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TECHNICAL REPORT 24-01

Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2021 and 2022

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February 23, 2024

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Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00, Contract 73354

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EXECUTIVE SUMMARY

A total of 1542 Sockeye Salmon, *Oncorhynchus nerka*, were sampled and 1499 PIT tagged at the Bonneville Dam Adult Fish Facility (AFF) in 2021; while in 2022 1375 were sampled and 1364 PIT tagged. Sockeye Salmon 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. Tracked upstream of Bonneville Dam were 1400 Sockeye Salmon in 2021 and 1354 in 2022. Upstream detections of PIT-tagged Sockeye Salmon tagged by this project at Bonneville Dam resulted in an estimated survival in 2021 of 70.4% to McNary Dam and 53.3% to Rock Island Dam compared to 91.3% to McNary Dam and 83.6% to Rock Island Dam in 2022.

Genetic stock identification (GSI) and Parental Based tagging (PBT) was combined with site of last PIT tag detection and used to classify the stock of Sockeye Salmon sampled at Bonneville Dam in 2021 and 2022. After correcting for likely errors in data collection, concurrence between Sockeye Salmon which could be classified both by genetics and final PIT tag detection site was 99.5 % in 2021 and 99.8% in 2022. In 2021, 2 of the 12 Snake River stock Sockeye Salmon sampled were detected in terminal areas above Lower Granite Dam while in 2022 only 1 in 4 was detected above Lower Granite Dam. Stock composition at Bonneville Dam in 2021 was estimated as 69.4% Okanagan, 28.4% Wenatchee, 0.9% Snake, and 1.3% Yakima. In 2022, Bonneville Dam stock composition was estimated as 77.4% Okanagan, 22.2% Wenatchee, and 0.4% Snake River.

Age 1.2 Sockeye Salmon were estimated to comprise 57.4% of the 2021 run passing Bonneville Dam followed by Age 1.1 at 27.3% of the run, 13.7% Age 1.3, 0.9% Age 2.1 and 0.7% Age 2.2. The estimated age composition for Okanogan Sockeye Salmon (based on GSI of Sockeye Salmon collected at Bonneville Dam) was 51.8% Age 1.2, 40.5% Age 1.1, 5.0% Age 1.3, 1.4% Age 2.1, and 1.2% Age 2.2. For Wenatchee-stock Sockeye Salmon passing Bonneville Dam, the estimated Age composition was 69.1% Age 1.2, 30.4% Age 1.3, 0.4% Age 2.2, 0.2% Age 2.1, and 0% Yakima.

In 2022, Age 1.2 Sockeye Salmon comprised 94.8% of the run, 2.1% were estimated to be Age 1.3, 2.0% Age 1.1, 0.6% Age 2.1, and 0.4% Age 2.2. The estimated age composition for Okanagan Sockeye Salmon (based on GSI of Sockeye Salmon

collected at Bonneville Dam) was 95.0% Age 1.2, 2.4% Age 1.1, 1.2% Age 1.3, 0.8% Age 2.1. For the Wenatchee stock passing Bonneville Dam, the estimated age composition was 94.6% Age 1.2, 5.3% Age 1.3, 0.1% Age 2.2, and 0% Age 1.1.

The estimated minimum fallback rates in Columbia River mainstem dams for adult Sockeye Salmon tagged at the AFF in 2021 ranged from 0.4% at Bonneville Dam, to 5.7% at John Day Dam, while in 2022 this range was from 0.4% at McNary Dam 3.0% at John Day Dam. The percentage tagged at Bonneville Dam with at least one fallback was 9.7% in 2021 compared to 10.5% in 2022.

Adult Sockeye Salmon travelled quickly upstream in 2021 with a median migration rates between mainstem Columbia River dams ranging from 29.7 km/day between Priest Rapids and Rock Island dams to 48.8 km/day between The Dalles and John Day dams for adults tagged at Bonneville Dam. In the higher flow year of 2022, migration rates ranged from 28.5 km per day between John Day and McNary dams to 41.0 km/day between The Dalles and John Day dams.

Upstream survival of Okanagan Sockeye Salmon to Rock Island Dam in 2021 was higher than the Wenatchee stock (58.1% vs 42.4%), however survival to the spawning grounds was lower (18.0% vs. 22.0%). In 2022, survival of Okanagan Sockeye Salmon from Bonneville to Rock Island Dam was 83.0% compared to 85.9% for Wenatchee Sockeye. Survival to the spawning grounds from Bonneville Dam was 68.6% for the Wenatchee Stock compared to 24.3% for Okanagan Stock Sockeye Salmon.

Okanagan juvenile PIT tagging in 2021 resulted in 5036 smolts tagged between April 23 and April 26, 2021, from Sockeye Salmon captured from a mid-lake trawl at the north basin of Osoyoos Lake (PTAGIS site OSOYOL - Appendix C and D). In 2022, 7435 smolts were tagged (Appendix D), which included 489 smolts were tagged from the Okanagan River screw trap downstream of Skaha Dam (OKANR), 6008 were captured from the OSOYOL mid-lake trawl and 938 were captured by a mid-lake trawl in Skaha Lake (SKAHAL). The survival rate of 2021 releases to Zosel Dam was 0.776 (se=0.079) and to Rocky Reach 0.523 (se=0.034); in 2022 the survival was 0.845 to Zosel Dam (se=0.162) and 0.332 (se=0.024) to Rocky Reach Dam.

This project is proposed to continue and evolve over the next several years as there are priority areas to investigate. One area of continuing concern is adult survival in the migration corridor between Wells Dam and Osoyoos Lake. From 2010 to 2015, we

used acoustic tags to assess this mortality, however, the high expense of acoustic tags and the required associated infrastructure led to us drop this type of tag in favor of increased PIT tagging as the number of PIT tag detection sites expanded in the Okanagan Basin during this same time. Unfortunately, the detection rate of returning adult Sockeye Salmon at Zosel Dam has varied from year to year depending on flow. At high flows, such as in 2020, a high percentage of Sockeye Salmon passed undetected through the spillway (76.2%) rather than using the fish ladders where PIT tag antennas are located. New antennas were installed in the Zosel tail race in September 2021 and an analysis of these is expected for our 2023 report.

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INTRODUCTION

Sockeye Salmon, *Oncorhynchus nerka,* is one of the species of Pacific salmon native to the Columbia River Basin. Prior to European settlement of the region, it is estimated the Columbia Basin supported an annual Sockeye Salmon run averaging over three million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, the Sockeye Salmon run has severely declined, reaching a low of fewer than 9,200 fish in 1995 before rebounding in recent years to highs of over 500,000 Sockeye Salmon counted at Bonneville Dam in 2012, 2014, and 2015 with a record high of over 660,000 in 2022 (DART 2023, FPC 2023).

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. Efforts to restore Sockeye Salmon to basins from which they had been extirpated due to impassible dams have also been underway in the Yakima Basin since 2009 and the Deschutes Basin since 2010[2].

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.

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 (Figure 1). The production of this run is believed to be limited

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

[2] The Yakima project consists of trapping Sockeye Salmon at Priest Rapids Dam and transportation them to Cle Elum Lake in the Yakima Basin. The Deschutes project traps Sockeye Salmon and kokanee at the base of impassible Deschutes River dams and transports these fish upstream.

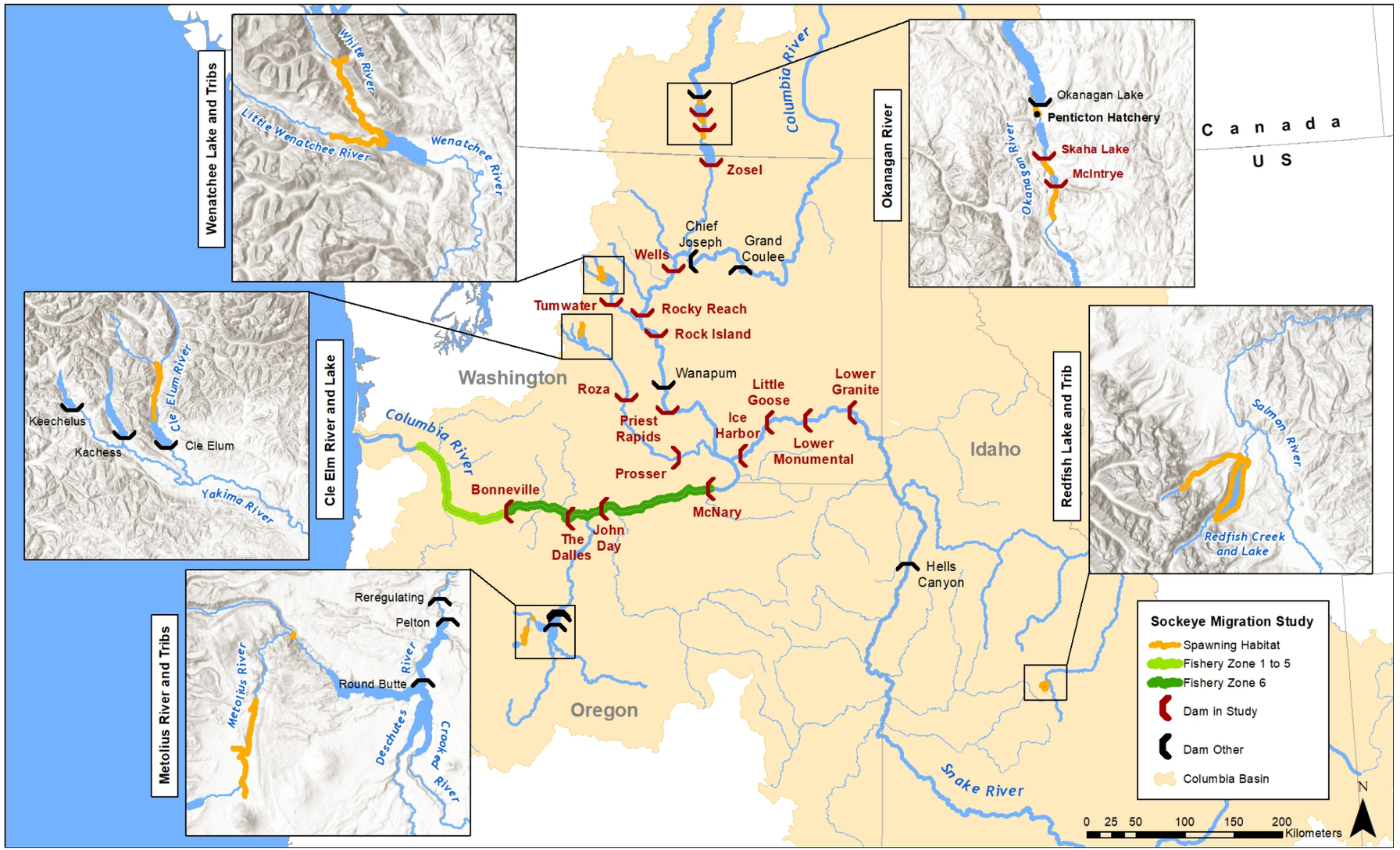

Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the major and minor Sockeye Salmon production areas and significant dams on their migration route.

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

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 Salmon sampled at Bonneville Dam as part of the annual Pacific Salmon Commission (PSC)-funded Sockeye Salmon stock identification project. These PIT-tagged fish can then be detected at upstream dam fish ladders with tag detection capability (The Dalles, John Day, McNary, Priest, 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, Tumwater Dam on the Wenatchee River, and Zosel and Skaha dams on the Okanagan River), as well as at in-stream tributary antennas.

Because only two significant Columbia Basin Sockeye Salmon stocks pass through multiple Columbia River dams with PIT tag detection makes the species ideal for PIT tag studies. 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 adult Columbia Basin Sockeye Salmon is of particular interest because the migration timing has shifted earlier over the years that

Sockeye Salmon 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 beginning in 2006 (Fryer 2007) conducted by this project have generally 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 in natal streams in the Wenatchee Basin (Little Wenatchee and White rivers), making it possible to track Wenatchee Sockeye Salmon to the spawning grounds in near real time at www.ptagis.org. 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 (with several upgrades, including floating antennas in the spill bays, in subsequent years). This was followed by installations at Skaha Dam fishway (SKA) and McIntyre Dam spill way (OKM) 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 annual acoustic surveys 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 Salmon in Osoyoos Lake. These data are used to estimate juvenile survival and compared to Wenatchee River smolt trap smolt estimates. Starting in 2012, this project has also funded limnological 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. 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 and a second OKC channel-width array was installed in 2017. In 2010, two antennas were installed in each of the two fish ladders at Zosel Dam (ZSL at www.ptagis.org) 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 floating antenna was installed in front of a second spillway in 2016; both antennas and electronics were upgraded in 2020. Antennas spanning the spill bay were added in 2021. An experimental PIT tag antenna was added to one spillway at McIntyre Dam (OKM, rkm 166) in 2015. Also, in 2015, two antennas were installed in the Skaha Dam fish ladder (SKA, rkm 177). The most upstream PIT array was installed in the Penticton Channel downstream of Okanagan Lake (OKP, rkm 196) in 2017.

Adult Sampling at Bonneville and Wells dams

Bonneville Dam Sampling

Sockeye Salmon were sampled and tagged at the Adult Fish Facility located adjacent to the Second Powerhouse at Bonneville Dam (river km 235) in conjunction with the sampling of steelhead (*O. mykiss)* and Chinook Salmon (*O. tshawytscha)*. Sampling and tagging typically occurred between approximately 0800 and 1300 hours on weekdays (Monday-Friday) except for holidays. 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 (Figure 2). Fish not selected and fish that have recovered from sampling then migrate back to the Washington Shore fish ladder above the picket weir.

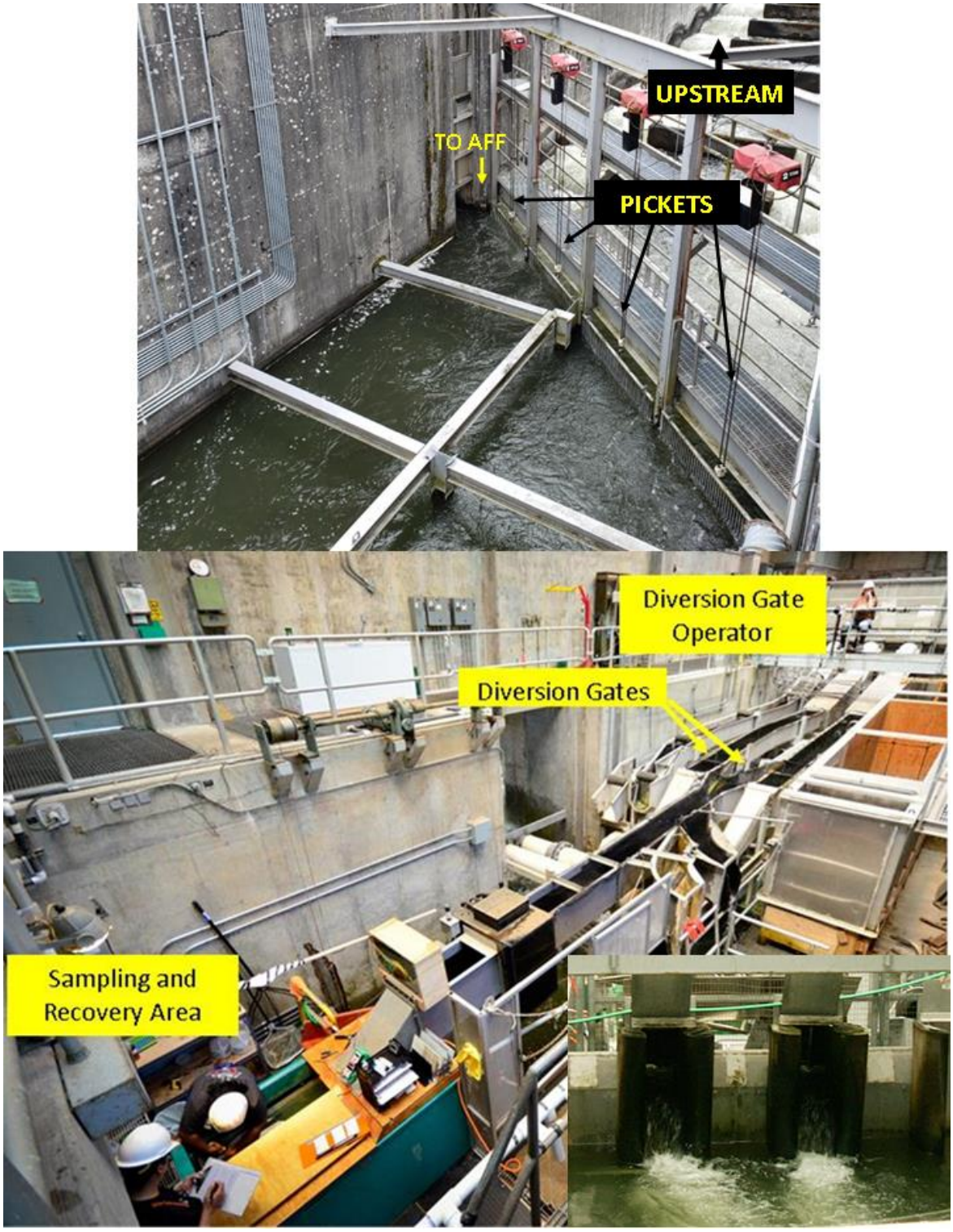

Figure 2. Images of Bonneville Adult Fish Facility. Top: Picket leads which divert fish from the fish ladder to the AFF. Bottom Right: False weir which fish must swim through to travel down the flume to the sampling area (lower left in middle photo).

Sockeye Salmon selected for tagging were examined (including scanning for existing PIT tags using a Biomark HPR reader) for fin clips, wounds, and condition. Fork length was recorded, and four scales were removed for later age analysis. If not already present, a PIT tag was inserted into the body cavity 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, John Day, 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 and Skaha dams on the Okanagan River, and Tumwater Dam on the Wenatchee River (array configurations are available at www.ptagis.org) as well as numerous in-stream detection arrays in the Wenatchee, Okanagan, Methow, Entiat, Yakima, and Snake basins. 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 at or upstream of the upper most Bonneville antennas (site BO1 antennas 1-4 and BO4 antennas 1-4 [Figure 3]), we removed it from further analysis. These fish could have shed their tags, died, or moved downstream through antennas at BO2 or BO3 undetected by passing through unmonitored overflow weirs rather than through the monitored underwater slots [Figure 4]. (The lower antennas at BO1 also have unmonitored overflow weirs Sockeye can pass through undetected.)

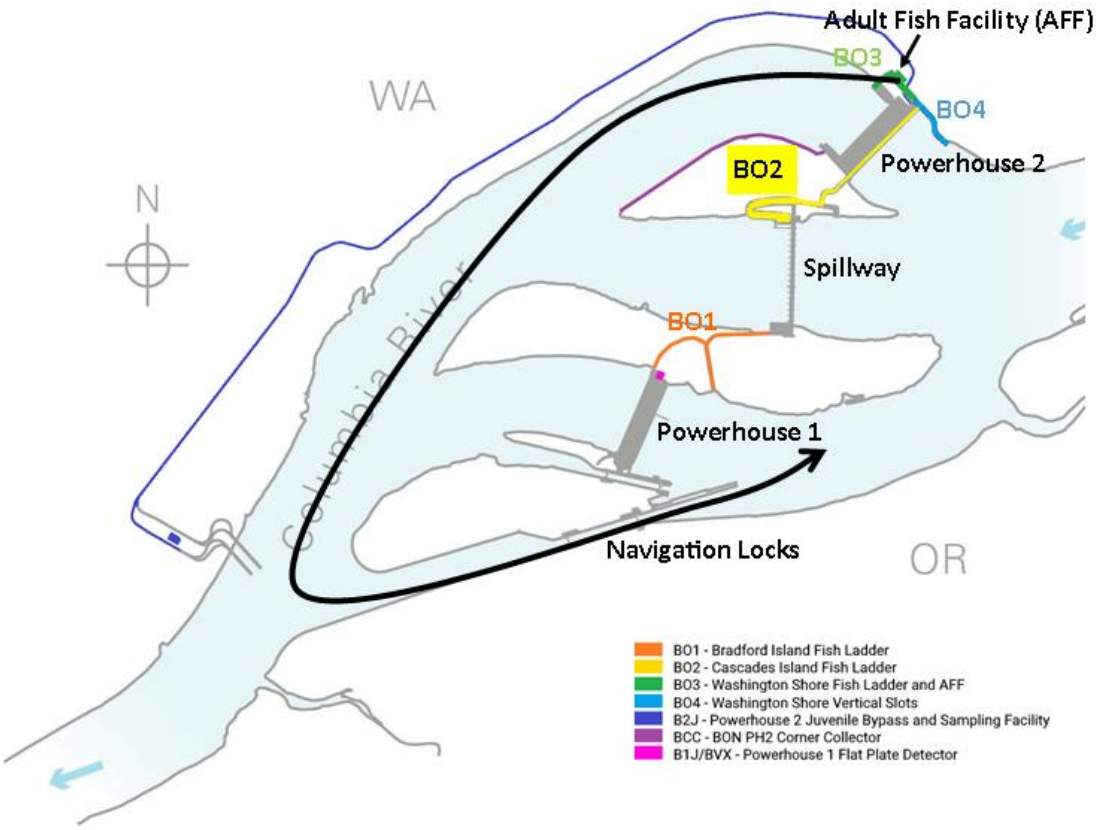

Figure 3. Site of Bonneville Dam PIT tag antennas (BO1, BO2, BO3, and BO4) and the most likely route (shown as a black line) for Sockeye Salmon tagged at the Adult Fish Facility to pass upstream undetected (Figure modified from www.ptagis.org).

Bonneville Dam Vertical Slot Antenna

Bonneville Dam underwater antenna with unmonitored overflow weir

Figure 4. Photos of the two types of PIT tag antennas at Bonneville Dam. The vertical slot antennas are at the upper end of both ladders, while the underwater antennas are in the lower parts of the ladders (photos courtesy of PTAGIS).

We also calculated some migratory characteristics of Sockeye Salmon PIT tagged as juveniles for comparison with adult Sockeye Salmon PIT tagged by this project. These Sockeye Salmon 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 (Keller and Hopkins, 2020).

Wells Dam Sampling

Sockeye Salmon 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 5.1 cm apart. This spacing is sufficient to allow smaller Sockeye to pass through these bars, resulting in a sample biased towards larger fish. Sockeye Salmon 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 chute leading to a large holding tank or returned them to the ladder upstream of the barrier gate. The Sockeye Salmon were netted from the large holding tank into a 380-liter tank and anesthetized in a 30ml solution of Aqui-S until they lost equilibrium and their opercular rate was slow but regular. Fish were examined for existing tags, fin clips, wounds, and condition. Fork length was also measured, and four scales were removed and placed on scale cards, each of which held scales from up to 20 Sockeye Salmon, for later age analysis. All fish not previously PIT tagged 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 supplied with oxygen at a rate of 1.5 L/min until they were partially recovered, and then placed back into a fish ladder pool immediately upstream of the picket weir.

In 2022, we also deployed archival weebit tags (www.alphamach.com, hereafter simply “button-tags”) on Sockeye Salmon sampled at Wells Dam. These tags were attached to the base of the Sockeye dorsal fin and record temperature every 15 minutes (Figure 5). The tag must be recovered to download data.

Figure 5. Temperature archival button-tag deployed on some Sockeye Salmon at Wells Dam in 2022.

Stock Identification and Classification

A primary goal of CRITFC's Sockeye Salmon sampling programs since the project began in 1985 has been to estimate the overall annual stock composition of Columbia Basin Sockeye Salmon at Bonneville Dam for use 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 (Schwartzberg and Fryer, 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 also began collecting genetics samples from Sockeye Salmon sampled to classify Sockeye Salmon using Genetics Stock Identification (GSI).

Genetic Stock Identification (GSI) and Parental Based Tagging (PBT)

Methods for estimating stock composition are available at (https://www.monitoringresources.org/Document/Protocol/Details/229). The Monitoring Methods Protocol is entitled Snake River steelhead and Chinook salmon stock composition estimates (2010-026-00) v1.0.

Molecular Data

Methods for DNA extraction, DNA amplification, and genotyping of SNP assays using genotyping-in-thousands by sequencing (GT-seq) are available at (Method: SNP genotyping using Genotyping in Thousands (GT-seq) on Illumina Sequencer platform v1.0 (monitoringresources.org)).

GSI analyses for *O. nerka* utilized a baseline that included Sockeye Salmon and kokanee populations from throughout the Columbia River Basin. This baseline included Sockeye Salmon populations from the Osoyoos (i.e., Okanogan), Wenatchee, and Redfish Lake (i.e., Snake), and a kokanee population from Lake Whatcom that were included in "Sockeye Salmon GSI baseline v1.0" and were shown to accurately discriminate among these major stock (Hess et al 2013). We updated our baseline to included additional kokanee

populations from Alturas Lake, Fishhook Creek, Lake Billy Chinook (Deschutes), Meadow Creek, Suttle Creek, Cougar, Gold, North Fork Tieton, Odell, Speylai, Stanley, Warm, Wizard, Wallowa River, and Wallowa Lake, and refer to this as "Sockeye Salmon GSI baseline v3.0". The transition to GT-seq required omission of a few loci due to poor genotyping quality with the new protocols. A total of 363 SNPs was used for these analyses.

Combined Application of PBT and GSI

We combined PBT and GSI results together by first accepting all confident PBT assignments to hatchery broodstock (i.e., LOD≥14 & FDR≤0.1) (See methods for Method: Parentage assignments using SNPPIT software v1.0 (monitoringresources.org)). For the remaining individuals, we used the best estimate of GSI assignments (regardless of the probability of assignment) provided by the program ONCOR to determine likely reporting group of origin (Method: Assigning individual samples using Individual Assignment (IA) genetic methods v1.0 (monitoringresources.org)). For the assignment of Sockeye Salmon, GSI via ONCOR was used. We also have a baseline of candidate parents used in the reintroduction of Sockeye Salmon which requires both SNPPIT and a program to perform single parentage assignments (SEQUOIA).

PIT Tag Stock Identification

Since PIT tag 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. In past reports through 2019, those individuals last observed in the Okanagan, Wenatchee, Yakima, or Snake basin were classified to those stocks, while those last detected in other basins or the mainstem Columbia River were classified as being of unknown stock. Given the evidence of Yakima-origin Sockeye Salmon straying into the Snake River (Fryer et al, 2021), beginning in 2020, based on final detection site, we required detection at Lower Granite Dam before we considered a Sockeye Salmon to be of Snake River origin. Those last detected at downstream Snake River dams were considered of unknown origin.

In 2012, GSI was in concurrence over 99% of the time with PIT stock classifications for those Sockeye Salmon that could be classified by terminal area PIT tag detections (Fryer et al. 2014). Given this concurrence, in both 2013 and 2014 we did GSI only from genetics samples of Sockeye Salmon classified as unknown by PIT tags or those with unusual PIT tag detection histories. However, since 2015, GSI has been conducted on all Sockeye Salmon sampled at Bonneville Dam which was the case in 2021 and 2022. In addition, GSI was also conducted on genetics samples from Sockeye Salmon PIT tagged at Wells Dam.

Final Stock Classification Rules

In 2021 and 2022 a combination of GSI, PBT, and PIT tag detections were used to classify Sockeye Salmon:

1.) If GSI classified a Sockeye Salmon to the Okanagan, Wenatchee, Snake or Deschutes stock, that classification was used. The exception was Yakima Sockeye Salmon as there is no GSI baseline for this stock as they are offspring of Wenatchee and Okanagan stock Sockeye Salmon reintroduced into the Yakima Basin (see 3 below) and thus would classify to those stocks.

2.) If no GSI results are available, classify any Sockeye Salmon last detected in the Snake Basin at or upstream of Lower Granite Dam as Snake River stock, in the Wenatchee Basin as Wenatchee stock, or Okanagan Basin as Okanagan stock. If last detected elsewhere, classify as unknown origin.

3.) For Yakima Sockeye Salmon, we do not have a GSI baseline but do have a limited baseline using parental-based tagging (PBT). If PBT indicated Yakima Sockeye Salmon, this classification was used. Also, if Sockeye Salmon were last detected in the Yakima Basin, they were classified as Yakima stock. In past years, Sockeye Salmon have been detected at the Priest Rapids Dam adult fish trap followed by Roza Dam (missing detection at Prosser Dam fish ladders), 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 to be detected at Roza Dam. For these fish, the GSI classification was used unless the fish was classified as Yakima by PBT and the PIT tag classification was changed to “Unknown”.

4.) Any differences in GSI and PIT tag stock classifications were examined. If

GSI and PIT tag stock classifications appeared to have been switched on consecutive (or nearly consecutive) scales (e.g., a Sockeye classified as being of Okanagan origin but last detected in the Wenatchee basin preceded or succeeded by a Sockeye classified by GSI as being of Wenatchee origin but last detected in the Okanagan Basin), the GSI samples were assumed to have been mishandled and discarded from further analysis.

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 phase, prevents age determination in any of the 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, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, 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) total visual count passing Bonneville Dam in week i (DART 2023, FPC 2023), T_i is the number of fish PIT tagged and detected at Bonneville Dam sites BO1 in week i, and R_i is the number of PIT tag detections at the dam where escapement is being estimated for those fish tagged in week i.

Upstream Survival/Conversion Rates

Survival/conversion rates were calculated for Sockeye Salmon 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 Salmon run passing Bonneville Dam in week i, D_i is the number of Sockeye Salmon 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 passing undetected 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 OKP in the Okanagan and LWN and WTL in the Wenatchee) where the percentage of PIT-tagged fish undetected 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 Salmon 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.*

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 for PIT-tagged adult Sockeye Salmon detected in the juvenile bypass systems. However, on the

Columbia River, only Bonneville, John Day, McNary, Rocky Reach dams have juvenile bypass system while all four Snake River dams (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite) do have such systems, all with PIT tag detection. Furthermore, there is no detection at any dam for fish falling back over the spillway[3] 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 at another ladder for multiple ladder dams). Finally, a third method of defining fallback was applied to 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 at 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. A fish passing downstream through the fish ladders was not considered a 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 Salmon Abundance

The goals of the Lake Wenatchee Sockeye Salmon research program are to quantify life history parameters for the population, investigate the physical, chemical, and biological factors that may be regulating population growth in

[3] This changed in 2020 with the installation of the GRS site at a single Lower Granite Dam spillway.

freshwater, and to estimate lake carrying capacity for this species. The in-lake program began in 2010 with a single acoustic and trawl survey. This was expanded to two acoustic and trawl surveys in 2011 and in 2012, the program was expanded to include a full limnological assessment including estimates of lake-turnover, oxygen-temperature profiles, water chemistry, phytoplankton, zooplankton, and Sockeye Salmon fry abundance. Between 2012 and 2023, survey frequency has increased. In recent years, the Okanagan Nation Alliance has conducted these surveys as they have the boat, equipment, and expertise from conducting similar surveys in Osoyoos, Skaha, and Okanagan lakes. However, the U.S.-Canadian border closure due to COVID 19 prevented this from occurring in 2020 as well as March 2021 resulting in the ONA subcontracting with the United States Geological Survey for these surveys using the ONA methodology.

Night-time juvenile Sockeye Salmon densities in Wenatchee, Osoyoos, and Skaha lakes[4] were estimated by executing specialized acoustics and trawl-based survey (ATS) methods by the USGS crew. Several whole-lake transects covering depth strata from the lake surface to bottom were traversed with hydro-acoustics gear (Biosonics sounders operating at 200 kHz) deployed from a boat at night (Hyatt et al. 1984). Acoustic signal returns from juvenile Sockeye Salmon 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) data 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 (5 x 7m mouth opening, 7.5-m length). Haul depths were based on echo-sounding results that indicate depths at which juvenile Sockeye Salmon were most likely to be caught.

[4] 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.

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 Salmon 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 trawls caught fish were released unharmed.

Juvenile PIT Tagging

Skaha and Osoyoos lakes were seined using a 183 m long seine of 1.27 cm (1/2") knotted mesh pulled behind an 8.5 m long purse seine boat to capture smolts for PIT tagging. Depths up to 12 m could be fished with this boat and gear. Purse seining concentrated in the central and northern basins of Osoyoos Lake where the majority of Sockeye smolts were congregating. Seining in Skaha Lake was concentrated in the southern area where smolts were congregating.

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The procedures outlined by PTAGIS (2014) and Biomark video (https://www.youtube.com/watch?v=QkZN_rRlU_o) were used for marking smolts. We deployed Biomark HPT 12 PIT tags (134.2 kHz) measuring 12.5 mm in length. Tags were implanted with the MK25 Rapid Implant Gun along with HPT9 pre-loaded sterile needles manufactured by Biomark. Fish were removed from holding pens and placed in a 19-L (5-gal) pail containing a 40 mg/l solution of tricaine methane sulfonate (MS 222). Fish were kept in the solution until they lost equilibrium (approximately 2-3 minutes). Each smolt was measured for fork length (mm) and a tag was inserted on the 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 Panasonic tablet which logged and saved each tag number into a P4 software tagging session

file. This configuration allowed taggers to enter 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 holding pens and released back into the lake the same day, typically between 21:00 and 23:00 to reduce predation. Fish were released from the North side of Haynes Point just offshore (OSOYHA), or in the North Basin at 20m depth (OSOYOL) in Osoyoos Lake. In Skaha Lake, smolts were released just offshore from the tagging site upstream of Skaha Dam. All post-tagged smolt mortalities were removed and sampled. PIT tag numbers from fish mortalities were removed from the database.

On-line tools (http://www.cbr.washington.edu/dart/query/pit_sum_tagfiles) developed by the University of Washington School of Aquatic and Fishery Sciences Columbia Basin Research were used to estimate Cormack-Jolly-Seber survival estimates as well as travel times. In addition, a request was made to the Fish Passage Center to analyze the data and the resulting memo is in Appendix D.

RESULTS

Migratory Conditions

The years covered by this report, 2021 and 2022, presented very different migration conditions for the Columbia Basin Sockeye Salmon run. When compared to the 10-year mean, Columbia River flows at Bonneville Dam were lower than average in 2021 but much higher than average in 2022 (Figure 6).

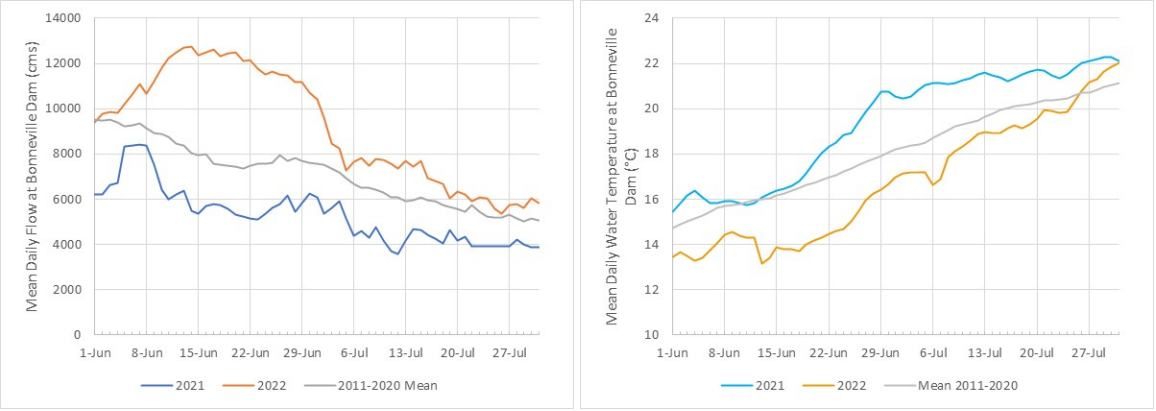

Figure 6. Mean daily water temperature (left) and flow (right) at Bonneville Dam between June 1 and July 31 in 2021, 2022, and the 2011-2020 mean daily temperature.

Conversely, the temperature of the Columbia River in 2021 was much higher than average for most of the run while water temperatures in 2022 were lower than average (Figure 6). Contributing to high river temperatures in 2021 were unprecedented air temperatures throughout the Columbia Basin hitting a peak of 46.7 C in Portland, Oregon on June 28.

Upstream Migration Analysis

Bonneville Sample Size and Upstream Detection

In 2021, a total of 1542 Sockeye Salmon were sampled for this project at the Bonneville Dam Adult Fish Facility between June 1 and August 10 (Table 1). A total of 40 fish were excluded from analysis. There was missing data from one group of Sockeye sampled on June 25, 2021, (a missing scale card representing 20 fish preventing aging) so the data were omitted. Also in this group was one Sockeye Salmon that was PIT tagged twice. Another scale card for fish sampled

on June 28, 2021, had a series of Sockeye where the age of the fish did not agree with the corresponding fish length and the stock as indicated by the final PIT tag detection site did not agree with the stock assigned by GSI. These have been found to be virtually non-existent in past years and, but when they do occur, they are almost always in pairs suggesting that data, likely genetics samples, have been placed in the wrong location on the Whatman sheet.

Table 1. Number of Sockeye Salmon sampled, and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2021.

Dates Sockeye Salmon Sampled	Statistical Week[5]	Percent of Run	Sampled (N)[6]	Excluded Due to Bad/Missing Data	Number Tagged	Previously Tagged		Mortalities	Not Detected After Tagging	Last Detected at Bonneville downstream of exit antennas	Detected at or upstream of Bonneville ladder exit antennas	Days Sampling Restrictions in Effect		
						At AFF by this Project	Tagged as Juveniles by Other Agencies					Reduced Sampling-Temperature	Reduced Sampling-Shad and Salmon Abundance	No Sampling -Temperature
6/1-6/4	23	0.1%	12	0	12	0	0	0	0	0	12	0	0	0
6/7-6/11	24	1.8%	62	0	62	0	0	0	0	0	62	0	5	0
6/14-6/18	25	6.5%	159	0	157	0	1	1	1	7	149	0	5	0
6/20-6/25	26	33.2%	423	20	383	0	0	2	5	7	371	0	5	0
6/28-6/30,7/1-7/2	27	31.1%	445	20	405	0	2	0	8	29	366	0	5	0
7/6-7/9	28	17.7%	202	0	202	0	1	2	2	13	186	4	0	1
7/12-7/15	29	6.8%	198	0	198	0	0	0	7	12	179	4	0	1
7/19-22,7/26, 8/10	30[7]	2.7%	81	0	80	0	1	0	1	4	75	4	0	1
Total			**1542**	**40**	**1499**	**0**	**5**	**5**	**24**	**72**	**1400**	**12**	**20**	**3**

After removing the 40 Sockeye with data mix-ups described in the previous paragraph and accounting for Sockeye for which no tag was read (likely due to a bad tag, improper tag placement, or a PIT tag reader problems), a total of 1499 Sockeye were tagged by this project. The 5 recaptured Sockeye tagged as juveniles were offset by the 5 mortalities of fish tagged by CRITFC. A total of 24

[5] Statistical weeks are sequentially numbered calendar-year weeks. Excepting the first and last week of most years, statistical weeks are seven days long beginning on Sunday and ending on Saturday. In 2021, for instance, statistical week 23 began on May 30 and ended on June 5.

[6] Data problems resulted in the removal of data from a scale card (20 Sockeye) from analysis on both June 25 and June 28. The June 25 scale card was missing while the June 28 scale card had numerous mismatches between age and length in addition to genetics classification and final PIT tag destination.

[7] One Sockeye was sampled on July 26 (Week 31) and one on August 10 (Week 33); these fish were pooled with Week 30.

Sockeye were not detected after tagging, and 72 were last detected at antennas at BO2 and BO3 with a total of 1400 tagged Sockeye detected at the upper most antennas at BO1 or BO4 or upstream of Bonneville Dam. Sampling restrictions were in place for 30 days over the 8 weeks Sockeye were sampled with reduced sampling on 27 days due to high temperatures or shad abundance, and 3 days of no sampling due to high temperatures.

In 2022, a total of 1375 Sockeye were sampled, and 1364 Sockeye tagged by this project (Table 2). A total of 4 Sockeye were previously tagged, 3 by other agencies as juveniles on their downstream migration and 1 by CRITFC. The previously tagged CRITFC Sockeye and 1 of the 3 previously tagged by other agencies were mistakenly given a second tag by CRITFC samplers. These fish were excluded from further analysis due to the small number, difficulties in analysis presented by double tagged fish, and possible differential detection rates at upstream detection sites. A total of 10 Sockeye were not detected after tagging and 3 were last detected at antennas BO2 and BO3 with a total of 1354 tagged Sockeye detected at the upper most antennas BO1 or BO4 or upstream of Bonneville Dam. In 2022, sampling restrictions were in place for 33 days over the 11 weeks (versus 30 over 8 weeks in 2021). Reduced sampling occurred on 18 days due to shad abundance and 12 days due to high temperatures during the last 3 weeks that we sampled Sockeye Salmon. There were 3 days of no sampling due to high temperatures. Temperature restrictions began in 2021 in Week 28, during that week 17.2% of the Sockeye run passed Bonneville Dam compared to 2022 in which temperature restrictions began on Week 31, during which 1.5% of the Sockeye run passed Bonneville Dam.

Table 2. Number of Sockeye Salmon sampled, and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2022.

Dates Sockeye Salmon Sampled	Stat. Week[8]	Percent of Run	Sampled (N)	Tagged	Excluded Due to Bad/Missing Data	Previously Tagged		Double Tagged	Mortalities	Last Detected at Bonneville downstream of exit antennas	Not Detected After Tagging	Detected at or upstream of Bonneville ladder exit antennas	Days Sampling Restrictions in Effect		
						At AFF by this Project	Tagged as Juveniles by Other Agencies						Reduced Sampling-Temperature	Reduced Sampling-Shad and Salmon Abundance	No Sampling-Temperature
6/1,3	23	0.1%	5	5	0	0	0	0	0	1	0	4	0	0	0
6/7-10	24	1.1%	66	63	0	0	1	0	0	0	2	62	0	0	0
6/13-17	25	4.2%	165	164	0	0	0	0	0	1	2	161	0	5	0
6/21-23	26	25.5%	259	259	0	0	0	0	0	0	1	258	0	5	0
6/27-30	27	43.2%	193	191	0	0	1	1	0	1	0	191	0	4	0
7/5-8	28	14.8%	277	273	0	1	0	1	0	0	1	272	0	4	0
7/11,13-15	29	6.4%	132	132	0	0	0	0	0	0	2	130	0	0	0
7/18-22	30	3.3%	135	135	0	0	0	0	0	0	1	134	0	0	0
7/25-29	31	1.2%	105	105	0	0	0	0	0	0	0	105	4	0	1
8/2,5	32	0.2%	30	29	0	0	1	0	0	0	1	29	4	0	1
8/8,11	33	0.1%	8	8	0	0	0	0	0	0	0	8	4	0	1
Total			**1375**	**1364**	**0**	**1**	**3**	**2**	**0**	**3**	**10**	**1354**	**12**	**18**	**3**

Sockeye Salmon were tracked upstream though the Columbia Basin. The percentage of Sockeye missing detection at each dam was calculated. At Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams it is possible for Sockeye to pass through navigation locks undetected. All other Columbia and Snake River dams with PIT tag detection arrays have antennas in fish ladders that Sockeye Salmon must navigate, though data from 2006-2022 indicate that, even at those dams without navigation locks, PIT-tagged Sockeye Salmon can and do avoid detection as they migrate upstream (Table 3).

[8] 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 2021, for instance, statistical week 23 began on May 30 and ended on June 5.

Table 3. Percentage by year and mean of Bonneville Dam PIT-tagged Sockeye Salmon not detected at upstream dams and in-stream PIT tag arrays on their migration route for 2006-2022. Dashes in table mean detectors were not deployed or no PIT-tagged fish passed this site.

	Percentage Not Detected by Dam and Year																	
Dam/Array	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Mean**
Bonneville (BO1 & BO4)	0.2	2.1	0.4	0.6	0.7	0.5	1.8	0.4	0.7	1.6	2.8	0.2	1.1	1.5	1.0	1.8	1.6	1.1
The Dalles	--	--	--	--	--	--	--	1.6	0.3	0.6	0.4	2.1	0.9	0.5	1.4	0.8	1.8	1.0
John Day	--	--	--	--	--	--	--	--	--	--	--	--	2.8	3.3	4.5	2.8	3.6	3.4
McNary	3.1	6.5	10.1	5.0	3.8	1.6	12.1	2.1	3.8	1.1	2.4	5.2	2.9	2.9	2.9	1.6	4.8	4.2
Priest Rapids	0.0	0.8	0.3	0.3	0.6	0.2	0.4	0.0	0.2	0.4	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.2
Rock Island	1.3	6.8	6.9	2.6	6.2	4.4	5.4	4.4	41.5	10.2	2.9	5.9	28.3	4.1	2.8	0.1	0.0	7.9
Rocky Reach	12.3	0.7	0.2	0	0.5	0.7	1.4	0.0	0.3	0.0	0.0	0.7	0.2	0.0	0.0	0.0	0.1	1.0
Wells	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ice Harbor	--	--	0.0	20.0	0.0	--	0.0	--	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Lower Monumental	--	--	--	--	--	--	--	--	--	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0	0.0
Little Goose	--	--	--	--	--	--	--	--	--	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0	0.0
Lower Granite	--	--	--	--	--	--	--	--	0.0	--	0.0	0.0	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	0.0	1.7	1.0	0.0	0.2
Zosel	--	--	--	--	--	98.6	83.0	87.3	0.9	0.0	1.6	74.5	57.5	0.0	76.2	0.0	70.9	46.2
Lower Wenatchee (LWE)	--	--	--	--	--	--	--	--	48.0	17.9	54.7	49.6	68.4	33.3	78.4	32.6	21.4	44.9
Upper Wenatchee (UWE)	--	--	--	--	--	--	--	--	52.7	24.6	9.7	9.3	9.9	3.2	11.3	49.4	32.3	22.5
Lower Okanagan (OKL)	--	--	--	--	--	--	--	--	68.9	13.8	59.4	47.4	50.1	66.7	40.4	83.7	77.7	56.4
Okanagan Channel (OKC)	--	--	--	--	--	--	--	--	--	--	16.9	--	7.7	5.3	5.7	0.0	5.9	6.9
Skaha	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0	41.5	0.0	40.0	20.4

Based on Sockeye Salmon PIT tagged at Bonneville Dam by this study, the mainstem dam with the highest percentage passing upstream undetected in 2021 was John Day Dam (2.8%, Table 3) and, in 2022, McNary Dam (4.8%, Table 3).

In the Okanagan Basin, both Zosel and Skaha dams had high rates of PIT-tagged Sockeye Salmon missing detection in 2022 due to high river flows allowing Sockeye Salmon to avoid detection by migrating through the unmonitored spillway rather than through fish ladders where PIT tag antennas were located. On the other hand, in 2021 which was a year of low flows, no Sockeye missed detection at either Zosel or Skaha dams.

Age and Sex Composition

The predominant age group in both 2021 and 2022 was Age 1.2 comprising 57.4% of the run in 2021 and 94.8% of the run in 2022 (Tables 4 and 5). In 2022, no other age group comprised more than 2.1% of the run, while in 2021, the Age 1.1 group comprised 27.3% of the run and the Age 1.3 group comprised 13.7% of the run.

