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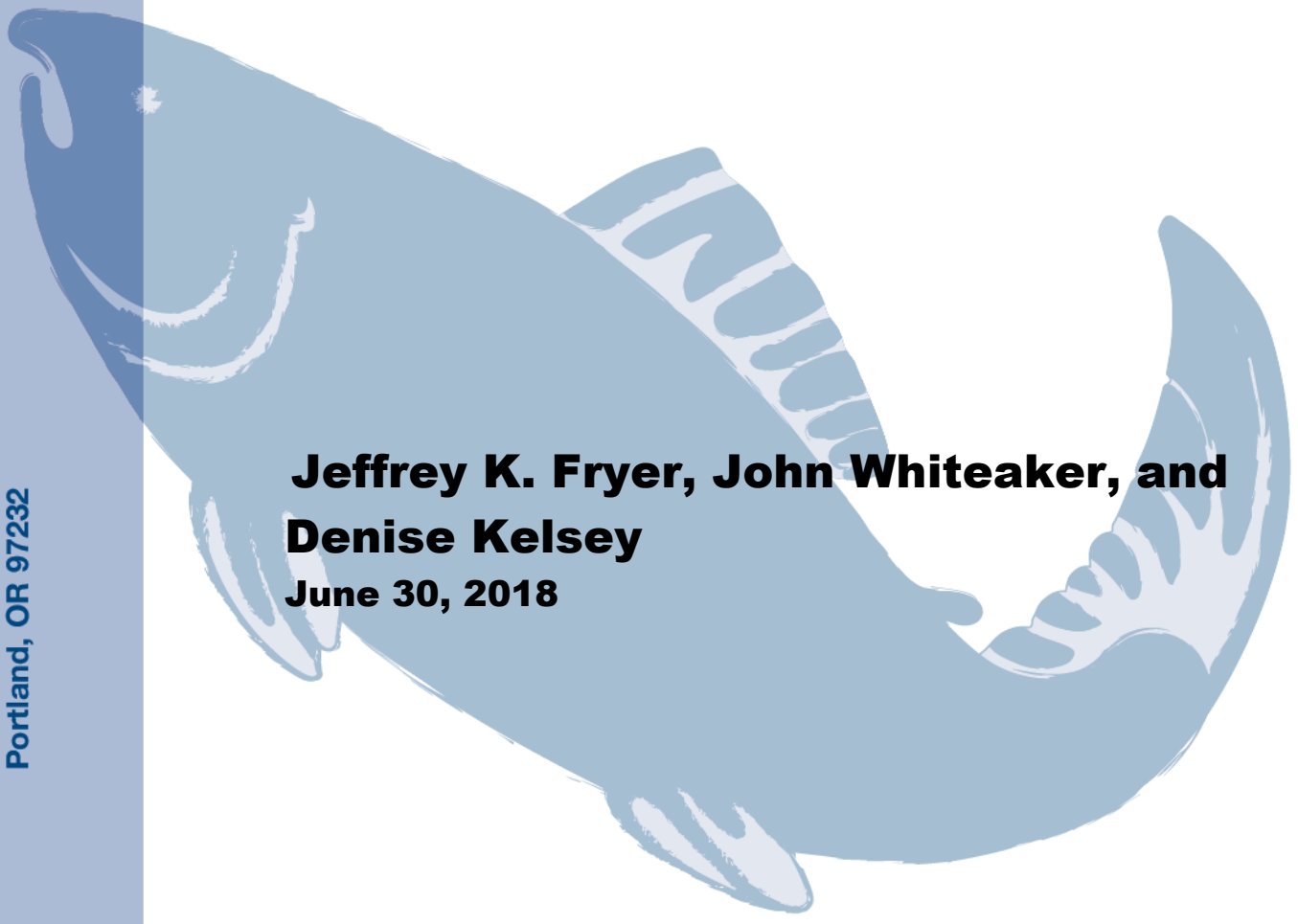
CRITFC

TECHNICAL REPORT 18-03

Upstream Migration Timing of Columbia Basin Chinook and Sockeye Salmon and Steelhead in 2016



Jeffrey K. Fryer, John Whiteaker, and Denise Kelsey

June 30, 2018

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Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-518-00, Contract 76151

Report date range: 1/16–12/16

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ABSTRACT

Between April 15 and October 14, 2016, we sampled Sockeye *(Oncorhynchus nerka)* and Chinook *(Oncorhynchus tshawytscha)* salmon as well as steelhead (*Oncorhynchus mykiss)* at the Bonneville Dam Adult Fish Facility (AFF). Fish were measured for fork length, scales were collected for analysis of age, tissue samples collected for genetic analysis, and the fish were tagged with Passive Integrated Transponder (PIT) tags. These fish were tracked upstream as they passed through sites with PIT tag antennas, including fish ladders at dams, juvenile bypasses, hatcheries, weirs, as well as in-stream antennas. Total numbers of fish tracked upstream were 1,255 spring Chinook, 876 summer Chinook, 1,265 fall Chinook, 1,610 steelhead, and 1,653 Sockeye Salmon.

Chinook Salmon median migration rates reported between mainstem dams ranged between 27.5 and 49.4 km/day. An estimated 48.1% of Spring Chinook passed into the Snake Basin upstream of Ice Harbor Dam, while an estimated 62.8% of summer Chinook passed upstream of Priest Rapids dam into the Upper Columbia Basin. Among Fall Chinook, the primary terminal area was between McNary Dam (passed by 52.1% of Fall Chinook) and Ice Harbor Dam (passed by 12.9% of Fall Chinook) and Priest Rapids Dam (passed by 7.0% of all Fall Chinook). Escapement estimates for the entire Chinook run derived from PIT tag detections result in estimates differing from those estimated by visual counts by -11.6% to +13.1% at mainstem dams.

Steelhead median migration rates reported between mainstem dams ranged from 11.2 km to 32.2 km/day. Among Steelhead classified as B-run (greater or equal to 78 cm fork length) that were last detected in terminal areas (tributaries between Bonneville and McNary Dam and above McNary Dam), 83.8% were detected in the Snake Basin. Based on the data reported, the percentage of steelhead classified as B-run at Bonneville Dam reached its highest level at 70.1% of the run in Statistical Week 41. The number of B-run steelhead peaked in Week 31 at 10,534 steelhead while the number of A-run (<78 cm) peaked in Week 31 at 15,766 fish. A total of 98 steelhead PIT tagged and tracked in 2016 (of the 1610 total, or 6.1%) were; detected moving downstream (mostly in juvenile bypasses) after spawning, recovered or detected in kelt programs, or detected moving upstream in summer/fall 2017 or in 2018, and were designated as kelt.

Sockeye median migration rates between mainstem dams ranged between 29.3 and 55.2 km/day. Escapement estimates for the entire Sockeye run derived from PIT tag detections at mainstem Columbia River dams result in estimates differing from those estimated by visual counts by -12.1% to +16.7% at Columbia River dams.

ACKNOWLEDGMENTS

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INTRODUCTION

Since 1985, the Columbia River Inter-Tribal Fish Commission (CRITFC) has, using Pacific Salmon Commission (PSC) funding, sampled Chinook *(Oncorhynchus tshawytscha)* and Sockeye *(Oncorhynchus nerka)* salmon at Bonneville Dam to determine age, length-at-age, and, in the case of Sockeye Salmon stock identification (Fryer 2009). In 2004, CRITFC took over a similar long-running steelhead (*Oncorhynchus mykiss)* sampling program at Bonneville Dam from Oregon Department of Fish and Wildlife (Whiteaker and Fryer 2008). The development and maturation of two new technologies, Passive Integrated Transponder (PIT) tags and genetic stock identification (GSI), have provided an opportunity to greatly expand the information obtained from our stock monitoring program at Bonneville Dam. PIT tag antennas are now installed in fish ladders at most mainstem Columbia and Snake River dams, as well as at dams and weirs on many of the Columbia Basin tributaries. By PIT tagging fish that we sample at Bonneville Dam, we can track tagged fish upstream providing valuable information on migration timing and survival rates. Data on the movement of PIT tagged fish through Columbia Basin receivers is readily available to all managers and researchers on a near real-time basis through the PIT Tag Information System (PTAGIS) at www.ptagis.org. The information obtained by PIT tags can be further expanded by identifying the origin of the fish using GSI. Using these two technologies it becomes possible, to determine migration timing, stray rates, and upstream survival on a stock-specific basis for Chinook and Sockeye salmon and steelhead.

The vast majority of PIT tagging in the Columbia Basin is conducted on juvenile salmonids, either at hatcheries, tributary smolt traps, or at dam juvenile bypasses. These efforts predominantly study the effects of the downstream juvenile migration, but rarely tag a sufficient number of juveniles to assess survival of returning adults as they pass Bonneville Dam and migrate to the spawning grounds. There are also many salmon stocks in the Columbia Basin which are not PIT tagged, thus it is difficult to answer questions on upstream migration timing, straying, and survival for those stocks. Because our project randomly samples adult salmon and steelhead passing the dam, this study tags salmonid stocks that have not previously been tagged and monitored.

METHODS

Sampling

Chinook and Sockeye salmon, and steelhead, were collected from April 15 through October 14, 2016, at the Bonneville Dam Adult Fish Facility (AFF), located adjacent to the Second Powerhouse at river km 235. This facility uses a weir with four pickets to divert fish ascending the Washington shore fish ladder into the AFF collection pool. An attraction flow is used to draw fish that enter the collection pool through a false weir where they then can be selected for sampling. Fish not selected, and fish that have recovered from sampling, migrate back to the Washington shore fish ladder above the pickets. We attempted to exclude minijacks (defined as Chinook spending no winters in saltwater) from our sample by not diverting Chinook Salmon into the sampling tank that were estimated to be less than 36 cm in length, and immediately releasing without sampling any fish diverted that turned out to be less than this threshold. In general, these small Chinook Salmon are excluded because sampling these fish would reduce our collection of larger Chinook, and other species, which are more important to managers. We also excluded from further analysis any Chinook, Steelhead, and Sockeye salmon that, based on scale analysis, did not spend a winter in saltwater.

Our use of the AFF is restricted by protocols established by the Fish Passage Operation and Maintenance Team (http://pweb.crohms.org/tmt/documents/fpp/2016/final/FPP16_AppG.pdf). These protocols have general restrictions on the number of salmonids we can simultaneously have in our anesthetic and recovery tanks and restrict picket lead operations at higher fish abundances. At temperatures above 21.1C, sampling is restricted to four days per week from 0600-1030 hours, the number of salmonids in the anesthetic tank is reduced and picket lead operations are changed to divert fewer fish into the AFF. Above 22C sampling is halted until temperatures drop to 21.9C. Picket lead deployment is also restricted when abundance of salmonids or shad is high.

Salmon and steelhead selected for sampling were diverted into a tank where they were anesthetized, examined for tags, fin clips, wounds, and condition. They were measured for fork length, and tissue and six scales (four scales for Sockeye) collected for later genetic and age analysis (Whiteaker and Fryer 2008, Kelsey et. al 2011). Fish were scanned for PIT tags. If no tags were detected, standard techniques were used to inject PIT tags through a needle that penetrates the fish between the posterior tip of the pectoral fin and the anterior point of the

pelvic girdle (CBFWA 1999). Tagged fish were then scanned for the PIT tag code, which was recorded if detected. If no tag was detected, no effort was made to re-tag the fish. Data on each PIT tagged fish was uploaded to www.ptagis.org.

Upstream Detection

As tagged salmon and steelhead continued their migration they were detected by PIT tag receivers located in the adult fish ladders at major Columbia Basin mainstem dams (Bonneville, The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams on the Columbia River; Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams on the Snake River) as well as in numerous tributaries and hatcheries in the Columbia Basin (Appendix - Table A1 and Figure A1). PIT tag detection data from these sites is uploaded to www.ptagis.org, which is then accessible to users of the site.

The vast majority of detections are at fish ladders of Columbia and Snake river dams. At these ladders, PIT tagged salmon typically pass by two or more weirs with one or more antennas. Salmon can be detected more than once as the pass over or through each weir. Each individual detection will subsequently be referred to as a "weir detection". The combination of all detections at the multiple weirs at a given site, regardless of the time between those detections, will subsequently be referred to as a "site detection". For example, the configuration of PIT tag antennas at Rock Island Dam is shown in Figure 1. Salmon or steelhead can pass this dam using any of three fish ladders. Each ladder has two weirs (referred to as baffles 2 and 4 at each ladder) with PIT tag detection and two antennas in each weir (numbered as 01 to 0C in hexadecimal format). If a fish ascended the left ladder and generated two detections at Baffle 2 and three at Baffle 4 (the word "baffle" and "weir" is interchangeable), this is five weir detections, but only one site detection (Rock Island Dam).

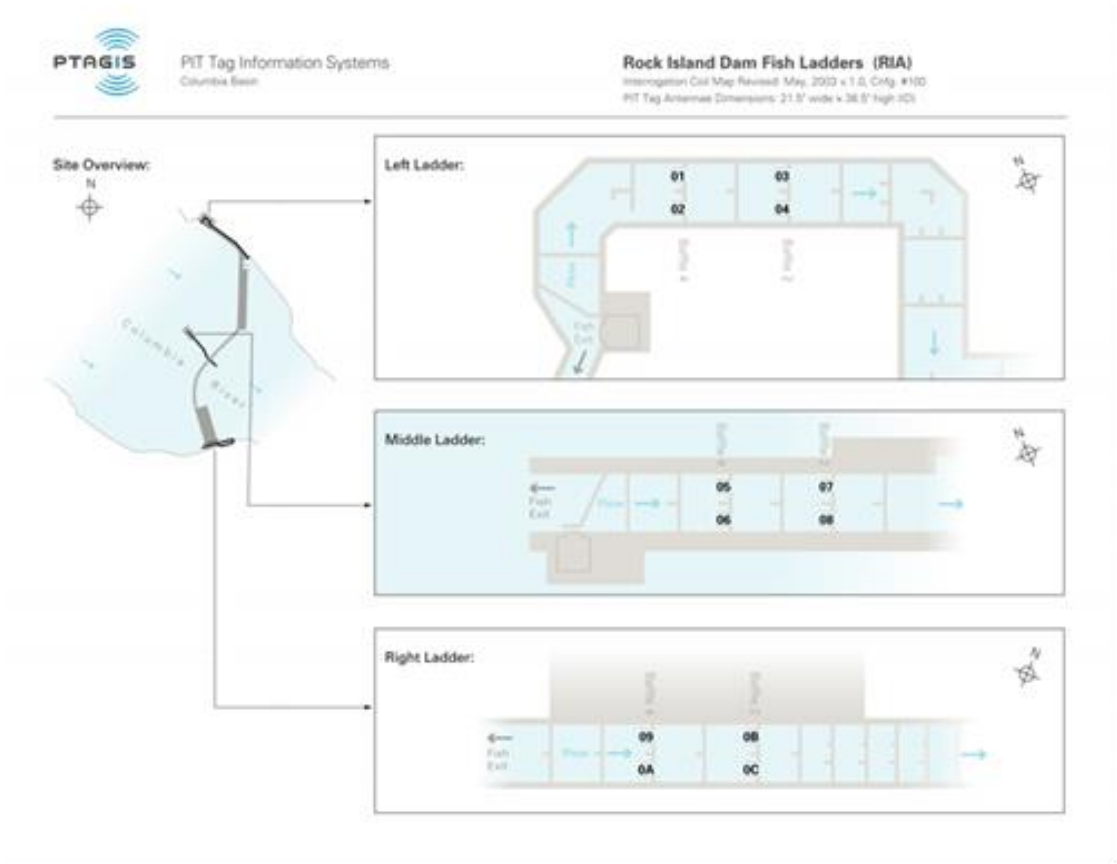

Figure 1. Example PIT tag detection configuration at Rock Island Dam showing two adjoining antennas at two weirs in each fish ladder. (Figure from www.ptagis.org.)

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.

PIT tag detection antennas in fish ladders are always placed in at least two

locations in relatively close proximity. PIT tag interrogation maps (available at www.ptagis.org) indicate that these antennas are placed at vertical slots, weirs, or pools. To simplify the nomenclature, these locations will all subsequently be referred to as weirs.

Age Analysis

Visual assessment of scale patterns was used to determine age composition through techniques developed for the Bonneville Stock Sampling project *(*Whiteaker and Fryer 2008, Kelsey et al. 2011*).* We used the European method for fish age description (Koo 1962) where the number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The number following the period indicates the number of winters a fish spent in saltwater. Total age, therefore, is equal to one plus the sum of both numerals. If poor scale quality, particularly in the freshwater prevents age determination in all scales collected from a particular fish, no age is assigned. The exception is steelhead, where if saltwater age can be reliably determined, the age is designated as r.y where y is the saltwater age and "r" stands for regenerated. Any salmonid (Chinook, steelhead, or Sockeye) judged by scale analysis to have spent no winters in saltwater were excluded from future analysis.

The origin and age of Chinook and steelhead previously PIT tagged in other projects and sampled in this project could be determined by querying PTAGIS for the tag code, thus providing a validation of age since release. Very few Sockeye Salmon are tagged as juveniles making it difficult to sample sufficient returning adults to validate ages for this species.

Escapement

Chinook and Sockeye salmon escapement at upstream detection sites were estimated as:

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

where N was the estimated escapement at a particular upstream site, *i* was the week at Bonneville Dam, B_i was the weekly count of fish passing Bonneville Dam in week *i*, T_i was the number of fish PIT tagged at Bonneville Dam in week *i,* and R_i was the number of PIT tag detections at the dam where escapement was being estimated of those fish tagged in week *i.* Estimated dam counts using PIT tag data

were compared with dam counts made at fish ladder viewing windows or weir counts. No estimates were made for steelhead, due to the fact that many overwinter between dams on their upstream migration making it difficult to compare PIT tag estimates with dam counts.

Migration Rates and Passage Times

Run timing was estimated using the date and time of detection between sites. Migration rates were calculated between sites as the time between the last detection at the first site and the first detection at the upper site. 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.

Upstream Age and Length-at-Age Composition Estimates

The age composition at upstream locations was calculated as:

$$T_j = \sum_k A_{j,k} * W_k$$

where T_j was the estimate for age group j at a particular location, $A_{j,k}$ was the percentage of fish for age group j in week k at Bonneville Dam (such that $\sum_j A_{j,k} = 1$) and W_k was the percentage of the run that passed Bonneville Dam in week k.

Fallback

Three methods were used to determine 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 was if an adult salmon or steelhead was detected in the juvenile bypass system. However, on the Columbia River, only Bonneville, John Day, McNary, Rocky Reach dams have juvenile bypass system PIT detection capability while all four dams in the Snake River have juvenile detection. Furthermore, there is no detection at any dam for fish falling back over the spillway or through the navigation locks or turbines. Therefore, a second method of estimating fallback was to look at each dam for fish detected at an "upper" weir followed by detection at a "lower" weir separated by more than two hours. At McNary and Bonneville dams, the upper detection weir is at the fish counting window (which are believed to detect all passing PIT tagged fish), while the PIT tag detectors near the entrance to the fish ladder. At Priest Rapids, Rock Island, Rocky Reach, and Wells dams, there are only two weirs with PIT tag detectors in each fish ladder so these were designated as the upper and lower

detection weirs, even if they are not at the top or bottom of the ladders. At McNary and Bonneville dams, detection histories of fish detected at multiple ladders were also reviewed (MC1 and MC2 for McNary and BO1 and BO4 for Bonneville (http://www.ptagis.org for maps of sites). Finally, a third method of defining fallback was ascertained by fish that passed an upstream PIT tag detector at a given dam, then were next observed at a site downstream of the dam in question. These methodologies will underestimate fallback as they do not include fish that fall back over a dam and are not subsequently detected.

Adult steelhead downstream movements on or after March 31, 2016 were not considered fallbacks; rather they were considered kelts on their way downstream. Some steelhead move out of the system before April 1st, and with more detections sites at dams and in-stream arrays placed in tributaries in the last few years, it has been easier to determine more kelts between March 1st and April 1st. Consideration of these fish as kelts versus assigning them as fallbacks is now part of the analysis process.

Night Passage

Fish counting at Columbia Basin dams is not consistent between dams. Salmonids passing Corps of Engineers-operated dams (Bonneville, The Dalles, McNary, Ice Harbor, Lower Monumental, Little Goose and Lower Granite are counted live by observers stationed at fish ladder viewing windows from 0400 to 2000 PST with most supplemented with video counts of passage between 2000 and 0400 from June through September (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2016/index.html) during the months salmonids are tagged by this study. Salmonids passing Priest Rapids, Rock Island, Rocky Reach, and Wells dams are all counted 24 hours per day from recorded video. Tributary dam passage is estimated using 24 hour recorded video and/or counts at adult fish traps.

Night passage rates (where night is defined as 2000 to 0400 PST) were calculated based on the last time fish were detected in a fish ladder for all dams passed. This last time detected at a ladder was used as an approximation for passage time at the counting window, as the uppermost weir is closest to the fish counting window at nearly all ladders. (For maps of site configeration for mainstem dams see http://www.ptagis.org).

Steelhead B-Run Analyses

For management purposes Columbia Basin steelhead are commonly referred to as being either A- or B-run. B-run steelhead are defined as greater than or equal to 78 cm in length, while A-run steelhead are under 78 cm (Busby et al. 1996). B-run steelhead are generally older, spending three winters in saltwater compared to one or two winters for A-run steelhead, and generally pass Bonneville Dam after August 25, while A-run steelhead generally pass earlier (Busby et al. 1996). Upstream, run timing separation is not observed and the groups are separated based on size and age (Busby et al. 1996). B-run steelheads are thought to only be produced in the Clearwater, Middle Fork Salmon and South Fork Salmon rivers (Busby et al. 1996).

Analyses of B-run steelhead consisted of comparing the timing of the A- and B-runs at Bonneville Dam with the established August 25 criteria, comparing the length group of sampled steelhead with where at which they were last detected, and looking at the destination of B-run-sized steelhead by statistical week sampled at Bonneville Dam.

Steelhead (Kelt) Analyses

Steelhead differ from other salmonids studied in this project for they are capable of spawning multiple times. After spawning in late winter or early spring, some steelhead will migrate downstream to the ocean to feed; these fish are known as kelt. The fish that survive return in a subsequent spawning season. We considered all steelhead detected moving downstream (mostly in juvenile bypasses) on or after March 31, the year after tagging, to be kelt and tabulated where they were last detected. We also careful consider fish moving between March 1st and April 1st through juvenile bypasses and the Bonneville Corner Collector as kelts, especially when tag detections indicate they have visited upper reaches of tributaries in late winter early spring.

RESULTS-CHINOOK

Sample Size

A total of 1,256 spring Chinook, 895 summer Chinook, and 1,275 fall Chinook Salmon were sampled in 2016 (Tables 1-3) between April 15 and October 14, 2016. Sampling restrictions due to water temperatures exceeding 21.1C reduced sampling days and hours during Statistical Week 31 of the summer Chinook run and weeks 32-36 of the fall Chinook run. In many years we miss entire weeks of sampling due to temperature restrictions (e.g. Fryer et al. 2017), such was not the case in 2017. Restrictions on the number of pickets which could be lowered to divert fish into the AFF due to fish abundance affected sampling in weeks 23-28 and 37-39. A total of 1,239 spring Chinook, 867 summer Chinook, and 1,274 fall Chinook Salmon were PIT tagged (Tables 1-3). After adding previously tagged fish (which were sampled and therefore identified for the tracking study and included in our sample), subtracting fish that were not detected after release (due to shed tags, mortalities, malfunctioning tags, or PIT tagged Chinook missing PIT tag antennas), and excluding 6 fall Chinook classified as minijacks, the numbers of Chinook tracked upstream consisted of 1,255 spring Chinook, 876 summer Chinook, and 1,265 fall Chinook Salmon (Table 1-3).

Table 1. Number of PIT tagged spring Chinook Salmon at Bonneville Dam and then tracked, by date and statistical week, in 2016.

Sample Dates	Week	Sampled	Tagged	Previously Tagged	Mortalities	Not Detected After Release	Total Tracked	Days Sampling Restrictions in Effect		
								Reduced Sampling-Temperature	Reduced Sampling-Shad or Salmonid Abundance	No Sampling-Temperature
4/15	16	8	8	0	0	0	8	0	0	0
4/18-22	17	111	111	0	0	0	111	0	0	0
4/26-29	18	121	119	2	0	0	121	0	0	0
5/2-6	19	298	297	1	0	0	298	0	0	0
5/9-13	20	175	169	6	0	0	175	0	0	0
5/16-20	21	286	283	3	0	1	285	0	0	0
5/23-27	22	227	223	4	0	0	227	0	0	0
5/31	23	30	29	1	0	0	30	0	0	0
Total		**1256**	**1239**	**17**	**0**	**1**	**1255**	**0**	**0**	**0**

Table 2. Number of PIT tagged summer Chinook Salmon tracked at Bonneville Dam by date and statistical week in 2016.

Sampling Dates	Week	Sampled	Tagged	Previously Tagged	Mortalities	Not Detected After Release	Total Tracked	Days Sampling Restrictions in Effect		
								Reduced Sampling-Temperature	Reduced Sampling-Shad or Salmonid Abundance	No Sampling-Temperature
6/1-6/3	23	99	95	4	0	0	99	0	2	0
6/6-6/10	24	148	141	7	1	0	147	0	5	0
6/13-6/18	25	95	80	1	0	1	80	0	5	0
6/20-6/24	26	78	78	0	0	0	78	0	5	0
6/27-7/1	27	110	110	0	0	0	110	0	5	0
7/4,6-8	28	94	92	2	0	0	94	0	2	0
7/11-7/15	29	87	87	0	2	0	85	0	0	0
7/18-7/22	30	104	104	0	0	0	104	0	0	0
7/25-29	31	80	80	0	1	0	79	4	0	0
Total		**895**	**867**	**14**	**4**	**1**	**876**	**4**	**24**	**0**

Table 3. Number of PIT tagged fall Chinook Salmon tracked at Bonneville Dam by date and statistical week in 2016.

Sampling Dates	Week	Sampled	Tagged	Previously Tagged	Mortalities	Not Detected After Release	Total Tracked	Days Sampling Restrictions in Effect		
								Reduced Sampling-Temperature	Reduced Sampling-Shad or Salmonid Abundance	No Sampling-Temperature
8/1-4	32	60	59	1	0	0	60	4	0	1
8/8-11	33	71	71	0	1	1	69	4	0	1
8/15-18	34	83	83	0	1	0	82	4	0	1
8/22-25	35	139	139	0	2	0	137	4	0	1
8/30-31,9/1-2	36	164	164	0	0	4	160	4	0	1
9/6-9	37	169	169	0	0	1	168	0	4	0
9/12-16	38	248	248	0	0	0	248	0	5	0
9/19-20,22-23	39	117	117	0	0	0	117	0	2	0
9/26-30	40	120	120	0	0	0	120	0	0	0
10/3-7	41	73	73	0	0	0	73	0	0	0
10/11,13,14	42	31	31	0	0	0	31	0	0	0
Total		**1275**	**1274**	**1**	**4**	**6**	**1265**	**20**	**11**	**5**

Distribution of Sample

The weekly distribution of Chinook sampled at Bonneville Dam differed from the actual run distribution (Figures 2-4) less than in many previous years due to continuous trap operations in 2016. In many past years, high water temperatures have shut down trapping for days or weeks; this did not occur in 2016. For spring Chinook, the largest deviations between weekly sample proportion and run proportion was Week 19. For summer Chinook, the largest deviations were in weeks 25 and 26 due to limitations in deployment of picket leads based on shad abundance protocols, as well as Sockeye sampling efforts. Fall Chinook sampling was limited in Week 37 by limitation in deploying picket leads due to Chinook and steelhead abundance protocols.

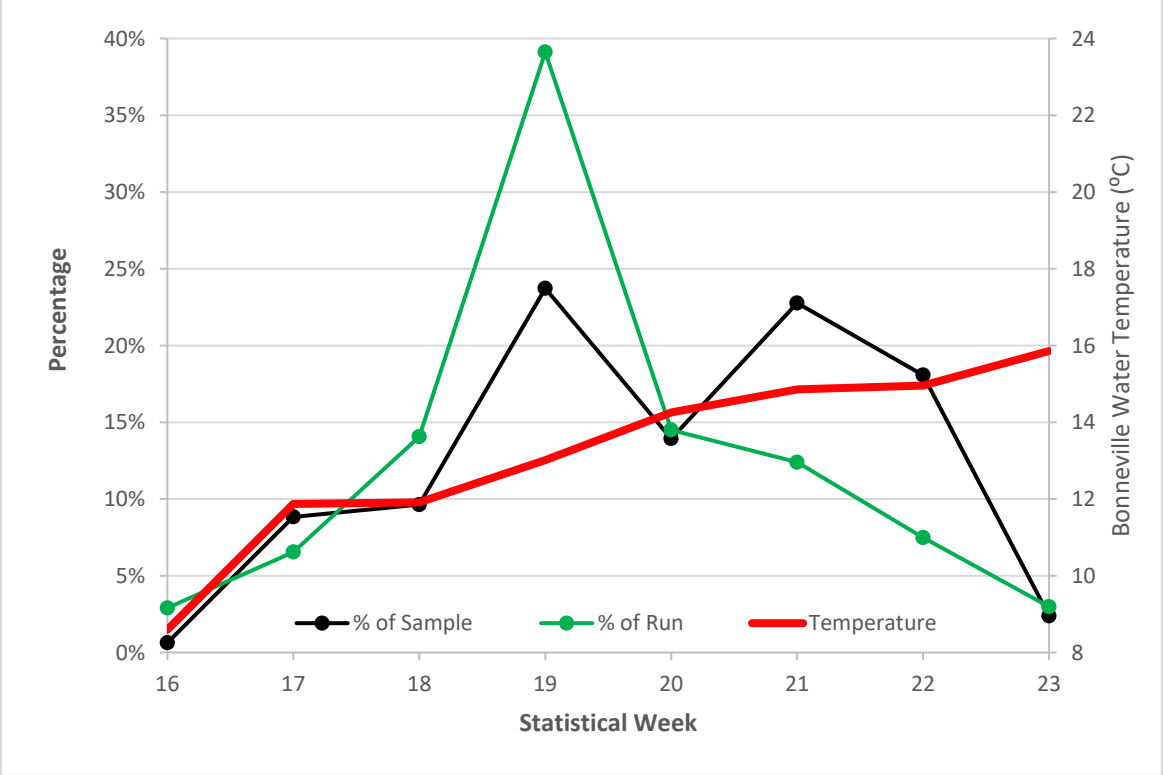

Figure 2. The weekly spring Chinook sample and run as a percentage of the total sample and run size at Bonneville Dam in 2016.

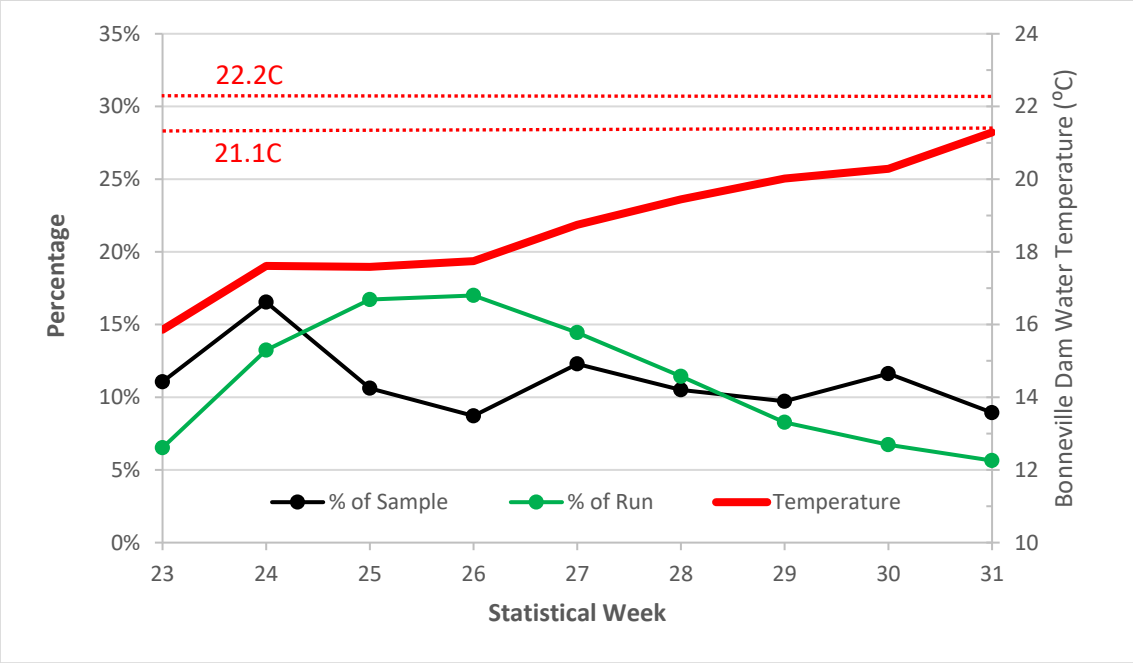

Figure 3. The weekly summer Chinook sample and run as a percentage of the total sample and run size at Bonneville Dam in 2016. Bonneville trap regulations require reduced sampling at 21.1C with sampling halted at 22.2C.

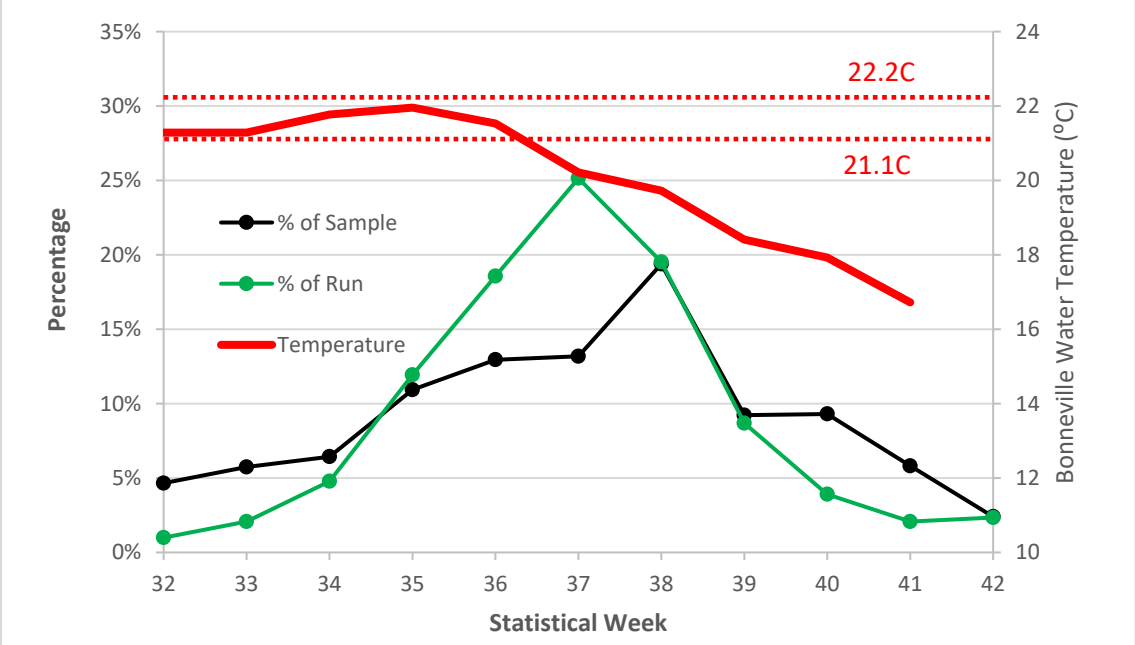

Figure 4. The weekly fall Chinook sample and run as a percentage of the total sample and run size at Bonneville Dam in 2016. Bonneville trap regulations require reduced sampling at 21.1C with sampling halted at 22.2C.

Detection Numbers

The tracking of 1255 spring Chinook generated 87460 weir detections, which were grouped into 7972 site detections at 110 sites. The 876 summer Chinook generated 51009 weir detections, grouped into 5829 site detections at 76 sites, and the 1265 fall Chinook generated 49809 weir detections grouped into 5235 site detections at 49 sites. Maps found in the Appendix (Figures A1-A15, and A21) show the sites and the categorical ranges of detection numbers at the sites throughout the Columbia Basin. Note that the number of Chinook tracked in each run is determined by the migration timing at Bonneville, with the spring Chinook run ending May 31st, the summer Chinook running from June 1 through July 31st, and the fall Chinook run starting August 1st (FPC 2017).

Age Analysis

We are able to validate our scale aging techniques by using fish sampled at Bonneville that were previously PIT tagged as juveniles for other projects or hatchery programs. In 2016, we had ageable scale patterns from 12 spring Chinook, 8 summer Chinook, but no fall Chinook, PIT tagged as juveniles that were sampled as returning adults by this project. Of these, all 12 spring Chinook and 7 out of the 8 summer Chinook were aged correctly. Only the total age was compared, as it is not possible to separate freshwater and saltwater age using PIT tag data.

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Spring Chinook Salmon that traveled upstream of McNary Dam were predominantly last detected at or upstream of Ice Harbor Dam in the Snake River (Table 4, Figures 5 and 6), while summer Chinook were primarily bound for the Columbia River upstream of Priest Rapids Dam (Table 4, Figures 5 and 7). Fall Chinook were primarily last detected at areas between McNary and Ice Harbor/Priest Rapids dams (the location of Ringold and Priest Rapids hatcheries, which rear fall Chinook Salmon) as well as the Hanford Reach spawning area (Table 4, Figures 5 and 8). The percentage of all Chinook that ultimately passed Ice Harbor Dam peaked during the spring Chinook migration, Chinook passing Priest Rapids Dam peaked during the summer Chinook migration, and the percentage last detected between McNary and Ice Harbor/Priest Rapids dams peaked during the fall Chinook migration (Figure 5). The percentage last detected downstream of McNary Dam during the early fall Chinook migration with another peak at the beginning of the spring Chinook migration.

Table 4. Percentage of spring, summer, and fall Chinook Salmon tracked from Bonneville Dam detected at upstream dams in 2016 by sex as estimated by GSI. (Note that GSI was not determined for all Chinook.)

Dam	Spring Chinook			Summer Chinook			Fall Chinook		
	% Female	% Male	% Total	% Female	% Male	% Total	% Female	% Male	% Total
Bonneville									
The Dalles	74.7	79.8	77.4	84.1	88.7	86.9	67.4	72.2	69.6
McNary	63.0	63.4	63.4	72.8	79.3	77.1	49.2	54.3	52.1
Priest Rapids	9.2	9.0	9.4	59.1	65.5	62.8	4.8	8.6	7.0
Rock Island	9.1	8.8	9.2	57.8	62.7	60.6	2.3	4.8	4.0
Rocky Reach	3.9	5.5	4.8	45.0	51.6	48.9	2.0	4.2	3.5
Wells	3.0	5.2	4.3	40.0	46.0	43.6	0.8	2.7	2.2
Ice Harbor	48.0	48.5	48.1	10.7	12.9	12.3	9.1	16.0	12.9
Lower Monumental	47.2	47.5	47.2	10.7	11.9	11.8	9.0	15.8	12.7
Little Goose	45.5	45.8	45.6	10.3	11.2	11.3	8.1	15.4	12.0
Lower Granite	43.9	45.3	44.4	10.1	11.1	11.1	7.7	14.6	11.4

The GSI results suggested the percentage of male Chinook detected increased upstream from Bonneville Dam (Table 5). For spring Chinook, the percentage of males exceeded the 52.9% estimated at Bonneville Dam at 8 out of the 10 upstream dams. For both summer and fall Chinook, all 10 dams upstream of Bonneville Dam had higher percentages of males than at Bonneville Dam. Despite these higher percentages of males at upstream dams for spring and summer Chinook, only summer Chinook at McNary Dam had a statistically significant difference ($p=0.05$). For fall Chinook, this difference was significant ($p<0.03$) at all dams except McNary and The Dalles.

