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TECHNICAL REPORT 13-04

Upstream Migration Timing of Columbia Basin Chinook Salmon, Sockeye Salmon, and Steelhead in 2011

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March 31, 2013

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

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ABSTRACT

In 2011 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) tags. These fish were tracked upstream as they passed through sites with PIT tag antennas, including fish ladders at dams, juvenile bypasses, hatcheries, weirs, as well as in-stream antennas. Total numbers of fish tracked upstream were 1045 spring Chinook, 814 summer Chinook, 1309 fall Chinook, 1377 steelhead, and 747 sockeye salmon.

Chinook travel rates between mainstem dams ranged between 20.6 and 37.5 km/day. 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 passed 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 -6.1% to +17.6% at mainstem dams.

Steelhead median rates between mainstem dams ranged from 15.8 km to 28.2 km/day. Steelhead classified as B-run (greater or equal to 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 late September and early October at over 40% of the total steelhead run, while the estimated weekly number of B-run steelhead passing Bonneville Dam peaked in mid-September at nearly 7,000 fish. A total of 49 PIT tagged steelhead tracked in 2011 were detected moving downstream (mostly in juvenile bypasses) after February, 12 presumably in an attempt to return to the ocean after spawning.

The estimated stock composition of sockeye salmon passing Bonneville Dam was 76.8% Okanagan, 21.9% Wenatchee, and 1.3% Snake. Upstream survival of sockeye salmon was highest early and late in the run.

The mean travel rate between Bonneville and Rock Island Dam was 34.4 km per day. Sockeye passing Bonneville Dam later in the migration traveled upstream faster than those earlier in the migration.

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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 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 antennas are now installed in fish ladders at most mainstem Columbia and Snake River dams, as well as at dams and weirs on many of the Columbia Basin tributaries. By PIT tagging fish that we sample at Bonneville Dam, we can track tagged fish upstream providing valuable information on migration timing and survival rates. 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, data on the movement of PIT tagged fish through Columbia Basin receivers is readily available to all managers and researchers on a near real-time basis through the PIT Tag Information System (PTAGIS) at www.ptagis.org. The information obtained by PIT tags can be further expanded by identifying the origin of the fish using GSI. Using these two technologies it becomes possible, to determine migration timing, stray rates, and upstream survival on a stock-specific basis for Chinook and sockeye salmon and steelhead.

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

METHODS

Sampling

Chinook and sockeye salmon, as well as steelhead, were PIT tagged from April 19 through October 11, 2011, at the Bonneville Dam Adult Fish Facility (AFF), located adjacent to the Second Powerhouse at river km 235. This facility uses a weir with four pickets to divert fish ascending the Washington shore fish ladder into the AFF collection pool. An attraction flow is used to draw fish that enter the collection pool through a false weir where they then can be selected for sampling. Fish not selected, and fish that have recovered from sampling, migrate back to the Washington shore fish ladder above the pickets.

Salmon and steelhead selected for sampling were anesthetized, 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 (Whiteaker and Fryer 2008, Kelsey et. al 2011). Fish were scanned for PIT tags. If no tags were detected, standard techniques were used to inject PIT tags through a needle that penetrates the fish between the posterior tip of the pectoral fin and the anterior point of the pelvic girdle (CBFWA 1999). Tagged fish were then scanned for the PIT tag code, which was recorded if detected. If no tag was detected, no effort was made to re-tag the fish. Data on each PIT tagged fish was uploaded to www.ptagis.org.

In 2011 a new 9 mm PIT tag (model TX149011B) was tested for effectiveness compared to the standard 12.5 mm tag (model TX1400SST). These tags measured 9.0 mm in length and 2.04 mm in diameter compared to the SST dimensions of 12.45 mm by 2.01 mm. In each day's sampling, every fifth steelhead, Chinook, and sockeye salmon was tagged with the 9 mm tag with the remaining fish being tagged with the 12.5 mm tags.

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 A4 and Figure A1). Many of the receivers automatically upload, nearly in real time, PIT tag detection data to www.ptagis.org, which is then accessible to users of the site.

Age Analysis

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

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

Upstream Detection

At each site with PIT tag detection, PIT tagged salmon typically pass by a weir with one or more antennas. Salmon can be detected more than once as the pass over or through each weir. Each individual detection will subsequently be referred to as a “weir detection”. The combination of all detections at the many weirs at a given site, regardless of the time between those detections, will subsequently be referred to as a “site detection”. For example, the configuration of PIT tag antennas at Rock Island Dam is shown in Figure 1.

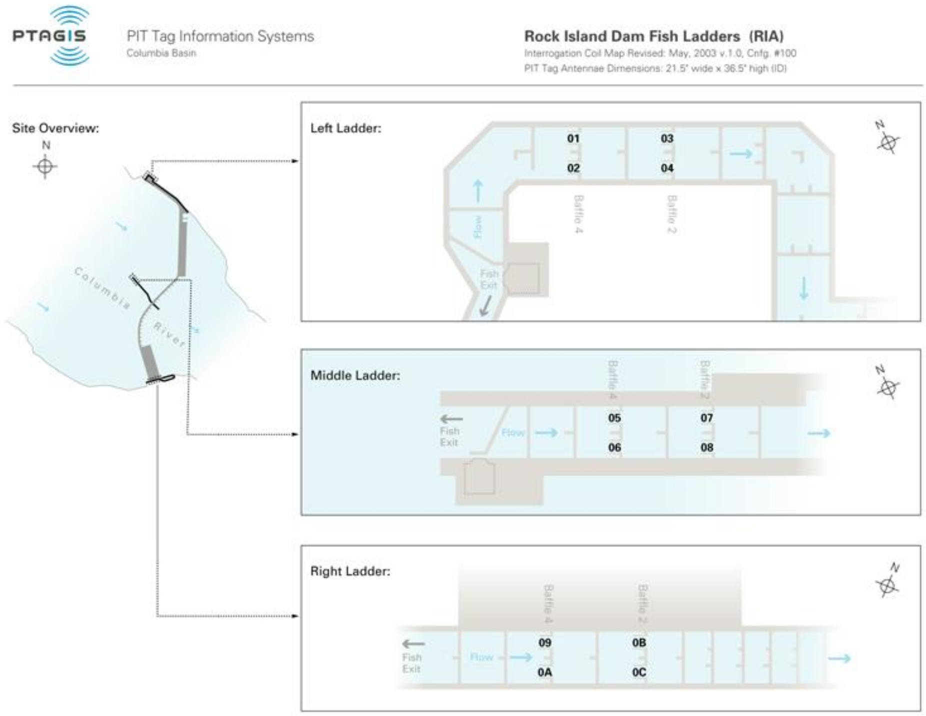

Figure 1. Example PIT tag configuration at Rock Island Dam showing two adjoining antennas at two weirs in each fish ladder.

Salmon can pass this dam using any of three fish ladders. Each ladder has two weirs (referred to as baffles 2 and 4 at each ladder) with PIT tag detection and two antennas in each weir (numbered as 01 to 0C in hexadecimal format). If a fish ascended the left ladder and generated two detections at Baffle 2 and three at Baffle 4 (the word “baffle” and “weir” is interchangeable), this is five weir detections, but only one site detection (Rock Island Dam).

Escapement

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

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

where N was the estimated escapement at a particular upstream site, i was the week at Bonneville Dam, B_i was the weekly count of fish passing Bonneville Dam in week i, T_i was the number of fish PIT tagged at Bonneville Dam in week i, and R_i was the number of PIT tag detections at the dam where escapement was being estimated of those fish tagged in week i. Estimated dam counts using PIT tag data were compared with dam counts made at fish ladder viewing windows or weir counts. No estimates were made for steelhead, due to the fact that many overwinter between dams on their upstream migration making it difficult to compare PIT tag estimates with dam counts.

Site Detection Efficiencies

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

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

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

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

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.

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, steelhead, and sockeye salmon tagged with the two tag types were observed at mainstem dams and weirs with PIT tag detection.

Migration Rates and Passage Times

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. Salmonids passing Bonneville, McNary, Ice Harbor, and Lower Granite dams are counted live by observers stationed at fish ladder viewing windows from 0400 to 2000 PST (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2012/index.html), while salmonids passing Priest Rapids, Rock Island, Rocky Reach and Wells dams are all counted 24 hours per day from recorded video. Tributary dam passage is estimated using 24 hour recorded video and/or counts at adult fish traps.

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

Fallback

Three methods were used to determine fallback, which is defined as a fish that ascends a fish ladder into the reservoir above the dam, then "falls back" to the downstream side of the dam either over the spillway, or through the navigation locks, juvenile bypass systems, or turbines. The first was if an adult salmon or steelhead was detected in the juvenile bypass system. However, on the Columbia River, only Bonneville, John Day, McNary, Rocky Reach dams have juvenile bypass system PIT detection capability while all four dams in the Snake River have juvenile detection. Furthermore, there is no detection at any dam for fish falling back over the spillway or through the navigation locks or turbines. Therefore, a second method of estimating fallback was to look at each dam for fish detected at an "upper" weir followed by detection at a "lower" weir separated by more than two hours. At McNary and Bonneville dams, the upper detection weir is at the fish counting window (which are believed to detect all passing PIT tagged fish), while the PIT tag detectors near the entrance to the fish ladder. At Priest Rapids, Rock Island, Rocky Reach, and Wells dams, there are only two weirs with PIT tag detectors in each fish ladder so these were designated as the upper and lower detection weirs, even if they are not at the top or bottom of the ladders. At McNary and Bonneville dams, detection histories of fish detected at multiple ladders were also reviewed (MC1 and MC2 for McNary and BO1 and BO4 for Bonneville (http://www.ptagis.org for maps of sites)). Finally, a third method of defining fallback was ascertained by fish that passed an upstream PIT tag detector at a given dam, then were next observed at a site downstream of the dam in question. These methodologies will underestimate fallback as they do not include fish that fall back over a dam and are not subsequently detected.

Adult steelhead detected at juvenile facilities on or after March 1, 2012 were not considered fallbacks; rather they were considered kelts on their way downstream.

Steelhead B-Run Analyses

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

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

Steelhead (Kelt) Analyses

Steelhead differ from other salmonids studied in this project for they are capable of spawning multiple times. After spawning in late winter or early spring, some steelhead will migrate downstream to the ocean to feed and return in another year to spawn again; these fish are known as kelt. We considered all steelhead detected moving downstream (mostly in juvenile bypasses) on or after March 31, 2011 to be kelt and tabulated where they were last detected.

Sockeye Stock Classification

Columbia Basin sockeye salmon consist of two major runs returning to the Okanogan and Wenatchee basins and one very small run returning to the Snake River that is listed under the Endangered Species Act. In addition, there are efforts underway to reintroduce sockeye to former habitat in the Deschutes and Yakima basins. Given the relatively small number of geographically separated stocks, sockeye PIT tagged at Bonneville Dam can be classified by stock based on the point where they were last detected. Those individuals last observed at or upstream of Rocky Reach Dam were classified as Okanagan stock, those last observed at or upstream of Tumwater Dam were classified as Wenatchee stock, those last observed at or upstream of Ice Harbor Dam were classified as Snake River stock, and those last observed downstream of all these sites were classified as unknown and were also considered mortalities. Sockeye (as well as other species tagged) never detected after release were subtracted from the number of fish tracked for subsequent analysis.

RESULTS-CHINOOK

Sample Size

A total of 1043 spring Chinook, 807 summer Chinook, and 1322 fall Chinook salmon were PIT tagged in 2011 (Tables 1-3). No sampling was conducted during Statistical Week 31 due to planned in-season modifications to the trap taking longer than anticipated. Sampling was also halted between August 12 and 17 (portions of Statistical weeks 33 and 34) and reduced September 12 (Week 38) due to water temperatures at the trap exceeding 22.2C. 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 (due to shed tags, mortalities, malfunctioning tags, or Chinook missing PIT tag antennas after tagging), the numbers of Chinook tracked upstream consisted of 1045 spring Chinook, 814 summer Chinook, and 1309 fall Chinook salmon (Table 1-3).

Table 1. Number of PIT tagged spring Chinook salmon tracked at Bonneville Dam by date and statistical week in 2011.

			Tagged		Recaptures of previously tagged fish	Tracked upstream of Bonneville	
Sampling Dates	**Statistical Week**	**Sampled (n)**	**12.5 mm**	**9 mm**	**12.5 mm**	**12.5 mm**	**9 mm**
4/19[a]	17	9	1	8	0	1	8
4/27-29	18	130	103	25	2	103	22
5/2-6	19	288	184	46	3	186	42
5/9-13	20	246	196	44	4	198	43
5/16-20	21	159	106	49	2	107	48
5/23-27	22	214	171	37	4	175	35
5/30-31	23	77	60	13	4	64	13
Total		**1123**	**821**	**222**	**19**	**834**	**211**

Table 2. Number of PIT tagged summer Chinook salmon tracked at Bonneville Dam by date and statistical week in 2011.

			Tagged		Recaptures of previously tagged fish	Tracked upstream of Bonneville	
Sampling Dates	**Statistical Week**	**Sampled (n)**	**12.5 mm**	**9 mm**	**12.5 mm**	**12.5 mm**	**9 mm**
6/3	23	52	42	10	0	42	10
6/6-6/10	24	240	184	41	12	193	40

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[a] On April 19, 12.5 and 9 mm tag trays were inadvertently switched; therefore mostly 9 mm tags were deployed.

6/13-6/17	25	190	151	35	4	150	34
6/20-6/23	26	82	66	14	2	68	14
6/27-7/1	27	92	76	16	0	73	16
7/5-7/8	28	57	43	10	4	45	10
7/11-7/14	29	67	51	14	2	53	11
7/18-7/22	30	56	45	9	2	47	8
Total		**836**	**658**	**149**	**26**	**671**	**143**

Table 3. Number of PIT tagged fall Chinook salmon tracked at Bonneville Dam by date and statistical week in 2011.

			Tagged		**Recaptures of previously tagged fish**	**Tracked upstream of Bonneville**	
Sampling Dates	**Statistical Week**	**Sampled (n)**	**12.5 mm**	**9 mm**	**12.5 mm**	**12.5 mm**	**9 mm**
8/1-8/5	32	24	22	2	0	21	2
8/9-8/11	33	7	6	0	1	7	
8/18-8/19	34	5	5	0	0	5	
8/22-8/25	35	68	54	12	2	55	10
8/29-9/1	36	87	68	16	1	69	16
9/5-9/9	37	217	171	41	3	164	36
9/12-9/16	38	206	162	39	5	163	36
9/19-9/23	39	262	208	49	5	208	47
9/26-9/30	40	233	182	41	10	187	39
10/3-10/7	41	211	164	40	7	166	37
10/10-10/11	42	42	33	7	2	34	7
Total		**1362**	**1075**	**247**	**36**	**1079**	**230**

Distribution of Sample

Compared to the distribution of the Chinook run past Bonneville Dam as determined by visual counts, spring Chinook were under-sampled early during the peak weeks of the run (Statistical weeks 18-20) and over-sampled late in the run (Figure 2). Summer Chinook were over-sampled early in the run while under-sampled during the middle of the run (Figure 3). Fall Chinook were under-sampled during the middle of the run and over-sampled at the end of the run (Figure 4).

