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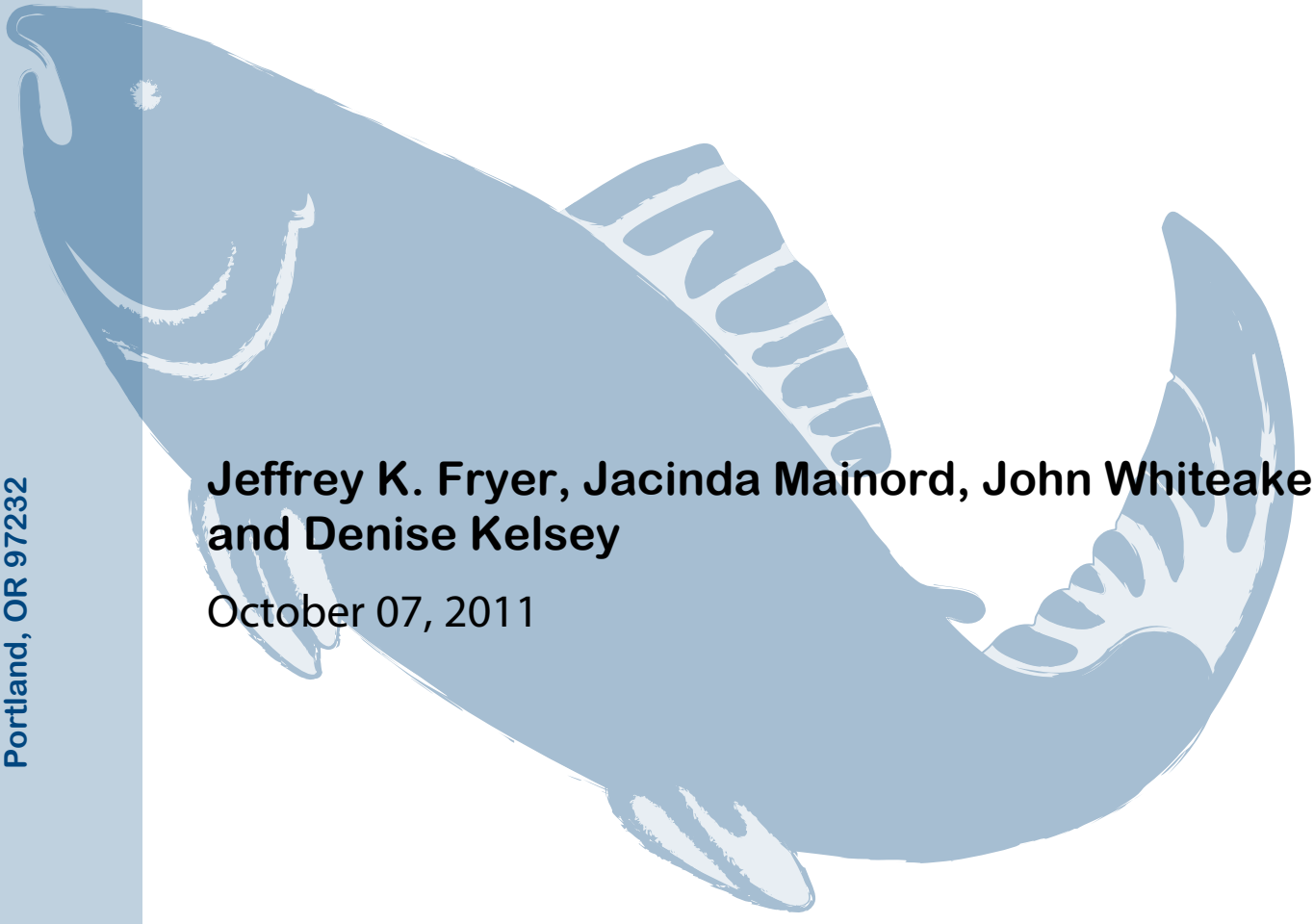
CRITFC

TECHNICAL REPORT 11-11

Upstream Migration Timing of Columbia Basin Chinook, Sockeye Salmon and Steelhead in 2009



Jeffrey K. Fryer, Jacinda Mainord, John Whiteaker, and Denise Kelsey

October 07, 2011

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

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ABSTRACT

In 2009 we sampled sockeye and Chinook salmon as well as steelhead at the Bonneville Dam Adult Fish Facility. Fish were measured for length and scales collected for later analysis for age and the fish were tagged with Passive Integrated Transponder (PIT). 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. Approximately one third of the steelhead and Chinook were tagged with a 20mm PIT tag (model TX1420SST), the remainder, as well as all sockeye, were tagged with a standard 12.5 mm tag (model TX1411SST). Total numbers of fish tracked upstream were 925 spring Chinook, 907 summer Chinook, and 1109 fall Chinook salmon, 2474 steelhead, and 807 sockeye salmon.

There was no significant difference (α=0.05) in the percentage of 12.5 and 20.0 mm tagged fish detected at any upstream locations for Chinook or steelhead, thus data from fish with the two tag types were pooled for subsequent analyses.

One ocean age fish were predominate among spring Chinook. This may have resulted from 2009 Adult Fish Facility trap operations which biased our sample by preferentially trapping the smaller, one-ocean fish (analysis based on data from Chinook tagged as juveniles). There were insufficient numbers of previously PIT tagged fish to detect any other biases in our Chinook sampling, or for sockeye or steelhead, if they existed.

Chinook travel times between mainstem dams ranged between 20-40 km/day. Spring Chinook that passed McNary Dam were primarily bound for the Snake River, while summer Chinook were primarily bound for upstream of Priest Rapids Dam.

Most spring Chinook salmon that traveled upstream of McNary Dam were last detected in the Snake River, most summer Chinook were last detected in the Columbia River upstream of Priest Rapids Dam, and the majority of fall Chinook did not pass upstream of McNary Dam. Escapement estimates for the entire Chinook run derived from PIT tag detections result in estimates differing from those estimated by visual counts by -7.4% to +12.4% at mainstem dams.

One-winter ocean aged steelhead predominated at most detection sites. Steelhead classified as B-run (being over 78 cm fork length) were overwhelmingly last detected in the Snake River. Based on the data reported, the percentage of steelhead classified as B-run at Bonneville Dam peaked in September at nearly 60% of the run, while the estimated weekly number of B-run steelhead passing Bonneville Dam peaked in August at nearly 8000 fish. A total of 101 PIT tagged steelhead tracked in 2009 were detected moving downstream (mostly in juvenile bypasses) after February, 2010, presumably in an attempt to return to the ocean after spawning.

The estimated stock composition of sockeye salmon passing Bonneville Dam was 82.6% Okanagan, 15.1% Wenatchee, and 2.3% Snake. Upstream survival of sockeye salmon steadily declined as the migration progressed; Bonneville-Rock Island survival declined from as much as 90% for sockeye salmon passing Bonneville Dam during June to less than 80% during July.

The mean travel time of sockeye salmon between Bonneville and Rock Island dams was 12.7 days, indicating a mean travel speed of 38.2 km per day. Fish passing Bonneville Dam later in the migration traveled upstream faster than those earlier in the migration.

ACKNOWLEDGMENTS

Bonneville field sampling was supervised by John Whiteaker and assisted by Bobby Begay of the Columbia River Inter-Tribal Fish Commission (CRITFC). The following individuals also assisted in this project: Rick Golden of the Bonneville Power Authority, Ryan Branstetter, David Graves, Doug Hatch, Marianne McClure, Shawn Narum, Rishi Sharma, Winfred Perez, Melissa Edwards, and Marc Whitman of CRITFC; Ben Hausmann, Tammy Mackey, and Jon Rerecich of the US Army Corps of Engineers; Steven Lee of the University of Idaho; David Marvin of the Pacific States Marine Fisheries Commission.

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INTRODUCTION

Since 1985, the Columbia River Inter-Tribal Fish Commission (CRITFC) has, using Pacific Salmon Commission (PSC) funding, sampled Chinook and sockeye salmon at Bonneville Dam to determine age, length-at-age, and, in the case of sockeye salmon (Kelsey et. al 2011), stock identification (Fryer 2009). In 2004, CRITFC took over a similar long-running steelhead 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 readers 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. PIT tags can provide much of the same information as radio tags, but at minimal expense. With the reduced cost greater numbers of fish can be tagged, thus increasing the sample size and the small tag reduces the impact on the tagged fish. Unlike radio tags, PIT tagged fish information is readily available to all managers and researchers on a real-time basis through the PTAGIS system. 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.

Almost all PIT tagging presently completed in the Columbia Basin is conducted on juvenile salmonids, either at hatcheries, tributary smolt traps, or juvenile bypasses at dams. 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 for which PIT tagging is not used as a tool, thus it is difficult to answer questions on upstream migration timing, straying, and survival for those stocks. Because the our project randomly samples adult salmon and steelhead passing the dam, this study will likely tag salmonid stocks that have not previously been tagged and monitored.

METHODS

Sampling

Chinook and sockeye salmon, as well as steelhead, were PIT tagged throughout the runs from April through October, 2009, 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. In past years of this study, all four pickets were dropped to divert fish. In 2009, a new center divider was installed which allowed CRITFC to drop only two pickets to divert the fish (Figure 1), so that not all fish ascending this ladder are required to enter the AFF. Fish swimming up the far side of the trap were not diverted.

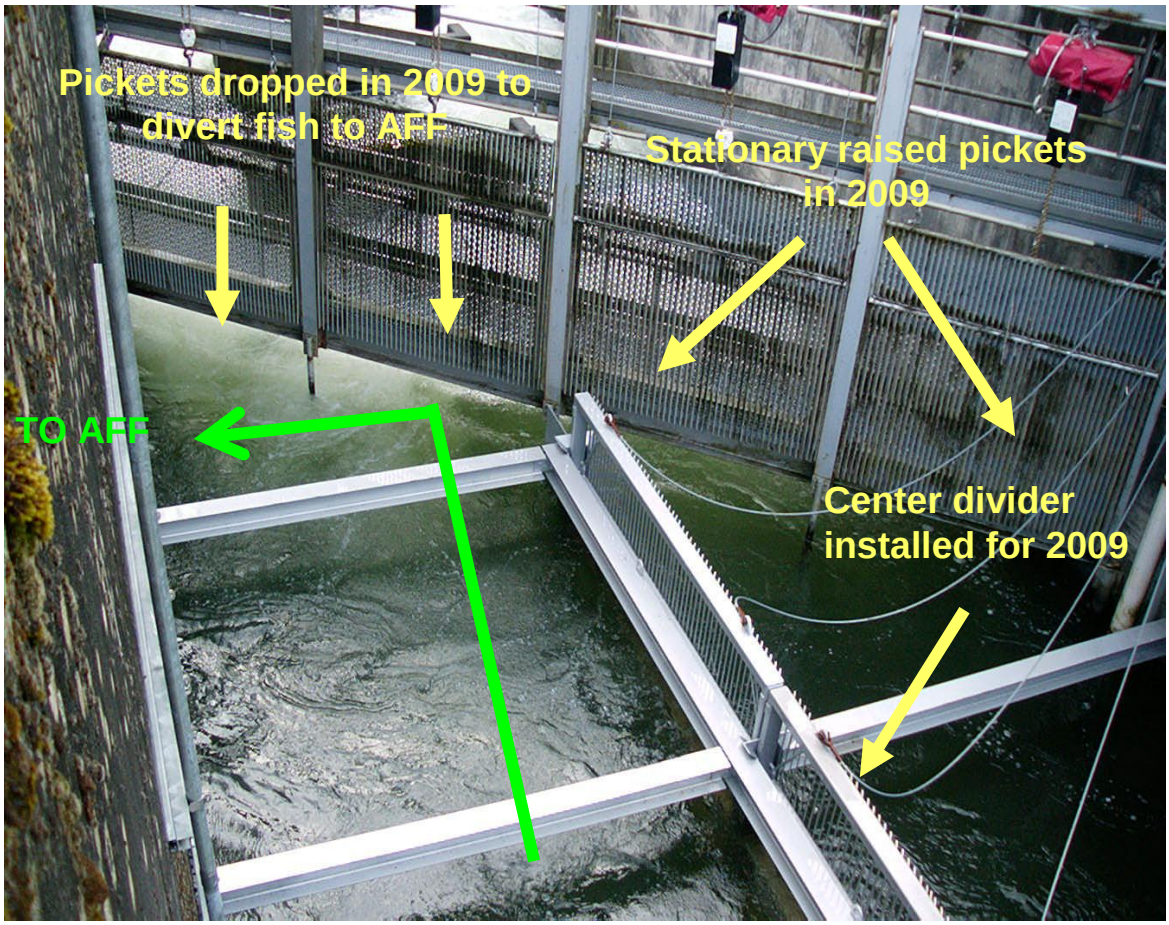

Figure 1. Picket leads with center divider that diverts fish into Bonneville Adult Fish Facility.

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.

Salmon and steelhead selected for sampling were examined for tags, fin clips, wounds, and condition. They were measured for length, and tissue and six scales (four scales for sockeye) collected for later genetic and age analysis (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. In 2009 a new 20.0 mm PIT tag (model TX1420SST) was tested for effectiveness compared to the standard 12.5 mm tag (model TX1411SST). The 20.0 mm tag was placed in one of every three steelhead and Chinook sampled, while the remaining two-thirds, along with all sockeye salmon received the 12.5 mm tags. Post-season, we examined weekly sample sizes to determine how far they deviated from weekly run sizes.

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, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams on the Columbia River; Ice Harbor, and Lower Granite dams on the Snake River) as well as in numerous tributaries and hatcheries in the Columbia Basin (Appendix Table A3 and Figure A1). Many of the receivers automatically upload (real-time) PIT tag detection data to www.ptagis.org, which is then accessible to registered users of the site.

Analysis of Impacts of the Center Divider in 2009

Several analyses were added after trapping commenced and it was observed that the numbers of fish sampled were less than expected, and that the percentage of smaller one-ocean jack Chinook salmon was less than expected. To investigate this phenomenon, we looked at the distribution of previously PIT tagged Chinook salmon (which were tagged as juveniles on, or prior to, their downstream migration) that used the Washington shore fish ladder. A statistical test comparing proportions in independent samples (Snedecor and Cochrane 1980) was used to compare the percentage of previously PIT tagged Chinook that were jacks (defined as one-ocean fish) passing on the AFF side of the ladder (subject to trapping) and the non-AFF side of the ladder (not subject to trapping)

during trapping hours. There was insufficient data to look at other age classes or other species (steelhead and sockeye). We also looked at the percentage of previously PIT tagged fish, which were jacks, using other ladders that were not subject to trapping both during trapping and non-trapping hours to look at potential ladder biases. .

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). The origin and age of Chinook and steelhead previously PIT tagged in other projects and sampled in this project could be determined through PTAGIS and 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 fish 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 mainstem dam counts made at fish ladder viewing windows or weir counts. Escapement estimates were not calculated for sites where $\sum T_i < 15$. 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 mainstem dam counts.

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; for example, the percentage missed at Rocky Reach Dam was calculated as:

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

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

If a fish is detected at one detection weir in a given fish ladder, it should also be detected at the rest of the weirs with PIT tag detection in that same ladder. This allows a probability of detection at the individual weirs in a ladder to be calculated by comparing it with other weirs in that same ladder. Detection probabilities were calculated as:

$$Pi = 1 - \prod_i (1 - \frac{N_i}{T})$$

where N_i is the number of fish detected at a given weir and T is the total number of fish detected by any weir at that ladder. This data was tabulated and is presented in the Appendix, Tables A1 and A2.

Also calculated was the percentage of fish using each ladder at the dams with multiple ladders with detection capabilities.

Comparison of Tag Types

A statistical test comparing the proportions of independent samples (Snedecor and Cochrane, 1980) was used to evaluate whether similar proportions of Chinook salmon tagged with the two tag types was observed at mainstem dams and weirs with PIT tag detection.

Migration Timing and Passage Time

Run timing was estimated using the date and time of detection between detection 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.

Night Passage

Fish counting at Columbia Basin dams is not consistent between dams. Fish at Bonneville and McNary dams are counted live by observers stationed at fish ladder viewing windows from 0400 to 2000 Pacific Standard Time, while fish at 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).

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 it. 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 lower weir is defined as lowest PIT tag detector in 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 downstream dam. These methodologies will underestimate fallback as they do not include fish that fall back over a dam and are not subsequently detected.

Adult steelhead detected at juvenile facilities after February, 2010 were not considered fallbacks, as they were likely kelts on their way downstream to the ocean.

RESULTS-CHINOOK

Trap Biases

In 9 out of 23 Statistical weeks, the percentage of jacks on the near side of the center divider, and subject to sampling, was significantly greater than on the far side, where they were not subject to sampling. Over the entire run, this difference was highly significant ($p<0.001$, Table 1). Furthermore, when the trap was in operation, 26.2% (496 out of 1877) of previously PIT tagged Chinook passed on the near side compared to 43.8% (2127 out of 4933, Table 2) when the trap was not in operation. When the trap was not in operation, there was no significant difference in the distribution of jacks across the fish ladder for any week (Table 2) which suggests that it is the operation of the trap, combined with the center divider, which is causing a bias.

Table 1. Percentage of jacks among previously PIT tagged Chinook salmon passing the entrance of the Bonneville Dam fish trap on the near and far sides of the trap when the trap is in operation and the results of a test for the difference in independent proportions by statistical week in 2009.

	Pass Far Side (not subject to trapping)		Pass Near Side (subject to trapping)		P-value (significant results are in **bold and underlined**)
Statistical Week	N	Percent Jacks	N	Percent Jacks	
17	15	7%	5	20%	0.389
18	46	9%	14	7%	0.854
19	136	26%	29	34%	0.382
20	128	35%	33	91%	**0.000**
21	148	34%	53	43%	0.212
22	42	29%	14	14%	0.285
23	55	33%	23	52%	0.107
24	55	44%	16	56%	0.373
25	70	46%	16	81%	**0.010**
26	57	49%	7	86%	0.067
27	80	49%	18	94%	**0.000**
28	35	46%	11	82%	**0.036**
29	7	43%	2	100%	0.151
30	8	25%	1	0%	0.571
31	2	50%	1	100%	0.386
33	15	40%	3	100%	0.058
34	42	40%	11	64%	0.170
35	53	38%	18	61%	**0.048**
36	81	48%	24	67%	0.111
37	133	45%	76	79%	**0.000**

38	108	49%	59	86%	**0.000**
39	63	43%	43	81%	**0.000**
40	2	0%	9	89%	**0.011**
Cumulative	**1381**	**39%**	**496**	**67%**	**0.000**

Table 2. Percentage of jacks among previously PIT tagged Chinook salmon passing the entrance of the Bonneville Dam fish trap on the near and far sides of the trap when the trap is not in operation and the results of a test for the difference in independent proportions by statistical week in 2009.

	Pass far side		Pass near side		P-value (no significant results)
Statistical Week	N	Percent Jacks	N	Percent Jacks	
17	37	8%	36	20%	0.317
18	111	16%	111	7%	0.571
19	213	30%	205	34%	0.772
20	388	37%	279	91%	0.457
21	201	26%	121	43%	0.360
22	156	25%	100	14%	0.721
23	114	31%	93	52%	0.794
24	168	39%	102	56%	0.576
25	209	42%	81	81%	0.833
26	91	45%	29	86%	0.983
27	34	47%	14	94%	0.853
28	49	47%	13	82%	0.960
29	36	47%	22	100%	0.837
30	6	17%	5	0%	0.387
31	8	38%	8	100%	1.000
33	5	40%	4	100%	0.764
34	19	21%	18	64%	0.401
35	91	35%	46	61%	0.649
36	251	43%	173	67%	0.918
37	294	45%	354	79%	0.777
38	325	45%	315	86%	0.778
39	257	47%	232	81%	0.975
40	189	48%	134	89%	0.945
Cumulative	**2806**	**38%**	**2127**	**39%**	**0.701**

While conducting this analysis, we also looked at the percentage of previously tagged fish that were returning as jacks at each of the three ladders at Bonneville Dam (Washington shore, Oregon shore, and Bradford Island), when the trap was and was not operating (Table 3). Percentages differed greatly; though the overall weighted percentage of jacks at all ladders (48.2%) was surprisingly close to what passed through the trap entrance when the trap was in

operation (46.1%).

Table 3. Percentage of previously PIT tagged Chinook that are jacks passing Bonneville Dam by ladder during all hours.

	Pass through Trap facility	Washington Shore fish ladder	Oregon Shore fish ladder	Bradford Island fish ladder	All ladders (weighted by abundance)
Trap in operation	71.7%	46.1%	60.4%	56.3%	53.0%
Trap not in operation		38.6%	59.1%	53.2%	46.9%
Overall		**40.0%**	**59.4%**	**53.9%**	**48.2%**
N	**746**	**7139**	**4335**	**1814**	**14934**

There was insufficient data to conduct trap bias analyses for other age groups of Chinook or for sockeye salmon or steelhead. No effort was made in subsequent analyses to correct for any of these trap biases.

Sample Size

A total of 611 spring Chinook, 602 summer Chinook, and 751 fall Chinook salmon were tagged with 12.5 mm PIT tags in 2009. An additional 293 spring, 299 summer, and 353 fall Chinook were tagged with 20 mm PIT tags (Table 4). No Chinook sampling was conducted during Statistical weeks 31-33 due to high temperatures. Due to similar detection rates (Effectiveness of 20.0 mm Tags section), tag types were pooled for subsequent analyses. 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 (likely a result of the tags being shed), the numbers of Chinook tracked upstream consisted of 925 spring Chinook, 907 summer Chinook, and 1109 fall Chinook salmon (Table 4).

Table 4. Number of Chinook salmon PIT tagged at Bonneville Dam and tracked, by date and statistical week in 2009.

Spring Chinook

Dates	Statistical Week	12.5 mm tagged (n)	20 mm tagged (n)	Previously tagged	Probable tag shed	Total Tracked (including recaps)
4/21,23,24	17	29	12	0	1	40
4/27-4/30,5/1	18	41	23	1	0	65
5/4-5/8	19	102	50	5	0	157
5/11-5/15	20	103	52	5	1	159

5/18-5/22	21	192	89	11	5	287
5/26-5/29	22	144	67	6	0	217
Total		**611**	**293**	**28**	**7**	**925**

Summer Chinook

6/1-6/5	23	175	86	8	5	264
6/8-6/11	24	108	54	3	0	165
6/15-6/18	25	109	54	2	3	162
6/22-6/26	26	90	44	0	2	132
6/29-7/2	27	50	26	3	0	79
7/6-7/9	28	35	18	0	0	53
7/13-7/17	29	23	11	0	0	34
7/20-7/24	30	12	6	0	0	18
Total		**602**	**299**	**16**	**10**	**907**

Fall Chinook

8/11-8/14	33	1	0	0	0	1
8/18-8/21	34	29	14	0	0	43
8/25-8/28	35	91	46	3	0	140
9/1-9/4	36	81	38	2	0	121
9/8-9/11	37	126	64	3	1	192
9/14-9/18	38	155	59	3	4	213
9/21-9/24	39	115	58	2	3	172
9/28-9/30	40	73	36	0	1	108
10/1,2,5,6,8,9	41	63	30	1	0	94
10/12,13	42	15	8	0	1	22
10/19-10/21	43	2	0	1	0	3
Total		**751**	**353**	**15**	**10**	**1109**
Grand Total		**1964**	**945**	**59**	**27**	**2941**

Distribution of Sample

Compared to the run distribution, spring Chinook were over-sampled early in the run and under-sampled late in the run (Figure 2). With the exception of Statistical Week 23, summer Chinook were sampled relatively proportional to the run (Figure 3). Fall Chinook were under-sampled early in the run, due to the restrictions on sampling during high water temperatures (Figure 4) that occurred during this part of the run. During Statistical weeks 34-36 for fall Chinook, our sample size consisted of 304 Chinook, representing 27.4% of our total sample, yet 53.6% of the run passed in these weeks.

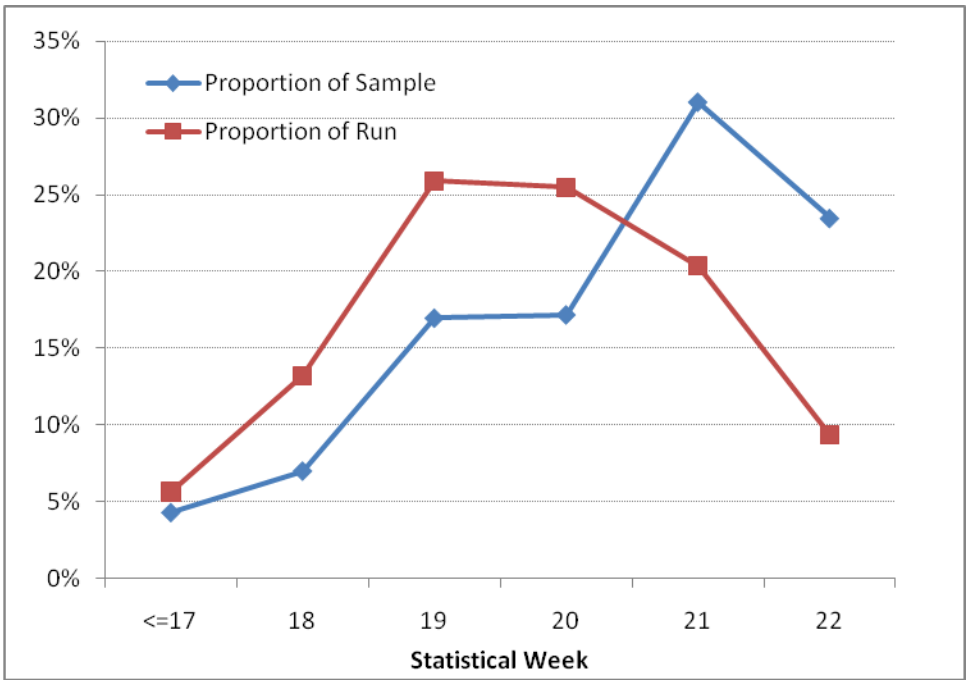

Figure 2. Proportion of the spring Chinook sample size and run size by statistical week at Bonneville Dam in 2009.

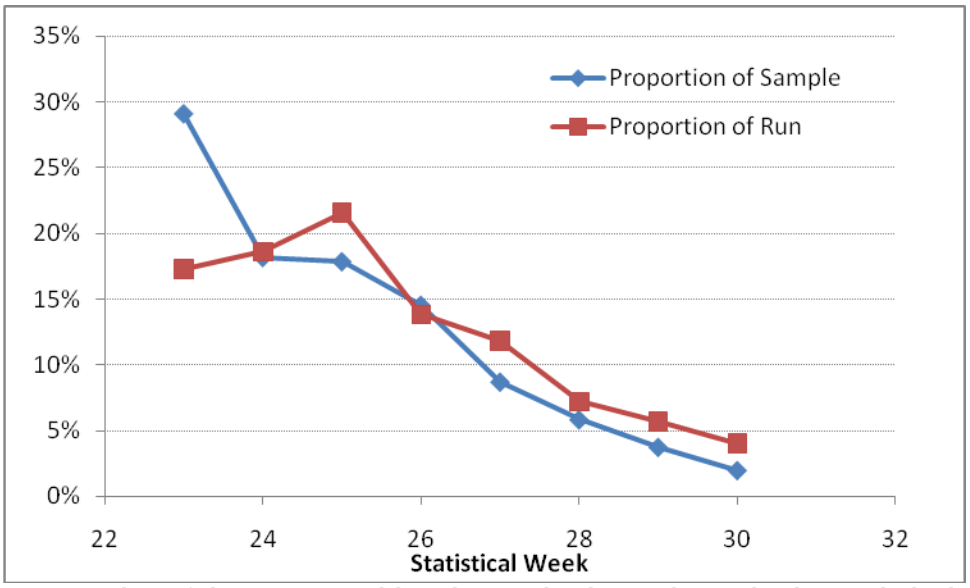

Figure 3. Proportion of the summer Chinook sample size and run size by statistical week at Bonneville Dam in 2009.

