



CRITFC

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Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 20**20**

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May 31, 2022



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and Wenatchee Sockeye Salmon in 2020**

**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 1757 Sockeye Salmon, *Oncorhynchus nerka*, were sampled and 1751 PIT tagged at the Bonneville Dam Adult Fish Facility (AFF) in 2020. 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. Upstream detections of PIT tagged Sockeye Salmon tagged by this project at Bonneville Dam resulted in an estimated survival in 2020 of 90.4% to McNary Dam and 77.3% to Rock Island Dam.

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 1718 Sockeye Salmon sampled at Bonneville Dam in 2020. After correcting for likely errors in data collection, concurrence between Sockeye Salmon classified both by genetics and final PIT tag detection site was 100% for the Wenatchee and Okanagan stocks. None of the 4 Snake River stock Sockeye Salmon sampled were detected in terminal areas above Lower Granite Dam. Stock composition at Bonneville Dam in 2020 was estimated as 80.7% Okanagan, 17.1% Wenatchee, 2.2% Yakima, and less than 0.1% Snake.

Age 1.2 Sockeye Salmon comprised 98.6% of the run followed by Age 1.1 at 0.9% of the run, 0.2% for both Age 1.3 and 2.2, and Age 2.1 at 0.1% of the run. The estimated age composition for Okanogan Sockeye Salmon (based on GSI of Sockeye Salmon collected at Bonneville Dam) was 98.4% Age 1.2, 1.1% Age 1.3, 0.2% Age 2.1 and 2.2, and 0.1% Age 1.3, while for Wenatchee Sockeye Salmon it was 99.8% Age 1.2, and 0.2% Age 1.3. Age 2.1 and 2.2 were not found in the Wenatchee stock.

The estimated minimum fallback rates in Columbia River mainstem dams for adult Sockeye Salmon tagged at the AFF in 2020 ranged from 0.4% at Bonneville Dam, to 6.0% at John Day Dam. The minimum fallback rate was 0.19 fallback events per Sockeye Salmon.

Adult Sockeye Salmon travelled quickly upstream in 2020 with a median migration rates between mainstem dams ranging from 30.1 km/day between Priest Rapids and Rock Island dams to 56.6 km/day between John Day and McNary dams for adults tagged at Bonneville Dam. Migration rates generally increased as the migration progressed and there was little difference between rates for Okanagan and Wenatchee Sockeye Salmon.

Upstream survival of Okanagan Sockeye Salmon to Rock Island Dam was higher than the Wenatchee stock (80.5% vs 71.6%), however survival to the spawning grounds was lower (41.2% vs. 44.1%)

There was no Okanagan juvenile PIT tagging in 2020 due to restrictions on field work due to the Covid-19 pandemic.

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. We expect to improve PIT tag detection at, or near, Zosel Dam to advance our understanding of adult survival in this area during these periods of high flows.

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INTRODUCTION

Sockeye Salmon, *Oncorhynchus nerka*, is one of the species of Pacific salmon native to the Columbia River Basin. Prior to European settlement of the region, it is estimated the Columbia Basin supported an annual Sockeye Salmon run averaging over three million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, the Sockeye Salmon run has severely declined, reaching a low of fewer than 9,200 fish in 1995 before rebounding in recent years to highs of over 500,000 Sockeye Salmon counted at Bonneville Dam in 2012, 2014, and 2015 (DART 2020, FPC 2020). The Bonneville Dam Sockeye Salmon count in the three years prior to the year of this report was 87,693 in 2017, 193,816 in 2018, and 63,046 in 2019. For 2020, the Sockeye Salmon count at Bonneville Dam was 347,739, the highest since 342,498 in 2016.

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 Okanagan¹ 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 in the Deschutes Basin since 2010.

Okanagan Sockeye Salmon spawn in the Canadian portion of the Okanagan River and then rear in Osoyoos Lake, through which runs the border between the United States and Canada. In recent years, the range of Okanagan Sockeye Salmon has been extended to Skaha Lake and a hatchery program is operated by the Okanagan Nation Alliance (ONA) near Penticton, BC.

Okanagan Sockeye Salmon have persisted despite one of the longest, most difficult migrations of any salmon stock in the world. The stock migrates 986 km between the spawning grounds and the ocean through one dam and a series of irrigation control structures on the Okanagan River as well as nine mainstem

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

Columbia River dams (Figure 1). The production of this run is believed to be limited by upstream and downstream migration survival as well as habitat factors in the spawning and rearing areas (Fryer 1995; Hyatt and Rankin 1999, Hyatt and Stockwell 2009).

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.

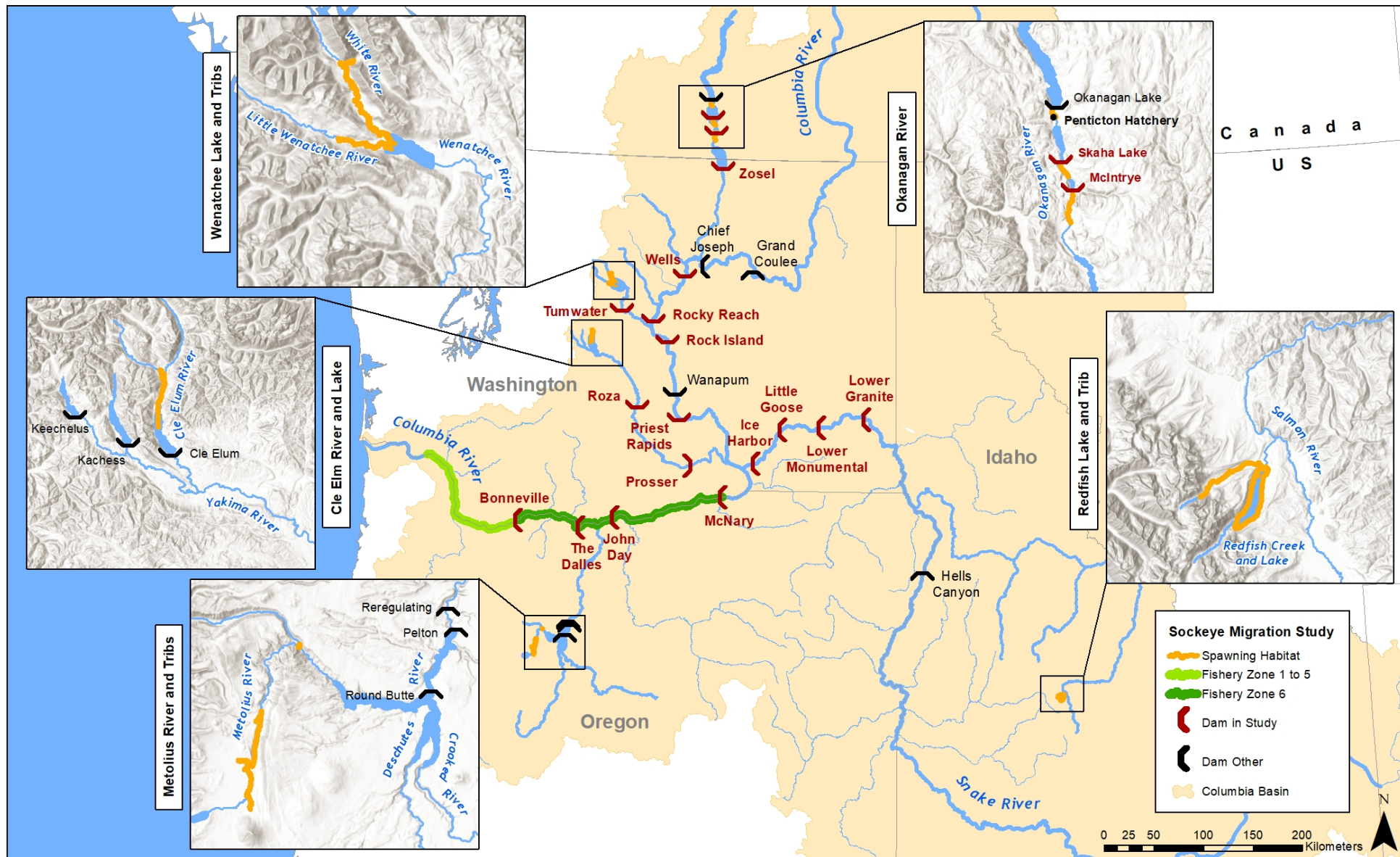


Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the major and minor Sockeye Salmon production areas and significant dams on their migration route.

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 an annual acoustic survey of Lake Wenatchee to initiate standardized Sockeye Salmon smolt abundance estimation for the Wenatchee stock for comparison with similar estimates already available for Okanagan Sockeye 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. 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. 2011a). 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. 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. There were no significant changes to the system in 2020.

Adult Sampling at Bonneville, Wells, and Priest Rapids dams

Bonneville Dam Sampling

Sockeye Salmon were sampled and tagged at the Adult Fish Facility located adjacent to the Second Powerhouse at Bonneville Dam (river km 235) in conjunction with the sampling of steelhead (*O. mykiss*) and Chinook Salmon (*O. tshawytscha*). Sampling and tagging typically occurred between approximately 0800 and 1300 hours five days per week. A picket weir diverts fish ascending the Washington Shore fish ladder into the adult sampling facility collection pool. An attraction flow is used to draw fish through a false weir where they may be selected for sampling (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.

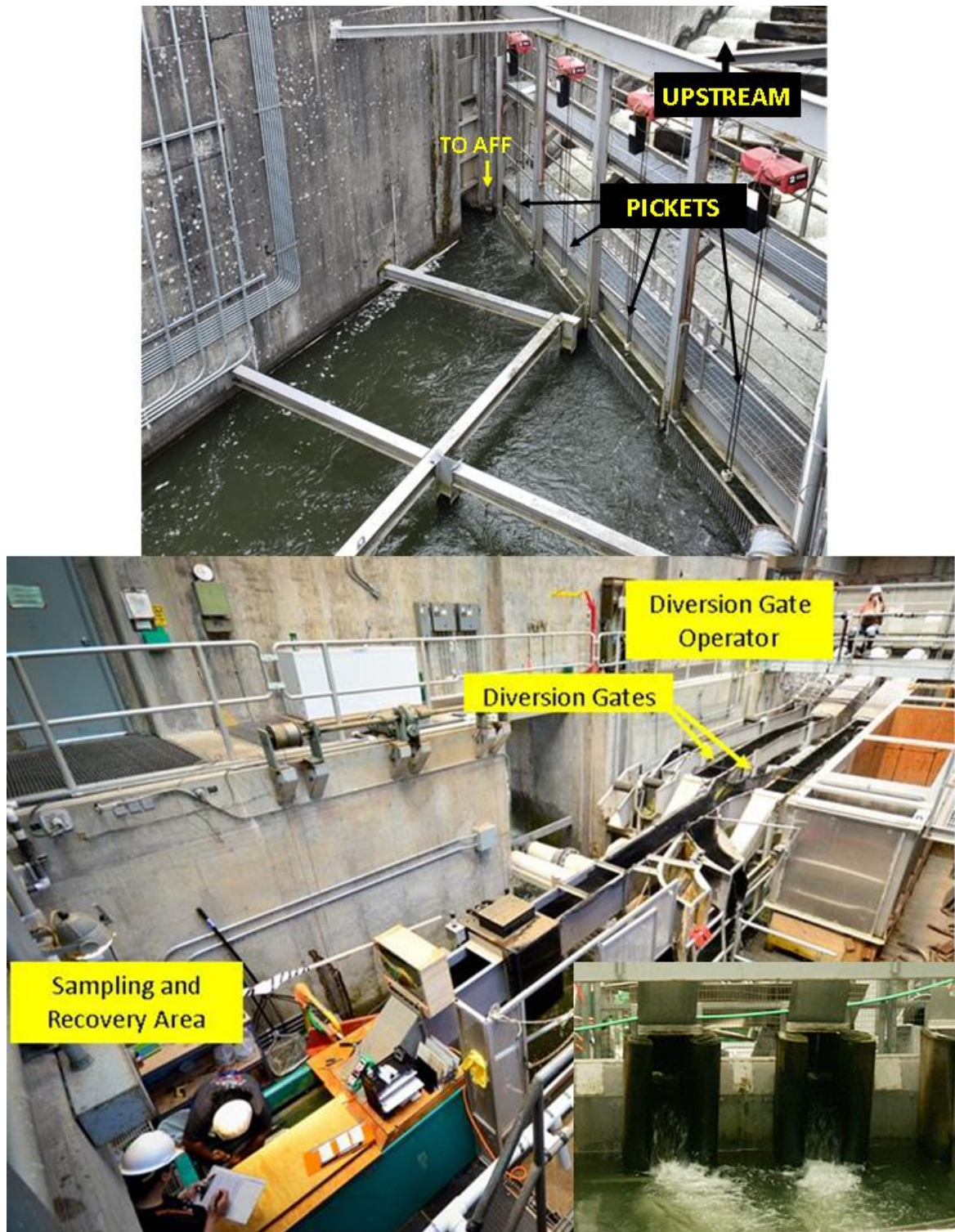


Figure 2. Bonneville Adult Fish Facility. Top: Picket leads which divert fish from the fish ladder to the AFF. Bottom Right: False weir which fish must swim through to travel down the flume to the sampling area (lower left).

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, PIT tags were 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 Okanogan River, and Tumwater Dam on the Wenatchee River (array configurations are available at www.ptagis.org) as well as several in-stream detection arrays. PIT tag detection data from these arrays are automatically uploaded several times daily to the PTAGIS database where they are immediately accessible to users of the site. If a tag was not detected after the fish was released, we removed it from further analysis.

We also calculated some migratory characteristics of Sockeye Salmon PIT tagged as juveniles for comparison with adult Sockeye Salmon PIT tagged by this project. These Sockeye Salmon were from PIT tagging programs in the Snake, Okanogan, 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. Fish were diverted up a steep pass Denil fishway where they accumulated in an upwell enclosure. An attraction flow into the enclosure encouraged fish to voluntarily swim down a sorting chute, where an operator either diverted them into a chute leading to a large holding tank or returned them to the ladder upstream of the barrier gate. The Sockeye Salmon were netted 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 five scales were removed and placed on scale cards 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.

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 with the data used in fisheries management and run forecasting. Scale pattern analysis was first used, where scale growth was measured from Okanagan and Wenatchee known stock samples as well as Bonneville Dam mixed-stock samples (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.monitoringmethods.org/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 (<https://www.monitoringresources.org/Document/Method/Details/5446>).

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 include 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., $LOD \geq 14$ & $FDR \leq 0.1$) (See methods for [Parentage assignments using SNPPIT software v1.0](#), ID: 1341). 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](#), ID: 1334). 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, Okanogan, Snake, or Unknown) have been made by the last detection point. In past reports through 2019, those individuals last observed in the Okanogan, 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 latest evidence of Yakima-origin Sockeye Salmon straying into the Snake River, in 2020 we required detection at Lower Granite Dam to consider a Sockeye Salmon to be of Snake River origin, those 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 2020. In addition, GSI was also conducted on genetics samples from Sockeye Salmon PIT tagged at Wells Dam that were not detected in the Okanagan River as past results have found 100% of Sockeye Salmon detected in the Okanagan were classified by GSI as Okanagan Stock with the exception of a handful of likely sample mix ups.

Final Stock Classification Rules

In 2020 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, Wenatchee, or Okanagan Basin as being of that 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, 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”.

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

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

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

Escapement

Escapement to upstream sites and dams was estimated as:

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

where N was the estimated escapement at a particular upstream site, B_i is the weekly (Sunday to Saturday) total visual count passing Bonneville Dam in week i (DART 2020, FPC 2020), 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 OKC in the Okanogan 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 group 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 spillway² 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

² This changed in 2020 with the installation of the GRS site at a single Lower Granite Dam spillway.

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 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 2020, survey intensity 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 prevented this from occurring in 2020, 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 lakes³ 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.

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.

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

Juvenile PIT Tagging

No PIT tagging of juvenile Okanagan stock Sockeye Salmon occurred in 2020 due to COVID restrictions on ONA field activities.

RESULTS

Upstream Migration Analysis

Bonneville Sample Size and Upstream Detection

In 2020, a total of 1757 Sockeye Salmon were sampled for this project at the Bonneville Dam Adult Fish Facility between May 21 and August 13 (Table 1). Of these, 1751 were tagged, to which were added 5 recaptures of Sockeye Salmon which had been previously PIT tagged as juveniles on their downstream migration. There was one additional recapture of a Sockeye Salmon first sampled the morning of June 25, 2020 and tagged with PIT tag 3DD.003D3654BD and then recaptured later that day and double tagged with tag 3DD.003D3654B5. In the analyses for this report, this fish will be considered to have a single tagging event and the detections upstream merged. Twenty-one Sockeye Salmon were not detected after release and there were 5 mortalities, resulting in a total of 1730 Sockeye Salmon tracked upstream (which will hereafter be referred to as Bonneville-tagged Sockeye Salmon although this includes recaptures). In 2020, sampling restrictions resulting in raised picket leads on 33 sampling days during weeks Sockeye Salmon were sampled; 25 of which were due to high shad abundance and 8 days due to high water temperatures (21.1 - 22.2C, Table 1)⁴. An additional 4 days of sampling were lost due to a 4-day weekly sampling limit when temperatures were between 21.1 and 22.2C in weeks 30 and 31.

Sockeye Salmon not detected after tagging may have shed their tags, had defective tags, or died. It is also possible that these fish passed downstream without being detected, as Sockeye Salmon often swim over the top of weirs in the fish ladder rather than through the underwater slots where PIT tag antennas are located (e.g. at PTAGIS site BO3; Figures 3 and 4). It is unlikely that Sockeye Salmon pass upstream through Bonneville Dam fish ladders undetected as that would require swimming through a series of antennas at the upper end of both the Oregon and Washington shore fish ladders that detect virtually all passing PIT tagged fish (antennas 1-4 at both BO1 and BO4, Figure 5). If a Sockeye Salmon does pass through the ladder downstream to the tailrace after tagging, it is possible to pass upstream through the navigation locks without being detected at PIT tag

⁴ Raising picket leads is required by trap regulations and decreases the number of fish going through the trap and can introduce trap biases (Fryer et al. 2011b).

antennas at Bonneville Dam (Figure 5). This is also possible at The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams. 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 2006-2020 indicate that, even at those dams without navigation locks, PIT tagged Sockeye Salmon can and do avoid detection as they migrate upstream (Table 2).

Table 1. Number of Sockeye Salmon sampled, and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2020.

| Sampling Dates | Statistical Week ⁵ | Percent of Run | Sampled (N) | Tagged | Previously Tagged | | Mortalities | Not Detected After Tagging | Detected at or upstream of Bonneville ladder exit antennas | Days Sampling Restrictions in Effect | | |
|-----------------------|-------------------------------|----------------|-------------|-------------|------------------------|----------------|-------------|----------------------------|--|--------------------------------------|----------------------------------|-------------------------|
| | | | | | At AFF by this project | Other Agencies | | | | Reduced Temperature | Reduced Shad or Salmon Abundance | No Sampling Temperature |
| 5/21-6/5 | 22-23 | 0.5 | 19 | 19 | 0 | 0 | 0 | 0 | 19 | 0 | 5 | 0 |
| 6/8-6/12 | 24 | 3.1 | 109 | 108 | 0 | 1 | 0 | 7 | 102 | 0 | 5 | 0 |
| 6/15-6/19 | 25 | 11.2 | 293 | 293 | 0 | 0 | 1 | 3 | 289 | 0 | 5 | 0 |
| 6/22-6/26 | 26 | 27.7 | 352 | 350 | 1 | 1 | 0 | 1 | 350 | 0 | 5 | 0 |
| 6/29-7/2 | 27 | 35.5 | 391 | 389 | 0 | 2 | 2 | 3 | 386 | 0 | 3 | 0 |
| 7/9-7/10 | 28 | 16.5 | 121 | 121 | 0 | 0 | 0 | 0 | 121 | 0 | 2 | 0 |
| 7/13-7/17 | 29 | 3.9 | 264 | 264 | 0 | 0 | 1 | 3 | 260 | 0 | 0 | 0 |
| 7/20-7/24 | 30 | 1.3 | 146 | 145 | 0 | 1 | 0 | 4 | 142 | 0 | 0 | 1 |
| 7/27-7/30 | 31 | 0.3 | 51 | 51 | 0 | 0 | 1 | 0 | 50 | 2 | 0 | 1 |
| 8/3-8/6, 8/10-8/13 | 32-33 | 0.1 | 11 | 11 | 0 | 0 | 0 | 0 | 11 | 6 | 0 | 2 |
| Total | | | 1757 | 1751 | 1 | 5 | 5 | 21 | 1730 | 8 | 25 | 4 |

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 2020, for instance, Statistical Week 23 began on May 31 and ended on June 6.

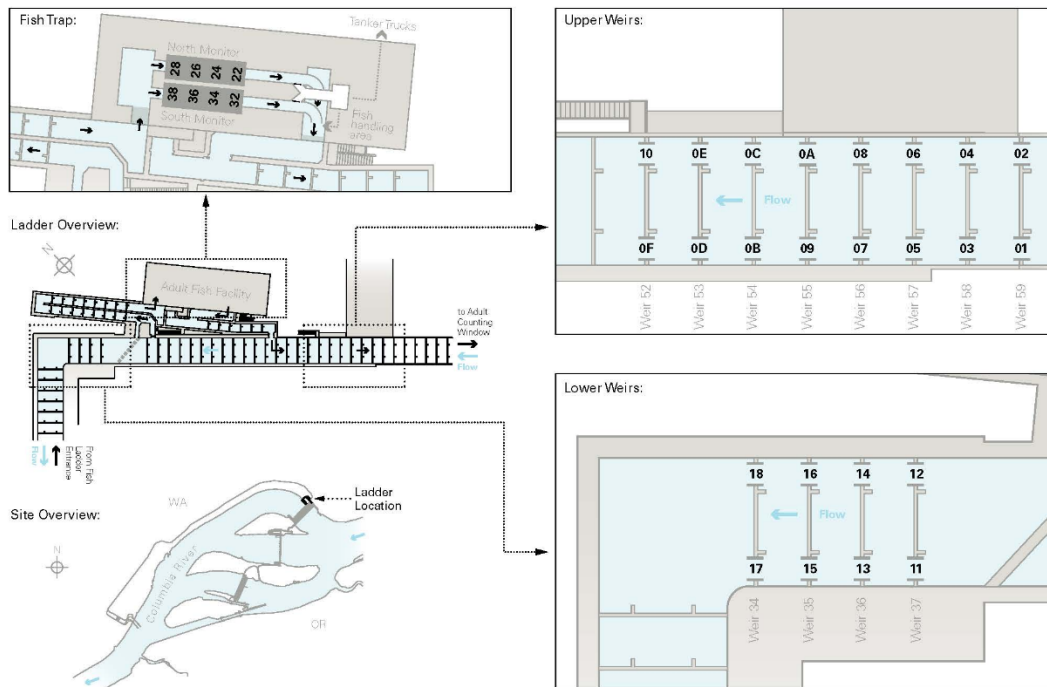
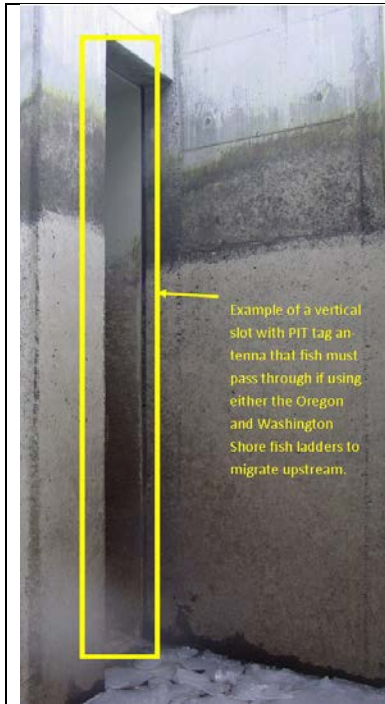


Figure 3. PTAGIS site BO3 Configuration. Antennas 01 to 10 are upstream of the Adult Fish Facility while antennas 11 to 18 are downstream. Antennas 22-28 and 32-38 are in the Adult Fish Facility flumes.

Bonneville Dam Vertical Slot Antenna



Bonneville Dam underwater antenna with unmonitored overflow weir



Figure 4. Pictures 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).