Table 4. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2021. (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)

Statistical Week	% of Run	% Females	N Ageable	Age Class				
				1.1	1.2	2.1	1.3	2.2
23	0.1%	25.0%	12	8.3%	91.7%	0.0%	0.0%	0.0%
24	1.8%	46.7%	60	16.7%	80.0%	1.7%	1.7%	0.0%
25	6.5%	32.5%	155	37.7%	56.5%	0.6%	3.9%	1.3%
26	33.2%	37.9%	373	23.6%	66.2%	0.5%	9.7%	0.0%
27	31.1%	47.1%	395	28.6%	56.2%	0.8%	13.9%	0.5%
28	17.7%	41.9%	198	27.3%	47.5%	1.0%	22.7%	1.5%
29	6.8%	47.1%	194	27.8%	48.5%	3.1%	18.6%	2.1%
30-33	2.7%	48.0%	77	39.0%	35.1%	2.6%	23.4%	0.0%
Composite	**100.0%**	**42.1%**	**1463**	**27.3%**	**57.4%**	**0.9%**	**13.7%**	**0.7%**
Standard Error		**1.3%**		**1.2%**	**1.3%**	**0.3%**	**0.3%**	**0.2%**
F statistic for linear regression between age and stat. week				**5.81**	**41.49**	**6.511**	**76.1**	**1.15**
P value				**0.053**	**<0.001**	**0.043**	**<0.001**	**0.325**
Females			**616**	**12.0%**	**73.3%**	**1.2%**	**12.8%**	**0.6%**
Standard Error				**1.4%**	**1.9%**	**0.4%**	**1.4%**	**0.3%**
Males			**837**	**38.6%**	**45.6%**	**0.8%**	**14.4%**	**0.6%**
Standard Error				**1.8%**	**1.8%**	**0.3%**	**1.3%**	**0.3%**
T-test p value for males vs females by age				**<0.01**	**<0.01**	**0.54**	**0.54**	**0.562**

Table 5. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2022. (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)

Statistical Week	% of Run	% Females	N Ageable	Age Class				
				1.1	1.2	2.1	1.3	2.2
23	0.1%	60.0%	5	0.0%	100.0%	0.0%	0.0%	0.0%
24	1.1%	47.7%	46	4.3%	93.5%	0.0%	2.2%	0.0%
25	4.2%	36.8%	164	1.8%	94.5%	1.8%	0.6%	1.2%
26	25.5%	48.6%	254	2.0%	93.7%	0.4%	3.9%	0.0%
27	43.1%	55.7%	186	1.6%	95.7%	0.5%	1.6%	0.5%
28	14.8%	57.8%	269	2.2%	95.2%	1.1%	1.5%	0.0%
29	6.4%	59.9%	171	3.5%	93.6%	0.6%	1.2%	1.2%
30	3.3%	67.4%	134	2.2%	94.0%	0.7%	1.5%	1.5%
31	1.2%	59.6%	104	1.9%	93.3%	0.0%	3.8%	1.0%
32	0.2%	75.9%	30	0.0%	100.0%	0.0%	0.0%	0.0%
33	0.1%	75.0%	8	0.0%	87.5%	0.0%	12.5%	0.0%
Composite	**100.0%**	**54.1%**	**1416**	**2.0%**	**94.8%**	**0.6%**	**2.1%**	**0.4%**
Standard Error		**1.8%**		**1.0%**	**1.6%**	**0.6%**	**0.6%**	**0.5%**
F statistic for linear regression between age and stat. week				**1.00**	**1.42**	**0.472**	**2.96**	**0.184**
P value				**0.344**	**0.263**	**0.562**	**0.120**	**0.678**
Females				**0.8%**	**96.8%**	**0.2%**	**1.5%**	**0.6%**
Standard Error				**0.3%**	**0.8%**	**0.1%**	**0.6%**	**0.4%**
Males				**3.3%**	**92.6%**	**1.1%**	**2.8%**	**0.1%**
Standard Error				**1.0%**	**1.4%**	**0.6%**	**0.9%**	**0.1%**
T-test p value for males vs females by age				**0.016**	**0.011**	**0.132**	**0.221**	**0.290**

The age composition of female Sockeye Salmon in 2021 was 73.3% Age 1.2 and 12.0% Age 1.1 in 2021 compared to 45.6% Age 1.2 and 38.6% Age 1.1 for males (Table 4). The age composition of females in 2022 was 96.8% Age 1.2, 1.5% Age 1.3 and 0.8% Age 1.1 compared to males at 92.6% Age 1.2, 3.3% Age 1.1, and 2.8% Age 1.3. The difference in the percentage of Age 1.1 and 1.2 Sockeye by sex was significant (α=0.10) in both 2021 and 2022 (Tables 4 and 5).

There was a significant linear relationship (α=0.10) between statistical week and the weekly percentage of Age 1.2, 1.2, 2.1, and 1.3 Sockeye, but not for Age 2.2 (Table 4, Figure 7) for fish tagged in 2021. There was not a significant linear relationship between any age group and statistical week in 2022 (Table 5, Figure 8) for any of the age classes.

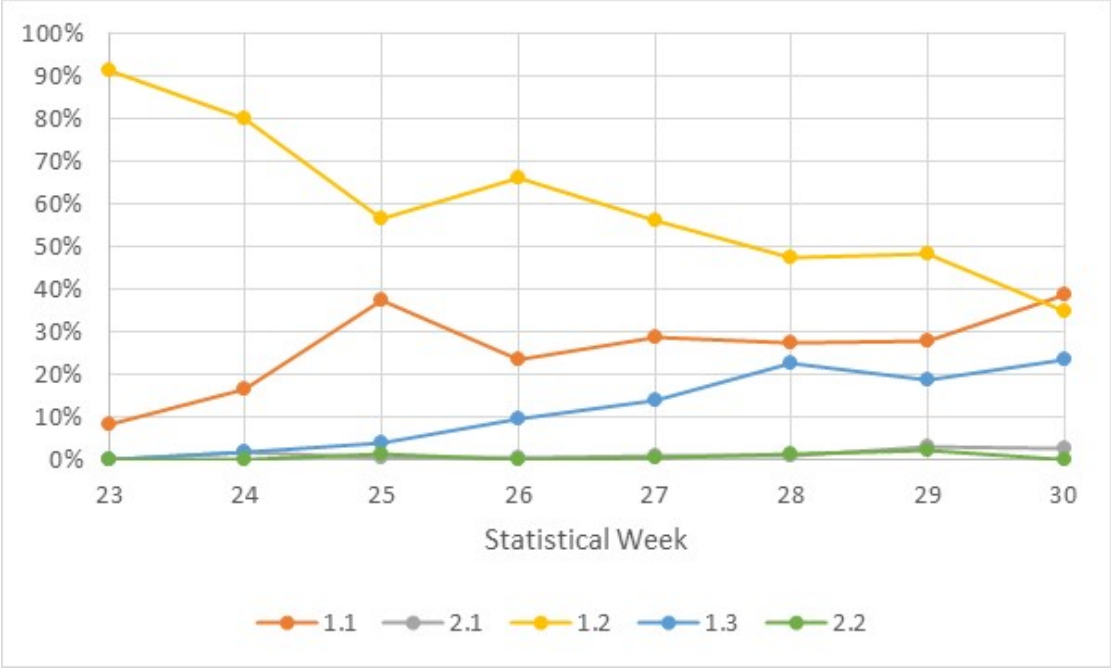

Figure 7. Weekly age composition estimates by statistical week for Sockeye Salmon sampled at Bonneville Dam in 2021.

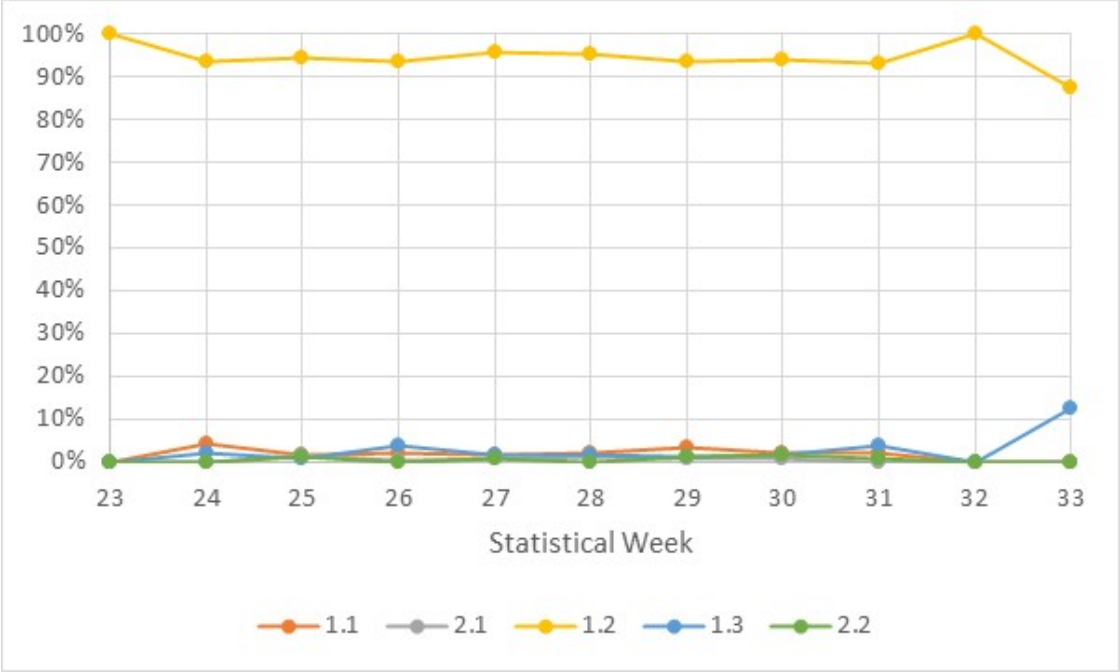

Figure 8. Weekly age composition estimates by statistical week for Sockeye Salmon sampled at Bonneville Dam in 2022.

The percentage of the run that was females showed a significant increase as the run progressed in both 2021 ($p=0.04$) and 2022 ($p<0.01$) (Tables 4 and 5, Figure 9).

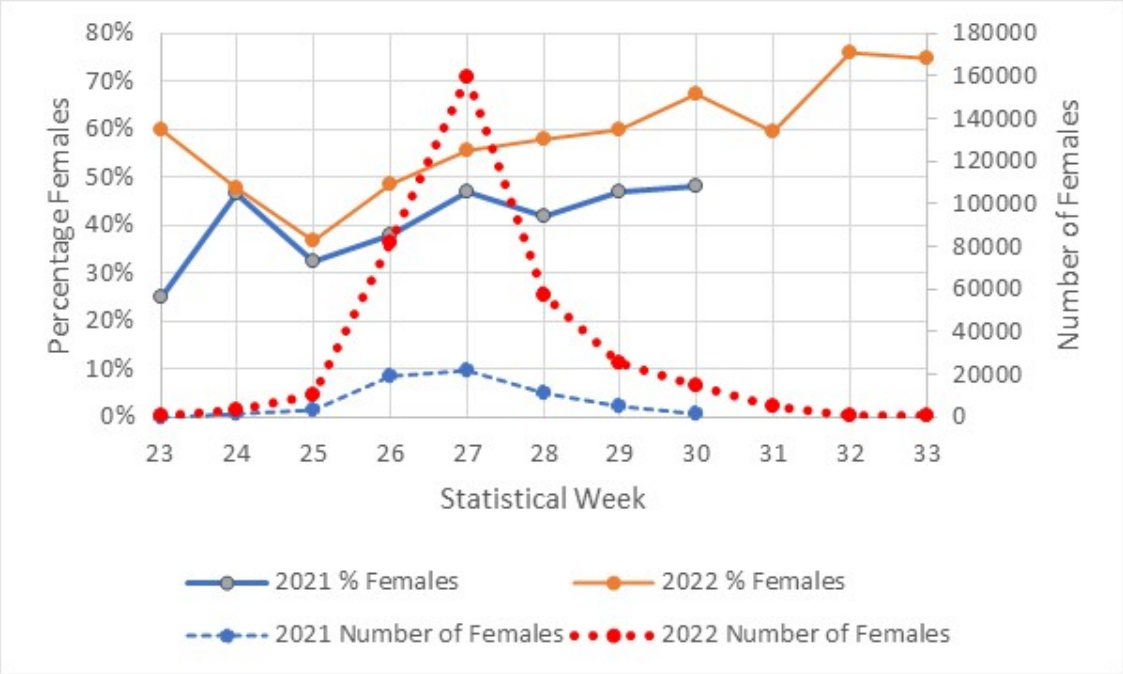

Figure 9. Weekly percentage and total number of females at Bonneville Dam estimated by this study for 2021 and 2022.

Upstream Recoveries, Mortality, and Escapement

The percentage of Sockeye Salmon passing Bonneville Dam that were estimated to pass upstream sites (Figures 10 and 11) was lower in 2021 than the 2006-2022 mean at all sites (Table 6)[9]; conversely the percentage estimated to pass upstream sites was higher at all sites other than OKC in 2022 when compared to the 2006-2022 mean.

[9] Tumwater Dam is only passed by Wenatchee stock Sockeye Salmon so differences to Tumwater Dam (as well as Rocky Reach and Wells dams) also reflect annual variations in stock composition.

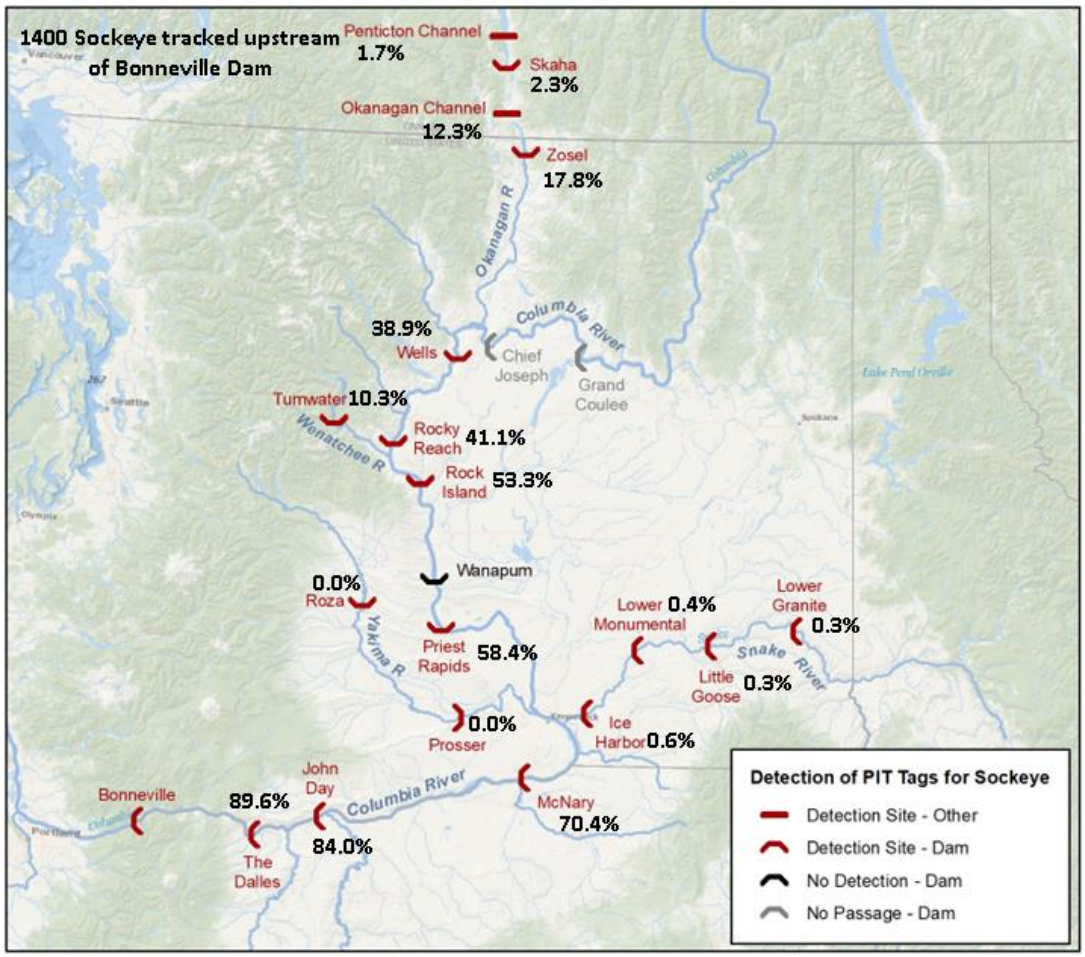

Figure 10. Map of the Columbia River Basin showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2021.

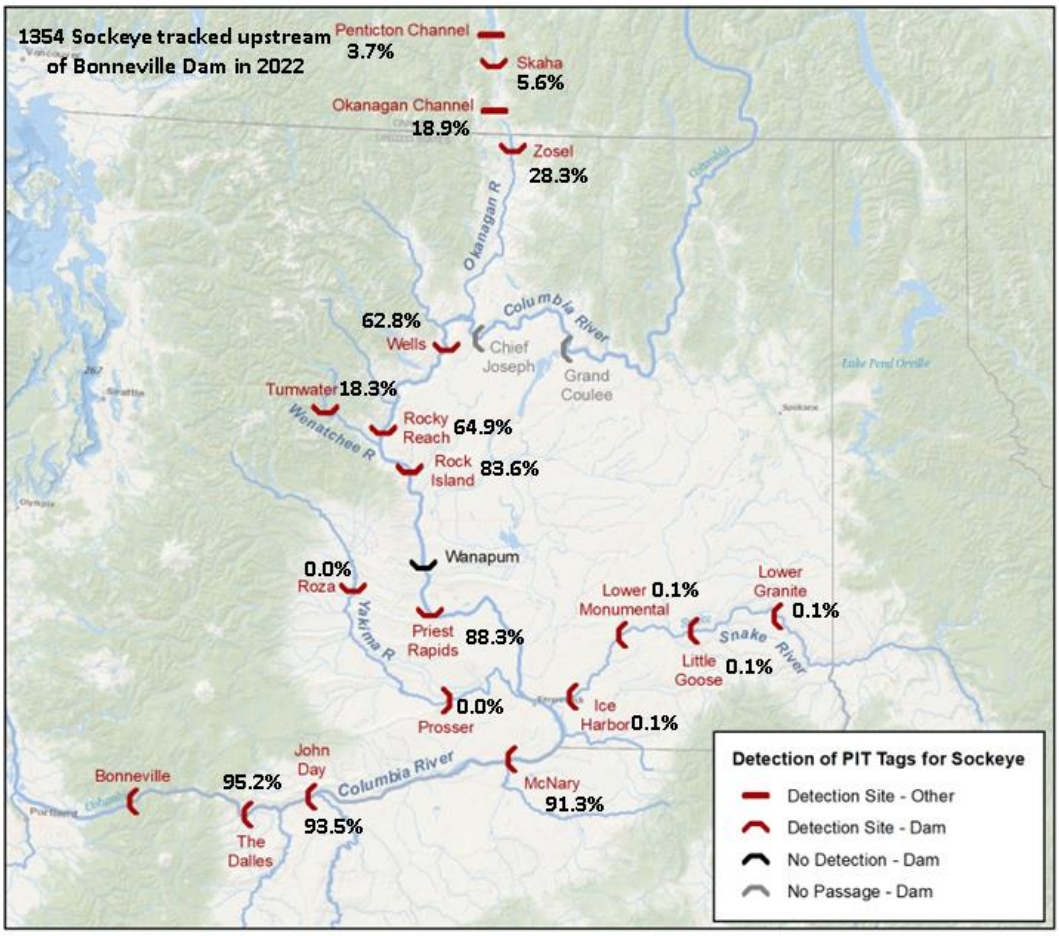

Figure 11. Map of the Columbia River Basin showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2022.

Table 6. Estimated survival of Sockeye Salmon PIT tagged at Bonneville Dam passing upstream dams and OKC in years 2006-2022.

	Percentage by Year																	
Dam or Site	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Mean**
The Dalles	--	--	--	--	--	--	--	89.5	93.1	82.8	94.0	89.3	93.3	94.6	95.0	89.6	95.2	91.6
John Day	--	--	--	--	--	--	--	--	--	--	--	--	90.9	92.7	92.1	84.0	93.5	90.7
McNary	88.4	84.0	89.4	85.7	81.5	76.1	82.4	83.6	88.3	54.0	89.2	81.7	88.9	84.2	90.4	70.4	91.3	82.9
Priest Rapids	84.8	77.4	86.3	82.1	78.4	71.9	77.3	78.6	84.5	44.9	85.3	74.6	85.4	82.4	84.9	58.4	88.3	78.0
Rock Island	81.1	73.4	85.8	80.2	76.3	68.9	75.0	74.2	79.5	40.6	81.6	70.8	80.7	81.6	77.3	53.3	83.6	74.3
Rocky Reach	58.8	62.2	73.7	67.1	63.7	55.3	62.1	52.4	65.3	31.6	60.5	43.7	73.9	73.4	65.0	41.1	64.9	59.7
Wells	53.8	60.9	71.1	65.2	62.6	53.9	60.8	50.5	64.2	29.4	59.3	42.5	72.7	72.4	63.7	38.9	62.8	57.9
Tumwater	--	--	9.4	12.2	13.3	14.2	12.9	20.9	13.6	8.3	20.8	25.8	6.0	8.7	11.2	10.3	18.3	13.8
Okanagan Channel (OKC)	--	--	--	--	32.5	40.2	25.9	30.7	22.5	2.2	38.1	25.1	45.7	44.6	33.5	12.3	18.9	28.7

The estimated escapement based on upstream PIT tag detections of the Bonneville-tagged Sockeye Salmon in 2021 was greater than the number of Sockeye Salmon counted at The Dalles, John Day, and Priest Rapids dams but less at all other dams with visual counts (Table 7, Figure 12). The PIT tag estimates show a consistent decrease in Sockeye Salmon escapement estimates as the run progresses upstream which is to be expected as fisheries and other sources of mortality take their toll. However, the visual dam counts show an irregular pattern of increases and decreases as the Sockeye Salmon run progresses upstream. There were more Sockeye Salmon counted at Rock Island Dam (109,367) than at Priest Rapids Dam downstream (76,855) and the sum of the Rocky Reach plus Tumwater counts (113,469) exceeded that of Rock Island Dam.

Table 7. Estimated Sockeye Salmon escapement using both PIT tag and visual means, and the difference between the PIT tag and visual escapement estimate at Columbia Basin dams in 2021.

Dam	Visual Dam Count	Escapement Estimate Using Bonneville PIT-Tagged Sockeye Salmon	Difference Between Bonneville PIT Tag and Visual Estimates
Bonneville	151,765	--	--
The Dalles	128,223	135,972	6.0%
John Day	126,708	127,445	0.6%
McNary	111,756	106,808	-4.4%
Priest Rapids	76,855	88,658	15.4%
Rock Island	109,367	80,909	-26.0%
Rocky Reach	82,643	62,412	-24.5%
Wells	76,255	59,028	-22.6%
Tumwater	30,826	15,654	-49.2%
Ice Harbor	954	946	-0.9%
L. Monumental	953	543	-43.0%
Little Goose	713	408	-42.8%
Lower Granite	645	408	-36.8%
Prosser	134	0	-100.0%
Roza	95	0	-100.0%

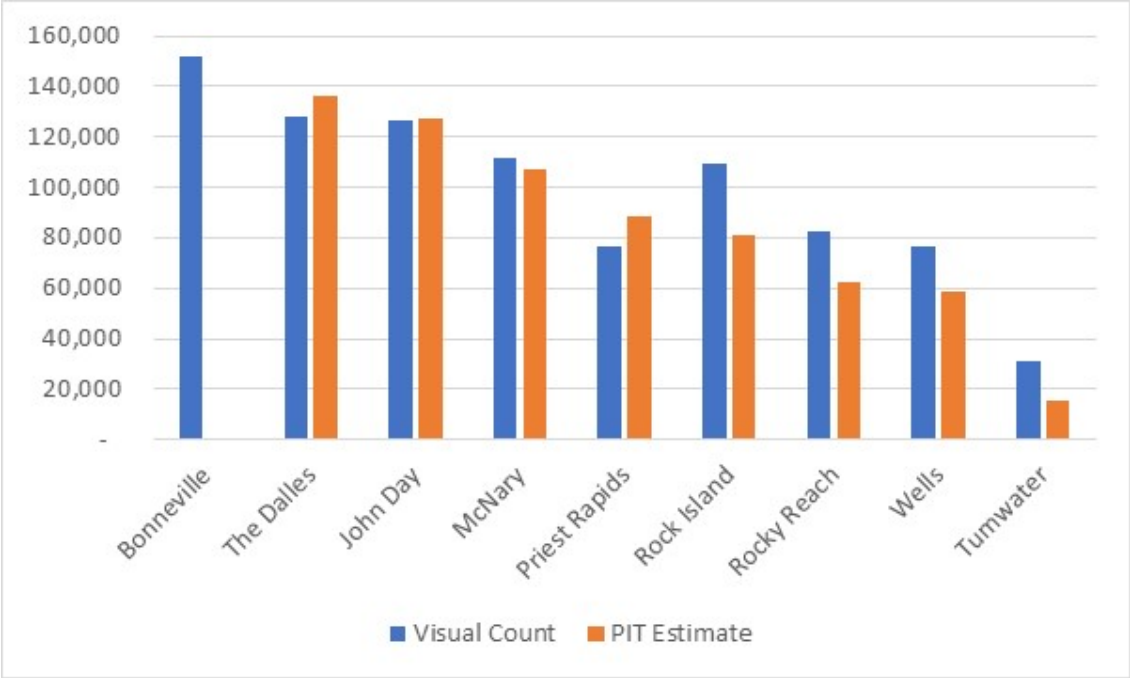

Figure 12. Estimated PIT tag and visual count estimates of escapement at Columbia River dams and Tumwater Dam in 2021.

In 2022, the number of Sockeye Salmon counted at John Day was greater than that of The Dalles, and the counts at Priest Rapids and Rock Island dams were greater than the three downriver dams (The Dalles, John Day, and McNary) compared to PIT tag estimates of escapement which follow the expected decline as the run moves upstream (Table 8, Figure 13). PIT tag estimates of escapement differ from visual counts at Columbia River dams from -23.5% at Rocky Reach Dam to 8.8% at The Dalles Dam.

Table 8. Estimated Sockeye Salmon escapement using both PIT tag and visual means, and the difference between the PIT tag and visual escapement estimate at Columbia Basin dams in 2022.

Dam	Visual Dam Count	Escapement Estimate Using Bonneville PIT-Tagged Sockeye Salmon	Difference Between Bonneville PIT Tag and Visual Estimates
Bonneville	663,253	663,253	--
The Dalles	580,582	631,572	8.8%
John Day	630,888	620,143	-1.7%
McNary	595,712	605,374	1.6%
Priest Rapids	654,407	585,695	-10.5%
Rock Island	659,933	554,519	-16.0%
Rocky Reach	562,721	430,559	-23.5%
Wells	478,418	416,766	-12.9%
Tumwater	110,693	121,534	9.8%
Ice Harbor	1,850	946	-48.9%
L. Monumental	1,953	543	-72.2%
Little Goose	2,099	408	-80.6%
Lower Granite	2,087	408	-80.5%
Prosser	157	0	-100.0%
Roza	510	175	-65.7%

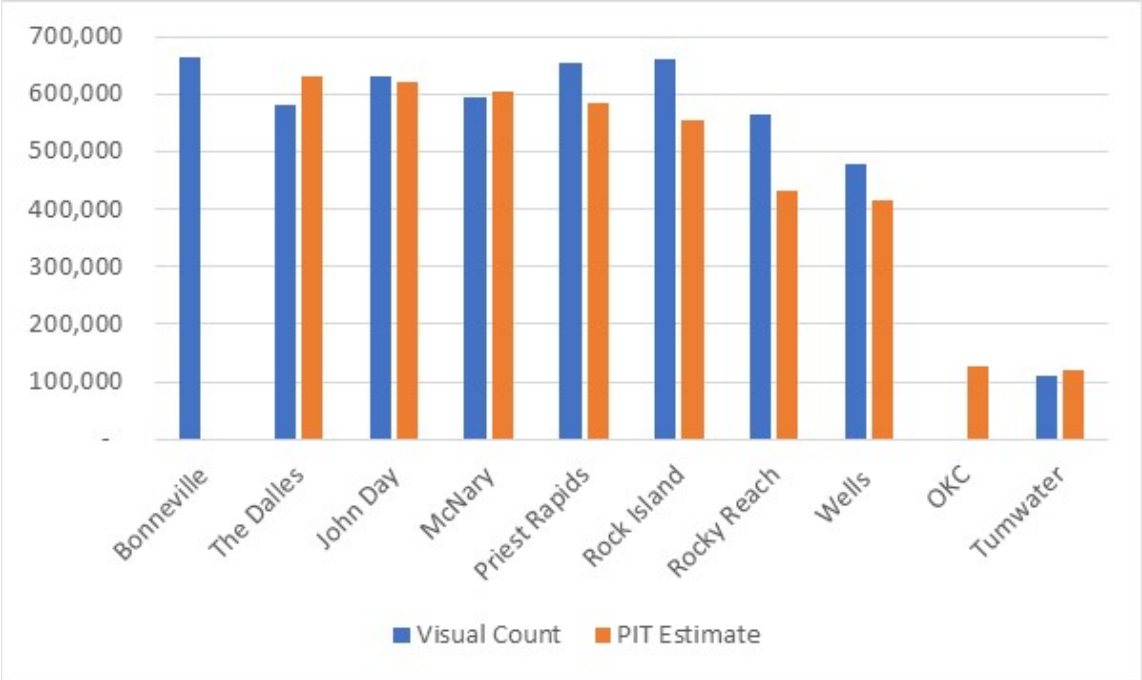

Figure 13. Estimated PIT tag and visual count estimates of escapement at Columbia River dams and Tumwater Dam in 2022.

There was a significant decrease in survival to upstream dams over the period of the run in 2021 (Table 9, Figure 14). There was also significant decrease in survival for Sockeye Salmon tagged as juveniles in the Okanagan Basin, but not for Sockeye tagged as juveniles in the Wenatchee Basin and at Rock Island Dam (Table 9).

Table 9. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2021 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Survival from Bonneville for Sockeye Salmon Tagged as Adults at Bonneville Dam					Sockeye Salmon Tagged as Juveniles Survival from Bonneville-Priest Rapids		
	The Dalles	John Day	McNary	Priest Rapids	Rock Island	Wenatchee (n=58)	Okanagan (n=168)	Rock Island (n=105)
23	100.0%	91.7%	83.3%	83.3%	83.3%	NA	100.0%	NA
24	98.4%	98.4%	93.5%	87.1%	87.1%	0.0%	100.0%	100.0%
25	96.6%	96.0%	91.9%	87.2%	86.6%	50.0%	94.1%	100.0%
26	94.3%	92.2%	87.9%	80.3%	76.0%	76.9%	80.3%	94.3%
27	89.3%	85.2%	73.0%	58.7%	50.0%	64.7%	72.1%	63.6%
28	87.1%	73.7%	43.5%	23.7%	19.4%	46.7%	50.0%	47.4%
29	74.9%	62.6%	35.2%	22.9%	21.8%	50.0%	33.3%	100.0%
30	64.0%	50.7%	21.3%	12.0%	9.3%	100.0%	0.0%	NA
31								0.0%
32							0.0%	
Composite[10]	**89.6%**	**84.0%**	**70.4%**	**58.4%**	**53.3%**	**58.6%**	**73.2%**	**75.2%**
p-value	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**0.39**	**<0.01**	**0.38**

[10] Composite estimates for Bonneville Dam Sockeye Salmon tagged as adults are weighted by statistical week, juvenile estimates are unweighted.

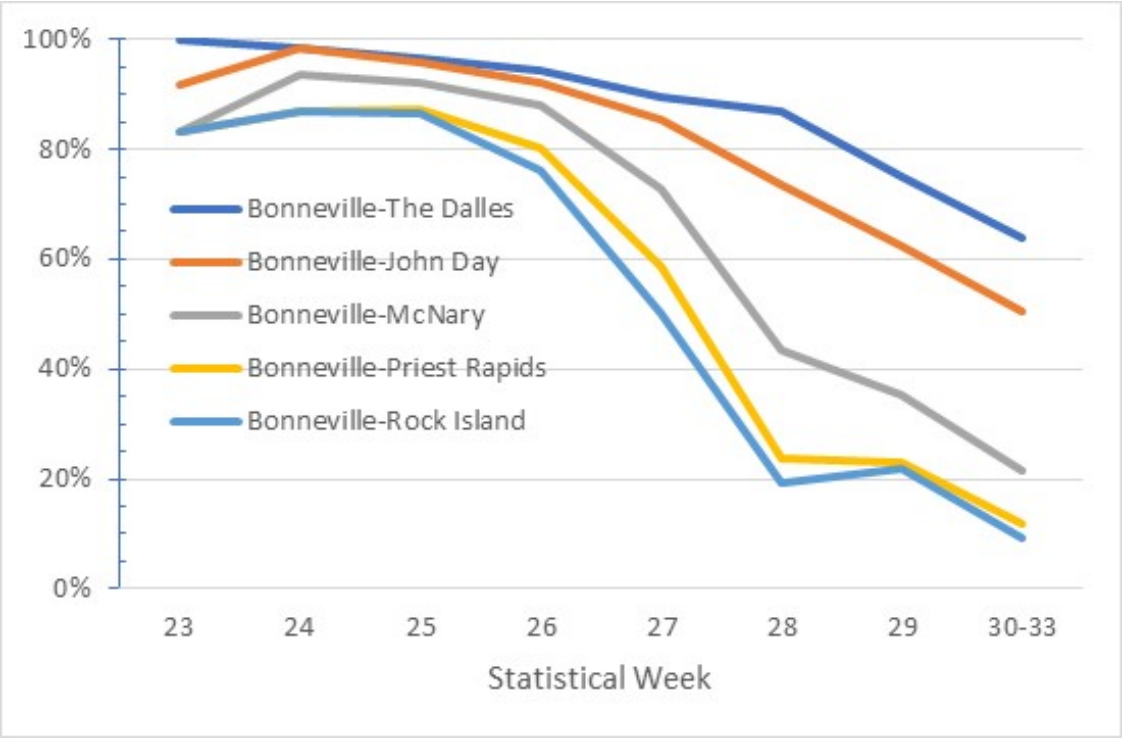

Figure 14. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, John Day, McNary, Priest Rapids, and Rock Island dams by statistical week in 2021.

Returning Rock Island juvenile-tagged Sockeye Salmon had the highest upstream survival to Priest Rapids Dam[11] in 2021 (75.2%) followed by juveniles tagged in the Okanagan Basin (73.2%), and with juveniles tagged in the Wenatchee Basin at 58.6% and adults tagged at Bonneville Dam at 58.4% (Table 9). Sockeye Salmon tagged as juveniles in the Okanagan Basin had the highest conversion from Bonneville Dam to the spawning ground arrays (30.4%) followed by juveniles tagged at Rock Island Dam (21.9%), juveniles tagged in the Wenatchee Basin (19.0%), adults tagged at Bonneville Dam (14.4%), and juveniles tagged in the Snake Basin (1.8%, Table 10).

[11] Priest Rapids Dam is used in this comparison because it has been the furthest upstream dam with consistently very high rates of PIT tag detection (Table 3) that is passed by both predominant stocks (Okanagan and Wenatchee).

Table 10. Survival of Sockeye Salmon groups PIT tagged as juveniles at different locations from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2021. Yellow shaded cells represent sites that are not on the migration route for the group tagged.

			Percent Survival to Upstream Dam									
Tagging Location	Life Stage at Tagging	# at BON	The Dalles	John Day	McNary	Priest Rapids	Rock Island	Rocky Reach	Wells	Tumwater	Ice Harbor	Conversion Rate BON to PIT Arrays on Spawning Ground (%)[12]
Okanagan	Juvenile	164	93.9	87.8	82.9	81.7	73.2	72.0	71.3	0.0	0.0	30.4
Wenatchee	Juvenile	100	91.0	90.0	87.0	83.0	71.0	14.0	10.0	66.0	0.0	19.0
Rock Island	Juvenile	78	100.0	100.0	90.0	85.0	85.0	55.0	55.0	25.0	0.0	21.9
Snake	Juvenile	5	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0	1.8
Bonneville	Adult	1848	95.0	92.1	90.4	84.9	77.3	65.0	63.7	11.2	0.4	14.4

Survival to Priest Rapids Dam was higher in 2022 (Table 11, Figure 15) than in 2021 (Table 9) for all groups. Sockeye tagged at Bonneville Dam had the highest survival to Priest Rapids Dam in 2022 (88.3% versus 58.4% in 2021) followed by Sockeye Salmon tagged as juveniles in the Okanagan Basin (87.1% versus 73.2%), Wenatchee Basin (81.9% versus 58.6%) and at Rock Island Dam (75.2% which was identical to 2021). Among Sockeye tagged as juveniles, there was a significant linear relationship between week at Bonneville and survival to Priest Rapids Dam for Sockeye Salmon tagged as juveniles in the Wenatchee Basin and at Rock Island Dam, but not for juveniles in the Okanagan Basin (Table 11).

[12] Spawning grounds refers to detection at or above OKC in the Okanagan, LWE or WTL in Wenatchee, or RFL in the Snake Basin.

Table 11. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2022 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Survival from Bonneville for Sockeye Salmon Tagged as Adults at Bonneville Dam					Sockeye Salmon Tagged as Juveniles Survival from Bonneville-Priest Rapids		
	The Dalles	John Day	McNary	Priest Rapids	Rock Island	Wenatchee (n=149)	Okanagan (n=31)	Rock Island (n=213)
23	100.0%	100.0%	100.0%	100.0%	100.0%	NA	NA	NA
24	96.8%	95.2%	95.2%	90.3%	82.3%	NA	NA%	100.0%
25	95.7%	92.5%	89.4%	84.5%	73.3%	100.0%	66.7%	100.0%
26	93.0%	90.3%	89.5%	85.3%	80.6%	84.1%	100.0%	86.2%
27	97.4%	96.3%	94.2%	93.2%	88.0%	84.5%	100.0%	89.4%
28	97.1%	96.0%	93.4%	90.1%	87.1%	83.3%	50.0%	78.3%
29	90.8%	89.2%	87.7%	86.9%	85.4%	100.0%	100.0%	80.0%
30	88.1%	85.8%	79.1%	70.9%	67.2%	16.7%	NA	100.0%
31	87.6%	81.0%	64.8%	36.2%	33.3%	50.0%	NA	33.3%
32	62.1%	55.2%	10.3%	3.4%	3.4%	0.0%	NA	0.0%
33	87.5%	75.0%	50.0%	12.5%	12.5%	NA	NA	NA
Composite[13]	**95.2%**	**93.5%**	**91.3%**	**88.3%**	**83.6%**	**81.9%**	**87.1%**	**75.2%**
p-value	**0.036**	**0.156**	**0.182**	**0.123**	**0.109**	**0.04**	**0.74**	**0.03**

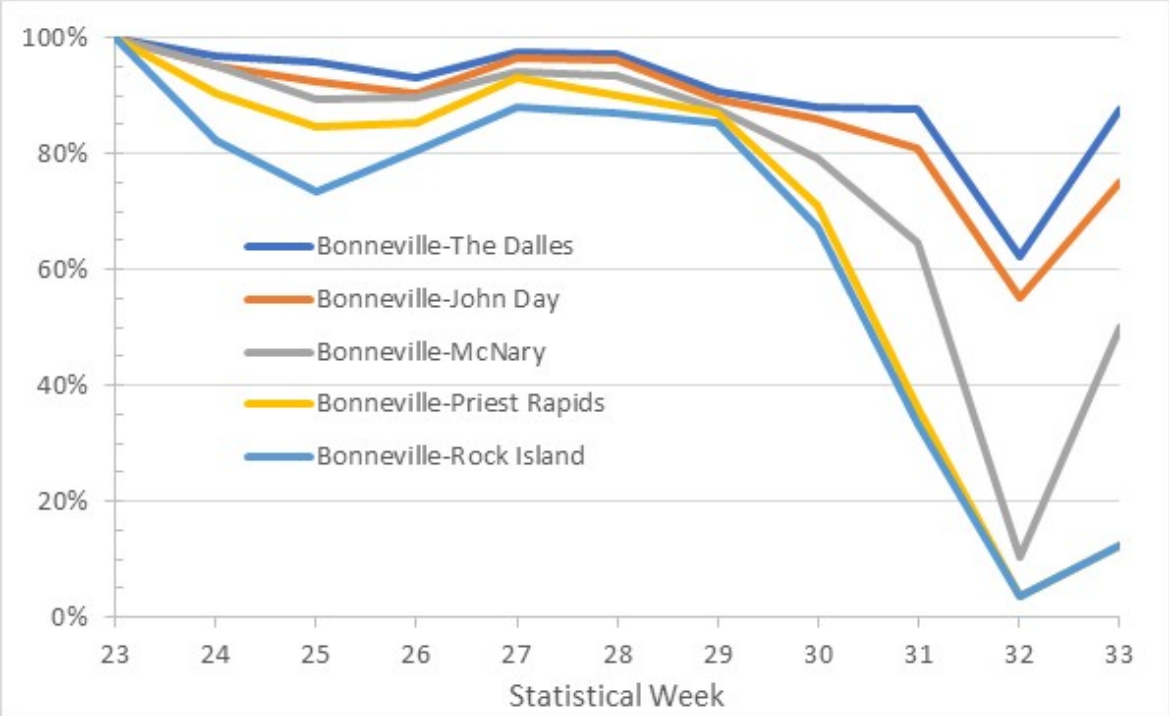

Figure 15. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, John Day, McNary, Priest Rapids, and Rock Island dams by statistical week in 2022.

[13] Composite estimates for Bonneville Dam Sockeye Salmon tagged as adults are weighted by statistical week, juvenile estimates are unweighted.

Sockeye Salmon tagged as juveniles in the Wenatchee Basin had the highest conversion from Bonneville Dam to the spawning ground arrays (47.0% vs 19.0% in 2021) followed by juveniles tagged in the Okanagan Basin (41.9% vs. 30.4%), juveniles tagged at Rock Island Dam (36.6% vs 21.9%), adults tagged at Bonneville Dam (34.2% vs 14.4%), and juveniles tagged in the Snake Basin (23.2% vs. 1.8%, Table 12).

Table 12. Survival of Sockeye Salmon groups PIT tagged as juveniles at different locations from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2022. Yellow shaded cells represent sites that are not on the migration route for the group tagged.

			Percent Survival to Upstream Dam									
Tagging Location	Life Stage at Tagging	# at BON	The Dalles	John Day	McNary	Priest Rapids	Rock Island	Rocky Reach	Wells	Tumwater	Ice Harbor	Conversion Rate BON to PIT Arrays on Spawning Ground (%)[14]
Okanagan	Juvenile	31	93.5	93.5	90.3	87.1	80.6	77.4	77.4	0.0	0.0	41.9
Wenatchee	Juvenile	149	94.6	94.6	89.3	81.9	71.8	66.4	6.0	61.1	0.0	47.0
Rock Island	Juvenile	213	94.8	93.9	89.2	86.4	81.2	79.8	39.9	38.0	0.0	36.6
Snake	Juvenile	155	91.6	91.0	85.8	12.9	11.0	10.3	10.3	0.0	63.2	23.2
Bonneville	Adult	1354	95.2	93.5	91.3	88.3	83.6	64.9	62.8	18.3	0.1	34.2

Migration Rates and Passage Time

Adult Sockeye Salmon traveled quickly upstream in 2021 with median migration rates between adjacent mainstem dams (which does not include Tumwater Dam) ranging between 29.7 and 48.8 km/day for adults tagged at Bonneville and 28.2 to 61.6 km/day for tagged juveniles returning as adults (Table 13).

[14] Spawning grounds refers to detection at or above OKC in the Okanagan, LWE or WTL in Wenatchee, or RFL in the Snake Basin.

Table 13. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2021.

		Adults Tagged at Bonneville Dam		Returning 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	1.6	46.3	1.2	61.6
The Dalles-John Day	39	0.8	48.8	0.8	48.9
John Day-McNary	63	2.1	30.0	2.1	30.5
McNary-Priest Rapids	167	4.0	41.8	3.9	43.2
Priest Rapids-Rock Island	89	3.0	29.7	3.0	29.3
Rock Island-Rocky Reach	33	1.1	30.0	1.2	28.2
Rocky Reach-Wells	65	1.9	34.2	2.0	33.0
Rock Island-Tumwater	73	10.0	7.3	9.3	7.8
Bonneville-John Day	113	2.4	47.1	2.0	55.2
Bonneville-McNary	231	4.7	49.1	4.2	55.4
Bonneville-Priest Rapids	329	8.8	37.4	8.0	40.9
Bonneville-Rock Island	487	12.0	40.6	11.4	42.9
Bonneville-Tumwater	560	22.8	24.6	21.1	26.5
Bonneville-Wells	585	15.0	39.0	14.8	39.4

Unlike most previous years, there was not a significant linear relationship (α=0.05) between the statistical week passing Bonneville Dam and travel time to upstream Columbia River dams (Table 14). The only significant relationship in Table 14 is from Bonneville and Wells dams to Zosel Dam. Median travel times between the Okanagan and Wenatchee stocks differed by 1.3 days or less for all dam pairs listed that are in the normal migration corridor for both stock while differences between males and females differed by 1.0 days or less. The nine Wenatchee-stock Sockeye Salmon which were detected at Wells Dam had longer migration times from Bonneville Dam to Rocky Reach and Wells dams than did Okanagan Sockeye Salmon on their usual migration route.

Table 14. Adult Sockeye Salmon tagged at Bonneville Dam median travel time in days between dam pairs by statistical week, 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 2021. Cells with yellow shading indicate travel outside the normal migration corridor for the stock in question. NA indicates no data between the two sites in question.

Statistical Week at Bonneville Dam	BON to TDA	BON to JDA	BON to MCN	BON to PRA	BON to RIA	BON to TUF	BON to RRF	BON to WEA	BON to ZSL	WEL to ZSL	RIA to TUF
23	1.7	2.9	4.7	11.9	16.5	NA	18.0	20.3	NA	NA	NA
24	1.8	2.7	4.8	10.8	14.8	NA	16.0	18.7	64.6	46.6	NA
25	1.7	2.6	4.8	9.6	12.9	24.8	14.1	15.9	58.4	42.9	10.6
26	1.5	2.3	4.7	8.6	11.6	21.3	12.5	14.4	52.0	37.8	8.9
27	1.5	2.2	4.7	8.0	11.2	23.1	12.1	14.0	45.4	31.5	10.6
28	1.4	2.2	4.4	8.9	12.0	20.9	12.6	14.6	37.5	22.5	8.1
29	1.7	2.6	4.8	9.0	13.0	25.5	12.9	15.2	31.0	16.6	12.1
30	1.9	3.0	6.0	31.4	34.9	49.6	13.0	14.6	21.4	9.3	14.7
p-value	**0.38**	**0.55**	**0.10**	**0.22**	**0.27**	**0.12**	**0.16**	**0.11**	**<0.01**	**<0.01**	**0.73**
Stock											
Okanagan	1.6	2.4	4.7	8.7	11.8	NA	12.9	15.0	50.7	36.2	NA
Wenatchee	1.6	2.3	4.8	9.1	13.1	22.8	15.4	17.8	NA	NA	10.0
Males	1.4	2.3	4.7	8.7	11.8	22.0	12.8	14.9	51.1	36.5	9.9
Females	1.7	2.6	4.8	8.9	12.2	23.0	13.1	15.1	50.1	35.6	10.3

The median passage time at a dam for Sockeye Salmon tagged at Bonneville Dam in 2021 was 19.5 minutes compared to 19.7 minutes for Sockeye Salmon tagged as juveniles (Table 15). Dams with the greatest times were those with more comprehensive networks of detection within ladders (e.g., Bonneville, McNary, Rock Island, and Lower Granite) or trapping activities which can slow migration (e.g., Bonneville, Priest Rapids, Tumwater, and Lower Granite). The one exception is the 578 minute median migration time for Sockeye tagged at Bonneville Dam passing Lower Monumental Dam due to two of four passing Sockeye falling back over this dam thus generating long passage times as estimated by the difference between first to last detection times.

Table 15. 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 2021.