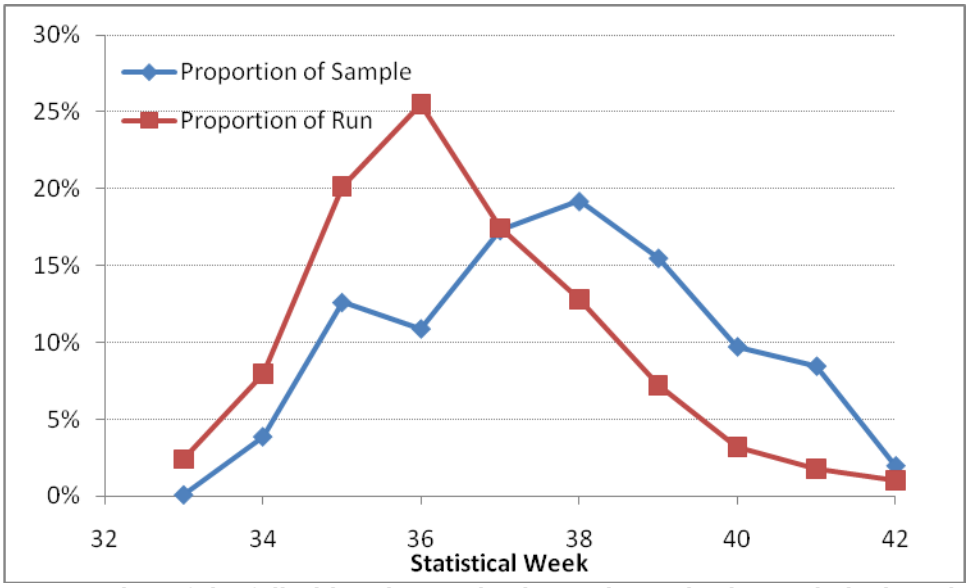

Figure 4. Proportion of the fall Chinook sample size and run size by statistical week at Bonneville Dam in 2009.

Effectiveness of 20.0 mm Tags

There was no significant difference (α=0.05) in the percentage of 12.5 and 20.0 mm tagged fish detected at any locations for Chinook (Table 5). Data from both tag types was pooled for subsequent analyses presented in this report.

Table 5. Total number and percentage of 12.5 and 20 mm PIT tagged Chinook salmon passing upstream sites and the p-value for a t-test comparing the two proportions in 2009 (minimum n=30).

Site with PTAGIS code in parentheses	Total passing	Percentage of 12.5 mm tagged Chinook passing site	Percentage of 20.0 mm tagged Chinook passing site	p-value
Bonneville Dam OR (BO1)	106	4.1%	3.4%	0.853
Bonneville Dam Bradford Island (BO2)	52	1.7%	1.9%	0.970
Bonneville Dam Lower WA ladder (BO3)	2542	87.7%	88.3%	0.659
Bonneville Dam WA shore (BO4)	2785	96.2%	96.7%	0.515
Lower Granite Dam (GRA)	822	26.8%	29.3%	0.459
Ice Harbor Dam (ICH)	867	28.6%	30.7%	0.521
Krassel Creek weir, South Fork Salmon (KRS)	130	4.1%	4.7%	0.893
McNary Dam OR(MC1)	1210	41.9%	42.0%	0.978
McNary Dam WA (MC2)	745	24.9%	26.3%	0.684
Priest Rapids Dam (PRA)	578	20.3%	19.9%	0.910
Prosser Dam (PRO)	82	3.4%	2.6%	0.825
Rock Island Dam (RIA)	527	18.3%	18.3%	0.994
Rocky Reach Dam n(RRF)	352	11.3%	12.6%	0.716
Roza Dam (RZF)	63	2.9%	1.9%	0.784

Tumwater Dam (TUF)	91	3.4%	3.0%	0.924
Wells Dam (WEA)	299	9.4%	10.8%	0.699

Detection Numbers

Tagged salmon and steelhead can be detected multiple times at each PIT tag detection site as they migrate, thus producing thousands of records of detection data. For most analyses, the multiple detections of a fish at the weirs of a site are combined into a single detection for that site. This still produces a large number of detection records, since a single fish will be detected at multiple sites in the Columbia River system. For each of the runs of Chinook salmon, detection and site numbers varied; spring Chinook had 3870 fish detections at 46 sites, summer Chinook had 4613 fish detections at 29 sites, and the fall run had 3185 fish detections at 24 sites. Maps (Figure A2-A12) found in the Appendix show the categorical ranges of detection numbers at the sites throughout the Columbia Basin. Note that the Chinook tracked in each run is determined by the migration timing at Bonneville, spring Chinook run ends May 31st, summer Chinook run ends July 31st, and therefore some overlap in runs influences the sites and numbers in each set.

Age Analysis

We are able to validate our scale aging techniques by using fish sampled for this project at Bonneville that were previously tagged as juveniles for other projects or hatchery programs. Age estimates from ageable scale patterns of 48 Chinook salmon that had been previously PIT tagged were correctly aged as follows: 20 out of 21 spring Chinook, all 14 summer Chinook, and all 13 fall Chinook salmon. Only the total age could be compared, for it was not possible to separately validate freshwater and ocean age.

We attempted to exclude minijacks (defined as Chinook spending no winters in saltwater) from our by not diverting Chinook less than approximately 36 cm into the sampling tank. These were excluded due to lack of importance to fishery managers and the fact that sampling these fish would reduce our sample of larger Chinook and other species. However five Chinook salmon were sampled (length ranged from 37.5 to 42 cm) and after aging of scales the fish were identified as minijacks (ages were 1.0 and 2.0). In addition, one steelhead (39.5 cm in length) was identified as spending no winters in saltwater. These fish were all treated like other fish at the time of sampling, so that genetic samples

were taken and they were tagged with PIT tags and tracked. However the age of these fish were not used in age composition analysis.

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Spring Chinook salmon that traveled upstream of McNary Dam were primarily bound for the Snake River (Table 6, Figures 5 and 6), while summer Chinook were primarily bound for the Columbia River upstream of Priest Rapids Dam (Table 6, Figures 5 and 7). Fall Chinook were primarily headed for areas downstream of Ice Harbor and Priest Rapids dams (Table 6, Figures 5 and 8). Over the spring/summer portion of the run, the percentage of Chinook salmon passing Priest Rapids Dam steadily increased, while the percentage of those last detected downstream of McNary Dam steadily decreased (Figure 5). The percentage of Chinook that ultimately passed Ice Harbor Dam rose through the early part of the run before dropping after Statistical Week 24.

Table 6. Percentage of spring, summer, and fall Chinook salmon tracked from Bonneville Dam detected at upstream dams and the percentage lost due to tributary escapement or mortality between dams in 2009.

	Spring Chinook		Summer Chinook		Fall Chinook	
Dam	Reach Dam	Lost	Reach Dam	Lost	Reach Dam	Lost
Bonneville	100.0%	--	100.0%	--	100.0%	--
McNary	70.5%	29.5%	86.5%	13.5%	61.8%	38.2%
Priest Rapids	12.7%	46.3%	45.4%	5.5%	7.8%	82.4%
Rock Island	12.3%	2.7%	44.6%	1.8%	3.9%	50.7%
Rocky Reach	6.2%	50.0%	32.6%	27.0%	1.7%	55.6%
Wells	5.6%	9.1%	27.6%	15.4%	0.9%	50.0%
Ice Harbor	46.9%	18.9%	38.4%	6.5%	17.2%	68.1%
Lower Granite	44.3%	5.5%	37.0%	3.6%	14.0%	18.8%

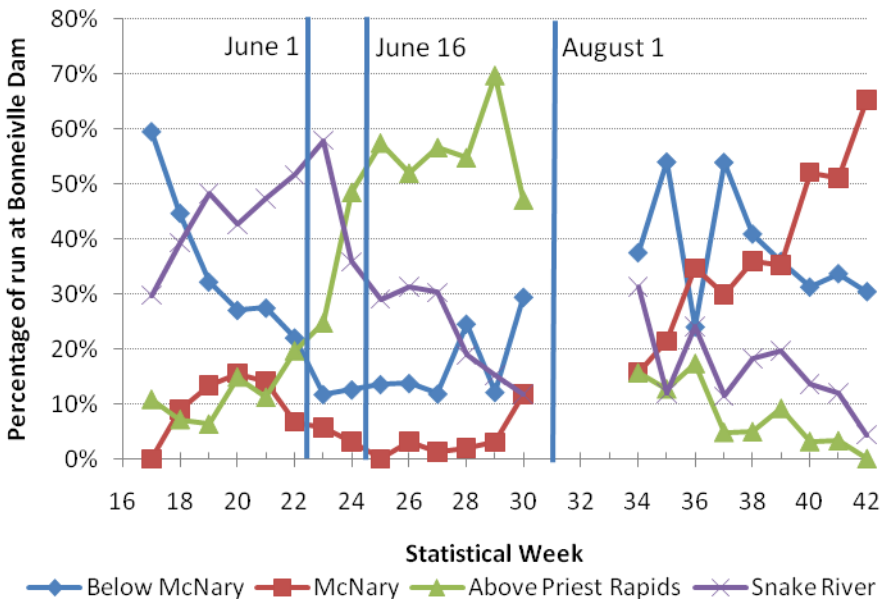

Figure 5. Distribution of final detection site by statistical week for Chinook salmon that were PIT tagged at Bonneville Dam in 2009.

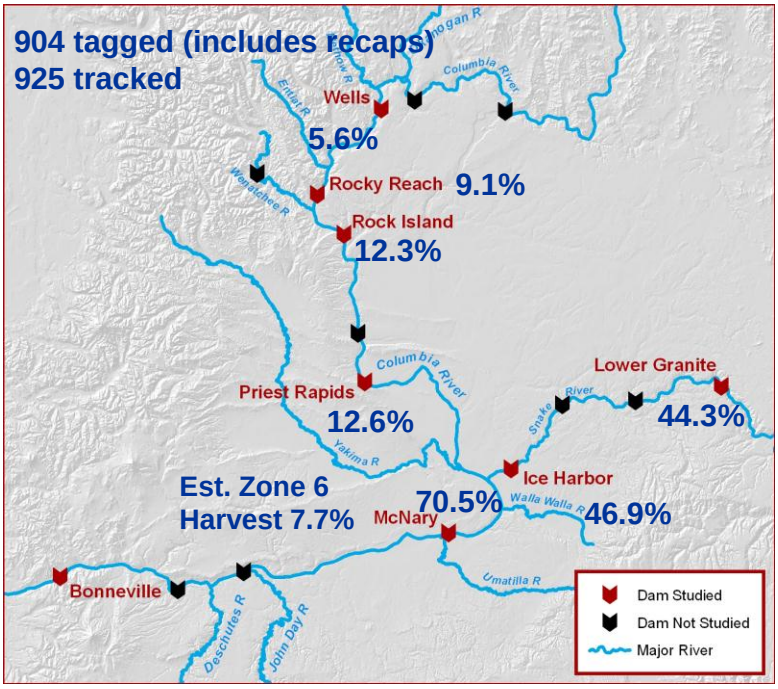

Figure 6. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of spring Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2009.

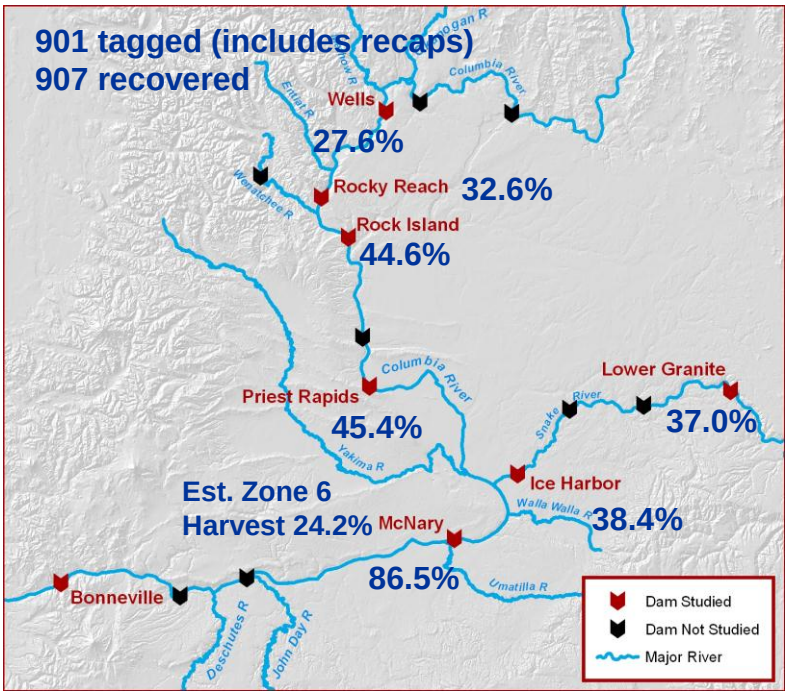

Figure 7. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of summer Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2009.

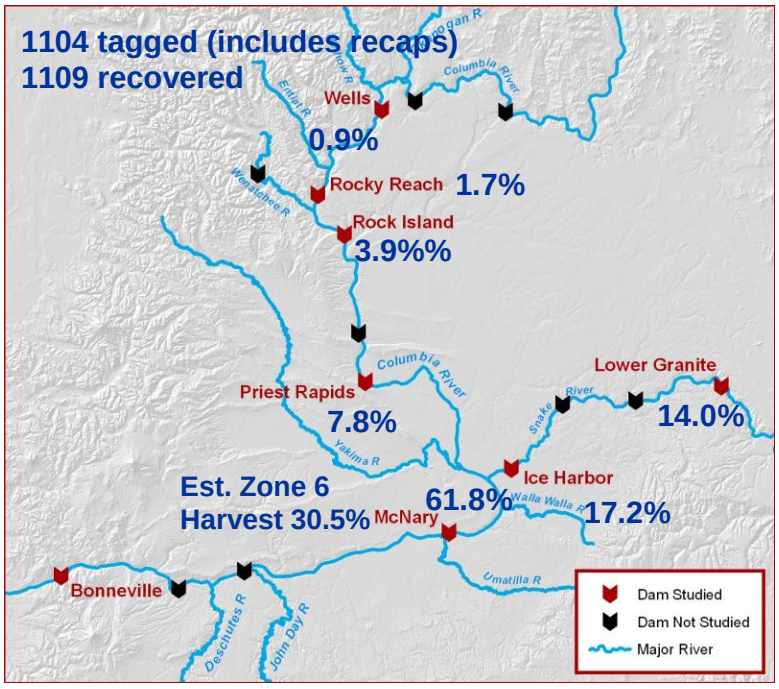

Figure 8. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fall Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2009.

The percentage of PIT tagged Chinook salmon passing a dam without detection was generally under 1% (Table 7). Two exceptions were McNary and

Ice Harbor dams where navigation locks provide a plausible explanation as to how fish could pass undetected[a]. Rock Island Dam is known to have problems with detection due to the antenna size and electrical noise (D. Marvin, Pacific States Marine Fisheries Commission, personal communication). The detection efficiency of individual weirs within ladders is found in Table A1.

Table 7. Percentage of Chinook salmon passing a dam undetected that were subsequently detected at an upstream dam in 2009.

Dam	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville	0.2%	0.3%	0.0%
McNary	1.1%	1.9%	1.7%
Priest Rapids	0.0%	1.5%	0.0%
Rock Island	0.9%	2.0%	0.0%
Rocky Reach	0.0%	0.7%	0.0%
Ice Harbor	3.2%	1.5%	0.0%

Escapement estimates for the entire Chinook run derived from PIT tag detections result in estimates differing from those estimated by visual counts by -7.4% to +12.4% at mainstem dams (Table 8).

Table 8. 2009 Chinook salmon escapement by run at Columbia Basin mainstem dams upstream of Bonneville Dam estimated from both PIT tag recoveries and dam counts and the differences between the two estimates.

	Spring Chinook Salmon			Summer Chinook Salmon		
Site	**Viewing Window Count**	**PIT Tag estimate**	**Percent Difference**	**Viewing Window Count**	**PIT Tag estimate**	**Difference**
McNary	113741	115104	1.2%	78319	97607	24.6%
Priest Rapids	83658	76156	-9.0%	33256	38327	15.2%
Rock Island	80731	71152	-11.9%	30849	36870	19.5%
Rocky Reach	16379	18957	15.7%	51534	56293	9.2%
Wells	18637	18241	-2.1%	52022	55199	6.1%
Ice Harbor	7176	8905	24.1%	40192	41787	4.0%
Lower Granite	8174	8032	-1.7%	29525	35057	18.7%
	Fall Chinook Salmon			**All Chinook Salmon**		
McNary	166445	190403	14.4%	358505	403114	12.4%

[a] Fish can also pass undetected through navigation locks at Bonneville and Lower Granite dams.

Priest Rapids	63435	58171	-8.3%	180349	172654	-4.3%
Rock Island	56453	47536	-15.8%	168033	155558	-7.4%
Rocky Reach	46224	34524	-25.3%	114137	109774	-3.8%
Wells	16760	17159	2.4%	87419	90599	3.6%
Ice Harbor	11980	10595	-11.6%	59348	61286	3.3%
Lower Granite	6327	5642	-10.8%	44026	48731	10.7%

Tributary escapement estimates for five sites with more than 15 detections are found in Table 9 alongside estimates using visual or trap counts at those sites. PIT tag estimates of tributary escapement differed from visual or trap count estimates by a much greater percentage than at mainstem dams (Table 8). This is likely a result of smaller sample sizes of tagged fish at the tributary sites.

Chinook destined for the Yakima, Wenatchee, and South Fork Salmon were primarily spring Chinook, while Chinook destined for the Umatilla River were primarily fall Chinook (Figure 9).

Table 9. Estimated 2009 Chinook salmon escapement, as estimated using PIT tag detections, to Tumwater, Three Mile, Prosser, and Roza dams and the South Fork Salmon Weir.

Location and River	Number of tag detections	Escapement Estimate from trap or visual counts	Estimated Escapement using PIT tags	Difference (%) between estimates
Tumwater Dam, Wenatchee River	91	9,304	10,165	9.3%
South Fork Salmon River Weir	96	Minimum estimate: 9,737[b]	14,966	53.7%
Three Mile Dam, Umatilla River	18	5,621	4,865	-13.5%
Prosser Dam, Yakima River	88	12,370	16,466	33.1%
Roza Dam, Yakima River	53	8,633	11,714	35.7%

[b] Weir counts are not available during the entire migration, therefore 9,737 is a minimum estimate.

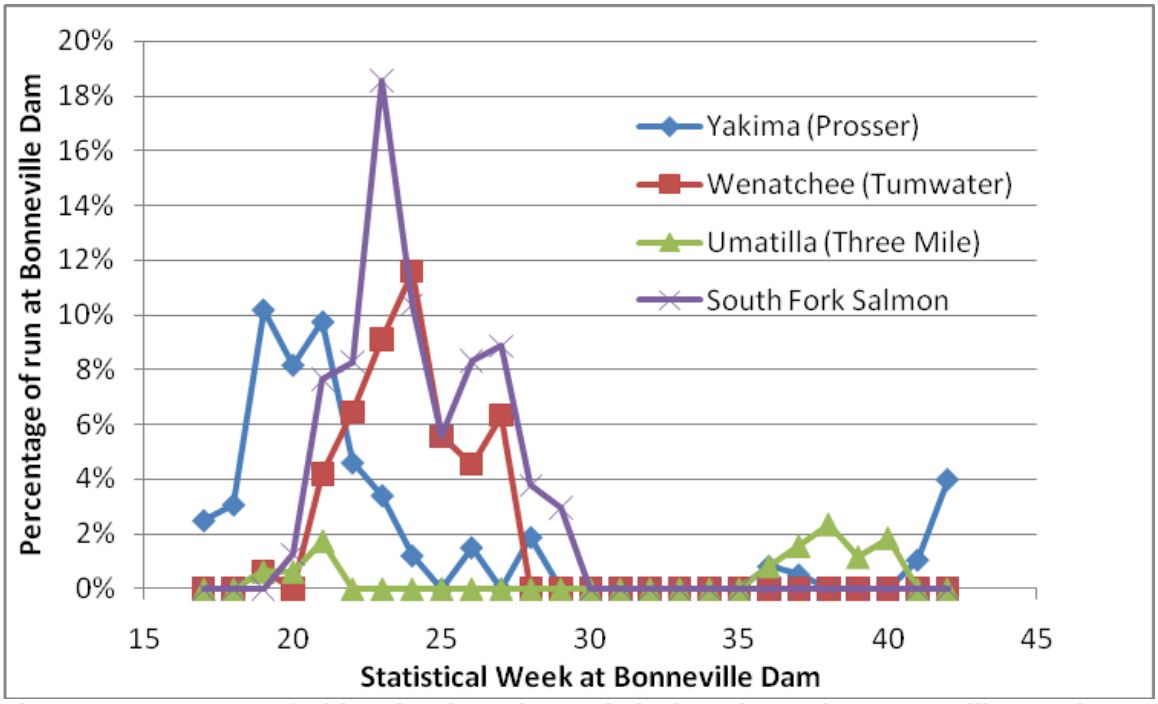

Figure 9. Percentage of Chinook salmon by statistical week passing Bonneville Dam in 2009 destined for the Yakima, Wenatchee, Umatilla, and South Fork Salmon based on upstream PIT tag detections at Prosser, Tumwater and Three Mile dams and the South Fork Salmon Krassel Creek weir.

Migration Timing and Passage Time

Chinook travel rates between mainstem dams generally ranged between 20 and 40 km/day. The slowest travel rates were observed between Rocky Reach and Wells dams as well as between Rock Island and Tumwater dams (Table 10).

Table 10. Chinook salmon travel rates between mainstem dams as estimated by PIT tag detections in 2009.

		Median travel rate (km/day)		
Dam pair	**Distance (km)**	**Spring Chinook**	**Summer Chinook**	**Fall Chinook**
Bonneville-McNary	231	40.1	40.2	38.7
McNary-Priest Rapids	167	33.8	40.8	27.6
Priest Rapids-Rock Island	89	29.6	30.6	25.3
Rock Island-Rocky Reach	33	32.9	31.4	28.6
Rocky Reach-Wells	65	20.2	20.1	20.7
Rock Island-Tumwater	73	4.2	4.8	--
Bonneville-Rock Island	487	31.4	35.2	25.3
Bonneville-Wells	585	29.4	31.0	30.4

McNary-Ice Harbor	67	34.7	49.1	37.3
Ice Harbor-Lower Granite	156	36.9	40.6	32.5

Among the mainstem Columbia and Snake River dams, Chinook salmon have the greatest median dam passage time (as determined by time between first detection time and last detection time at a dam) at Bonneville, McNary, and Lower Granite dams (Table 11). However, at both Bonneville and McNary dams there is a much greater distance between the furthest downstream and furthest upstream PIT tag detection antennas than at all other dams; conversely, the distance between the PIT tag detection antennas at Priest Rapids, Rock Island, Rocky Reach, and Wells dams is very short. Travel times at both Lower Granite and Bonneville dams may also be inflated because at both sites fish may take time to recover from sampling before moving upstream again (many fish are trapped and sampled at Lower Granite Dam for other projects, while this project samples fish at Bonneville Dam). Spring Chinook salmon passing Tumwater Dam on the Wenatchee River had the greatest median passage time of over 6 days (Table 11). The median time passing Tumwater Dam decreased to 1.9 days for summer Chinook, although the percentage taking more than 12 hours to pass the dam only dropped from 70.4% to 57.8%. Fall Chinook do not migrate passed the dam.

Table 11. Median passage time in minutes by run from the time of first detection at a dam to time of last detection and the percentage taking more than 12 hours between first detection and last detection in 2009.

	Median Passage Time (minutes)			Percentage with more than 12 hours between first detection and last detection at a dam		
Dam	Spring Chinook	Summer Chinook	Fall Chinook	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville	72.7	79.3	100.5	5.9%	5.5%	9.5%
McNary-OR Shore	114.8	117.6	116.2	6.3%	5.9%	8.1%
McNary-WA Shore	58.0	64.6	55.2	1.4%	2.0%	3.5%
Priest Rapids	5.6	5.3	2.8	0.0%	1.0%	2.7%
Rock Island	21.9	33.2	125.5	12.0%	15.3%	30.6%
Rocky Reach	5.6	5.3	2.8	0.0%	1.0%	2.7%
Wells	0.5	0.8	0.5	6.0%	6.6%	0.0%
Ice Harbor	2.3	1.7	2.7	4.2%	3.3%	2.5%
Lower Granite	84.5	78.8	83.1	7.6%	5.8%	9.9%
Tumwater	9350.9	2714.8	--	70.4%	57.8%	--

Upstream Age and Length-at-Age Composition

All upstream age composition estimates are affected by the biased sample caused by 2009 Bonneville Trap operations which overestimated the percentage of Age 1.1 spring Chinook salmon (and may have also have had other undetectable biases) as described earlier in this section (Table 12, Figure 10). Based on this biased sample, Age 1.1 was the dominate age group passing all Columbia and Snake river dams in 2009 for the spring run. The age composition of summer Chinook varied; the principle age component was 1.1 passing Bonneville, McNary, Ice Harbor, and Lower Granite dams, while Age 0.3 was observed as the dominant age at Priest Rapids Dam and all other dams upstream (Table 12, Figure 11). Fall Chinook were primarily Age 0.3 at all Columbia River dams, but overwhelming jacks (Age 0.1 and 1.1) at Snake River dams (Table 12, Figure 12). The percentage of subyearling juvenile Chinook life history types (i.e. Age 0.x summer and fall) passing upstream of Ice Harbor into the Snake River was much greater than the percentage passing upstream of Priest Rapids Dam into the mid-Columbia River (Table 12, Figures 11 and 12). Mean length-at-age composition estimates at these sites are given in Tables 13-15.

Table 12. Age composition estimates (%) as estimated by PIT tag detections at mainstem dams of fish aged using scale pattern analysis at Bonneville Dam, for spring, summer, and fall Chinook salmon in 2009. No effort was made to adjust for Bonneville Dam trap biases.