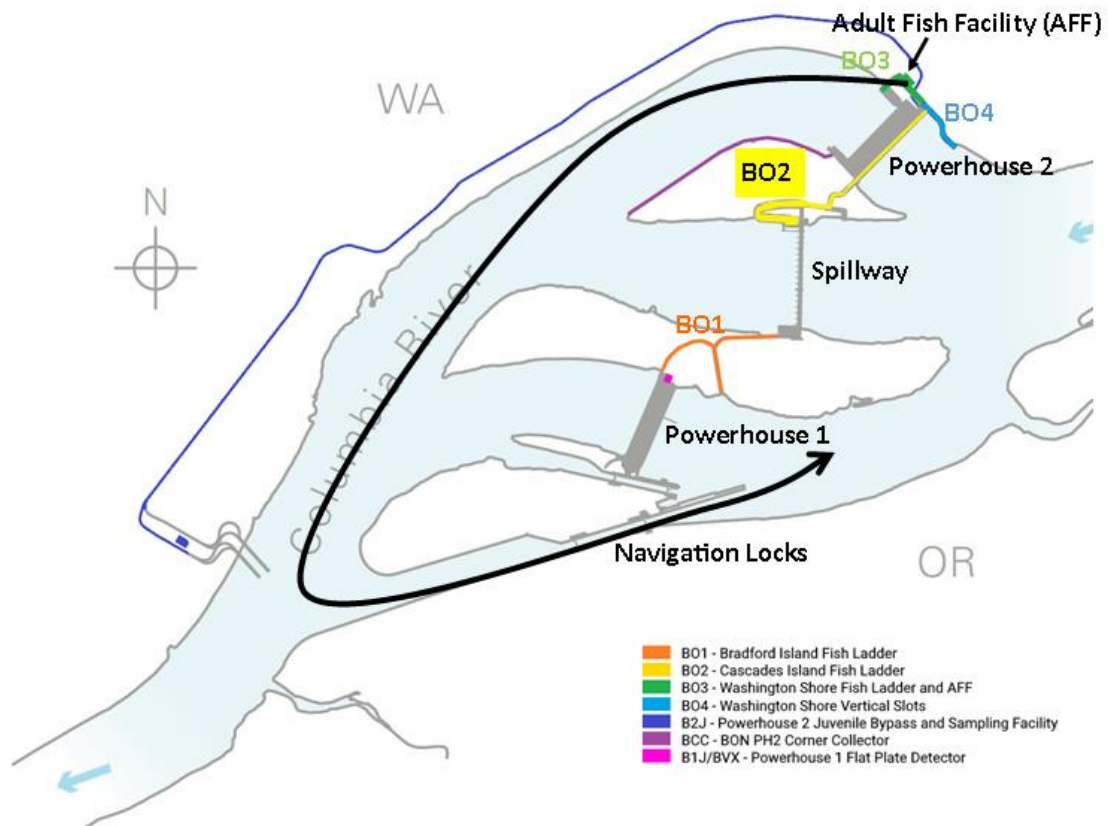


Figure 5. Site of Bonneville Dam PIT tag antennas and the most likely route (shown as a black line) for Sockeye Salmon tagged at the Adult Fish Facility to pass upstream undetected (Figure modified from www.ptagis.org).

Table 2. Percentage of Bonneville Dam PIT tagged Sockeye Salmon not detected at upstream dams and in-stream PIT tag arrays on their migration route for 2006-2020.

| Dam/Array | Percentage Not Detected by Dam and Year | | | | | | | | | | | | | | | |
|------------------------|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------------------|------|
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 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 | 1.0 |
| The Dalles | -- | -- | -- | -- | -- | -- | -- | 1.6 | 0.3 | 0.6 | 0.4 | 2.1 | 0.9 | 0.5 | 1.4 | 1.0 |
| John Day | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.8 | 3.3 | 4.5 | 3.5 |
| 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 | 4.4 |
| 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 | 0.2 |
| 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 | 8.9 |
| 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 | 1.1 |
| 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 |
| Ice Harbor | -- | -- | 0.0 | 20.0 | 0.0 | -- | 0.0 | -- | 12.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 |
| Lower Monumental | -- | -- | -- | -- | -- | -- | -- | -- | -- | 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 |
| Lower Granite | -- | -- | -- | -- | -- | -- | -- | -- | -- | 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 ⁶ | 0.1 |
| Zosel | -- | -- | -- | -- | -- | 98.6 | 83.0 | 87.3 | 0.9 | 0.0 | 1.6 | 74.5 | 57.5 | 0.0 | 76.2 | 48.0 |
| Lower Wenatchee (LWE) | -- | -- | -- | -- | -- | -- | -- | -- | 48.0 | 17.9 | 54.7 | 49.6 | 68.4 | 33.3 | 78.4 | 50.0 |
| Upper Wenatchee (UWE) | -- | -- | -- | -- | -- | -- | -- | -- | 52.7 | 24.6 | 9.7 | 9.3 | 9.9 | 3.2 | 11.3 | 17.2 |
| Lower Okanagan (OKL) | -- | -- | -- | -- | -- | -- | -- | -- | 68.9 | 13.8 | 59.4 | 47.4 | 50.1 | 66.7 | 40.4 | 49.5 |
| Okanagan Channel (OKC) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 16.9 | -- | 7.7 | 5.3 | 5.7 | 8.9 |
| Skaha | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0 | 41.5 | 20.8 |

⁶ The two Sockeye Salmon not detected likely passed during a power outage at Tumwater Dam on 7/21/20 from 15:40 until 01:06 on 7/22/20. These were the first Sockeye Salmon this project has observed missing Tumwater Dam since antennas were installed at this site in 2008.

Based on Sockeye Salmon PIT tagged at Bonneville Dam by this study, the mainstem dam with the highest percentage passing upstream undetected in 2020 was John Day Dam (4.5%, Table 2). In the Okanagan Basin, Zosel and Skaha dams had high rates of PIT-tagged Sockeye Salmon missing detection due to high river flows allowing Sockeye Salmon to avoid detection by migrating through the unmonitored spillway rather than through fish ladders where there was PIT tag detection.

Age Composition

The predominant age group in 2020 was Age 1.2 at 98.6% of the run, followed by Age 1.1 at 0.9% of the run (Table 3). Over the run, the percentage of Age 1.2 Sockeye Salmon ranged from 90.3% (Week 30) to 100.0% (weeks 24, 28, 32-33). The only other age group with weekly percentage greater than 3.0% was Age 1.1 in weeks 22-23 (5.6%) and in Week 30 (7.1%, Figure 6).

Table 3. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2020. (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)

| Statistical Week | % of Run | N Ageable | Age Class | | | | |
|------------------|---------------|-------------|-------------|--------------|-------------|-------------|-------------|
| | | | 1.1 | 1.2 | 2.1 | 1.3 | 2.2 |
| 22-23 | 0.5% | 18 | 5.6% | 94.4% | 0.0% | 0.0% | 0.0% |
| 24 | 3.1% | 106 | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| 25 | 11.2% | 260 | 2.7% | 96.5% | 0.0% | 0.8% | 0.0% |
| 26 | 27.7% | 342 | 1.2% | 98.0% | 0.3% | 0.3% | 0.3% |
| 27 | 35.5% | 385 | 0.3% | 99.5% | 0.0% | 0.0% | 0.3% |
| 28 | 16.5% | 120 | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| 29 | 3.9% | 257 | 1.2% | 98.4% | 0.0% | 0.4% | 0.0% |
| 30 | 1.3% | 113 | 7.1% | 90.3% | 0.0% | 2.7% | 0.0% |
| 31 | 0.3% | 39 | 2.6% | 97.4% | 0.0% | 0.0% | 0.0% |
| 32-33 | 0.1% | 11 | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| Composite | 100.0% | 1651 | 0.9% | 98.6% | 0.1% | 0.2% | 0.2% |

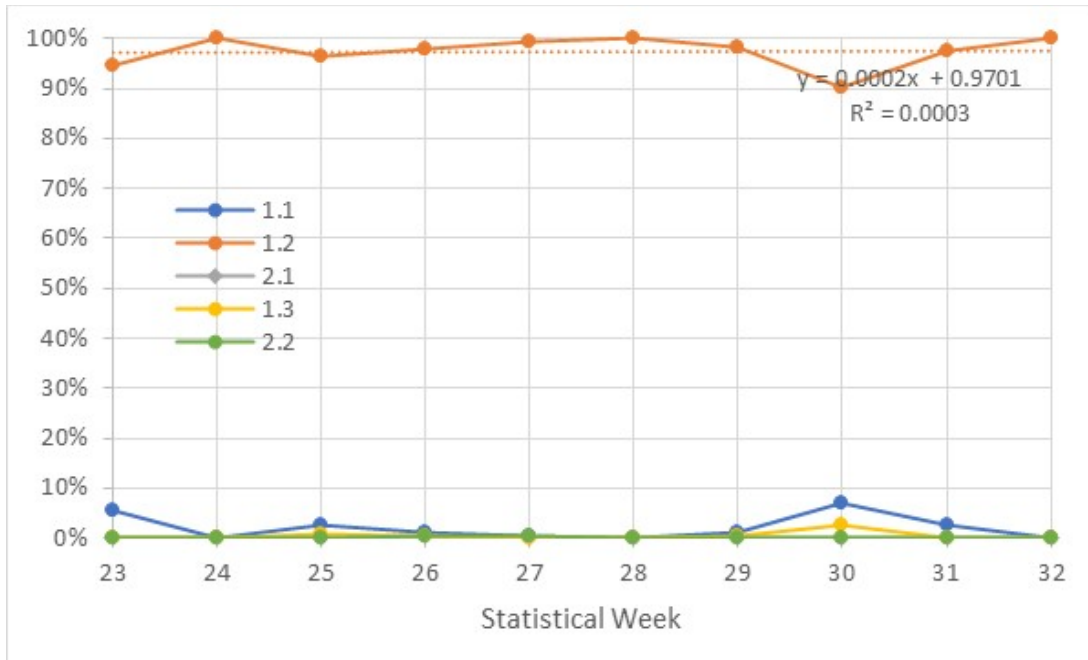


Figure 6. Weekly age composition estimates by Statistical Week for Sockeye Salmon sampled at Bonneville Dam in 2020.

Upstream Recoveries, Mortality, and Escapement

The percentage of Sockeye Salmon passing Bonneville Dam that were estimated to pass upstream sites (Figure 7) was higher in 2020 than the 2006-2020 mean at all sites but Tumwater Dam (Table 4)⁷.

⁷ Tumwater Dam is only passed by Wenatchee stock Sockeye Salmon so rate differences to Tumwater Dam (as well as Rocky Reach and Wells dams) also reflect annual variations in stock composition.

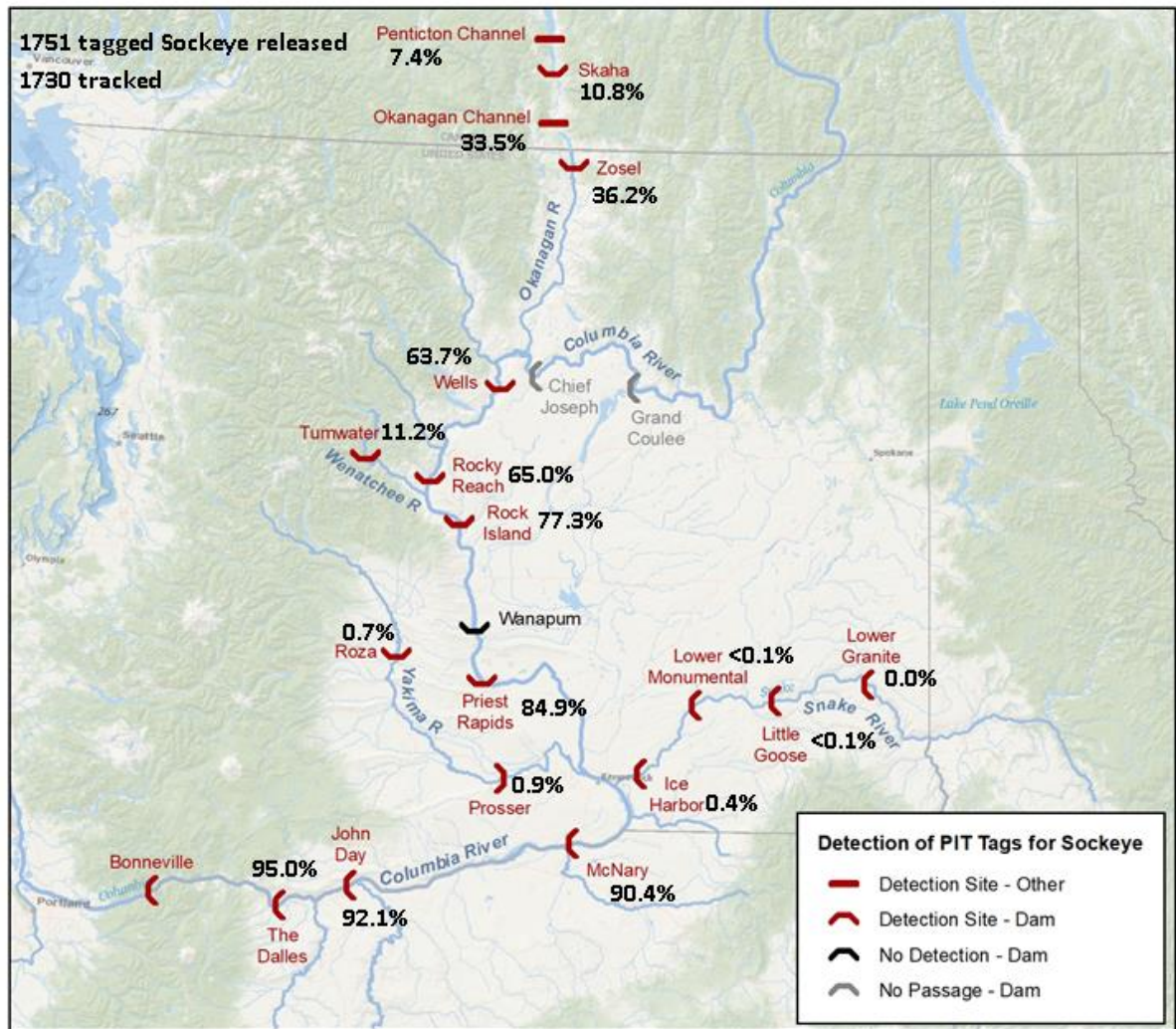


Figure 7. Map of the Columbia River Basin showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2020.

Table 4. Estimated survival of Sockeye Salmon PIT tagged at Bonneville Dam passing upstream dams 2006-2020.

| | Percentage by Year | | | | | | | | | | | | | | | |
|------------------------|--------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Dam or Site | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Mean |
| The Dalles | -- | -- | -- | -- | -- | -- | -- | 89.5 | 93.1 | 82.8 | 94.0 | 89.3 | 93.3 | 94.6 | 95.0 | 91.4 |
| John Day | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 90.9 | 92.7 | 92.1 | 91.8 |
| 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 | 83.2 |
| 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 | 78.5 |
| 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 | 75.1 |
| 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 | 60.5 |
| 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 | 58.8 |
| 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 | 13.6 |
| 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 | 32.5 |

Survival rates were also calculated using similar methods for returning adults from a group of juvenile Sockeye Salmon (project goal is 3000) captured and PIT tagged annually at the Rock Island Dam juvenile bypass since 2008⁸ (Table 5). Both Wenatchee and Okanagan juvenile Sockeye Salmon are tagged at this site, making it a mixed stock most similar to Sockeye Salmon tagged as adults at Bonneville Dam⁹. Sample sizes of returning adults from the Rock Island tagging program are often small with only 16-35 returns annually between 2016-2019, however this increased to 78 returning in 2020 (Table 5). Sockeye Salmon tagged by this program which passed Bonneville Dam in 2020 had survival rates from 0.7 to 2.9 percentage points higher than those tagged as juveniles at Rock Island Dam at all 5 dams (Bonneville-Rock Island) passed by both stocks (Figure 8). Annual survival rates for these fish from Bonneville Dam to Priest Rapids Dam are compared with adults tagged by this study at Bonneville Dam in Figure 9¹⁰. This survival rate was greater for returning Rock Island-tagged juvenile salmon compared to Bonneville-tagged adults in 8 out of 14 years, however only in 2018 was this difference significant at $\alpha=0.05$ ($p=0.002$).

Upstream of Rock Island Dam, some differences are apparent for Rock Island-tagged Sockeye Salmon which likely reflect a higher percentage of Wenatchee versus Okanagan stock Sockeye Salmon in the returning Rock Island-tagged Sockeye Salmon compared with those tagged at Bonneville Dam (Figure 9).

⁸ Tagging of juvenile Sockeye Salmon at Rock Island Dam has occurred since 1992; however, returns from these fish were lower and there were fewer detection sites prior to 2008.

⁹ Juvenile Sockeye Salmon are also tagged in the Okanagan and Wenatchee basins. However, these programs have a shorter data set in terms of years tagged with collection methods and tag numbers that have varied by year.

¹⁰ Priest Rapids was chosen as it is the last dam with a high PIT tag detection rate passed by both Okanagan and Wenatchee Sockeye Salmon.

Table 5. Survival of Sockeye Salmon PIT tagged as smolts at Rock Island Dam, on their adult upstream migration from Bonneville Dam to upstream dams for years 2008-2020¹¹.

| | Percentage by Year and Mean of All Years | | | | | | | | | | | | | |
|----------------------|--|------|------|------|------|------|------|------|------|------|-------|-------|------|-------|
| Dam | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Mean |
| # at Bonneville | 38 | 33 | 130 | 125 | 121 | 66 | 155 | 128 | 35 | 16 | 32 | 20 | 78 | 74.9 |
| # Tagged at Rock Is. | 1910 | 2059 | 3528 | 2977 | 3231 | 2674 | 3131 | 1689 | 4109 | 2210 | 3332 | 2859 | 3115 | 2809 |
| The Dalles | No PIT tag detection at this site | | | | | 87.9 | 92.9 | 85.9 | 82.9 | 87.5 | 100.0 | 100.0 | 93.6 | 91.0 |
| John Day | No PIT tag detection at this Site | | | | | | | | | | 100.0 | 100.0 | 89.7 | 100.0 |
| McNary | 89.5 | 100 | 82.3 | 74.4 | 74.4 | 80.3 | 87.1 | 60.2 | 74.3 | 81.3 | 100.0 | 90.0 | 89.7 | 82.8 |
| Priest Rapids | 89.5 | 93.9 | 81.5 | 73.6 | 71.9 | 74.2 | 83.9 | 54.7 | 74.3 | 68.8 | 100.0 | 85.0 | 83.3 | 79.3 |
| Rock Island | 81.6 | 90.9 | 79.2 | 68.8 | 69.4 | 68.2 | 77.4 | 46.9 | 68.6 | 68.8 | 93.9 | 85.0 | 74.4 | 74.9 |
| Rocky Reach | 55.3 | 87.9 | 70.0 | 55.2 | 48.8 | 56.1 | 60.0 | 36.7 | 45.7 | 68.8 | 65.6 | 55.0 | 56.4 | 58.8 |
| Wells | 55.3 | 87.9 | 68.5 | 52.8 | 43.8 | 56.1 | 58.7 | 32.8 | 42.9 | 62.5 | 62.5 | 55.0 | 55.1 | 56.6 |
| Tumwater | 26.3 | 3.0 | 10.0 | 14.4 | 23.1 | 10.6 | 16.1 | 13.3 | 22.9 | 6.3 | 25.0 | 25.0 | 16.7 | 16.3 |

¹¹ Years prior to 2008 were not included due to low sample sizes for returning Sockeye Salmon tagged as juveniles at Rock Island Dam. (From 2002-2007, the number of Sockeye Salmon PIT tagged at Rock Island Dam as juveniles detected returning to Bonneville ranged between one and eight fish annually.) Year 2013 the first year for detection at The Dalles Dam, and 2018 the first year for John Day Dam.

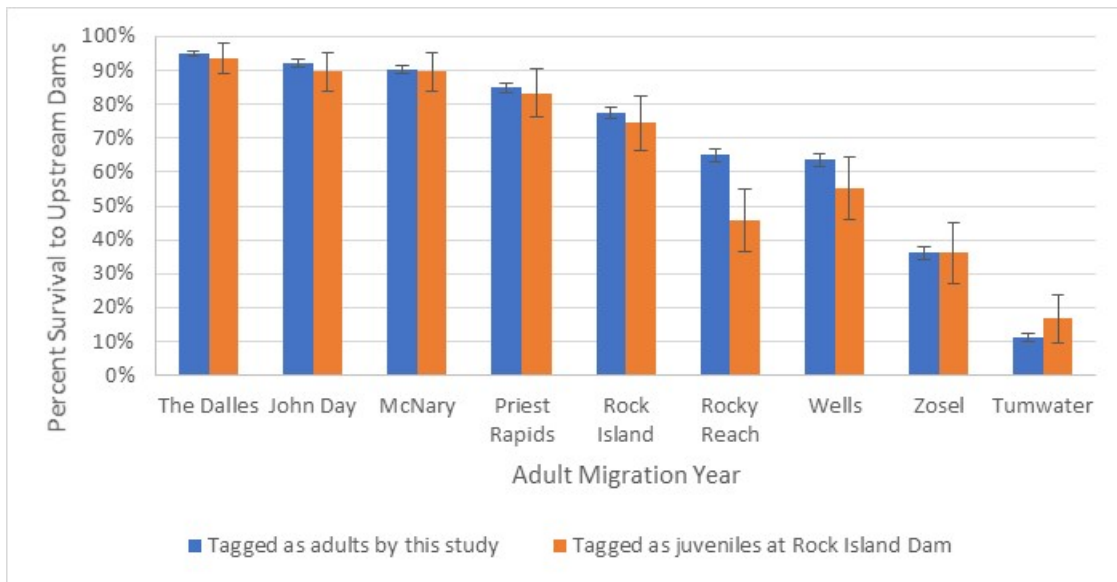


Figure 8. Estimated percentage of Sockeye Salmon passing Bonneville Dam detected at or upstream of The Dalles, John Day, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, Zosel and Tumwater dams with 90% CI for Sockeye Salmon PIT tagged as juveniles at Rock Island Dam and as adults at Bonneville Dam in 2020.

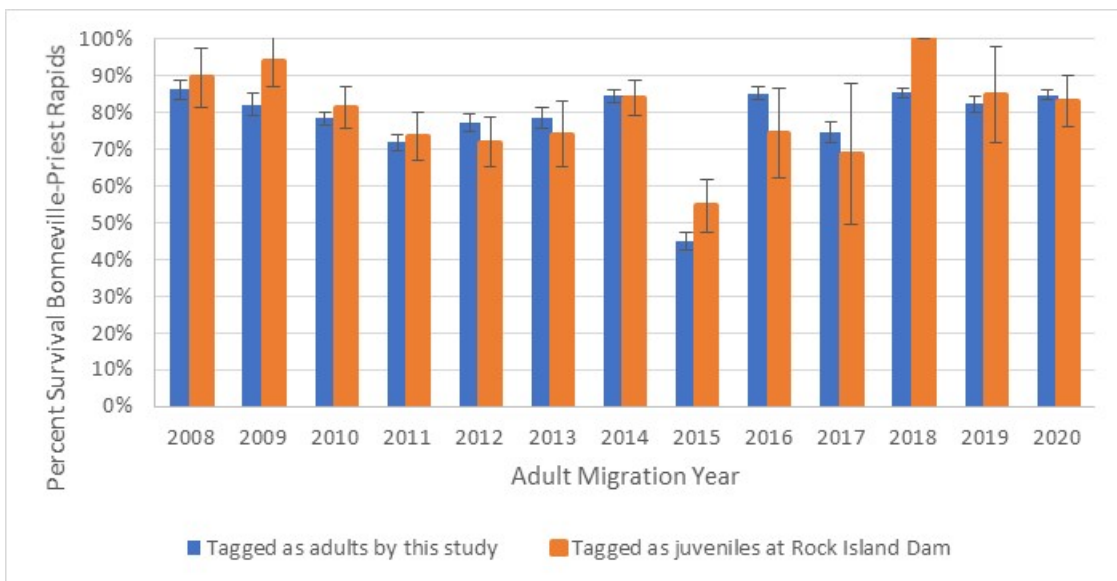


Figure 9. Annual estimated survival rate with 90% CI from Bonneville Dam to Priest Rapids Dam for adult Sockeye Salmon tagged by this study and for returning Sockeye Salmon tagged as juveniles at Rock Island Dam 2008-2020. (Priest Rapids Dam was chosen for this comparison as it is the most upstream dam with consistently high rates of PIT tag detection passed by both Okanagan and Wenatchee Sockeye Salmon.

The estimated escapement based on upstream PIT tag detections of the Bonneville-tagged Sockeye Salmon was greater than the number of Sockeye Salmon counted at The Dalles, John Day, and McNary dams, but less at Rock Island, Priest Rapids, Rocky Reach, Wells, and Tumwater dams (Table 6, Figure 10). 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 John Day Dam (309,959) than at any other dam upstream of Bonneville Dam on the river and more Sockeye Salmon were counted at Priest Rapids Dam than downstream at McNary Dam. PIT tag estimates for Snake River and Yakima River dams were based on very few detections (1 to 6 for the Snake River, 12 at Roza, and 16 at Prosser), resulting in larger differences between PIT and visual estimates for these sites.