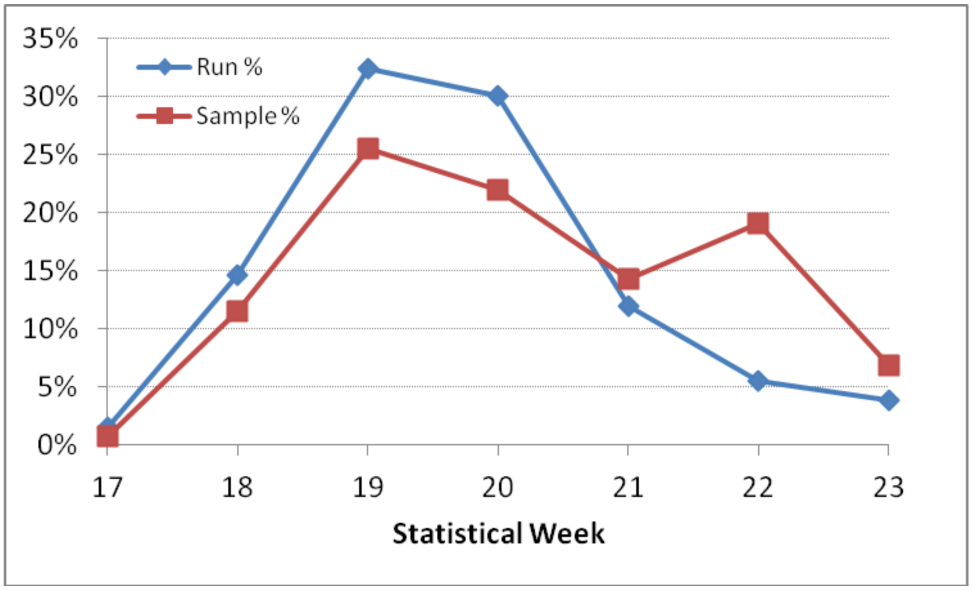

Figure 2. The weekly spring Chinook sample and run as a percentage of the total sample and run size at Bonneville Dam in 2011.

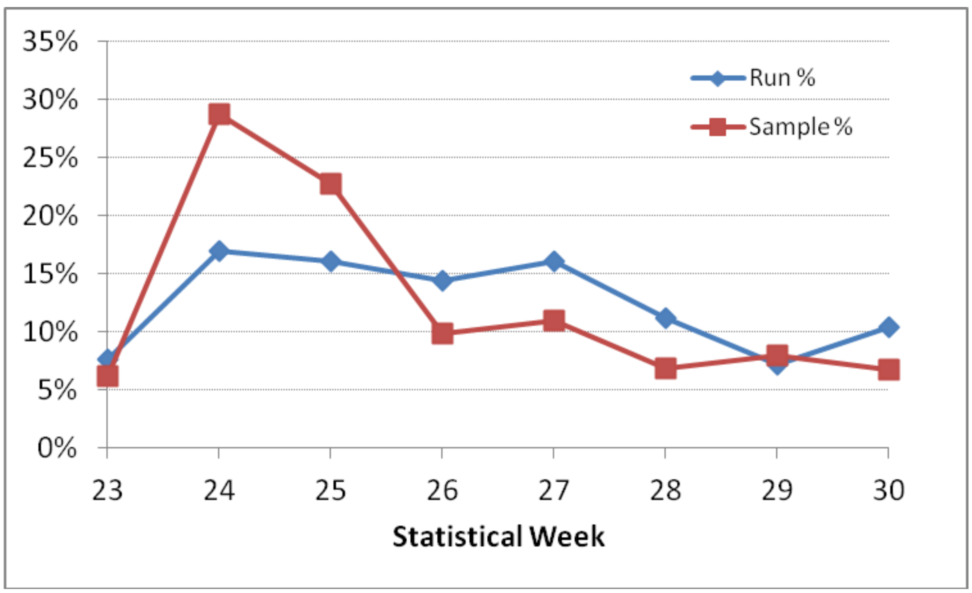

Figure 3. The weekly summer Chinook sample and run as a percentage of the total sample and run size at Bonneville Dam in 2011. No sampling occurred during Statistical Week 31.

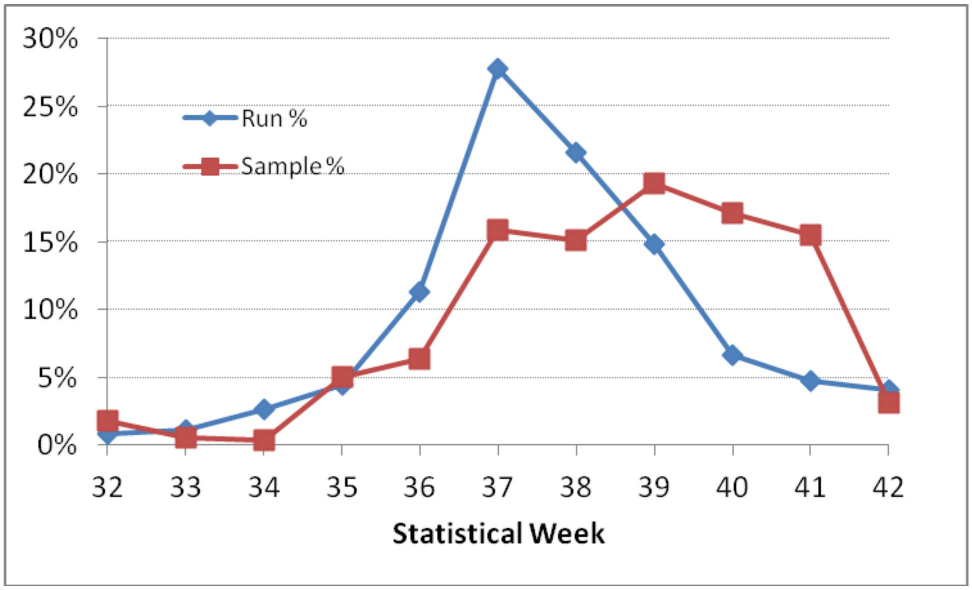

Figure 4. The weekly fall Chinook sample and run as a percentage of the total sample and run size at Bonneville Dam in 2011.

Detection Numbers

The tracking of 1045 spring Chinook generated 44,818 weir detections, which were grouped into 4,228 site detections at 63 sites. The 814 summer Chinook generated 33,370 weir detections, grouped into 3,925 site detections at 62 sites, and the 1309 fall Chinook generated 36,718 weir detections grouped into 3,885 site detections at 33 sites. Maps found in the Appendix (Figure A1-A16) show the sites and 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, with the spring Chinook run ending May 31st, the summer Chinook run ending July 31st, and the fall Chinook run starting August 1st (FPC 2012).

Comparison of 9 and 12.5 mm tags

At 13 out of 21 sites with more than 40 detections of Chinook PIT tagged by this study (Table 4), the percentage of tagged Chinook detected with 9 mm tags was less than expected percentage of 18.7% (the percentage of Chinook in our sample that were tagged with 9 mm tags). Only at Rock Island Dam (p=0.014) and the South Fork Salmon weir (SFG, p=0.035) was this difference statistically significant. In both cases, a lower percentage of 9 mm tagged Chinook was detected than would be expected; suggesting that 9 mm tagged fish may have been missed. Combining all in-stream arrays and weirs also resulted in a statistically significant difference (p=0.015) with 9 mm tagged fish being under-detected. Due to the sparseness of data from most weir and in-river array sites, this report will deal primarily with detection sites at dams. Unless otherwise indicated, data from both tag types was pooled for subsequent analyses presented in this report.

Table 4 Total number of tagged Chinook detected (40 detection minimum) by site, the percentage which were 9 mm tags and the p-value for a comparison with the percentage of 9 mm tags deployed (18.7% in 2011). Significant p-values (α=0.05) are highlighted.

Site	PTAGIS site code	Total Tags Detected at site (9 and 12.5 mm)	% 9 mm tags of total tags detected	P-value for a test comparing the percentage of 9 mm tags detected from an expected value of 18.7%
Bonneville Dam WA Shore Vertical Slots	BO4	3152	17.4%	0.086
Bonneville Dam WA Shore Fishway & AFF	BO3	2970	18.5%	0.417
McNary Dam Oregon Shore Fishway	MC1	1272	20.3%	0.885
Ice Harbor Dam Fishways and Juvenile Bypass	ICH	832	20.2%	0.833
Lower Granite Dam Adult Fishway and Trap	GRA	796	20.5%	0.871
McNary Dam Washington Shore Fishway	MC2	708	19.2%	0.618
Priest Rapids Dam Adult Fishways	PRA	455	19.1%	0.581
Rock Island Dam Adult Fishways	RIA	326	13.8%	**0.014**
Rocky Reach Fishway	RRF	259	20.8%	0.800
Wells Dam Adult Fishways	WEA	216	19.4%	0.604
Prosser Dam Fishways and screened Diversion	PRO	117	18.8%	0.509
Roza Dam Juvenile Diversion	ROZ	84	17.9%	0.420
SF Salmon River at Krassel Cr	KRS	69	11.6%	0.066
Bonneville Dam Bradford Island Fishway	BO1	67	11.9%	0.079
Tumwater Dam Adult Fishway	TUF	64	17.2%	0.377
Lower Imnaha River ISA at river km 7	IR1	54	16.7%	0.350
Lower Imnaha River ISA at river km 10	IR2	50	12.0%	0.113
Bonneville Dam Cascades Island Fishway	BO2	49	16.3%	0.335
Upper Imnaha River ISA at river km 41	IR3	40	17.5%	0.422
Little White Salmon NFH adult fish ladder	LWL	40	10.0%	0.079
SF Salmon River near Guard Station Rd Bridge	SFG	40	7.5%	**0.035**
All weirs and in-stream arrays		466	14.6%	**0.015**

Age Analysis

We are able to validate our scale aging techniques by using fish sampled at Bonneville for this project that were previously tagged as juveniles for other projects or hatchery programs. Age estimates from ageable scale patterns of 38

Chinook salmon that had been previously PIT tagged were correctly aged as follows: all 13 spring Chinook, all 18 summer Chinook, and 7 out of 8 fall Chinook salmon. Only the total age was compared, for it is not possible to separately validate freshwater and ocean age.

We attempted to exclude minijacks (defined as Chinook spending no winters in saltwater) from our sample by not diverting Chinook salmon into the sampling tank that were estimated to be less than 36 cm in length, and immediately releasing without sampling any fish diverted that turned out to be less than this threshold. In general these small Chinook salmon are excluded 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, 16 Chinook salmon sampled with lengths between 38 and 46 cm were subsequently identified from scale patterns as being Age 1.0 and therefore minijacks. Although these fish were PIT tagged, they were excluded from analyses subsequently presented in this study except to indicate their last known location. Six of these minijacks were tagged at Bonneville Dam between May 12 and 23 during the spring Chinook migration. Among these fish, three were last detected at Lower Granite Dam and one each at Bonneville, Priest Rapids, and Roza dams. The remaining ten minijacks were tagged between August 19 and September 30 during the fall Chinook migration; four of which were last detected at McNary Dam, two each at Ice Harbor and Lower Granite dams, and one at Priest Rapids Dam.

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Spring Chinook salmon that traveled upstream of McNary Dam were predominantly bound for the Snake River upstream of Ice Harbor Dam (Table 5, Figures 5 and 6), while summer Chinook were primarily bound for the Columbia River upstream of Priest Rapids Dam (Table 5, Figures 5 and 7). Fall Chinook were primarily headed for areas between McNary and Ice Harbor/Priest Rapids dams which are where the Hanford Reach and Priest Rapids Hatchery are located (Table 5, Figures 5 and 8). Over the first half of the entire Chinook run, the percentage of Chinook salmon passing Priest Rapids Dam steadily increased, while the percentage of those last detected below McNary Dam decreased (Figure 5). The percentage of all Chinook that ultimately passed Ice Harbor Dam rose through the early part of the run before dropping after Statistical Week 24. The majority of the fall Chinook run, after Statistical Week 38, is last detected in-between McNary and Priest Rapids/Ice Harbor dams which is the spawning grounds for the Hanford Reach fall Chinook, as well as the location of Ringold and Priest Rapids hatcheries, which rear fall Chinook salmon.

Table 5. Percentage of spring, summer, and fall Chinook salmon tracked from Bonneville Dam detected at upstream dams and the percentage lost due to tributary escapement, tag loss, harvest, spawning, or mortality between dams in 2011.

	Spring Chinook		Summer Chinook		Fall Chinook	
Dam	% Reaching Dam	Decrease from Downstream Dam	% Reaching Dam	Decrease from Downstream Dam	% Reaching Dam	Decrease from Downstream Dam
Bonneville	100.0%	--	100.0%	--	100.0%	--
McNary	61.6%	38.4%	72.8%	27%	50.2%	49.8%
Priest Rapids	8.5%	86.2%	40.2%	45%	6.1%	87.9%
Rock Island	7.4%	12.8%	38.2%	5%	2.9%	52.6%
Rocky Reach	3.5%	53.2%	28.9%	24%	2.2%	24.2%
Wells	2.7%	21.1%	23.8%	18%	1.5%	29.4%
Ice Harbor	42.0%	31.7%	28.7%	61%	14.8%	70.6%
Lower Granite	38.7%	8.0%	27.2%	5%	12.1%	18.3%

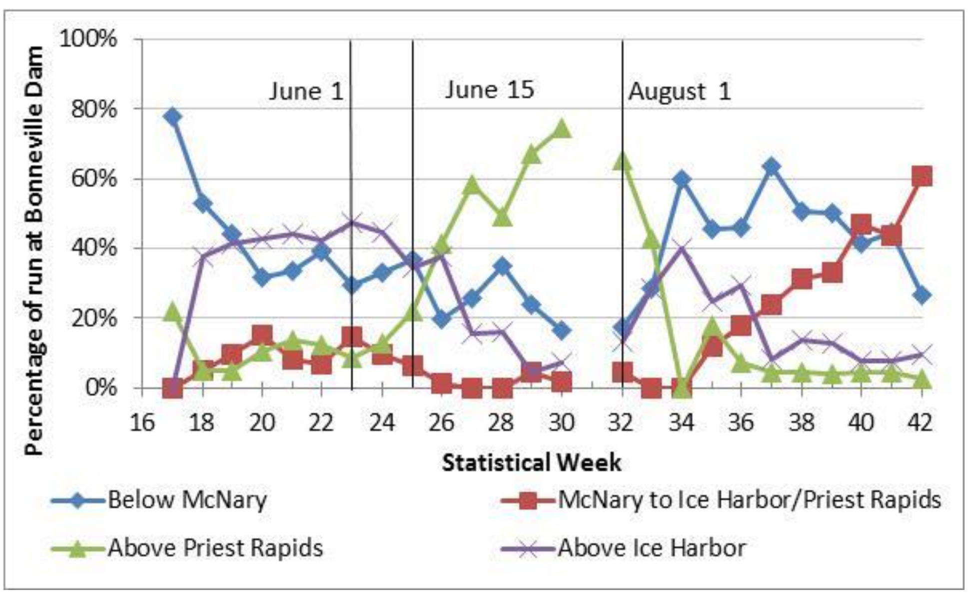

Figure 5. Distribution of final detection areas of the Columbia Basin by statistical week for Chinook salmon PIT tagged at Bonneville Dam in 2011.