	Adults Tagged at Bonneville Dam			Previously Tagged as Juveniles		
Dam	N	Median Passage (Minutes)	%>12 Hours	N	Median Passage (Minutes)	%>12 Hours
Bonneville	1378	72.8	12.8%	385	64.8	8.6%
The Dalles	1229	0.1	1.1%	337	0.1	1.5%
John Day	1130	1.0	8.6%	310	1.0	12.3%
McNary	680	0.4	2.5%	281	0.2	2.8%
Priest Rapids	801	9.1	2.4%	237	8.5	1.7%
Rock Island	740	28.0	0.7%	218	29.4	0.5%
Rocky Reach	579	5.8	2.1%	170	5.9	2.9%
Wells	547	8.3	5.3%	161	9.2	8.7%
Zosel	238	1.3	5.0%	79	3.8	7.6%
Tumwater	131	37.7	9.9%	40	36.8	7.5%
Ice Harbor	7	6.0	0.0%	25	4.3	16.0%
Lower Monumental	4	578.0	50.0%	18	1.2	5.6%
Little Goose	3	0.1	33.3%	18	0.1	11.1%
Lower Granite	3	163.4	0.0%	15	460.5	33.3%
Weighted Mean (by number of detections)		**19.5**	**5.3%**		**19.7**	**5.6%**

With higher flows, median migration travel times from Bonneville to upstream Columbia River dams were 0.2 to 1.0 days longer for adults and 0.2 to 2.2 days longer for returning Sockeye tagged as juveniles in 2022 than in 2021 (Table 13 and 16). Median migration rates between mainstem dams in 2022 (which does not include Tumwater Dam) ranged between 28.5 and 45.8 km/day for adults tagged at Bonneville and 28.2 to 45.5 km/day for tagged juveniles returning as adults (Table 16).

Table 16. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2022.

		Adults Tagged at Bonneville Dam		Returning 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	40.4	1.8	42.0
The Dalles-John Day	39	1.0	41.0	1.0	40.7
John Day-McNary	63	2.2	28.5	2.2	28.2
McNary-Priest Rapids	167	4.3	38.9	4.6	36.2
Priest Rapids-Rock Island	89	2.9	31.2	3.1	28.6
Rock Island-Rocky Reach	33	1.0	33.5	1.0	34.7
Rocky Reach-Wells	65	2.0	32.5	2.1	30.6
Rock Island-Tumwater	73	9.1	8.0	11.0	6.6
Bonneville-John Day	113	2.8	39.9	2.8	40.2
Bonneville-McNary	231	5.0	45.8	5.1	45.5
Bonneville-Priest Rapids	329	9.8	33.7	9.8	33.7
Bonneville-Rock Island	487	12.6	38.6	13.0	37.4
Bonneville-Tumwater	560	21.4	26.1	24.5	22.9
Bonneville-Wells	585	15.7	37.2	17.0	34.5

Unlike 2021, there was a significant linear relationship (α=0.05) between the statistical week passing Bonneville Dam and travel time to all upstream Columbia River dams (Table 17) except The Dalles and McNary dams. Median travel times between the Okanagan and Wenatchee stocks differed by 0.6 days or less for all dam pairs listed that are in the normal migration corridor for both stocks. The difference between males and females was 0.9 days or less to all mainstem dams; however, the median time for males to travel from Bonneville to Zosel Dam was 8.2 days greater, and Wells to Zosel 5.9 days greater, than females.

Table 17. Adult Sockeye Salmon tagged at Bonneville Dam median travel time in days between dam pairs by statistical week, 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 2022. Cells with yellow shading indicate travel outside the normal migration corridor for the stock in question. NA indicates no data between the two sites in question.

Statistical Week at Bonneville Dam	BON to TDA	BON to JDA	BON to MCN	BON to PRA	BON to RIA	BON to TUF	BON to RRF	BON to WEA	BON to ZSL	WEL to ZSL	RIA to TUF
23	1.8	3.5	5.7	16.5	21.2	NA	23.9	26.8	NA	NA	NA
24	2.2	4.1	11.7	19.0	22.7	37.4	23.9	26.6	29.8	5.2	18.1
25	2.4	4.7	8.0	14.7	18.1	33.9	19.1	21.9	25.4	4.6	16.5
26	2.0	3.1	5.8	10.7	13.7	29.0	14.7	16.9	23.3	4.5	13.8
27	1.9	2.9	5.0	9.8	12.7	23.0	13.7	15.2	41.9	24.9	10.2
28	1.7	2.7	4.8	8.8	11.1	19.6	12.0	13.9	54.7	40.2	7.7
29	1.7	2.6	4.7	8.5	10.9	17.8	11.8	13.6	42.2	28.8	6.1
30	1.7	2.7	4.7	7.8	10.0	16.2	10.9	13.1	39.7	26.3	7.0
31	1.7	2.6	4.8	8.0	10.9	20.4	11.9	13.5	36.1	23.4	9.1
32	1.9	2.9	5.8	11.1	14.1	NA	15.2	17.8	28.4	10.7	NA
33	2.0	3.0	5.0	9.1	11.6	NA	12.4	14.3	NA	NA	NA
p-value	**0.188**	**0.031**	**0.072**	**0.006**	**0.005**	**0.001**	**0.006**	**0.031**	**0.001**	**0.001**	**0.001**
Stock											
Okanagan	1.9	2.8	5.1	9.8	12.7	NA	13.7	15.8	40.0	24.1	NA
Wenatchee	1.8	2.8	4.9	9.2	12.2	21.4	13.0	15.1	NA	NA	21.4
Males	1.9	2.8	5.1	10.0	12.8	22.0	13.8	16.1	46.1	29.8	2.8
Females	1.8	2.8	4.9	9.6	12.1	21.1	13.0	15.2	37.9	22.9	2.8

The median passage time at a dam for Sockeye Salmon tagged at Bonneville Dam in 2022 was 9.1 minutes compared to 25.7 minutes for Sockeye Salmon tagged as juveniles (Table 18). Since this statistic was weighted by the number of fish detected at each site, this was attributable to the large number of Sockeye previously tagged as juveniles that passed Lower Granite Dam combined with the long median passage time at that dam. As in 2021, dams with the greatest median passage times were those with more comprehensive detection networks within ladders (e.g., Bonneville, McNary, Rock Island, and Lower Granite) or trapping activities which can slow migration (e.g., Bonneville, Priest Rapids, Tumwater, and Lower Granite).

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 2022.

	Adults Tagged at Bonneville Dam			Previously Tagged as Juveniles		
Dam	N	Median Passage (Minutes)	%>12 Hours	N	Median Passage (Minutes)	%>12 Hours
Bonneville	1337	12.5	1.2%	540	15.2	7.4%
The Dalles	1240	0.1	1.6%	506	0.1	1.8%
John Day	1190	0.0	3.6%	488	0.0	3.9%
McNary	1122	0.2	1.4%	471	0.2	2.5%
Priest Rapids	1088	9.0	3.0%	354	11.6	4.0%
Rock Island	1025	28.4	1.0%	323	26.0	2.2%
Rocky Reach	832	4.3	3.1%	154	5.1	3.9%
Wells	815	4.9	3.3%	136	4.3	8.8%
Zosel	218	65.8	15.1%	34	19.6	14.7%
Tumwater	184	22.8	4.9%	172	23.6	6.4%
Ice Harbor	1	2.7	0.0%	98	5.5	8.2%
Lower Monumental	1	0.1	0.0%	102	0.2	8.8%
Little Goose	1	0.1	0.0%	104	0.1	12.5%
Lower Granite	1	501.7	100.0%	103	626.0	44.7%
Weighted Mean (by detection number)		**9.1**	**2.6%**		**25.7**	**5.9%**

Night Passage

Okanagan Sockeye Salmon tagged at Bonneville Dam passed PIT tag antennas at night (2000-0400 hours) at a higher rate than Wenatchee Sockeye Salmon at all 6 Columbia River dams passed by both stocks on their typical migration route (Bonneville, The Dalles, John Day, McNary, Priest Rapids and Rock Island) for both 2021 and 2022 (Tables 19 and 20). Adults tagged at Bonneville passed dams at night at a higher rate than Sockeye Salmon tagged as juveniles at 7 out of 10 dams in both 2021 and 2022.

Table 19. Estimated Sockeye Salmon night passage (2000-0400) by stock at Columbia River, Zosel, and Tumwater dams in 2021. Dams outside the typical migratory corridor for the stock in question are shaded yellow.

Dam	Adults Tagged at Bonneville Dam			Sockeye Salmon Tagged as Juveniles
	All Adults	Okanagan	Wenatchee	
Bonneville	1.5%	1.9%	0.3%	5.1%
The Dalles	9.4%	9.7%	8.5%	6.5%
John Day	8.1%	8.8%	6.2%	8.7%
McNary	8.4%	8.6%	8.5%	7.1%
Priest Rapids	4.1%	5.2%	0.6%	3.8%
Rock Island	3.4%	3.8%	1.8%	4.1%
Rocky Reach	10.2%	10.1%	10.0%	8.2%
Wells	12.6%	12.9%	0.0%	9.9%
Tumwater	3.1%	NA	3.1%	2.5%
Zosel	42.0%	42.0%	NA	40.5%

Table 20. Estimated Sockeye Salmon night passage (2000-0400) by stock at Columbia River, Zosel, and Tumwater dams in 2022. Dams outside the typical migratory corridor for the stock in question are shaded yellow.

Dam	Adults Tagged at Bonneville Dam			Sockeye Salmon Tagged as Juveniles
	All Adults	Okanagan	Wenatchee	
Bonneville	0.7%	0.9%	0.0%	2.2%
The Dalles	10.1%	10.4%	8.6%	7.7%
John Day	5.0%	5.1%	4.6%	3.7%
McNary	6.8%	6.9%	6.0%	5.1%
Priest Rapids	2.8%	3.2%	1.4%	1.7%
Rock Island	4.3%	4.5%	3.5%	2.2%
Rocky Reach	6.3%	6.2%	7.1%	8.4%
Wells	11.5%	11.4%	22.2%	8.1%
Tumwater	2.7%	NA	2.7%	1.7%
Zosel	20.6%	20.6%	NA	26.5%

Fallback

Fallback rates at mainstem Columbia River dams for adults tagged at Bonneville Dam in 2021 ranged from 0.4% at Bonneville Dam to 5.7% at John Day Dam while among returning Sockeye Salmon tagged as juveniles, the range was from 0.5% at Rock Island Dam to 6.9% at John Day Dam (Table 21).

Table 21. Estimated minimum fallback rates for Sockeye Salmon at dams in 2021[15]. The sample size (n) is the number of tagged Sockeye Salmon detected moving upstream past Bonneville Dam. Dams outside the typical migratory corridor for the stock in question are shaded yellow. NA indicates Sockeye Salmon were not detected at a dam outside the range of the particular stock.

Dam	Tagged as Adults	Tagged as Juveniles by Tagging Location				
	Bonneville AFF (n=1400)	Okanagan Basin (n=164)	Rock Island Dam (n=101)	Snake Basin (n=55)	Wenatchee Basin (n=51)	Total (n=371)
Bonneville	0.4%	1.2%	0.0%	12.7%	0.0%	2.4%
The Dalles	2.2%	2.6%	4.3%	25.6%	0.0%	5.8%
John Day	5.7%	6.3%	7.9%	11.4%	2.7%	6.9%
McNary	0.5%	0.0%	2.3%	0.0%	3.0%	1.1%
Priest Rapids	1.6%	0.8%	2.5%	0.0%	3.3%	1.7%
Rock Island	1.2%	0.9%	0.0%	0.0%	0.0%	0.5%
Rocky Reach	1.9%	0.0%	4.0%	0.0%	25.0%	1.8%
Wells	0.7%	0.0%	4.2%	0.0%	0.0%	1.2%
Tumwater	2.3%	NA	0.0%	NA	6.3%	2.6%
Zosel	4.2%	1.7%	4.8%	NA	NA	2.5%
Skaha	0.0%	33.3%[16]	0%	NA	NA	33.3%
Ice Harbor	14.3%	0%	NA	4.0%	NA	4.0%
Lower Monumental	25.0%	0%	NA	0.0%	NA	0.0%
Little Goose	33.3%	0%	NA	33.3%	NA	33.3%
Lower Granite	0.0%	0%	NA	13.3%	NA	13.3%

Of the 134 Sockeye Salmon tagged as adults by this project in 2021 which fell back over at least one dam, 14 fell back over two dams and 3 fell back over three dams (Table 22). Among Sockeye Salmon tagged as juveniles, the mean number of fallback events per Sockeye Salmon ranged from 0.10 for Sockeye Salmon tagged in the Wenatchee (n=51) to 0.56 for those tagged in the Snake Basin (n=55) compared to 0.11 for adult-tagged Sockeye Salmon in our Bonneville study (Table 14).

[15] Does not include Sockeye Salmon that fell back over a dam and were not subsequently detected.
[16] Only three juvenile-tagged Sockeye salmon passed upstream of Skaha Dam, one of which fell back and was detected a second time.

Table 22. Number of fallback events by tag group for returning Sockeye Salmon tagged as juveniles and as adult Sockeye Salmon included in our Bonneville adult tagging study in 2021.

Fallback Events	Sockeye Salmon Tagged as Adults	Sockeye Salmon Tagged as Juveniles by Tagging Location				
	Bonneville Dam AFF	Okanagan Basin	Rock Island Dam	Snake Basin	Wenatchee Basin	Total
1	117	17	17	10	5	49
2	14	1	0	1	0	2
3	3	0	1	0	0	1
5	0	0	0	2	0	2
9	0	0	0	1	0	1
Number of Sockeye Salmon falling back at least once	**134**	**18**	**18**	**14**	**5**	**55**
% of Sockeye Salmon with at least one fallback event	**9.7%**	**11.0%**	**17.8%**	**25.5%**	**9.8%**	**14.8%**
Total fallback events	**154**	**19**	**20**	**31**	**5**	**75**
Number of Sockeye Salmon detected at or upstream of Bonneville Dam	**1378**	**164**	**101**	**55**	**51**	**371**
Mean fallbacks events per Sockeye Salmon	**0.11**	**0.12**	**0.20**	**0.56**	**0.10**	**0.20**

Fallback rates at mainstem Columbia River dams for adults tagged at Bonneville Dam in 2022 ranged from 0.4% at McNary Dam to 3.0% at John Day Dam while among 548 returning Sockeye Salmon tagged as juveniles, the range was from 0.2% at McNary Dam to 8.1% at Wells Dam (Table 23). Higher rates were estimated for returning juveniles passing Ice Harbor and Lower Granite dams.

Table 23. Estimated minimum fallback rates for Sockeye Salmon at dams in 2022[17]. The sample size (n) is the number of tagged Sockeye Salmon detected moving upstream past Bonneville Dam. Dams outside the typical migratory corridor for the stock in question are shaded yellow. NA indicates Sockeye Salmon were not detected at a dam outside the range of the particular stock.

Dam	Tagged as Adults	Tagged as Juveniles by Tagging Location				
	Bonneville AFF (n=1354)	Okanagan Basin (n=31)	Rock Island Dam (n=213)	Snake Basin (n=155)	Wenatchee Basin (n=149)	Total (n=548)
Bonneville	0.7%	12.9%	3.3%	3.9%	5.4%	4.7%
The Dalles	2.9%	0.0%	2.5%	2.8%	1.6%	2.4%
John Day	3.0%	0.0%	6.0%	2.8%	3.5%	4.1%
McNary	0.4%	0.0%	0.0%	0.8%	0.0%	0.2%
Priest Rapids	1.9%	0.0%	1.1%	5.0%	1.6%	1.4%
Rock Island	2.8%	0.0%	1.7%	5.9%	3.7%	2.5%
Rocky Reach	0.5%	0.0%	2.4%	0.0%	12.1%	2.5%
Wells	1.0%	0.0%	5.9%	0.0%	66.7%	8.1%
Tumwater	0.5%	NA	3.7%	NA	0.0%	2.9%
Zosel	6.0%	0.0%	5.9%	NA	NA	3.7%
Skaha	4.9%	0.0%	12.5%	NA	NA	8.3%
Ice Harbor	0.0%	NA	NA	8.2%	NA	8.2%
Lower Monumental	0.0%	NA	NA	2.9%	NA	2.9%
Little Goose	0.0%	NA	NA	1.0%	NA	1.0%
Lower Granite	0.0%	NA	NA	23.3%	NA	23.3%

Of the 143 Sockeye Salmon tagged as adults by this project in 2022 which fell back over at least one dam, 18 fell back over two dams and 1 fell back over four dams (Table 24). Among Sockeye Salmon tagged as juveniles, the mean number of fallback events per Sockeye Salmon ranged from 0.13 for Sockeye Salmon tagged in the Okanagan to 0.34 for those tagged in the Snake Basin compared to 0.12 for adult-tagged Sockeye Salmon in our Bonneville study (Table 24).

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

Table 24. Number of fallback events by tag group for returning Sockeye Salmon tagged as juveniles and as adult Sockeye Salmon included in our Bonneville adult tagging study in 2022.

Fallback Events	Sockeye Salmon Tagged as Adults	Sockeye Salmon Tagged as Juveniles by Tagging Location				
	Bonneville Dam AFF	Okanagan Basin	Rock Island Dam	Snake Basin	Wenatchee Basin	Total
1	124	4	32	27	26	87
2	18	0	6	10	6	33
3	0	0	0	2	1	4
4	1	0	0	0	0	0
Number of Sockeye Salmon falling back at least once	**143**	**0**	**38**	**39**	**33**	**124**
% of Sockeye Salmon with at least one fallback event	**10.5%**	**12.9%**	**17.8%**	**25.6%**	**22.1%**	**22.6%**
Total fallback events	**164**	**0**	**44**	**53**	**41**	**165**
Number of Sockeye Salmon detected at or upstream of Bonneville Dam	**1365**	**31**	**213**	**155**	**149**	**548**
Fallbacks events per Sockeye Salmon	**0.12**	**0.13**	**0.21**	**0.34**	**0.28**	**0.30**

Stock Composition Estimates

AFF Sample

In both 2021 and 2022, Genetic Stock Identification (GSI) and Parental Based Tagging (PBT) were used to classify tissue samples from all Sockeye Salmon. Results of samples collected at Bonneville Dam in 2021are compared in Table 25. There was one Sockeye on June 24, 2021) classified by GSI as being of Okanagan stock last detected in the Wenatchee River. However, the next Sockeye Sampled was classified by a GSI as being a Wenatchee Sockeye stock last detected at Wells Dam, suggesting the likelihood of a sample mix-up. Therefore, both GSI samples were removed from further analysis.

In 2021, stock composition estimates concurred for 383 out of 385 (99.5%) Sockeye for which both PIT Tag and GSI stock could be derived (Table 25). One exception was 3DD.003D82A408 which was identified by GSI as Okanagan origin was tagged June 24, 2021, and subsequently detected at the upstream the White River upstream array (WTL) September 15. Twelve Sockeye Salmon were

classified as being of Snake River origin, however, only two of these were last detected at or above Lower Granite Dam. Six Snake River Sockeye were last detected at Bonneville Dam and one each at The Dalles, John Day, and McNary dams with one not detected after release.

Table 25. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2021. Green shading indicates agreement between the two methods orange indicates disagreement. Yakima Sockeye Salmon are primarily from Okanagan and Wenatchee broodstock thus no determination on agreement could be made for Sockeye Salmon returning to the Yakima River that were classified by GSI as being of Okanagan or Wenatchee origin.

Stock Estimated Using PIT Tags	Stock Estimated by Genetics (PBT or GSI)					
	Okanagan	Wenatchee	Snake	Yakima	Unknown[18]	Total
Okanagan	244				3	**247**
Wenatchee	1	138			1	**140**
Snake	0		2	1		**3**
Unknown[19]	812	267	11	17	5	**1072**
Total	**1057**	**405**	**13**	**18**	**9**	**1502**

Three Sockeye Salmon were last detected in the Yakima River, all at Roza Dam and all were previously detected at the Priest Rapids fish trap and are presumed to have been transported to Cle Elum Lake. They then moved downstream where they were detected at Roza Dam (ROZ). All three were classified by GSI as being of Okanagan stock.

Among the 18 Sockeye classified by PBT as being of Yakima origin, none were detected in the Yakima River (Table 26). Twelve were last detected in the Columbia River downstream of the confluence with the Snake River (4 at Bonneville, 3 at John Day, and 5 at McNary) while 3 were detected upstream of the Yakima River in the Columbia Basin (1 each at Priest Rapids Dam, Rocky Reach Dam, and the Methow River) and 3 in the Snake River (2 at Ice Harbor and 1 in the Clearwater River.) The Sockeye last detected in the Clearwater River (3DD.003D82A3C4) passed McNary Dam June 29, Priest Rapids Dam on July 3, Priest Rapids again on July 15, and Ice Harbor Dam on July 19 before proceeding up the Snake River. This behavior suggests that the fish may have been waiting

[18] Either no genetics sample available, the sample did not classify to a particular stock, or GSI data removed by a suspected data collection error.
[19] No PIT tag or not detected in terminal area (at or upstream of OKL, LWN, PRO, or GRA or upstream of DRM). This also includes 20 Sockeye Salmon sampled on 6/23 where there was a suspected mix up of genetics samples.

for the Yakima River to cool off and eventually gave up and moved up the Snake River.

Table 26. Final stock classification of Sockeye Salmon by using GSI, PBT, and last detection area/site for Sockeye Salmon PIT tagged at Bonneville Dam in 2021.

Area (Site) of Last Detection	Final Stock Classification Using GSI, PBT, and Last PIT Tag Detection as described in This Report					
Non-Terminal Areas	**Okanagan**	**Wenatchee**	**Snake**	**Yakima**	**Unknown[20]**	**Total**
Bonneville (BCC, BO1, BO2, BO3, BO4)	166	57	6	4	2	235
The Dalles (TD1, TD2)	46	34	1	0	0	81
John Day Dam (JO1, JO2, JDJ)	108	85	1	3	0	197
McNary Dam (MC1, MC2, MCJ)	100	44	1	5	0	150
Priest Rapids Dam (PRA, PRH, RSH)	40	17	0	1	0	58
Rock Island Dam (RIA)	18	5	0	0	0	23
Rocky Reach Dam (RRF, RRJ)	8	1	0	1	0	10
Entiat River (ENL)	2	0	0	0	0	2
Wells Dam (WEA,WEJ)	289	4	0	0	3	296
Wells Hatchery (WEH)	1	0	0	0	0	1
Methow River (LMR, MRC)	0	0	0	1	0	1
Snake River below GRA (ICH, LMA)	1	0	1	2	0	4
Yakima River (ROZ but not detected at PRO)	3	0	0	0	0	3
Terminal Areas						
Wenatchee River (ICL, LWE, LWN, TUF, UWE, WTL)	0	153	0	0	1	154
Okanagan River (LLC, OKC, OKL, OKM, OKP, OKS, SKA, ZSL)	254	0	0	0	0	254
Snake River above GRA (GRA, LRU)	0	0	2	1	0	3
Fish Not Part of Analysis						
No Tag or Tag Not Subsequently Detected	23	5	1	0	1	30
Total	**1059**	**405**	**13**	**18**	**7**	**1502**

In 2022, as in 2021, there was high concurrence between PIT tag and GSI stock classifications with 624 out of 625 (99.8%) being classified similarly (Table 27). The sole exception was a Sockeye classified by GSI as Wenatchee stock last detected in the lower Okanagan River at OKL (3DD.003DEAAE). This fish was tagged at Bonneville Dam on July 29, passed Wells Dam on August 20, and was detected moving upstream at OKL on September 1.

[20] Either no genetics sample available or the sample did not classify to a particular stock.

Table 27. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2022. Green shading indicates agreement between the two methods, orange indicates the stock estimates differed.

Stock Estimated Using PIT Tags	Stock Estimated by Genetics (PBT or GSI)				
	Okanagan	Wenatchee	Snake	Unknown[21]	Total
Okanagan	433	1	0	1	**435**
Wenatchee	0	190	0	0	**190**
Snake	0	0	1	0	**1**
Unknown[22]	668	75	3	4	**750**
Total	**1101**	**266**	**4**	**5**	**1376**

No Sockeye were classified by PIT or GSI as being of Yakima stock. There were two Sockeye Salmon last detected in the Yakima River, one at Roza Dam (ROZ) and the other at the Sunnyside Diversion (SSJ, Table 28). However, as with the one Sockeye detected in the Yakima River in 2021, both of these fish were detected at the Priest Rapids Dam fish trap and likely transported to Cle Elum Lake, before migrating downstream to ROZ and SSJ. As with the 2021 Yakima Sockeye, both fish were classified by GSI as being of Okanagan stock.

Among the four Sockeye classified by GSI as being Snake River origin, one was last detected at Bonneville Dam (BO4), one at McNary Dam (MC1), and one at Lower Granite Dam (GRA) with a fourth not detected after release.

No Sockeye Salmon were classified as Deschutes stock in either 2021 nor 2022, nor were any Sockeye Salmon last detected in the Deschutes River.

Two Sockeye were last detected in the Entiat Basin in both 2021 and 2022. In 2021 these classified as Okanagan Stock, while in 2022 they classified as Wenatchee Stock. One Sockeye was last detected in the Methow Basin in 2021, the aforementioned Sockeye of Yakima origin. Again in 2022, one Sockeye was last detected in the Methow Basin, this time of Wenatchee origin.

[21] Either no genetics sample available, the sample did not classify to a particular stock, or GSI data removed by a suspected data collection error.
[22] No PIT tag or not detected in terminal area (at or upstream of OKL, LWN, PRO, or ICH or upstream of DRM). This also includes 20 Sockeye Salmon sampled on 6/23 where there was a suspected mix up of genetics samples.

Table 28. Final stock classification of Sockeye Salmon by using GSI, PBT, and last detection area/site for Sockeye Salmon PIT tagged at Bonneville Dam in 2022.

Area (Site) of Last Detection	Final Stock Classification Using GSI, PBT, and Last PIT Tag Detection as Described in This Report					
Non-Terminal Areas	**Okanagan**	**Wenatchee**	**Snake**	**Yakima**	**Unknown[23]**	**Total**
Bonneville (B2J, BCC, BO1, BO3, BO4)	75	20	1	0	2	98
The Dalles (TD1, TD2)	27	5	0	0	0	32
John Day Dam (JO1, JO2, JDJ)	44	17	0	0	0	61
McNary Dam (MC1, MC2, MCJ)	62	15	1	0	0	78
Ringold Hatchery (RSH)	1	0	0	0	0	1
Priest Rapids Dam (PRA)	52	9	0	0	0	61
Rock Island Dam (RIA)	7	1	0	0	0	8
Rocky Reach Dam (RRF, RRJ)	14	0	0	0	0	14
Entiat River (ENA, ENL)	0	2	0	0	0	2
Methow River (TWR)	0	1	0	0	0	1
Wells Dam (WEA)	369	4	0	0	1	374
Yakima River (ROZ but not detected at PRO)	1	0	0	0	0	1
Terminal Areas						
Wenatchee River (ICL, LWE, LWN, TUF, UWE, WTL)	0	190	0	0	0	190
Okanagan River (OKC, OKL, OKM, OKP, OKV, SKA, ZSL)	434	1[24]	0	0	0	435
Snake River above GRA (GRA, SSJ)	1	0	1	0	0	2
Yakima River (ROZ, SSJ)	2	0	0	0	0	2
Fish Not Part of Analysis						
No Tag or Tag Not Subsequently Detected	15	1	1	0	0	17
Total	**1104**	**266**	**4**	**0**	**3**	**1377**

Among the 163 Sockeye Salmon classified as Wenatchee stock detected passing Rock Island Dam in 2021 (Table 26)[25], 20 (12.3%) were next detected at Rocky Reach Dam with 7 (4.3%) also detected at Wells Dam. Of the 20 Sockeye bypassing the Wenatchee River, 15 were subsequently detected in the Wenatchee River with 5 last detected on the spawning grounds (4 at WTL and 1 and LWN), another 4 last detected at Tumwater Dam (TUF) and 6 last detected downstream of Tumwater (2 at ICL and 4 at LWE).

[23] Either no genetics sample available or the sample did not classify to a particular stock.
[24] Last detected at OKL in the lower Okanagan River.
[25] 153 last detected in the Wenatchee River plus 5 last detected at RIA, 1 at RRF, and 4 at Wells Dam equals 163.

In 2022, of the 199 Sockeye Salmon classified as Wenatchee stock detected at Rock Island Dam, 14 (7.0%) overshot the Wenachee River and were detected at Rocky Reach Dam and 9 (4.5%) were detected at Wells Dam (Table 28). Of these overshoots, 6 eventually returned to the Wenatchee River with 5 detected on the spawning grounds (4 at WTL and 1 at LWN), and 1 last detected at Tumwater Dam. One Sockeye classified as Wenatchee stock was last detected at OKL at Okanagan River km 25. Straying of Okanagan Stock Sockeye Salmon into the Okanagan River has been a very rare occurrence in this study.

When combining PIT and GSI stock determinations as described in the methods, this study estimated that the stock composition at Bonneville Dam in 2021 was 69.4% Okanagan, 28.4% Wenatchee, 0.9% Snake and 1.3% Yakima (Table 29 and Figure 16). Using only PIT tag detections of Sockeye Salmon last detected in terminal areas resulted in a stock composition of 61.0% Okanagan, 38.4% Wenatchee, 0.6% Snake and 0.0% Yakima. Using visual fish counts at dams to estimate Okanagan stock abundance relative to the Wenatchee yielded a higher percentages of 72.1 to 74.8% (Table 29).

There was a significant linear relationship between statistical week and the percentage for all four stocks with the Okanagan Stock showing a decrease over week while the other stocks showed an increase (Table 29 and Figure 16).

Table 29. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2021 with a comparison to stock composition estimated using visual dam counts as well as using only PIT tags and only GSI.

Statistical Week at Bonneville Dam	N	% of Sockeye Salmon Run	% Okanagan	% Wenatchee	% Snake	% Yakima
23	19	0.1%	100.0%	0.0%	0.0%	0.0%
24	109	1.8%	100.0%	0.0%	0.0%	0.0%
25	290	6.5%	87.3%	12.7%	0.0%	0.0%
26	331	33.2%	76.4%	21.6%	1.0%	1.0%
27	390	31.1%	68.2%	29.4%	0.7%	1.7%
28	121	17.7%	53.0%	44.6%	1.0%	1.5%
29	264	6.8%	62.8%	34.7%	1.0%	1.5%
30-32	142	2.7%	65.0%	31.3%	2.5%	1.3%
Combined PIT and GSI Estimate	**1502**		**69.4%**	**28.4%**	**0.9%**	**1.3%**
Standard Error			**0.012**	**0.012**	**0.003**	**0.013**
PIT Tag Only Estimate	**390**		**61.0%**	**38.4%**	**0.6%**	**0.0%**
GSI Only Estimate	**1056**		**69.6%**	**28.2%**	**0.9%**	**1.3%**
P value for linear relationship between combined stock composition estimate and Statistical Week			**0.002**	**0.002**	**0.004**	**0.011**
Visual Fish Counts at dams[26]			74.8%	24.2%	0.9%	0.1%
Visual Fish Counts at dams[27]			72.1%	26.9%	0.8%	0.1%

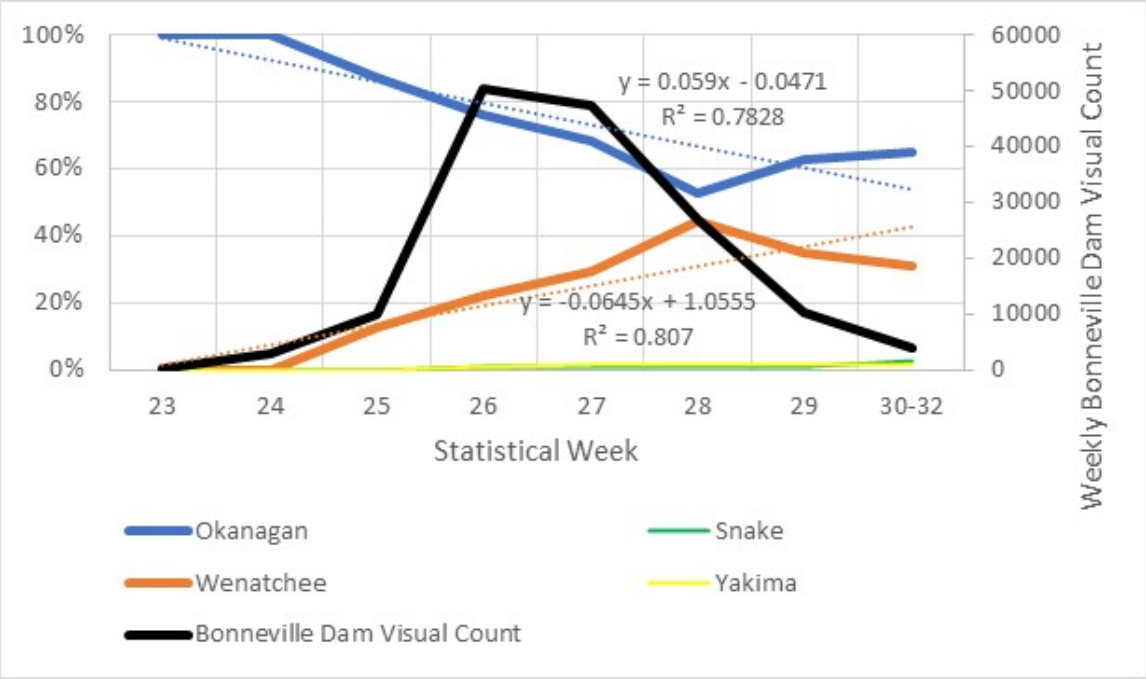

Figure 16. Percentage of the Sockeye Salmon run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, Yakima, and Snake origin using genetics and PIT tag data by week in 2021.

[26] Using difference between counts at Rock Island and Rocky Reach to estimate proportion Wenatchee escapement; count at Rocky Reach is used to estimate Okanagan escapement.
[27] Using Tumwater count to estimate proportion Wenatchee escapement; count at Rocky Reach is used to estimate Okanagan escapement.

When combining PIT and GSI stock determinations as described in the methods, this study estimated that the stock composition at Bonneville Dam in 2022 was 77.4% Okanagan, 22.2% Wenatchee, 0.4% Snake (Table 30 and Figure 17). Using only PIT tag detections of Sockeye Salmon last detected in terminal areas resulted in a stock composition of 77.0% Okanagan (Table 30), 22.8% Wenatchee, 0.1% Snake. Using visual fish counts at dams to estimate Okanagan stock abundance relative to the Wenatchee yielded a higher percentages.

Table 30. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2022 with a comparison to stock composition estimated using visual dam counts as well as using only PIT tags and only GSI.

Statistical Week at Bonneville Dam	N	% of Sockeye Salmon Run	% Okanagan	% Wenatchee	% Snake
23	3	0.1%	100.0%	0.0%	0.0%
24	66	1.1%	95.5%	4.5%	0.0%
25	165	4.2%	92.1%	7.9%	0.0%
26	259	25.5%	84.6%	15.1%	0.4%
27	193	43.1%	70.5%	29.0%	0.5%
28	277	14.8%	79.4%	20.6%	0.0%
29	172	6.4%	79.5%	20.5%	0.0%
30	135	3.3%	77.8%	20.7%	1.5%
31	73	1.2%	70.2%	29.8%	0.0%
32	20	0.2%	66.7%	33.3%	0.0%
33	6	0.1%	75.0%	25.0%	0.0%
Combined PIT and GSI Estimate	**1412**		**77.4%**	**22.2%**	**0.4%**
Standard Error			**1.6%**	**1.6%**	**0.4%**
P value for linear relationship between combined stock composition estimate and Statistical Week			**<0.001**	**<0.001**	**0.747**
PIT Tag Only Estimate	**390**		**77.0%**	**22.8%**	**0.1%**
GSI Only Estimate	**1056**		**77.4%**	**22.2**	**0.4%**
Visual Fish Counts at dams[28]			85.2%	14.7%	0.1%
Visual Fish Counts at dams[29]			80.2%	19.7%	0.1%

[28] Using difference between counts at Rock Island and Rocky Reach to estimate proportion Wenatchee escapement; count at Rocky Reach is used to estimate Okanagan escapement.
[29] Using Tumwater count to estimate proportion Wenatchee escapement; count at Rocky Reach is used to estimate Okanagan escapement.

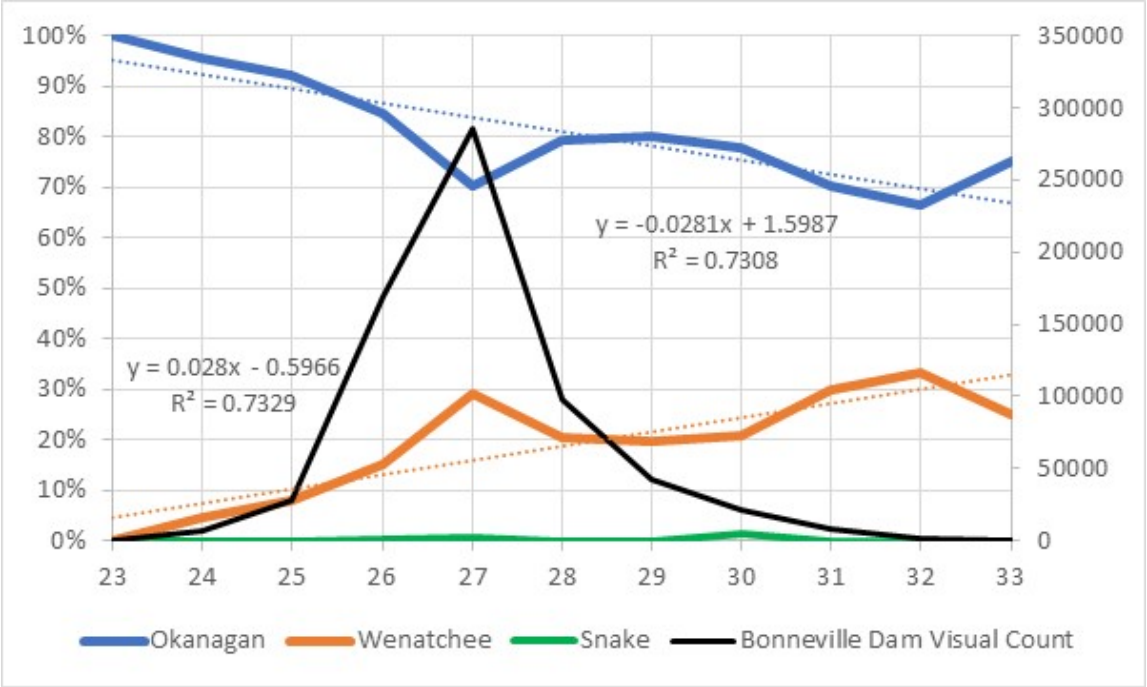

Figure 17. Percentage of the Sockeye Salmon run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, and Snake origin using genetics and PIT tag data by week in 2021.

There were 11 adipose fin clipped Sockeye Salmon sampled at Bonneville Dam in 2021, 7 of which were identified using GSI as Snake River Sockeye Salmon, 2 as Wenatchee and 2 as Okanagan stock (Table 31). There were 4 adipose clipped Sockeye Salmon sampled at Bonneville Dam in 2022, 3 of which were classified by GSI as being of Snake River origin and 1 of Okanagan origin. Of the 8 Sockeye in both years classified as Snake River, only 3 were last detected in the Snake Basin (all at GRA). While hatchery-origin Snake River Sockeye Salmon are adipose clipped, there is no known adipose clipping program elsewhere in the Columbia Basin.

Table 31. Sample Date, PIT tag, last site, and GSI classification of adipose clipped Sockeye Salmon sampled in 2021 and 2022.

Date Sample	Week	PIT Tag	Last Site	GSI
2021				
6/17/21	25	3DD.003D8299FF	Okanagan Channel (OKC)	Okanagan
6/21/21	26	3DD.003D82999D	Bonneville Dam (BO4)	Wenatchee
6/23/21	26	3DD.003D8295FC	McNary Dam (MC1)	Okanagan
6/24/21	26	3DD.003D82A3DA	McNary Dam (MC1)	Snake
6/24/21	26	3DD.003D82A402	Lower Granite Dam (GRA)	Snake
6/24/21	26	3DD.003D82A3D3	Lower Granite Dam (GRA)	Snake
6/30/21	27	3DD.003D8295F5	The Dalles Dam (TD1)	Snake
7/7/21	28	3DD.003D829474	Bonneville Dam (BO1)	Snake
7/13/21	29	3DD.003D82A57E	The Dalles Dam (TD1)	Wenatchee
7/14/21	29	3DD.003D82A566	Bonneville Dam (BO4)	Snake
7/21/21	30	3DD.003D82953A	Bonneville Dam (BO4)	Snake
2022				
6/21/2022	26	3DD.003DEAB3E2	Lower Granite Dam (GRA)	Snake
7/18/22	30	3DD.003DEAB6CC	McNary Dam (MC1)	Snake
7/21/22	30	3DD.003DEAB00D	Bonneville Dam (BO4)	Snake
7/22/22	30	3DD.003DEAAC8D	Okanagan Channel (OKC)	Okanagan

Stock Specific Upstream Survival

For 2021, upstream survival of Okanagan Sockeye Salmon to Rock Island Dam was higher than the Wenatchee stock (58.1% vs. 42.4%), however survival to the spawning area was lower (18.0% vs. 22.0%, Table 32). For 2022, survival to Rock Island Dam was considerably higher than 2021, 83.0% for the Okanagan stock and 85.9% for the Wenatchee stock (Table 33). Survival to the spawning grounds was 24.3% for the Okanagan stock and 68.6% for the Wenatchee stock.

Table 32. Stock specific survival from Bonneville Dam weighted by estimated stock-specific weekly Bonneville Dam run size, as estimated by GSI and PIT tags for Okanagan, Wenatchee and combined Sockeye Salmon tagged at Bonneville Dam in 2021.

	Estimated Survival from Bonneville Dam by Stock (%)						
	Okanagan (n=967)			Wenatchee (n=393)			Combined (n=1360)
Statistical Week	Rock Island Dam	Zosel Dam	Okanagan Spawning (OKC)	Rock Island Dam	Tumwater Dam	Wenatchee Spawning (LWE or WTL)	Okanagan/ Wenatchee Spawning (LWE, WTL, OKC)
23	83.3%	0.0%	0.0%	NA	NA	NA	73.7%
24	87.1%	21.0%	11.3%	NA	NA	NA	51.0%
25	84.1%	25.4%	15.9%	100.0%	95.0%	70.0%	43.4%
26	77.9%	33.9%	24.6%	74.7%	70.9%	45.6%	41.0%
27	53.3%	25.8%	17.9%	45.2%	31.3%	19.1%	41.7%
28	25.8%	16.1%	9.7%	13.6%	9.1%	5.7%	42.9%
29	25.0%	15.7%	10.2%	18.2%	13.6%	6.1%	36.5%
30-33	4.4%	2.2%	0.0%	20.8%	4.2%	4.2%	25.9%
Total	**58.1%**	**26.0%**	**18.0%**	**42.4%**	**34.6%**	**22.0%**	**19.1%**

Table 33. Stock specific survival from Bonneville Dam weighted by estimated stock-specific weekly Bonneville Dam run size, as estimated by GSI and PIT tags for Okanagan, Wenatchee and combined Sockeye Salmon tagged at Bonneville Dam in 2022.

	Estimated Survival from Bonneville Dam by Stock (%)						
	Okanagan (n=1085)			Wenatchee (n=264)			Combined (n=1349)
Statistical Week	Rock Island Dam	Zosel Dam	Okanagan Spawning (OKC)	Rock Island Dam	Tumwater Dam	Wenatchee Spawning (LWE or WTL)	Okanagan/ Wenatchee Spawning (LWE, WTL, OKC)
23-24	82.3%	43.5%	37.1%	100.0%	100.0%	100.0%	39.4%
25	75.2%	40.3%	38.9%	50.0%	50.0%	33.3%	38.5%
26	80.3%	36.2%	31.7%	84.6%	84.6%	64.1%	36.4%
27	87.4%	34.1%	22.2%	89.3%	85.7%	73.2%	37.2%
28	87.5%	38.0%	17.6%	85.7%	78.6%	69.6%	28.3%
29	83.5%	46.6%	17.5%	92.6%	81.5%	66.7%	27.7%
30	68.3%	44.2%	10.6%	67.9%	57.1%	50.0%	18.7%
31	27.4%	13.7%	9.6%	48.4%	38.7%	32.3%	16.2%
32	5.3%	5.3%	5.3%	0.0%	0.0%	0.0%	3.4%
33	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	**83.0%**	**36.6%**	**24.3%**	**85.9%**	**81.8%**	**68.6%**	**34.2%**

Wells Dam Sampling

A total of 355 Sockeye Salmon were sampled at the Wells Dam east bank fish ladder in 2021 (Table 34), 7 of which were recaptures of previously PIT-tagged Sockeye. The number of PIT-tagged Sockeye Salmon detected and tracked was 321. In 2022, a total of 360 Sockeye Salmon were sampled, 3 of which were previously PIT tagged (Table 35). In 2022, 92 temperature tags were deployed, and the number of Sockeye Salmon detected and tracked was 358. No temperature tags were recovered which was necessary to download data.

Table 34. Number of Sockeye Salmon sampled, and PIT tagged at Wells Dam by date and statistical week in 2021.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	PIT-Tagged Sockeye Salmon Released	Tracked
6/29	27	2	2	0	2	2
7/6,7/8	28	137	135	2	137	129
7/12,7/13	29	99	97	2	99	93
7/19,21	30	79	77	2	79	67
7/26,27	31	35	34	1	35	27
8/2	32	3	3	0	3	3
Total		**355**	**348**	**7**	**355**	**321**

Table 35. Number of Sockeye Salmon sampled, and PIT tagged at Wells Dam by date and statistical week in 2022.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	PIT-Tagged Sockeye Salmon Released	Temperature Tagged	Tracked no temp tags	Tracked with temp tags	Total Tracked
6/27,6/28	27	22	20	2	22	0	21	0	21
7/5,7/8	28	148	147	1	148	0	148	0	148
7/11-7/12	29	70	70	0	70	10	59	10	69
7/18,7/21	30	60	60	0	60	24	36	24	60
7/25,26	31	46	46	0	46	44	2	44	46
8/4	32	14	14	0	14	14		14	14
Total		**360**	**348**	**3**	**360**	**92**	**266**	**92**	**358**

Age composition in 2021 was estimated as 46.2% Age 1.2, 42.4% Age 1.3, and 11.1% Age 1.1 (Table 36) while in 2022 it was 89.9% Age 1.2, 6.5% Age 1.3, and 2.0% Age 1.1 (Table 37)[30] for Sockeye sampled at Wells Dam. For the first time in 2021 and 2022, sex was estimated from analysis of genetics samples rather than from visual assessments which were part of the Wells Dam sampling protocol. The estimated percentage of the run at Wells Dam that was females in 2021 was 36.5% (se=4.6%) and in 2022, 33.8% (se=1.0%). The percentage of males and females that were of Age 1.1 and 1.2 differed significantly (Table 36) in 2021 with Age 1.1 comprising a higher percentage of males and Age 1.2 a higher percentage of females. There were no significant differences between males and female age composition in 2022.

Table 36. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2021. Sex was estimated using GSI.