Table 6. Estimated Sockeye Salmon escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate at Columbia Basin dams in 2020.

| Dam | Escapement Estimate Using Bonneville PIT Tagged Sockeye Salmon | Visual Dam Count | Difference Between Bonneville PIT Tag and Visual Estimates |
|---------------|---|-------------------------|---|
| Bonneville | -- | 341,716 | -- |
| The Dalles | 324,617 | 295,776 | 9.8% |
| John Day | 314,814 | 309,959 | 1.6% |
| McNary | 308,849 | 284,924 | 8.4% |
| Priest Rapids | 290,044 | 291,106 | -0.4% |
| Rock Island | 264,141 | 280,440 | -5.8% |
| Rocky Reach | 222,209 | 249,521 | -10.9% |
| Wells | 217,833 | 226,107 | -3.7% |
| Tumwater | 38,429 | 43,391 | -11.4% |
| Ice Harbor | 1,474 | 2,330 | -36.7% |
| L. Monumental | 51 | 1,257 | -95.9% |
| Little Goose | 51 | 831 | -93.9% |
| Lower Granite | 38,429 | 43,391 | -11.4% |
| Little Goose | 51 | 831 | -93.9% |
| Prosser | 3,201 | 2,549 | 25.6% |
| Roza | 2,510 | 4,379 | -42.7% |

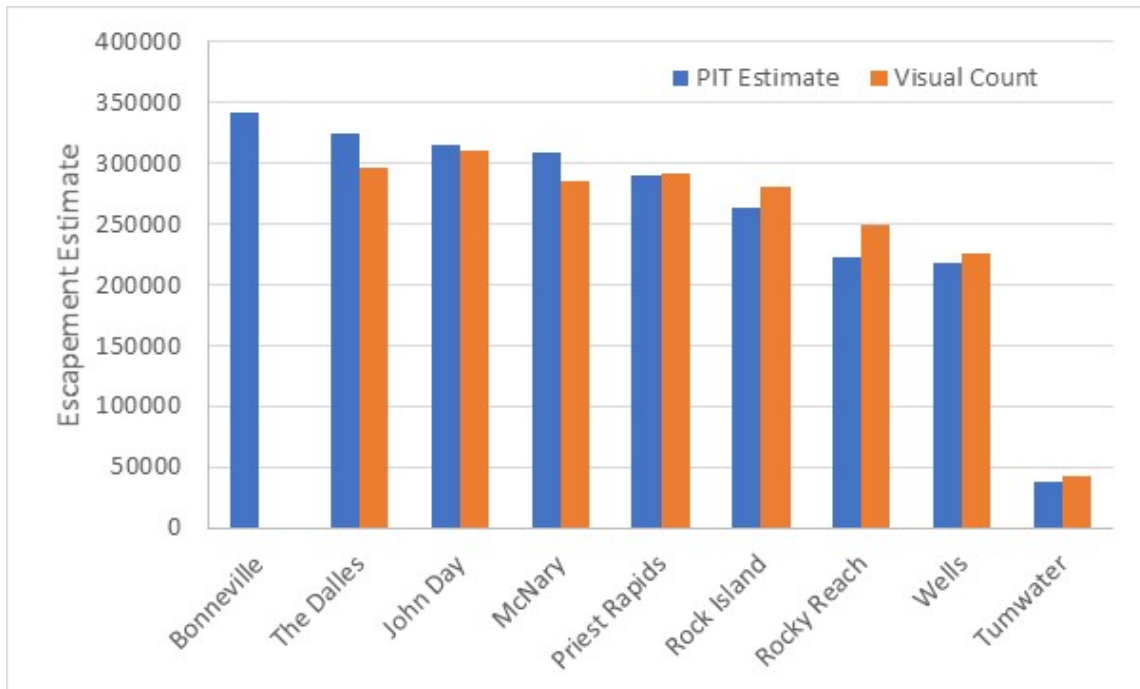


Figure 10. Estimated PIT tag and visual count estimates of escapement at Columbia River and Tumwater dams in 2020.

Sockeye Salmon tagged at Bonneville Dam show a significant decrease in survival to upstream dams over the period of the run in 2020 (Table 7, Figure 11). There was not a significant decrease in survival for Sockeye Salmon tagged as juveniles although sample sizes were lower (Table 7).

Table 7. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2020 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=83) | Okanagan (n=164) | Rock Island (n=78) |
| 22-23 | 100.0% | 100.0% | 100.0% | 100.0% | 89.8% | NA | 100.0% | 100.0% |
| 24 | 92.9% | 88.8% | 88.8% | 81.6% | 71.4% | 100.0% | 80.0% | 71.4% |
| 25 | 97.6% | 96.2% | 95.1% | 88.5% | 72.7% | 66.7% | 92.3% | 70.0% |
| 26 | 94.3% | 91.1% | 89.4% | 83.9% | 76.1% | 71.0% | 88.0% | 91.3% |
| 27 | 96.1% | 93.0% | 92.4% | 86.4% | 78.6% | 76.9% | 82.0% | 85.0% |
| 28 | 94.2% | 91.7% | 88.4% | 86.0% | 83.5% | 56.3% | 80.8% | 91.7% |
| 29 | 91.5% | 88.0% | 82.2% | 75.7% | 73.4% | 100.0% | 20.0% | 50.0% |
| 30 | 86.0% | 82.6% | 73.6% | 58.7% | 56.2% | 0.0% | 50.0% | 100.0% |
| 31 | 84.0% | 80.0% | 56.0% | 44.0% | 42.0% | 50.0% | 100.0% | NA |
| 32-33 | 72.7% | 72.7% | 54.5% | 45.5% | 36.4% | NA | NA | NA |
| Composite¹² | 95.0% | 92.1% | 90.4% | 84.9% | 77.3% | 71.0% | 81.7% | 83.3% |
| p-value | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.14 | 0.37 | 0.76 |

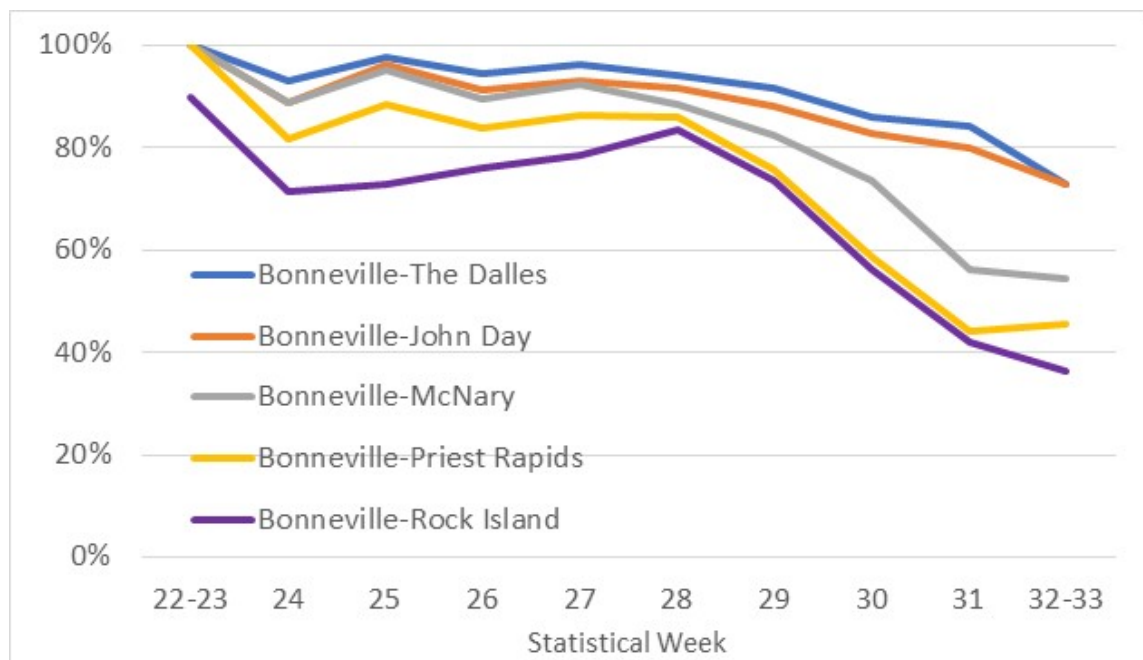


Figure 11. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, John Day, McNary, Priest Rapids, and Rock Island dams by statistical week in 2020.

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

The returning Rock Island juvenile-tagged Sockeye Salmon had highest upstream survival to Priest Rapids Dam¹³ (85.0%) followed by adults tagged at Bonneville Dam (84.9%, Table 8). Sockeye Salmon tagged as juveniles in the Wenatchee basin had the highest conversion rate to spawning ground arrays (45.0%) followed by adults tagged at Bonneville Dam (41.1%), juveniles tagged at Rock Island (41.0%) and juveniles tagged in the Okanagan basin (38.1%, Table 8).

Table 8. Survival of Sockeye Salmon groups PIT tagged as juveniles from Bonneville Dam to upstream dams with adults tagged by this study at Bonneville Dam included for comparison in 2020. Yellow shaded cells represent sites that are not on the migration route for the group tagged.

| Tagging Location | Life Stage at Tagging | # at BON | Percent Survival to Upstream Dam | | | | | | | | | Conversion Rate BON to PIT Arrays on Spawning Ground (%) ¹⁴ |
|------------------|-----------------------|----------|----------------------------------|----------|--------|---------------|-------------|-------------|-------|----------|------------|--|
| | | | The Dalles | John Day | McNary | Priest Rapids | Rock Island | Rocky Reach | Wells | Tumwater | Ice Harbor | |
| Okanagan | Juvenile | 164 | 93.9 | 87.8 | 82.9 | 81.7 | 73.2 | 72.0 | 71.3 | 0.0 | 0.0 | 38.1 |
| Wenatchee | Juvenile | 100 | 91.0 | 90.0 | 87.0 | 83.0 | 71.0 | 14.0 | 10.0 | 66.0 | 0.0 | 45.0 |
| Rock Island | Juvenile | 78 | 100.0 | 100.0 | 90.0 | 85.0 | 85.0 | 55.0 | 55.0 | 25.0 | 0.0 | 41.0 |
| Snake | Juvenile | 5 | 100.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 20.0 |
| Bonneville | Adult | 1848 | 95.0 | 92.1 | 90.4 | 84.9 | 77.3 | 65.0 | 63.7 | 11.2 | 0.4 | 41.1 |

Migration Rates and Passage Time

Adult Sockeye Salmon travelled quickly upstream in 2020 with median migration rates between mainstem dams ranging between 30.0 and 56.6 km/day for adults tagged at Bonneville and 29.2 to 55.6 km/day for tagged juveniles returning as adults (Table 9).

Like most previous years, Sockeye Salmon tagged at Bonneville Dam later in the migration traveled significantly faster than those tagged earlier in the migration through the mainstem Columbia River (Table 10). Median travel times between the Okanagan and Wenatchee stocks differed by 0.2 days or less for all

¹³ 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 2] that is passed by both predominant stocks (Okanagan and Wenatchee).

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

dam pairs listed that are in the normal migration corridor for both stocks. The nine Wenatchee-stock Sockeye Salmon which were detected at Wells Dam had shorter migration times to Rocky Reach and Wells Dam than did Okanagan Sockeye Salmon on their usual migration route.

Table 9. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2020.

| Dam Pair | Distance (km) | Adults Tagged at Bonneville Dam | | Returning Adults Tagged as Juveniles | |
|---------------------------|---------------|---------------------------------|--------------------------------|--------------------------------------|--------------------------------|
| | | Median Travel Time (days) | Median Migration Rate (km/day) | Median Travel Time (days) | Median Migration Rate (km/day) |
| Bonneville-The Dalles | 74 | 1.8 | 40.5 | 1.6 | 44.3 |
| The Dalles-John Day | 39 | 0.9 | 46.4 | 0.9 | 48.3 |
| John Day-McNary | 63 | 2.1 | 56.6 | 2.1 | 55.6 |
| McNary-Priest Rapids | 167 | 4.9 | 34.5 | 5.0 | 33.9 |
| Priest Rapids-Rock Island | 89 | 3.0 | 30.1 | 3.1 | 29.2 |
| Rock Island-Rocky Reach | 33 | 1.0 | 32.6 | 1.0 | 32.6 |
| Rocky Reach-Wells | 65 | 1.8 | 36.7 | 1.9 | 36.5 |
| Rock Island-Tumwater | 73 | 9.6 | 7.2 | 9.7 | 7.1 |
| Bonneville-John Day | 113 | 2.8 | 41.6 | 2.6 | 44.1 |
| Bonneville-McNary | 231 | 4.9 | 47.7 | 4.8 | 48.1 |
| Bonneville-Priest Rapids | 329 | 9.9 | 40.5 | 10.0 | 40.3 |
| Bonneville-Rock Island | 487 | 13.0 | 37.8 | 13.4 | 36.7 |
| Bonneville-Tumwater | 560 | 24.0 | 23.3 | 23.8 | 23.5 |
| Bonneville-Wells | 585 | 16.0 | 37.0 | 16.4 | 36.1 |

Table 10. Adult Sockeye Salmon median travel time in days between dam pairs by statistical week tagged at Bonneville Dam, the p-value for a linear regression between travel time and statistical week, and mean travel time by stock as estimated using PIT tags in 2020.

| 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 | 1.9 | 3.1 | 6.9 | 15.1 | 20.4 | 0.0 | 21.9 | 24.1 | NA | NA | NA |
| 24 | 1.9 | 3.1 | 5.6 | 13.8 | 17.3 | 38.6 | 19.0 | 21.1 | NA | NA | 17.7 |
| 25 | 1.8 | 2.9 | 5.2 | 11.7 | 16.4 | 31.4 | 17.7 | 19.8 | 89.8 | 59.6 | 14.9 |
| 26 | 1.8 | 2.8 | 4.9 | 11.0 | 14.2 | 26.0 | 15.0 | 17.0 | 69.4 | 44.7 | 10.7 |
| 27 | 1.8 | 2.8 | 4.8 | 9.0 | 11.8 | 20.9 | 12.7 | 14.7 | 60.9 | 45.2 | 8.7 |
| 28 | 1.7 | 2.7 | 4.7 | 8.7 | 11.9 | 21.0 | 12.0 | 13.9 | 40.2 | 26.1 | 7.4 |
| 29 | 1.7 | 2.6 | 4.7 | 8.6 | 11.0 | 20.2 | 11.9 | 13.7 | 42.6 | 28.5 | 8.1 |
| 30 | 1.7 | 2.7 | 4.8 | 8.8 | 11.7 | 22.6 | 12.8 | 14.7 | 26.7 | 12.2 | 8.3 |
| 31 | 1.5 | 2.3 | 4.5 | 8.1 | 10.7 | 23.7 | 12.0 | 14.1 | 30.0 | 8.7 | 12.9 |
| 32 | 1.6 | 2.8 | 4.3 | 10.2 | 13.3 | 0.0 | 15.1 | 17.0 | 25.2 | 10.2 | NA |
| p-value | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.03 | 0.01 | 0.01 | <0.01 | <0.01 | 0.12 |
| Stock | | | | | | | | | | | |
| Okanagan | 1.8 | 2.8 | 4.9 | 9.8 | 13.0 | NA | 13.9 | 16.0 | 43.0 | 29.6 | NA |
| Wenatchee | 1.8 | 2.8 | 4.9 | 10.0 | 13.0 | 23.8 | 13.1 | 15.2 | NA | NA | 9.6 |

The median passage time at a dam for Sockeye Salmon tagged at Bonneville Dam in 2020 was 12.2 minutes compared to 8.0 minutes for Sockeye Salmon tagged as juveniles (Table 11). The greatest median passage time was at Tumwater Dam for both tag groups, likely due to trapping activities at that site.

Table 11. Sockeye Salmon median passage time (from time of first detection at a dam to last detection at a dam) and the percentage of Sockeye Salmon taking greater than 12 hours between first detection and last detection in 2020.

| Dam | Adults Tagged at Bonneville Dam | | | Previously Tagged as Juveniles | | |
|--|------------------------------------|--------------------------------|---------------|--------------------------------|--------------------------------|---------------|
| | N | Median Passage (Minutes) | %>12 Hours | N | Median Passage (Minutes) | %>12 Hours |
| Bonneville | 1730 | 12.2 | 9.1% | 231 | 8.0 | 0.0% |
| The Dalles | 1589 | 0.0 | 2.1% | 322 | 0.1 | 0.6% |
| John Day | 1494 | 0.1 | 5.0% | 301 | 0.5 | 6.6% |
| McNary | 1466 | 0.1 | 1.0% | 300 | 0.2 | 1.0% |
| Priest Rapids | 1393 | 4.7 | 3.4% | 282 | 11 | 4.3% |
| Rock Island | 1235 | 11.8 | 2.2% | 232 | 12.6 | 3.0% |
| Rocky Reach | 1076 | 3.1 | 2.6% | 176 | 6.0 | 2.3% |
| Wells | 1046 | 3.8 | 7.6% | 170 | 5.9 | 8.8% |
| Zosel | 188 | 0.4 | 2.1% | 27 | 2 | 11.1% |
| Tumwater | 166 | 24.0 | 18.1% | 79 | 41.7 | 16.5% |
| Ice Harbor | 6 | 4.2 | 16.7% | 5 | 7 | 0.0% |
| Lower Monumental | 1 | 0.1 | 0.0% | 5 | 7.2 | 20.0% |
| Little Goose | 1 | 0.0 | 0.0% | 5 | 0.1 | 20.0% |
| Lower Granite | 0 | NA | NA | 5 | 578.2 | 0.0% |
| Weighted Mean (by detection number) | | 4.7 | 4.4% | | 7.7 | 3.8% |

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 6 out of 9 dams where Sockeye Salmon from both stocks were detected (Table 12. Adults tagged at Bonneville passed dams at night at a higher rate than Sockeye Salmon tagged as juveniles at 6 out of 10 dams.

Table 12. Estimated Sockeye Salmon night passage (2000-0400) by stock at Columbia River, Zosel, and Tumwater dams in 2020.

| Dam | Adults Tagged at Bonneville Dam | | | Sockeye Salmon Tagged as Juveniles |
|---------------|---------------------------------|----------|-----------|------------------------------------|
| | All Adults | Okanagan | Wenatchee | |
| Bonneville | 0.6% | 0.7% | 0.0% | 2.2% |
| The Dalles | 8.1% | 9.0% | 3.9% | 7.5% |
| John Day | 4.0% | 4.9% | 0.5% | 2.3% |
| McNary | 7.2% | 8.3% | 0.9% | 3.7% |
| Priest Rapids | 3.4% | 3.9% | 1.0% | 4.3% |
| Rock Island | 4.3% | 4.2% | 4.5% | 3.9% |
| Rocky Reach | 7.2% | 7.3% | 4.5% | 9.7% |
| Wells | 11.2% | 11.0% | 33.3% | 8.2% |
| Tumwater | 3.6% | NA | 3.7% | 3.8% |
| Zosel | 27.1% | 27.1% | NA | 11.1% |

Fallback

Fallback rates at mainstem Columbia River dams for adults tagged at Bonneville Dam in 2020 ranged from 0.3% at McNary Dam to 6.0% at John Day Dam while among all 347 returning Sockeye Salmon tagged as juveniles, the range was from 0.0% at Rock Island Dam to 9.1% at Rocky Reach Dam (Table 13).

Of the 295 Sockeye Salmon tagged as adults by this project in 2020 which fell back over at least one dam, 13 fell back over two dams 2 fell back over three dams, and one fell back over four dams (Table 14). Among Sockeye Salmon tagged as juveniles, the mean number of fallback events per Sockeye Salmon ranged from 0.16 for Sockeye Salmon tagged in the Okanagan (n=164) to 0.60 for those tagged in the Snake Basin (n=5) compared to 0.19 for adult-tagged Sockeye Salmon in our Bonneville study (Table 14).

Table 13. Estimated minimum fallback rates for Sockeye Salmon at dams in 2020¹⁵. NA indicates Sockeye Salmon were not detected at a dam outside the range of the particular stock. The sample size (n) is the number of tagged Sockeye Salmon detected moving upstream past Bonneville Dam.

| Dam | Tagged as Adults | Tagged as Juveniles by Tagging Location | | | | |
|------------------|-------------------------|---|------------------------|-------------------|-------------------------|---------------|
| | Bonneville AFF (n=1696) | Okanagan Basin (n=164) | Rock Island Dam (n=78) | Snake Basin (n=5) | Wenatchee Basin (n=100) | Total (n=347) |
| Bonneville | 0.4% | 0.6% | 1.3% | 0.0% | 0.0% | 0.6% |
| The Dalles | 3.0% | 1.9% | 1.4% | 0.0% | 1.1% | 1.5% |
| John Day | 6.0% | 4.9% | 8.6% | 20.0% | 6.7% | 6.5% |
| McNary | 0.3% | 1.5% | 1.4% | 0.0% | 0.0% | 1.0% |
| Priest Rapids | 2.3% | 3.7% | 0.0% | NA | 0.0% | 1.8% |
| Rock Island | 1.1% | 0.0% | 0.0% | NA | 0.0% | 0.0% |
| Rocky Reach | 5.5% | 1.7% | 6.8% | NA | 78.6% | 9.1% |
| Wells | 2.3% | 1.7% | 2.3% | NA | 100.0% | 7.6% |
| Tumwater | 1.2% | NA | 7.7% | NA | 7.6% | 7.6% |
| Zosel | 0.3% | 5.9% | 0.0% | NA | NA | 4.0% |
| Skaha | 3.3% | 5.0% | 10.0% | NA | NA | 6.7% |
| Ice Harbor | 33.3% | NA | NA | NA | NA | NA |
| Lower Monumental | 0.0% | 0.0% | 0.0% | 20.0% | NA | 20.0% |
| Little Goose | 0.0% | 0.0% | 0.0% | 20.0% | NA | 20.0% |
| Lower Granite | NA | NA | NA | 0.0% | NA | 0.6% |

Table 14. Number of fallback events by tag group for returning Sockeye Salmon tagged as juveniles and Sockeye Salmon included in our Bonneville adult tagging study in 2020.

| 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 |
| 1 | 279 | 27 | 14 | 3 | 26 |
| 2 | 13 | 0 | 1 | 0 | 7 |
| 3 | 2 | 0 | 0 | 0 | 0 |
| ≥4 | 1 | 0 | 0 | 0 | 0 |
| Number of Sockeye Salmon falling back at least once | 295 | 27 | 15 | 3 | 33 |
| % of Sockeye Salmon with at least one fallback event | 16.5% | 16.5% | 19.2% | 60.0% | 33.3% |
| Total fallback events | 315 | 27 | 16 | 3 | 40 |
| Number of Sockeye Salmon detected at or upstream of Bonneville Dam | 1696 | 164 | 78 | 5 | 100 |
| Fallbacks events per Sockeye Salmon | 0.19 | 0.16 | 0.21 | 0.60 | 0.40 |

¹⁵ Does not include Sockeye Salmon that fell back over a dam and were not subsequently detected.

Stock Composition Estimates

AFF Sample

In 2020, Genetic Stock Identification (GSI) and Parental Based Tagging (PBT) were used to classify samples from all Sockeye Salmon collected at Bonneville Dam. The GSI classification for all Sockeye Salmon on one scale card (June 23, card 3) was changed to “Unknown” due to a suspected data collection error as there were a total of 6 Sockeye Salmon where the PIT and GSI classifications disagreed were from this group of 20 fish. The only other classification disagreements occurred on July 1 (scale card 5, positions 10 and 11) where a Sockeye Salmon last detected on the Wenatchee spawning grounds, but classified by GSI as Okanagan stock, was followed by a Sockeye Salmon last detected on the Okanagan spawning grounds but classified by GSI as Wenatchee stock. This mix up, similar to those occasionally observed in past years, was confirmed by conducting GSI on scale samples also collected from those Sockeye Salmon and the error corrected. There were no other stock classification disagreements between final PIT tag destination and GSI stock classification among those Sockeye Salmon classified by GSI as being of Okanagan or Wenatchee origin (Table 15). There was one Sockeye Salmon classified by PBT (which classified genetically as Wenatchee) last detected in the Okanagan at OKL, and two Sockeye Salmon (which classified genetically as Wenatchee, but PBT classified as Yakima stock) last detected at WTL and LWN on the Wenatchee spawning grounds). Of the four Sockeye Salmon sampled at Bonneville Dam that classified as Snake River stock, one (3DD.003D53AFC0) was not detected after tagging, one (3DD.003D3659DA) was last detected exiting Bonneville Dam and two (3DD.003D53AD9F and 3DD.003D53AE1B) were last detected exiting the Oregon shore ladder at John Day Dam. A total of six Sockeye Salmon were detected at Snake River dams, five of which were classified by PBT as being of Yakima origin with the sixth classified as Wenatchee Stock¹⁶. A more detailed summary of these Yakima-stock Sockeye Salmon will be included in the discussion.

¹⁶ It is quite possible that this sixth “Wenatchee” Sockeye Salmon detected in the Snake River was also of Yakima origin as not all Yakima Sockeye Salmon broodstock are sampled for GSI/PBT.

Table 15. Comparison of stock composition estimates for individual Sockeye Salmon sampled at Bonneville Dam in 2020. Green shading indicates agreement between the two methods, orange indicates the stock estimates differed. 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) | | | | | Total |
|--------------------------------|--|------------|----------|-----------|-----------------------|-------------|
| | Okanagan | Wenatchee | Snake | Yakima | Unknown ¹⁷ | |
| Okanagan | 660 | 0 | 0 | 1 | 15 | 676 |
| Wenatchee | 0 | 168 | 0 | 2 | 3 | 173 |
| Snake | 0 | 0 | 0 | 0 | 0 | 0 |
| Yakima | 5 | 5 | 0 | 4 | 1 | 15 |
| Unknown ¹⁸ | 747 | 99 | 4 | 26 | 19 | 888 |
| Total | 1412 | 272 | 4 | 30 | 38 | 1756 |

Table 16 shows the last detection site, by stock, for Sockeye Salmon in our Bonneville Dam sample. Four Sockeye Salmon were last detected in the Snake River at Ice Harbor Dam, however all four were classified by PBT as being of Yakima stock.