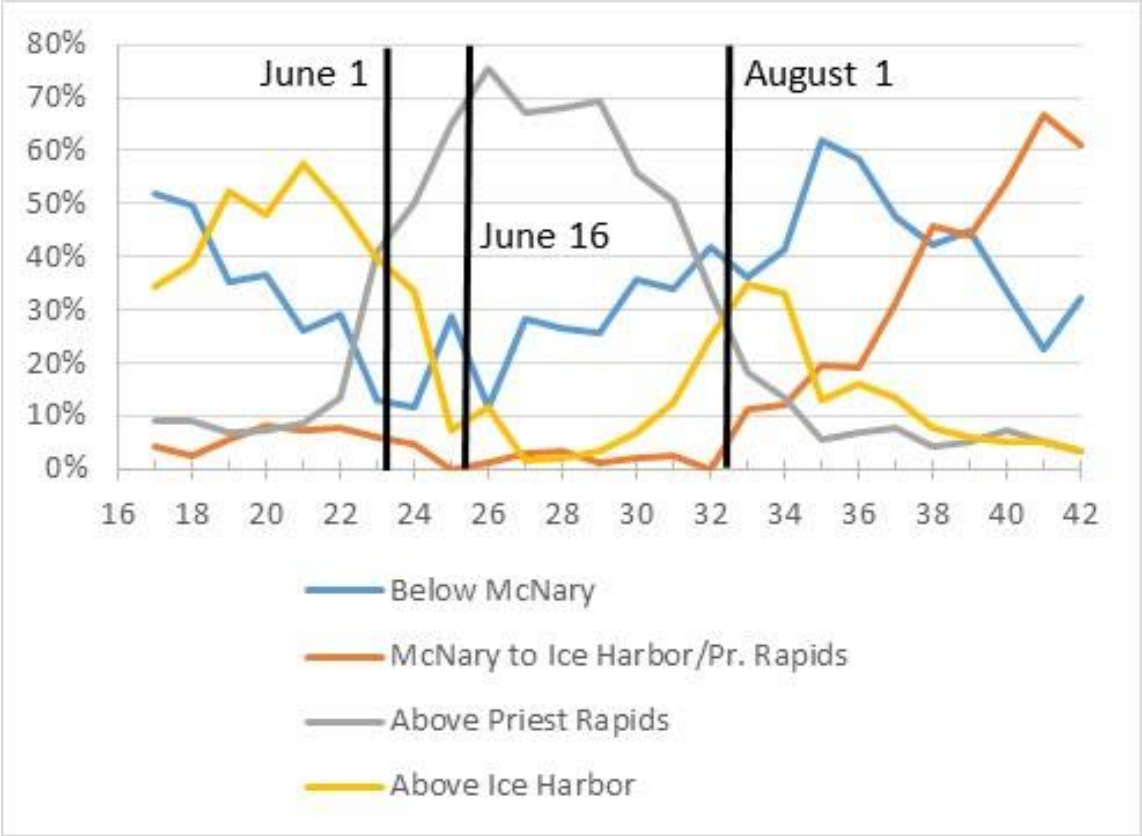

Figure 5. Distribution of final detection areas of the Columbia Basin by statistical week for Chinook Salmon PIT tagged at Bonneville Dam in 2016. Dates used to differentiate spring, summer, and fall Chinook are shown.

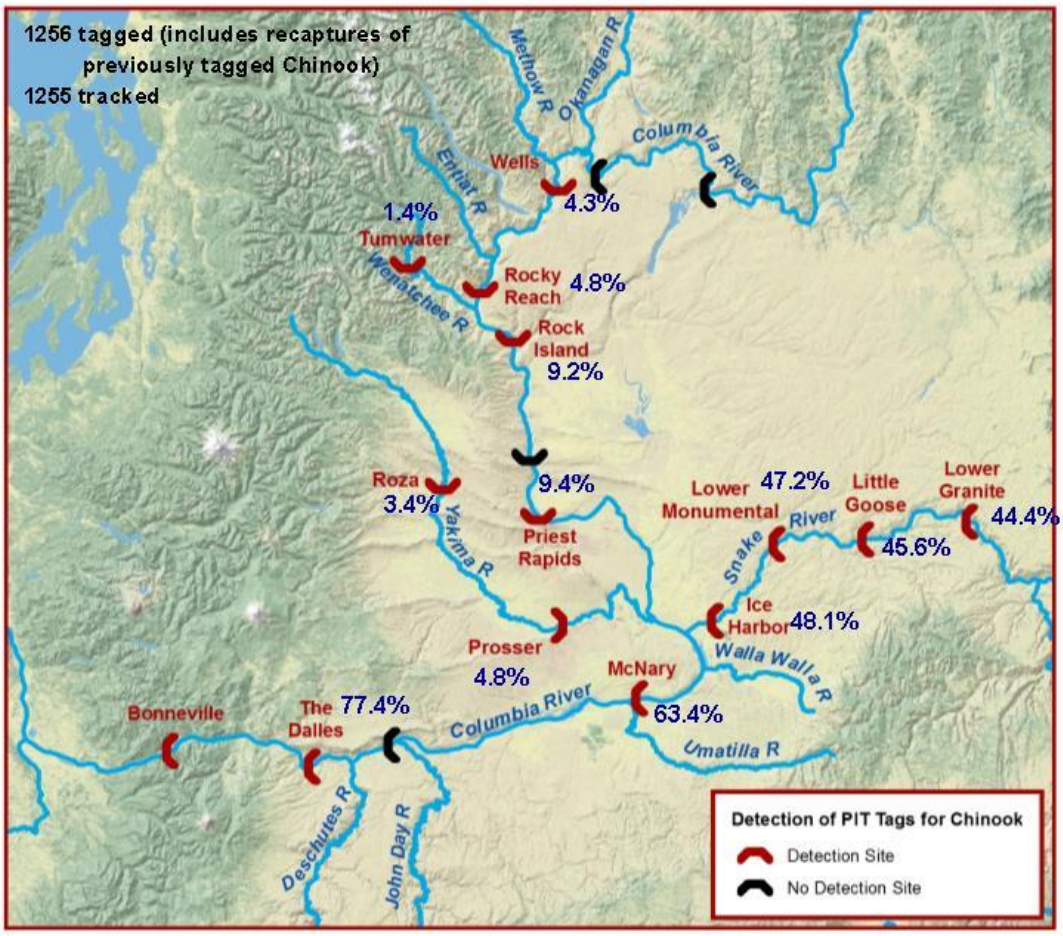

Figure 6. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of spring Chinook Salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2016.

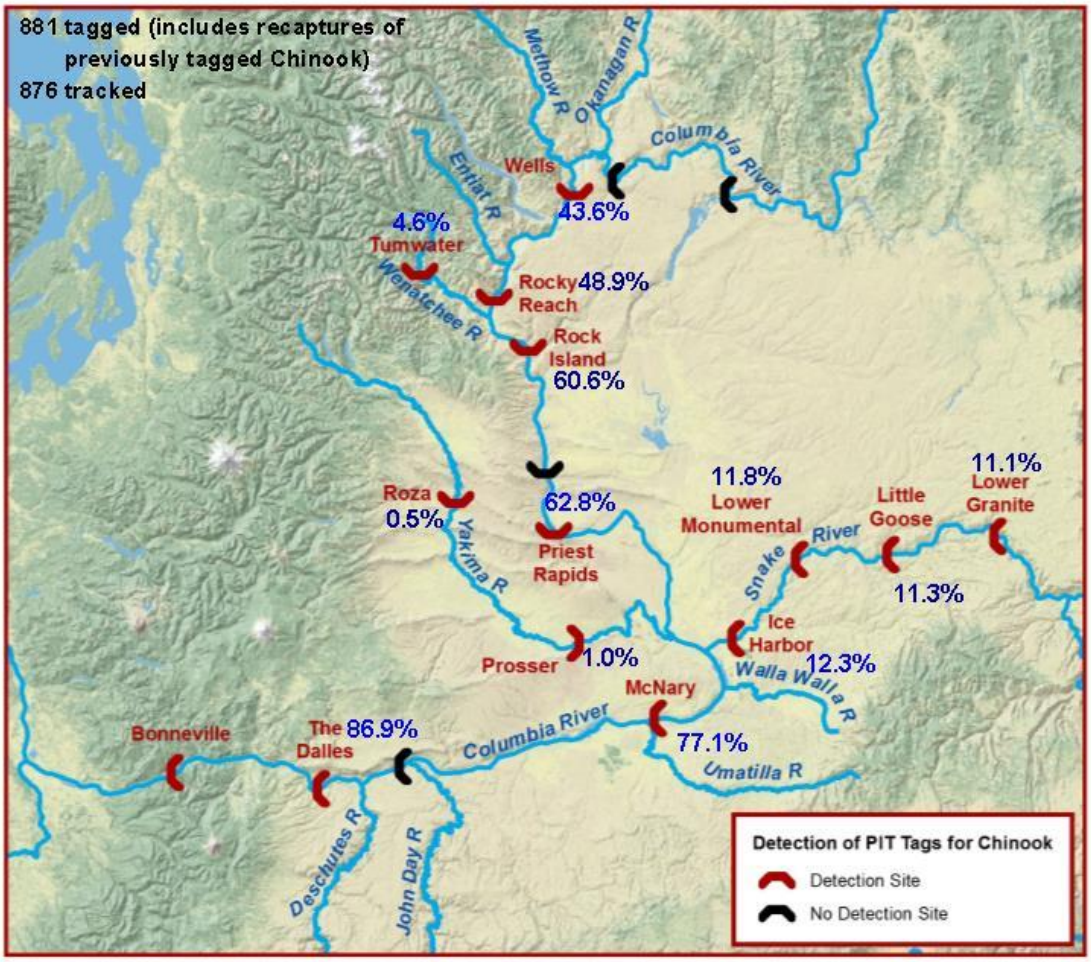

Figure 7. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of summer Chinook Salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2016.

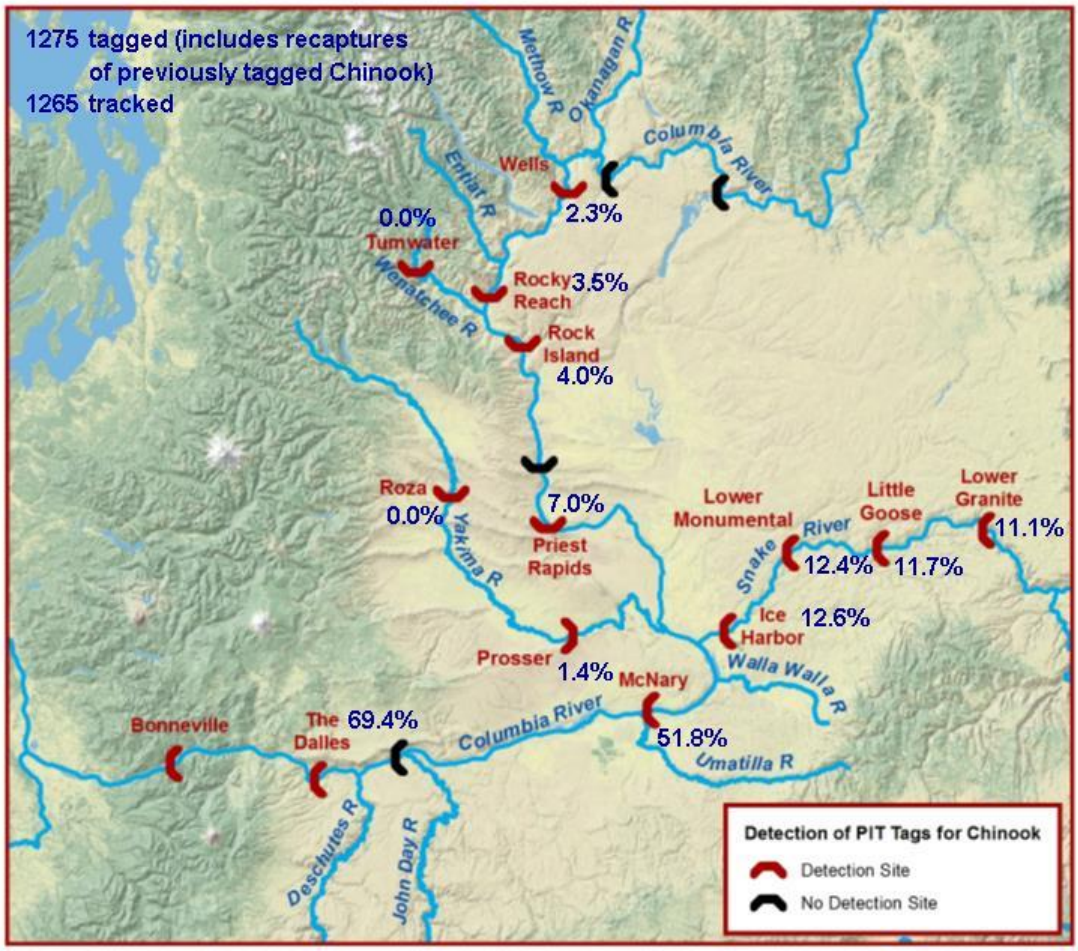

Figure 8. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fall Chinook Salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2016. Fifteen minijacks sampled and tagged are excluded.

Table 5. Percentage males at upstream dams by run as estimated by GSI in 2016.

Dam	Spring	Summer	Fall
Bonneville	52.9%	52.6%	54.7%
The Dalles	54.8%	53.9%	56.4%
McNary	53.2%	54.8%	57.1%
Priest Rapids	50.5%	55.0%	72.4%
Rock Island	50.6%	54.5%	79.9%
Rocky Reach	59.6%	56.0%	77.3%
Wells	65.4%	55.6%	96.4%
Ice Harbor	53.6%	63.0%	69.4%
Lower Monumental	53.5%	61.0%	70.1%
Little Goose	53.4%	60.6%	70.9%
Lower Granite	54.1%	60.7%	68.9%

The mean percentage of PIT tagged Chinook Salmon documented passing a dam without detection, excluding Rock Island Dam, was 0.2% for spring Chinook, 0.3% for summer Chinook, and 0.4% for fall chinook (Table 6). At Rock Island Dam, the rate for missed tags ranged from 4.5% for fall Chinook to 19.3% for spring Chinook. High rates of missed PIT tagged fish at Rock Island Dam have also been observed in other years and are likely attributable to antenna size and electrical noise (Fryer et al. 2011). Bonneville, The Dalles, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams all have navigation locks where it is possible that PIT tagged salmon could pass upstream undetected.

Table 6. Percentage of Chinook Salmon detected upstream that missed detection at mainstem dams in 2016.

Dam	Spring	Summer	Fall
Bonneville	0.0%	0.0%	0.0%
The Dalles	0.1%	0.1%	0.3%
McNary	0.1%	0.9%	0.8%
Priest Rapids	0.8%	0.4%	0.0%
Rock Island	19.3%	5.0%	4.5%
Rocky Reach	1.5%	0.0%	0.0%
Wells	0.0%	0.0%	4.0%
Ice Harbor	0.7%	0.8%	0.6%
Lower Monumental	0.2%	0.9%	1.2%
Little Goose	0.0%	0.0%	0.0%
Lower Granite	0.0%	0.0%	0.0%
Weighted Mean (by sample size) excluding Rock Island Dam	**0.2%**	**0.3%**	**0.4%**

Escapement estimates based on PIT tags greatly underestimated spring Chinook upstream of Priest Rapids Dam when compared to viewing window counts, while McNary, Ice Harbor, Lower Monumental, Little Goose and Lower Granite dams differed by 3.2% or less (Table 7). Summer Chinook counts differed by 11.3% or less between the two methods, with the exception of Wells Dam at 20.7%. Fall Chinook counts deviated from visual counts by up to 84.4%; however, for all Chinook counts deviated by 13.1% or less (Table 7).

Table 7. Spring, summer, fall, and total Chinook Salmon escapement at Columbia Basin mainstem dams upstream of Bonneville Dam in 2016. Estimates are from both PIT tag recoveries and dam counts (FPC 2017) and the differences between the two estimates are estimated.

	Spring Chinook Salmon			Summer Chinook Salmon		
Site	Viewing Window Count	PIT Tag Estimate	Percent Difference	Viewing Window Count	PIT Tag Estimate	Percent Difference
The Dalles	115,503	114,875	-0.5%	104,564	113,403	8.5%
McNary	94,565	94,015	-0.6%	90,395	100,594	11.3%
Priest Rapids	17,846	13,886	-22.2%	85,414	81,948	-4.1%
Rock Island	19,361	13,690	-29.3%	82,687	79,087	-4.4%
Rocky Reach	9,800	7,156	-27.0%	61,386	63,758	3.9%
Wells	12,622	6,370	-49.5%	47,138	56,889	20.7%
Ice Harbor	72,513	71,355	-1.6%	15,518	15,991	3.1%
Lower Monumental	72,381	70,054	-3.2%	14,804	15,435	4.3%
Little Goose	68,962	67,587	-2.0%	14,399	14,729	2.3%
Lower Granite	67,530	65,940	-2.4%	14,223	14,524	2.1%
	Fall Chinook Salmon			**All Chinook Salmon**		
The Dalles	365,023	344,049	-5.7%	585,090	572,327	-2.2%
McNary	264,661	256,628	-3.0%	449,621	451,238	0.4%
Priest Rapids	44,517	34,869	-21.7%	147,777	130,703	-11.6%
Rock Island	20,229	19,906	-1.6%	122,277	112,682	-7.8%
Rocky Reach	15,066	17,412	15.6%	86,252	88,325	2.4%
Wells	6,062	11,177	84.4%	65,822	74,436	13.1%
Ice Harbor	49,779	62,348	25.3%	137,810	149,695	8.6%
Little Goose	48,128	61,385	27.5%	135,313	146,873	8.5%
Lower Monumental	45,797	57,860	26.3%	129,158	140,176	8.5%
Lower Granite	47,080	55,145	17.1%	128,833	135,609	5.3%

Between 2.8% and 5.4% of spring Chinook (as determined by tagging dates at Bonneville Dam) passing dams at or upstream of Priest Rapids Dam would have been counted as summer Chinook at those dams compared to 0.8% to 1.1% for dams at or upstream of Ice Harbor Dam (Table 8). Summer Chinook were much more likely to be misclassified at upstream sites, with up to 33.8% being misclassified as spring Chinook at Lower Monumental, while only up to 2.9% misclassified as summer Chinook at Wells Dam. Up to 36.7% of the fall Chinook were misclassified as summer Chinook at Wells Dam.

Table 8. Percentage of Chinook sampled at Bonneville Dam as one race (as determined by run timing) that passed upstream dams as another race (as determined by run timing) in 2016.

Last Date Spring Run	First Date Fall Run	Race at Bonneville	Spring	Summer	Summer	Fall
		Race at Dam Listed Below	Summer	Spring	Fall	Summer
May 31	August 1	Bonneville				
June 3	August 4	The Dalles	0.1%	4.7%	0.9%	1.4%
June 8	August 9	McNary	1.0%	9.3%	1.6%	2.5%
June 13	August 14	Priest Rapids	2.8%	5.6%	1.5%	14.0%
June 17	August 18	Rock Island	3.5%	6.1%	1.6%	18.8%
June 19	August 20	Rocky Reach	3.4%	4.6%	2.2%	26.2%
June 28	August 29	Wells	5.4%	14.2%	2.9%	36.7%
June 11	August 12	Ice Harbor	0.8%	31.9%	0.7%	1.8%
June 13	August 14	Lower Monumental	0.9%	33.8%	1.4%	1.2%
June 15	August 16	Little Goose	1.1%	31.5%	0.8%	1.2%
June 17	August 18	Lower Granite	1.0%	9.3%	1.6%	2.5%

Dam escapement estimates for three tributary dams (Tumwater Dam on the Wenatchee River and Prosser and Roza dams on the Yakima River), each with more than 20 detections, are found in Table 9 alongside estimates using visual counts. Chinook passing all three sites were primarily spring or summer Chinook (Figure 9).

Table 9. Estimated 2016 Chinook Salmon escapement, as estimated using PIT tag detections, to Tumwater, Prosser, and Roza dams.

Location and River	Number of Tag Detections	Escapement Estimate from Visual Counts	Estimated Escapement Using PIT Tags	Percent Difference
Tumwater Dam	22	7,686	8,026	4.5%
Prosser Dam	69	12,410	15,422	24.3%
Roza Dam	54	5,361	5,708	6.5%

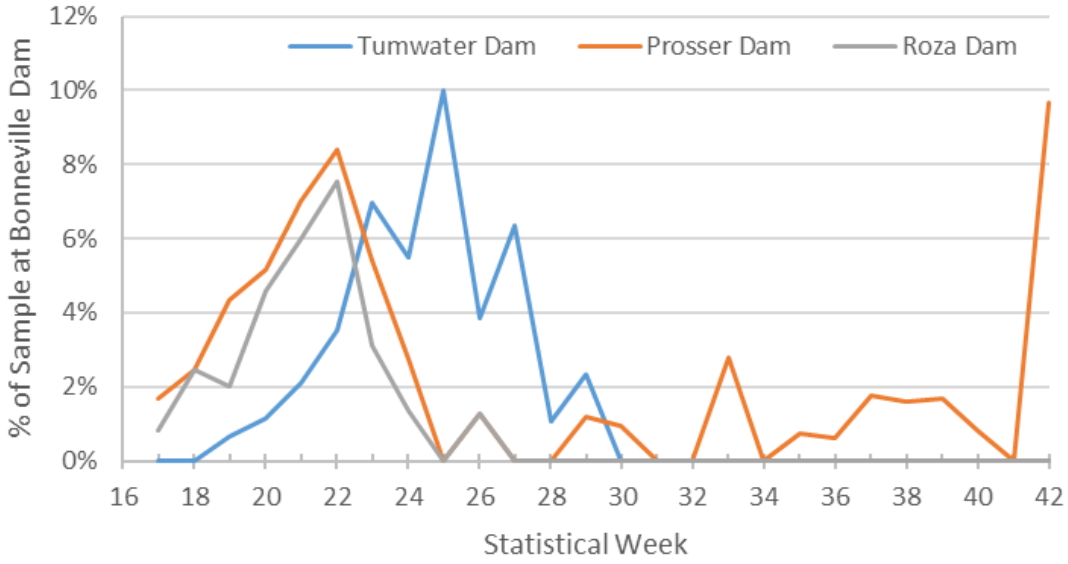

Figure 9. Percentage of Chinook Salmon by statistical week tagged at Bonneville Dam in 2016 destined for the Tumwater Dam (Wenatchee River), Prosser Dam (Yakima River) and Roza Dam (Yakima River) based on upstream PIT tag detections.

Migration Rates and Passage Time

Chinook migration rates between mainstem dams ranged between 27.5 and 49.4 km/day (Table 10). Migration rates to and between tributary sites were generally less than those in the mainstem Columbia and Snake rivers (Table 10).

Among the mainstem Columbia and Snake River dams, Chinook Salmon had the greatest median dam passage time (as determined by minutes between first detection time and last detection time at a dam) at Lower Granite, Wells, McNary, Tumwater, and Rocky Reach dams (Table 11). At Lower Granite, McNary, and Rocky Reach dams, there is a greater distance between the furthest downstream and furthest upstream PIT tag detection antennas than at other dams; conversely, the distance between the PIT tag detection antennas at most other dams are placed at adjacent or nearby weirs. Passage times at Lower Granite, Bonneville, Priest Rapids, and Tumwater, and Wells dams may also be inflated by trapping operations that take place at fish ladders at those dams.

Table 10. Chinook Salmon travel rates between Columbia Basin dams estimated using PIT tag data in 2016.

		Median Migration Rate (km/day)		
Between Mainstem Dams	Distance (km)	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville-The Dalles	74	40.0	39.7	35.3
The Dalles-McNary	157	49.4	49.4	41.6
Bonneville – McNary	231	46.3	45.8	39.0
McNary - Priest Rapids	167	41.5	42.4	27.7
Priest Rapids - Rock Island	89	32.3	31.2	34.1
Rock Island - Rocky Reach	33	29.0	31.5	27.5
Rocky Reach – Wells	65	29.0	31.7	29.2
Bonneville - Rock Island	487	37.3	38.7	34.1
Bonneville – Wells	585	34.2	35.1	31.3
McNary - Ice Harbor	67	48.1	40.4	41.5
Ice Harbor - Lower Granite	156	39.4	36.8	31.6
To and Between Tributary Sites				
Rock Island - Tumwater	73	3.2	3.1	--
McNary - Prosser	141	28.5	10.4	6.0
Prosser - Roza	133	18.3	16.7	--
Lower Granite - South Fork Salmon (SFG)	375	22.3	33.5	--

Table 11. Median passage time in minutes by run, from the time of first detection to time of last detection at a dam and the percentage of Chinook taking more than 12 hours between first and last detection in 2016.

	Median Passage Time (minutes)			Percentage of run with more than 12 hours between first and last detection at a dam		
Dam	Spring Chinook	Summer Chinook	Fall Chinook	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville	6.7	8.1	11.6	1.4%	0.8%	1.5%
The Dalles	0.2	0.1	0.1	2.6%	2.0%	1.3%
McNary	94.0	89.0	86.2	6.7%	5.0%	5.8%
Priest Rapids	3.2	5.1	4.7	1.6%	1.0%	13.1%
Rock Island	0.1	0.1	0.1	1.0%	1.9%	1.4%
Rocky Reach	15.7	11.0	23.0	2.9%	0.5%	3.1%
Wells	113.1	121.8	90.4	12.9%	10.1%	4.1%
Ice Harbor	2.8	1.8	1.7	3.9%	6.3%	1.8%
Lower Monumental	0.4	2.6	0.2	3.5%	11.2%	5.4%
Little Goose	0.0	0.0	0	3.1%	0.8%	2.5%
Lower Granite	138.9	164.7	181.0	10.0%	18.8%	21.2%
Tumwater	50.4	5.3	--	31.8%	8.8%	--
Prosser	5.6	2.9	0.1	0.0%	9.1%	5.9%
Roza	2.1	2.3	--	24.1%	40.0%	--

Upstream Age and Length-at-Age Composition

Age 1.2 was the predominant age class for spring Chinook passing each mainstem dam in this study (Table 12, Figure 10). Among summer Chinook, Age 1.2 were at Bonneville, The Dalles, and McNary and in the Snake River, while Age 1.3 was predominant at and above Priest Rapids Dam in the Columbia River

(Table 13, Figure 11). Among fall Chinook, Age 0.3 was the predominant age above Columbia River dams, but Age 0.2 was the predominant age class above Snake River dams (Table 14, Figure 12). Mean length-at-age composition estimates at mainstem dam sites are shown in Tables 12-14.

Table 12. Age composition estimates (%) as determined from passing fish PIT tag detections at mainstem dams of fish aged using scale pattern analysis from scales collected at Bonneville Dam, for spring, summer, and fall Chinook Salmon in 2016.

Run and Site	Ageable	2014	2013		2012		2011		2010	
Spring	**N**	**0.1**	**0.2**	**1.1**	**0.3**	**1.2**	**0.4**	**1.3**	**0.5**	**1.4**
Bonneville	1009	0.0	0.0	9.8	0.0	78.2	0.1	11.7	0.0	0.1
The Dalles	837	0.0	0.0	9.8	0.0	78.6	0.1	11.5	0.0	0.1
McNary	677	0.0	0.0	10.6	0.0	76.0	0.1	13.3	0.0	0.1
Priest Rapids	101	0.0	0.0	12.3	0.0	75.8	0.7	11.2	0.0	0.0
Rock Island	99	0.0	0.0	12.4	0.0	75.5	0.7	11.4	0.0	0.0
Rocky Reach	59	0.0	0.0	17.0	0.0	67.9	1.0	14.0	0.0	0.0
Wells	55	0.0	0.0	17.2	0.0	67.4	1.0	14.4	0.0	0.0
Ice Harbor	519	0.0	0.0	9.7	0.0	77.1	0.0	13.0	0.0	0.1
Low. Mon.	511	0.0	0.0	9.5	0.0	77.5	0.0	12.9	0.0	0.1
Little Goose	491	0.0	0.0	9.2	0.0	77.5	0.0	13.1	0.0	0.1
Lower Granite	483	0.0	0.0	9.2	0.0	77.2	0.0	13.5	0.0	0.1
Summer	**N**	**0.1**	**0.2**	**1.1**	**0.3**	**1.2**	**0.4**	**1.3**	**0.5**	**1.4**
Bonneville	774	0.4	0.8	10.3	10.3	36.7	2.7	37.1	0.1	1.5
The Dalles	668	0.5	0.9	11.6	11.5	34.9	2.9	35.9	0.1	1.6
McNary	591	0.4	1.0	12.1	11.6	35.2	2.4	35.9	0.1	1.2
Priest Rapids	462	0.3	1.0	10.8	13.1	31.2	2.2	40.0	0.0	1.3
Rock Island	443	0.3	1.1	10.5	13.4	31.7	2.3	39.3	0.0	1.4
Rocky Reach	361	0.3	1.2	10.7	14.1	32.8	1.6	38.3	0.0	1.0
Wells	331	0.4	1.4	10.5	13.2	34.3	1.7	37.7	0.0	0.9
Ice Harbor	108	1.0	0.6	23.6	3.4	53.4	1.9	16.1	0.0	0.0
Low. Mon.	106	1.0	0.6	20.8	3.4	53.4	1.9	18.9	0.0	0.0
Little Goose	99	1.0	0.7	21.1	3.5	53.0	1.9	18.8	0.0	0.0
Lower Granite	98	1.0	0.7	21.2	3.5	53.0	1.9	18.8	0.0	0.0
Fall	**N**	**0.1**	**0.2**	**1.1**	**0.3**	**1.2**	**0.4**	**1.3**	**0.5**	**1.4**
Bonneville	1168	6.3	17.4	3.3	49.5	5.4	13.3	3.2	1.2	0.3
The Dalles	839	7.8	20.4	4.2	47.0	5.2	12.1	2.3	0.8	0.2
McNary	637	8.7	20.5	4.8	47.2	4.7	11.7	1.5	0.7	0.2
Priest Rapids	97	12.3	30.0	10.8	34.8	1.4	9.0	0.3	1.5	0.0
Rock Island	65	18.2	26.4	11.4	35.7	1.6	6.3	0.3	0.0	0.0
Rocky Reach	58	21.2	28.4	7.6	36.2	2.0	4.3	0.4	0.0	0.0
Wells	43	36.0	30.8	9.3	20.9	2.6	0.0	0.4	0.0	0.0
Ice Harbor	134	12.6	37.0	7.2	25.0	8.9	5.0	4.5	0.0	0.0
Low. Mon.	133	12.7	36.0	7.2	25.2	9.2	5.0	4.6	0.0	0.0
Little Goose	131	12.9	36.2	7.3	25.7	8.3	5.0	4.6	0.0	0.0
Lower Granite	128	13.2	37.3	7.5	26.3	7.6	3.5	4.6	0.0	0.0

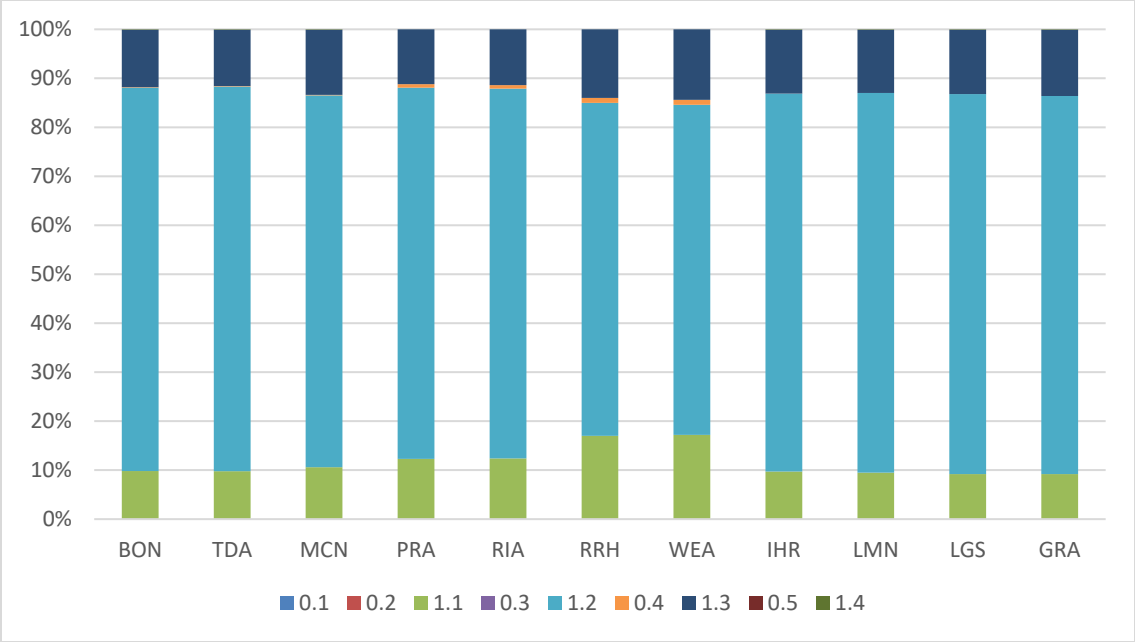

Figure 10. Spring Chinook age composition at Columbia and Snake River dams estimated using PIT tagged Chinook tracked by this project. Spring Chinook are defined as passing Bonneville Dam between April 1 and May 31, 2016.

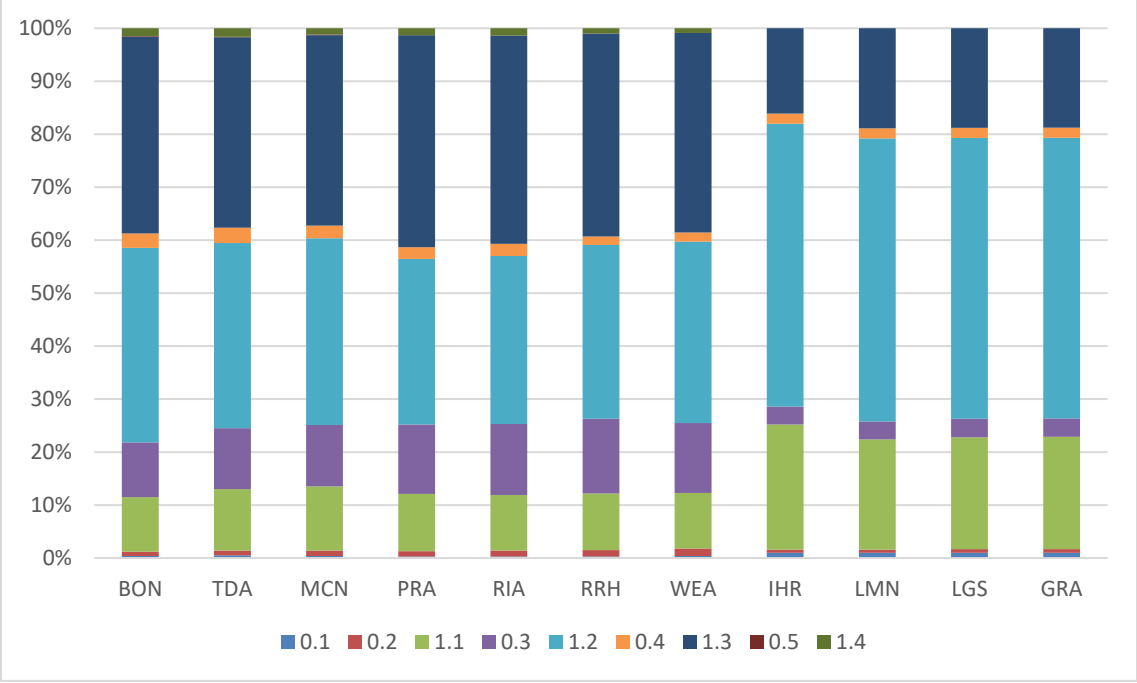

Figure 11. Summer Chinook age composition at Columbia and Snake River dams estimated using PIT tagged Chinook tracked by this project. Summer Chinook are defined as passing Bonneville Dam between June 1 and July 31, 2016.

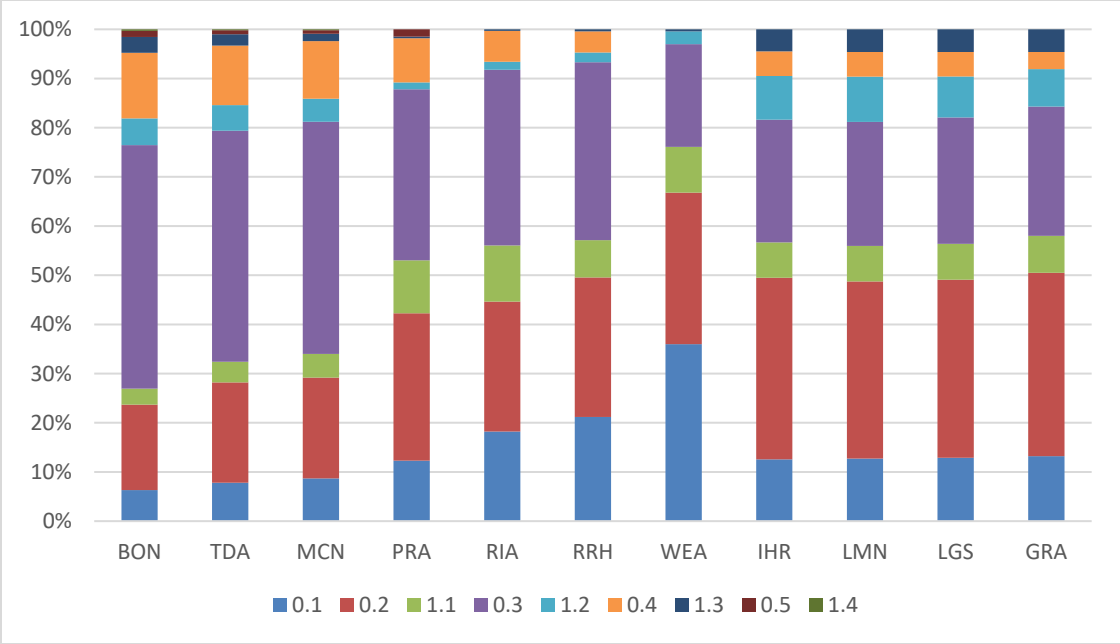

Figure 12. Fall Chinook age composition at Columbia and Snake river dams estimated using PIT tagged Chinook tracked by this project. Fall Chinook are defined as passing Bonneville Dam on or after August 1, 2016.

Table 13. Spring Chinook Salmon length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville Dam on or before May 31, at Columbia and Snake River dams in 2016.

Dam	Statistic	Brood Year and Age Class						
		2014	2013		2012		2011	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3
Bonneville	μ			50.9		72.0	97.0	84.7
	s			3.6		5.4	5.7	6.2
	n			136		746	2	123
The Dalles	μ			50.9		71.9	93.0	84.9
	s			3.6		5.5	--	6.3
	n			121		613	1	101
McNary	μ			50.7		72.2	93.0	85.2
	s			3.3		5.8	--	6.3
	n			106		475	1	94
Priest Rapids	μ			50.7		72.9	93.0	85.4
	s			3.0		5.1	--	7.1
	n			19		63	1	18
Rock Island	μ			50.7		73.2	93.0	85.4
	s			3.0		5.0	--	7.1
	n			19		61	1	18
Rocky Reach	μ			50.7		72.9	93.0	86.0
	s			3.0		4.5	--	6.6
	n			18		27	1	13
Wells	μ			50.7		73.0	93.0	86.0
	s			3.0		4.6	--	6.9
	n			18		24	1	12
Ice Harbor	μ			50.9		72.2		85.5
	s			3.4		6.0		6.0
	n			71		378		69
Lower Monumental	μ			50.9		72.1		85.6
	s			3.4		6.1		6.0
	n			69		374		67
Little Goose	μ			50.7		72.2		85.5
	s			3.4		6.1		6.0
	n			64		361		65
Lower Granite	μ			50.6		72.2		85.5
	s			3.4		6.2		6.0
	n			63		354		65

Table 14. Summer Chinook Salmon length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville Dam between June 1-July 31, at Columbia and Snake River dams in 2016.

