wenatchee	Snake
25	20	100.0%	0.0%				
26	108	100.0%	0.0%				
27	268	97.8%	2.2%	132	95.5%	4.5%	0.0%
28	224	98.2%	1.8%	213	85.4%	14.6%	0.0%
29	152	98.7%	1.3%	238	92.9%	7.1%	0.0%
30	82	100.0%	0.0%	97	83.5%	16.5%	0.0%
31	49	95.9%	4.1%	116	85.3%	13.8%	0.9%
32	17	100.0%	0.0%				
33-35	12	83.3%	16.7%				
Total	**932**	**98.2%**	**1.8%**	**796**	**89.6%**	**10.3%**	**0.0%**

In 2017, 1.8% of the run at Wells Dam was estimated to be of Wenatchee origin using Wells Dam-tagged fish compared to 1.2% when estimated using Bonneville-tagged Sockeye (Table 47). No Sockeye samples collected at Wells Dam and analyzed using GSI were classified as Snake River Sockeye in 2017.

Table 47. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI and PIT tags in 2017. (Wells Dam estimates are weighted by the weekly Wells Dam run size, Bonneville estimates are unweighted.)

Week at	Bonneville Tagged			Wells Tagged			
Wells Dam	N	Okanagan	Wenatchee	N	Okanagan	Wenatchee	Snake
25-26	36	100.0%	0.0%				
26	125	99.2%	0.8%	24	100.0%	0	0.0%
27	146	99.3%	0.7%	63	100.0%	0	0.0%
28	69	97.1%	2.9%	120	100.0%	0.0%	0.0%
29	45	100.0%	0.0%	91	94.5%	5.5%	0.0%
30	29	93.1%	6.9%	29	93.1%	6.9%	0.0%
31-33	36	100.0%	0.0%				
Total	**450**	**98.8%**	**1.2%**	**327**	**98.2%**	**1.8%**	**0.0%**

Migration into Natal Areas-Okanagan River

Based on PIT tag detections, the estimated percentage of Sockeye surviving from Wells Dam to Zosel Dam in 2016 was 74.4% for Sockeye tagged at Wells Dam (32.3% last detected at Zosel plus 36.8% last detected at OKC plus 5.3% last detected at Skaha Dam) compared to 89.0% for Sockeye tagged at Bonneville Dam and 88.1% for Sockeye tagged at Priest Rapids Dam (Table 48). Of the Sockeye Salmon tagged at Wells Dam, 7.7% were last detected downstream of Wells Dam compared to 1.3% of the Sockeye tagged at Bonneville Dam and 0.8% of the Sockeye tagged at Priest Rapids Dam which were detected at Wells Dam and were last detected downstream of Wells Dam in the Wenatchee Basin, Entiat River, East Bank Hatchery, or at Rocky Reach Dam (Table 49). GSI classified all Wells-tagged Sockeye (five fish) last detected in the Wenatchee Basin as being of Wenatchee origin, while all Sockeye last detected at Eastbank Hatchery or Rocky Reach Dam (six fish) were of Okanagan origin (Table 49). Nineteen Sockeye were last detected in the Methow Basin, 26.3% (5 fish) classified as Okanagan origin and 73.7% (14 fish) as Wenatchee origin. Of the 100 Sockeye Salmon last detected at Wells Dam, GSI classified 99 as Okanagan origin and 1 as Snake origin.

Given the high percentage of tagged Sockeye Salmon which passed Zosel Dam by ascending the open spill gates in 2017, thus evading detection, survival to

Zosel Dam was not possible to estimate in 2017. The conversion rate[27] from Wells to OKC of tagged Sockeye in 2017 (45.8% for Wells-tagged Sockeye and 45.1% for Bonneville-tagged Sockeye, Table 50) was similar to that in 2016 (42.1% for Wells-tagged and 47.7% for Bonneville-tagged Sockeye, Table 48). Straying downstream to sites other than those in the Okanagan River was estimated at 1.8% for the Wells-tagged Sockeye and 0.8% for the Bonneville-tagged Sockeye Salmon. GSI classified all Sockeye (four fish) last detected in the Wenatchee Basin as Wenatchee origin and all Sockeye (three fish) last detected in Okanagan River tributaries downstream of Zosel Dam as being of Okanagan origin (Table 51). Only three Sockeye were last detected in the Methow (one classified as Wenatchee, the other two as Okanagan) and two were last detected in the Entiat (one Wenatchee, one Okanagan) (Table 51).

[27] Since the detection rate at OKC is unknown and likely well under 100%, conversion rate is the term normally used in place of survival.

Table 48. Number of Wells Dam sampled and tagged Sockeye released upstream at the Wells Dam East Bank Fish ladder in 2016 with the estimated percentage last detected by site (weighted by weekly run size at Wells Dam). Rates for Bonneville and Priest Rapids dams' tagged Sockeye Salmon detected at Wells Dam are shown for comparison.

			Detection Sites are in Order from Downriver to Upriver – Left to Right											
Week	% Wells Run	N	Wenatchee Basin	East Bank Hatchery	Rocky Reach Fishway	Entiat River	Wells Dam	Methow River	OKL Array	Okanagan Tributaries	Zosel Dam	OKC	Skaha Dam	Not Detected
26	10.7%	132	2.3%	0.0%	0.0%	0.0%	4.5%	0.8%	0.0%	0.0%	40.9%	40.2%	9.8%	1.5%
27	35.5%	218	10.1%	0.0%	0.5%	0.5%	11.0%	0.9%	0.5%	0.0%	32.6%	37.6%	4.1%	2.3%
28	37.5%	241	4.6%	0.0%	0.4%	0.4%	17.0%	2.5%	4.1%	0.0%	30.3%	36.1%	3.3%	1.2%
29	10.2%	99	8.1%	0.0%	0.0%	4.0%	25.3%	5.1%	11.1%	1.0%	14.1%	28.3%	1.0%	2.0%
30	2.7%	119	5.0%	0.8%	4.2%	4.2%	29.4%	3.4%	5.9%	0.8%	10.1%	24.4%	0.8%	10.9%
Weighted Total		**809**	**6.4%**	**0.0%**	**0.5%**	**0.8%**	**12.1%**	**1.6%**	**2.0%**	**0.1%**	**32.3%**	**36.8%**	**5.3%**	**2.3%**
Bonneville Tagged Sockeye Detected at Wells		**932**	**1.0%**	**0.1%**	**0.1%**	**0.1%**	**6.9%**	**0.5%**	**2.3%**	**0.0%**	**41.3%**	**41.8%**	**5.9%**	**NA**
Priest Rapids Dam		**476**	**0.6%**	**0.0%**	**0.1%**	**0.1%**	**9.2%**	**0.3%**	**1.7%**	**0.0%**	**38.3%**	**46.3%**	**3.5%**	**NA**
Additional Sockeye Tagging Conducted by WDFW During Chinook Broodstock Collection														
33	0.4%	10	0.0%	0.0%	0.0%	10.0%	20.0%	30.0%	0.0%	0.0%	0.0%	30.0%	0.0%	0.0%
34	0.2%	12	0.0%	0.0%	0.0%	0.0%	54.5%	10.0%	0.0%	0.0%	0.0%	27.3%	0.0%	9.9%
35	0.1%	2	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 49. GSI stock classification by basin of last detection for Sockeye Salmon tagged at Wells Dam in 2016 which were not detected at, or upstream of, Zosel Dam.

	GSI Classification			
Last Detection	**Okanagan**	**Wenatchee**	**Snake**	**Total**
Wenatchee Basin	0	5	0	5
Rocky Reach/Eastbank Hatchery	6	0	0	6
Wells Dam	99	0	1	100
Methow Basin	5	14	0	19
Okanagan downstream of Zosel Dam	2	0	0	2
Total	**112**	**19**	**1**	**132**

Table 50. Number of Wells Dam sampled and tagged Sockeye released in the Wells Dam East Bank fish ladder in 2017 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.

			Detection Sites are in Order from Downriver to Upriver – Left to Right									
Week	Wells Run %	N	Wenatchee River	Rocky Reach Juv Bypass	Entiat River	Wells Dam	Methow River	OKL Array	Omak Creek (Okanagan Tributary)	Zosel Dam	OKC	Not Detected
26	10.7%	25	0.0%	0.0%	0.0%	25.0%	2.8%	2.7%	0.0%	2.9%	26.5%	4.0%
27	35.5%	67	0.0%	0.0%	0.0%	21.8%	0.0%	4.7%	0.0%	2.1%	33.7%	1.6%
28	37.5%	118	0.0%	0.0%	0.0%	19.9%	0.6%	7.7%	0.6%	4.3%	33.3%	1.0%
29	10.2%	96	3.5%	0.0%	1.2%	13.8%	1.4%	6.2%	0.0%	6.3%	33.8%	2.3%
30	2.7%	28	3.6%	1.8%	0.0%	14.8%	2.2%	0.0%	0.0%	2.2%	31.8%	6.7%
Weighted Total		**334**	**1.0%**	**0.4%**	**0.4%**	**34.2%**	**1.3%**	**8.9%**	**0.3%**	**5.4%**	**45.8%**	**2.1%**
Bonneville Tagged Sockeye Detected at Wells		**874**	**0.5%**	**0.0%**	**0.3%**	**37.5%**	**0.1%**	**10.8%**	**0.0%**	**5.7%**	**45.1%**	**NA**

Table 51. GSI stock classification by basin of last detection for Sockeye Salmon tagged at Wells Dam in 2017.

Last Detection	GSI Classification		
	Okanagan	Wenatchee	Total
Wenatchee Basin	0	4	4
Rocky Reach/Eastbank Hatchery	1	0	1
Entiat River	1	1	2
Wells Dam	23	1	24
Methow Basin	2	1	3
Okanagan River tributaries downstream of Zosel Dam	3	0	3
Total	**29**	**3**	**32**

In 2016, only 6.2% (50 of 817) of Sockeye detected at OKL passed during days when the mean daily temperature was above 22C (June 29-July 3, July 24-August 7, August 11-August 21, and August 26-27, Figure 12). Despite the high-water temperatures, survival of PIT-tagged Sockeye from OKL to Zosel Dam was generally high (Figure 13), trending down as the run progressed. This same trend of declining survival as the run progressed can also be seen when looking at survival from Wells Dam to Zosel Dam by date at Wells Dam (Figure 14) with no sockeye tagged at, or passing, Wells Dam after July 28, 2016 being detected at Zosel Dam. However, only 2.3% of the run passed Wells Dam on or after July 29.

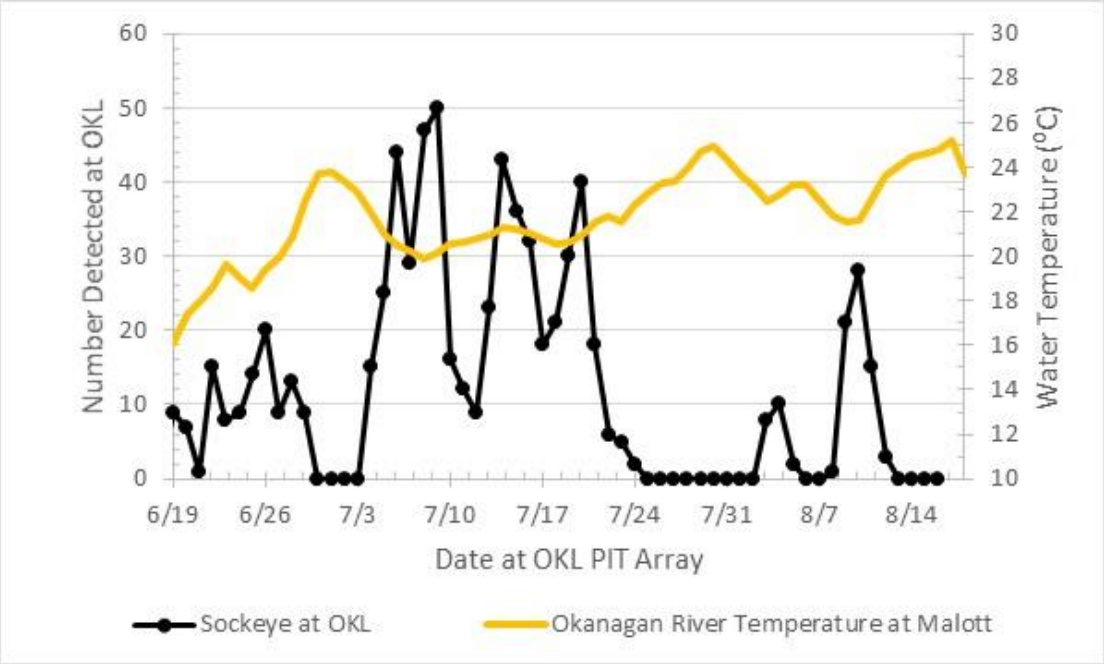


Figure 12. Number of Sockeye (PIT tagged at Bonneville, Priest Rapids, and Wells dams) detected at OKL by date in 2016 with daily Okanagan River temperatures.

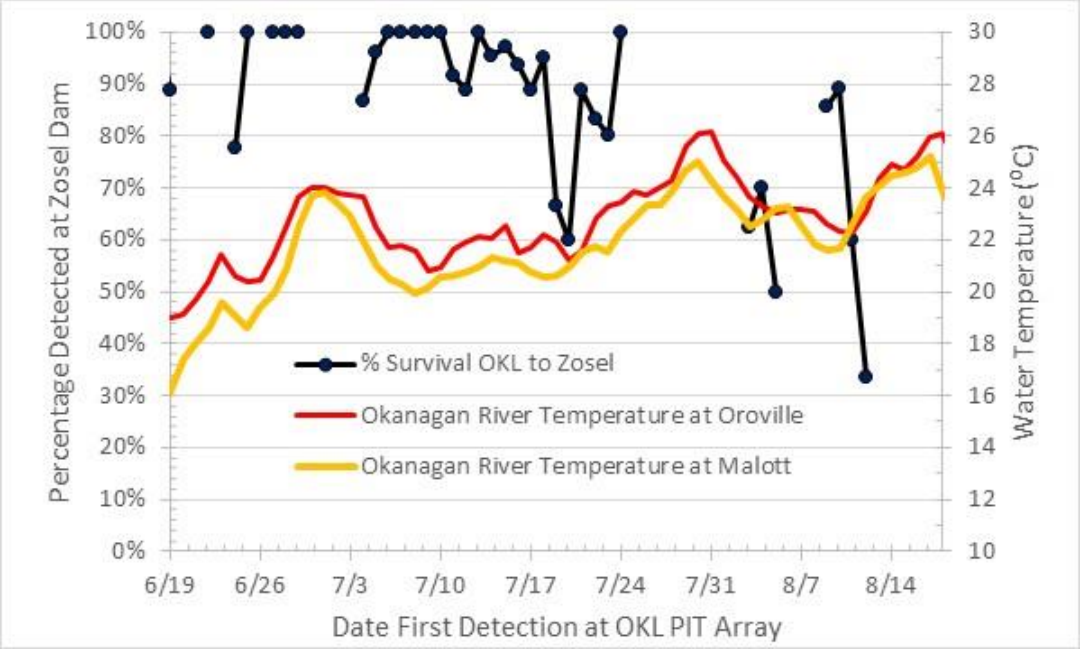


Figure 13. Percentage of Sockeye Salmon tagged at Bonneville, Priest Rapids, and Wells dams passing OKL and detected at Zosel Dam in 2016 with daily Okanagan River temperatures.

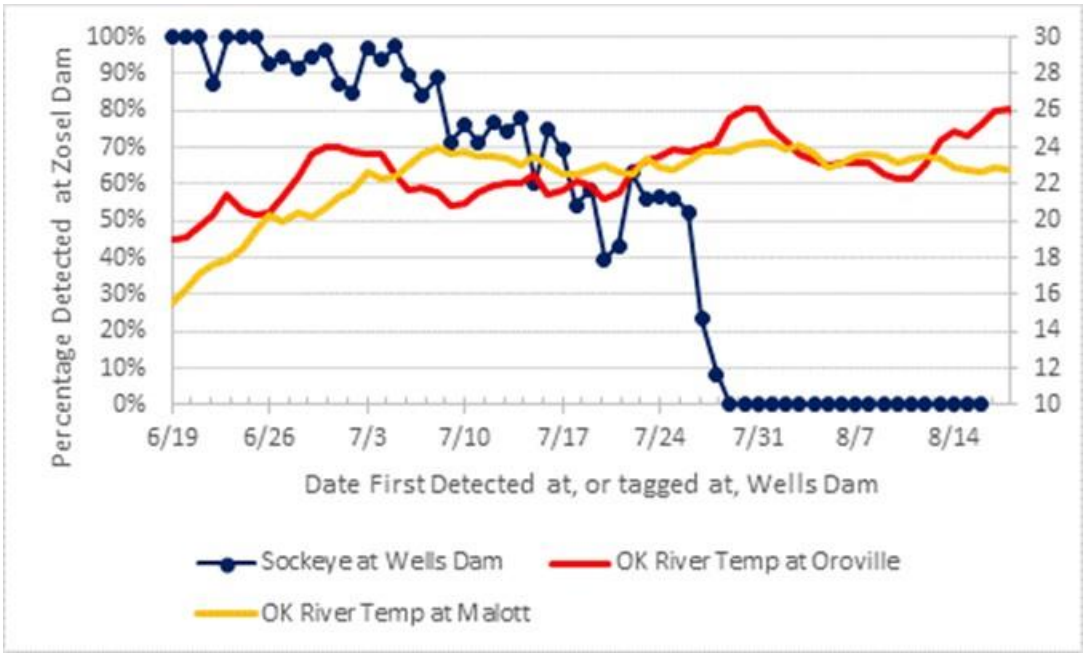


Figure 14. Percentage of Sockeye tagged at Bonneville, Priest Rapids, and Wells Dam passing Wells Dam subsequently detected at Zosel Dam by date past Wells Dam in 2016. Okanagan River temperatures were recorded at the Malott and Oroville gaging station. (http://waterdata.usgs.gov/nwis).

The 2017, upstream migration in the Okanagan River was unusual for having high flows combined with high temperatures. The mean Okanagan River water temperature at the USGS gaging station at Malott, at rkm 27, averaged 22C or more for 53 consecutive days beginning July 3, 2017 (Figure 15). Since 2008, the number of days with a mean water temperature above 22C in 2017 was second only to 2015 with 61 days. These high temperatures occurred despite higher than average flows in 2017. The mean Okanagan River flow at Oroville was the highest in the past 10 years in August second highest during those years in July. High flows meant that Sockeye primarily passed Zosel Dam through open spillways, rather than the fish ladder where the PIT tag antennas are located. Passage through the spillways occurred until the gates were lowered to 30 cm on August 23, which is the approximate level at which Sockeye cannot pass spillways and must use the fishway (Sonya Schaller, Confederated Colville Tribes, personal communication).

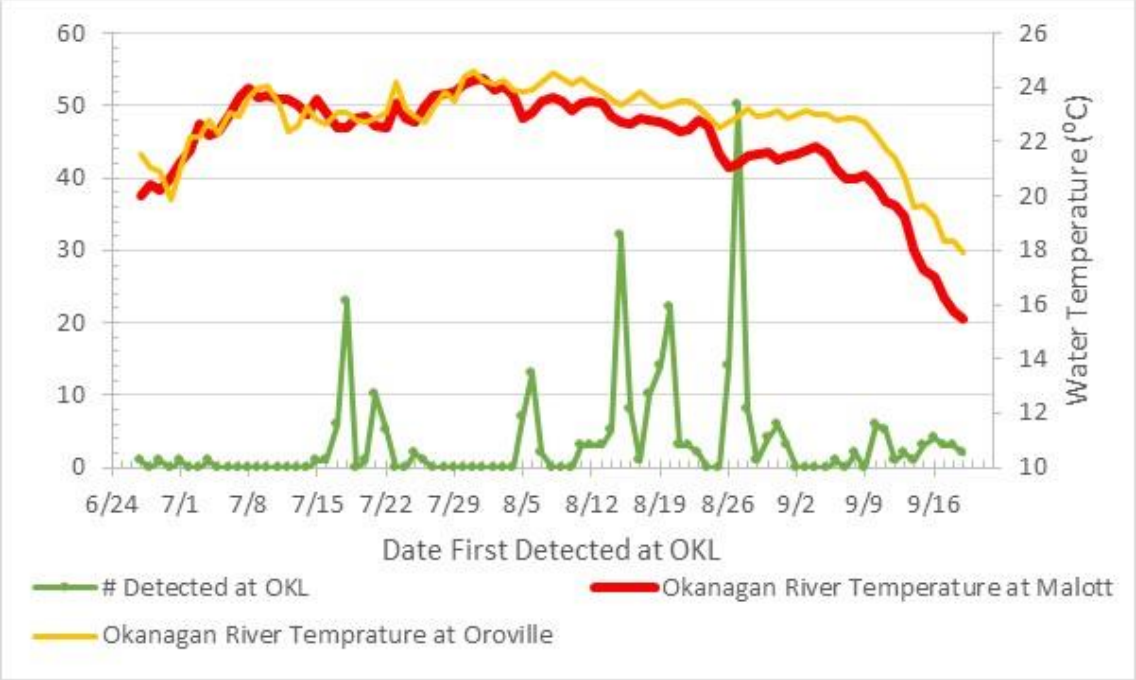


Figure 15. Number of Sockeye Salmon tagged passing OKL by date and Okanagan River temperatures at Malott and Oroville in 2017.

It was difficult to examine run timing or survival to Zosel Dam because of the low PIT tag detection rate at the site. However, run timing as determined by PIT tag detections at OKL[28] shows that Sockeye moved into the Okanagan at dips in temperature that occurred around July 14-26, August 11-23, and 26 to September 1, with the largest movement occurring August 26-28 (Figure 16, Table 52). In addition, four Sockeye were detected before temperatures reached 22C between June 27 and July 4 and an additional 33 were detected after September 6 when temperatures were below 22C. The highest percentage detected upstream at OKC was the found with the earliest two groups which migrated in June and July. The lowest survival was among those fish detected at OKL between August 26 and September 1 which migrated on a dip in river temperatures of 22.7 on August 26. However, after entering the river, temperatures then ascended to 23.3 on August 28 and did not decline to 22.7 again until September 9. Another group with low survival were those fish migrating between August 5 and 7 which migrated on a dip in temperatures to 23.9 on August 5. After these fish entered the river the temperature subsequently climbed to 24.6 and did not return to 23.9 until August 13.

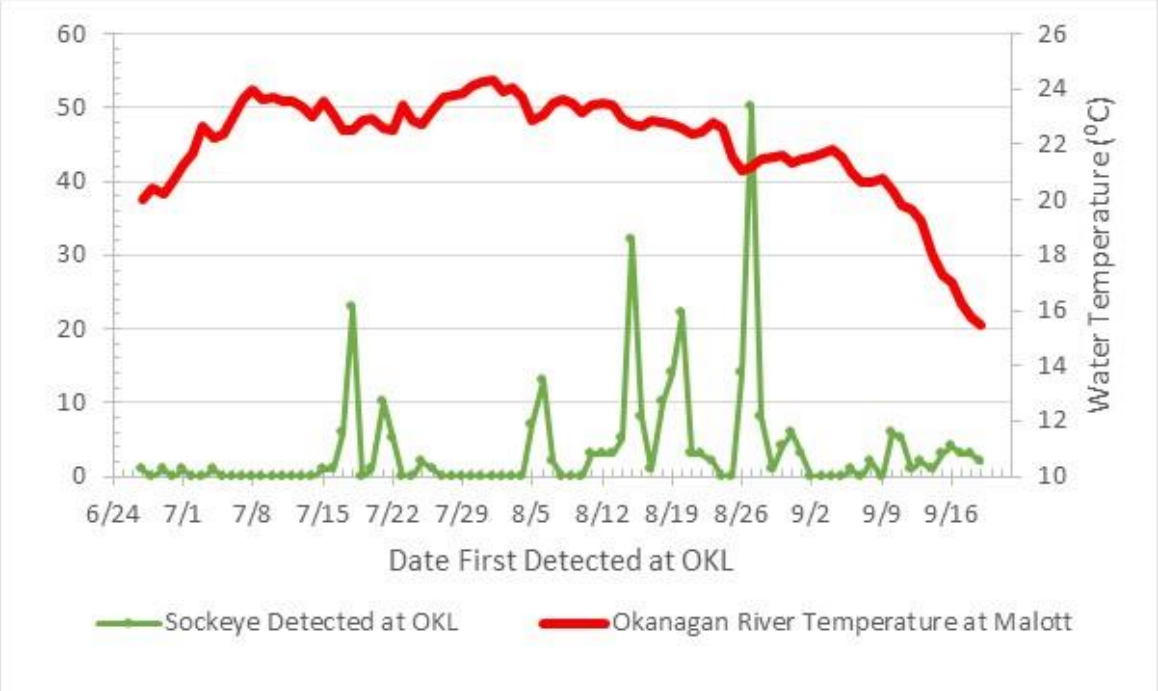


Figure 16. Number of PIT tagged adult Sockeye PIT detected by date at OKL with mean daily Okanagan River temperatures at the USGS Malott gauging station in 2017.

[28] Returning juveniles detected at OKL (n=11) were added to tagged Sockeye from this project (n=293) in this analysis.

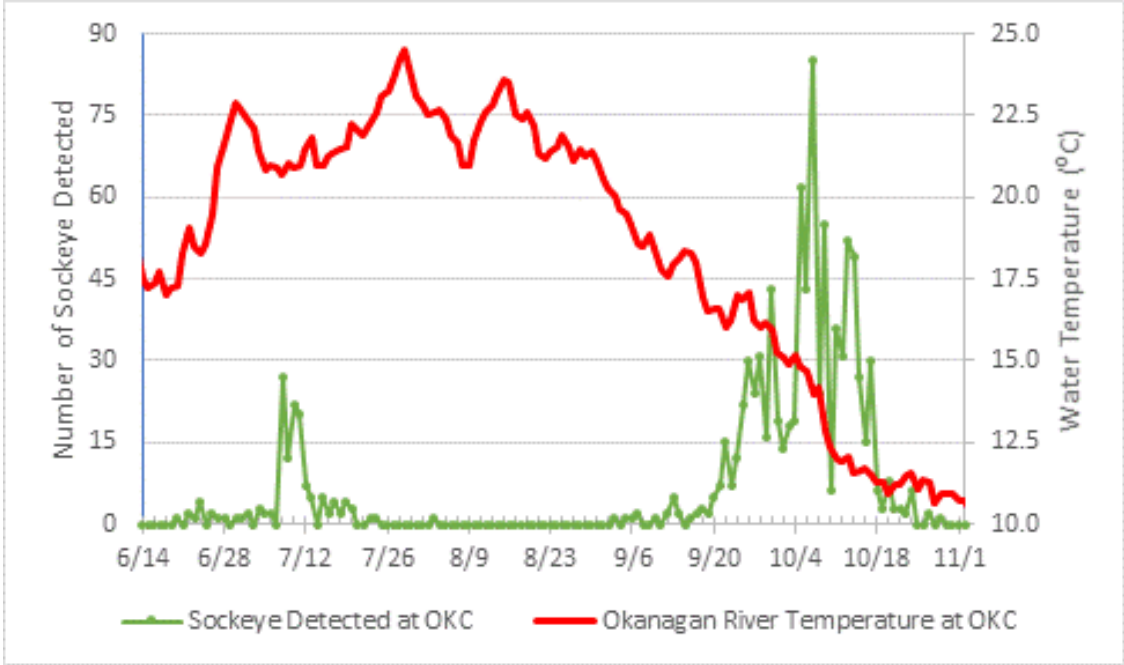


Figure 17. Number of Sockeye detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2016.

Table 52. Groups of PIT tagged Sockeye passing OKL and percent detected upstream at OKC by date at passing OKL in 2017.

Dates	N at OKL	% Detected at OKC
6/27-7/4	4	75.0%
7/14-7/26	50	82.0%
8/5-8/7	22	36.4%
8/11-8/23	109	65.1%
8/26-9/1	86	35.7%
9/6-9/19	33	63.6%
All	**304**	**62.2%**

In both 2016 and 2017, a small number of early migrating Sockeye were detected at OKC in late June and early July prior to temperatures ascending past 22C (Figures 17 and 18). Sockeye then migrated past OKC again during temperature drops in July in both 2016 and 17 and, in 2017, again in August. These Sockeye were likely migrating to the cool water of Skaha Lake as they were not detected dropping back over OKC later in the year. In both years, increasing numbers of Sockeye were detected heading upstream to spawn in September as temperatures dropped below about 17C.

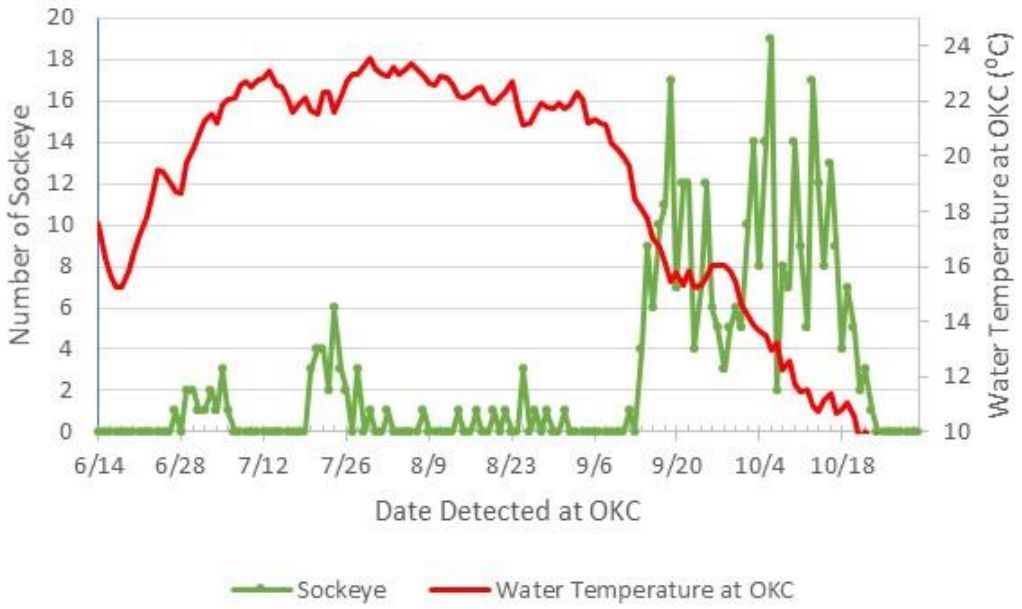


Figure 18. Number of Sockeye detected at Okanagan Channel PIT tag array (OKC) and Okanagan River water temperatures by date in 2017.

Migration into Natal Areas-Wenatchee River

In 2015, survival of Wenatchee-stock Sockeye Salmon tagged at Bonneville Dam from Lower Wenatchee River (LWE) to Tumwater Dam was only 71.3% due to the high-water temperatures with the average water temperature above 22C in 4 weeks during the peak of the migration (Fryer et al. 2017). Under much more typical conditions in 2016 and 2017with mean water temperatures rarely exceeding 20C, survival over this reach was 97.5% in 2016 and 99.2% in 2017 (Tables 53 and 54). No Sockeye strayed to any tributaries downstream of Tumwater Dam in the Wenatchee Basin in 2016, only one did in 2017.

Table 53. 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 2016.

Statistical Week Detected at LWE	Number at LWE	Mean Temperature at LWE	% to Icicle Creek	% Survival LWE to Tumwater Dam	Median Travel Time LWE to Tumwater Dam
25	2	11.8	0.0%	100%	21.7
26	12	13.6	0.0%	100%	14.5
27	52	16.1	0.0%	100%	11.3
28	39	15.7	0.0%	97.4%	9.2
29	16	16.7	0.0%	100%	7.4
30	11	17.0	0.0%	100%	7.6
31	17	20.3	0.0%	100%	7.0
32	7	19.6	0.0%	71.4%	8.3
34	1	21.5	0.0%	0.0%	21.7
Unweighted Total	**157**[29]		**0.0%**	**97.5%**	**9.4**

Table 54. 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 2017.

Statistical Week Detected at LWE	Number at LWE	Mean Temperature at LWE	% to Icicle Creek (ICL)	% Survival LWE to Tumwater Dam	Median Travel Time LWE to Tumwater Dam
26	7	14.0	0	85.7%	16.2
27	62	15.7	0	100.0%	13.0
28	39	16.9	2.6%	84.6%	12.1
29	11	17.7	0	90.9%	8.8
30	10	19.9	0	100.0%	6.9
31	5	20.5	0	100.0%	7.2
33	3	19.9	0	33.3%	14.6
Unweighted Total	**137**[30]		**0.7%**	**92.7%**	**5.4**

[29] An additional 185 Sockeye Salmon were not detected at LWE but detected upstream in 2016.
[30] An additional 126 Sockeye Salmon were not detected at LWE but detected upstream.

Upstream Survival Comparisons with Sockeye Tagged as Juveniles

In 2016, Sockeye tagged by this project at Bonneville AFF had survival to McNary Dam similar to that of Sockeye tagged as juveniles in the Okanagan River by this project, and those values are higher than the survival of those tagged (not by this project) as juveniles at Rock Island Dam and the Snake and Wenatchee rivers (Table 55). Survival to terminal areas in the Okanagan and Wenatchee was also similar, varying by 4.7 percentage points to Tumwater (66.7% for Wenatchee Sockeye tagged as juveniles compared to 71.4% for Sockeye tagged at the AFF identified as Wenatchee origin) and 2.7 points to the Zosel Dam (72.1% for Sockeye tagged as juveniles and 74.4 points for those tagged as adults).

Table 55. 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 2016. 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
Okanagan River[31]	Primarily Wild[32]	Okanagan	Juvenile	68	94.1	88.2	85.3	79.4	72.1	NA
Rock Island Dam	Mixed	Mixed	Juvenile	35	82.9	74.3	74.3	68.6	37.1	22.9
Snake River	Mixed	Snake	Juvenile	183	86.9	73.2	1.1*	NA	NA	NA
Wenatchee	Wild	Wenatchee	Juvenile	45	88.9	82.2	80.0	75.6	NA	66.7
Bonneville AFF	Mixed	Mixed	Adult	1635	93.9	87.9	85.6	80.5	52.9	21.0
Bonneville AFF	Mixed	Wenatchee	Adult	479	91.3	86.0	80.4	73.9	NA	71.4
Bonneville AFF	Mixed	Okanagan	Adult	1117	93.9	88.4	87.8	83.3	74.4	0.3

The percentage of Bonneville-tagged Sockeye passing Tumwater Dam were detected at spawning ground PIT arrays on the Little Wenatchee and White rivers was similar to that of Sockeye tagged as juveniles in the Wenatchee Basin or adults tagged at Tumwater dam by WDFW in 2016 (Figure 19, Table 56).

[31] Juvenile Okanagan Sockeye Salmon tagging is funded in part by this project.
[32] Some Penticton Hatchery-raised Sockeye Salmon are included in the juvenile Sockeye Salmon tagged.