Among Sockeye Salmon detected in the Yakima River, one Sockeye Salmon (3DD.003D53AC88) was last detected in the Columbia River at a PIT tag antenna in the Priest Rapids Dam fish trap followed by Roza Dam. This Sockeye was likely transported from Priest Rapids Dam to Cle Elum Lake as part of a Sockeye Salmon restoration program and then subsequently moved downstream to Roza Dam. A second Sockeye Salmon (3DD.003D365598) also was likely transported to Cle Elum as it was detected at the Priest Rapids trap followed by Sunnyside Diversion located downstream of Roza Dam. Both of these Sockeye Salmon classified genetically as Osoyoos stock but were given a PIT tag classification as “unknown” since it was uncertain where they would have migrated to if they had not been transported from Priest Rapids Dam to Cle Elum Lake. Of the 14 Sockeye Salmon that were detected at Prosser Dam as they presumably migrated up the Yakima River, 10 were last detected at Roza Dam (6 of which were also detected at Sunnyside diversion) located between Prosser and Roza dams with 4 not detected after Prosser Dam. Combining PIT and PBT analyses resulted in a total of 39 Sockeye Salmon were classified as Yakima Stock, 13 of which were detected in the Yakima River (Table 16). Among these 39 Sockeye

¹⁷ Either no genetics sample available, the sample did not classify to a particular stock, or GSI data removed by a suspected data collection error.

¹⁸ 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.

Salmon 15 were classified by GSI as Osoyoos stock with the other 24 as Wenatchee stock.

Table 16. Final stock classification of Sockeye Salmon by last detection area/site for Sockeye Salmon PIT tagged at Bonneville Dam in 2020.

| Area (Site) of Last Detection | Final Stock Classification Using GSI, PBT, and Last PIT Tag Detection as Described in This Report | | | | | |
|---|---|------------|----------|-----------|-----------------------|-------------|
| | Okanagan | Wenatchee | Snake | Yakima | Unknown ¹⁹ | Total |
| Non-Terminal Areas | | | | | | |
| Bonneville (BCC, BO1, BO2, BO3, BO4) | 81 | 32 | 1 | 1 | 4 | 119 |
| Entiat River (ENL) | 1 | 1 | 0 | 0 | 0 | 2 |
| John Day Dam (JO1, JO2, JDJ) | 42 | 11 | 2 | 1 | 0 | 56 |
| McNary Dam (MC1, MC2, MCJ) | 67 | 15 | 0 | 12 | 1 | 95 |
| Methow River (LMR, MRC) | 1 | 2 | 0 | 0 | 1 | 4 |
| Priest Rapids Dam (PRA, PRH, RSH) | 92 | 24 | 0 | 3 | 4 | 123 |
| Rock Island Dam (RIA) | 26 | 7 | 0 | 0 | 1 | 34 |
| Rocky Reach Dam (RRF, RRJ) | 15 | 2 | 0 | 1 | 0 | 18 |
| The Dalles (TD1, TD2) | 44 | 3 | 0 | 1 | 1 | 49 |
| Wells Hatchery | 5 | 0 | 0 | 0 | 0 | 5 |
| Wells Dam (WEA) | 349 | 0 | 0 | 0 | 5 | 354 |
| Terminal Areas | | | | | | |
| Wenatchee River (ICL, LWE, LWN, TUF, UWE, WTL) | 0 | 168 | 0 | 2 | 3 | 173 |
| Okanagan River (OKC, OKL, OKM, OKP, OKS, OMK, SKA, ZSL) | 668 | 0 | 0 | 1 | 7 | 676 |
| Snake River (ICH) | 0 | 0 | 0 | 4 | 0 | 4 |
| Yakima River (PRO, ROZ, SUN) | 3 | 0 | 0 | 13 | 1 | 17 |
| | | | | | | |
| No Tag or Tag Not Subsequently Detected | 22 | 2 | 1 | 0 | 0 | 25 |
| Total | 1416 | 267 | 4 | 39 | 28 | 1754 |

No Sockeye Salmon were classified as Deschutes stock in 2020, nor were any Sockeye Salmon last detected in the Deschutes River. (The site at the mouth of the Deschutes River, DRM, where most Deschutes Sockeye Salmon detections have been in the past, was not operational in 2020.)

Of the two Sockeye Salmon last detected in the Entiat River, 1 was Okanagan stock while the other was Wenatchee stock (Table 16). Of the three Sockeye Salmon last detected in the Methow at LMR or MRC, two classified as Wenatchee stock and one as Okanagan stock. Five Sockeye Salmon, all

¹⁹ Either no genetics sample available or the sample did not classify to a particular stock.

classified as Okanagan stock were last detected at Wells Hatchery and one last detected at Priest Rapids Hatchery was classified as Yakima Stock. No other stock Sockeye Salmon were detected outside the migration corridor (Columbia River) on their way to the Okanagan Basin, although there was one detection at the mouth of Omak Creek (OMK, located at Omak Creek rkm 0 in the Okanagan Basin.)

Among the 179 Sockeye Salmon of Wenatchee origin that passed Rock Island Dam, 22 (12.3%) bypassed the Wenatchee River and were detected at Rocky Reach Dam with 9 (3.5%) also detected at Wells Dam. All of these Wenatchee-stock Sockeye Salmon were subsequently detected at Tumwater Dam and all but 2 were last detected on the White or Little Wenatchee River PIT arrays located immediately downstream of spawning areas. No Wenatchee Sockeye Salmon (as classified by GSI/PBT) were last detected in the Columbia Basin upstream of the Wenatchee River confluence. (However, one Sockeye Salmon with PIT tag 3DD.003D53B01D classified by GSI as Wenatchee origin, but by PBT as being of Yakima origin, was last detected in the Okanagan River at OKL.)

When combining PIT and GSI stock determinations as described in the methods, this study estimated that the stock composition at Bonneville Dam in 2020 was 80.7% Okanagan, 17.1% Wenatchee, and 2.2% Yakima, with less than 0.1% of Snake River (Table 17 and Figure 12). Using only PIT tag detections of Sockeye Salmon last detected in terminal areas resulted in a stock composition of 76.3% Okanagan, 22.2% Wenatchee, 1.6% Yakima, 0.0% Snake. Using visual fish counts at dams to estimate Okanagan stock abundance relative to the Wenatchee yielded a higher percentages (87.6% and 82.6%), respectively, Table 17) than did PIT and GSI estimates.

There was a significant linear relationship between statistical week and the percentage of Okanagan Sockeye Salmon ($p=0.03$) at Bonneville Dam (estimated using PIT and GSI as well as for the Wenatchee stock at $\alpha=0.10$ ($p=0.10$) (Table 17 and Figure 12).

Table 17. Weekly and composite Sockeye Salmon stock composition at Bonneville Dam as estimated by PIT tags and GSI in 2020 with a comparison to stock composition estimates estimated using visual dam counts as well as using only PIT tags and GSI.

| Statistical Week at Bonneville Dam | N | % of Sockeye Salmon Run | % Okanagan | % Wenatchee | % Snake | % Yakima |
|---|-------------|--------------------------------|-------------------|--------------------|-----------------|-----------------|
| 22-23 | 19 | 0.9 | 100.0% | 0.0% | 0.0% | 0.0% |
| 24 | 109 | 6.6 | 96.3% | 3.7% | 0.0% | 0.0% |
| 25 | 290 | 23.7 | 87.2% | 9.0% | 0.0% | 3.8% |
| 26 | 331 | 35.1 | 75.9% | 21.9% | 0.0% | 2.3% |
| 27 | 390 | 20.6 | 78.7% | 18.7% | 0.0% | 2.6% |
| 28 | 121 | 8.2 | 84.3% | 14.0% | 0.0% | 1.7% |
| 29 | 264 | 3.1 | 77.7% | 18.6% | 0.4% | 3.4% |
| 30 | 142 | 1.2 | 85.9% | 12.7% | 0.7% | 0.7% |
| 31 | 49 | 0.6 | 85.7% | 10.2% | 2.0% | 2.0% |
| 32-33 | 11 | | 72.7% | 18.2% | 9.1% | 0.0% |
| Combined PIT and GSI Estimate | 1726 | | 80.7% | 17.1% | <0.1% | 2.2% |
| PIT Tag Only Estimate | 865 | | 76.3% | 22.2% | 0.0% | 1.6% |
| GSI Only Estimate | 1718 | | 81.0% | 17.3% | <0.1% | 1.7% |
| Visual Fish Counts at dams ²⁰ | | | 87.6% | 12.4% | NA | NA |
| Visual Fish Counts at dams ²¹ | | | 82.6% | 17.4% | NA | NA |

²⁰ Using difference between Rock Island and Rocky Reach counts to estimate proportion Wenatchee escapement; Rocky Reach to estimate Okanagan escapement.

²¹ Using Tumwater count to estimate proportion Wenatchee escapement; Rocky Reach to estimate Okanagan.

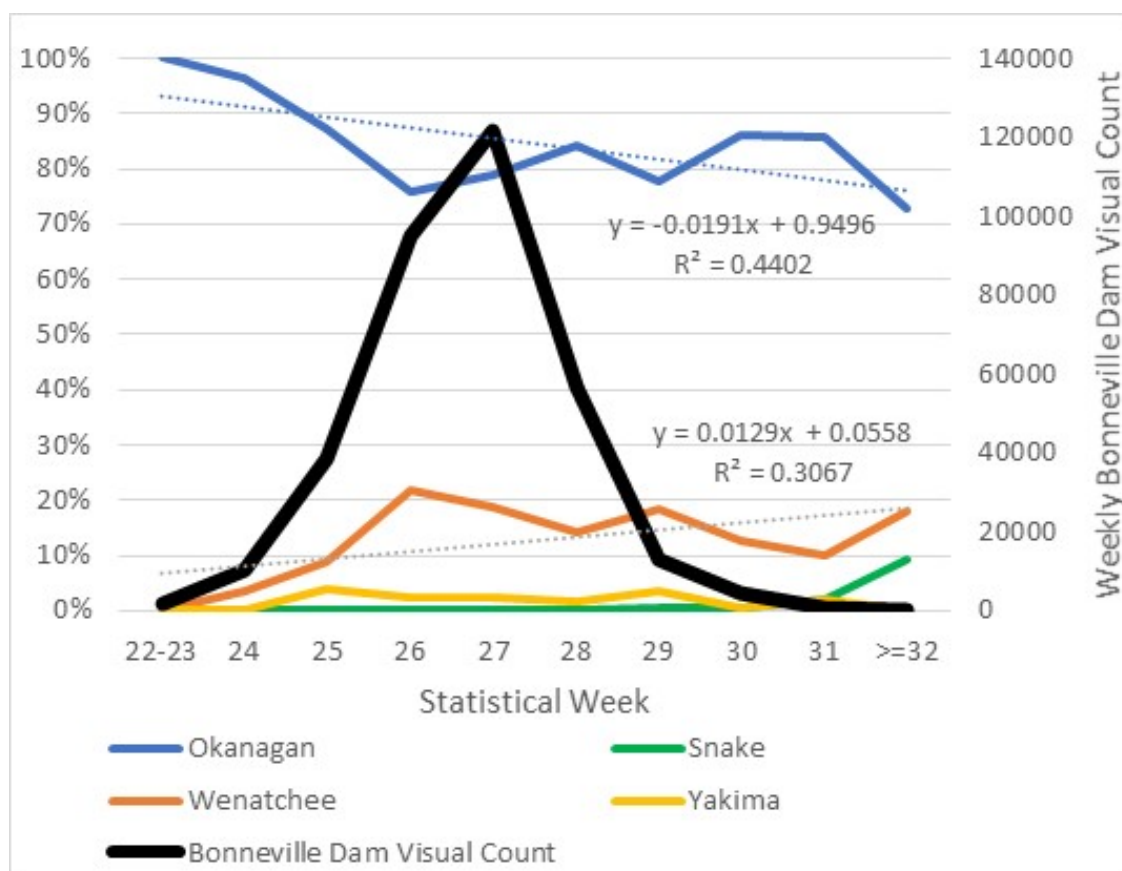


Figure 12. Percentage of the Sockeye Salmon run at Bonneville Dam estimated to be of Okanagan, Wenatchee, Snake, Yakima, and Snake origin using genetics and PIT tag data by week in 2020.

There were five adipose fin clipped Sockeye Salmon sampled at Bonneville Dam in 2020, 3 of which were identified using GSI as Snake River Sockeye Salmon observed in each of weeks 30-32. Another adipose fin clipped Sockeye Salmon was sampled in Week 30 for which no genetics sample was collected (and which was last detected at BO3), and the fifth was a Sockeye Salmon sampled in Week 25 which was classified using GSI as being of Okanagan Stock and was last detected at Priest Rapids Dam²².

²² There is no known adipose clipping program for Okanagan Sockeye Salmon.

Stock Specific Upstream Survival

Upstream survival of Okanagan Sockeye Salmon to Rock Island Dam was higher than the Wenatchee stock (80.5% vs. 71.6%), however survival to the spawning area was lower (41.7% vs. 44.1%, Table 18).

Table 18. Stock specific survival from Bonneville Dam weighted by estimated stock-specific weekly Bonneville Dam run size, as estimated by GSI and PIT tags for Sockeye Salmon tagged at Bonneville Dam in 2020.

| Statistical Week | Estimated Survival from Bonneville Dam by Stock (%) | | | | | | |
|------------------|---|--------------|-------------------------|-------------------|--------------|---------------------------------|--|
| | Okanagan (n=1364) | | | Wenatchee (n=260) | | | Combined (n=1624) |
| | Rock Island Dam | Zosel Dam | Okanagan Spawning (OKC) | Rock Island Dam | Tumwater Dam | Wenatchee Spawning (LWE or WTL) | Okanagan/ Wenatchee Spawning (LWE, WTL, OKC) |
| 22-23 | 94.7% | 73.7% | 73.7% | NA | NA | NA | 73.7% |
| 24 | 71.6% | 51.6% | 51.6% | 66.7% | 66.7% | 33.3% | 51.0% |
| 25 | 75.4% | 43.7% | 43.3% | 69.2% | 65.4% | 46.2% | 43.4% |
| 26 | 79.8% | 42.9% | 40.9% | 67.6% | 62.0% | 42.3% | 41.0% |
| 27 | 82.2% | 44.9% | 40.3% | 75.4% | 73.9% | 47.8% | 41.7% |
| 28 | 86.3% | 49.0% | 43.1% | 76.5% | 64.7% | 41.2% | 42.9% |
| 29 | 76.0% | 41.5% | 34.5% | 73.5% | 59.2% | 44.9% | 36.5% |
| 30 | 62.2% | 34.7% | 25.5% | 33.3% | 33.3% | 27.8% | 25.9% |
| 31 | 50.0% | 37.5% | 30.0% | 20.0% | 20.0% | 20.0% | 28.9% |
| 32-33 | 50.0% | 25.0% | 25.0% | 0.0% | 0.0% | 0.0% | 25.0% |
| Total | 80.5% | 44.8% | 41.2% | 71.6% | 66.6% | 44.1% | 41.7% |

Wells Dam Sampling

A total of 545 Sockeye Salmon were sampled at the Wells Dam east bank fish ladder in 2020 (Table 19), 2 of which were previously PIT tagged by this project at Bonneville Dam. The number of PIT tagged Sockeye Salmon detected and tracked was 531.

Table 19. Number of Sockeye Salmon sampled, and PIT tagged at Wells Dam by date and statistical week in 2020.

| Sampling Dates | Statistical Week | Sampled (n) | PIT Tagged | Previously Tagged | PIT Tagged Sockeye Salmon Released | Tracked |
|----------------|------------------|-------------|------------|-------------------|------------------------------------|------------|
| 6/24 | 26 | 1 | 1 | 0 | 1 | 1 |
| 6/29,30 | 27 | 11 | 11 | 0 | 11 | 11 |
| 7/6,7/7 | 28 | 44 | 44 | 0 | 44 | 43 |
| 7/13,7/14 | 29 | 169 | 168 | 1 | 169 | 166 |
| 7/20,21 | 30 | 176 | 176 | 0 | 176 | 171 |
| 7/27,28 | 31 | 99 | 98 | 1 | 99 | 95 |
| 8/3 | 32 | 30 | 29 | 0 | 29 | 29 |
| 8/10 | 33 | 11 | 11 | 0 | 11 | 11 |
| 8/17 | 34 | 4 | 4 | 0 | 4 | 4 |
| Total | | 545 | 542 | 2 | 544 | 531 |

Sex was visually estimated as part of the Wells Dam sampling protocol. Based on these visual estimations, 97.8% of females were age 1.2 compared to 85.7% of the males (Table 20). Age 1.3 comprised 11.6% of the males and 1.8% of the females.

Table 20. Age composition by week and sex for Sockeye Salmon sampled at Wells Dam in 2020. Sex was visually estimated when the fish were sampled.

| Stat Week | Sampling Dates | Percentage of Run | N | N Ageable | Percentage at Age | | | | |
|---------------------|----------------|-------------------|------------|------------|-------------------|--------------|-------------|-------------|-------------|
| | | | | | 1.1 | 1.2 | 2.1 | 1.3 | 2.2 |
| 26-27 | 6/24,29,30 | 5.1% | 11 | 11 | 0.0% | 90.9% | 0.0% | 9.1% | 0.0% |
| 28 | 7/6,7/7 | 22.5% | 44 | 43 | 2.3% | 95.3% | 0.0% | 0.0% | 2.3% |
| 29 | 7/13,7/14 | 44.2% | 169 | 166 | 0.6% | 86.7% | 0.0% | 12.7% | 0.0% |
| 30 | 7/20,21 | 19.8% | 176 | 166 | 0.6% | 95.2% | 0.0% | 3.6% | 0.6% |
| 31 | 7/27,28 | 5.3% | 99 | 96 | 1.0% | 95.8% | 1.0% | 2.1% | 0.0% |
| 32 | 8/7 | 2.0% | 30 | 30 | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| 33-34 | 8/10,17 | 1.1% | 15 | 11 | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| Composite | | | 545 | 527 | 1.0% | 91.4% | 0.1% | 6.9% | 0.6% |
| Males (visual ID) | | | 259 | 253 | 1.7% | 85.7% | 0.0% | 11.6% | 0.9% |
| Females (visual ID) | | | 286 | 274 | 0.1% | 97.8% | 0.1% | 1.8% | 0.2% |

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

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 21. The GSI estimates found that Wenatchee stock were comprised primarily of Age 1.2 Sockeye Salmon which is similar to that for Sockeye Salmon sampled at Tumwater Dam by Washington Department of Fish and Wildlife (WDFW).

The age distribution of Sockeye Salmon sampled at Wells Dam differed from that estimated for the Okanagan Stock at Bonneville Dam using GSI (Table 21). While the Bonneville Dam estimate for Okanagan age composition was 97.8% 1.2 and 0.1% 1.3, the Wells Dam sample was 91.4% Age 1.2 and 6.9% Age 1.3. This is likely attributed to the 5.1 cm spacing of the bars on the weir diverting fish into the Wells Dam fish trap being sufficiently wide for smaller fish to slip the weir and thus avoid being diverted into the trap while the larger (Age 1.3) Sockeye Salmon are diverted.

Table 21. Age composition (%) of Columbia Basin Sockeye Salmon stocks as estimated by PIT tag detections as well as by sampling at Wells and Tumwater dams²³ in 2020.

| Sampling Site | Stock | Ageable Sample Size | Brood Year and Age Class | | | | |
|----------------|--|---------------------|--------------------------|-------|------|------|------|
| | | | 2017 | 2016 | | 2015 | |
| | | | 1.1 | 1.2 | 2.1 | 1.3 | 2.2 |
| Bonneville Dam | Mixed | 1724 | 0.9% | 98.6% | 0.1% | 0.2% | 0.2% |
| Bonneville Dam | Wenatchee: Stock determined as described on page 11 of this report | 265 | 0.0% | 99.8% | 0.0% | 0.2% | 0.0% |
| Tumwater Dam | Wenatchee | 1035 | 0.2% | 97.8% | 0.0% | 1.1% | 0.9% |
| Bonneville Dam | Okanagan Stock determined as described on page 11 of this report | 1346 | 1.1% | 98.4% | 0.2% | 0.1% | 0.2% |
| Wells Dam | Okanagan | 545 | 1.0% | 91.4% | 0.1% | 6.9% | 0.6% |

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 (Table 22). The aforementioned trap bias at Wells Dam may explain this difference at Wells Dam. 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.

²³ Tumwater Dam age data were provided by WDFW which samples Sockeye Salmon at that site (Alainah Hendrickx email dated October 28, 2020).

Table 22. 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 2020.

| Stock | Statistic | Brood Year and Age Class | | | | | All Ages ²⁴ |
|--|-------------|--------------------------|------|------|------|------|------------------------|
| | | 2017 | 2016 | | 2015 | | |
| | | 1.1 | 1.2 | 2.1 | 1.3 | 2.2 | |
| Bonneville Dam-Mixed Stock | Mean Length | 38.1 | 46.6 | 40.8 | 52.1 | 47.8 | 46.5 |
| | St. Dev. | 2.7 | 2.2 | 1.8 | 3.1 | 0.4 | 2.5 |
| | N | 28 | 1685 | 2 | 7 | 2 | 1757 |
| Okanagan-based on GSI of Sockeye Salmon tagged at Bonneville Dam | Mean Length | 38.2 | 46.4 | 40.8 | 51.5 | 47.8 | 46.2 |
| | St. Dev. | 2.6 | 2.3 | 1.8 | 3.1 | 0.4 | 2.6 |
| | N | 27 | 1363 | 2 | 5 | 2 | 143 |
| Okanagan-Wells Sampling | Mean Length | 40.0 | 49.3 | 41.0 | 54.0 | 50.0 | 49.5 |
| | St. Dev. | 2.2 | 2.7 | NA | 2.7 | 7.1 | 3.0 |
| | N | 4 | 490 | 1 | 30 | 2 | 545 |
| Wenatchee based on GSI of Bonneville Dam-tagged Sockeye Salmon | Mean Length | NA | 47.5 | NA | 51.0 | 46.7 | 47.5 |
| | St. Dev. | NA | 1.8 | NA | -- | 3.1 | 1.8 |
| | N | 0 | 267 | 0 | 1 | 3 | 267 |
| Wenatchee adult sampling at Tumwater Dam ²⁵ | Mean Length | 48.3 | 49.4 | 49.6 | 52.1 | 49.4 | 48.3 |
| | St. Dev. | 1.2 | 2.0 | 4.1 | 2.8 | 2.0 | 1.2 |
| | N | 3 | 1012 | 9 | 11 | 49 | 3 |

²⁴ Includes lengths of Sockeye Salmon with unageable scales.

²⁵ Tumwater Dam length-at-age data was provided by WDFW which samples Sockeye Salmon at that site (Alainah Hedrickx email dated October 28, 2020).

Stock Composition at Wells Dam

In 2020, GSI was conducted on all Sockeye Salmon sampled at Wells Dam. Among the Sockeye Salmon PIT tagged at Wells Dam that moved downstream, all 21 detected in the Wenatchee Basin were classified as Wenatchee stock while among the 9 Sockeye Salmon last detected at Rocky Reach Dam or East Bank Hatchery 1 km upstream, 8 were classified as Okanagan stock and 1 was classified as Wenatchee stock. Among the 5 Wells-tagged Sockeye Salmon last detected in the Entiat Basin, 1 was Okanagan Stock and 4 were Wenatchee Stock. (Table 23). Of the 7 Sockeye Salmon last detected upstream of Wells Dam in the Methow River, 6 were classified by GSI as Wenatchee stock, 2 of which were classified by PBT as having Yakima parents while no genetics sample was collected for the 7th. . Among the 6 Sockeye Salmon classified by PBT as Yakima stock (1 of which classified by GSI as Okanagan stock and 5 as Wenatchee stock), none were last detected downstream of Wells Dam.

Table 23. Stock Classification for Sockeye Salmon sampled at Wells Dam using GSI in 2020.

| Last Detection | Classification ²⁶ | | | | | Total |
|--|------------------------------|-----------|-----------------|------------------|-------------------|------------|
| | Okanagan | Wenatchee | Yakima-Okanagan | Yakima-Wenatchee | N/A ²⁷ | |
| Wenatchee Basin (LWE, LWN, NAL, UWE, WTL) | 1 | 21 | 0 | 0 | 0 | 22 |
| Rocky Reach Dam (RRF, RRJ, EBO) | 8 | 1 | 0 | 0 | 0 | 9 |
| Entiat Basin (ENL, ENA) | 1 | 4 | 0 | 0 | 0 | 5 |
| Wells Dam (WEA) | 203 | 9 | 0 | 2 | 1 | 215 |
| Wells Hatchery (WEH) | 5 | 0 | 0 | 0 | 0 | 5 |
| Methow Basin (LMR, MRC, TWR) | 0 | 4 | 0 | 2 | 1 | 7 |
| Okanagan Basin (OKC, OKL, OKM, OKP, OKS, SKA, ZSL) | 262 | 0 | 1 | 1 | 4 | 268 |
| Not Detected | 10 | 3 | 0 | 0 | 1 | 14 |
| Total | 490 | 42 | 1 | 5 | 7 | 545 |

The overall stock composition estimated from Sockeye Salmon sampled and tagged at Wells Dam was 94.4% Okanagan, 5.1% Wenatchee, and 0.4% Yakima compared to 98.5% Okanagan, 1.5% Wenatchee, and 0% Yakima for

²⁶ Sockeye Salmon were classified using GSI. However, since Yakima Sockeye Salmon are all descended from Okanagan or Wenatchee stock Sockeye Salmon, 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.