Dam	Statistic	Brood Year and Age Class							
		2014	2013		2012		2011		2010
		0.1	0.2	1.1	0.3	1.2	0.4	1.3	1.4
Bonneville	μ	45.7	63.4	52.4	79.0	74.6	88.9	82.7	95.5
	s	3.0	6.8	5.2	5.7	7.6	5.9	6.2	4.9
	n	5	8	93	83	272	22	279	2
The Dalles	μ	45.7	63.6	52.6	79.1	74.6	88.9	83.1	99.0
	s	3.0	7.3	5.1	5.9	7.9	6.2	6.4	--
	n	5	7	89	76	233	19	229	1
McNary	μ	46.5	63.6	52.8	79.2	74.6	88.1	83.0	99.0
	s	3.1	7.3	4.8	5.9	8.0	6.2	6.4	--
	n	3	7	82	67	207	15	203	1
Priest Rapids	μ	45.3	63.8	52.2	79.1	74.7	88.4	82.8	
	s	3.2	8.0	5.2	6.1	6.4	7.1	6.3	
	n	2	6	58	62	138	10	180	
Rock Island	μ	45.3	63.8	52.4	79.1	74.8	88.4	83.0	
	s	3.2	8.0	5.2	6.1	6.4	7.1	6.2	
	n	2	6	54	61	134	10	170	
Rocky Reach	μ	45.3	63.8	52.7	78.8	74.4	89.0	82.3	
	s	3.2	8.0	5.3	6.3	6.6	7.8	5.9	
	n	2	6	47	54	112	6	130	
Wells	μ	45.3	63.8	52.7	78.5	74.2	89.0	82.4	
	s	3.2	8.0	5.4	6.0	6.8	7.8	5.9	
	n	2	6	42	47	105	6	120	
Ice Harbor	μ	49.0	62.5	54.2	77.5	74.1	88.5	85.1	
	s	--	--	3.4	2.1	10.9	4.2	7.0	
	n	1	1	22	2	65	2	15	
Lower Monumental	μ	49.0	62.5	53.8	77.5	74.0	88.5	85.1	
	s	--	--	3.1	2.1	10.9	4.2	7.0	
	n	1	1	21	2	64	2	15	
Little Goose	μ	49.0	62.5	53.8	77.5	75.3	88.5	84.2	
	s	--	--	3.1	2.1	5.8	4.2	6.4	
	n	1	1	20	2	59	2	14	
Lower Granite	μ	49.0	62.5	53.8	77.5	75.1	88.5	84.2	
	s	--	--	3.1	2.1	5.7	4.2	6.4	
	n	1	1	20	2	58	2	14	

Table 15. Fall Chinook Salmon length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville after July 31, for fall Chinook Salmon at Columbia and Snake River dams in 2016.

Dam	Statistic	Brood Year and Age Class								
		2014	2013		2012		2011		2010	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3	0.5	1.4
Bonneville	μ	48.0	62.9	57.5	75.5	70.4	83.2	80.1	85.1	84.5
	s	4.7	6.7	4.8	5.8	7.3	6.2	5.7	5.4	4.9
	n	77	196	48	551	66	163	47	16	4
The Dalles	μ	47.0	62.6	57.3	75.0	70.5	83.8	79.3	83.6	82.7
	s	3.7	7.0	4.9	5.6	6.6	6.2	5.5	5.8	4.0
	n	66	161	43	370	46	111	28	11	3
McNary	μ	46.8	62.5	57.1	74.7	70.3	84.0	79.2	84.7	82.7
	s	3.6	7.5	5.0	5.5	6.0	6.4	6.2	4.9	4.0
	n	51	125	38	284	35	78	15	8	3
Priest Rapids	μ	46.2	62.6	56.0	73.9	70.5	80.2	80.8	87.5	
	s	4.0	5.4	6.2	5.7	6.2	8.2	11.1	--	
	n	11	19	14	38	5	6	3	1	
Rock Island	μ	45.8	61.4	54.8	74.1	70.5	83.2	80.8		
	s	3.7	5.9	7.1	6.3	6.2	6.8	11.1		
	n	9	11	9	25	5	3	3		
Rocky Reach	μ	46.3	61.3	55.1	74.7	70.5	85.3	80.8		
	s	3.7	6.2	7.6	6.3	6.2	8.1	11.1		
	n	8	10	8	22	5	2	3		
Wells	μ	44.9	58.6	54.9	73.8	70.5		80.8		
	s	3.0	4.4	8.1	7.0	6.2		11.1		
	n	6	7	7	15	5		3		
Ice Harbor	μ	47.7	62.6	56.6	74.9	69.1	85.8	77.3		
	s	3.4	4.4	5.5	5.8	6.9	6.3	5.7		
	n	23	36	7	38	12	12	6		
Lower Monumental	μ	47.7	62.4	56.6	74.9	69.1	85.8	77.3		
	s	3.4	4.4	5.5	5.8	6.9	6.3	5.7		
	n	23	35	7	38	12	12	6		
Little Goose	μ	47.7	62.4	56.6	74.9	68.9	85.5	77.3		
	s	3.4	4.4	5.5	5.8	7.2	6.5	5.7		
	n	23	35	7	38	11	11	6		
Lower Granite	μ	47.7	62.4	56.6	74.9	69.7	85.3	77.9		
	s	3.4	4.4	5.5	5.8	7.1	6.8	6.1		
	n	23	35	7	38	10	10	5		

Fallback

Estimated fallback rates, based on Chinook Salmon reascending fish ladders or being detected downstream after ascending a fish ladder, ranged from 0.0% to 28.0% (Table 16). These rates likely underestimate the true fallback rates as they do not include any fish that ascended a dam, fell back, and then were not subsequently detected.

Table 16. Estimated minimum Chinook Salmon fallback rates by race at Bonneville Dam at Columbia Basin dams with PIT tag detection in 2016 as estimated by PIT tags[1].

Dam	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	2.2%	1.1%	1.4%
The Dalles	4.9%	2.5%	1.6%
McNary	4.9%	1.8%	2.3%
Priest Rapids	2.4%	1.5%	28.0%
Rock Island	1.0%	0.6%	0.0%
Rocky Reach	7.4%	2.0%	0.0%
Wells	7.9%	8.7%	2.0%
Ice Harbor	5.4%	8.7%	1.8%
L. Monumental	4.0%	8.0%	2.4%
Little Goose	5.9%	1.7%	6.2%
Lower Granite	0.7%	0.9%	1.9%
Mean	**4.2%**	**3.4%**	**4.3%**

A total of 268 Chinook generated 443 fallback events (Table 17). A large number of Chinook had more than one fallback event at a single dam or several dams (2 to 10 dams fallen back over). Fall Chinook at Priest Rapids Dam had the highest fallback rate with 15 fall Chinook generating 30 fallback events out of 107 fall Chinook detected passing the site with 7 of these fish being last detected downstream of Priest Rapids Dam at Priest Rapids Hatchery. One spring Chinook, 3DD.00775EA23F, fell back 11 times, twice over Bonneville Dam, three times over The Dalles, five times over McNary, and once over Ice Harbor Dam. Figures showing the movement of this Chinook and three other Chinook with an unusual number of fallbacks are in the Appendix (Figures A22 – A25).

[1] Fallback rates do not include Chinook Salmon which fell back over a dam and were not subsequently detected.

Table 17. Frequency of fallback events for Chinook Salmon tagged by this project.

Number of Dams Fallen Back Over	Total Number of Chinook
1	189
2	50
3	10
4	4
5	3
6	5
7	0
8	3
9	2
10	1
11	1
Total	**268**

Night Passage

Night passage (2000-0400 Pacific Standard Time) of tagged Chinook Salmon was under 10% at all dams except for tributary dams (Prosser, Roza, and Tumwater) as well as fall Chinook at Rock Island Dam where 13 out of 69 passed at night (Table 18). The Bonneville Dam estimate of night passage is likely biased low, due to the fact that tagging occurred during morning and early afternoon hours and that the median Bonneville Dam passage time is less than two hours, tagged Chinook would be expected to pass during daytime hours.

Table 18. Estimated Chinook Salmon night passage (2000-0400) in 2016 at Columbia Basin dams as estimated by PIT tag detections.

Site	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	0.2%	0.8%	0.2%
The Dalles	2.9%	2.8%	1.7%
McNary	2.7%	2.3%	1.0%
Priest Rapids	1.6%	1.0%	6.5%
Rock Island	8.1%	3.8%	18.8%
Rocky Reach	1.5%	0.2%	4.6%
Wells	6.3%	2.7%	2.0%
Ice Harbor	0.8%	0.8%	1.8%
Lower Monumental	1.3%	2.4%	3.0%
Little Goose	1.4%	5.0%	2.5%
Lower Granite	1.8%	8.5%	1.9%
Prosser	10.3%	36.4%	11.8%
Roza	16.7%	40.0%	NA
Tumwater	13.6%	5.9%	NA

RESULTS-STEELHEAD

Sample Size

A total of 1610 steelhead were sampled at Bonneville Dam in 2016, of which 1576 were PIT tagged (Table 19). After adding previously tagged fish (which were sampled and therefore identified for the tracking study and included in our sample) and subtracting fish that were not detected after release (possibly a result of tag shed, tag malfunction, mortality, or the fish moving downstream after tagging) or which spent no winters in the ocean, the number of steelhead tracked upstream totaled 1608 (Table 19).

Table 19. Number of steelhead PIT tagged at Bonneville Dam and tracked past Bonneville by date and statistical week in 2016.

Dates	Week	Sampled	PIT Tagged	Previously Tagged	Not Detected After Release	Total Tracked	Days Sampling Restrictions in Effect		
							Reduced Sampling-Temperature	Reduced Sampling-Shad or Salmon Abundance	No Sampling Due to Temperature
4/15	16	2	2	0	0	2	0	0	0
4/18-22	17	4	4	0	0	4	0	0	0
4/26-29	18	7	7	0	0	7	0	0	0
5/2-6	19	6	4	2	0	6	0	0	0
5/9-13	20	21	21	0	0	21	0	0	0
5/16-20	21	9	9	0	0	9	0	0	0
5/23-27	22	18	18	0	0	18	0	0	0
5/31, 6/1-3	23	14	12	2	0	14	0	2	0
6/6-6/10	24	12	12	0	0	12	0	5	0
6/13-6/18	25	8	8	0	0	8	0	5	0
6/20-6/24	26	12	12	0	0	12	0	5	0
6/27-7/1	27	41	41	0	0	41	0	5	0
7/4,6-8	28	75	75	0	0	75	0	2	0
7/11-7/15	29	78	74	4	0	78	0	0	0
7/18-7/22	30	120	120	0	0	120	0	0	0
7/25-29	31	168	164	4	0	168	4	0	0
8/1-4	32	151	147	4	0	151	4	0	1
8/8-11	33	157	152	5	0	157	4	0	1
8/15-18	34	124	121	3	0	124	4	0	1
8/22-25	35	99	98	1	0	99	4	0	1
8/30-31,9/1-2	36	30	30	0	0	30	4	0	1
9/6-9	37	48	46	2	0	48	0	4	0
9/12-16	38	136	134	2	0	136	0	5	0
9/19-20,22-23	39	57	57	0	0	57	0	2	0
9/26-30	40	80	80	0	0	80	0	0	0
10/3-7	41	97	94	3	0	97	0	0	0
10/11,13,14	42	36	34	2	0	36	0	0	0
Total		**1610**	**1576**	**34**	**0**	**1610**	**24**	**35**	**5**

Distribution of Sample

As with Chinook, the weekly distribution of the steelhead sampled at Bonneville Dam differed from the actual run distribution less than in previous years due to the lack of trap closures resulting from high water temperatures. The largest deviations between weekly sample proportion and run proportion was in week 37 (Figure 13) due to sampling restrictions due to high salmon abundance and concurrent sampling of fall Chinook

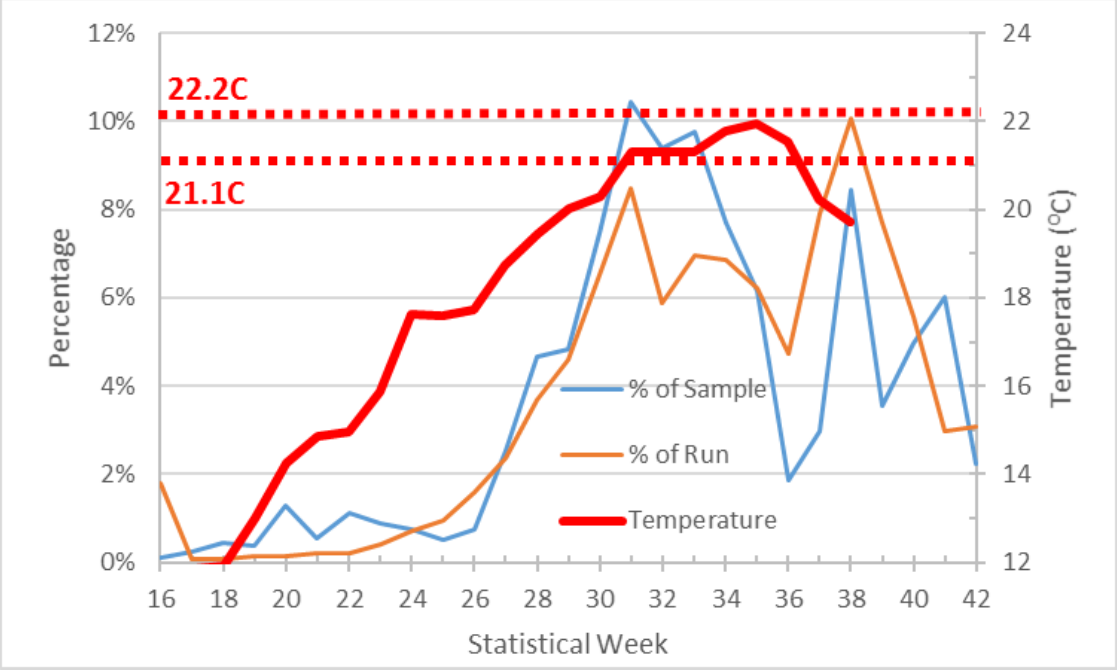

Figure 13. The weekly steelhead sample and run as a percentage of the total sample and run size at Bonneville Dam in 2016. Sampling was reduced at 21.1C but temperatures never reached 22.2C which would halt sampling.

Detection Numbers

The 1610 steelhead tracked in 2016 generated 102756 weir detections and 9694 site detections at 117 sites. Maps (Figures A1, A16-A20) found in the Appendix show the categorical ranges of detection numbers at the sites throughout the Columbia Basin.

Age Analysis

We were able to validate our scale aging techniques by using fish sampled at Bonneville that were previously tagged as juveniles for other projects or hatchery programs. Our age estimates for 24 previously tagged steelhead with readable scales concurred with the information from juvenile PIT tagging. Only the total age

could be compared for it was not possible to separately validate freshwater and ocean age.

In 2016 ocean age estimates were available from analysis of genetics samples collected by this study. Ages estimated using the scale patterns agreed with estimates using GSI for 992 out of 1015 steelhead samples (Table 20). All GSI ages were from hatchery-origin steelhead. All steelhead scale ages that differed from PBT ages were changed to the PBT age with the exception of a steelhead sampled on July 13 which was a PIT tag recapture (384.3B239AA711). GSI indicated that this should have been an age 1.3 steelhead, however the PIT tag indicated that it was released in 2014 indicating that it was a two-ocean steelhead (e.g. Age 1.2) which is how it was aged using scale patterns. This steelhead was kept as Age 1.2.

Table 20. Comparison of age estimates using genetics and scale pattern analysis for Chinook Salmon sampled at Bonneville Dam in 2016. Green shading indicates agreement between the two methods, orange indicates the age estimates differed.

Ocean Age Using Genetic Stock ID	Ocean Age Estimated Using Scale Patterns			% Concurrence
	1	2	3	
1	3	13		18.8%
2	3	848	3	99.3%
3	1	3	141	97.2%
Total	**7**	**864**	**144**	**97.7%**

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Data on tag detections was last downloaded from www.ptagis.org on January 20, 2018. An estimated 54.9% of the steelhead run passing Bonneville Dam was last detected at or above Ice Harbor Dam, compared to only 4.6% above Priest Rapids Dam (Figure 14). The early portion of the run through Statistical Week 26 was dominated by steelhead last detected at Bonneville or The Dalles Dam. After Week 28, the dominant portion of the run was estimated to pass Ice Harbor Dam into the Snake River (Figure 15). The dominance of the Snake River component is clearer in Figure 16 where the weekly percentage of the run to upstream sites was multiplied by the number of steelhead passing in that week.

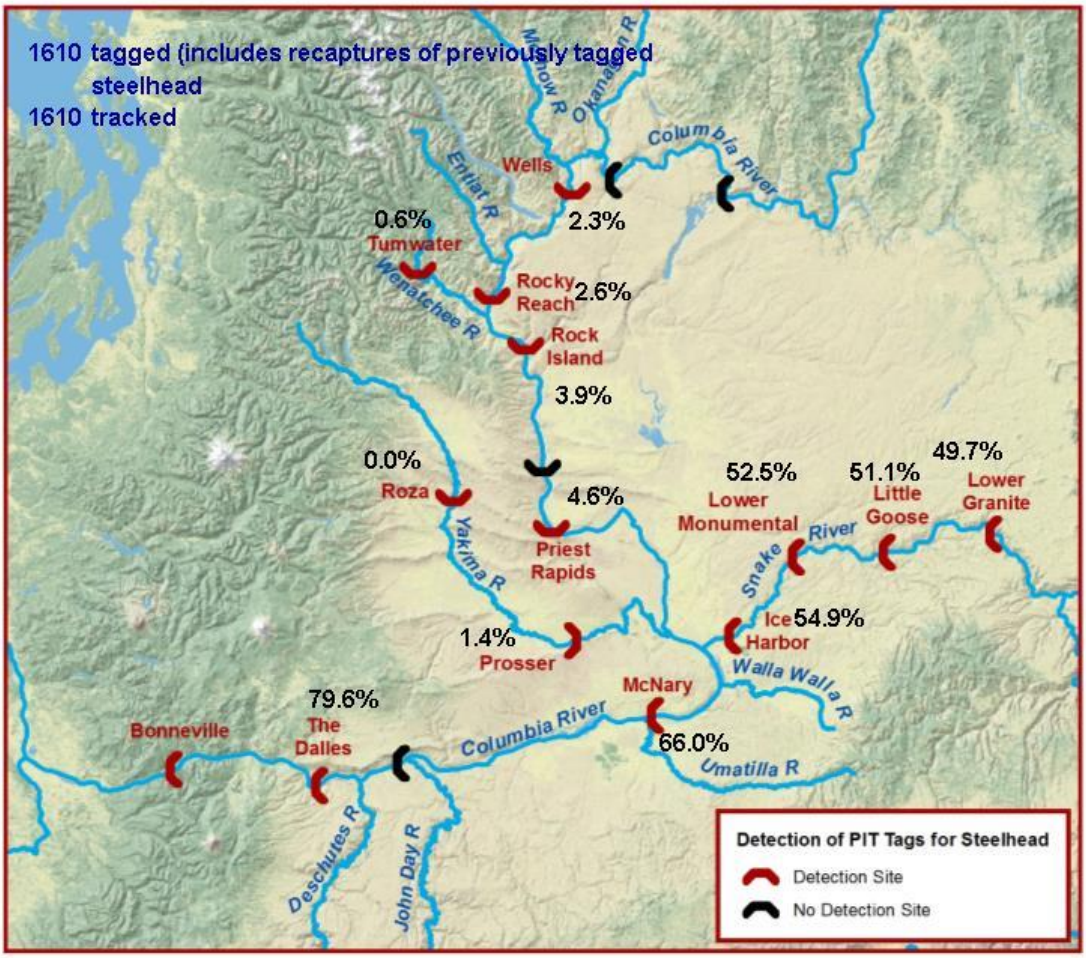

Figure 14. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of steelhead PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2016.

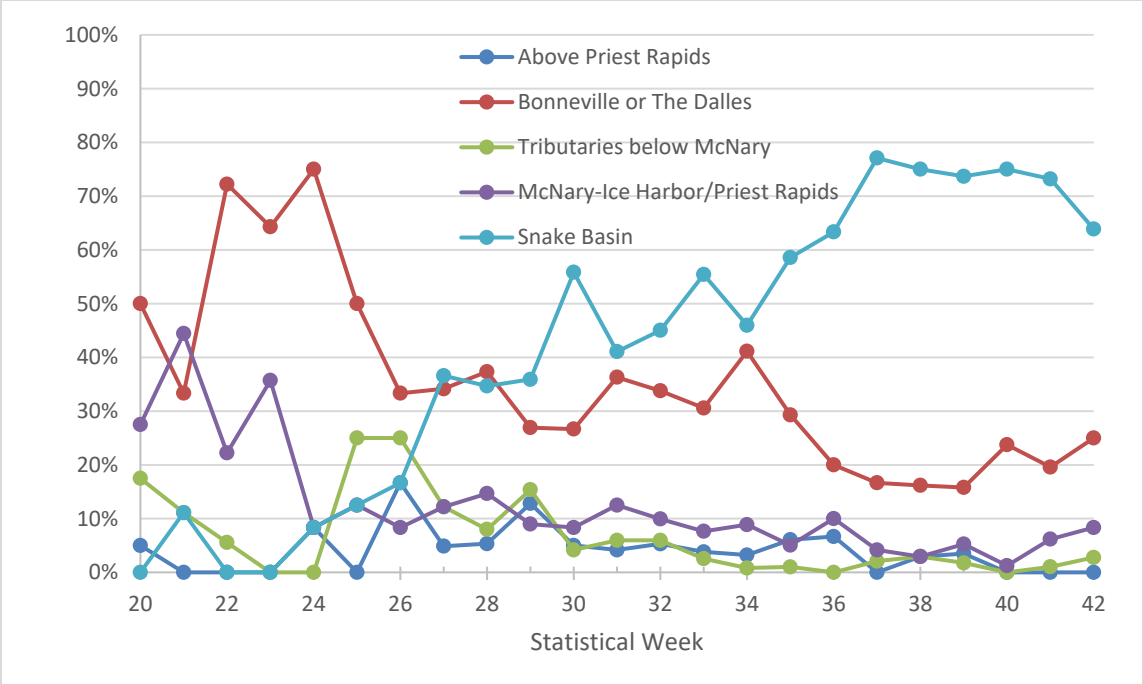

Figure 15. Distribution of final upstream detection site by statistical week for steelhead PIT tagged at Bonneville Dam in 2016 estimated as a percentage of the weekly run.

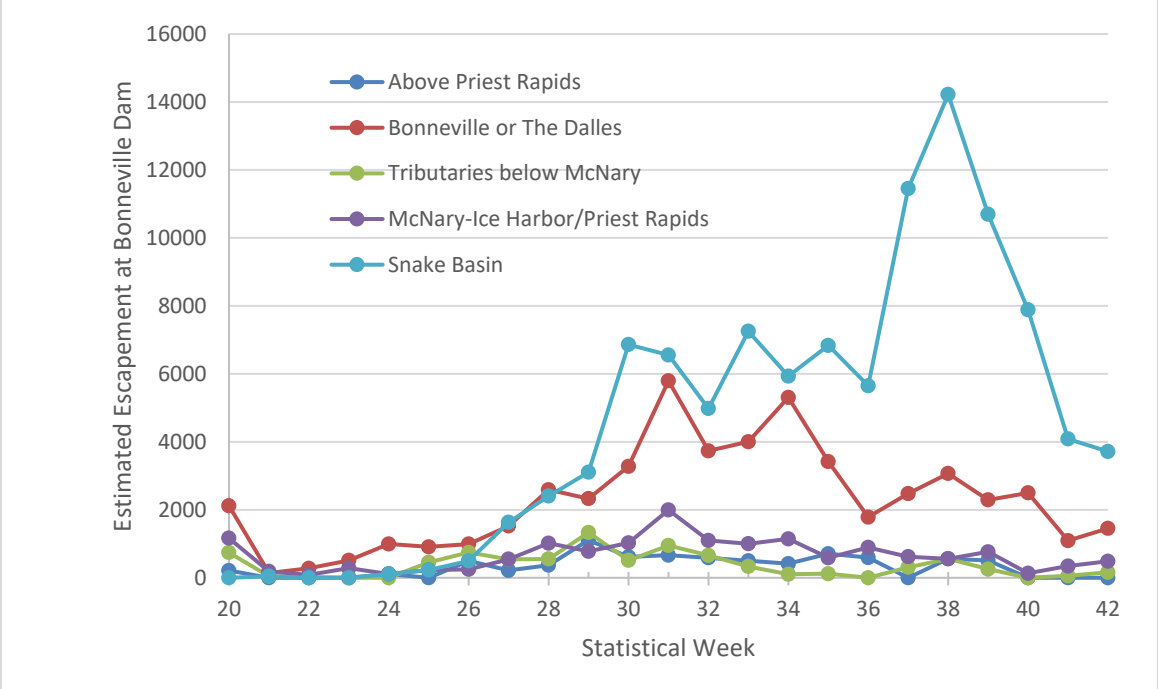

Figure 16. Distribution of final detection site by statistical week for steelhead PIT tagged at Bonneville Dam in 2016 estimated in numbers of fish passing Bonneville Dam by week.

In 2013, a PIT tag site (DRM) was installed across the mouth of the Deschutes River just upstream of the river's mouth. A total of 89 of the 1608 steelhead tracked in 2016 by this study were detected at this site. Of these 89 steelhead, the most upstream detection of 34 fish subsequent to detection at DRM was in the Snake River, 1 steelhead above Priest Rapids Dam, 13 between McNary and Priest Rapids, 37 in Deschutes Basin (with 33 not being detected past DRM), and 4 elsewhere between Bonneville and McNary dams (Figure 17). Fourteen steelhead tagged by this project were recaptured upstream of DRM at the trap at Sherar's Falls; of these, only two were detected at DRM. An additional four steelhead were detected at the Sherar's Falls ladder PIT array, two of which were also detected at DRM. One of these four (3DD.00778A95E2) was last detected at Lower Granite Dam on March 27, 2017.

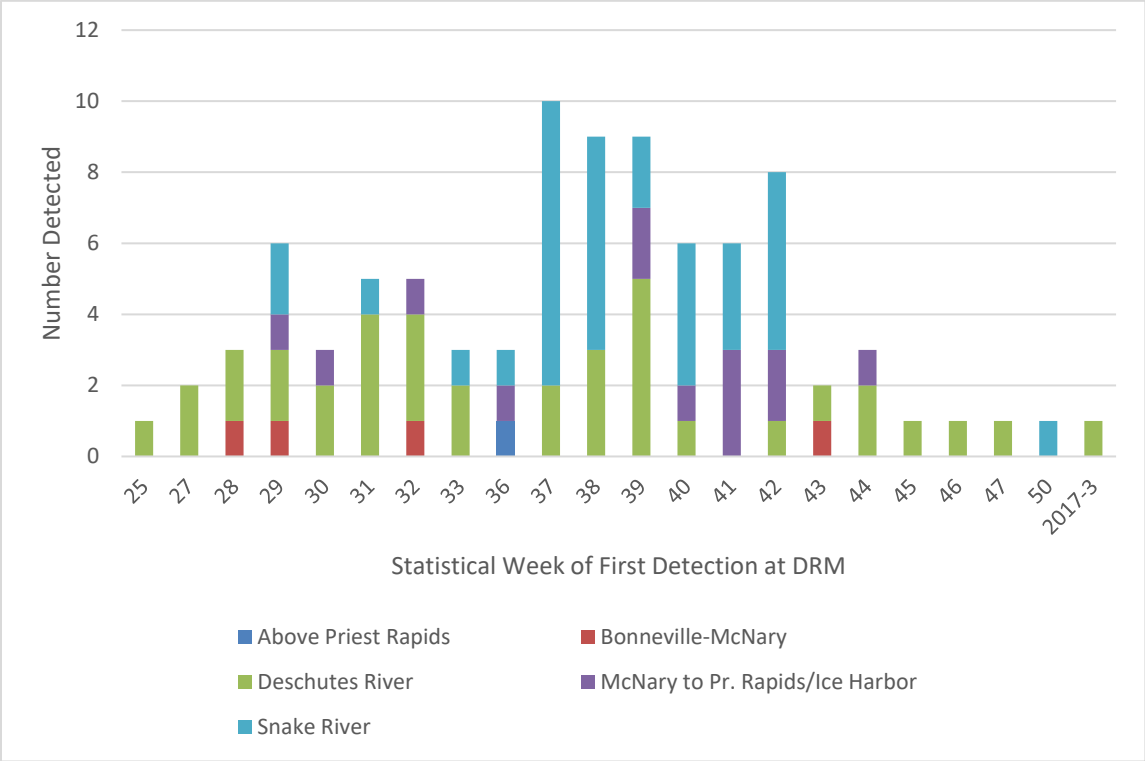

Figure 17. Distribution of final detection site by statistical week for steelhead PIT tagged at Bonneville Dam which were detected at the Deschutes River Mouth antenna (DRM) in 2016.

As with Chinook Salmon, the percentage of PIT tagged steelhead passing a dam without detection was generally under 1% (Table 21). Exceptions were Wells Dam (where only 1 out of the 17 steelhead detected upstream of Wells was missed), Lower Monumental, and Rock Island dams. Rock Island has known detection issues due to antenna size and electrical noise (Fryer et al. 2014), however, the rate at Lower Monumental was surprising. Upon investigation, it was

found that pickets, which divert fish to the fish viewing window and the PIT tag detections, were removed at the end of the fish counting season, resulting in steelhead passing undetected during the winter. Procedures at Lower Monumental have been changed (during winter 2017), so steelhead cannot avoid these antennas when fish counting is not occurring.

Table 21. Percentages of steelhead passing a dam undetected that were subsequently detected upstream in 2016.

Dam	2016
Bonneville	0.0%
The Dalles	0.7%
McNary	0.2%
Priest Rapids	0.0%
Rock Island	2.1%
Rocky Reach	0.0%
Wells	5.9%
Ice Harbor	0.5%
Lower Monumental	5.2%
Little Goose	0.6%
Lower Granite	0.0%
Mean (weighted by number passing each dam)	**0.9%**

Migration Rates and Passage Time

The fastest median migration rate between mainstem dams, as measured in kilometers per day, was between The Dalles and McNary dams (32.2 km/day), while the slowest was 11.2 km/day between Bonneville and McNary dams (Table 22).

Table 22. Steelhead migration rate between Columbia Basin dams as estimated by PIT tag detections in 2016.

Dam Pair	Distance (km)	Median Migration Rate (km/day)
Bonneville-The Dalles	74	17.1
The Dalles-McNary	157	32.2
Bonneville - McNary	231	11.2
McNary - Priest Rapids	167	26.4
Priest Rapids - Rock Island	89	21.1
Rock Island - Rocky Reach	33	18.5
Rocky Reach - Wells	65	24.8
Rock Island - Tumwater	73	3.5
Bonneville – Rock Island	487	13.6
Bonneville - Wells	585	11.4
McNary - Ice Harbor	67	29.1
Ice Harbor - Lower Granite	156	22.9
Bonneville-Lower Granite	461	11.9

Lower Granite, Wells, and McNary dams had the greatest median passage time among mainstem Columbia Basin dams (Table 23). Passage times at Wells, Lower Granite, Priest Rapids, Tumwater, and Bonneville dams may be inflated because of fish trapping programs. Small median passage times are a reflection of a very short distance between lower-most and upper-most PIT tag antennas at a given site.

Table 23. Steelhead median passage times from time of first detection at a dam to time of last detection and the percentage of steelhead taking more than 12 hours between first detection and last detection in 2016.

Dam	Median Passage Time (minutes)	Percentage with more than 12 hours between first detection and last detection at a dam
Bonneville	8.6	1.9%
The Dalles	0.1	3.1%
McNary	86.0	6.7%
Priest Rapids	6.6	11.0%
Rock Island	1.1	5.1%
Rocky Reach	7.8	2.3%
Wells	90.2	13.2%
Ice Harbor	3.0	3.7%
Lower Monumental	1.2	6.5%
Little Goose	0.0	4.0%
Lower Granite	185.4	20.6%
Tumwater	17.2	37.5%

Upstream Age and Length-at-Age Composition

Age 1.2 steelhead had the highest abundance among all age classes at Bonneville Dam in 2016 (Table 24, Figure 18) and at all other dams, reaching over 59% of steelhead passing Rock Island dams. Length-at-age composition data are found in Table 25.

Table 24. Age composition estimates for steelhead at upstream Columbia and Snake River dams in 2016. These were estimated from scale patterns and Genetic Stock Identification of steelhead sampled at Bonneville Dam. The "r" in age r.X means that the freshwater zone of the scale was regenerated, and therefore, the age is not possible to determine.

		2012	2011		2010			2009			Unknown				Repeat Spawners
Site	n	1.1	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2	r	r.1	r.2	r.3	
Bonneville	1607	8.0%	49.4%	2.8%	0.3%	12.1%	0.2%	0.1%	0.6%	0.5%	1.0%	3.5%	20.4%	0.2%	0.8%
The Dalles	1237	8.4%	47.6%	3.1%	0.2%	13.5%	0.1%	0.1%	0.5%	0.6%	2.3%	3.7%	19.0%	0.2%	0.8%
McNary	1019	8.7%	46.1%	3.1%	0.3%	14.7%	0.1%	0.1%	0.6%	0.6%	2.2%	3.6%	19.3%	0.1%	0.5%
Priest Rapids	75	4.5%	55.8%	3.7%	1.1%	16.4%	0.0%	0.0%	0.9%	0.0%	1.4%	0.9%	15.3%	0.0%	0.0%
Rock Island	62	6.8%	59.0%	1.6%	1.3%	18.5%	0.0%	0.0%	0.9%	0.0%	1.4%	0.0%	10.4%	0.0%	0.0%
Rocky Reach	45	7.5%	53.3%	2.2%	2.4%	16.3%	0.0%	0.0%	1.5%	0.0%	3.5%	0.0%	13.4%	0.0%	0.0%
Wells	40	10.1%	51.4%	2.2%	2.4%	14.8%	0.0%	0.0%	1.8%	0.0%	3.5%	0.0%	13.9%	0.0%	0.0%
Ice Harbor	840	9.0%	49.3%	1.4%	0.2%	12.7%	0.1%	0.1%	0.5%	0.7%	0.8%	3.7%	21.1%	0.1%	0.2%
Lower Monumental	806	9.0%	49.5%	1.1%	0.2%	12.6%	0.1%	0.1%	0.3%	0.7%	0.7%	3.8%	21.4%	0.1%	0.2%
Little Goose	784	9.0%	49.1%	1.3%	0.2%	12.1%	0.1%	0.1%	0.6%	0.8%	0.8%	3.9%	21.7%	0.1%	0.2%
Lower Granite	770	9.1%	49.4%	1.4%	0.2%	11.7%	0.1%	0.1%	0.6%	0.8%	0.8%	3.7%	21.8%	0.1%	0.2%

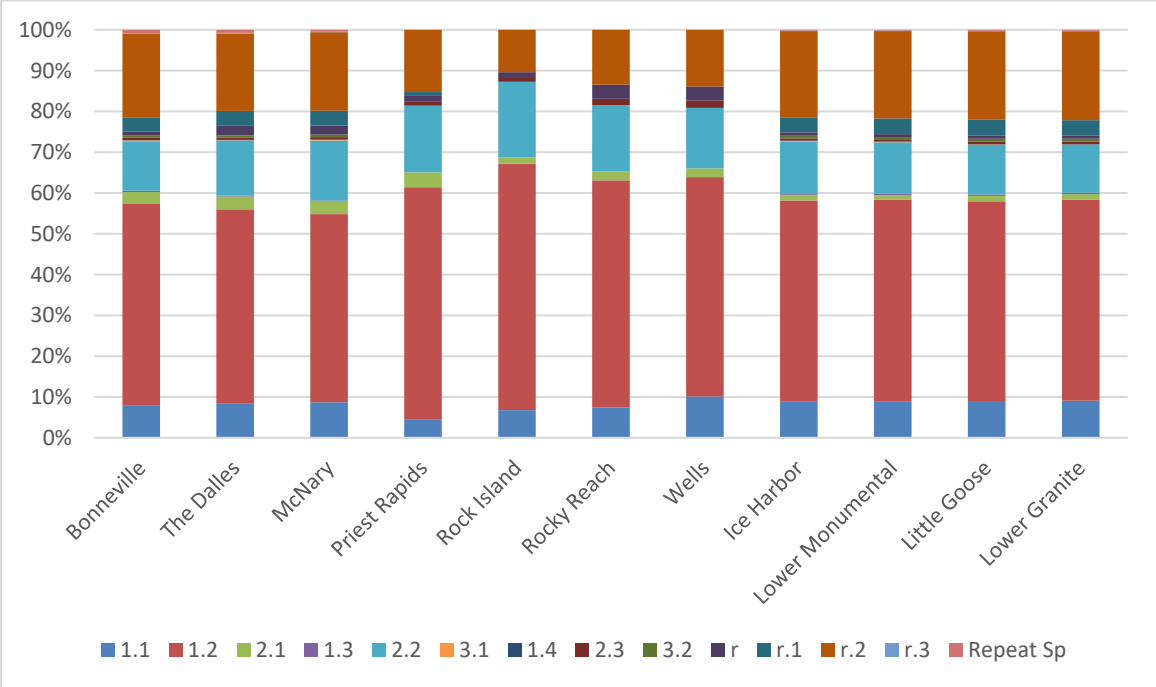

Figure 18. Steelhead age composition at Columbia and Snake River dams estimated from upstream detections of steelhead aged using scales at Bonneville Dam in 2016. The "r" in age r.X means that the freshwater zone of the scale was regenerated and the age therefore not possible to determine.

Table 25. Steelhead length-at-age composition, as estimated by PIT tag detections of fish aged from scales at Bonneville Dam in 2016.

		Brood Year and Age Class											
Dam	Stat	2013	2012		2011				2010	2009	Unknown		
		1.1	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2	r.1	r.2	r.3
Bonneville	μ	55.6	73.1	56.6	82.9	69.5	58.3	90.0	79.8	71.6	56.2	71.6	87.7
	s	3.1	8.0	3.0	8.6	6.8	2.6	--	3.1	6.5	2.7	6.5	5.3
	n	134	746	55	5	216	3	1	9	8	60	333	3
The Dalles	μ	55.6	73.7	56.7	78.8	69.2	59.8	90.0	80.0	70.6	56.1	72.1	85.0
	s	3.2	7.7	3.1	7.1	7.3	1.1	--	2.3	6.4	2.6	6.9	3.5
	n	111	574	45	3	167	2	1	6	7	49	244	2
McNary	μ	55.8	74.1	56.8	78.8	69.4	59.8	90.0	80.0	71.3	56.2	72.1	87.5
	s	3.1	7.8	3.1	7.1	7.5	1.1	--	2.3	6.8	2.7	7.0	--
	n	94	472	34	3	142	2	1	6	6	39	203	1
Priest Rapids	μ	51.0	70.3	58.0		69.8			81.0		59.5	68.9	
	s	4.7	3.3	1.0		2.7			--		--	2.5	
	n	4	37	3		16			1		1	12	
Rock Island	μ	51.0	70.5	57.0		69.8			81.0			69.5	
	s	4.7	3.3	--		2.9			--			2.8	
	n	4	33	1		14			1			8	
Rocky Reach	μ	52.2	70.0	57.0		70.1			81.0			69.3	
	s	5.0	3.0	--		2.5			--			3.2	
	n	3	25	1		8			1			6	
Wells	μ	52.2	69.8	57.0		70.1			81.0			69.1	
	s	5.0	3.0	--		2.7			--			3.6	
	n	3	22	1		7			1			5	
Ice Harbor	μ	55.9	74.6	57.2	78.8	69.4	60.5	90.0	80.1	72.4	56.1	72.6	87.5
	s	3.1	7.2	3.1	7.1	8.8	--	--	2.8	7.0	2.8	7.2	--
	n	79	421	13	3	97	1	1	4	5	31	175	1
Lower Monumental	μ	56.0	74.5	57.6	78.8	69.3	60.5	90.0	79.8	72.4	56.1	72.7	87.5
	s	2.8	7.2	3.4	7.1	8.6	--	--	3.3	7.0	2.8	7.3	--
	n	76	404	9	3	94	1	1	3	5	31	170	1
Little Goose	μ	55.8	74.5	57.7	78.8	69.3	60.5	90.0	80.1	72.4	56.1	72.8	87.5
	s	3.2	7.2	3.1	7.1	8.9	--	--	2.8	7.0	2.8	7.3	--
	n	74	391	11	3	87	1	1	4	5	31	167	1
Lower Granite	μ	55.8	74.6	57.7	78.8	69.4	60.5	90.0	80.1	72.4	56.1	72.9	87.5
	s	3.2	7.2	3.1	7.1	9.1	--	--	2.8	7.0	2.9	7.3	--
	n	73	387	11	3	83	1	1	4	5	29	164	1

Fallback

Estimated minimum fallback rates based on steelhead either reascending fish ladders or steelhead subsequently detected downstream, ranged from 1.5% at The Dalles to 28.0% at Priest Rapids Dam (Table 26). These rates likely underestimate the true fallback rates as they do not include any fish that ascended a dam, fell back, and then were not subsequently detected.