	Brood Year and Age Class								
Run and Site	**2007**	**2006**		**2005**		**2004**		**2003**	
Spring	**0.1**	**0.2**	**1.1**	**0.3**	**1.2**	**0.4**	**1.3**	**0.5**	**1.4**
Bonneville			48.7%	1.2%	40.9%	1.4%	7.8%	0.0%	0.0%
McNary	0.0%	0.0%	52.8%	0.6%	39.9%	0.7%	6.0%	0.0%	0.0%
Priest Rapids	0.0%	0.0%	66.0%	1.5%	22.9%	3.1%	6.5%	0.0%	0.0%
Rock Island	0.0%	0.0%	64.8%	1.5%	23.6%	3.1%	7.1%	0.0%	0.0%
Rocky Reach	0.0%	0.0%	83.1%	2.1%	1.8%	1.7%	4.6%	0.0%	0.0%
Wells	0.0%	0.0%	83.2%	2.4%	1.8%	2.0%	3.9%	0.0%	0.0%
Ice Harbor	0.0%	0.0%	49.4%	0.3%	44.1%	0.0%	6.1%	0.0%	0.0%
Lower Granite	0.0%	0.0%	49.5%	0.3%	44.5%	0.0%	5.7%	0.0%	0.0%
Summer									
Bonneville	0.9%	2.3%	35.3%	17.0%	17.5%	7.8%	17.9%	0.2%	1.2%
McNary	1.1%	2.4%	34.9%	16.8%	16.6%	8.7%	18.0%	0.2%	1.5%
Priest Rapids	1.3%	2.9%	16.5%	27.5%	10.2%	16.6%	22.2%	0.3%	2.3%

Rock Island	1.3%	2.9%	16.3%	27.6%	10.3%	16.5%	22.1%	0.3%	2.4%
Rocky Reach	1.5%	2.9%	15.5%	29.0%	9.2%	11.3%	27.4%	0.3%	2.3%
Wells	1.2%	2.9%	16.2%	30.4%	7.0%	10.7%	27.9%	0.4%	2.8%
Ice Harbor	0.6%	0.7%	67.6%	0.0%	21.1%	0.6%	9.4%	0.0%	0.0%
Lower Granite	0.6%	0.7%	67.6%	0.0%	21.1%	0.6%	9.4%	0.0%	0.0%
Fall									
Bonneville	12.8%	11.4%	7.7%	53.8%	2.8%	10.2%	1.3%	0.1%	0.0%
McNary	16.9%	11.5%	10.3%	48.1%	2.4%	9.4%	1.3%	0.0%	0.0%
Priest Rapids	11.5%	12.9%	4.8%	59.7%	0.0%	7.2%	3.9%	0.0%	0.0%
Rock Island	0.0%	13.5%	8.2%	73.9%	0.0%	4.4%	0.0%	0.0%	0.0%
Rocky Reach	0.0%	15.5%	20.6%	64.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wells	0.0%	22.2%	11.4%	66.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Ice Harbor	35.8%	6.9%	27.2%	22.6%	5.9%	0.7%	1.0%	0.0%	0.0%
Lower Granite	41.9%	7.1%	19.6%	23.4%	6.8%	0.0%	1.2%	0.0%	0.0%

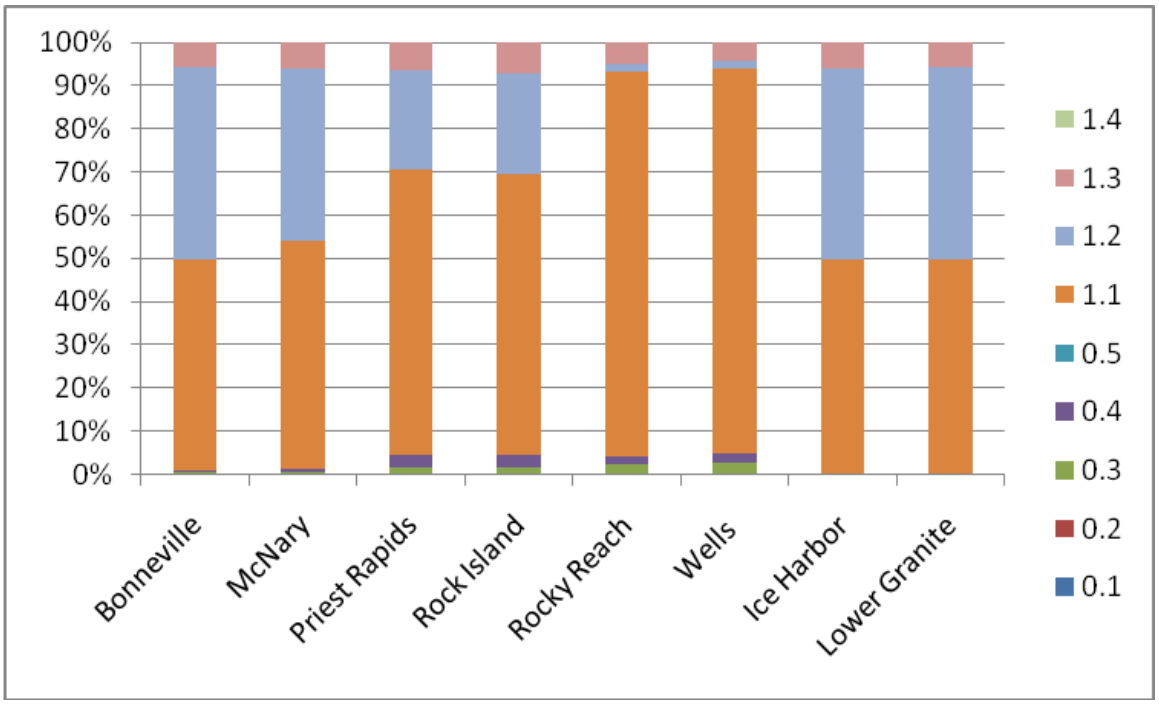

Figure 10. Spring Chinook age composition at Columbia and Snake river dams estimated using PIT tagged Chinook tracked by this project passing Bonneville Dam between April 1 and May 31, 2009. No effort was made to adjust for biases resulting from 2009 trap operations.

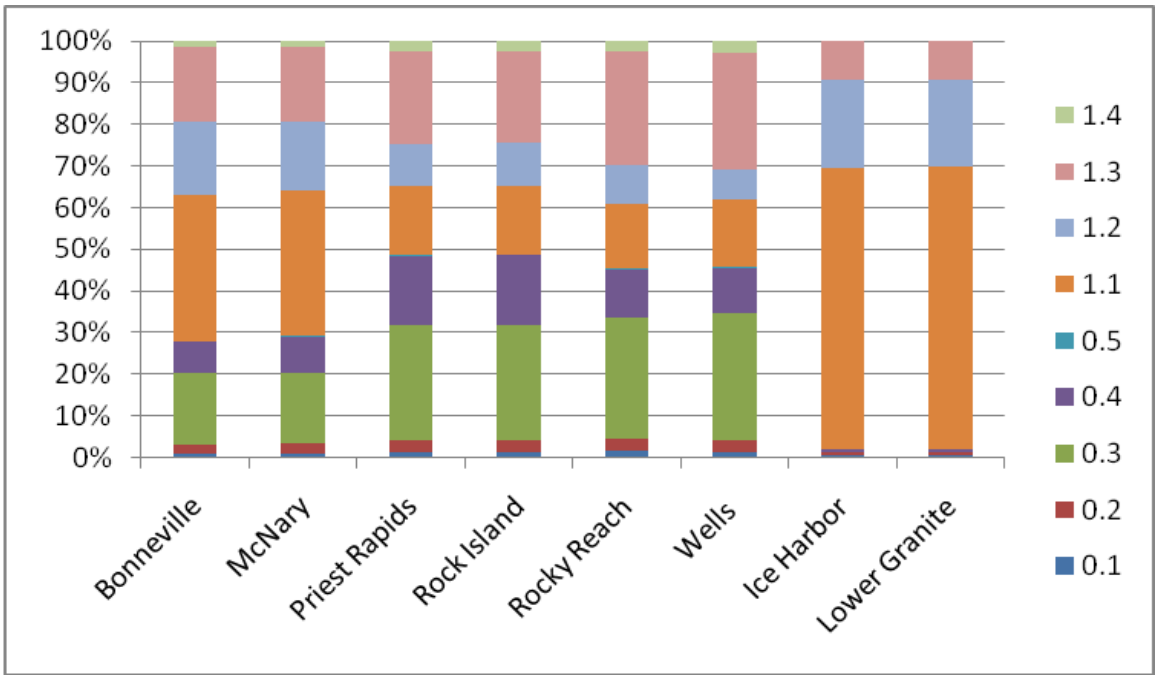

Figure 11. Summer Chinook age composition at Columbia and Snake river dams estimated using PIT tagged Chinook tracked by this project passing Bonneville Dam between June 1 and July 31, 2009. No effort was made to adjust for biases resulting from 2009 trap operations.

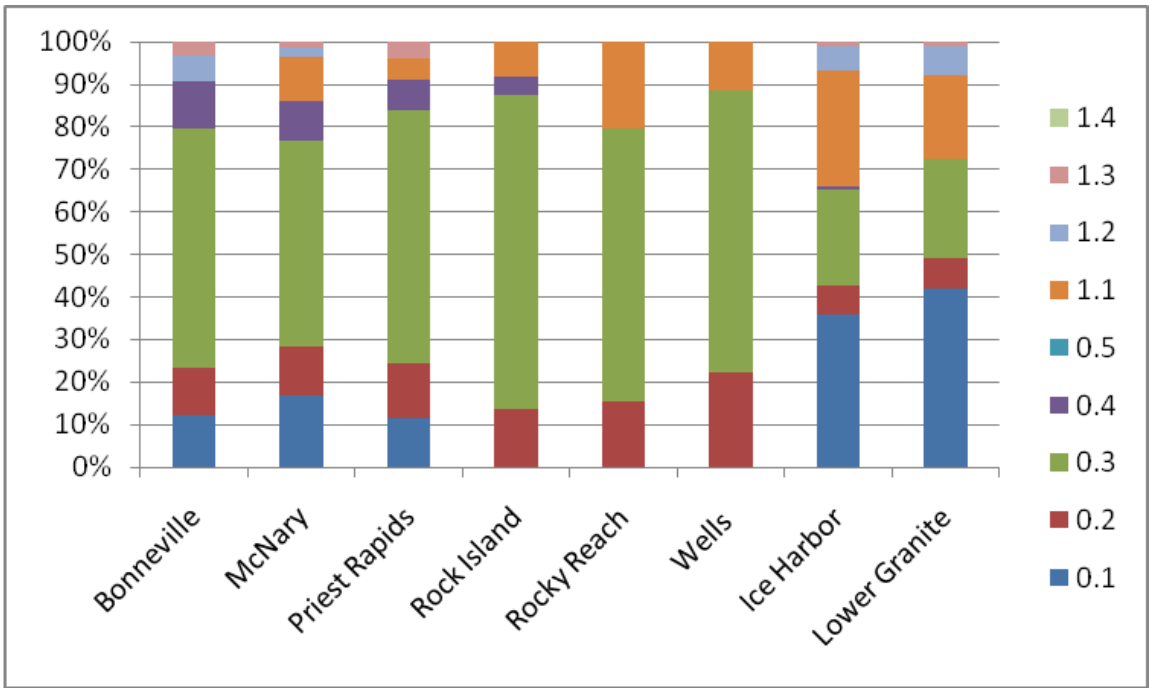

Figure 12. Fall Chinook age composition at Columbia and Snake River dams estimated using PIT tagged Chinook tracked by this project passing between August 1 and October 31, 2009. No effort was made to adjust for biases resulting from 2009 trap operations.

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 prior to between April 1 and May 31, at Columbia Basin dams upstream of McNary Dam in 2009.

Dam	Statistic	Brood Year and Age Class				
		2006	2005		2004	
		1.1	1.2	0.3	1.3	0.4
Priest Rapids	μ	52.5	76.4	81.8	85.6	90.1
	s	3.2	4.7	5.4	4.4	4.7
	n	51	18	6	17	9
Rock Island	μ	52.5	76.5	81.8	85.6	90
	s	3.3	4.8	5.4	4.4	4.7
	n	50	17	6	17	9
Rocky Reach	μ	52.2	61	82.4	84.9	87.5
	s	2.7		5.8	3.9	2.1
	n	29	1	5	11	4
Wells	μ	52.3	61	82.4	83.7	87.5
	s	2.7		7.8	3.7	2.1
	n	28	1	5	8	4
Tumwater	μ	52.3	77.5		85	90.2
	s	4.5	1.9		6.4	4.3
	n	7	4		3	4
Ice Harbor	μ	51.8	74.8	78	87	
	s	5.5	9.4	5.6	6	
	n	168	168	3	31	
Lower Granite	μ	51.6	74.8	78	86.6	
	s	5.5	9.5	5.6	6	
	n	160	161	3	29	

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 June 1-July 31, 2009, at Columbia Basin dams upstream of McNary Dam in 2009.

Dam	Statistic	Brood Year and Age Class								
		2007	2006		2005		2004		2003	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3	0.5	1.4
Priest Rapids	μ	41.9	65.5	52.4	82.5	72.8	91.8	86.6	88	91
	s	4.2	7.1	9.5	6.3	7.8	6	5.6		4.5
	n	5	11	59	98	34	60	83	1	7
Rock Island	μ	41.9	65.5	52.2	82.6	72.8	91.8	86.6	88	91
	s	4.2	7.1	9.6	6.3	7.8	6	5.6		4.5
	n	5	11	57	97	34	59	81	1	7
Rocky Reach	μ	41.9	66.8	53.4	82.6	70.7	90.5	86.5	88	91
	s	4.2	7.2	6.9	6.4	7.4	6.1	5.6		5.5
	n	5	9	43	73	23	26	75	1	5
Wells	μ	40.5	68.8	53.4	82.2	70.2	89.7	86.9	88	91
	s	3.5	5.3	7.1	6.3	7.3	6	5.7		5.5
	n	3	7	37	65	16	22	63	1	5
Tum-water	μ		60	48.5	83.4	75	92	84.1		
	s			14.9	4.9	6.8	6.1	1.4		
	n		1	14	14	5	16	4		
Ice Harbor	μ	56	70.8	56.1		78.2	92.2	85.6		
	s		7	7.5		4.2	7.9	7.6		
	n	1	3	161		100	3	32		
Lower Granite	μ	56	70.8	55.9		78.2	92.2	85.8		
	s		7	7.6		4.2	7.9	4.6		
	n	1	3	155		97	3	31		

Table 15. Chinook salmon length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville, for fall Chinook salmon at Columbia Basin dams upstream of McNary Dam in 2009.

Dam	Statistic	Brood Year and Age Class						
		2007	2006		2005		2004	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3
Priest Rapids	μ	49.5	65.3	55.5	81.4		92.2	77.8
	s	3.2	6	8.3	5.4		6.1	5.3
	n	8	11	4	40		4	2
Rock Island	μ		67	57	82		98	
	s		2.9	9.5	3.7			
	n		5	3	25		1	
Rocky Reach	μ		67.7	57	82.1			
	s		3.3	9.5	3.1			
	n		3	3	9			
Wells	μ		69.8	67	82.2			
	s		3.9		1.8			
	n		2	1	4			
Tumwater	μ							
	s							
	n							
Ice Harbor	μ	47.4	67.6	58.5	80.7	73.2	90	81
	s	3.6	4	4.3	7.3	5.9		
	n	63	9	36	21	6	2	1
Lower Granite	μ	47.5	67.7	58.2	79.6	75.3		81
	s	3.6	4.3	3.3	6.6	3.4		
	n	61	8	23	19	5		1

Fallback

Estimated fallback-reascension rates based on Chinook salmon reascending fish ladders ranged from 0% to 11.4% (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 Chinook salmon fallback and reascension at mainstem Columbia River dams in 2009 as estimated by PIT tags.

Dam	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
McNary	2.0	1.4	2.8
Priest Rapids	0.0	1.3	2.7
Rock Island	0.7	4.7	11.4
Rocky Reach	0.0	6.3	0.0
Wells	8.0	7.0	0.0
Tumwater	4.7	5.7	na
Ice Harbor	0.0	11.1	3.2

Lower Granite	0.0	8.3	8.1
Mean	**1.9**	**5.7**	**3.5**

A total of five tagged Chinook salmon were detected falling back over multiple dams. Two of these fish passed Wells Dam and ended up above Tumwater Dam, thus falling back over two dams. A third passed Ice Harbor Dam and ended up at Three Mile Dam in the Umatilla River, again falling back over two dams. A fourth fell back through McNary and John Day dams and the final Chinook passed McNary dam and was last detected passing Bonneville Dam, thus falling back over four dams.

Night Passage

Night passage (2000-0400 Pacific Standard Time) by tagged Chinook salmon was less than 2% at Bonneville and McNary dams, but increased further upstream (Table 17). Tributary dam and weir night passage was higher, ranging up to 76.2% for spring Chinook passing the South Fork Salmon weir. The Bonneville Dam estimate of night passage is likely biased low, due to the fact that tagging occurring during morning and early afternoon hours and, given the median Bonneville Dam passage time of less than two hours, Chinook would be expected to pass during daytime hours.

Table 17. Estimated Chinook salmon night passage (2000-0400) in 2009 at mainstem Columbia River dams as estimated by PIT tags.

Site	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	0.1%	0.2%	0.3%
McNary	1.7%	1.0%	1.5%
Priest Rapids	1.8%	2.0%	4.1%
Rock Island	5.6%	4.2%	13.9%
Rocky Reach	1.82%	0.0%	0.0%
Wells	6.0%	5.0%	0.0%
Ice Harbor	1.7%	1.5%	5.1%
Lower Granite	3.5%	3.1%	1.5%
Prosser	0.0%	14.3%	0.0%
Roza	19.6%	10.0%	--
Tumwater	7.4%	1.6%	--
Three Mile	42.9%	--	14.3%
South Fork Salmon weir	76.2%	69.8%	14.3%

RESULTS-STEELHEAD

Sample Size

A total of 1614 steelhead were tagged with 12.5 mm PIT tags in 2009. An additional 794 steelhead were tagged with 20 mm PIT tags. 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 (likely a result of the tags being shed), the numbers of steelhead tracked upstream consisted of 2474 steelhead, 1641 with 12.5mm tags and 790 with 20 mm tags (Table 18).

Table 18. Number of steelhead PIT tagged at Bonneville Dam and tracked by date and statistical week in 2009. No sampling occurred during Statistical Week 32 due to water temperatures above 22.2 C (72.0 F) shutting down the Bonneville Dam Adult Fish Facility.

Dates	Pooled Statistical Week	12.5 mm tagged (n)	20 mm tagged (n)	Previously tagged	12.5 mm Not Detected Passing Bonneville	20 mm Not Detected Passing Bonneville	12.5 mm tracked	20 mm tracked	Total Tracked
4/21,23,24, 27-30,5/1,4-8	19	17	10	2	2	1	17	9	26
5/11-5/15	20	12	5	0	0	0	12	5	17
5/18-5/22	21	7	4	0	0	0	7	4	11
5/26-5/29	22	12	7	0	1	0	11	7	18
6/1-6/5	23	25	11	1	1	0	25	11	36
6/8-6/11	24	18	9	1	1	0	18	9	27
6/15-6/18	25	11	5	0	0	0	11	5	16
6/22-6/26	26	37	17	3	3	0	37	17	54
6/29-7/2	27	39	20	1	1	1	39	19	58
7/6-7/9	28	83	42	1	1	0	83	42	125
7/13-7/17	29	203	100	4	8	2	199	98	297
7/20-7/24	30	224	111	3	3	0	224	111	335
7/27-7/28	31	68	33	2	3	0	67	33	100
8/11-8/14	33	129	60	8	9	0	128	60	188
8/18-8/21	34	126	62	3	5	1	124	61	185
8/25-8/28	35	87	41	4	4	0	87	41	128
9/1-9/4	36	44	22	0	0	0	44	22	66
9/8-9/11	37	60	28	4	4	0	60	28	90
9/14-9/18	38	130	50	1	1	0	130	50	180
9/21-9/24	39	81	40	0	0	0	81	40	121

9/28-9/30	40	107	53	0	0	0	107	53	160
10/1,2,5,6, 8,9	41	82	42	0	0	0	82	42	124
10/12,13	42	30	15	1	3	0	28	15	43
10/19-10/21	43	19	8	0	1	1	18	7	25
Total		**1651**	**795**	**39**	**51**	**6**	**1639**	**789**	**2428**

Distribution of sample

Compared to the run distribution, steelhead were over-sampled early in the run and under-sampled during the peak of the run (Figure 13). No sampling was conducted during Statistical Week 32, a week in which 3.6% of the steelhead run passed, due to water temperatures above 22.2C (72.0 F) closing the Bonneville Dam Adult Fish Facility. During three weeks that the run quickly jumps to its' peak (Statistical weeks 32-34), our sample size consisted of 380 steelhead (15.4% of our total sample) during which 45.3% of the run passed Bonneville Dam. During Statistical weeks 31-36 when 70.7% of the run passed Bonneville Dam, our sample consisted of 677 steelhead (27.4% of our sample).

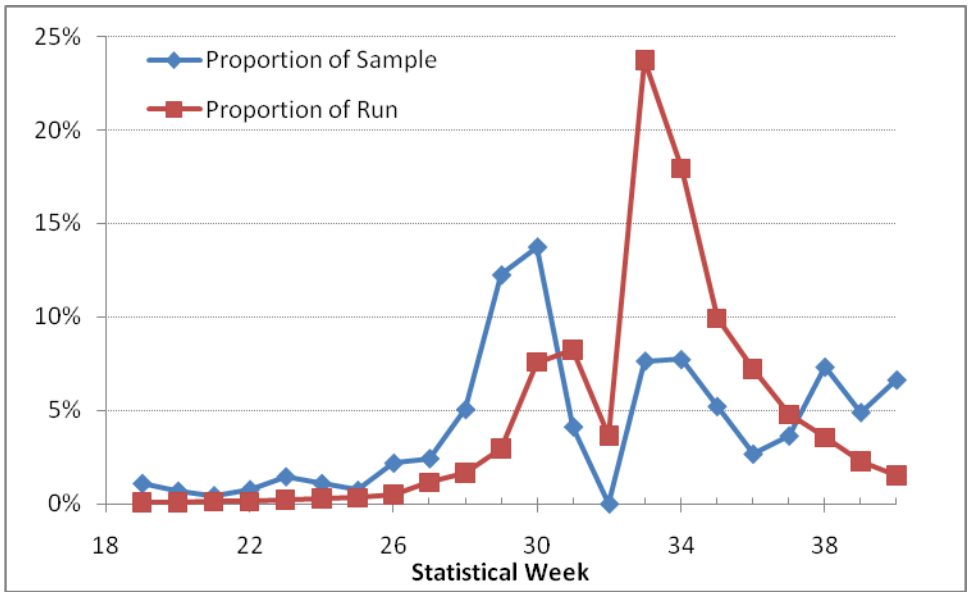

Figure 13. Proportion of the steelhead sample size and run by statistical week at Bonneville Dam in 2009.

Effectiveness of 20 mm Tags

There was no significant difference (α=0.05) in the percentage of 12.5 and 20.0 mm tagged steelhead detected at any upstream locations for steelhead (Table 19). Data from both tag types was pooled for subsequent analyses presented in this report.

Table 19. Total number and percentage of 12.5 and 20 mm PIT tagged steelhead passing upstream sites and the p-value for a t-test comparing the tag type proportions in 2009 (minimum n=30).

PTAGIS Site	Location	Total Passing	% of 12.5 mm Tagged Steelhead Passing	% of 20.0 mm Tagged Steelhead Passing	P-Value
BO1	Bonneville Dam	129	5.0%	5.9%	0.819
BO2	Bonneville Dam	72	3.0%	2.8%	0.951
BO3	Bonneville Dam	2033	82.2%	84.9%	0.128
BO4	Bonneville Dam	2309	95.0%	93.1%	0.058
GRA	Lower Granite Dam	1037	43.3%	40.6%	0.416
ICH	Ice Harbor Dam	1211	50.0%	48.5%	0.625
MC1	McNary Dam	1211	50.1%	48.2%	0.543
MC2	McNary Dam	385	16.1%	14.9%	0.771
PRA	Priest Rapids Dam	157	6.8%	5.5%	0.762
PRO	Prosser Dam	36	1.2%	2.0%	0.843
RIA	Rock Island Dam	131	5.8%	4.4%	0.749
RRF	Rocky Reach Dam	109	4.7%	3.9%	0.849
WEA	Wells Dam	91	4.0%	3.1%	0.847

Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes.

Detection Numbers

Like Chinook salmon, steelhead can be detected multiple times at each PIT tag detection site as they migrate, and some of them can be detected for multiple years as repeat spawners (see the Kelt section). For the 2431 steelhead tracked in 2009, there were 9752 fish detections at 66 sites. Maps (Figure A13-A16) found in the Appendix show the categorical ranges of detection numbers at the sites throughout the Columbia Basin.

Age Analysis

We are able to validate our scale aging techniques by using fish sampled for this project at Bonneville that were previously tagged as juveniles for other projects or hatchery programs. Age estimates from ageable scale patterns for 31 out of 33 steelhead that had been previously PIT tagged were correctly aged. Only the total age could be compared for it was not possible to separately validate freshwater and ocean age.

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Data on tag detections was last downloaded from www.ptagis.org on July 13, 2011. An estimated 51.8% of the steelhead run passed Ice Harbor Dam (Table 20, Figure 14). The proportion of steelhead bound for the Snake River steadily increased as the run progressed (Figures 15 and 16).

Table 20. Percentage of Steelhead tracked from Bonneville Dam and detected at upstream dams and the percentage "lost" between sequential dams in 2009.

Dam	Dam Reached	Lost
Bonneville	100.0%	--
McNary	66.1%	33.9%
Priest Rapids	6.5%	90.2%
Rock Island	5.5%	15.9%
Rocky Reach	4.5%	16.7%
Wells	3.8%	16.4%
Ice Harbor	51.8%	21.7%
Lower Granite	45.5%	12.2%

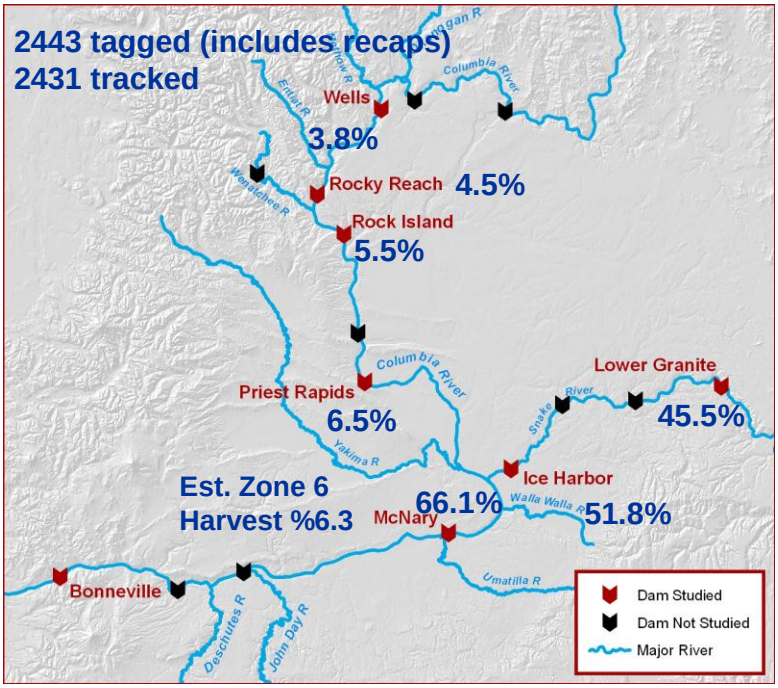

Figure 14. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of steelhead PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2009.

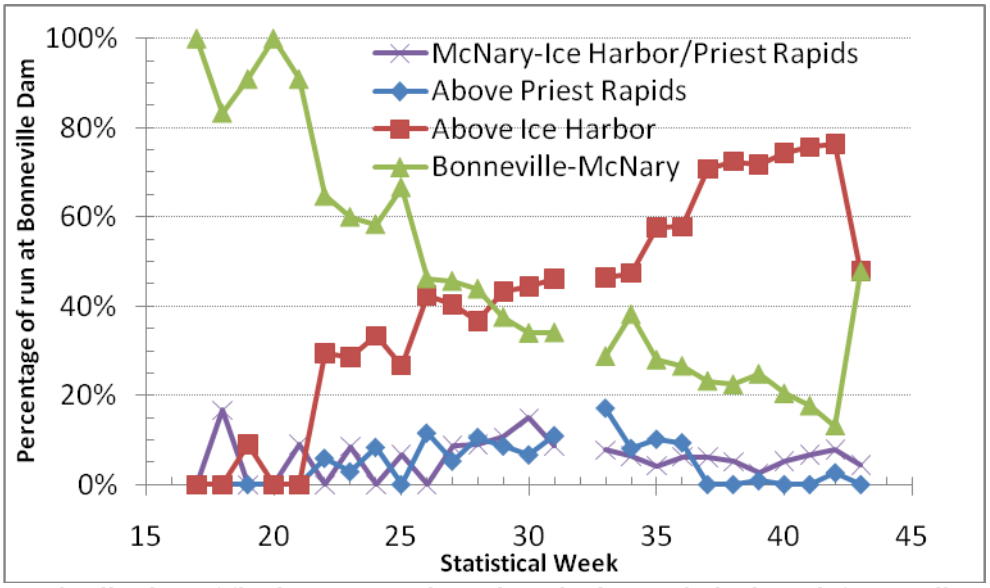

Figure 15. Distribution of final upstream detection site by statistical week for steelhead PIT tagged at Bonneville Dam in 2009.