²⁷ Either no genetic samples or the genetic sample could not be analyzed.

Sockeye Salmon tagged at Bonneville Dam that were detected at Wells Dam (Table 24). 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 22) 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 diverting Sockeye Salmon into the trap.

Table 24. Stock composition of Sockeye Salmon tagged at Wells Dam and Sockeye Salmon passing Wells Dam as estimated using GSI and PIT tags in 2020. (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 | Yakima | N | Okanagan | Wenatchee | Yakima |
| 25-26 | 9 | 100.0% | 0.0% | 0.0% | 0 | NA | NA | NA |
| 27 | 80 | 100.0% | 0.0% | 0.0% | 8 | 100.0% | 0.0% | 0.0% |
| 28 | 231 | 99.1% | 0.9% | 0.0% | 43 | 97.7% | 2.3% | 0.0% |
| 29 | 352 | 97.8% | 2.2% | 0.0% | 169 | 96.4% | 3.6% | 0.0% |
| 30 | 100 | 99.0% | 1.0% | 0.0% | 175 | 89.1% | 10.9% | 0.6% |
| 31 | 143 | 97.9% | 2.1% | 0.0% | 99 | 84.8% | 15.2% | 2.0% |
| 32 | 66 | 100.0% | 0.0% | 0.0% | 30 | 83.3% | 16.7% | 6.7% |
| 33 | 35 | 100.0% | 0.0% | 0.0% | 11 | 90.9% | 9.1% | 9.1% |
| 34-38 | 7 | 100.0% | 0.0% | 0.0% | 4 | 100.0% | 0.0% | 0.0% |
| Total | 1023 | 98.5% | 1.5% | 0.0% | 539 | 94.4% | 5.1% | 0.4% |

Migration into Natal Areas - Okanagan River

The percentage of Sockeye Salmon passing or tagged at Wells Dam that were detected on the Okanagan spawning grounds was 52.6% for Bonneville-tagged Sockeye Salmon and 53.1% for Wells-tagged Sockeye Salmon with this percentage decreasing as the run progressed (Table 25). Sockeye Salmon tagged at Wells Dam in weeks 26-27 had the highest conversion rate to spawning areas above OKC at 83.3%, declining to a low of 13.3% for Sockeye Salmon tagged in weeks 33-38 (Figure 13, Table 25) A similar trend was observed for Bonneville-tagged Sockeye Salmon with the rate dropping from 79.8% in weeks 26-27 to 37.2% in weeks 33 and 38 (Figure 13, Table 25).

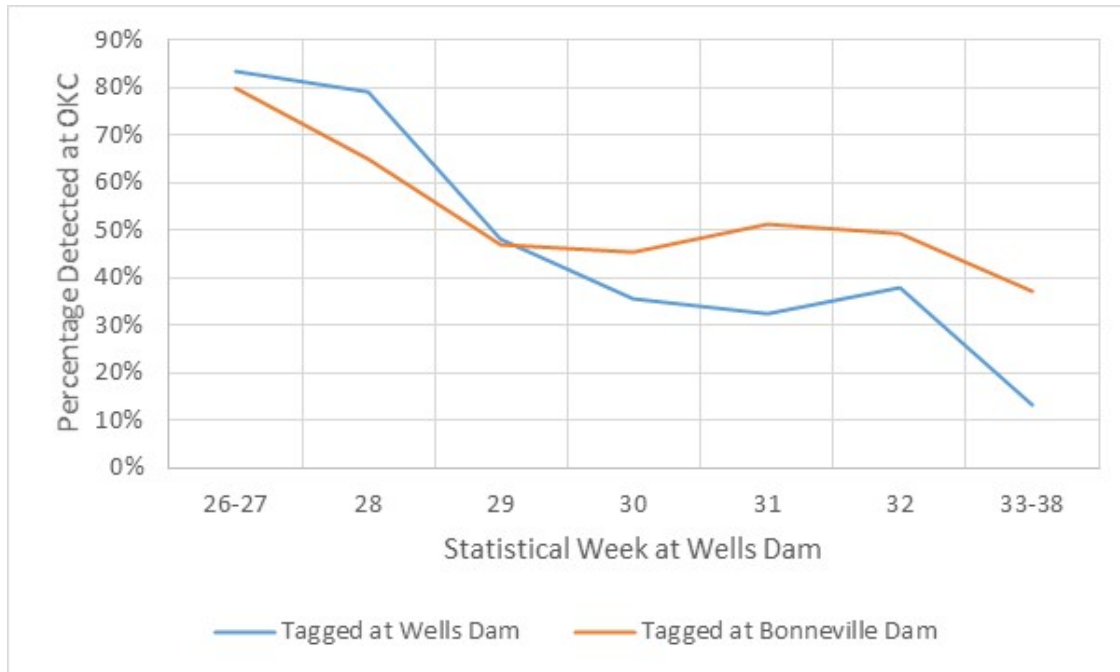


Figure 13. Percentage of Sockeye Salmon tagged at Bonneville and Wells dams last detected on Okanagan River spawning grounds (at or upstream of OKC) by week passing Wells Dam in 2020.

Table 25. Number of Sockeye Salmon tagged at Wells Dam and subsequent last detection site by week in 2020 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 | BON Tagged ²⁸ |
|--|---|------|---|-----------------|--------------|----------------|----------------------|--------------|-----------|-----------------|-----------|-------------------------|-----------------|---------|-------------------------------------|---------------------------------------|
| Week Tagged or Passing at Wells Dam | % of Total Wells Count by Week (Weight) | N | Wenatchee Basin | Rocky Reach Dam | Entiat River | Wells Hatchery | Wells Dam (WEA, WEJ) | Methow River | OKL Array | Zosel Dam (ZSL) | OKC Array | McIntyre Dam (OKM, OKV) | Skaha Dam (SKA) | OKP/OKS | Last Detected OKC, SKA, OKP, or OKS | Last Detected (OKC, SKA, OKP, or OKS) |
| 26-27 | 5.1% | 12 | 0.0% | 0.0% | 0.0% | 0.0% | 16.7% | 0.0% | 0.0% | 0.0% | 41.7% | 8.3% | 0.0% | 33.3% | 83.3% | 79.8% |
| 28 | 22.5% | 43 | 0.0% | 0.0% | 0.0% | 2.3% | 16.3% | 2.3% | 0.0% | 0.0% | 44.2% | 2.3% | 11.6% | 20.9% | 79.1% | 65.1% |
| 29 | 44.2% | 166 | 1.8% | 0.0% | 0.0% | 1.8% | 42.8% | 0.0% | 2.4% | 3.0% | 30.7% | 0.0% | 3.6% | 13.9% | 48.2% | 46.8% |
| 30 | 19.8% | 171 | 6.4% | 2.3% | 1.8% | 0.0% | 43.9% | 0.6% | 2.9% | 6.4% | 24.6% | 0.0% | 1.2% | 9.9% | 35.7% | 45.5% |
| 31 | 5.3% | 95 | 6.3% | 2.1% | 2.1% | 0.0% | 48.4% | 1.1% | 2.1% | 5.3% | 26.3% | 0.0% | 0.0% | 6.3% | 32.6% | 51.4% |
| 32 | 2.0% | 29 | 3.4% | 0.0% | 0.0% | 3.4% | 27.6% | 10.3% | 17.2% | 0.0% | 34.5% | 0.0% | 0.0% | 3.4% | 37.9% | 49.3% |
| 33-38 | 1.1% | 15 | 6.7% | 20.0% | 0.0% | 0.0% | 40.0% | 6.7% | 0.0% | 13.3% | 6.7% | 0.0% | 0.0% | 6.7% | 13.3% | 37.2% |
| Weighted Total | | 531 | 2.5% | 0.8% | 0.5% | 1.4% | 35.6% | 1.0% | 2.1% | 3.0% | 32.7% | 1.0% | 4.4% | 15.0% | 53.1% | |
| Bonneville Tagged Sockeye Salmon Detected at Wells | | 1046 | 0.7% | 0.1% | 0.1% | 0.5% | 35.5% | 0.4% | 5.7% | 4.5% | 34.9% | 2.4% | 0.4% | 14.9% | | 52.6% |

²⁸ One Bonneville-tagged Sockeye Salmon was detected at Wells Dam in Week 34 and two in Week 35, none were detected at, or upstream of OKC.

In 2020 Sockeye Salmon entered the Okanagan River either prior to river temperatures exceeding 22C (as recorded at the Okanagan River Malott USGS gauge) or on subsequent drops in temperature (Figures 14 and 15, Table 26). The first group of Sockeye Salmon detected at OKL (Figure 16) passed between 7/1 and 7/18, a period during which the mean daily river temperature increased from 19.5C to 23.2C with a 55.8% of those detected at OKL being detected at or above OKC. (Poor detection at ZSL caused by Sockeye Salmon passing through the unmonitored spillways made it impossible to get meaningful survival rates from OKL to ZSL). Migration ceased as the temperature climbed to 26.0C but resumed between 8/7 and 8/16, a period when the mean daily river temperature ranged from 23.1 to 24.1C. The largest number of Sockeye Salmon detected at OKL occurred between 8/22 and 9/3 as temperatures dropped from 22.4 to 21.8C. Temperatures subsequently increased to 22.4C and migration ceased until 9/10 when the temperature dropped to 19.3C and the last five Sockeye Salmon were detected at OKL, only two of which were detected at OKC. Overall weighted survival from OKL to OKC was 66.8% (Table 26).

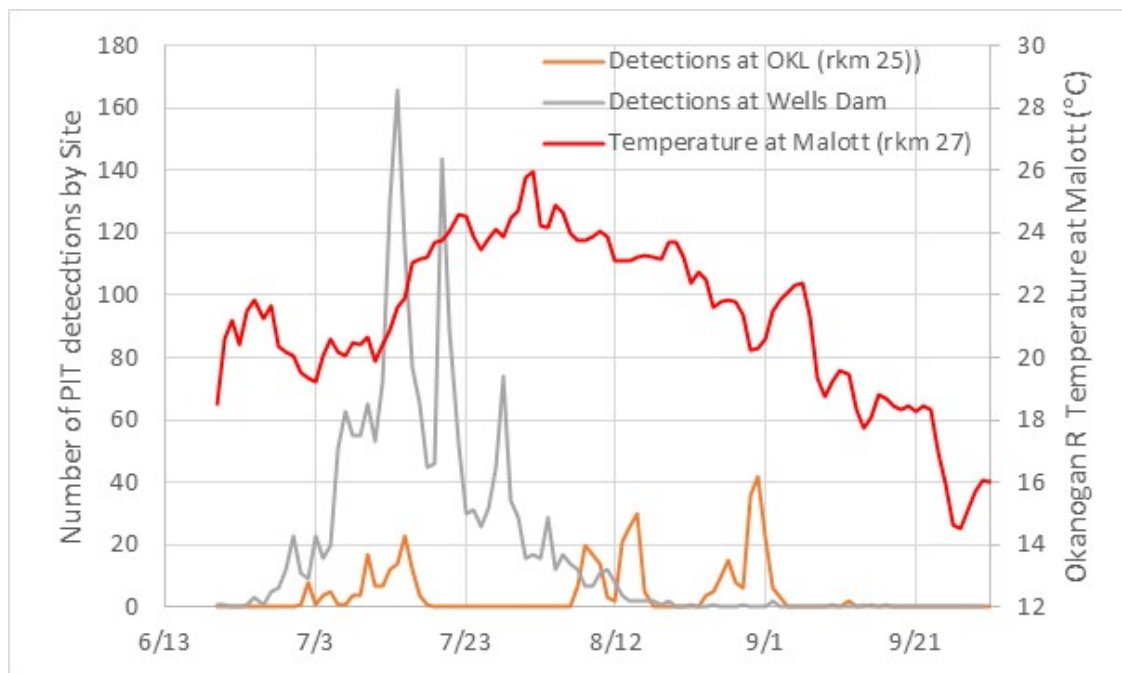


Figure 14. Number of PIT tagged adult Sockeye Salmon detected at Wells Dam and the OKL PIT array at Okanagan rkm 25, and mean Okanagan River water temperature at Malott (rkm 27) by date in 2020.

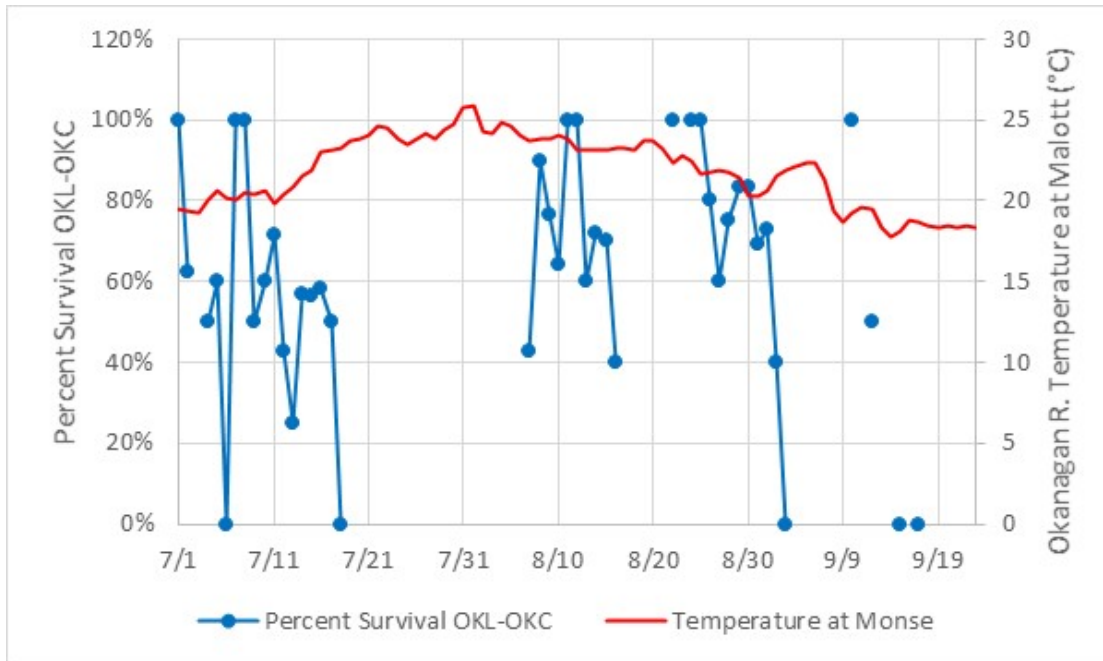


Figure 15. Minimum survival rate by date from the lower Okanagan River PIT tag array (OKL) to OKC for Sockeye Salmon detected at Wells Dam in 2020.

Table 26. Groups of PIT tagged Sockeye Salmon passing OKL by date and percentage detected upstream in 2020.

| Dates | N at OKL | % Detected at OKC |
|--------------|------------|-------------------|
| 7/1-7/18 | 123 | 55.8% |
| 8/7-8/16 | 143 | 70.6% |
| 8/22-9/3 | 156 | 73.1% |
| 9/10-9/17 | 5 | 40.0% |
| Total | 461 | 66.8% |

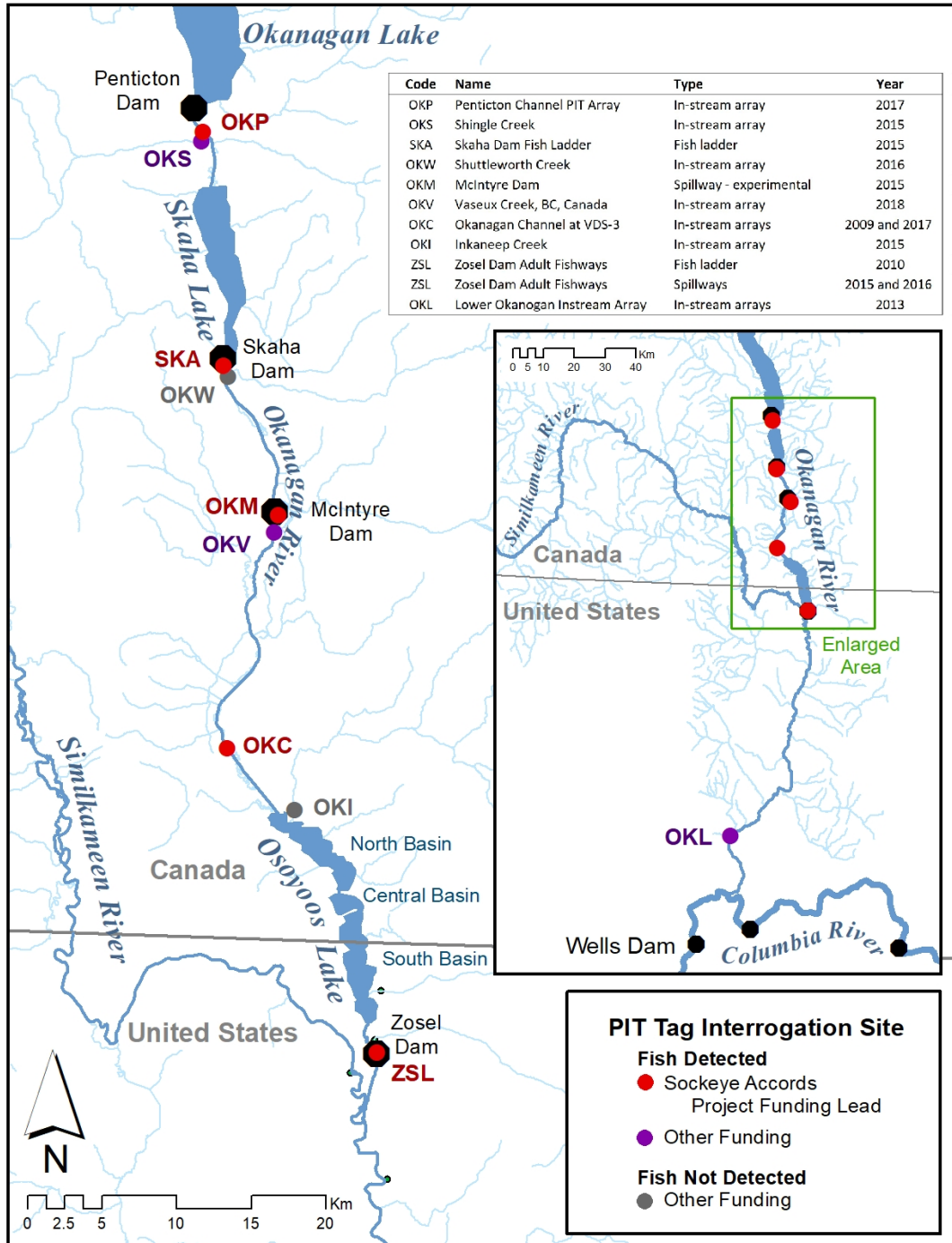


Figure 16. Map of the Okanagan River showing locations of PIT tag antennas funded by this project since its inception. Zosel, Skaha, and McIntyre dams, and in-river array immediately downstream of spawning areas at OKC and an in-river array immediately downstream of Penticton Channel spawning areas at OKP.

Migration into Natal Areas-Wenatchee River

Of the 97 adult Bonneville-tagged Sockeye Salmon detected at LWE (Figure 17) in 2020, 92 were detected at Tumwater Dam (Table 27) resulting in an estimated survival of 94.8% compared to 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). A single Sockeye Salmon (3DD.003D53AFE4) was detected at the PIT tag array at Icicle Creek (ICL at rkm 0.4), downstream of Tumwater Dam on September 27, 2020. This Sockeye Salmon missed detection at LWE but did pass over Tumwater Dam on July 31, 2020, before dropping downstream and last being detected at ICL.

Table 27. 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 2020.

| Statistical Week Detected at LWE | Number Detected at LWE | Mean Temperature at Monitor (rkm 11.1) | % Survival from Detection at LWE to Tumwater Dam | Median Travel Time LWE to Tumwater Dam (days) | Mean Daily flow at Monitor (CMS) |
|----------------------------------|------------------------|--|--|---|----------------------------------|
| 27 | 3 | 13.0 | 100.0% | 14.5 | 154.8 |
| 28 | 20 | 14.6 | 95.0% | 10.0 | 101.6 |
| 29 | 36 | 16.4 | 94.4% | 7.6 | 85.7 |
| 30 | 11 | 18.4 | 100.0% | 6.7 | 74.7 |
| 31 | 16 | 20.3 | 87.5% | 6.6 | 48.7 |
| 32 | 9 | 19.7 | 100.0% | 7.2 | 37.3 |
| 33 | 2 | 19.0 | 100.0% | 7.3 | 24.0 |
| Unweighted | 97²⁹ | 17.3 | 94.8% | 8.6 | 75.3 |

Of the Bonneville-tagged Sockeye Salmon detected at Tumwater Dam, 71.1% were detected by spawning ground arrays at LWN and WTL (Table 28, Figure 17). Of these fish, 86.4% were last detected in the White River and 13.6% were last detected in the Little Wenatchee River. Returning Sockeye Salmon tagged as juveniles had a higher rate of detection at LWN, and conversely a lower rate at WTL, when compared to Sockeye Salmon tagged as adults at either Tumwater or Bonneville dams although sample sizes were lower.

²⁹ An additional 76 Sockeye Salmon were not detected at LWE but detected upstream in 2020.

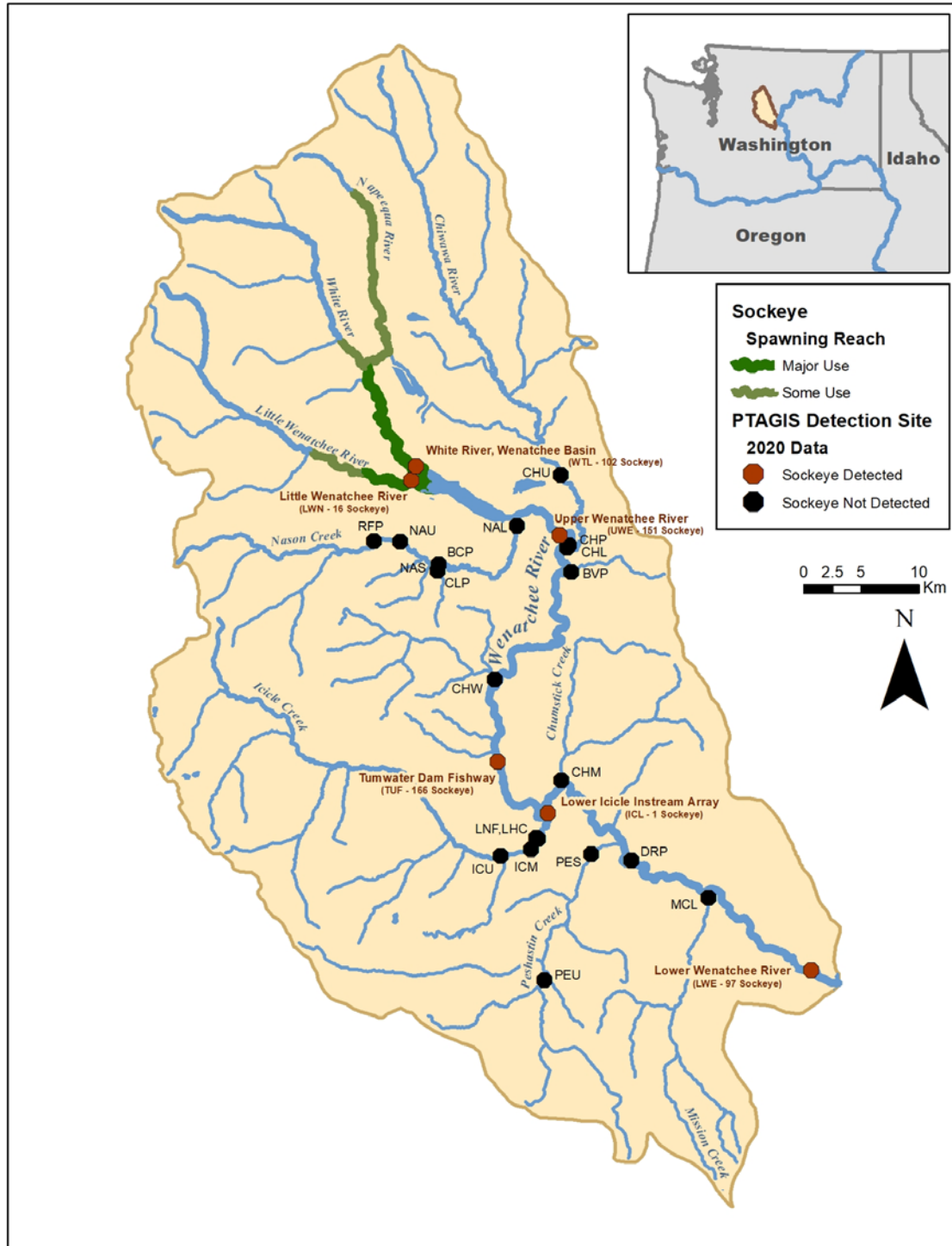


Figure 15. The Wenatchee Basin showing PIT tag interrogation sites and highlights the sites where Sockeye Salmon were detected in 2020. Also displayed is the spawning area of Sockeye Salmon. Appendix B, Table B1 has site information.