Although Rock Island tagged Sockeye had a higher percentage detected on the spawning grounds, there were only 8 fish.

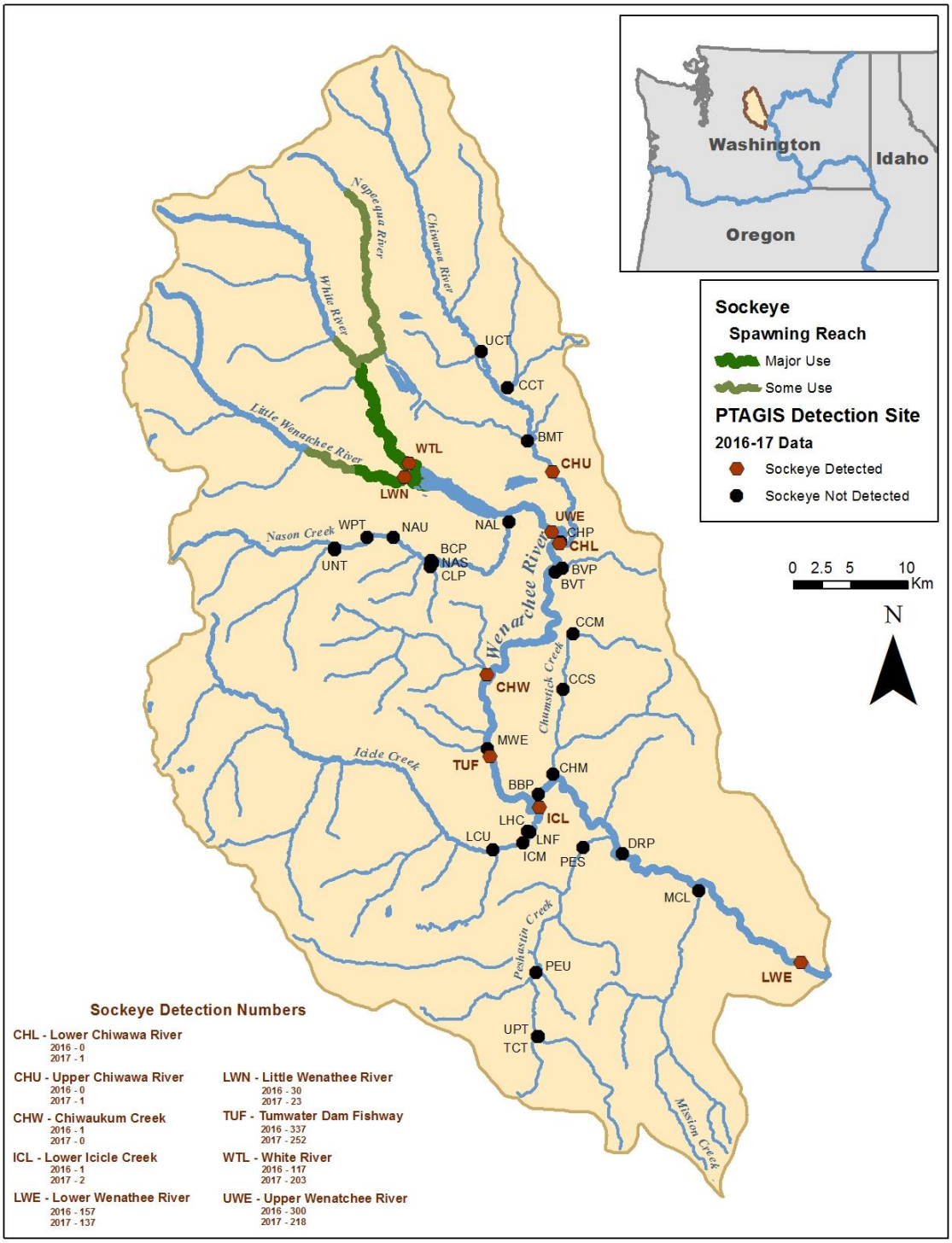


Figure 19. The Wenatchee Basin showing PIT tag interrogation sites and highlighting sites where Sockeye were detected in 2016 and 2017. Also displayed is the spawning area of Sockeye. Appendix B Table B1 has site information.

Table 56. Distribution of Sockeye Salmon in the Wenatchee Basin in 2016 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)
Wenatchee	Wild	Juvenile	30	10.0%	53.3%	63.3%
Rock Island	Mixed	Juvenile	8	0.0%	75.0%	75.0%
Bonneville AFF	Mixed	Adult	337	8.9%	52.6%	61.4%
Tumwater Dam	Mixed	Adult	72	11.1%	52.8%	63.9%

In 2017, Sockeye tagged by this project at Bonneville AFF generally had lower survival than those Sockeye tagged as juveniles (Table 57). To Rock Island Dam, AFF-tagged Sockeye had survival rates of 70.6 to 72.5% compared to 79.3% for Sockeye tagged as juveniles in the Okanagan River and 78.9% for those tagged in the Wenatchee River (but only 68.8% for those tagged at Rock Island Dam). Survival to OKC was comparable between Sockeye tagged as juveniles and adults (31.0% versus 32.9%) but survival to the Wenatchee spawning grounds was 9 points higher for Sockeye tagged as juveniles compared to Sockeye tagged as adults (73.7% vs 64.2%). Survival to McNary dam was much lower for Sockeye tagged as juveniles in the Snake River compared to any other group.

As in 2016, for year 2017, the percentage of Bonneville-tagged Sockeye passing Tumwater Dam was detected in the Little Wenatchee and White rivers was similar to that of Sockeye tagged as juveniles in the Wenatchee Basin or as adults tagged at Tumwater dam by WDFW (Figure 19, Table 58). Only one Sockeye tagged as a juvenile at Rock Island Dam was detected at Tumwater Dam.

Table 57. 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 2017. 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	OKC	Tumwater Dam
Okanagan River[33]	Primarily Wild[34]	Okanagan	Juvenile	58	96.6	94.8	81.0	79.3	31.0	NA
Rock Island Dam	Mixed	Mixed	Juvenile	16	87.5	81.3	68.8	68.8	25.0	6.3
Snake River	Mixed	Snake	Juvenile	77	76.6	62.3	1.3*	NA	NA	NA
Wenatchee	Wild	Wenatchee	Juvenile	38	94.7	89.5	86.8	78.9	NA	73.7
Bonneville AFF	Mixed	Mixed	Adult	1079	89.3	81.7	74.6	70.8	19.2	25.8
Bonneville AFF	Mixed	Wenatchee	Adult	409	87.8	78.5	75.9	70.6	NA	64.2
Bonneville AFF	Mixed	Okanagan	Adult	643	90.4	84.1	76.1	72.5	32.9	NA

Table 58. Distribution of Sockeye Salmon in the Wenatchee Basin in 2017 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)
Wenatchee	Wild	Juvenile	28	17.9%	67.9%	85.8%
Rock Island	Mixed	Juvenile	1	0.0%	100.0%	100.0%
Bonneville AFF	Mixed	Adult	252	9.1%	80.6%	89.7%
Tumwater Dam	Mixed	Adult	493	8.1%	75.9%	84.0%

[33] Juvenile Okanagan Sockeye Salmon tagging is funded in part by this project.
[34] Some Penticton Hatchery-raised Sockeye Salmon are included in the juvenile Sockeye Salmon tagged.

Lake Wenatchee Acoustic Trawl and Limnology Surveys

A detailed multi-year report was included in the 2015 report for this project (Fryer et al. 2017) which included 2016 results and included as Appendix C in that report. No updated report is available for 2017, thus this report will give a summary of results of sampling conducted in 2016 and 2017.

Brood Year 2015 nerkids (Sockeye and Kokanee)

- Acoustic trawl surveys and biological sampling on September 1, 2016; November 2, 2016 (fall surveys) and April 12, 2017 (early Spring),
- Zooplankton on six dates between June and October 2016,
- Phytoplankton on four dates between June and September 2016,
- Temperature, dissolved oxygen, and transparency on six dates between June and October 2016,

Brood Year 2016 nerkids (Sockeye and Kokanee)

- Acoustic trawl surveys and biological sampling of BY 2016 nerkids on June 28, 2017; August 21, 2017; September 15, 2017 (summer surveys); November 20, 2017 (fall survey) and March 15, 2018 (late Winter),
- Zooplankton on six dates between June and October 2017,
- Phytoplankton on four dates between June and October 2017, and
- Temperature, dissolved oxygen, and transparency on six dates between June and October 2017.

Total limnetic fish abundance was estimated to be 1,514,848 on September 1, 2016; 1,205,735 on November 2, 2016; and 650,885 on April 12, 2017. (Table 59). These values are similar to those observed since 2010 when acoustic trawl surveys began.

Table 59. 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%
2015	1-Sep-16	1,514,848	1,509	738,718	49%
2015	2-Nov-16	1,205,735	1,201	238,298	20%
2016	12-Apr-17	650,885	648	130,548	32%
2016	28-Jun-17	3,543,581	3,529	1,120,391	32%
2016	21-Aug-17	2,967,288	2,955	1,557,471	52%
2016	15-Sep-17	2,567,039	2,557	698,238	27%
2016	20-Nov-17	2,111,701	2,103	209,447	10%
2016	15-Mar-18	1,961,536	1,954	305,242	16%

The average length and weight of BY 2015 Lake Wenatchee nerkids in late April 2017 was 75 mm and 4.7 g (Table 60). These measurements are smaller than both Osoyoos Lake and Skaha Lake pre-smolts; both of which are sampled in acoustic trawl surveys conducted by the ONA using funding from other sources.

Table 60. Brood Year 2016 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.

			Estimates from last survey prior to outmigration	
Lake	Pre-Smolt Abundance (No.)	Pre-Smolt Density (No. per Ha)	Mean Weight (g)	Mean Length (mm)
Wenatchee	930,000	925	4.7	75
Osoyoos	1,600,000	1,713	6.1	84
Skaha (Wild Sockeye)	650,000	334	5.4	81
Skaha (Stocked Sockeye)	123,000	64	8.5	94

Lake Wenatchee typically has a well-oxygenated, cold, hypolimnion and stratifies in late July or August. 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 increased in 2016 and 2017 after a low year in 2015. Total phytoplankton biovolume 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.

2016 Juvenile PIT Tagging

In 2016, a total of 10,241 Sockeye smolts were captured, PIT tagged, and release between March 22 and April 29, in Skaha Lake (SKAHAL), the Skaha Dam tailrace (SKAHTAL), Osoyoos Lake (OSOYOL), and at the Osoyoos Narrows (OSOYBR) (Table 61). No Sockeye smolts were captured in Skaha Lake.

Downstream survival estimates were calculated for all release groups. In 2016, survival from release to Rocky Reach Dam was significantly greater for those Sockeye released in Osoyoos Lake compared to those released in Skaha Lake ($p<0.01$) (Table 62). Among the two groups tagged at Osoyoos Lake, those tagged at the Osoyoos Bridge site in Osoyoos Narrows (OSOYBR) had a significantly higher survival rate to Rocky Reach Dam than the OSOYOL group ($p<0.01$). There was little difference in Skaha Lake between survival rates to Rocky Reach Dam between the two groups/collection sites. The combined Osoyoos Lake group had significantly higher survival to Rocky Reach Dam than did the combined Skaha Lake group ($p<0.01$). Low precision of survival estimates, a consequence of insufficient detections at downstream dams, meant no other comparisons in survival yielded significant results.

Table 61. Summary of Okanagan Sockeye smolt PIT tagging effort, 2016.

	Number of PIT Tagged Sockeye Released and Capture Method				
	SKATAL	SKAHAL	OSOYOL	OSOYOBR	
Date	Rotary Screw Trap	Mid-Lake Trawl	Mid-Lake Trawl	Fyke Net	Total
22-Mar-16			190		190
6-Apr-16	172		251		423
7-Apr-16			143		143
8-Apr-16	755				755
9-Apr-16	196				196
11-Apr-16	1123				1123
12-Apr-16	50		642	203	895
13-Apr-16	133		1072		1205
14-Apr-16	673				673
15-Apr-16				938	938
19-Apr-16				612	612
20-Apr-16			747		747
26-Apr-16		518			518
27-Apr-16		1196			1196
28-Apr-16		526			526
29-Apr-16		101			101
Total	**3102**	**2341**	**3045**	**1753**	**10241**
Mean Fork Length at Tagging (mm)	**111.1**	**103.8**	**81.5**	**82.6**	**95.7**

Table 62. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2016[35].

Release Site (individual or pooled)	Release-Rocky Reach		Rocky Reach-McNary		McNary-John Day		John Day-Bonneville		Release-Bonneville	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
SKATAL	0.468	0.030	0.843	0.128	2.267	0.931	0.269	0.146	0.240	0.092
SKAHAL	0.485	0.024	0.796	0.166	0.685	0.284	0.346	0.163	0.091	0.027
OSOYBR	0.747	0.048	0.683	0.145	1.081	0.549	0.403	0.314	0.222	0.139
OSOYOL	0.560	0.028	0.914	0.173	0.449	0.145	2.515	1.813	0.578	0.388
Below are Summaries of the Data Above										
Skaha (SKATAL + SKAHAL)	0.497	0.021	0.794	0.097	1.401	0.409	0.286	0.104	0.158	0.039
Osoyoos Lake (OSOYBR +OSOYOL)	0.628	0.025	0.812	0.115	0.649	0.178	1.203	0.629	0.398	0.185
Combined Okanagan	0.561	0.016	0.796	0.074	0.968	0.193	0.514	0.147	0.222	0.050

[35] Estimates were compiled March 30, 2018 using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

Survival to downstream points was also estimated for other groups of PIT tagged Columbia Basin Sockeye Salmon that out-migrated in 2016 and 2017. In 2016, these included a group of 1,063 juvenile Wenatchee Sockeye Salmon tagged at a RST in the Wenatchee River, 4,109 out-migrating juveniles trapped at Rock Island Dam that consisted of mixed Okanagan and Wenatchee stock origin Sockeye, and 57,186 juvenile Snake River Sockeye tagged at traps and hatcheries the Snake Basin. Survival of the Rock Island and Wenatchee Sockeye releases to McNary Dam was significantly lower than that of the combined Okanagan releases ($p<0.01$), (Table 63, Figure 20). Snake River Sockeye had a significantly lower survival to McNary Dam than did other groups ($p<0.01$). There were insufficient detections to estimate survival to Bonneville Dam for Wenatchee Sockeye Salmon.

Table 63. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2016[36].

Capture Group	Release- McNary		McNary-John Day		John Day-Bonneville		Release-Bonneville	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Osoyoos Lake	0.509	0.070	0.649	0.178	1.203	0.628	0.398	0.185
Skaha Lake	0.394	0.046	1.401	0.409	0.286	0.104	0.158	0.039
Combined Okanagan	0.447	0.040	0.968	0.193	0.514	0.147	0.222	0.050
Wenatchee	0.256	0.049	0.811	0.312	NA	NA	NA	NA
Rock Island	0.781	0.071	1.129	0.239	0.488	0.174	0.43	0.129
Snake	0.066	0.008	0.766	0.149	0.743	0.264	0.038	0.012

[36] Estimates were compiled March 30, 2018 using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

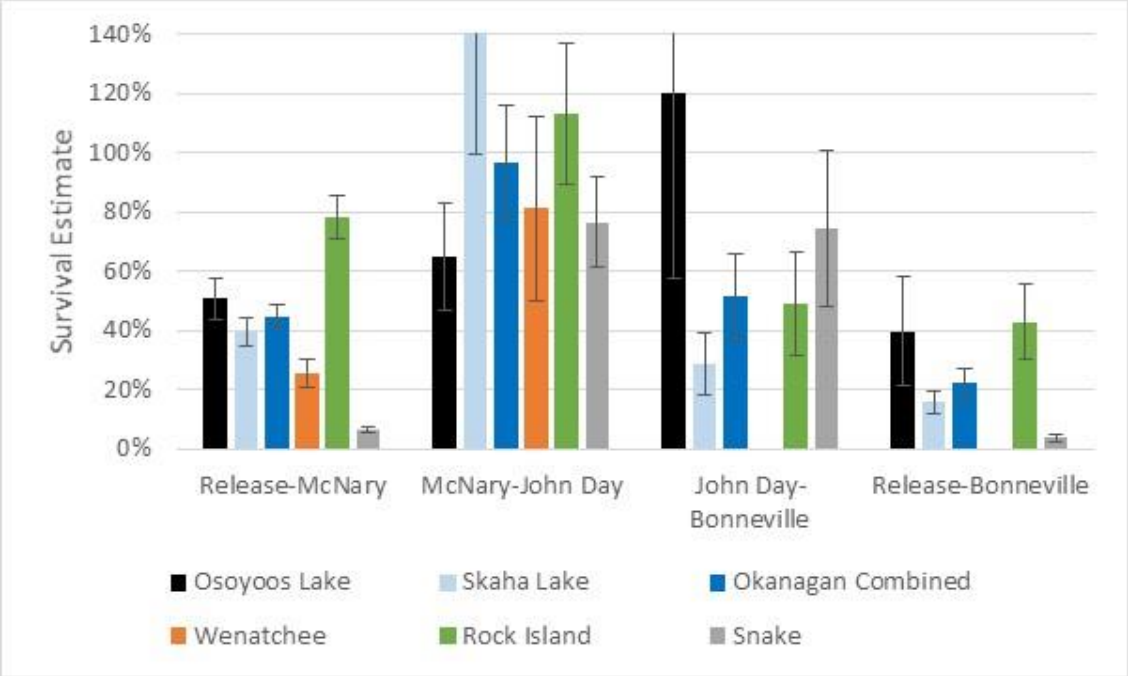


Figure 20. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam to McNary, John Day, and Bonneville dams with 95% confidence intervals in 2016.

Travel times to downstream detection locations were also analyzed for 2016 smolts. Sockeye tagged at SKATAL and SKAHAL had similar travel times to all downstream points except for John Day Dam. The OSOYOL smolts had a mean travel time to downstream points anywhere from 4.1 to 6.8 days greater the OSOYBR group. Skaha Lake combined smolts migrated more rapidly to downstream dams than did the Osoyoos combined group (Table 64), with a mean travel times of between 5.6 and 9.7 days less to downstream Columbia River dams with juvenile PIT tag detection.

Table 64. Mean travel time from release to downstream sites for Sockeye tagged in the Okanagan, Wenatchee, and Snake basins in 2016.

Release Site	Statistic	Mean Travel Time from Release to:				
		Rocky Reach	McNary	John Day	Bonneville	Estuary Trawl
SKATAL	Mean	13.3	17.6	19.4	21.8	22.7
	SE	0.2	0.2	0.4	0.2	0.6
SKAHAL	Mean	11.2	17.1	32.5	19.2	21.7
	SE	0.5	0.4	9.6	0.4	1.2
Skaha Combined	Mean	12.1	17.4	23.5	21.0	22.2
	SE	0.3	0.2	3.1	0.2	0.6
OSOYBR	Mean	18.7	23.9	27.3	27.4	26.4
	SE	0.2	0.5	1.1	0.5	2.2
OSOYOL	Mean	23.9	29.0	31.4	32.3	33.2
	SE	0.3	0.5	1.6	0.7	2.0
Osoyoos Combined	Mean	21.7	26.9	29.2	30.7	31.1
	SE	0.2	0.4	1.0	0.5	1.6
Wenatchee	Mean		21.2	23.5	28.5	28.2
	SE		1.1	1.1	1.1	1.7
Rock Island	Mean		8.0	12.4	12.4	15.9
	SE		0.3	0.4	0.4	1.1
Snake	Mean		15.5	18.2	17.9	16.5
	SE		0.1	0.5	0.2	0.4

2017 Juvenile PIT Tagging

In 2017, 11,588 Sockeye smolts were captured, PIT tagged, and released between April 26 and May 3, at OSOYOL and OSOYBR (Table 65). No Sockeye smolts were captured in Skaha Lake. The mean fork length of Sockeye PIT tagged at OSOYOL was slightly more than those tagged at the OSOYBR site (100.7 mm vs 99.6 mm). The OSOYBR group had a significantly higher survival to Rocky Reach Dam than did the OSOYOL group ($p<0.01$) (Table 66). Standard errors to downstream sites were too large to statistically compare survival to points downstream of Rocky Reach Dam.

Table 65. Summary of Okanagan Sockeye smolt PIT tagging effort, 2017.

	Number of PIT Tagged Sockeye Released and Capture Method		
	OSOYOL	OSOYOBR	
Date	Seine	Fyke Net	Total
26-Apr-17	396		396
28-Apr-17	2580	152	2732
29-Apr-17	198		198
30-Apr-17	839	893	1732
1-May-17	1284	1749	3033
2-May-17	2862		2862
3-May-17	635		635
Total	**8794**	**2794**	**11588**
Mean Fork Length at Tagging (mm)	**100.7**	**99.6**	**100.2**

Table 66. Mean survival estimate for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2017[37].

Release Site	Release-Rocky Reach		Rocky Reach-McNary		McNary-John Day		John Day-Bonneville		Release-Bonneville	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
OSOYBR	0.804	0.076	1.183	0.366	0.579	0.234	0.580	0.414	0.320	0.210
OSOYOL	0.621	0.026	0.925	0.110	0.950	0.174	0.653	0.250	0.357	0.126
Combined Okanagan	0.655	0.025	0.956	0.107	0.873	0.145	0.637	0.215	0.348	0.109

In 2017, Okanagan Sockeye smolt survival was compared to that of 51,290 Sockeye tagged at Snake River, 2,210 tagged at Rock Island Dam and 932 tagged at a Wenatchee River RST. The mean survival to McNary Dam was significantly greater for the Combined Okanagan group compared to the Snake group ($p<0.01$) (Table 67 and Figure 22). High standard errors resulting from low numbers of Sockeye detected downstream resulted in high confidence intervals in Figure 22.

[37] Estimates were compiled March 30, 2018 using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

Table 67. Mean survival estimates for juvenile Sockeye released in the Okanagan and Wenatchee basins and Rock Island Dam in 2017[38].

	Release- McNary		McNary-John Day		John Day-Bonneville		Release-Bonneville	
Capture Group	Mean	SE	Mean	SE	Mean	SE	Mean	SE
OSOYBR	0.952	0.281	0.579	0.234	0.580	0.414	0.320	0.210
OSOYOL	0.575	0.064	0.95	0.174	0.653	0.250	0.357	0.126
Combined Okanagan	0.626	0.066	0.873	0.145	0.637	0.215	0.348	0.109
Wenatchee	0.589	0.160	0.558	0.219	NA	NA	NA	NA
Rock Island Dam	0.719	0.113	0.887	0.242	0.784	0.550	0.500	0.332
Snake	0.066	0.008	0.766	0.149	0.743	0.264	0.038	0.012

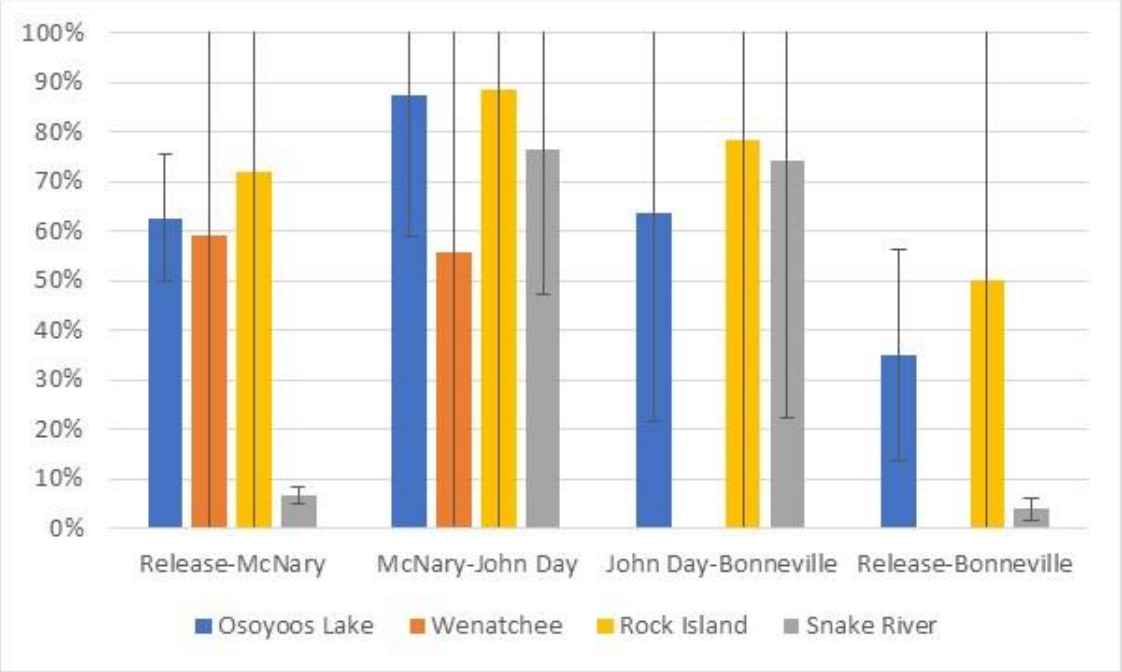


Figure 21. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam to McNary, John Day, and Bonneville dams with 95% confidence intervals in 2017.

Travel times to downstream detection locations were also analyzed for 2017 smolts. Sockeye tagged and released at OSOYOL and OSOYBR had mean travel times to downstream dams that varied by 1.24 days or less to downstream dams (Table 68).

[38] Estimates were compiled March 30, 2018 using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

Table 68. Mean travel time from release to downstream sites for Sockeye tagged in the Okanagan, Wenatchee, and Snake basins in 2017.

Release Site	Statistic	Mean Travel Time from Release to:				
		Rocky Reach	McNary	John Day	Bonneville	Estuary Trawl
OSOYOL	Mean	11.77	15.81	16.49	18.46	19.92
	SE	0.13	0.23	0.2	0.24	0.57
OSOYBR	Mean	12.76	16.25	17.73	19.51	22
	SE	0.27	0.5	0.49	0.56	1.01
Osoyoos Combined	Mean	12.01	15.91	16.77	18.72	20.35
	SE	0.12	0.21	0.19	0.23	0.51
Wenatchee	Mean		10.11	16.91	22.41	28.01
	SE		0.52	0.71	1.91	3.23
Rock Island	Mean		6.4	9.0	8.9	13.5
	SE		0.4	0.4	0.4	1.6
Snake Basin	Mean		28.85	29.88	29.53	27.57
	SE		0.51	0.51	0.44	0.94

A report detailing Okanagan Sockeye juvenile PIT tagging can be found in Appendix C and Fish Passage Center memos reviewing survival and migration times in both 2016 and 2017 found in Appendix D.

DISCUSSION

This report covers years 2016 and 2017 which were the eighth and ninth years of this Accords study. After the abnormally high temperature year of 2015, which resulted in high mortality (Fryer et al. 2017), both 2016 and 2017 had upstream migration survivals closer to normal levels (Table 6). Survival to Priest Rapids Dam estimated by this study was 85.3% in 2016 and 74.6% in 2017 compared to 44.9% in 2015 and a mean of 80.1% for 2006-2017[39]. The river temperatures at Bonneville Dam, in both 2016 and 2017, was far below the records set in June and much of July during the 2015 migration, but still generally above the 10-year average (Figure 23). This was particularly noticeable in early June 2016 when water temperatures were closer to those of 2015 than the 10-year average. River temperatures did spike in early August 2017, however 99% of the 2017 Sockeye run passed Bonneville Dam by July 22.

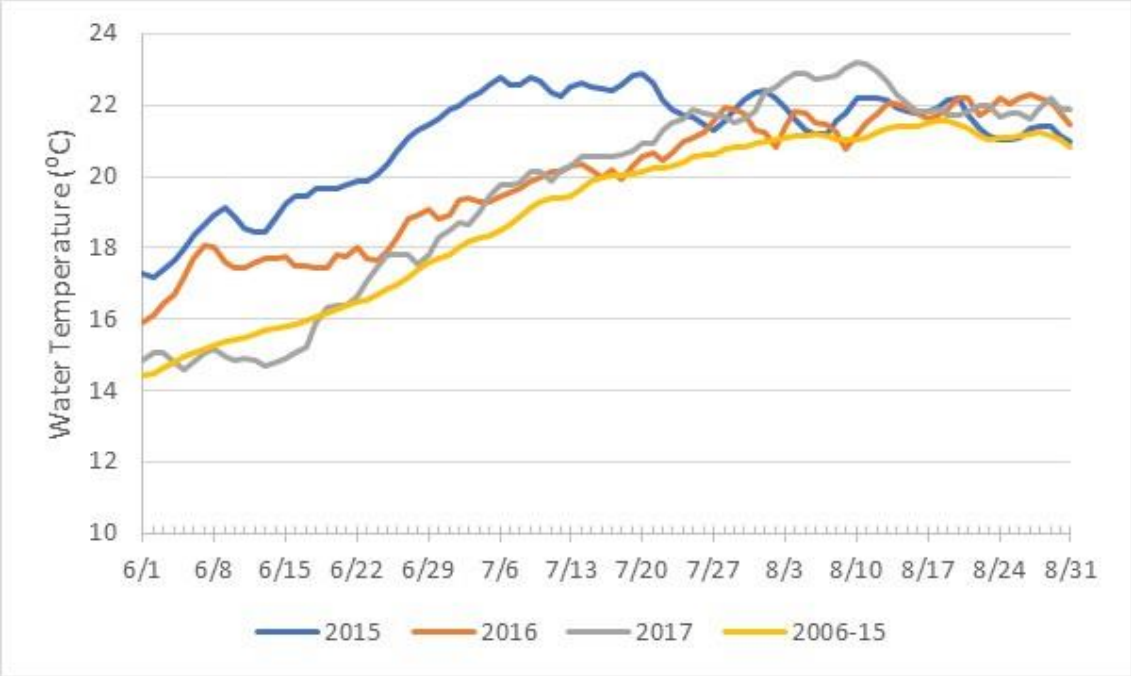


Figure 22. Mean daily water temperature at Bonneville Dam during the months of June-August in the years 2015-2017.

[39] Sockeye were tagged at Bonneville Dam in 2006-2008 as part of a Pacific Salmon Commission-funded project.

Columbia River flows encountered by sockeye migrating in 2016 and 2017 contrasted greatly. Flows in 2016 at Bonneville Dam during the sockeye migration approached the low flows of 2015 and were up to 100 kcfs below the 10-year average (Figure 24). In contrast, 2017 had flows above the 10-year average throughout for most of the month of June (Figure 24). The higher flows in 2017 were likely responsible for the slower migration rate of Sockeye Salmon compared to 2016. Median travel time from Bonneville Dam in 2017 was 0.1 days slower to The Dalles, 0.3 days slower to McNary, 1.5 days slower to Priest Rapids, and 1.3 days slower to Wells Dam than in 2016 (Tables 14 and 15). The much slower travel times in the McNary to Priest Rapids reach are likely attributable to passing through the free-flowing Hanford Reach as opposed to through reservoirs where high flows have a much smaller effect on water velocity.

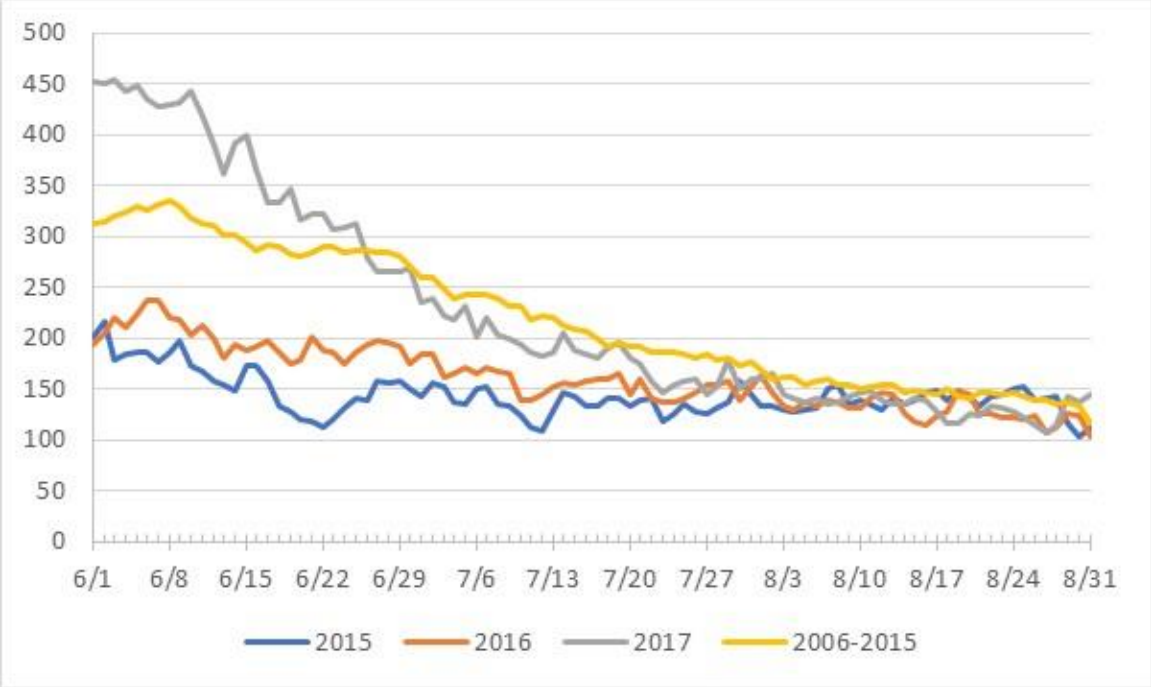


Figure 23. Mean daily flow at Bonneville Dam during the months of June-August in the years 2015-2017 with the mean 2006-2015 flow for comparison.

In 2015, we noted a 26.2% of Sockeye Salmon detected in the Wenatchee River were previously detected at Rocky Reach Dam (Fryer et al. 2017). This appeared to be a result of high temperatures in the lower Wenatchee River as there was little straying at lower temperatures. In 2016 and 2017, Wenatchee River temperatures were much lower than in 2015 and under 18C until late July when the bulk of the run had already passed through Tumwater Dam and were likely in Lake Wenatchee (Figure 25)[40]. Stray rates based on Bonneville-tagged Sockeye of Wenatchee stock- were only 1.8% in 2016 and 1.2% of the run in 2017. However, Sockeye trapped at Wells Dam were estimated to be 10.3% Wenatchee stock in 2016 and 1.2% in 2017. No reason is apparent for the wide disparity in the estimated percentage of Sockeye of Wenatchee origin at Wells Dam in 2016.