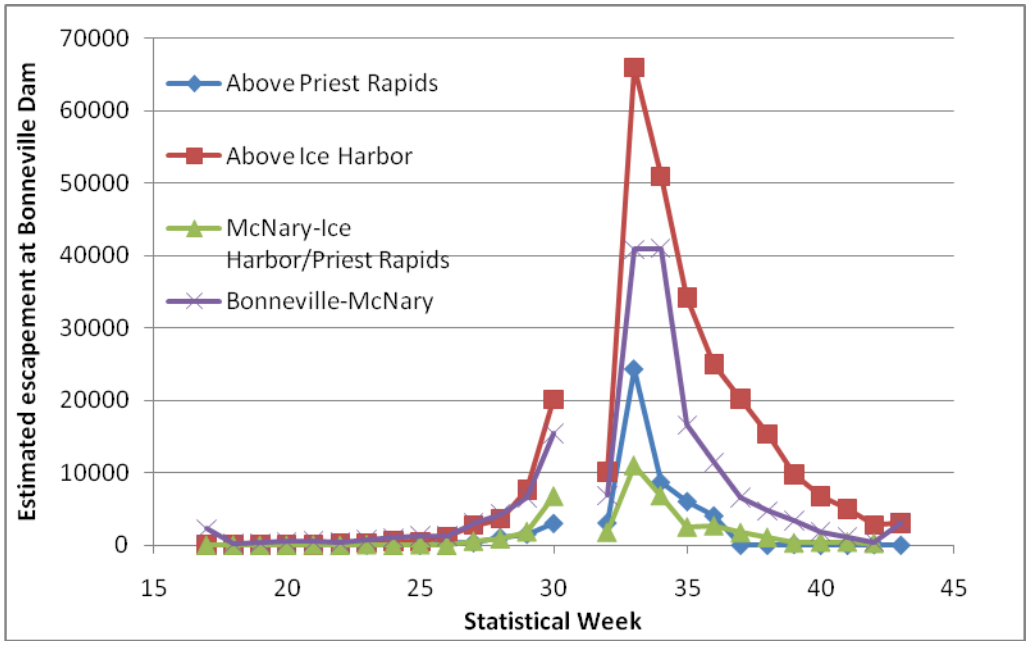

Figure 16. Distribution of final detection site by statistical week for steelhead PIT tagged at Bonneville Dam in 2009.

Like Chinook salmon the percentage of PIT tagged steelhead passing a dam without detection was generally under 1% (Table 21). Two exceptions were McNary and Ice Harbor dams where navigation locks provide a plausible explanation as to how fish could pass undetected. (Again, Rock Island Dam is known to have problems with detection due to the antenna size and electrical noise [D. Marvin, Pacific States Marine Fisheries Commission, personal communication]).

Table 21. Percentage of steelhead passing a dam undetected that were subsequently detected at an upstream dam in 2009 (12 mm & 20 mm tags pooled).

Dam	20.0 mm tags	12.5 mm tags	Combined
Bonneville	0.25%	0.12%	0.16%
McNary	0.59%	0.82%	0.74%
Priest Rapids	0.00%	0.00%	0.00%
Rock Island	0.00%	1.02%	0.76%
Rocky Reach	0.00%	0.00%	0.00%
Ice Harbor	1.00%	0.47%	0.64%

Migration Timing and Passage Time

The fastest median travel rate between dams, as measured in kilometers per day, was between McNary and Priest Rapids Dam (27.6 km per day), while the slowest was 2.8 km/day between Rock Island and Tumwater dams (Table 22).

Table 22. Steelhead travel rate between mainstem dams as estimated by PIT tag detections in 2009.

Steelhead		
Dam pair	Distance (km)	Median travel rate (km/day)
Bonneville-McNary	231	15.5
McNary-Priest Rapids	167	27.6
Priest Rapids-Rock Island	89	22.6
Rock Island-Rocky Reach	33	17.1
Rocky Reach-Wells	65	19.6
Rock Island-Tumwater	73	2.8
Bonneville-Rock Island	487	21.3
Bonneville-Wells	585	17.6
McNary-Ice Harbor	67	27.3
Ice Harbor-Lower Granite	156	22.5

Median steelhead passage times (Table 23) at the mainstem dams, as measured from first to last detection within the ladders, were generally less than that for Chinook salmon (Table 11). Bonneville, McNary, and Lower Granite dams had the greatest median passage time among mainstem Columbia Basin dams. However, at both Bonneville and McNary dams there is a much greater distance between the furthest downstream and furthest upstream PIT tag detection antennas than at all other dams; conversely, the distance between the PIT tag detection antennas at Priest Rapids, Rock Island, Rocky Reach, and Wells dams is very short. Travel times at both Lower Granite and Bonneville dams may also be inflated, because at both sites, fish may take time to recover from sampling before moving upstream again (many fish are trapped and sampled at Lower Granite Dam for other projects, while this project samples fish at Bonneville Dam).

Table 23. Steelhead median passage times from time of first detection at a dam to time of last detection and the percentage taking more than 12 hours between first detection and last detection in 2009.

Dam	Median Passage Time (minutes)	Percentage with more than 12 hours between first detection and last detection at a dam
Bonneville	76.8	8.5%
McNary-OR Shore	98.5	7.5%
McNary-WA Shore	60.7	7.0%
Priest Rapids	4.4	2.7%
Rock Island	28.0	4.0%
Rocky Reach	6.2	1.9%
Wells	0.7	2.2%
Ice Harbor	3.9	3.5%
Lower Granite	83.4	11.4%
Tumwater	3.9	3.5%

Upstream Age and Length-at-Age Composition

As was previously noted, Bonneville trap operations resulted in a biased Chinook sample that affected Chinook age composition. It is unknown whether there were similar biases affecting steelhead age composition. The percentage of Age 1.1 steelhead passing upstream dams ranged from 42.2% at Lower

Granite Dam to 58.1% at Wells Dam (Table 24, Figure 17). Length-at-age composition data is found in Table 25.

Table 24. Age composition estimates (%) as estimated by PIT tag detections of steelhead aged using scale patterns at Bonneville Dam, for steelhead at Priest Rapids, Rock Island, Rocky Reach, Wells, Tumwater, Ice Harbor, and Lower Granite dams in 2009.

	Brood Year And Age Class											
	2007	2006		2005			2004			2003		Unknown
Site	1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	4.1	3.3	4.2	Repeat Spawners
Bonneville	50.7	21.6	12.4	1.3	8.1	3.1	0.1	1.6	0.2	0.1	0.0	0.7
McNary	51.8	20.0	12.8	1.4	7.3	3.1	0.1	1.8	0.3	0.0	0.0	0.7
Priest Rapids	45.1	27.9	16.4	0.0	7.4	0.8	0.8	0.0	0.0	0.0	0.0	1.6
Rock Island	48.5	26.7	14.9	0.0	6.9	1.0	1.0	0.0	0.0	0.0	0.0	1.0
Rocky Reach	54.2	24.1	13.3	0.0	6.0	1.2	1.2	0.0	0.0	0.0	0.0	0.0
Wells	58.1	24.2	9.7	0.0	6.5	0.0	1.6	0.0	0.0	0.0	0.0	0.0
Ice Harbor	42.4	30.9	6.8	5.9	7.1	2.7	0.2	2.9	0.2	0.1	0.3	0.2
Lower Granite	42.2	31.0	6.3	6.4	7.0	2.4	0.2	3.2	0.2	0.1	0.4	0.2

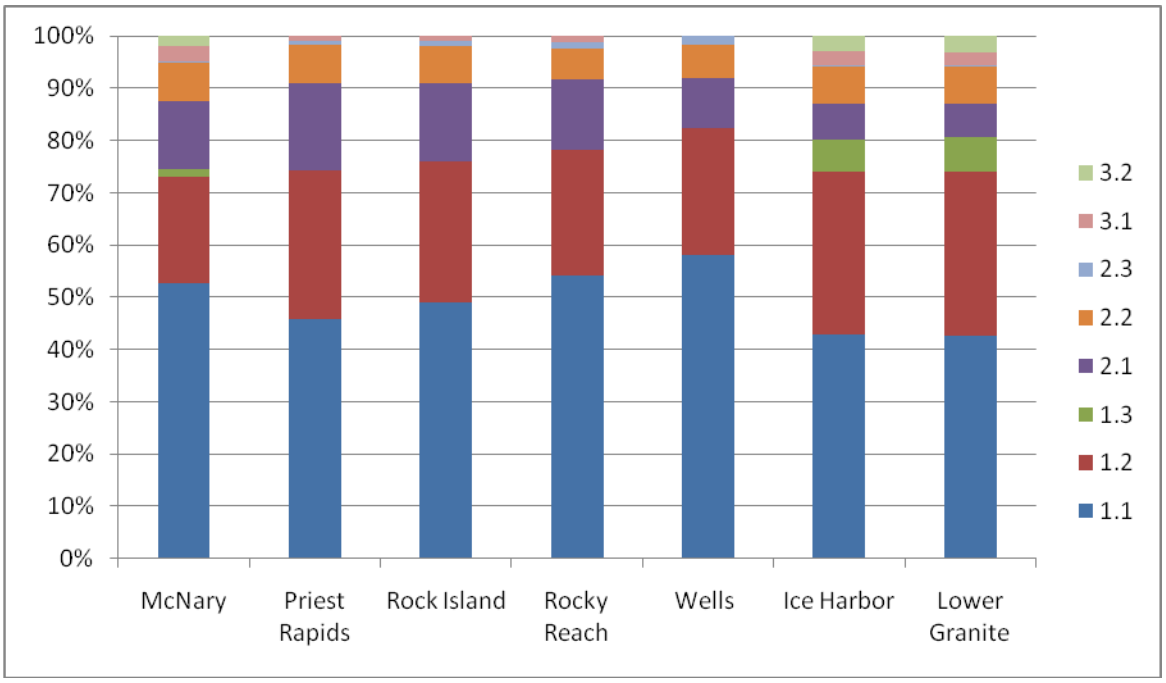

Figure 17. Steelhead age composition at Columbia Basin dams upstream of McNary Day estimated using PIT tags in 2009.

Table 25. Steelhead length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville Dam, at Columbia Basin dams upstream of McNary Dam in 2009.

Dam	Statistic	2007	2006		2005			2004			2003	
		1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	4.1	3.3	4.2
McNary	μ	59.1	73.2	58.5	84.7	71.2	59.5	83.5	71.5	58.9	86	68.2
	s	3.12	10.3	5.3	3.9	7.6	3.2	1.8	12.5	3.9	3.6	1.9
	n	719	567	210	567	165	50	3	43	5	3	2
Priest Rapids	μ	59.8	68.7	60		69.2	59.5	85				
	s	2.4	12.7	4		5						
	n	55	34	20	0	9	1	1	0	0	0	0
Rock Island	μ	59.9	70.9	61.4		68.4	59.5	85				
	s	2.4	3.8	3.4		5.1						
	n	49	27	15	0	**7**	1	1	0	0	0	0
Rocky Reach	μ	59.7	71.2	61		66.2	59.5	85				
	s	2.3	3.3	3.4		3.9						
	n	45	20	11	0	5	1	1	0	0	0	0
Wells	μ	59.9	71.4	62.2		64.9		85				
	s	2.1	3.7	3.6		3						
	n	36	15	6	0	4	0	1	0	0	0	0
Ice Harbor	μ	58.9	75.1	59.2	84.8	71.3	59.8	82.8	71.9	60.8	87	68.2
	s	3.2	9.8	3.6	3.9	10.4	3.1	1.8	15.1	1.8		1.9
	n	409	298	66	57	68	26	2	28	2	1	3
Lower Granite	μ	59.1	75.2	59.9	84.9	71.4	59.8	82.8	72.1	60.8	87	68.2
	s	3.3	10.2	3.5	3.9	11	2.6	1.8	15.4	1.8		1.9
	n	355	261	53	54	59	20	2	27	2	1	3

B-Run Analyses

The percentage of steelhead sampled and tagged that were classified as B-run (>78 cm) peaked in Statistical Week 41, by contrast the estimated B-Run 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 37 (Figure 18). 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), steelhead with fork lengths greater than 78 cm were almost entirely destined for the Snake River (Figure 19).

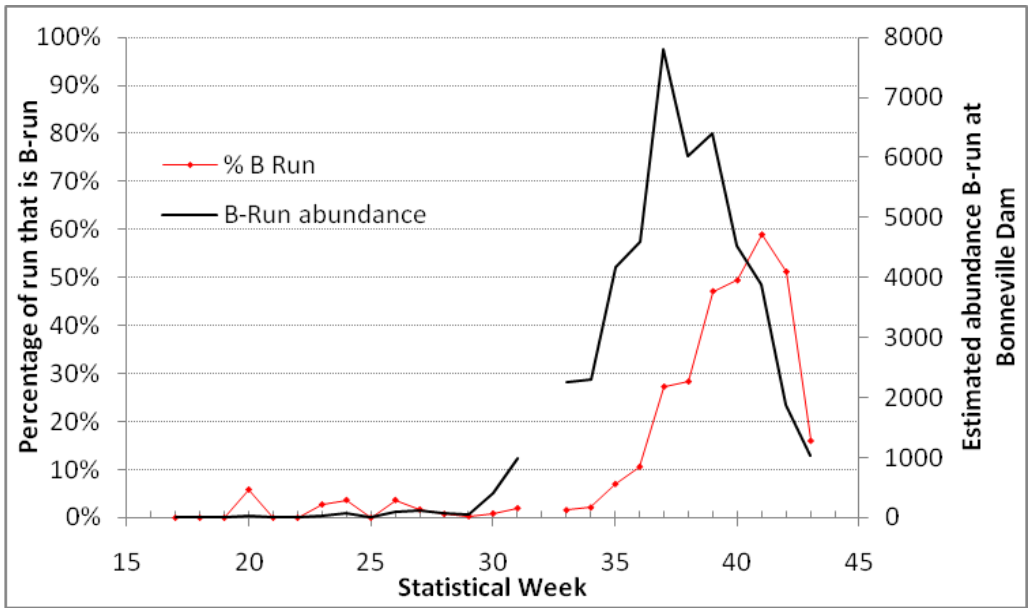

Figure 18. Percentage of B-run steelhead and estimated B-run size passing Bonneville Dam by statistical week in 2009.

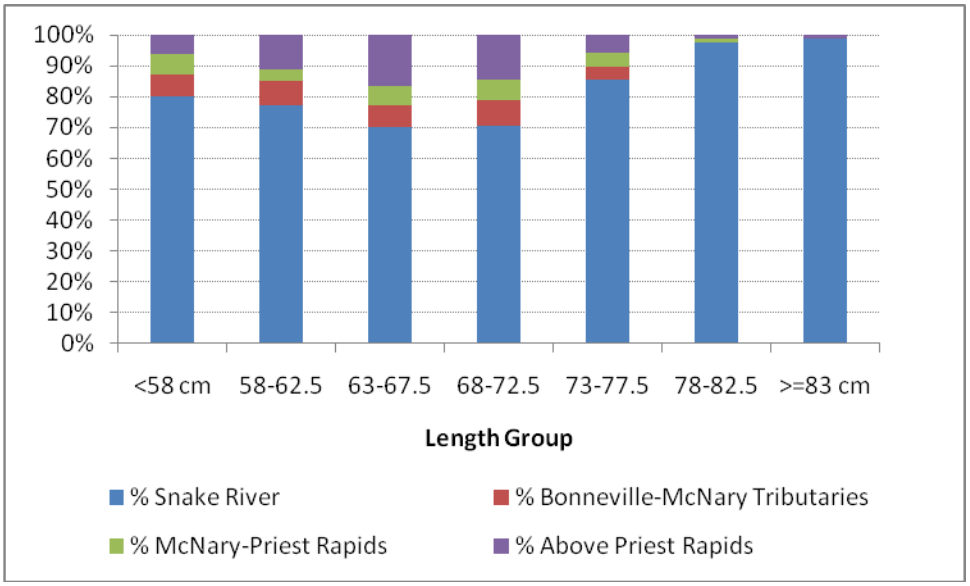

Figure 19. Final detection site for steelhead PIT tagged at Bonneville Dam in 2009 by length group.

Kelt analyses

A total of 101 PIT tagged steelhead tracked in 2009 were detected moving downstream (mostly in juvenile bypasses) after February, 2010, presumably in an attempt to return to the ocean after spawning (Table 26). Of these steelhead, nine were detected after July, 2010 (Table 27). Of these nine fish, two were detected both winters in Rock Creek where they presumably spawned. It is

interesting to note that four of the six steelhead detected moving downstream through Bonneville Dam in the spring of 2010 were detected in the Bonneville Corner Collector April 14 and 15. One of these six steelhead spent 36 hours in the Bonneville juvenile bypass (B2J). The 101 steelhead we designated as kelt formed a relatively consistent percentage of the run (between 3 and 7% in 14 statistical weeks) on a weekly basis at Bonneville Dam on their 2009 upstream migration (Figure 20).

Table 26. PIT tagged steelhead tracked in 2009 last detected moving downstream listed by last downstream detection site.

Last site	Number
Bonneville Corner Collector	61
Bonneville Juvenile Bypass	7
Rocky Reach Juvenile Bypass	7
Little Goose Juvenile Bypass	6
Lower Monumental Juvenile Bypass	4
McNary Dam Juvenile Bypass	4
Lower Granite Juvenile Bypass	3
John Day Juvenile Bypass	3
Lower Washington Shore McNary Dam ladder, likely moving downstream.	1
Estuary trawl	1

Table 27. Season by season activities of several steelhead tagged in 2009 and later labeled as kelts when they began migrating downstream and upstream presumably to and from the ocean.

Tag Number	Last Summer Detection After Tagging 2009	Fall 2009	Winter 2009/10	Spring 2010	Summer 2010	Fall 2010	Winter 2010/11	Spring 2011	Summer 2011	Comments
3D9.1C2D2CA56A	Bonneville Washington Shore Ladder - August 19th	John Day Juvenile - November 27th	Rock Creek Lower - January 22nd to February 24th	Rock Creek Lower - March 5th Bonneville Dam Corner Collector - April 14th.	Bonneville Oregon Shore Ladder - August 21st		Rock Creek Lower - December 21st to February 22nd	Bonneville Dam Corner Collector - April 7th.		Tracked to Rock Creek for spawning in two consecutive years and is headed out to the ocean again.
3D9.1C2D0B162E	Bonneville Washington Shore Ladder - August 11th	Bonneville Oregon Shore Ladder - October 19th Bonneville Washington Shore Ladder - October 21st		Bonneville Dam Corner Collector - April 15th.		Bonneville Oregon Shore Ladder - September 10th				
3D9.1C2D0A2039	McNary - September 7th		Rock Creek two sites - February 6th to 27th.	Bonneville Dam Corner Collector - April 14th.	Bonneville Oregon Shore Ladder - August 21st	McNary - September 21st	Rock Creek Lower - February 6th into March	Rock Creek two sites - From February to March 22nd		Tracked to Rock Creek for spawning in two consecutive years.
3D9.1C2D07DAB8	Bonneville Washington Shore Ladder - June 8th			Bonneville Dam Corner Collector - April 14th.	Bonneville Washington Shore Ladder - July 29th			Bonneville Dam Corner Collector - April 18th.		Unknown spawning location, but tracked two different years leaving in the spring for the ocean.
3D9.1C2D077D0D	Lower Granite - September 27th			Bonneville Dam Corner Collector - May 5th.	Bonneville Oregon Shore Ladder - August 27th	Lower Granite - September 17th				
3D9.1C2D070406	McNary - July 17th	Ice Harbor - November 4th							Bonneville Washington Shore Ladder - July 12th	
3D9.1C2D0A1E39	Bonneville Washington Shore Ladder - July 21st			Threemile Dam Umatilla R - May 17th					Bonneville Washington Shore Ladder - July 1st	
3D9.1C2D08326A	Ice Harbor - July 26th	Lower Monumental Juvenile - Oct 12th		Bonneville Juvenile - April 26th to 28th	Bonneville Washington Shore Ladder - July 14th Ice Harbor - August 14th					Spent 36 hours in Bonneville Juvenile Bypass, moving up and down passed the detection coils .
3D9.1C2D2C8D5A	Priest Rapids Dam - August 13th	Prosser Dam - November 4th				Prosser Dam - October 14th				Female steelhead collected at Prosser Dam for reconditioning and released in October 2010 for spawning.
			Key - - -	Upstream	Downstream	Spawning				

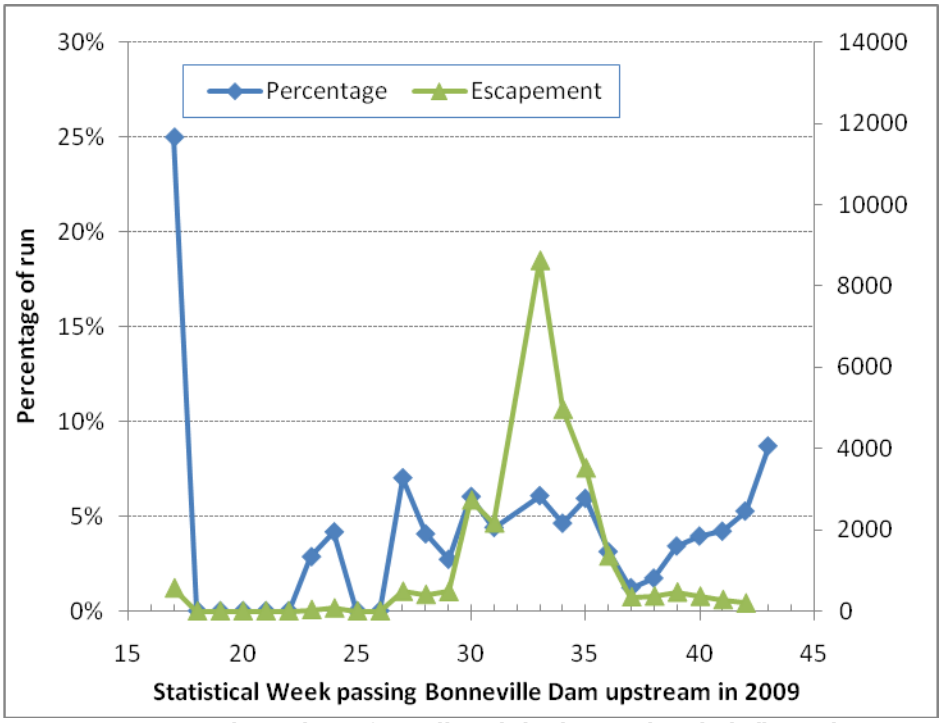

Figure 20. Percentage and number of steelhead designated as kelt (based on 2010 detections) passing Bonneville Dam by statistical week in 2009.

Fallback

Estimated fallback-reascension rates based on steelhead reascending fish ladders ranged from 2.2% to 13.4% (Table 28). 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. Unlike Chinook salmon, who had high fallback rates (relative to other dams) at Rock Island Dam and Ice Harbor, Priest Rapids Dam had the highest fallback rate. Of the 156 steelhead detected at Priest Rapids Dam, 16 were subsequently detected downstream at other dams on the mainstem or in other systems (Prosser Dam 8, Rock Island Dam 6, Rock Creek 1, and Walla Walla River 1), while 8 others reascended the Priest Rapids fish ladders after falling back over the dam following the initial ascent.

Table 28. Estimated steelhead fallback/reascension.

Dam	Percent Fallback%
Bonneville	2.2%
McNary	3.6%
Priest Rapids	15.3%
Rock Island	6.1%
Rocky Reach	3.6%
Wells	2.2%
Ice Harbor	4.5%
Lower Granite	3.6%
Mean	**5.1%**

Night Passage

Night passage (2000-0400 Pacific Standard Time) by tagged steelhead was under 7% at all mainstem dams except Rock Island (Table 29). Night passage at the two tributary dams with greater than 15 detections, Prosser Dam on the Yakima River, and Three Mile Dam on the Umatilla River, were higher than at mainstem dams. The Bonneville Dam estimate of night passage is likely biased with low numbers due to the day time tagging, which occurred between about 0700 and 1400 PST. Given the median Bonneville Dam passage time of 77 minutes (Table 23), steelhead would be expected to pass during daytime hours.

Table 29. Estimated steelhead night passage (2000-0400) in 2009 at Columbia Basin dams with a minimum of 15 detections as estimated by PIT tags.

Site	Steelhead (%)
Bonneville	2.2%
McNary	4.6%
Priest Rapids	1.3%
Rock Island	16.8%
Rocky Reach	0.9%
Wells	4.4%
Ice Harbor	6.4%
Lower Granite	4.7%
Prosser	18.6%
Three Mile	46.2%

RESULTS-SOCKEYE[c]

Sample Size

A total of 850 sockeye salmon were sampled between June 3 and July 9, 2009. Sampling was halted when PIT tag detections at Ice Harbor and Lower Granite dams indicated we had exceeded our permitted sample size of three ESA-listed Snake River sockeye salmon. Less than 3% of the sockeye run passed Bonneville Dam subsequent to the termination of sampling. Of the 850 fish sampled, a total of 838 sockeye salmon were released with working PIT tags (Table 30). The remaining 12 fish were either not PIT tagged, or were PIT tagged but the tags were not detected when scanned. An additional 31 fish were never detected after release. These fish may have shed their tags, had defective tags, died, or passed downstream undetected through antennas that do not detect sockeye salmon well (Table A2). It is less likely that sockeye salmon pass upstream undetected as they must swim through antennas at fish counting windows, but data from 2006-2009 indicates it does happen (Table 31), particularly at dams with navigation locks that fish can pass through (Bonneville, McNary, Ice Harbor, and Lower Granite). PIT tag detection data were downloaded from www.ptagis.org on November 23, 2009.

Table 30. Number of PIT tagged sockeye salmon tagged at Bonneville Dam and tracked, by date and statistical week in 2009.

Sampling Dates	Statistical Week	Sampled (n)	Number Tagged	Number Tracked
6/1,2,3,4,5	23	10	10	10
6/8,9,10,11,	24	75	75	74
6/15,16,17,18	25	200	199	196
6/22,23,24,25,26	26	275	271	259
6/29,30,7/1,2	27	196	190	178
7/6,7,8,9	28	94	93	90
	Total	**850**	**838**	**807**

[c] The information presented in this section of the report is a summary of Fryer et al. 2010.

Table 31. Percentage of PIT tagged fish by tag type not detected at dam detection sites as estimated from upstream detections in 2009 with comparison data for 2006-2008.

Dam	2009	2008 (12.5mm tags only)	2007	2006	Mean
Bonneville*	0.6%	0.4%	2.1%	0.2%	**0.8%**
McNary*	5.0%	10.1%	6.5%	3.1%	**6.2%**
Priest Rapids	0.3%	0.3%	0.8%	0.0%	**0.4%**
Rock Island	2.6%	6.9%	6.8%	1.3%	**4.4%**
Rocky Reach	0.0%	0.2%	0.7%	12.3%	**3.3%**
Ice Harbor*[a]	20.0%	0.0%			**10.0%**
Mean		**3.0%**	**3.4%**	**3.4%**	**3.3%**

*Navigation locks at these dams permit adult sockeye to bypass weirs equipped with pit-tag detectors.
[a]Only five sockeye salmon PIT tagged by this project passed Ice Harbor Dam.

Distribution of sample

The weekly distribution of our sockeye salmon sample size was relatively similar to that of the sockeye run as a whole (Figure 21).