Stat Week	Sampling Dates	Percentage of Run	N	N Ageable	Percentage at Age				% Females
					1.1	1.2	2.1	1.3	
27	6/29	11.0	2	2	0.0	0.0	0.0	100.0	50.0
28	7/6,7,8	43.4	136	136	11.8	42.6	0.0	45.6	33.6
29	7/12,13	26.5	96	96	15.6	64.6	1.0	18.8	33.3
30	7/19,21	12.0	80	77	11.7	55.8	0.0	32.5	44.2
31	7/26,27	4.8	36	34	8.8	50.0	0.0	41.2	31.3
32	8/2	2.3	3	3	0.0	66.7	0.0	33.3	33.3
Composite		**Mean**	**353**	**348**	**11.1**	**46.2**	**0.3**	**42.4**	**36.5**
		SE			**1.6**	**2.5**	**0.3**	**2.4**	**4.6**
Females		Mean	124	123	5.3	54.4	0.0	40.3	
		SE			1.4	1.9	0.4	0.3	
Males		Mean	221	218	14.7	42.0	0.4	42.8	
		SE			1.5	2.0	0.3	2.0	
P-value for male/female age comparison					0.00	0.00	0.06	0.14	

[30] Note that, as described in the methods, these estimates are biased towards larger (and thereby older) Sockeye due to smaller fish avoiding the trap by slipping through the bars of the diversion gate.

Table 37. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2022. Sex was estimated using GSI.

Stat Week	Sampling Dates	Percentage of Run	N	N Ageable	Percentage at Age				% Female
					1.1	1.2	1.3	2.2	
27	6/29	0.4	21	21	0.0	76.2	23.8	0.0	38.1
28	7/6,7,8	19.0	148	145	1.4	89.7	9.0	0.0	34.3
29	7/12,13	48.5	70	69	2.9	85.5	8.7	2.9	29.4
30	7/19,21	20.0	60	58	0.0	98.3	1.7	0.0	26.8
31	7/26,27	7.8	46	46	0.0	95.7	2.2	2.2	66.7
32	8/2	4.3	14	13	7.7	92.3	0.0	0.0	54.5
Composite		**Mean**	**359**	**352**	**2.0**	**89.9**	**6.5**	**1.6**	**33.8**
		SE			**1.0**	**2.2**	**1.7**	**1.0**	**1.0**
Females		Mean	128	125	0.4	93.8	3.1	2.7	
		SE			0.4	3.1	2.2	2.2	
Males		Mean	216	212	2.0	89.1	8.0	0.9	
		SE			1.2	2.6	2.2	0.9	
P-value for male/female age comparison					0.12	0.12	0.06	0.22	

A comparison of visual and genetics sex identification found that there was 80.4% concurrence in 2021 (Table 38) and 80.8% in 2022 (Table 39). Females were correctly identified visually at a lower rate than males in both 2021 and 2022 (Tables 38 and 39).

Table 38. Comparison of visual and genetics classification of sex of Sockeye Salmon sampled at Wells Dam in 2021.

	2021 Classification using GSI			
Visual Classification	**Female**	**Male**	**Total**	**% Concurrence**
Female	90	34	124	72.6
Male	34	189	223	84.8
Total	**124**	**223**	**347**	**80.4**

Table 39. Comparison of visual and genetics classification of sex of Sockeye Salmon sampled at Wells Dam in 2022.

	2022 Classification using GSI			
Visual Classification	**Female**	**Male**	**Total**	**% Concurrence**
Female	115	53	168	68.5
Male	13	163	176	92.6
Total	**128**	**216**	**344**	**80.8**

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

In 2021, age composition estimates for Sockeye Salmon sampled at Bonneville, Tumwater, and Wells dams are presented with Bonneville Dam GSI-based stock-age composition in Table 40. Differences in the two Okanagan Sockeye age composition estimates are likely attributable to aforementioned trap bias selecting larger (Age 1.3) Sockeye and against smaller (Age 1.1) Sockeye Salmon at Wells Dam. Differences in the Wenatchee stock age composition between those aged by CRITFC (Bonneville Dam) and WDFW (Tumwater Dam) personnel suggest differences in aging techniques.

Table 40. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag detections as well as by sampling at Wells and Tumwater dams[31] in 2021.

Sampling Site	Stock	Ageable Sample Size	Brood Year and Age Class				
			2018	2017		2016	
			1.1	1.2	2.1	1.3	2.2
Bonneville Dam	Mixed	1463	27.3%	57.4%	0.9%	13.7%	0.7%
Bonneville Dam	Wenatchee: Stock determined as described on page 11 of this report	348	0.0%	69.1%	0.2%	30.4%	0.4%
Tumwater Dam	Wenatchee	1118	0.2%	68.7%	0.0%	23.9%	7.2%
Bonneville Dam	Okanagan Stock determined as described on page 11 of this report	1027	40.5%	51.8%	1.4%	5.0%	1.2%
Wells Dam	Okanagan	298	12.4%	50.0%	0.3%	37.3%	0.0%

In 2002, Age 1.2 Sockeye dominated all groups (Table 41). Of some note was the fact that the highest percentage of Age 1.1 Sockeye was at Tumwater Dam at 2.5% compared to the 0.0% estimated by this study at Bonneville Dam.

[31] Tumwater Dam age data were provided by WDFW which samples Sockeye Salmon at the site (Alainah Hendrickx email dated August 10, 2023).

The Tumwater Age 1.1 Sockeye were up to 55.0 cm in length, a length far exceeding what this study has observed at Bonneville Dam for Age 1.1 Sockeye. A possible explanation is that the reading of Tumwater Dam-collected scales does not take into account resorption of the outer edges of the scale which can erode away the final saltwater annulus from the scale.

Table 41. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag detections as well as by sampling at Wells and Tumwater dams[32] in 2022.

Sampling Site	Stock	Ageable Sample Size	Brood Year and Age Class					
			2019	2018		2017		2016
			1.1	1.2	2.1	1.3	2.2	2.3
Bonneville Dam	Mixed	1416	2.0%	94.8%	0.6%	2.1%	0.4%	0.0%
Bonneville Dam	Wenatchee: Stock determined as described on page 11 of this report	268	0.0%	94.6%	0.0%	5.3%	0.1%	0.0%
Tumwater Dam	Wenatchee	1069	2.5%	84.3%	0.3%	4.1%	8.7%	0.1%
Bonneville Dam	Okanagan Stock determined as described on page 11 of this report	1115	2.4%	95.0%	0.8%	1.2%	0.5%	0.0%
Wells Dam	Okanagan	326	1.7%	89.8%	0.0%	6.8%	1.7%	1.7%

Both Okanagan Sockeye Salmon sampled at Wells Dam and Wenatchee Sockeye Salmon sampled at Tumwater Dam had a greater mean fork length than was estimated for those stocks from GSI of Bonneville-tagged Sockeye Salmon for all age groups (Tables 42 and 43, Figures 18 and 19) in 2021 and 2022. The aforementioned trap bias at Wells Dam may explain this difference for the Okanagan stock. The difference at Tumwater Dam is smaller and likely due to sampling more mature fish where the males become longer by beginning to develop a kype. Fish with resorbed scales may also result in underestimating of ocean age for Wells- and Tumwater-sampled Sockeye, thus resulting in a greater mean length-at-age.

[32] Tumwater Dam age data were provided by WDFW which samples Sockeye Salmon at the site (Alainah Hendrickx email dated August 10, 2023).

Table 42. 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 and Tumwater dams in 2021.

Sampling Sight	Stock (Based on GSI)	Statistic	Brood Year and Age Class					All Sockeye[33]
			2018	2017		2016		
			1.1	1.2	2.1	1.3	2.2	
Bonneville Dam	Mixed Stock	Mean Length	37.1	49.1	41.8	53.0	49.1	46.2
		St. Dev.	1.8	2.1	2.1	2.1	2.6	6.2
		N	408	830	17	197	11	1463
Bonneville Dam	Okanagan	Mean Length	37.1	49.0	41.8	52.0	49.6	44.3
		St. Dev.	1.8	2.3	2.1	2.2	2.9	6.3
		N	406	544	17	53	8	1027
Wells Dam	Okanagan	Mean Length	39.1	52.1	47.0	55.1		51.1
		St. Dev.	2.1	2.7	--	2.5		5.7
		N	43	167	1	87		302
Bonneville Dam	Wenatchee	Mean Length		49.2		53.3	47.7	50.5
		St. Dev.		1.7		2.0	0.3	2.7
		N		274		124	3	406
Tumwater Dam	Wenatchee	Mean Length	48.3	49.4	49.6	52.1	49.4	52.2
		St. Dev.	1.2	2.0	4.1	2.8	2.0	2.8
		N	3	1012	9	11	49	1019
Bonneville Dam	Snake	Mean Length		52.8		55.8		53.0
		St. Dev.		1.4		1.8		1.9
		N		10		2		13
Bonneville Dam	Yakima	Mean Length				53.0		52.8
		St. Dev.				2.0		3.1
		N				17		18

[33] Includes lengths of Sockeye Salmon with unageable scales.

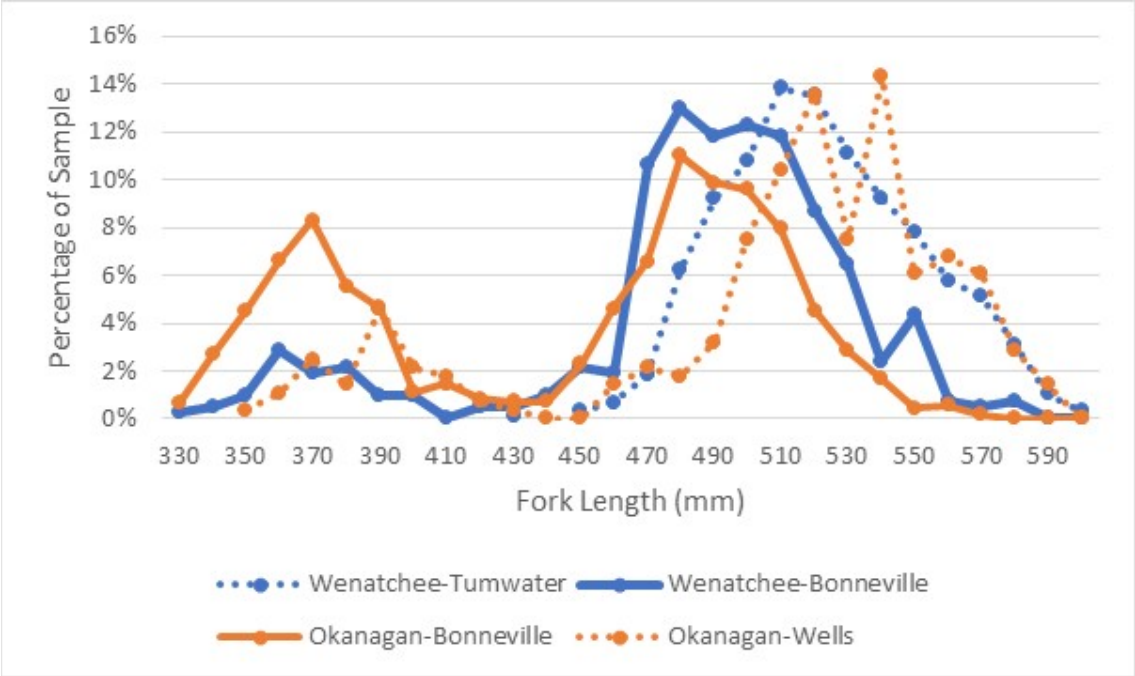

Figure 18. Length distribution for Okanagan and Wenatchee Sockeye sampled at Bonneville, Wells, and Tumwater dams in 2021[34].

[34] Okanagan and Wenatchee stock Sockeye Salmon were identified at Bonneville and Wells dams using genetics and PIT tag detection as described in the methods. Tumwater Dam Sockeye were assumed to all be Wenatchee stock.

Table 43. 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 and Tumwater dams in 2022.

Sampling Site	Stock	Statistic	Brood Year and Age Class						All Sockeye[35]
			2019	2018		2017		2016	
			1.1	1.2	2.1	1.3	2.2	2.3	
Bonneville Dam	Mixed	Mean Length	40.4	47.6	43.1	52.5	49.4		47.5
		St. Dev.	2.0	2.2	1.3	2.5	2.5		2.6
		N	29	1279	11	27	7		1376
Bonneville Dam	Okanagan	Mean Length	40.3	47.4	43.1	51.1	49.1		47.2
		St. Dev.	2.0	2.2	1.3	2.4	2.5		2.6
		N	28	1025	11	13	6		1101
Wells Dam	Okanagan	Mean Length	43.8	49.7		55.0	52.0		50.1
		St. Dev.	7.8	2.7		2.3	2.0		3.2
		N	4	293		26	3		333
Bonneville Dam	Wenatchee	Mean Length		48.4		53.6	51.5	55.0	48.6
		St. Dev.		1.8		1.9		--	2.1
		N		248		12	1	1	266
Tumwater Dam	Wenatchee[36]	Mean Length	52.6	52.2	52.0	52.1	52.0		52.2
		St. Dev.	1.8	2.2	1.5	2.4	1.7		2.3
		N	27	901	3	44.	93		1069
Bonneville Dam	Snake	Mean Length	42.0	48.0		56.0			48.5
		St. Dev.	--	0.0		--			5.7
		N	1	2		1			4

[35] Includes lengths of Sockeye Salmon with unageable scales.
[36] Tumwater Dam length-at-age data was provided by WDFW which samples Sockeye Salmon at the site (Alainah Hedrickx email dated March 30, 2023).

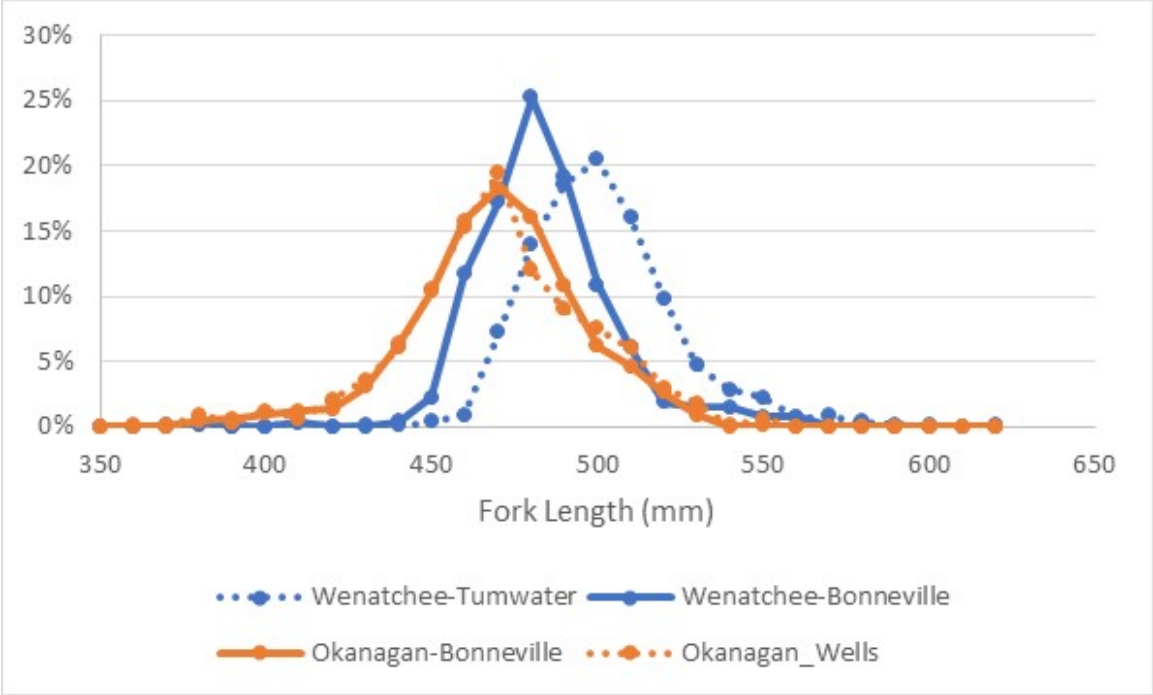

Figure 19. Length distribution for Okanagan and Wenatchee Sockeye sampled at Bonneville, Wells, and Tumwater dams in 2022[37].

Stock Composition at Wells Dam

In 2021 and 2022, GSI was conducted on all Sockeye Salmon sampled at Wells Dam. Among the Sockeye Salmon PIT tagged at Wells Dam in 2021 that moved downstream, 7 of the 8 Sockeye last detected in the Wenatchee Basin were classified as Wenatchee stock (with 1 classifying as Okanagan stock) as were the 2 Sockeye Salmon last detected at Rocky Reach Dam and 1 in the Entiat River. A Wenatchee-classified Sockeye was last detected in the Yakima Basin and a Yakima-classified Sockeye in the Snake River (Table 44). Of the 4 Sockeye Salmon last detected upstream of Wells Dam in the Methow River, 2 were classified as Wenatchee and 2 as Yakima stock. All 130 last detected in the Okanagan Basin were classified as Okanagan stock.

[37] Okanagan and Wenatchee stock Sockeye Salmon were identified at Bonneville and Wells dams using genetics and PIT tag detection as described in the methods. Tumwater Dam Sockeye were assumed to all be Wenatchee stock.

Table 44. Stock classification (using GSI) and site of last detection for Sockeye Salmon sampled at Wells Dam 2021.

	Classification[38]					
Last Detection	**Okanagan**	**Wenatchee**	**Snake**	**Yakima**	**N/A[39]**	**Total**
Snake Basin (ICH)	0	0	0	1	0	1
Yakima Basin (SUN)	0	1	0	0	0	1
Wenatchee Basin (LWE, WTL, TUF)	1	7	0	0	0	8
Rocky Reach Dam (RRF)	0	2	0	0	0	2
Entiat (ENL)	0	1	0	0	0	1
Wells Hatchery (WEH)	3	0	0	0	0	3
Wells Dam (WEA)	147	20	1	0	3	171
Methow River (LMR, MRW, TWR)	0	2	0	2	0	4
Okanagan Basin (OKL, ZSL, OKC, SKA, OKS, OKP)	130	0	0	0	1	131
No Detection	22	9	2	0	1	34
Total	**303**	**42**	**3**	**3**	**5**	**356**

In 2022, the only Sockeye sampled that moved downstream were 8 fish, all classified as Wenatchee stock, which were last detected in the Wenatchee River (Table 45). Of the 3 Sockeye last detected in the Methow Basin, 2 were classified as Okanagan Stock and 1 Wenatchee Stock. A total of 183 out of 349 (52.4%) Sockeye tagged, all classified as Okanagan Stock, were last detected in the Okanagan Basin in 2022 compared to 130 out of 356 (36.5%) in 2021 (Table 44).

Table 45. Stock classification (using GSI) and site of last detection for Sockeye Salmon sampled at Wells Dam 2022.

	Classification			
Last Detection	**Okanagan**	**Wenatchee**	**N/A[40]**	**Total**
Wenatchee Basin (ICL, TUF, WTL)	0	8	0	8
Wells Hatchery (WEH)	5	0	0	5
Wells Dam (WEA)	144	2	3	149
Methow River (LMR, MRC)	2	1	0	3
Okanagan Basin (OKL, ZSL, OKC, SKA, OKM, OKP)	183	0	0	183
No Detection	1	0	0	1
Total	**335**	**11**	**3**	**349**

[38] Sockeye Salmon were classified using GSI. However, since Yakima Sockeye Salmon are all descended from Okanagan or Wenatchee stocks, PBT was used to identify Sockeye Salmon with parents who spawned in the Cle Elum Basin and thus were Yakima stock. These Sockeye Salmon are classified as Yakima-Okanagan and Yakima-Wenatchee stock.
[39] Either no genetic samples or the genetic sample could not be analyzed.
[40] Either no genetic samples or the genetic sample could not be analyzed.

The overall stock composition estimated from Sockeye Salmon sampled and tagged at Wells Dam in 2021 was 90.6% Okanagan, 8.7% Wenatchee, 0.4% Yakima, and 0.3% Snake compared to 98.7% Okanagan, 1.3% Wenatchee, 0.0% Yakima, and 0.0% Snake for Sockeye Salmon tagged at Bonneville Dam that were detected at Wells Dam (Table 46). The higher percentage of the Wenatchee stock in the Wells sample is likely due to the generally larger size of Wenatchee-stock Sockeye Salmon relative to Okanagan-stock Sockeye Salmon (Table 42) combined with the fact that the Wells Dam trap tends to exclude smaller Sockeye Salmon due to the spacing of the bars in the weir only diverting larger Sockeye Salmon into the trap while smaller fish pass through the bars.

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 2021. (Both Wells and Bonneville-tagged groups are weighted by the weekly Wells Dam run size).

Week at Wells Dam	Tagged at Bonneville Dam					Tagged at Wells Dam				
	N	Okanagan	Wenatchee	Snake	Yakima	N	Okanagan	Wenatchee	Snake	Yakima
26	18	100.0%	0.0%	0.0%	0.0%	0				
27	89	100.0%	0.0%	0.0%	0.0%	2	100.0%	0.0%	0.0%	0.0%
28	245	99.6%	0.4%	0.0%	0.0%	137	95.6%	4.4%	0.0%	0.0%
29	123	99.2%	0.8%	0.0%	0.0%	99	99.0%	1.0%	0.0%	0.0%
30	34	97.1%	2.9%	0.0%	0.0%	79	67.9%	28.2%	2.6%	1.3%
31	25	92.0%	8.0%	0.0%	0.0%	35	61.8%	32.4%	0.0%	5.9%
>32	13	81.8%	18.2%	0.0%	0.0%	3	33.3%	66.7%	0.0%	0.0%
Total	**547**	**98.7%**	**1.3%**	**0.0%**	**0.0%**	**355**	**90.6%**	**8.7%**	**0.3%**	**0.4%**

The overall stock composition estimated from Sockeye Salmon sampled and tagged at Wells Dam in 2022 was 95.6% Okanagan, 3.6% Wenatchee, and 0.8% Snake compared to 99.2% Okanagan and 0.8% Wenatchee, and 0% Snake for Sockeye tagged at Bonneville Dam (Table 47).

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 2022. (Both Wells and Bonneville-tagged groups are weighted by the weekly Wells Dam run size). There were no Sockeye Salmon tagged at Bonneville that were classified as Yakima stock that passed Wells Dam.

Week at Wells Dam	Tagged at Bonneville Dam			Tagged at Wells Dam			
	N	Okanagan	Wenatchee	N	Okanagan	Wenatchee	Snake
26	18	100.0%	0.0%	0			
27	9	100.0%	0.0%	22	100.0%	0.0%	0.0%
28	233	100.0%	0.0%	147	100.0%	0.0%	0.0%
29	184	99.5%	0.5%	68	98.5%	1.5%	0.0%
30	189	98.4%	1.6%	59	89.8%	8.5%	1.7%
31	98	100.0%	0.0%	46	91.3%	6.5%	2.2%
32	69	98.6%	1.4%	13	76.9%	15.4%	7.7%
33	24	87.5%	12.5%	0			
Total	**805**	**99.2%**	**0.8%**	**355**	**95.6%**	**3.6%**	**0.8%**

Migration into Natal Areas - Okanagan River

The percentage of Sockeye Salmon passing or tagged at Wells Dam in 2021 that were detected on the Okanagan spawning grounds peaked in Week 29 at 29.0% for Wells-tagged Sockeye and 38.2% in Week 30 for Bonneville-tagged Sockeye (Figure 20, Table 48). The percentage of Wells-tagged Sockeye detected on the spawning grounds was 25.5% (se=0.025) compared to 31.1% (se=0.025) for Bonneville-tagged Sockeye.

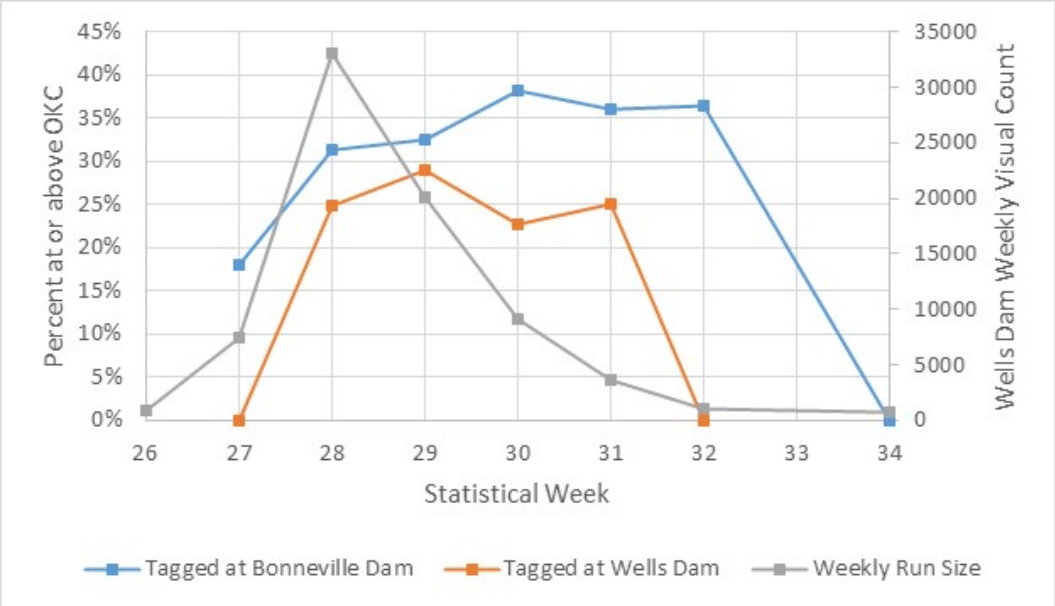

Figure 20. Percentage of Sockeye Salmon tagged at Bonneville and Wells dams last detected on Okanagan River spawning grounds (at or upstream of OKC) by statistical week passing Wells Dam in 2021.

Table 48. Number of Sockeye Salmon tagged at Wells Dam and subsequent last detection site by week in 2021 as well as the percentage detected at or upstream of OKC in Okanagan River spawning areas. Rates for adults tagged at Bonneville Dam and detected at Wells Dam are shown for comparison.

			Site of Last Detection (Downstream to Upstream)													Wells Tagged	Tagged at Bonneville Dam	
Week Tagged or Passing at Wells Dam	% of Total Wells Count by Week (Weight)	N	Snake (ICH)	Yakima (SUN)	Wenatchee (LWE, TUF WTL)	Rocky Reach *(RRF)	Entiat (ENL)	Wells Hatchery (WEH)	Wells (WEA, WEJ)	Methow (WMR, TWR, MRW)	Lower Okanagan (OKL/LLC)	Zosel (ZSL)	OKC/OKM	Skaha Dam (SKA)	OKP/OKS	Last Detected Spawning areas (OKC, OKM, SKA, OKP, OKS)	Number Detected at Wells Dam	Last Detected Spawning areas (OKC, OKM, SKA, OKP, or OKS)
26`	1.1%	0															18	
27	9.9%	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	90	18.0%
28	43.4%	137	0.0%	0.0%	1.6%	0.0%	0.0%	0.8%	57.4%	0.8%	0.8%	14.0%	20.9%	0.0%	3.9%	24.8%	245	31.4%
29	26.5%	99	0.0%	0.0%	1.1%	1.1%	0.0%	1.1%	53.8%	0.0%	2.2%	11.8%	26.9%	0.0%	2.2%	29.0%	126	32.5%
30	12.0%	79	0.0%	1.5%	6.1%	0.0%	0.0%	1.5%	42.4%	3.0%	3.0%	19.7%	19.7%	1.5%	1.5%	22.7%	34	38.2%
31	4.8%	35	3.6%	0.0%	3.6%	3.6%	3.6%	0.0%	50.0%	3.6%	0.0%	7.1%	21.4%	0.0%	3.6%	25.0%	25	36.0%
32	1.4%	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	66.7%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	11	36.4%
33	0.4%	0															0	
34	0.1%	0															2	0.0%
Wells Weighted Total		**355**	**0.2%**	**0.2%**	**2.1%**	**0.5%**	**0.2%**	**0.9%**	**54.2%**	**1.0%**	**1.6%**	**13.6%**	**22.3%**	**0.2%**	**3.0%**	**25.5%**		
Standard Error			**0.002**	**0.002**	**0.008**	**0.004**	**0.002**	**0.005**	**0.029**	**0.005**	**0.007**	**0.020**	**0.024**	**0.002**	**0.010**	**0.025**		
Bonneville Tagged Sockeye Salmon Detected at Wells			**0.0%**	**0.0%**	**0.5%**	**0.0%**	**0.0%**	**0.0%**	**50.5%**	**0.0%**	**3.1%**	**14.8%**	**25.2%**	**1.6%**	**4.3%**		**551**	**31.1%**
Standard Error			**NA**	**NA**	**0.001**	**0.003**	**NA**	**NA**	**0.008**	**0.0**	**0.010**	**0.019**	**0.024**	**0.007**	**0.011**			**0.025**

The percentage of Sockeye Salmon passing or tagged at Wells Dam in 2022 that were detected on the Okanagan spawning grounds peaked at Week 27 for Wells-tagged Sockeye at 59.1% and in Week 28 at 53.6% in Week 28 (Figure 21, Table 49). The percentage of Wells-tagged Sockeye detected on the spawning grounds was 26.9% (se=0.003) compared to 29.7% (se=0.019) for Bonneville-tagged Sockeye.

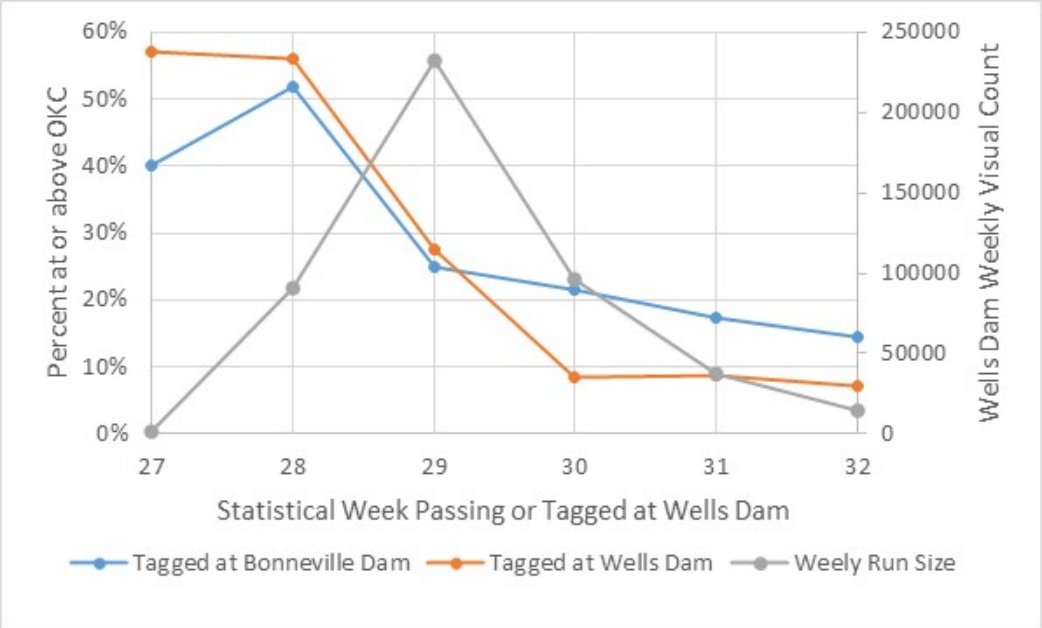

Figure 21. Percentage of Sockeye Salmon tagged at Bonneville and Wells dams last detected on Okanagan River spawning grounds (at or upstream of OKC) by statistical week passing Wells Dam in 2022.

Table 49. Number of Sockeye Salmon tagged at Wells Dam and subsequent last detection site by week in 2022 as well as the percentage detected at or upstream of OKC in Okanagan River spawning areas. Rates for adults tagged at Bonneville Dam and detected at Wells Dam are shown for comparison. NA indicates no Sockeye Salmon detections at Wells Dam for the tag group.

			Site of Last Detection (Downstream to Upstream											Wells Tagged	Tagged at Bonneville Dam	
Week Tagged or Passing at Wells Dam	% of Total Wells Count by Week (Weight)	N	Wenatchee (LWE, TUF WTL)	Rocky Reach *(RRF)	Entiat (ENL)	Wells Hatchery (WEH)	Wells (WEA)	Methow (WMR, TWR, MRW)	Lower Okanagan OKL, LLC	Zosel (ZSL)	OKC/OKM	Skaha Dam (SKA)	OKP/OKS	Last Detected Spawning Areas (OKC, SKA, OKP, or OKS)	Number Detected at Wells Dam	Last Detected Spawning Areas (OKC, SKA, OKP, OKS, OKM, OKV)
26	<0.1%	0														0.0%
27	0.3%	22	0.0%	0.0%	0.0%	4.5%	31.8%	0.0%	0.0%	4.5%	31.8%	18.2%	9.1%	59.1%	10	40.0%
28	19.0%	148	0.0%	0.0%	0.0%	0.7%	36.5%	0.0%	2.0%	4.7%	43.2%	2.7%	10.1%	56.1%	233	53.6%
29	48.5%	69	0.0%	0.0%	0.0%	4.3%	55.1%	0.0%	0.0%	13.0%	20.3%	0.0%	7.2%	27.5%	184	26.1%
30	20.0%	60	6.7%	0.0%	3.3%	0.0%	43.3%	3.3%	8.3%	26.7%	8.3%	0.0%	0.0%	8.3%	188	21.3%
31	7.8%	46	4.3%	2.2%	6.5%	0.0%	47.8%	2.2%	0.0%	28.3%	4.3%	2.2%	2.2%	8.7%	98	17.3%
32	3.0%	14	14.3%	0.0%	0.0%	0.0%	50.0%	0.0%	14.3%	14.3%	7.1%	0.0%	0.0%	7.1%	69	15.9%
33	0.9%	0													24	29.2%
34	0.2%	0													7	28.6%
35	0.1%	0													1	0.0%
Wells Weighted Total		**355**	**1.9%**	**0.5%**	**0.2%**	**0.8%**	**59.2%**	**0.9%**	**2.0%**	**11.9%**	**19.6%**	**0.2%**	**2.6%**	**26.9%**		
Standard Error			**0.008**	**0.002**	**0.005**	**0.012**	**0.034**	**0.005**	**0.008**	**0.024**	**0.026**	**0.003**	**0.016**	**0.008**		
Bonneville Tagged Sockeye Salmon Detected at Wells			**0.5%**	**0.0%**	**0.0%**	**0.0%**	**50.9%**	**0.2%**	**3.1%**	**14.2%**	**25.3%**	**7.3%**	**16.1%**		**814**	**29.7%**
Standard Error			**0.001**	**0.000**	**0.001**	**0.003**	**0.021**	**0.000**	**0.007**	**0.013**	**0.017**	**0.003**	**0.010**			**0.019**

In 2021 the first Sockeye Salmon detected at OKL in the lower Okanagan was detected on June 26 when the mean temperature was 20.7C (Table 50, Figures 22 and 23). It likely died as it was not subsequently detected at ZSL in a year in which detection rate at Zosel was 100.0%. The next detections at OKL were a group representing 15.0% of OKL detections that migrated between July 21 and 25 as mean river temperatures dropped from 24.1C on July 20 to a low of 22.4 on July 24 before rebounding to over 25.0C by July 30. Of this group 87.5% were detected at ZSL and 50.0% ultimately detected at OKC. Two groups migrated in August, the first with a 72.7% detection rate at ZSL, but only 39.4% at OKC. The second group had a 90.5% detection rate at ZSL and 76.2% of the run detected at OKC. Finally, the tail of the run had a 78.5% survival at ZLS, but only 25.0% survival to OKC. Overall survival to ZSL was 78.5% and 53.3% to OKC.

Table 50. Groups of PIT-tagged Sockeye Salmon passing OKL by date and percentage detected upstream in 2021.

Dates	% of OKL Detections	N at OKL	% Detected at ZSL	% Detected at OKC
7/21-7/25	15.0%	16	87.5%	50.0%
8/8-8/12	30.8%	33	72.7%	39.4%
8/18-8/25	39.2%	42	90.5%	76.2%
Tail of Run (8/28-10/16)	15.0%	16	50.0%	25.0%
Total		**107**	**78.5%**	**53.3%**

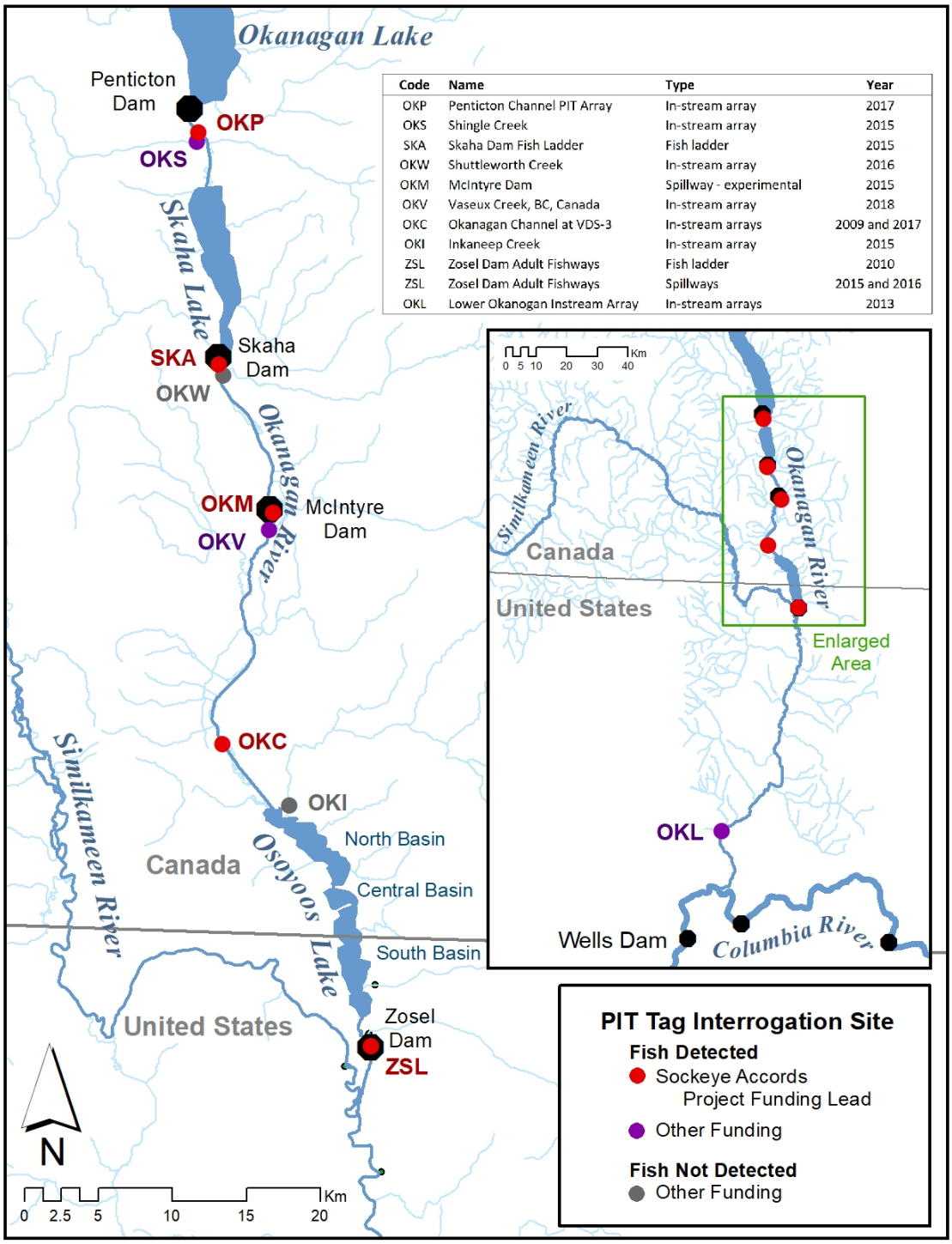

Figure 22. Map of the Okanagan River showing locations of PIT tag antennas funded by this project since its inception. Zosel, Skaha, and McIntyre dams, and in-river array immediately downstream of spawning areas at OKC and an in-river array immediately downstream of Penticton Channel spawning areas at OKP.

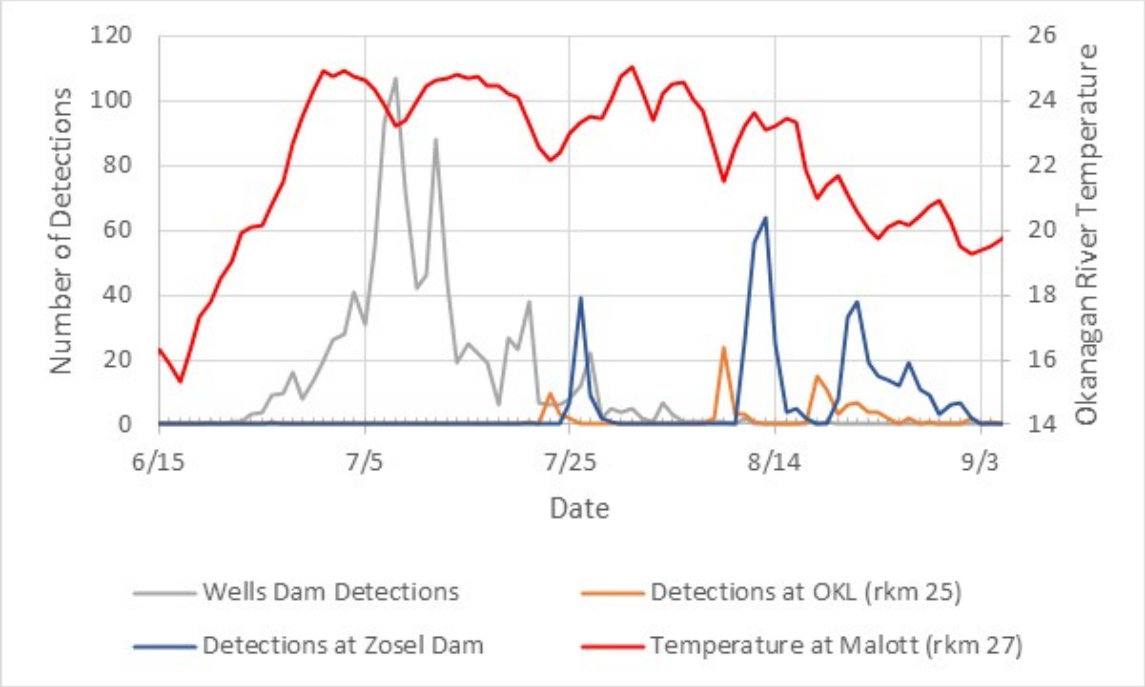

Figure 23. Number of PIT-tagged adult Sockeye Salmon detected at Wells Dam and the OKL PIT array at Okanagan rkm 25, and mean Okanagan River water temperature at Malott (rkm 27) by date in 2021.

In 2022, the first PIT-tagged adult Sockeye Salmon detected at OKL was on July 1; it missed detection at Zosel Dam but was detected at OKC on October 16 (Figure 22, Table 51). The first pulse of Sockeye detected at OKL passed between July 1 and July 12, comprising an estimate 20.1% of all detections at OKL; 56.8% of the Sockeye detected at OKL were also detected at OKC. (High flows resulted in very low detection rates at ZSL [Table 3] making it difficult to use this data for estimating survival.). During this period the mean daily river temperature as measured at the Wakefield gauge (Okanagan 16 rkm) increased from 17.6C on July 7 to 21.1C on July 12 and with mean temperatures ranging from 21.6 to 22.0C on July 12-16 (Figure 24). There were six Sockeye detected at OKL between July 17 and July 19 despite daily temperatures of 22.1-22.5C, only 16.7% (one fish) was ultimately detected at OKC. Temperatures between 7/20 and 8/5 ranged between 22.7C and 27.0C before a cooling dip to 22.4C resulted in 54 detections at OKL between August 5 and August 9, only 14.8% (8 fish) of which were detected at OKC. Okanagan River temperatures then increased, with means ranging from 24.2 to 25.4C before dropping to 22.1C in August 28 which prompted the largest pulse of Sockeye with 87 detections at

OKL through 9/19, 36.8% of which were detected at OKC. Daily survival rates from OKL to OKC are shown in Figure 25.

Table 51. Groups of PIT-tagged Sockeye Salmon passing OKL by date and percentage detected upstream in 2022.[41]

Dates	% of OKL Detections	N at OKL	% Detected at OKC
7/1-7/12	20.1%	37	56.8%
7/17-7/19	3.2%	6	16.7%
8/5-8/9	29.3%	54	14.8%
8/28-9/19	47.2%	87	36.8%
Total	**100.0%**	**184**	**33.7%**

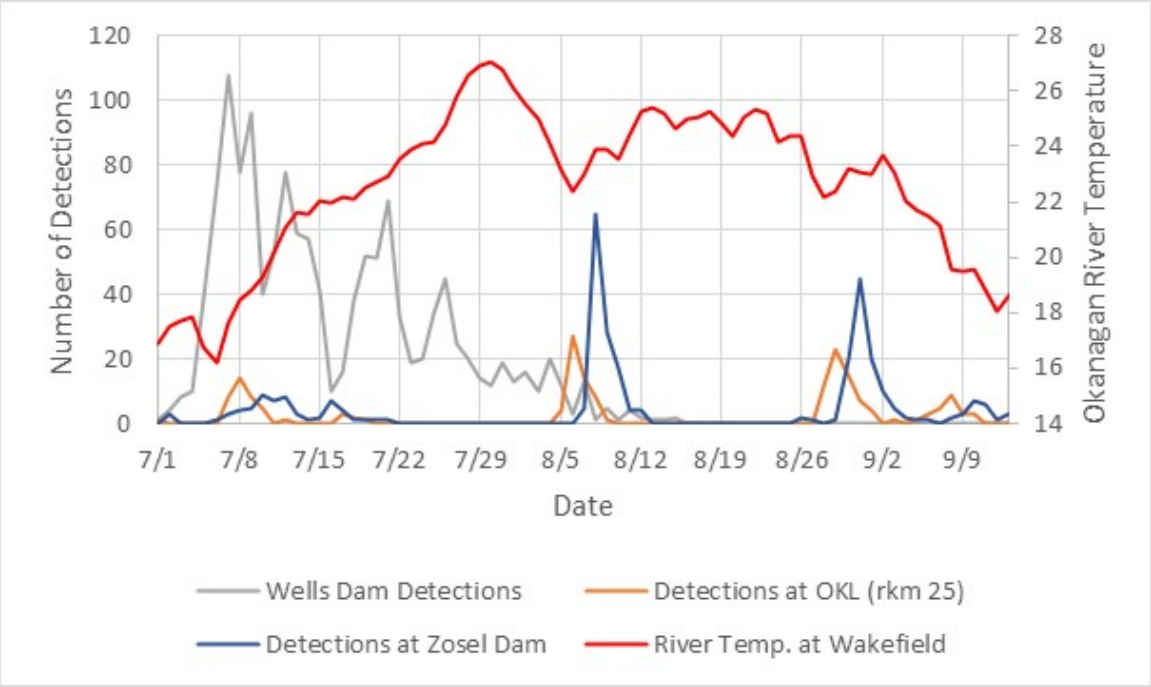

Figure 24. Number of PIT-tagged adult Sockeye Salmon detected at Wells Dam and the OKL PIT array at Okanagan rkm 25, and mean Okanagan River water temperature at Wakefield (rkm 17) by date in 2022.

[41] Zosel Dam is omitted from this table in 2022 due to high flows resulting in Sockeye passing through open spill gates for most of the migration. An estimated 70.9% of 2022 upstream migrating PIT-tagged Sockeye Salmon missed detection at Zosel Dam (Table 3).