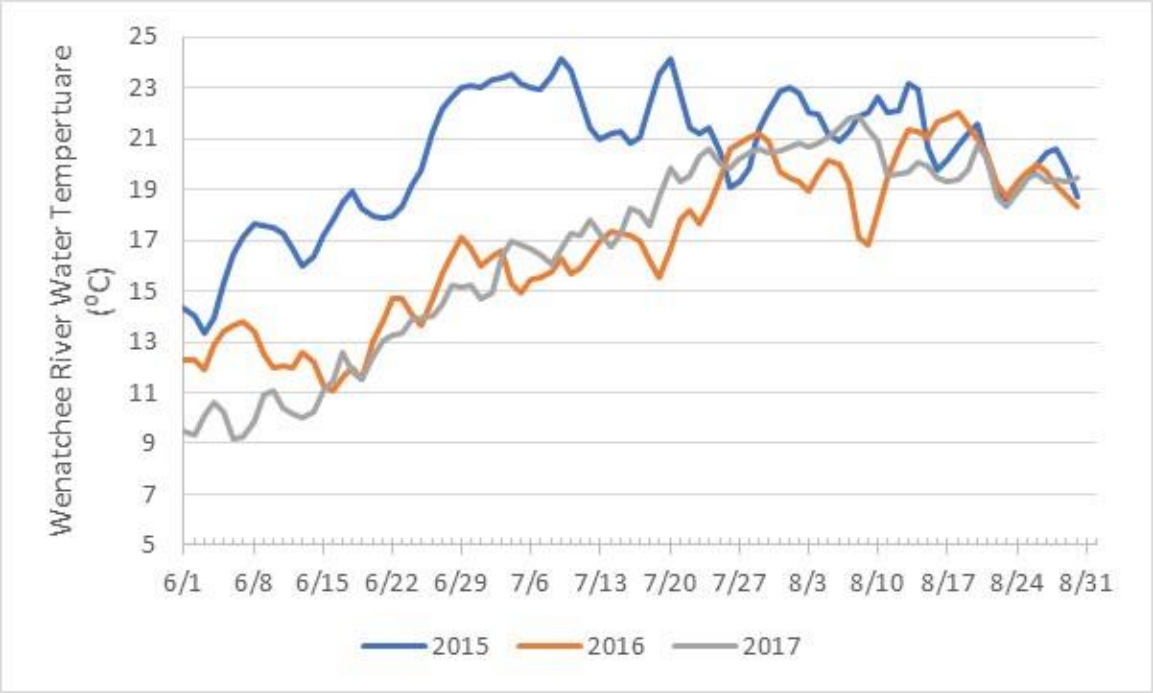


Figure 24. Lower Wenatchee River water temperatures 2015-2017.

This project funded the installation of PIT tag antennas at the Zosel Dam fishways in 2010 and the addition of a floating array in 2015 which worked well at detecting juvenile Sockeye passing through the west-most spillway during the low-flow year of 2015. Therefore, we added a floating antenna to the east-most spillway in 2016 as PIT tag detections suggested that was the side where the bulk of juvenile passage was in 2015 (Fryer et al. 2017). High flows resulted in only 13 detections of juveniles at these antennas in 2016, 10 on the east side and 3 on the

[40] Through July 20, 95.6% of the Sockeye run had passed Rock Island Dam in 2016 and 92.1% in 2017.

west side. The antennas oscillated from side to side and they were removed on May 17, 2016 and redeployed on June 7, 2016 after flows dropped. There were no detections from reinstallation until they antennas were removed in early October. Upon removal we discovered that the side-to-side oscillation had caused the metal cable to almost chew its way through the fiberglass sled the antennas rode on. These were reinforced but flows were judged too high in 2017 to deploy these floating antennas again. Overall, the performance of the floating antennas was disappointing as they required regular readjustment as flows changed and detected fewer juveniles (and no adults) than we expected, possibly due to electrical noise caused by their oscillation in the high flows.

By the time adult Sockeye arrived at Zosel in 2016, flows were reduced sufficiently that Sockeye had to use the fishways. Of the Sockeye detected upstream 98.4% were detected by Zosel ladder PIT tagged antennas. The year 2017 was a different story as only 25.5% of PIT tagged Sockeye detected upstream were detected in Zosel ladders as adult Sockeye transited the dam via the spillways until late August.

The OKC site had a second array added on March 16, 2017. Unfortunately, a “ghost” tag (3D9.1C2DB01432) which was from a Sockeye Salmon tagged at Wells Dam in 2011. After this Sockeye died, this tag was deposited in the gravel only to move downstream in the high 2017 flows to be deposited on top of the new antenna on May 11, 2017 and has generated near-constant detections ever since, which has significantly degraded the performance of Antenna 2 in the new array. As a result, estimated detection efficiency for the new array was only 62.0% in 2017 compared to the older array with 93.2%. A task for 2018 will be to remove the tag generating detections. However, flows are forecast to again be high so this will be challenging.

Based on upstream detections at our Skaha Dam fish ladder site, the detection efficiency of OKC in 2016 was 83.1%. No detection efficiency could be calculated in 2017 as there were no detections at Skaha Dam in 2017. This resulted from high flows resulting in the spillways at Skaha being open sufficiently so that Sockeye used the spillways for upstream passage with no PIT tagged Sockeye using the ladders.

A total of 16 Sockeye Salmon tagged at Bonneville Dam in 2016 and 12 tagged in 2017 were last detected at the Priest Rapids fish trap and likely were captured and transported to Cle Elm Lake for the Yakama-run Cle Elum Sockeye reintroduction program. An additional single Sockeye Salmon (3DD.00775E35E4) was detected at the Priest Rapids fish trap followed by Roza Dam in 2016, on the Yakima River, so was presumed to have been transported to Cle Elum Lake and then fell back over Cle Elum Dam to Roza Dam.

In both 2016 and 2017, the PIT tags from nine adults tagged by this study at Bonneville Dam were found at the Badger Island pelican colony (Figure 26). In 2016, five were last detected at The Dalles Dam, three at McNary Dam, and one at Priest Rapids Dam prior to being detected on Badger Island. In 2017, four were last detected McNary Dam, three at The Dalles Dam, and two at Priest Rapids Dam. The PIT tags from 169 juvenile Sockeye tagged, with funding provided in part from this project at Skaha and Osoyoos lakes in 2016 and 2017 were detected at eight different avian colonies from Lenore lake to East Sand Island in the estuary (Figure 26). An additional 5 adult Sockeye PIT tagged at Bonneville Dam were recovered in tribal fisheries between Bonneville and John Day dams. No adult Sockeye PIT tagged at Bonneville Dam were recovered from tribal fisheries in 2017.

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. In 2016, Wells to Zosel survival was estimated to be 89.0% for Sockeye tagged at Bonneville Dam, 88.1% for Sockeye tagged at Priest Rapids Dam, but only 74.4% for Sockeye tagged at Wells Dam. However, much of this difference can be attributed to the high percentage of Wenatchee Sockeye which were in our Wells tagged group but not in the Bonneville-tagged group. (We did not do GSI on sufficient numbers of Priest Rapids-tagged Sockeye to estimate stock composition at Wells Dam.) In 2017, we had too few detections at Zosel to estimate survival from Wells Dam to Zosel. From Wells Dam to OKC the conversion rate for Wells-tagged Sockeye was 45.8% compared to 45.1% for Bonneville-tagged Sockeye.

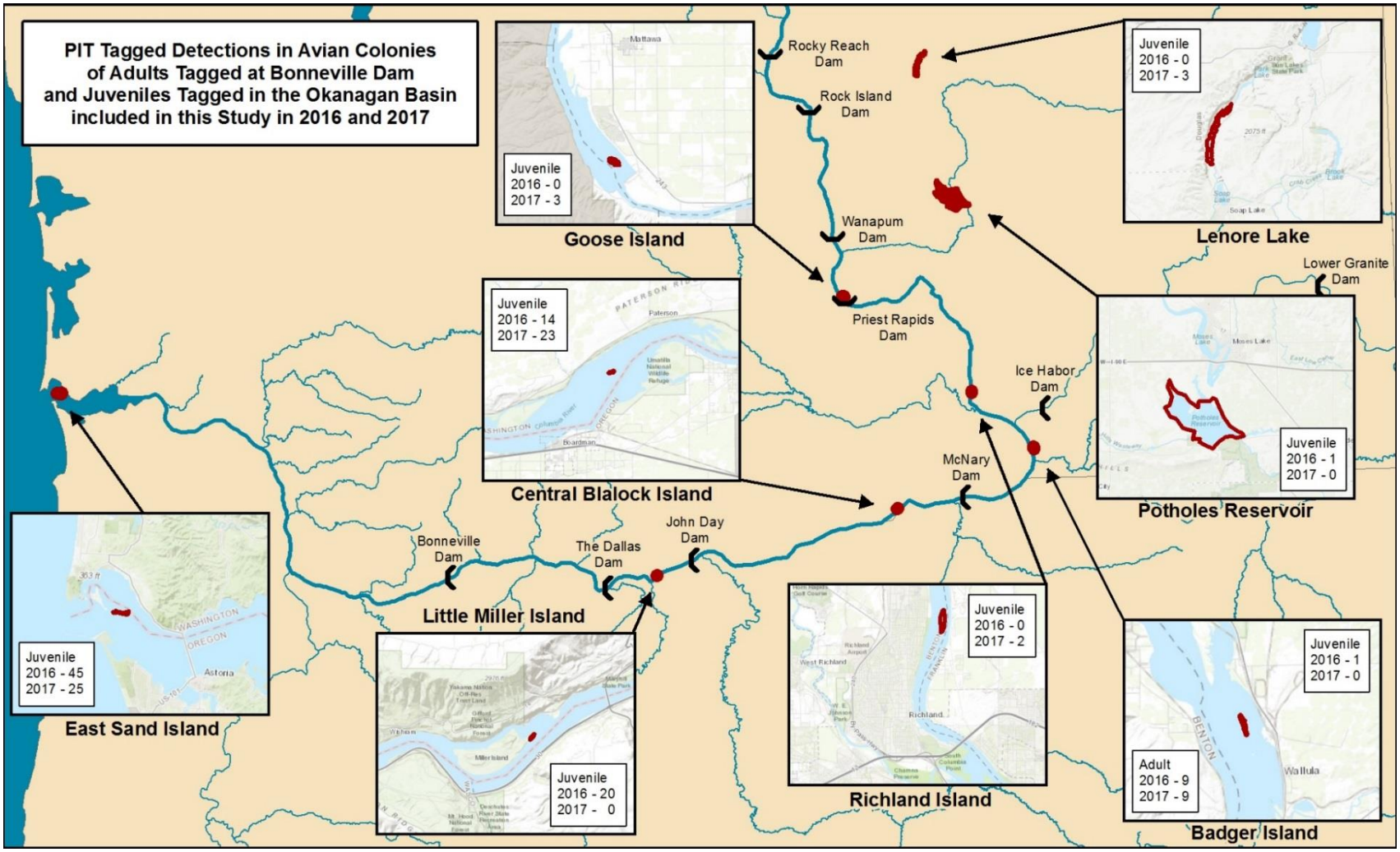


Figure 25. Detections at avian colonies in 2016 and 2017of Sockeye Salmon PIT tagged by this project.

The percentage of Sockeye missing PIT tag detection at mainstem dams was 1.0% or less for all dams but The Dalles, McNary and Rock Island dams in 2016 and all but The Dalles, McNary and Rock Island in 2017 (Table 3). At Bonneville, The Dalles and McNary 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.

Fallback rates at Columbia River mainstem dams (Table 22) in 2016 through Rock Island Dam ranged from 0.1% at Bonneville Dam to 2.6% at Rocky Reach Dam with higher rates at Ice Harbor and Lower Monumental but these dams were passed by only four Sockeye Salmon included in this study. In 2017 (Table 24), rates ranged from 0.3% at Bonneville Dam to 3.1% at The Dalles and Priest Rapids dams. Sockeye tagged as juveniles in the Snake Basin had high fallback rates at Bonneville (16.4%) and The Dalles dams (39.6%) in 2016 (Table 22), but much lower fallback rates in 2017 despite much higher flows (Table 24). Fallback rates for the lower Snake River dams ranged from 7.3% to 16.8% in 2016 and from 9.5% to 19.6% in 2017 (Tables 22 and 24).

This project is proposed to continue and evolve over the next several years as there are several priority areas to investigate. One area of continuing concern is adult survival between Wells Dam and Osoyoos Lake. We had thought we had a good understanding of mortality sites upstream of Wells Dam, thanks to PIT tag detection in Zosel fish ladders as well as acoustic tag results. However, in 2016, we dropped the acoustic tagging due to the large expense for the relatively small number of tags we could deploy, and instead focused on PIT tags. We had good PIT tag detection at Zosel Dam in 2016, but in 2017 over 70% of the run passed through the spillways at Zosel Dam, and we predict that 2018 may be the same as flows are forecast to be high. Of the Sockeye Salmon passing Wells Dam in 2017, only 45.2% were detected at OKC. It is unknown what portion of this mortality may have been associated with migration conditions downstream of Zosel Dam or in Osoyoos Lake. We would like to improve PIT tag detection at, or near, Zosel Dam to improve our understanding of adult survival to this point at high flows when Sockeye Salmon do not use the fish ladders.

There are two focal areas for improved PIT tag detection. The first is Zosel Dam. In 2018 we plan to re-deploy one of the floating arrays that worked well in

2015, but that was nearly lost in 2016 high flows. The array will be upgraded with new rigging that will perform better in high flows for both juvenile and adult detection. If the performance is encouraging we will consider upgrading and deploying the second antenna in 2019, as well as, upgrading the electronics at Zosel Dam which should increase tag read range. We may also look further at work with WDFW and the Confederated Colville Tribes on an in-stream array approximately 200 meters downstream of Zosel, that would have the added advantage of providing data on steelhead spawning in the reach between the proposed array site and Zosel Dam.

A second site for improved PIT tag detection is the Highway 3 Bridge in Osoyoos between the north and central basins of Osoyoos Lake. The north basin is deep enough to provide a cold-water refuge for Sockeye Salmon and most hold here prior to moving upstream to spawn in late September and early October. We did some testing of the use of a Dual Frequency IDentification SONar, or DIDSON, in 2017 to capture images of Sockeye Salmon passing the area and hope to do more in 2018, though high flows may make this challenging. 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. Another option for this area, which is currently being investigated by the ONA is the installation of a PIT tag barge (Rundio et al., 2017).

Lake Wenatchee acoustic trawl surveys (ATS) are expected to continue through along with limnological sampling to better estimate the annual production and future productive potential of Lake Wenatchee Sockeye Salmon. The ATS data from Skaha, Osoyoos, and Wenatchee lakes are also used in Columbia Basin run forecasting for Sockeye. 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.

An exciting development in recent years has been the colonization of Sockeye in Skaha Lake once passage was provided at McIntyre and Skaha dams. Spawning beds, funded by Grant and Chelan Public Utility District (PUD)s have been built to encourage Sockeye spawning in the Penticton Channel immediately downstream of Okanagan Lake. We plan to test the use of sidescan sonar in 2018 to map and assess the quality of the spawning gravels in this area and correlate the data with the actual distribution of redds. This also will serve as baseline data to evaluate how the quantity and quality of these spawning beds changes over time.

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 500,000 Sockeye Salmon have occurred with less than 5% of historical Columbia Basin habitat available (Fryer 1995), making historical estimates appear conservative. To further explore this question, we are working with the ONA, DFO, and Grant, Chelan, and Douglas PUDsto 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. We expect at least one peer-reviewed journal article in the upcoming year as well as a Master's thesis to be published from this work.

REFERENCES

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

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

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

DART (Columbia River Data Access in Real Time). 2017. Online at: http://www.cbr.washington.edu/dart/dart.html

FPC (Fish Passage Center). 2017. Adult fish counts online at: http://www.fpc.org.

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

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

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

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

Fryer, J.K. 2017. Results of a PIT tag study at Priest Rapids Dam to assess the impact of the Whooshh Fish Transport System on upstream migrating Sockeye Salmon. Columbia River Inter-Tribal Fish Commission. 26 pp.

Fryer, J. K. and M. Schwartzberg. 1988. Identification of Columbia Basin Sockeye Salmon stocks based on scale pattern analysis. Columbia River Inter-Tribal Fish Commission Technical Report 89-2,

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

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

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

Fryer, J.K.., D. Kelsey, H. Wright, S. Folks, R Bussanich, K. Hyatt and M. Stockwell. 2017. Studies into factors limiting the abundance of Okanagan and Wenatchee Sockeye Salmon in 2015. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00.

Fryer, J. K., J. Mainord, J. Whiteaker, and D. Kelsey. Upstream migration timing of Columbia Basin Chinook and Sockeye Salmon and steelhead in 2009. Columbia Basin Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00.

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

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

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

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

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

Kelsey, D., H. Ballantyne, J. Whiteaker, and J.K. Fryer. 2011. Age and length composition of Columbia Basin Chinook and Sockeye Salmon and

Steelhead at Bonneville Dam in 2009. Columbia River Inter-Tribal Technical Report 11-08. Portland.

Koo, T.S.Y. 1955. Biology of the red salmon, *Oncorhynchus nerka* (Walbaum), of Bristol Bay, Alaska, as revealed by a study of their scales. Ph.D. thesis, University of Washington, Seattle.

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

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

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

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

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

Rundio, D. E. and 9 co-authors. 2017. Central Valley Passive Integrated Transponder (PIT) Tag Array Feasibility Study. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-573, 130 pp.

Whiteaker, J. and J.K. Fryer. 2008. Age and length composition of Columbia Basin Chinook and Sockeye salmon and Steelhead at Bonneville Dam in 2007. Columbia Basin Inter-Tribal Fish Commission Technical Report 08-04. Portland.

APPENDIX A

2016 and 2017 Performance of Okanagan Basin PIT Tag Detection Infrastructure Funded by this Project.

This project has funded PIT tag antennas at both Zosel Dam fish ladders (installed in 2010) with one floating antenna added to a spillway in 2015 and a second in 2016, although neither was deployed in 2017 and at the Skaha Dam fish ladder (2015) as well at McIntyre Dam spillway (2015) and an instream array at OKC (2009 with expansion in March 2017) and another instream array in the Okanagan Channel at Penticton (OKP, installed November 2017) (Figure A1).

Accords-project Funded PIT Tag Antenna Performance in 2016

At Zosel Dam, PIT tags from 1795 Sockeye, 28 steelhead, and 26 Chinook were detected at Zosel Dam between January 1, 2016 and December 31, 2016 (Table A1 and Figure A2). The first detection (3DD.003BA0F24E) of a white sturgeon at this site was also made on June 2, 2016. This sturgeon was released into Wells Pool on April 10, 2014, detected at OKL on September 2014 with the last detection at the upper OKL array and then not detected until the lower antenna (antenna A4) on the west side but was never detected at the upper antenna (antenna A3).

Among the Sockeye detections were 22 juveniles detected between April 20, 2016 and May 18, 2016, 9 of which were detected in Zosel fish ladders (6 west and 3 east) with the remaining 13 detected at two floating PIT tag antennas installed prior to the juvenile out-migration immediately upstream of the east- and west-most spillway (Figure A3). High flows resulted in the floating antennas being removed from May 18 through June 7, a period in which only 1 of the 9 Sockeye smolt detections in fish ladders were made. Sockeye Salmon tagged by CRITFC tagging projects at Bonneville, Priest Rapids and Wells dams comprised 1,850 or 95.0% of the Sockeye Salmon detected at Zosel Dam in 2016. Of the 1080 PIT tagged Sockeye detected upstream of Zosel Dam, 988 (91.5%) were also detected at Zosel Dam. The vast majority of adult Sockeye Salmon moved through Zosel Dam on a dip in water temperatures in early July with over 100 Sockeye detected per day between July 7 and 11, 2016 (Figure A4).

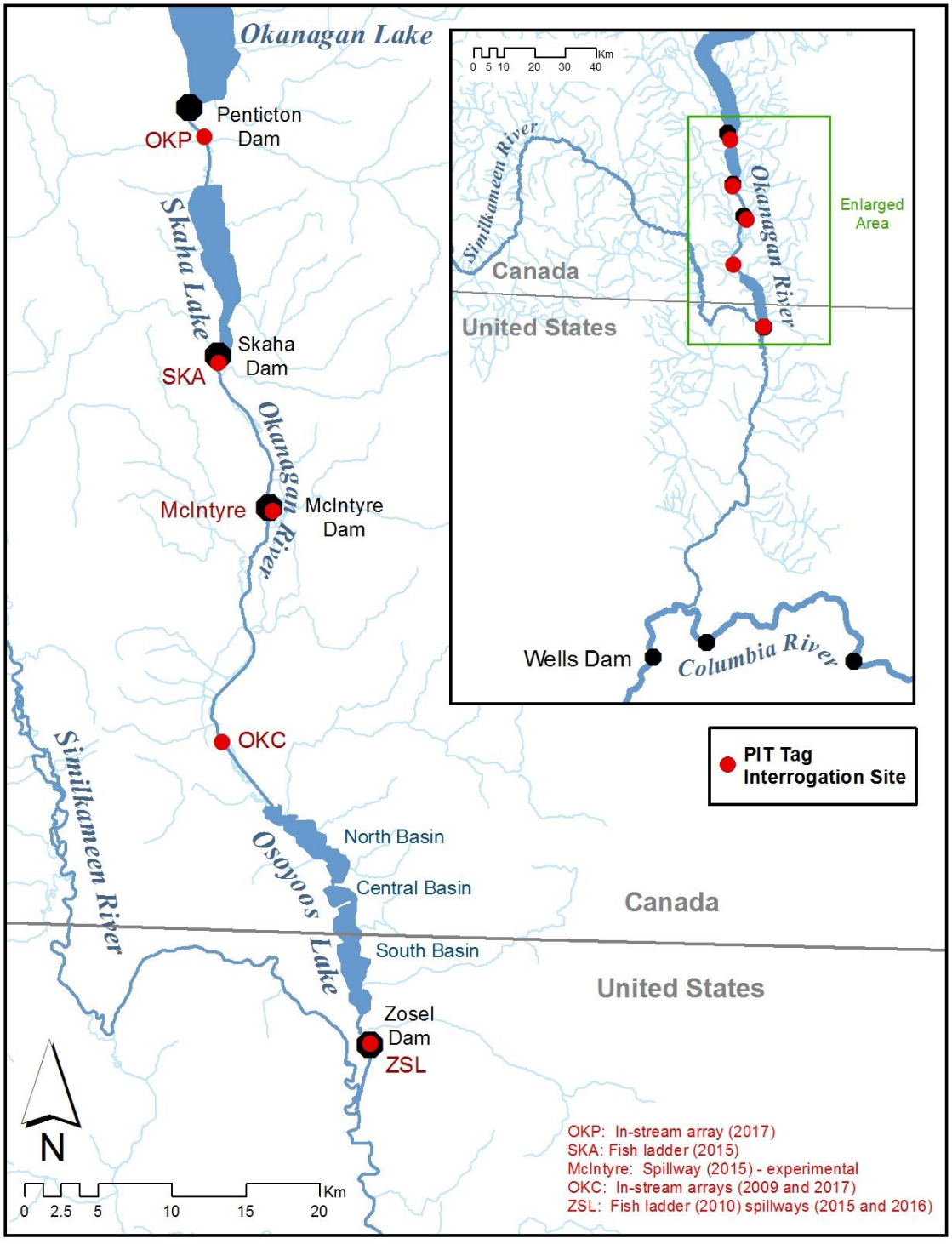


Figure A1. Map of the Okanagan River showing locations of PIT tag antennas funded by this project since its inception. Zosel, Skaha, and McIntyre dams, an in-river array immediately downstream of spawning areas at OKC and an in-river array immediately downstream of Penticton Channel spawning areas at OKP.

Table A1. Number of PIT tagged Chinook, steelhead, and Sockeye detected at Zosel Dam ladders between January 1, 2016 and December 31, 2016, by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye Returning Adults	Sockeye Downstream Juveniles	White Sturgeon	Total
Bonneville Dam	Adult	11	1	804			816
Entiat River	Adult	1					1
Winthrop Hatchery	Juvenile	2					2
Columbia River (rkm 661-960)	Juvenile	2					2
Priest Rapids	Adult		23	376			399
Rock Island	Juvenile	3	1	13			17
Wells Dam	Adult	7		535			542
Wells Hatchery	Juvenile		2			1	3
Methow Basin	Juvenile						0
Okanagan Basin (U.S.)	Juvenile		1				1
Osoyoos Lake	Juvenile			25	12		37
Skaha Tailrace	Juvenile			20	6		26
Skaha Hatchery	Juveniles			0	4		4
Total		**26**	**28**	**1,773**	**22**	**1**	**1850**

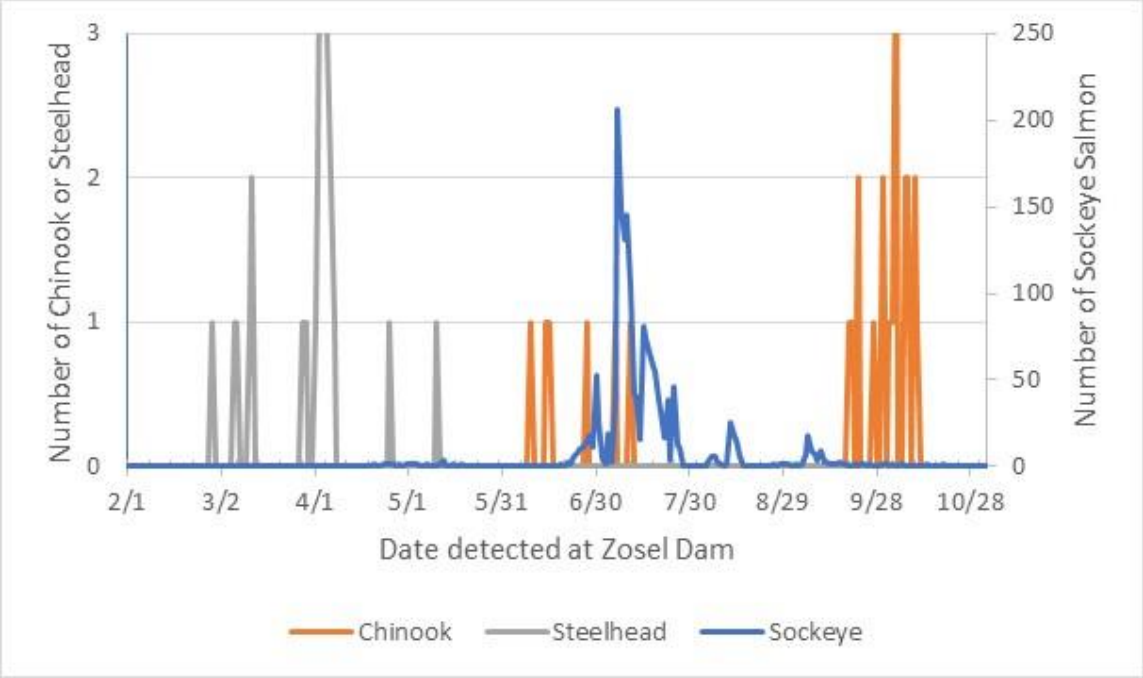


Figure A2. Number of PIT tagged Chinook, Steelhead, and Sockeye detected by date at Zosel Dam in 2016.

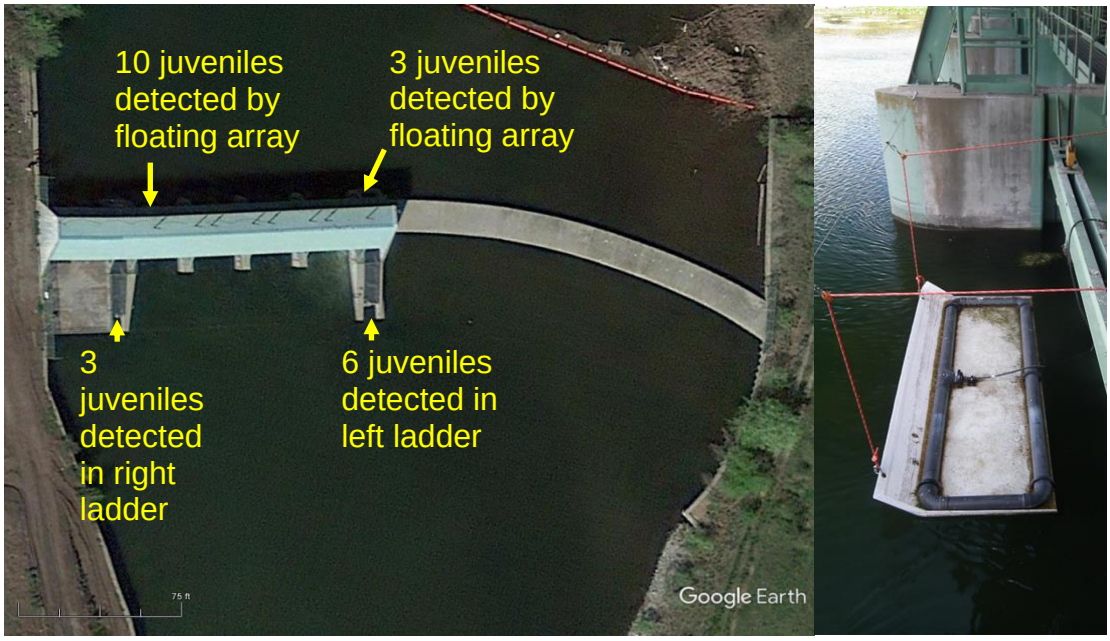


Figure A3. Zosel Dam showing a floating PIT tag array (right) and the number of Sockeye detected at each floating array and ladder in 2016.

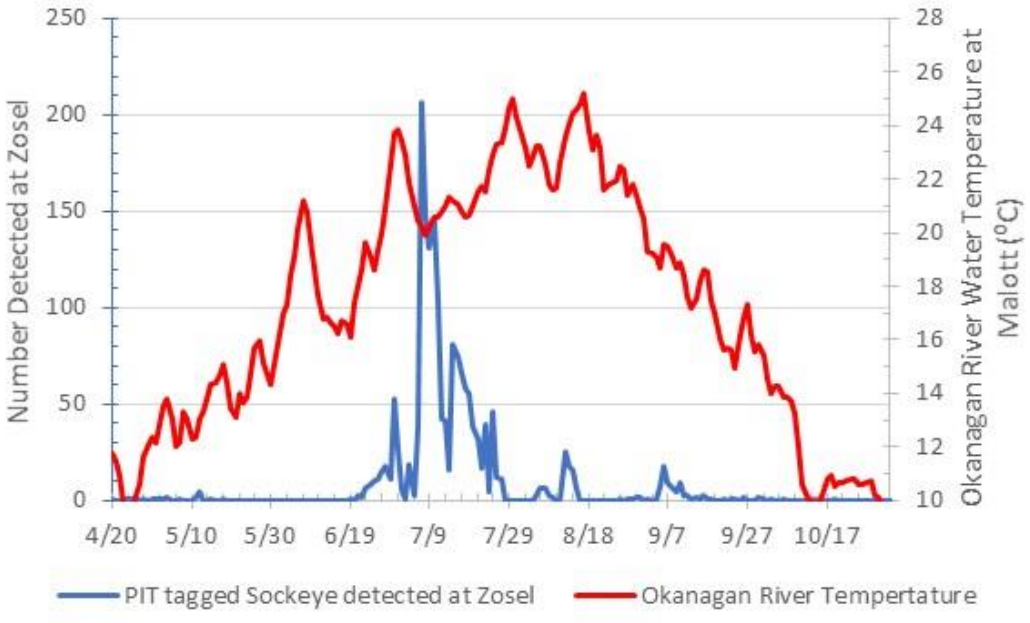


Figure A4. Number of PIT tagged Sockeye Salmon detected by date at Zosel Dam and mean daily Okanagan River water temperature at Monse, WA between June 1 and October 31, 2016.

A total of 965 Sockeye Salmon and 5 Chinook Salmon were detected at OKC in 2016 (Table A2). No PIT tagged steelhead were detected. Only 8 of the Sockeye were downstream migrating juveniles, the remainder were tagged as adults at Bonneville, Priest Rapids, or Wells dams. All Chinook were adults tagged at Bonneville or Wells dams. Of the Sockeye detected at OKC, 84.1% passed after temperatures dropped below 18C on September 18, 2018 (Figure A5) with most of the rest passing in early July.

Table A2. Number of PIT tagged Chinook, steelhead, and Sockeye detected at OKC between January 1, 2016 and December 31, 2016, by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Sockeye Returning Adults	Sockeye Downstream Juveniles	Total
Bonneville Dam	Adult	2	430	0	432
Osoyoos Lake	Juvenile	0	0	6	6
PRD	Adult	0	216	0	216
SKATAL	Juvenile	0	0	2	2
Wells Dam	Adult	3	311	0	314
Grand Total		**5**	**957**	**8**	**970**

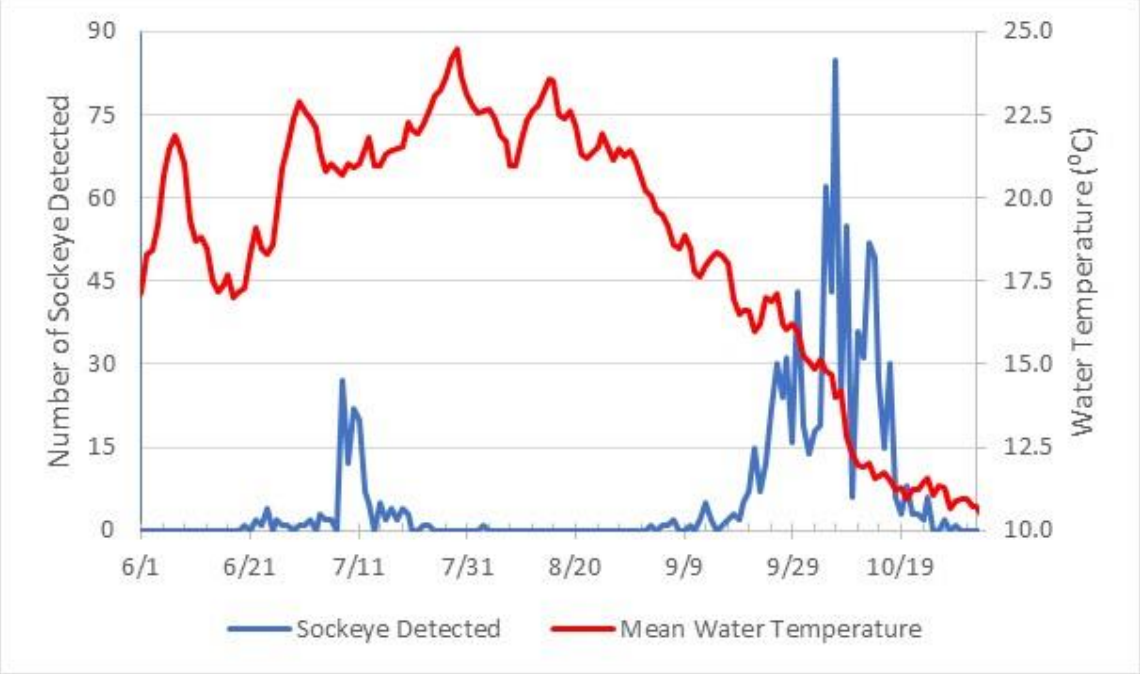


Figure A5. Number of PIT tagged Sockeye Salmon detected by date at OKC and mean daily Okanagan River water temperature at OKC between June 1 and October 31, 2016.