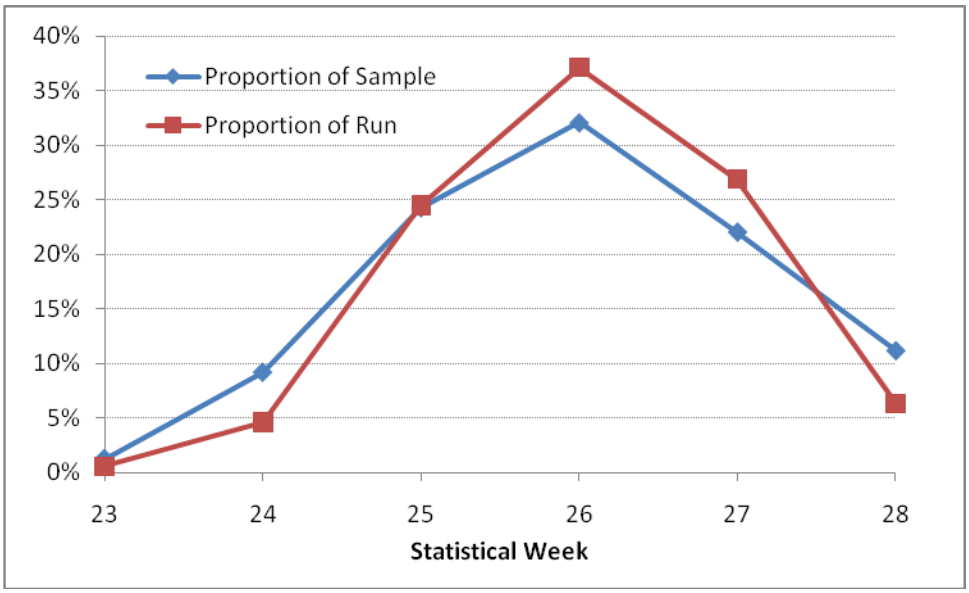

Figure 21. Proportion of the sockeye salmon sample size and run size by statistical week at Bonneville Dam in 2009.

Upstream Detections, Mortality, and Escapement

Most of the tagged sockeye salmon that were not detected at Rock Island Dam (the last dam that both Wenatchee and Okanagan sockeye stocks pass) failed to reach McNary Dam (Table 32, Figure 22). This reach of river is where

the Zone 6 tribal fishery occurs, which was estimated to harvest of 10,374 sockeye salmon in 2009 (Table A2) and accounts for 41.8% of these missing fish.

Table 32. Percentage of PIT tagged sockeye salmon detected at upstream dams subsequent to tagging, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2009.

Dam	Estimated percentage reaching dam	Estimated escapement using PIT tag data	Visual Dam count	Difference between PIT tag and visual estimate
Bonneville	100.0	--	177823	--
McNary	85.7	152395	121672	25.3%
Priest Rapids	82.1	145977	153466	-4.9%
Rock Island	80.2	142551	162830	-12.5%
Rocky Reach	67.1	119307	133106	-10.4%
Wells	65.2	115943	134937	-14.1%
Tumwater	12.2	21732	16076	35.2%
Ice Harbor	1.8	3131	867	261.1%
Lower Granite	1.8	3131	1219	156.8%

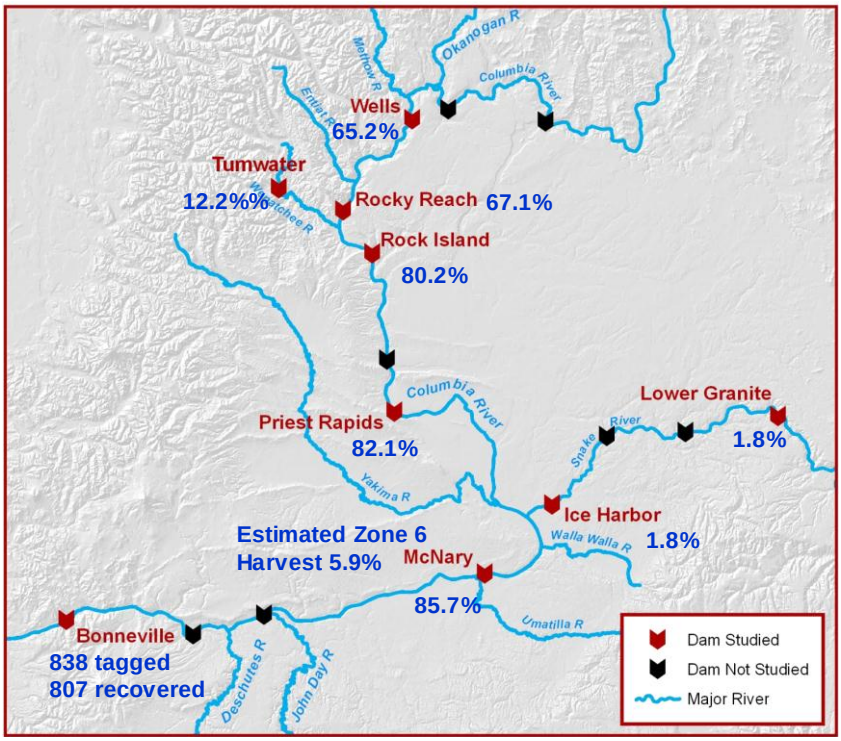

Figure 22. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, Ice Harbor, Lower Granite, and Tumwater dams in 2009.

A total of 5 PIT tagged sockeye salmon were detected on the Okanagan spawning ground, by Okanagan Nation Alliance staff using hand-held scanners, out of approximately 2430 checked as part of brood stock collection and spawning ground survey activities.

The predominant age class for the mixed stock at Bonneville Dam as well as that at upstream locations was Age 1.2 (Table 33).

Table 33. Age composition (%) of Columbia Basin sockeye salmon stocks at Bonneville Dam as well as by PIT tags detected at upstream locations.

		Age					
Stock and Location	**Sample Size**	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**
Mixed stock at Bonneville Dam	818	10.7	78.7	1.1	5.8	3.6	0.1
Wenatchee stock at Tumwater Dam	87	0.8	75.9		22.5	1.0	
Okanogan stock at Wells Dam[d]	504	12.5	79.2	1.0	2.6	4.6	
Snake River at Ice Harbor dam	12	26.3	73.7				

Using detections of fish PIT tagged by this project to estimate sockeye numbers passing dams resulted in greater variation from visual fish counts at those same dams than in previous years. For instance, in 2008 estimates from this project were within 6.4% of the visual count at Priest Rapids, Rock Island, Rocky Reach, and Wells dams, whereas in 2009, these estimates differed by up to 16.1%. At McNary, Ice Harbor, and Lower Granite dams, it is possible for fish to use navigation locks to bypass fish ladders, thus avoiding both PIT tag and visual detection. At all of these dams, PIT tag estimates exceeded visual estimates of abundance; however, the magnitude of this difference was far greater than the percentage of sockeye estimated to have missed tag detection at these dams (Table 31).

The 2009 results were similar to 2006-2008 results where there were significant linear relationships between survival within specific river segments and the statistical week in which the fish were tagged; fish tagged later in the migration exhibited a lower survival rate (Table 34). In 2009, there was a significant linear relationship between statistical week tagged at Bonneville Dam and survival from Bonneville to Priest Rapids ($p=0.02$), but not with survival between Rocky Reach and Wells dams ($p=0.11$).

[d] Wells Dam age composition estimates are corrected from those found in Fryer et al. (2009).

Table 34. Sockeye salmon survival through selected reaches, by statistical week as estimated by PIT tag detections in 2009.

Statistical Week at Bonneville Dam	Bonneville to McNary	Bonneville to Priest Rapids	Bonneville to Rock Island	Rocky Reach to Wells
23	90.0%	90.0%	90.0%	100.0%
24	91.8%	90.4%	89.0%	98.4%
25	89.5%	88.4%	87.4%	100.0%
26	83.7%	79.3%	77.6%	95.2%
27	84.3%	79.1%	76.2%	96.6%
28	83.7%	80.2%	76.7%	96.8%
Composite	**85.7%**	**82.1%**	**80.2%**	**97.0%**

Stock Composition, Migration Timing and Passage Time

The percentage of Wenatchee stock sockeye salmon was higher during the middle of the run when compared to the beginning and end with no significant linear relationship between weekly stock composition and statistical week (p=0.21, Table 8). The overall stock composition estimate was 15.1% Wenatchee, 82.6% Okanagan, and 2.3% Snake River. The Wenatchee/ Okanagan split was similar to that estimated using Rocky Reach Dam counts but varied greatly from that estimated using Tumwater Dam counts (Table 35).

Sockeye salmon travel quickly upstream with a median migration time between Bonneville and Rock Island Dam of 12.7 days (Table 36). Sockeye salmon passing Bonneville Dam later in the migration, traveled upstream faster than those earlier in the migration. There is a significant (α=0.05) linear relationship between statistical week passing Bonneville Dam and passage time from Bonneville Dam to McNary, Rock Island, Rocky Reach, and Wells dams. The median difference in migration time from Bonneville Dam to all upstream mainstem dams was one day or less between the two major stocks (Okanagan and Wenatchee, Table 37). There were insufficient numbers of Snake River sockeye to conduct this analysis.

Table 35. Weekly and composite sockeye salmon stock composition at Bonneville Dam as estimated by PIT tags in 2009.

Statistical Week (and Dates)	Run Size	PIT Tag sample size	Percent Wenatchee	Percent Okanagan	Percent Snake River
23 (On or before June 6)	968	9	0.0%	100.0%	0.0%
24 (June 7-13)	8007	64	1.6%	98.4%	0.0%
25 (June 14-20)	42515	163	16.0%	84.0%	0.0%
26 (June 21-27)	64451	194	22.2%	74.7%	3.1%
27 (June 28-July 4)	46675	134	8.2%	88.1%	3.7%
28 (On or after July 5)	10954	62	11.3%	87.1%	1.6%
Composite	213564	9	15.1%	82.6%	2.3%

Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach to estimate proportion Wenatchee)			17.8	79.9	
Visual Fish Counts at dams (Tumwater count to estimate the proportion Wenatchee)			9.6	88.1	

Table 36. Median sockeye salmon migration time and travel rates between mainstem dams as estimated by PIT tag detections in 2009.

Dam Pair	Distance (km)	Median Time (days)	Median Travel Rate (km/day)
Bonneville-McNary	231	5.1	45.2
McNary-Priest Rapids	167	4.0	41.4
Priest Rapids-Rock Island	89	3.1	28.7
Rock Island-Rocky Reach	33	1.1	29.1
Rocky Reach-Wells	65	2.2	29.6
Rock Island-Tumwater	73	11.2	6.5
Bonneville-Rock Island	487	12.7	38.2
Bonneville-Tumwater	560	26.0	21.6
Bonneville-Wells	585	16.2	36.2

Table 37. Median sockeye salmon migration time in days between dam pairs by statistical week that they passed Bonneville Dam. The F-statistic for a linear regression between migration time and statistical week, and mean migration time by stock as estimated using PIT tags in 2009.

Statistical Week at Bonneville Dam	Bonneville-McNary	Bonneville-Priest Rapids	Bonneville-Rock Island	Bonneville-Rocky Reach	Bonneville-Tumwater	Bonneville-Wells	McNary-Rock Island	Rock Island-Rocky Reach	Rocky Reach-Wells
23	5.9	10.3	14.6	15.4	–	17.2	8.9	1.2	2.6
24	5.2	10.0	14.8	17.0	37.6	19.3	9.2	1.8	2.8
25	5.1	9.8	13.9	14.9	28.5	17.2	8.4	1.2	2.2
26	5.2	9.4	12.7	13.6	25.0	15.9	7.1	1.1	2.1
27	5.0	8.8	11.7	12.8	22.2	15.2	6.7	1.1	2.1
28	4.8	8.8	11.6	12.4	21.8	14.5	6.4	1.0	2.1
P-value	**0.03**	**<0.01**	**<0.01**	**0.01**	**0.01**	**0.03**	**<0.01**	**0.08**	**0.10**
Stock									
Okanagan	5.1	9.2	12.7	13.9	23.8	16.2	7.1	1.1	2.2
Wenatchee	5.1	9.8	13.7	13.0	26.0	15.6	8.0	1.1	2.8
Snake River	5.3	–	–	–	–	–	–	–	–
Unknown*	5.2	9.1	12.9	11.9	–	13.5	8.0	0.9	2.1

*Unknown stock sockeye salmon are those that passed Bonneville but were not detected at Tumwater, Rocky Reach or Wells, or Ice Harbor or Lower Granite dams.

The median time passing a dam (defined as time difference between first detection and last detection) was five minutes or less at all dams except for Bonneville, Lower Granite, and Tumwater dams (Table 38). At Bonneville Dam,

many sockeye were detected in underwater orifices just upstream and downstream of the fish trap where sampling occurred. If these detections are excluded, making the array of PIT tag detection antennas at Bonneville Dam more comparable to that at most other dams, the median time drops to 21 minutes. Extensive trapping operations at Lower Granite and Tumwater dams likely contributed to delays.

Table 38. Sockeye salmon median travel time passing dams and the percentage of sockeye salmon taking greater than 12 hours to pass in 2009.

Dam	Median Passage Time (Minutes)	Taking more than 12 hours (%)
Bonneville	58	5.7%
McNary	0	2.1%
Priest Rapids	5	1.2%
Rock Island	3	1.1%
Rocky Reach	2	1.5%
Wells	3	2.1%
Tumwater	159	41.4%
Ice Harbor	4	0.0%
Lower Granite	141	16.7%

Fallback

Estimated fallback and reascension rates for sockeye salmon ranged from 0.7% at Tumwater Dam to 33.3% at Lower Granite Dam (Table 39). However, the Lower Granite estimate is based on only 12 fish. Four PIT tagged sockeye salmon fell back through the John Day juvenile bypass system, while three sockeye at Bonneville Dam fell back through the juvenile bypass system.

Table 39. Estimated sockeye salmon fallback at mainstem Columbia River dams in 2009 as estimated by PIT tag detections.

Dam	n	Sockeye (%)
Bonneville	796	1.1
McNary	646	3.3
Priest Rapids	642	1.4
Rock Island	612	1.3
Rocky Reach	535	1.5
Wells	522	1.0
Tumwater	87	5.7
Ice Harbor	9	11.1
Lower Granite	12	33.3

DISCUSSION

This study sampled and PIT tagged over 7000 salmonids at Bonneville Dam in 2009 and then tracked these fish upstream to estimate parameters such as upstream escapement, age composition, length composition, and migration rates at mainstem dams and other tributary interrogation sites. PIT tags provide an easier, much cheaper, and less intrusive method of monitoring the upstream migration of fish than radio tags used in past studies. However, PIT tags do not always provide the same amount of data as can be collected in a radio tag study. For example, PIT tag detection is not installed at all mainstem dams, nor is it present in many tributaries. It is far less expensive, and often more feasible, to add a radio tag receiver at a desired site, than a PIT tag antenna. New detection sites for PIT tags are continually being added into the system, particularly in tributaries, making PIT tag data more useful, but also much more complex to analyze.

This study compared the performance of 12.5 and 20.0 mm tags implanted in steelhead and Chinook salmon and found no significant difference in the percentage of each tag-type group of fish detected at upstream sites. The similar performance of these tags differed from 2008 when we compared 8.5 mm tags with 12.5 mm tags and found that that sockeye and Chinook salmon tagged with 8.5 mm PIT tags were significantly less likely to be detected at numerous sites upstream than those fish tagged with 12.5 mm tags (Fryer et al. 2010).

This study was adversely affected by the trap configuration imposed in 2009 that biased our sample by causing us to sample a higher percentage of smaller one-ocean Chinook (jacks) than were present in the general fish population migrating in the ladder at the time of sampling. It is unknown why a higher percentage of jack Chinook chose the trap side of the divider. Whatever the reason, the bias adversely affects our age composition estimates for Chinook salmon. This type of analysis for trap bias requires a sufficient number of previously PIT tagged fish (from other studies) to determine if a bias exists. While sufficient numbers existed for Chinook, the sample of previously tagged sockeye and steelhead was too small to make any comparisons for these two species. Furthermore, there are also insufficient previously PIT tagged fish of any species to determine whether there were any stock composition or other biases.

The discovery of biases imposed by the trap configuration in 2009 resulted in an investigation and analysis of other potential biases imposed on the fish by dam configuration or operations. Fish passing Bonneville Dam may enter any one of four ladder entrances plus use the navigation locks. However, only fish using the Washington Shore ladder entrance can be trapped by the Adult Fish Facility and sampled. If any of the other three ladder entrances are attracting fish of different stocks, age, or length then this would be another source of bias. Also, we typically only trap and sample four to six hours daily during weekday mornings and early afternoon, suggesting another possible source of bias, if fish stock, sizes, or ages migrate at different times of the day or night. An analysis of the percentage of jacks passing through the different ladder entrances during hours of trapping and hours of not trapping, found that the percentage of jacks varied from 38.6% for those entering the Washington Shore ladder entrance during non-trapping hours to 60.4% at the Oregon Shore ladder during trapping hours. Given this variability, it was surprising that as a whole the percentage of PIT tagged Chinook passing Bonneville Dam that were jacks (48.2%) was close to the percentage of jacks passing through the Washington Shore ladder during hours the trap was in operation (46.1%). This suggests that, if we had been allowed to trap the entire ladder, rather than half the ladder, our estimated jack composition would have been within 2.1 percentage points (or 4.6%) of that for the entire population of previously tagged Chinook salmon passing Bonneville Dam. In future years, we will continue to look for possible biases in trapping, and if warranted, we may alter sampling hours and days in an effort to reduce sampling biases. Sampling other fish ladders at Bonneville Dam to reduce biases between ladders or Washington Shore versus Oregon shore is not feasible.

Steelhead were detected at a higher rate than Chinook or sockeye salmon as they passed mainstem Columbia and Snake river dams. For all the mainstem dams the highest percentage of missed steelhead at a dam was 0.8% at Rock Island Dam, compared to 3.2% for spring Chinook passing Ice Harbor Dam, and 5.0% for sockeye salmon passing McNary Dam. Undetected passage was more likely at dams with navigation locks which fish can use, avoiding PIT tag arrays in ladders.

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 passage 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 2009 the percentage of Snake River origin Chinook salmon was about 39% for the week of April 26 (Week 1 of sampling), peaking at 57.9% the week of May 31 (Week 23 and previous spring Chinook cut off), and staying above 30% through the week of June 28 (Week 27). The portion of the Chinook run heading above Priest Rapids Dam was 48% or over from the week of June 7 through the week of July 19 (Weeks 24-30).

Escapement estimates using PIT tag data for mainstem dam passage varied from the traditional methods (i.e. visual counts) and ranged from -7.4% to +12.4% for Chinook salmon and from -7.2% to 31.9% for sockeye salmon (Lower Granite and Ice Harbor PIT tag sample sizes were too small for a comparison of sockeye run sizes.) Many factors can cause these discrepancies including inaccuracies of visual or video counts, fallback/reascension rates, tagging effects, and a biased sampled of fish being PIT tagged. Tagging additional adults, as well as better detection in terminal areas, would likely improve the precision and accuracy of stock specific escapement and survival estimates.

In 2009, when water temperatures exceeded 70.0 F (21.1 C) as measured at Bonneville Dam, sampling (which includes trap set up) at the Adult Fish Facility was restricted to four mornings per week from 6 AM to 10 AM. Fish typically take 1.0 to 1.5 hours to reach the sampling tank after the trap is set up, which allows for 2.5 to 3 hours of actual sampling to collect data and tag both steelhead and fall Chinook salmon. These restrictions continue until water temperatures drop below 69.5º F (20.8 C). If temperatures reach 22.2 C (72.0º

F) or above sampling is not allowed. In 2009, CRITFC was shut down during Statistical Week 32 and under restricted sampling hours for Statistical weeks 31, 33, 34, and the start of Week 35. Relatively small numbers of Chinook passed Bonneville Dam during these weeks until temperatures started dropping in Statistical Week 34. During Statistical weeks 34-36, our sample size consisted of 304 Chinook, representing 27.4% of our total fall Chinook sample, but was 53.6% of the run. Our steelhead sample was even less representative. As described earlier, during Statistical weeks 31-36 and the restricted sampling schedule, 70.7% of the steelhead run passed Bonneville Dam; only 27.4% (Figure 13) of our sample (totaling 677 fish) was collected. We do weight composite samples by weekly run size (Cochrane 1977), thus reducing potential biases. However, having such a large portion of the run represented by such a small portion of the sample increases the variance and thus decreases the reliability of results.

As in 2008, delays were observed for both sockeye and Chinook salmon in passing Tumwater Dam. The median delay for Chinook was 2.33 days (compared to less than 2 hours at other dams), while for sockeye salmon it was 154 minutes (compared to five minutes or less at all dams other than Lower Granite and Bonneville). Fryer et al. (2010) estimated that 20.4% of sockeye salmon reaching the Tumwater Dam fish ladder in 2009 did not pass over the dam. Chinook salmon may have a similar story as 11 out of the 76 Chinook detected in Tumwater Dam fish ladders were last detected at the lower antenna, therefore it is assumed that they did not pass the dam. These delays and fish failing to ascend Tumwater Dam are likely due, at least in part, to a 24-hour operation of the fish trap at that site.

In 2008, the median delay for sockeye salmon passing Tumwater Dam was 4.6 days Tumwater Dam (Fryer 2009). This was may be attributed to the 24-hour operation of the fish trap at Tumwater Dam. Fish were observed “stacking up” in the fish ladder below the trap (Keely Murdoch, Yakama Nation, personal communication), and it was evident that there were significant delays. Fryer (2009) speculated that that “it is possible that some sockeye salmon were not passing the Tumwater Dam due to the passage delays – 7.6% of those sockeye salmon detected at Tumwater Dam were last detected at the lower Tumwater Dam fishway detection site suggesting that these fish turned around and went downstream and were not detected again”. In 2009, changes in operation of the fish trap at Tumwater Dam likely resulted in reduced the median delay from 4.6 days to 159 minutes. However, 41.4% of sockeye in 2009 still took

more than 12 hours to pass Tumwater Dam, suggesting that trap-operations may continue to influence adult fish behavior.

This study estimated fallback rates at dams using PIT tag detections of individual fish. This likely underestimates fallback rates as a fish that falls back over a dam and is not subsequently detected would not be included. Data from two hatcheries located immediately downstream of two mainstem dams indicate high rates of fallback, at least for the two hatchery stocks. Twenty Chinook tagged by this study were recovered at Wells Hatchery in 2009. Of these fish, six ascended the fish ladders at Wells Dam and were detected at the upstream antenna before presumably falling back over Wells Dam and entering Wells Hatchery. Similarly, 12 of the 29 Chinook recovered at Lyons Ferry Hatchery fell back over Little Goose or both Little Goose and Lower Granite dams before entering the hatchery.

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APPENDIX

Table A1. Probability of detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for Chinook salmon in 2009.

Dam, Site, Tag Type, and Number		Weir and Probability of Detection at Weir										Overall Detection Probability
Bonneville	**N**	**1**	**2**	**3**	**4**							
BO4-12.5	1918	99.3	98.0	99.0	99.2							100.0
BO4-20	902	99.1	98.3	99.4	99.5							100.0
BO1-12.5	65	100.0	100.0	100.0	96.5							100.0
BO1-20	39	100.0	100.0	100.0	100.0							100.0
McNary	**N**	**1**	**2**	**288**	**287**	**286**	**284**	**283**	**282**	**280**	**279**	
MC1-12.5	825	99.4	100	89.8	89.9	89.1	91.0	85.0	82.5	70.1	52.8	100.0
MC1-20	386	99.1	99.5	90.0	88.2	88.6	92.1	86.3	82.1	72.5	53.4	100.0
	N	**1**	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**303**	**302**	
MC2-12.5	515	97.5	99.2	99.1	63.4	49.2	49.3	64.9	70.3	66.7	69.2	100.0
MC2-20	227	98.1	100	99.6	49.6	48.1	45.8	52.0	54.1	48.8	51.4	100.0
Priest Rapids	**N**	**3**	**7**									
East -12.5	328	99.0	99.4									100.0
East -20	160	96.9	100									100.0
	N	**3**	**5**									
West-12.5	60	96.7	100									100.0
West-20	29	48.3	100									100.0
Rock Island	**N**	**1-2**	**3-4**									
Left (east)-12.5	85	99.7	100									100.0
Left (east)-20	40	100	99.7									100.0
	N	**5-6**	**7-8**									
Middle-12.5	29	94.6	99.0									100.0
Middle-20	10	96.6	98.6									100.0
	N	**09-0A**	**0B-0C**									
Right (west)-12.5	265	99.7	62.5									99.6
Right (west)-20	134	92.8	69.7									99.7
Rocky Reach	**N**	**1-2**	**3-4**									
12.5	61	93.9	80.2									98.7
20	197	97.7	80.3									99.3

Wells	**N**	**1-2**	**3-4**									
Left (east)-12.5	69	100	100									100.0
Left (east)-20	25	100	100									100.0
	N	**5-6**	**7-8**									
Right (west)-12.5	129	100	100									100.0
Right (west)-20	59	98.3	100									100.0
Ice Harbor	**N**	**438**	**437**	**436**	**435**							
South-12.5	472	95.8	99.4	99.6	99.8							100.0
South-20	205	96.9	98.4	98.4	100							100.0
North-12.5	168	93.4	99.4	98.8	99.4							100.0
North-20	64	96.9	98.4	98.4	100							100.0
Lower Granite	**N**	**733**	**732**	**731**	**730**							
12.5	360	100	99.3	100	100							100.0
20	150	100	100	100	100							100.0
Tumwater	**N**	**A1**	**A2**									
12.5	59	100	100									100.0
20	26	100	100									

Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank.

Table A2. Probability of detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for sockeye salmon in 2009.

Dam, site, and tag type	Weir and probability of detection at weir											Overall Detection Probability
Bonneville	**N**	**1**	**2**	**3**	**4**							
BO4	718	99.9	98.6	99.4	99.3							100.0
BO1	82	100.0	100.0	100.0	100.0							100.0
McNary		**1**	**2**	**288**	**287**	**286**	**284**	**283**	**282**	**280**	**279**	
MC1	313	99.0	99.3	9.1	10.4	12.7	12.1	11.1	12.4	14.3	11.4	100.0
		1	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**305**	**303**	
MC2	333	100.0	100.0	100.0	7.5	6.0	4.5	7.2	5.7	5.4	5.1	100.0
P. Rapids		**3**	**7**									
East	521	99.6[a]	99.8									100.0
		3	**5**									
West	120	100.0	99.2									100.0
Rock Island		**1-2**	**3-4**									
Left (east)	149	100.0	99.3									100.0
		5-6	**7-8**									
Middle	89	91.0	100.0									100.0
		09-0A	**0B-0C**									
Right (west)	379	95.5	83.9									99.3
		1-2	**3-4**									
Rocky Reach	535	99.6	100.0									100.0
Wells		**1-2**	**3-4**									
Left (east)	246	99.6	100									100.0
		5-6	**7-8**									
Right (west)	280	100	99.6									100.0
		161	**162**									
Tumwater	87	100.0	100.0									100.0

a Fish bypass this weir when the Priest Rapids adult fish trap is in operation.
Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank.

Table A3. List of PTAGIS interrogation sites (three letter code, name, and description).