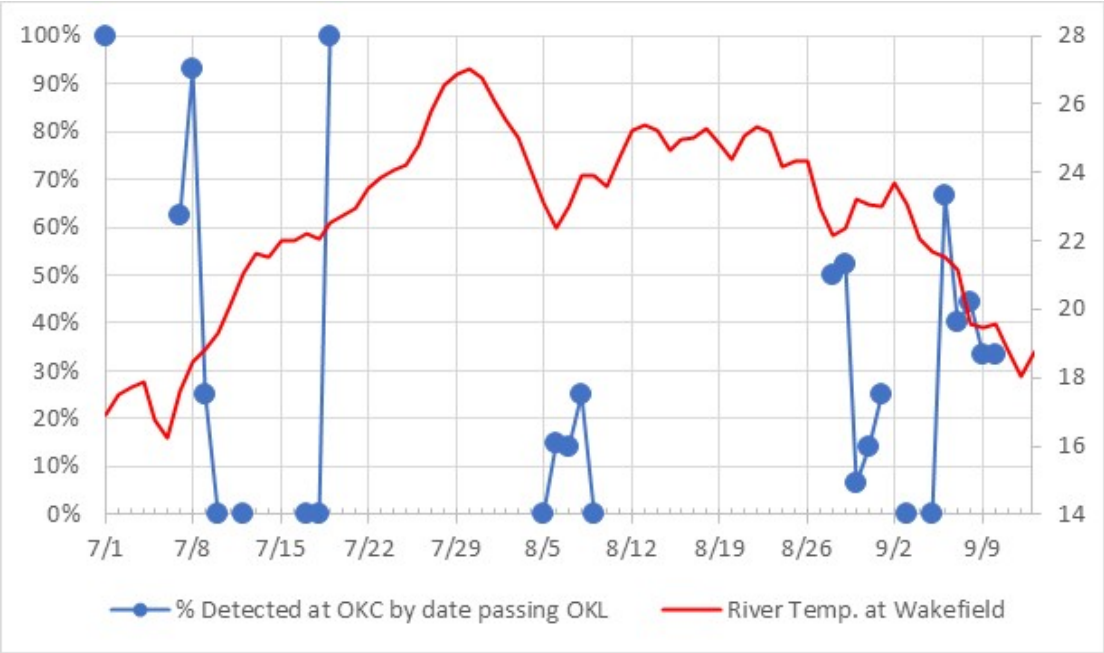

Figure 25. Percentage of PIT tagged Sockeye detected at OKC by date detected at OKL in 2022.

Migration into Natal Areas-Wenatchee River

Of the 110 adult Bonneville-tagged Sockeye Salmon detected at LWE (Table 52 and Figure 26) in 2021, 85.1% were detected at Tumwater Dam. In the higher flow and lower temperature year of 2022, survival from LWE to Tumwater was 97.3% (Table 53). This compares to 85.8% in 2020, 98.0% in 2019, 99.2% in 2018, 97.5% in 2016, and 71.3% in the high temperature year of 2015 (Fryer et al. 2017, 2018, 2019, 2020, 2021).

Table 52. Survival of Bonneville PIT-tagged 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 2021.

Statistical Week Detected at LWE	Number Detected at LWE	Mean Temperature at Monitor (rkm 11.1)	% Survival from Detection at LWE to Tumwater Dam	Mean Travel Time LWE to Tumwater Dam (days)	Mean Daily flow at Monitor (CMS)
27	12	16.6	100.0%	10.1	140.9
28	36	18.9	97.2%	8.9	73.6
29	27	19.3	85.2%	10.1	45.6
30	12	20.9	83.3%	8.2	30.3
31	3	21.9	33.3%	6.0	26.7
32	7	21.0	71.4%	11.3	22.4
33	6	21.6	0.0%	NA	18.1
34	3	18.6	0.0%	NA	14.9
35	2	17.6	50.0%	13.1	12.5
36	2	18.5	0.0%	NA	10.5
Unweighted	**110**[42]	**19.5**	**85.1%**	**8.6**	**39.6**

Table 53. Survival of Bonneville PIT-tagged 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 2022.

Statistical Week Detected at LWE	Number Detected at LWE	Mean Temperature at Monitor (rkm 11.1)	% Survival from Detection at LWE to Tumwater Dam	Mean Travel Time LWE to Tumwater Dam (days)	Mean Daily flow at Monitor (CMS)
27	1	12.0	100.0%	17.3	291.9
28	29	12.2	100.0%	13.4	217.4
29	47	14.7	100.0%	10.4	169.5
30	41	16.2	97.6%	7.0	119.7
31	12	19.1	91.7%	6.4	92.1
32	11	19.3	90.9%	6.9	58.3
33	5	20.0	100.0%	6.9	39.5
34	3	20.4	100.0%	7.9	31.3
35	1	21.2	0.0%	NA	26.0
Unweighted	**150**	**18.0**	**97.3%**	**9.3**	**89.7**

[42] An additional 44 Sockeye Salmon were not detected at LWE but detected at upstream Wenatchee River PIT tag sites in 2021.

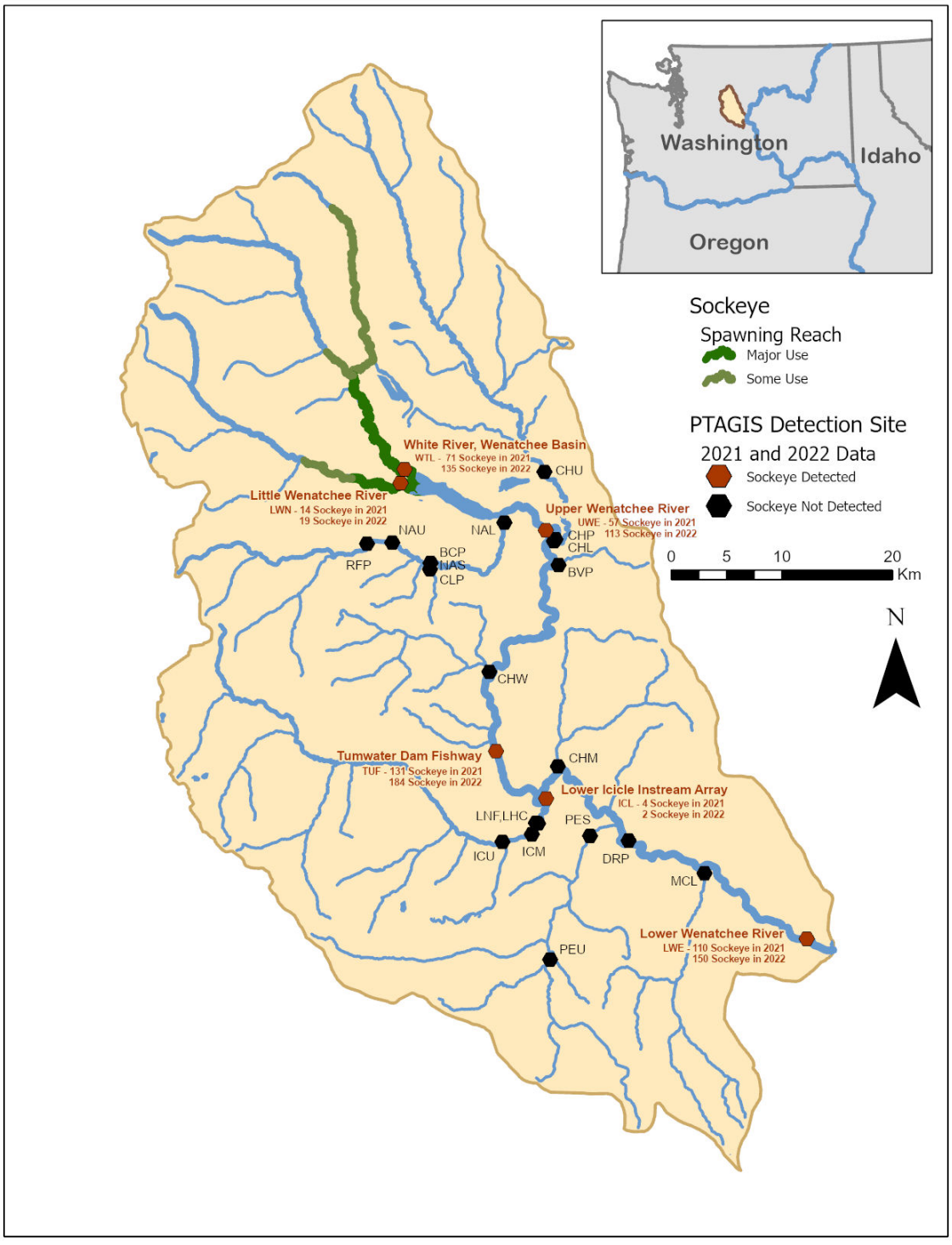

Figure 26. The Wenatchee Basin showing PIT tag interrogation sites and highlights the sites where Sockeye Salmon were detected in 2021 and 2022. Also displayed is the spawning area of Sockeye Salmon. Appendix B, Table B1 has site information.

Of the Bonneville-tagged Sockeye Salmon detected at Tumwater Dam in 2021, 64.1% were detected by spawning ground arrays at LWN and WTL in 2021 compared to 83.7% in 2022 (Tables 54 and 55, Figure 26). Of the Sockeye on the spawning grounds, 83.3% were last detected in the White River and 16.7% were last detected in the Little Wenatchee River. Sockeye tagged as adults at Tumwater Dam had a lower percentage detected at spawning ground arrays (61.4%) and a similar distribution (81.5% White River and 18.5% Little Wenatchee). Sample sizes of previously tagged Sockeye salmon at Tumwater Dam were small.

The 2022 spawning ground distribution was similar to 2021 with 87.7% of Bonneville-tagged adults were detected on the White River and 12.3% on the Little Wenatchee (Table 55), with Tumwater tagged Sockeye having a nearly identical distribution. Returning Sockeye Salmon which were tagged as juveniles had a lower percentage of those passing Tumwater Dam detected at LWN or WTL and a lower percentage detected at LWN relative to WTL. All seven of the Wells Dam tagged Sockeye detected at Tumwater Dam were Sockeye to which temperature tags were applied.

Table 54. Spawning ground distribution of adult PIT-tagged Sockeye Salmon detected or tagged at Tumwater Dam in 2021.

Tagging Location	Life Stage at Tagging	Number Detected or Tagged at Tumwater Dam	Percentage Detected at LWN or WTL	Percent Spawning Ground Distribution (Last Detection)	
				Little Wenatchee (LWN)	White River (WTL)
Bonneville AFF	Adult	131	64.1	16.5	83.5
Tumwater Dam Adult Ladder (2 detected at both LWN and WTL)	Adult	1170	61.4	18.5	81.5
Wells Dam	Adult	4	75.0	0.0	100.0
Rock Island Juvenile Bypass	Juvenile	23	52.2	16.7	83.3
Wenatchee River	Juvenile	17	70.6	8.3	91.7

Table 55. Spawning ground distribution of adult PIT-tagged Sockeye Salmon detected or tagged at Tumwater Dam in 2022.

Tagging Location	Life Stage at Tagging	Number Detected or Tagged at Tumwater Dam	Percentage Detected at LWN or WTL	Percent Spawning Ground Distribution (Last Detection)	
				Little Wenatchee (LWN)	White River (WTL)
Bonneville AFF	Adult	184	83.7	12.3	87.7
Tumwater Dam Adult Ladder[43] (2 detected at both LWN and WTL	Adult	1066	77.9	12.2	87.8
Wells Dam	Adult	7	57.1	0.0	100.0
Rock Island Juvenile Bypass	Juvenile	81	69.1	10.7	89.3
Wenatchee River	Juvenile	91	76.9	10.0	90.0

Juvenile PIT Tagging

In 2021, a total of 5,036 Sockeye smolts were captured, PIT tagged, and released between April 23 and April 26, 2021, in the Osoyoos Lake North Basin (OSOYOL) with a mean length of 97.0 mm (Table 56). Mean length in 2022 was 95.9 mm (Table 57), however lengths were only recorded on May 13, 2022, from a total of 57 juvenile Sockeye Salmon.

Table 56. Number of PIT-tagged juvenile Okanagan Sockeye released by date in 2021. All Sockeye were captured in an Osoyoos Lake (PTAGIS site OSOYOL) mid-lake trawl.

Date	PIT Tag Releases
23-Apr-21	1,089
24-Apr-21	2,615
25-Apr-21	567
26-Apr-21	765
Total	**5,036**
Mean Fork Length at Tagging (mm) n=614	**97.0 (se=4.7)**

[43] One Sockeye Salmon, 3DD.003E2266B2, was detected at WTL followed by LWN. The last detection site, LWN was used to calculate spawning ground distribution.

Table 57. Number of PIT-tagged juvenile Okanagan Sockeye Salmon released by date, tagging site and method in 2022.

	Number of PIT-Tagged Sockeye Released by Site (with Capture Method)			
	OKANR	OSOYOL	SKAHAL	
Date	Screw Trap	Mid-Lake Trawl	Mid-Lake Trawl	Total
5/6/2022	49			49
5/10/2022	54	541		595
5/11/2022	54			54
5/12/2022		692		692
5/13/2022	2	57		59
5/14/2022	41	1274		1315
5/15/2022		3444		3444
5/17/2022	89			89
5/19/2022	14			14
5/20/2022	114			114
5/25/2022	3			3
5/26/2022	56			56
5/28/2022			864	864
5/30/2022	10			10
5/31/2022	2			2
6/1/2022	1		74	75
Total	**489**	**6008**	**938**	**7,435**
Mean Fork Length at Tagging (mm) n=57	**NA**	**95.9 (se=11.7)**	**NA**	

Downstream survival estimates were calculated for both 2021 and 2022 (Table 58). Survival differed significantly (α=0.10) between the two years for Zosel Dam to Rocky Reach Dam (p=0.06) and for release to Rocky Reach Dam (p=0.02) (Table 58). In both cases survival rates were higher in 2021 compared to 2022. Low precision of survival estimates, a consequence of low numbers of detections at downstream sites, resulted in high standard errors.

Table 58. Mean survival estimates on downstream migration for juvenile Sockeye released at Osoyoos Lake 2021 and 2022[44].

Year	N	Statistic	Release-Zosel Dam	Zosel-Rocky Reach	Release-Rocky Reach	Rocky Reach-McNary	Release-McNary	McNary-John Day	John Day-Bonneville	Release-Bonneville
2021	5036	Mean	0.776	0.673	0.523	2.156	1.127	0.357	NA	NA
		SE	0.079	0.081	0.034	1.490	0.774	0.313	NA	NA
2022	7435	Mean	0.845	0.387	0.332	0.660	0.221	1.316	0.537	0.155
		SE	0.162	0.081	0.024	0.206	0.084	0.686	0.422	0.103
		P-value	0.63	0.06	0.02	0.21	0.50	0.83	0.78	0.80

Survival to downstream points was also estimated for other groups of PIT-tagged Columbia Basin Sockeye Salmon that out-migrated in 2021 and 2022 (Tables 59 and 60, Figures 27 and 28). In 2021 these included a group of

[44] Estimates were compiled July 21, 2023, using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

Wenatchee Sockeye Salmon tagged at a rotary screw trap in the Wenatchee River, out-migrating juveniles trapped at Rock Island Dam that consisted of mixed Okanagan and Wenatchee origin, and juvenile Snake River Sockeye tagged at traps and hatcheries in the Snake Basin[45]. The same groups were used in 2022 with the exception of the Rock Island Dam group which was eliminated after the 2021 tagging. High standard errors make it difficult to assess differences in survival, especially to points downstream of McNary Dam.

Table 59. Mean survival estimates for juvenile Sockeye released in the Okanagan, Wenatchee, and Snake basins and Rock Island Dam in 2021[46].

		Release-McNary		McNary-John Day		John Day-Bonneville		Release-Bonneville	
Release Group	N	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Osoyoos Lake	5036	0.523	0.034	2.156	1.490	0.357	0.313	0.403	0.217
Wenatchee	1973	0.765	0.250	1.007	0.642	0.422	0.356	0.325	0.208
Rock Island	3115	0.900	0.228	3.633	2.684	0.119	0.093	0.390	0.138
Snake	49986	0.588	0.067	1.061	0.256	0.387	0.094	0.241	0.028

Table 60. Mean survival estimates for juvenile Sockeye released in the Okanagan, Wenatchee, and Snake basins in 2022.

		Release-McNary		McNary-John Day		John Day-Bonneville		Release-Bonneville	
Release Group	N	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Okanagan Basin	7,435	0.221	0.072	1.101	0.587	0.892	0.935	0.217	0.208
Wenatchee	6,878	0.572	0.104	0.871	0.224	0.914	0.389	0.455	0.175
Snake	49,986	0.613	0.113	0.649	0.221	0.608	0.189	0.242	0.030

[45] 2021 was the last year juvenile Sockeye Salmon were PIT tagged at Rock Island Dam as the program was terminated.

[46] Estimates were compiled October 21, 2022, using www.cbr.washington.edu/dart/query/pit_sum_tagfiles.

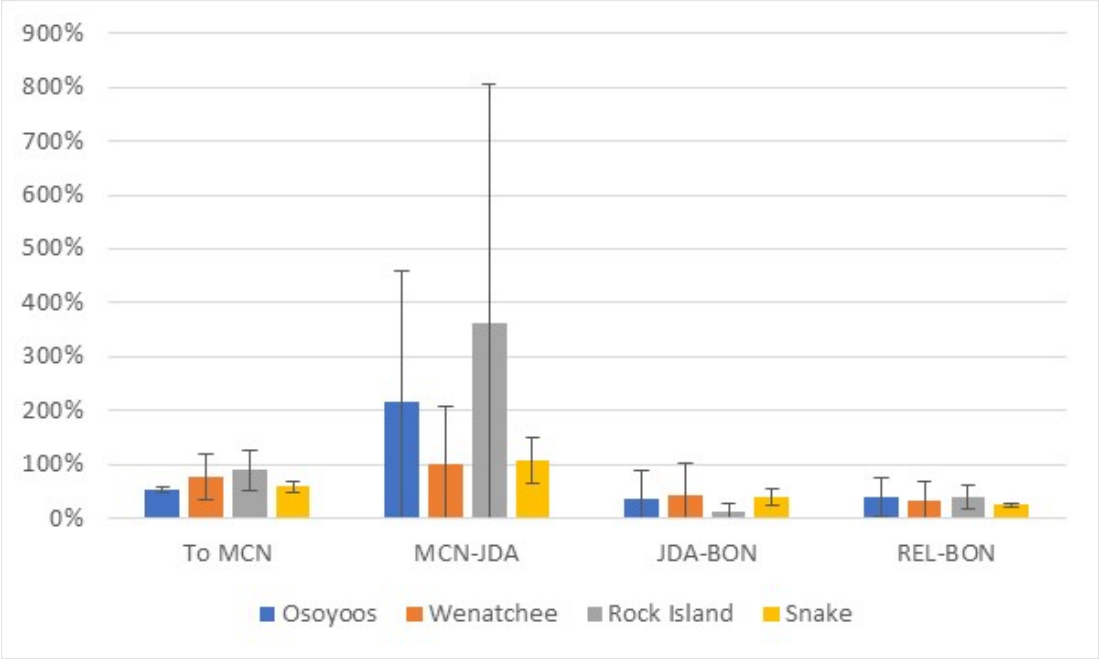

Figure 27. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam to McNary, John Day, and Bonneville dams with 90% confidence intervals in 2021.

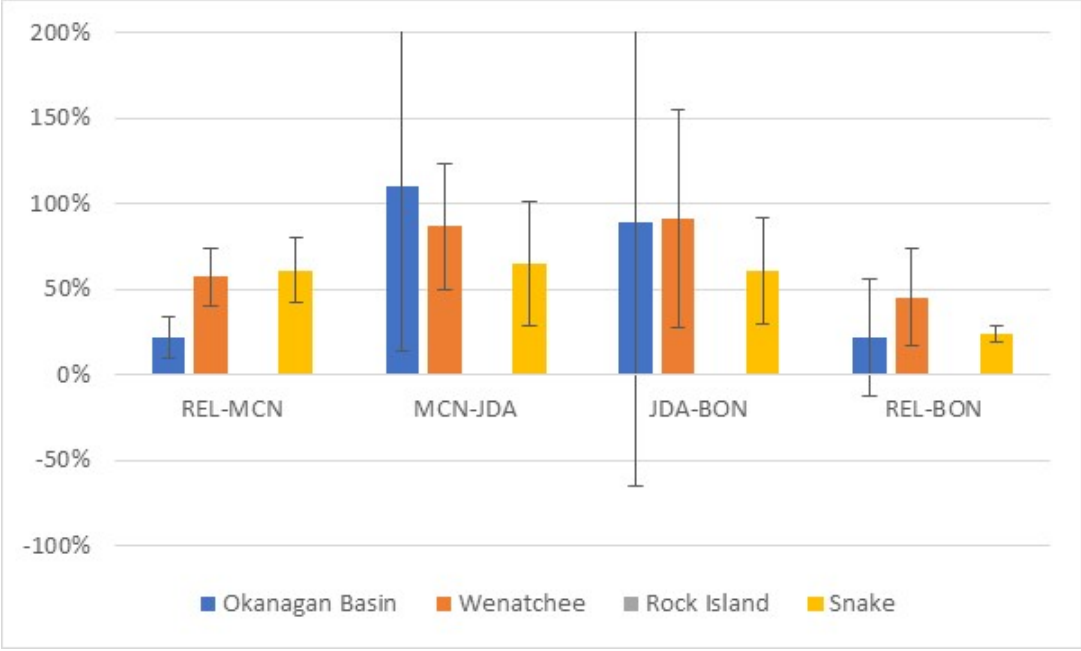

Figure 28. Survival of juvenile Sockeye PIT tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam to McNary, John Day, and Bonneville dams with 90% confidence intervals in 2022. (OKA MCN-JDA 206.7%, JDA-BON 243%).

Travel times to downstream detection locations were also compiled for 2021 and 2022 smolts (Tables 61 and 62). Okanagan Sockeye travel times were lower to all sites in 2022 compared to 2021. The opposite was generally the case for Wenatchee and Snake river-tagged Sockeye.

Table 61. Mean travel time from release to downstream sites for juvenile Sockeye tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam in 2021[47].

Release Site	Statistic	Mean Travel Time from Release to:					
		Zosel	Rocky Reach	McNary	John Day	Bonneville	Estuary Trawl
Osoyoos Lake	Mean	32.3	21.8	25.4	30.2	29.1	31.3
	SE	6.0	0.2	0.9	0.9	0.3	1.0
Wenatchee	Mean			17.6	28.6	28.4	33.7
	SE			0.8	1.3	0.7	2.2
Rock Island	Mean			10.4	18.9	14.8	18.6
	SE			0.6	1.2	0.5	1.6
Snake	Mean			17.4	20.4	18.5	20.7
	SE			0.2	0.5	0.0	0.2

Table 62. Mean travel time from release to downstream sites for juvenile Sockeye tagged in the Okanagan, Wenatchee, and Snake basins as well as at Rock Island Dam in 2022.[48]

Release Site	Statistic	Mean Travel Time from Release to:					
		Zosel	Rocky Reach	McNary	John Day	Bonneville	Estuary Trawl
Osoyoos Lake	Mean	16.7	13.8	24.2	23.8	21.3	18.9
	SE	1.5	0.3	1.3	0.9	0.7	1.3
Wenatchee	Mean			20.2	29.5	30.6	31.2
	SE			0.5	0.4	0.4	0.7
Snake	Mean			20.0	23.0	19.9	20.6
	SE			0.2	0.5	0.0	0.2

A report detailing Okanagan Sockeye juvenile PIT tagging can be found in Appendix C and Fish Passage Center memos reviewing survival and migration times for years 2021 and 2022 can be found in Appendix D.

Lake Wenatchee Acoustic Trawl and Limnology Surveys

An acoustic trawl survey was conducted in Lake Wenatchee in March 2022 prior to smolt emigration (Table 63) with an estimated abundance of Sockeye Salmon smolts of 1,827,568. Data from individual trawls is in Table 64. Acoustic trawl survey results for 2021 outmigrants can be found in Fryer et al.

[47] Estimated using http://www.cbr.washington.edu/dart/query/pit_sum_tagfiles on March 16, 2023, for 2021 and 2022.
[48] Tagging of juvenile Sockeye Salmon at Rock Island Dam was discontinued after 2021.

2022 while summary of 2012-2019 results can be found in Appendix E of the 2019 report Fryer et al. 2020 for this project.

Table 63. Number of limnetic fish and nerkas estimated by Lake Wenatchee acoustic trawls between August 24, 2021, and March 31, 2022.

	Dates of Trawls			
	24-Aug-2021	**28-Sep-2021**	**11-Nov-2021**	**31-Mar-2022**
Total Limnetic Fish	2,622,438	2,683,353	2,121,376	1,827,568
95% CI for Total Limnetic Fish	749,092	673,230	365,651	252,902
95% CI as Percentage of Mean	28.6%	25.1%	17.2%	13.8%
Age-0 nerkid	2,160,621	2,235,167	2,010,875	1,745,165
Age-1 nerkid	391,252	423,081	107,990	80,176
Other Fish	70,565	25,105	2,511	2,227
Total	2,622,438	2,683,353	2,121,376	1,827,568

Table 64. Mean nerkid density and length by date estimated by Lake Wenatchee acoustic trawl surveys between August 24, 2021, and March 31, 2022.

	Trawl Date			
	24-Aug-2021	**28-Sep-2021**	**11-Nov-2021**	**31-Mar-2022**
Density Per Ha (Area = 1004 Ha)				
Age-0 nerkid	2152	2226	2003	1738
Age-1 nerkid	390	421	108	80
Other Fish	70	25	3	2
Total:	**2,612**	**2,673**	**2,113**	**1,820**
Sample Size from Trawl (n)				
Age-0 nerkid	91	348	69	173
Age-1 nerkid	--	8	2	9
Total:	**91**	**356**	**71**	**182**
Mean Length (cm) (SD)				
Age-0 nerkid	5.77 (0.72)	6.73 (0.81)	6.54 (0.98)	7.16 (0.90)
Age-1 nerkid	-	10.78 (0.68)	10.25 (0.64)	11.12 (0.82)
Mean Weight (g) (SD)				
Age-0 nerkid	2.00 (0.78)	2.60 (1.11)	2.61 (0.97)	2.25 (0.94)
Age-1 nerkid	--	14.03 (2.76)	12.68 (3.26)	9.76 (2.71)

DISCUSSION

This report covers 2021 and 2022 which comprised the 13th and 14th year of this Accords study (which began in 2019) and the 16th and 17th year of PIT tagging Sockeye Salmon at Bonneville Dam. As indicated earlier in this report, the river environment encountered in 2021 and 2022 by upstream migrating Sockeye Salmon was very different from each other. The 2021 migration period was notable for high water temperatures and low flows at Bonneville Dam; conversely, 2022 had relatively low water temperatures and high flows when compared to the 2011-2020 mean (Figure 6). The survival rate to McNary Dam estimated by this study in 2021 of 70.4% was, with the exception of the 2015 rate of 54.0%, the lowest since this study began (Table 6, Figures 29 and 30). Conversely, the 2022 survival rate of 91.3% (Table 6) was the highest recorded by this study since its inception and the third coolest water temperature, although the coolest year (2011) had the third lowest survival from Bonneville to McNary (Figure 30). The relationship between mean flow and survival is even less clear with the lowest survival rates being in the year of lowest flow (2015) and highest flow (2011) (Figure 29).

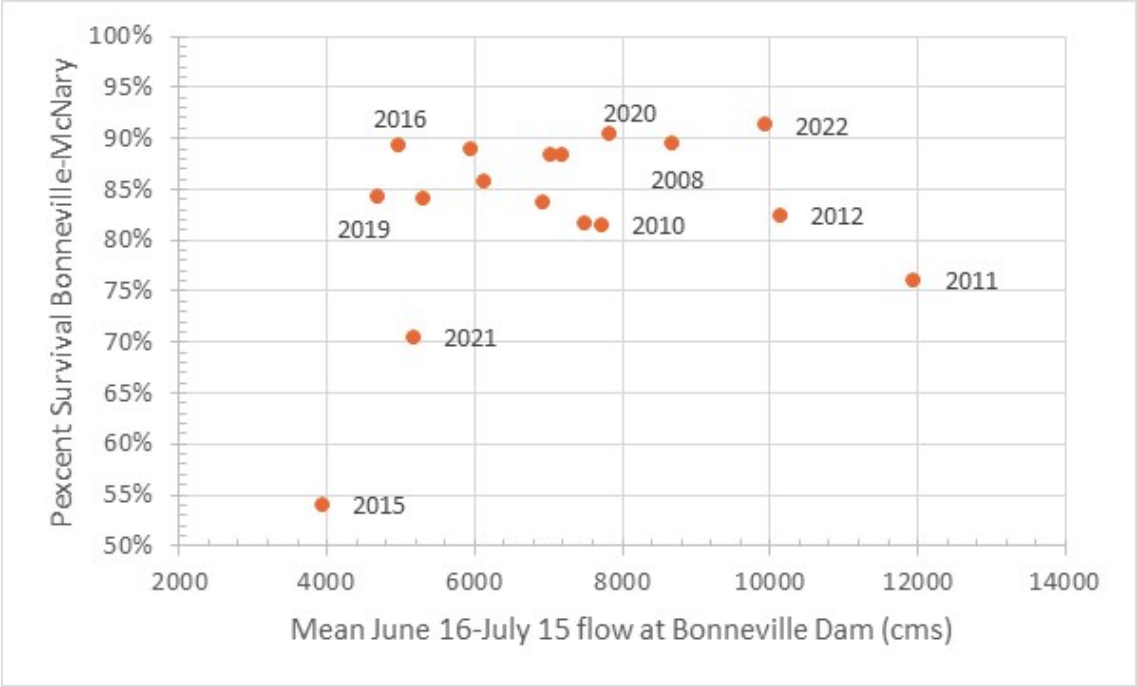

Figure 29. Mean daily flow at Bonneville Dam by year between June 16 and July 15 and Bonneville-McNary survival estimated by this study for 2011-2022.

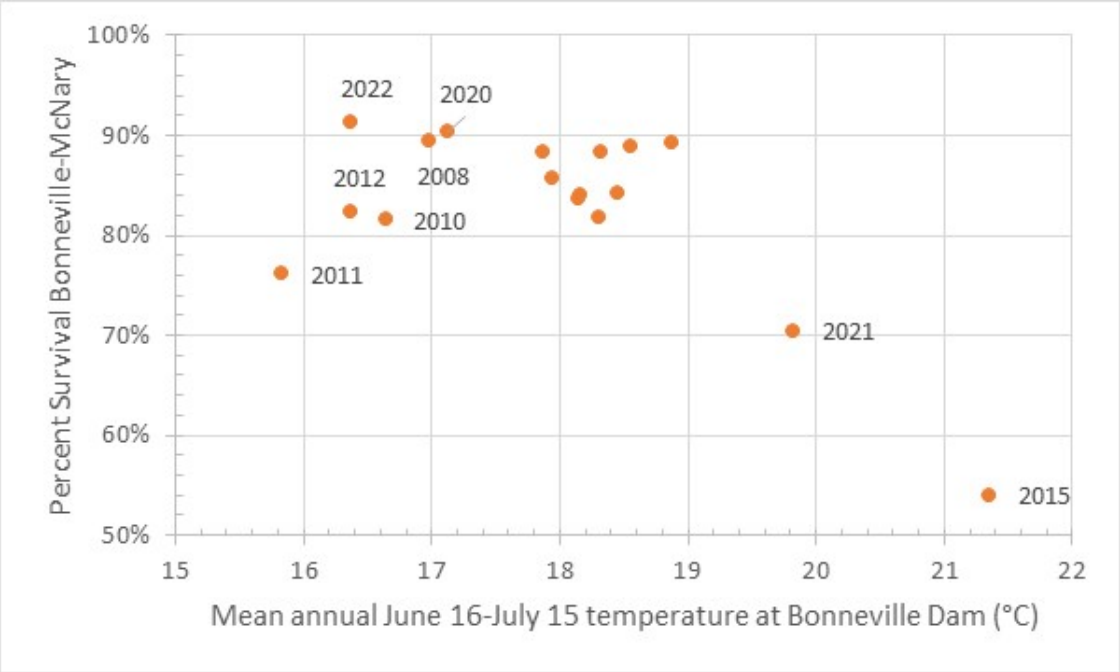

Figure 30. Comparison of mean annual water temperature at Bonneville Dam for June 16 to July 31 and Bonneville-McNary Dam survival estimated by this study for 2011-2022.

Mean travel times from Bonneville to McNary for 2021 and 2022 fit relatively well with the flow-travel time relationship derived for previous years with slower migrations in the high flow year of 2022 compared to the low flow year of 2021 (Figures 31 and 32).

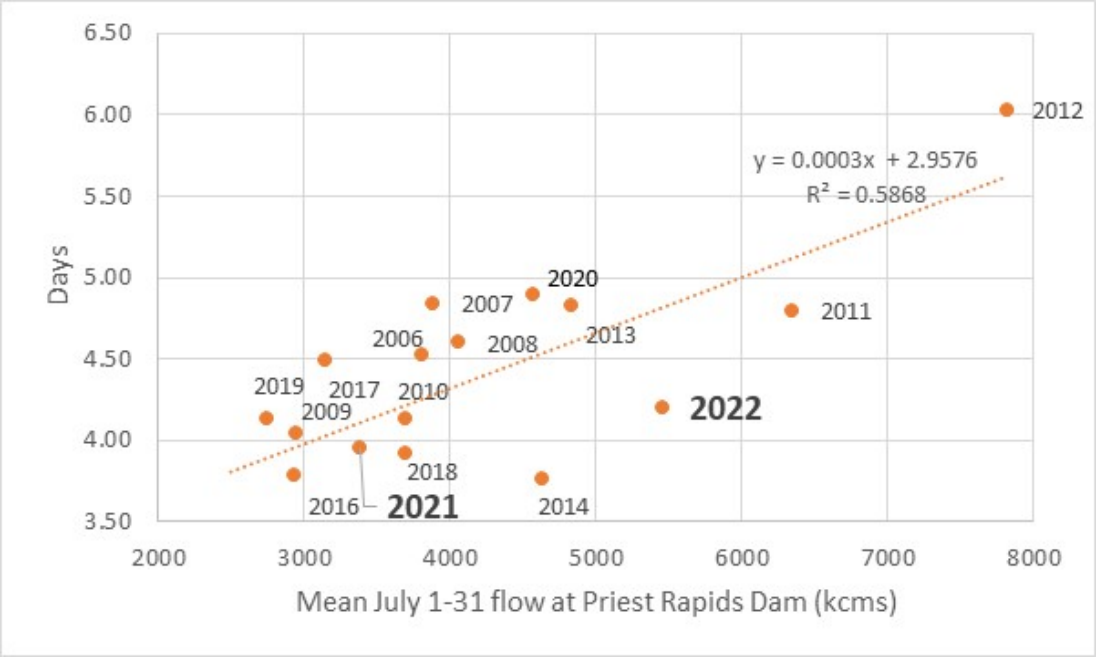

Figure 31. Relationship between mean annual Sockeye Salmon travel time for fish PIT tagged at Bonneville Dam from McNary to Priest Rapids Dam and mean annual July flow at Priest Rapids Dam for migration years 2006-2022.

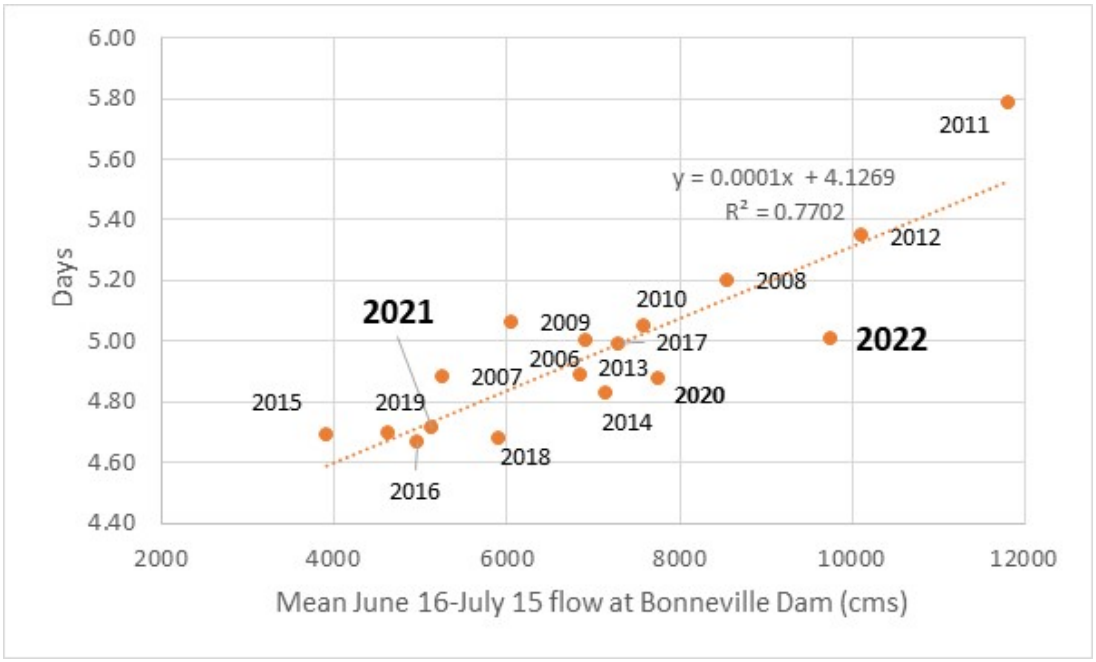

Figure 32. Relationship between mean annual Sockeye Salmon travel time for fish PIT tagged at Bonneville Dam and then traveling to McNary Dam and mean annual flow between June 16 to July 15 at Bonneville Dam for migration years 2006-2022.

PIT tags (56) were recovered on avian nesting islands from adults tagged by this study at Bonneville Dam in the low flow, higher temperature year of 2021 and 12 in the high flow, lower temperature year of 2022[49] (Table 65). Both the number and percentage of tags recovered from avian colonies in 2021 were the highest since the inception of this project in 2006. Among tags detected in 2021, all but 4 were detected at the Badger Island pelican colony while all were detected in 2022 on the island (Figures 33 and 34, Table 65).

Table 65. Number of PIT tags detected on avian colonies for 2006-2022 from Sockeye Salmon tagged by this study at Bonneville Dam (data from www.ptagis.org).

Year	Number in Study at Bonneville	Astoria-Megler Bridge	Badger Island	Central Blalock Island	Crescent Island	Foundation Island	Hanford Reach Islands	Preacher's Island	Little Miller Island	Rock Island	Total	% Detected on Avian Colonies
2006	504	0	2	0	0	0	0	0	0	0	2	0.4
2007	507	0	1	0	1	1	0	0	0	0	3	0.6
2008	1,134	0	3	0	0	0	0	0	0	0	3	0.3
2009	838	0	4	0	0	1	0	0	0	0	5	0.6
2010	913	0	2	0	0	0	0	0	0	0	2	0.2
2011	765	0	2	0	0	0	0	0	0	0	2	0.3
2012	1,614	0	3	0	0	0	0	0	0	0	3	0.2
2013	793	0	6	0	0	0	0	0	0	0	6	0.8
2014	1,412	0	11	0	0	0	0	0	1	0	12	0.8
2015	915	0	16	0	0	0	0	1	0	0	17	1.9
2016	1,658	0	16	0	0	0	0	1	0	0	17	1.0
2017	1,093	0	13	0	0	0	0	0	0	1	14	1.3
2018	1,859	0	8	0	0	0	0	0	0	0	8	0.4
2019	980	0	6	1	0	0	1	0	0	0	8	0.8
2020	1,733	0	18	0	0	0	1	0	0	0	19	1.1
2021	1,400	1	52	0	0	1	1	0	1	0	56	4.0
2022	1,354	0	12	0	0	0	0	0	0	0	12	0.9
Total	**19,472**	**1**	**175**	**1**	**1**	**3**	**3**	**2**	**2**	**1**	**114**	**1.0**

[49] One of the tags (3DD.003D829578) recovered in 2021 was from a Sockeye Salmon tagged in Statistical Week 27 in 2021, which was excluded from further analysis due to data collection problems described earlier. This Sockeye is excluded from analysis in this discussion but is included in the total number of tags detected on avian islands for comparisons with other years.

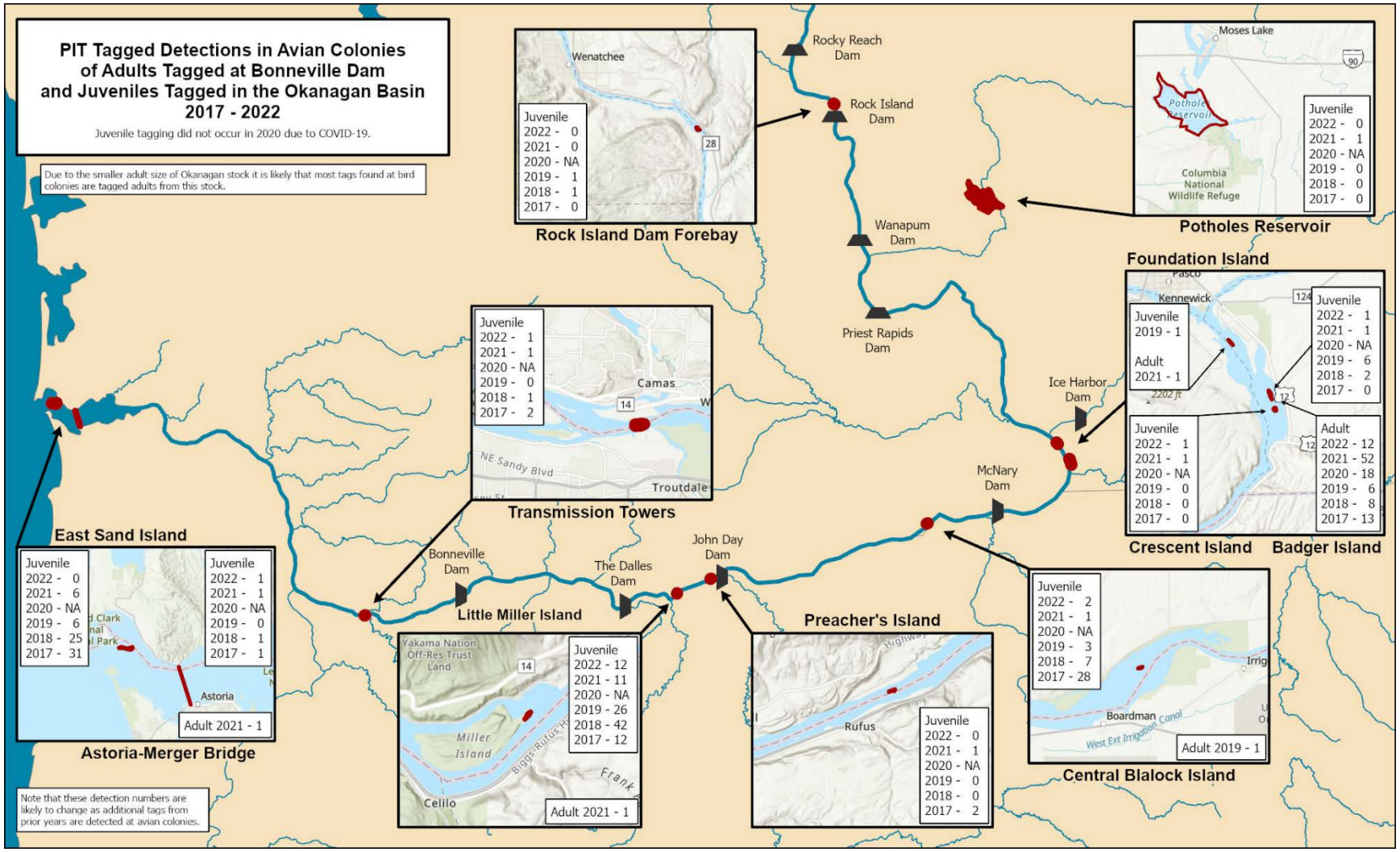

Figure 33. Avian colony site PIT tag detections of Sockeye Salmon tagged as adults by this project and as juveniles in years 2017-2022. Note that no juvenile Sockeye Salmon were PIT tagged in the Okanagan Basin in 2020 due to COVID restrictions.

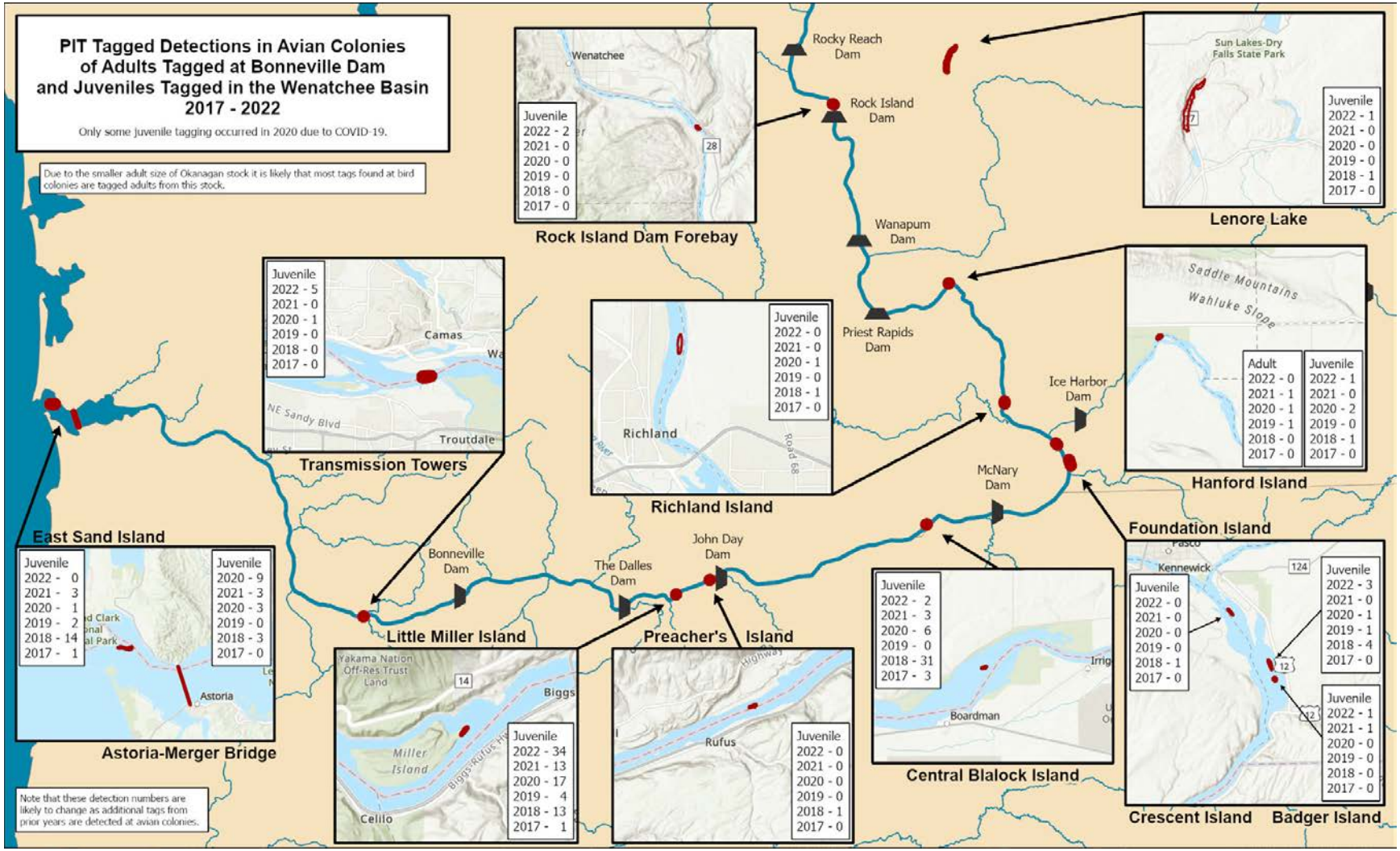

Figure 34. Avian colony site PIT tag detections of Sockeye Salmon tagged as adults by this project and as juveniles in years 2017-2022. Note that no juvenile Sockeye Salmon were PIT tagged in the Okanagan Basin in 2020 due to COVID restrictions.