A total of 114 Sockeye were detected at the Skaha Dam fish ladders in 2016, 84.7% of which were detected on or after August 24, 2016 (Figure A6).

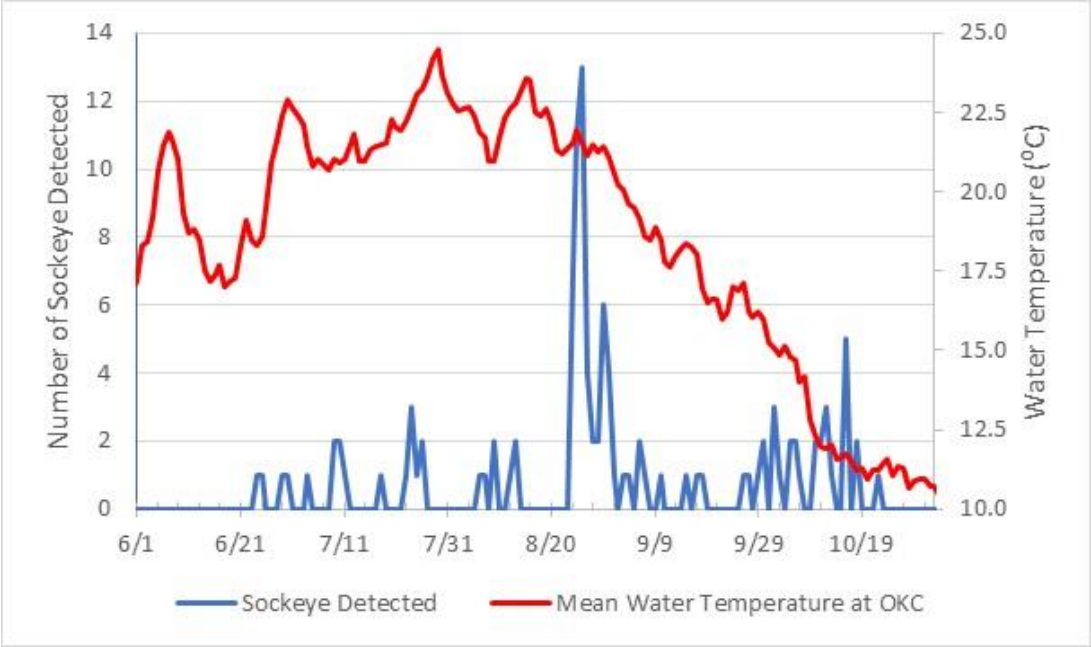


Figure A6. Number of PIT tagged Sockeye Salmon detected by date at Skaha Dam (SKA) and mean daily Okanagan River water temperature at Oliver, BC between June 1 and October 31, 2016.

Accords-project Funded PIT Tag Antenna Performance in 2017

At Zosel Dam, PIT tags from 165 Sockeye, 9 steelhead, and 7 Chinook were detected at Zosel Dam between January 1, 2017 and December 31, 2017 (Table A3 and Figure A7). Also detected was a Winthrop Hatchery coho released at Gold Creek (PTAGIS site GOLD2C) on April 24, 2016 that was detected on October 26, 2017 and again on November 16, 2017. Again in 2017, there were two detections of sturgeon. The first, (3DD.003BA0EFF2) was detected at OKL on July 20, 2014 and detected four times at antennas A4 but never detected at A3. The second (3DD.003BB8E913) was released into Wells Pool on June 12, 2014, detected at OKL on July 31, 2017 and then at Zosel Dam on August 23 and again on August 27, 2017. This steelhead was detected at the upper antenna (A3) three times, but each time it was detected within 2 minutes at the lower antenna (A4) and was last detected at the lower antenna so it is unlikely this fish ever passed Zosel Dam (unless it went through the spillway earlier in the summer when gates were open).

Like the other 2 steelhead described in this appendix, it has not been detected subsequent to Zosel Dam.

Table A3. Number of PIT tagged Chinook, steelhead, and Sockeye detected at Zosel Dam ladders between January 1, 2017 and December 31, 2017, by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye Returning Adults	Sockeye Downstream Juveniles	Coho	WhiteSturgeon	Total
Bonneville Dam	Adult	4		76				80
Priest Rapids	Adult		7					7
Wells Dam	Adult	3		74				77
Wells Hatchery	Juvenile						2	2
Osoyoos Lake	Juvenile				7			7
Rock Island	Juvenile		1	3				4
Skaha Tailrace	Juvenile			5				5
Winthrop Hatchery	Juvenile					1		1
Wanapum	Juvenile		1					1
Total		**7**	**9**	**158**	**7**	**1**	**2**	**184**

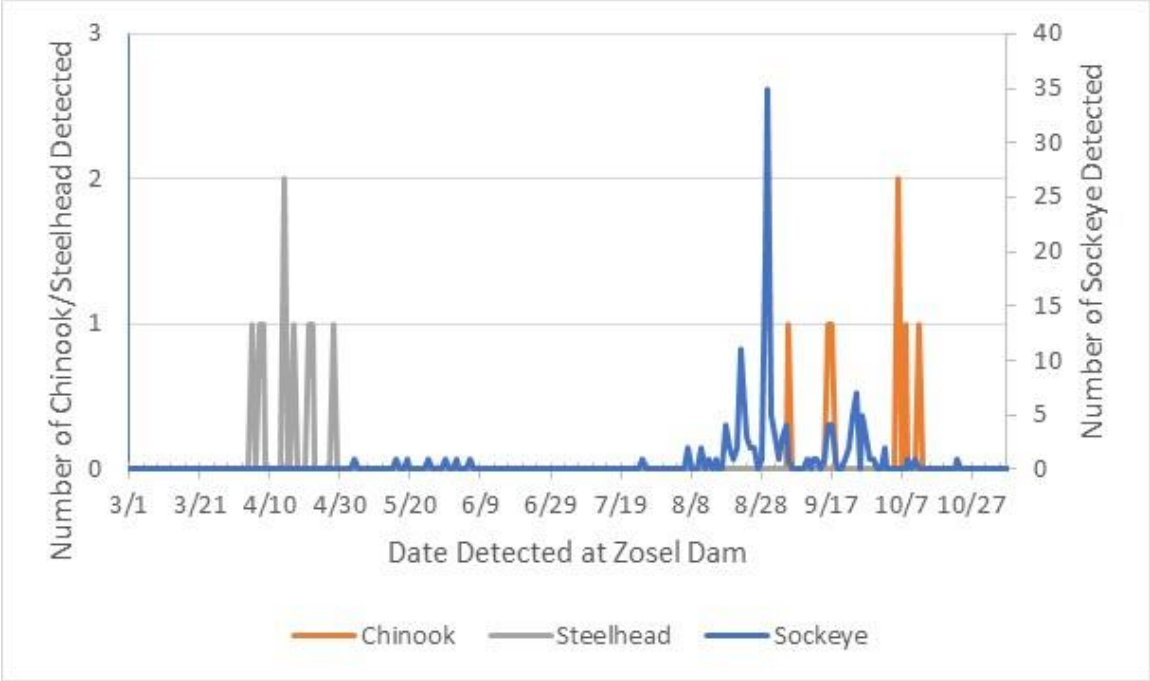


Figure A7. Number of PIT tagged Chinook, Steelhead, and Sockeye detected by date at Zosel Dam in 2017.

Among the Sockeye detections were 7 juveniles detected between May 4, 2017 and June 6, 2017. Six of these 7 were detected at the east fish ladder and none on the west fish ladder. The floating antennas were not deployed in 2017 due to high flows. High flows also meant the spillway gates were raised high enough (over 12", Sonya Schaller, CCT personal communication) that salmon could swim through the spillways for most of the spring and summer. These gates were not lowered until August 23; after which 79.4% of the Sockeye Salmon detections were made. Peak days for passage of PIT tagged Sockeye Salmon were August 29 when 35 Sockeye passed (Figure A7). The high flows as well as a lower tagging output at Bonneville and Wells dams as well as no tagging at Priest Rapids Dam are reasons for the over 90% reduction in Sockeye detected in 2017 compared to 2016. Sockeye Salmon tagged by CRITFC tagging projects at Bonneville, Priest Rapids and Wells dams comprised 157, 85.3% of the Sockeye Salmon detected at Zosel Dam in 2017. Of the 424 PIT tagged Sockeye detected upstream of Zosel Dam, 312 (73.6%) were also detected at Zosel Dam.

A total of 407 sockeye were detected at OKC in 2017; 391 adult Sockeye, 9 Chinook, and 4 Steelhead and 3 juvenile Sockeye were detected (Table A4). Of the Sockeye detected, 84.8% were detected after the water temperature dropped below 18C on September 15, 2017 (Figure A8).

TableA4. Number of PIT tagged Chinook, steelhead, and Sockeye detected at OKC between January 1, 2017 and December 31, 2017, 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
Columbia River Estuary	Adult	1				1
Bonneville Dam	Adult	2		211		213
Priest Rapids	Adult		3			3
Wells Dam	Adult	1	1	152		154
Methow Hatchery	Juvenile	1				1
Okanagan River	Juvenile	3				3
Osoyoos Lake	Juvenile			3	3	6
Rock Island	Juvenile	0		4		4
Skaha Tailrace	Juvenile			20		20
Wanapum	Juvenile		0	1		1
Winthrop Hatchery	Juvenile	1				1
Total		**9**	**4**	**391**	**3**	**407**

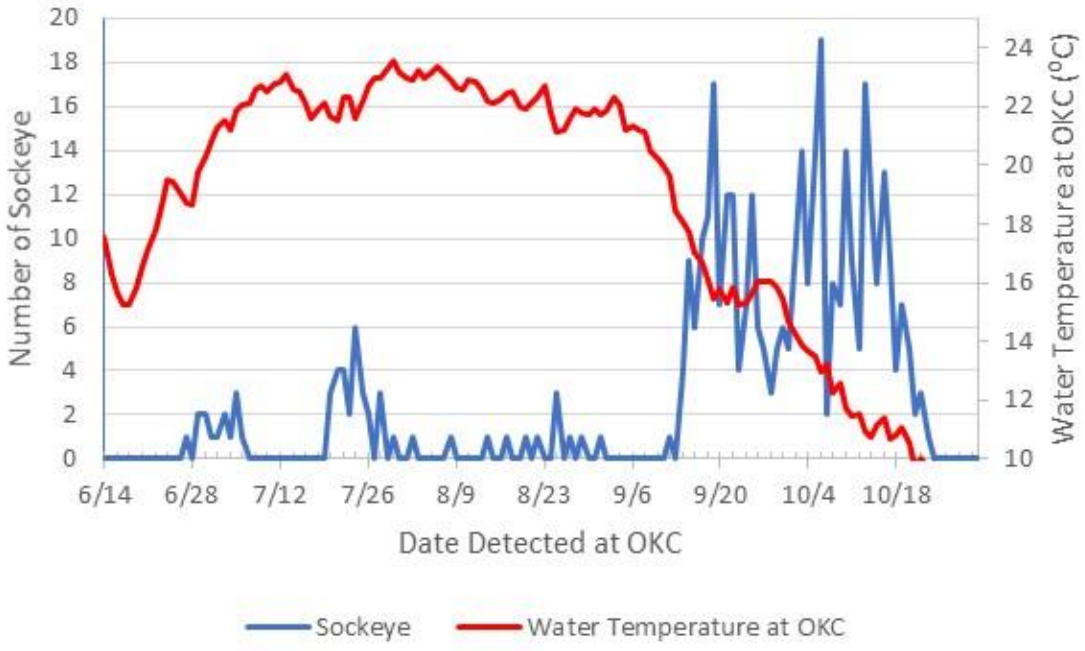


Figure A8. Number of PIT tagged Sockeye Salmon detected by date at OKC and mean daily Okanagan River water temperature at Oliver, BC between June 14 and October 31, 2017.

A second array was added to OKC on March 16, 2017. Unfortunately, a "ghost" tag (3D9.1C2DB01432) which was from a Sockeye Salmon tagged at Wells Dam in 2011, was deposited in the new antenna on May 11, 2017 and has generated near-constant detections ever since significantly degrading the performance of Antenna 2 in the new array. As a result, estimated detection efficiency of the older array in 2017 was 93.2%, for the new array only 62.0%.

High flows in 2017 resulted in no Sockeye Salmon being detected at the Skaha Dam fish ladders as any Sockeye passing went through the open spillways.

A new PIT tag array (PTAGIS site OKP) was installed in the Penticton Channel downstream of Okanagan Lake but upstream of Sockeye Salmon spawning grounds. The site became operational on November 29, 2017 and no tags were detected prior to January 1, 2018.

APPENDIX B

Interrogation Sites in the Columbia Basin that have Detected Sockeye Salmon

Table B1. Information on interrogation sites for detection of PIT tags in the Columbia Basin that have detected Sockeye tagged and/or tracked by this project (2006-17).

Site Code	Site Name	Site Description
BCC	BON PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel.
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.
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.
CRW	Chewuch River above Winthrop	Chewuch River at river km 1, above Winthrop, WA.
DRM	Deschutes River mouth	Mouth of the Deschutes River in the west channel at Moody Island (rkm 0.46).
EBO	East Bank Hatchery Outfall	Located in the East Bank Hatchery outfall channel.
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.
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
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
ICH	Ice Harbor Dam (Combined)	Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass.
ICL	Lower Icicle Instream Array	Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA.
IR1	Lower Imnaha River ISA 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).
IR4	Imnaha Weir Downstream Array	Located downstream of the Oregon Dept. of Fish and Wildlife (ODFW) fish weir on the Imnaha River.
IR5	Imnaha Weir Upstream Array	Located upstream of the Oregon Dept. of Fish and Wildlife (ODFW) fish weir on the Imnaha River.
JDJ	John Day Dam Juvenile	John Day Dam Juvenile Fish Bypass and Sampling Facility.
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.
LWE	Lower Wenatchee River	Wenatchee River rkm 2.
LWN	Little Wenatchee River	Instream PIT tag interrogation site at rkm 4 located at the old fish weir.
MC1	McNary Oregon Shore Ladder	Oregon Shore Adult Fishway at McNary Dam.
MC2	McNary Washington Shore Ladder	Washington Shore Adult Fishway at McNary Dam.
MCJ	McNary Dam Juvenile	McNary Dam Juvenile Fish Bypass/Transportation Facility.
MRC	Methow River at Carlton	Located in the mainstem Methow River near the town of Carlton at rkm 45.
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.
MWE	Middle Wenatchee River	This is an in-stream interrogation system at Wenatchee River rkm 50 above Tumwater Dam.
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.
PES	Peshastin Creek	Instream interrogation system at rkm 3 on the Peshastin River (Wenatchee River Basin), located just below the bridge at Smithson's property.
PRA	Priest Rapids Adult	Priest Rapids Dam Adult Fishways (both).
PRH	Priest Rapids Hatchery Outfall	Priest Rapids Hatchery outfall channel. The site is located just upstream of the typical point of inundation in the channel.
PRO	Prosser Diversion Dam Combined	Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam.
RIA	Rock Island Adult	Rock Island Dam Adult Fishways (all three).
ROZ	Roza Diversion Dam (Combined)	Roza Dam Smolt Bypass.
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway.
RRJ	Rocky Reach Dam Juvenile	Juvenile Fish Bypass Surface Collector.
RSH	Ringold Springs Hatch. Outfall	PIT tag detection system located in the Ringold Springs Hatchery outfall channel.
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.
STL	Sawtooth Hatchery Adult Trap	Ladder of the Sawtooth Hatchery adult fish trap.
SUN	Sunnyside Instream Array	Located 600 M below Sunnyside Dam on the Yakima River.
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.
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.
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).
UWE	Upper Wenatchee River	Located at rkm 81.2 on the Wenatchee River, near Plain, WA.
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).
WTL	White River, Wenatchee Basin	A permanent instream PIT tag interrogation site at RKM 2.88 on the White River.
ZSL	Zosel Dam Adult Fishways	Zosel Dam is located at Okanogan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos

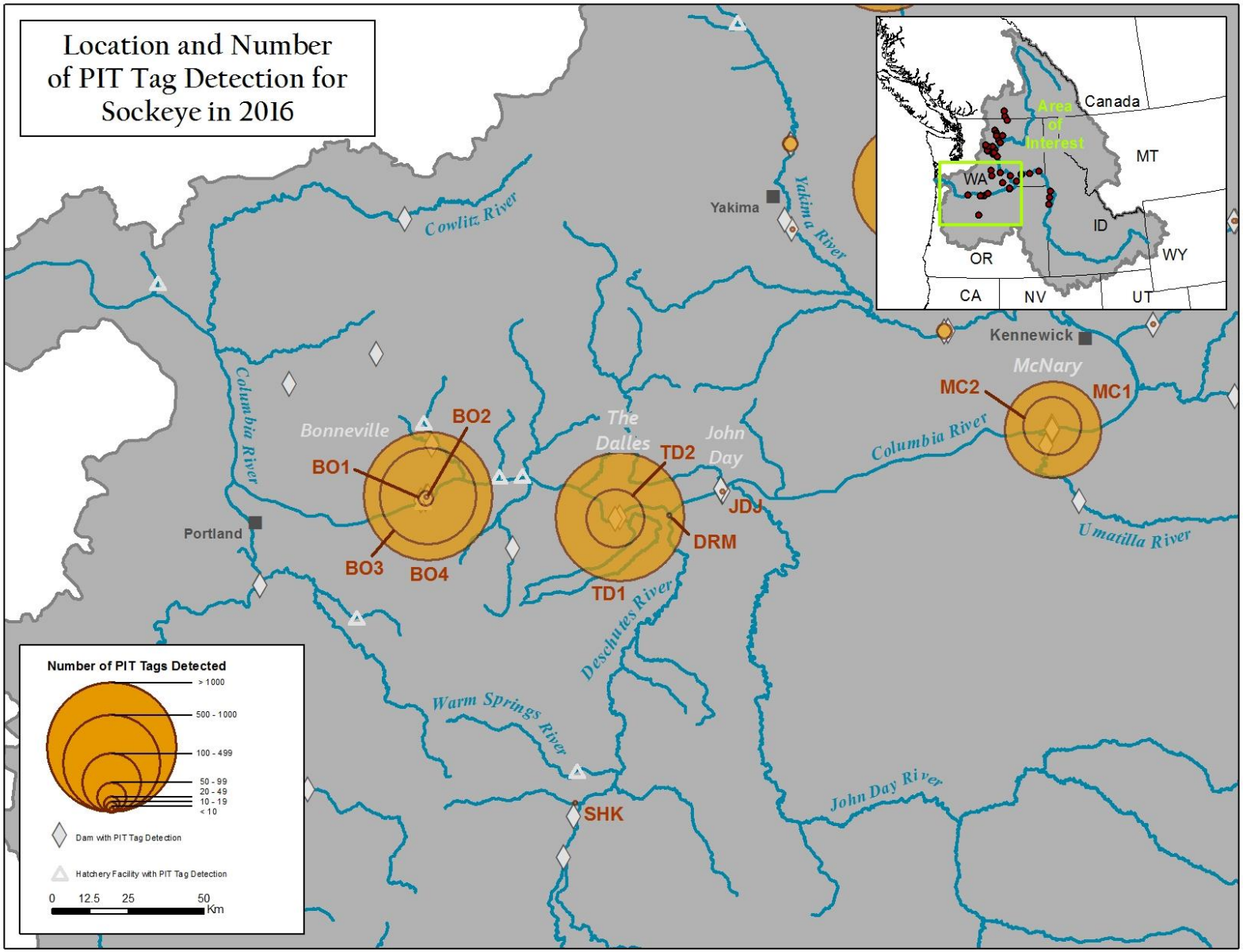


Figure B1. Map of Lower Columbia River detection sites (below Snake River) and number of Sockeye Salmon detected in 2016. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

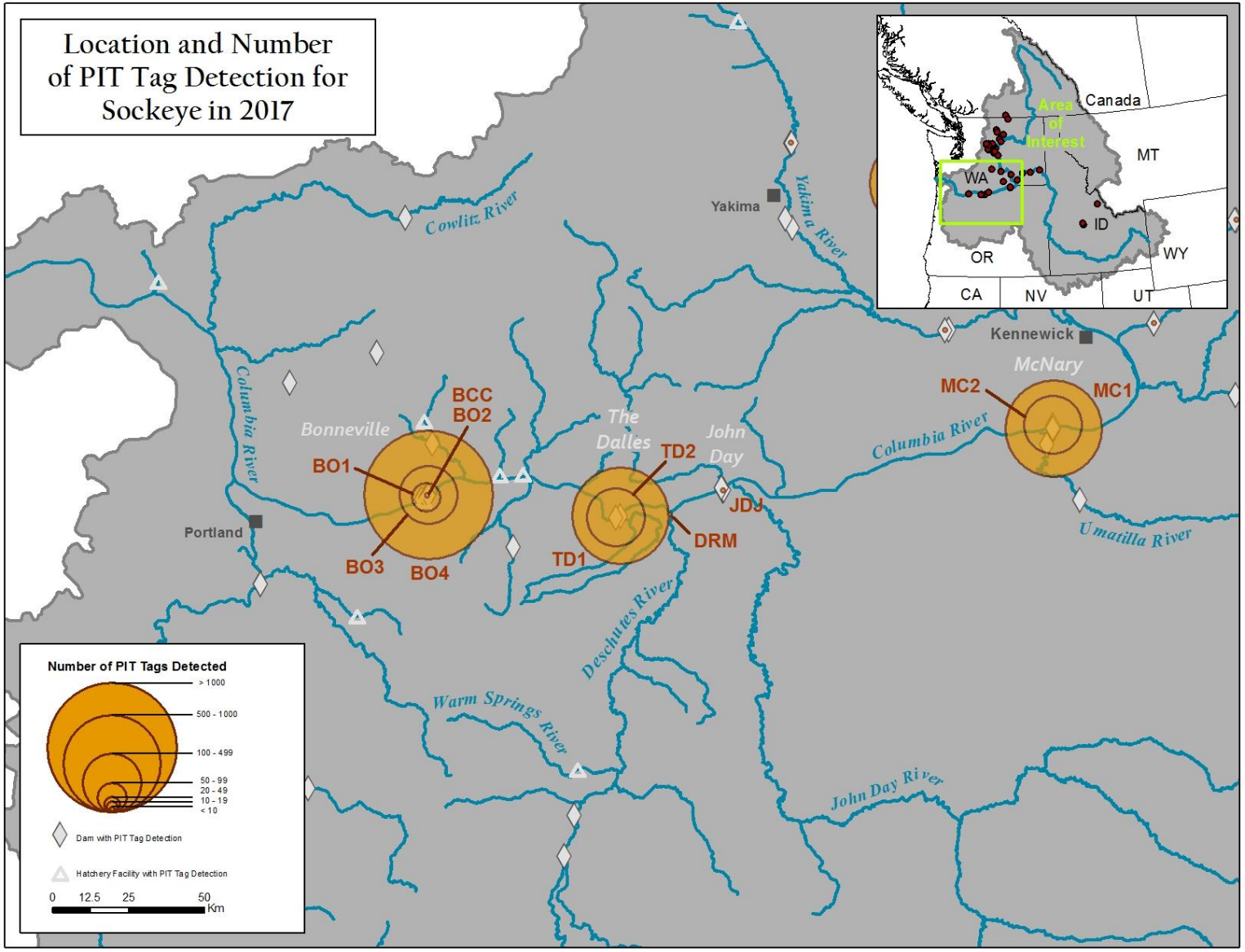


Figure B2. Map of Lower Columbia River detection sites (below Snake River) and number of Sockeye Salmon detected in 2017. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

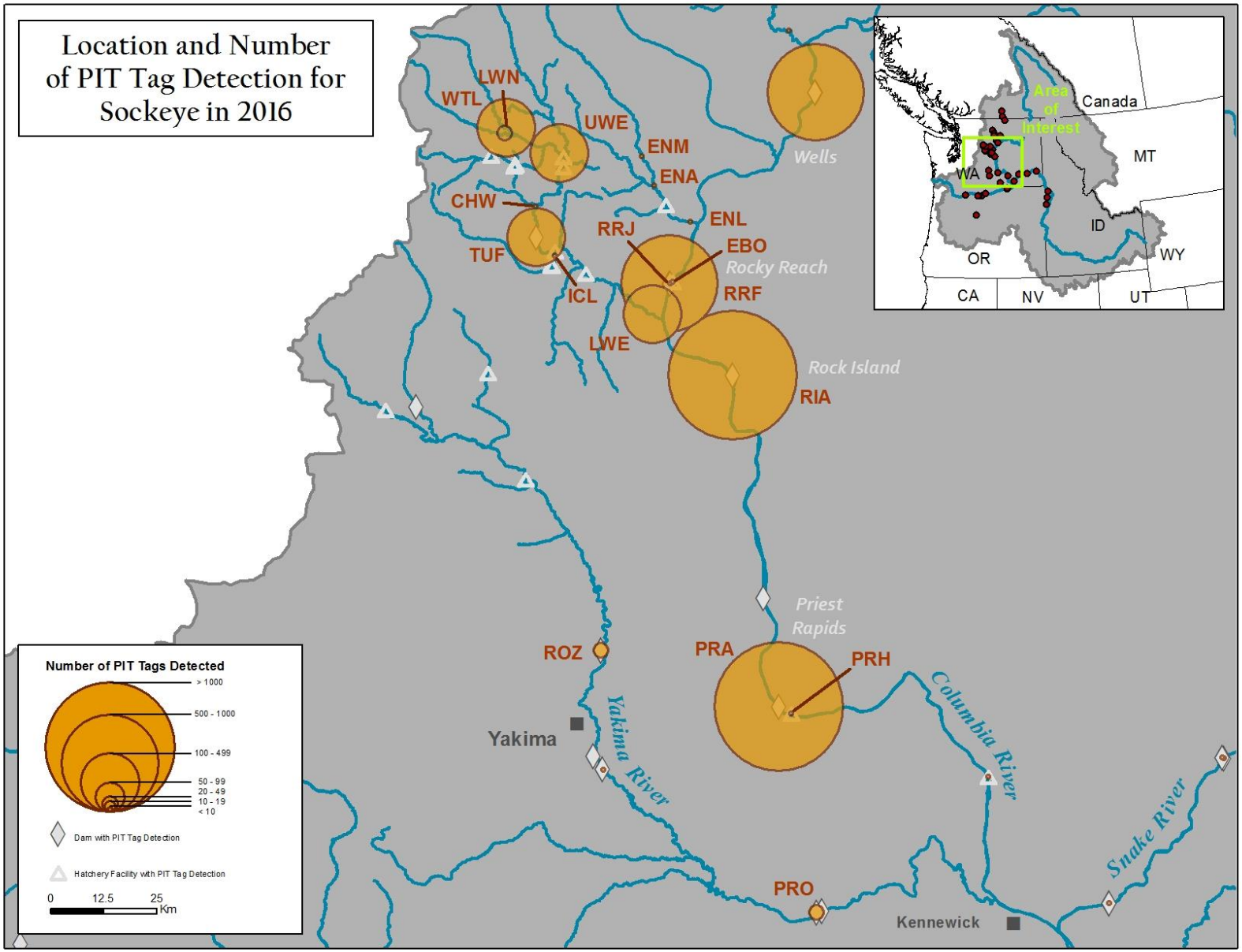


Figure B3. Map of Upper Middle Columbia River (between the Snake River and Wells Dam) detection sites and number of Sockeye Salmon detected in 2016. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

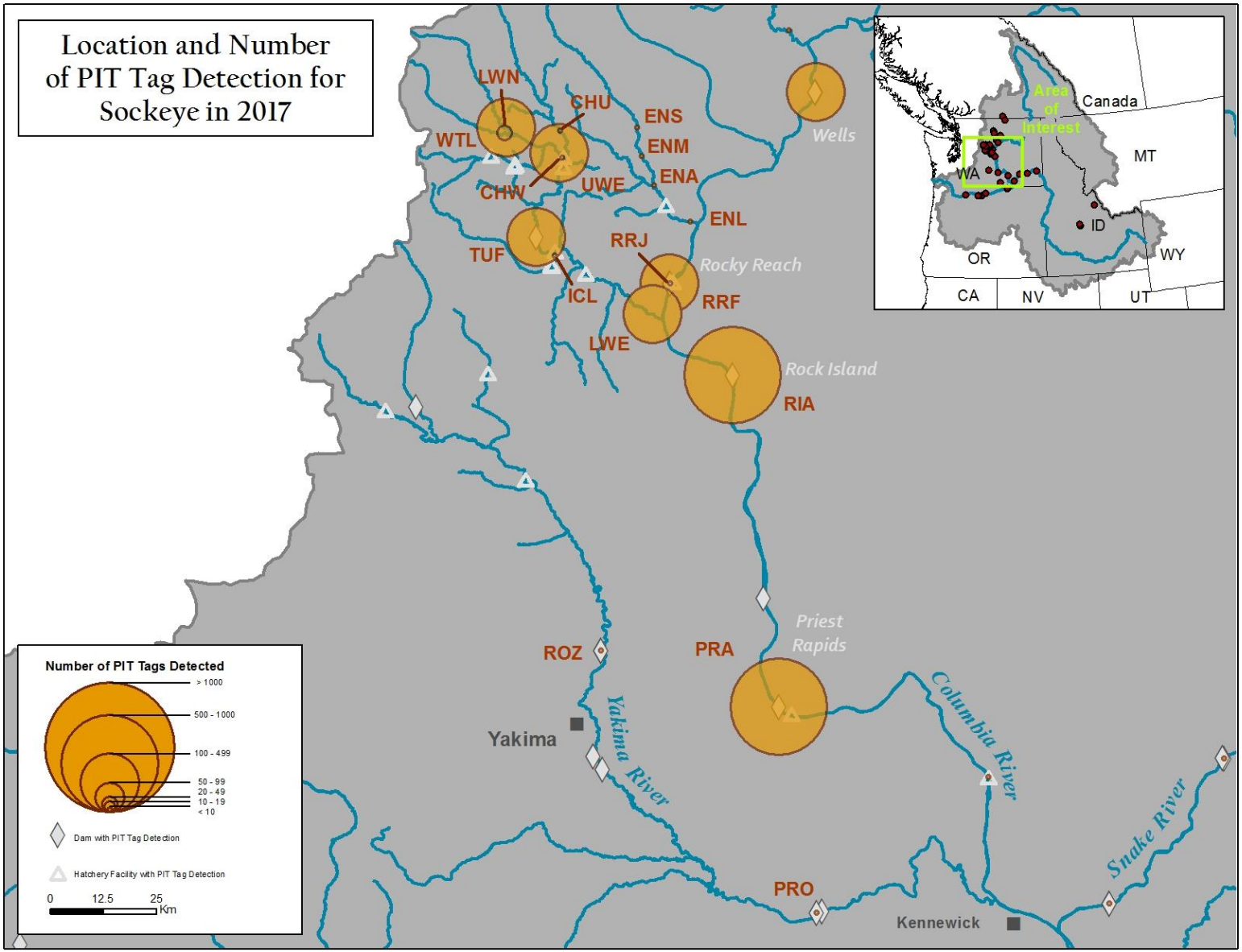


Figure B4. Map of Upper Middle Columbia River (between the Snake River and Wells Dam) detection sites and number of Sockeye Salmon detected in 2017. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

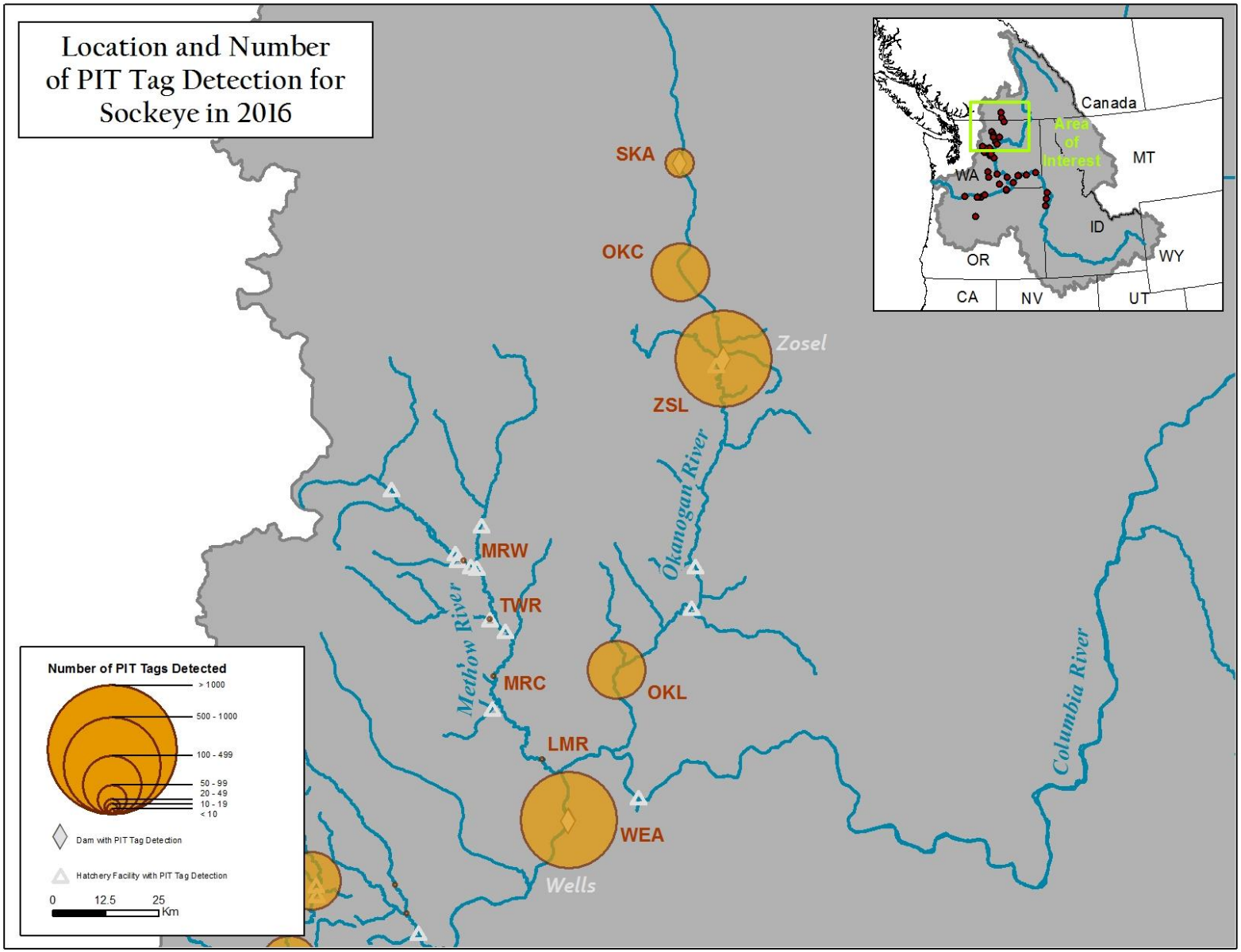


Figure B5. Map of Upper Columbia River (Wells Dam and above) detection sites and number of Sockeye Salmon detected 2016. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