Site Code	Site Name	Description
AB1	Abernathy Creek, Technology Center Bridge	Bridge over Abernathy Creek (WA.) at Abernathy Fish Technology Center (AFTC)
AB2	Abernathy Creek, Farmer's Bridge	Private bridge over Abernathy Creek (WA.) at rkm 3, 1.5 km downstream from Abernathy FTC
AB3	Lower Abernathy Creek	The PIT tag interrogation antennas are installed in parallel as a passover array located in the thalweg of the floodplain at Abernathy Creek (WA.) rkm 1. Coverage of the creek is 100% at baseflow but will decrease during floods or large freshets.
B1J	Bonneville Dam DSM1 Flat Plate Detector	Flat Plate Detector in the Bonneville Dam PH1 Downstream Migrant Bypass Channel
B2A	Bonneville Dam Adult Fish Facility	Adult Fish Facility in the WA Shore Fishway at Bonneville Dam; replaced by BO3
B2J	Bonneville Dam PH2 Juvenile Bypass System	Bonneville Dam PH2 Juvenile Bypass and Sampling Facility
BCC	Bonneville Dam PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel
BCP	Butcher Creek Acclimation Pond	Butcher Creek Acclimation Pond, Wenatchee River Basin
BGM	Burlingame Diversion Dam	Burlingame Diversion Dam is located on the lower Walla Walla River. This site consists of detectors in the dam's fish passage facilities, as well as in the canal intake.
BO1	Bonneville Dam Bradford Island Fishway	Bradford Island Adult Fishway at Bonneville Dam
BO2	Bonneville Dam Cascades Island Fishway	Cascades Island Adult Fishway at Bonneville Dam
BO3	Bonneville Dam WA Shore Fishway & AFF	Washington Shore Adult Fishway and AFF at Bonneville Dam; replaces B2A and BWL
BO4	Bonneville Dam WA Shore Vertical Slots	Washington Shore Fishway Vertical Slots at Bonneville Dam
BSC	Big Sheep Creek (Imnaha) ISA at river km 6	In-stream detectors on Big Sheep Creek (Imnaha River Basin) at river km 6.
BTC	Big Timber Creek,Lemhi River Basin	In-stream array on Big Timber Creek, Lemhi River Basin near Leadore, ID.
BVC	Beaver Creek In-stream Array,Methow River	Instream arrays on Beaver Creek, Methow River Basin
BVJ	Bonneville Dam DSM1 Subsample	Bonneville Dam PH1 Juvenile Bypass (DSM1) sub-sample
BVP	Beaver Creek Acclimation Pond	Beaver Creek Acclimation Pond, Wenatchee River Basin
BVX	Bonneville Dam PH1 Flat Plate (Experimental)	Flat Plate Detector (experimental) at Bonneville Dam PH1 DSM; replaced by B1J
BWL	Bonneville Dam Washington Shore Fishway	Washington Shore Adult Fishway at Bonneville Dam; replaced by BO3
CAC	Canyon Creek (Lemhi Basin) ISA at river km 1	In-stream detectors on Canyon Creek (Lemhi River Basin) at river km 1.
CAL	Carson NFH Adult Return Ladder	Adult Fishway at Carson National Fish Hatchery
CAP	Carlton Acc. Pond	Carlton Acclimation Pond, Methow River Basin
CCC	Carrolls Channel, Lwr Col Riv	Instream detectors in upper Carrolls Channel, lower Columbia River at rkm 115
CCP	Catherine Creek Acclimation Pond	Catherine Creek Acclimation Pond
CFJ	Clark Flat Acclimation Ponds	Clark Flat Acclimation Pond Outfall
CHL	Lower Chiwawa River	This is a passive in-stream interrogation system at Chiwawa River rkm 1, located between the Chiwawa smolt trap and the Chiwawa Acclimation Ponds, consisting of a single antenna array spanning the width of the river.
CHN	Challis - North	Challis Diversion North (Diversion 27)
CHP	Chiwawa Acclimation Pond	Chiwawa Acclimation Pond, Wenatchee River Basin
CHS	Challis - South	Challis Diversion South (Diversion 29)
CHU	Upper Chiwawa River	This is a passive in-stream interrogation system at Chiwawa River rkm 12, located above the Forest Road 62 bridge and below Alder Creek, consisting of a single antenna array spanning the width of the river.
CIC	Cottonwood Island, Lwr Col Rvr	Instream detectors on Cottonwood Island, lower Columbia River at rkm 112
CLE	Cle Elum Dam Interim Spillway Bypass	The experimental juvenile fish bypass flume is located in the second bay of the Cle Elum Dam spillway.
CLJ	Clearwater River Trap	The Clearwater River Smolt Trap is located 10 kilometers above the mouth of the Clearwater River. CLJ was deployed during the Spring migration annually between 1989-1998, and has been deployed each spring since 2002.
CLP	Coulter Creek Acclimation Pond	Coulter Creek Acclimation Pond, Wenatchee River Basin
CR1	Chinook River at Sea Resources Hatchery	This is an in-stream interrogation system located near the Sea Resources Hatchery adult fish facility, on the Chinook River in the Columbia River Estuary near Chinook, Washington.
CR2	Chinook River at HWY 101 Bridge	This is an in-stream interrogation system located near the tidal gates at the Hwy. 101 bridge over the Chinook River in the Columbia River Estuary near Chinook, Washington.
CR3	Chinook River at a Culvert	This is an in-stream interrogation system located at a road culvert on the Chinook River in the Columbia River Estuary near Chinook, Washington.
CRW	Chewuch River above Winthrop	In-stream array on the Chewuch River above Winthrop, WA.
DRP	Dryden Acc. Pond	Dryden Acclimation Pond, Wenatchee River Basin
DWL	Dworshak NFH adult trap	Dworshak National Fish Hatchery Adult Trap

Table A3. Continued.

Site Code	Site Name	Description
EMC	Eightmile Creek In-stream Array,Methow River	Instream detector on Eightmile Creek, Methow River Basin
ENL	Lower Entiat River	This is a passive in-stream interrogation system at Entiat River rkm 2, located immediately upstream of Entiat, WA. The system consists of two sets of three antennae. Each set of antennae spans the river; the sets are arrayed in tandem to provide directi
ENM	Middle Entiat River	This is a passive in-stream interrogation system at Entiat River rkm 26, below the McKenzie Diversion Dam. The system consists of two sets of three antennae. Each set of antennae spans the river; the sets are arrayed in tandem to provide directionality
ESJ	Easton Acclimation Pond	Easton Acclimation Pond Outfall
ESS	East Fk South Fk Salmon River at Parks Cr.	This is an in-stream interrogation system consisting of two separate antenna arrays, 790 meters apart, on the East Fk South Fk Salmon River (rkm 21) near Parks Creek.
ESX	Estuary Saltwater Trawl (Experimental)	Salt Water & Estuary Trawl Detector. The ESX experimental saltwater trawl detector was typically deployed in the lower Columbia River estuary, downsteam of the Highway 101 bridge.
FDC	Feed Canal,Umatilla River	Feed Canal, on the Umatilla River at rkm 47. FDC is operated by USFWS for the Bureau of Reclamation.
FDD	Feed Diversion Dam	Feed Diversion Dam, at Umatilla River rkm 47.
GL2	SF Gold Creek In-stream Array,Methow River	Instream detector on S. F. Gold Creek, Methow River Basin
GLC	Gold Creek In-stream Array,Methow River	Instream detector on Gold Creek, Methow River Basin
GOJ	Little Goose Dam Juvenile Bypass System	Little Goose Dam Juvenile Fish Bypass/Transportation Facility
GRA	Lower Granite Dam Adult Fishway and Trap	Lower Granite Dam Adult Fishway and Fish Trap
GRJ	Lower Granite Dam Juvenile Bypass System	Lower Granite Dam Juvenile Fish Bypass/Transportation Facility
GRP	Grande Ronde Acclimation Pond	Upper Grande Ronde River Acclimation Pond
GRX	Lower Granite Dam Sep-by-Code (Experimental)	Lower Granite Juvenile Bypass Experimental Site
HLM	Potlatch River near Helmer	This in-stream site is located near the town of Helmer, on the mainstem Potlatch River at km 66, just below the confluence of the West Fork and East Fork Potlatch rivers.
HLX	Hemlock Dam (Trout Cr,Wind River) Fishway	This experimental interrogation system was located in the adult fish passage ladder at Hemlock Dam, on Trout Creek in the Wind River (WA) Basin.
HYC	Hayden Creek in-stream array,Lemhi Basin	This is an in-stream interrogation system located on the lower section of Hayden Creek, in the Lemhi River Basin. The system consists of two parallel pass-by antennas, one each 10 and 20 feet in length, spanning 30 feet across the creek.
ICH	Ice Harbor Dam Fishways and Juvenile Bypass	Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass
IHA	Ice Harbor Adult Fishways	Ice Harbor Dam Adult Fishways (both); replaced by ICH
IMJ	Imnaha River Juvenile Trap	Imnaha River Smolt Trap
IR1	Lower Imnaha River ISA at river km 7	In-stream detectors on the Imnaha River at river km 7.
IR2	Lower Imnaha River ISA at river km 10	In-stream detectors on the Imnaha River at river km 10.
JCJ	Jack Creek Acclimation Pond	Jack Creek Acclimation Pond Outfall
JD1	John Day River near McDonald Ferry at RM 20	John Day River in-stream detection, near McDonald Ferry at RM 20
JDJ	John Day Dam Juvenile Bypass System	John Day Dam Juvenile Fish Bypass and Sampling Facility
JOC	Joseph Creek (Grande Ronde) ISA at river km 3	In-stream detectors on Joseph Creek (Grande Ronde River Basin) at river km 3.
JUL	Potlatch River near Juliaetta	This in-stream interrogation system is located near Juliaetta at rkm 14 on the Potlatch River.
KCB	Kiwanis Camp Bridge,upper Mill Creek	This in-stream interrogation system is located at the bridge at the Kiwanis Camp on upper Mill Creek, Walla Walla Basin.
KEN	Kenney Creek In-stream Arrays	In-stream array near the mouth of Kenney Creek, Lemhi River Basin
KHS	Big Bear Cr. at Kendrick HS	This in-stream interrogation system is located near the mouth of Big Bear Creek (in the Potlatch River Basin) adjacent to the high school in the town of Kendricks, ID.
KRS	SF Salmon River at Krassel Cr.	This in-stream interrogation system is located near Krassel Creek at rkm 65 on the South Fork Salmon River.
LAP	Lapwai Creek near the mouth	This is an in-stream interrogation system consisting of two separate antennas, 10 feet apart and approximately 0.3 miles upstream from the mouth of Lapwai Creek.
LBC	Libby Creek In-stream Array,Methow River	Instream detector on Libby Creek, Methow River Basin
LEA	Leaburg Dam smolt bypass and adult fishways	
LLR	Lower Lemhi River ISA at Salmon	This is an in-stream interrogation system consisting of three 20-foot pass-by antennae (arrayed in parallel) on the lower Lemhi River in Salmon, ID.
LMJ	Lower Monumental Dam Juvenile Bypass System	Lower Monumental Dam Juvenile Fish Bypass/Transportation Facility
LMR	Lower Methow River near Pateros	This is an in-stream interrogation system consisting of two separate antenna arrays. LMR is located on the lower Methow River near the WDFW 'Miller Hole' access site on the lower Methow River immediately upstream of Pateros, WA.
LMT	Lower Mainstem Teanaway River	In-stream array at km 0.4 on the Teanaway River, upper Yakima River Basin
LOP	Lostine River Acclimation Pond	Lostine River Acclimation Pond
LRW	Lemhi River ISA below the IDFG weir	This is an in-stream interrogation system consisting of two 20-foot pass-by antennae (arrayed in parallel) on the Lemhi River above the mouth of Hayden Creek and below the IDFG weir.

Table A3: Continued.

Site Code	Site Name	Description
LTR	Lower Tucannon River,near the river mouth	This is an in-stream interrogation system that has variously consisted of two groups of arrays, about a kilometer apart, located near the mouth of the Tucannon River.
LWD	Lowden Diversion Dam	This interrogation system currently consists of a single antenna at the entrance to the fish ladder at Lowden Diversion Dam. Lowden Dam is located at rkm 51 on the Walla Walla River.
LWE	Lower Wenatchee River	This is a passive in-stream interrogation system at Wenatchee River rkm 2, consisting of a single antenna array spanning the width of the river.
LWL	Little White Salmon NFH adult fish ladder	Adult fish ladder allowing passage from the Little White Salmon River into the adult holding ponds at Little White Salmon NFH. All fish captured in the ponds are sorted and may either be surplused/spawned or returned to the river via an underground tube.
LWN	Little Wenatchee River	This is a passive in-stream interrogation system at Little Wenatchee River rkm 4, located at the old fish weir site, consisting of a single antenna array spanning the width of the river.
MAD	Mad River,Entiat River Basin	This is a passive in-stream interrogation system at Mad River rkm 1, located at Ardenvoir, WA. The system consists of three sets of two antennae. Each pair of antennae spans the river; the pairs are arrayed in tandem to provide directionality data.
MC1	McNary Dam Oregon Shore Fishway	Oregon Shore Adult Fishway at McNary Dam
MC2	McNary Dam Washington Shore Fishway	Washington Shore Adult Fishway at McNary Dam
MCD	Placed at Mill Cr Diversion Dam (StreamNet Data) in Walla Walla River Basin	This interrogation system includes the fish bypass and passage facilities at the (Bennington) Diversion Dam and the first Division Works in the Mill Creek Diversion Project in the Walla Walla Basin.
MCJ	McNary Dam Juvenile Bypass System	McNary Dam Juvenile Fish Bypass/Transportation Facility
MCX	McNary Dam Juvenile Experimental Site	McNary Dam - Full-Flow Bypass (NMFS, 2002); non-ISO coils (Chelan Co. PUD, 1996)
MRB	Lower Methow River Basin below Twisp	Instream detectors deployed at 10 sites in tributaries to the lower Methow River below Twisp, WA.
MRT	Methow River array at Twisp	In-stream array on the Methow River at Twisp, WA.
MRW	Methow River array at Winthrop	In-stream array on the Methow River at Winthrop, WA.
MSC	Methow River Side Channel Array	Instream arrays on a side channel to the Methow River
MWC	Maxwell Canal,Umatilla River	Maxwell Canal is located at rkm 24 on the Umatilla River. MWC is operated by USFWS for the Bureau of Reclamation.
MWE	Middle Wenatchee River	This is a passive in-stream interrogation system at Wenatchee River rkm 50 above Tumwater Dam, consisting of a single antenna array floated off the bottom spanning the river.
NAL	Lower Nason Creek	This is an in-stream interrogation system at Nason Creek rkm 1, located within Lake Wenatchee State Park, consisting of six hybrid antennae (3 upstream, 3 downstream) spanning 16.7m across the low-water channel.
NAU	Upper Nason Creek	This is an in-stream interrogation system at Nason Creek rkm 19 (Wenatchee River Basin), consisting of six pass-by antennae (3 upstream, 3 downstream) spanning 17.6m across the low-water channel.
NBA	Nursery Bridge Diversion Dam Fishways	Nursery Bridge Dam Fishways (both), Walla Walla River at Milton-Freewater, OR.
OKC	Okanagan Channel at VDS-3	Okanagan Channel VDS-3, at Okanogan River km 149 upstream of Osoyoos Lake
OMK	Omak Creek Crump Weir	Instream detectors at the mouth of Omak Creek.
ORB	Oasis Road Bridge,lower Walla Walla River	Instream detectors at Oasis Road Bridge, lower Walla Walla River
PES	Peshastin Creek	This is a passive in-stream interrogation system at rkm 3 on the Peshastin River (Wenatchee River Basin), located just below the bridge at Smithson's property. It consists of a single antenna array spanning the width of the river.
PRA	Priest Rapids Dam Adult Fishways	Priest Rapids Dam Adult Fishways (both)
PRJ	Prosser Dam screened Juvenile Diversion	Chandler Canal Diversion Bypass and Sampling Facility at Prosser Dam
PRO	Prosser Dam Fishways and screened Diversion	Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam
RBF	Round Butte Dam Fish Transfer Facility	Round Butte Dam Fish Transfer Facility
RCL	Rock Creek (WA) near Yakima Nation Longhouse	Instream detection system on Rock Creek (WA) near the YIN Longhouse
RCS	Rock Creek (WA) at Squaw Creek	Instream detection system on Rock Creek (WA) at Squaw Creek
RCX	Rattlesnake Creek Flat Plates (Experimental)	This in-stream interrogation system is located on Rattlesnake Creek, in the White Salmon River Basin on the Lower Columbia River above Bonneville Dam.
RFP	Rolfing Acclimation Pond	Rolfing Acclimation Pond, Wenatchee River Basin.
RIA	Rock Island Dam Adult Fishways	Rock Island Dam Adult Fishways (all three)
ROZ	Roza Dam Juvenile Diversion	Roza Dam Smolt Bypass
RPJ	Rapid River Hat. Juvenile Volitional Release	Rapid River Hatchery (IDFG) outfall
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway
RRJ	Rocky Reach Dam Juvenile Bypass System	Rocky Reach Dam Juvenile Fish Bypass System
RSB	Roosevelt Street Bridge	Instream detectors on Mill Creek at the Roosevelt St. bridge, Walla Walla, WA.
RZF	Roza Dam Adult Fishway	Adult Fishway at Roza Dam
SAJ	Salmon River Trap	The Salmon River Smolt Trap is located at rkm 103 on the Salmon River. SAJ has been deployed annually during the Spring since 1993. PIT tag interrogation data are generated for previously-tagged fish recaptured at the trap.
SCL	Spring Creek NFH Adult Ladder	Adult Fishway at Spring Creek National Fish Hatchery

Table A3. Continued.

SCP	Spring Creek Acc. Pond behind Winthrop NFH	Monitored Release at Spring Creek Acc. Pond at Winthrop NFH
SFG	SF Salmon River near Guard Station Rd. Bridge	This is an in-stream interrogation system located at rkm 30 near the lower South Fork Salmon River Guard Station on the South Fork Salmon River. It consists of six flat plate antennas, spanning 36 meters across the low-water channel.
SFL	Shipherd Falls Ladder	This site is located at Shipherd Falls adult fish ladder, on the Wind River near Carson, WA. The PIT tag interrogation antennas are installed in series in the second and third slots below the adult fish trap. Antenna F1 is upstream of antenna F2.
SIP	Similkameen Acc. Pond	Similkameen Acclimation Pond
SNJ	Snake River Trap	The Snake River Smolt Trap is located at River Kilometer 225 on the Snake River, immediately above the confluence with the Clearwater River. SNJ has been deployed annually during the Spring since 1989.
SSJ	Sunnyside Dam Juvenile Diversion	Sunnyside Dam Smolt Bypass
STL	Sawtooth Hatchery Adult Trap	Sawtooth Hatchery Adult Trap
STR	SF Salmon Satellite Facility	South Fork Salmon Satellite Facility downstream of Knox Bridge
SUJ	Sullivan Dam Juvenile Bypass System	The Sullivan Dam smolt bypass trap is located in the Sullivan Dam powerhouse (operated by PGE) at Willamette Falls on the Willamette River.
SWT	Sweetwater Creek near its mouth	In-stream detectors on Sweetwater Creek, near the confluence with Lapwai Creek. This is an in-stream interrogation system consisting of two separate antennas, 10 feet apart and approximately 0.2 miles upstream from the mouth of Sweetwater Creek.
TAY	Big Creek (Idaho) at Taylor Ranch	In-stream detectors centered around the bridge at Taylor Ranch, Big Creek, ID. It consists of two MUX arrays, spanning Big Creek, above and below the bridge.
TMA	Three Mile Falls Dam Adult Fishway	Three Mile Falls Dam (Umatilla River) Adult Fishway. This was a modest detection system in the adult ladder on the east shore at TMF. It consisted of one or two DF-2001F transceivers and racket antennas, with the antennae affixed externally to the count
TMF	Three Mile Falls Dam Fishway and Diversion	Adult Fishway and Juvenile Bypass/subsampling facility at Three Mile Falls Dam
TMJ	Three Mile Falls Dam Juvenile Diversion	Three Mile Falls Dam (Umatilla River) Juvenile Fish Bypass System. The TMF smolt bypass trap is located at the irrigation diversion screen on the west shore at TMF.
TRC	Trout Creek In-stream Detection,Wind River	The Trout Creek interrogation system is located at RKM 4 on Trout Creek, in the Wind River (WA.) Basin above Hemlock Lake.
TUF	Tumwater Dam Adult Fishway	Adult Fishway at Tumwater Dam
TWR	Lower Twisp River near MSRF Ponds	In-stream detectors on the lower Twisp River adjacent to the Methow Salmon Recovery Foundation Ponds.
TWX	Estuary Towed Array (Experimental)	The TWX experimental trawl detector is typically deployed in the Columbia River estuary, at and above Jones Beach (rkm 75).
UM1	NF Umatilla River at Forks Campground Bridge	In-stream detectors on the North Fork Umatilla River at Forks Campground. This site is located at a bridge approximately 100m above the mouth of the North Fork Umatilla River.
UM2	Umatilla River Array above Imeques Acc. Pond	In-stream detectors on the mainstem Umatilla River upstream of Imeques Acc. Pond.
UWE	Upper Wenatchee River	This is a passive in-stream interrogation system at Wenatchee River rkm 86, below the confluence with the Chiwawa River, consisting of a single antenna array spanning the width of the river.
VC1	Valley Creek,in-river at Stanley,ID	This is an in-stream interrogation system located on Valley Creek at Stanley, ID., in the Upper Salmon River.
VC2	Valley Creek,in-river below Stanley,ID	This is an in-stream interrogation system located on Valley Creek below Stanley, ID., in the Upper Salmon River.
WAJ	Wanapum Dam Juvenile (gatewell dip)	Wanapum Dam Smolt Bypass (Gatewell Dip)
WEA	Wells Dam Adult Fishways	Wells Dam Adult Fishways (both)
WFC	Wolf Creek In-stream Array,Chewuck River	In-stream detector on Wolf Creek, Methow River Basin
WFF	Willamette Falls Adult Fishway	Willamette Falls Adult Fishway
WHC	Mouth of White Creek,Klickitat River Basin	Instream detection system near the mouth of White Creek, Klickitat River Basin
WPJ	Wapato Dam Juvenile Diversion	Wapato Dam Smolt Bypass
WSH	Adult fishway at Warm Springs NFH	Adult Fishway at Warm Springs NFH
WTL	White River,Wenatchee Basin	This is a passive in-stream interrogation system at White River rkm 4, located at the old fish weir site, consisting of a single antenna array spanning the width of the river.
WW1	SF Walla Walla River at Harris Park Bridge	In-stream detectors at Harris County Park Bridge, South Fork Walla Walla River
WW2	SF Walla Walla River at Bear Creek	In-stream detectors at Bear Creek, South Fork Walla Walla River
Y1J	Yakima River Trap	Yakima River Smolt Trap at Van Giesen Bridge
YHC	Yellowhawk Creek	Yellowhawk Creek in-stream detection site, between Mill Creek and Walla Walla River. The interrogation system consists of a two full-stream antenna (A1) located below the Mill Creek Diversion headgate, and a second full-stream antenna (B1) located near W
ZEN	Secesh River near Zena Creek Ranch	This is an in-stream interrogation system consisting of two separate antenna arrays, 130 meters apart, near the Zena Creek Ranch.
ZSL	Zosel Dam Adult Fishways	Adult Fishways at Zosel Dam, Okanogan River below Osoyoos Lake

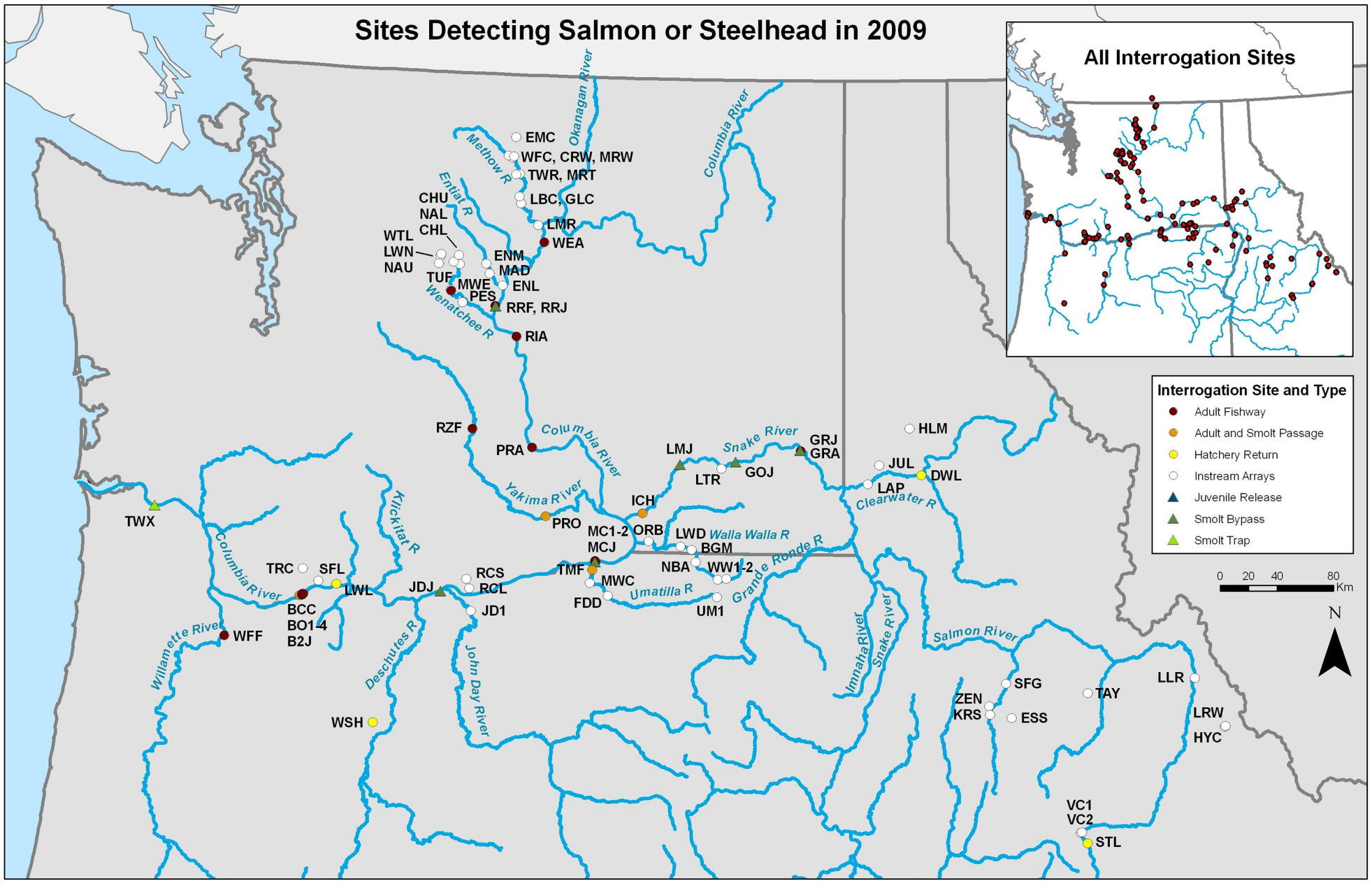

Figure A1. Map of Columbia River interrogation sites that detected Chinook and sockeye salmon, and steelhead in 2009. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