Table 26. Estimated minimum steelhead fallback at Columbia Basin dams in 2016 as estimated by PIT tag[2] detections.

Dam	Percent Fallback
Bonneville	1.6%
The Dalles	1.5%
McNary	4.5%
Priest Rapids	28.0%
Rock Island	23.0%
Rocky Reach	8.9%
Wells	12.8%
Ice Harbor	5.0%
Lower Monumental	5.6%
Little Goose	7.8%
Lower Granite	9.1%

Night Passage

Night passage (2000-0400 Pacific Standard Time) by tagged steelhead ranged from 1.9% at Bonneville Dam to 21.1% at Wells Dam (Table 27). Given the median Bonneville Dam passage time of 8.6 minutes (Table 23), and the fact that sampling was generally conducted between 0800 and 1400, steelhead would be expected to pass during daytime hours.

Table 27. Estimated steelhead night passage (2000-0400 PST) at Columbia Basin dams in 2016.

Site	Percentage Night Passage
Bonneville	1.9%
The Dalles	4.5%
McNary	5.9%
Priest Rapids	5.5%
Rock Island	20.3%
Rocky Reach	7.0%
Wells	21.1%
Ice Harbor	8.2%
Lower Monumental	8.8%
Little Goose	8.9%
Lower Granite	4.8%

B-Run Analyses

A total of 312 B-run steelhead were sampled (where B-run is defined as steelhead greater than or equal to 78.0 cm fork length). Among the weeks sampled, the percentage of steelhead sampled and tagged that were classified as B-run peaked in Statistical Week 41 at 70.1% (Figure 19). The estimated B-Run

[2] Fallback rates do not include steelhead which fell back over a dam and were not subsequently detected.

escapement at Bonneville Dam (estimated by multiplying the weekly run size using counting window data by the percentage B-run in that week estimated by this project) peaked in Week 31 at 10,534 fish while the A-run steelhead peaked in Week 31 at 15,766 fish. Overall, an estimated 24.2% of the 2016 run was B-run. Among steelhead detected above McNary Dam and in tributaries between Bonneville and McNary dams (thereby eliminating most of the steelhead that may have been captured in the Zone 6 fishery in the mainstem Columbia between those dams), 83.8% steelhead with fork lengths 78.0 cm and greater were destined for the Snake Basin (Figure 20). Among the 1,573 steelhead sampled at Bonneville Dam where ocean age could be estimated, B-run steelhead were comprised entirely of two-, three-, and four-ocean steelhead, while A-run steelhead were comprised almost entirely of one- and two-ocean steelhead (Table 28). The mean length of sampled A-Run steelhead was 66.5 cm compared to 82.5 cm for B-Run steelhead.

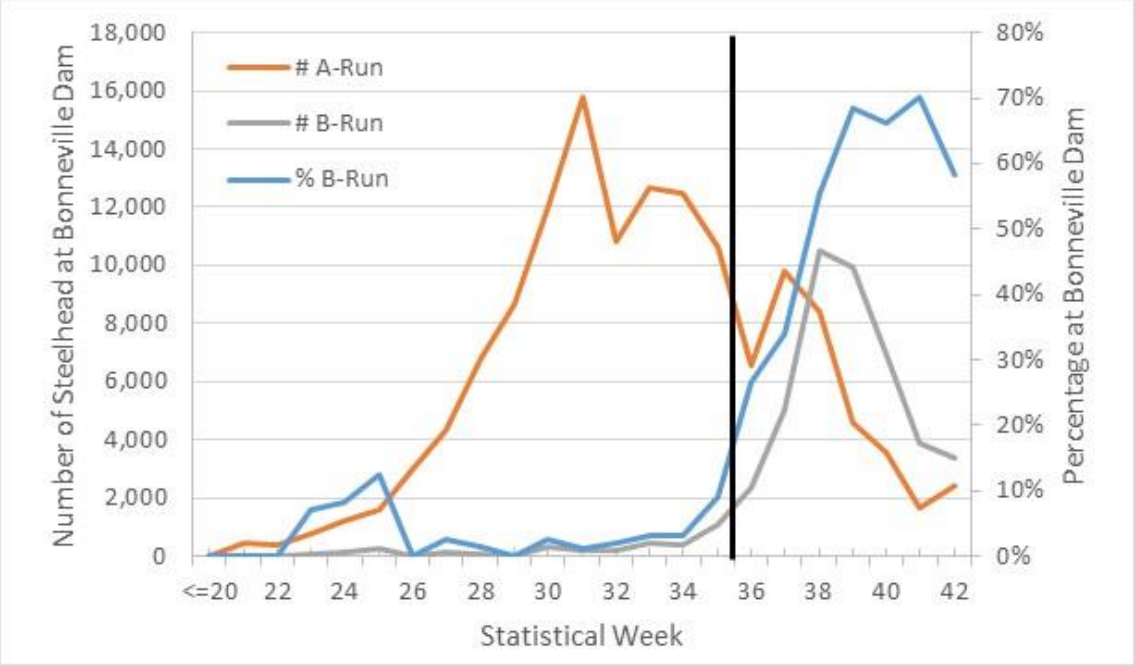

Figure 19. Percentage of B-run steelhead and estimated A- and B-run escapement at Bonneville Dam by statistical week in 2016. The vertical line shows the approximate location of August 25 which is considered the date that separates A- and B-run steelhead.

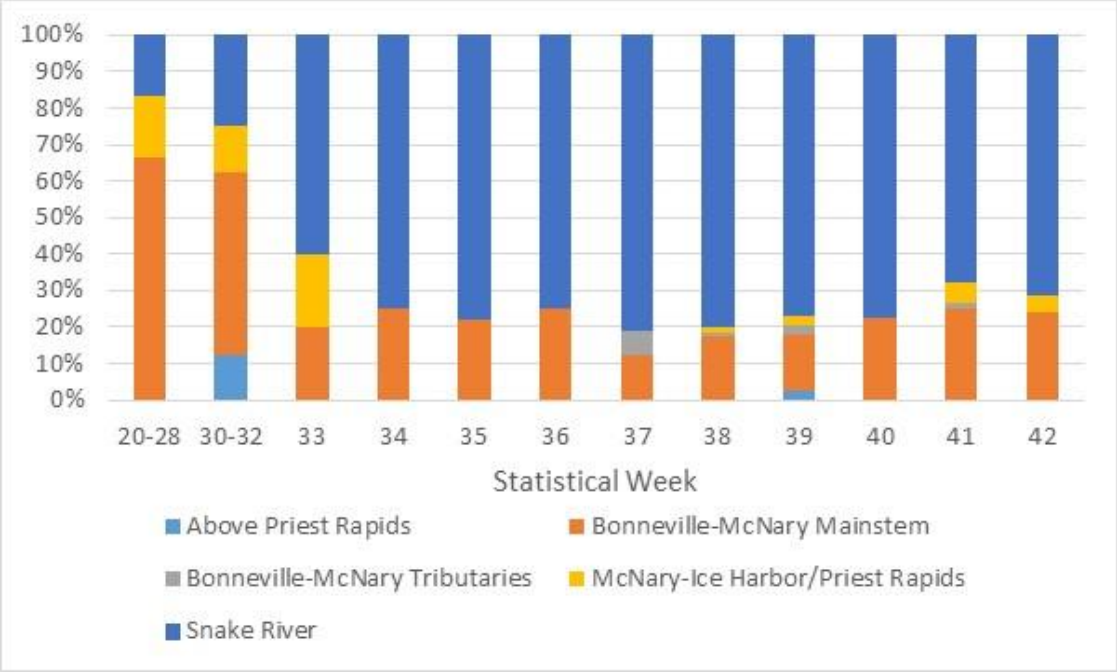

Figure 20. Most upstream detection site for B-run steelhead (≥78 cm fork length) by Statistical Week they were sampled at Bonneville Dam in 2016. Statistical weeks prior to Week 33 are pooled due to low sample sizes.

Table 28. Ocean age composition of A- (<78 cm fork length) and B-Run (≥78 cm fork length) steelhead sampled at Bonneville Dam in 2016.

Run	N	One-Ocean (x.1)	Two-Ocean (x.2)	Three Ocean (x.3)	Four Ocean (x.4)
A-Run	1262	20.2%	79.4%	0.4%	0.0%
B-Run	311	0.0%	95.8%	3.9%	0.3%
All Steelhead	**1573**	**16.2%**	**82.6%**	**1.1%**	**0.1%**

Kelt Analyses

A total of 98 steelhead PIT tagged and tracked in 2016 were either detected going downstream in the Columbia Basin, presumably in an attempt to return to the ocean after spawning (kelts), or detected moving back upstream later in 2017 or early 2018 as repeat spawners (Table 29 and A2). At the start of this study in 2009, we assigned a cutoff date of March 31st, so that any steelhead moving downstream before April 1st were assumed to still be wandering the basin and would eventually spawn. However, in the last few years, as more and more PIT detector systems have been placed in the Columbia Basin, we can now track and observe that several steelhead move out of the system before April 1st after visiting the upper reaches of tributaries (assumed to spawn). Therefore, each year we assess and add several more steelhead that have left the system before the cutoff date to the list of kelts, based on the detailed movements of these fish. In 2016, six steelhead were added (Table 29 and A3). An additional eight steelhead were

recognized in the CRITFC Kelt Project as spawned-out and moving back downriver (collected for study – Hatch et. al. Multiple Years) (Table 29 and Table A2) and were added to the list of kelts. Both the highest percentage of steelhead passing Bonneville and the greatest number of kelt were estimated to be in Week 33 (Figures 21 and 22).

Table 29. Some biological and detection information on the steelhead moving in the Columbia Basin system in 2016 that were determined to be kelts (CRITFC Kelt Project), or repeat spawners and potential kelts (because of their behavior). Please see Tables A2 and A3 for more details on the detected behavior of the steelhead.

					Most Upstream Site		Last Site Detected				
PIT Tag	Date Tagged	Fin Clip	Age	Fork Length	Basin and Site	Date	Basin and Site	Date	Comment	Detected Migrating Downstream in Spring 2017	Detected Migrating Upstream in Fall 2017
3DD.00775E177B	5/10/2016		2.2	64	Wind (WRU)	4/14/2017	Columbia (BCC)	5/4/2017		X	
3DD.00775E2B53	5/13/2016	RM	r.2	67.5	Wind (TRC)	3/21/2017	Columbia (BCC)	4/7/2017		X	
3DD.00775E91C7	5/27/2016		2.2	69	Wind (TRC)	10/8/2016	Columbia (BCC)	5/24/2017		X	
3DD.00775DCF60	6/1/2016		2.2	69	Klickitat (LFF)	6/12/2016	Columbia (BCC)	6/7/2017			
3DD.00775D21AD	6/14/2016		r.2	63	Wind (TC4)	3/18/2017	Columbia (PD7)	7/23/2017		X	
3DD.00775E91E8	6/21/2016		r.2	75	Wind (TRC)	3/21/2017	Columbia (BCC)	4/19/2017		X	
3DD.00775E08E9	6/28/2016		r.2	71	Imnaha (IR3)	4/2/2017	Columbia (BCC)	5/22/2017		X	
3DD.00778AB02A	8/23/2016	AD	TROUT-1.0	40.5	Columbia (BO4)	8/26/2016	Columbia (BCC)	4/2/2017		X	
3DD.00779937A4	6/30/2016		2.1	63.5	Snake (BSC)	3/28/2017	Snake (BSC)	3/28/2017	Kelt Program		
3DD.00779747F0	6/30/2016		r.2	67	Touchet (BBT)	3/1/2017	Columbia (BCC)	4/27/2017		X	
3DD.007797A2E7	6/30/2016		2.2	67.5	Yakima (PRO)	10/22/2016	Columbia (JDJ)	5/29/2017		X	
3DD.00779787C3	6/30/2016		r.2	64	Snake (GRA)	10/4/2016	Snake (GRJ)	3/20/2017	Before April 1	X	
3DD.00778B388B	7/7/2016		r.2	67	Snake (GRA)	10/1/2016	Snake (GRA)	10/1/2016	Kelt Program		
3DD.00778A911C	7/8/2016		2.2	64.5	Snake (GRA)	10/19/2016	Columbia (BCC)	5/19/2017		X	
3DD.0077992B24	7/11/2016		2.2	72.5	Umatilla (TMF)	5/12/2017	Columbia (BCC)	5/17/2017		X	
3DD.0077972340	7/11/2016		2.1	56.5	Yakima (PRO)	10/11/2016	Yakima (PRO)	10/11/2016	Kelt Program		
3DD.00778A366D	7/14/2016		2.2	70	Snake (GRA)	9/24/2016	(Columbia (MC2))	4/29/2017		X	
3DD.00778AE678	7/14/2016	AD	1.2	67	Columbia (WEA)	10/29/2016	Columbia (RRJ)	4/20/2017		X	
3DD.00778B4C27	7/15/2016		r	60.5	John Day (JD1)	11/3/2016	Columbia (JDJ)	4/6/2017		X	
3DD.00778BDA34	7/15/2016		2.1	54	John Day (JD1)	10/19/2016	Columbia (JDJ)	4/17/2017		X	
3DD.00778BD2E3	7/15/2016		2.2	69.5	Snake (CCW)	3/15/2017	Snake (CCW)	3/15/2017	Kelt Program		
3DD.00778B9DFB	7/18/2016		2.1	56.5	Snake (GRA)	9/16/2016	Snake (GRJ)	3/21/2017	Before April 1	X	
3DD.00778A9ADB	7/20/2016		2.1	59	Snake (GRA)	8/1/2016	Snake (GRJ)	4/19/2017		X	
3DD.007789C5A6	7/20/2016		2.2	69.5	Columbia (WEA)	10/10/2016	Columbia (BCC)	6/5/2017			

3DD.00778A63A0	7/21/2016		2.2	61	Snake (ICH)	12/16/2016	Columbia (BCC)	5/7/2017		X	
3DD.00778B9995	7/21/2016		2.1	55.5	Columbia (MC1)	10/5/2016	Columbia (JDJ)	5/29/2017		X	
3DD.00778AB50B	7/21/2016		2.2	66.5	Snake (GRA)	9/22/2016	Columbia (BCC)	4/29/2017		X	
3DD.00778A7B99	7/21/2016	AD	1.2	68.5	Snake (GRA)	9/29/2016	Columbia (JDJ)	4/26/2017		X	
3DD.00778AB096	7/21/2016		2.2	67	Snake (GRA)	8/10/2016	Columbia (BCC)	6/21/2017			
3DD.00778AC2DE	7/22/2016	AD	1.1	54	Snake (GRA)	9/18/2016	Snake (LMJ)	4/29/2017		X	
3DD.00778BB9ED	7/25/2016	AD	r.2	77.5	Hood (MVF)	11/2/2016	Columbia (BCC)	4/8/2017		X	
3DD.00778B3BA4	7/25/2016		2.2	61.5	Snake (GRA)	8/16/2016	Snake (GOJ)	6/15/2017			
3DD.00778A2851	7/25/2016		2.2	77	John Day (JD1)	11/8/2016	Columbia (JDJ)	5/19/2017		X	
3DD.00778B3166	7/26/2016		2.1	57	Methow (LMR)	1/4/2017	Snake (GOJ)	5/30/2017		X	
3DD.00778B3741	7/26/2016		2.2	66	Columbia (MC2)	9/26/2016	Columbia (BCC)	5/27/2017		X	
3DD.00778A82F5	7/26/2016		2.2	72	Columbia (MC2)	9/20/2016	Columbia (BCC)	5/13/2017		X	
3DD.00778B25C7	7/26/2016		2.2	63	Tucannon (MTR)	3/2/2017	Tucannon (LTR)	4/13/2017		X	
3DD.00778A3CDB	7/26/2016		r.2	67	Yakima (SAT)	2/20/2017	Columbia (BCC)	4/24/2017		X	
3DD.00778A09D5	7/27/2016		r.1	57	Columbia (MC1)	10/24/2016	Umatilla (TMF)	5/15/2017		X	
3DD.00778AB1F1	7/27/2016		2.2	66	Snake (GRA)	9/26/2016	Snake (GOJ)	5/30/2017		X	
3DD.00778AD51D	7/27/2016		r.2	69.5	Columbia (BO3)	9/12/2017	Columbia (BO4)	9/12/2017			X
3DD.00778BAA71	7/27/2016	AD	r.2	67	Columbia (BCC)	3/4/2017	Columbia (BCC)	3/4/2017	Before April 1	X	
3DD.00778AE6FC	7/29/2016		2.2	72	Tucannon (MTR)	2/20/2017	Columbia (BCC)	5/4/2017		X	
3DD.00778AC5E7	7/29/2016		2.1	48	Walla Walla (NBA)	3/20/2017	Columbia (JDJ)	4/29/2017		X	
3DD.00778A0D2A	8/1/2016		2.2	68.5	Snake (GRA)	8/14/2016	Snake (ICH)	4/5/2017		X	
3DD.00778B7712	8/1/2016		2.1	52.5	Walla Walla (PRV)	2/20/2017	Columbia (JDJ)	5/9/2017		X	
3DD.00778BC7EB	8/1/2016		2.1	55	Snake (GRA)	9/6/2016	Columbia (MCJ)	4/19/2017		X	
3DD.00778B29ED	8/1/2016		r.1	53	John Day (JD1)	10/26/2016	Columbia (JDJ)	5/21/2017		X	
3DD.00778BD869	8/1/2016		2.2	72	Columbia (MC1)	9/26/2016	Columbia (BCC)	5/30/2017		X	
3DD.00778B7461	8/1/2016		2.3	81	Methow (CRU)	4/24/2017	Columbia (BCC)	5/12/2017		X	
3DD.00778B66E8	8/2/2016	AD	1.2	67.5	Lemhi (LLR)	3/19/2017	Columbia (JDJ)	5/1/2017		X	
3DD.00778B73D4	8/2/2016	AD	1.2	67.5	Imnaha (BSC)	3/16/2017	Columbia (BCC)	4/26/2017		X	
3DD.00778BB941	8/2/2016		r.1S	64	John Day (JD1)	10/21/2016	Columbia (BCC)	5/9/2017		X	

3DD.00778A8F07	8/3/2016		r.2	66	Wallowa (WR1)	2/23/2017	Snake (GOJ)	4/24/2017		X	
3DD.00778A19EB	8/3/2016		2.2	73	Snake (GRA)	10/2/2016	Snake (GOJ)	4/3/2017		X	
3DD.00778A494B	8/8/2016	RM	2.1	56	Grand Ronde (UGR)	2/26/2017	Columbia (JDJ)	5/9/2017		X	
3DD.0077898BA3	8/8/2016		r.2	67	Snake (GRA)	9/30/2016	Snake (GRA)	9/30/2016	Kelt Program		
3DD.00778A0E52	8/8/2016		r	56.5	Umatilla (FDD)	11/14/2016	Columbia (JDJ)	4/19/2017		X	
3DD.00778A267C	8/9/2016		1.2	67	Lemhi (LLR)	3/31/2017	Columbia (BCC)	5/5/2017		X	
3DD.00778A270A	8/9/2016		r.1S	63	Walla Walla (NBA)	4/20/2017	Columbia (MCJ)	5/19/2017		X	
3DD.00778B32C3	8/9/2016		3.1	59	Yakima (PRO)	10/18/2016	Columbia (BCC)	6/1/2017			
3DD.00778A3751	8/9/2016		2.1	54.5	Yakima (SAT)	4/22/2017	Columbia (BCC)	4/28/2017		X	
3DD.00778ADC90	8/9/2016		2.2	68	Snake (GOA)	10/31/2016	Snake (GOJ)	3/20/2017	Before April 1	X	
3DD.00778A5048	8/9/2016		1.2	78	Snake (GRA)	9/26/2016	Snake (GOJ)	4/10/2017		X	
3DD.00778B29DB	8/9/2016		r.2	70	Yakima (PRO)	11/5/2016	Columbia (BO4)	8/20/2017			X
3DD.00778B9B86	8/10/2016		2.1	58	Wallowa (WR1)	3/3/2017	Snake (LMJ)	4/10/2017		X	
3DD.007789A9DF	8/10/2016	AD	1.2	67.5	Snake (GRA)	9/20/2016	Columbia (JDJ)	4/24/2017		X	
384.3B23A7E6C5	8/10/2016	AD	1.2	71.5	Snake (GRA)	9/16/2016	Snake (ICH)	4/29/2017		X	
3DD.00778A0E41	8/10/2016	AD	r.2	61	Snake (GRA)	9/16/2016	Snake (GOJ)	4/25/2017		X	
3DD.00778AFAE2	8/10/2016		2.2	73	Snake (GRA)	10/6/2016	Columbia (MCJ)	4/10/2017		X	
3DD.00778BA840	8/10/2016	AD	r.1S	67	Walla Walla (BGM)	4/9/2017	Columbia (JDJ)	4/27/2017		X	
3DD.00778A6DD4	8/11/2016	AD	1.2	70.5	Salmon (USE)	3/11/2017	Snake (LMJ)	4/6/2017		X	
3DD.00778B34BD	8/11/2016		2.1	53	Columbia (BO3)	10/2/2017	Columbia (BO4)	10/2/2017			X
3DD.00778B146F	8/11/2016	AD RV	r.1	51.5	Snake (GRA)	10/1/2016	Snake (GOJ)	4/14/2017			X
3DD.00778B1762	8/11/2016		r.2	63	Walla Walla (PRV)	2/26/2017	Columbia (MC2)	4/22/2017		X	
384.3B23ACF9E9	8/15/2016		r.s	64.5	Tucannon (UTR)	3/24/2016	Columbia (JDJ)	5/8/2017		X	
3DD.00778A920D	8/16/2016	AD	1.1	55	Snake (GRA)	10/24/2016	Columbia (JDJ)	6/1/2017			
3DD.00778B22F7	8/16/2016	AD	1.1	58	Snake (GRA)	9/5/2016	Snake (GRJ)	4/24/2017		X	
3DD.00778AFE71	8/17/2016	AD	1.2	67	Touchet (PAT)	3/27/2017	Columbia (JDJ)	4/8/2017		X	
3DD.00778A9336	8/17/2016		2.2	64.5	Columbia (MC1)	9/27/2016	Columbia (BCC)	5/7/2017		X	
3DD.00778A1EDC	8/17/2016		1.2	74	Snake (GRA)	9/18/2016	Snake (GRA)	9/18/2016	Kelt Program		

3DD.00778A67EB	8/18/2016		2.1	52.5	Snake (GRA)	9/3/2016	Columbia (JDJ)	5/7/2017		X	
3DD.00778B534C	8/23/2016		2.1	56.5	Snake (GRA)	9/24/2016	Snake (GOJ)	3/21/2017	Before April 1	X	
3DD.00778BC210	8/23/2016		2.2	67.5	Yakima (PRO)	10/25/2016	Columbia (MCJ)	5/7/2017		X	
3DD.00778B65BB	8/23/2016	AD	1.1	56	Snake (GRA)	10/4/2016	Columbia (JDJ)	4/23/2017		X	
3DD.00778ABEA2	8/25/2016		1.1	42	Snake (GRA)	11/12/2016	Columbia (BCC)	6/17/2017			
3DD.00778B2DC4	8/25/2016		2.2	75	Snake (GRA)	10/4/2016	Columbia (BCC)	5/30/2017		X	
3DD.00778A12EF	8/25/2016	AD	1.2	64	Snake (USE)	4/14/2017	Columbia (LMJ)	5/11/2017		X	
3DD.00778A59F7	9/1/2016	AD	1.2	79	Snake (SC2)	3/6/2017	Snake (SC2)	3/6/2017	Kelt Program		
3DD.00778A6F91	9/8/2016	AD	1.1	57.5	Snake (GRA)	10/16/2016	Columbia (BCC)	6/10/2017			
3DD.00778980A0	9/8/2016		r.2	74	Snake (SC2)	2/21/2017	Columbia (TD1)	3/30/2017	Before April 1	X	
3DD.00778BC3C6	9/12/2016	AD	1.2	62	Snake (GRA)	10/2/2016	Columbia (B2J)	5/15/2017		X	
3DD.00778A702A	9/12/2016	AD	1.2	75.5	Snake (DWL)	10/10/2016	Columbia (MC2)	4/9/2017		X	
3DD.00778B1204	9/22/2016		1.2	74	Snake (SC2)	2/17/207	Snake (GOJ)	4/9/2017		X	
3DD.00778AE8A5	9/29/2016		r.2	71	Columbia (BO4)	9/29/2016	Columbia (BCC)	5/7/2017		X	
3DD.00778A5770	10/3/2016		2.2	76	Snake (LRL)	4/4/2017	Columbia (JDJ)	5/8/2017		X	
3DD.00778B0B87	10/7/2016		2.2	73.5	Snake (GRA)	3/29/2017	Columbia (BCC)	4/14/2017		X	
3DD.00778A91E8	10/14/2016	AD	1.2	80	Snake (GRA)	3/30/2017	Snake (GRA)	3/30/2017	Kelt Program		

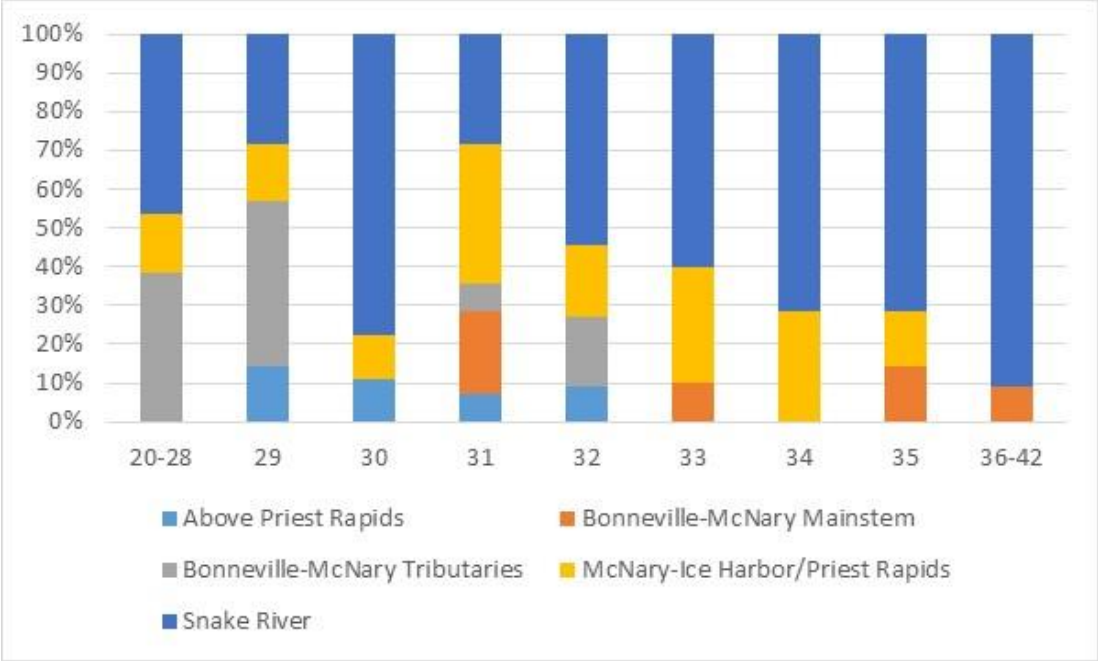

Figure 21. Most upstream detection site for kelt steelhead by Statistical Week sampled at Bonneville Dam in 2016.

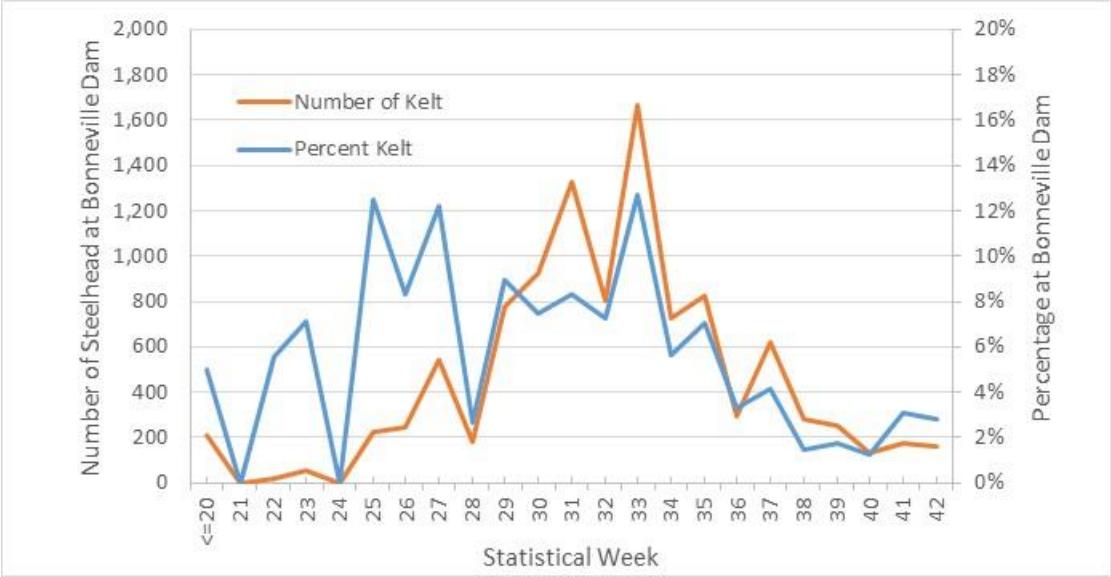

Figure 22. Percentage and number of kelt passing Bonneville Dam by Statistical Week as estimated by this project in 2016.

Many kelts that are detected moving out of the system are detected in the juvenile bypasses (last detection location) of the major Columbia and Snake dams. For 2016, the juvenile bypass at these dams detected kelts; Bonneville (1), John Day (20), McNary (4), Ice Harbor (2), Lower Monumental (4), Little Goose (11), Lower Granite (9, with 4 of these collected for the Kelt Program), and Rocky Reach (1) (Table 30). Another major exit location for kelts is Bonneville Dam's Corner Collector, where 32 steelhead tagged by this study were last detected migrating downstream past this location in spring and summer 2016 (Tables 30 and A2). Of the 98 identified kelts, 54 of them were tracked into the Columbia River tributaries; many had multiple hits in the tributaries as they made their way to the spawning grounds and back out after spawning (Tables A1, A2, and Figure A1 - map of all detection locations). Four steelhead were collected by the Kelt Project in tributaries as they were moving downstream after spawning. Four steelhead appeared to be repeat spawners as they were last seen in the spring of 2016 heading downstream, and then in the fall of 2016 were detected moving upstream through the Bonneville Dam fish ladders.

Among the 1,573 steelhead sampled at Bonneville Dam where ocean age could be estimated, when compared to non-kelt, kelt had a higher percentage of one-ocean fish (28.3% vs. 15.4%) and lower percentage of two ocean fish (70.7% vs. 83.4%). The mean length of non-kelt was 59.9 cm compared to 64.9 cm for kelt (Table 31).

We have also updated information on kelts/repeat spawners from past annual reports with data from 2016/2017 movements. Some steelhead already identified as kelts or repeat spawners in the reports have new information added, others are newly added because they were detected a year or two later moving upriver again to spawn. Usually, up to three past years of tagged steelhead have appeared in the detection system, however, for steelhead tagged in 2013, 2014 and 2015 there was no additional detection in the system in 2016/2017.

Table 30. PIT tagged steelhead sampled at Bonneville Dam subsequently designated as kelt by being last detected moving downstream the year after sampling or being last detected moving upstream the year after sampling for sampling years 2009-2016. Data is categorized by last detection site.

	Tag Year							
Last site	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Bonneville Corner Collector	32	25	38	30	25	10	23	61
Bonneville Juvenile Bypass	1	5	3	6	5	1	4	7
Bonneville Dam Bradford Island Ladders heading downstream	0	2	1	3	2	0	0	0
Estuary Trawl or Pile Dikes (TWX or PD7)	1	0	0	2	2	0	0	1
Ice Harbor Juvenile Bypass	2	1	0	0	0	1	6	0
Ice Harbor Ladders heading downstream	0	0	0	1	0	NA	NA	NA
John Day Juvenile Bypass	20	6	2	8	6	3	11	3
Little Goose Juvenile Bypass	11	5	2	9	5	11	13	6
Lower Granite Juvenile Bypass	5	0	3	4	3	4	10	3
Lower Monumental Juvenile Bypass	4	0	2	7	1	12	9	4
Washington Shore McNary Dam ladder downstream.	3	0	1	0	0	0	2	1
McNary Dam Juvenile Bypass	4	1	1	4	4	3	2	4
Rocky Reach Juvenile Bypass	1	2	10	1	0	4	6	7
Migrating downstream in tributaries	2	6	NA	4	3	0	0	0
Repeat spawners, at Bonneville Dam or above migrating upstream	4	4	5	12	1	NA	NA	NA
Trapped by CRITFC Kelt Program								
Snake Basin	7	5	4	11	NA	NA	NA	NA
Yakima Basin	1	1	6	6	1	NA	NA	NA
Total	**98**	**63**	**77**	**108**	**58**	**49**	**86**	**97**
Percent of steelhead tracked designated as kelt	**6.1%**	**5.3%**	**4.5%**	**7.2%**	**4.0%**	**3.1%**	**5.2%**	**4.8%**
Additional steelhead detected migrating upstream in subsequent migration year	**0**	**0**	**2**	**5**	**13**	**3**	**9**	**5**
Minimum number of kelt	**98**	**63**	**79**	**113**	**71**	**52**	**95**	**102**

Table 31. Ocean age composition of steelhead designated as kelt or non-kelt sampled at Bonneville Dam in 2016.

Run	N	One-Ocean (x.1)	Two-Ocean (x.2)	Three Ocean (x.3)	Four Ocean (x.4)
Kelt	92	28.3%	70.7%	1.1%	0.0%
Non-Kelt	1485	15.4%	83.4%	1.1%	0.1%

RESULTS-SOCKEYE[3]

Sample Size

In 2016, a total of 1,706 Sockeye Salmon were sampled for this project at the Bonneville Dam Adult Fish Facility from May 26 to August 18 (Table 32). Of these, 51 were not tagged[4], and 1 fish died prior to release. Three Sockeye were previously tagged and added to the remaining 1,655 Sockeye tagged and released resulting in a total sample size of 1,657 tagged Sockeye Salmon, 1653 of which were detected after release. In 2016, our project was impacted by sampling restrictions on 24 days that were imposed due to high shad abundance as well as 16 days due to high water temperatures (21.1 to 22.2C, Table 1)[5]. Sampling was shut down an additional 3 days at the very end of the Sockeye run due to high temperatures (>22.2C). All sampling days subject to temperature restrictions were in weeks 31-34 which were weeks in which only 1.9% of the Sockeye run passed Bonneville Dam (FPC 2017).

Table 32. Number of Sockeye Salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2016.

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

[3] The information presented in this section of the report is a summary of Fryer et al. 2018.
[4] Of the 51 Sockeye not tagged, 48 were on June 17 when our sampling crew ran out of PIT tags.
[5] Raising picket leads is required by trap regulations and decreases the number of fish going through the trap and can introduce trap biases (Fryer et al. 2011).
[6] Statistical weeks are sequentially numbered calendar-year weeks. Excepting the first and last week of most years, statistical weeks are seven days long beginning on Sunday and ending on Saturday. In 2016, for instance, Statistical Week 24 began on June 6 and ended on June 11.

Distribution of Sample

The weekly distribution of the Sockeye sample at Bonneville Dam differed from the actual run distribution (Figure 23) less than in 2015 due to continuous trap operations in 2016. The largest deviation was in Week 26 due to the large proportion of returning Sockeye Salmon making it impossible to trap sufficient Sockeye while also trapping summer Chinook.

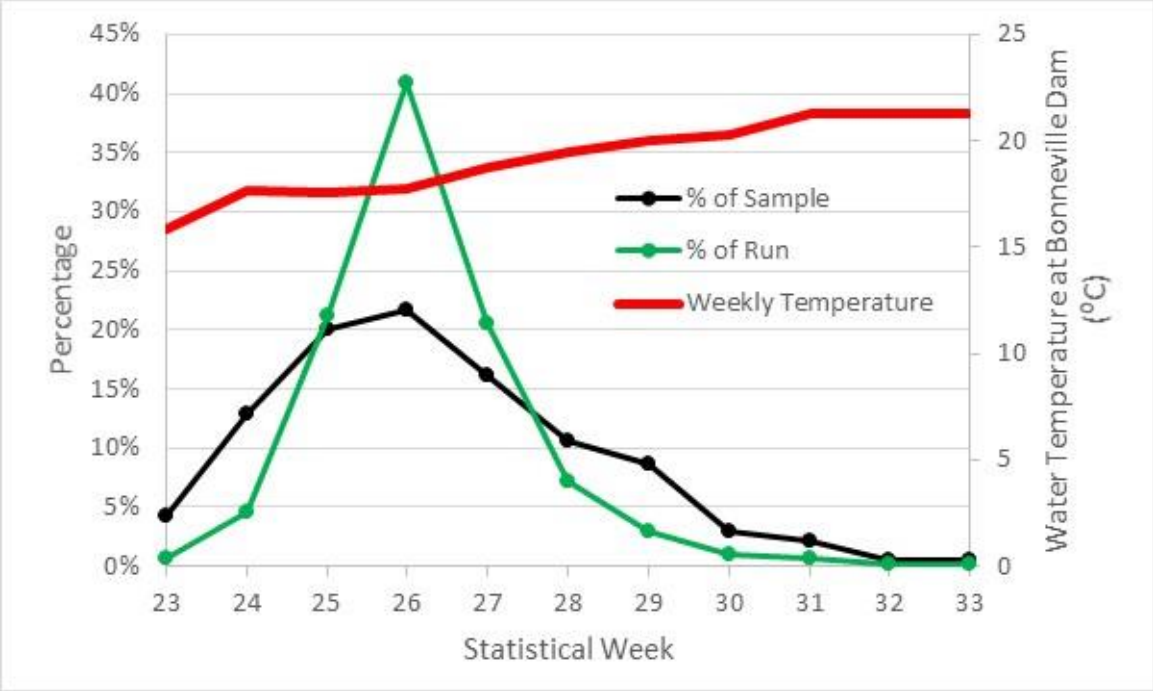

Figure 23. The weekly Sockeye sample and run as a percentage of the total sample and run size at Bonneville Dam in 2016.

Detection Numbers

The tracking of 1,653 Sockeye generated 53,762 weir detections, which were grouped into 12,454 site detections at 50 sites. Of the 1,658 tagged Sockeye released in this study, 4 were not detected after release. These fish may have shed their tags, had defective tags, or died. It is also possible that these Sockeye Salmon passed downstream without being detected as Sockeye often pass over the top of weirs in the fish ladder rather than through the underwater slots where PIT tag antennas are located in the lower portions of Bonneville Dam fish ladders. It is unlikely that Sockeye Salmon pass upstream through fishways undetected as, at Bonneville Dam, they must pass through four PIT tag antennas on the Washington shore ladder or three antennas on the Oregon shore ladder near the fish counting window that detect very close to 100% of passing PIT tagged fish. However, at Bonneville Dam (as well as The Dalles, McNary, Ice Harbor, and

Lower Granite dams) fish can pass upstream through the navigation locks. All other dams with PIT tag detection have antennas in fish ladders that Sockeye Salmon must pass, through data from 2006-2016 indicate that PIT tagged Sockeye are missed at fish ladder sites (Table 33).