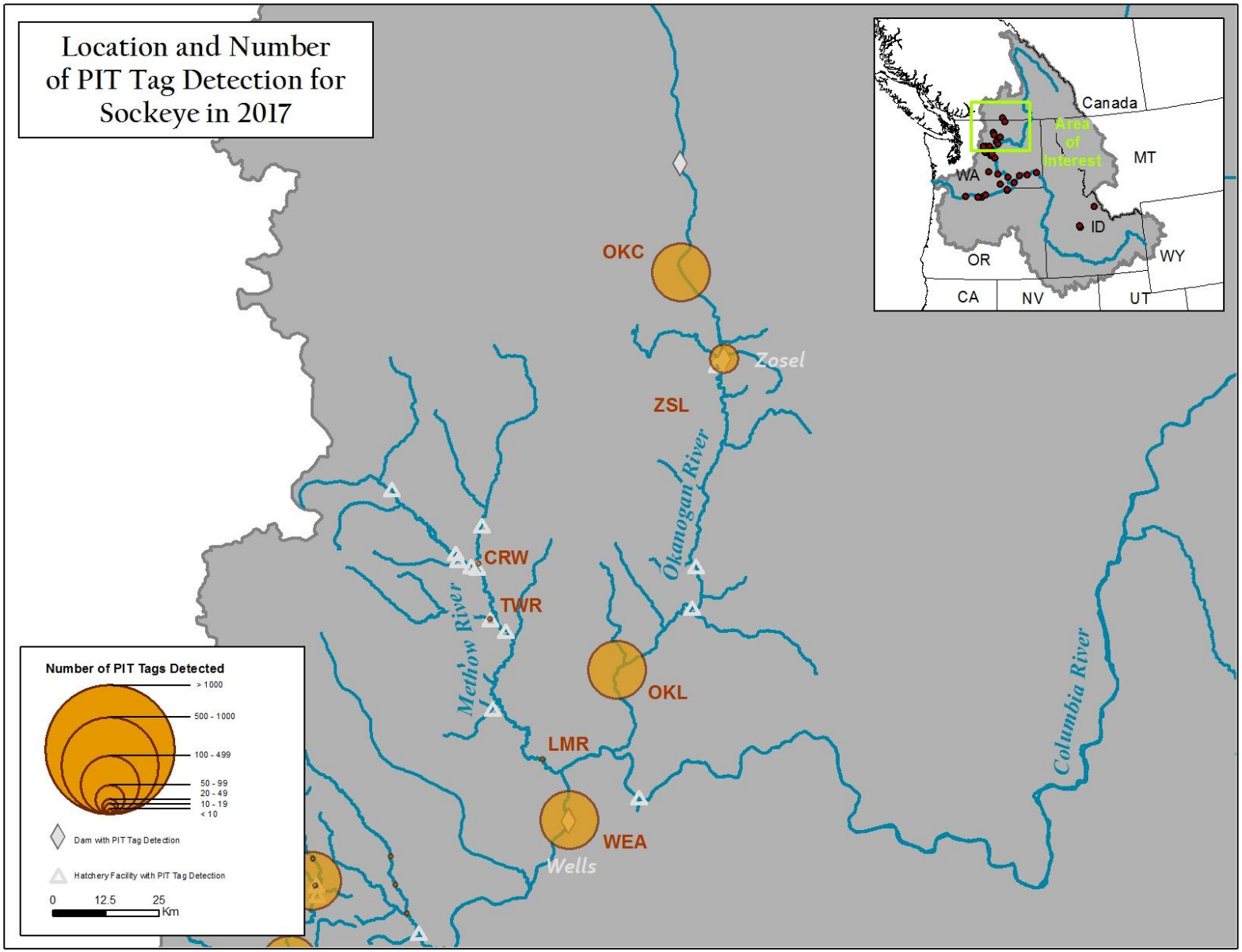


Figure B6. Map of Upper Columbia River (Wells Dam and above) detection sites and number of Sockeye Salmon detected 2017. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

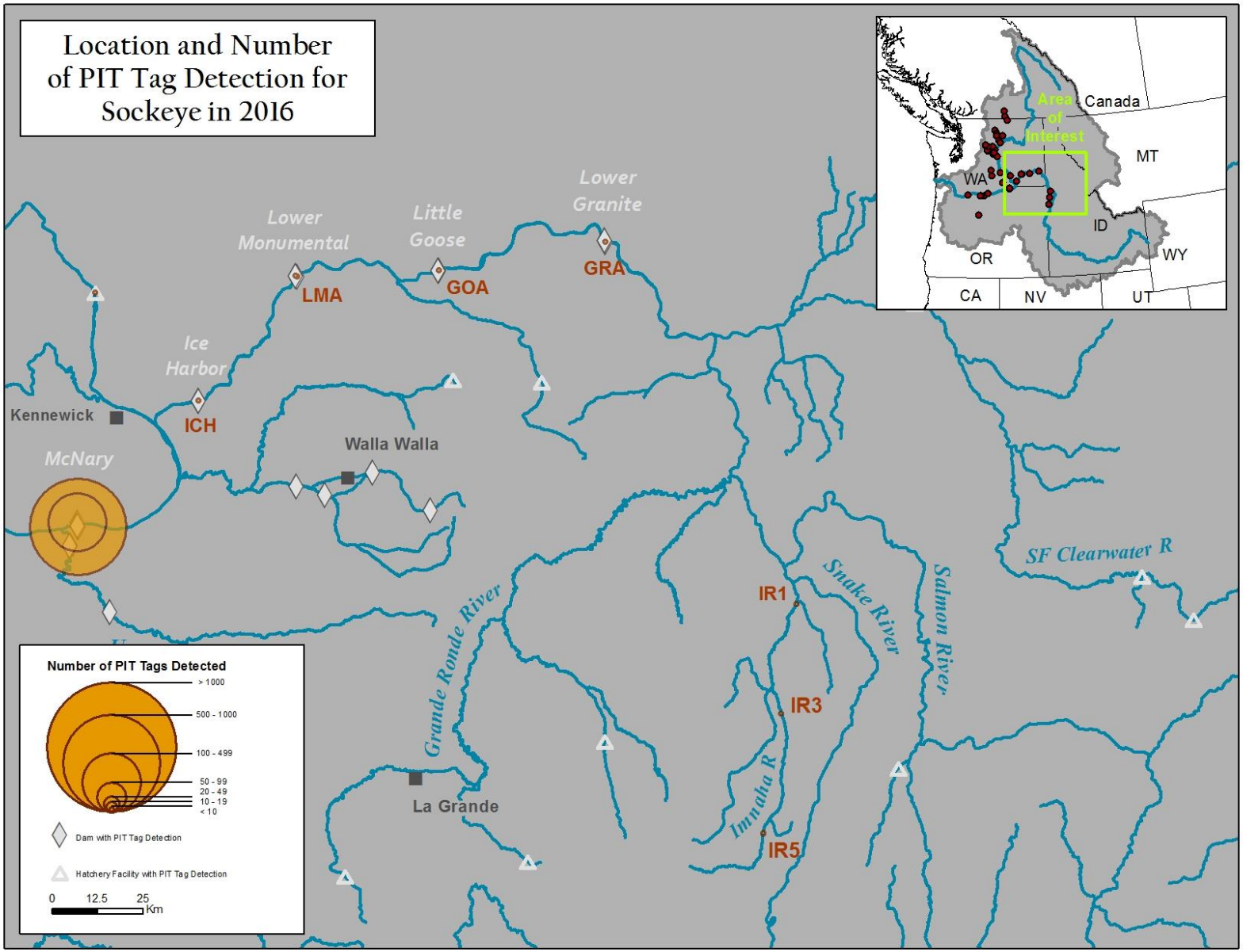


Figure B7. Map of Lower Snake River detection sites (Salmon River not included) and number of Sockeye Salmon detected in 2016. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

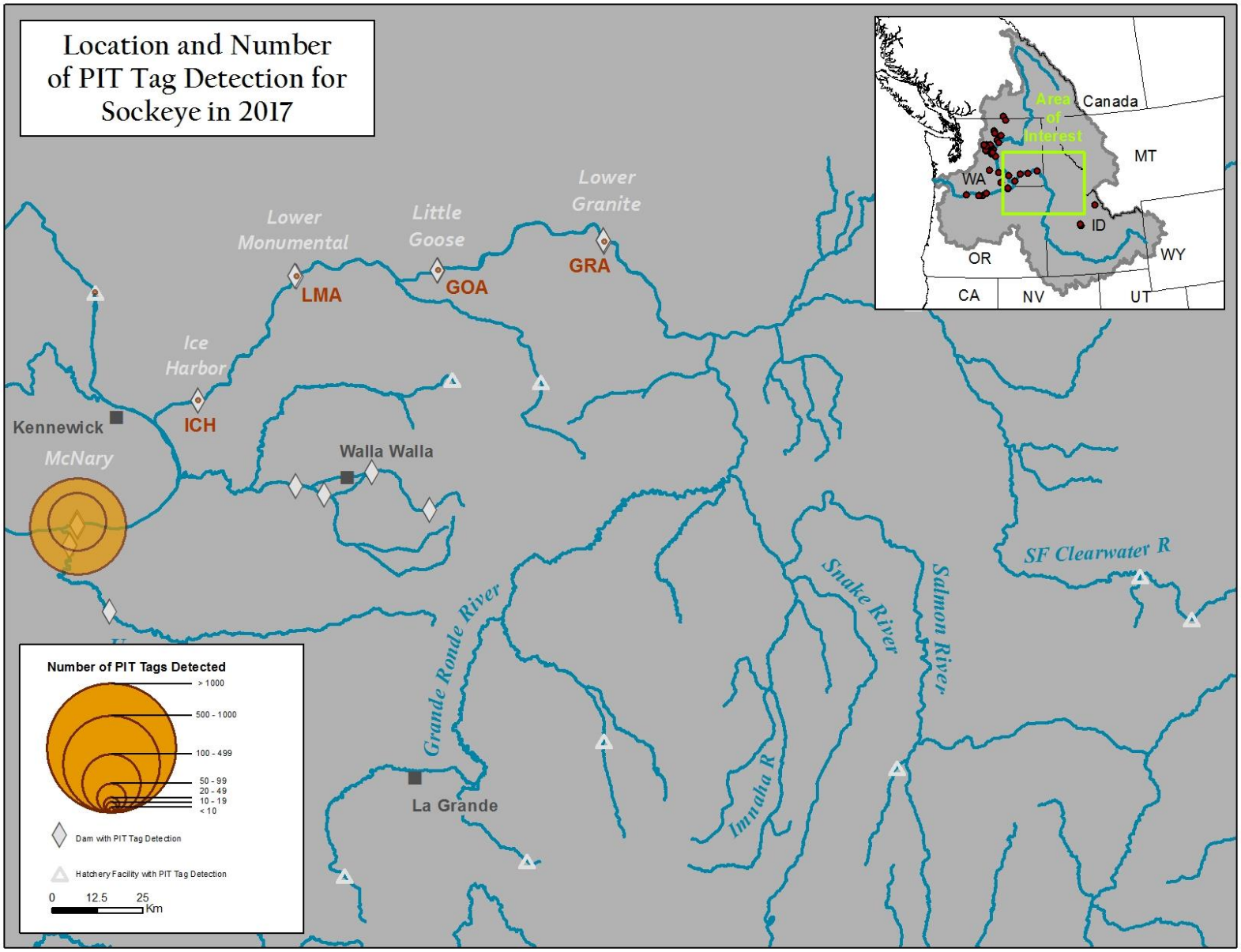


Figure B8. Map of Lower Snake River detection sites (Salmon River not included) and number of Sockeye Salmon detected in 2017. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

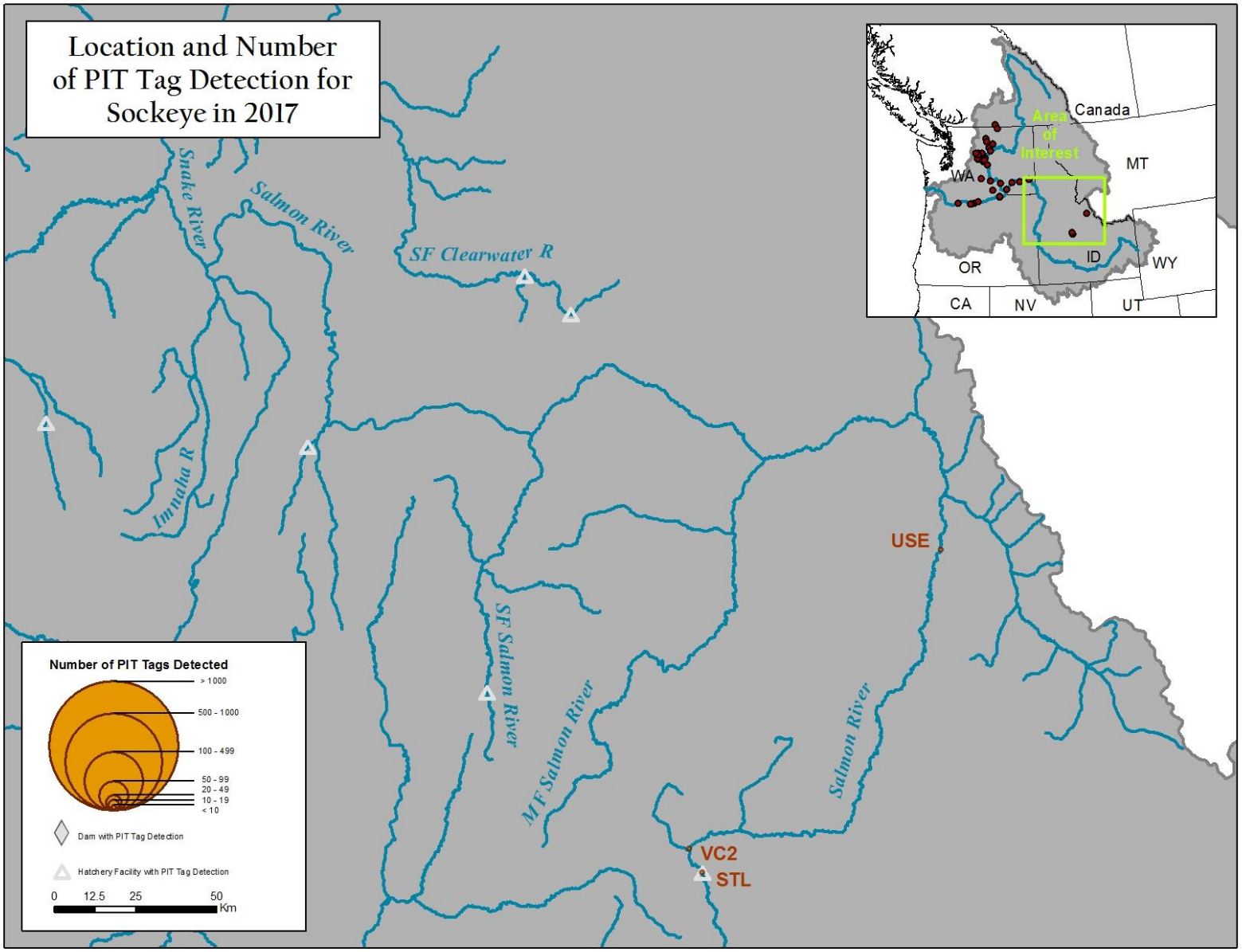


Figure B9. Map of Salmon River detection sites and number of Sockeye Salmon detected in 2017 (Note that in 2016 Sockeye were not detection in the Salmon River). Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

APPENDIX C

ʔAWST'IKʷ [Okanagan River] Sockeye Smolt out of Basin Survival: PIT Tagging 2015 and 2016

ʔaawsitkʷ (Okanagan River) Sockeye Smolt Out of Basin Survival: Purse Seining & PIT Tagging BY 2015

Prepared by:
Skyeler Folks, B.Sc.
Molly Teather, B.Sc.
Ryan Benson, M.Sc.

Okanagan Nation Aquatic Enterprises Ltd.

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

August 2017

Okanagan Nation Aquatic Enterprises Ltd.
101-3535 Old Okanagan Highway
Westbank, BC, V4T 3L7
Phone: (250) 707-0095 Fax: (250) 707-0166

Disclaimer: Okanagan Nation Aquatic Enterprises reports frequently contain preliminary data, and conclusions based on these may be subject to change.

Citation: Folks, S, M. Teather, and R. Benson. 2017. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: Purse Seining and PIT Tagging BY 2015. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 16 pp.

Executive Summary

The q̓awsitkʷ[1] (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 2013-2016 monitoring seasons, 2017 study objectives include:

1. PIT tag a minimum 10,000 hatchery- and natural-origin smolts combined from suwiẁs (Osoyoos Lake).
2. Monitor PIT tagged smolt survival and travel rates to the nxˇʷəntkʷitkʷ (Columbia River) estuary.
3. Synthesize an efficient study design and data management protocol that will address out of basin survival.

In 2017, 11,588 smolts were released during seven tagging sessions between 26 April and 3 May, 2017 at two sites: OSOYOL, the north basin of suwiẁs, and OSOYBR, downstream of the Highway 3 bridge at the Osoyoos Narrows. Survival probability for suwiẁs combined release groups to Rocky Reach Dam was 0.67 (SE=0.023). Survival from release to Bonneville Dam was 0.35 (SE=0.11). Travel time from release to Rocky Reach Dam was approximately 10.2 days. The overall travel time (release to Bonneville) for both groups combined was 17.7 days.

Recommendations from the 2016 sampling year include the following: 1) capture smolts exclusively in suwiẁs, expanding seining operations into the Central Basin if necessary; 2) PIT tag a minimum of 10,000 smolts annually, continue to use a purse seine as the primary capture platform, with a fyke net as a back-up method; and 3) continue to monitor the hatchery and natural smolt component in suwiẁs to test the 10% hatchery proportion assumption.

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

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. The Fish Passage Center and GCPUD were able to provide CSS PIT tags to support our efforts.

ONA staff that made this work possible include: Sheena Hooley, Jessica Hilton-McPherson, Dave Tom, Andrew Clark, Chelsea Mathieu, Casmir Tonasket, Saul Squakin, Nicolas Yaniw, Joe Gabriel, Paul Snow, Lindsay Bellingham, and Jamison Squakin. We wish to thank Osoyoos Indian Band for their support, and OIB Fisheries Technicians Colette Louie, Lindsay George, and Zachery Chapman.

All field data collection related to this project was implemented according to the directions we received to date from traditional ecological knowledge keepers. This include acknowledgments and respect of the siwłkʷ and tmʼxʷulaʔx. Indigenous Peoples of the Okanagan are the exclusive owners of their cultural and intellectual properties.

Table of Contents

Executive Summary **1**
Acknowledgements **2**
Table of Contents **3**
List of Tables **4**
List of Figures **4**
Table of N'syilxcen Place Names **4**
1.0 Introduction **5**
1.1 Project Background 5
1.2 Study Area 6
1.3 Project Objectives 8
2.0 Methods **8**
2.1 Smolt Capture **8**
2.2 PIT Tagging Procedures 8
3.0 Results **9**
3.1 Smolt Capture 9
3.2 PIT Tagging Results 9
3.1.1 Survival 10
3.1.2 Travel Time 11
4.0 Discussion and Recommendations **12**
4.1 PIT Tagging 12
5.0 References **15**

List of Tables

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2017.....10
Table 2. Survival and Arithmetic mean travel time for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (OSOYBR and OSOYOL combined), 2017.....10
Table 3. Comparison of annual survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, 2013-2015 (SKATAL and OSOYOL combined), 2016 (SKAHAL, SKATAL, OSOYOL and OSOYBR combined), and 2017 (OSOYOL and OSOYBR combined). Standard Errors of mean presented in brackets.....11

List of Figures

Figure 1. q'awsitkw juvenile PIT tagging locations in 2017. 7
Figure 2. Survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (OSOYOL and OSOYBR combined), 2017. 11
Figure 3. Arithmetic Meantravel time for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (OSOYOL and OSOYBR combined), 2017. 12
Figure 4. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam. 13

Table of N'syilxcen Place Names

N'syilx'cin Place Name	**(Okanagan-English Translation)**
nxˇʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
q̓awstʼikʼʷt, also known as t̓iwcən	Skaha Lake
suwiẁs	Osoyoos Lake

Indigenous Peoples of the Okanagan are the exclusive owners of their cultural and intellectual properties.

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 where they rear for one year before migrating to nxˇʷəntkʷitkʷ (Columbia River) and the Pacific Ocean as smolts (Stefanovic et al. 2016). Two main unanswered questions are out of basin survival of both hatchery and natural Okanagan smolts, and Smolt to Adult Ratios (SAR) for returning adults. 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.

To determine freshwater outmigration survival, Passive Integrated Transponder (PIT) tag technology has been used by researchers and fisheries managers in the nxˇʷəntkʷitkʷ 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 suwiẇs (Osoyoos Lake) 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 Okanagan Nation Aquatic Enterprises (OAE) commenced with a trial PIT tagging program, releasing 534 tagged smolts (Benson et al. 2013). A number of logistical and operational recommendations were made, including tagging smolts from both q'awst'ik'ʷt and suwiẇs, and a total of 4018 tags were released in 2013 (Benson et al. 2014). PIT tagged sample sizes have increased each year: 5,054 in 2014, 7,176 in 2015; and 10,241 in 2016 (Folks et al. 2016a, 2016b).

In 2016, OAE piloted purse seining in both lakes as a method of capturing smolts (Folks et al. 2016b). Based on these results and the recommendation of the Canadian Okanagan Basin Technical Working Group (COBTWG), the direction was to rely solely on purse seining as a capture platform, with the fyke net set at the Osoyoos Lake Narrows Bridge as a backup (see Benson 2016 for methods). Furthermore, to streamline logistics for smolt capture, purse seining was conducted only in suwiẇs. This was based on the assumption that both q'awst'ik'ʷt and suwiẇs Sockeye populations would be thoroughly mixed in suwiẇs during the sampling period.

In this report, we summarize the capture and tagging program for the 2017 season (2015 Broodyear). During this year, we were able to increase the number of deployed PIT tags (>10,000) in an effort to refine survival estimates to Lower nxˇʷəntkʷitkʷ 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 suwiẇs (Figure 1). Sockeye that rear in the North Basin of suwiẇs 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 suwiẇs 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 2015 brood year, 357,500 hatchery-reared fry were released into q’awst’ik’ʷt (Stefanovic et al. 2016). This was the second lowest hatchery release since the start of the program in 2003. In addition, approximately 1,600 natural Sockeye spawned in Penticton Channel (Yaniw and Benson 2017). Therefore, smolts outmigrating from q’awst’ik’ʷt in 2017 were of mixed natural and hatchery origin.

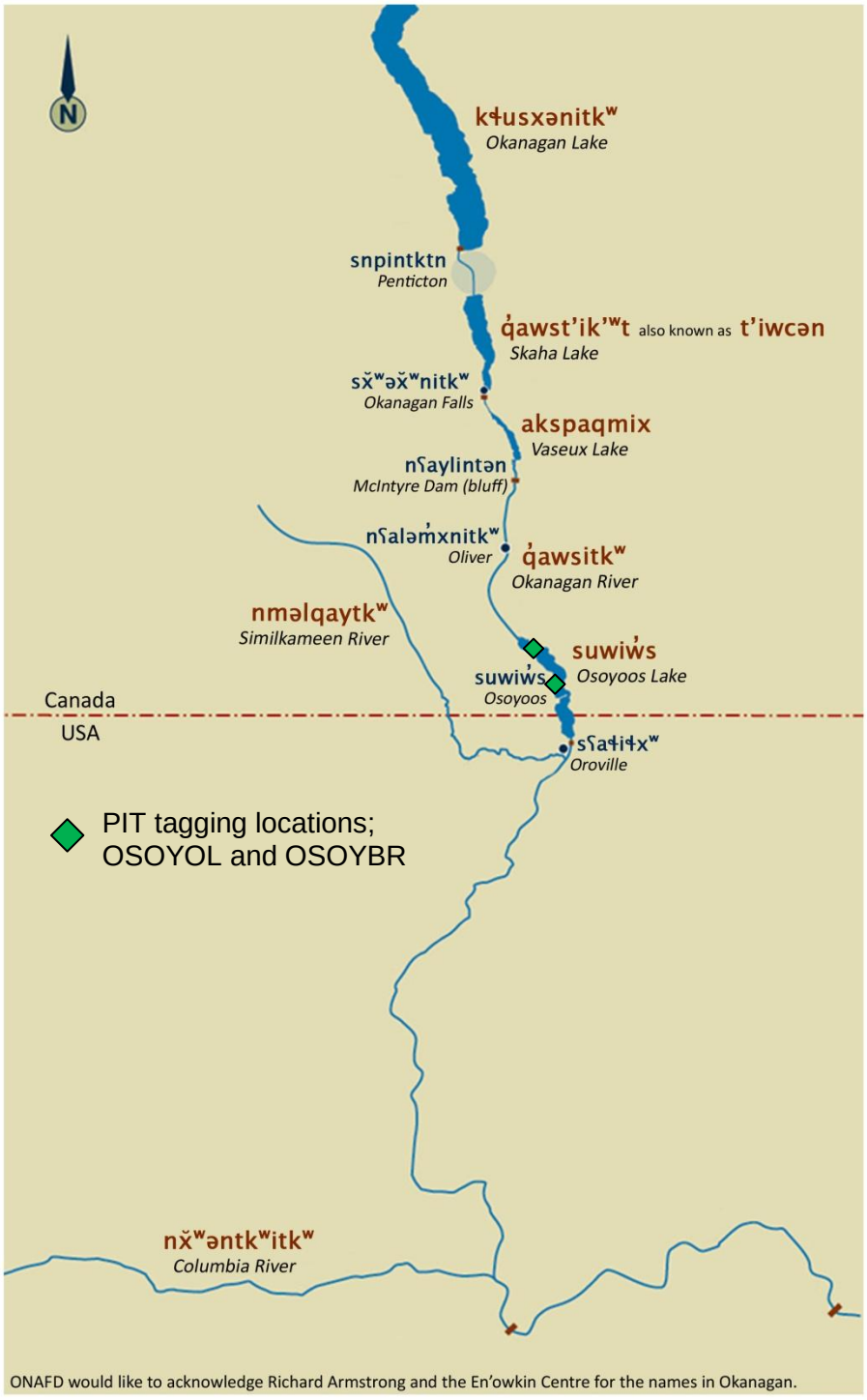


Figure 1. q'awsitkw juvenile PIT tagging locations in 2017.

1.3 Project Objectives

The main objective was to PIT tag a minimum of 10,000 smolts combined from both lakes, q̓awst'ik'ʷt and suwiẇs, 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 a minimum of 10,000 hatchery- and natural-origin smolts combined from both lake populations; q'awst'ik'ʷt and suwiẇs.

2. Test assumptions population mixing: 10% of smolts in suwiẇs are of q̓awst'ik'ʷt origin

3. Monitor PIT tagged smolt survival and travel rates to the nxˇʷəntkʷitkʷ estuary.

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

2.0 Methods

2.1 Smolt Capture

We exclusively purse seined suwiẇs to capture smolts for PIT tagging. We used a 8.5 m (28') long purse seiner fishing with a 183 m (600') long seine net with 1.27 cm (1/2") knotted mesh. The purse seiner was able to fish up to a depth of 12 m (40'). Purse seining concentrated in the central basin of suwiẇs where the majority of Sockeye smolts were congregating.

Two fyke net capture sessions were conducted to monitor migration timing to determine optimal purse seine sampling, and to increase captures for PIT tagging. Fyke sampling occurred 10 and 27 April. Fyke methods were the same as OAE's annual smolt migration monitoring (see Benson 2016).

2.2 PIT Tagging Procedures

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. Tags were implanted with the MK-25 Rapid Implant Gun along with HPT9 pre-loaded sterile needles manufactured by Biomark. Fish were removed from kitoi boxes and holding pens 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 (approximately 1.5 minutes). Each smolt was measured for fork length (mm) and general body condition/descaling percentage was recorded. The tagging needle was inserted on the left or right side between the pectoral fin and lateral line, and 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 Trimble® Yuma® 2 computer or tablet, which logged and saved each tag number into a P4 software tagging session file. 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 holding pens and released back into the lake the same day, typically between 22:00 and 24:00 to reduce predation. Fish were released either downstream of the Highway 3 bridge on suwiẇs (OSOYBR), or in the North Basin just offshore (OSOYOL). All post-tagged smolt mortalities were removed and bio-sampled.

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

3.0 Results

3.1 Smolt Capture

All smolts in 2017 were captured in suwiẇs. The majority of the smolts were captured in the Central Basin of suwiẇs, while a small number were captured in the North Basin. Captured smolts were held in holding pens attached to the end dock in the North Basin of suwiẇs, and in aluminum kitoi boxes at the Hwy 3 narrows for tagging the following day.

The fyke net was deployed to gauge smolt migration timing. The net was set on 10 and 27 of April. No smolts were captured on 10 April, while a total of 172 were captured on 27 April.

Following capture and tagging, smolts were held in the lake to monitor acute tagging mortality and to remove mortalities from the tagged population. In total, 864 dead smolts were biosampled (n_{fyke} = 97; n_{seine} = 767). Thermal marks from otoliths were checked for 142 (16%) smolts. Of the 142 otoliths, all were natural origin.

We conducted a two sample KS-test for the fyke vs. purse seine groups tagged on 28 April (n_{fyke} = 97; n_{seine} = 119). The critical D-value (α 0.05) was 0.186. Results of the KS-test indicate no significant difference between the two populations ($D = 0.09$, $P < 0.05$). There appears to be no difference in the length distribution between fyke and purse seined smolts. The scope of the KS-test was only for one day due to the potential to double sample (re-capture) previously seined smolts and thus bias the length distribution, to standardize the purse seine capture date with the fyke capture, and to balance the sample size for each group. Although the scope was limited to one day, preliminary results suggests the two gear types were not size selective.

3.2 PIT Tagging Results

In total, 11,588 smolts were tagged and released during 7 tagging days, between 26 April and 3 May, 2017 at the two sites; OSOYBR and OSOYOL. Tagging effort has been summarized (Table 1).

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2017

Site		
Date	**OSOYOL**	**OSOYBR**
26-Apr-17	396	
28-Apr-17	2580	*152
29-Apr-17	198	
30-Apr-17	839	893
01-May-17	1284	1749
02-May-17	2862	
03-May-17	635	
TOTAL	**8794**	**2794**

* smolts were captured with the fyke net

3.1.1 Survival

Reliable estimates of survival from release to Rocky Reach Dam were calculated for both release groups, combined as one population. Survival from release to Rocky Reach Dam was 0.675 (SE = 0.0256) (Table 2). After Rocky Reach, error associated with survival estimates typically increases, namely the Rocky Reach to McNary, and McNary to John Day (Figure 2, Table 3).

Table 2. Survival and Arithmetic mean travel time for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (OSOYBR and OSOYOL combined), 2017.

Period	Survival	SE	Travel time	SE
Release to Rocky Reach	0.67	0.026	11.9	5.20
Rocky Reach to McNary	0.94	0.105	4.2	1.49
McNary to John Day	0.88	0.146	2.4	0.72
John Day to Bonneville	0.63	0.214	1.3	0.17
Release to Bonneville	0.35	0.110	18.7	4.75

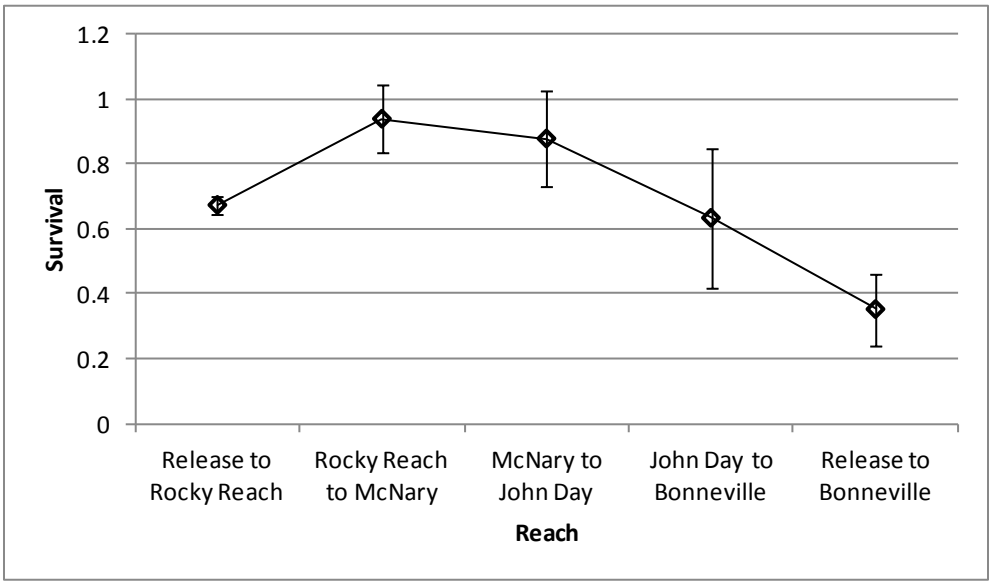


Figure 2. Survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (OSOYOL and OSOYBR combined), 2017.

Table 3. Comparison of annual survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, 2013-2015 (SKATAL and OSOYOL combined), 2016 (SKAHAL, SKATAL, OSOYOL and OSOYBR combined), and 2017 (OSOYOL and OSOYBR combined). Standard Errors of mean presented in brackets.

Period	2013	2014	2015	2016	2017
Release to Rocky Reach	0.48 (0.03)	0.57 (0.08)	0.42 (0.02)	0.56 (0.02)	0.67 (0.03)
Rocky Reach to McNary	1.14 (0.26)	0.68 (0.44)	0.80 (0.13)	0.79 (0.07)	0.94 (.11)
McNary to John Day	1.25 (0.66)	2.80 (0.65)	0.72 (0.18)	0.97 (0.19)	0.88 (0.15)
John Day to Bonneville	0.70 (0.58)	0.26 (0.24)	1.79 (0.66)	0.49 (0.14)	0.63 (0.21)
Overall	0.48 (0.33)	0.03 (0.08)	0.44 (0.14)	0.21 (0.04)	0.35 (0.11)

3.1.2 Travel Time

Travel time from release to Rocky Reach Dam was approximately 11.9 days (Figure 3, Table 4). Overall travel time from release to Bonneville Dam was approximately 18.7 days (Figure 3). Between the years of 2013-2017, combined release group travel time estimates from release to Rocky Reach Dam range from 16.4 days, and 25.6 days overall (Table 4).