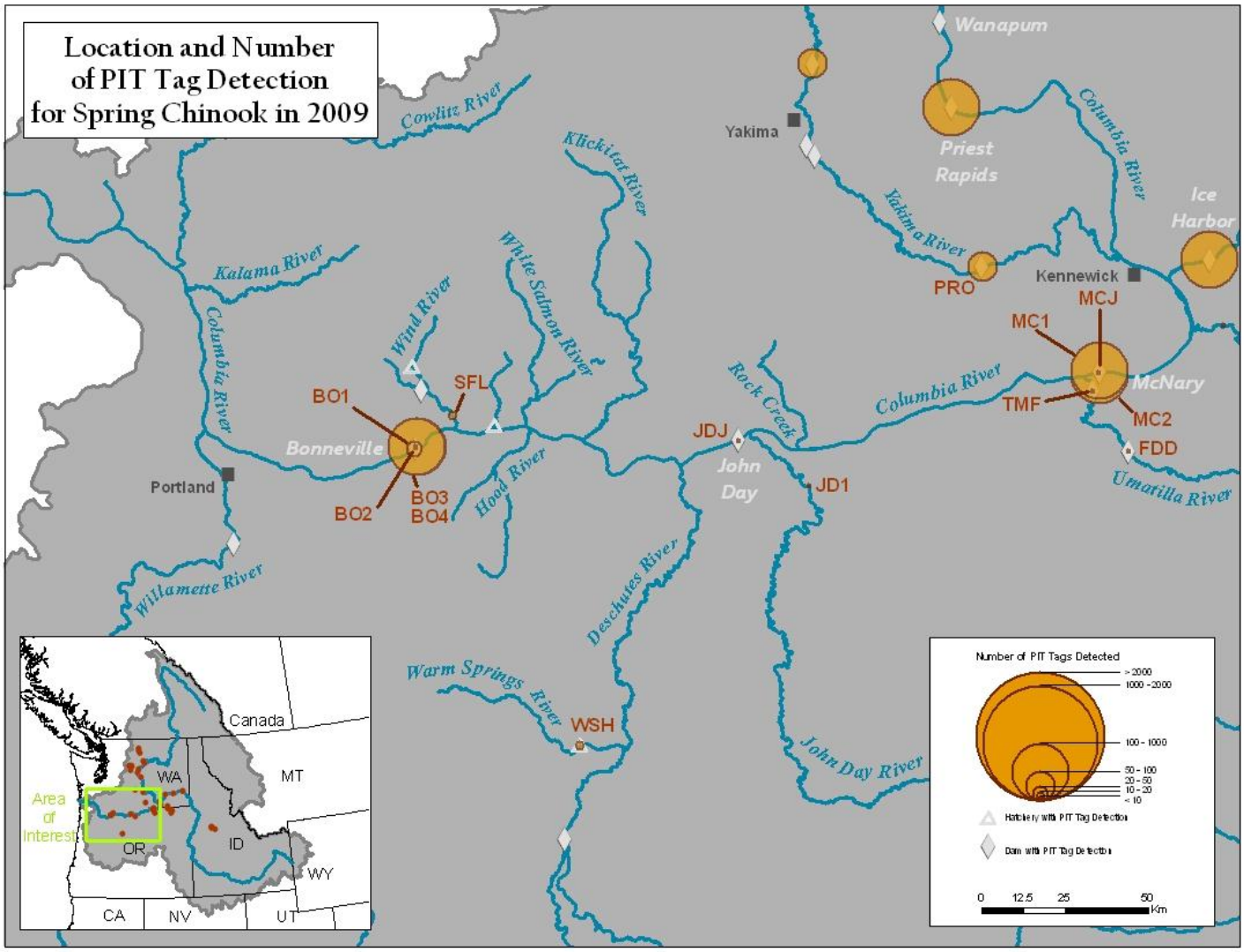

Figure A2. Map of Lower Columbia River detections sites and number of spring Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

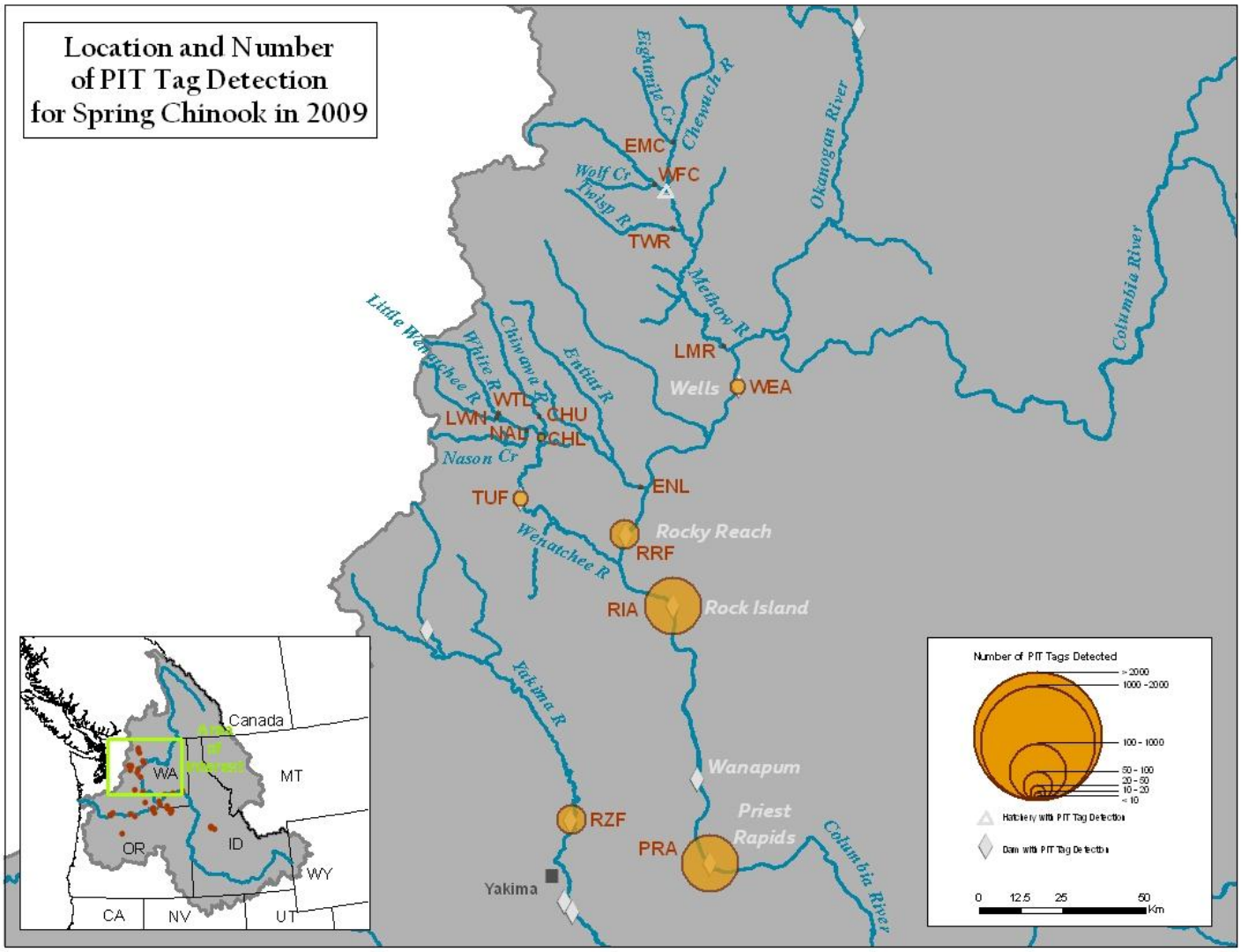

Figure A3. Map of Upper Columbia River detections sites and number of spring Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

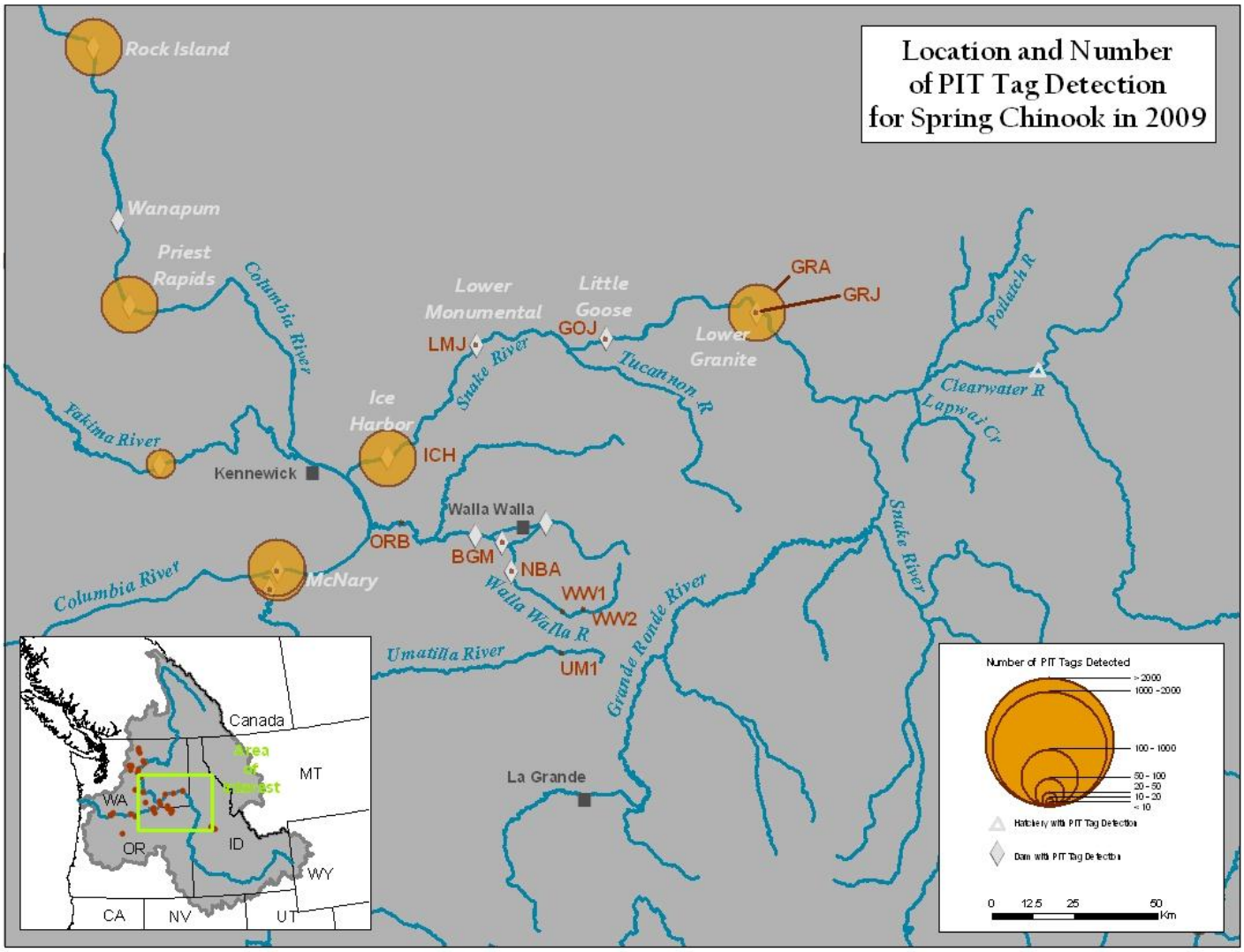

Figure A4. Map of Lower Snake River detections sites and number of spring Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

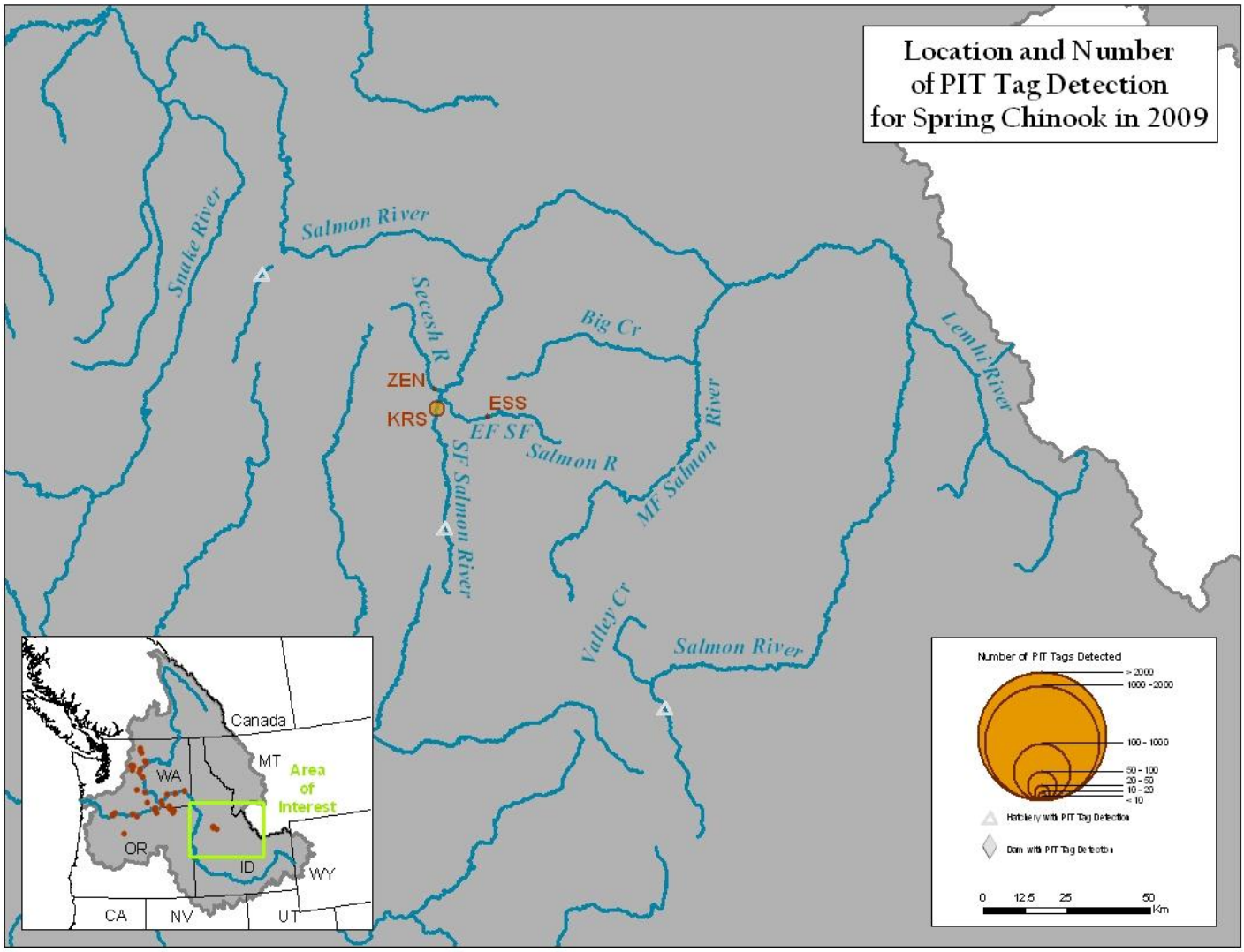

Figure A5. Map of Salmon River detections sites and number of spring Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Spring Chinook is defined as fish passing Bonneville Dam from January 1 to June 1.

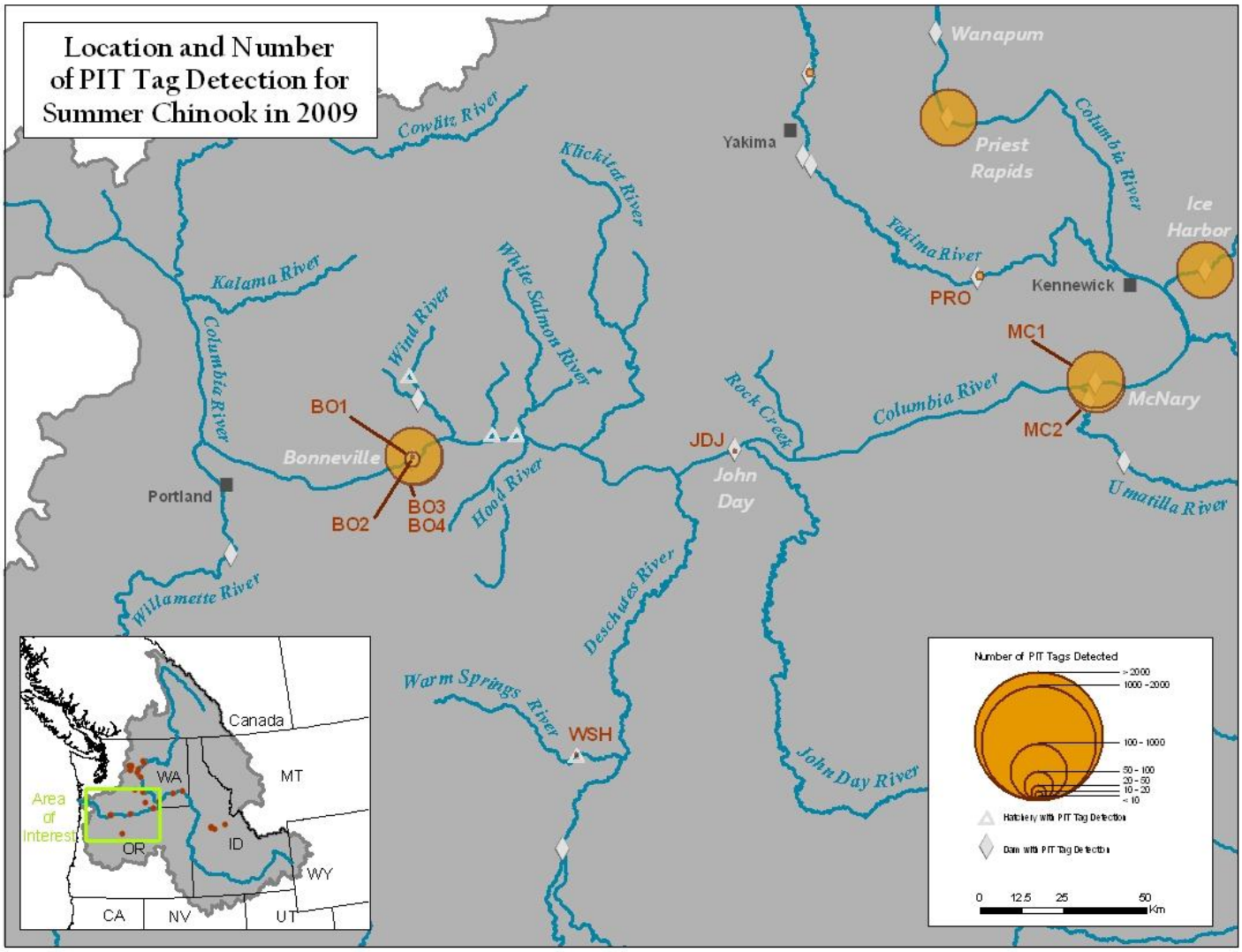

Figure A6. Map of Lower Columbia River detections sites and number of summer Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

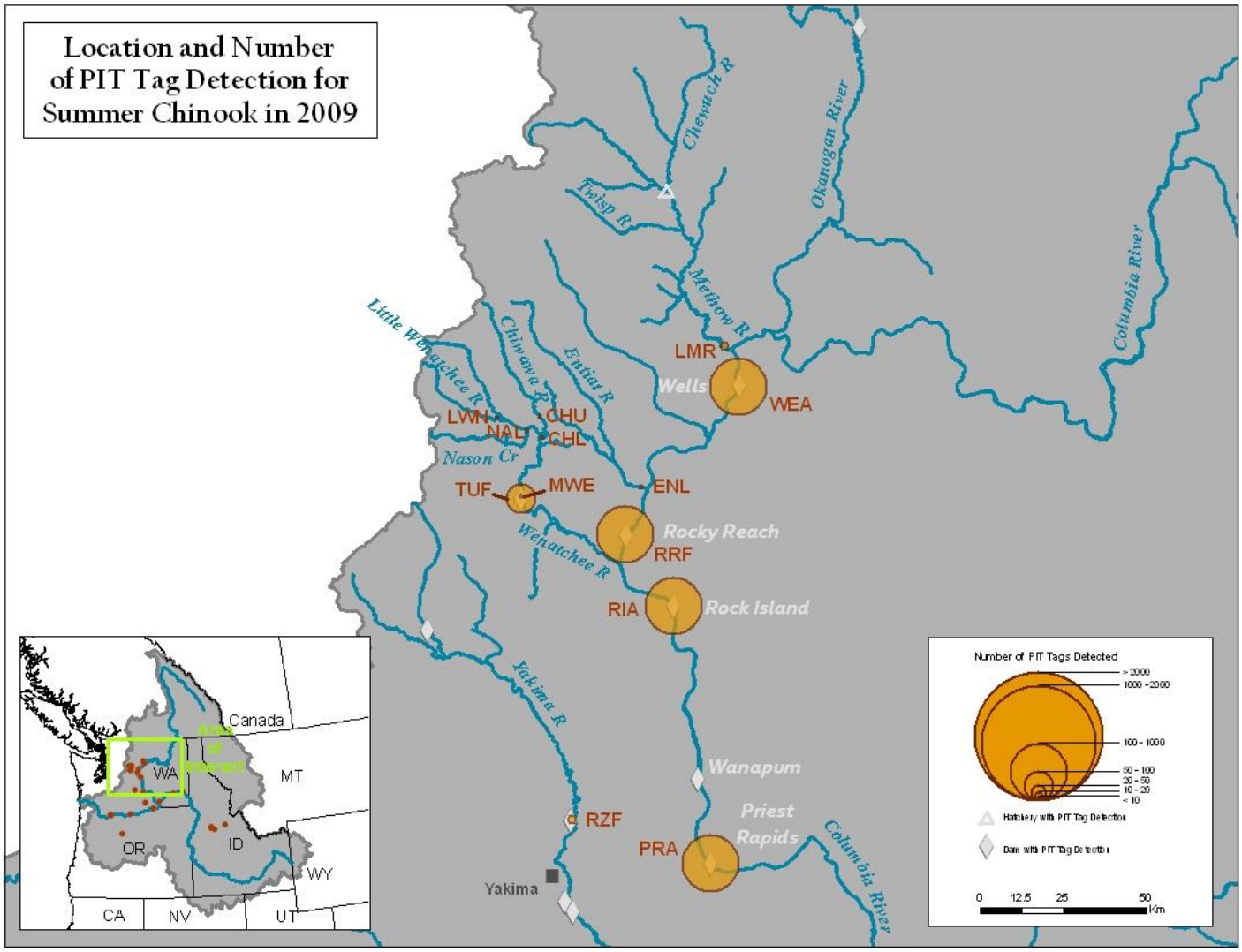

Figure A7. Map of Upper Columbia River detections sites and number of summer Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

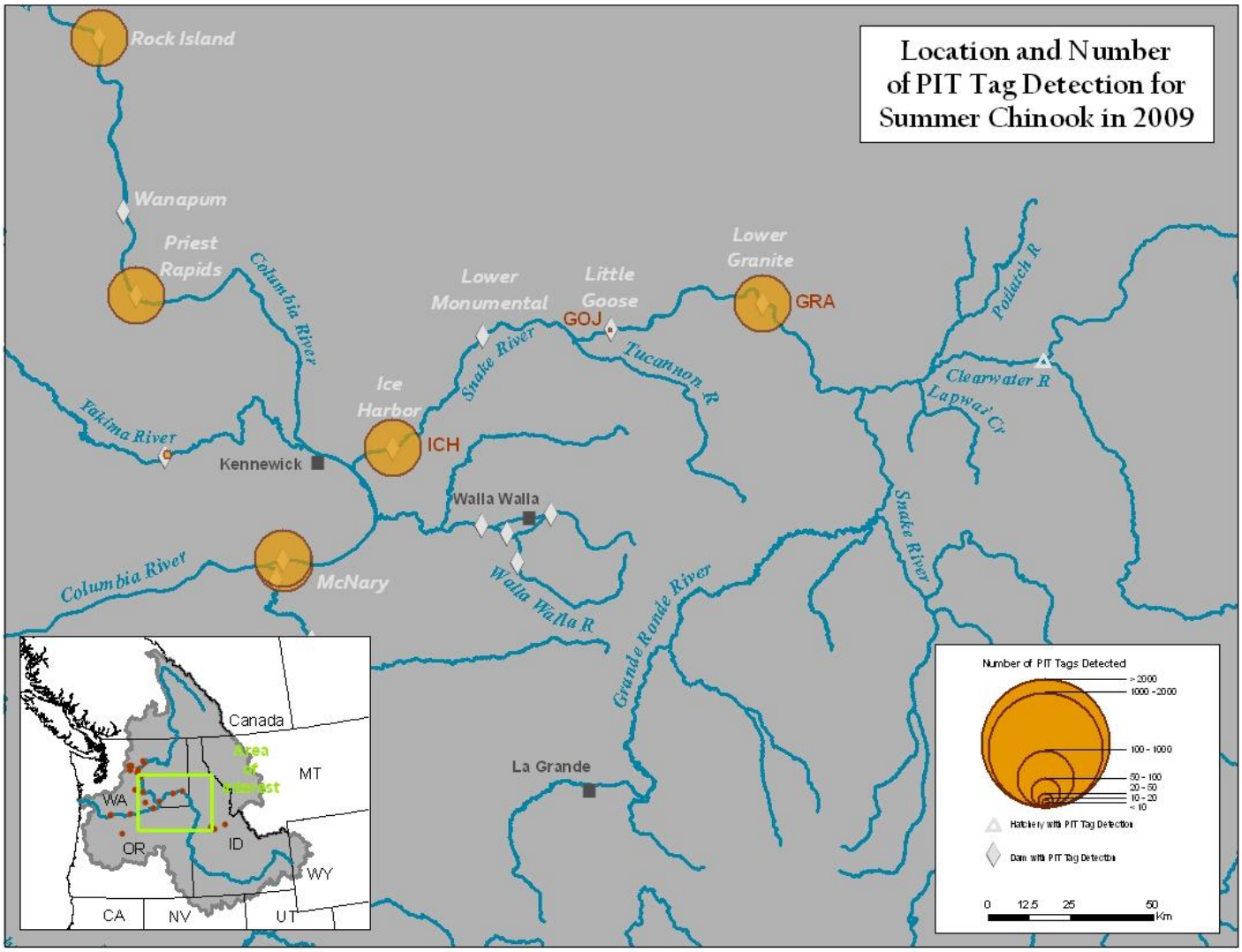

Figure A8. Map of Lower Snake River detections sites and number of summer Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

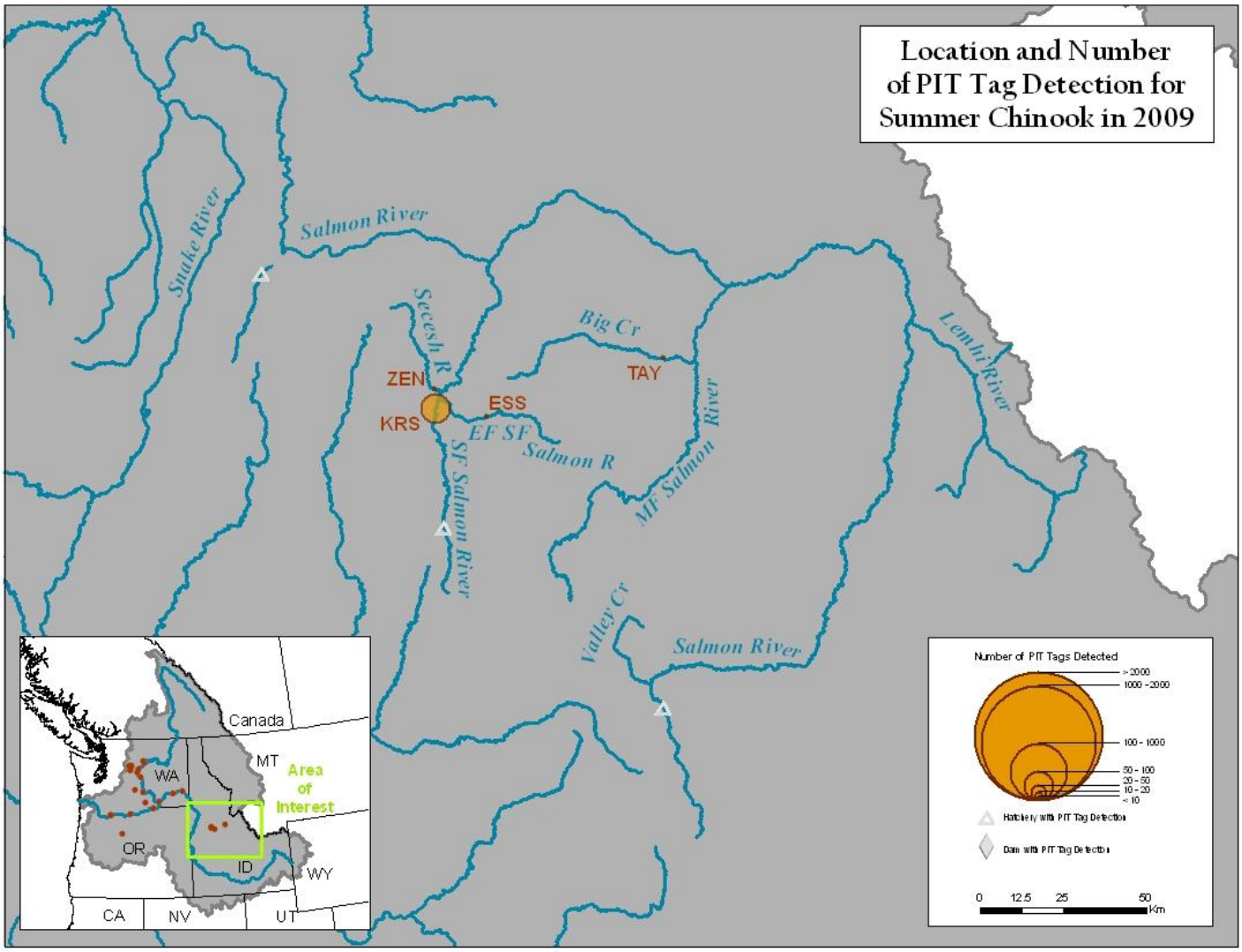

Figure A9. Map of Salmon River detections sites and number of summer Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Summer Chinook is defined as fish passing Bonneville Dam from June 1 to August 1.