Table 33. Number and percentage of PIT tagged fish tracked by this project after sampling at Bonneville Dam not detected at dam detection sites as estimated from upstream detections in 2016 compared to 2006-2015.

	Percentage by Year											
Dam	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Mean
Bonneville	2.8	1.6	0.7	0.4	1.8	0.5	0.7	0.6	0.4	2.1	0.2	1.1
The Dalles	0.4	0.6	0.3	1.6	--	--	--	--	--	--	--	0.7
McNary	2.4	1.1	3.8	2.1	12.1	1.6	3.8	5.0	10.1	6.5	3.1	4.7
Priest Rapids	0.3	0.4	0.2	0.0	0.4	0.2	0.6	0.3	0.3	0.8	0.0	0.3
Rock Island	2.9	10.2	41.5	4.4	5.4	4.4	6.2	2.6	6.9	6.8	1.3	8.4
Rocky Reach	0.0	0.0	0.3	0.0	1.4	0.7	0.5	0.0	0.2	0.7	12.3	1.5
Wells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	--	--	--	0.0
Ice Harbor	0.0	0.0	12.5	NA	0.0	--	0.0	20.0	0.0	--	--	4.6
Lower Monumental	0.0	0.0										0.0
Little Goose	0.0	0.0										0.0
Lower Granite	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

Annual rates of PIT tagged Sockeye tracked by this project missing detection at upstream dams since this project began in 2006 are given in Table 33. Sockeye were only missed at 5 dams in 2016, 3 of which (Bonneville, The Dalles, and McNary) have navigation locks which PIT tagged fish can pass through undetected. The dam with the highest rate of missed Sockeye, Rock Island Dam, has had had the highest rate among Columbia River dams every year since 2013, likely due to electrical noise adversely affecting the ability of PIT tag antennas to detected PIT tags (Fryer et al. 2011).

Age Analysis

The predominant age group in 2016, at 88.1% of the run, was estimated to be Age 1.2 (Table 34). The other age groups with over 10% of the run was Age 1.3. Among these major age groups, in 2016, the percentage of 1.2 Sockeye showed a significant linear increase as the run progressed ($p=0.004$) over the run, while the percentage of Age 1.3 Sockeye decreased ($p=0.017$).

Table 34. Weekly and total age composition of Sockeye Salmon at Bonneville Dam as estimated from scale patterns in 2016. (Composite estimates are weighted by the percentage of the run passing Bonneville Dam in each week.)

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

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Survival rates to upstream dams, as estimated from detections of Sockeye PIT tagged by this study at Bonneville Dam, are compiled in Table 35. Survival to The Dalles Dam (TDA) was the highest since detection at TDA began in 2013, while survival to McNary Dam was the highest since 2008.

Table 35. Survival of Sockeye PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams 2006-2016 (%).

	Percentage by Year and Mean of All Years											
Dam	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	Mean
TDA	94.0	82.8	93.1	89.5								89.9
MCN	89.2	54.0	88.3	83.6	82.4	76.1	81.5	85.7	89.4	84.0	88.4	82.1
PRA	85.3	44.9	84.5	78.6	77.3	71.9	78.4	82.1	86.3	77.4	84.8	77.4
RIA	81.6	40.6	79.5	74.2	75.0	68.9	76.3	80.2	85.8	73.4	81.1	74.2
RRF	60.5	31.6	65.3	52.4	62.1	55.3	63.7	67.1	73.7	62.2	58.8	59.3
WEA	59.3	29.4	64.2	50.5	60.8	53.9	62.6	65.2	71.1	60.9	53.8	57.4
TUF	20.8	8.3	13.6	20.9	12.9	14.2	13.3	12.2	9.4	NA	NA	14.0
Mean BON Temperature 6/15-7/14	18.8	21.3	17.9	18.2	16.4	15.8	16.6	17.9	17.0	18.2	18.3	17.9

In 2016, estimated escapement based on upstream PIT tag detections was greater than the number of Sockeye counted at The Dalles and McNary dams, but less than at Priest Rapids, Rock Island, Rocky Reach, Wells, and Tumwater dams (Table 36, Figure 24) with a range of -12.1% to 16.7% at Columbia River dams. Relatively large deviations between these estimates at Ice Harbor and Prosser

dams are likely explained, at least in part, by the low number of Sockeye PIT tagged by this project passing these sites.

Table 36. Percentage of PIT tagged Sockeye Salmon detected at upstream dams subsequent to tagging at Bonneville Dam, estimated escapement from both PIT tags and visual counts, and the difference between the PIT tag and visual escapement estimate in 2016.

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

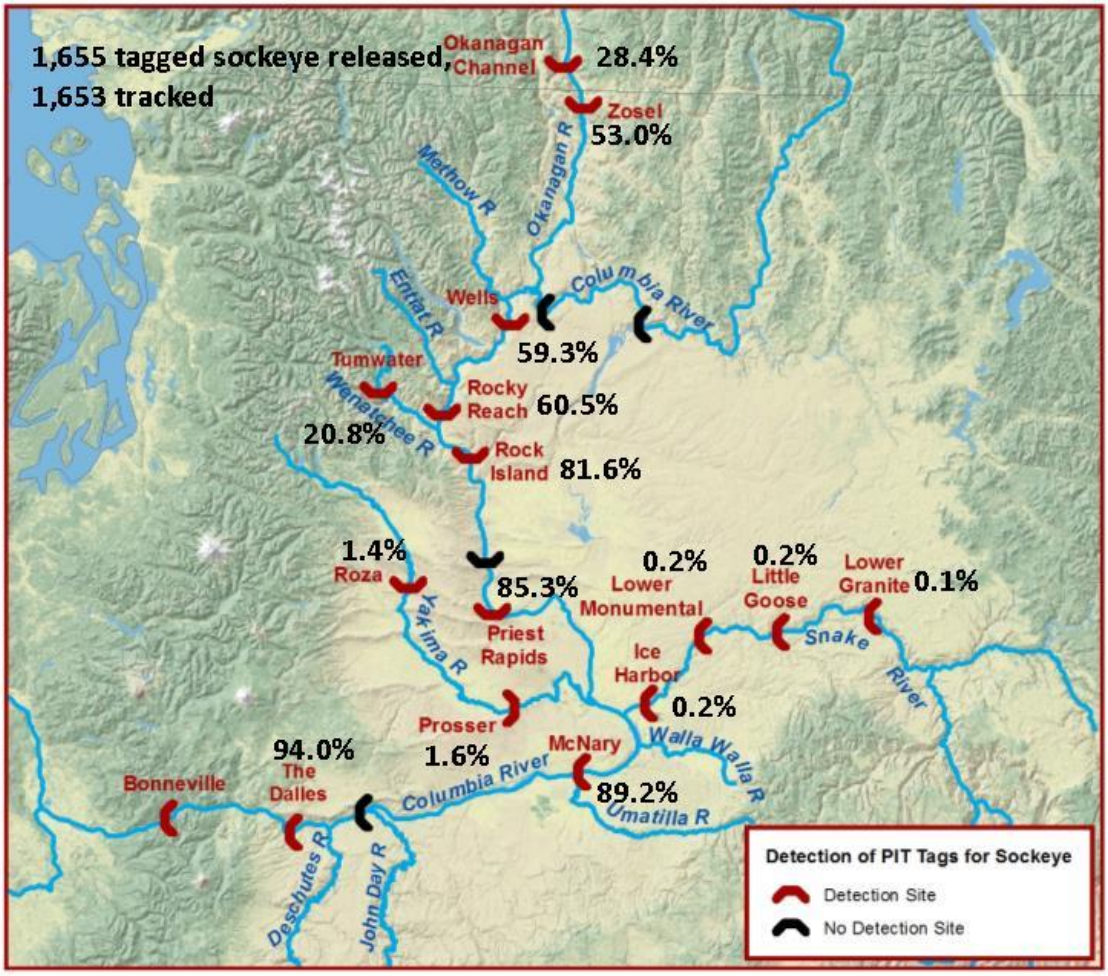

Figure 24. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2016.

Sockeye Salmon show a significant linear decrease in survival over the period of the run to upstream dams in 2016 with the exception of Bonneville-The Dalles (Table 37, Figure 25). This exception is driven by the high survival rates in weeks 31 and 32-34 to The Dalles, however survival to points further upstream for Sockeye tagged in those weeks was much lower.

Table 37. Sockeye Salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2016 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Bonneville-The Dalles	Bonneville-McNary	Bonneville-Priest Rapids	Bonneville-Rock Island
22-23	97.1%	94.2%	92.8%	91.3%
24	94.4%	93.0%	90.6%	90.1%
25	97.6%	93.4%	91.6%	88.0%
26	95.8%	92.8%	90.0%	86.1%
27	91.1%	85.7%	78.0%	72.6%
28	90.8%	83.3%	79.9%	78.7%
29	77.3%	67.4%	59.6%	56.0%
30	75.0%	62.5%	54.2%	50.0%
31	91.4%	51.4%	42.9%	40.0%
32-34	92.9%	7.1%	7.1%	7.1%
Composite[7]	**94.0%**	**89.2%**	**85.3%**	**81.6%**
p-value	**0.115**	**0.001**	**<0.001**	**<0.001**

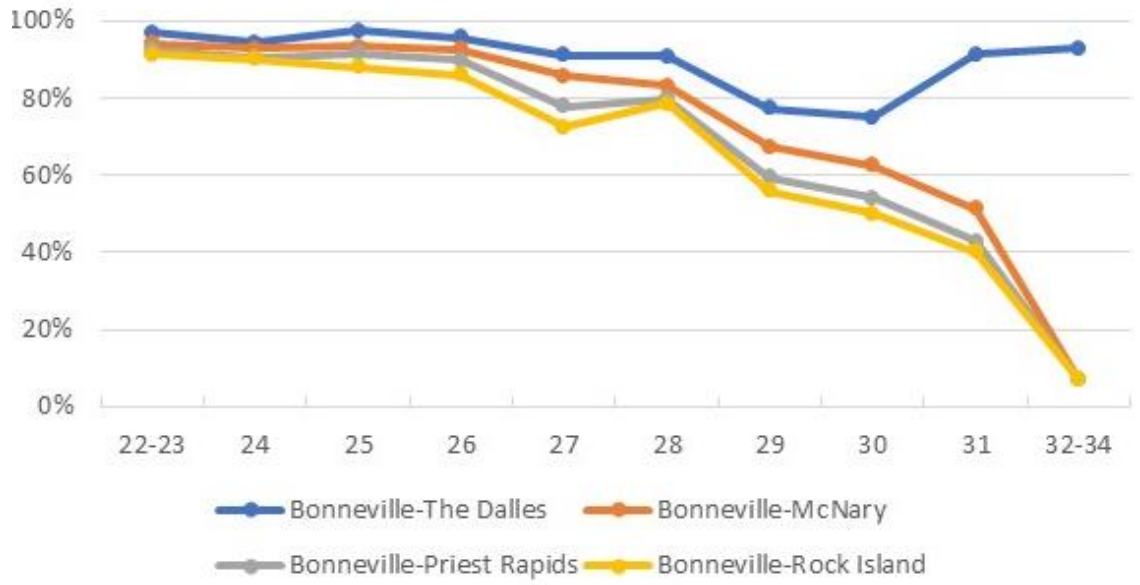

Figure 25. Survival of Sockeye Salmon PIT tagged at Bonneville Dam to The Dalles, McNary, Priest Rapids, and Rock Island dams by statistical week in 2016.

[7] Composite estimates for Bonneville Dam-tagged Sockeye Salmon are weighted by Statistical Week.

Migration Rates and Passage Time

Adult Sockeye Salmon travel quickly upstream with a median migration rates between mainstem dams ranging between 29.3 and 55.2 km/day in 2016 for Sockeye tagged at Bonneville Dam (Table 38).

Table 38. Median Sockeye Salmon migration rates and travel time between dams as estimated by PIT tag detections in 2016.

Dam Pair	Distance (km)	Median Travel Time (days)	Median Migration Rate (km/day)
Bonneville-The Dalles	74	1.7	42.7
The Dalles-McNary	162	2.9	55.2
McNary-Priest Rapids	167	3.8	44.4
Priest Rapids-Rock Island	89	3.1	29.3
Rock Island-Rocky Reach	33	1.1	30.3
Rocky Reach-Wells	65	1.9	36.8
Rock Island-Tumwater	73	10.7	6.5
Bonneville-McNary	231	4.7	49.8
Bonneville-Priest Rapids	329	8.3	48.5
Bonneville-Rock Island	487	11.7	41.8
Bonneville-Tumwater	560	23.4	23.9
Bonneville-Wells	585	14.7	40.2

Sockeye Salmon tagged at Bonneville Dam later in the migration travel upstream faster than those tagged earlier in the migration (Table 39). This relationship was significant from Bonneville to McNary, Priest Rapids, Rock Island, Tumwater, and Zosel dams.

Table 39. Adult Sockeye Salmon median travel time in days between dam pairs by statistical week tagged at Bonneville Dam, the p-value for a linear regression between travel time and statistical week, and mean travel time by stock as estimated using PIT tags in 2016.

Statistical Week at Bonneville Dam	BON-TDA	BON-MCN	BON-PRA	BON-RIA	BON-TUM	BON-RRH	BON-WEL	BON-ZSL	WEL-ZSL	RIA-TUM
22-23	1.7	4.7	8.1	11.5	23.6	12.8	15.1	20.5	4.68	11.9
24	1.7	4.7	8.5	11.8	25.1	12.8	14.8	20.8	5.06	11.3
25	1.7	4.7	8.7	12.0	25.9	12.9	14.9	21.0	4.97	11.9
26	1.7	4.7	8.6	11.8	25.1	12.3	14.4	19.8	4.75	11.9
27	1.6	4.3	8.0	11.3	21.8	12.3	13.9	21.2	6.54	8.9
28	1.5	4.6	8.0	11.0	20.9	12.0	14.2	18.8	4.97	8.3
29	1.5	4.5	8.0	11.7	20.9	12.6	14.1	18.7	4.42	8.6
31-32	1.2	3.9	7.4	10.8	20.0	12.0	13.9	17.6	3.64	9.0
p-value	**0.001**	**0.013**	**0.014**	**0.019**	**0.002**	**0.328**	**0.109**	**0.038**	**0.473**	**0.001**

The median passage time at a dam (defined as the difference between the first and last detection at a dam) for Sockeye tracked from Bonneville Dam, with the exception of at Snake River dams where sample sizes of AFF-tagged Sockeye

were small (only four Sockeye passed up the Snake in both 2016), was under 1 minute in 2016 (Table 40).

Table 40. Sockeye Salmon median passage time from time of first detection at a dam to last detection at a dam and the percentage of Sockeye Salmon taking greater than 12 hours between first detection and last detection in 2016.

	Adults Tagged at Bonneville Dam	
Dam	Median Passage (Minutes)	%>12 Hours
Bonneville	10.2	0.2%
The Dalles	0.1	0.6%
McNary	0.1	0.7%
Priest Rapids	5.4	1.6%
Rock Island	0.1	0.7%
Rocky Reach	6.5	0.5%
Wells	7.7	6.2%
Zosel	0.4	0.9%
Tumwater	6.9	5.3%
Ice Harbor	122.7	33.3%
Lower Monumental	9539.1	66.7%
Little Goose	0.1	0.0%
Lower Granite	420.4	0.0%

Fallback

Fallback rates for adults tagged at Bonneville Dam in 2016 ranged from 0.1% at Bonneville Dam to 2.6% at Rocky Reach Dam for sites with 10 or more detections (Table 41). Snake River dams had fallback rates ranging from 0 to 50% but that was based on only 4 detections. Of the 85 Sockeye tagged by this project in 2016, which were estimated to fall back over at least one dam, 16 had multiple fallbacks (Table 42).

Table 41. Estimated fallback rates at dams for Sockeye Salmon included in our Bonneville adult tagging study in 2016[8].

Dam	Adults Tagged at Bonneville	Dam	Adults Tagged at Bonneville
Bonneville	0.1%	Zosel	0.4%
The Dalles	1.1%	Tumwater	0.6%
McNary	0.3%	Ice Harbor	50.0%
Priest Rapids	1.5%	Lower Monumental	50.0%
Rock Island	0.6%	Little Goose	0.0%
Rocky Reach	2.6%	Lower Granite	0.0%
Wells	2.0%		

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

Table 42. Number of fallback events for Sockeye included in our Bonneville adult tagging study in 2016.

Fallback Events	Adults Tagged at Bonneville
1	69
2	14
3	2
4	0
5	0
6	0
7	0
8	0
9	0
Number of Sockeye falling back at least once	85
% of Sockeye with at least one fallback event	5.2%
Total fallback events	103
Number of Sockeye in study	183
Fallbacks events per Sockeye	0.84

Night Passage

Sockeye had the highest rate of night passage at Wells Dam (Table 43). Bonneville Dam had the lowest rate (0.8%), however this is likely biased low as sampling was conducted during the day and median passage to the uppermost PIT tag antennas at Bonneville was only 10.2 minutes (Table 40).

Table 43. Estimated Sockeye Salmon night passage (2000-0400) at mainstem Columbia River dams in 2016.

Dam	Percent Night Passage
Bonneville	0.8%
The Dalles	8.2%
McNary	7.4%
Priest Rapids	3.6%
Rock Island	5.4%
Rocky Reach	8.3%
Wells	13.0%

DISCUSSION

This study sampled 6,742 and PIT tagged 6,611 salmonids at Bonneville Dam in 2016 and then tracked (6,659 – includes previously tagged fish) these fish upstream to estimate parameters such as upstream escapement, age composition, length composition, and migration rates at and between mainstem dams and other tributary interrogation sites. The year 2016 marked the 11th year we have been PIT tagging Sockeye Salmon, the 10th year we have tagged Chinook Salmon and the 8th year we have tagged steelhead at Bonneville Dam. Over this time, the number of PIT tag detection sites has continually increased, allowing us to learn more about the movement of tagged salmonids throughout the Columbia Basin.

For both Chinook Salmon and steelhead, there are management concerns regarding the timing of run components. One question of interest to fish managers is the definition of a summer Chinook Salmon. Traditionally, spring Chinook Salmon were defined as those migrating past Bonneville Dam through May 31, with summer Chinook Salmon passing from June 1 through July 31, and fall Chinook Salmon defined as passing on or after August 1. Dates of defining a Chinook run at upstream dams were lagged to take into account migration times from Bonneville Dam to the dam in question. However, in 2005, for management purposes the spring-summer differentiation at Bonneville Dam was moved from June 1 to June 16 (though visual counts are typically reported using the old cutoff). Managers moved this date because radio tagging studies suggested that many of the Chinook Salmon migrating in early June are from the Snake River (many spring/summer Chinook in the Snake River Basin are listed as endangered under ESA), while Chinook migrating in late June are mid-Columbia summers. Tag detection data from this project showed that in 2016 the percentage of Chinook Salmon at Bonneville Dam, which ultimately passed Ice Harbor Dam, peaked at 57.5% of the run for the week starting May 15. By week 23 (which started May 29), the percentage of Chinook tagged at Bonneville which were detected at Priest Rapids Dam exceeded that at Ice Harbor, and by week 25 (June 12), the percentage which ultimately passed Ice Harbor Dam had declined to 7.5% of the run. The percentage detected above Priest Rapids Dam reached 75.6% for those Chinook tagged in Week 26. In years 2010-2013, the run at Bonneville Dam transitioned over the month of June from being primarily Snake River spring/summer to being primarily mid-Columbia summer Chinook, in 2016, as in

2015 and 2014 this transition started earlier in May than in past years.

As at Bonneville Dam, Chinook runs (spring, summer, and fall) passing dams upstream of Bonneville Dam are differentiated based on the date they pass, and these dates per dam are based on fixed migration rates assumed by managers. For instance, spring Chinook transition to summer Chinook on June 1 at Bonneville Dam, June 11 at Ice Harbor Dam and June 13 at Priest Rapids Dam. This means that the same Chinook traveling slower than expected could be classified differently at different dams. For example, a “spring” Chinook passing Bonneville Dam on May 31 would be a “summer” Chinook passing Priest Rapids Dam on June 13. Using PIT tag data, this study found that 2.8% of spring, 7.1% of the summer, and 14.0% of the fall Chinook at Bonneville Dam were classified differently at Priest Rapids Dam (Table 8). Misclassified Bonneville spring Chinook were all classified as summers, misclassified summers were classified mostly as springs, and misclassified fall Chinook were all classified as summer Chinook at Priest Rapids Dam. This study found that 0.8% of spring, 32.6% of summer, and 1.8% of the fall Chinook at Bonneville Dam were classified differently at Ice Harbor Dam. Chinook classified at Bonneville Dam as spring Chinook were misclassified as summer Chinook at Ice Harbor Dam, while Chinook classified as summer Chinook at Bonneville Dam were most commonly misclassified as spring Chinook at Ice Harbor Dam and all misclassified fall Chinook were classified as summer Chinook.

The number of fish tagged in 2016 was second only to 2014 in the 8 years since this Accords project began in 2009 (Table 44) and the percentage of the run sampled, at 0.51%, was the highest since the project began. A primary reason for the high samples sizes was lower water temperatures meaning fewer days of no trapping. For the first time since the Accords began in 2009, temperatures did not rise above 22.2C, which triggers no sampling. We also had fewer weeks of reduced sampling than in previous years due to high temperatures. The lowest combined return of Chinook, steelhead and Sockeye since the project began in 2009 contributed to the comparative high percentage of the run tracked.

Table 44. Total number of Chinook and Sockeye salmon and steelhead PIT tags tracked by year (includes recaptures of previously PIT tagged fish).

	Total Tracked				Percent of Run Tracked			
Year	Chinook	Steelhead	Sockeye	Total	Chinook	Steelhead	Sockeye	Total
2009	2968	2485	838	6291	0.42%	0.41%	0.47%	0.42%
2010	2579	1741	913	5233	0.29%	0.42%	0.24%	0.31%
2011	3253	1377	763	5393	0.38%	0.37%	0.41%	0.38%
2012	3438	1451	1601	6496	0.50%	0.62%	0.31%	0.45%
2013	3406	1276	772	5454	0.26%	0.55%	0.42%	0.32%
2014	3869	1717	1400	6986	0.27%	0.63%	0.27%	0.33%
2015	3563	898	901	5362	0.25%	0.33%	0.18%	0.24%
2016	3396	1610	1653	6659	0.44%	0.86%	0.48%	0.51%

In 2016, we had two Chinook that were inadvertently double tagged. The first was released at Warm Springs Hatchery with 3DD.007745DBC3 on April 3, 2014 and we tagged it again on May 18, 2016 with tag 3DD.00775DD0DB. Following the double tagging, the original tag was detected four times at BO3 and once at TD1, while our tag was detected two times at BO3 and once in TD1. All BO3 detections were at antennas 0F, 0D and 0B upstream of the return from the AFF.

The second Chinook double tagged, first left Chiwawa Rearing Ponds (CHIP) with tag 3D9.1C2DF77E9D on June 17, 2013 and retagged at the AFF on June 8, 2016 with tag 3DD.00775D8220. After the double tagging event, the AFF tag was only detected at BO3, BO4, and RIS, while both tags were detected at TD2, MC2, and TUF.

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APPENDIX

Table A1. List of PTAGIS interrogation sites (three letter code, name, and description) to use with maps that follow. Out of 303 active sites, 155 sites detected the fish tagged in 2016.

Site Code	Site Name	Site Description
ACM	Asotin Creek near mouth	Near the mouth of Asotin Creek 50 m upstream of the Highway 129 bridge spanning the mainstem of Asotin Creek in two serial sets of two antennas.
B2J	Bonneville PH2 Juvenile	Bonneville Dam PH2 Juvenile Bypass and Sampling Facility.
BBT	Touchet River at Bolles Bridge	The Bolles Bridge site is located about 200 feet above the State HWY 124 bridge on the Touchet River, near Bolles Road, at River Kilometer 65.2.
BCC	BON PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel.
BGM	Burlingame Dam and Canal	Burlingame Diversion Dam is located on the lower Walla Walla River.
BHC	Bohannon Creek Lemhi R Basin	The array is located in Bohannon Creek, 40 m upstream of the confluence with the Lemhi River.
BO1	Bonneville Bradford Is Ladder	Bradford Island Adult Fishway at Bonneville Dam.
BO2	Bonneville Cascades Is Ladder	Cascades Island Adult Fishway at Bonneville Dam.
BO3	Bonneville WA Shore Ladder/AFF	Washington Shore Adult Fishway and AFF at Bonneville Dam; replaces B2A and BWL.
BO4	Bonneville WA Ladder Slots	Washington Shore Fishway Vertical Slots at Bonneville Dam.
BRC	Bear Valley Adult Video Weir	Interrogation system on the existing Bear Valley Creek Chinook adult monitoring weir.
BSC	Big Sheep Creek ISA at km 6	In-stream detection system located in Big Sheep Creek at river km 6 (N 45.50649, W -116.85067).
CAL	Carson NFH Adult Return Ladder	Hatchery adult spring Chinook return ladder from the Wind River to Carson NFH.
CCW	Catherine Creek Ladder/Weir	Instream detection array located in the adult return fish ladder at the Catherine Creek weir.
CEY	Cearley Creek Side Channel	Instream array in the creek a small tributary of the Yankee Fork of the Salmon River, Idaho and flows into a newly constructed side channel and then into the Yankee Fork main stem.
CFF	Castile Falls Fishway	The Castile Falls Adult Fishway interrogation site consists of three pass-through antennas in series in the fishway channel.
CFJ	Clark Flat Acclimation Facility	Clark Flat Acclimation Pond Outfall.
CHL	Lower Chiwawa River	Chiwawa River rkm 1, located between the Chiwawa smolt trap and the Chiwawa Acclimation Ponds.
CHP	Chiwawa River Salmon Rearing and Acclimation Facility	PIT tag detection system located at the Chiwawa Acclimation Pond.
CHU	Upper Chiwawa River	Chiwawa River rkm 12, located above the Forest Road 62 bridge and below Alder Creek.
CLC	Clear Creek near Kooskia NFH	Instream detection array located in lower Clear Creek, a tributary to the Clearwater River, just downstream of Kooskia National Fish Hatchery.
CRU	Upper Chewuch instream Array	Instream PIT tag interrogation site at RKM 28.35 on the Chewuch River.
CRW	Chewuch River above Winthrop	Chewuch River at river km 1, above Winthrop, WA.
CWP	Chewuch Acclimation Facility	Remote acclimation pond located approximatley 6 miles north of Winthrop on Boulder Creek Rd.
CZY	Crazyman Creek at 0.6 km	Instream tandum array located in the Imnaha River basin on Crazyman Creek at rkm 522.308.80.001 (N 45.22930 W -116.84478).
DBO	Bakeoven Ck Deschutes Trib	Instream array in Bakeoven Creek, a trib to the Deschutes River, the site is approximately 1/4 mile from the mouth.
DSF	Sherars Falls Fish Ladder	Site consists of two monitored weirs in the main fishway and two monitored weirs in the high flow fishway.
DRM	Deschutes River mouth	Mouth of the Deschutes River in the west channel at Moody Island (rkm 0.46).
DWL	Dworshak NFH adult trap	Located at the terminus of the Dworshak National Hatchery adult fish ladder in the North Fork Clearwater River.
EBO	East Bank Hatchery Outfall	Located in the East Bank Hatchery outfall channel.
EFD	East Fork Diversion Fishway	Located in a fish ladder at a irrigation diversion site for the East Fork Irrigation District on the East Fork of the Hood River.
EHL	Entiat NFH Adult Ladder	This adult interrogation site is located in the Entiat National Fish Hatchery adult ladder.
ENA	Upper Entiat River at rkm 17.1	The site is located approximately 400 meters above the mouth of the Mad River near the township of Ardenvoir at river kilometer 17.1.
ENL	Lower Entiat River	Entiat River rkm 2, located immediately upstream of Entiat, WA.
ENM	Middle Entiat River	Entiat River rkm 26, below the McKenzie Diversion Dam.
ENS	Upper Entiat River at rkm 35.7	The site is located approximately 4.3 km above Stormy Creek at river kilometer 35.7 and near the entrance of the
ESS	EFSF Salmon River at Parks Cr	East Fk South Fk Salmon River (rkm 21) near Parks Creek.
EWC	Early Winters Creek rkm 0.36	Instream PIT tag detection system located at rkm 0.36 on Early Winters Creek (Methow River Basin), near Early Winters Campground.
FDD	Feed Diversion Dam	Feed Diversion Dam, at Umatilla River rkm 47.
FST	Foster Creek	Foster Creek enters the Columbia River at RKM 876.9, approximately 2.2 KM up river from the town of Bridgeport, WA. The FST site is located approximately 0.15 KM upstream from the confluence of the Columbia River.
GOA	Little Goose Fish Ladder	Adult Fishway at Little Goose Dam.
GOJ	Little Goose Dam Juvenile	Little Goose Dam Juvenile Fish Bypass/Transportation Facility.
GLC	Gold Creek, Methow River	Instream PIT tag interrogation site at RKM 0.18 of Gold Creek in the Methow River basin.
GRA	Lower Granite Dam Adult	Lower Granite Dam Adult Fishway and Fish Trap.
GRJ	Lower Granite Dam Juvenile	Lower Granite Dam Juvenile Fish Bypass/Transportation Facility.
HRM	Hood River Mouth	Located at the mouth of the Hood River against the west side jetty just inside the bar where the Hood River
HYC	Hayden Creek Instream Array	Lower section of Hayden Creek, in the Lemhi River Basin.

Table A1. Continued.

Site Code	Site Name	Site Description
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.
IML	Imnaha River Weir Adult Ladder	Located in the adult return fish ladder at the Imnaha River weir. Site is on public land.
IR1	Lower Imnaha River ISA at km 7	Lower Imnaha River at river km 7 (N 45.761162, W -116.750658).
IR2	Lower Imnaha River ISA at km 10	Lower Imnaha River at river km 10 (N 45.742839 W -116.764563).
IR3	Upper Imnaha River ISA at km 41	Upper Imnaha River at river km 41 (N 45.49004 W 116.80393).
IR4	Imnaha Weir Downstream Array	Located downstream of the Oregon Dept. of Fish and Wildlife (ODFW) fish weir on the Imnaha River.
IR5	Imnaha Weir Upstream Array	Located upstream of the Oregon Dept. of Fish and Wildlife (ODFW) fish weir on the Imnaha River.
JCJ	Jack Creek Acclimation Facility	Jack Creek Acclimation Pond Outfall.
JD1	John Day River, McDonald Ferry	John Day River in-stream detection, near McDonald Ferry at RM 20.
JDJ	John Day Dam Juvenile	John Day Dam Juvenile Fish Bypass and Sampling Facility.
JDM	Upper John Day Array	Located on the Upper Mainstem John Day River approximately 7 miles upstream of Dayville, Oregon.
JOC	Joseph Creek ISA at km 3	Joseph Creek, Grande Ronde basin at river km 3 (N 46.030016, W -117.016042).
KHS	Big Bear Creek at Kendrick High School	Located near the mouth of Big Bear Creek (in the Potlatch River Basin) adjacent to the high school in the town of Kendricks, ID.
LAP	Lapwai Creek, near its mouth	In-stream detection system consisting of three arrays located in Lapwai Creek.
LC1	Lower Lolo Creek at rkm 21	Lolo Creek, a tributary to the Clearwater River located at river km 522.224.087.021 (N 46.294434 W -115.976119).
LC2	Upper Lolo Creek at rkm 25	Lolo Creek, a tributary to the Clearwater River located at river km 522.224.087.025 (N 46.290562 W -115.934153.
LFF	Lyle Falls Fishway	The Lyle Falls Fishway in Klickitat River.
LLR	Lower Lemhi River	Lower Lemhi River in Salmon, ID.
LMA	Lower Monumental Adult Ladders	This interrogation site is in both ladders at Lower Monumental Dam.
LMJ	Lower Monumental Dam Juvenile	Lower Monumental Dam Juvenile Fish Bypass/Transportation Facility.
LMR	Lower Methow River at Pateros	Lower Methow River near the WDFW 'Miller Hole' access site on the lower Methow River immediately upstream of Pateros, WA.
LNF	Leavenworth NFH Adult Ladder	Located in the Leavenworth National Fish Hatcheries adult ladder and holding pond.
LRL	Lower Lochsa River Array Site	Site is located in lower 1km of the mainstem Lochsa River.
LRW	Lemhi River Weir	Lemhi River above the mouth of Hayden Creek and below the IDFG weir.
LTR	Lower Tucannon River	Near the mouth of the Tucannon River. The upstream array group was located at an abandoned railroad bridge abutment upstream of Hwy 261 on the Tucannon River downstream from Starbuck. The CO in-stream array was relocated below the Hwy 261 bridge on Sept. 29, 2010.
LWE	Lower Wenatchee River	Wenatchee River rkm 2.
LWL	Ltl. White Salmon NFH returns	Adult fish ladder allowing passage from the Little White Salmon River into the adult holding ponds at Little White Salmon NFH.
LWN	Little Wenatchee River	Instream PIT tag interrogation site at rkm 4 located at the old fish weir.
MAD	Mad River, Entiat River Basin	Instream interrogation system at Mad River rkm 1, located at Ardenvoir, WA.
MC1	McNary Oregon Shore Ladder	Oregon Shore Adult Fishway at McNary Dam.
MC2	McNary Washington Shore Ladder	Washington Shore Adult Fishway at McNary Dam.
MCJ	McNary Dam Juvenile	McNary Dam Juvenile Fish Bypass/Transportation Facility.
MCL	Lower Mission Creek Instream	Instream PIT tag detection system located at rkm 0.7 on Mission Creek (Wenatchee River Basin), near Cashmere, WA.
MDR	McDonald Road Bridge	Middle Walla Walla River at McDonald Road Bridge.
MIS	Mission Creek	Instream interrogation system approximately 0.1 kilometers upstream from the mouth of Mission Creek.
MJ1	Middle Fork John Day Array	The Middle Fork John Day Array is near the current confluence with Mosquito Creek on Malheur National Forest Service Land.
MRC	Methow River at Carlton	Located in the mainstem Methow River near the town of Carlton at rkm 45.
MRW	Methow River at Winthrop	Methow River. During 2009 and early 2010, the array was located at river km 81, above Winthrop, WA near Winthrop National Fish Hatchery. In Sept. 2010 it was moved upstream to its new location below Wolf Creek on the mainstem Methow River, at river km 85.
MSH	Methow Fish Hatchery Outfall	On the outlet of the Washington Department of Fish and Wildlife (WDFW) Methow Hatchery located on the Methow River at Rk 82.3 from the confluence with the Columbia River.
MTR	Middle Tucannon River	The Middle Tucannon River site is located about 250 feet above the River Ranch Ln bridge on the Tucannon River, at River Kilometer 19.5.
MVF	Moving Falls Fish Ladder	Located in the fish ladder at a site known as Moving Falls on the West Fork of the Hood River.
MWF	Whitefish SC in Methow River	PIT tag interrogators at the entrance and exit of Whitefish Island side channel (rkm 76).
NAL	Lower Nason Creek	Nason Creek rkm 1, located within Lake Wenatchee State Park.
NAU	Upper Nason Creek	Nason Creek rkm 19 (Wenatchee River Basin).
NBA	Nursery Bridge Adult	Nursery Bridge Dam Fishways (both), Walla Walla River at Milton-Freewater, OR.
NFS	North Fork Salmon River	Located on the North Fork Salmon River approximately 0.5 km above the confluence with the Salmon River.
OKC	Okanagan Channel at VDS-3	The OKC site is located in the Okanagan (Canadian spelling) Channel at 310th Avenue/Road 18 upstream from Osoyoos Lake.
OKL	Lower Okanogan Instream Array	Site at RKM 24.9 on the mainstem Okanogan River, upstream of Chiliwist area in Okanogan County.
OKW	Shuttleworth Creek	Shuttleworth Creek, a tributary to the Okanagan River in Canada, immediately upstream of the bridge at Cedary Street.
OMK	Omak Creek Instream Array	Omak Creek enters the Okanogan River at RKM 51.5, approximately 1 km upstream from the city of Omak, WA. The OMK site is located on Omak Creek, 0.24 km from the confluence with the Okanogan River.
ORB	Oasis Road Bridge	Instream arrays at Oasis Road Bridge, lower Walla Walla River.

Table A1. Continued.