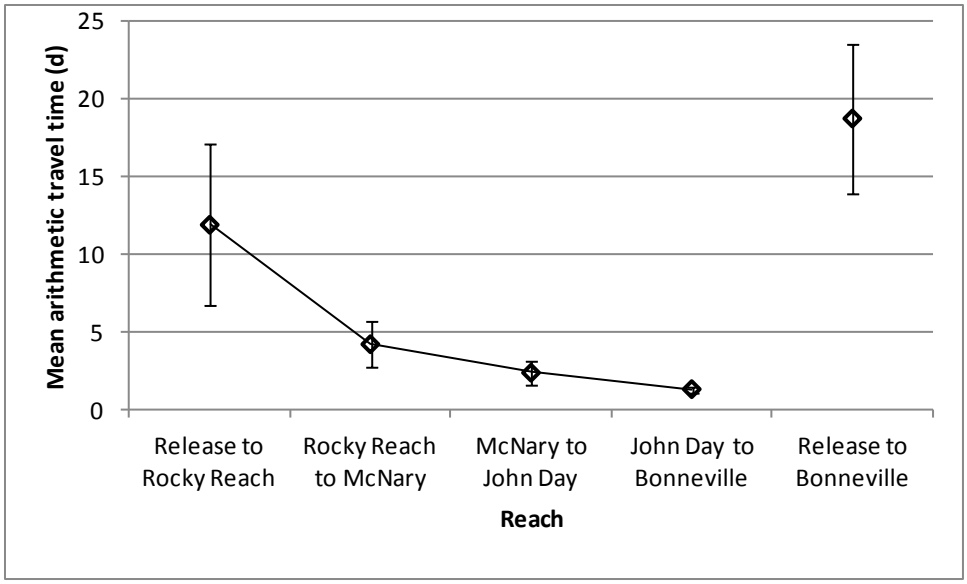


Figure 3. Arithmetic Meantravel time for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (OSOYOL and OSOYBR combined), 2017.

Table 4. Comparison of Harmonic mean travel time for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, 2013-2015 (SKATAL and OSOYOL combined), 2016 (SKAHAL, SKATAL, OSOYOL and OSOYBR combined), and 2017 (OSOYOL and OSOYBR combined). Standard Errors of mean presented in brackets.

Reach	2013	2014	2015	2016	2017
Release to Rocky Reach	19.3 (0.25)	15.9 (0.19)	16.2 (0.14)	14.2 (0.13)	10.2 (0.078)
Rocky Reach to McNary	4.4 (0.14)	3.9 (0.07)	5.9 (0.14)	4.9 (0.07)	3.9 (0.073)
McNary to John Day	2.3 (0.22)	2.4 (0.11)	2.7 (0.28)	2.6 (0.17)	2.2 (0.08)
John Day to Bonneville	1.5 (0.15)	1.4 (0.16)	1.7 (0.05)	1.4 (0.04)	1.3 (0.03)
Overall	29.0 (0.74)	23.2 (0.56)	26.6 (0.27)	23.4 (0.29)	17.7 (0.19)

4.0 Discussion and Recommendations

4.1 PIT Tagging

The program *SampleSize* (Lady et al. 2003) was used to develop confidence intervals for a single-release survival estimates of juvenile Sockeye Salmon through the Columbia River Basin (Figure 4). 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 4).

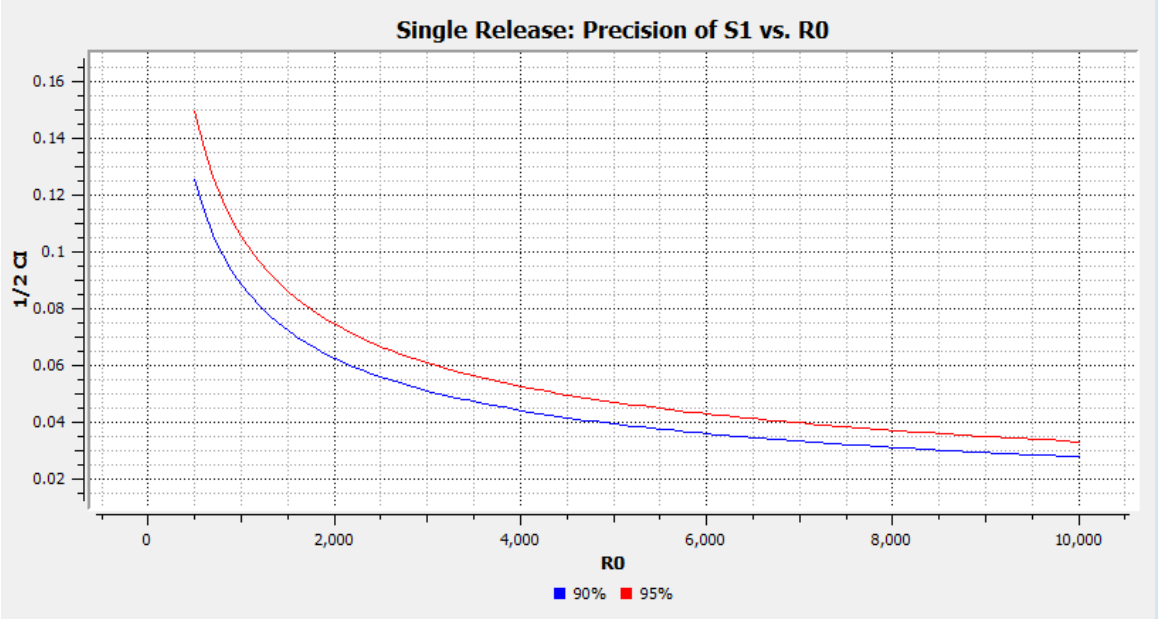


Figure 4. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam.

In 2017, 11,588 smolts were tagged from suwiẁs. Therefore, it was possible to determine survival and travel time for the combined population (>10,000) as far as Bonneville. Survival from release to Bonneville was the highest since the PIT monitoring program started in 2013. Overall survival to Bonneville was higher than in 2016, and the third highest since 2013 (Table 3). Travel time (both from release to Rocky Reach and release to Bonneville) was the lowest since 2013 (Table 4). A likely explanation for elevated survival and rapid migration was the higher than average spring flow in q̓awsitkʷ.

Survival estimates are reliable from release to Rocky Reach, and release to Bonneville. However, estimates from Rocky Reach to McNary and McNary to John Day are typically unreliable, with survival probability often exceeding 1.0 (Table 3).

For 2017, we captured solely within suwiẁs, to test the assumption q̓awst̓ik̓ʷt and suwiẁs smolts would be thoroughly mixed and that at least 10% of total tagged would be q̓awst̓ik̓ʷt origin. Since 2011, the mean proportion of q̓awst̓ik̓ʷt hatchery smolts captured in suwiẁs was 9.1% (range 0.6-17.1%) (Benson et al. 2011; Benson and Warman 2012; Benson and Stevens 2014; Benson 2014, 2016). Given that in 2016 the methods were changed to capture live smolts for PIT tagging (thus decreasing the number of smolts lethally collected for biosampling), the mean proportion of hatchery smolts in suwiẁs was 11.25% (range 3.1-17.1%). In 2017, all biosampled smolts were of natural origin.

Based on previous smolt monitoring efforts, the assumption of 10% hatchery proportion in suwiẇs is potentially still valid. BY 2015 was the lowest hatchery outplant in the history of the Re-introduction Program (Stefanovic et al. 2016). This was mainly due to stressful river conditions nxˇʷəntkʷitkʷ which caused high adult Sockeye mortality and poor egg quality. The estimated pre-smolt composition was: 90.6% suwiẇs, 6.2% q'awst'ik'ʷt natural, and 3.2% q'awst'ik'ʷt hatchery (OAE, unpubl. data). Finally, spring conditions in 2017 were atypical; weather was colder for a longer duration and both lakes had ice well into March. The cold weather likely altered smolt behavior and delayed out-migration. Considering all these factors, this smolt year would be considered an outlier. A repeat of the 2017 PIT tagging methods is warranted.

Recommendations for future monitoring include:

- Continue to capture smolts exclusively in suwiẇs, expanding seining operations into the Central Basin if necessary. The minimum target will remain 10,000 smolts;
- Purse seining will remain the primary capture method. The fyke net should be a back-up capture method.
- Continue to monitor the hatchery smolt component to test the 10% proportion assumption in suwiẇs.

5.0 References

Benson, R. (2014). Okanagan Sockeye smolt migration from suwiẁs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2012 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 28 pp.

Benson, R. 2016. Okanagan Sockeye smolt migration from suwiẁs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2014 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 23 pp.

Benson, R., & A. Stevens. 2014. Okanagan Sockeye smolt migration from suwiẁs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2011 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 24 pp.

Benson, R., & A. Warman. 2012. Okanagan Sockeye smolt migration from suwiẁs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2010 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 27 pp.

Benson, R.L., A. Warman, and R. Bussanich. 2011. Okanagan sockeye smolt migration from suwiẁs (Osoyoos Lake) and q'awst'ik'ʷt (Skaha Lake) 2009 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 36 pp.

Benson, R., S. Folks, A. Stevens, and R. Bussanich. 2013. Brood year 2011 – Sockeye smolt out of basin survival pilot study in q'awsitkʷ (Okanagan River). Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 37 pp.

Benson, R., S. Folks, A. Stevens, and R. Bussanich. 2014. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT and Acoustic Tagging 2013. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 17 pp.

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

Folks, S, R. Benson, A. Stevens, and R. Bussanich. 2016a. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT Tagging 2014 & 2015. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 17 pp.

Folks, S, R. Bussanich, A. Stevens, and M. Teather. 2016b. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT Tagging 2016. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 12 pp.

Fryer, J. K., H. Wright, S. Folks, K. D. Hyatt, and M. M. Stockwell. 2012. Limiting Factors of the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2011. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00

Lady, J.M., P. Westhagen, and J.R. Skalski. 2003. SampleSize 1.1. Sample size calculations for fish and wildlife survival studies. School of Aquatic and Fishery Sciences, University of Washington. Seattle, WA.

PTAGIS (1999) PIT tag Marking Procedures Manual version 2.0: Retrieved online November 2013: http://php.ptagis.org/wiki/images/e/ed/MPM.pdf

Stefanovic, D., R. Benson, C. Fuller, and L. Wiens. 2016. Collection and Rearing of Okanagan Sockeye Salmon for the Skaha Re-introduction Program: Brood Year 2015 Annual Report. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2015. Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC.

Wright, R.H. and H. Smith (Ed). 2003. Management plan for experimental reintroduction of sockeye into Skaha Lake: Proposed implementation, monitoring and evaluation. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC.

Yaniw, N., and R. Benson. 2017. ʔqawst'ik'^{w}t (Skaha Lake) Nerkid Spawner Enumeration and Biological Sampling 2015. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2015. Okanagan Nation Alliance Aquatic Enterprises Ltd., Westbank, BC.

ʔawsitkʷ (Okanagan River) Sockeye Smolt Out of Basin Survival: PIT Tagging 2016

Prepared by:
Skyeler Folks, B.Sc.
Richard Bussanich, M.Sc.
Amanda Stevens, B.Sc.
Molly Teather, B.Sc.
Okanagan Nation Alliance Aquatic Enterprises Ltd.

Reviewed by:
Ryan Benson, M.Sc.,

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

December 2016

Okanagan Nation Aquatic Enterprises Ltd.
101-3535 Old Okanagan Highway
Westbank, BC, V4T 3L7
Phone: (250) 707-0095 Fax: (250) 707-0166

Disclaimer: Okanagan Nation Aquatic Enterprises reports frequently contain preliminary data, and conclusions based on these may be subject to change. Reports may be cited in publications but their manuscript status (MS) must be noted. Please obtain the individual author's permission before citing their work.

Citation: Folks, S, R. Bussanich, A. Stevens, and M. Teather. 2016. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT Tagging 2016. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 12 pp.

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[1] (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 2013-2015 sampling season, 2016 study objectives were to:

1. PIT tag a minimum 10,000 hatchery- and natural-origin smolts combined from both lake populations; q'awst'ik'ʷt (Skaha Lake) and suwiẇs (Osoyoos Lake).
2. Monitor PIT tagged smolt survival and travel rates to the nxˇʷəntkʷitkʷ (Columbia River) estuary.
3. Synthesize an efficient study design and data management protocol that will address out of basin survival.

In 2016, 10,241 smolts were released during 20 tagging sessions between March 22 and April 29, 2016 at four sites; , SKAHAL, the south basin of q'awst'ik'ʷt , SKATAL, the tailrace downstream of Skaha Outlet Dam , OSOYOL, the north basin of suwiẇs, and OSOYBR, downstream of the Highway 3 bridge at the Osoyoos Narrows. Reliable estimates of survival from release to Rocky Reach Dam for combined sites were possible for 2016 and were determined to be 0.56 (SE=0.0161). Survival estimates for suwiẇs combined release groups to Rocky Reach Dam were 0.63 (0.0248), and for q'awst'ik'ʷt combined release groups were 0.49 (0.0208). After Rocky Reach, error associated with survival estimates vary depending on release group. A combined group, and a q'awst'ik'ʷt combined release group survival estimate was possible to lower Dams (survival to Bonneville; 0.21, SE = 0.0449, and 0.15, SE=0.0333, respectively). Alternatively, beyond Rocky Reach survival estimates were not possible for suwiẇs combined release groups, as error was too large.

The Travel time from release to Rocky Reach Dam (RRD) was approximately 10.8 days for the q'awst'ik'ʷt combined release groups, 19.0 days for the suwiẇs combined release groups, and 14.2 days for all release groups combined. The overall travel time (release to Bonneville) for all groups combined was 23.4 days.

Recommendations from the 2016 sampling year are to continue to develop the logistics and capacity to enable PIT tagging a minimum of 10,000 Okanagan Sockeye smolts combined from both lake populations; q̓awst'ik'ʷt and suwiẇs. Improvements include developing capture, holding, and handling techniques within the North Basin of suwiẇs to improve post tagging survival in periods of higher water temperatures. As well as to continue purse seining as the primary method of capture, while monitor and test assumptions for captured fish in suwiẇs as being a representative mixed sample of both q'awst'ik'ʷt and suwiẇs origin smolts.

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

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. The Fish Passage Center was able to provide CSS PIT tags to support our efforts.

Our ever valuable ONA staff that make this one the ground work possible; Sheena Hooley, Jessica Hilton – McPherson, Dave Tom, Andrew Clark, Chelsea Mathieu, Casmir Tonasket, Saul Squakin, Nicolas Yaniw, Joe Gabriel, and Jamison Squakin. Thanks to David Southgate and Regan Birch for their purse seining technical support and to the Department of Fisheries and Oceans for the use of their purse seine vessel and operator (Chris Narver). Lastly, the project has the appreciated support of the Osoyoos Indian Band, and OIB fisheries technicians Colette Louie and Lindsay George.

Table of Contents

Executive Summary ..... **ii**
Acknowledgements ..... **iii**
Table of Contents ..... **iv**
List of Tables ..... **v**
List of Figures ..... **vi**
Table of N'syilxcen Place Names ..... **vi**
1.0 Introduction **1**
1.1 Project Background 1
1.2 Study Area 1
1.3 Project Objectives 4
2.0 Methods **4**
2.1 PIT Tagging Procedures 4
3.0 Results **5**
3.1 PIT Tagging Results 5
3.1.1 Survival 6
3.1.2 Travel Time 7
4.0 Discussion and Recommendations **9**
4.1 PIT Tagging 9
5.0 References **11**

List of Tables

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2016 5
Table 2. Mean survival for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKATAL and SKAHAL combined, OSOYOL and OSOYBR combined, and OSOYOL, OSOYBR, SKATAL, and SKAHAL combined), 2016. 6
Table 3. Comparison of annual survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, (SKATAL and OSOYOL combined) 2013-2015, and (SKATAL, SKAHAL, OSOYOL and OSOYBR combined) 2016; Standard Errors of mean presented in brackets. 7
Table 4. Mean travel time for PIT tagged q'awsitk^{w} Sockeye smolts (SKATAL and SKAHAL combined, OSOYOL and OSOYBR combined, and OSOYOL, OSOYBR, SKATAL, and SKAHAL combined), 2016; Standard Errors of mean presented in brackets. 8
Table 5. Comparison of mean travel time for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, (SKATAL and OSOYOL combined) 2013-2015, and (SKATAL, SKAHAL, OSOYOL and OSOYBR combined) 2016; Standard Errors of mean presented in brackets. 8

List of Figures

Figure 1. q'awsitkw juvenile PIT tagging locations in 2016. 3
Figure 2. Mean survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (SKATAL, SKAHAL, OSOYOL and OSOYBR combined), 2016. 6
Figure 3. Mean travel time for PIT tagged q'awsitkʷ (Okanagan River) Sockeye smolts (SKATAL, SKAHAL, OSOYOL and OSOYBR combined), 2016. 7
Figure 4. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam. 9

Table of N'syilxcen Place Names

N'syilx'cin Place Name	(Okanagan-English Translation)
nxˇʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
suwiẁs	Osoyoos Lake
q̓awst'ik'ʷt, also known as t̓iwcən	Skaha Lake
nʔaylintən	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 suwiẁs (Osoyoos Lake), where they rear for one year before migrating to nxˇʷəntkʷitkʷ (Columbia River) and the Pacific Ocean as smolts (Stefanovic et al. 2016). 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.

To determine freshwater outmigration survival, Passive Integrated Transponder (PIT) tag technology has been used by researchers and fisheries managers in the nxˇʷəntkʷitkʷ 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 suwiẁs 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 (Benson et al. 2013). 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 suwiẁs (Osoyoos Lake) smolts (Benson et al. 2014).

In this report, we cover the tagging programs from the 2016 season. During this year, we were able to increase the number of deployed PIT tags (>10,000) in an effort to refine survival estimates to Lower nxˇʷəntkʷitkʷ 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 suwiẁs (Figure 1). Sockeye that rear in the North Basin of suwiẁs 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

suwiẇs 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 2014 brood year, hatchery-reared fry were released into q’awst’ik’ʷt. In addition, 20,000 to 40,000 natural Sockeye spawned in Penticton Channel (Benson and Bussanich 2016). Therefore, smolts outmigrating from q’awst’ik’ʷt in 2016 were of mixed natural and hatchery origin.

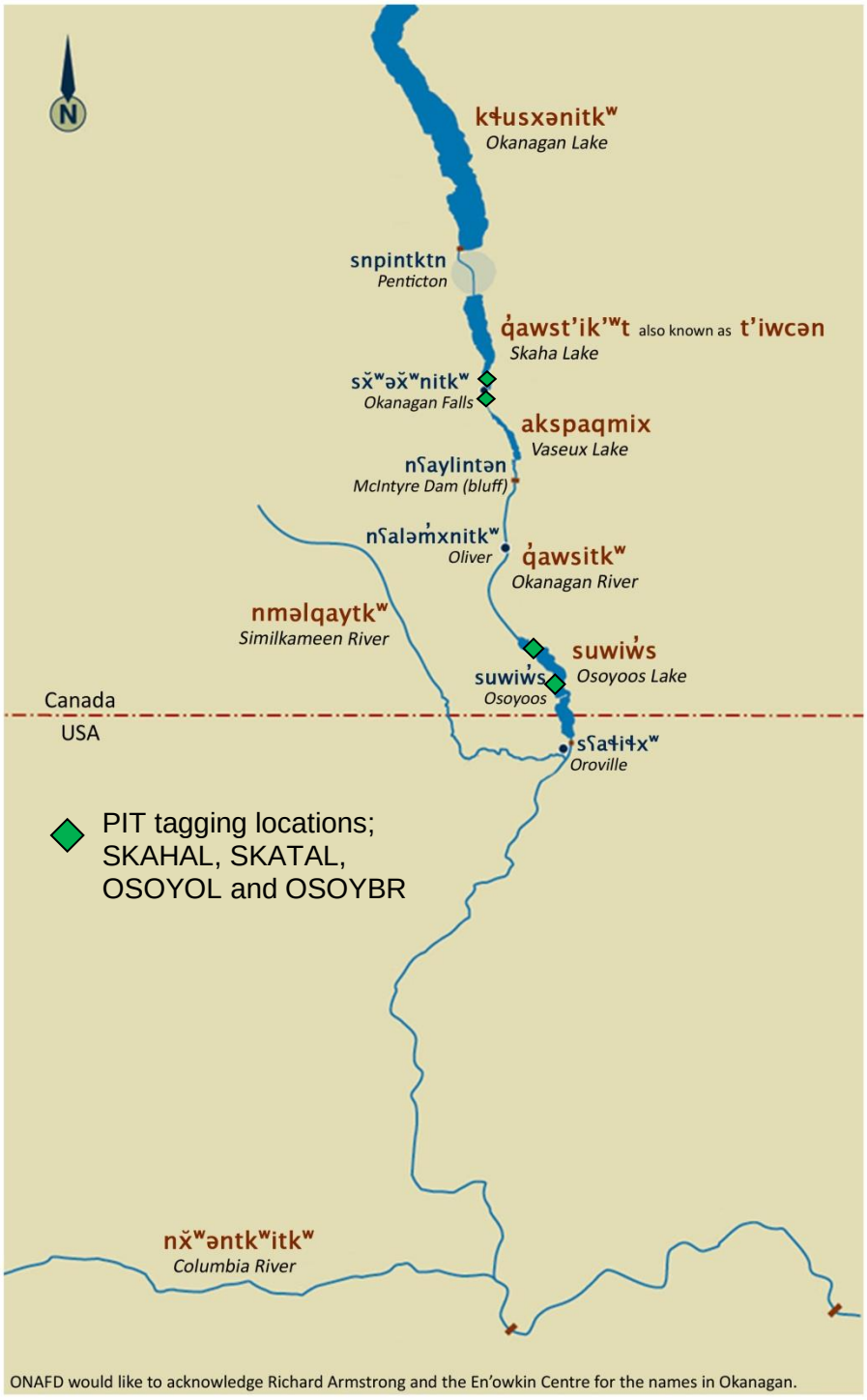


Figure 1. q'awsitkw juvenile PIT tagging locations in 2016.

1.3 Project Objectives

The main objective was to PIT tag a minimum of 10,000 smolts combined from both lakes, q̓awst'ik'ʷt and suwiẇs, 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 a minimum of 10,000 hatchery- and natural-origin smolts combined from both lake populations; q'awst'ik'ʷt and suwiẇs.

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

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

2.0 Methods

2.1 PIT Tagging Procedures

q'awst'ik'ʷt smolts were captured in the south basin of Skaha Lake, and downstream of Skaha Lake Outlet Dam. suwiẇs smolts were captured in the north basin of Osoyoos Lake, and at Osoyoos Lake Narrows at the Highway 3 Bridge during the smolt outmigration monitoring program (Benson 2016).

q'awst'ik'ʷt and suwiẇs smolts were captured using a purse seine net set one to five times a week (depending on boat availability) from 21 March to 29 April, 2016. The smolts were held in aluminum kitoi boxes and holding pens attached to the end of a privately owned dock in the south basin of Skaha Lake and the North Basin of Osoyoos Lake for tagging the following day (Benson 2016).

Two (2) Rotary Screw Traps (RSTs) were installed 15 March, 2016 downstream of Skaha Lake Outlet Dam. Cones were raised for seven days, then lowered and fished for 24 hour periods every day, excluding weekends until 8 April, when daily catches exceeded 100 smolts in either trap. Both RSTs were demobilized on 14 April due to projected flow increases from dam opening the following morning (Benson 2016).

suwiẇs smolts were captured using a floating fyke net set every 3 nights from 12 April to 20 April, 2016, and held in aluminum kitoi boxes placed in the shallows of Osoyoos Narrows for tagging the following day. Fyke net use was discontinued on 20 April due to unusually warm water temperatures (Benson 2016).

.

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 holding pens 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 (approximately 1.5 minutes). Each smolt was measured for fork length (mm) and general body condition/descaling percentage was recorded. The tagging needle was inserted on the left or right side between the pectoral fin and lateral line, and 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 Trimble® Yuma® 2 computer or tablet, which logged and saved each tag number into a P3 software tagging session file. 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 holding pens and released back into river or lake 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), in deeper open water north of the dock on q'awst'ik'ʷt (SKAHAL), downstream of the Highway 3 bridge on suwiẁs (OSOYBR), or near the confluence of suwiẁs and q̓awsitkʷ (OSOYOL).

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

3.0 Results

3.1 PIT Tagging Results

In total, 10,241 smolts were released during 16 tagging days, between March 22 and April 29, 2016 at four sites; SKATAL, the tailrace downstream of Skaha Outlet Dam, SKAHAL, the south basin of Skaha Lake, OSOYBR, downstream of the Highway 3 bridge at the Osoyoos Narrows, and OSOYOL, the north basin of Osoyoos Lake. Tagging effort is summarized in Table 1.

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2016

	SITE			
Date	**SKATAL**	**SKAHAL**	**OSOYOL**	**OSOYBR**
22-Mar-16			190	
06-Apr-16	172		251	
07-Apr-16			143	
08-Apr-16	755			
09-Apr-16	196			
11-Apr-16	1123			
12-Apr-16	50		642	203
13-Apr-16	133		1072	
14-Apr-16	673			
15-Apr-16				938
19-Apr-16				612
20-Apr-16			747	
26-Apr-16		518		
27-Apr-16		1196		
28-Apr-16		526		
29-Apr-16		101		
TOTAL	**3102**	**2341**	**3045**	**1753**

3.1.1 Survival

Reliable estimates of survival from release to Rocky Reach Dam were able to be calculated for all release groups. Survival from release to Rocky Reach Dam was 0.49 (SE = 0.0208) for the SKAHAL and SKATAL release group, and 0.63 (SE = 0.0248) for the OSOYBR and OSOYOL release group (Table 2). After Rocky Reach, error associated with survival estimates for both release groups, and all release groups combined, was large. Survival estimates for combined release groups to Rocky Reach was 0.56 (SE = 0.0161(Figure 2). Combined release group survival estimates from release to Rocky Reach Dam averaged 0.51 from 2013-2016 (Table 3).

Table 2. Mean survival for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKAHAL and SKATAL combined, OSOYBR and OSOYOL combined, and all four sites combined), 2016.

Period	Survival combined OSOYOL and OSOYBR	SE	Survival combined SKAHAL and SKATAL	SE	Survival combined SKAHAL, SKATAL, OSOYOL, OSOYBR	SE
Release to Rocky Reach	0.63	0.0248	0.49	0.0208	0.56	0.0161
Rocky Reach to McNary	0.81	0.1147	0.79	0.0962	0.79	0.0734
McNary to John Day	0.65	0.1777	1.40	0.4085	0.97	0.1929
John Day to Bonneville	1.20	0.6276	0.27	0.0937	0.49	0.1358
Overall	0.40	0.1848	0.15	0.0333	0.21	0.0449

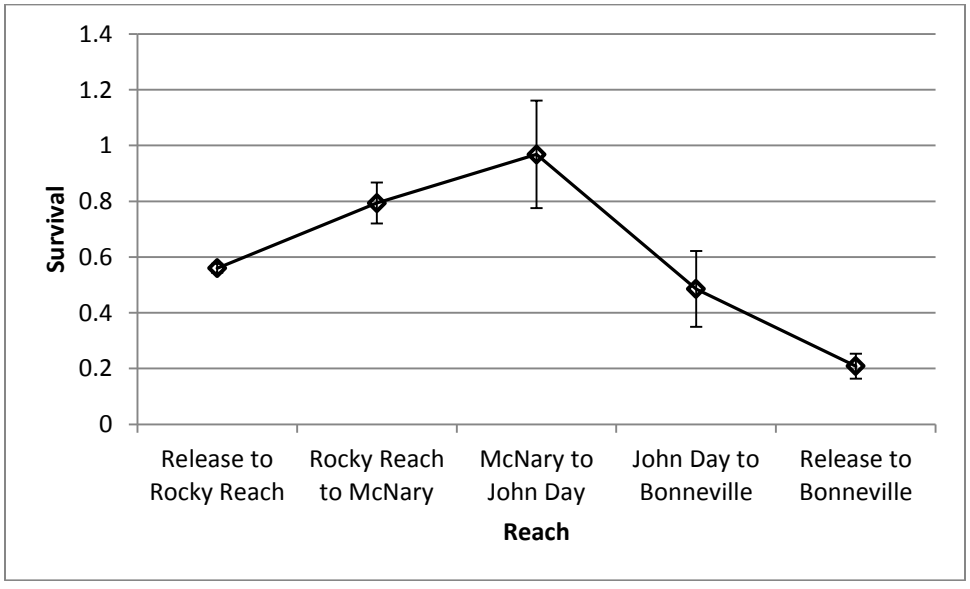


Figure 2. Mean survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts (SKAHAL, SKATAL, OSOYOL and OSOYBR combined), 2016.

Table 3. Comparison of annual survival for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, (SKATAL and OSOYOL combined) 2013-2015, and (SKAHAL, SKATAL, OSOYOL and OSOYBR combined) 2016; Standard Errors of mean presented in brackets.

Period	2013	2014	2015	2016	Average
Release to Rocky Reach	0.48 (0.03)	0.57 (0.08)	0.42 (0.02)	0.56 (0.02)	0.51 (0.04)
Rocky Reach to McNary	1.14 (0.26)	0.68 (0.44)	0.80 (0.13)	0.79 (0.07)	0.85 (0.23)
McNary to John Day	1.25 (0.66)	2.80 (0.65)	0.72 (0.18)	0.97 (0.19)	1.40 (0.42)
John Day to Bonneville	0.70 (0.58)	0.26 (0.24)	1.79 (0.66)	0.49 (0.14)	0.81 (0.41)
Overall	0.48 (0.33)	0.03 (0.08)	0.44 (0.14)	0.21 (0.04)	0.29 (0.15)

3.1.2 Travel Time

Travel time from release to Rocky Reach Dam was approximately 10.8 days for the SKAHAL and SKATAL release group, and 19.0 days for the OSOYOL and OSOYBR release group, as shown in Table 4. Travel time from release to Rocky Reach Dam for both groups combined was 14.17 days. Overall travel time from release to Bonneville Dam was approximately 23.4 days for all groups combined (Figure 3). Between the years of 2013-2016, combined release group travel time estimates from release to Rocky Reach Dam average 16.4 days, and 25.6 days overall (Table 3).

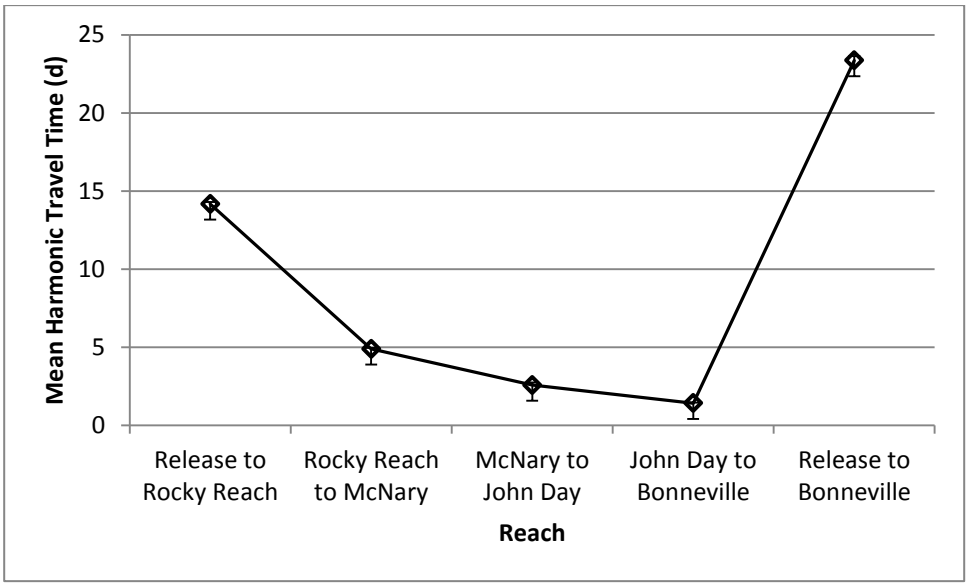


Figure 3. Mean travel time for PIT tagged q'awsitk^{w} (Okanagan River) Sockeye smolts (SKAHAL, SKATAL, OSOYOL and OSOYBR combined), 2016.

Table 4. Mean travel time for PIT tagged q'awsitk^{w} Sockeye smolts (SKATAL and SKAHAL combined, OSOYOL and OSOYBR combined, and all four sites combined), 2016; Standard Errors of mean presented in brackets.

Period	OSOYOL and OSOYBR Combined Travel Time (d)	SKAHAL and SKATAL Combined Travel Time (d)	All four sites Combined Travel Time (d)
Release to Rocky Reach	19.0 (0.25)	10.8 (0.09)	14.17 (0.13)
Rocky Reach to McNary	4.91 (0.09)	4.86 (0.10)	4.89 (0.07)
McNary to John Day	2.72 (0.30)	2.46 (0.19)	2.58 (0.17)
John Day to Bonneville	1.40 (0.04)	1.42 (0.07)	1.41 (0.04)
Overall	28.37 (0.61)	20.37 (0.21)	23.35 (0.29)

Table 5. Comparison of mean travel time for PIT tagged q'awsitkw (Okanagan River) Sockeye smolts, (SKATAL and OSOYOL combined) 2013-2015 and (all four sites combined) 2016; Standard Errors of mean presented in brackets.

Period	2013	2014	2015	2016
Release to Rocky Reach	19.3 (0.25)	15.9 (0.19)	16.2 (0.14)	14.2 (0.13)
Rocky Reach to McNary	4.41 (0.14)	3.90 (0.07)	5.79 (0.14)	4.89 (0.07)
McNary to John Day	2.32 (0.22)	2.35 (0.11)	2.71 (0.28)	2.58 (0.17)
John Day to Bonneville	1.53 (0.15)	1.40 (0.16)	1.66 (0.05)	1.41 (0.04)
Overall	29.0 (0.74)	23.2 (0.56)	26.6 (0.27)	23.4 (0.29)

4.0 Discussion and Recommendations

4.1 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 2016, 4798 smolts were tagged from q̓awst'ik'ʷt and 5443 smolts were tagged from suwiẁs. Therefore, it was possible to determine survival for the combined populations (<10,000), and for the q̓awst'ik'ʷt and suwiẁs populations separately, as far as Rocky Reach.