Prior to being detected on avian islands, the most common last detection sites on the migratory corridor for these groups of fish for both 2021 and 2022 was John Day Dam, followed by McNary Dam with smaller percentages at Priest Rapids, The Dalles, and Bonneville dams (Table 66). Tags deposited on avian islands were mostly from Sockeye tagged late in the run in 2021 reaching 8.4% in Week 28 and 9.1% in Week 29[50] a high of over 8% in weeks 28 and 29 (Table 67). In 2022, the highest rate was 3.1% in Week 24 and 2.5% for those passing during or after Week 30 (Table 67).

Table 66. Last Columbia River PIT tag detection site for Sockeye Salmon detected on avian colonies in 2021 and 2022.

	2021		2022	
Site of Last Migration Detection	**Number**	**Percentage**	**Number**	**Percentage**
Bonneville (BO3)	1	1.8%	0	0.0%
The Dalles (TD1,TD2)	2	3.6%	2	16.7%
John Day (JO1, JO2, JDJ)	32	57.1%	5	41.7%
McNary (MC1, MC2)	19	33,9%	4	33.3%
Priest Rapids (PRA)	2	3.6%	1	8.3%
Total	**56**	**100.0%**	**12**	**100.0%**

Table 67. Percentage of Sockeye Salmon PIT tagged at Bonneville Dam recovered on avian islands and mean water temperature at Bonneville Dam by statistical week for 2021 and 2022.

	2021			2022		
Statistical Week	**Number Tagged**	**% Recovered on Avian Islands**	**Mean Temperature (°C)**	**Number Tagged**	**% Recovered on Avian Islands**	**Mean Temperature (°C)**
23	12	8.3%	15.4	5	0.0%	13.3
24	62	0.0%	15.6	64	3.1%	14.2
25	159	0.6%	16.1	164	0.6%	13.7
26	383	1.6%	17.9	259	0.0%	14.5
27	405	2.7%	20.2	194	0.0%	16.4
28	202	8.4%	20.4	275	0.7%	17.3
29	198	9.1%	21.5	132	0.0%	18.8
>=30	81	1.3%	21.2	137	2.5%	19.5
Total	**1502**	**3.7%**		**1376**	**0.9%**	

[50] The rate in Week 23 was 8.3%, however this was based on a sample size of only 12 Sockeye.

Among Sockeye Salmon tagged as juveniles, the percentage of PIT tags recovered on avian islands has generally less than 2% (Table 68, Figure 35). Peak rates for both Wenatchee- and Okanagan-tagged Sockeye were in 2014.

Table 68. Number of juvenile Sockeye PIT tagged in the Okanagan and Wenatchee basins and percentage recovered on avian islands by year for 2006-2022.

	Okanagan		Wenatchee	
Outmigration Year	Number Tagged	% Recovered on Avian Islands	Number Tagged	% Recovered on Avian Islands
2006	0	NA	14859	1.0%
2007	0	NA	14764	1.1%
2008	0	NA	18114	1.7%
2009	0	NA	18541	2.2%
2010	0	NA	24489	2.0%
2011	0	NA	5039	1.4%
2012	534	1.69%	5081	1.2%
2013	4043	1.09%	0	NA
2014	5054	3.46%	1143	7.8%
2015	7176	1.67%	2877	3.6%
2016	10241	1.07%	997	1.0%
2017	11595	0.74%	933	0.6%
2018	11053	0.71%	7061	1.0%
2019	9085	0.47%	1062	0.7%
2010	0	NA	3497	0.9%
2021	5036	0.48%	1221	1.9%
2022	7435	0.24%	5502	1.1%

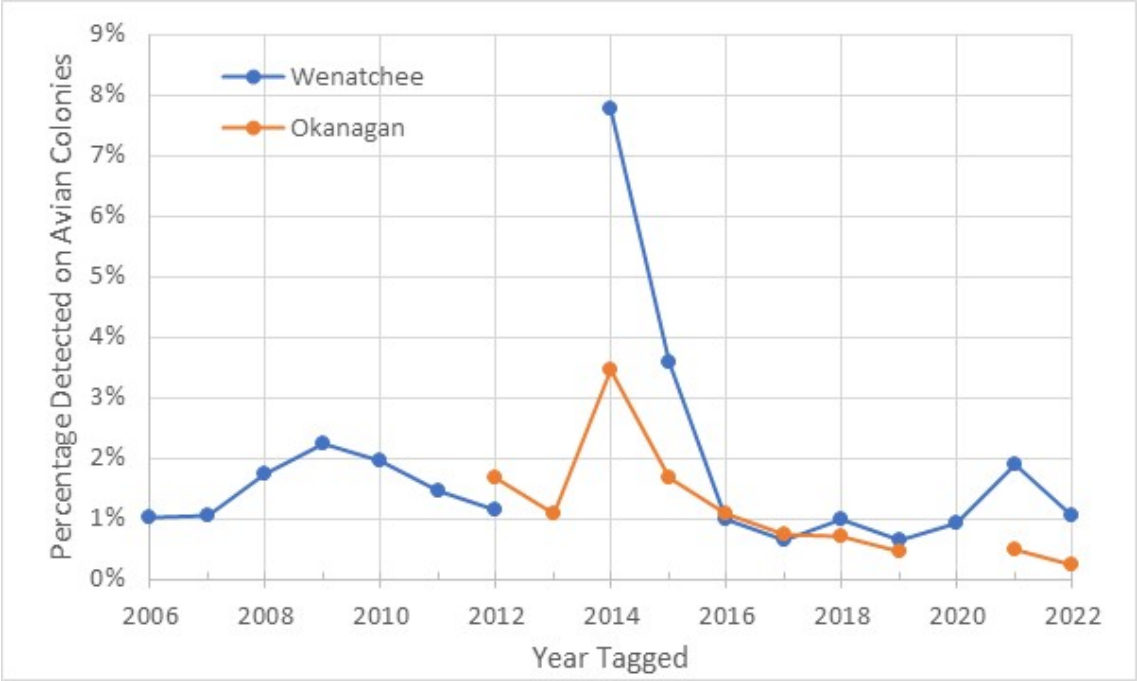

Figure 35. Percentage of juvenile Sockeye Salmon tagged in the Wenatchee and Okanagan basins detected on avian colonies 2008-2022.

The only Sockeye Salmon PIT tagged by this study in 2021 (3) and 2022 (2) that were detected in the Yakima River were detected only at Roza Dam after being detected at the Priest Rapids Dam adult trap. As previously mentioned, these Sockeye most likely were trapped at Priest Rapids and transported to Cle Elum Lake, only to leave the lake and drop back downstream where they were detected at Roza Dam.

No adult Sockeye Salmon PIT tagged at Bonneville Dam were recovered in tribal fisheries between Bonneville and McNary dams (Figure 1) in 2021; however, one Sockeye with tag 3DD.003DEAB3DA was recovered in this fishery on June 28, 2023, after being released and detected at BO3 on June 21 then detected passing the uppermost BO4 antenna on June 25.

Of the 18 Sockeye classified by PBT as being of Yakima-origin tagged at Bonneville Dam in 2021, none were subsequently detected in the Yakima River. Seven were last detected downstream of McNary Dam (4 at Bonneville, 3 at John Day and 5 at McNary). The 5 remaining Sockeye spent between 8.3 and 39.4 days

in the region bounded by McNary Dam and the Ice Harbor and Priest Rapids pools, compared to a mean of 4.0 days for the 2021 run at large (Table 69) with at least 7 fallbacks of Ice Harbor and/or Priest Rapids among 3 of these Sockeye Salmon (Appendix A mapping of movements for a couple of the Sockeye). As was noted in 2020 (Fryer et al. 2021), it appears that Yakima Sockeye Salmon were holding in McNary Pool and possibly the Hanford Reach waiting for the Yakima River to cool off sufficiently for upstream migration. Those that will not, or cannot, wait long enough to migrate up the Yakima River end up migrating upstream of Ice Harbor or Priest Rapids dams or dying downstream of Ice Harbor or Priest Rapids or in the lower Yakima River downstream of the first PIT tag detection site at Prosser Dam. In 2021 the Yakima River was warmer than both the Snake River at Ice Harbor Dam and Columbia River at Priest Rapids Dam from May through August 20 (Figure 36). Only 134 Sockeye were counted at Prosser Dam in 2021, all but two passed after August 20.

Table 69. The 2021 Sockeye classified as Yakima stock by PBT in 2021 detected upstream of PRA and ICH, and days from first McNary detection to last ICH or PRA detection, and last site.

Tag	First McNary Detection	Last Detection at ICH or PRA	Days	Last Dam/Basin and date	Intermediate Ladder Ascensions
3DD.003D82942A	7/10	8/19	39.4	Snake (ICH-8/19)	PRA 7/14, ICH 7/30
3DD.003D8295A6	7/4	7/25	20.3	Snake (ICH-7/25)	
3DD.003D829ABC	6/29	8/7	39.2	Methow Basin (TWR-9/23)	At PRA 7/14, 8/7
3DD.003D82A3C4	6/29	7/19	19.5	Snake River (LRU-10/15)	At PRA 7/3, 7/15, ICH 7/19
3DD.003D82A64A	7/16	7/24	8.3	Columbia (RRF-8/4)	
Mean All fish			**4.0**		

In 2022, no Sockeye sampled by this study at Bonneville Dam were classified by PBT at Bonneville Dam as being of Yakima-origin. This is not surprising as Sockeye returning in 2022 would have primarily outmigrated in 2020, a year in which the rearing lake (Cle Elum Lake) did not fill to a level at which exiting the lake was possible until well after outmigration would normally occur (Andrew Matala, YN personal communication, November 14, 2023).

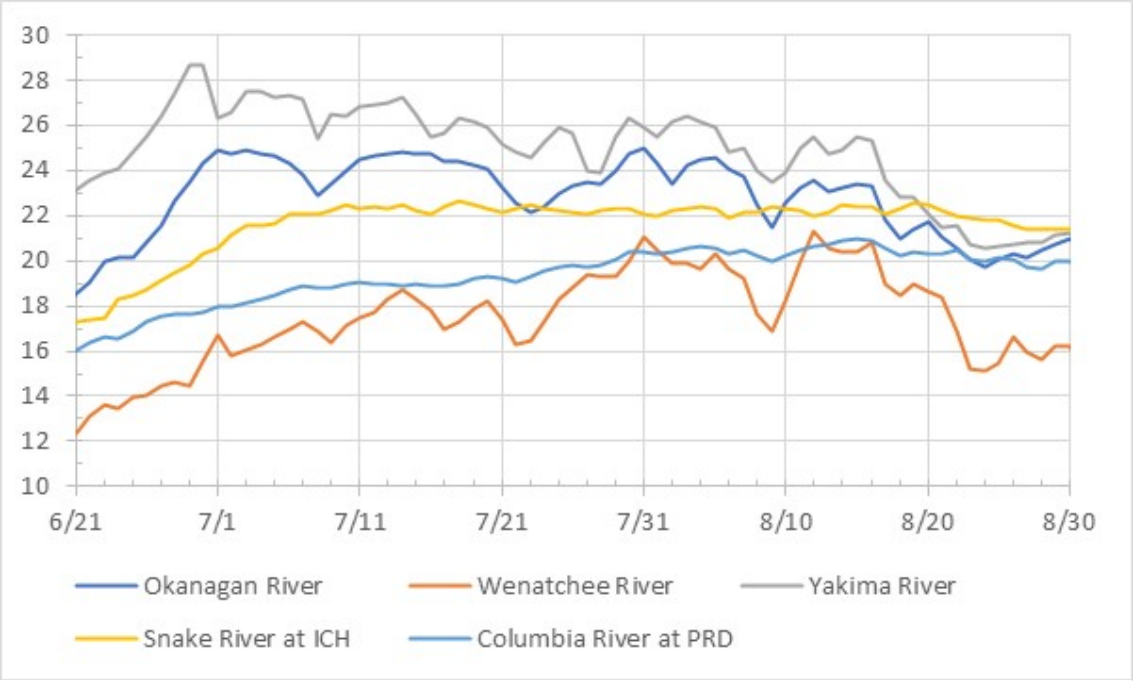

Figure 36. Mean river temperatures by date near mouths of Okanagan, Wenatchee, Yakima, and Snake rivers and the Columbia River at Priest Rapids Dam between June 21 and August 30, 2021.

This project is proposed to continue and evolve over the next several years as there are several priority areas to investigate. We continue to work to improve PIT tag detection at Zosel Dam, a key point on both the upstream and downstream migration which has had low detection of upstream migrating Sockeye Salmon due to fish swimming through the unmonitored spillways rather than the fish ladders where PIT tag antennas are located. Sockeye Salmon also avoided detection in 2022 by moving through spillways rather than ladders at Skaha Dam.

Lake Wenatchee ATS studies funded by this project are expected to continue 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 Salmon.

An exciting development in recent years has been the colonization of Sockeye Salmon in Skaha Lake once passage was provided at McIntyre and

Skaha dams in 2009 and 2014 respectively[51]. With 2023 as the first year of unfettered Sockeye Salmon access into Okanagan Lake, the new OKD PIT tag array partially funded by this project will provide a similar role to assess movement of Sockeye into Okanagan Lake. We plan to continue to work with the Okanagan Nation Alliance and Canada Department of Fisheries and Oceans on expanding the system of PIT arrays to Okanagan Lake.

[51] Prior to changes to allow passage, in rare years with very high flows, hydraulic conditions would sometimes allow Sockeye Salmon to pass upstream of these dams through the spillways.

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APPENDIX A:

Salmon Identified by PBT as of Yakima Origin between Priest Rapids and Ice Harbor Dams

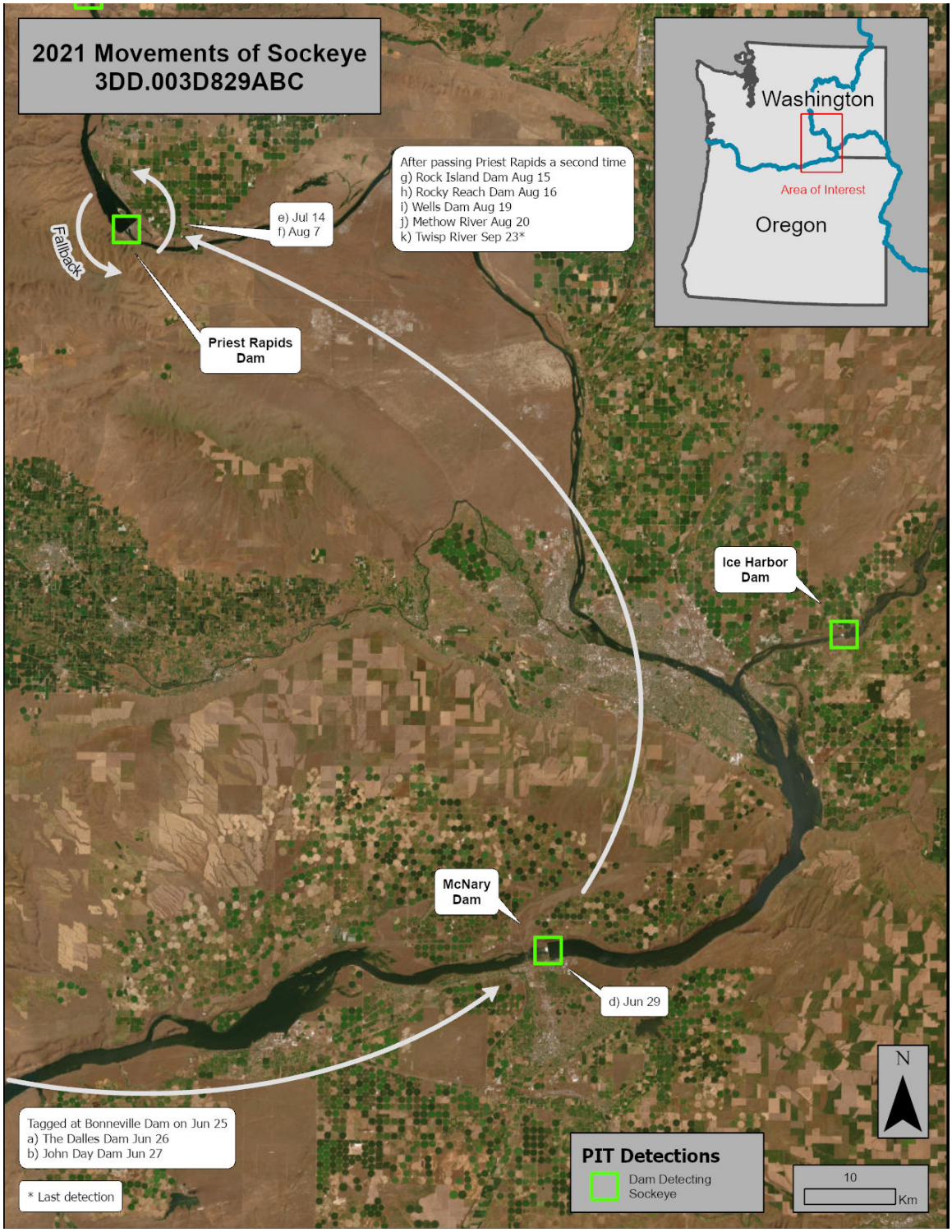

Figure A1. Map showing movements of Sockeye Salmon 3DD.003D829ABC around dams near the mouth of the Yakima River.

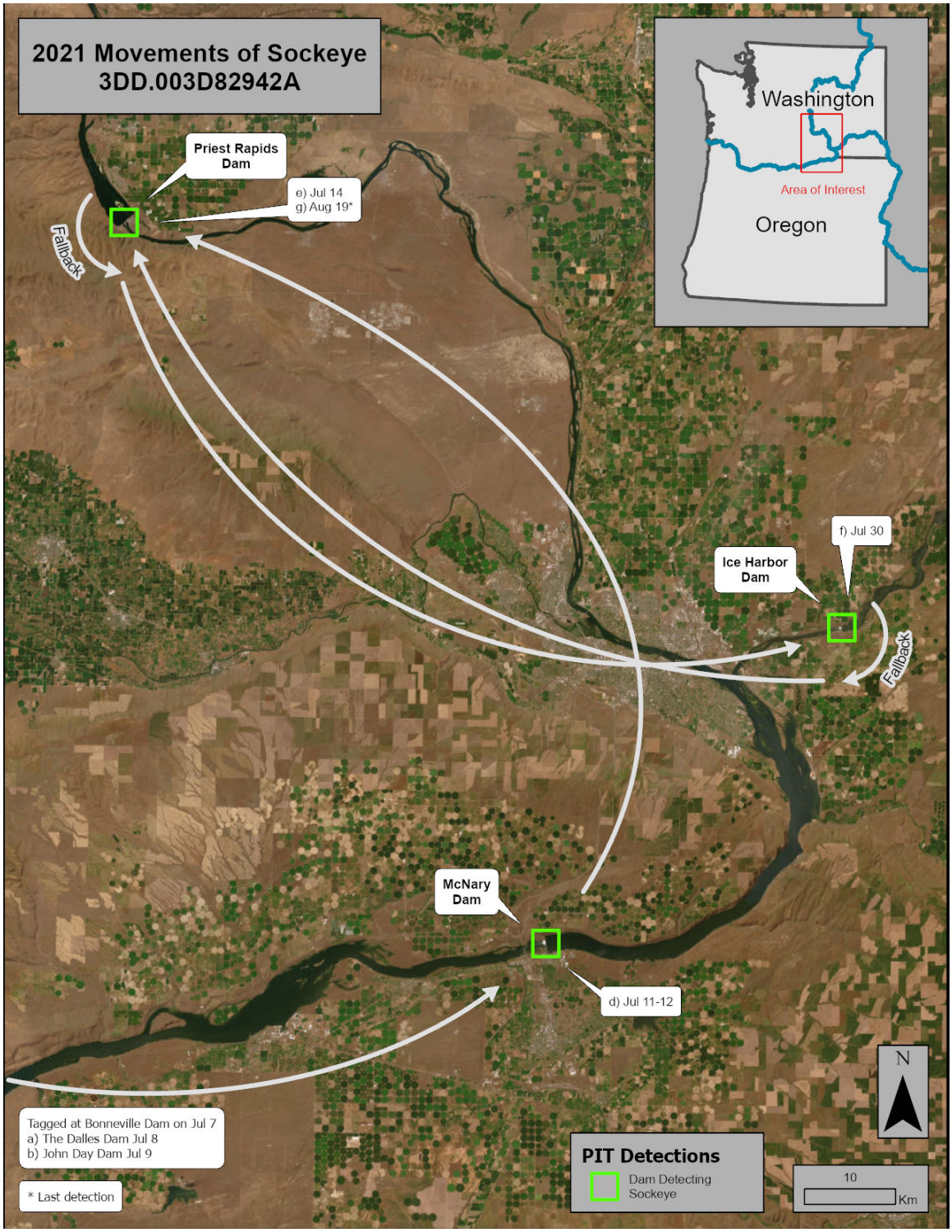

Figure A2. Map showing movements of Sockeye Salmon 3DD.003D82942A around dams near the mouth of the Yakima River.

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 Salmon tagged and/or tracked by this project in 2021 and 2022.

Site Code	Site Name	Site Description	Year
ACM	Asotin Creek near mouth	Near the mouth of Asotin Creek 50 m upstream of the Highway 129 bridge spanning the mainstem of Asotin Creek in two serial sets of two antennas.	2021
B2J	Bonneville PH2 Juvenile	Bonneville Dam PH2 Juvenile Bypass and Sampling Facility.	2022
BCC	BON PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel.	Both
BO1	Bonneville Bradford Is Ladder	Bradford Island Adult Fishway at Bonneville Dam.	Both
BO2	Bonneville Cascades Is Ladder	Cascades Island Adult Fishway at Bonneville Dam.	Both
BO3	Bonneville WA Shore Ladder/AFF	Washington Shore Adult Fishway and AFF at Bonneville Dam; replaces B2A and BWL.	Both
BO4	Bonneville WA Ladder Slots	Washington Shore Fishway Vertical Slots at Bonneville Dam.	Both
CRW	Chewuch River above Winthrop	Chewuch River at river km 1, above Winthrop, WA.	2022
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.	2022
ENL	Lower Entiat River	Entiat River rkm 2, located immediately upstream of Entiat, WA.	Both
GOA	Little Goose Fish Ladder	Adult Fishway at Little Goose Dam.	Both
GOJ	Little Goose Dam Juvenile	Little Goose Dam Juvenile Fish Bypass/Transportation Facility.	2021
GRA	Lower Granite Dam Adult	Lower Granite Dam Adult Fishway and Fish Trap.	Both
ICH	Ice Harbor Dam (Combined)	Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass.	Both
ICL	Lower Icicle Instream Array	Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA.	Both
JDJ	John Day Dam Juvenile	John Day Dam Juvenile Fish Bypass and Sampling Facility.	Both
JO1	John Day Dam South Fish Ladder	The interrogation site at the John Day Dam south fish ladder.	Both
JO2	John Day Dam North Fish Ladder	The interrogation site at the John Day Dam north fish ladder.	Both
LLC	Loup Loup Creek Instream Array	This site is located 0.42 km from the confluence with the Okanogan River on Loup Loup Creek which enters the Okanogan River at RKM 27.2, within the city of Malott, WA.	2021
LMA	Lower Monumental Adult Ladders	This interrogation site is in both ladders at Lower Monumental Dam.	Both
LMJ	Lower Monumental Dam Juvenile	Lower Monumental Dam Juvenile Fish Bypass/Transportation Facility.	2021
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.	2021
LRL	Lower Lochsa River Array Site	Site is located in lower 1km of the mainstem Lochsa River.	2021
LRU	Lochsa River Upper Site	Site is located in lower 3km of the mainstem Lochsa River.	2021
LWE	Lower Wenatchee River	Wenatchee River rkm 2.	Both
LWN	Little Wenatchee River	Instream PIT tag interrogation site at rkm 4 located at the old fish weir.	Both
MC1	McNary Oregon Shore Ladder	Oregon Shore Adult Fishway at McNary Dam.	Both
MC2	McNary Washington Shore Ladder	Washington Shore Adult Fishway at McNary Dam.	Both
MCJ	McNary Dam Juvenile	McNary Dam Juvenile Fish Bypass/Transportation Facility.	Both
MRC	Methow River at Carlton	Located in the mainstem Methow River near the town of Carlton at rkm 45.	Both
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.	2022
MSH	Methow Fish Hatchery Outfall	On the outlet of the Washington Department of Fish and Wildlife (WDFW) Methow Hatchery located on the Methow River at Rk 82.3 from the confluence with the Columbia River.	2022
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.	Both
OKL	Lower Okanogan Instream Array	Site at RKM 24.9 on the mainstem Okanogan River, upstream of Chiliwist area in Okanogan County.	Both
OKM	McIntyre Dam	Site has antennas on each side of spill bay 1 at McIntyre Dam, which is located downstream of Vaseux Lake and upstream of Okanagan Lake.	Both
OKP	Penticton Channel PIT Array	Penticton Channel, is the channelized portion of the Okanagan River connecting Okanagan Lake with Skaha Lake, within the city of Penticton BC.	Both
OKS	Shingle Creek	Site is on a a tributary to the Okanagan River in Canada, immediately adjacent to the Okanagan Shingle Creek	2021
OKV	Vaseux Creek, BC, Canada	The site is located 200m upriver from mouth of Vaseux Creek a trib of Okanogan River.	2022
PRA	Priest Rapids Adult	Priest Rapids Dam Adult Fishways (both).	Both
RFL	Redfish Lake Creek	The site is located on Redfish Lake Creek approximately one half mile upstream from the confluence with the Salmon River.	2021
RIA	Rock Island Adult	Rock Island Dam Adult Fishways (all three).	Both
ROZ	Roza Diversion Dam (Combined)	Roza Dam Smolt Bypass.	Both
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway.	Both
RRJ	Rocky Reach Dam Juvenile	Juvenile Fish Bypass Surface Collector.	Both
RSH	Ringold Springs Hatch. Outfall	PIT tag detection system located in the Ringold Springs Hatchery outfall channel.	Both
SC1	Lower SF Clearwater R at rkm 1	Lower South Fork Clearwater River at river km 0.9 (N 46.13685 W -115.98091).	2021
SC2	Lower SF Clearwater R at rkm 2	Lower South Fork Clearwater River at river km 2 (N 46.12749 W -115.97730).	2021
SKA	Skaha Dam Fish Ladder	Skaha Dam is located within the community of Okanagan Falls at the south end of Skaha Lake, BC along the Okanagan River. The fishway is at the western edge of the dam.	Both
SSJ	Sunnyside Juvenile Fish Bypass	The site is located at Sunnyside Dam in the canal starting about 320 meters below the headgate.	2022
SUN	Sunnyside Instream Array	Located 600 M below Sunnyside Dam on the Yakima River.	2021
TD1	The Dalles East Fish Ladder	East Fish Ladder at The Dalles Dam.	Both
TD2	The Dalles North Fish Ladder	North Fish Ladder at The Dalles Dam.	Both
TUF	Tumwater Dam Adult Fishway	Adult Fishway at Tumwater Dam.	Both
TWR	Lwr Twisp Rvr near MSRF Ponds	Lower Twisp River adjacent to the Methow Salmon Recovery Foundation Ponds.	Both
UWE	Upper Wenatchee River	Located at rkm 81.2 on the Wenatchee River, near Plain, WA.	Both
WEA	Wells Dam, DCPUD Adult Ladders	Wells Dam Adult Fishways (both).	Both
WEH	Wells Dam Hatchery	Points of detection include the adult fish handling facility, juvenile pond outflows and adult volunteer channel.	Both
WEJ	Wells Dam Bypass Bay Sample	Site is located in Bypass Bay 2 on the right (west) side of Wells dam on the Columbia River, Washington.	2021
WTL	White River, Wenatchee Basin	A permanent instream PIT tag interrogation site at RKM 2.88 on the White River.	Both
ZSL	Zosel Dam Adult Fishways	Zosel Dam is located at Okanogan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos in the town of Oroville, Washington.	Both

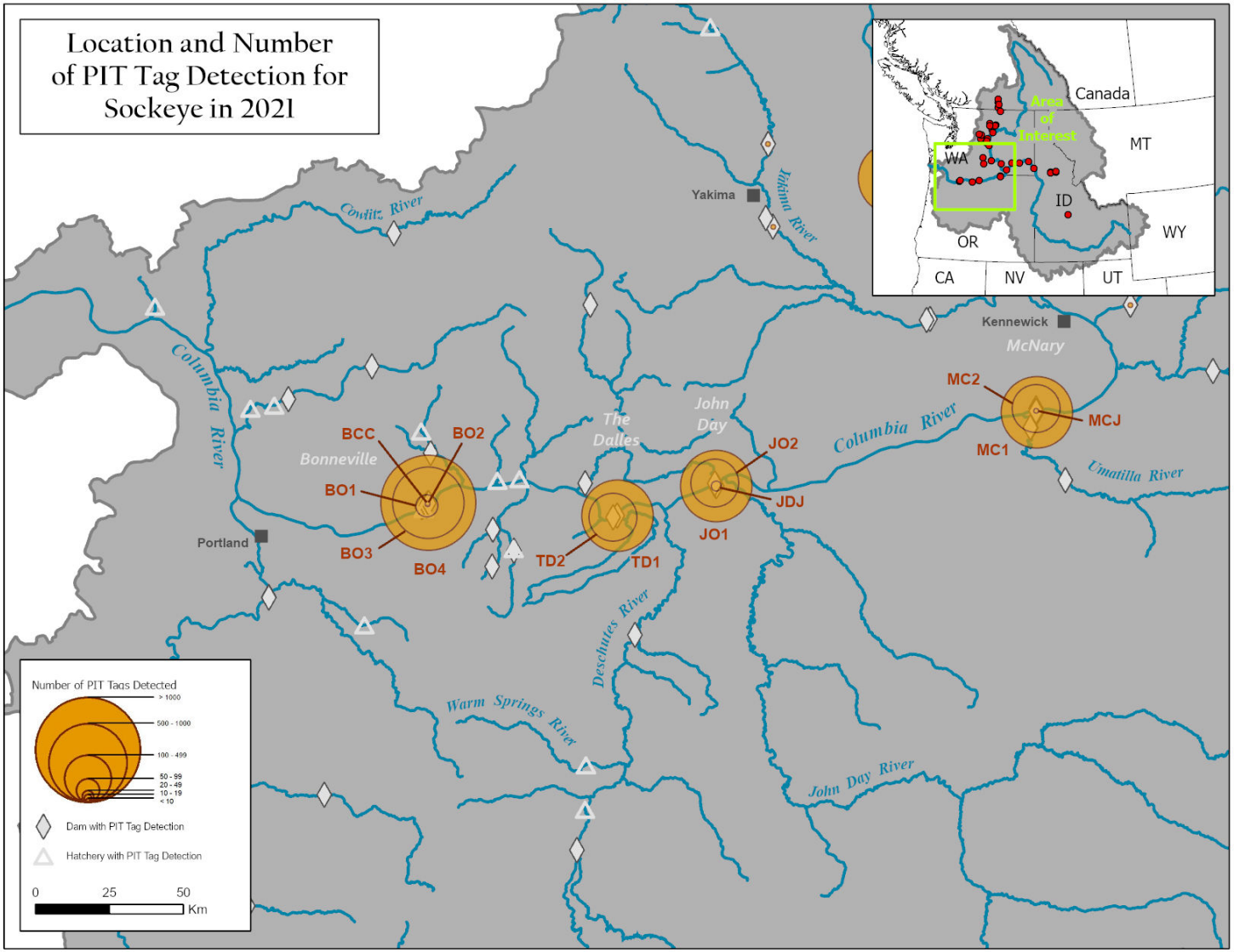

Figure B1. Map of Lower Columbia River detection sites (below Snake River) and number of Sockeye Salmon detected in 2021. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

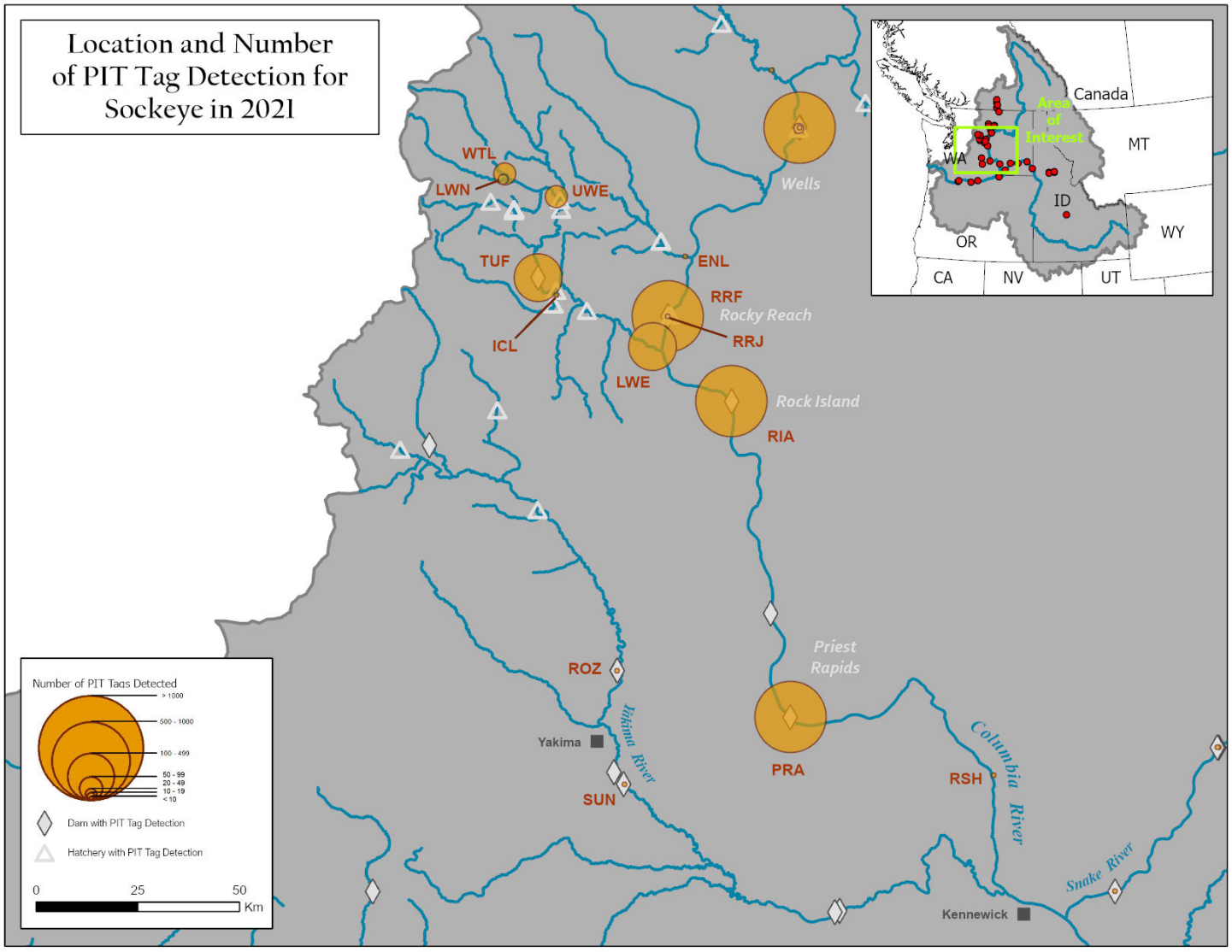

Figure B2. Map of Upper Middle Columbia River (between the Snake River and Wells Dam) detection sites and number of Sockeye Salmon Salmon detected in 2021. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

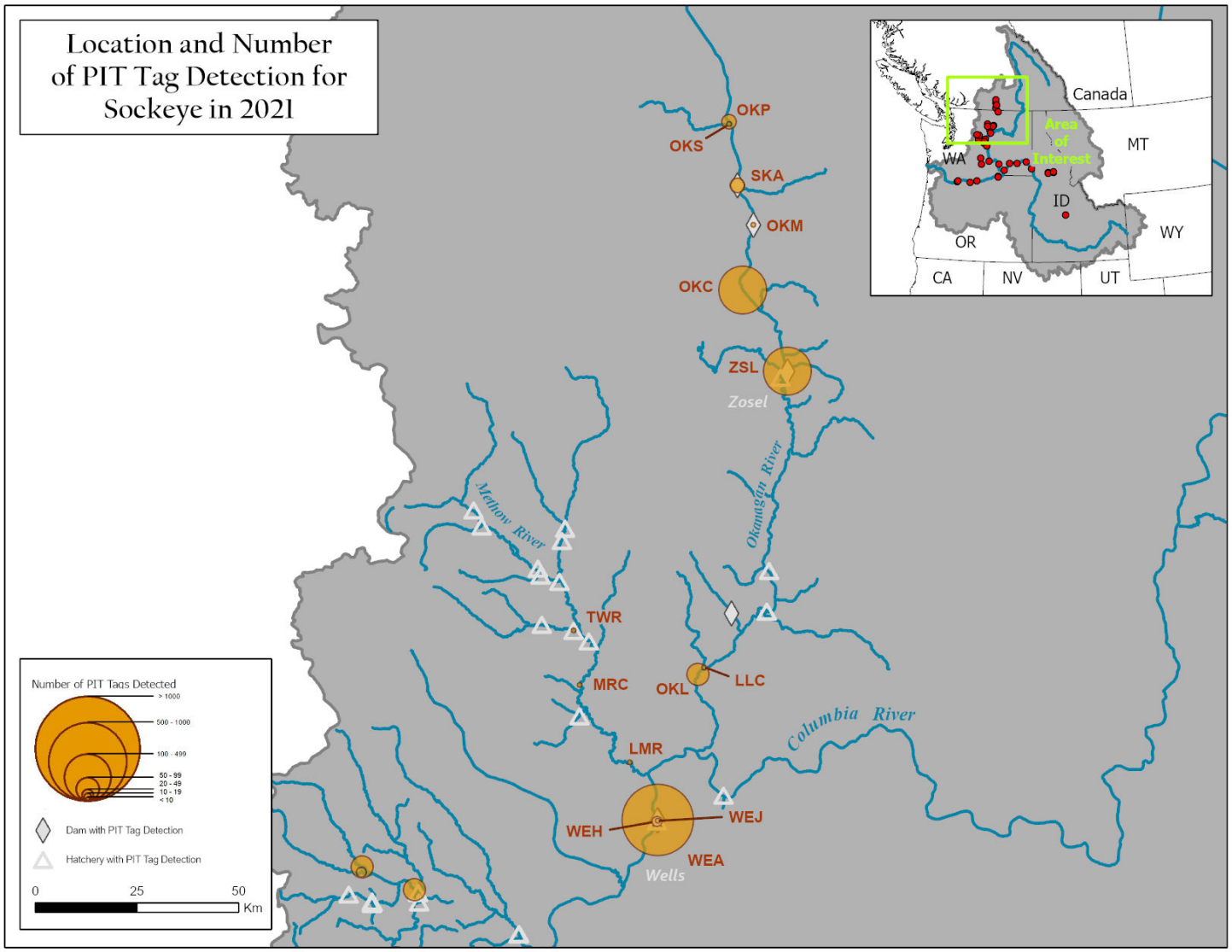

Figure B3. Map of Upper Columbia River (Wells Dam and above) detection sites and number of Sockeye Salmon detected 2021. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

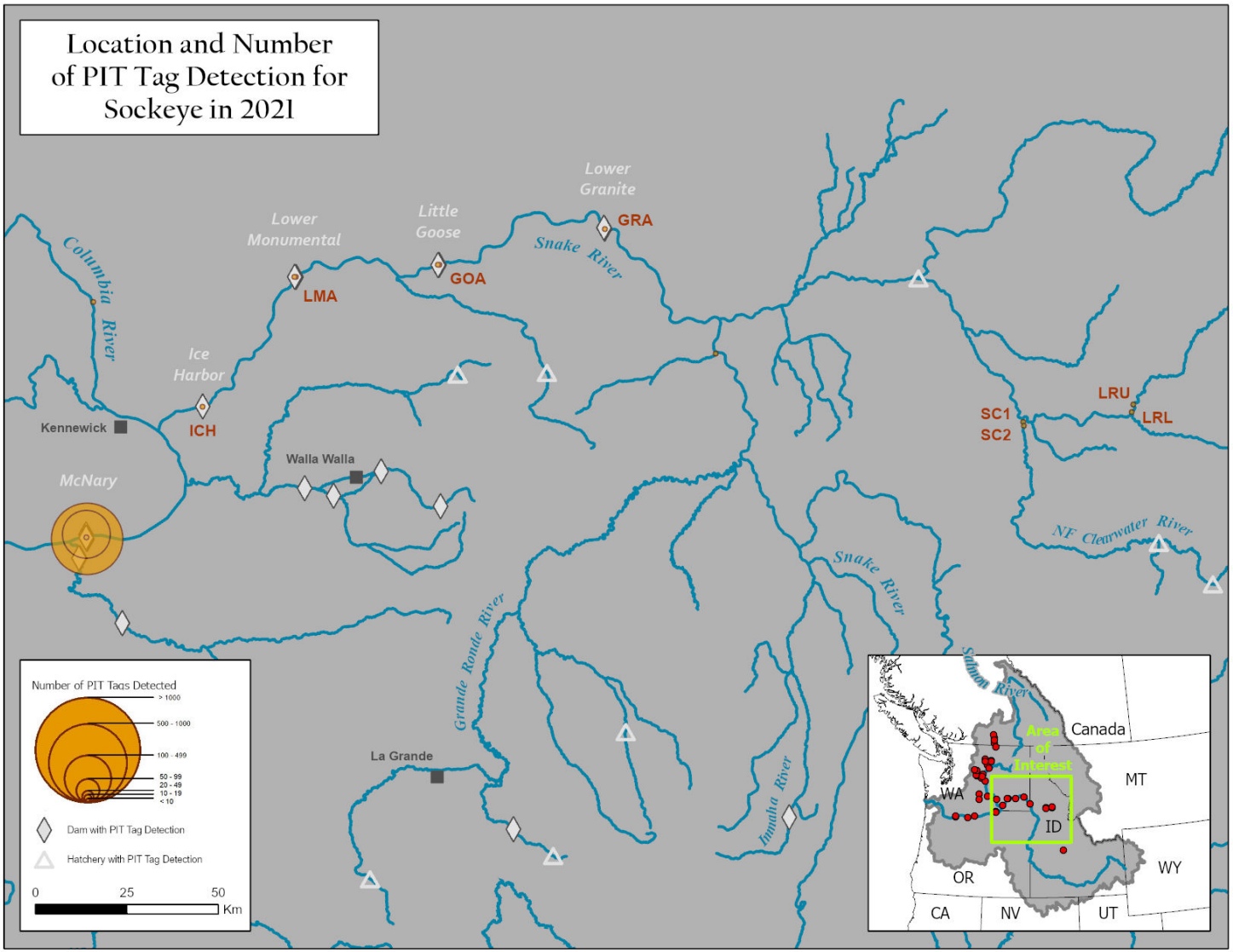

Figure B4. Map of Lower Snake River detection sites (Salmon River not included) and number of Sockeye Salmon detected in 2021. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

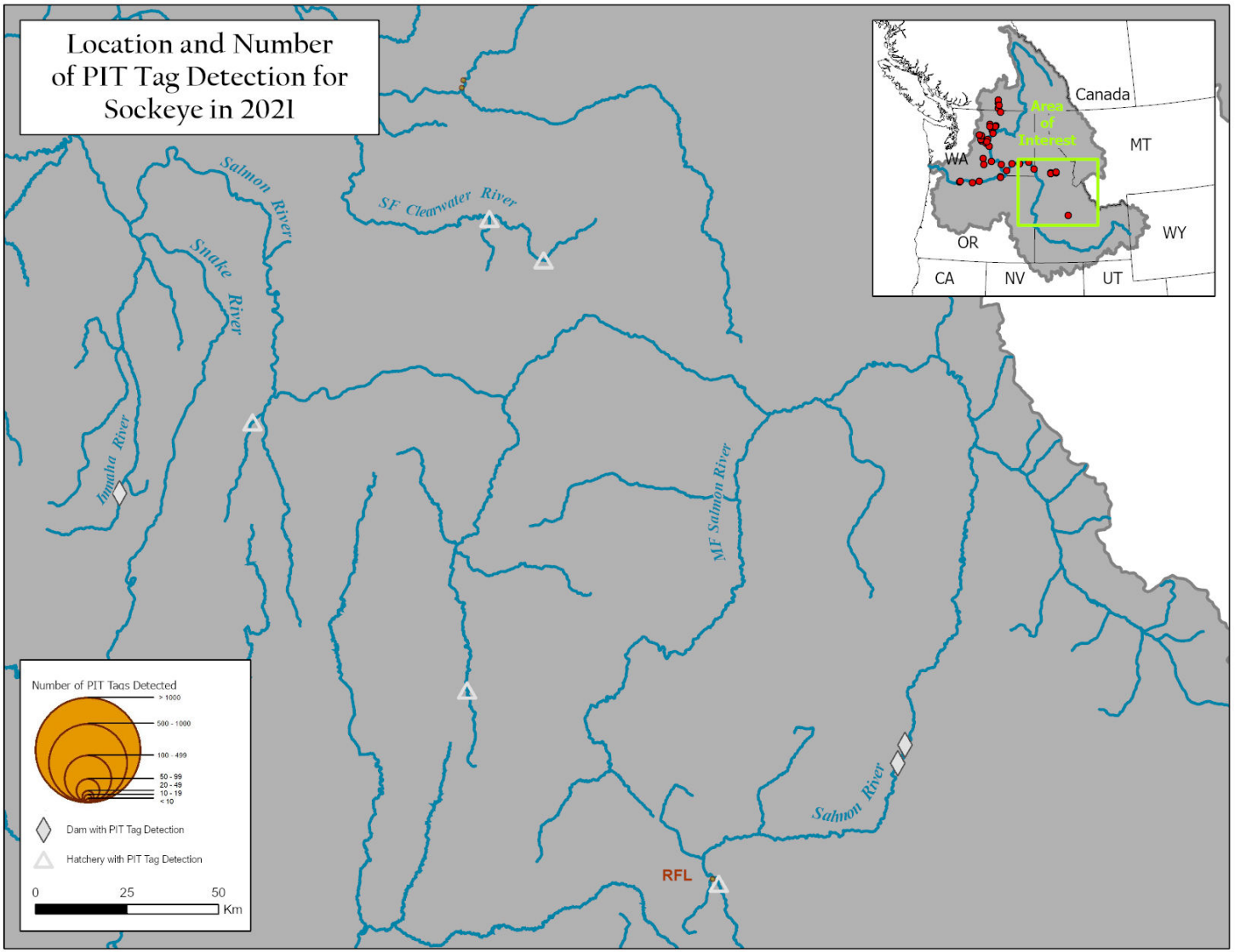

Figure B5. Map of Salmon River detection sites and number of Sockeye Salmon detected in 2021. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