Site Code	Site Name	Site Description
PAT	Pattit Creek Instream Site	Instream PIT tag interrogation site at RKM 1.3 on Pattit Creek a tributary to the Touchet River.
PD7	Columbia River Estuary rkm 70	The array (PD7) is located at river km 70 (46.14661N, -123.379867W).
PEU	Upper Peshastin Creek	Located at rkm 17 on Peshastin Creek.
PRA	Priest Rapids Adult	Priest Rapids Dam Adult Fishways (both).
PRH	Priest Rapids Hatchery Outfall	Priest Rapids Hatchery outfall channel. The site is located just upstream of the typical point of inundation in the channel.
PRO	Prosser Diversion Dam Combined	Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam.
PRV	Walla Walla R at Pierce RV Prk	Lower Walla Walla River at Pierce Green Valley RV Park.
RCL	Rock Creek (WA) at rkm 5	Rock Creek (WA) at rkm 5 near the Yakama Nation Longhouse.
RIA	Rock Island Adult	Rock Island Dam Adult Fishways (all three).
ROZ	Roza Diversion Dam (Combined)	Roza Dam Smolt Bypass.
RPJ	Rapid River Hatchery Pond	Rapid River Hatchery (IDFG) outfall.
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway.
RRJ	Rocky Reach Dam Juvenile	Juvenile Fish Bypass Surface Collector.
RSH	Ringold Springs Hatch. Outfall	PIT tag detection system located in the Ringold Springs Hatchery outfall channel.
SAT	Lower Satus Creek	The site is located approximately 1700 meters upstream from the confluence of Satus Creek with the Yakima River at rkm 112.
SC1	Lower SF Clearwater R at rkm 1	Lower South Fork Clearwater River at river km 0.9 (N 46.13685 W -115.98091).
SC2	Lower SF Clearwater R at rkm 2	Lower South Fork Clearwater River at river km 2 (N 46.12749 W -115.97730).
SCL	Spring Creek NFH Adult Ladder	Fish ladder allowing passage from the Columbia River into the adult holding ponds at Spring Creek NFH.
SCP	Spring Creek Acclimation Pond	Juvenile releases from and adults returning to Winthrop National Fish Hatchery.
SFG	SF Salmon at Guard Station Br.	Located at rkm 30 near the lower South Fork Salmon River Guard Station on the South Fork Salmon River.
SHK	Shitike Creek PIT Array	he array is located across the tailout of a pool created by a bridge (known as the Scale Bridge) that is used by logging truck to deliver lumber to the Warm Springs Mill.
STL	Sawtooth Hatchery Adult Trap	Ladder of the Sawtooth Hatchery adult fish trap.
STR	SF Salmon Satellite Facility	Ladder of the South Fork Salmon River adult fish trap.
SUN	Sunnyside Instream Array	Located 600 M below Sunnyside Dam on the Yakima River.
SW1	Lower Selway River Array	PIT tag array is located 5 rkm upstream of the mouth of the Selway River in the upper Clearwater Basin Idaho.
TAY	Big Creek at Taylor Ranch	Centered around the bridge at Taylor Ranch, Big Creek, ID.
TC4	Trout Creek at 43 Road Bridge	Instream arrays at rkm 11.0 of Trout Creek, a tributary of the Wind River, WA.
TD1	The Dalles East Fish Ladder	East Fish Ladder at The Dalles Dam.
TD2	The Dalles North Fish Ladder	North Fish Ladder at The Dalles Dam.
TFH	Tucannon Fish Hatchery	The Tucannon Fish Hatchery site is located about 200 feet above the Tucannon Fish Hatchery Adult Trap and Water Intake System on the Tucannon River, at River Kilometer 59.4.
TMF	Three Mile Falls Dam Combined	Adult Fishway and Juvenile Bypass/subsampling facility at Three Mile Falls Dam.
TON	Tonasket Creek	Tonasket Creek enters the Okanogan River in Lake Osoyoos at rkm 129.4, in the town of Oroville, WA. The site is approximately 0.40 KM upstream from the confluence of Lake Osoyoos.
TRC	Trout Creek, Wind River	Located at river km 2 on Trout Creek, in the Wind River (WA.)
TR1	Lower Trout Cr - Deschutes	Lower Trout Creek is located at RKM 0.7 upstream from the confluence with the Deschutes River on privately owned land.
TR2	Trout/Antelope Cr - Deschutes	Trout and Antelope Creek array is located at RKM 20.7 upstream from the confluence with the Deschutes River on privately owned land.
TUF	Tumwater Dam Adult Fishway	Adult Fishway at Tumwater Dam.
TWR	Lwr Twisp Rvr near MSRF Ponds	Lower Twisp River adjacent to the Methow Salmon Recovery Foundation Ponds.
TWX	Estuary Towed Array (Exp.)	The TWX experimental trawl detector is typically deployed in the Columbia River estuary, at and above Jones Beach (rkm 75).
UGR	Upper Grande Ronde at rkm 155	Grand Ronde River located at river km 522.271.155 (45. 593338, -117.903124).
USE	Upper Salmon River at rkm 437	Located in the Salmon River at river km 522.303.437 (N45.028939 W-113.915892).
USI	Upper Salmon River at rkm 460	Located in the mainstem Salmon River at river km 522.303.460 (N44.890380 W-113.962575).
UTR	Upper Tucannon River	The Upper Tucannon River site is located about 200 yards above Don Howards House on the Tucannon River, at River Kilometer 53.2.
UWE	Upper Wenatchee River	Located at rkm 81.2 on the Wenatchee River, near Plain, WA.
VC1	Valley Creek, Upstream Site	Located on Valley Creek at Stanley, ID., in the Upper Salmon River.
VC2	Valley Creek, Downstream Site	Located on Valley Creek below Stanley, ID., in the Upper Salmon River.
WEA	Wells Dam, DCPUD Adult Ladders	Wells Dam Adult Fishways (both).
WEB	Webb Creek	Located approximately 1.0 kilometers upstream from the mouth of Webb Creek.
WFC	Wolf Creek, Methow River	Instream detector on Wolf Creek, Methow River Basin
WHC	Lwr White Creek, Klickitat Bsn	Instream interrogation system in White Creek (Klickitat River Basin) approximately 150 meters upstream from the mouth.
WR1	Wallowa River at river km 14	Instream array located in the Wallowa River, Oregon rkm 522.271.131.014 (N 45.633769 ° W -117.73369°).
WRU	Upper Wind River (WA) rkm 30	At rkm 30 of the Wind River, WA. The site is at the FR3065 bridge over the Wind River.
WSH	Warm Springs Hatchery	Adult Fishway at Warm Springs NFH.
WSR	Warm Springs River PIT Array	The Warm Springs River PIT tag array is installed end-to-end across the entire river channel.
WTL	White River, Wenatchee Basin	A permanent instream PIT tag interrogation site at RKM 2.88 on the White River.
WW1	Harris Bridge S F Walla Walla	Site is located on the South Fork Walla Walla River approximately 13 kilometers upstream from the confluence with the North Fork Walla Walla River.
YFK	Yankee Fork Salmon River	The site is located 3.14 river kilometers upstream from the confluence with the Salmon River at an elevation of 1855m.
ZEN	Secesh River at Zena Cr Ranch	Near the Zena Creek Ranch.
ZSL	Zosel Dam Adult Fishways	Zosel Dam is located at Okanogan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos

Table A2. Season by season activities of steelhead tagged in 2016 and later labeled as kelts or repeat spawners when they began migrating downstream and upstream (after March 31st) in spring, summer, or fall of 2017, presumably to and from the ocean.

Tag Year	Tag Number	First Detection After Tagging 2016 in Spring/Summer/Fall	Fall 2016	Winter 2016/17	Spring 2017	Summer 2017	Fall 2017	Comments
2016	3DD.0077992B24	The Dalles East Ladder - July 14th			Three Mile Falls Dam (Umatilla) - May 12th Bonneville Dam Corner Collector - May 17th			
2016	3DD.00778BD869	The Dalles East Ladder - August 4th	Lower John Day River - October 24th		Bonneville Dam Corner Collector - May 30th			
2016	3DD.00775DCF60	Lyle Falls Fishway (Klickitat) - June 12th				Bonneville Dam Corner Collector - June 7th		
2016	3DD.00778BB9ED	Lyle Falls Fishway (Klickitat) - July 31st	Moving Falls Fish Ladder (Hood) - November 2nd		Bonneville Dam Corner Collector - April 8th			
2016	3DD.00779747F0	The Dalles North Ladder - July 2nd	Lower Walla Walla River - November 2nd		Middle Touchet River (Walla Walla) - March 1st Bonneville Dam Corner Collector - April 27th			
2016	3DD.00778B7461	The Dalles East Ladder - September 10th	Lower Methow River - October 1st		Middle Methow River - March 24th Upper Methow River - April 19th to 24th Bonneville Dam Corner Collector - May 3rd			
2016	3DD.00778BB941	The Dalles East Ladder - August 4th	Lower John Day River - October 21st		Bonneville Dam Corner Collector - May 9th			
2016	3DD.00778AB096	The Dalles East Ladder - July 24th				Bonneville Dam Corner Collector - June 21st		
2016	3DD.00778B73D4	The Dalles East Ladder - August 31st	Lower Granite - September 12th	Lower Imnaha River - February 15th	Big Sheep Creek (Imnaha)- March 16th Bonneville Dam Corner Collector - April 26th			
2016	3DD.00778A267C	The Dalles East Ladder - August 11th	Lower Granite - September 22nd		Lower Lemhi River (Salmon) - March 31st Bonneville Dam Corner Collector - May 5th			
2016	3DD.00778B3741	The Dalles East Ladder - September 12th	McNary - September 26th		Bonneville Dam Corner Collector - May 27th			
2016	3DD.00775E91E8	Lower Trout Creek (Wind) - July 19th			Lower Trout Creek (Wind) - July 19th Bonneville Dam Corner Collector - April 26th			
2016	3DD.00778A82F5	The Dalles East Ladder - September 16th	McNary - September 20th		Bonneville Dam Corner Collector - May 13th			
2016	3DD.00778A63A0	The Dalles East Ladder - September 4th	McNary - September 11th	Ice Harbor - December 16th	Bonneville Dam Corner Collector - May 7th			
2016	3DD.00778A3CDB	The Dalles North Ladder - October 11th	Prosser Dam (Yakima) - October 24th	Lower Status Creek (Yakima) - February 20th	Bonneville Dam Corner Collector - April 24th			
2016	3DD.00778A9336	The Dalles East Ladder - September 24th	McNary - September 27th		Bonneville Dam Corner Collector - May 7th			
2016	3DD.00778A6F91	The Dalles East Ladder - September 24th	Lower Granite - October 16th			Bonneville Dam Corner Collector - June 10th		
2016	3DD.00778A911C	The Dalles East Ladder - October 2nd	Lower Granite - October 19th		Bonneville Dam Corner Collector - May 19th			
2016	3DD.00778AB50B	The Dalles East Ladder - September 10th	Lower Granite - September 22nd		Bonneville Dam Corner Collector - April 29th			
2016	3DD.00778B32C3	The Dalles North Ladder - October 8th	Prosser Dam (Yakima) - October 18th			Bonneville Dam Corner Collector - June 1st		
2016	3DD.00778ABEA2	The Dalles East Ladder - September 23rd	Lower Granite - November 12th			Bonneville Dam Corner Collector - June 17th		
2016	3DD.007789C5A6	The Dalles East Ladder - September 5th	Wells - October 10th		Lower Entiat River - April 8th Mad River (Entiat) - May 3rd to 18th Lower Entiat River - May 20th	Bonneville Dam Corner Collector - June 5th		
2016	3DD.00778B2DC4	The Dalles East Ladder - September 21st	Lower Granite - October 4th		Bonneville Dam Corner Collector - May 30th			
2016	3DD.00775E91C7	Lower Trout Creek (Wind) - July 9th	Lower Trout Creek (Wind) - October 8th		Bonneville Dam Corner Collector - May 24th			
2016	3DD.00778A3751	The Dalles East Ladder - August 11th	Prosser Dam (Yakima) - October 21st	Lower Status Creek (Yakima) - February 19th	Lower Status Creek (Yakima) - April 22nd Bonneville Dam Corner Collector - April 28th			
2016	3DD.00778AE6FC	The Dalles East Ladder - October 6th	Lower Monumental - October 17th	Lower Tucannon River - February 12th Middle Tucannon River - February 20th	Bonneville Dam Corner Collector - May 4th			Fish tagged on July 29th, where it was between July and October is unknown.
2016	3DD.00778AE8A5				Bonneville Dam Corner Collector - May 7th			Fish tagged on May 10th.
2016	3DD.00775E177B				Bonneville Dam Corner Collector - May 4th			Fish tagged on September 29th.
2016	3DD.00775E2B53	Lower Trout Creek (Wind) - October 8th			Lower Trout Creek (Wind) - March 21st Bonneville Dam Corner Collector - April 7th			
2016	3DD.00778AB02A				Bonneville Dam Corner Collector - April 2nd			Fish tagged on August 26th, with age 1.0 and only 40.5 cm. We believe this to be a rainbow trout.
2016	3DD.00775E08E9	The Dalles East Ladder - July 2nd			Lower Imnaha River - March 24th Upper Imnaha River - April 2nd Bonneville Dam Corner Collector - May 22nd			
2016	3DD.00778BC3C6	The Dalles East Ladder - September 18th	Lower Granite - October 2nd		Bonneville Juvenile Bypass - May 15th			
2016	3DD.00778B34BD						Bonneville WA Shore Ladder - October 2nd	Repeat Spawner - this fish was tagged by this project August of 2016 over a year before it was seen again migrating upriver passed Bonneville Dam again. We assume this fish spent time in the ocean between detections.
2016	3DD.00778AD51D						Bonneville WA Shore Ladder - September 12th	Repeat Spawner - this fish was tagged by this project July of 2016 over a year before it was seen again migrating upriver passed Bonneville Dam again. We assume this fish spent time in the ocean between detections.
2016	3DD.00778B29DB	The Dalles East Ladder - September 8th	Prosser Dam (Yakima) - November 5th			Upper Columbia Estuary - August 15th Bonneville Cascades Ladder - August 20th		Repeat Spawner - we assume this fish spent some time in the ocean between 2016 last detection and migrating upriver passed Bonneville Dam again.
2016	3DD.00775D21AD	Lower Trout Creek (Wind) - October 7th	Middle Trout Creek (Wind) - October 11th		Middle Trout Creek (Wind) - March 18th	Upper Columbia Estuary - July 23rd		
2016	384.3B23ACF9E9	The Dalles North Ladder - October 12th	McNary - November 21st		Lower Walla Walla River - March 14th John Day Juvenile Bypass - May 5th			Repeat Spawner - this fish was tagged as an adult passing Lower Granite in October of 2015. It left the system through the Bonneville Corner Collector in April 2016 and was recaptured returning to Bonneville in August of 2016.
2016	3DD.007797A2E7	The Dalles East Ladder - July 3rd	Prosser Dam (Yakima) - October 22nd		Lower Naches River (Yakima) - March 29th John Day Juvenile Bypass - May 29th			
2016	3DD.00778BDA34	The Dalles East Ladder - September 12th	Lower John Day River - October 19th		John Day Juvenile Bypass - April 17th			
2016	3DD.00778BA840	The Dalles East Ladder - September 12th	McNary - September 18th	Lower Walla Walla River - January 24th	Middle Walla Walla River - April 9th John Day Juvenile Bypass - April 27th			
2016	3DD.00778B9995	The Dalles East Ladder - July 25th	McNary - October 5th		John Day Juvenile Bypass - May 29th			
2016	3DD.00778B7712	The Dalles East Ladder - September 24th	McNary - October 9th	Lower Walla Walla River - February 20th	John Day Juvenile Bypass - May 9th			
2016	3DD.00778B66E8	The Dalles East Ladder - September 14th	Lower Granite - October 2nd		Lower Lemhi River (Salmon) - March 19th John Day Juvenile Bypass - May 1st			
2016	3DD.00778B65BB	The Dalles East Ladder - September 9th	Lower Granite - October 4th	Lower Walla Walla River - February 28th	John Day Juvenile Bypass - April 23rd			
2016	3DD.00778B4C27	The Dalles East Ladder - July 16th	Lower John Day River - November 3rd		John Day Juvenile Bypass - April 6th			
2016	3DD.00778B29ED	The Dalles East Ladder - August 4th	Lower John Day River - October 26th		John Day Juvenile Bypass - May 21st			
2016	3DD.00778AFE71	The Dalles East Ladder - September 18th	McNary - September 23rd	Lower Walla Walla River - January 25th	Middle Touchet (Walla Walla) - March 3rd Pattit Creek (Walla Walla) - March 17th to 27th John Day Juvenile Bypass - April 8th			
2016	3DD.00778AC5E7	The Dalles East Ladder - September 5th	Lower Walla Walla River - November 2nd	Middle Walla Walla River - February 27th	Middle Walla Walla River - March 20th John Day Juvenile Bypass - April 29th			
2016	3DD.00778A920D	The Dalles East Ladder - September 27th	Lower Granite - October 24th		Little Goose Juvenile Bypass - May 27th	John Day Juvenile Bypass - June 1st		
2016	3DD.00778A7B99	The Dalles East Ladder - July 24th	Lower Granite - September 29th		John Day Juvenile Bypass - April 26th			
2016	3DD.00778A67EB	The Dalles North Ladder - August 21st	Lower Granite - September 3rd		John Day Juvenile Bypass - May 7th			Steelhead tagged at Bonneville AFF on August 18th, 2016 and was also recaptured/released April 26th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project and by its out-migration behavior.
2016	3DD.00778A5770	The Dalles East Ladder - October 7th	Lower Granite - October 27th		Lower Lochsa River - April 4th John Day Juvenile Bypass - May 8th			
2016	3DD.00778A2851	The Dalles East Ladder - July 29th	Lower John Day River - November 8th		John Day Juvenile Bypass - May 19th			
2016	3DD.00778A0E52	The Dalles East Ladder - September 16th	Lower Umatilla River (Feed Diversion Dam) - November 14th		John Day Juvenile Bypass - April 19th			
2016	3DD.007789A9DF	The Dalles East Ladder - September 4th	Lower Granite - September 20th		John Day Juvenile Bypass - April 24th			
2016	3DD.00778A494B	The Dalles North Ladder - August 10th	Lower Granite - September 28th	Upper Grande Ronde - February 26th	John Day Juvenile Bypass - May 9th			
2016	3DD.00778BC7EB	The Dalles North Ladder - August 12th	Lower Granite - September 6th		McNary Juvenile Bypass - April 19th			
2016	3DD.00778BC210	The Dalles East Ladder - August 26th	Prosser Dam (Yakima) - October 25th		McNary Juvenile Bypass - May 7th			

Table A2 (Continued).

Tag Year	Tag Number	First Detection After Tagging 2016 in Spring/Summer/Fall	Fall 2016	Winter 2016/17	Spring 2017	Summer 2017	Fall 2017	Comments
2016	3DD.00778A270A	The Dalles North Ladder - August 11th	McNary - October 18th		Middle Walla Walla River - April 20th McNary Juvenile Bypass - May 19th			
2016	3DD.00778AFAE2	The Dalles East Ladder - September 24th	Lower Granite - October 6th		McNary Juvenile Bypass - April 10th			
2016	3DD.00778B1762	The Dalles East Ladder - August 11th	McNary - October 29th	Lower Walla Walla River - February 26th	McNary Dam WA Ladder - April 22nd			
2016	3DD.00778A702A	The Dalles East Ladder - September 14th	Lower Granite - September 25th		McNary Dam WA Ladder - April 9th			
2016	3DD.00778A366D	The Dalles East Ladder - July 17th	Lower Granite - September 24th		McNary Dam WA Ladder - April 29th			
2016	384.3B23A7E6C5	The Dalles East Ladder - September 6th	Lower Granite - September 16th		Ice Harbor Dam - April 29th			
2016	3DD.00778A0D2A	The Dalles East Ladder - August 2nd			Ice Harbor Dam - April 5th			
2016	3DD.00778B9B86	The Dalles East Ladder - August 12th	Lower Granite - October 3rd		Wallowa River (Grande Ronde) - March 3rd Lower Monumental Juvenile Bypass - April 10th			
2016	3DD.00778AC2DE	The Dalles East Ladder - September 1st	Lower Granite - September 18th		Lower Monumental Juvenile Bypass - April 29th			
2016	3DD.00778A6DD4	The Dalles East Ladder - September 1st	Lower Granite - September 12th		Upper Salmon River - March 11th Lower Monumental Juvenile Bypass - April 6th			
2016	3DD.00778A12EF	The Dalles East Ladder - September 20th	Lower Granite - November 10th		Upper Salmon River - April 14th Lower Monumental Juvenile Bypass - May 11th			
2016	3DD.00778B3BA4	The Dalles East Ladder - July 27th			Lookingglass Creek (Grande Ronde) - May 1st	Little Goose Juvenile Bypass - June 15th		Steelhead tagged at Bonneville AFF on July 25th, 2016 and was also recaptured/released June 13th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project and by its out-migration behavior.
2016	3DD.00778B3166	The Dalles East Ladder - September 10th	Wells - October 1st Lower Methow River - October 18th to November 26th	Lower Methow River - December 21st to January 4th	Ice Harbor Dam - March 22nd Lapwai Creek (Clearwater) - March 29th Webb Creek (Clearwater) - April 2nd Sweetwater Creek (Clearwater) - May 23rd Little Goose Juvenile Bypass - May 30th			This fish went all the way up to the Lower Methow where it had many detections over 4 months in fall and winter of 2016/17, then it headed to the Snake River.
2016	3DD.00778B146F	The Dalles East Ladder - September 13th	Lower Granite - October 1st		Wallowa Hatchery (Grande Ronde) - March 7th Little Goose Juvenile Bypass - April 14th			
2016	3DD.00778B1204	The Dalles East Ladder - September 25th	Lower Granite - October 9th	Lower SF Clearwater - February 17th	Little Goose Juvenile Bypass - April 9th			
2016	3DD.00778AB1F1	The Dalles East Ladder - September 17th	Lower Granite - September 26th		Little Goose Juvenile Bypass - May 30th			
2016	3DD.00778A8F07	The Dalles East Ladder - September 2nd	Lower Granite - September 17th	Lower Walla Walla River - February 23rd	Little Goose Juvenile Bypass - April 24th			
2016	3DD.00778A5048	The Dalles East Ladder - September 12th	Lower Granite - September 26th		Little Goose Juvenile Bypass - April 10th			
2016	3DD.00778A19EB	The Dalles East Ladder - September 14th	Lower Granite - October 2nd		Lookingglass Creek (Grande Ronde) - March 8th Little Goose Juvenile Bypass - April 3rd			
2016	3DD.00778A0E41	The Dalles North Ladder - August 21st	Lower Granite - September 16th		Little Goose Juvenile Bypass - April 25th			
2016	3DD.00778B22F7	The Dalles North Ladder - August 18th	Lower Granite - September 5th		Lower Granite Juvenile Bypass - April 24th			
2016	3DD.00778B0B87	The Dalles East Ladder - October 7th	Lower Deschutes River - October 29th		The Dalles North Ladder - March 1st Lower Granite - March 29th Lower Granite Juvenile Bypass - April 14th			This fish had a spring run up the Snake River after entering the Columbia in the previous fall.
2016	3DD.00778A9ADB	The Dalles East Ladder - July 22nd	Lower Granite - August 1st		Lower Granite Juvenile Bypass - April 19th			
2016	3DD.00778AE678	The Dalles East Ladder - July 18th	Wells - October 29th		Lower Entiat River - April 20th Rocky Reach Juvenile Bypass - April 20th			
2016	3DD.00778B25C7	The Dalles East Ladder - October 7th	Little Goose - October 28th	Lower Tucannon River - February 23rd	Middle Tucannon River - March 30th Lower Tucannon River - April 13th			
2016	3DD.00778A09D5	The Dalles East Ladder - October 7th	McNary - October 24th		Three Mile Falls Dam (Umatilla) - May 15th			
2016	3DD.0077972340	The Dalles East Ladder - July 15th	Prosser Dam (Yakima) - October 11th		Prosser Dam (Yakima) - May 15th			Steelhead was collected on May 15th, 2017 and is currently in the CRITFC Kelt Project for reconditioning.
2016	3DD.0077898BA3	The Dalles East Ladder - August 11th	Lower Granite - September 30th					Steelhead tagged at Bonneville AFF on August 8th, 2016 and was also recaptured/released May 29th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project.
2016	3DD.00778A1EDC	The Dalles East Ladder - September 6th	Lower Granite - September 18th					Steelhead tagged at Bonneville AFF on August 17th, 2016 and was also recaptured/released June 9th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project.
2016	3DD.00778A59F7	The Dalles East Ladder - September 12th	Lower Granite - October 13th		Lower SF Clearwater River - March 6th			Steelhead tagged at Bonneville AFF on September 1st, 2016 and was also recaptured/released April 9th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project.
2016	3DD.00778A91E8	The Dalles East Ladder - October 18th	The Dalles East Ladder - November 25th		McNary - March 15th Lower Granite - March 30th			Steelhead tagged at Bonneville AFF on October 14th, 2016 and was also recaptured/released April 19th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project.
2016	3DD.00778B388B	The Dalles East Ladder - July 16th	Lower Granite - October 1st					Steelhead tagged at Bonneville AFF on July 7th, 2016 and was also recaptured/released April 12th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project.
2016	3DD.00778BD2E3	The Dalles North Ladder - July 17th	Lower Granite - October 5th		Catherine Creek (Grande Ronde) - March 16th			Steelhead tagged at Bonneville AFF on July 15th, 2016 and was also recaptured/released May 6th, 2017 by CRITFC Kelt Project. Considered a kelt, by Kelt Project.
2016	3DD.00779937A4	The Dalles East Ladder - July 3rd			Lower Imnaha River - March 17th Big Sheep Creek (Imnaha) - March 28th			Steelhead tagged at Bonneville AFF on June 30th, 2016 and was also recaptured on May 26th, 2017 by CRITFC Kelt Project. Entered reconditioning program at Nez Perce Tribal Hatchery.

Key - - - Upstream Downstream Spawning

Table A3. Season by season activities of steelhead tagged in 2016 and later labeled as kelts or repeat spawners when they began migrating downstream and upstream (before April 1st) in spring, summer, or fall of 2017, presumably to and from the ocean.

Tag Year	Tag Number	First Detection After Tagging 2016 in Spring/Summer/Fall	Fall 2016	Winter 2016/17	Spring 2017	Comments
2016	3DD.00778BAA71				Bonneville Dam Corner Collector - March 4th	Fish tagged on July 28th.
2016	3DD.00778ADC90	The Dalles East Ladder - August 11th	Lower Goose - October 31st		Little Goose Juvenile Bypass - March 20th	
2016	3DD.00779787C3	The Dalles East Ladder - July 2nd	Lower Granite - October 4th		Lower Granite Juvenile Bypass - March 20th	
2016	3DD.00778B9DFB	The Dalles East Ladder - September 5th	Lower Granite - September 16th		Lower Granite Juvenile Bypass - March 21st	
2016	3DD.00778B534C	The Dalles East Ladder - September 5th	Lower Granite - September 24th		Little Goose Juvenile Bypass - March 21st	
2016	3DD.00778980A0	The Dalles East Ladder - September 11th	Lower Granite - October 1st	Lower SF Clearwater - February 21st	The Dalles North Ladder - March 30th	

Key - - -	Upstream	Downstream	Spawning

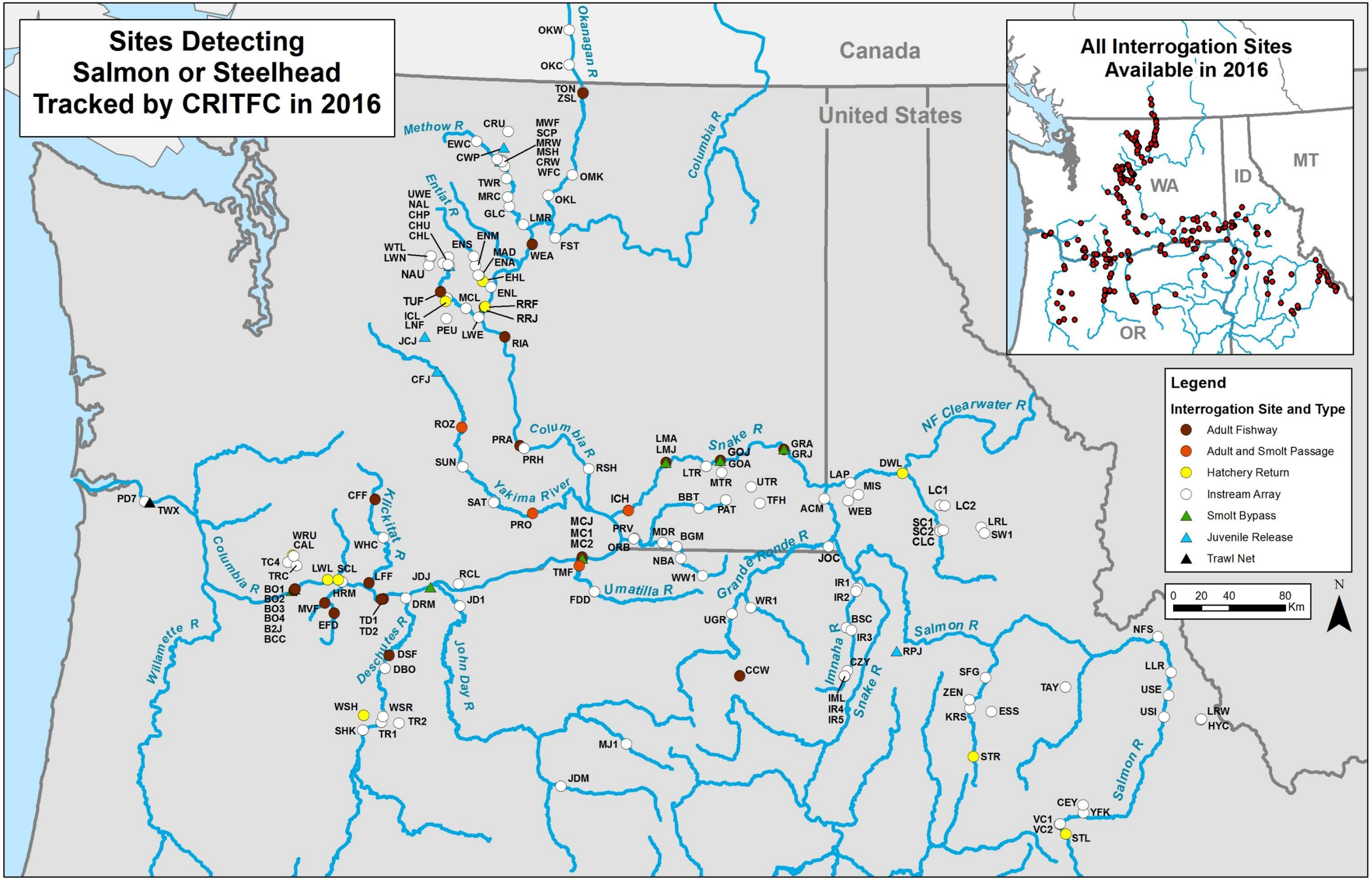

Figure A1. Map of Columbia River interrogation sites that detected Chinook and Sockeye salmon, and steelhead in 2016. Table A1 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

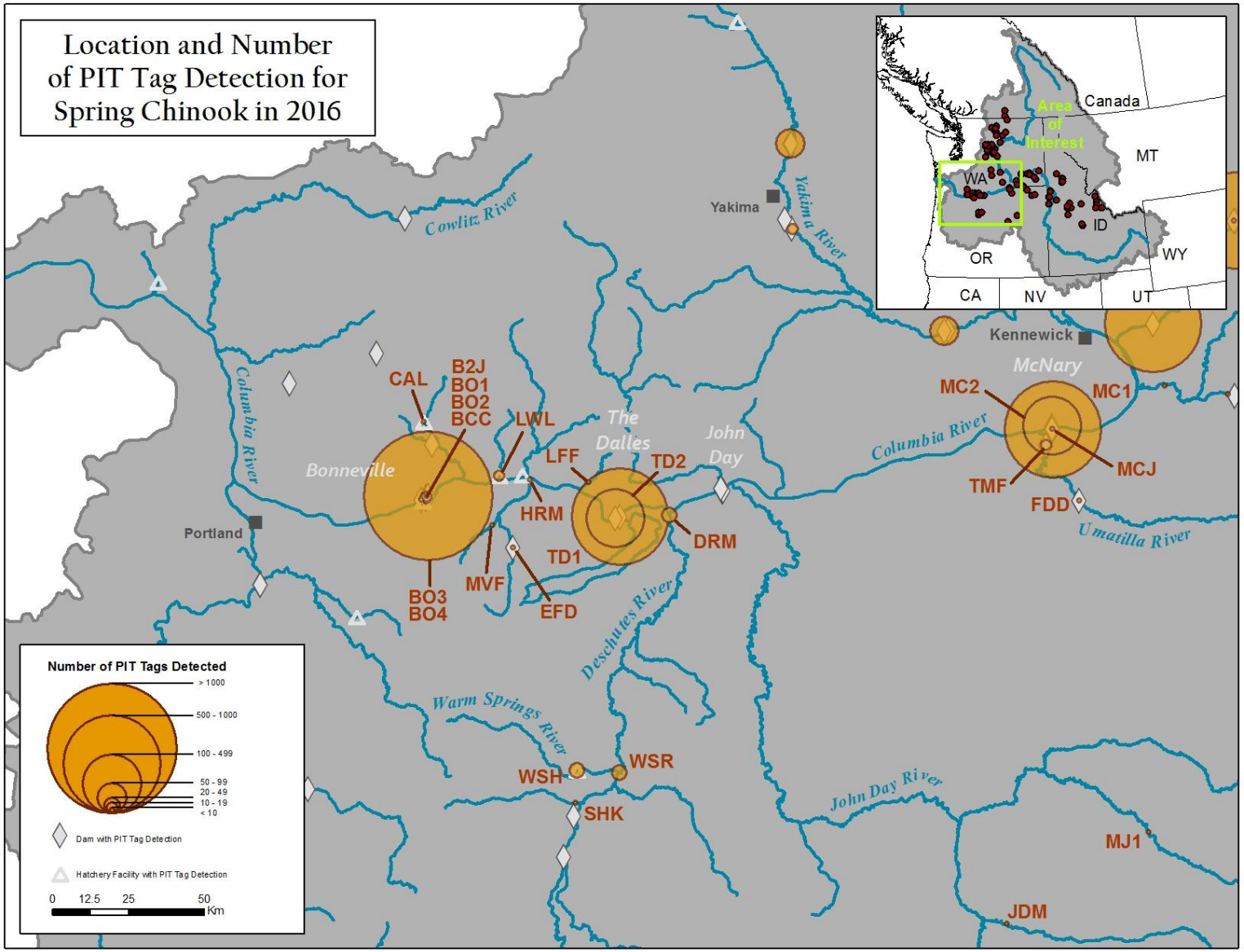

Figure A2. Map of Lower Columbia River detection sites (below Snake River) and number of spring Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

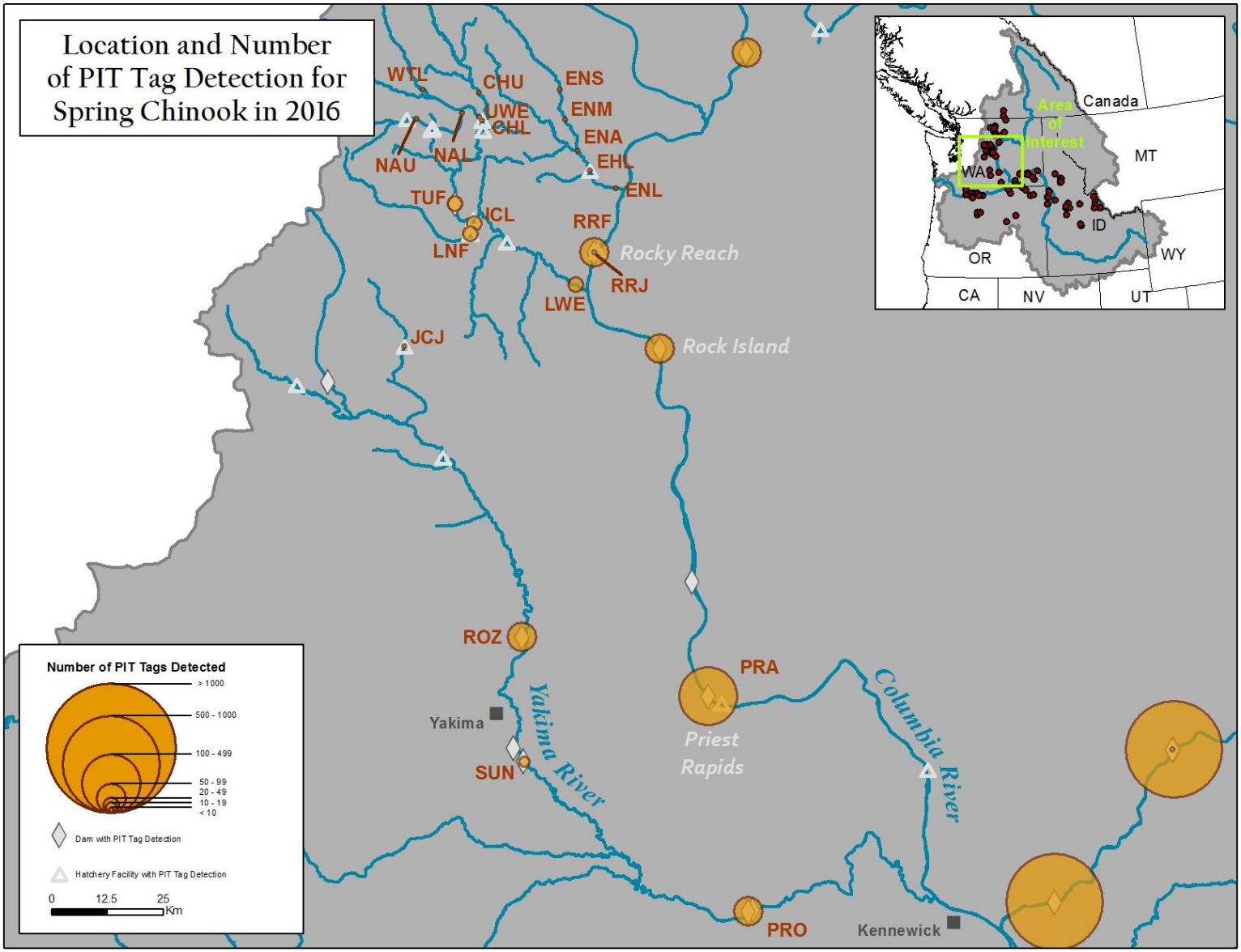

Figure A3. Map of Upper Columbia River (between the Snake River and Wells Dam) detection sites and number of spring Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

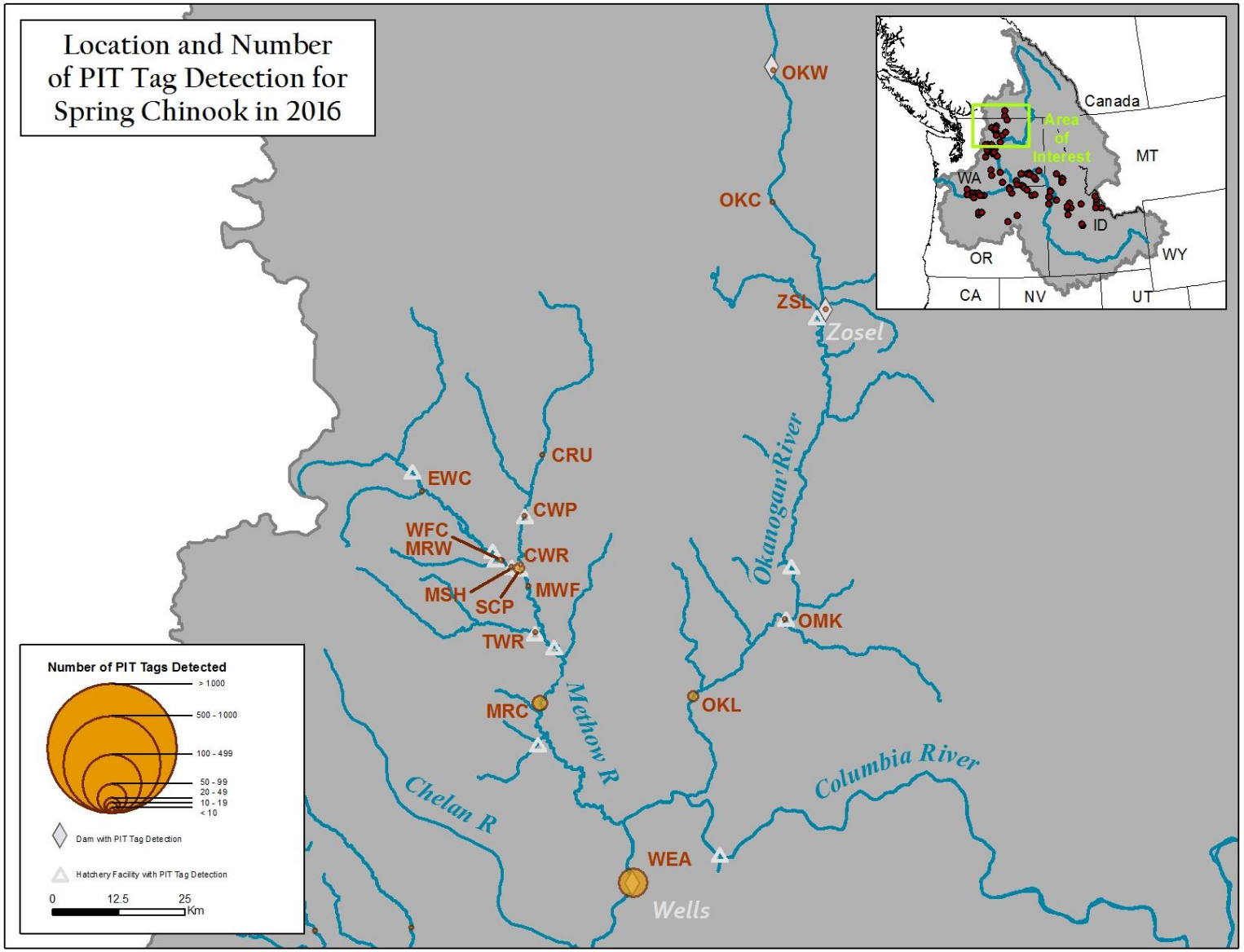

Figure A4. Map of Upper Columbia River (Wells Dam and above) detection sites and number of spring Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