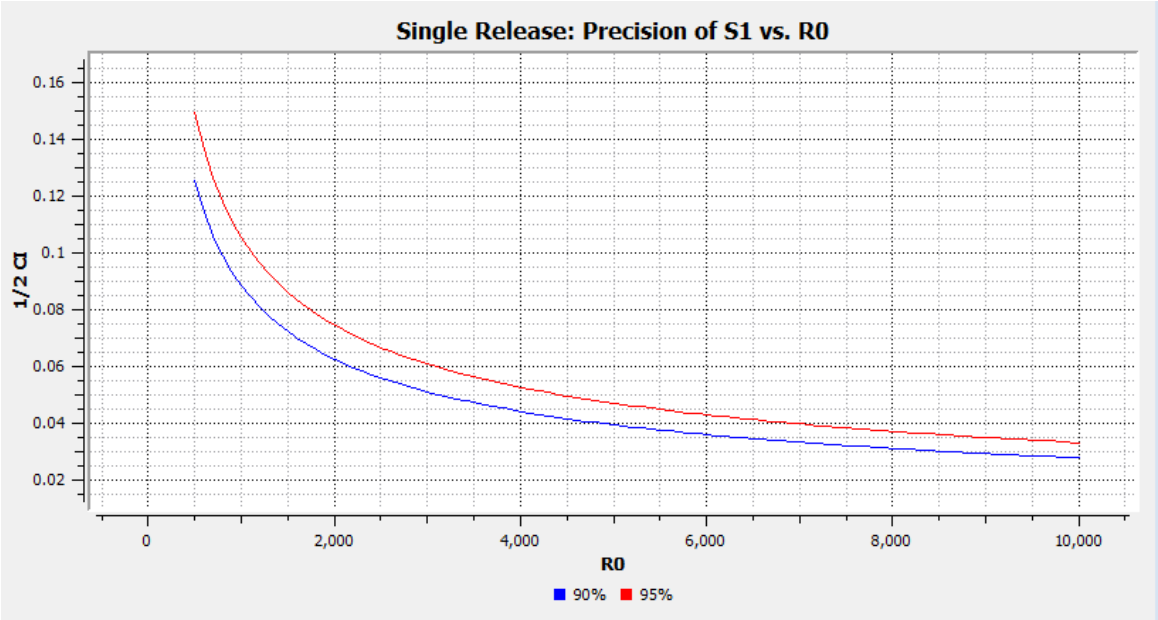


Figure 4. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam.

The survival by lake of origin to Rocky Reach shows a marked difference in survival (0.14 SE 0.02, Table 2) between the Skaha Lake origin smolts and those of the Osoyoos Lake Origin smolts. There may be a number of factors contributing to this including predation rates in Vaseux Lake (between Skaha and Osoyoos Lakes), residualization of smolts in either Skaha or Osoyoos Lakes, or some other factor. Additional study is warranted to determine the discrepancy in survival by lake population.

We propose the following recommendations for future studies:

- For long term Okanagan smolt monitoring (combined Skaha and Osoyoos Lake), assess single lake capture within Osoyoos Lake. Continue to develop representative sampling for PIT tagging a minimum of 10,000 Okanagan Sockeye smolts.
- Focus primary gear type for capture of smolts to purse seining. Trial in 2017 all smolts captured and tagged within Osoyoos Lake. If assumptions of mixing fail (Skaha and Osoyoos Lake origin smolts) - we would propose to remobilize efforts to other sampling methods (ie RST) to capture Skaha origin smolts.
- Continue to refine capture methods and holding techniques to improve on tagging efficiencies. This includes:
    - Adjusting holding and tagging locations on suwiẁs (ie. seek out deeper sites with flow) to improve on post tag survival in periods of warmer water temperatures.
- Pending funding availability, develop study to examine the dropout rate within Vaseux Lake. Replicate study design for 1-2 years to assess losses.

5.0 References

Benson, R. 2016. Okanagan Sockeye smolt migration from suwiẁs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2014 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 23 pp.

Benson, R. and R. Bussanich. 2016. q̓awst'ik'ʷt (Skaha Lake) Nerkid Spawner Enumeration and Biological Sampling 2014. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2014. Okanagan Nation Alliance Aquatic Enterprises Ltd., Westbank, BC.

Benson, R., S. Folks, A. Stevens, and R. Bussanich. 2013. Brood year 2011 – Sockeye smolt out of basin survival pilot study in q'awsitkʷ (Okanagan River). Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 37 pp.

Benson, R., S. Folks, A. Stevens, and R. Bussanich. 2014. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT and Acoustic Tagging 2013. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 17 pp.

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

Fryer, J. K., H. Wright, S. Folks, K. D. Hyatt, and M. M. Stockwell. 2012. Limiting Factors of the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2011. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00

PTAGIS (1999) PIT tag Marking Procedures Manual version 2.0: Retrieved online November 2013: http://php.ptagis.org/wiki/images/e/ed/MPM.pdf

Stefanovic, D., R. Benson, A. Stevens, C. Fuller, L. Wiens, K. Garver, and D. Stefanovic. 2015. Collection and Rearing of Okanagan Sockeye Salmon for the Skaha Re-introduction Program: Brood Year 2014. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2014. Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 61 pp.

Wright, R.H. and H. Smith (Ed). 2003. Management plan for experimental reintroduction of sockeye into Skaha Lake: Proposed implementation, monitoring and evaluation. Prepared by Okanagan Nation Alliance Fisheries Department,

APPENDIX D

Fish Passage Center Memoranda regarding 2016 and 2017 Okanagan Sockeye Smolt Survival

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

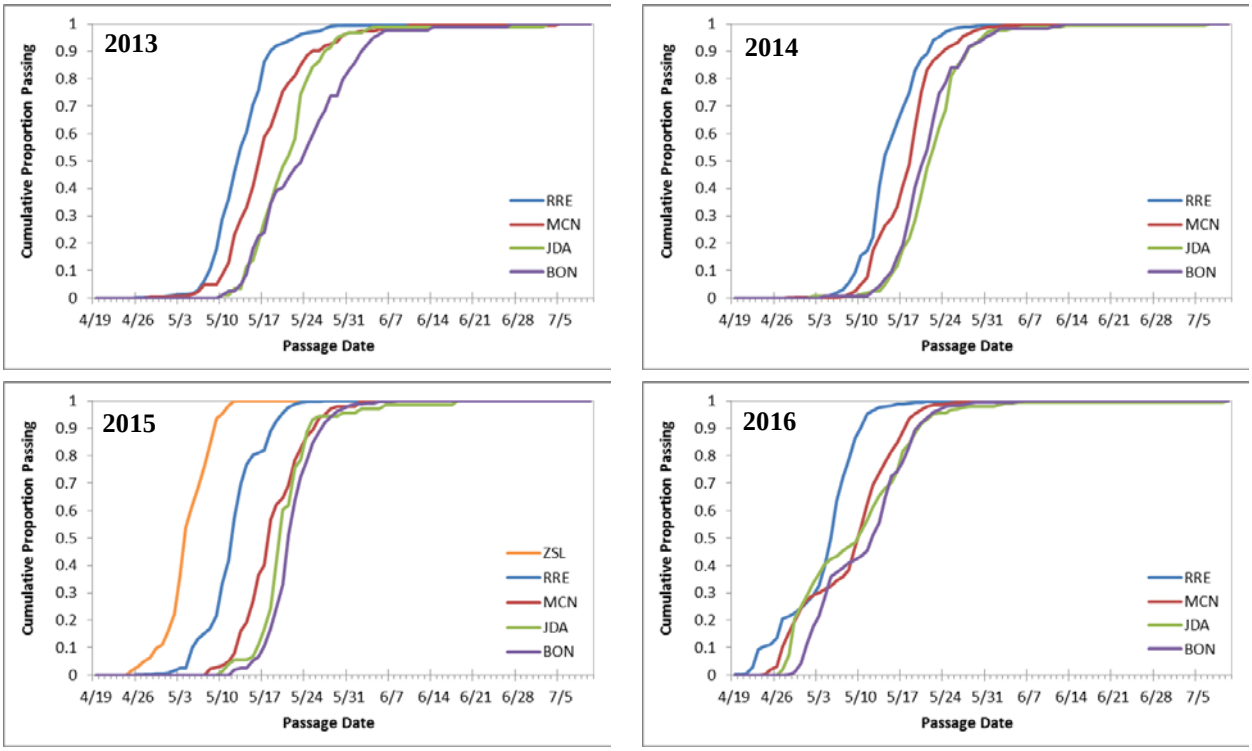


Figure 1. Cumulative passage timing of PIT-tagged wild Okanogan River basin sockeye smolts at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013, 2014, 2015, and 2016. Cumulative passage timing to Zosel Dam (ZSL) is provided for MY 2015.

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

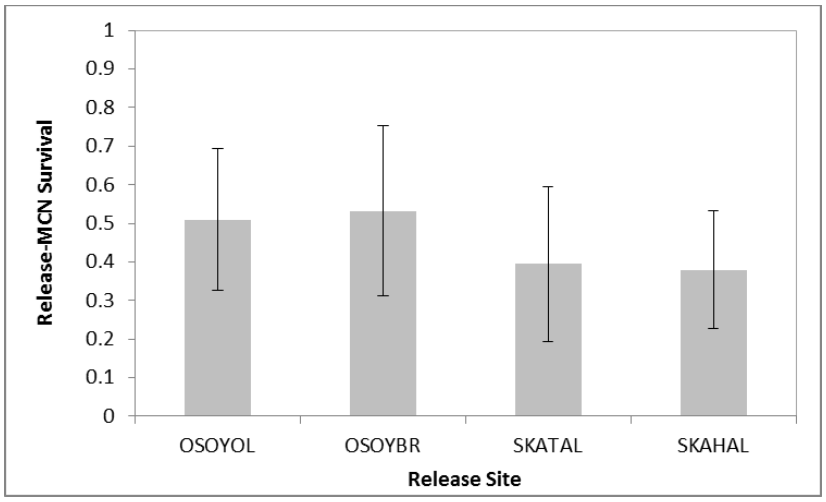


Figure 2. Estimated Release-MCN survivals (95% confidence intervals in parentheses) of PIT-tagged wild Okanogan River wild sockeye from each of four release sites used in 2016.

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 sockeye, 2013-2014.

Juvenile migration year	MCN-to-BOA				RRE-to-BOA			
	Smolts arriving MCN[A]	%SAR Estimate	Non-parametric CI		Smolts arriving RRE[B]	%SAR Estimate	Non-parametric CI	
			90% LL	90% UL			90% LL	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.

References

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

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

McCann, J., B Chockley, E. Cooper, T. Garrison, H. Schaller, S. Haeseker, R. Lessard, C. Petrosky, T. Copeland, E. Tinus, E. VanDyke, and R. Ehlke. 2016. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye: Draft 2016 Annual Report. BPA Contract #19960200.

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

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

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: November 15, 2017

Re: Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, migration years 2013-2017.

In 2013, the Comparative Survival Study (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 has transferred surplus PIT-tags to the ONA since 2013 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 began including estimates of overall SARs from this group (Okanogan River sockeye) in their annual report. In response to your request, we have updated analyses from previous year's data requests to include estimates of juvenile survival, timing, and travel time for the 2017 PIT-tagged sockeye smolts. In addition, we provide updated estimates of overall SARs from migration years 2013-2015, with adults detected at Bonneville Dam through September 15, 2017. Below are results from these updated analyses, followed by more specific details.

- In all years of tagging (2013-2017), reliable estimates of juvenile survival from Release to Rocky Reach Dam were possible. Juvenile survival from Release to Rocky Reach Dam (all release sites combined) in 2017 was 0.67 (95% CI: 0.62-0.72).
- 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. Survival from Release-MCN (all release sites combined) in 2017 was 0.65 (95% CI: 0.51–0.78).

- The 2017 CSS Annual Report provided estimates of smolt-to-adult return (SAR) rates for Rocky Reach-to-Bonneville (RRE-to-BOA) for migration years 2013-2015 and McNary-to-Bonneville (MCN-to-BOA) for migration years 2014 and 2015. The RRE-to-BOA SARs for 2013-2015 ranged from 1.24% (95% CI: 0.94-1.59%) in 2015 to 8.13% (95% CI: 6.96-9.45%) in 2013. The MCN-to-BOA SAR for 2014 and 2015 were 2.99% (95% CI: 2.14-3.54%) and 1.51% (95% CI: 0.99-2.09%), respectively.

Methods

Timing and Travel Time

Juvenile passage timing and fish travel times were estimated for 2013-2017 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

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 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 estimated 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 and 2014 out-migrations and the nearly complete return from the 2015 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 returns at BON (RRE-to-BOA) and 2) juveniles at MCN to adult returns at BON (MCN-to-BOA). The methodology for estimating SARs is discussed in Chapter 4 of the CSS Annual Report (McCann et al., 2017).

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 2013-2017.

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 2013-2017.

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
2017	238.0	0.47	0.53	0.36	0.32	0.18

Travel Time and Timing

Over the last five years, PIT-tagging of juvenile sockeye in the Okanogan River Basin has varied, in both timing and the number of PIT-tags that have been released (Table 2). It is important to consider the variability in the timing of PIT-tagging efforts when assessing passage timing between years.

Table 2. Timing of PIT-tagging efforts and number of PIT-tagged Okanogan River Basin sockeye smolts released in migration years 2013-2017.

Migration Year	PIT-tagging Dates (Min and Max)	Total Tags Released
2013	Apr. 12-May 7	4,018
2014	Apr. 7-May 5	5,055
2015	Apr. 9-May 6	7,176
2016	Mar. 22-Apr. 29	10,238
2017	Apr. 26-May 3	11,588

Estimates of minimum, median, and maximum travel times from release to RRE, MCN, JDA, and BON dams are provided below (Table 3). 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 3. Travel times from release to juvenile detection site of PIT-tagged Okanogan River Basin sockeye smolts from migration years 2013 to 2017. PIT-tag detection sites include: Zosel (ZSL), Rock Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams.

Migration		Release to Project Travel Time (days)			95% Confidence Limits	
Year	Project	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
2017	RRE	4.5	10.5	61.4	10.4	10.6
	MCN	8.1	15.0	31.5	14.2	15.4
	JDA	9.9	15.9	40.1	15.2	16.0
	BON	10.8	17.8	46.4	17.5	18.4

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 4, Figure 1). In 2015, PIT-tagged sockeye smolts generally passed through Zosel Dam in late April to early May.

Table 4. 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 2017.

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
2017	RRE	8-May	11-May	20-May
	MCN	12-May	14-May	23-May
	JDA	13-May	16-May	24-May
	BON	14-May	18-May	26-May

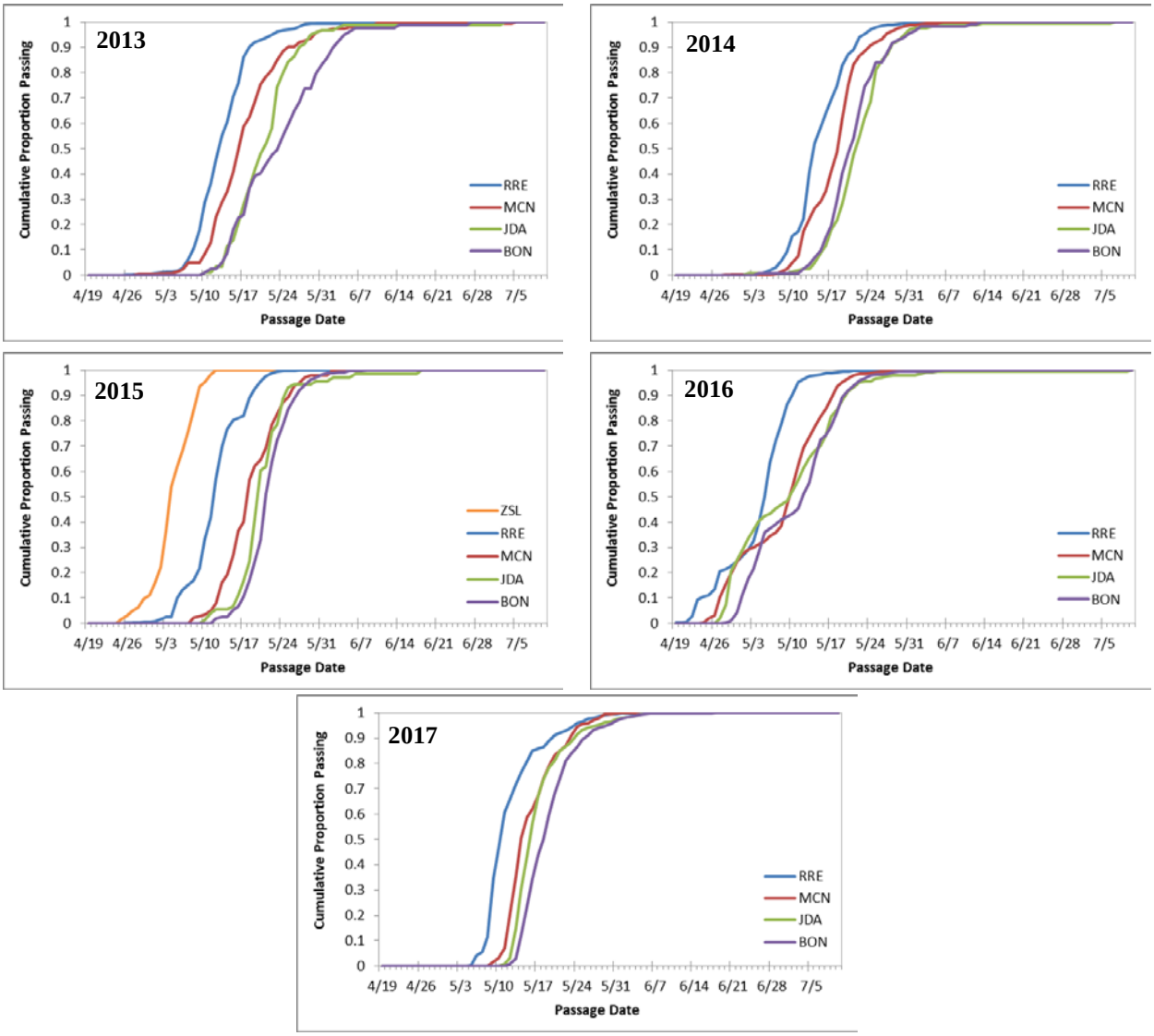


Figure 1. Cumulative passage timing of PIT-tagged wild Okanogan River basin sockeye smolts at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013-2017. Cumulative passage timing to Zosel Dam (ZSL) is provided for MY 2015.

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 5. For 2013, we were only able to estimate survival from Release-RRE (0.49, 95% CI: 0.42-0.56). The total number of 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 2014-2017 had higher total release numbers, which allowed for the estimation of not only individual reach survivals but also a combined (Release-MCN) reach survival for each year (Table 5).

Table 5. Survival of PIT-tagged sockeye juveniles tagged and released into the Okanogan River Basin in 2013-2017.

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)
2017	11,588	0.67 (0.62-0.72)	0.96 (0.09-1.00)	0.52 (0.26-0.78)

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. 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 6). Estimates of survival for the RRE-MCN reach were unreliable for both release sites and, therefore, are not reported in Table 6.

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 6). 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 6). 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 6). 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. This indicates that these differences in survival are likely not significant.

A total of 11,588 sockeye smolts were PIT-tagged and released from two different release sites in 2017. Of these, 2,794 were tagged and released from Osoyoos Lake Narrows Bridge (OSOYBR) and 8,794 were tagged and released from Osoyoos Lake (OSOYOL). We were able generate estimates of Release-RRE survival for both release sites (Table 6). However, we were only able to estimate RRE-MCN survival for the OSOYOL release site, as the estimate for the OSOYBR release site was unreliable. Therefore, we were only able to estimate Release-MCN survival for the OSOYOL release site. The 2017 Release-MCN survival for the OSOYOL release site was 0.60 (95% CI: 0.46-0.73).

It is 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 6). Unfortunately, it is not possible to isolate the effects of capture method on estimates of survival as each release site typically relied on a single capture method each year and, therefore, capture method effects would be confounded with the effects of release site. The one exception to this is OSOYBR in 2017, where both the fyke net and purse sein methods were used. However, of the 2,794 total sockeye smolts that were tagged and released at this site, only 152 were captured using the fyke net method. With so few tags being released from the fyke net capture method, we were unable to generate reliable estimates of reach survivals for this capture method. Therefore, we were unable to compare the two capture methods.

Table 6. Survival of PIT-tagged sockeye juveniles, by release site, tagged and released into the Okanogan River in 2013-2017.

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)
2017	OSOYBR	2,794	PS,FN	0.82 (0.63-0.93)	N/A	N/A
	OSOYOL	8,794	PS	0.64 (0.59-0.69)	0.93 (0.31-1.00)	0.60 (0.46-0.73)

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

Smolt to Adult Survival (SARs)

To date, the CSS Annual Report has provided SARs for Okanogan River Basin sockeye for both the Rocky Reach-to-Bonneville (RRE-to-BOA) and McNary-to-Bonneville (MCN-to-BOA) reaches for migration years 2013-2015. These estimates of SARs are based on all release sites combines and are summarized below (Table 7). Due to an unreliable estimate of juvenile survival for the RRH-MCN reach in 2013 (Table 5), the MCN-to-BOA SAR for 2013 is not provided.

Table 7. Overall McNary-to-Bonneville (MCN-to-BOA) and Rocky Reach-to-Bonneville (RRE-to-BOA) SARs for Okanogan River wild sockeye, 2013-2015.

Juvenile migration year	MCN-to-BOA				RRE-to-BOA			
	Smolts arriving MCN[A]	%SAR Estimate	Non-parametric CI		Smolts arriving RRE[B]	%SAR Estimate	Non-parametric CI	
			90% LL	90% UL			90% LL	90% UL
2013[C,D]	--	--	--	--	1,993	8.13	6.96	9.45
2014[C]	2,110	2.99	2.25	3.71	2,937	2.15	1.70	2.66
2015[E]	2,524	1.51	0.99	2.09	3,060	1.24	0.94	1.59

[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] PIT-tagged sockeye were coded as "unknown" rearing type. Some PIT-tagged smolts may have been hatchery sockeye released into Skaha Lake as fry.

[D] 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.

[E] Incomplete, 2-salt returns through Sept. 15, 2017

Conclusions

The CSS Oversight Committee continues to believe that a long-term monitoring group for wild sockeye from the Okanogan Basin would be valuable. Results from the last five years of tagging indicate that, with a minimum of 5,000 PIT-tags released per year, the CSS will continue to be able to estimate juvenile survival from release to MCN and SARs for both the RRE-to-BOA and MCN-to-BOA reaches. The CSS Oversight Committee hopes to continue to incorporate results from this group into future annual reports.

References

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

McCann, J., B Chockley, E. Cooper, B. Hsu, H. Schaller, S. Haeseker, R. Lessard, C. Petrosky, T. Copeland, E. Tinus, E. Van Dyke, and D. Rawding. 2017. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye: 2017 Annual Report. BPA Contract #19960200.

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

APPENDIX E

History of Okanagan Network of PIT Sites Funded by the Accords

Passive Integrated Transponder (PIT) Tag Interrogation Array Sites and Operations in the Okanagan, BC, Canada

Okanagan Nation Alliance

Prepared for:
Columbia River Inter-Tribal Fisheries Commission

March 2018

Okanagan Nation Alliance
101-3535 Old Okanagan Highway
Westbank, BC, V4T 3L7
Phone: (250) 707-0095 Fax: (250) 707-0166

Disclaimer: Okanagan Nation Alliance reports frequently contain preliminary data, and conclusions based on these may be subject to change.

Citation: ONA 2018. Passive Integrated Transponder (PIT) Tag Interrogation Array Sites and Operations in the Okanagan, BC, Canada. Prepared by Okanagan Nation Alliance., Westbank, BC. 16 pp.

Executive Summary

As part of the Sockeye Limiting factors Study initiated by the Columbia River Inter – Tribal Fish Commission (CRITFC), funded by BPA Accords, this project since inception (2009) has installed and operated a number of Passive Integrated Transponder (PIT) tag interrogation arrays throughout the Canadian Okanagan. These interrogation arrays have been vital for stock assessment objectives for the recovery of the Okanagan Sockeye population.

The installation of PIT arrays in the Okanagan Basin commenced in 2009 with the installation of OKC, a mainstem array downstream of Road 18 in Oliver BC. This site has quickly become a keystone detection point for determination of escapement returns to the Okanagan basin. Following the installation of OKC, the PIT array infrastructure has quickly expanded with the installations of temporary floating PIT arrays upstream of OKC, trial PIT installation at McIntyre Dam, fishway installations at Skaha Dam, the addition of a second array at OKC, and finally the installation of the Northernmost mainstem PIT array at OKP in the Penticton Channel.

This document serves as a brief description of each of these sites, a description of the site location, operations to date, along with challenges and successes at each.

Acknowledgements

Okanagan Nation Alliance would like to thank the following people for their continued support: Richard Bussanich, and Ryan Benson for leadership and project support. Nick Yaniw, Casimir Tonasket, Saul Squakin, Paul Snow, Dave Tom, Andrew Clarke, Chelsea Mathieu, Lynnea Wiens, Sheena Hooley, Amanda Stevens, and other ONA staff that have supported this project over the years. This project is supported by Dr Kim Hyatt, DFO Pacific Biological Station, and Dr. Daniel Selbie, DFO Cultus Lake. Dr Jeffery Fryer, Columbia River Inter-Tribal Fish Commission

Table of Contents

Executive Summary **1**
Acknowledgements **2**
Table of Contents **3**
List of Tables **4**
List of Figures **4**
Table of N'syilxcen Place Names **4**
1.0 Introduction **5**
1.1 Project Background 5
1.2 Study Area 5
1.3 Project Objectives ..... **Error! Bookmark not defined.**
2.0 Sites **7**
2.1 OKC 7
2.1.1 Site Description 7
2.1.2 Operations 10
2.1.3 Next steps 12
2.2 OKC Upstream floating Array Trials **12**
2.1.1 Site Description 12
2.1.2 Operations 13
2.1.3 Next steps 14
2.3 McIntyre Dam 14
2.3.1 Site Description 14
2.3.2 Operations 17
2.3.3 Next steps 18
2.2 Skaha Dam 18
2.3.1 Site Description 18
2.3.2 Operations 20
2.3.3 Next steps 23
2.2 Penticton Channel 23
2.3.1 Site Description 23
2.3.2 Operations 24
2.3.3 Next steps 25
5.0 Supporting Projects References **26**

6.0 Appendix 28

List of Tables

Table 1 Operational dates for OKC since installation 10

List of Figures

Figure 1. Okanagan Basin Map with Nsyilxcen site names 6
Figure 2 Site map of OKC configuration 8
Figure 3 Google Earth Image of OKC downstream of VDS 3 at Road 18, Oliver BC 8
Figure 4 Photos of OKC installation November 2009 9
Figure 5 IS1001 HDPE antennas installed at OKC 11
Figure 6 Trial floating PIT antennas in place upstream of Road 18 and OKC 13
Figure 7 McIntyre Dam downstream of Vaseux Lake with two of the 5 bays spilling water 15
Figure 8 Wall mounted PIT antenna trials in Bay 1 McIntyre Dam 16
Figure 9 McIntyre Dam post gate modifications in 2009. 17
Figure 10 View of the two PIT antennas installed at Skaha Dam fishway in 2015. 19
Figure 11 View of the master control IS1001 unit outside and inside of its enclosure. 20
Figure 12 View of the wooden PIT antenna support and PIT antenna installed below the level of the stoplogs. 22
Figure 13 Site map of OKP within the Penticton channel, upstream of the KVR bridge 24

Table of N'syilxcen Place Names

N'syilx'cin Place Name	(Okanagan-English Translation)
nxˇʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
q̓awst'ikʷt, also known as t̓iwcən	Skaha Lake
suwiẁs	Osoyoos Lake

Indigenous Peoples of the Okanagan are the exclusive owners of their cultural and intellectual properties.

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). Also starting in 2009 the Columbia Inter-Tribal Fish Commission (CRITFC), funded via a BPA accords project, initiated a study to examine factors limiting the success of Okanagan Sockeye. Since inception, this project has been a collaborative effort by three parties; the ONA, CRITFC, and the Canadian Federal Department of Fisheries and Oceans (DFO). As part of an assessment of limiting factors this project has included monitoring of adult migratory returns via acoustic tagging and deployment of Passive Integrated Transponder (PIT) tags. In order to detect PIT tags, the expansion of PIT array network into the Canadian portion of the Okanagan River was required.

Starting in 2009 the Northernmost PIT array (OKC) in the Columbia River Basin was installed downstream of Road 18 in Oliver BC. This site was upgraded from a MUX FS1001 to an MSC IS1001 in 2015, along with the most recent upgrade adding four (4) additional antennas upstream of the original location in the fall of 2016. Other project sites have followed; the installation and operation of McIntyre Dam in 2014, Skaha Dam in 2015, and most recently the installation of a mainstem PIT array in Penticton Channel in the fall of 2017. This report is a descriptive document of each of the sites and presents a history of the operations of each along with the challenges and successes at each of the 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). Sockeye that rear in the North Basin of suwiẇs 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 suwiẇs 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. Similarly adult Sockeye

returning to the Okanagan endure the same migration in reverse working upstream through the many Hydro electric dams on the nxˇʷəntkʷitkʷ.

Figure 1. Okanagan Basin Map with Nsyilxcen site names

2.0 Sites

2.1 OKC

2.1.1 Site Description

OKC was the first PIT detection array installed in the Canadian portion of the q'awsitkʷ in the fall of 2009. At the time of installation this was the first PIT tag array to be installed within the transboundary portion of the nxˇʷəntkʷitkʷ Basin and was the Northernmost PIT array within the entire basin.The site was chosen based on proximity downstream of the natal spawning areas of the Okanagan Sockeye, while being upstream of suwiẇs. The site is located downstream of Vertical Drop Structure number 3 at Road 18 in Oliver BC.

The OKC site is located in the Okanagan (Canadian spelling) Channel at 310th Avenue/Road 18 upstream from suwiẇs. The river in this section is channelized and Vertical Drop Structures (n=17) are used to control the river gradient. The array is located approximately 130 ft downstream of VDS-3. The river at this location is approximately 80 ft wide, enabling nearly full coverage of the width with four 20-ft antennas. Detection of adult sockeye salmon (Oncorhynchus nerka) is the primary focus of the array. Water depth during the sockeye salmon migration ranges from 10 to 24 inches. Optimal read range of 12-mm TX1411SST PIT tags in pass-by orientation ranges between 18 and 20 inches resulting in high detection efficiency. Four new antennas were added to the site in a second array in March 2017.

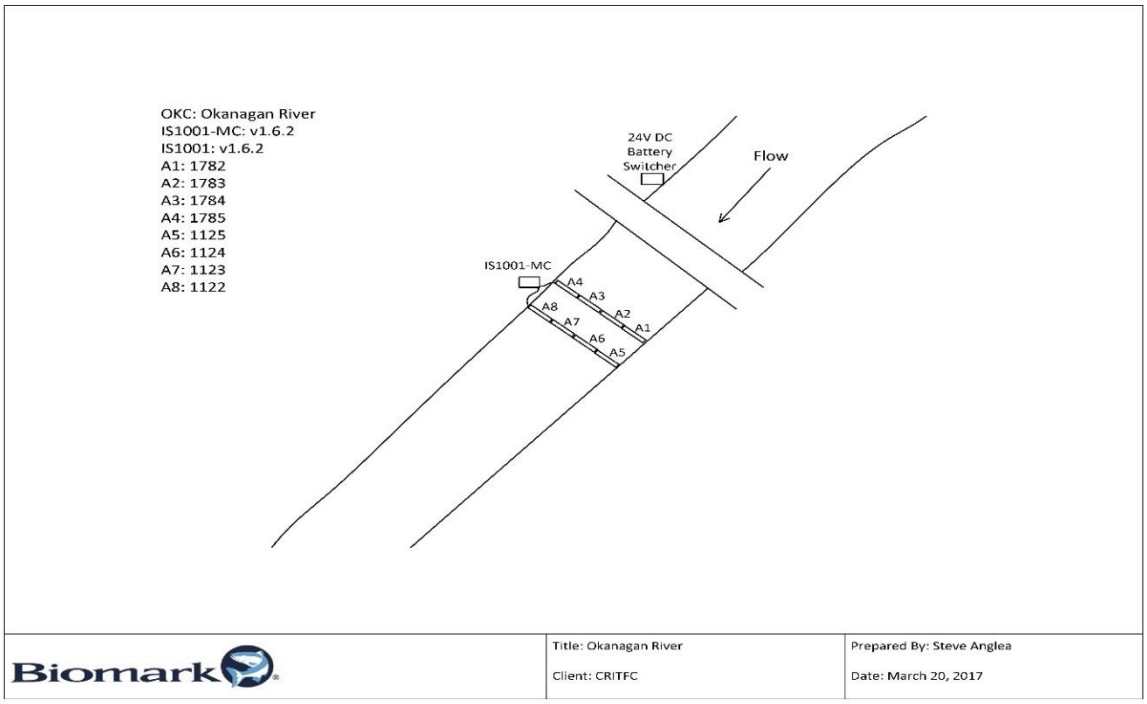


Figure 2 Site map of OKC configuration

Figure 3 Google Earth Image showing the first OKC array downstream of VDS 3 at Road 18, Oliver BC. The second array was built 30 feet upstream in October, 2017.

The site location (Figure 2 & 3) was chosen due to its proximity both upstream of suwiẁs while still being downstream of the spawning grounds upstream. The channelized section of river at the location of OKC both upstream and downstream is not suitable spawning substrate. Therefore better suited for PIT detection as fish move through the area and are less likely to mill around. The location 45ft downstream of the VDS structure was chosen as a function of distance from the nearest power lines as well as Provincial permitting available at the time (2009).

OKC was installed initially with three (3) antennas in November 2009 covering 75% of the wetted width due to a miscalculation of available area for the antennas. It was soon decided to add a 4th antenna in the winter of 2010 to provided 100% wetted width coverage. A FS1001 MUX powered the unit, connected via 100ft of underground cable to the power supply North Road 18 at the site of the Water Survey of Canada hydrometric station. A dedicated 120v power outlet was connected to the electrical panel already in place to provide power to a battery switcher and batteries connected in two banks of two 12V batteries connected in series to provide 24v of DC power to OKC. The battery switcher was timed to charge the battery banks in 3 hour intervals before switching to the alternate bank.

Figure 4 Photos of OKC installation November 2009

2.1.2 Operations

OKC since installation has operated well. The site has had remote access and connection to a 4G Telus network for remote polling and downloading of data for auto uploading of data files to PTAGIS. Biomark has been retained by CRITFC to monitor and auto load the data files generated by OKC into the PTAGIS database. Key points in the operation history are noted in table 1.

Upon installation in 2009 the site has had operated most of the time since. Exceptions have included the winter of 2009 into 2010 when it was powered down to reduce costs. The site has had continuous operation since this date and has not been powered down through winter months. The site between 2010 and 2014 operated well with regular and routine maintenance site visits.

Table 1 Operational dates for OKC since installation

Year	Start Date	End Date	Notes
2009	6/11/2009	11/19/2009	First year of operation. Three antennas cover ~75% of the channel width.
2010	3/18/2010	1/1/2011	Interrogation activities were suspended from November 19, 2009 through March 18, 2010, and again from March 27 through May 14.
2011	1/1/2011	1/1/2012	Functional year round
2012	1/1/2012	1/1/2013	Functional year round
2013	1/1/2013	1/1/2014	Functional year round
2014	1/1/2014	1/1/2015	Site down July 5-7. Tags with 3DD prefix were not recorded prior to October 22.
2015	1/1/2015	1/1/2016	Mux replaced with IS1001 master controller and readers August 25.
2016	1/1/2016	1/1/2017	Functional year round
2017	1/1/2017	1/1/2018	Added a second array of 4 antennas upstream of OKC. Antennas labelled 1-8.
2018	1/1/2018	Present	Operating as normal, has a pit tag lodged on antenna 2

Through 2014 OKC experienced an issue with detecting tags with a sub mask 3DD between July 5 and October 22, 2014. This was a programming issue due to the firmware and was not detected by Biomark. The issue became apparent as very few sockeye were detected during this period, despite good numbers of fish observed at other sites downstream (Wells, Zosel Dams), as well as upstream enumeration counts. The issue was rectified in the fall of 2014, however, late and missed a cohort worth of detections during the migratory year of 2014. Approaching 5 years in age, and with PIT technology improvements it was thereafter recommended that OKC be upgraded from the aging FS1001MUX to the new IS1001 MC standard.