Table 28. Spawning ground distribution of adult PIT tagged Sockeye Salmon detected or tagged at Tumwater Dam in 2020.

| 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 | 166 | 71.1 | 13.6 | 86.4 |
| Tumwater Dam Adult Ladder | Adult | 1077 | 61.8 | 20.9 | 79.1 |
| Rock Island Juvenile Bypass | Juvenile | 13 | 69.2 | 44.4 | 55.6 |
| Wenatchee River | Juvenile | 66 | 68.2 | 24.4 | 75.9 |

2020 Okanagan Basin Juvenile PIT Tagging

There was no juvenile PIT tagging in the Okanagan Basin in 2020 due to staffing restrictions resulting from the COVID-19 pandemic.

Lake Wenatchee Acoustic Trawl and Limnology Surveys

An acoustic trawl survey was conducted in Lake Wenatchee in March 2020 prior to smolt emigration with an estimated 459,000 Sockeye Salmon smolts or a density of 457 per hectare. In comparison, surveys in Okanagan Basin for Osoyoos Lake estimated 1,981,000 smolts or 2,123 per hectare, and for Skaha Lake were 970,000 smolts or 498 per hectare. A detailed past report of 2012-2019 results can be found in Appendix E of the 2019 report for this project (Fryer 2021). The 2020 estimate of 457 smolts per hectare is only 21% of the 2012-2019 mean reported mean of 2,121 per hectare.

DISCUSSION

This report covers 2020 which was the 12th year of this Accords study and the 15th year of PIT tagging Sockeye Salmon at Bonneville Dam.

After the abnormally high temperature year of 2015 which resulted in high mortality of Sockeye Salmon on their upstream migration through the Columbia River and tributaries (Fryer et al. 2017), temperatures and survival through the Columbia River have returned to more typical levels. The mean survival to McNary Dam estimated by this study over the past four years (2017-2020) of 86.0% has been the highest since the first four years of PIT tagging (2006-2009) when the mean survival was 86.9% (Table 4). River temperatures were generally below the ten-year (2010-2019) mean temperature at Bonneville Dam (Figure 18).

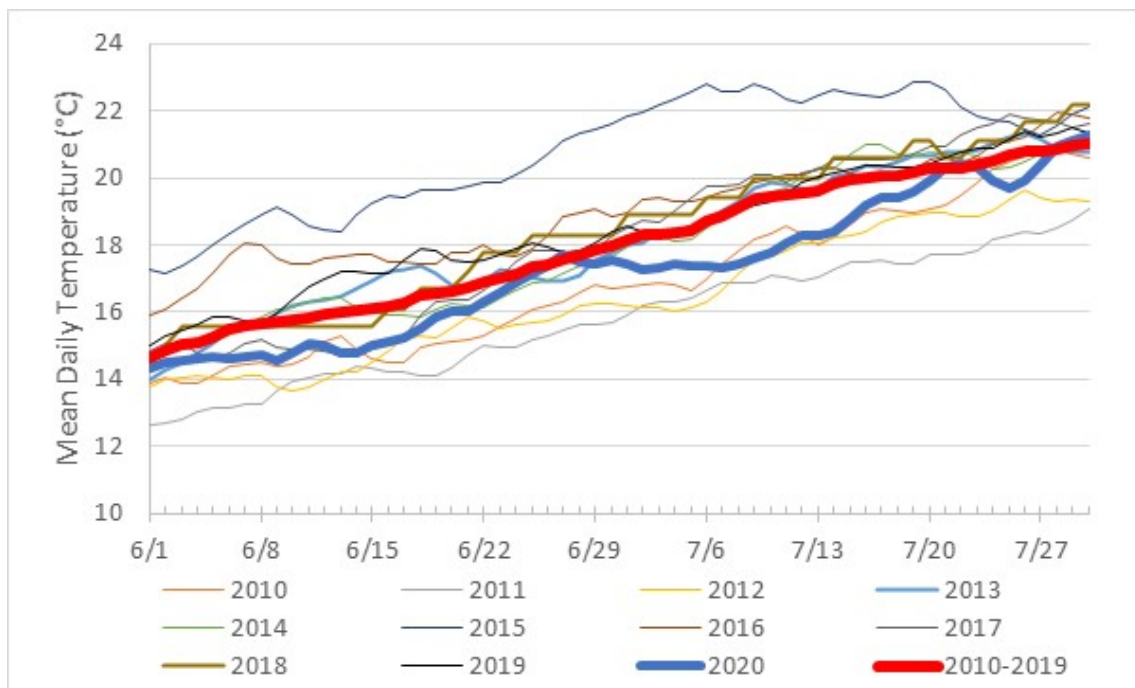


Figure 16. Mean daily water temperature at Bonneville Dam by year during the months of June for 2020 with the 2010-2019 mean.

Columbia River flows encountered by Sockeye Salmon migrating in 2020 were generally slightly above the 10-year average (Figure 19). The median travel time of 4.9 days from Bonneville to McNary Dam was 6th shortest in the 15 years of PIT tagging Sockeye Salmon at Bonneville Dam. Over that period, there has been a significant positive linear relationship between mean travel time and mean flow at Bonneville Dam ($p < 0.01$, Figure 20). The median time of 4.9 days from McNary to Priest Rapids for Sockeye Salmon tagged at Bonneville Dam by this study was second longest since we started this study in 2006. There is a significant relationship between mean flow at Priest Rapids Dam and mean travel time from McNary to Priest Rapids ($p < 0.01$, Figure 21). For both relationships, as flow increases, so does travel time between the dams.

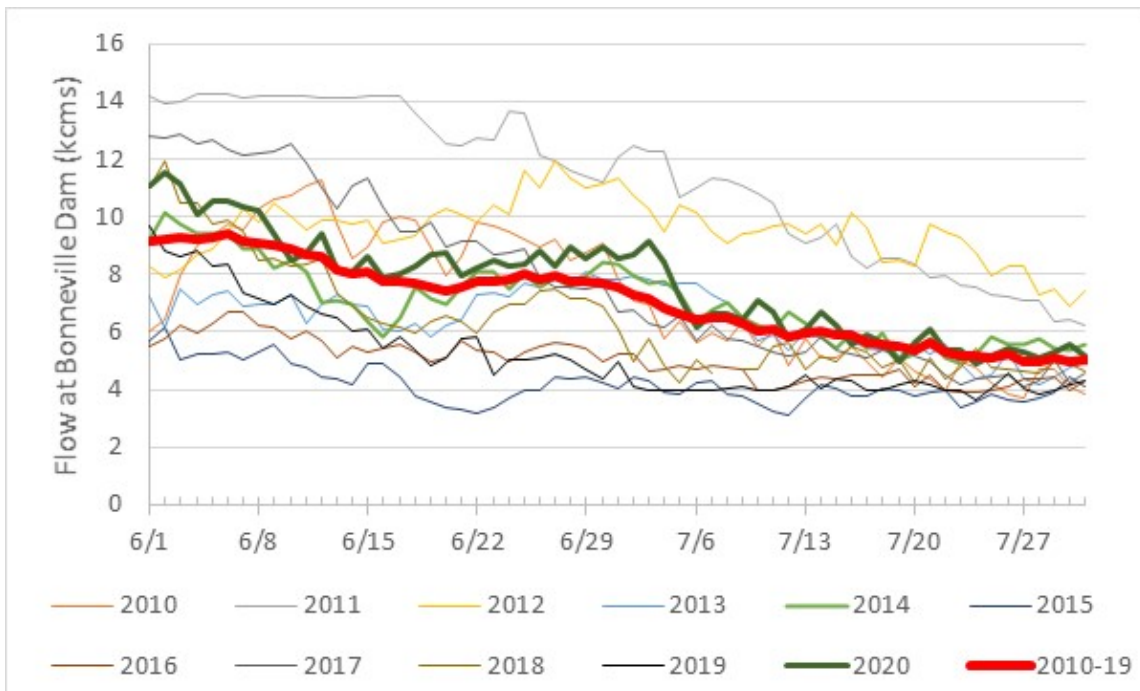


Figure 179. Mean daily flow at Bonneville Dam by year during the months of June and July in the years 2010-2020 with the mean flow of years 2010-2019 for comparison.

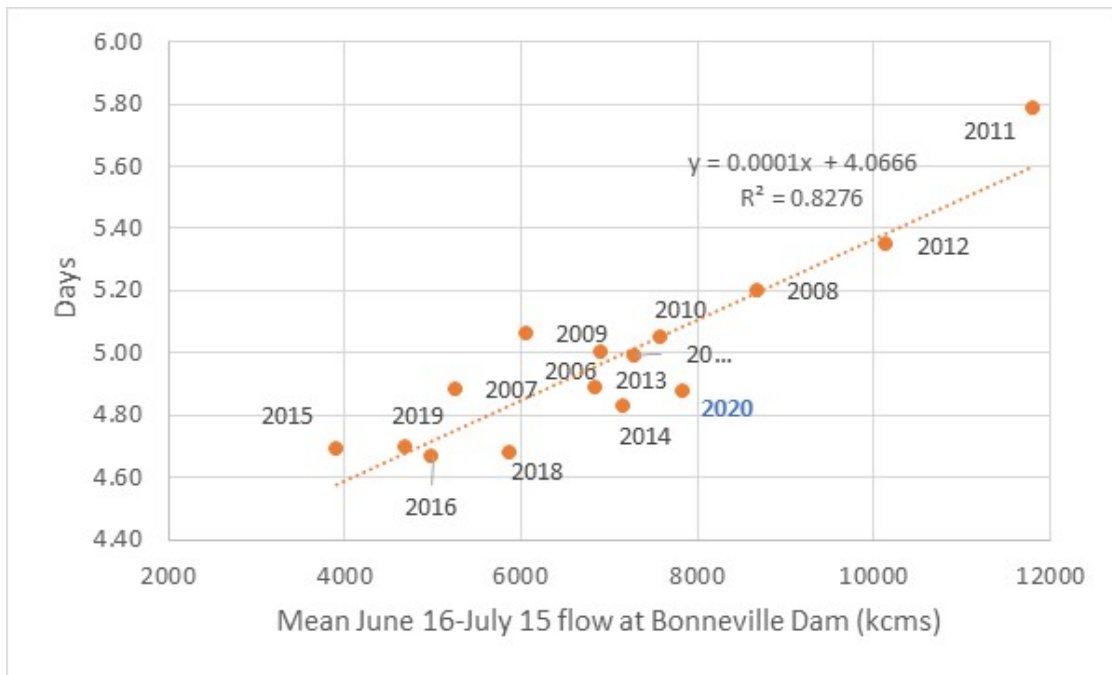


Figure 18. Relationship between mean annual Sockeye Salmon travel time for Sockeye Salmon PIT tagged at Bonneville Dam from Bonneville to McNary Dam and mean annual June 15-July 14 flow at Bonneville Dam for migration years 2006-2020.

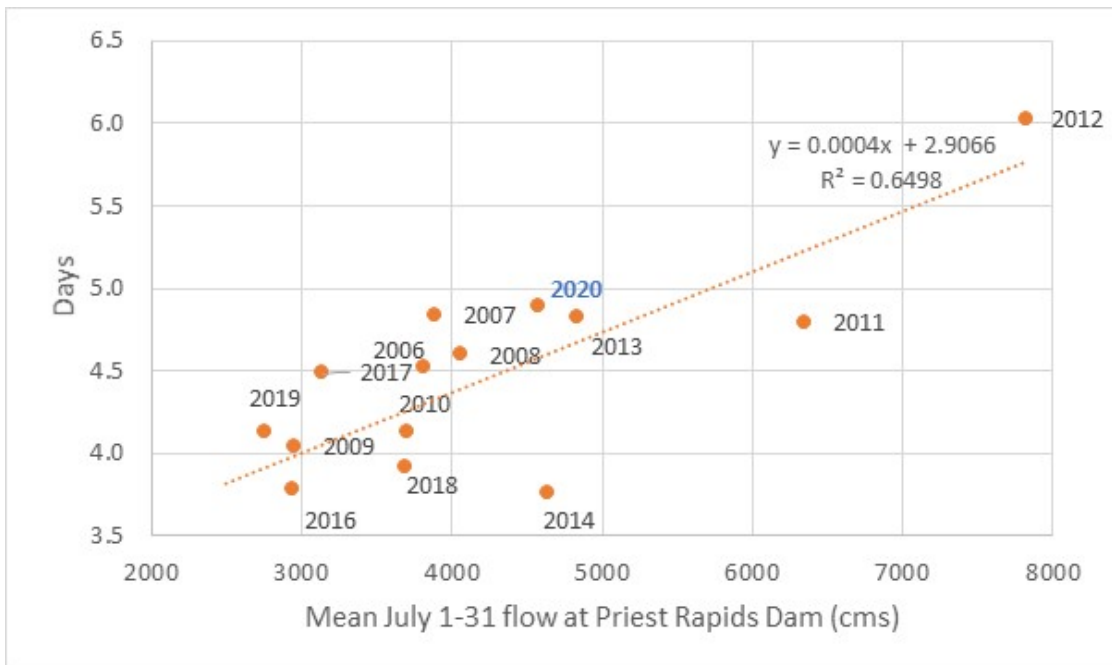


Figure 19. Relationship between mean annual Sockeye Salmon travel time for Sockeye Salmon PIT tagged at Bonneville Dam from McNary to Priest Rapids Dam and mean annual July flow at Priest Rapids Dam for migration years 2006-2020.

PIT tags from 17 adults tagged by this study at Bonneville Dam in 2020 were detected at the Badger Island pelican colony (Figure 22). Last detection sites for the Badger Island recoveries were 1 at Bonneville, 2 at The Dalles, 6 at John Day, 7 at McNary, 1 at Priest Rapids Dam. This was the highest number tags recovered from avian colonies of adult Sockeye Salmon from the study since its inception in 2006 and the percentage detected was third highest (Table 29). No juvenile Sockeye Salmon were PIT tagged in 2020; however, these are included in Figure 22 for consistency with previous reports. Note that tag recovery numbers can increase over time as additional surveys detect tags deposited in prior years.

Table 29. Number of PIT tags detected on avian colonies for 2006-2020 from Sockeye Salmon tagged by this study at Bonneville Dam.

| Year | Number in Study at Bonneville | Badger Island | Central Blalock Island | Crescent Island | Foundation Island | Preacher's Island | Little Miller Island | Rock Island | Total | Percentage Detected on Avian Colonies |
|--------------|-------------------------------|---------------|------------------------|-----------------|-------------------|-------------------|----------------------|-------------|------------|---------------------------------------|
| 2006 | 504 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.4% |
| 2007 | 507 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 3 | 0.6% |
| 2008 | 1,134 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.3% |
| 2009 | 838 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0.6% |
| 2010 | 913 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.2% |
| 2011 | 765 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.3% |
| 2012 | 1,614 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.2% |
| 2013 | 793 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0.8% |
| 2014 | 1,412 | 11 | 0 | 0 | 0 | 0 | 1 | 0 | 12 | 0.8% |
| 2015 | 915 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 1.7% |
| 2016 | 1,658 | 15 | 0 | 0 | 0 | 1 | 0 | 0 | 16 | 1.0% |
| 2017 | 1,093 | 13 | 0 | 0 | 0 | 0 | 0 | 1 | 14 | 1.3% |
| 2018 | 1,859 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.4% |
| 2019 | 980 | 5 | 1 | | 0 | 0 | 0 | 0 | 6 | 0.6% |
| 2020 | 1,733 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 1.0% |
| Total | 16,718 | 107 | 1 | 1 | 2 | 1 | 1 | 1 | 114 | 0.7% |

No adult Sockeye Salmon PIT tagged at Bonneville Dam were recovered in tribal fisheries between Bonneville and McNary dams in 2020.

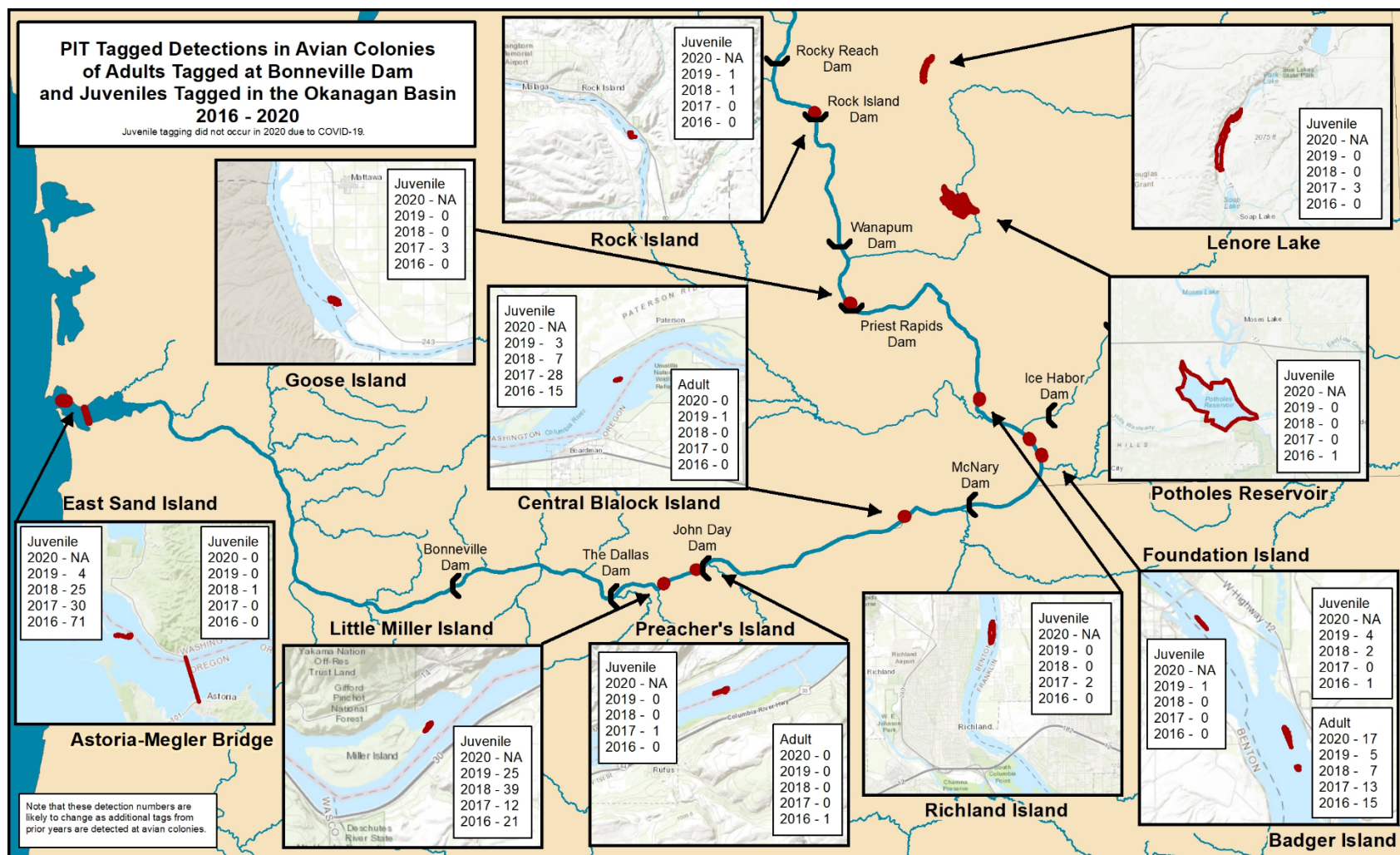


Figure 20. PIT tag detections at avian colonies of Sockeye Salmon tagged by this project in years 2016-2020.

The number of Sockeye Salmon classified as Yakima origin was higher than we have observed in past years. A total of 13 Sockeye Salmon tagged by this project at Bonneville Dam were detected at Prosser Dam, with 10 of these also being detected at Roza Dam. These Sockeye Salmon were classified as being of Yakima origin by last PIT tag site. However, Sockeye Salmon not detected in the Yakima River would not be so classified and there is no way to know the proportion of Yakima Sockeye Salmon tagged that did not survive to the Yakima River. A measure of this survival rate can be determined by looking at the 30 Sockeye Salmon classified as Yakima origin by PBT (Table 15). Of these fish, 27 (90.0%) were detected at McNary Dam (with the other 3 last detected at each of these dams BO4, JO1, and TD1) and of the 30 only 5 (16.7%) were detected in the Yakima River (at Prosser [PRO] followed by Roza [ROZ] dams). Among the remaining 22 Sockeye Salmon detected at McNary Dam but not in the Yakima River, 6 were last detected above Priest Rapids Dam (with a mean travel time from MCN to PRA of 12.1 days compared to 4.9 days for all Bonneville-tagged Sockeye Salmon in this study (Table 9)). Median travel time to ICH from MCN for those 4 Sockeye Salmon last detected at or above ICH (Table 16) was 17.3 days while median travel time from MCN to Prosser was 34.9 days. It would appear that Yakima Sockeye Salmon may be 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, Priest Rapids, or Prosser dams.

Visual counts at Prosser Dam (DART 2020), similar to analysis of PIT tag data from the Okanogan River (Figures 14, 15, and Table 26), shows the importance of Yakima River temperature on Sockeye Salmon migration. Over 66% of the Prosser Dam Sockeye Salmon count was between June 30 and July 7 which was immediately following a drop in river temperatures to 21C (Figure 23). Much smaller groups of Sockeye Salmon migrated on drops in water temperature in August and September. One Sockeye Salmon tagged at Bonneville by this project passed Prosser Dam on July 1, four on dates of July 4, 5, and September 3, 5, and two on the dates of September 14, 20, 21, and 27.

Of the 13 Sockeye Salmon from this project detected at Prosser Dam, 4 were also classified by PBT as being of Yakima stock. However, there were an additional 26 Sockeye Salmon classified by PBT as being Yakima stock. Among

the 30 Sockeye Salmon classified by PBT as being of Yakima Stock, 27 were detected at McNary Dam, passing between June 22 and July 27, 2020 (Figure 23). Of these 27 Sockeye Salmon, in addition to the 4 Sockeye Salmon last detected in the Yakima River, 12 had no detections after McNary Dam, with 7 last detected above Priest Rapids Dam, 4 above Ice Harbor Dam.

All six Sockeye Salmon tagged by this project that were detected upstream of Ice Harbor Dam were classified by PBT as being Yakima Stock (maps of their movements are in Appendix A). Four of the six Sockeye Salmon were also detected at Priest Rapids Dam, and they spent extensive time in the area of the Yakima River moving between McNary, Priest Rapids, and Ice Harbor dams. These six Sockeye Salmon spent a mean time of 25.8 days in the area (measured from first detection at McNary to last detection at Ice Harbor or Priest Rapids) compared to 4.9 days for the run at large (from McNary to Priest Rapids) with an average of 2.2 fallback events per Sockeye Salmon compared to 0.19 fallback events for the run at large.

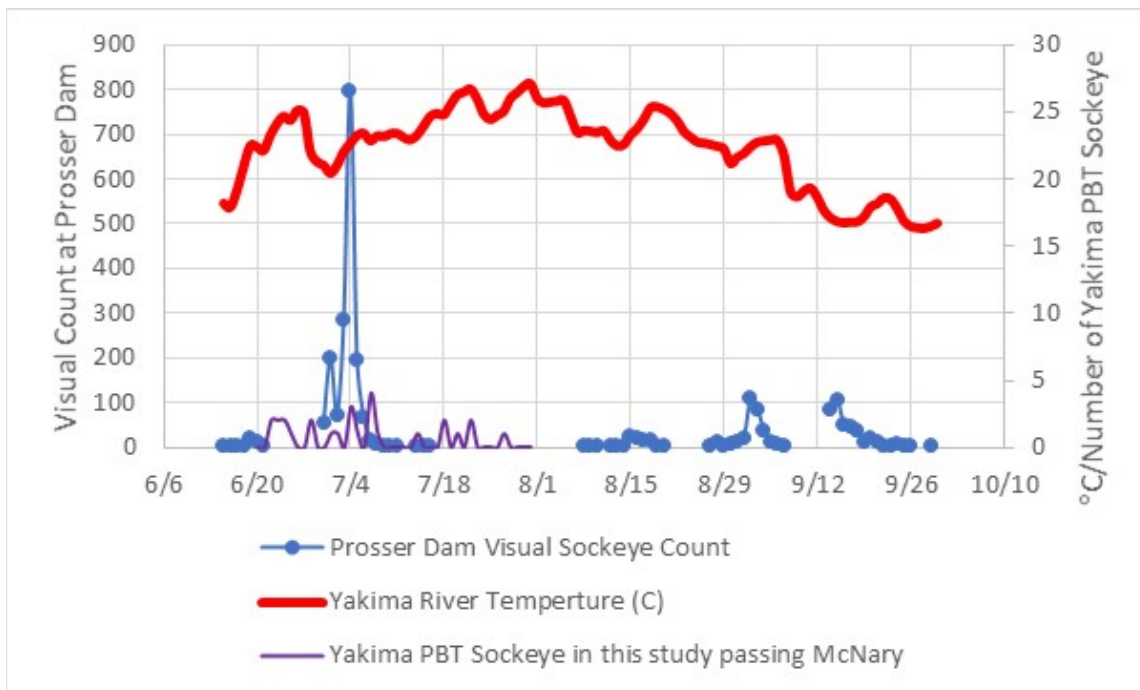


Figure 21. Daily visual counts of Sockeye Salmon at Prosser Dam, Yakima River water temperatures, and number of PIT tagged Yakima Sockeye Salmon (as identified by PBT) that passed McNary Dam in 2020.