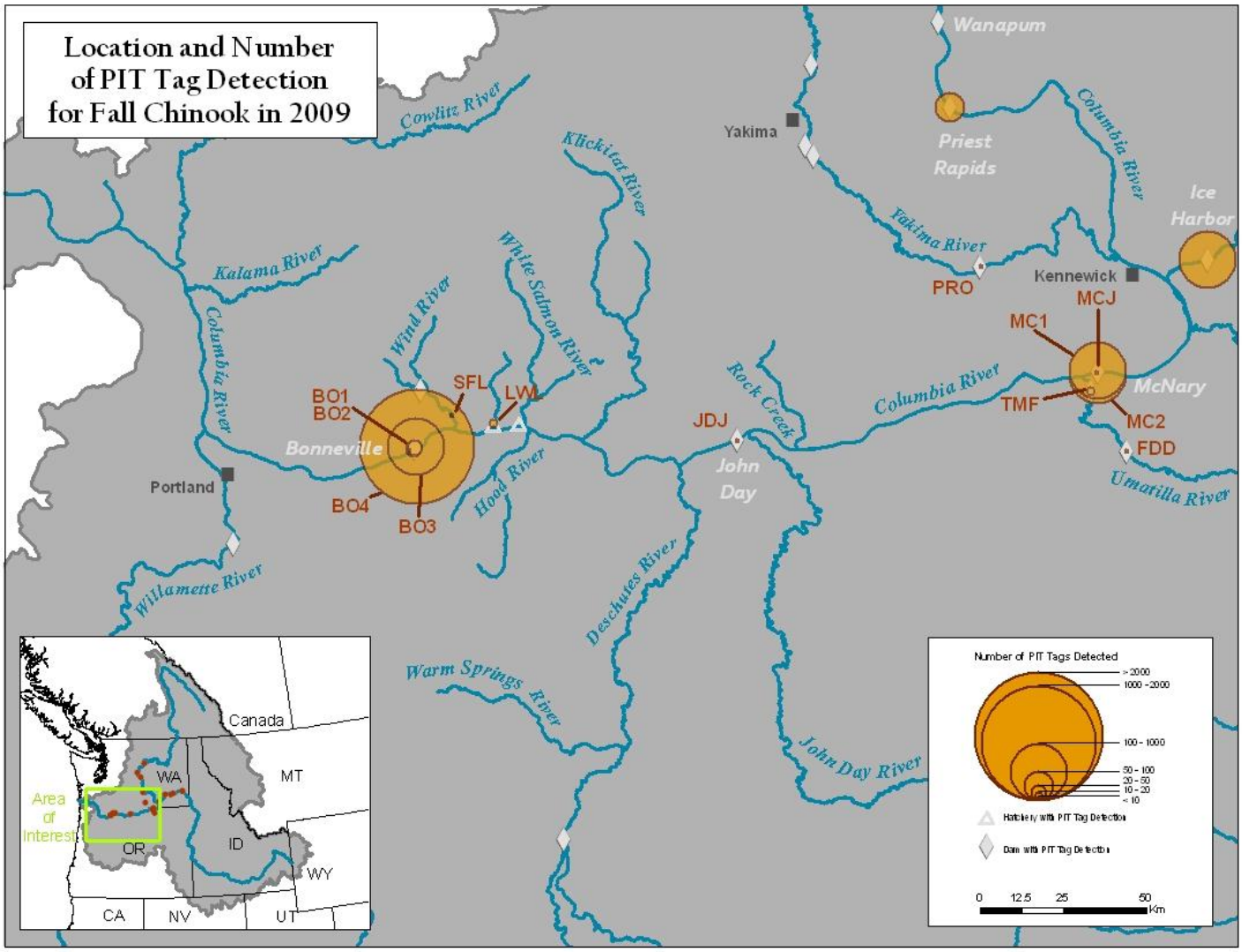

Figure A10. Map of Lower Columbia River detections sites and number of fall Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

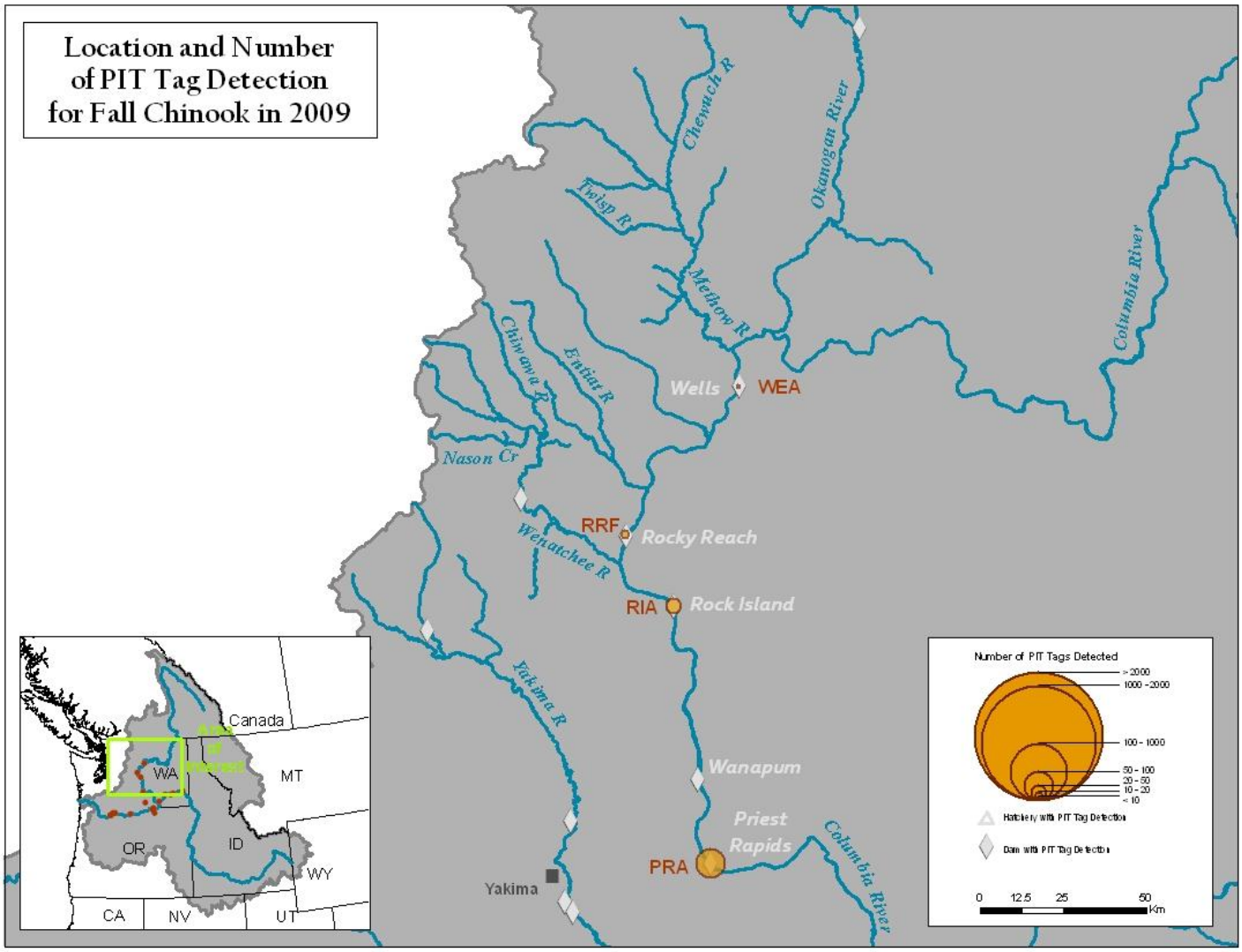

Figure A11. Map of Upper Columbia River detections sites and number of fall Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

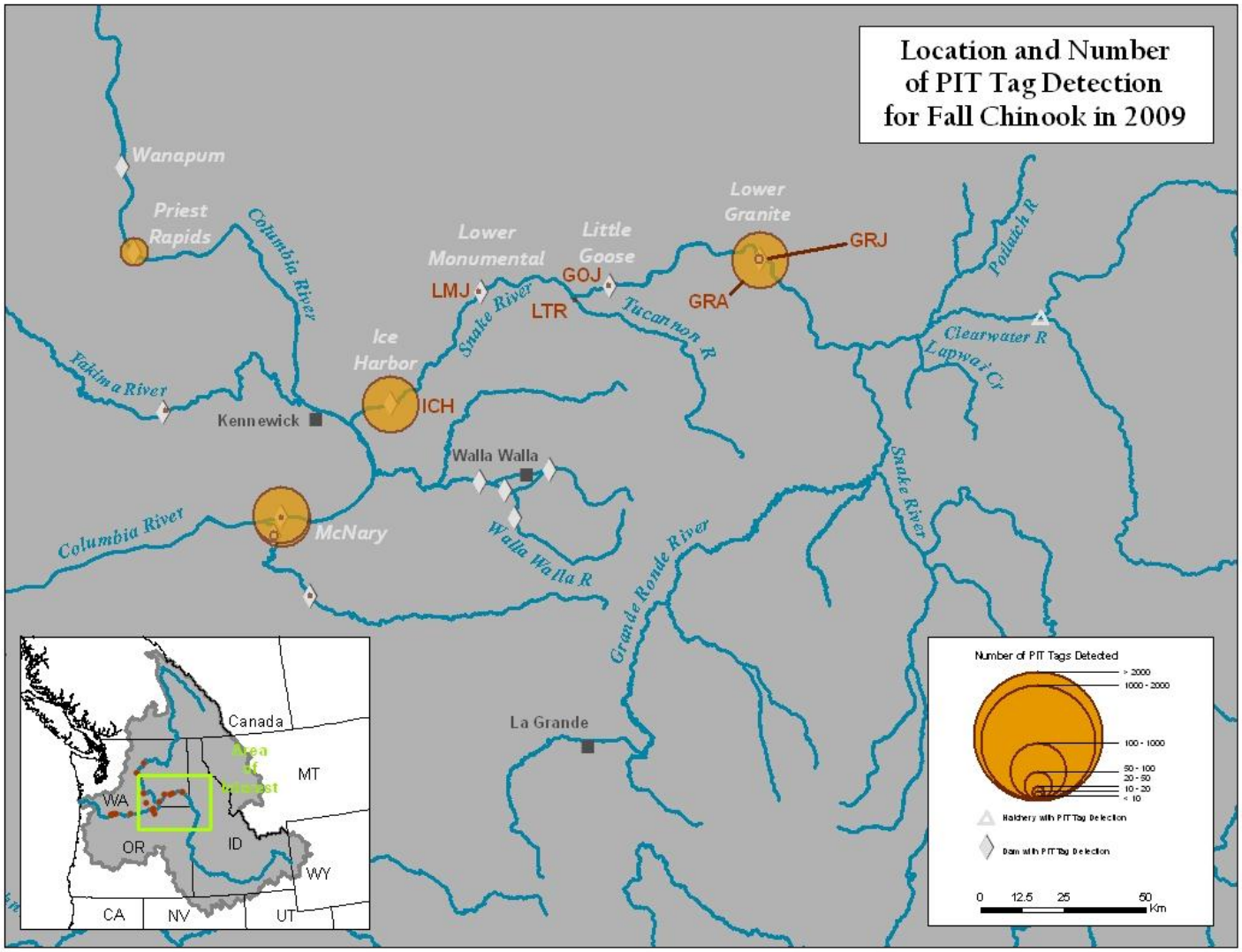

Figure A12. Map of Lower Snake River detections sites and number of fall Chinook detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map. Fall Chinook is defined as fish passing Bonneville Dam from August 1 to end of year.

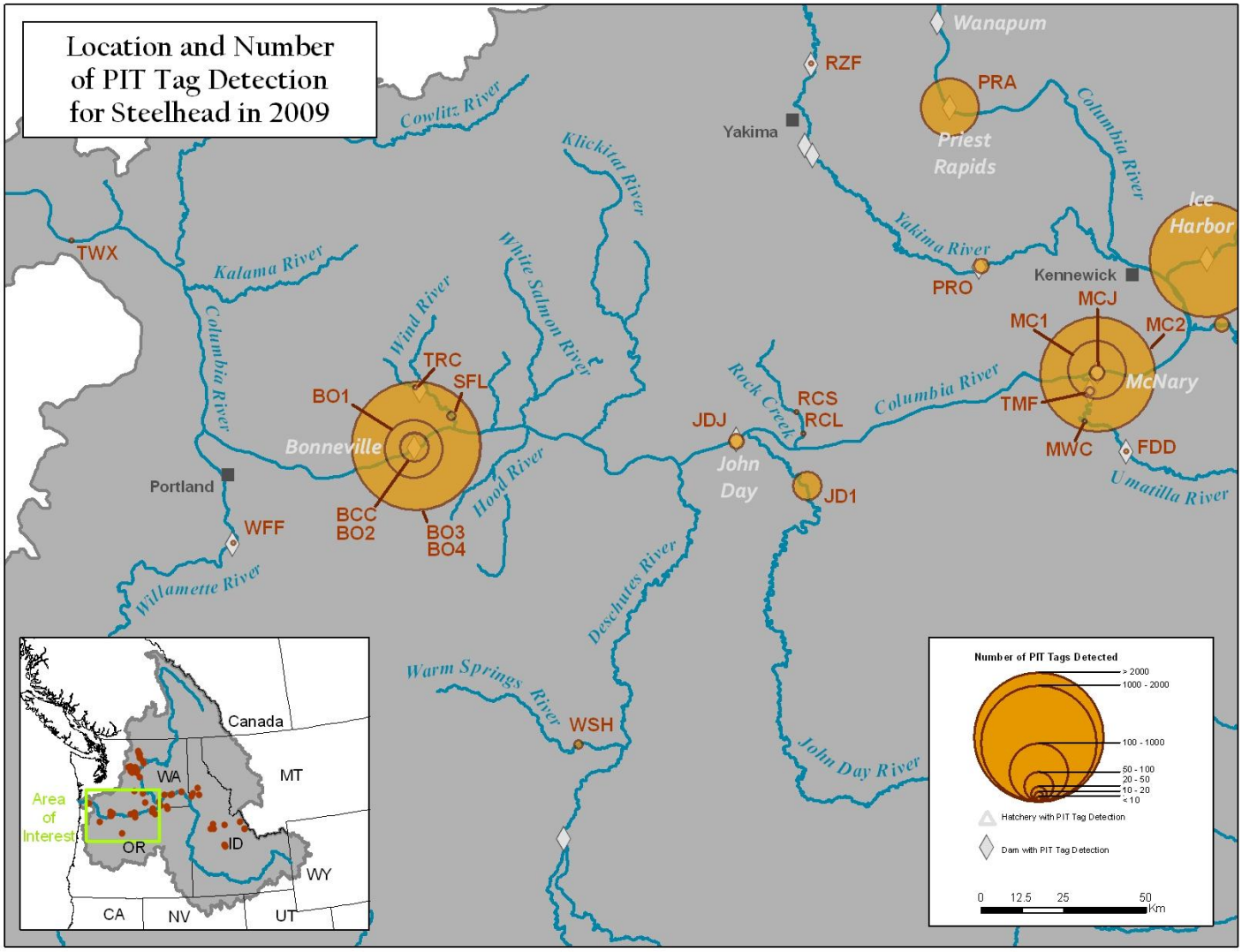

Figure A13. Map of Lower Columbia River detections sites and number of steelhead detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

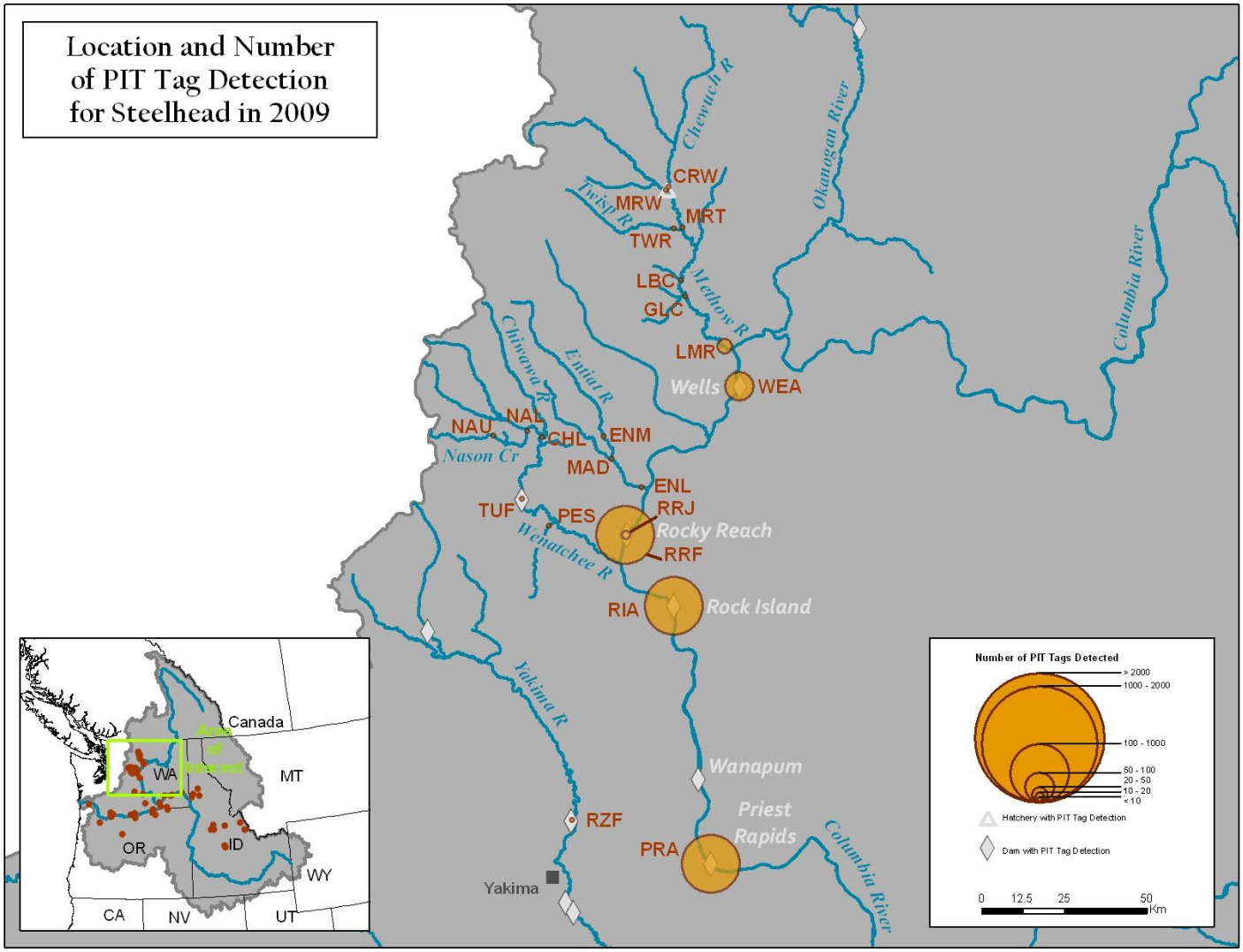

Figure A14. Map of Upper Columbia River detections sites and number of steelhead detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

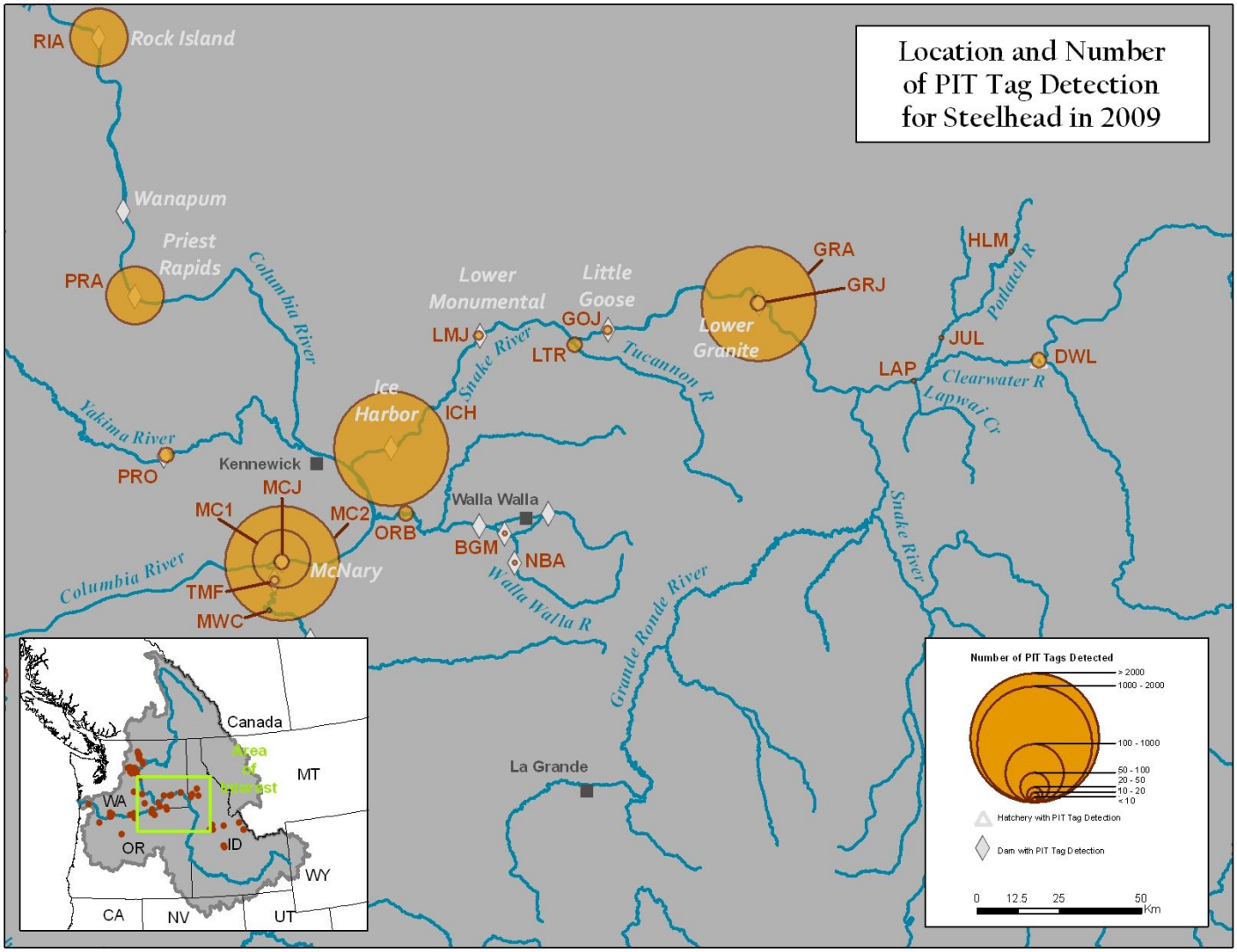

Figure A15. Map of Lower Snake River detections sites and number of steelhead detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

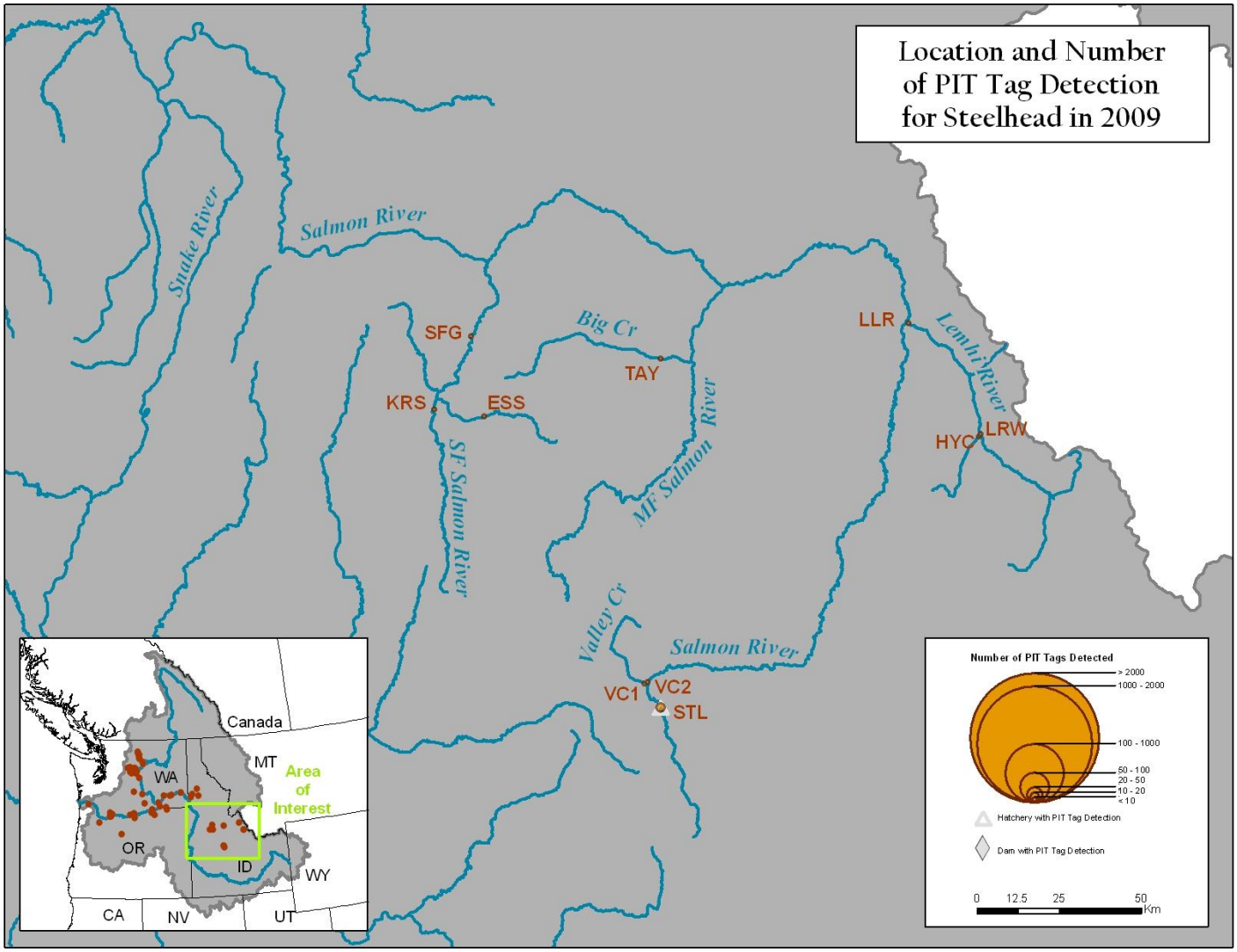

Figure A16. Map of Salmon River detections sites and number of steelhead detected. Table A3 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.