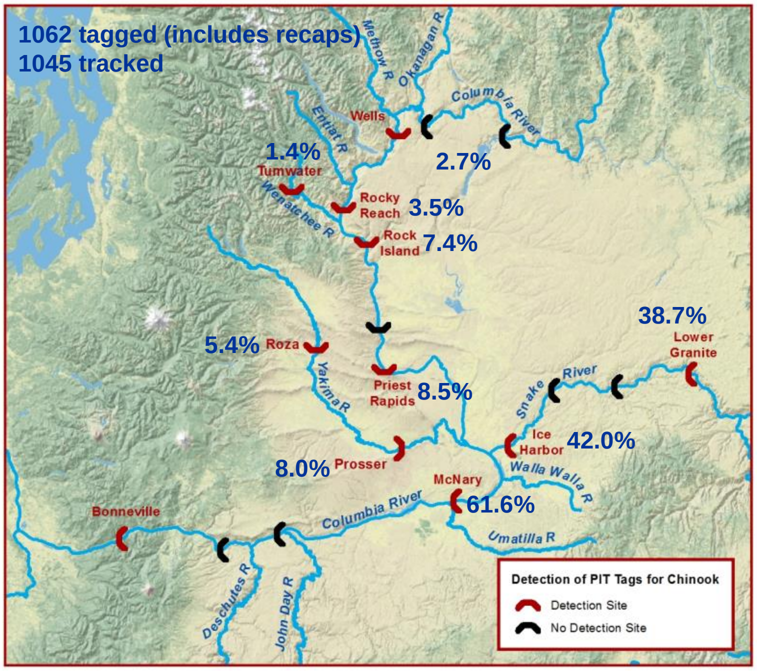

Figure 6. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of spring Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2011.

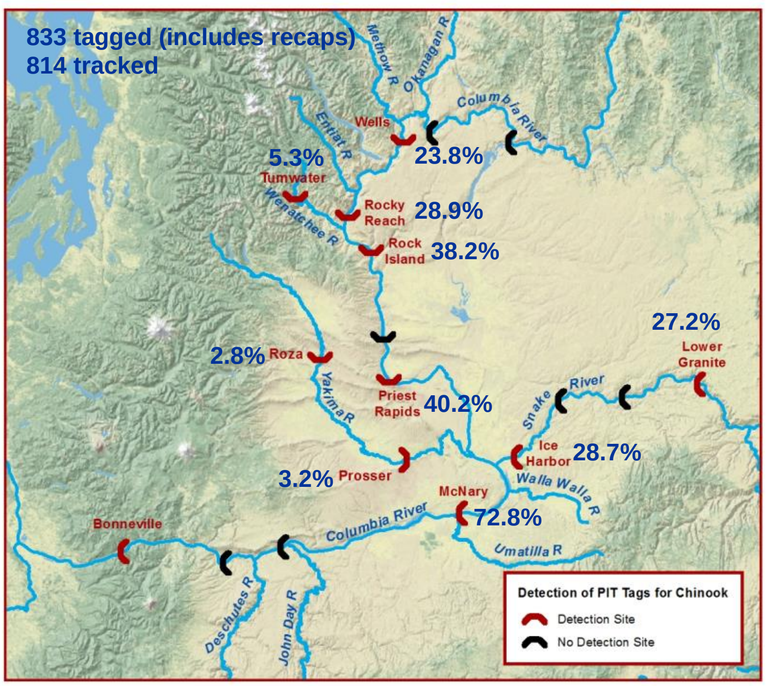

Figure 7. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of summer Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2011.

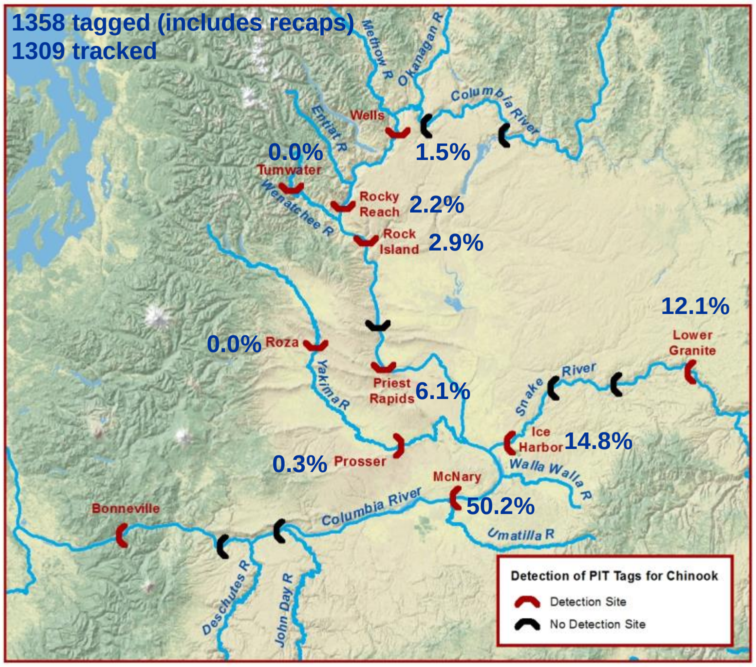

Figure 8. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fall Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2011.

The percentage of 12.5 mm PIT tagged Chinook salmon over the entire run passing a dam without detection was less than 2.5% for all dams except Ice Harbor and Rock Island dams (Table 6). At Ice Harbor Dam, navigation locks provide a potential route that tagged fish can pass undetected. The rate of missed spring and summer Chinook at Rock Island Dam was likely inflated by a lightning strike adversely affecting PIT tag detection at the left bank (east) fishway from 1530 PDT on May 31, 2011 to 1430 PDT on June 29, 2011 (www.ptagis.org). Rock Island Dam is also known to have problems with detection due to the antenna size and electrical noise (Fryer et al. 2011). Chinook tagged with 9 mm tags were more likely to be missed than those tagged with 12.5 mm tags at all dams. The rates of detection efficiency of individual weirs within ladders at dams listed in Table 6 are found in the Appendix (Table A1).

Table 6. Percentage of Chinook salmon detected upstream that missed detection at given dams in 2011.

	Spring Chinook		Summer Chinook		Fall Chinook		All Chinook	
Dam	**9 mm**	**12.5 mm**	**9 mm**	**12.5 mm**	**9 mm**	**12.5 mm**	**9 mm**	**12.5 mm**
Bonneville	6.2%	0.9%	9.8%	1.7%	9.2%	0.9%	8.2%	1.2%
McNary	2.2%	1.3%	1.8%	1.5%	0.0%	0.5%	1.8%	1.3%
Priest Rapids	0.0%	0.0%	5.7%	0.5%	20.0%	2.7%	4.9%	0.6%
Rock Island	36.0%	25.9%	31.3%	6.9%	42.9%	9.7%	33.3%	11.0%
Rocky Reach	0.0%	0.0%	0.0%	2.3%	0.0%	4.3%	0.0%	2.2%
Wells	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ice Harbor	9.0%	6.5%	3.9%	3.4%	0.0%	2.7%	6.3%	4.8%
Lower Granite	0.0%	0.0%	0.0%	0.0%	0.0%	NA[b]	0.0%	0.0%

Escapement estimates for the entire Chinook run derived from PIT tag detections result in estimates that are relatively similar for the entire Chinook run (spring, summer, and fall, Table 7); however there are some differences by race by dam. In 2011, between 11.3% and 27.1% of Chinook salmon tagged at Bonneville Dam during the spring Chinook migration (through May 31) passed upstream dams during the summer migration (Table 8). The percentage of summer Chinook tagged at Bonneville Dam passing upstream dams as spring Chinook ranged between 0 and 1.3%, while the percentage passing as fall Chinook ranged from 0 to 5.2%. The percentage of fall Chinook tagged at Bonneville passing upstream dams as summer Chinook ranged between 0.6 and 56.0%. No spring Chinook tagged at Bonneville Dam passed any upstream dam as a fall Chinook.

Table 7. Chinook salmon escapement in 2011, by run, at Columbia Basin mainstem dams upstream of Bonneville Dam. Estimates are from both PIT tag recoveries and dam counts and the differences between the two estimates are displayed.

	Spring Chinook Salmon			Summer Chinook Salmon		
Site	**Viewing Window Count**	**PIT Tag Estimate**	**Percent Difference**	**Viewing Window Count**	**PIT Tag Estimate**	**Percent Difference**
McNary	132,996	134,130	0.9%	102,786	116,311	13.2%
Priest Rapids	21,276	18,541	-12.9%	55,088	64,289	16.7%

[b] There were no detections at PIT tag arrays upstream of Lower Granite Dam so this rate cannot be calculated using the described methods.

Rock Island	20,681	16,317	-21.1%	55,527	61,002	9.9%
Rocky Reach	10,480	7,645	-27.1%	46,992	46,113	-1.9%
Wells	8,122	6,035	-25.7%	38,286	37,981	-0.8%
Ice Harbor	87,467	91,599	4.7%	39,136	45,766	16.9%
Lower Granite	81,405	84,219	3.5%	53,189	43,446	-18.3%
	Fall Chinook Salmon			**All Chinook Salmon**		
McNary	204,646	243,376	18.9%	440428	493817	12.1%
Priest Rapids	40,550	29,240	-27.9%	116914	112070	-4.1%
Rock Island	16,642	14,013	-15.8%	92850	91332	-1.6%
Rocky Reach	11,070	10,622	-4.0%	68542	64380	-6.1%
Wells	5,337	7,505	40.6%	51745	51521	-0.4%
Ice Harbor	50,983	71,509	40.3%	177586	208874	17.6%
Lower Granite	44,903	58,375	30.0%	179497	186040	3.6%

Table 8. Percentage of Chinook sampled at Bonneville Dam as one race (as determined by run timing) that passed upstream dams as another race (as determined by run timing) in 2011.

Race at Bonneville			Spring	Summer	Summer	Fall
Race at dam listed below	**Last Date Spring Run**	**First date Fall Run**	**Summer**	**Spring**	**Fall**	**Summer**
Bonneville Dam	May 31	August 1				
McNary	June 8	August 9	11.4%	0.0%	0.2%	0.9%
Priest Rapids	June 13	August 14	23.0%	0.0%	0.4%	8.3%
Rock Island	June 17	August 18	19.0%	0.0%	0.4%	25.7%
Rocky Reach	June 19	August 20	24.4%	0.0%	1.1%	31.3%
Wells	June 28	August 29	14.7%	1.3%	5.2%	56.0%
Ice Harbor	June 11	August 12	11.3%	0.4%	0.0%	0.6%
Lower Granite	June 17	August 18	27.1%	0.4%	0.0%	0.8%

Tributary escapement estimates for five sites, each with more than 50 detections, are found in Table 9 alongside estimates using visual or trap counts at three of the sites. PIT tag estimates of tributary escapement differed from visual or trap count estimates by a much greater percentage than at mainstem dams (Table 9). This is likely the result of relatively few tagged fish entering tributary sites, creating smaller sample sizes for analysis.

Chinook destined for all five tributary sites were primarily spring or summer Chinook (Figure 9).

Table 9. Estimated 2011 Chinook salmon escapement, as estimated using PIT tag detections, to Tumwater, Prosser, and Roza dams and the South Fork Salmon and Imnaha rivers.

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	65	9,552	11,460	20.0%
Krassel Weir, South Fork Salmon River	70	NA	11,168	NA
Prosser Dam, Yakima River	121	18,098	24,115	33.2%
Roza Dam, Yakima River	84	10,520	16,265	54.6%
Imnaha PIT tag antennas	57	NA	9,913	NA

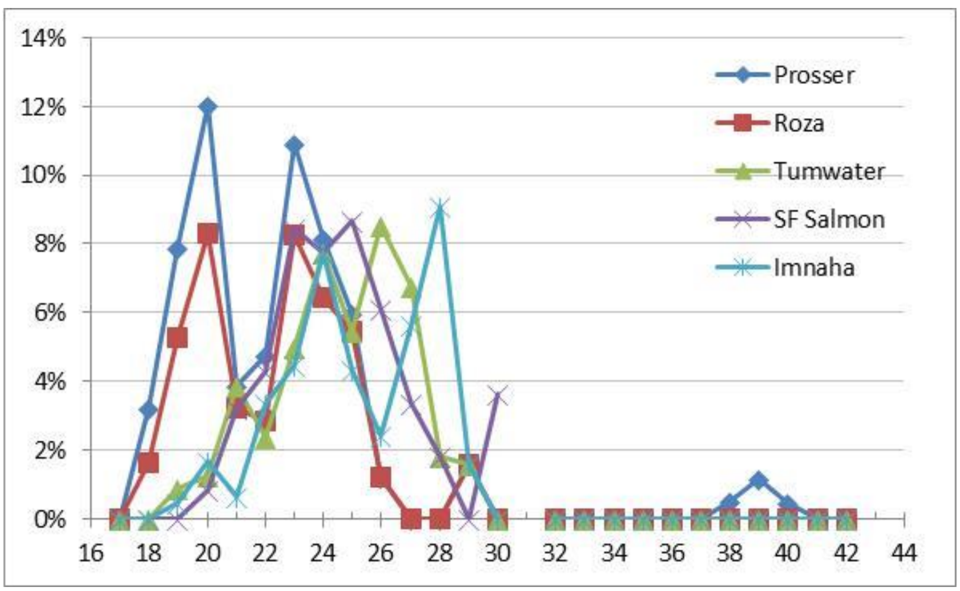

Figure 9. Percentage of Chinook salmon by statistical week tagged at Bonneville Dam in 2011 destined for the Yakima, Wenatchee, South Fork Salmon and Imnaha subbasins based on upstream PIT tag detections at Prosser, Roza, and Tumwater dams, and the Salmon River and Imnaha weirs.

Travel Rates and Passage Time

Chinook travel rates between mainstem dams ranged between 20.6 and 38.1 km/day (Table 10). The slowest travel rates were observed between Rocky Reach and Wells dams, which were often half the rate for all three Chinook runs compared to the rates between other dams. Travel rates to and between tributary sites were generally less than those in the Columbia and Snake rivers (Table 10). The only tributary site listed in Table 10 where fall Chinook were detected was Prosser Dam.

Table 10. Chinook salmon travel rates between Columbia Basin dams estimated using PIT tag data in 2011.

		Median Travel Rate (km/day)		
Between mainstem dams	**Distance (km)**	**Spring Chinook**	**Summer Chinook**	**Fall Chinook**
Bonneville – McNary	231	33.5	33.3	38.1
McNary - Priest Rapids	167	34.1	27.8	26.8
Priest Rapids - Rock Island	89	29.2	26.3	30.6
Rock Island - Rocky Reach	33	30.8	20.6	29.2
Rocky Reach – Wells	65	27.8	31.8	30.2
Bonneville - Rock Island	487	31.8	27.4	34.2
Bonneville – Wells	585	30.6	24.0	34.9
McNary - Ice Harbor	67	33.9	33.9	37.5
Ice Harbor - Lower Granite	156	29.1	20.7	31.1
To and between tributary sites				
Rock Island - Tumwater	73	3.5	2.9	
McNary - Prosser	141	32.3	21.1	5.2
Prosser - Roza	133	13.7	7.2	
Lower Granite - South Fork Salmon (SFG)	375	18.8	15.0	

Among the mainstem Columbia and Snake River dams, Chinook salmon have the greatest median dam passage time (as determined by minutes 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. Passage 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 1,217 minutes or over 20 hours (Table 11) with summer Chinook having a median passage time of almost nine hours (539.5 minutes). The percentage of spring Chinook taking more than 12 hours to pass the dam was 63.2%, it dropped to 48.9% for summer Chinook. No fall Chinook passed Tumwater Dam.