During August of 2015 OKC was upgraded to an IS1001 master controller. As a result, the PIT antennas were also upgraded by modifying the existing antennas amperage calibrations and connecting IS1001 nodes to each of the antennas. This upgrade provided an increase in read range from 8-12inches to 16-18 inches vertically in the water column. The move to the new IS1001 platform also allowed for optimizing the effieciency of individual antenna tuning as each of the nodes attached to each antenna operate independent of the others with respect to power, noise, and tuning.

The most recent update to OKC has been the installation of a secondary array upstream of the original location. Four new 20ft Biomark HDPE IS1001 antennas were installed 30 ft upstream the first antennas (Figure 2 & 5). With changes in technology Biomark altered the design of the stout antennas. The original antennas are encased in rigid FRP channel, while the new antennas are attached to the river bed via duckbill anchors with no external casing. Figure 5 shows the antennas getting prepared for install long with the IS1001 nodes attached to the downstream side of the antenna.

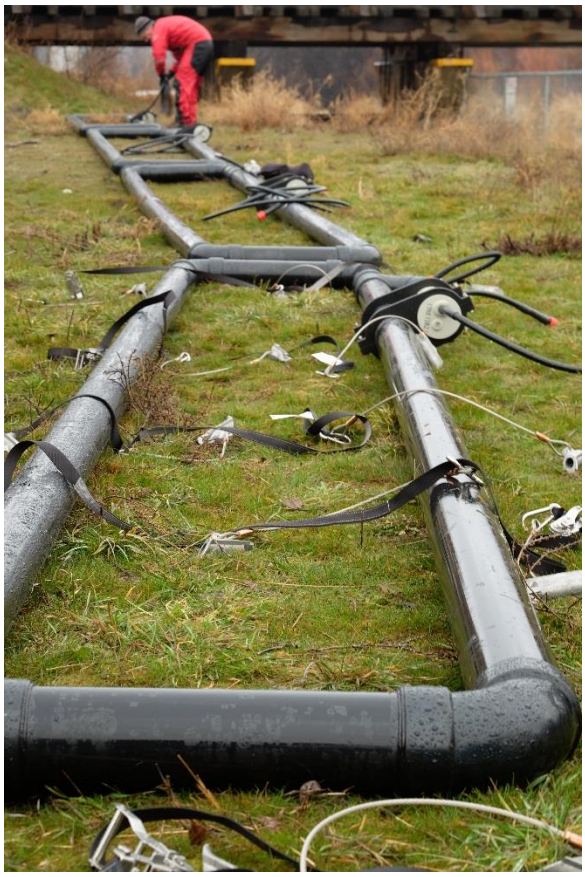


Figure 5 IS1001 HDPE antennas installed at OKC

After installation, on May 11, 2017, high flows deposited a “ghost tag” (3D9.1C2DB01432) from a sockeye tagged at Wells Dam in 2011 on top of Antenna 2 in the new array. This resulted in near-constant detections, degrading the performance of this array. High flows have made it impossible to remove this tag and it remains as of the publication date of this report.

2.1.3 Next steps

OKC has quickly become a keystone to our monitoring efforts for the Okanagan populations of anadromous fish. Recently the Fish Passage Centre (FPC) has recommended the Okanagan Sockeye population be added as an annual mark group for continued monitoring as part of the Comparative Survival Study (CSS). Next steps for OKC are to continue the operations and maintenance of the site and repair as required. Two of eight antennas are the original installed in 2009 and may soon need replacing – as has already been completed with the remaining antennas.

Also, as PIT technology advances, updates where required should be considered to improve read range and detection of all life stages (smolt – adult).

2.2 OKC Upstream floating Array Trials

2.1.1 Site Description

One of the initial issues with the original installation of 4 antennas at OKC was the lack of a secondary array – to provide site redundancy, detection efficiency determination, and more importantly directionality. In an effort to provide additional detection and directionality at OKC a trial effort using floating PIT arrays was attempted in 2014. The site location for the floating antennas was just upstream of Road 18 adjacent to the Water Survey of Canada site that powers OKC.

Figure 6 Trial floating PIT antennas in place upstream of Road 18 and OKC

2.1.2 Operations

Floating antennas (v1.0) were acquired from Biomark and installed upstream of VDS 3 on March 18, 2014. These antennas were an initial design and a first effort by Biomark to produce a floating PIT antenna. They were made with a soft fabric used for construction of river rafts surrounding a dense foam and measured 10ft x 3ft with a leading edge oriented at 45 degrees to the surface of the water and held in place with 1 inch irrigation pipe attached to the matting to hold the leading edge upright (Figure 6).

Two 200lb concrete lock blocks were installed along the banks of the river that formed that anchors for the aircraft cable to span the river crossing. The antennas attached to the aircraft cable via a series of cam straps. The cam straps were attached to a separate smaller diameter aircraft cable that was connected in a loop similar to a clothes line to facilitate deploying and holding the antennas in place. Each antenna was connected in series to the adjacent antenna via a ridged flexible conduit. The antennas weighed approximately 70lbs and connected to an IS1001 Canbus via a pig tail connector at the downstream end.

In 2015 four (4) additional 10 foot floating PIT arrays were installed to increase the wetted with of detection. About 60ft was covered via the antennas covering approximately 75% of the channel.

The antennas were powered by a dedicated 120V electrical outlet installed adjacent to the WSC station and the battery bank powering OKC. A SolaHD isolation transformer was installed to clean up the incoming AC power to provide noise free 120V AC power to the IS1001MC powering the floating antennas.

The floating anntennas appeared to operate well, until freshet of 2015 during which a large rootwad and tree debris entangled the aircraft cable and dragged the lock blocks into the river. ONA staff were able to recover the antennas, cabling, and lock blocks. However installation and operations at this site has not resumed since.

2.1.3 Next steps

The floating antennas trials at OKC failed. The floating antennas are still functional and are in inventory awaiting their next deployment. However the IS1001 nodes and the IS1001 MC have been re-purposed and relocated to the installation within Penticton Channel in 2017

2.3 McIntyre Dam

2.3.1 Site Description

McIntyre dam, along with the vertical drop structures along the Okanagan River, form part of the water management system operated by the Province of British Columbia Water Stewardship Devision of the Ministry of Forests, Lands, Natural resource Operations, and Rural Development FLNRORD). McIntryre Dam is a small non-power generating facility that was originally constructed in 1954 with undershot gates that were considered not fish passable to upstream migration. In 2009 ONA working with many agency partners work to retrofit these gates to fish friendly overshot gates. The fish passage efficiency of these gates is still being determined, and as such on March 31, 2015 we installed trial PIT antennas to the walls of one of the 5 bays at McIntyre Dam.

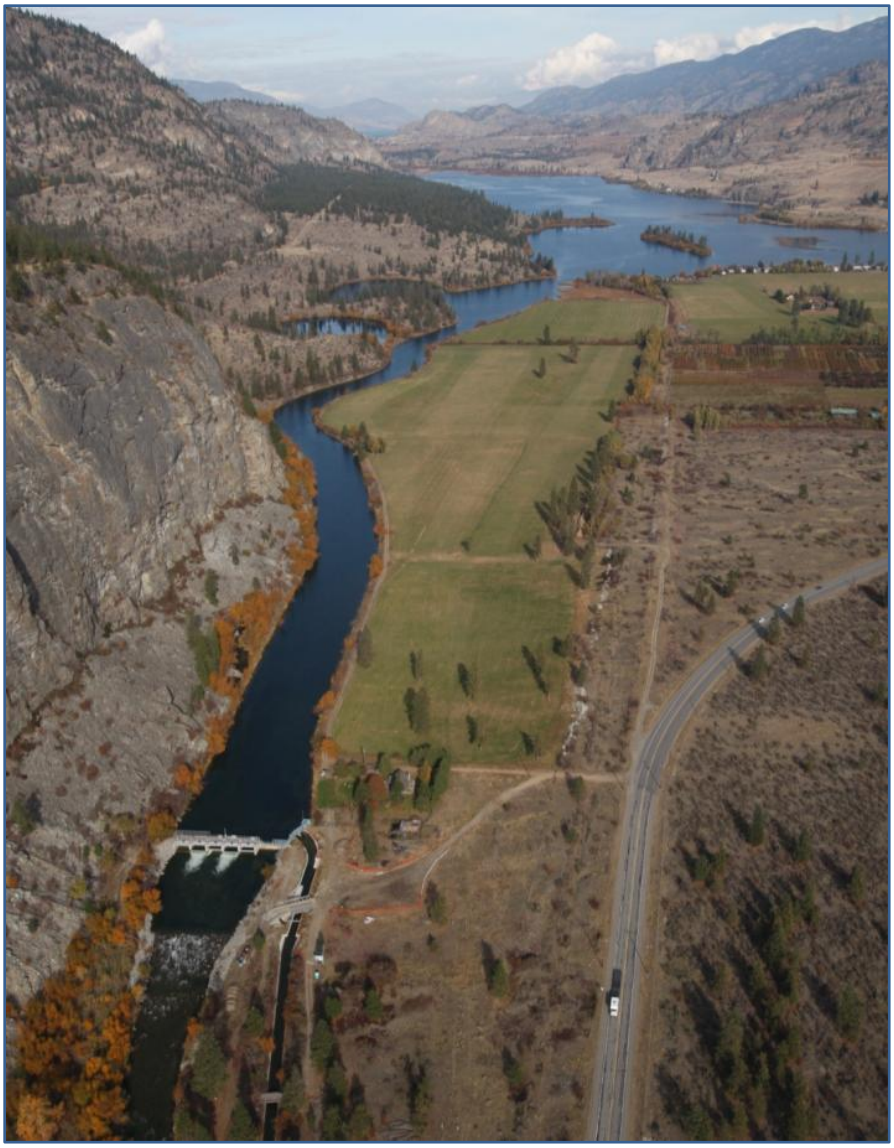


Figure 7 McIntyre Dam downstream of Vaseux Lake with two of the 5 bays spilling water

Figure 8 Wall mounted PIT antenna trials in Bay 1 McIntyre Dam

With the failure of the floating antenna trials at OKC, a different approach was developed for McIntyre Dam. As the overshot gates at McIntyre Dam, by design they spill a laminar homogenous flow over the gates into the plunge pool downstream of the structure. The bubble curtain that is created discourages fish jumping efforts. In video enumeration trials to determine fish passage efficiency of the newly installed gates it has been demonstrated that the majority of fish jump attempts occurs downstream of the new wing walls of each of the gates. Figure 8 shows one of these concrete walls that the PIT array was attached to. Our hypothesis for these trials was that fish jumping upstream would follow or be near the concrete walls on the upstream side of the dam. Therefore, we trialed the installs of two biolite IS1001 antennas with a custom ferrous mounting plate – to limit background noise for the antenna.

The antennas are installed in bay 1, the Eastern most, river left bay. The antennas are installed at the base of the gate on each of the walls and have a read range of 18 inches from either side horizontally into the bay. Figure 9 is a view looking upstream to the dam from downstream showing the 5 gates – the PIT arrays are located to the bay on the right. This location was chosen based on video work being conducted by ONA to determine the overall fish passage efficiency of the gates – suggesting that the majority of sockeye fish jumping effort occurs within this bay.

The antennas are connected to the power supply on the dam, with a dedicated 120V outlet connected to a SolaHD isolation transformer. Stand alone IS1001s are encased within a small enclosure mounted adjacent to the control tower on the upstream side of the dam.

Figure 9 McIntyre Dam post gate modifications in 2009.

2.3.2 Operations

Data collection commenced as soon as the site was installed. However, as no cell service or modem was part of the install – data collection is conducted via downloading data files manually. As a trial operation downloads of data initially commenced weekly decreasing to monthly once a data processing system was established. The data has not been uploaded to PTAGIS nor has the site been registered as an interrogation site within the PTAGIS database. The intention here is to demonstrate the proof of concept prior to officially requesting a site.

Operations of the site also requires communications within the dam operators as not all gates are open at all times depending on flows. Typically gate 1 is operating at all times, however during the fall of 2015 the gate was sporadically operated. Efforts have been made to continue the working relationship with dam operators to ensure a line of communication for operating times. In December of 2015 the site was powered down as dam operators had a planned closure of the gate through the winter. Operations resumed in the spring of 2016 – since this date a power supply issue causes the IS1001s to turn off. This issue remains unsolved as PIT

priorities have moved to other sites. However, revisiting McIntyre Dam PIT detection will add strength to the PIT detection network in the Canadian Okanagan.

2.3.3 Next steps

Issues pertaining to the power supply require solving, in addition to continued communication with dam operators for bay operation. A cell modem and extender would also serve the site well to remotely view and troubleshoot from a desktop space. Funds allocated to a modem and retrofit would likely be recovered in the first year saving personnel travel and site visit time to manually download, upload, and troubleshoot on site.

.

2.2 Skaha Dam

2.3.1 Site Description

Skaha Dam is a non power generating facility that forms part of the water management system operated by FLNRORD located within the community of Okanagan Falls at the south end of Skaha Lake, BC along the Okanagan River. The fishway is a small weir-pool fishway at the western edge of the dam that was only recently opened to fish passage – allowing anadromous fish free access into Skaha Lake. Installing a PIT array here was a logical choice based on location and proximity to upstream spawning locations, as well as being a fishladder – providing easy access and installation options.

Two custom built Biomark IS1001 PIT antennas (182.88cm L x 81.28cm W x 12.7cm H) designed to exactly fit the fishway were installed on May 13, 2015 (Figure. 10). The antennas have IS1001 master controllers, stand-alone units. Many PIT interrogation sites across the Columbia basin have upgraded to the new IS1001 standard (Fryer, J. Pers Comm 2015) “The IS1001 is a high performance, ISO- compliant stationary RFID transceiver designed for detecting, storing and transmitted FDX (Full duplex) and HDX (Half Duplex) PIT tag ID’s in permanently installations. It is specifically designed for applications that require low power consumption and a large detection area” (Biomark 2012). In field testing at Skaha Dam and at VDS 3 OKC in Oliver BC, upgrading to the IS1001 system has shown improved detection range over the older MS1001 MUX system (ONA unpublished data).

The PIT antennas were installed at the entrance and exit to the fishway to attempt to determine fish migration timing, delay, and direction of travel within the fishway as well as to provide an additional opportunity for detection at the site. The lower most antenna was installed within bay 2 on the upstream side of jump 2 of the fishway. The upstream antenna, was located upstream

of jump 6 within Skaha Lake, until low water levels in 2015 necessitated the installation of the antenna just downstream of jump 6. Moving the antenna to the downstream end of the stoplogs required the installation of a wooden support, which lowered the antenna below the jump 6 nappe depth. The success of this modification in 2015 resulted in the refitting of the lower antenna to below the nappe depth of jump #2 in August, 2016. Figure 10 shows the view of the two PIT antennas installed at Skaha Dam fishway in 2015. The first photo (L) shows the placement of the upstream antenna above the 6th stoplog at the top of the fishway and (R) shows the placement of the lower antenna above the 2nd stoplog.

Figure 10 View of the two PIT antennas installed at Skaha Dam fishway in 2015.

The IS1001 unit was installed within a 24’ x 24’ enclosure and secured to the steel perimeter fence of Skaha Dam. The units have also been connected to the electrical power grid and are now autonomously powered eliminating the need for batter swaps as per previous years. As a means to reduce the electrical noise inherent to 120V AC power, a SOLA HD Isolation transformer was installed and connected to buffer the incoming power supply for the antennas (Figure 11).

Data from the antennas was managed by the data logger board within the IS1001 logger board. Data was stored on an external portable USB drive that was downloaded on a regular basis. On site visits data was downloaded to a Yuma 2 Trimble tablet and was then transferred to our ONA offices for data management. The data was managed and manipulated using Biomark Log File Viewer Version 1.0.1 and exported to excel for further analysis.

Figure 11 View of the master control IS1001 unit outside and inside of its enclosure.

2.3.2 Operations

In 2016, 3349 adult sc̓win were PIT tagged at Bonneville, Priest Rapids, and Wells dams in the Columbia River through funding from Columbia River Inter-Tribal Fish Commission (CRITFC) projects examining limiting factors affecting the abundance of Columbia River sc̓win. 1657 were tagged at Bonneville Dam between May 26 and August 18, 2016. 894 were tagged at Priest Rapids Dam between June 29th and July 22, 2015, while finally 798 were tagged at Wells Dam between June 27 and July 28, 2016.

Of the fish tagged at lower Columbia River dams, 993 were detected at OKC – the mainstem PIT array within the lower Okanagan River at Road 18, Oliver BC. Of these, 114 PIT tags were detected within the Skaha Dam Fishway between June 24th and October 22nd, 2016 (Appendix B).

Four (4) scenarios can describe the detections for the 114 unique PIT tagged sockeye within the fishway;

1) the fish were successfully detected by the downstream antenna, followed shortly by the upstream antenna,
2) the fish were only detected by the downstream antenna,
3) the fish were only detected by the upstream antenna, and
4) the fish were detected first by the upstream antenna, followed shortly by the downstream antenna.

The first scenario is ideal and lends to calculating upstream transit time through the fishway. Calculated as time of last detection by the upstream antenna – (minus) the first time of detection by the downstream antenna. This was the case for only 79 of the 114 fish detected within the fishway. These fish were detected between June 29th and October 22nd, 2016. The average travel time, calculated as first time detected at the downstream array within the fishway and the last time detected by the upstream array, was 4:55:29hrs (hrs:minutes:seconds). The range of timing of these tags varied from short times 2 minutes and 56 seconds, to longest durations of 29 hours, 17minutes, 11 seconds.

The second scenario, of fish being only detected by the downstream antenna occurred for 21 fish occurring between June 24th and October 12th, 2016. Average time from first detection at the downstream antenna to last time detected by the downstream antenna was 4:44:21 (hrs:minutes:seconds). The range in timing of these tags varied from short times of 51 seconds, to longer durations of 30 hours, 41 minutes, and 42 seconds.

The third scenario occurred for fish only detected by the upstream antenna occurred for 4 fish between July 26th and September 29th, 2016. Average time from first detection at the upstream antenna to last time detected by the upstream antenna was 3:19:21 (hrs:minutes:seconds). The range in timing varied from one single detection to 13 hours, 3 minutes, 21 seconds.

The fourth scenario occurred for 10 fish in which the direction of travel appeared to be downstream by being first detected by the upstream antenna, then shortly thereafter by the downstream antenna. The timing of these fish occurred between August 13th and August 29th, 2016. The range in timing is narrow for this scenario (range: 31 seconds to 6 minutes) with an average downstream travel time of 3mins 3 seconds.

Detection and operation of the PIT arrays for the 2016 season was improved over previous years, however presented operation issues with installation mechanisms within the fishway itself. Figure 18 demonstrates the *in situ* modifications with wooden bracing to attach the PIT arrays in a manner that permitted flow through the fishway. As a result of these modifications, we observed an increasing number of fish striking the downstream antenna due to the placement of the antenna within the jump path of sockeye. The video analysis of this confirms an increased number of attempts in order to pass this antenna.

Detection of sockeye within the PIT array, correlates with the upstream enumerations of sockeye within Penticton Channel. An AUC estimate of spawners entering and successfully spawning within Penticton Channel for 2016 is 75,200 nerkids, with early estimates of 4000 sockeye (ONA unpublished data, 2016).

Figure 12 View of the wooden PIT antenna support and PIT antenna installed below the level of the stoplogs.

By contrast to the success of 2016 and the possible PIT scenarios of fish movement through the fishway, the 2017 season observed no PIT detections. This is likely due to modifications as noted in Figure 12 that were required to brace the PIT antennas dislodged from debris entering the fishway. Metal pipeclamps were used by ONA staff unfamiliar with PIT operations to secure the antenna to the modified bracing for the antennas. Additionally freshet of 2017 dislodged the lower most antenna necessitating an emergency rescue of the antenna. ONA staff were able to recover the antenna and secure to the walls of the fishway. Due to a number of circumstances the antenna remains in this place at time of writing (April 2018). High water through most of 2017, and staffing and budgetary constraints through the fall and winter of 2017 and 2018 followed by a high freshet in the spring of 2018.

2.3.3 Next steps

Following freshet of 2018, repairs will be required for the Skaha Dam PIT arrays. Not only will the downstream array require re-installation, the braces used to attach the PIT arrays to the fishway walls and weirs will require modifications. These repairs will improve the PIT detection of the fishway and hopefully return PIT interrogation events to the site missing in 2017. Continuation of the cell service and modem added in 2017 will be vital to the monitoring and operation of the PIT array.

2.2 Penticton Channel

2.3.1 Site Description

Penticton Channel, is the channelized portion of the q̓awsitkʷ connecting Okanagan Lake with Skaha Lake, within the city of Penticton BC. This represents the upstream most accessible portion of mainstem river for Columbia River anadromous fish. The channel was constructed in the 1950's in an effort to control flooding and irrigation, as well as to dewater a portion of land adjacent to the airport in Penticton to land larger planes. Recently however, the ONA have been actively involved in habitat projects to improve spawning habitat within the channel. The Okanagan River Restoration Initiative (ORRI) has taken action to install spawning platforms in the upstream most sections of the Penticton Channel.

The sections of river suitable for spawning are upstream of the Green Mountain Road Bridge – where downstream the channel is low gradient and a backwatered portion of Skaha Lake pending flows. In the upstream section of the channel, while downstream of the spawning platforms we installed a mainstem PIT array in November 2017. The site is just upstream of the old KVR bridge abutment.

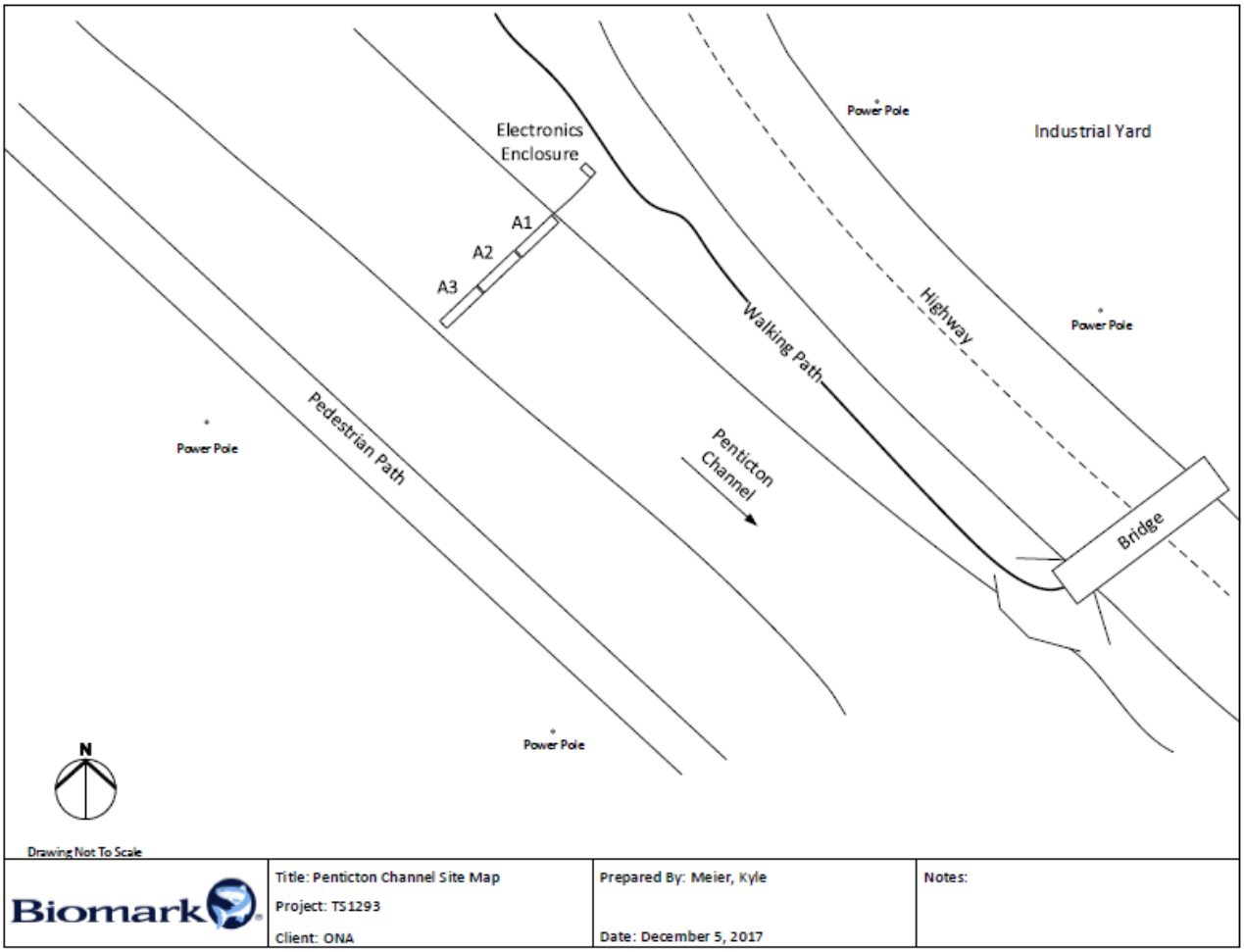


Figure 13 Site map of OKP within the Penticton channel, upstream of the KVR bridge

2.3.2 Operations

The site is currently powered by an enclosure originally designed for Biomark Biolite antennas. It contains 4 12v batteries connected in series, attached to a DC-DC power supply box connected to a IS1001MC. Rigid flexible conduit is buried subsurface and runs from the box located on the river left bank (East) side of the river connecting 3 20ft ABS Biomark PIT anntenas, with IS1001 nodes. Upon installation, staff made every effort to fully conceal the PIT array as public and recreational use of both the pathway and river channel is extremely busy in summer months with thousands of tubers floating the channel daily. It is expected that this site will greatly improve our estimates of terminal spawning ground counts of sockeye.

INSERT Jeff'S photo of site

2.3.3 Next steps

As the site is powered by 12v batteries, the next logical installation upgrade for the site is to connect to the power grid to ensure seamless, autonomous operation – similar to OKC. The intention for this site would be to operate authomously as a mainstem river PIT array – as OKC. Additionally, as there is much traffic passing the site effort made to communicate the project to the broader public – a permanent information panel should be created and installed.

5.0 Supporting Projects References

Benson, R. (2014). Okanagan Sockeye smolt migration from suwiẃs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2012 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 28 pp.

Benson, R. 2016. Okanagan Sockeye smolt migration from suwiẃs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2014 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 23 pp.

Benson, R., & A. Stevens. 2014. Okanagan Sockeye smolt migration from suwiẃs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2011 brood year. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 24 pp.

Benson, R., & A. Warman. 2012. Okanagan Sockeye smolt migration from suwiẃs [Osoyoos Lake] and q̓awst'ik'ʷt [Skaha Lake] 2010 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 27 pp.

Benson, R.L., A. Warman, and R. Bussanich. 2011. Okanagan sockeye smolt migration from suwiẃs (Osoyoos Lake) and q'awst'ik'ʷt (Skaha Lake) 2009 brood year. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC. 36 pp.

Benson, R., S. Folks, A. Stevens, and R. Bussanich. 2013. Brood year 2011 – Sockeye smolt out of basin survival pilot study in q'awsitkʷ (Okanagan River). Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 37 pp.

Benson, R., S. Folks, A. Stevens, and R. Bussanich. 2014. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT and Acoustic Tagging 2013. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 17 pp.

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

Folks, S, R. Benson, A. Stevens, and R. Bussanich. 2016a. q̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT Tagging 2014 & 2015. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 17 pp.

Folks, S, R. Bussanich, A. Stevens, and M. Teather. 2016b. ḳawsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: PIT Tagging 2016. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 12 pp.

Fryer, J. K., H. Wright, S. Folks, K. D. Hyatt, and M. M. Stockwell. 2012. Limiting Factors of the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2011. Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00

Lady, J.M., P. Westhagen, and J.R. Skalski. 2003. SampleSize 1.1. Sample size calculations for fish and wildlife survival studies. School of Aquatic and Fishery Sciences, University of Washington. Seattle, WA.

PTAGIS (1999) PIT tag Marking Procedures Manual version 2.0: Retrieved online November 2013: http://php.ptagis.org/wiki/images/e/ed/MPM.pdf

Stefanovic, D., R. Benson, C. Fuller, and L. Wiens. 2016. Collection and Rearing of Okanagan Sockeye Salmon for the Skaha Re-introduction Program: Brood Year 2015 Annual Report. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2015. Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC.

Wright, R.H. and H. Smith (Ed). 2003. Management plan for experimental reintroduction of sockeye into Skaha Lake: Proposed implementation, monitoring and evaluation. Prepared by Okanagan Nation Alliance Fisheries Department, Westbank, BC.

Yaniw, N., and R. Benson. 2017. ḳawstʼikʼʷt (Skaha Lake) Nerkid Spawner Enumeration and Biological Sampling 2015. Prepared as part of the Skaha Lake Sockeye Salmon Re-Introduction Monitoring and Evaluation Program: Brood Year 2015. Okanagan Nation Alliance Aquatic Enterprises Ltd., Westbank, BC.

6.0 Appendix

OKC Site Log

Date	Comments	Who
3/16/2017	Installed four new 20' antennas and IS1001 readers upstream of the existing array. New antennas are A1-A4 and existing antennas were renamed to A5-A8.	sanglea
10/26/2016	A new modem was installed by Skyeler Folks and the site is now automatically uploading data again. I turned on site checking	bturley
9/21/2016	Master Controller and IS-1001 firmware was updated from version 1.6.0 to 1.6.1	bturley
9/20/2016	I changed the exciter voltage level on all antennas from 4 to 3.	bturley
11/7/2016	Switcher batteries were swapped out on Saturday 7/9. I increased the input voltage level to 3 on Monday 7/11.	bturley
4/6/2016	The input voltage at the site dropped below 18V on Saturday morning at about 07:45 am PST. This caused the readers to automatically go into standby. I put the readers back into scan mode on 6/6 at about 05:45 am. The input voltage is currently about 22V. One of the switcher batteries has possibly gone bad causing the input voltage to drop.	bturley
4/26/2016	The Master Controller and reader firmware were upgraded to version 1.6.0. After the upgrade the Master Controller reverted back to it's default ID of 01 instead of the correct A0. This caused a couple of rejected files last night. I changed the ID back to the correct one and will manually repair the rejected files and re submit them.	bturley
9/15/2015	Site file checking has been temporarily disabled.	bturley
9/15/2015	A new cell modem was installed at OKC. I configured the modem and downloaded the MC buffer and uploaded the buffer to PTAGIS.	bturley
9/15/2015	I reset the MC time, changed the noise alarm threshold to 50% and set the tag unique delay to 1 minute.	bturley
9/15/2015	On 8/25 and 8/26, the mux reader was replaced with a Master Controller and four IS-1001's.	bturley
9/15/2015	Site checking enabled on 9/15/2015 at 1300 hrs.	bturley
8/25/2015	OKC site is down during reader upgrade since 8/25 a.m. We are replacing the mux with a Master Controller and IS1001 readers. Site checking is off until installation is complete.	bturley
1/6/2015	Installed new CR1000 program ver 9.01 which eliminates the manufacturer tag prefix filter.	bturley
12/3/2015	O&M visit on 3/12/15. I changed the lithium battery on the mux and re-tuned.	bturley
12/15/2014	Tags with the 3DD prefix were not recorded before 10/22 because the datalogger had incorrect software that did not recognize tags with the 3DD prefix. The correct program was loaded on 11/19 and the mux buffer - which contained tags going back to 10/22 - was uploaded to PTAGIS on files OKC14295.ALL.	bturley

8/7/2014	Site went down on 7/5 due to dead batteries. Possible power outage disabled the battery charger? Skyeler Folks replaced batteries on site on 7/7 and got the site back up and running.	bturley
3/2/2014	Battery bank B was swapped out with new batteries on 1/31 at 1300 hours.	bturley
08/20/2013	On 7/25 at around 00:00 PST, the current of antenna 2 dropped from @ 4.20A to 3.33 A. On 8/7, the current dropped to @ 2.73A. On 8/9 at about 17:30, the current returned to about 4.00 A.	Bturley
2/1/2013	annual log file initiation for OKC	POC Bot
1/1/2012	annual log file initiation for OKC	POC Bot
1/1/2011	annual log file initiation for OKC	POC Bot
09/15/2010	Replaced faulty exciter cable for Antenna 1. At this point, the entire array is functioning and interrogation is finally consistent and continuous and numerous sockeye salmon Oncorhynchus nerka are being detected.	sanglea
05/14/2010	Problem with power solved - faulty relay in battery switcher. Relay replaced. Interrogation is continuous and consistent at this point.	sanglea
03/27/2010	Something is up with Antenna 1 - high noise. Antenna removed from sampling sequence until problem is resolved.	sanglea
03/27/2010	Power issues again. Power not being provided to transceiver enclosure consistently. Interrogation interrupted from March 27, 2010 through May 14, 2010.	sanglea
03/18/2010	Fourth antenna installed at the OKC array. Batteries in battery switcher replaced.	sanglea
11/19/2009	Based on the lack of test tag detections, interrogation was interrupted from November 19, 2009 through March 18, 2010.	sanglea
11/19/2009	Power to transceiver is intermittent. Based on the lack of test tag detections, interrogation was interrupted from November 19, 2009 through March 18, 2010.	sanglea
6/11/2009	Installation in-stream PIT-tag detection array 130' downstream of VDS-3 on the Okanagan River is complete. Array consists of 3-20' Biomark pass-by antennas. Array extends out from right-bank.	sanglea
6/11/2009	Biomark, with the cooperation and assistance of the Columbia RiverInter-Tribal Fish Commission and the Okanagan Nation Alliance, installed an instream PIT-tag detection array in the Okanagan River, upstream of Lake Osoyoos, British Columbia, CA in fall 2009. Three antennas were installed in November 2009 and a fourth antenna wasinstalled in March 2010. Opportunistic detections occurred during this time period due to issues with consistent power and communication. The system is powered using a Biomark battery switcher and data is transmitted using Campbell Scientific data collection and monitoring hardware and software.	sanglea

SKA SITE Log

Date	What	Who		
3/24/2017	Swapped Reader IDs, so now 01 is the upstream reader/antenna and 02 is the downstream reader/antenna.	sanglea	Upstream Antenna	1
12/5/2015	Site became fully operational	mteather	Downstream Antenna	2