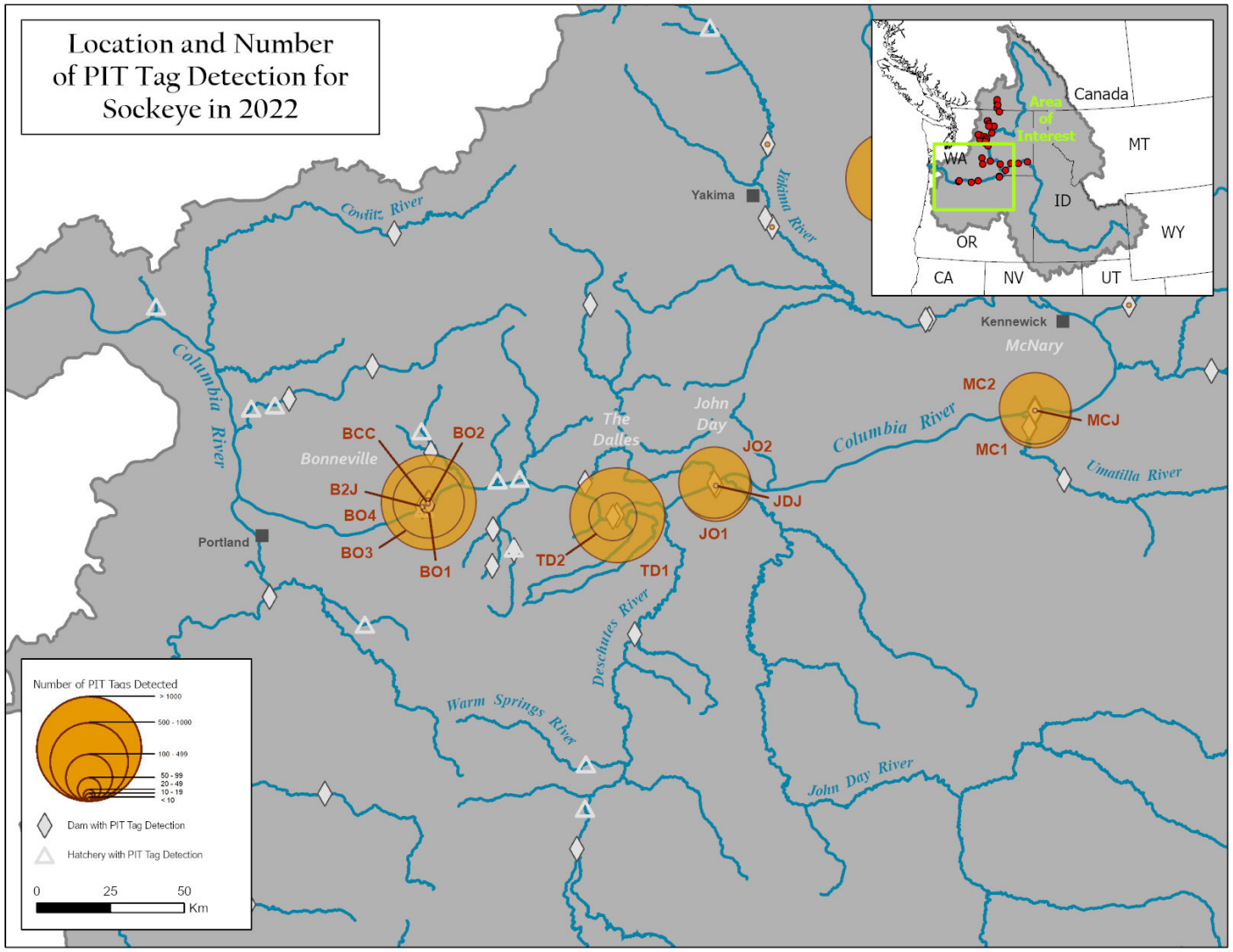

Figure B6. Map of Lower Columbia River detection sites (below Snake River) and number of Sockeye Salmon detected in 2022. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

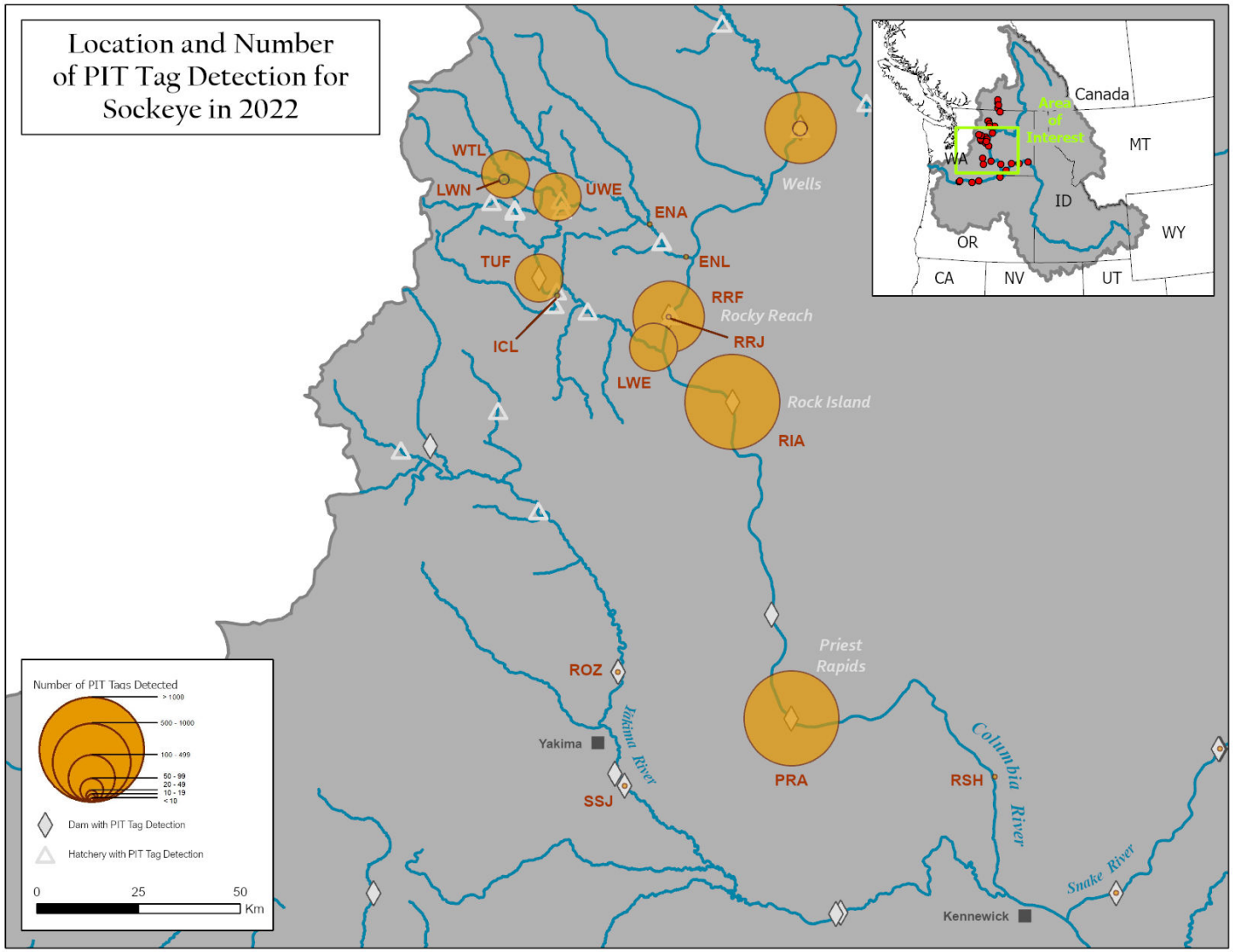

Figure B7. Map of Upper Middle Columbia River (between the Snake River and Wells Dam) detection sites and number of Sockeye Salmon Salmon detected in 2022. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

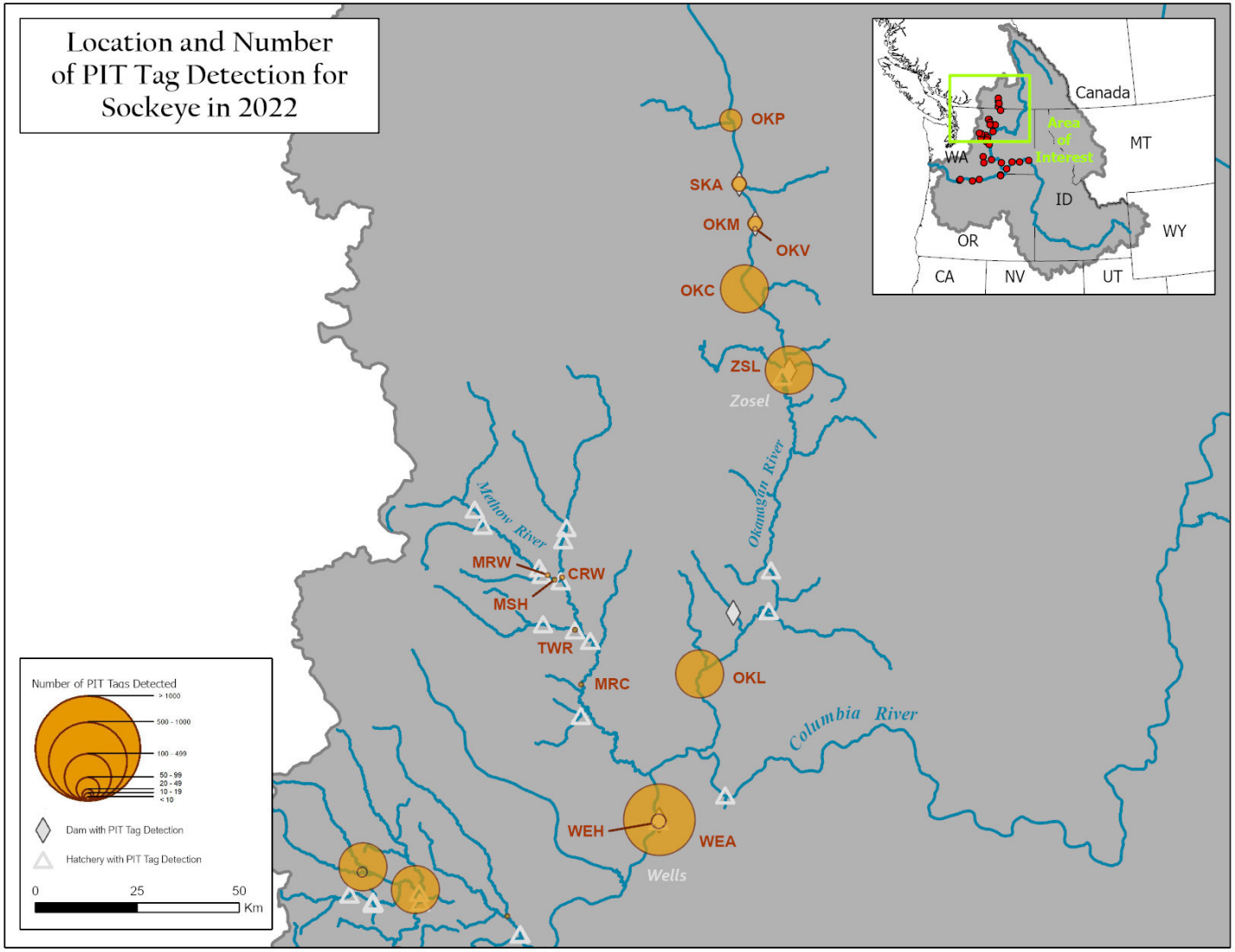

Figure B8. Map of Upper Columbia River (Wells Dam and above) detection sites and number of Sockeye Salmon detected 2022. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

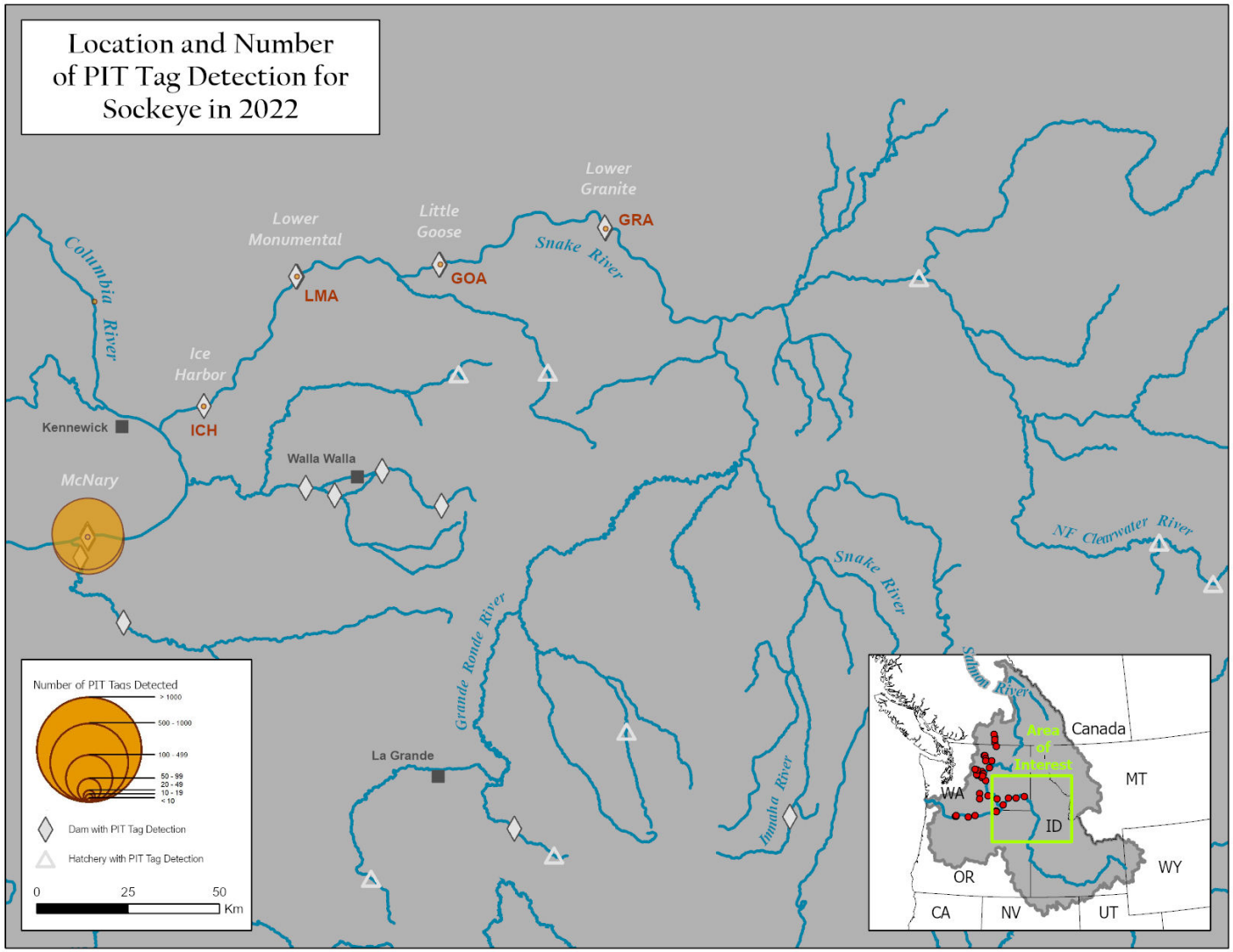

Figure B9. Map of Lower Snake River detection sites (Salmon River not included) and number of Sockeye Salmon detected in 2022. Table B1 in the Appendix B lists the PTAGIS sites' full name and the three-letter codes on this map.

APPENDIX C:

Okanagan Nation Report

sc̓awsitkʷ (Okanagan River) Sockeye Smolt Out of Basin Survival: Purse Seining & PIT Tagging BY 2019

Prepared by:
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Skyeler Folks, B.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 2021

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Executive Summary

sq̓awsitkʷ[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 a re-introduction of hatchery-reared Sockeye Salmon into tu̓ʔcin (Skaha Lake). Out of basin survival of both hatchery and natural Okanagan Sockeye smolts remains an important unanswered question. In 2012, Okanagan Nation Aquatic Enterprises (OAE) conducted a pilot study to evaluate Passive Integrated Transponder (PIT) technology to test the methodology, effectiveness, and survival and travel time of smolts as they migrate out of the Okanagan River basin. Since the initial pilot study, OAE has made improvements in both smolt capture and tagging techniques, resulting in the current smolt monitoring methodology.

In 2021, 5,036 smolts were successfully tagged and released during five tagging sessions between 23 April and 26 April. A total of 5,077 smolts were tagged at sẁiẁs, with 41 post-tagmortalities. Tagging location was OSOYOL, in the north end of the lake, although fish were captured in the central basin of the lake and the area just north of the Highway 97 Bridge. Smolts were transported in fish totes on boats to the tagging location. The Osoyoos sessions lasted four days, from 23 April to 26 April. Survival probability for sẁiẁs smolts to Rocky Reach Dam was 0.57 (SE=0.05). Survival from release to Bonneville Dam was 0.27 (SE=0.57). Travel time from release to Rocky Reach Dam was approximately 20.4 days. The overall travel time (release to Bonneville) for Osoyoos smolts was 28.5 days.

Due to weather, environmental conditions, and the relatively small 2019 brood year resulting in low smolt numbers, there were no fish caught or tagged from tu̓ʔcin in 2021. Fishing occurred May 5-14, 2021 and Due to the absence of smolts tagged in tu̓ʔcin, travel times and survival probabilities for the tu̓ʔcin or aggregate population were not reported.

[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, GCPUD, BPA and CRITFC were able to provide CSS PIT tags to support our efforts.

ONA staff that contributed to this project: Nick Yaniw, Belinda Kruger, Lynnea Wiens, Dave Tom, Chelsea Mathieu, Casmir Tonasket, Paul Snow, Darwyn Haller, Jamison Squakin, and Saul Squakin. We wish to thank Osoyoos Indian Band for their support, and OIB Fisheries Technicians Lindsay George and Collette Louie.

ONA also thanks the Baptiste Family (OIB) and Bob and Pat from the Sun & Sand RV Park (Okanagan Falls) for allowing access to private property.

Citation: Simpson C. and S. Folks. 2021. sc̓awsitkʷ (Okanagan River) Sockeye Smolt Out-of-Basin Survival: Purse Seining and PIT Tagging BY 2021. Prepared by Okanagan Nation Aquatic Enterprises Ltd., Westbank, BC. 10 pp.

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Table of N'syilxcen Place Names

N'syilx'cin Place Name	(Okanagan-English Translation)
nx̌ʷəntkʷitkʷ	Columbia River
sḵawsitkʷ	Okanagan River
tʼuʔcin	Skaha Lake
swiẇs	Osoyoos Lake
sx̌wəx̌wnikw	Okanagan Falls
akspaqmix	Vaseux Lake
nʕaylintən	McIntyre Dam
akɬxʷminaʔ	Shingle Creek

Translation provided by Richard Armstrong, Penticton Indian Band and the Okanagan Nation Alliance. Indigenous Peoples of the Okanagan Nation are the exclusive owners of their cultural and intellectual properties as asserted through the United Nations Declaration on the Rights of Indigenous Peoples (2007).

1.0 Introduction

1.1 Project Background

sq̓awsitkʷ (Okanagan River) Sockeye Salmon (*Oncorhynchus nerka*) population is one of the last few remaining viable Sockeye Salmon stocks in nx̌ʷəntkʷitkʷ (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 t̓uʔcin (Skaha Lake) beginning in 2003 (Wright and Smith, 2003). Sockeye eggs collected from sq̓awsitkʷ broodstock are hatchery reared then released into t̓uʔcin where they rear for one year before migrating to nx̌ʷəntkʷitkʷ and the Pacific Ocean as smolts (Stefanovic et al. 2020). 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 nx̌ʷəntkʷitkʷ 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 sq̓awsitkʷ upstream of sẁiẁs (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 t̓uʔcin and sẁiẁs, and a total of 4,018 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; 10,241 in 2016; 11,588 in 2017; 10,943 in 2018; 9,083 in 2019 (Folks et al. 2016a; 2016b; 2017; 2019, Yaniw & Benson 2018). No fish were tagged in 2020, and only 5,036 were tagged in 2021, all purse seined from sẁiẁs.

In 2016, OAE piloted purse seining in both lakes as a method of capturing smolts (Benson 2016; 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. As in previous years, purse seining was conducted in both sẁiẁs and t̓uʔcin. This was based on the assumption that t̓uʔcin and sẁiẁs Sockeye populations would not be sufficiently mixed in sẁiẁs during the sampling period. One of OAE's objectives was to tag and monitor both populations.

This report summarizes the capture and tagging program for the 2021 season (2019 Broodyear). Tagging targets of at least 10,000 (5,000 from each lake) were set to optimize survival estimates to Lower nxˇʷəntkʷitkʷ PIT detection sites.

1.2 Study Area

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

Figure 1. sq̓awsitkʷ juvenile PIT tagging locations in 2021.

1.3 Project Objectives

The main objective was to PIT tag a minimum of 5,000 smolts from each lake, tu̓ʔcin and sẇiẇs, 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 5,000 hatchery- and natural-origin smolts from each lake population; tu̓ʔcin and sẇiẇs, for a total of 10,000.

2. Continue to refine smolt capture techniques using a purse seine.

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

ONA purse seined sẇiẇs 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 and the southern end of the north basin of sẇiẇs where the majority of Sockeye smolts were congregating. Purse seining in tu̓ʔcin was concentrated in the south end of the lake, as has been done in previous years.

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 initially held in submerged net pens or oxygenated fish totes. Fish were then removed from holding pens and placed in a 45-litre cooler containing a 40 mg/l solution of tricaine methanesulfonate (MS 222). Fish were kept in the solution until they lost equilibrium (approximately 2-3 minutes), and then transferred to a smaller bin. These smaller bins contained a lower concentration of MS 222, enabling fish to partially recover. This system was an improvement on previous years; it allowed the fish to be processed with minimal handling and stress. As in previous years, individual smolts were measured for fork length and general condition/descaling. 614 lengths were recorded on the first tagging day, April 23, and were not recorded on subsequent days as sufficient length data had already been obtained, and to reduce sampling time with high catch rates. Size constraints were set for tagged fish in 2021. Only fish between 70-120 mm were tagged; smaller fish would be more likely to experience tagging mortality, and larger fish were likely to be kokanee.

Tagging procedures did not change from previous years, the tagging needle was inserted on the 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 HPR was connected to a Panasonic 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 holding pens and released back into the lake the same day, typically between 20:00 and 21:00 to reduce predation. Fish were released in the North Basin, at OSOYOL, in sẇiẇs. All post-tagged smolt mortalities were removed and the PIT tag numbers from fish mortalities were deleted from the tagging file to improve accuracy of survival estimates.

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

In 2021, we captured 100% (n=5,077) of smolts in sẇiẇs. All sẇiẇs smolts were captured in the Central and North basins of sẇiẇs (Figure 1).

Following capture and tagging, smolts were held in net pens to allow the fish to recover, monitor immediate post-tagging mortality, and to remove mortalities from the tagged population. A random sample of smolts was collected directly from purse seine catches for biosampling. In total, 402 smolts were biosampled. Smolts had a mean fork length of 9.3 cm and mean weight of 8.18 g. To determine origin, otoliths were checked for hatchery thermal marks. In total, 350 otoliths were successfully checked for origin; 98.6% (n=345) were natural origin.

3.2 PIT Tagging Results

5,036 smolts were successfully tagged and released during 4 tagging days: 23-26 April 2021 at OSOYOL (Baptiste property, north end of sẇiẇs). From May 5 – May 14, the purse seiner fished daily on tu̓ʔcin, but no smolts were captured. Daily tagging effort has been summarized (Table 1). Total fish tagged from OSOYOLS was 5077, with 41 mortalities; 5,036 were successfully released to the lake.

Table 1. Summary of Okanagan Sockeye smolt PIT tagging effort, 2021.

Date	OSOYOOS
23-Apr-21	1096
24-Apr-21	2642
25-Apr-21	572
26-Apr-19	767
TOTAL	**5077**

3.2.1 Survival

Estimates of survival from release to Rocky Reach Dam, Rocky Reach to Bonneville, and Release to Bonneville were calculated for the release group (Table 2). In addition, survival estimates since 2013 have been summarized (Table 3).

Table 2. Survival for PIT tagged sc'awsitk^{w} (Okanagan River) Sockeye smolts from Osoyoos Lake, 2021.

Period	Survival	SE
Release to Rocky Reach	0.57	0.05
Rocky Reach to Bonneville	0.48	0.26
Release to Bonneville	0.27	0.14

Table 3. Comparison of annual survival for PIT tagged sc'awsitk^{w} (Okanagan River) Sockeye smolts, 2013-2021. Standard Errors of mean presented in brackets. Survival from Rocky Reach to Bonneville was not calculated between 2013-2018.

River Reach Interval	2013	2014	2015	2016	2017	2018	2019	2021
Release to Rocky Reach	0.48 (0.03)	0.57 (0.08)	0.42 (0.02)	0.56 (0.02)	0.67 (0.03)	0.62 (0.02)	0.51 (0.03)	0.57 (0.05)
Rocky Reach to Bonneville	-	-	-	-	-	-	0.55 (0.11)	0.48 (0.26)
Release to Bonneville	0.48 (0.33)	0.03 (0.08)	0.44 (0.14)	0.21 (0.04)	0.35 (0.11)	0.41 (0.13)	0.28 (0.05)	0.27 (0.14)

* survival estimates are pooled across lakes and sites, representing an aggregate survival for all Okanagan Basin smolts.
* * 2021 estimates are based on Osoyoos Lake smolts only.

3.2.2 Travel Time

Estimates of travel time were calculated for Osoyoos smolts (Table 4). Travel time to Rocky Reach was approximately 20.4 days for Osoyoos smolts. Travel time to Bonneville was approximately 28.5 days for Osoyoos smolts. Travel time since 2013 has also been summarized (Table 5).

Table 4. Mean Harmonic Travel Time for PIT tagged sc̓awsitkʷ (Okanagan River) Sockeye smolts from Osoyoos Lake, 2021.

Period	Travel time (days)	SE
Release to Rocky Reach	20.4	0.19
Rocky Reach to Bonneville	9.0	0.12
Release to Bonneville	28.5	0.26

Table 5. Comparison of Harmonic mean travel time for PIT tagged sc̓awsitkʷ (Okanagan River) Sockeye smolts, 2013-2021. Standard Errors of mean presented in brackets. Travel Time from Rocky Reach to Bonneville was not estimated from 2013-2018. 2021 Data is based on Osoyoos poplation.

River Reach Interval	2013	2014	2015	2016	2017	2018	2019	2021
Release to Rocky Reach	19.3 (0.25)	15.9 (0.19)	16.2 (0.14)	14.2 (0.13)	10.2 (0.08)	13.0 (0.13)	20.7 (0.13)	20.4 (0.19)
Rocky Reach to Bonneville	-	-	-	-	-	-	8.4 (0.11)	9.0 (0.12)
Release to Bonneville	29.0 (0.74)	23.2 (0.56)	26.6 (0.27)	23.4 (0.29)	17.7 (0.19)	19.7 (0.27)	29.1 (0.17)	28.5 (0.26)

* travel time estimates are pooled across lakes and sites, representing an aggregate survival for all Okanagan Basin smolts.

4.0 Discussion and Recommendations

In 2021, 5,036 smolts were successfully tagged and released in sẁiẁs. While we reached the minimum sample size target for sẁiẁs, purse seine crews were not able to capture any smolts from t̓u?cin. Purse seining was discontinued on t̓u?cin May 14, after 10 days without capturing smolts. While it is possible smolts migrated prior to start of fishing, it is more likely smolts were too deep for the purse seine (minimum 40-60m below the surface. Throughout the seine operation, smolts were either not detected with the depth sounder, or were schooled near the lake substrate (R. Birch, Farside Fishing, *pers. comm.*). In addition, natural recruitment and hatchery production in 2019 was below average, which may have reduced the total number of smolts present in t̓u?cin (Stefanovic et al. 2020; Yaniw and Benson 2021)

Survival estimates are typically reliable from release to Rocky Reach, and release to Bonneville. However, Okanagan Basin smolt survival estimates from Rocky Reach to McNary and McNary to John Day have historically been unreliable. Detection probabilities from the PITPro calculations are very low, resulting in survival probability often exceeding 1.0. Due to the configuration of PIT arrays at McNary and John Day dams, detection probabilities have been consistently low resulting in unreliable survival estimates for the associated reaches (DeHart 2018). As a result, McNary and John Day dam detection results were removed from the analysis in 2019 and 2021 (Yaniw et al. 2020; this report).

Survival from release to Rocky Reach falls with the annual estimated range since 2013. However, survival from release to Bonneville is relatively low for 2021, estimated as the third lowest since 2013 (Table 3). Travel time, both from release to Rocky Reach and release to Bonneville was longer relative to previous smolt years (Table 5). Travel time is a function of river flow, with reduced flow increasing total migration time. It is likely that increased travel time estimated in 2021 caused a decrease in smolt survival.

t̓u?cin smolts were difficult to locate and purse seine. Future purse seining efforts should be timed when smolts/pre-smolts are near the surface, staging for outmigration. While synchronizing effort with this smolt behavior is challenging, additional depth-sounding prior to start up could be a solution. Although purse seining on t̓u?cin was unsuccessful in 2021, this is still the preferred method over trapping smolts downstream of Skaha Dam due to spring freshet and hazardous river flows (Benson 2016).

Recommendations for future monitoring include:

- Capture smolts from both lakes. The minimum target will remain 10,000 smolts (5000 from each lake).
- Purse seining will remain the primary capture method. The fyke net and RSTs should be a back-up capture method, only if the purse seine vessel is unavailable. Attempt to refine seining start date to be closer to smolt staging at the surface with pre-season depth soundings
- McNary and John Day dam PIT detection data should continue to be excluded from future analyses. Survival and travel time estimates should only include Release to Rocky Reach Dam, Rocky Reach Dam to Bonneville Dam, and Release to Bonneville Dam intervals.
- Biosampling should only be conducted on random smolt collections from trawl catches, not smolt mortalities.

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APPENDIX D:

Fish Passage Center Memorandas regarding 2021 and 2022 Okanagan Sockeye Smolt Survival

FISH PASSAGE CENTER

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MEMORANDUM

To: Jeff Fryer, CRITFC
Skyeler Folks, ONA

From: Michele DeHart

Date: December 28, 2021

Re: Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, migration years 2013-2021.

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 Okanagan 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. Over the years, these efforts have been supported and/or funded by several agency and tribal organizations, including: Department of Fisheries and Oceans Canada, CRITFC, Chelan and Grant PUDs, and the ONA.

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 reports. In response to your request, we have updated analyses from previous year's data requests and have included estimates of juvenile travel time, timing, and survival for the 2021 out-migration year. This memorandum does not provide estimates for migration year 2020, as there was no PIT-tagging in 2020, due to COVID restrictions. In addition, we provide updated estimates of overall SARs from migration years 2013-2019, with adults detected at Bonneville Dam and Wells Dam through September 25, 2021.

In 2019, the FPC and Comparative Survival Study (CSS) revised their methodology for estimating juvenile reach survivals by using a Logit link function and incorporating PIT-tag recoveries on bird colonies in the Columbia River estuary and adult detections at Bonneville Dam to augment the NOAA trawl detections below Bonneville Dam (McCann et al. 2019). We used a similar methodology for estimating juvenile survivals for this update. In addition, the CSS uses downstream detections of wild PIT-tagged fish to determine whether certain size-classes of tagged may have a higher propensity to out-migrate in a year other than indicated at tagging. For this update, we have included only those PIT-tagged fish that the CSS has determined to be "out-migrants" for each migration year (herein referred to as total "out-migrant" tags). This is important to note, as some of our estimates of travel times, timing, and juvenile survival in this update may differ from past versions of this memo, due to these changes in methodology.

Methods

Travel Time and Timing

Minimum, median, and maximum fish travel times of PIT-tagged fish were estimated for 2013-2021 out-migrants from release to detection at each of the following mainstem Columbia River dams: Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON). In addition, juvenile passage timing was estimated for 2013-2021 out-migrants based on PIT-tag detections at RRW, MCN, JDA, and BON. For each year, we estimated cumulative juvenile passage timing based on daily PIT-tag detections at these projects. Daily PIT-tag detections at each project were summed and adjusted based on the daily average proportion of flows that passed through the powerhouse.

Juvenile Survival

As noted above, the FPC and CSS revised their methodology for estimating juvenile reach survivals in 2019 by using a Logit link function (i.e., capping individual reach survivals at 1.0) and incorporating PIT-tag recoveries on bird colonies in the Columbia River estuary and adult detections at Bonneville Dam to augment the NOAA trawl detections below Bonneville Dam (McCann et al. 2019). Using this new methodology, we estimated juvenile survivals for wild sockeye smolts tagged and released from Skaha Lake and/or Osoyoos Lake. For this analysis, we provide estimates of juvenile survival from: 1) release to Rocky Reach Dam (Rel-RRE), 2) Rocky Reach Dam to McNary Dam (RRE-MCN), 3) release to McNary Dam (Rel-MCN), and 4) release to Bonneville Dam (Rel-BON). To estimate survivals, we developed a 6-digit capture history for each PIT-tagged fish. This 6-digit capture history included: 1) release, 2) detection at RRE, 3) detection at MCN, 4) detection at JDA, 5) detection at BON, and 6) detection at the estuary trawl, recoveries at estuary bird colonies, and/or adult detections at BON. When applicable, annual survival estimates were generated for the release aggregate (i.e., both lakes combined), as well as by release lake (i.e., Skaha vs. Osoyoos).

The Cormack-Jolly-Seber (CJS) survivals were estimated in program Mark and implemented in R using packages 'RMark' and 'marked'. When computing survival estimates over multiple reaches (e.g., Rel-MCN and Rel-BON), we multiplied individual reach survival estimates to calculate the full reach estimate. It should be noted that estimating survival over multiple reaches was not always possible, as there were many instances when individual reach

survival estimates were unreliable and, therefore, the multiple reach survival estimate may have also been deemed unreliable, particularly for the shorter Rel-MCN reach. Finally, we provide nonparametric bootstrap confidence intervals for the closed form CJS estimators of juvenile reach survival using the same methodology as the CSS (McCann et al. 2021 in preparation).

Smolt to Adult Survival (SARs)

With the complete return of adults from the 2013-2018 out-migrations and the nearly complete return from the 2019 out-migration, we were able to estimate Smolt-to-Adult Returns (SARs). Given the juvenile detection capabilities at RRE and adult detection capabilities at Bonneville Dam (BOA) and Wells Dam (WEA), we estimated SARs for four different reaches: 1) juveniles at RRE to adult returns at BON (RRE-to-BOA), 2) juveniles at RRE and adult returns at WEA (RRE-to-WEA), 3) juveniles at MCN to adult returns at BON (MCN-to-BOA), and juveniles at MCN and adult returns at WEA (MCN-to-WEA). The methodology for estimating SARs is discussed in Chapter 4 of the CSS Annual Report (McCann et al., 2021 in preparation). Estimates of SARs that are provided in McCann et al. (2021 in preparation) include adults detected at BOA and WEA through September 25, 2021.

Results

To put out-migration conditions into context, Table 1 and Figure 1 provide 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 2013-2021.

Table 1. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wells (WEL), Rocky Reach (RRE), Rock Island (RIS), Wanapum (WAN), and Priest Rapids (PRD) dams in 2013-2021.

Migration Year	Average Flow at PRD (Kcfs)	Average Spill Proportion				
		WEL	RRE	RIS	WAN	PRD
2013	186.6	0.11	0.10	0.15	0.26	0.29
2014	189.4	0.13	0.10	0.21	0.31	0.35
2015	114.3	0.08	0.04	0.14	0.15	0.23
2016	156.2	0.11	0.08	0.17	0.19	0.27
2017	238.0	0.18	0.32	0.36	0.47	0.53
2018	235.5	0.27	0.28	0.32	0.41	0.43
2019	126.8	0.10	0.06	0.14	0.21	0.23
2020	184.1	0.19	0.20	0.27	0.33	0.32
2021	137.2	0.13	0.05	0.14	0.18	0.21

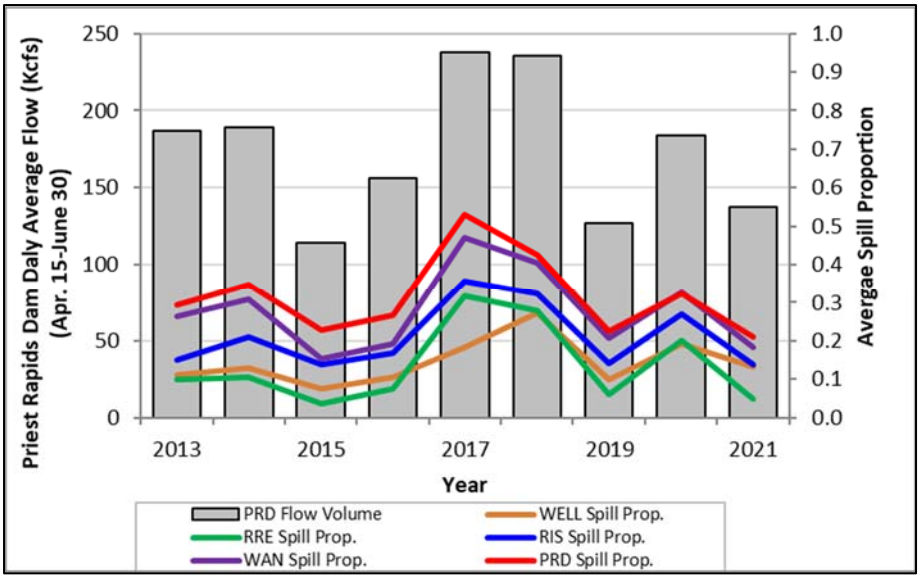

Figure 1. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wells (WEL), Rocky Reach (RRE), Rock Island (RIS), Wanapum (WAN), and Priest Rapids (PRD) dams in 2013-2021.

Travel Time and Timing

Over the years included in this analysis, 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). Due restrictions for COVID-19, PIT-tagging of Okanogan River sockeye was not conducted in 2020. 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 (i.e., release aggregate) released in migration years 2013-2021.

Migration Year	PIT-tagging Dates (Min and Max)	Total Tags Released	Total "Out-migrant" Tags
2013	Apr. 12-May 7	4,018	4,018
2014	Apr. 7-May 5	5,055	5,055
2015	Apr. 9-May 6	7,176	7,176
2016	Mar. 22-Apr. 29	10,238	10,237
2017	Apr. 26-May 3	11,588	8,153
2018	Apr. 16-18, May 2-9	10,943	6,691
2019	Apr. 25-May 9	9,082	9,082
2020	---	---	---
2021	Apr. 23-Apr. 26	5,036	5,036*

* Total "Out-migrant" tags for 2021 is preliminary and subject to change, as some of the tags released in 2021 may be detected in later years.

Travel Time

Estimates of minimum, median, and maximum travel times from release to RRE, MCN, JDA, and BON dams are provided below (Table 3). These travel times are based on fish that

were detected at each of the detection 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 (i.e., release aggregate) from migration years 2013 to 2021. PIT-tag detection sites include Rock Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams.

Migration Year	Detection Site	Number Detected	Release to Project Travel Time (days)			95% Confidence Limits	
			Min	Med	Max	Lower	Upper
2013	RRE	607	5.6	19.4	56.3	18.7	19.9
	MCN	181	10.0	23.7	63.7	22.1	24.7
	JDA	90	12.0	25.5	62.3	24.0	27.2
	BON	84	16.3	28.2	57.3	26.6	29.0
2014	RRE	812	5.4	17.2	41.0	16.9	18.0
	MCN	421	9.1	20.0	55.2	19.4	20.5
	JDA	155	13.5	23.5	68.0	22.6	24.6
	BON	108	12.9	23.4	59.4	21.5	25.2
2015	RRE	1334	5.9	15.7	39.4	15.4	16.1
	MCN	143	14.0	23.2	43.0	21.6	24.0
	JDA	73	17.0	24.5	49.5	23.0	25.7
	BON	367	16.9	25.9	48.2	24.9	26.4
2016	RRE	2632	3.8	16.7	49.5	16.4	17.4
	MCN	574	8.0	21.4	51.5	20.6	22.3
	JDA	206	11.2	22.0	72.1	21.0	23.0
	BON	511	12.4	23.7	58.9	23.3	24.6
2017	RRE	1579	4.5	10.4	46.9	10.0	10.5
	MCN	338	8.1	14.8	30.6	14.0	15.0
	JDA	434	9.9	15.8	40.1	15.0	16.0
	BON	323	10.8	17.6	46.4	17.0	18.1
2018	RRE	1340	5.4	17.6	54.3	17.4	17.7
	MCN	476	7.8	21.1	43.6	20.7	21.9
	JDA	170	10.1	21.0	42.5	19.4	22.1
	BON	283	11.0	23.9	46.0	23.4	24.6
2019	RRE	1415	6.4	19.7	85.6	19.6	20.0
	MCN	190	16.0	24.1	48.1	23.8	24.8
	JDA	150	20.3	27.7	53.2	27.1	29.1
	BON	666	16.6	28.5	66.9	28.0	28.7
2021	RRE	1132	6.4	22.3	36.1	21.9	22.6
	MCN	43	13.2	25.2	34.1	24.3	27.0
	JDA	27	20.7	30.8	40.7	26.8	32.6
	BON	218	19.0	28.4	43.6	27.6	29.0

Timing

Estimated passage timing at Rocky Reach, McNary, John Day, and Bonneville dams for migration years 2013-2021 are summarized below (Table 4). Passage timing at each of these

projects is also illustrated in Figure 1. As mentioned above, it is important to consider the variability in the timing of PIT-tagging efforts when assessing passage timing between years. Therefore, Table 4 also includes the release date range for each migration year.

Table 4. Migration timing of PIT-tagged Okanogan River Basin sockeye smolts (i.e., release aggregate) detected at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013 to 2021.

Migration Year	Release Date Range	Detection Site	Number Detected	Estimated Passage Date		
				10%	50%	90%
2013	Apr. 12-May 7	RRE	607	8-May	13-May	18-May
		MCN	181	11-May	17-May	25-May
		JDA	90	14-May	21-May	27-May
		BON	84	15-May	24-May	2-Jun
2014	Apr. 7-May 5	RRE	812	10-May	14-May	22-May
		MCN	421	12-May	19-May	24-May
		JDA	155	16-May	22-May	28-May
		BON	108	16-May	21-May	28-May
2015	Apr. 9-May 6	RRE	1334	6-May	12-May	19-May
		MCN	143	13-May	18-May	26-May
		JDA	73	16-May	20-May	25-May
		BON	367	17-May	21-May	27-May
2016	Mar. 22-Apr. 29	RRE	2632	24-Apr	5-May	10-May
		MCN	574	27-Apr	10-May	18-May
		JDA	206	29-Apr	10-May	20-May
		BON	511	1-May	12-May	20-May
2017	Apr. 26-May 3	RRE	1579	8-May	10-May	19-May
		MCN	338	12-May	14-May	23-May
		JDA	434	13-May	16-May	24-May
		BON	323	14-May	18-May	25-May
2018	Apr. 16-18 & May 2-9	RRE	1340	2-May	8-May	16-May
		MCN	476	6-May	11-May	18-May
		JDA	170	9-May	16-May	22-May
		BON	283	10-May	15-May	24-May
2019	Apr. 25-May 9	RRE	1415	14-May	17-May	30-May
		MCN	190	19-May	21-May	1-Jun
		JDA	150	21-May	25-May	3-Jun
		BON	666	22-May	25-May	5-Jun
2021	Apr. 23-Apr. 26	RRE	1132	10-May	17-May	22-May
		MCN	43	12-May	21-May	26-May
		JDA	27	19-May	25-May	29-May
		BON	218	20-May	23-May	29-May

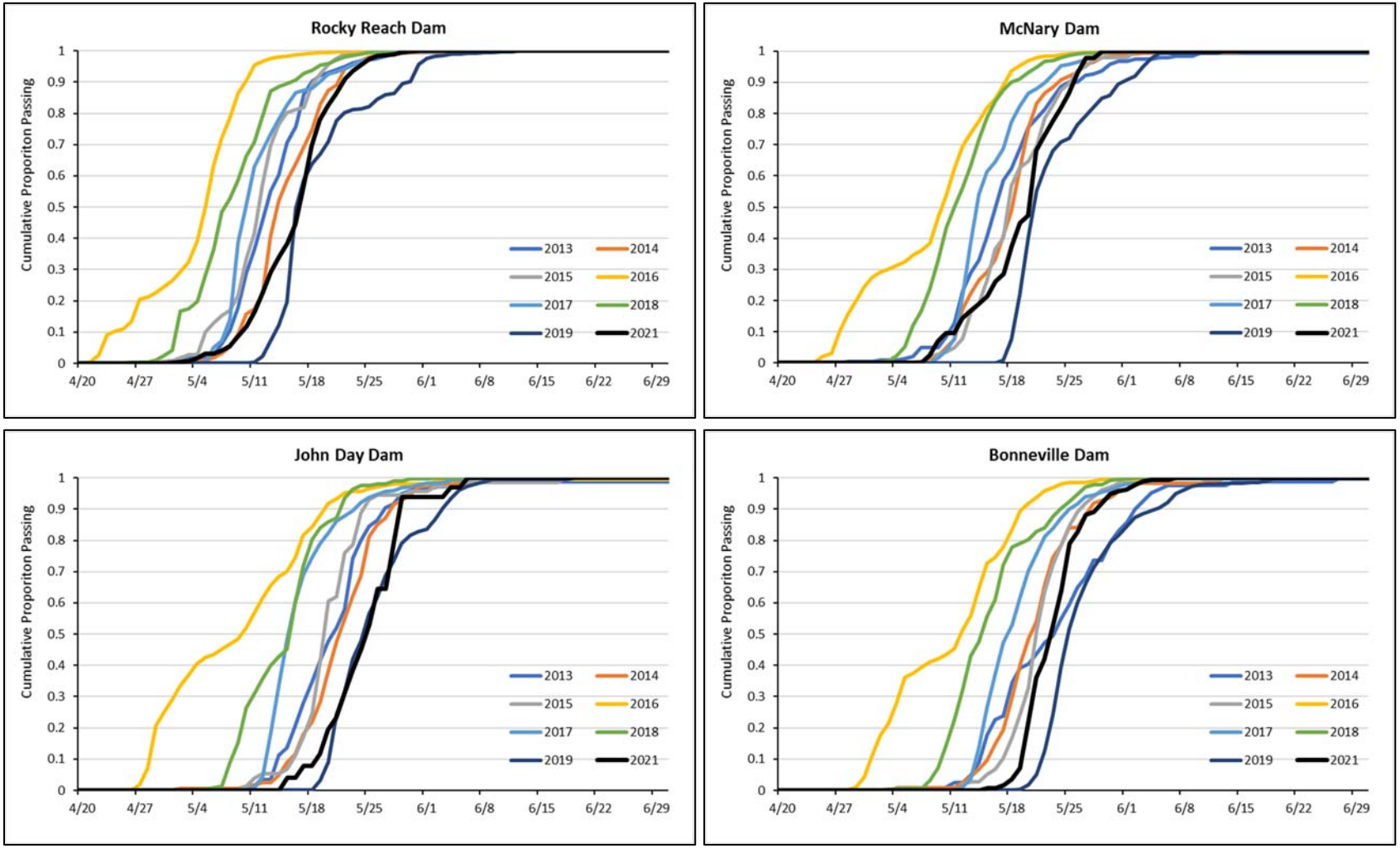

Figure 1. Cumulative passage timing of PIT-tagged wild Okanogan River basin sockeye smolts (i.e., release aggregate) at Rocky Reach, McNary, John Day, and Bonneville dams in migration years 2013-2021. Release date ranges for each migration year are summarized in Table 4.

Juvenile Survival

Release Aggregate

Estimates of individual reach survival (Release-RRE and RRE-MCN) and combined survival (Release-MCN and Release-BON) for each migration year (all release sites combined) are provided in Table 5. For migration years 2013, 2017, and 2021, we were only able to provide estimates of survival from Release-RRE and Release-BON. Estimates of survival from RRE-MCN and Release-MCN were deemed unreliable and, therefore are not reported. This is likely due to a combination of lower numbers of tags released in (e.g., 2013 and 2021) and low numbers of downstream detections, particularly at MCN. For example, in 2013, 183 PIT-tagged sockeye smolts were detected at MCN. Of these, only 20 were subsequently detected downstream of MCN. This low number of downstream detections led to an anomalous estimate of survival from RRE-MCN. Given the anomalous estimate of survival from RRE-MCN, the estimate of survival from Release-MCN for 2013 was deemed unreliable.