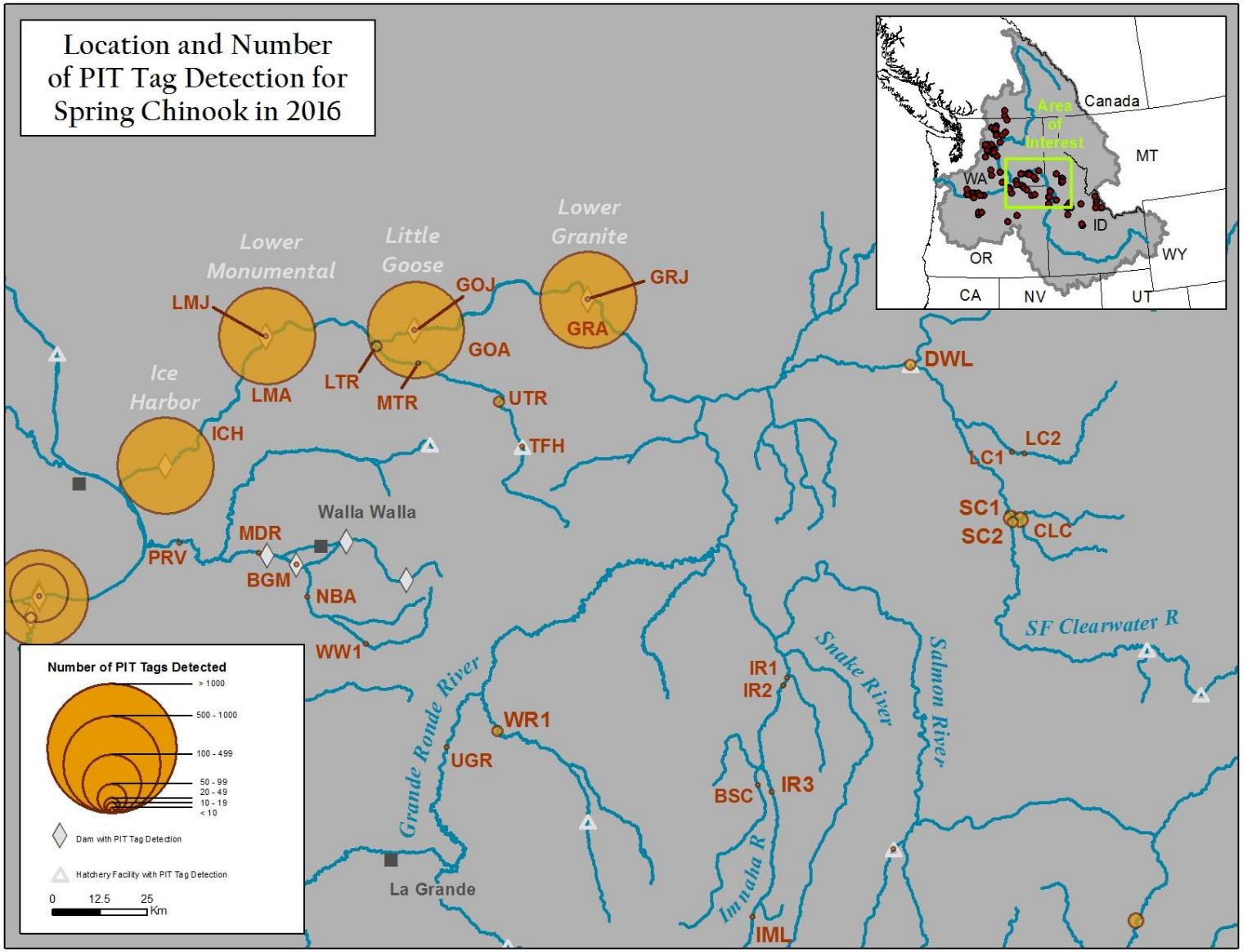

Figure A5. Map of Lower Snake River detection sites (Salmon River not included) and number of spring Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

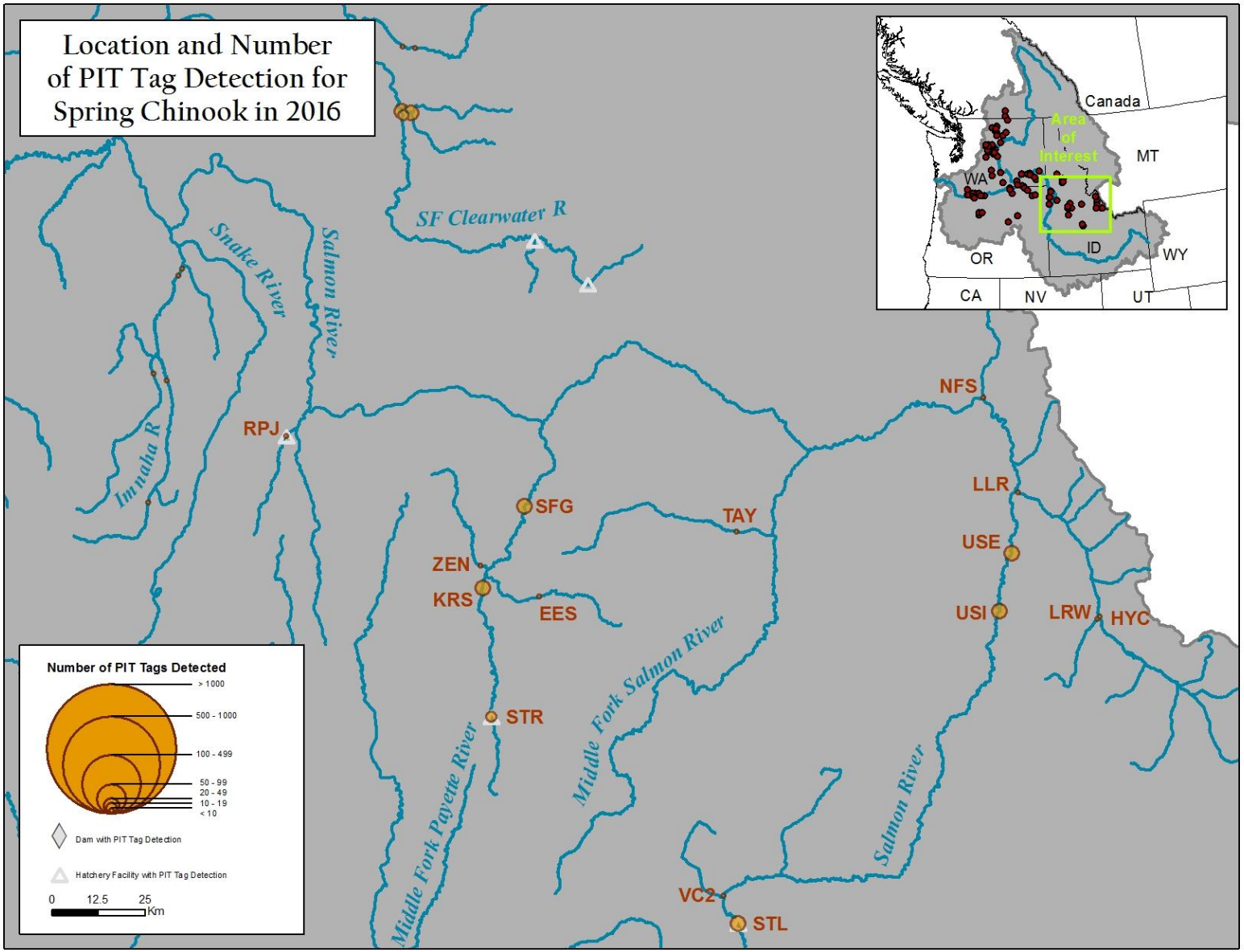

Figure A6. Map of Salmon River detection sites and number of spring Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

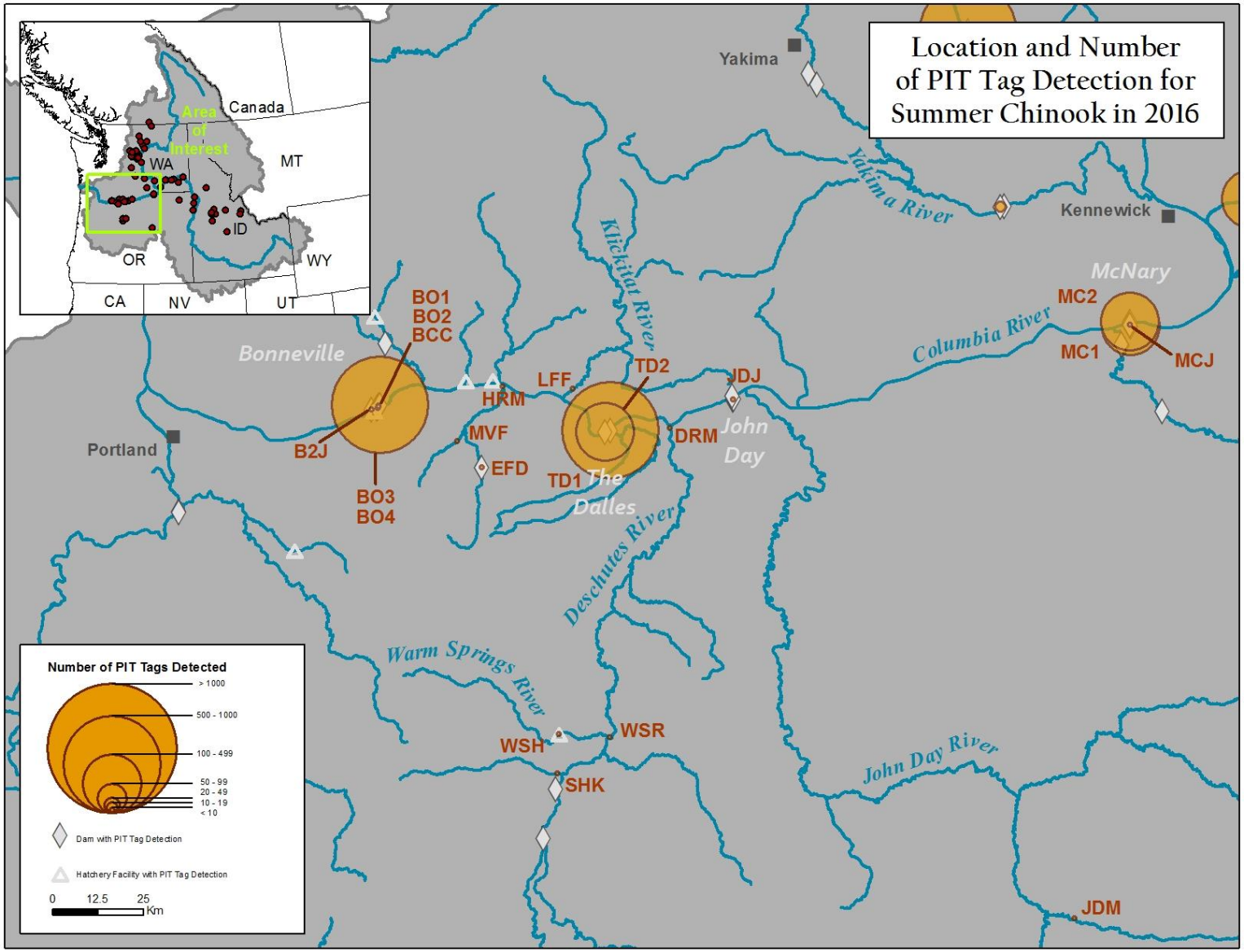

Figure A7. Map of Lower Columbia River detection sites (below Snake River) and number of summer Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

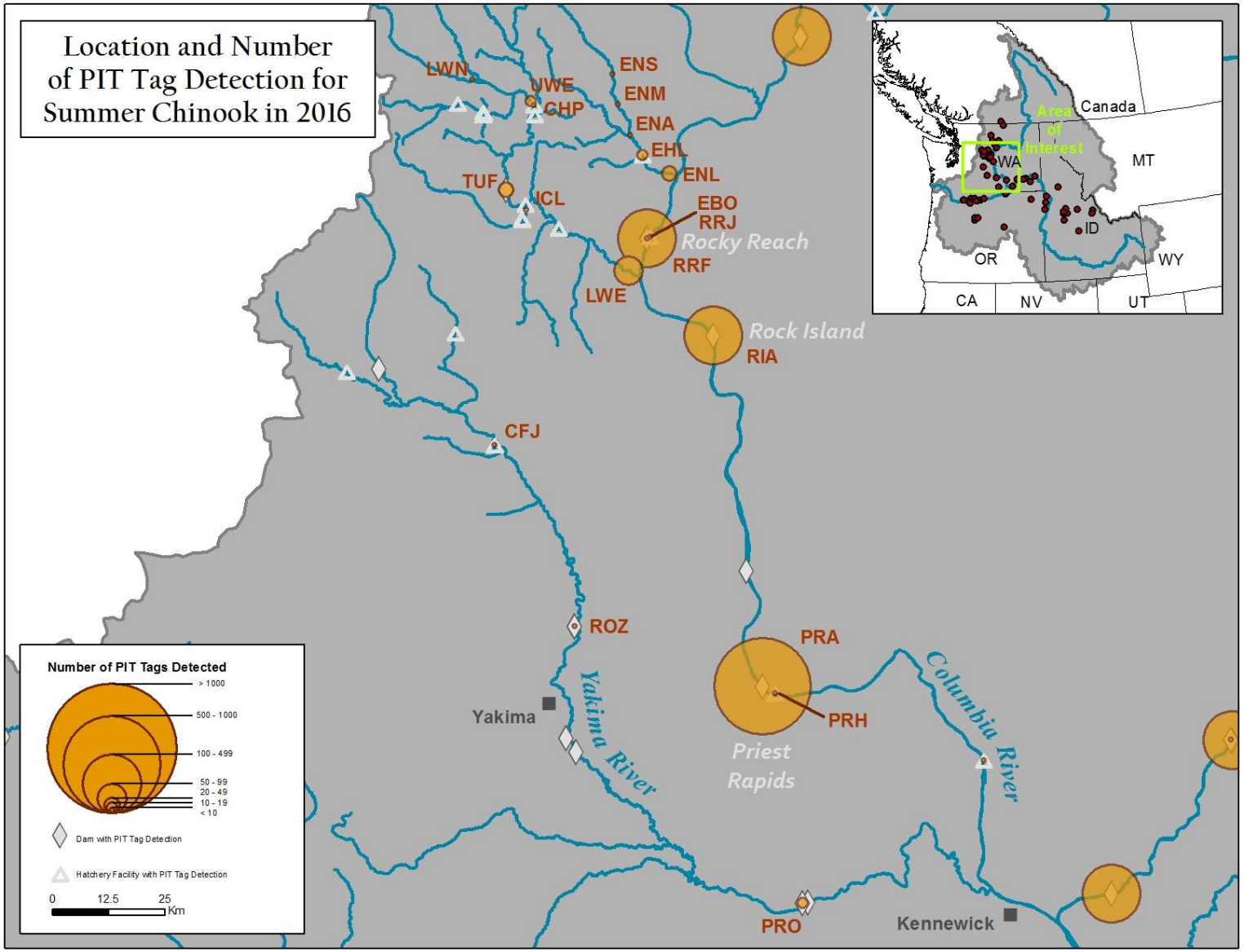

Figure A8. Map of Upper Columbia River (between the Snake River and Wells Dam) detection sites and number of summer Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

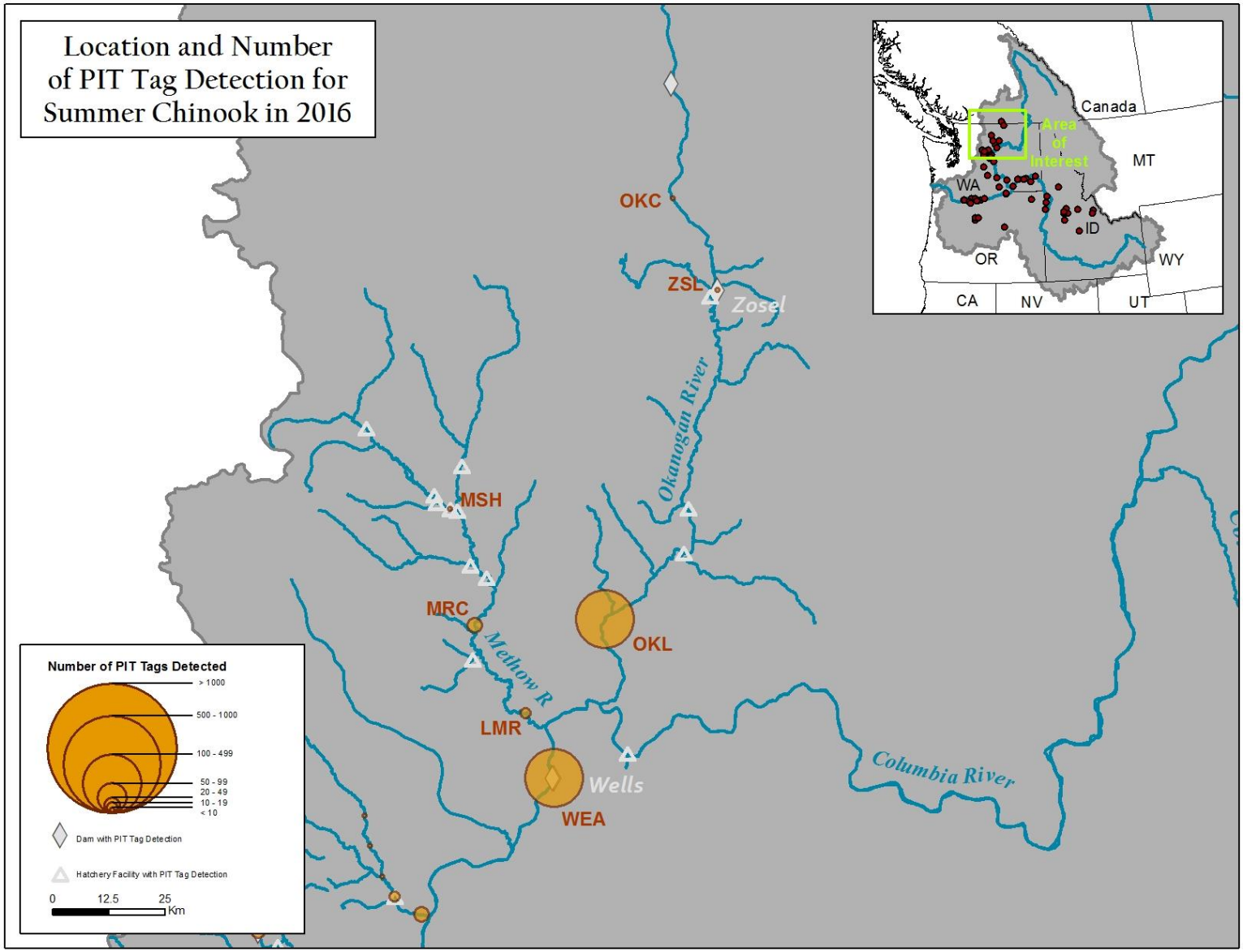

Figure A9. Map of Upper Columbia River (Wells Dam and above) detection sites and number of summer Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

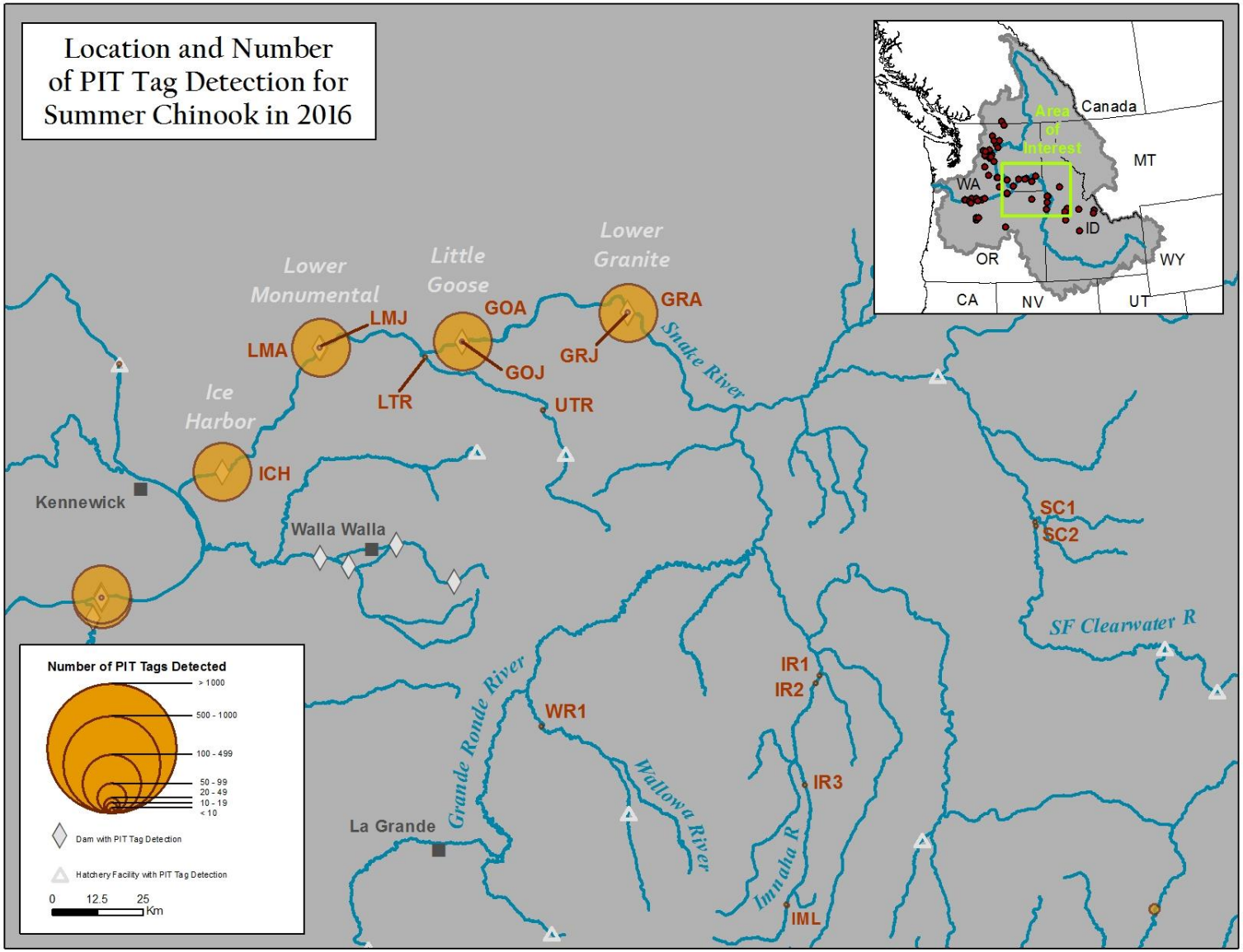

Figure A10. Map of Lower Snake River detection sites (Salmon River not included) and number of summer Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

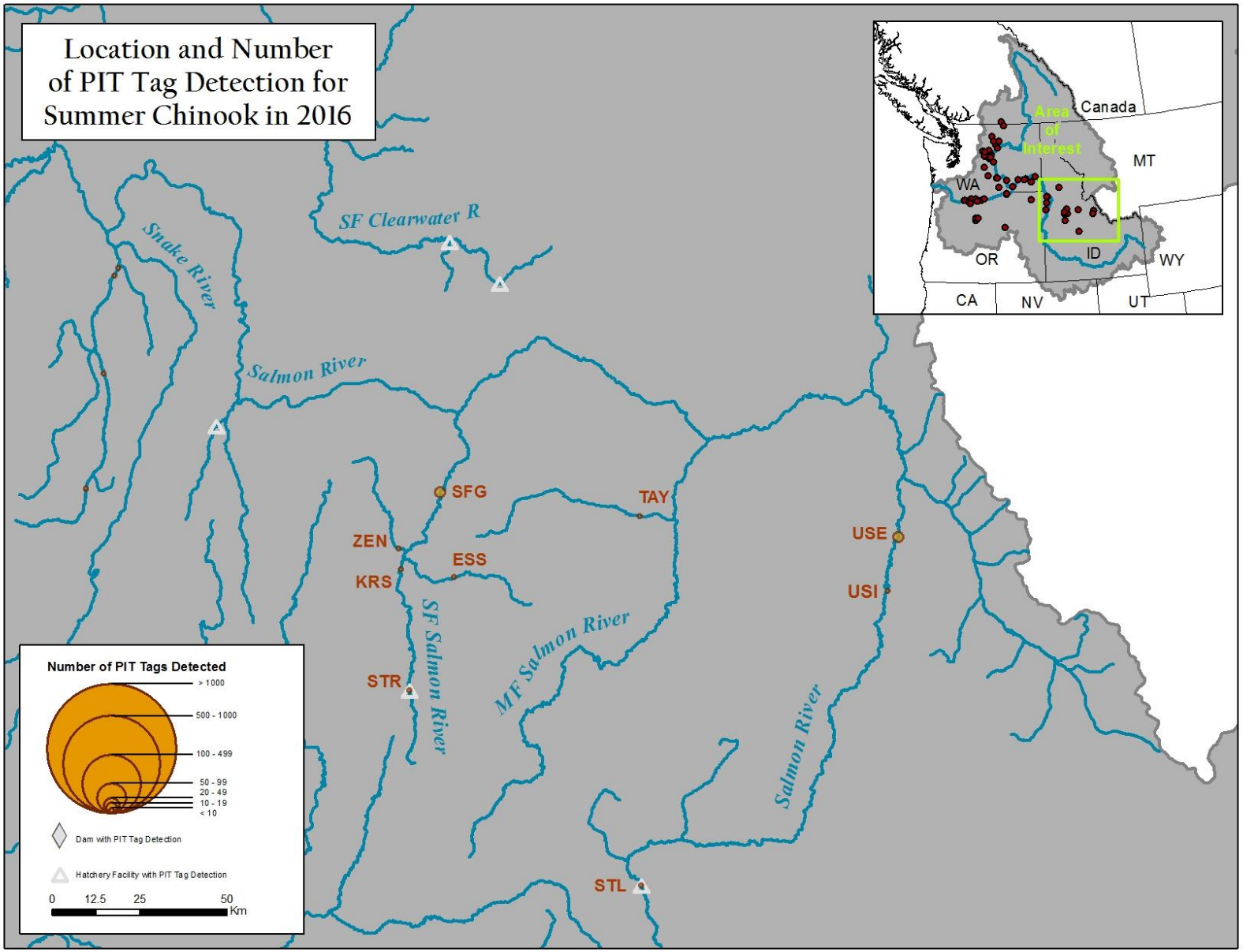

Figure A11. Map of Salmon River detection sites and number of summer Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

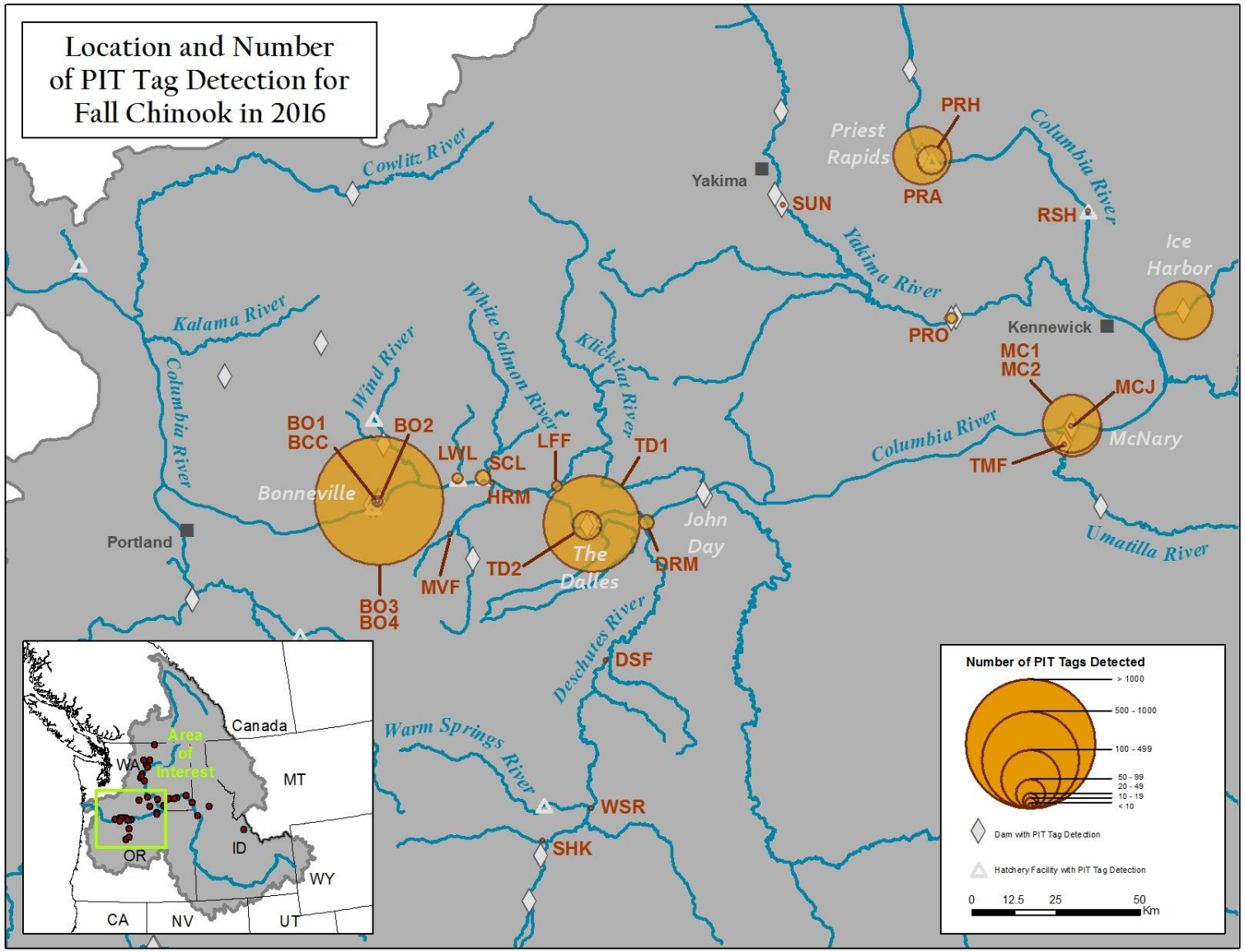

Figure A12. Map of Lower and Middle Columbia River detection sites (below Rock Island Dam) and number of fall Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

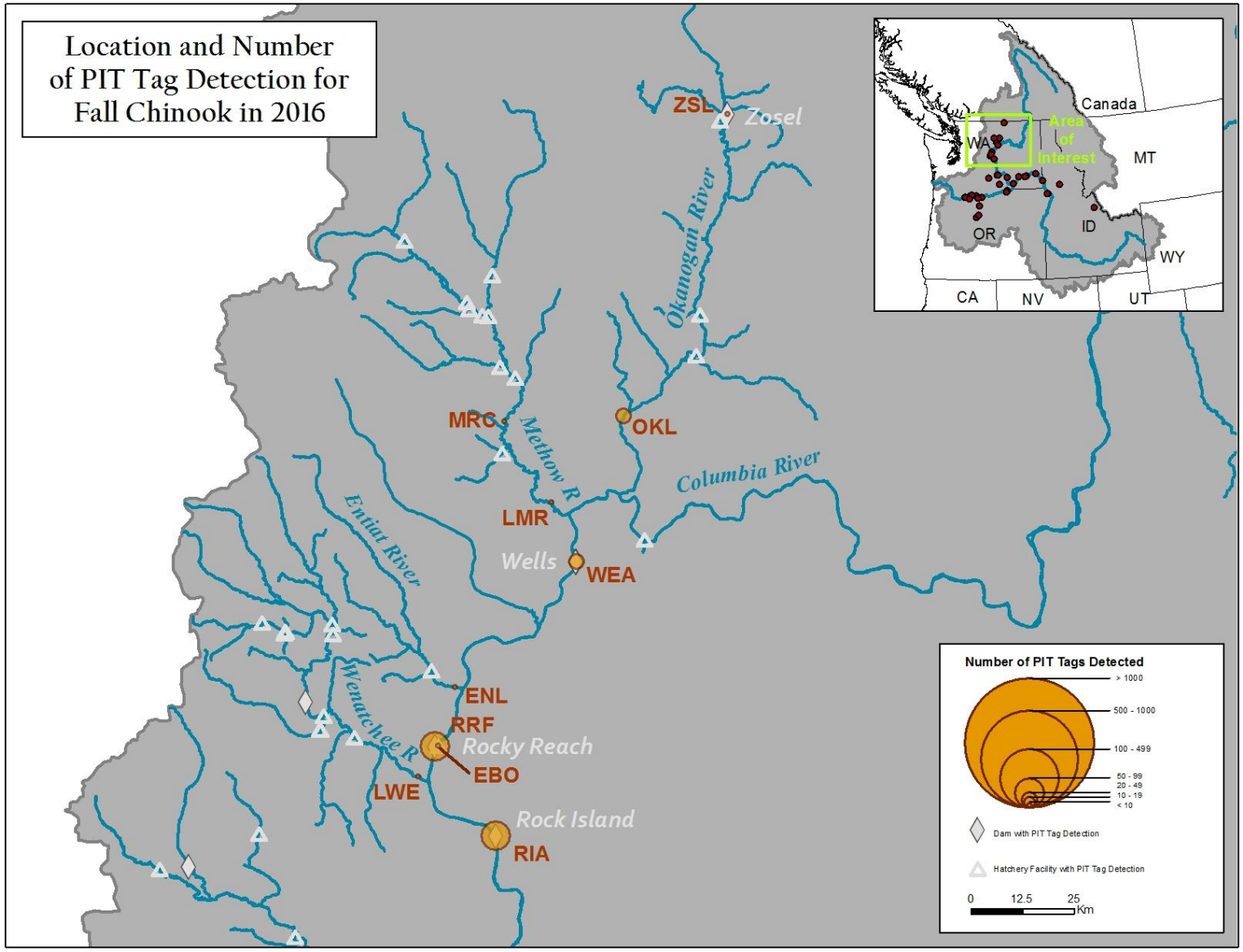

Figure A13. Map of Upper Columbia River detection sites (Rock Island Dam and above) and number of fall Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

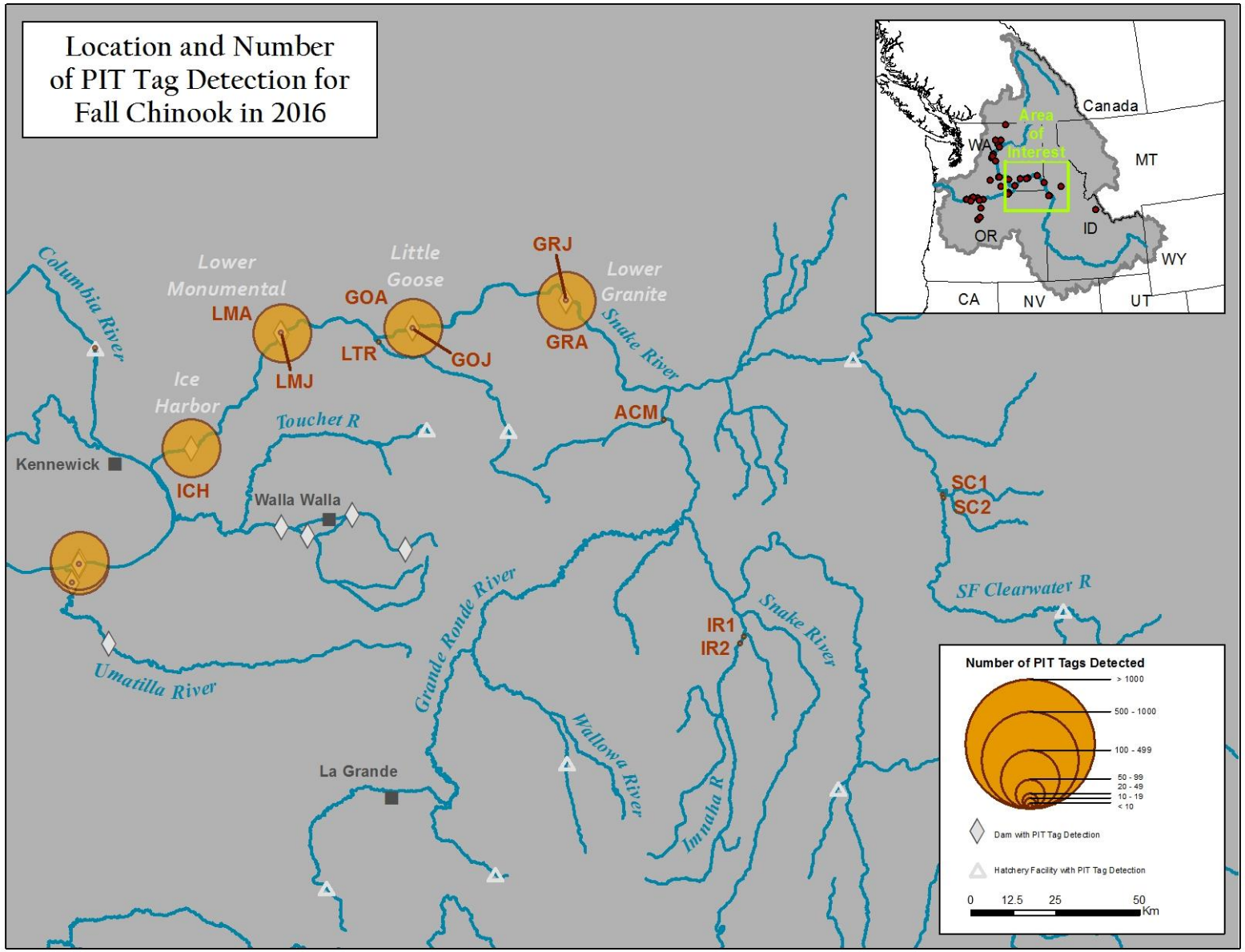

Figure A14. Map of Lower Snake River detection sites and number of fall Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

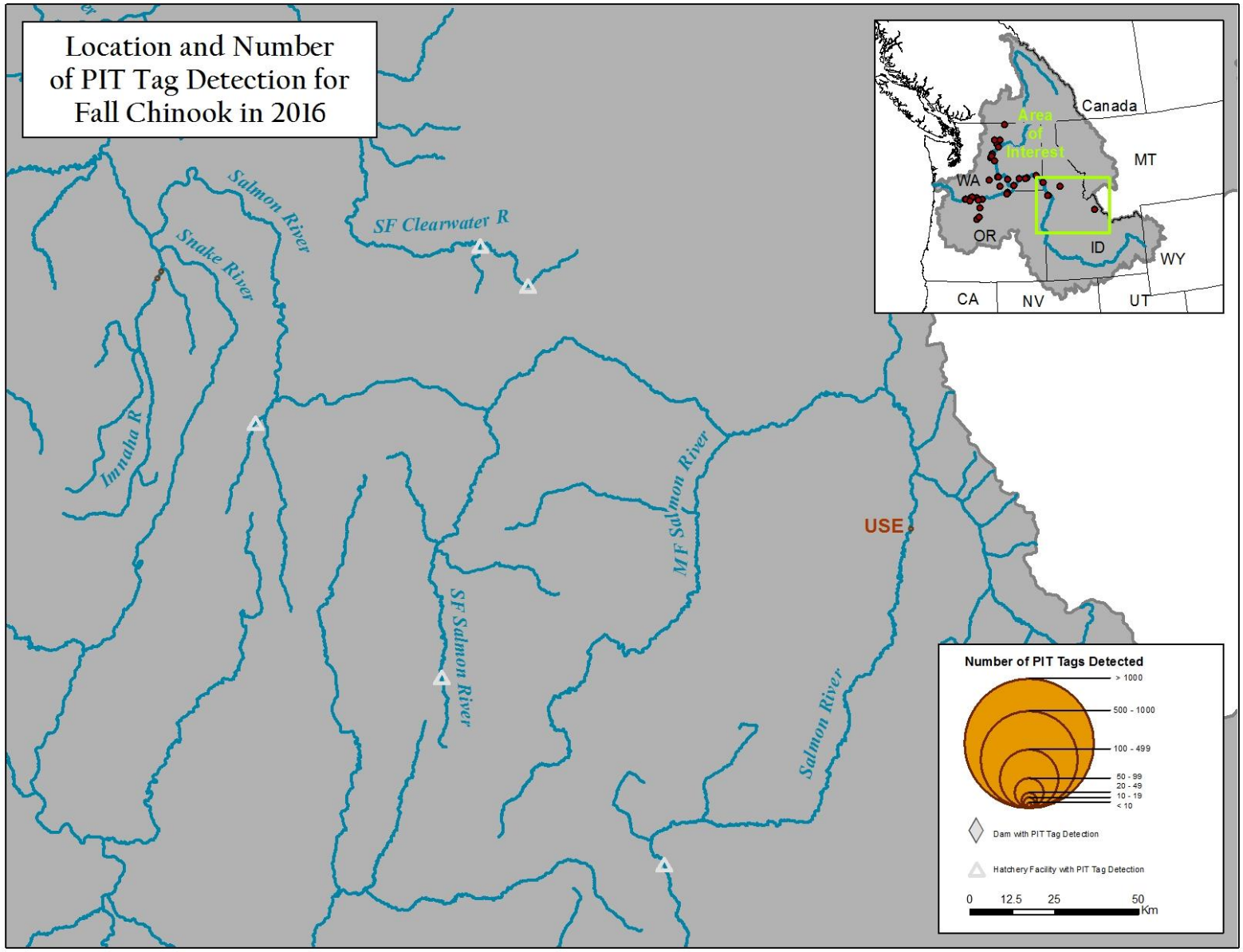

Figure A15. Map of Salmon River detection sites and number of fall Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