This project has reported in past years that the percentage of adult PIT Sockeye Salmon PIT tagged at Bonneville Dam missing detection at Rock Island has been greater than that at any other Columbia River dam despite the fact that fish cannot bypass detection antennas as there are no navigation locks (Table 2). The mean annual percentage missing detection at Rock Island since 2006 has been 8.9%; second highest dam with detection issues has been McNary Dam (which does have navigation locks) at 4.4% (Table 2). The issue at Rock Island has been a result of electrical noise in the right bank ladder (Fryer 2021). To compensate for the issue, additional antennas (31 through 38) were added to the right bank ladder on July 9, 2019, with more antennas (2A through 2D) added in January 2020 (Figure 24). Prior to the addition of these antennas, in 2018 Rock Island Dam missed 28.3% of passing Sockeye Salmon tagged by this project, while in 2020 only 2.8% were missed. If detections at antennas installed in January 2020 are removed from the data an additional 27 Sockeye Salmon (beyond the 30 that were missed in 2020) would have been missed, increasing the percentage to 4.7%, if data from antennas installed July 9, 2019, are also removed 104 more Sockeye Salmon would have not been detected increasing the percentage missed to 13.2%.

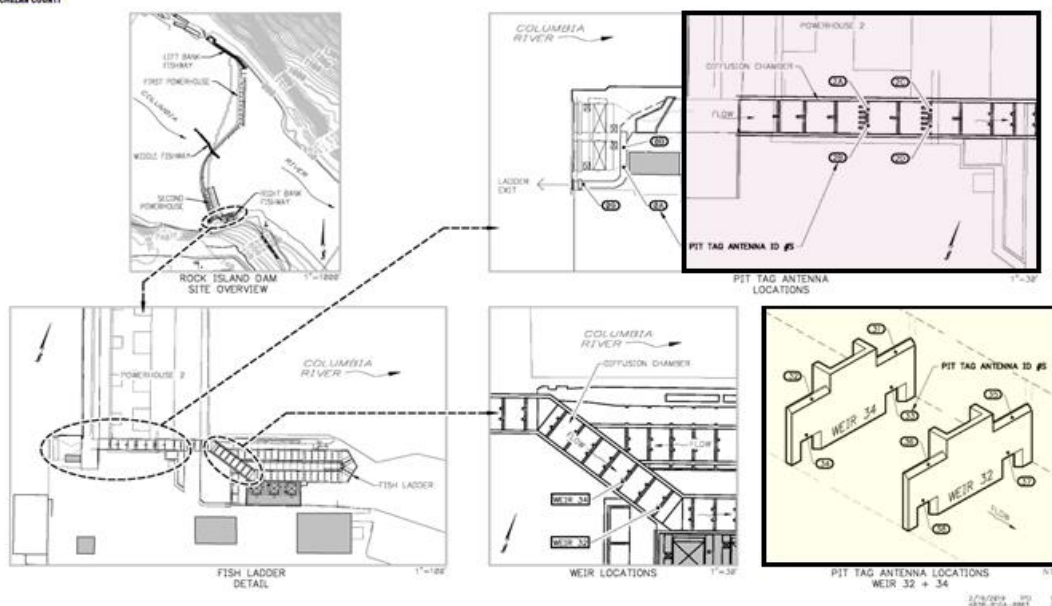


Figure 22. Configuration of PIT tag antennas at the Rock Island Dam Right Bank ladder. Pink shading shows antennas added January 30, 2020 while the yellow shading shows antennas added July 9, 2019.

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 by moving through spillways rather than ladders at Skaha Dam.

Lake Wenatchee ATS studies 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 respectively³⁰. The PIT tag arrays at SKA and OKP funded by this project have been important in assessing the success of this restoration work. With Sockeye Salmon passage planned into Okanagan Lake in the near future, we hope 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.

³⁰ 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***

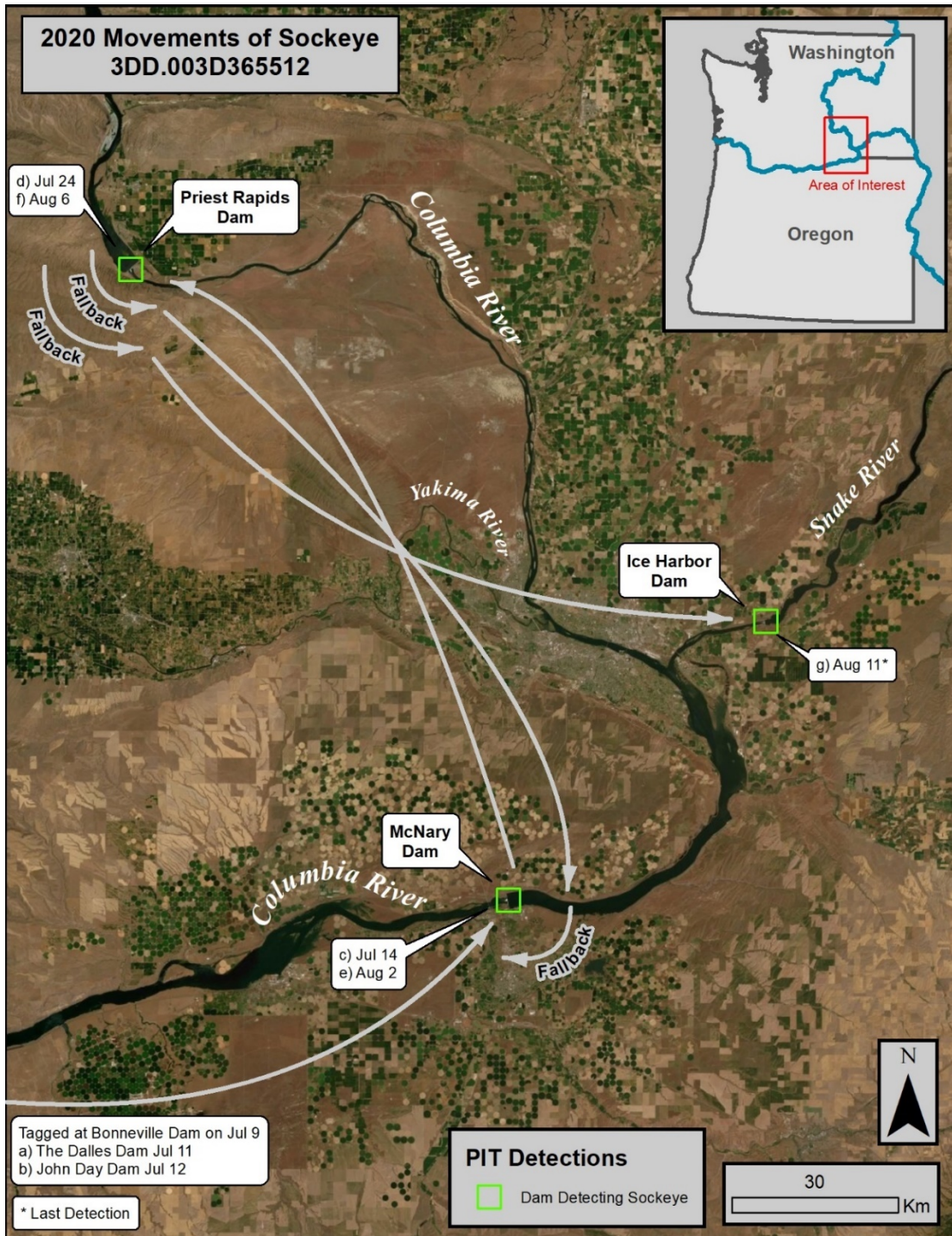


Figure A1. Map showing movements of Sockeye Salmon 3DD.003D365512 around dams near the mouth of the Yakima River.

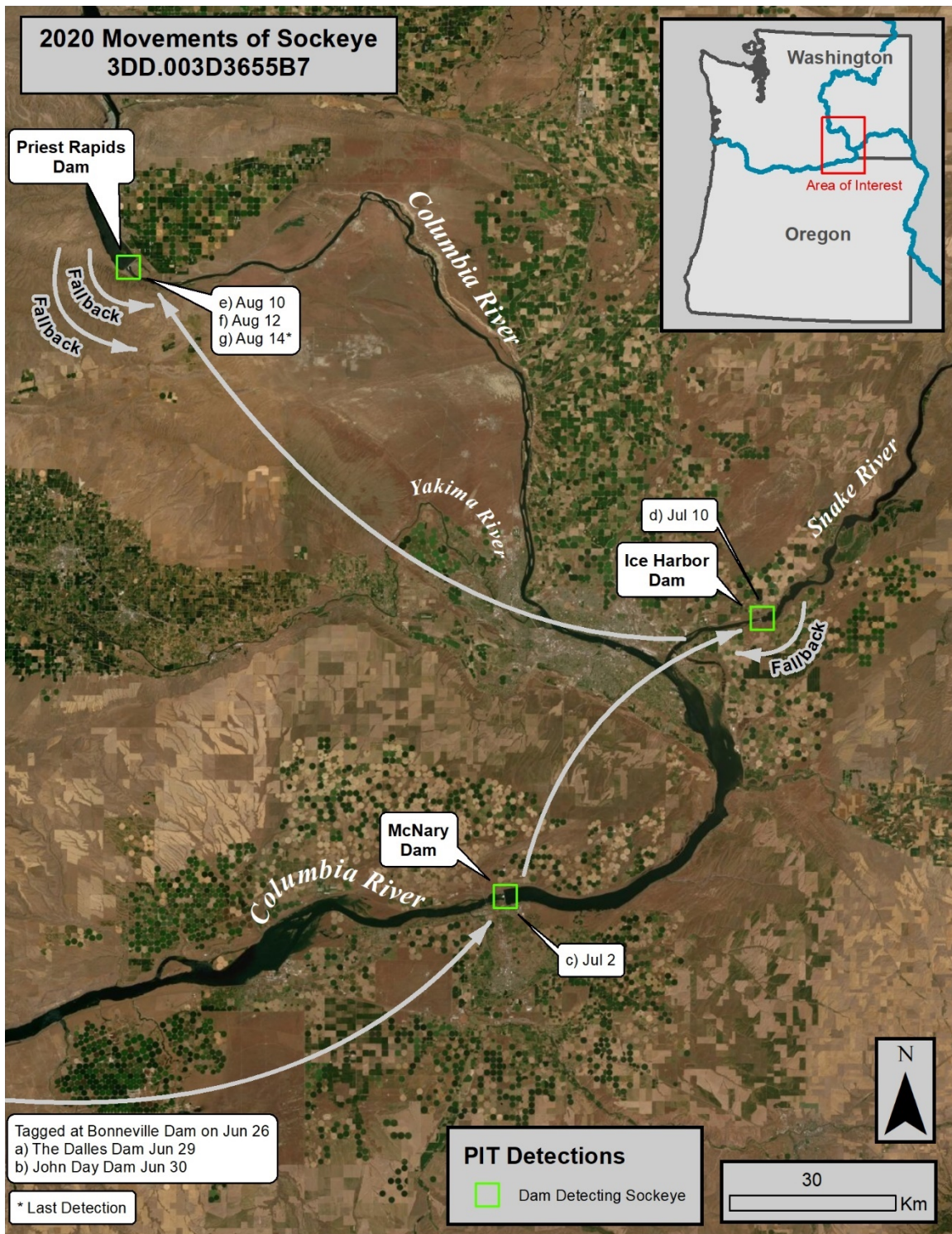


Figure A2. Map showing movements of Sockeye Salmon 3DD.003D3655B7 around dams near the mouth of the Yakima River.

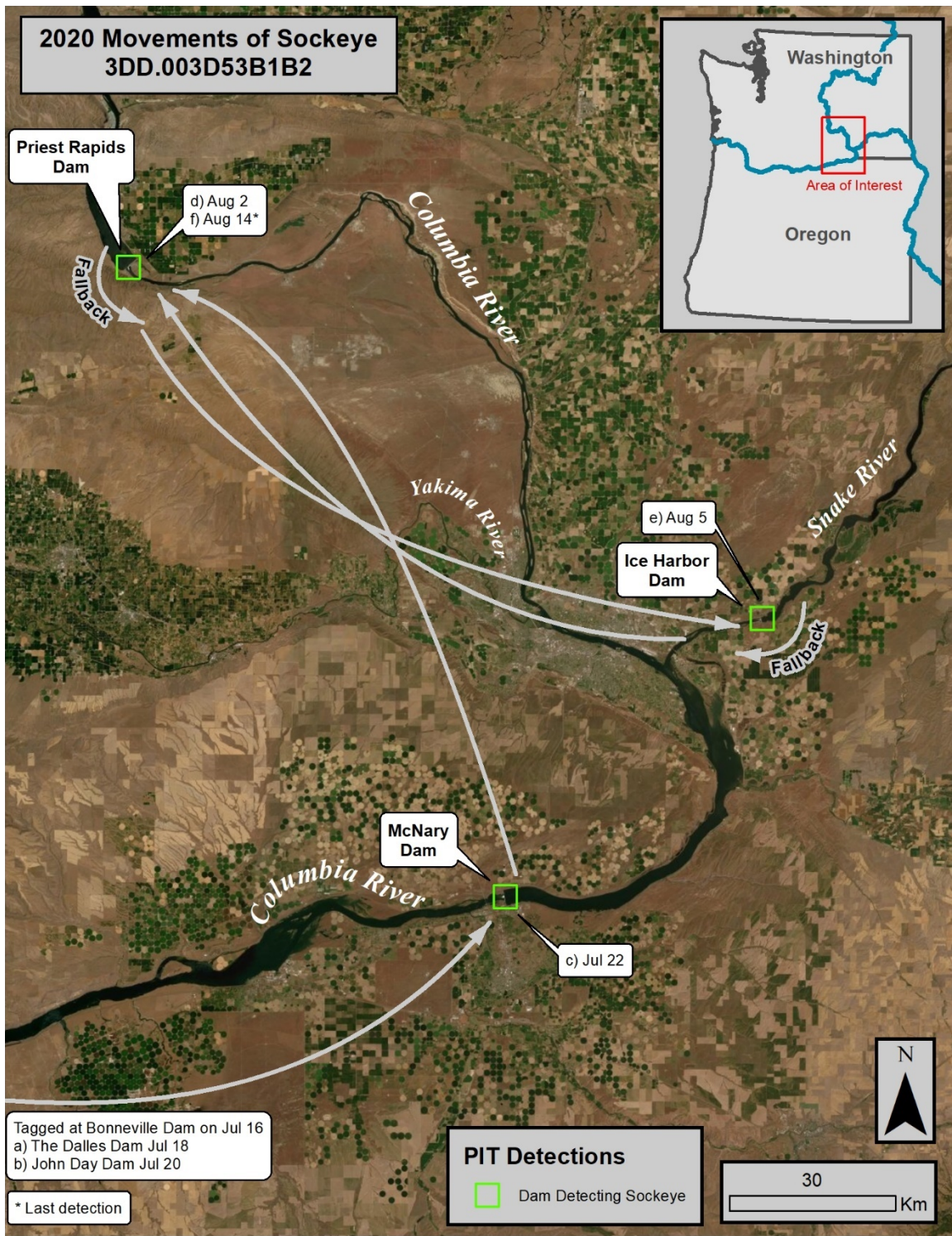


Figure A3. Map showing movements of Sockeye Salmon 3DD.003D53B1B2 around dams near the mouth of the Yakima River.

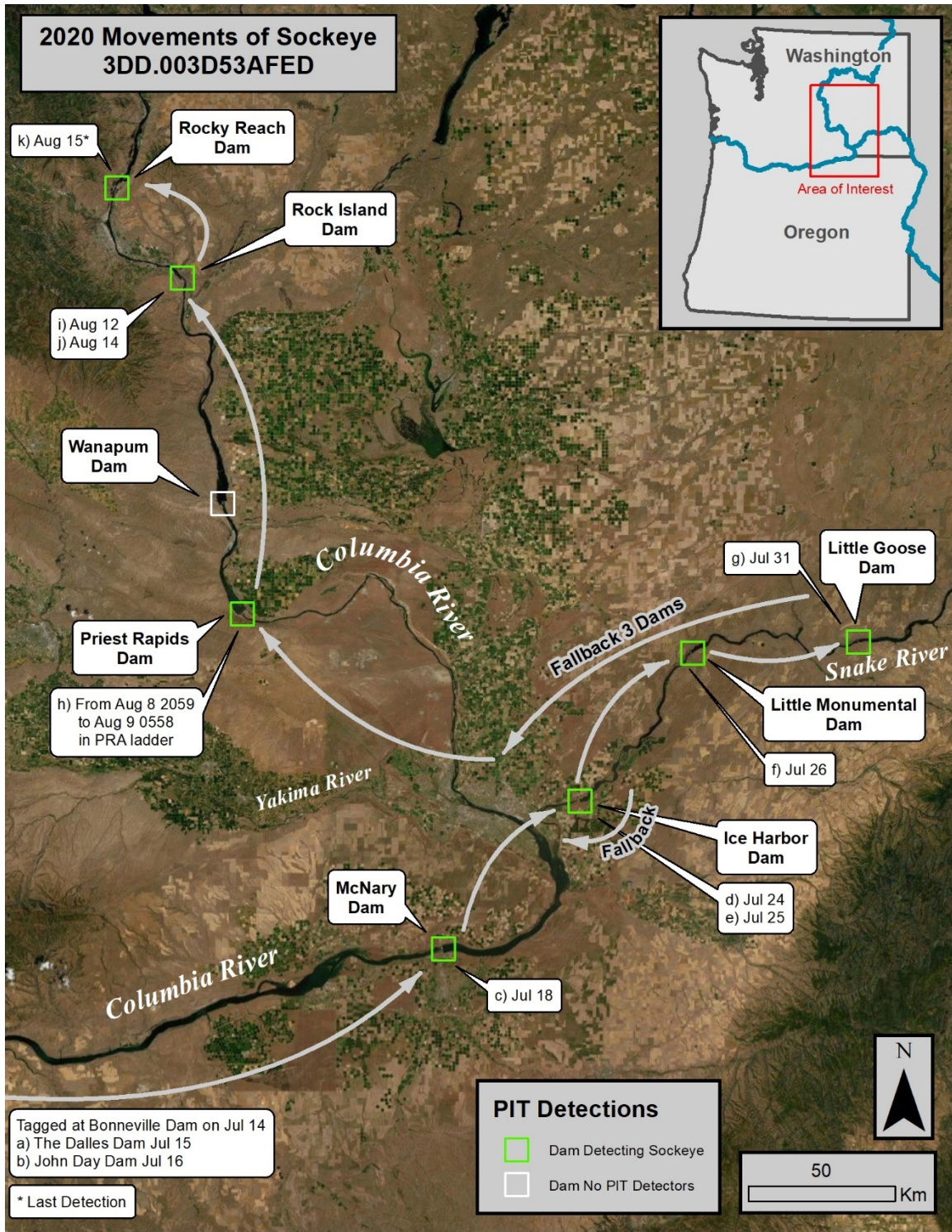


Figure A4. Map showing movements of Sockeye Salmon 3DD.003D53AFED around dams near the mouth of the Yakima River.

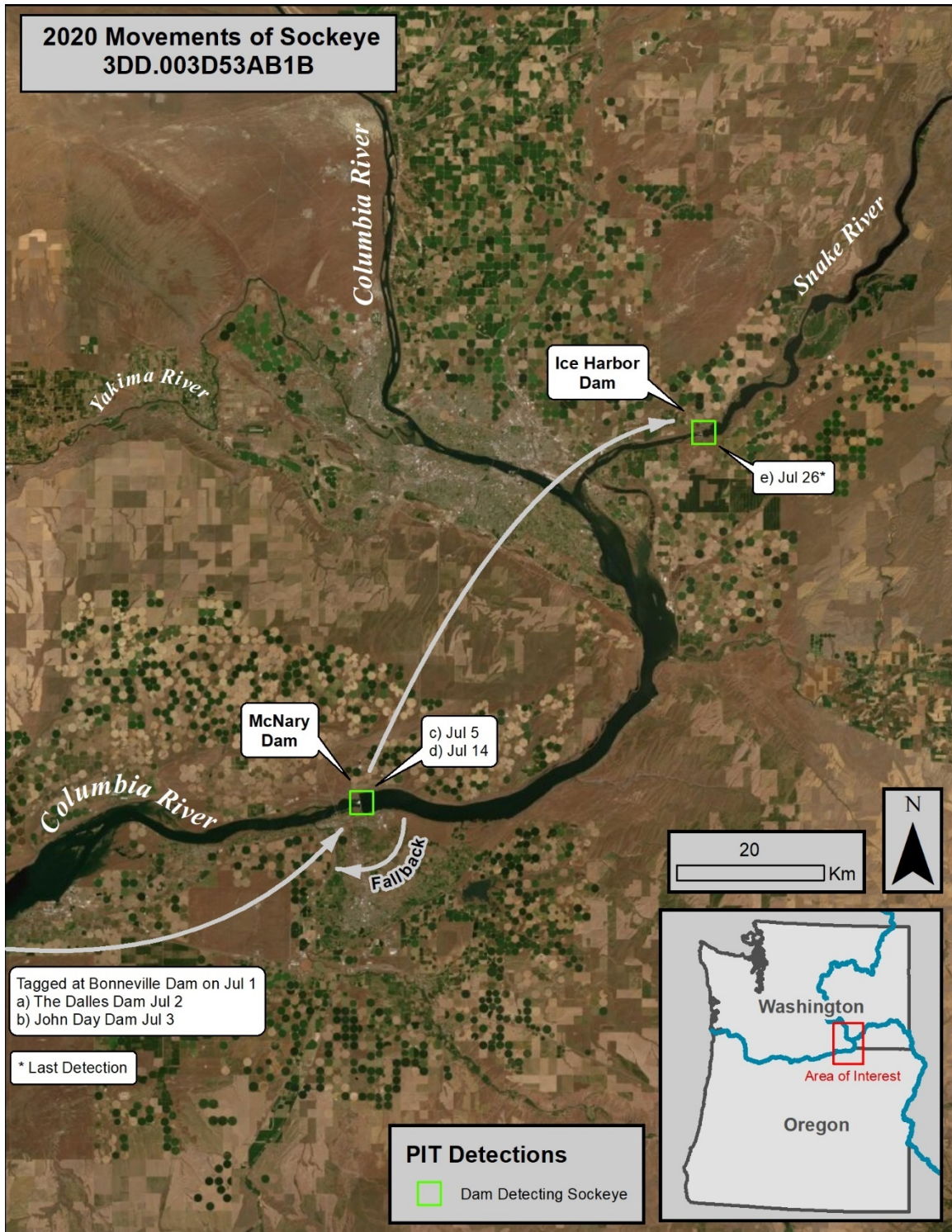


Figure A5. Map showing movements of Sockeye Salmon 3DD.003D53AB1B around dams near the mouth of the Yakima River.