Table 5. Survivals of PIT-tagged sockeye juveniles tagged and released into the Okanogan River Basin (i.e., release aggregate) in 2013-2019. Number is parentheses are 90% bootstrap confidence intervals.

Migration Year	Total "Out-migrant" Tags	Release-RRE (90% CI)	RRE-MCN (90% CI)	Release-MCN (90% CI)	Release-BON (90% CI)
2013	4,018	0.50 (0.46-0.55)	---	---	0.35 (0.25-0.50)
2014	5,055	0.58 (0.54-0.63)	0.74 (0.63-0.88)	0.43 (0.38-0.50)	0.33 (0.22-0.46)
2015	7,176	0.43 (0.40-0.46)	0.83 (0.68-1.00)	0.35 (0.29-0.43)	0.28 (0.22-0.34)
2016	10,237	0.56 (0.54-0.59)	0.78 (0.69-0.90)	0.44 (0.39-0.51)	0.26 (0.21-0.34)
2017	8,153	0.73 (0.69-0.79)	0.98 (0.81-1.00)	0.72 (0.59-0.77)	0.34 (0.22-0.56)
2018	6,691	0.66 (0.61-0.71)	0.83 (0.72-1.00)	0.55 (0.48-0.64)	0.51 (0.36-0.60)
2019	9,082	0.51 (0.48-0.54)	0.87 (0.73-1.00)	0.44 (0.37-0.52)	0.30 (0.25-0.34)
2021[A]	5,036[B]	0.53 (0.48-0.59)	---	---	0.39 (0.18-0.56)

[A] 2021 survival estimates are preliminary and subject to change, as future detections at bird colonies and adult detections occur.

[B] Total "out-migrant" tags for 2021 are preliminary and subject to change, as some of the tags released in 2021 may be detected in later years.

Survival by Release Lake

Over the years that juvenile sockeye from the Okanogan River have been incorporated into the CSS for Smolt-to-Adult survival estimation (2013-2019), tagging and releases have occurred from several different sites, all of which are from two release lakes (Skaha Lake and Osoyoos Lake). When applicable, we estimated survivals for each release lake over several reaches: 1) release to Rocky Reach Dam (Rel-RRE), 2) Rocky Reach Dam to McNary Dam (RRE-MCN), 3) release to McNary Dam (Rel-MCN), and 4) release to Bonneville Dam (Rel-BON). Summaries of these survival estimates, by release lake, are provided in Table 6.

In 2017 and 2021, tagging only occurred at Osoyoos Lake. Therefore, survivals for this lake release were the same as the aggregate group in these two years (Tables 5 and 6). In all other years (2013-2016 and 2018-2019), tagging occurred at both Skaha and Osoyoos lakes.

Because the sample sizes for estimating survival by release lake were smaller than for the release aggregate, some reach survival estimates were less reliable at this level of detail. For Skaha Lake releases, we were not able to estimate survival from RRE-MCN in 2013 and,

therefore were not able to provide estimates of survival from release to MCN (Table 6). In addition, we were not able to estimate survival from release to BON for Skaha Lake releases in 2014, due to unreliable reach estimates between MCN and BON. For Osoyoos Lake releases, we were not able to estimate survival from RRE-MCN in 2013, 2015, and 2021 and, therefore were not able to provide estimates of survival from release to MCN (Table 6). In addition, we were not able to estimate survival from release to BON for Osoyoos Lake releases in 2015 and 2018.

Table 6. Survivals of PIT-tagged sockeye juveniles tagged and released into the Okanogan River, by release lake, in 2013-2021. Number is parentheses are 90% bootstrap confidence intervals.

Migration Year	Release Lake	Total "Out-migrant" Tags	Release-RRE (90% CI)	RRE-MCN (90% CI)	Release-MCN (90% CI)	Release-BON (90% CI)
2013	Skaha	1,178	0.49 (0.43-0.57)	---	---	0.32 (0.19-0.51)
	Osoyoos	2,840	0.51 (0.46-0.59)	---	---	0.39 (0.24-0.54)
2014	Skaha	1,348	0.45 (0.37-0.59)	0.69 (0.47-1.00)	0.31 (0.24-0.43)	---
	Osoyoos	3,707	0.63 (0.58-0.69)	0.75 (0.64-0.91)	0.47 (0.41-0.57)	0.29 (0.20-0.47)
2015	Skaha	5,435	0.43 (0.40-0.46)	0.73 (0.61-1.00)	0.31 (0.26-0.42)	0.24 (0.19-0.31)
	Osoyoos	1,741	0.43 (0.38-0.50)	---	---	---
2016	Skaha	5,439	0.50 (0.47-0.54)	0.77 (0.66-0.92)	0.39 (0.33-0.46)	0.24 (0.18-0.32)
	Osoyoos	4,798	0.63 (0.59-0.67)	0.86 (0.70-1.00)	0.54 (0.44-0.64)	0.34 (0.23-0.45)
2017	Osoyoos	8,153	0.73 (0.69-0.79)	0.98 (0.81-1.00)	0.72 (0.59-0.77)	0.34 (0.22-0.56)
2018	Skaha	1,608	0.73 (0.63-0.89)	0.98 (0.81-1.00)	0.71 (0.54-0.86)	0.47 (0.26-0.75)
	Osoyoos	5,083	0.64 (0.60-0.70)	0.78 (0.67-0.96)	0.50 (0.44-0.60)	---
2019	Skaha	4,114	0.33 (0.30-0.37)	0.85 (0.62-1.00)	0.28 (0.21-0.35)	0.22 (0.16-0.29)
	Osoyoos	4,968	0.66 (0.61-0.71)	0.88 (0.70-1.00)	0.58 (0.47-0.69)	0.36 (0.30-0.43)
2021[A]	Osoyoos	5,036[B]	0.53 (0.48-0.59)	---	---	0.39 (0.18-0.56)

[A] 2021 Survival estimates are preliminary and subject to change, as future detections at bird colonies and adult detections occur.

[B] Total "out-migrant" tags for 2021 are preliminary and subject to change, as some of the tags released in 2021 may be detected in later years.

It should be noted that, while we were not always able to estimate survival from release to BON by release lake (Table 6), we were able to estimate survival from release to Bonneville for the release aggregate in all years that tagging has occurred (Table 5) Our inability to consistently estimate survivals by release lake is largely due to the smaller sample sizes when conducting analyses at this level of detail. The ability to estimate juvenile survival and the precision of those estimates, for both the release aggregate and releases by lake, would be improved by increased marking and increased detection capacity at downstream PIT-tag detection sites.

Smolt to Adult Survival (SARs)

To date, the CSS Annual Report has provided estimates of overall SARs for Okanogan River Basin sockeye over several reaches: McNary-to-Bonneville (MCN-to-BOA), McNary-to-Wells (MCN-to-WEA), Rocky Reach-to-Bonneville (RRE-to-BOA), and Rocky Reach-to-Wells (RRE-to-WEA). These estimates of overall SARs are based on all release sites combined (i.e., release aggregate) and are summarized below (Tables 8 and 9). In addition, the SARs for adults returning to Bonneville (RRE-to-BOA and MCN-to-BOA) are provided in Figure 2.

Table 8. Overall McNary-to-Bonneville (MCN-to-BOA) and Rocky Reach-to-Bonneville (RRE-to-BOA) SARs for Okanogan River wild sockeye (i.e., release aggregate), 2013-2019.

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[B,C]	---	---	---	---	2,012	8.05	6.82	9.31
2014[B]	2,170	2.90	2.24	3.61	2,937	2.15	1.72	2.63
2015	2,538	1.58	1.04	2.16	3,064	1.31	0.97	1.66
2016[B]	4,337	1.82	1.41	2.21	5,782	1.37	1.12	1.63
2017[B]	5,864	0.12	0.05	0.21	5,956	0.12	0.05	0.19
2018[B]	3,628	2.78	2.15	3.39	4,405	2.29	1.88	2.70
2019[B,D]	4,161	4.23	3.18	5.51	4,603	3.82	3.33	4.39

[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 and the Logit link.
[B] PIT-tagged sockeye were coded as "unknown" rearing type. Some PIT-tagged smolts may have been hatchery sockeye released into Skaha Lake as fry.
[C] Due to an unreliable survival estimate in the RRH-MCN reach, SAR (MCN-BOA) was not possible.
[D] Incomplete, 2-salt returns through Sept. 25, 2021.

Table 9. Overall McNary-to-Wells (MCN-to-WEA) and Rocky Reach-to-Wells (RRE-to-WEA) SARs for Okanogan River wild sockeye (i.e., release aggregate), 2013-2019.

Juvenile migration year	MCN-to-WEA				RRE-to-WEA			
	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[B,C]	---	--	--	--	2,012	4.32	3.50	5.24
2014[B]	2,170	2.35	1.75	2.94	2,937	1.74	1.36	2.16
2015	2,538	1.22	0.79	1.71	3,064	1.01	0.72	1.32
2016[B]	4,337	1.36	1.03	1.70	5,782	1.02	0.81	1.25
2017[B]	5,864	0.12	0.05	0.21	5,956	0.12	0.05	0.19
2018[B]	3,628	1.98	1.46	2.46	4,405	1.63	1.31	1.96
2019[B,D]	4,161	2.84	2.10	3.64	4,603	2.56	2.14	3.00

[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 and the Logit link.
[B] PIT-tagged sockeye were coded as "unknown" rearing type. Some PIT-tagged smolts may have been hatchery sockeye released into Skaha Lake as fry.
[C] Due to an unreliable survival estimate in the RRH-MCN reach, SAR (MCN-WEA) was not possible.
[D] Incomplete, 2-salt returns through Sept. 25, 2021.

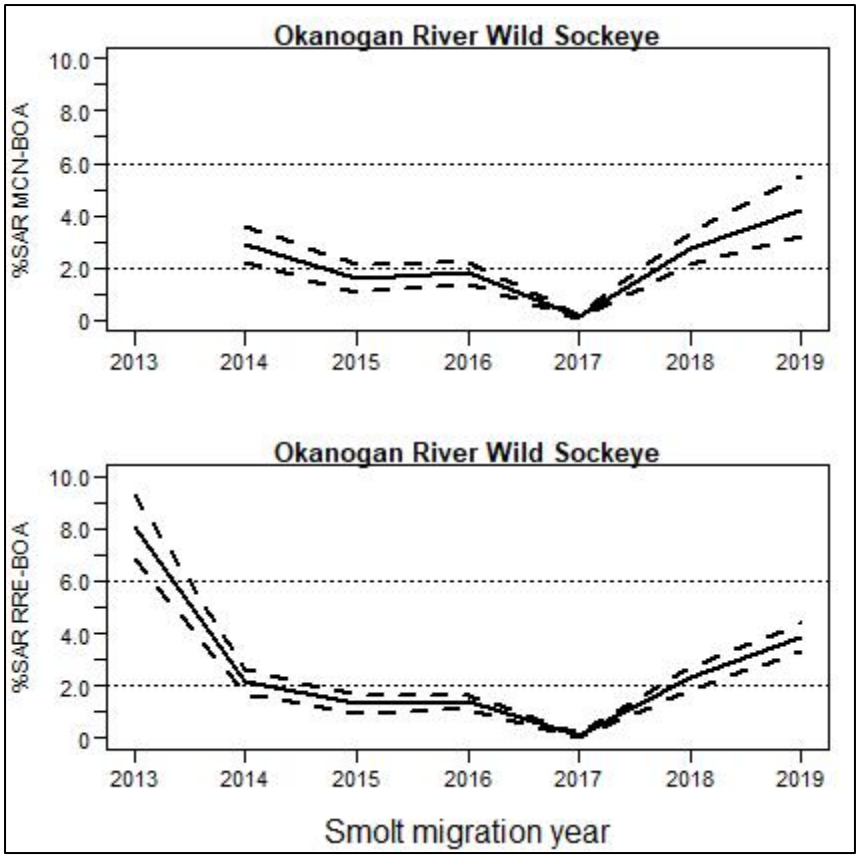

Figure 2. Bootstrapped SAR (MCN-to-BOA and RRE-to-BOA) and upper and lower CI for Okanogan River sockeye (i.e., release aggregate), 2013-2019 migration years. The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference.

References

McCann, J, B. Chockley, E. Cooper, B. Hsu, G. Sheer, S. Haeseker, R. Lessard, T. Copeland, E. Tinus, A. Storch, and D. Rawding. 2019. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye DRAFT 2019 Annual Report. BPA Contract #19960200. December 2019. https://www.fpc.org/documents/CSS/2019CSSAnnualReport.pdf

McCann, J, B. Chockley, E. Cooper, G. Sheer, S. Haeseker, R. Lessard, T. Copeland, J. Ebel, A. Storch, and D. Rawding. 2021 in preparation. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye 2021 Annual Report. BPA Contract #19960200. https://www.fpc.org/documents/Q_fpc_cssreports.php

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MEMORANDUM

To: Jeff Fryer, CRITFC
Carley Simpson, ONA
Skyeler Folks, ONA

From: Michele DeHart

Date: December 8, 2022

Re: Okanogan River sockeye passage timing, travel times, juvenile survival, and smolt-to-adult returns, migration years 2013-2022.

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 Okanagan Nation Alliance (ONA) and the Columbia River Inter-Tribal Fish Commission (CRITFC), the CSS Oversight Committee transferred surplus PIT-tags to the ONA for migration years 2013-2020, to supplement PIT-tagging efforts at Skaha and Osoyoos lakes in the spring. Over the years, these efforts have been supported and/or funded by several agency and tribal organizations, including Department of Fisheries and Oceans Canada, CRITFC, Chelan and Grant PUDs, and the ONA.

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 reports. In response to your request, we have updated analyses from previous year's data requests and have included estimates of juvenile travel time, timing, and survival for the 2022 out-migration year. This memorandum does not provide estimates for migration year 2020, as there was no PIT-tagging in 2020, due to COVID restrictions. In addition, we provide updated estimates of overall SARs from migration years 2013-2019, with adults detected at Bonneville Dam and Wells Dam through September 10, 2022.

In 2019, the FPC and Comparative Survival Study (CSS) revised their methodology for estimating juvenile reach survivals by using a Logit link function and incorporating PIT-tag recoveries on bird colonies in the Columbia River estuary and adult detections at Bonneville Dam to augment the NOAA trawl detections below Bonneville Dam (McCann et al. 2019). In addition, the CSS will be adding additional estuary bird colony detection sites and begin incorporating detections at interrogation sites associated with estuary pile dikes (PD6 and PD7) into future analyses to further augment detections below Bonneville Dam. Therefore, we have updated past survival estimates by incorporating these detection sites for this update. In addition, the CSS uses downstream detections of wild PIT-tagged fish to determine whether certain size-classes of tagged fish may have a higher propensity to out-migrate in a year other than indicated at tagging. For this update, we have included only those PIT-tagged fish that the CSS has determined to be "out-migrants" for each migration year (herein referred to as total "out-migrant" tags). These changes in methodology are important to note, as some of our estimates of juvenile survival in this update may differ from past versions of this memo.

Methods

Travel Time and Timing

Minimum, median, and maximum fish travel times of PIT-tagged fish were estimated for 2013-2022 out-migrants from release to detection at each of the following mainstem Columbia River dams: Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON). In addition, juvenile passage timing was estimated for 2013-2022 out-migrants based on PIT-tag detections at RRE, MCN, JDA, and BON. For each year, we estimated cumulative juvenile passage timing based on daily PIT-tag detections at these projects. Daily PIT-tag detections at each project were summed and adjusted based on the daily average proportion of flows that passed through the powerhouse.

Juvenile Survival

As noted above, the FPC and CSS revised their methodology for estimating juvenile reach survivals in 2019 by using a Logit link function (i.e., capping individual reach survivals at 1.0) and incorporating PIT-tag recoveries on bird colonies in the Columbia River estuary and adult detections at Bonneville Dam to augment the NOAA trawl detections below Bonneville Dam (McCann et al. 2019). In addition, the CSS will be adding additional estuary bird colony detection sites and begin incorporating detections at interrogation sites associated with estuary pile dikes (PD6 and PD7) into future analyses to further augment detections below Bonneville Dam. We have incorporated these additional estuary bird colony detection sites and pike dike interrogation sites into this update.

Using this new methodology and new detection sites, we estimated juvenile survivals for wild sockeye smolts tagged and released from Skaha Lake and/or Osoyoos Lake. In 2022, a small number of PIT-tagged sockeye from Okanogan Lake were also PIT-tagged. Therefore, we added this Okanogan Lake group for 2022. For this analysis, we provide estimates of juvenile survival from: 1) release to Rocky Reach Dam (Rel-RRE), 2) Rocky Reach Dam to McNary Dam (RRE-MCN), 3) release to McNary Dam (Rel-MCN), and 4) release to Bonneville Dam (Rel-BON). To estimate survivals, we developed a 6-digit capture history for each PIT-tagged

fish. This 6-digit capture history included: 1) release, 2) detection at RRE, 3) detection at MCN, 4) detection at JDA, 5) detection at BON, and 6) detection at the estuary trawl, recoveries at estuary bird colonies, detections at estuary pile dike interrogation sites, and/or adult detections at BON. When applicable, annual survival estimates were generated for the release aggregate (i.e., all lakes combined), as well as by release lake (i.e., Skaha, Osoyoos, and Okanogan).

The Cormack-Jolly-Seber (CJS) survivals were estimated in program Mark and implemented in R using packages 'RMark' and 'marked'. When computing survival estimates over multiple reaches (e.g., Rel-MCN and Rel-BON), we multiplied individual reach survival estimates to calculate the full reach estimate. It should be noted that estimating survival over multiple reaches was not always possible, as there were many instances when individual reach survival estimates were unreliable and, therefore, the multiple reach survival estimate may have also been deemed unreliable, particularly for the shorter Rel-MCN reach. Finally, we provide nonparametric bootstrap confidence intervals for the closed form CJS estimators of juvenile reach survival using the same methodology as the CSS (McCann et al. 2022 in preparation).

Smolt to Adult Survival (SARs)

With the complete return of adults from the 2013-2019 out-migrations, the CSS was able to estimate Smolt-to-Adult Returns (SARs). Given the juvenile detection capabilities at RRE and adult detection capabilities at Bonneville Dam (BOA) and Wells Dam (WEA), the CSS estimates SARs for the release aggregate over four different reaches: 1) juveniles at RRE to adult returns at BON (RRE-to-BOA), 2) juveniles at RRE and adult returns at WEA (RRE-to-WEA), 3) juveniles at MCN to adult returns at BON (MCN-to-BOA), and juveniles at MCN and adult returns at WEA (MCN-to-WEA). The methodology for estimating SARs is discussed in Chapter 4 of the CSS Annual Report (McCann et al., 2022 in preparation). Estimates of SARs that are provided in McCann et al. (2022 in preparation) include adults detected at BOA and WEA through September 15, 2022.

Results

Outmigration Conditions

To put out-migration conditions into context, Table 1 and Figure 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 2013-2022.

Table 1. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wells (WEL), Rocky Reach (RRE), Rock Island (RIS), Wanapum (WAN), and Priest Rapids (PRD) dams in 2013-2022.

Migration Year	Average Flow at PRD (Kcfs)	Average Spill Proportion				
		WEL	RRE	RIS	WAN	PRD
2013	186.6	0.11	0.10	0.15	0.26	0.29
2014	189.4	0.13	0.10	0.21	0.31	0.35
2015	114.3	0.08	0.04	0.14	0.15	0.23
2016	156.2	0.11	0.08	0.17	0.19	0.27
2017	238.0	0.18	0.32	0.36	0.47	0.53
2018	235.5	0.27	0.28	0.32	0.41	0.43
2019	126.8	0.10	0.06	0.14	0.21	0.23
2020	184.1	0.19	0.20	0.27	0.33	0.32
2021	137.2	0.13	0.05	0.14	0.18	0.21
2022	177.8	0.22	0.14	0.24	0.30	0.35

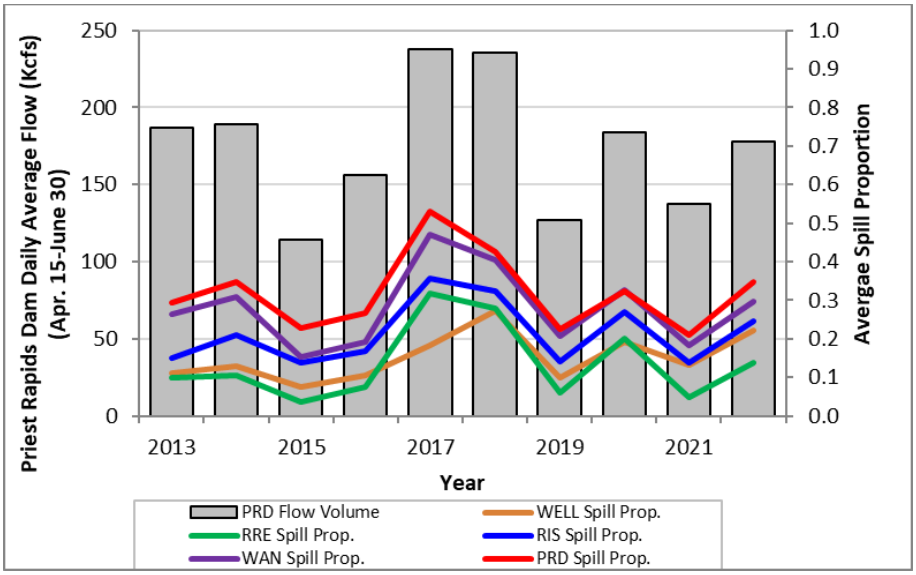

Figure 1. Average spring (April 15–June 30) flow at Priest Rapids Dam (PRD) and average spill proportion at Wells (WEL), Rocky Reach (RRE), Rock Island (RIS), Wanapum (WAN), and Priest Rapids (PRD) dams in 2013-2022.

Travel Time and Timing

Over the years included in this analysis, 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). Due restrictions for COVID-19, PIT-tagging of Okanogan River sockeye was not conducted in 2020. It is important to consider the variability in the timing of PIT-tagging efforts when assessing passage timing between years. This is particularly true for 2022, as tagging in 2022 occurred much later than all other years analyzed. For example, tagging in 2022 began on May 6th while, in most other years, tagging had usually ended by around this time (Table 2). In

addition, tagging in 2022 ended on June 1st, which is over three weeks later than the second next latest end-date of May 9th (2018 and 2019; Table 2).

Table 2. Timing of PIT-tagging efforts and number of PIT-tagged Okanogan River Basin sockeye smolts (i.e., release aggregate) released in migration years 2013-2022.

Migration Year	PIT-tagging Dates (Min and Max)	Total Tags Released	Total "Out-migrant" Tags
2013	Apr. 12-May 7	4,018	4,018
2014	Apr. 7-May 5	5,055	5,055
2015	Apr. 9-May 6	7,176	7,176
2016	Mar. 22-Apr. 29	10,238	10,237
2017	Apr. 26-May 3	11,588	8,153
2018	Apr. 16-18, May 2-9	10,943	6,691
2019	Apr. 25-May 9	9,082	9,082
2020	---	---	---
2021	Apr. 23-Apr. 26	5,036	5,036
2022	May 6-June 1	7,435	7,435*

* Total "Out-migrant" tags for 2022 is preliminary and subject to change, as some of the tags released in 2022 may be detected in later years.

Estimates of minimum, median, and maximum travel times from release to RRE, MCN, JDA, and BON dams are provided in Table 3. These travel times are based on fish that were detected at each of the detection sites in their respective year of out-migration. Also provided are estimates of the 95% confidence limits around the estimated median travel time.

Estimated passage timing at Rocky Reach, McNary, John Day, and Bonneville dams for migration years 2013-2022 are summarized in Table 4. Passage timing at each of these projects is also illustrated in Figure 2. As mentioned above, it is important to consider the variability in the timing of PIT-tagging efforts when assessing passage timing between years. Therefore, Table 4 also includes the release date range for each migration year.

Table 3. Travel times from release to juvenile detection site of PIT-tagged Okanogan River Basin sockeye smolts (i.e., release aggregate) from migration years 2013 to 2022. PIT-tag detection sites include Rock Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams.

Migration Year	Detection Site	Number Detected	Release to Project Travel Time (days)			95% Confidence Limits	
			Min	Med	Max	Lower	Upper
2013	RRE	607	5.6	19.4	56.3	18.7	19.9
	MCN	181	10.0	23.7	63.7	22.1	24.7
	JDA	90	12.0	25.5	62.3	24.0	27.2
	BON	84	16.3	28.2	57.3	26.6	29.0
2014	RRE	812	5.4	17.2	41.0	16.9	18.0
	MCN	421	9.1	20.0	55.2	19.4	20.5
	JDA	155	13.5	23.5	68.0	22.6	24.6
	BON	108	12.9	23.4	59.4	21.5	25.2
2015	RRE	1334	5.9	15.7	39.4	15.4	16.1
	MCN	143	14.0	23.2	43.0	21.6	24.0
	JDA	73	17.0	24.5	49.5	23.0	25.7
	BON	367	16.9	25.9	48.2	24.9	26.4
2016	RRE	2632	3.8	16.7	49.5	16.4	17.4
	MCN	574	8.0	21.4	51.5	20.6	22.3
	JDA	206	11.2	22.0	72.1	21.0	23.0
	BON	511	12.4	23.7	58.9	23.3	24.6
2017	RRE	1579	4.5	10.4	46.9	10.0	10.5
	MCN	338	8.1	14.8	30.6	14.0	15.0
	JDA	434	9.9	15.8	40.1	15.0	16.0
	BON	323	10.8	17.6	46.4	17.0	18.1
2018	RRE	1340	5.4	17.6	54.3	17.4	17.7
	MCN	476	7.8	21.1	43.6	20.7	21.9
	JDA	170	10.1	21.0	42.5	19.4	22.1
	BON	283	11.0	23.9	46.0	23.4	24.6
2019	RRE	1415	6.4	19.7	85.6	19.6	20.0
	MCN	190	16.0	24.1	48.1	23.8	24.8
	JDA	150	20.3	27.7	53.2	27.1	29.1
	BON	666	16.6	28.5	66.9	28.0	28.7
2021	RRE	1132	6.4	22.3	36.1	21.9	22.6
	MCN	43	13.2	25.2	34.1	24.3	27.0
	JDA	27	20.7	30.8	40.7	26.8	32.6
	BON	218	19.0	28.4	43.6	27.6	29.0
2022	RRE	863	3.9	11.9	52.5	10.6	12.6
	MCN	67	8.5	23.5	63.7	20.7	28.1
	JDA	72	12.3	22.6	44.8	21.2	26.6
	BON	117	11.9	17.8	46.8	16.1	20.9

Table 4. Migration timing of PIT-tagged Okanogan River Basin sockeye smolts (i.e., release aggregate) detected at Rocky Reach (RRE), McNary (MCN), John Day (JDA), and Bonneville (BON) dams in migration years 2013 to 2022.

Migration Year	Release Date Range	Detection Site	Number Detected	Estimated Passage Date		
				10%	50%	90%
2013	Apr. 12-May 7	RRE	607	8-May	13-May	18-May
		MCN	181	11-May	17-May	25-May
		JDA	90	14-May	21-May	27-May
		BON	84	15-May	24-May	2-Jun
2014	Apr. 7-May 5	RRE	812	10-May	14-May	22-May
		MCN	421	12-May	19-May	24-May
		JDA	155	16-May	22-May	28-May
		BON	108	16-May	21-May	28-May
2015	Apr. 9-May 6	RRE	1334	6-May	12-May	19-May
		MCN	143	13-May	18-May	26-May
		JDA	73	16-May	20-May	25-May
		BON	367	17-May	21-May	27-May
2016	Mar. 22-Apr. 29	RRE	2632	24-Apr	5-May	10-May
		MCN	574	27-Apr	10-May	18-May
		JDA	206	29-Apr	10-May	20-May
		BON	511	1-May	12-May	20-May
2017	Apr. 26-May 3	RRE	1579	8-May	10-May	19-May
		MCN	338	12-May	14-May	23-May
		JDA	434	13-May	16-May	24-May
		BON	323	14-May	18-May	25-May
2018	Apr. 16-18 & May 2-9	RRE	1340	2-May	8-May	16-May
		MCN	476	6-May	11-May	18-May
		JDA	170	9-May	16-May	22-May
		BON	283	10-May	15-May	24-May
2019	Apr. 25-May 9	RRE	1415	14-May	17-May	30-May
		MCN	190	19-May	21-May	1-Jun
		JDA	150	21-May	25-May	3-Jun
		BON	666	22-May	25-May	5-Jun
2021	Apr. 23-Apr. 26	RRE	1132	10-May	17-May	22-May
		MCN	43	12-May	21-May	26-May
		JDA	27	19-May	25-May	29-May
		BON	218	20-May	23-May	29-May
2022	May 6-June 1	RRE	863	18-May	28-May	11-Jun
		MCN	67	21-May	10-Jun	18-Jun
		JDA	72	27-May	8-Jun	17-Jun
		BON	117	26-May	5-Jun	17-Jun

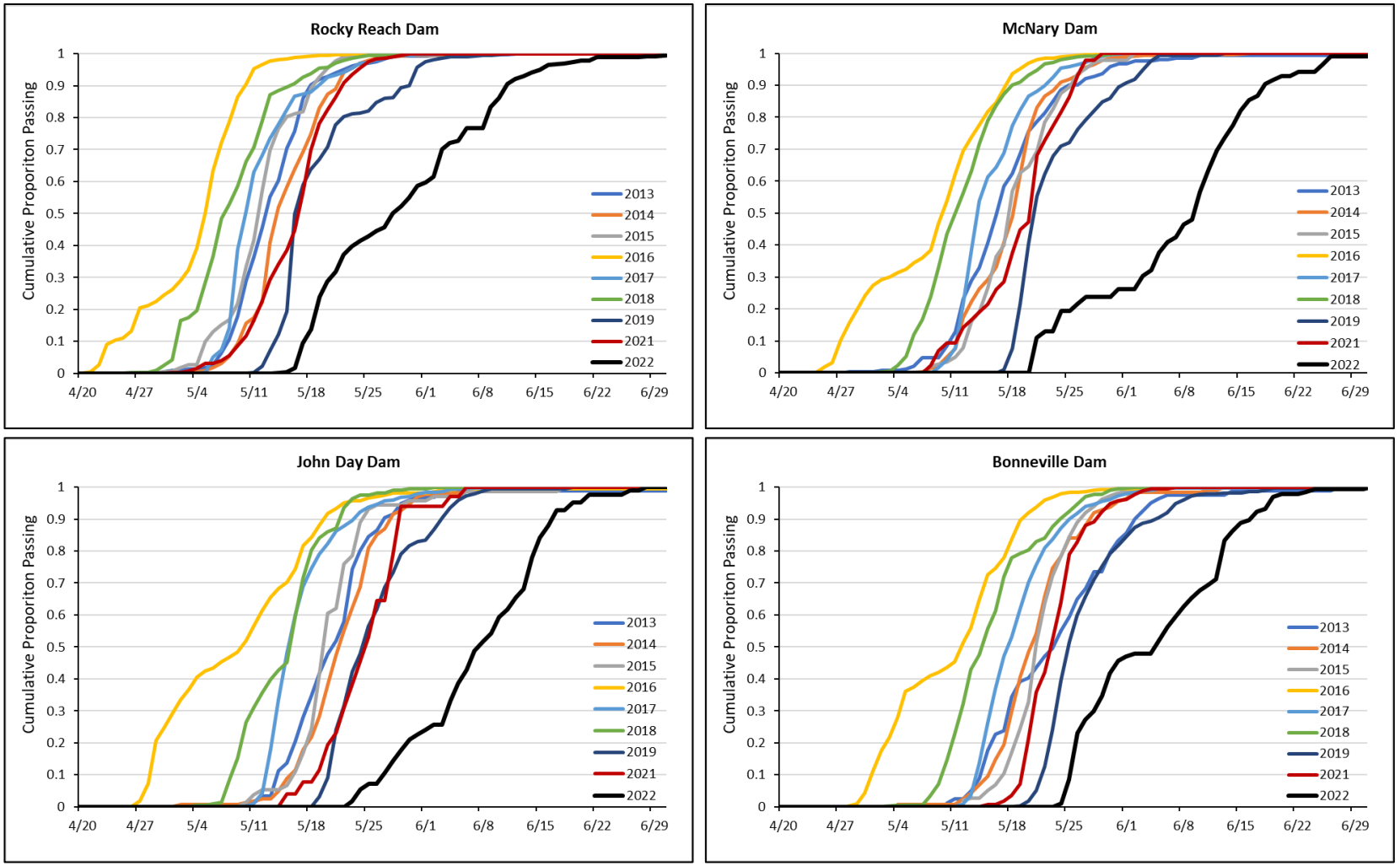

Figure 2. Cumulative passage timing of PIT-tagged wild Okanogan River basin sockeye smolts (i.e., release aggregate) at Rocky Reach, McNary, John Day, and Bonneville dams in migration years 2013-2022. Release date ranges for each migration year are summarized in Table 4.

Juvenile Survival

Release Aggregate

Estimates of individual reach survival (Release-RRE and RRE-MCN) and combined survival (Release-MCN and Release-BON) for each migration year (all release sites combined) are provided in Table 5. However, there were a few years where individual reach survivals and/or combined survivals were deemed unreliable and, therefore, are not reported. For example, for migration year 2013, we were only able to provide estimates of survival from Release-RRE and Release-BON. For migration year 2021, we were only able to provide estimates of survival from release-RRE. The unreliable survival estimates were likely due to a combination of lower numbers of tags released in (e.g., 2013 and 2021) and/or low numbers of downstream detections, particularly at MCN. For example, in 2013, 183 PIT-tagged sockeye smolts were detected at MCN. Of these, only 20 were subsequently detected downstream of MCN. This low number of downstream detections led to an anomalous estimate of survival from RRE-MCN. Given the anomalous estimate of survival from RRE-MCN, the estimate of survival from Release-MCN for 2013 was deemed unreliable.

Table 5. Survivals of PIT-tagged sockeye juveniles tagged and released into the Okanogan River Basin (i.e., release aggregate) in 2013-2022. Number is parentheses are 90% bootstrap confidence intervals.

Migration Year	Total "Out-migrant" Tags	Release-RRE (90% CI)	RRE-MCN (90% CI)	Release-MCN (90% CI)	Release-BON (90% CI)
2013	4,018	0.49 (0.43-0.57)	---	---	0.33 (0.21-0.51)
2014	5,055	0.58 (0.54-0.64)	0.74 (0.62-0.88)	0.43 (0.37-0.50)	0.33 (0.22-0.45)
2015	7,176	0.43 (0.40-0.46)	0.83 (0.68-1.00)	0.35 (0.29-0.43)	0.29 (0.22-0.34)
2016	10,236	0.56 (0.54-0.59)	0.78 (0.68-0.91)	0.44 (0.39-0.51)	0.26 (0.21-0.34)
2017	8,153	0.73 (0.68-0.79)	0.99 (0.81-1.00)	0.72 (0.60-0.77)	0.35 (0.23-0.57)
2018	6,691	0.66 (0.62-0.72)	0.83 (0.71-1.00)	0.55 (0.48-0.64)	0.52 (0.37-0.60)
2019	9,082	0.51 (0.48-0.54)	0.86 (0.71-1.00)	0.44 (0.36-0.51)	0.31 (0.26-0.35)
2020[A]	---	---	---	---	---
2021[B]	5,036	0.54 (0.49-0.60)	---	---	---
2022[B]	7,435[C]	0.31 (0.27-0.35)	0.72 (0.53-1.00)	0.22 (0.17-0.32)	0.21 (0.08-0.29)

[A] No tagging in 2020 due to COVID restrictions.

[B] 2021 and 2022 survival estimates are preliminary and subject to change, as future detections at bird colonies and adult detections occur.

[C] Total "out-migrant" tags for 2022 are preliminary and subject to change, as some of the tags released in 2022 may be detected in later years.

Survival by Release Lake

Over the years, tagging of Okanogan Basin sockeye has occurred from several different sites, most of which are from two release lakes (Skaha Lake and Osoyoos Lake). When applicable, we estimated survivals for each release lake over several reaches: 1) release to Rocky Reach Dam (Rel-RRE), 2) Rocky Reach Dam to McNary Dam (RRE-MCN), 3) release to McNary Dam (Rel-MCN), and 4) release to Bonneville Dam (Rel-BON). Summaries of these survival estimates, by release lake, are provided in Table 6.

In 2017 and 2021, tagging only occurred at Osoyoos Lake. Therefore, survivals for this lake release were the same as the aggregate group in these two years (Tables 5 and 6). In all other years (2013-2016 and 2018-2019), tagging occurred at Skaha and Osoyoos lakes. In 2022,

489 sockeye juveniles from Okanogan Lake were PIT-tagged. This was the first attempt at PIT-tagging sockeye known to originate from Okanogan Lake, above Skaha Lake.

Because the sample sizes for estimating survival by release lake were smaller than for the release aggregate, some reach survival estimates were less reliable at this level of detail. For Skaha Lake releases, we were not able to estimate survival from RRE-MCN in 2013 and, therefore were not able to provide estimates of survival from release to MCN (Table 6). In addition, we were not able to estimate survival from release to BON for Skaha Lake releases in 2014, due to unreliable reach estimates between MCN and BON. For Osoyoos Lake releases, we were not able to estimate survival from RRE-MCN in 2013, 2015, and 2021 and, therefore were not able to provide estimates of survival from release to MCN (Table 6). In addition, we were not able to estimate survival from release to BON for Osoyoos Lake releases in 2015, 2018, and 2022. Finally, for the 2022 Okanogan Lake release, we were only able to estimate survival for the release-RRE reach. The inability to estimate survival for the other reaches is largely due to the small sample size for this group (N=489; Table 6).

Table 6. Survivals of PIT-tagged sockeye juveniles tagged and released into the Okanogan River, by release lake, in 2013-2022. Number is parentheses are 90% bootstrap confidence intervals.

Migration Year	Release Lake	Total "Out-migrant" Tags	Release-RRE (90% CI)	RRE-MCN (90% CI)	Release-MCN (90% CI)	Release-BON (90% CI)
2013	Skaha	1,178	0.49 (0.43-0.57)	---	---	0.33 (0.21-0.51)
	Osoyoos	2,840	0.51 (0.46-0.59)	---	---	0.39 (0.24-0.53)
2014	Skaha	1,348	0.45 (0.36-0.58)	0.69 (0.48-1.00)	0.31 (0.24-0.43)	---
	Osoyoos	3,707	0.63 (0.58-0.69)	0.75 (0.64-0.91)	0.47 (0.41-0.57)	0.29 (0.20-0.47)
2015	Skaha	5,435	0.43 (0.39-0.46)	0.73 (0.59-1.00)	0.31 (0.26-0.42)	0.24 (0.19-0.31)
	Osoyoos	1,741	0.43 (0.38-0.50)	---	---	---
2016	Skaha	5,439	0.50 (0.47-0.54)	0.77 (0.65-0.91)	0.39 (0.33-0.45)	0.24 (0.18-0.33)
	Osoyoos	4,798	0.63 (0.59-0.67)	0.86 (0.7-1.00)	0.54 (0.44-0.64)	0.34 (0.23-0.45)
2017	Osoyoos	8,153	0.73 (0.68-0.79)	0.99 (0.81-1.00)	0.72 (0.60-0.77)	0.35 (0.23-0.57)
2018	Skaha	1,608	0.73 (0.62-0.90)	0.98 (0.71-1.00)	0.71 (0.54-0.85)	0.47 (0.26-0.75)
	Osoyoos	5,083	0.64 (0.60-0.70)	0.78 (0.66-0.97)	0.50 (0.44-0.61)	---
2019	Skaha	4,114	0.33 (0.30-0.37)	0.86 (0.63-1.00)	0.28 (0.22-0.35)	0.22 (0.17-0.30)
	Osoyoos	4,968	0.66 (0.61-0.71)	0.86 (0.68-1.00)	0.57 (0.46-0.68)	0.38 (0.31-0.43)
2020[A]	---	---	---	---	---	---
2021[B]	Osoyoos	5,036	0.53 (0.48-0.59)	---	---	0.39 (0.18-0.56)
2022[B]	Okanogan	489[C]	0.45 (0.24-1.00)	---	---	---
	Skaha	938[C]	0.18 (0.11-0.41)	0.36 (0.12-1.00)	0.07 (0.03-0.23)	0.02 (0.00-0.06)
	Osoyoos	6008[C]	0.32 (0.28-0.37)	0.93 (0.61-1.00)	0.30 (0.20-0.35)	---

[A] No tagging in 2020 due to COVID restrictions.
[B] 2021 and 2022 survival estimates are preliminary and subject to change, as future detections at bird colonies and adult detections occur.
[C] Total "out-migrant" tags for 2022 are preliminary and subject to change, as some of the tags released in 2022 may be detected in later years.

It should be noted that, while we were not always able to estimate survival from release to BON by release lake (Table 6), we were able to estimate survival from release to Bonneville for the release aggregate in nearly all years that tagging has occurred (Table 5) Our inability to consistently estimate survivals by release lake is largely due to the smaller sample sizes when conducting analyses at this level of detail. The ability to estimate juvenile survival and the precision of those estimates, for both the release aggregate and releases by lake, would be improved by increased marking and increased detection capacity at downstream PIT-tag detection sites.

Smolt to Adult Survival (SARs)

To date, the CSS Annual Report has provided estimates of overall SARs for Okanogan River Basin sockeye over several reaches: McNary-to-Bonneville (MCN-to-BOA), McNary-to-Wells (MCN-to-WEA), Rocky Reach-to-Bonneville (RRE-to-BOA), and Rocky Reach-to-Wells (RRE-to-WEA). These estimates of overall SARs are based on all release sites combined (i.e., release aggregate) and are summarized below (Tables 8 and 9). In addition, the SARs for adults returning to Bonneville (RRE-to-BOA and MCN-to-BOA) are provided in Figure 3.

Table 8. Overall McNary-to-Bonneville (MCN-to-BOA) and Rocky Reach-to-Bonneville (RRE-to-BOA) SARs for Okanogan River wild sockeye (i.e., release aggregate), 2013-2020.

Juvenile migration year	MCN-to-BOA				RRE-to-BOA			
	Smolts arriving MCN[A]	%SAR Estimate	Non-parametric CI		Smolts arriving RRE[A]	%SAR Estimate	Non-parametric CI	
			90% LL	90% UL			90% LL	90% UL
2013[B,C]	---	---	---	---	2,012	8.05	6.82	9.31
2014[B]	2,170	2.90	2.24	3.61	2,937	2.15	1.72	2.63
2015	2,538	1.58	1.04	2.16	3,064	1.31	0.97	1.66
2016[B]	4,337	1.82	1.41	2.21	5,782	1.37	1.12	1.63
2017[B]	5,864	0.12	0.05	0.21	5,956	0.12	0.05	0.19
2018[B]	3,628	2.78	2.15	3.39	4,405	2.29	1.88	2.70
2019[B]	4,104	4.53	3.46	5.73	4,623	4.02	3.52	4.57
2020[D]	---	---	---	---	---	---	---	---

[A] Estimated population of tagged study fish alive to MCN or RRE 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 and the Logit link.

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

[C] Due to an unreliable survival estimate in the RRH-MCN reach, SAR (MCN-BOA) was not possible.

[D] No tagging in 2020 due to COVID restrictions.

Table 9. Overall McNary-to-Wells (MCN-to-WEA) and Rocky Reach-to-Wells (RRE-to-WEA) SARs for Okanogan River wild sockeye (i.e., release aggregate), 2013-2020.

Juvenile migration year	MCN-to-WEA				RRE-to-WEA			
	Smolts arriving MCN[A]	%SAR Estimate	Non-parametric CI		Smolts arriving RRE[A]	%SAR Estimate	Non-parametric CI	
			90% LL	90% UL			90% LL	90% UL
2013[B,C]	---	--	--	--	2,012	4.32	3.50	5.24
2014[B]	2,170	2.35	1.75	2.94	2,937	1.74	1.36	2.16
2015	2,538	1.22	0.79	1.71	3,064	1.01	0.72	1.32
2016[B]	4,337	1.36	1.03	1.70	5,782	1.02	0.81	1.25
2017[B]	5,864	0.12	0.05	0.21	5,956	0.12	0.05	0.19
2018[B]	3,628	1.98	1.46	2.46	4,405	1.63	1.31	1.96
2019[B]	4,104	3.07	2.30	3.91	4,623	2.73	2.32	3.18
2020[D]	---	---	---	---	---	---	---	---

[A] Estimated population of tagged study fish alive to MCN or RRE 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 and the Logit link.

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

[C] Due to an unreliable survival estimate in the RRH-MCN reach, SAR (MCN-BOA) was not possible.

[D] No tagging in 2020 due to COVID restrictions.

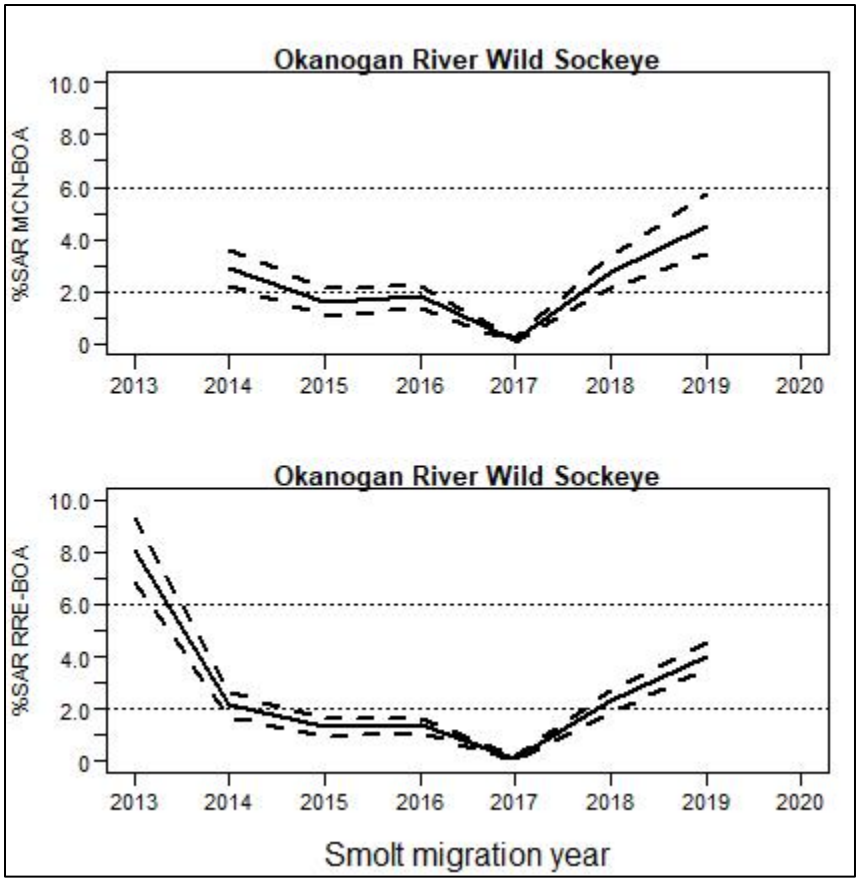

Figure 3. Bootstrapped SAR (MCN-to-BOA and RRE-to-BOA) and upper and lower CI for Okanogan River sockeye (i.e., release aggregate), 2013-2020 migration years. The NPCC (2014) 2%-6% SAR objective for listed wild populations is shown for reference.

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McCann, J, B. Chockley, E. Cooper, B. Hsu, G. Sheer, S. Haeseker, R. Lessard, T. Copeland, E. Tinus, A. Storch, and D. Rawding. 2019. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye DRAFT 2019 Annual Report. BPA Contract #19960200. December 2019. https://www.fpc.org/documents/CSS/2019CSSAnnualReport.pdf

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