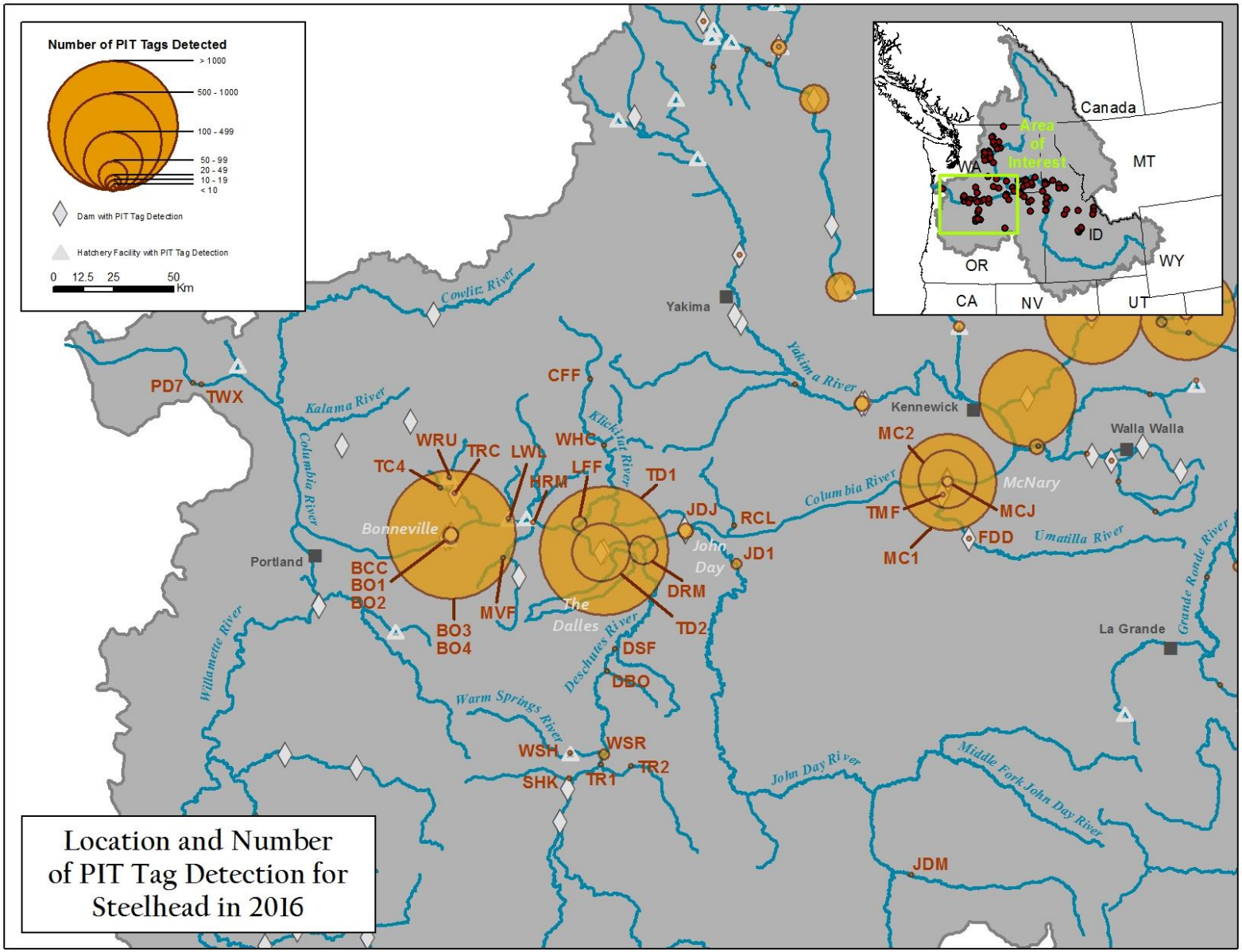

Figure A16. Map of Lower Columbia River detection sites (below Snake River) and number of steelhead detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

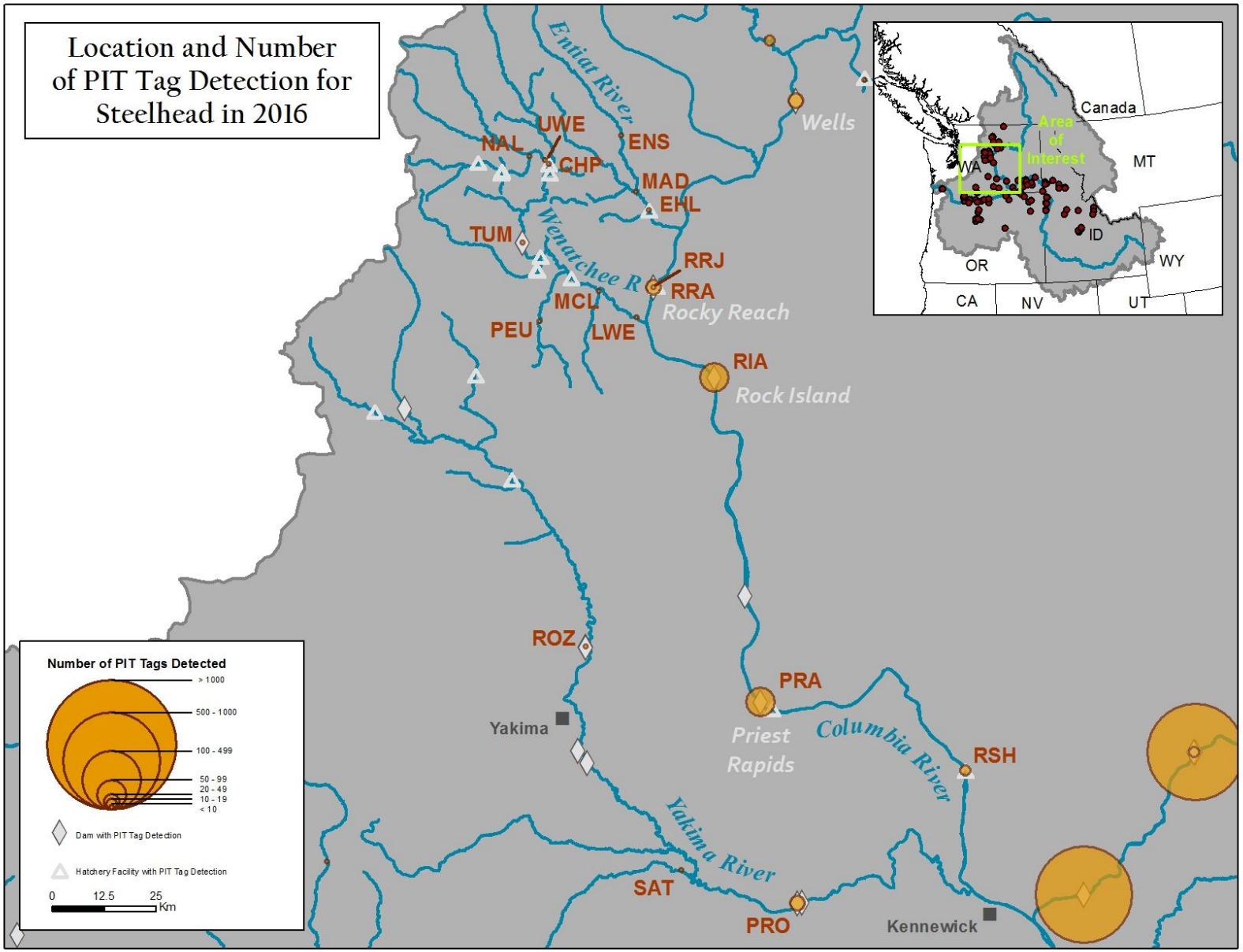

Figure A17. Map of Upper Columbia River (between the Snake River and Wells Dam) detection sites and number of steelhead detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

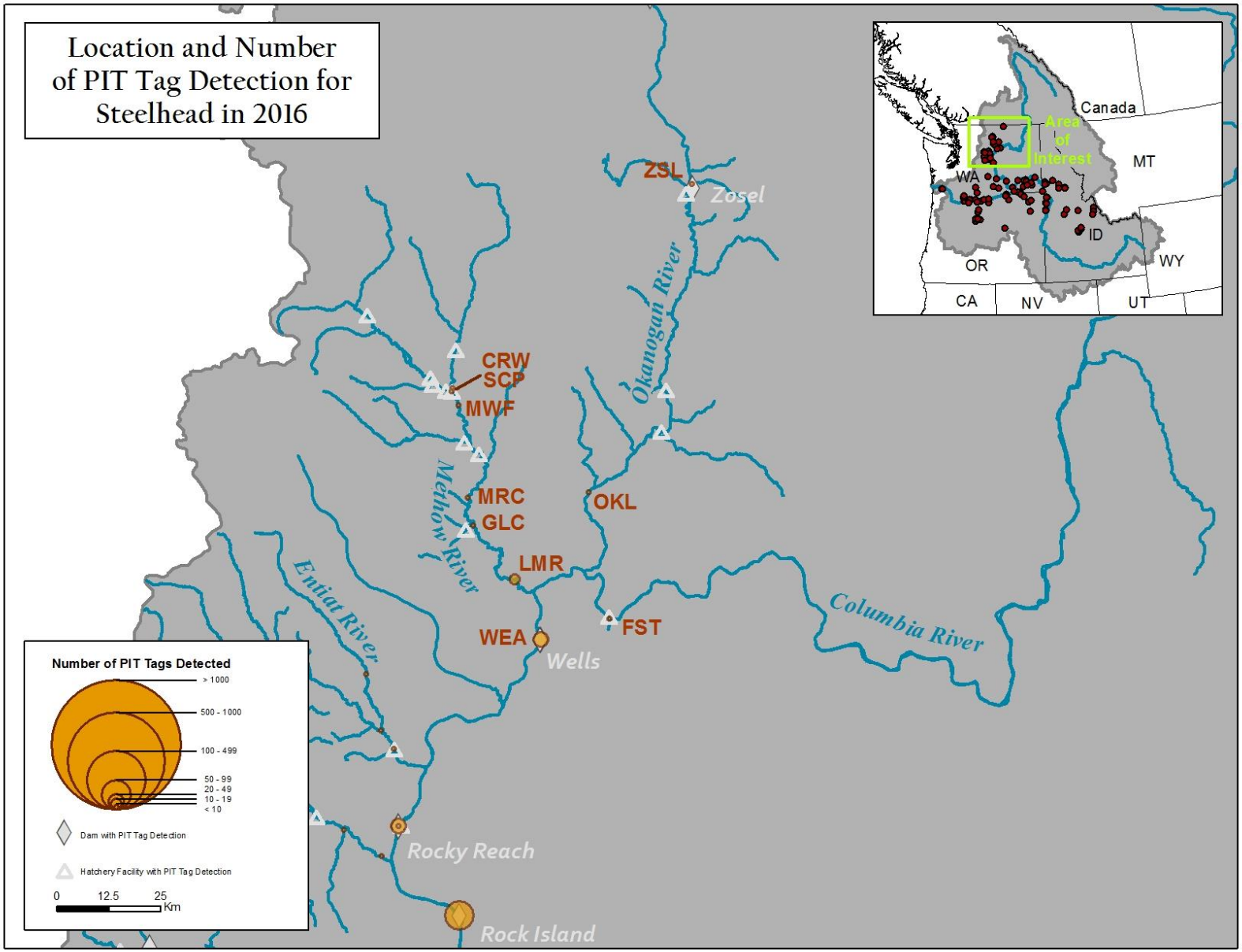

Figure A18. Map of Upper Columbia River (Wells Dam and above) detection sites and number of steelhead detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

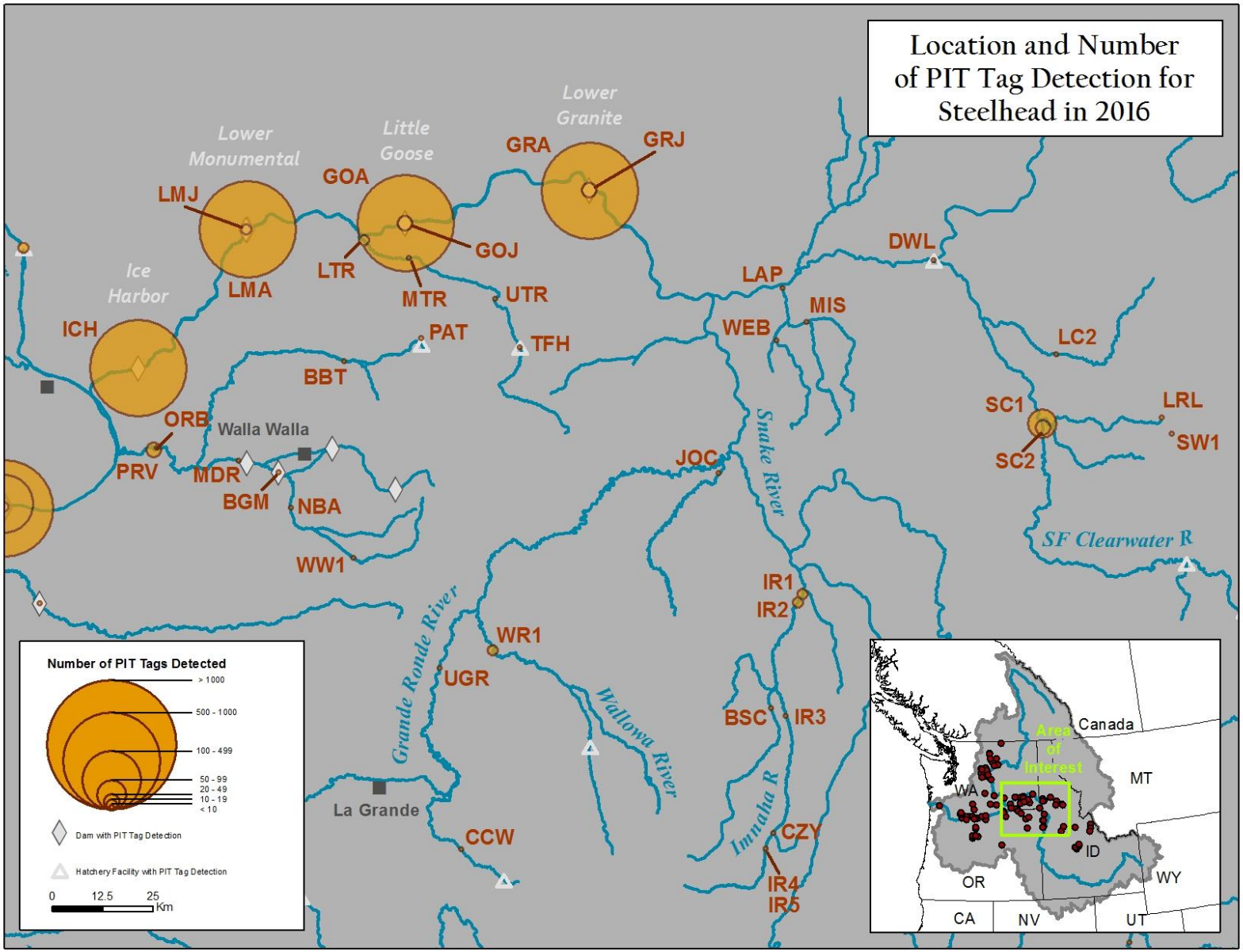

Figure A19. Map of Lower Snake River detection sites (Salmon River not included) and number of steelhead detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

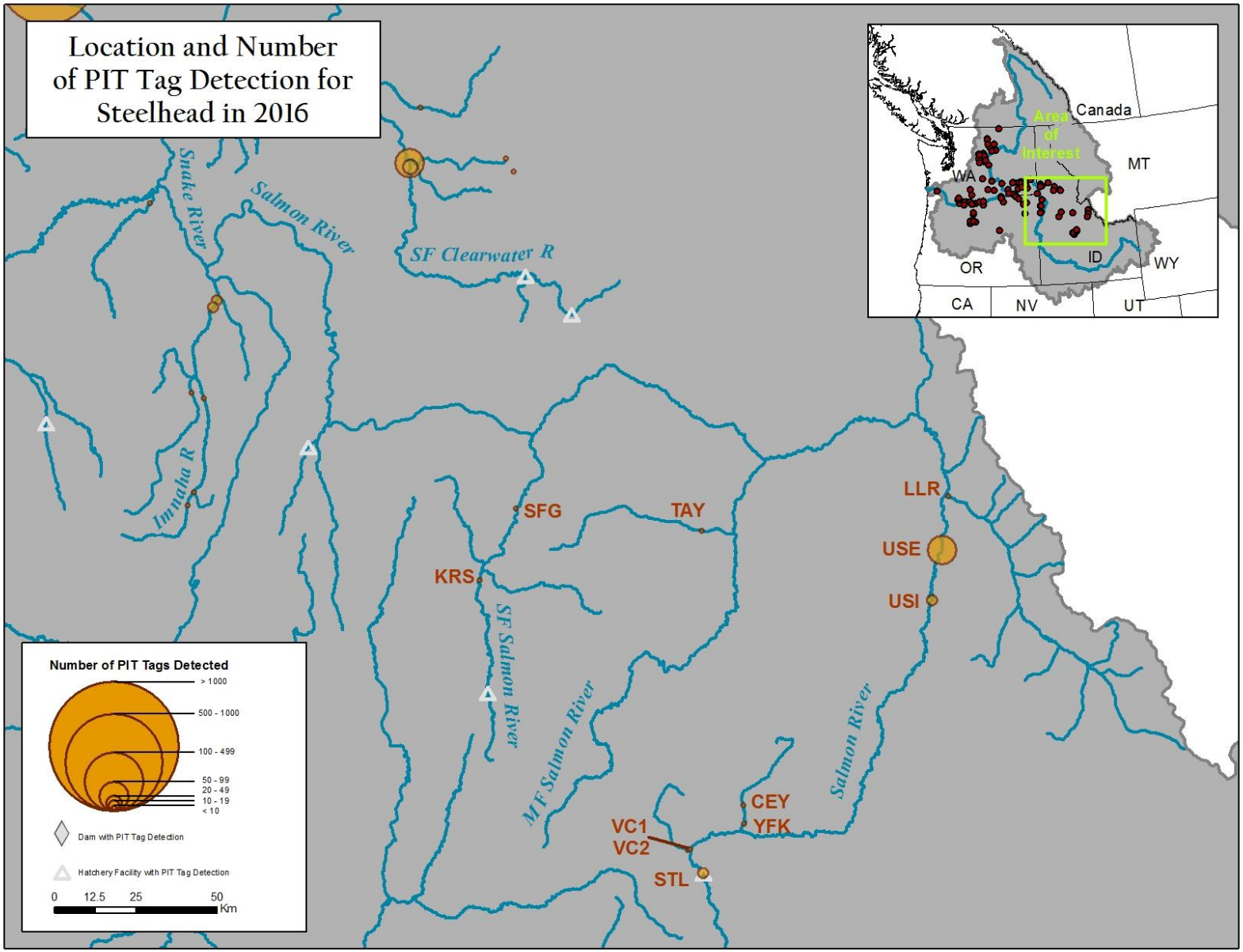

Figure A20. Map of Salmon River detection sites and number of steelhead detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map.

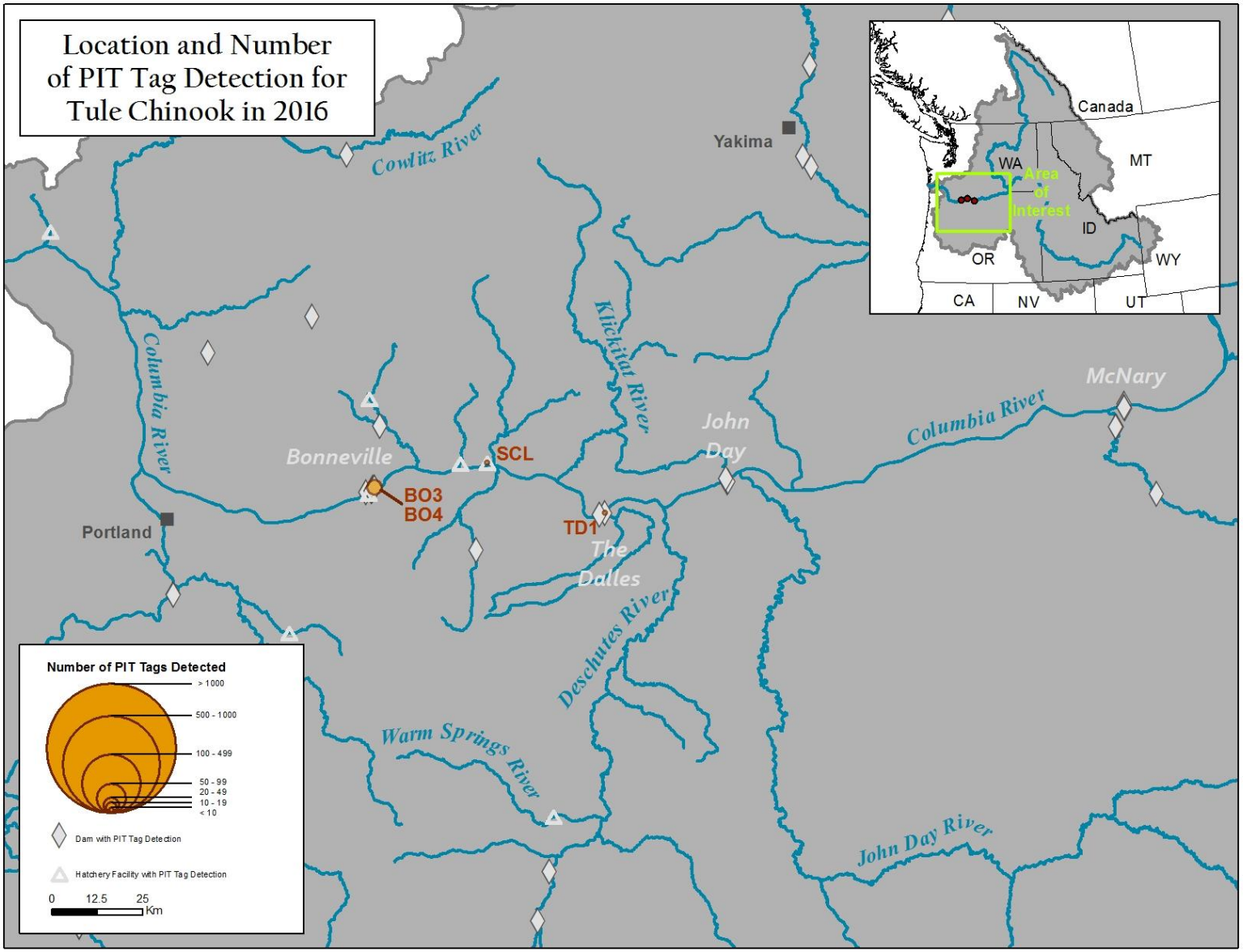

Figure A21. Map of Lower Columbia River detection sites (below Snake River) and number of Tule Chinook Salmon detected. Table A1 in the Appendix lists the PTAGIS sites' full name and the three-letter codes on this map. Tule Chinook is defined as fish passing Bonneville Dam in the fall and maturation (showing spawning colors).

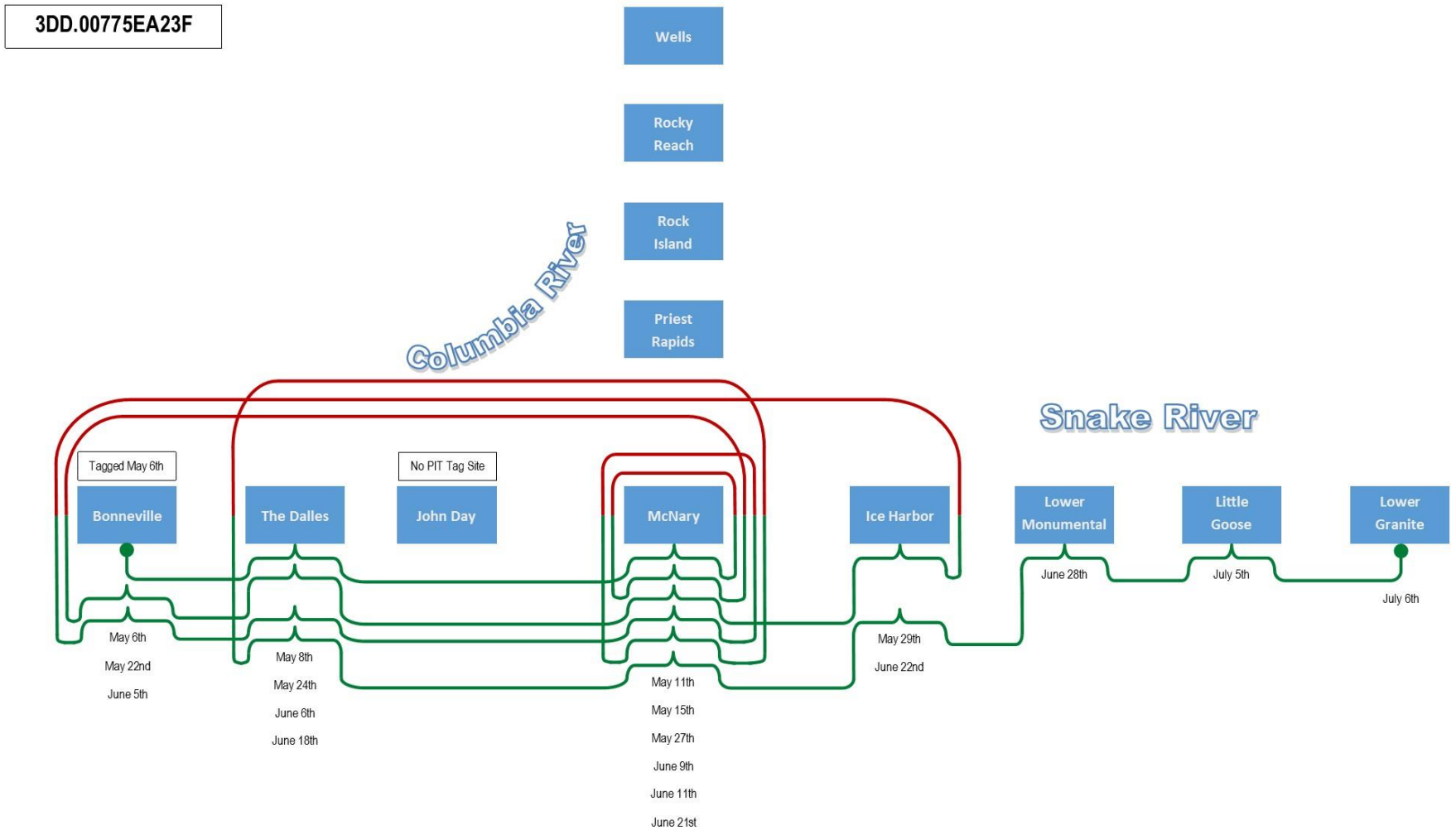

Figure A22. Chart showing the pattern and location of fall back events at mainstem dams on the Columbia and Snake rivers for Chinook Salmon with PIT tag 3DD.00775EA23F, tagged and tracked in 2016.

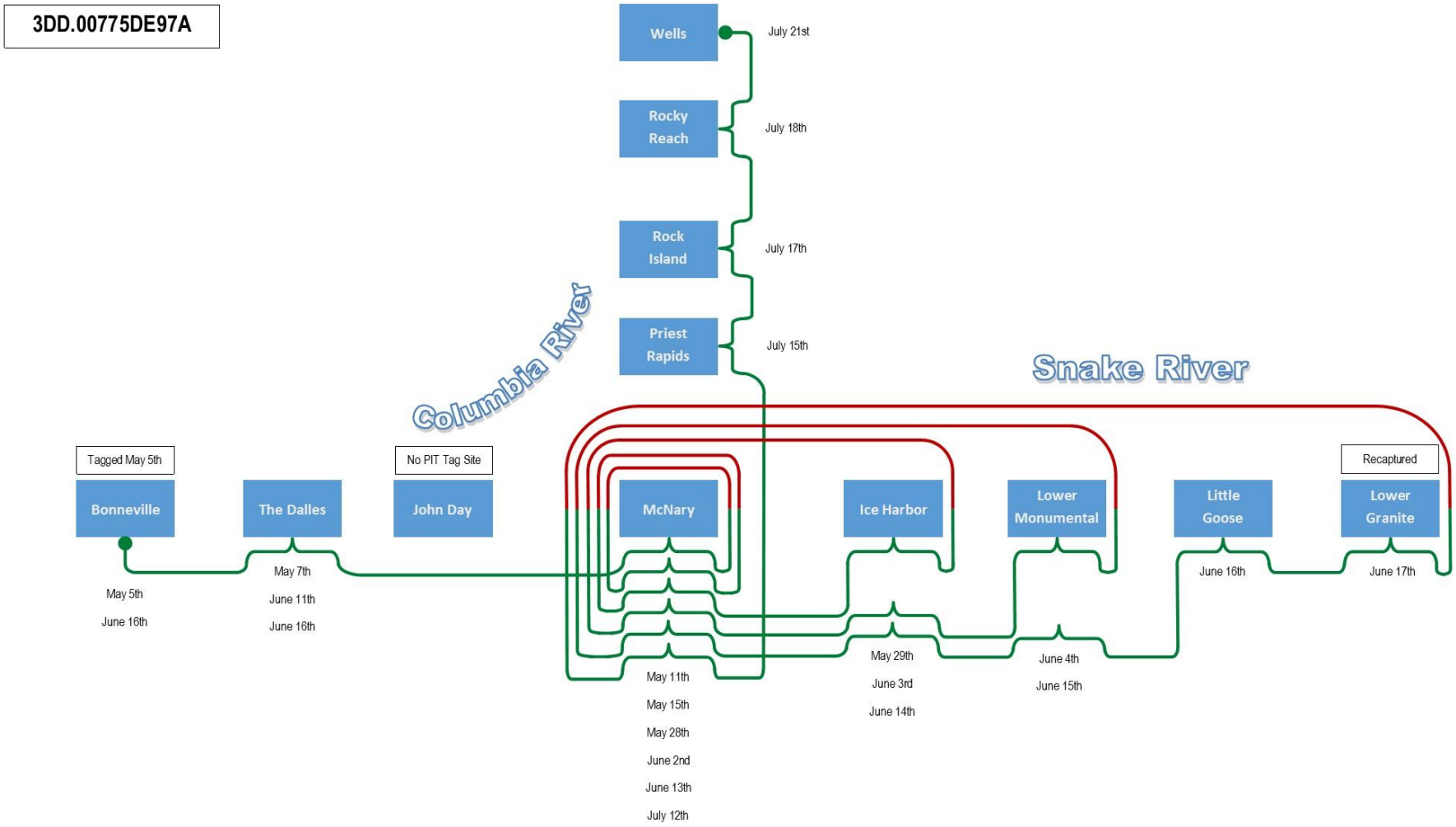

Figure A23. Chart showing the pattern and location of fall back events at mainstem dams on the Columbia and Snake rivers for Chinook Salmon with PIT tag 3DD.00775DE97A, tagged and tracked in 2016.

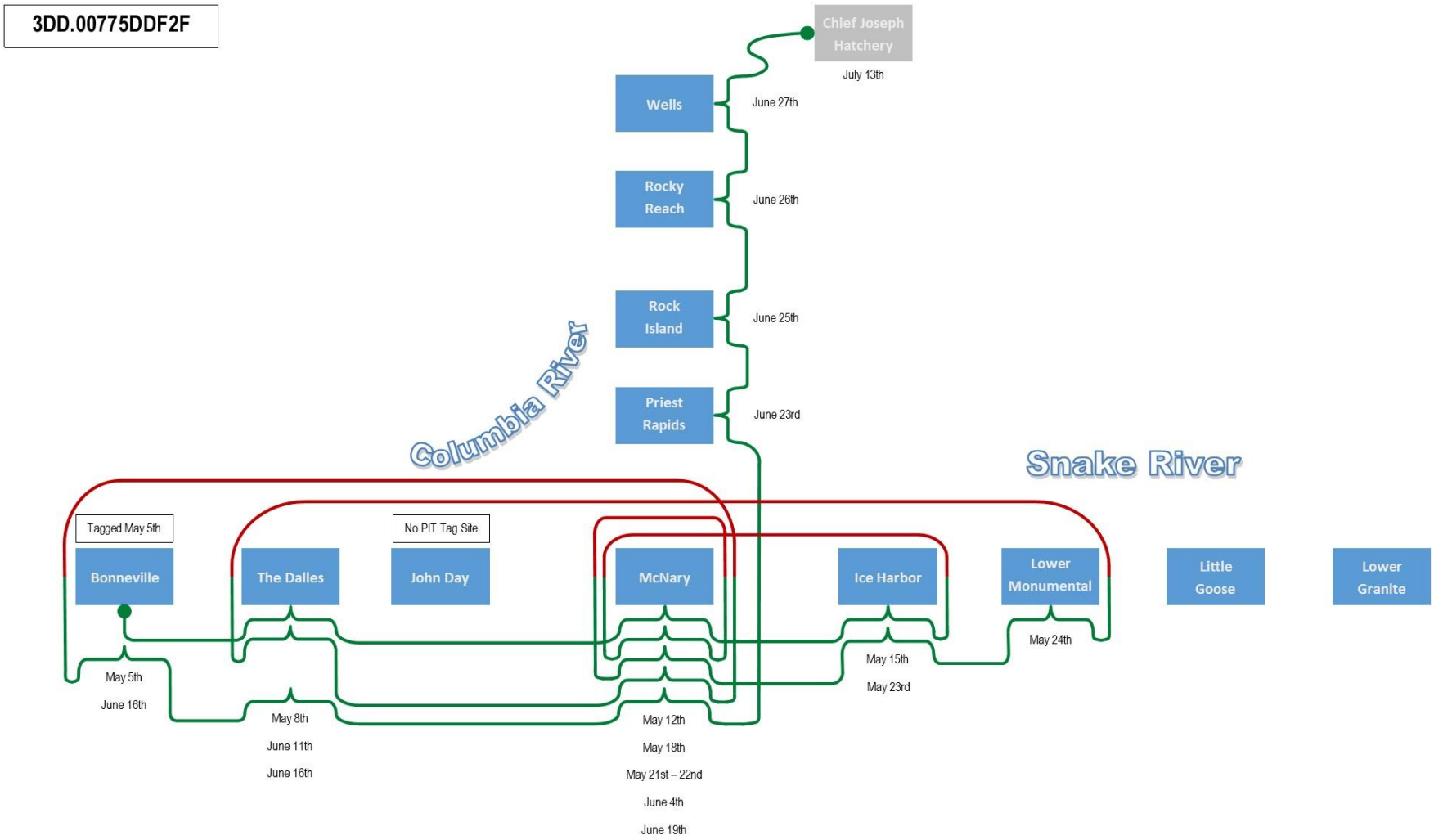

Figure A24. Chart showing the pattern and location of fall back events at mainstem dams on the Columbia and Snake rivers for Chinook Salmon with PIT tag 3DD.00775DDF2F, tagged and tracked in 2016.

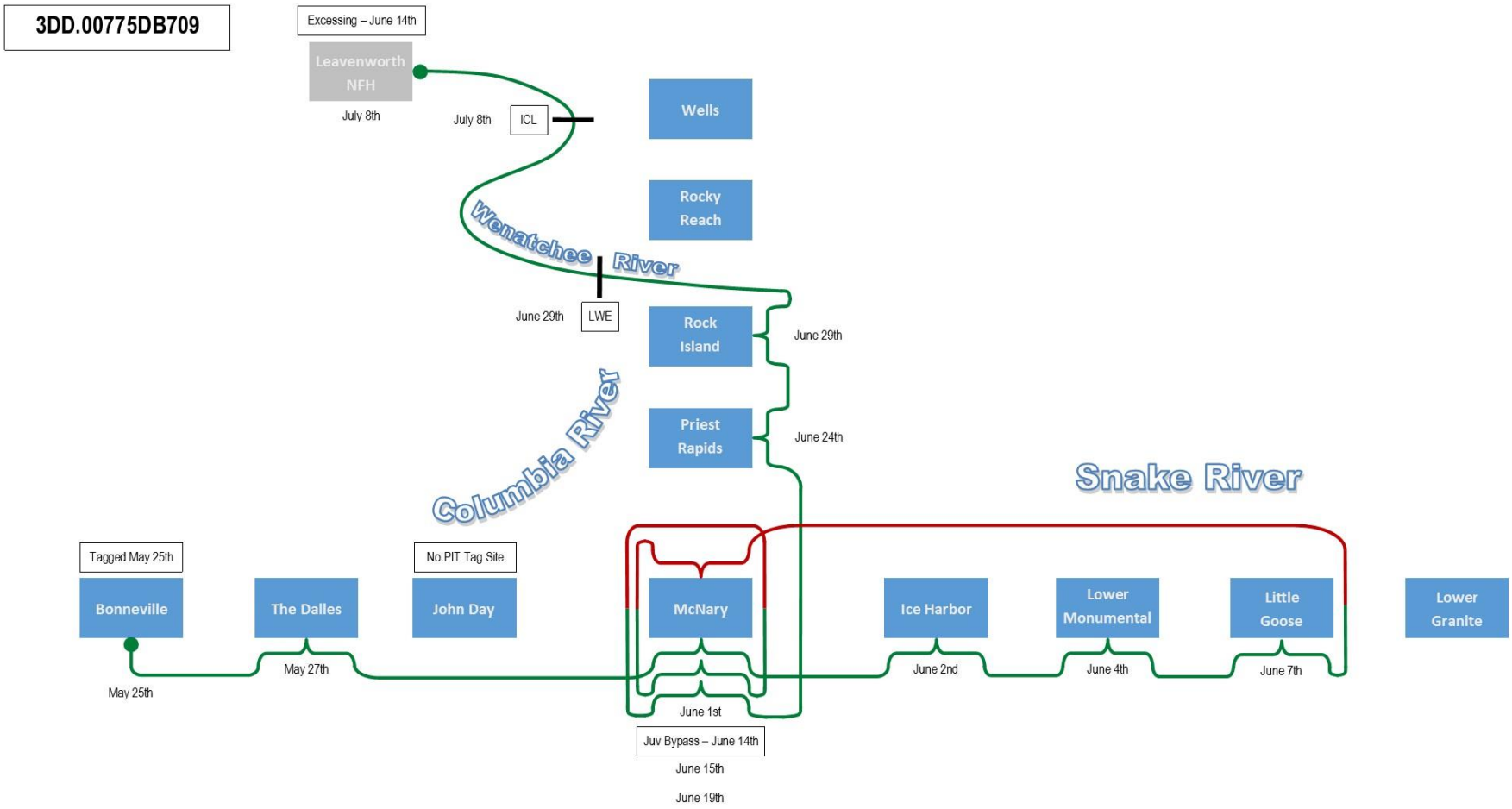

Figure A25. Chart showing the pattern and location of fall back events at mainstem dams on the Columbia and Snake rivers for Chinook Salmon with PIT tag 3DD.00775DB709, tagged and tracked in 2016.