Table 11. Median passage time in minutes by run, from the time of first detection to time of last detection at a dam and the percentage of Chinook taking more than 12 hours between first detection and last detection in 2011.

	Median Passage Time (minutes)			Percentage of run 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	74.6	66.9	86.7	7.3%	8.4%	6.1%
McNary	108.7	87.3	72.2	11.1%	3.7%	7.4%
Priest Rapids	4.0	5.2	3.3	3.0%	3.3%	3.7%
Rock Island	7.0	18.2	26.9	6.3%	7.0%	14.7%
Rocky Reach	33.2	9.1	2.3	9.8%	7.6%	0.0%
Wells	0.5	2.1	0.9	5.9%	21.8%	4.2%
Ice Harbor	2.5	2.0	2.0	5.1%	3.6%	4.9%
Lower Granite	97.4	77.3	87.7	19.2%	12.0%	15.3%
Tumwater	1217.0	539.5		63.2%	48.9%	
Prosser	2.6	5.9	4.3	4.3%	0.0%	4.7%
Roza	1.4	1.6	1.5	11.1%	9.1%	11.8%

Upstream Age and Length-at-Age Composition

Age 1.2 was the predominant age class for spring Chinook passing Bonneville, McNary, Wells, Ice Harbor and Lower Granite dams (Table 12, Figure 10); at the other dams, Age 1.1 was the most abundant age class for spring Chinook. Age 1.1 was the most abundant age class for summer Chinook passing all mainstem dams with PIT tag detection (Table 12, Figure 11). Age 0.3 was the most abundant age class for fall Chinook passing Bonneville, McNary, and Priest Rapids dams, while Age 0.1 was most abundant at Ice Harbor and Lower Granite dams (Table 12, Figure 12). Mean length-at-age composition estimates at mainstem dam 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 from scales collected at Bonneville Dam, for spring, summer, and fall Chinook salmon in 2011.

		Brood Year and Age Class								
Run, Site, Number		**2009**	**2008**		**2007**		**2006**		**2005**	
Spring	**N**	**0.1**	**0.2**	**1.1**	**0.3**	**1.2**	**0.4**	**1.3**	**0.5**	**1.4**
Bonneville	922	0.4%	0.0%	22.2%	0.0%	65.7%	0.0%	11.7%	0.0%	0.0%
McNary	566	0.2%	0.0%	24.9%	0.0%	61.6%	0.0%	13.4%	0.0%	0.0%
Priest Rapids	83	0.6%	0.0%	46.6%	0.0%	40.5%	0.0%	12.2%	0.0%	0.0%
Rock Island	71	0.8%	0.0%	48.1%	0.0%	37.4%	0.0%	13.8%	0.0%	0.0%
Rocky Reach	32	1.2%	0.0%	63.7%	0.0%	35.1%	0.0%	0.0%	0.0%	0.0%
Wells	27	0.9%	0.0%	35.3%	0.0%	63.8%	0.0%	0.0%	0.0%	0.0%
Ice Harbor	386	0.1%	0.0%	22.0%	0.0%	62.9%	0.0%	15.1%	0.0%	0.0%
Lower Granite	357	0.1%	0.0%	15.3%	0.0%	62.9%	0.0%	21.7%	0.0%	0.0%
Summer										
Bonneville	740	2.4%	3.8%	40.2%	10.3%	26.8%	0.6%	15.9%	0.0%	0.0%
McNary	438	2.5%	3.4%	44.2%	9.0%	25.3%	0.7%	15.0%	0.0%	0.0%
Priest Rapids	202	2.9%	4.5%	43.2%	12.8%	17.8%	1.8%	17.1%	0.0%	0.0%
Rock Island	193	2.9%	4.2%	42.2%	13.6%	18.2%	1.9%	17.0%	0.0%	0.0%
Rocky Reach	131	2.7%	3.2%	41.7%	10.7%	17.2%	1.9%	22.5%	0.0%	0.0%
Wells	110	3.2%	2.7%	42.6%	10.9%	17.9%	2.8%	19.9%	0.0%	0.0%
Ice Harbor	206	2.7%	1.2%	62.5%	0.7%	23.9%	0.0%	9.0%	0.0%	0.0%
Lower Granite	198	2.4%	1.2%	62.0%	0.7%	24.6%	0.0%	9.1%	0.0%	0.0%
Fall										
Bonneville	1258	14.7%	20.1%	6.0%	48.7%	6.3%	2.0%	1.8%	0.3%	0.2%
McNary	659	21.7%	19.7%	7.1%	43.4%	5.3%	1.6%	1.2%	0.0%	0.0%
Priest Rapids	81	29.7%	21.9%	3.1%	42.4%	3.0%	0.0%	0.0%	0.0%	0.0%
Rock Island	40	44.9%	23.4%	2.0%	23.8%	5.8%	0.0%	0.0%	0.0%	0.0%
Rocky Reach	30	53.2%	15.3%	3.2%	17.6%	10.7%	0.0%	0.0%	0.0%	0.0%
Wells	22	41.7%	18.2%	6.6%	0.6%	32.9%	0.0%	0.0%	0.0%	0.0%
Ice Harbor	144	34.8%	17.1%	23.2%	16.6%	7.7%	0.0%	0.5%	0.0%	0.0%
Lower Granite	116	39.2%	19.1%	15.3%	17.5%	8.9%	0.0%	0.0%	0.0%	0.0%

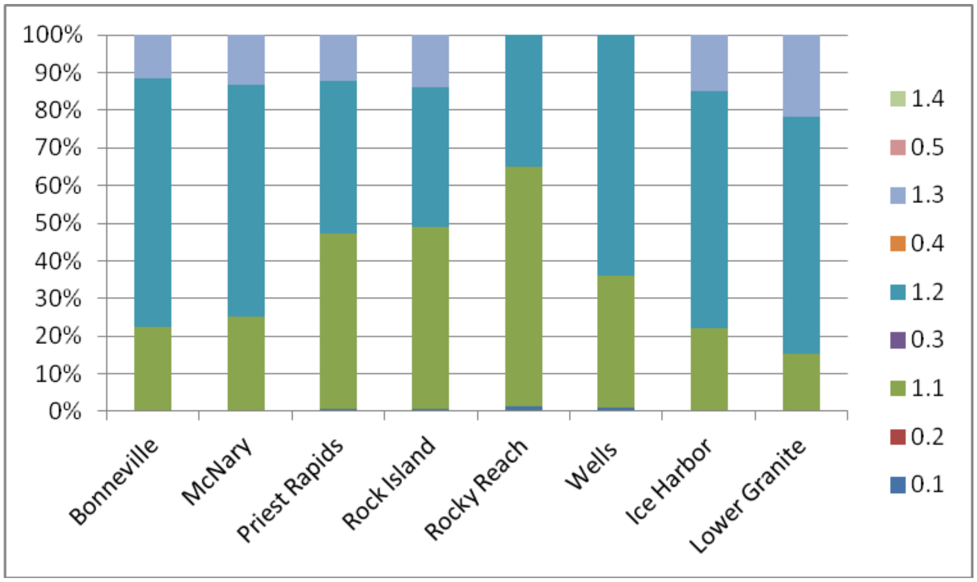

Figure 10. Spring Chinook age composition at Columbia and Snake river dams estimated using PIT tagged Chinook tracked by this project. Spring Chinook are defined as passing Bonneville Dam between April 1 and May 31, 2011.

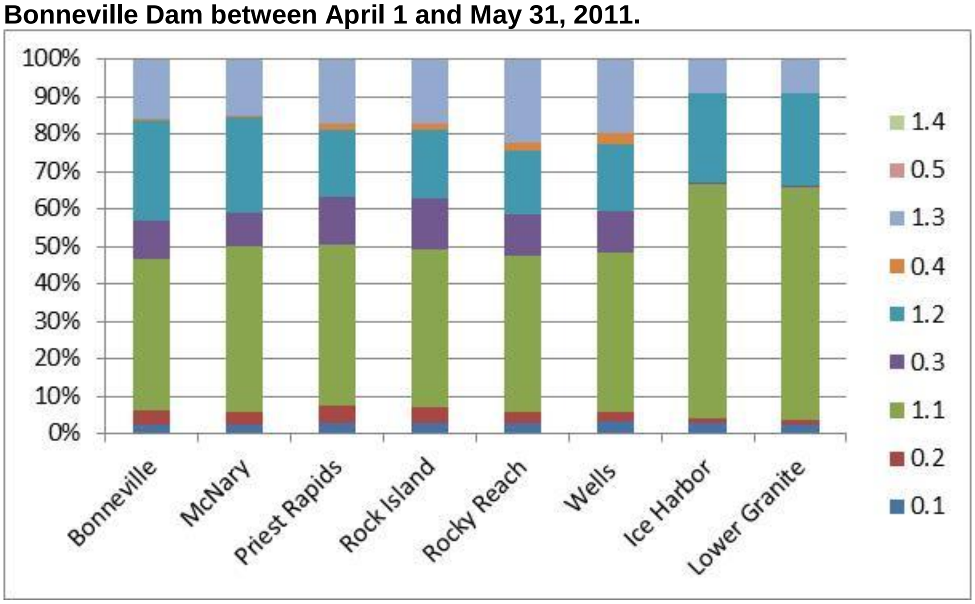

Figure 11. Summer Chinook age composition at Columbia and Snake river dams estimated using PIT tagged Chinook tracked by this project. Summer Chinook are defined as passing Bonneville Dam between June 1 and July 31, 2011.

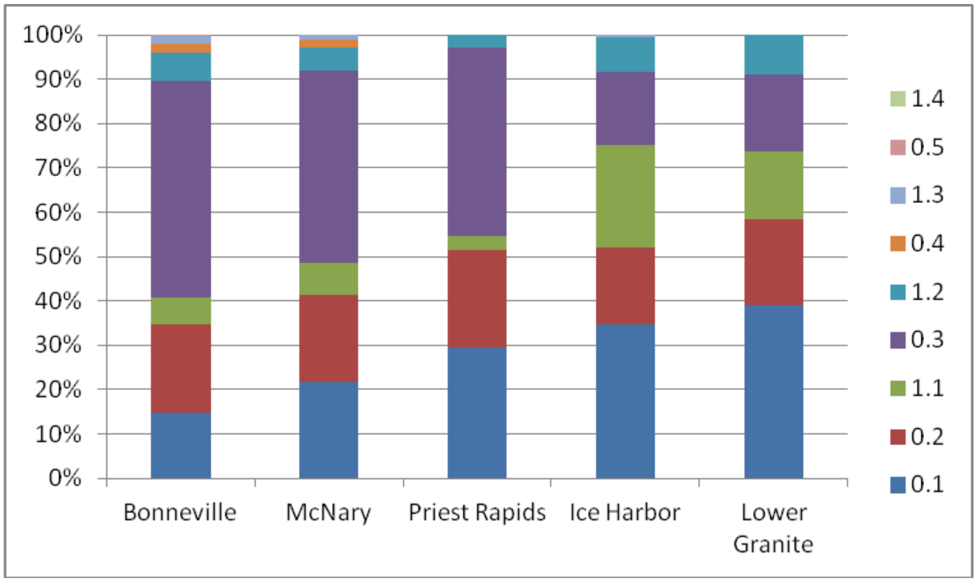

Figure 12. Fall Chinook age composition at Columbia and Snake river dams estimated using PIT tagged Chinook tracked by this project passing between August 1 and October 31, 2011.

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 between April 1 and May 31, at Columbia and Snake River dams in 2011.

Dam	Statistic	Brood Year and Age Class						
		2009	2008		2007		2006	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3
Bonneville	µ	45.7		50.5		72.7		85.3
	s	4.0		7.1		7.7		14.0
	n	3		272		490		93
McNary	µ	47.5		50.2		73.2		84.6
	s	3.5		6.1		6.0		16.7
	n	2		202		299		63
Priest Rapids	µ	45.0		50.1		76.2		67.4
	s	---		3.1		5.2		37.7
	n	1		58		19		5
Rock Island	µ	45.0		50.1		76.7		67.4
	s	---		3.1		5.6		37.7
	n	1		50		15		5
Rocky Reach	µ	45.0		49.3		76.5		
	s	---		1.9		2.2		
	n	1		28		3		
Wells	µ	45.0		49.1		76.0		
	s	---		2.0		2.8		
	n	1		24		2		
Ice Harbor	µ	50.0		50.1		73.5		87.7
	s			7.6		4.1		6.0
	n	1		116		218		51

Lower Granite	µ	50.0		50.3		73.4		88.1
	s			7.8		4.1		6.0
	n	1		110		200		46

Table 14. Summer Chinook salmon length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville Dam between June 1-July 31, at Columbia and Snake River dams in 2011.

Dam	Statistic	Brood Year and Age Class						
		2009	2008		2007		2006	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3
Bonneville	µ	46.9	65.8	53.5	80.3	75.1	90.3	85.5
	s	5.3	5.7	3.7	11.9	7.3	7.8	9.8
	n	15	20	269	58	239	5	116
McNary	µ	47.0	66.0	53.3	78.9	75.1	93.4	86.1
	s	5.6	5.6	3.8	14.5	8.3	4.2	5.9
	n	12	14	215	37	156	4	77
Priest Rapids	µ	46.7	65.0	53.0	78.9	74.7	93.4	85.2
	s	6.2	4.3	3.8	14.9	7.5	4.2	6.2
	n	9	13	97	35	44	4	45
Rock Island	µ	46.7	65.2	53.1	78.9	74.9	93.4	85.0
	s	6.2	4.5	3.8	14.9	7.4	4.2	6.3
	n	9	12	90	35	43	4	43
Rocky Reach	µ	45.8	65.4	52.8	79.4	75.2	98.5	84.4
	s	6.0	4.2	3.9	5.5	7.2	---	6.3
	n	8	8	64	21	29	1	36
Wells	µ	45.8	64.6	52.8	79.8	74.7	98.5	85.0
	s	6.0	3.2	4.0	5.7	7.3	---	6.6
	n	8	6	51	18	26	1	26
Ice Harbor	µ	48.3	79.0	53.7	79.3	75.5		87.6
	s	6.0	---	3.8	5.3	9.1		5.2
	n	2	1	102	2	99		31
Lower Granite	µ	52.5	79.0	53.6	79.3	75.5		87.8
	s	---	---	3.9	5.3	9.1		5.2
	n	1	1	96	2	98		30

Table 15. Chinook salmon length-at-age composition, as estimated by PIT tag detections of fish aged using scale pattern analysis that passed Bonneville after July 31st, for fall Chinook salmon at Columbia and Snake River dams in 2011.