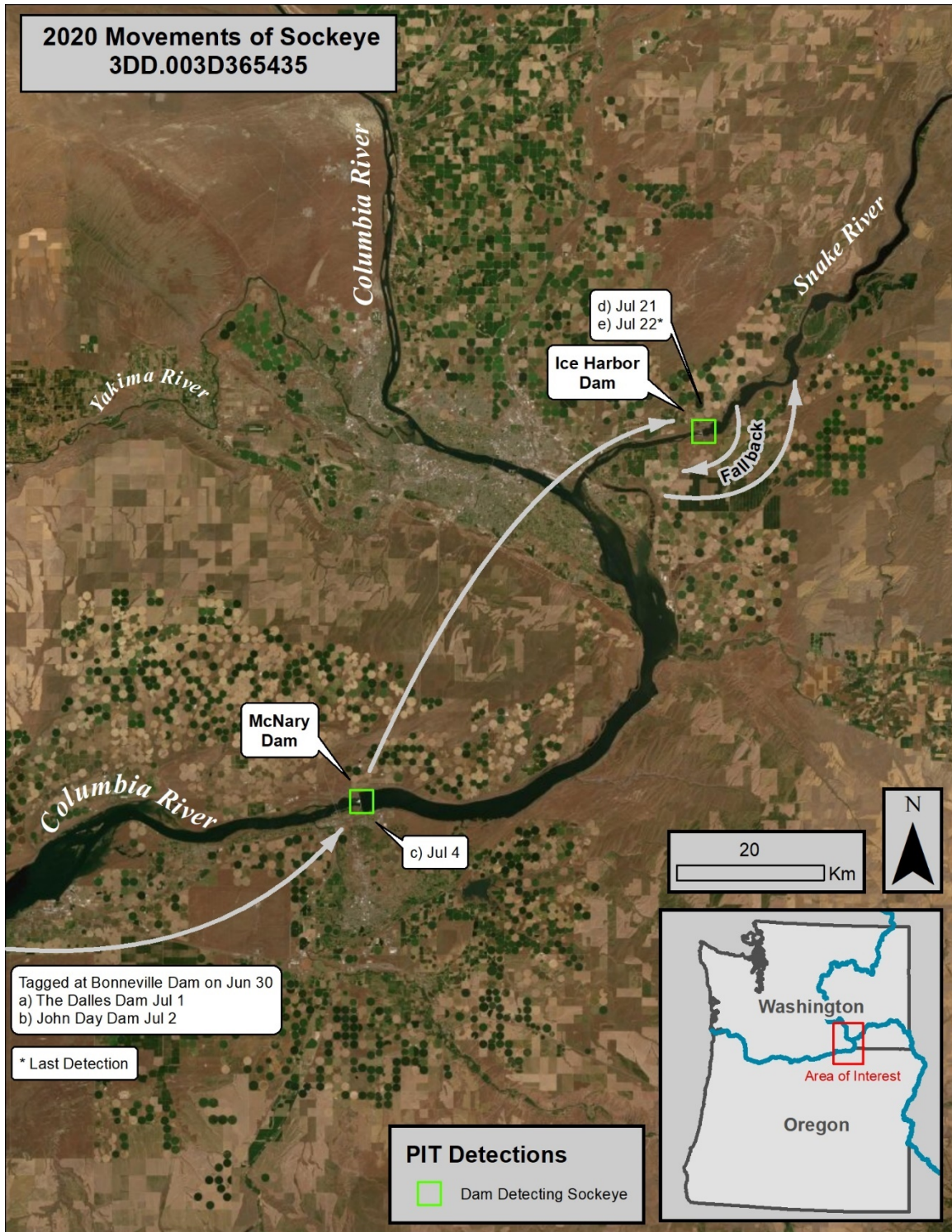


Figure A6. Map showing movements of Sockeye Salmon 3DD.003D365435 around dams near the mouth of the Yakima River.

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 2020.

| Site Code | Site Name | Site Description |
|-----------|--------------------------------|---|
| BCC | BON PH2 Corner Collector | Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel. |
| BO1 | Bonneville Bradford Is Ladder | Bradford Island Adult Fishway at Bonneville Dam. |
| BO2 | Bonneville Cascades Is Ladder | Cascades Island Adult Fishway at Bonneville Dam. |
| BO3 | Bonneville WA Shore Ladder/AFF | Washington Shore Adult Fishway and AFF at Bonneville Dam; replaces B2A and BWL. |
| BO4 | Bonneville WA Ladder Slots | Washington Shore Fishway Vertical Slots at Bonneville Dam. |
| EHL | Entiat NFH Adult Ladder | This adult interrogation site is located in the Entiat National Fish Hatchery adult ladder. |
| ENA | Upper Entiat River at rkm 17.1 | The site is located approximately 400 meters above the mouth of the Mad River near the township of Ardenvoir at river kilometer 17.1. |
| ENL | Lower Entiat River | Entiat River rkm 2, located immediately upstream of Entiat, WA. |
| GOA | Little Goose Fish Ladder | Adult Fishway at Little Goose Dam. |
| ICH | Ice Harbor Dam (Combined) | Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass. |
| ICL | Lower Icicle Instream Array | Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA. |
| JDJ | John Day Dam Juvenile | John Day Dam Juvenile Fish Bypass and Sampling Facility. |
| JO1 | John Day Dam South Fish Ladder | The interrogation site at the John Day Dam south fish ladder. |
| JO2 | John Day Dam North Fish Ladder | The interrogation site at the John Day Dam north fish ladder. |
| LMA | Lower Monumental Adult Ladders | This interrogation site is in both ladders at Lower Monumental Dam. |
| LMR | Lower Methow River at Pateros | Lower Methow River near the WDFW 'Miller Hole' access site on the lower Methow River immediately upstream of Pateros, WA. |
| LWE | Lower Wenatchee River | Wenatchee River rkm 2. |
| LWN | Little Wenatchee River | Instream PIT tag interrogation site at rkm 4 located at the old fish weir. |
| MC1 | McNary Oregon Shore Ladder | Oregon Shore Adult Fishway at McNary Dam. |
| MC2 | McNary Washington Shore Ladder | Washington Shore Adult Fishway at McNary Dam. |
| MCJ | McNary Dam Juvenile | McNary Dam Juvenile Fish Bypass/Transportation Facility. |
| MRC | Methow River at Carlton | Located in the mainstem Methow River near the town of Carlton at rkm 45. |
| OKC | Okanagan Channel at VDS-3 | The OKC site is located in the Okanagan (Canadian spelling) Channel at 310th Avenue/Road 18 upstream from Osoyoos Lake. |
| OKL | Lower Okanagan Instream Array | Site at RKM 24.9 on the mainstem Okanagan River, upstream of Chilliwig area in Okanagan County. |
| 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. |
| OKP | Pentiction Channel PIT Array | Pentiction Channel, is the channelized portion of the Okanagan River connecting Okanagan Lake with Skaha Lake, within the city of Pentiction BC. |
| OKS | Shingle Creek | Site is on a tributary to the Okanagan River in Canada, immediately adjacent to the Okanagan Shingle Creek Hatchery. |
| PRA | Priest Rapids Adult | Priest Rapids Dam Adult Fishways (both). |
| PRH | Priest Rapids Hatchery Outfall | Priest Rapids Hatchery outfall channel. The site is located just upstream of the typical point of inundation in the channel. |
| PRO | Prosser Diversion Dam Combined | Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam. |
| RIA | Rock Island Adult | Rock Island Dam Adult Fishways (all three). |
| ROZ | Roza Diversion Dam (Combined) | Roza Dam Smolt Bypass. |
| RRF | Rocky Reach Fishway | Rocky Reach Dam Adult Fishway. |
| RRJ | Rocky Reach Dam Juvenile | Juvenile Fish Bypass Surface Collector. |
| RSH | Ringold Springs Hatch. Outfall | PIT tag detection system located in the Ringold Springs Hatchery outfall channel. |
| 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. |
| SUN | Sunnyside Instream Array | Located 600 M below Sunnyside Dam on the Yakima River. |
| TD1 | The Dalles East Fish Ladder | East Fish Ladder at The Dalles Dam. |
| TD2 | The Dalles North Fish Ladder | North Fish Ladder at The Dalles Dam. |
| TUF | Tumwater Dam Adult Fishway | Adult Fishway at Tumwater Dam. |
| TWR | Lwr Twisp Rvr near MSRF Ponds | Lower Twisp River adjacent to the Methow Salmon Recovery Foundation Ponds. |
| UWE | Upper Wenatchee River | Located at rkm 81.2 on the Wenatchee River, near Plain, WA. |
| WEA | Wells Dam, DCPUD Adult Ladders | Wells Dam Adult Fishways (both). |
| WEH | Wells Dam Hatchery | Points of detection include the adult fish handling facility, juvenile pond outflows and adult volunteer channel. |
| WTL | White River, Wenatchee Basin | A permanent instream PIT tag interrogation site at RKM 2.88 on the White River. |
| ZSL | Zosel Dam Adult Fishways | Zosel Dam is located at Okanagan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos in the town of Oroville, Washington. |

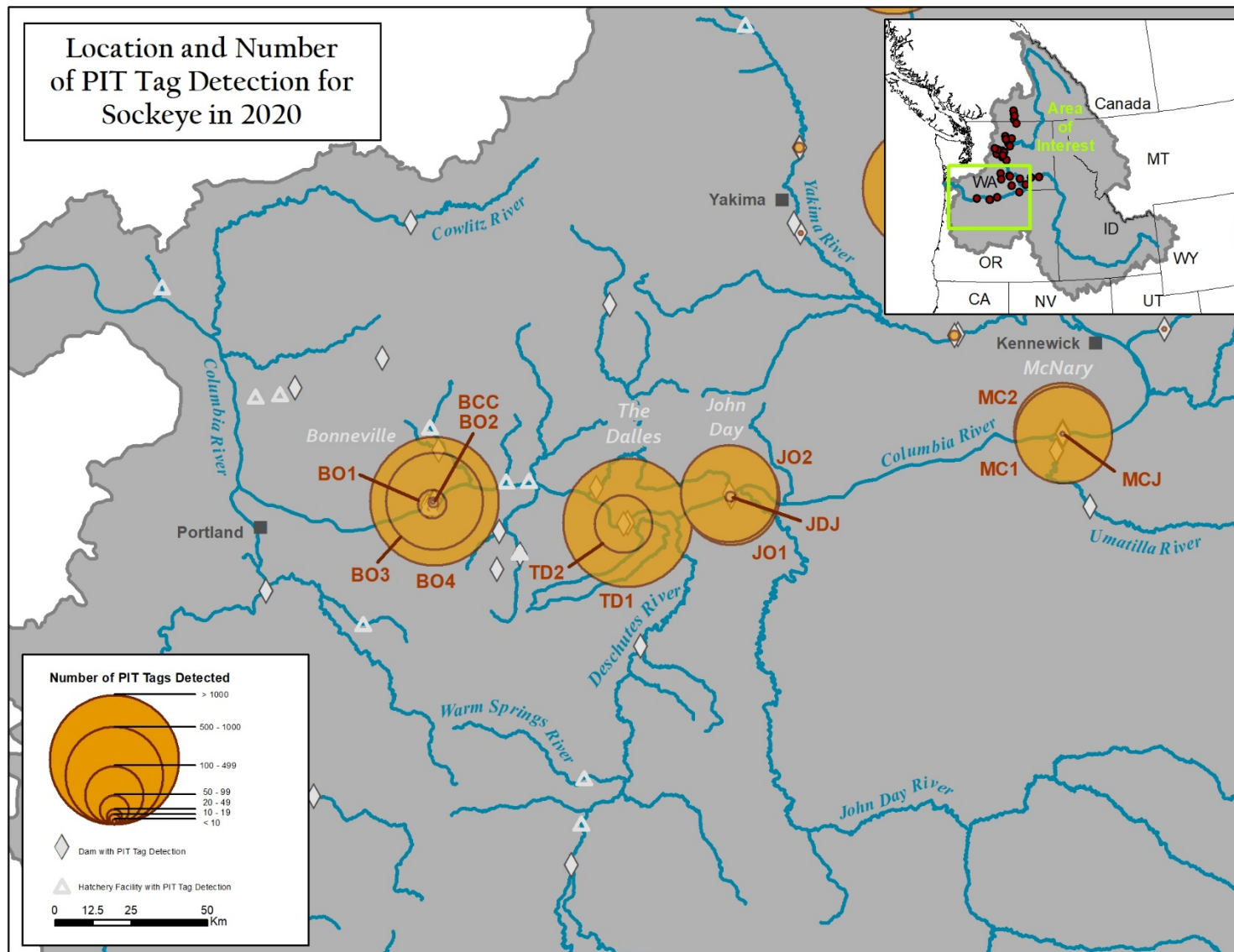


Figure B1. Map of Lower Columbia River detection sites (below Snake River) and number of Sockeye Salmon detected in 2020. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

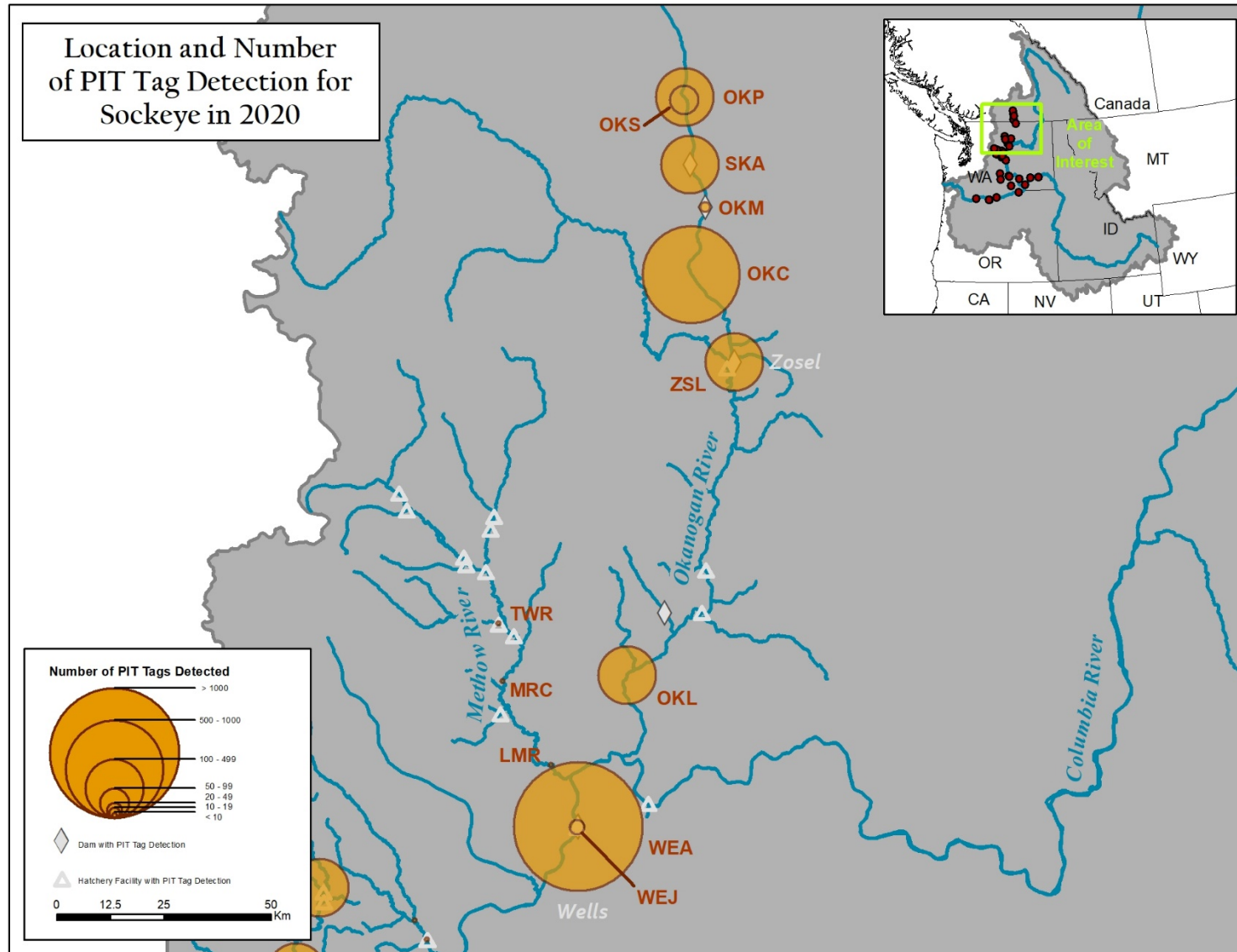


Figure B3. Map of Upper Columbia River (Wells Dam and above) detection sites and number of Sockeye Salmon detected 2020. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

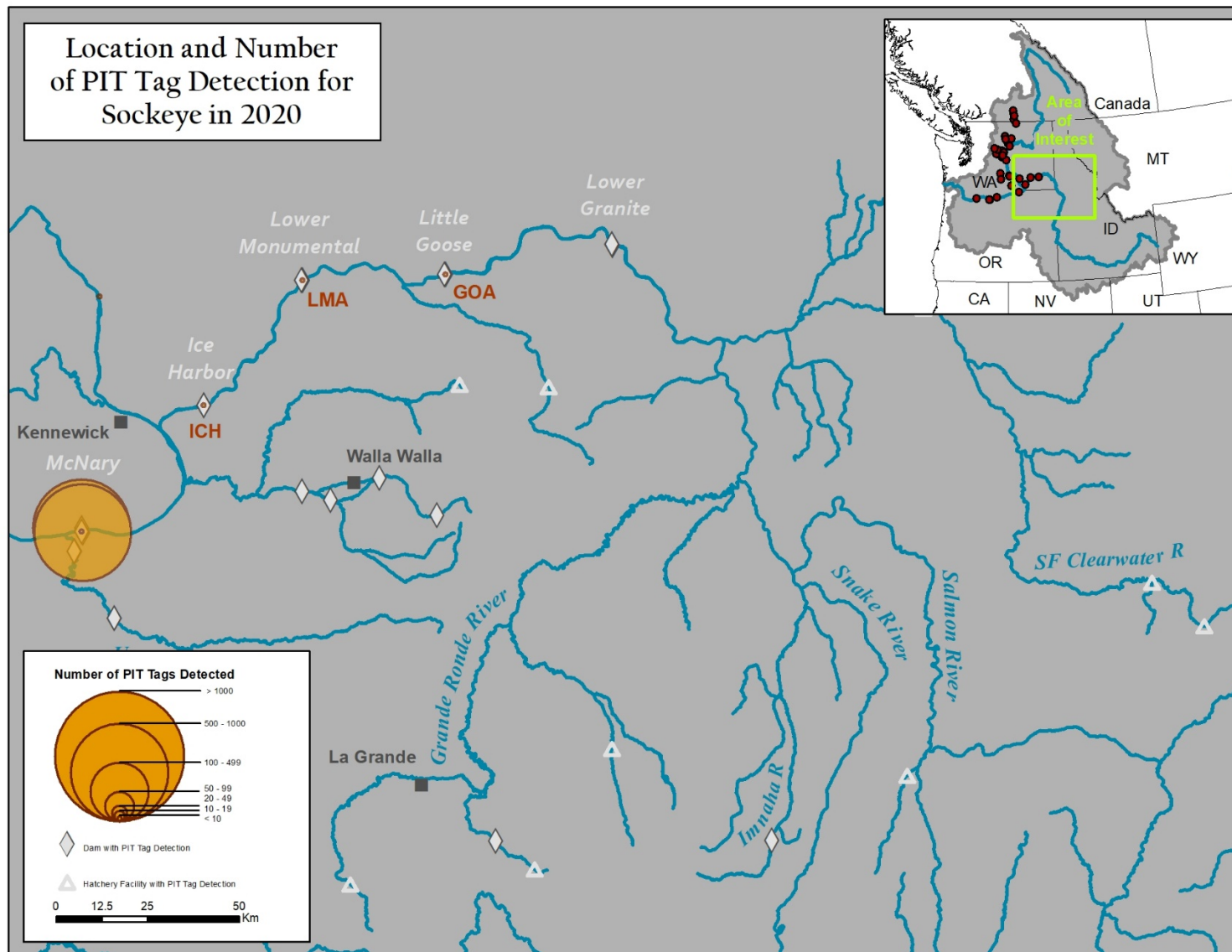


Figure B4. Map of Lower Snake River detection sites (Salmon River not included) and number of Sockeye Salmon detected in 2020. Table B1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

APPENDIX C:

Response to 2021 ISRP Review of this Project

This project underwent ISRP review in 2021 ([ISRP 2021-08 PrelimAFHH23Sept 0.pdf \(nwcouncil.org\)](#)) and the ISRP requested that the proponents assist in development of an M&E matrix summarizing linkages between this project and the Upper Columbia River Programmatic Habitat Project (2010000100). A discussion by email with Joe Connor of BPA and Tracy Bowerman of the Upper Columbia Salmon Recovery Board (UCSRB) indicated that such linkages were not made a requirement of the UCSRB by the NPCC and there is thus no funding or scope of work to do so. It is something that the UCSRB is hoping to develop and this project is willing to participate in if it occurs.

Another comment was one from Dr. Chris Wood questioning Table 5 regarding acoustic survival from the Similkameen to Osoyoos Lake. This generated some reanalysis of results along with several emails between Dr. Jeff Fryer and Dr. Wood. This reanalysis was predicated on there being minimal delay and mortality caused by Zosel Dam which seems reasonable given the high number of Sockeye that pass this site. However, very preliminary data from Zosel spillbay antennas funded by this project that were installed in September 2021 suggests that this assumption of minimal mortality and delay may not necessarily be the case, at least in the fall of a difficult passage year such as was the case in 2021. We will revisit these issues in a subsequent report after we have more data on Zosel Dam passage.

ISRP Item #2: Use of M&E assessments. Describe how expected monitoring and evaluation outcomes will be used, and by whom.

PIT tags have been used in fisheries management and fisheries research to monitor the movement and behavior of anadromous salmonids in the Columbia River Basin since 1987. Tag data from this joint project of the CRITFC and Okanagan Nation Alliance (ONA) contribute to the [PTAGIS program](#) (implemented in 1991 to manage PIT tag data), upon which approximately 40 different state, federal, and tribal agencies; public utility districts; universities; and research organizations in three U.S. states and one Canadian province rely for fisheries management (32% of PIT data usage) and fisheries research (53%) ([PTAGIS User Survey Results](#)). The PTAGIS program also utilizes PIT tag data, including Okanagan Sockeye data, to assess tag detection efficiency at Columbia mainstem USACE dams.

PIT tag data from this project are also incorporated into the Comparative Survival Study (CSS) annual reports since 2016. The objective of the CSS program is to establish a long-term data set of annual estimates of the survival probability of generations of salmon. This is based on the tally of the number of tagged juveniles released each year on their outbound journey downriver and the number of fish from each release year that were later detected as adults returning upriver from the ocean. Comparing these two quantities – taken at Bonneville Dam, the nearest dam to the ocean on the Columbia River – provides an estimate of how many fish survived the ocean phase of the salmonid life cycle.

Specifically, this project's focus on Okanagan Sockeye also supports specific DFO/ONA research on within- and between-year variations in smolt and adult migration timing, speed, and success ([Hyatt et al. 2020](#); [Murauskis et al. 2021](#)), and is currently contributing to life-cycle modelling efforts and population viability assessments currently in development for Okanagan wild and hatchery Sockeye stocks (pers. comm., R. Bussanich, ONA Fisheries). These models incorporate reach-level (inter-dam) survival, timing and straying statistics, drawn from PIT tag data analyses in relation to environmental factors throughout the Columbia mainstem and Okanagan watersheds to evaluate current and future impacts (under climate change) of water temperature and flow levels on factors affecting the sustainability of Okanagan Sockeye (and Chinook) populations. PIT tag data contribute to in-season harvest management and reporting, straying and homing metrics, brood-stock allocation and collection for compliance with hatchery genetic management plans, and juvenile survival and migration timing analyses on the Canadian side of the border to analyze the impact of predators in lakes (pers. comm., R Bussanich, ONA Fisheries).

ISRP Item 3: Biological goals and objectives. Describe the biological goals and objectives related to the Problem Statement that will be addressed over the next funding period?

PIT tag data from this project have been and will continue to be a critical source of information for understanding the limiting factors affecting Okanagan Sockeye salmon migrants. PIT tag data have revealed how Temperature is a key issue for Okanagan Sockeye reproductive success. Okanagan-bound Sockeye are particularly vulnerable to prolonged high temperatures in the Okanogan River which exert negative impacts on travel time (TT) and “conversion rate” (CR) survival between Wells Dam and tag detection sites in the Okanogan watershed, including Zosel Dam. In cool, wet years when Okanogan River water temperatures average less than 22°C during adult Sockeye passage (e.g. 2010 and 2011), the Wells-to-Okanogan CR was 79-87%. In recent warm years (e.g. 2013, 2014, 2016-2018) when Okanogan mean temperatures ranged from 22-23°C during adult migration, the Wells-to-Okanogan CR averaged 43% (range 34-65%). In 2015, when Okanogan mean temperatures during peak migration reached ~24°C, the CR value fell to 8.5%, indicating a 91.5% natural enroute mortality rate for the passage between Wells Dam and the spawning grounds. Median TT between Wells and Zosel dams averaged ~5 days (range 3-7) in 2016 and 2017, but averaged 28 days (range 13-35) due to temperature-induced migration delays during the hot spell in 2015 (Fryer et al. 2018). Minimum travel times in 2015 (6.5 - 7.8 days) were restricted to the earliest tag groups (stat week 22-23) which encountered slightly better thermal conditions for migration, after which tagged fish took 13.3 - 35.4 days to travel between Wells and Zosel dams (Fryer et al. 2016).

These types of PIT tag data will continue to inform fisheries management and research (ONA/DFO/CRITFC) on both sides of the border over the next funding period regarding the effects of temperature on Sockeye migration, especially in light of the increasing frequency and duration of heat waves (as in 2021) and drought effects. In-season PIT tag data, in conjunction with hydrometric dataloggers at dams and other key sites, would enable development of an early-warning system for projecting thermal conditions during adult migration, and stimulate a cross-border mitigation strategy for transfer of thermally-blocked fish (or their eggs) to hatcheries for emergency biological salvage.

PIT tag data will be used by ONA fisheries management to test selective harvest and brood-stock collection strategies, and assist with scientific analysis of various release strategies of hatchery outplants, including: size-at-release experiments to maximize smolt

quality, reduce precocious maturation, and track downstream survival; and seasonal release studies to assess over-wintering survival response. PIT tag data from this project will further be used to develop and test assumptions in an integrated Columbia River Life Cycle Model that will ultimately be extended to hypothetical populations of Sockeye and Chinook salmon reintroduced into the upper Columbia River (R. Bussanich, pers. comm.).