Dam	Statistic	Brood Year and Age Class						
		2009	2008		2007		2006	
		0.1	0.2	1.1	0.3	1.2	0.4	1.3
Bonneville	μ	46.2	67.7	55.5	78.5	72.6	84.3	86.5
	s	7.4	7.1	11.1	9.4	6.7	23.0	4.8
	n	184	252	64	605	75	32	24
McNary	μ	46.4	66.8	56.0	77.8	71.4	83.9	88.1
	s	5.8	5.0	9.4	10.7	6.8	22.1	4.5
	n	136	141	48	278	30	18	8
Priest Rapids	μ	44.7	67.3	55.4	76.0	65.5		
	s	10.8	5.2	5.0	15.6	1.3		
	n	23	18	8	29	3		
Rock Island	μ	41.0	65.6	54.0	80.3	65.8		
	s	13.6	5.2	3.5	7.6	1.8		
	n	12	9	7	8	2		
Rocky Reach	μ	40.8	67.3	54.0	80.1	64.5		
	s	14.2	4.2	3.5	9.9	---		
	n	11	6	7	5	1		
Wells	μ	38.8	65.2	54.0	82.8	64.5		
	s	16.3	1.3	3.5	12.9	---		
	n	8	3	7	3	1		
Ice Harbor	μ	47.3	66.3	55.9	67.5	73.0		86.5
	s	3.6	4.4	10.6	27.0	5.5		---
	n	48	26	35	24	10		1
Lower Granite	μ	47.4	66.8	57.4	69.3	73.6		
	s	3.7	4.2	4.0	24.9	5.6		
	n	45	23	19	20	9		

Fallback

Estimated fallback-reascension rates based on Chinook salmon reascending fish ladders ranged from 0% to 35.0% (Table 16). These rates likely underestimate the true fallback rates as they do not include any fish that ascended a dam, fell back, and then were not subsequently detected.

Table 16. Estimated Chinook salmon fallback and reascension at mainstem Columbia River dams in 2011 as estimated by PIT tags.

Dam	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	4.1%	2.1%	0.9%
McNary	8.3%	2.2%	2.7%
Priest Rapids	2.3%	4.2%	7.5%
Rock Island	1.1%	4.2%	10.0%
Rocky Reach	24.4%	13.8%	0.0%
Wells	8.8%	35.0%	4.2%
Ice Harbor	6.8%	4.6%	6.0%
Lower Granite	16.6%	8.8%	11.5%
Tumwater	26.3%	22.2%	---
Mean	**11.0%**	**10.8%**	**5.3%**

A total of 92 tagged Chinook salmon were detected falling back over multiple dams, with one jack Chinook (3D9.1C2DB3464D) tagged on May 5, 2011 falling back at least nine times over dams (McNary four times, John Day, The Dalles, Bonneville all once, and Little Goose Dam twice), being last detected in the Little Goose juvenile bypass on July 1.

Night Passage

Night passage (2000-0400 Pacific Standard Time) of tagged Chinook salmon was less than 1% at Bonneville, but increased further upstream (Table 17) and was highest at Roza Dam. The Bonneville Dam estimate of night passage is likely biased low, due to the facts that tagging occurred during morning and early afternoon hours and that the median Bonneville Dam passage time is less than two hours, Chinook would be expected to pass during daytime hours.

Table 17. Estimated Chinook salmon night passage (2000-0400) in 2011 at Columbia Basin dams as estimated by PIT tags.

Site	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	0.3%	0.5%	0.2%
McNary	2.4%	0.0%	0.0%
Priest Rapids	2.9%	0.7%	6.1%
Prosser	4.5%	5.7%	0.0%
Rock Island	2.9%	3.1%	0.0%
Roza	19.4%	22.6%	---
Rocky Reach	0.0%	2.7%	6.5%
Wells	1.8%	3.8%	4.2%
Tumwater	8.7%	6.7%	---
Ice Harbor	1.1%	2.4%	2.5%
Lower Granite	5.5%	4.4%	2.3%

RESULTS-STEELHEAD

Sample Size

A total of 1348 steelhead were PIT tagged in 2011. After adding previously tagged fish (which were sampled and therefore identified for the tracking study and included in our sample) and subtracting fish that were not detected after release (possibly a result of tag shed, tag malfunction, mortality, or the fish moving downstream after tagging), the number of steelhead tracked upstream totaled 1377 (Table 18).

Table 18. Number of steelhead PIT tagged at Bonneville Dam and tracked by date and statistical week in 2011. No sampling occurred during Statistical Week 31 due to trap modifications.

Dates	Statistical Week	Tagged (12 mm)	Tagged (9 mm)	Previously Tagged	Not Detected Passing Bonneville	Total Tracked
4/27-28	18	1	0	1	0	2
5/3-4	19	1	0	0	0	1
5/10	20	2	0	0	0	2
5/16,18	21	3	1	0	0	4
5/24-27	22	11	1	0	1	11
5/30, 6/3	23	7	1	0	0	8
6/6-6/10	24	14	2	0	0	16
6/13-6/17	25	16	0	0	0	16
6/21-6/23	26	6	0	0	0	6
6/27-7/1	27	15	1	1	0	17
7/5-7/8	28	24	3	2	2	27
7/11-7/14	29	52	11	0	1	62
7/18,19, 21, 22	30	125	27	4	1	155
No sampling	31					
8/1-8/5	32	167	40	5	1	211
8/8-8/11	33	131	29	2	0	162
8/18-8/19	34	59	14	0	0	73
8/22-8/25	35	124	26	6	0	156
8/29-9/1	36	87	19	0	1	105
9/5-9/9	37	46	10	1	1	56
9/12-9/16	38	52	11	2	1	64
9/19-9/23	39	46	8	4	1	57
9/26-9/30	40	63	13	5	0	81
10/3-10/7	41	54	11	6	1	70
10/10-10/11	42	12	2	1	0	15
Total		1118	230	40	11	1377

Distribution of Sample

Our steelhead sample distribution was much closer to the run distribution than in many past years. We did under sample the peak of the run with the four peak weeks (30-33) representing 49.6% of the run but only 23.7% of our sample (Figure 13). We did not sample during week 31 due to trap modifications taking longer than anticipated. The trap was shut down due to temperatures exceeding 22.2C (72.0C) from August 12 through August 17 (part of weeks 33 and 34).

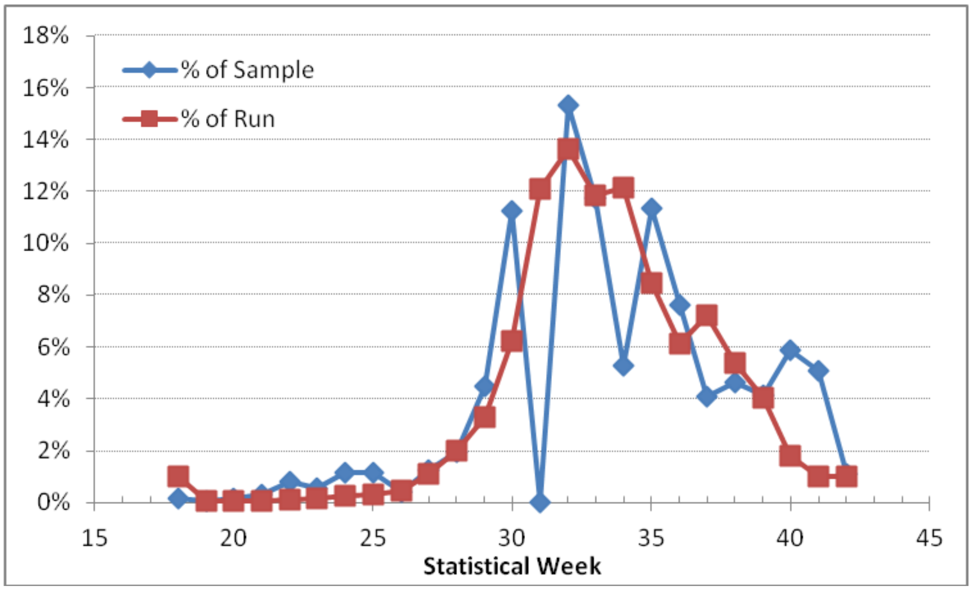

Figure 13. The weekly steelhead sample and run as a percentage of the total sample and run size at Bonneville Dam in 2011.

Detection Numbers

The 1,377 steelhead tracked in 2011 generated 62,857 weir detections and 5,752 site detections at 76 sites. Maps (Figure A1-A16) found in the Appendix show the categorical ranges of detection numbers at the sites throughout the Columbia Basin.

Age Analysis

We were able to validate our scale aging techniques by using fish sampled at Bonneville for this project that were previously tagged as juveniles for other projects or hatchery programs. Age estimates from ageable scale patterns for 28 out of 30 steelhead that had been previously PIT tagged were correctly aged (93.3%). Only the total age could be compared for it was not possible to separately validate freshwater and ocean age.

Mainstem Dam Recoveries and Mortality,

Data on tag detections was last downloaded from www.ptagis.org on March 19, 2013. An estimated 56.5% of the steelhead run was last detected upstream of Ice Harbor Dam while only 4.6% of the run was last detected upstream of Priest Rapids Dam (Figure 14). The proportion of steelhead bound for the Snake River steadily increased as the run progressed (Figures 15 and 16). The proportion bound for the areas between McNary and Priest Rapids/Ice Harbor (primarily Hanford Reach and Yakima) and above Priest Rapids Dam was both generally under 10% of the run.

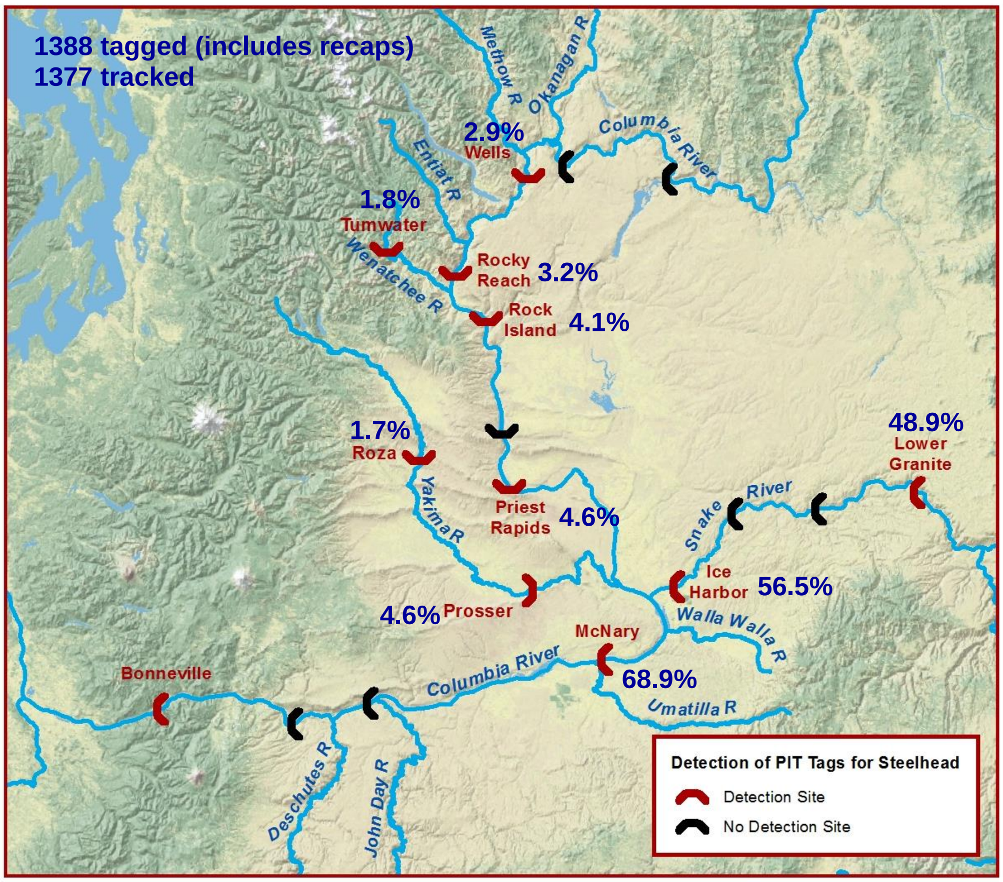

Figure 14. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of steelhead PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2011.

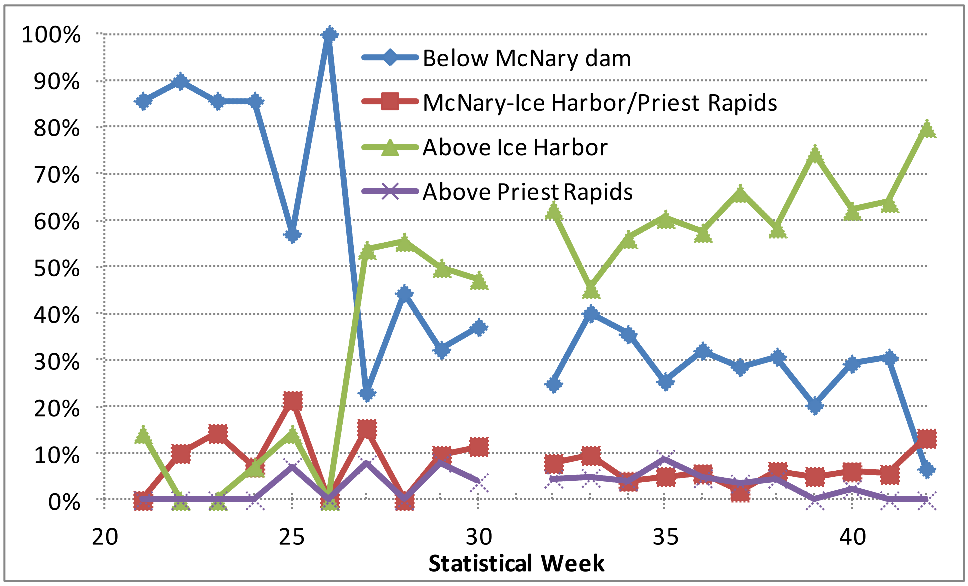

Figure 15. Distribution of final upstream detection site by statistical week for steelhead PIT tagged at Bonneville Dam in 2011 estimated as a percentage of the weekly sample.[c]

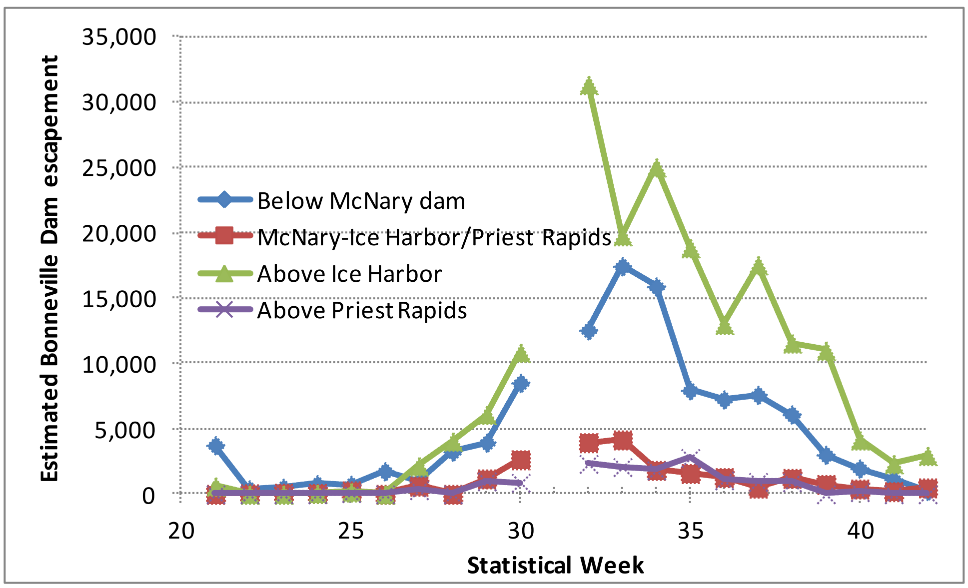

Figure 16. Distribution of final detection site by statistical week for steelhead PIT tagged at Bonneville Dam in 2011 estimated in numbers of fish passing Bonneville Dam by week.

Like Chinook salmon the percentage of steelhead PIT tagged with a 12.5 mm tag passing a dam without detection was generally under 1% (Table 19) with

[c] Note that the point indicating that 100% of those fish in Statistical Week 26 were last detected between Bonneville and McNary dams is based on only six steelhead sampled that week.

the exception of Rock Island Dam which had the previously mentioned problems with a power outage and electrical noise. Sample sizes were also relatively small at Rock Island Dam, with only 56 steelhead detected upstream, 12 of which were not detected by PIT tag arrays in Rock Island Dam fish ladders.

Table 19. Percentage of steelhead passing a dam undetected that were subsequently detected at an upstream dam in 2011.

Dam	Percent Undetected 12.5 mm	Percent Undetected 9 mm
Bonneville	0.8%	5.3%
McNary	0.4%	1.4%
Priest Rapids	0.0%	0.0%
Rock Island	15.0%	60.0%
Rocky Reach	0.0%	0.0%
Wells	0.0%	0.0%
Ice Harbor	1.4%	1.9%
Lower Granite	0.0%	0.0%

Comparison of 9 and 12.5 mm tags

At 7 out of 11 sites with more than 40 detections of steelhead PIT tagged by this study (Table 20), the percentage of tagged steelehad detected with 9 mm tags was less than expected percentage of 18.7% (the percentage of Chinook in our sample that were tagged with 9 mm tags). At no site was this difference statistically significant, however when all weir sites were combined, only 6.9% of detected steelhead were tagged with 9 mm tags and this difference was significant (p=0.001)

Table 20. Total number of tagged steelhead detected (40 detection minimum) by site, the percentage which were 9 mm tags and the p-value for a comparison with the percentage of 9 mm tags deployed (18.7% in 2011). Significant p-values (α=0.05) are highlighted.

Site	PTAGIS site code	Tags Detected at site	% of tags detected that were 9 mm tags	P-value for a test comparing the percentage of 9 mm tags detected from an expected value of 16.6%
Bonneville Dam WA Shore Vertical Slots	BO4	1329	16.1%	0.377
Bonneville Dam WA Shore Fishway & AFF	BO3	1299	16.1%	0.374
McNary Dam Oregon Shore Fishway	MC1	783	16.3%	0.452
Ice Harbor Dam Fishways and Juvenile Bypass	ICH	763	16.5%	0.492
Lower Granite Dam Adult Fishway and Trap	GRA	664	16.3%	0.436

McNary Dam Washington Shore Fishway	MC2	171	19.3%	0.818
Priest Rapids Dam Adult Fishways	PRA	62	19.4%	0.719
Bonneville Dam Bradford Island Fishway	BO1	46	8.7%	0.078
Rocky Reach Fishway	RRF	46	17.4%	0.560
Rock Island Dam Adult Fishways	RIA	44	9.1%	0.094
Wells Dam Adult Fishways	WEA	41	17.1%	0.536
All weirs and instream arrays		146	6.9%	0.001

Travel Rates and Passage Time

The fastest median travel rate between dams, as measured in kilometers per day, was between McNary and Ice Harbor dams (28.2 km per day), while the slowest was 3.0 km/day between Rock Island and Tumwater dams (Table 21).

Table 21. Steelhead travel rate between Columbia Basin dams as estimated by PIT tag detections in 2011.

Steelhead		
Dam Pair	**Distance (km)**	**Median Travel Rate (km/day)**
Bonneville - McNary	231	21.3
McNary - Priest Rapids	167	24.1
Priest Rapids - Rock Island	89	21.4
Rock Island - Rocky Reach	33	15.8
Rocky Reach - Wells	65	24.0
Rock Island - Tumwater	73	3.0
Bonneville – Rock Island	487	22.7
Bonneville - Wells	585	22.8
McNary - Ice Harbor	67	28.2
Ice Harbor - Lower Granite	156	21.9

Median steelhead passage times (Table 22) 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 our project samples fish at Bonneville Dam). Tumwater Dam, a tributary dam in the Wenatchee, had 24 hour trapping program for Chinook that likely impeded steelhead passage.

Table 22. Steelhead median passage times from time of first detection at a dam to time of last detection and the percentage of steelhead taking more than 12 hours between first detection and last detection in 2011.

Dam	Median Passage Time (minutes)	Percentage with more than 12 hours between first detection and last detection at a dam
Bonneville	69.8	10.4%
McNary - OR Shore	85.6	6.4%
McNary - WA Shore	5.3	3.2%
Priest Rapids	11.3	4.5%
Rock Island	2.7	0.0%
Rocky Reach	1.2	9.8%
Wells	3.4	5.0%
Ice Harbor	82.5	12.5%
Lower Granite	102.8	42.9%
Tumwater	69.8	10.4%

Upstream Age and Length-at-Age Composition

Three age classes, 1.1, 1.2, and 2.2 predominated in 2011 (Table 23, Figure 17.) Length-at-age composition data is found in Table 24.

Table 23. Age composition estimates (%) as estimated by sampling at Bonneville Dam and upstream PIT tag detections of steelhead aged using scale patterns at Columbia and Snake River dams in 2011.

	Brood Year And Age Class														
	2008	2007		2006			2005			2004	Unknown				
Site	1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	4.1	3.3	4.2	r.1	r.2	r.3	Repeat Spawners
Bonneville	31.8	15.7	7.8	3.6	8.6	1.3	1.0	1.0	0.4	0.0	0.1	16.2	10.2	1.7	0.5
McNary	36.5	14.8	6.0	3.6	8.4	1.3	0.6	1.3	0.4	0.0	0.1	17.3	8.1	1.3	0.3
Priest Rapids	30.1	30.0	2.9	2.3	17.6	0.8	0.0	1.5	2.3	0.0	0.0	5.4	7.2	0.0	0.0
Rock Island	26.5	33.2	3.1	2.3	21.6	1.0	0.0	1.5	2.3	0.0	0.0	5.4	3.1	0.0	0.0
Rocky Reach	35.1	37.6	3.4	2.3	9.2	1.2	0.0	1.6	2.3	0.0	0.0	5.6	1.6	0.0	0.0
Wells	37.0	36.6	4.2	2.3	8.5	1.4	0.0	1.6	2.3	0.0	0.0	4.5	1.6	0.0	0.0
Ice Harbor	40.1	14.1	5.1	3.5	6.4	1.0	0.7	1.1	0.0	0.0	0.1	18.7	7.6	1.4	0.2
Lower Granite	38.6	14.0	5.5	3.8	6.4	1.0	0.7	1.2	0.0	0.1	0.1	18.8	8.2	1.5	0.2

Table 24. 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 2011.

		2008	2007		2006			2005			2004		Unknown		
Dam	**Statistic**	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**3.1**	**2.3**	**3.2**	**4.1**	**3.3**	**4.2**	**r.1**	**r.2**	**r.3**
Bonneville	μ	57.9	71.7	58.8	83.3	69.7	59.0	82.2	70.4	58.1	89.5	80.0	57.6	70.7	81.0
	s	3.0	5.3	3.8	3.8	4.3	2.7	3.4	4.0	2.3	0.7	---	3.2	4.7	3.6
	n	404	213	101	72	125	17	17	16	4	2	1	202	135	30
McNary	μ	57.8	72.0	58.7	83.2	69.8	59.4	82.2	69.7	58.8	89.5	80.0	57.4	71.7	81.1
	s	3.0	5.2	3.6	3.8	4.0	2.7	1.9	3.8	1.1	0.7	---	3.0	4.8	3.8
	n	309	142	60	49	78	13	9	13	2	2	1	156	73	18
Priest Rapids	μ	57.5	69.7	57.8	77.5	71.5	56.0		70.0	58.0			56.9	69.8	
	s	2.4	2.7	6.7	---	4.8	---		---	---			3.2	3.8	
	n	17	18	2	1	10	1		1	1			5	5	
Rock Island	μ	57.3	69.7	57.8	77.5	71.5	56.0		70.0	58.0			57.5	73.8	
	s	2.3	2.8	6.7	---	4.8	---		---	---			3.4	1.8	
	n	16	17	2	1	10	1		1	1			4	2	
Rocky Reach	μ	57.3	70.0	57.8	77.5	71.1	56.0		70.0	58.0			56.3	75.0	
	s	2.3	3.0	6.7	---	4.1	---		---	---			3.1	---	
	n	16	14	2	1	5	1		1	1			3	1	
Wells	μ	57.3	69.8	57.8	77.5	70.1	56.0		70.0	58.0			55.0	75.0	
	s	2.4	3.2	6.7	---	4.0	---		---	---			2.8	---	
	n	15	12	2	1	4	1		1	1			2	1	
Ice Harbor	μ	57.7	72.8	59.1	83.0	70.2	59.8	82.2	70.0		89.5	80.0	57.3	72.0	81.2
	s	2.9	5.3	3.8	3.6	3.7	3.0	2.0	4.1		0.7	---	3.1	4.7	4.0
	n	271	112	39	44	48	8	8	9		2	1	137	56	16
Lower Granite	μ	57.8	72.7	59.1	83.0	70.5	59.0	82.2	69.6		89.5	80.0	57.2	72.1	81.2
	s	2.8	5.3	3.9	3.8	3.7	2.4	2.0	4.3		0.7	---	3.0	4.8	4.1
	n	223	101	35	41	39	7	8	8		2	1	120	51	15

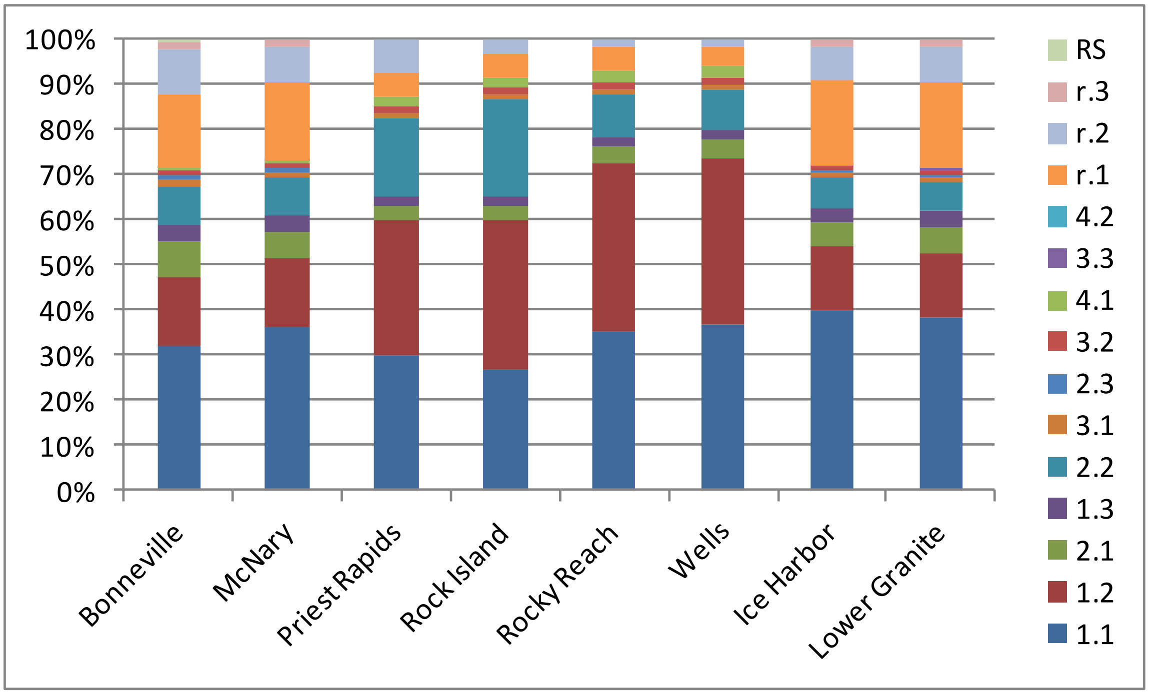

Figure 17. Steelhead age composition at Columbia and Snake river dams estimated using PIT tags in 2011. RS are repeat spawners. The "r" in age r.X means that the freshwater zone of the scale was regenerated and the age therefore unreadable.

B-Run Analyses

The percentage of steelhead sampled and tagged that were classified as B-run (≥78 cm) peaked in Statistical Week 41 with 47.9% of the run being B-run. In 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 39 (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 78.0 cm and greater were almost entirely destined for the Snake River (Figures 19 and 20).

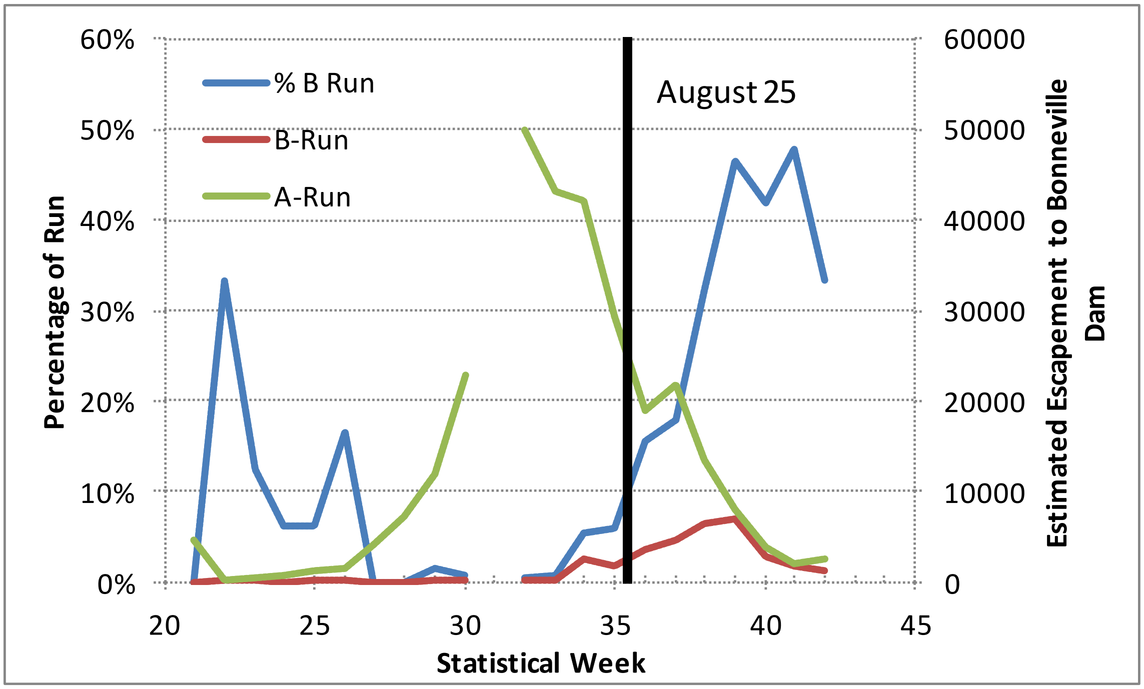

Figure 18. Percentage of B-run steelhead and estimated A- and B-run escapement at Bonneville Dam by statistical week in 2011. August 25 is noted as it is considered the date that separates A- and B-run steelhead.

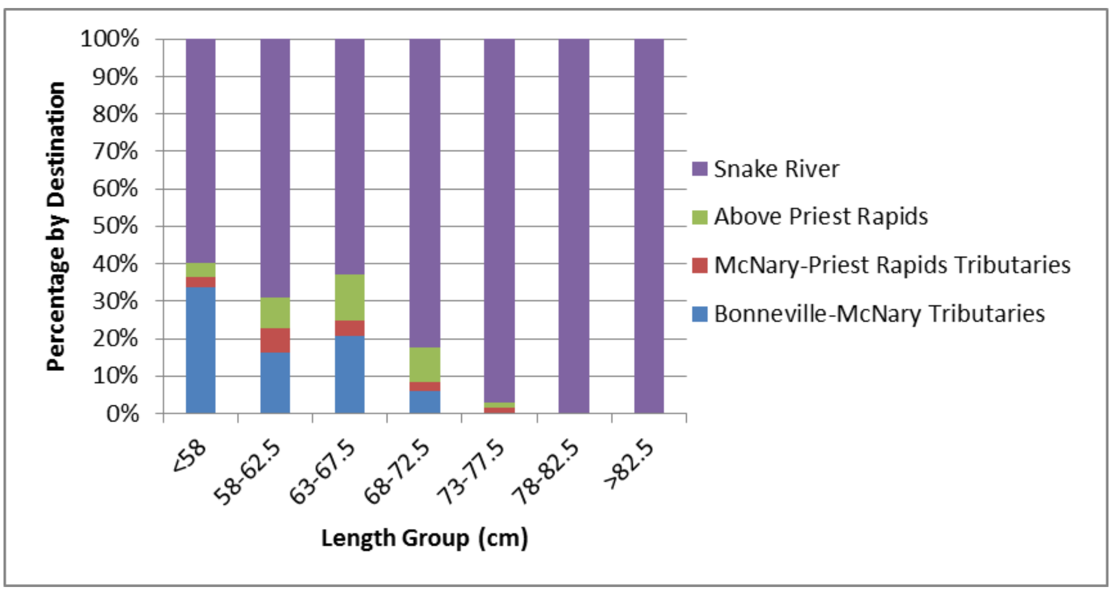

Figure 19. Final detection site for steelhead PIT tagged at Bonneville Dam in 2011 by length group. Due to small sample sizes for all but the Snake River, steelhead were grouped by 5 cm increments above and below the 78 cm B-run threshold.

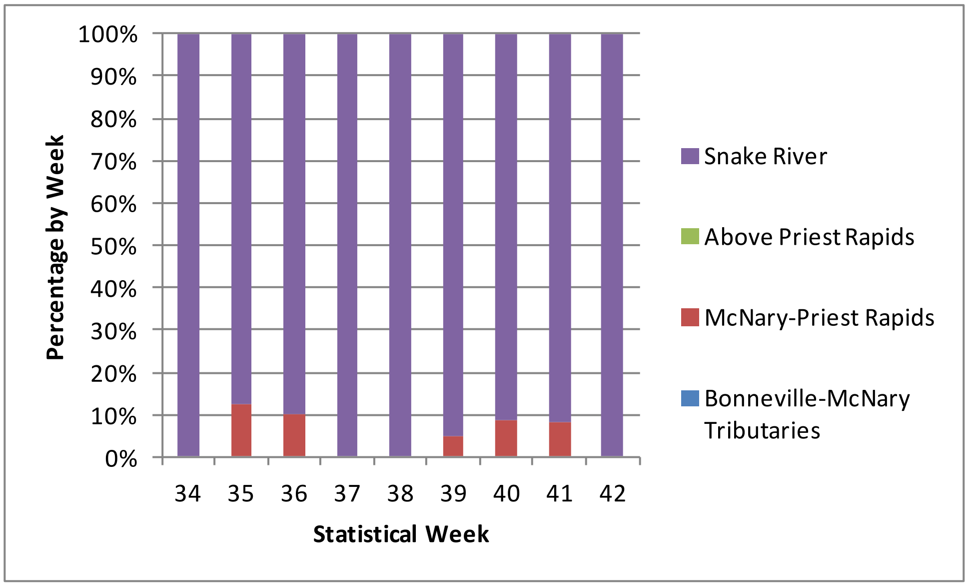

Figure 20. Final detection site for B-run steelhead (>78 cm fork length) by Statistical Week in 2011. No B-run steelhead were detected above Priest Rapids Dm or at Bonneville-McNary tributaries.

Kelt Analyses

A total of 49 PIT tagged steelhead tracked in 2011 were detected moving downstream (mostly in juvenile bypasses) after February, 1 2012, presumably in an attempt to return to the ocean after spawning. The 49 steelhead we designated as kelt represented between 0.0% and 7.18% of the run at Bonneville Dam between Statistical weeks 27 and 42 (Table 25 and Figure 21) with an overall mean of 3.1% of the run. Of these steelhead, two were detected after July, 2012 and were tracked in the Columbia Basin into the fall of 2012 (Table 26). We were also able to add additional steelhead to the table of kelts tagged in 2010 (Table 27) as new fish returned in the spring and summer of 2012 at Bonneville Dam.

Table 25. PIT tagged steelhead tracked from Bonneville Dam in 2009-2011 last detected moving downstream, listed by last downstream detection site.

Last site	2011	2010	2009
Bonneville Corner Collector	10	23	61
Bonneville Juvenile Bypass	1	4	7
Estuary trawl	0	0	1
Ice Harbor Juvenile Bypass	1	6	0
John Day Juvenile Bypass	3	11	3
Little Goose Juvenile Bypass	11	13	6
Lower Granite Juvenile Bypass	4	10	3
Lower Monumental Juvenile Bypass	12	9	4
Lower Washington Shore McNary Dam ladder, likely moving downstream.	0	2	1
McNary Dam Juvenile Bypass	3	2	4
Rocky Reach Juvenile Bypass	4	6	7
Total	**49**	**86**	**97**

Table 26. Season by season activities of steelhead tagged in 2011 and later labeled as kelts when they began migrating downstream and upstream presumably to and from the ocean.

Tag Year	Tag Number	Last Summer Detection After Tagging 2011	Fall 2011	Winter 2011/12	Spring 2012	Summer 2012	Fall 2012	Comments
2011	3D9.1C2DABFB17	Bonneville Washington Shore Ladder - May 27th					Bonneville Oregon Shore Ladder - October 3rd	
2011	3D9.1C2DAFDADD	McNary Juvenile Bypass - August 15th					Bonneville Oregon Shore Ladder - September 12th McNary - September 20th	

Key - - -			
Key - - -	Upstream	Downstream	Spawning

Table 27. Season by season activities of several steelhead tagged in 2010 and later labeled as kelts when they began migrating downstream and upstream presumably to and from the ocean. Additional information was added to this 2010 report table as new data on migration information became available in 2012

Tag Year	Tag Number	Last Summer Detection After Tagging 2010	Fall 2010	Winter 2010/11	Spring 2011	Summer 2011	Fall 2011	Winter 2011/12	Spring 2012	Summer 2012	Fall 2012	Winter 2012/13	Spring 2013	Comments
2010	3D9.1C2D416B93	McNary - June 30th	Prosser Dam - October 3rd				Prosser Dam - October 26th							Female steelhead collected at Prosser Dam for reconditioning in 2010 and released in October 2011 for spawning.
2010	3D9.1C2D3F364C	Bonneville Washington Shore Ladder - August 6th	McNary - September 13th	McNary - January 25th McNary - January 25th	McNary - March 5th	Bonneville Washington Shore Ladder - September 23rd	McNary - October 3rd							
2010	3D9.1C2D3F0E59	Lower Granite - August 10th				Bonneville Washington Shore Ladder - August 19th	McNary - September 10th Ice Harbor - September 13th Lower Granite - September 18th							
2010	3D9.1C2D3F1CC4	Bonneville Washington Shore Ladder - July 20th								Bonneville Cascade Island - July 21st				Newly added to this table based on return detections.
2010	3D9.1C2D3F1847	Bonneville Washington Shore Ladder - June 14th								Bonneville Bradford Island - June 26th				Newly added to this table based on return detections.
2010	3D9.1C2D3F2A4F	Bonneville Washington Shore Ladder - August 4th		McNary - October 10th McNary - October 10th	Feed Diversion Dam in Umatilla River - March 5th					Bonneville Washington Shore - August 18th				Newly added to this table based on return detections. Most likely spawned in Umatilla River.
2010	3D9.1C2D3F4923	Bonneville Cascades Island - July 13th	McNary - September 9th Ice Harbor - September 11th Lower Granite - September 18th							Bonneville Washington Shore Ladder - July 28th	McNary - September 14th Ice Harbor - September 16th Lower Granite - October 6th			Newly added to this table based on return detections.
2010	3D9.1C2D3FE181	Bonneville Washington Shore Ladder - July 20th			McNary - March 11th Walla Walla River - March 12th and 24th Bonneville Dam Corner Collector - May 8th					Bonneville Cascade Island - July 29th	McNary - November 27th	Walla Walla River - February 5th and 6th	Walla Walla River - March 2nd and 10th	Newly added to this table based on return detections. Tracked to the Walla Walla River for spawning in 2011 and 2013. May have spent 2012 in the ocean.
2010	3D9.1C2D416459	Bonneville Washington Shore Ladder - July 26th	McNary - October 23rd Ice Harbor - October 26th Lower Granite - November 9th		Joseph Creek (Grande Ronde) - March 4th Little Goose Juvenile Bypass - May 6th					Bonneville Washington Shore Ladder - August 17th	McNary - October 21st Ice Harbor - October 23rd Lower Granite - November 6th		Joseph Creek (Grande Ronde) - March 12th	Newly added to this table based on return detections. Tracked to a Grande Ronde Trib for spawning in 2011 and 2013. May have spent 2012 in the ocean.
2010	3D9.1C2D06BF24	Wind River - June 14th							Bonneville Washington Shore Ladder - May 27th					Newly added to this table based on return detections.
2010	3D9.1C2D3CA357	Bonneville Washington Shore Ladder - July 10th								Bonneville Bradford Island - July llth Lyle Falls Klickitat - July 15th				Newly added to this table based on return detections.
2010	3D9.1C2D3CB44E	McNary - June 16th	Ice Harbor - October 15th Lower Granite - October 22nd	Imnaha River - February 13th and 14th	Imnaha River - May 12th Lower Granite Juvenile Bypass - May 21st					Bonneville Bradford Island - July 15th McNary - July 23rd	Ice Harbor - October 23rd Lower Granite - November 6th		Imnaha River - March 12th and 13th	Newly added to this table based on return detections. Tracked to the Imnaha RIver for spawning in 2011 and 2013. May have spent 2012 in the ocean.

Key - - - Upstream | Downstream | Spawning

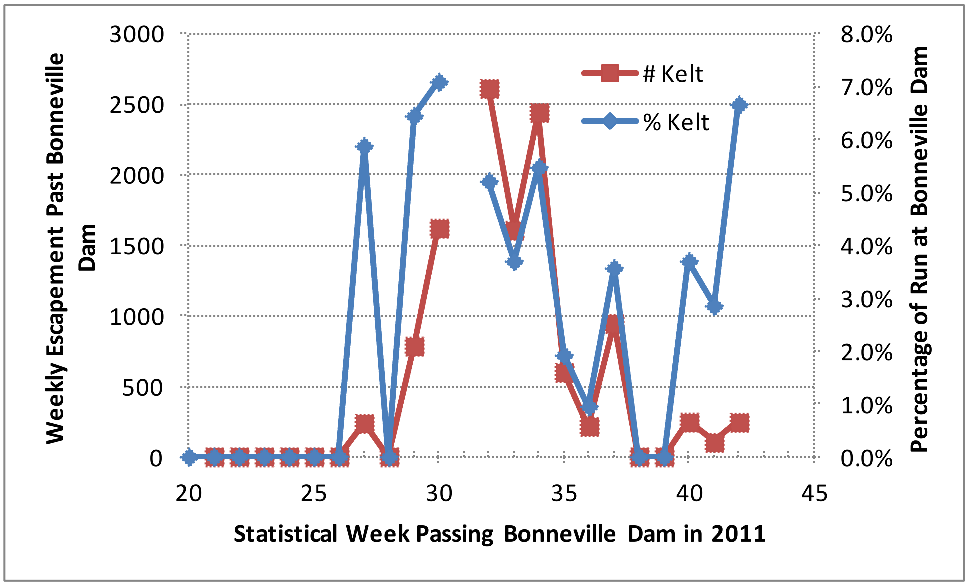

Figure 21. Percentage and number of steelhead designated as kelt passing Bonneville Dam by statistical week in 2011.

Fallback

Estimated fallback-reascension rates based on steelhead reascending fish ladders ranged from 0.9% to 13.9% (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. Steelhead in 2011 had the highest fallback rate at Lower Granite Dam.

Table 28. Estimated 2011 steelhead fallback/reascension.

Dam	Percent Fallback%
Bonneville	0.9%
McNary	1.0%
Priest Rapids	4.8%
Rock Island	1.8%
Rocky Reach	4.3%
Wells	2.4%
Ice Harbor	2.5%
Lower Granite	13.9%

Night Passage

Night passage (2000-0400 Pacific Standard Time) by tagged steelhead was under 7% at all mainstem dams (Table 29). The Bonneville Dam estimate of night passage is likely biased with low numbers due to the time tagging, which occurred between 0700 and 1400 PST. Given the median Bonneville Dam passage time of 69.8 minutes (Table 22), steelhead would be expected to pass during daytime hours.

Table 29. Estimated steelhead night passage (2000-0400) in 2011 at Columbia Basin dams with a minimum of 15 detections as estimated by PIT tags.

Site	Steelhead (%)
Bonneville	1.3%
McNary	2.5%
Priest Rapids	3.2%
Rock Island	2.3%
Rocky Reach	4.3%
Wells	4.9%
Ice Harbor	4.1%
Lower Granite	6.6%

RESULTS-SOCKEYE[d]

Sample Size

A total of 767 sockeye salmon were sampled between June 6 and July 19, 2011. We halted sampling 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. Only 1.6% of the sockeye run passed Bonneville Dam subsequent to the termination of sampling. Of the 767 fish sampled, all were PIT tagged prior to release with the exception of three that were already tagged (Table 30). A total of 19 sockeye were not detected after release.

Table 30. Number of PIT tagged sockeye salmon tagged at Bonneville Dam and tracked upstream by date and statistical week at Bonneville in 2011.

			Tagged		Recaptures of Previously Tagged Fish	Tracked Upstream of Bonneville	
Sampling Dates	**Statistical Week**	**Sampled (n)**	**12.5 mm**	**9 mm**	**12.5 mm**	**12.5 mm**	**9 mm**
6/6,7,9,10	24	19	17	2		17	2
6/13,14,15,16,17	25	82	68	14		66	12
6/20,21,22,23	26	127	102	24	1	100	25
6/27,28,29,30,7/1	27	211	172	38	1	169	37
7/5,6,7,8,	28	178	142	34	1	141	32
7/11,12,13,14	29	125	101	24		100	22
7/18,19	30	25	21	4		20	4
Total		**767**	**623**	**140**	**3**	**613**	**134**

The predominant age class at Bonneville Dam was Age 1.2, comprising an estimated 65.2% of the run (Table 31). The percentage of Age 1.1 sockeye generally increased as the run progressed, while Age 1.3 sockeye decreased and the percentage of Age 1.2 sockeye remained relatively consistent.

Table 31. Weekly and total age composition of sockeye salmon PIT tagged at Bonneville Dam as estimated from scale patterns in 2011.

Statistical Week	N Ageable	Age Class					
		1.1	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**
24	19	15.8%	63.2%	15.8%	0.0%	5.3%	0.0%
25	79	5.1%	60.8%	25.3%	2.5%	6.3%	0.0%
26	125	8.8%	63.2%	19.2%	2.4%	6.4%	0.0%

[d] The information presented in this section of the report is a summary of Fryer et al. 2011.

27	201	10.9%	71.1%	11.4%	1.0%	5.5%	0.0%
28	171	25.7%	64.3%	6.4%	1.2%	2.3%	0.0%
29	123	33.3%	56.9%	3.3%	5.7%	0.8%	0.0%
30	24	29.2%	62.5%	0.0%	4.2%	0.0%	4.2%
Composite	**742**	**17.6%**	**65.2%**	**10.9%**	**2.0%**	**4.1%**	**0.1%**

Comparison of 9 and 12.5 mm Tags

At 10 out of 12 sites with more than 10 detections of sockeye PIT tagged by this study (Table 32), the percentage of tagged sockeye detected with 9 mm tags was less than expected percentage of 18.3% (the percentage of Chinook in our sample that were tagged with 9 mm tags). Only at Rock Island Dam and at in-stream arrays in the Okanagan River and White River was this difference significant. Data from both tag types was pooled for most subsequent analyses presented in this report.

Table 32 Total number of tagged Chinook detected (40 detection minimum) by site, the percentage which were 9 mm tags and the p-value for a comparison with the percentage of 9 mm tags deployed (18.3% in 2011). Significant differences (α=0.05) are in bold.

Detection Location	PTAGIS Site Code	Tags Detected	% 9 mm	P-value
Bonneville Dam, Washington Shore Upper	BO4	725	17.8%	0.404
Priest Rapids Dam	PRA	536	17.2%	0.303
Rock Island Dam	**RRF**	**460**	**12.0%**	**0.002**
Rocky Reach Dam	RIA	404	14.9%	0.069
Wells Dam	WEA	403	15.6%	0.128
Bonneville Dam, Washington Shore Lower	BO3	397	19.1%	0.641
Okanagan Channel antenna	**OKC**	**294**	**12.9%**	**0.018**
McNary Dam - Washington Shore	MC1	256	14.8%	0.105
McNary Dam - Oregon Shore	MC2	238	15.5%	0.167
Tumwater Dam	TUF	103	21.4%	0.775
White River Antenna	**WTL**	**19**	**0.0%**	**0.020**
Little Wenatchee River Antenna	LWN	13	15.4%	0.394

Upstream Recoveries, Mortality, and Escapement

Sockeye salmon tagged with 9 mm tags were less likely to be detected at all dams with the exception of Wells Dam, which was the only dam where no PIT tagged sockeye were missed based on upstream detection data (Table 33). At Rock Island, Priest Rapids, and Rocky Reach dams, the percentage of 9 mm tagged fish missed was 6-14 times that of 12.5 mm tagged fish, although the number of fish missed at both Priest Rapids and Rocky Reach dams was small. At Rock Island, a lightning strike on May 31, 2011 disabled the PIT tag detection system at the left bank fish way until it was fixed on June 29, 2011, however the number of PIT tagged sockeye salmon missed was likely extremely small as less than 0.5% of the sockeye salmon counted at Rock Island fish ladders passed during this outage.

Most of the tagged sockeye salmon that were not detected at Rock Island Dam were lost before reaching McNary Dam (Figure 22). This reach of river is where the tribal Zone 6 fishery occurs that was estimated to harvest 12,849 sockeye salmon with an additional 197 sockeye harvested by sport fishers (Stuart Ellis, U.S. v. Oregon Technical Advisory Committee, personal communication). However, adding this harvest to our estimated escapement to McNary Dam (141,337) still leaves 31,413 sockeye salmon unaccounted for between Bonneville and McNary dams.

Table 33. Percentage of PIT tagged fish by tag type not detected at dam detection sites as estimated from upstream detections in 2011 with comparison data for 2006-2010[e].

Dam	2011 (12.5 mm)		2011 (9 mm)		2010	2009	2008	2007	2006
	N	%	N	%					
Bonneville*	3	0.7%	1	1.3%	0.7%	0.6%	0.4%	2.1%	0.2%
McNary*	57	12.6%	24	24.7%	3.8%	5.0%	10.1%	6.5%	3.1%
Priest Rapids	2	0.5%	5	5.7%	0.6%	0.3%	0.3%	0.8%	0.0%
Rock Island	23	5.5%	34	39.1%	6.2%	2.6%	6.9%	6.8%	1.3%
Rocky Reach	5	1.5%	6	9.5%	0.5%	0.0%	0.2%	0.7%	12.3%
Wells	0	0.0%	0	0.0%	0.0%	--	--	--	--
Ice Harbor*	0	0.0%	--	--	0.0%	20.0%	0.0%	--	--

[e] 2011 results differ slightly from those reported in Fryer et al. 2012 due to a different calculation methodology (see methods) and an error discovered in calculations of the Bonneville rates.

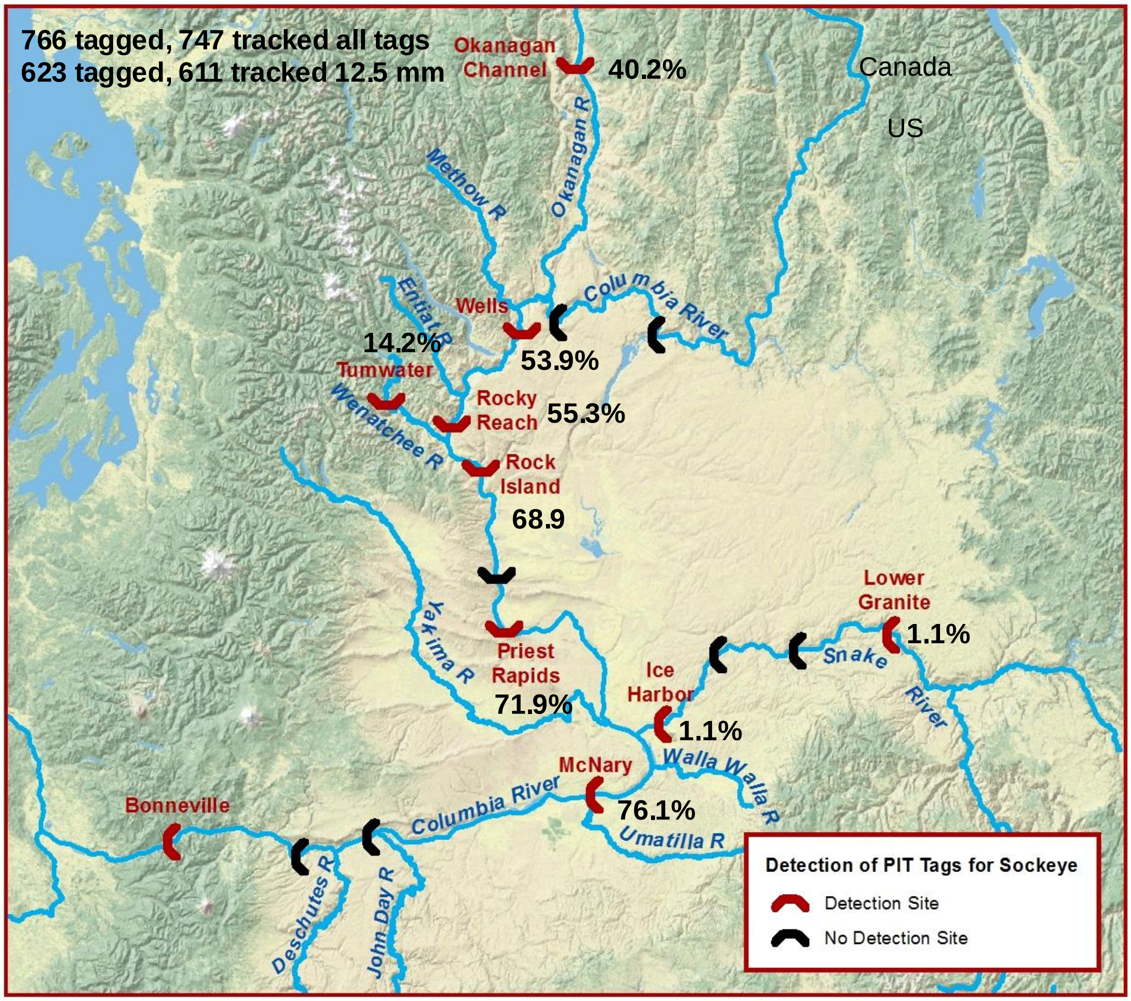

Figure 22. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of sockeye salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream sites with PIT tag detection in 2011.

Using detections of fish PIT tagged by this program to estimate fish counts at dams resulted in estimates that varied from actual visual fish counts by 7.9% to 80.0% (Table 34). 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 detection and visual detection. In 2011, as in previous years, PIT tag estimates exceeded visual counts at McNary Dam, likely due at least in part to navigation lock passage. At all other Columbia River dams visual counts exceeded PIT tag estimates.

Table 34. Percentage of PIT tagged sockeye salmon detected subsequent to tagging at upstream dams, estimated escapement from both PIT tags (12.5 mm only) and visual means, and the difference between the PIT tag and visual escapement estimate in 2011.

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using PIT Tag Data	Visual Dam Count	Difference Between PIT Tag and Visual Estimate
Bonneville	100.0%	--	185796	--
McNary	76.1%	141337	113952	24.0%
Priest Rapids	71.9%	133567	145070	-7.9%
Rock Island	68.9%	128036	146111	-12.7%
Rocky Reach	55.3%	102686	132096	-22.2%
Wells	53.9%	100132	111508	-10.2%
Tumwater	14.2%	26311	18622	41.3%
Ice Harbor	1.1%	2054	1141	80.0%
Lower Granite	1.1%	2054	1502	36.7%

Survival from Bonneville to McNary, Priest Rapids, and Rock Island was highest in Statistical weeks 24 and 30, and lowest in Statistical Week 26 (Table 35, Figure 23). The Zone 6 harvest may have contributed to lower survival in Weeks 27 and 28 as 71.6% of the harvest was during these weeks.

Table 35. Sockeye salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2011.

Statistical Week at Bonneville Dam	Bonneville-McNary	Bonneville-Priest Rapids	Bonneville-Rock Island	Rocky Reach-Wells
24	100.0%	100.0%	94.7%	100.0%
25	70.5%	69.2%	66.7%	97.7%
26	68.0%	68.0%	64.0%	95.2%
27	75.7%	71.4%	67.0%	100.0%
28	75.6%	70.9%	66.9%	98.0%
29	81.5%	76.6%	75.0%	96.2%
30	91.7%	87.5%	87.5%	81.3%
Composite	**75.3%**	**71.8%**	**71.8%**	**97.4%**
p-value	**0.05**	**0.22**	**<0.01**	**0.10**

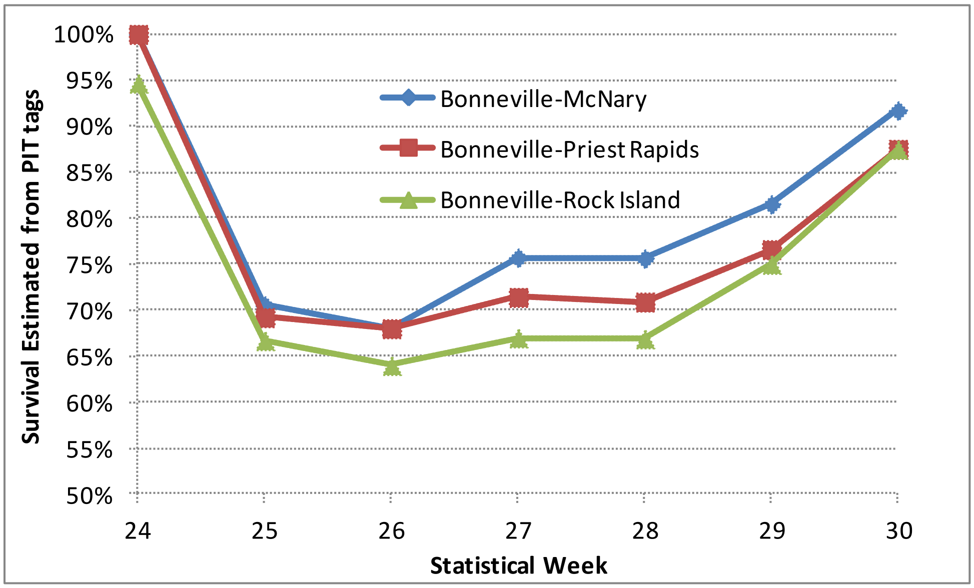

Figure 23. Survival from to McNary, Priest Rapids, and Rock Island dams by statistical week tagged at Bonneville Dam as estimated by PIT tags in 2011.

Travel Rates and Passage Time

Sockeye salmon travel quickly upstream with a median travel time between Bonneville and Rock Island Dam of 14.2 days (Table 36). Sockeye salmon passing Bonneville Dam later in the migration travel upstream faster than those earlier in the migration (Table 37). 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, Tumwater, and Wells dams as well as between McNary and Rock Island, Rock Island and Rocky Reach, and Rocky Reach and Wells dams.

Table 36. Median sockeye salmon migration time and travel rates between dams as estimated by PIT tag detections in 2011.

Dam Pair	Distance (km)	Median Time (days)	Median Travel Time (km/day)
Bonneville-McNary	231	5.8	39.9
McNary-Priest Rapids	167	4.8	34.8
Priest Rapids-Rock Island	89	3.2	28.1
Rock Island-Rocky Reach	33	1.1	28.7
Rocky Reach-Wells	65	2.2	29.5
Rock Island-Tumwater	73	20.3	3.6
Bonneville-Rock Island	487	14.2	34.4
Bonneville-Tumwater	560	35.3	15.9
Bonneville-Wells	585	18.0	32.6

The median difference in travel time from Bonneville Dam to all upstream mainstem dams except Wells Dam (where only six sockeye classified as

Wenatchee stock were detected) was one day or less between the two major stocks (Table 37).

Table 37. Adult sockeye salmon travel median time in days between dam pairs by statistical week passing Bonneville Dam, the F-statistic for a linear regression between travel time and statistical week, and mean travel time by stock as estimated using PIT tags in 2011.

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
24	6.7	14.2	17.5	18.9	--	22.0	10.9	1.6	2.9
25	7.2	15.4	18.2	20.7	47.4	23.7	10.5	1.6	2.7
26	5.8	11.9	15.8	17.3	41.2	20.0	9.9	1.4	2.3
27	5.8	10.8	14.5	15.7	35.1	18.2	8.5	1.1	2.4
28	5.6	10.1	13.6	14.6	31.1	16.8	8.0	1.1	2.0
29	5.1	9.7	12.7	13.7	25.5	15.8	7.4	1.0	2.0
30	5.5	9.7	12.6	13.7	26.7	15.2	6.7	1.0	1.8
P-value	**0.01**	**0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Stock									
Okanagan	5.7	10.7	14.0	15.7	--	17.9	8.7	1.2	2.2
Wenatchee	5.9	11.0	15.0	16.7	35.3	20.3	9.6	0.9	3.1
Snake River	6.0	--	--	--	--	--	--	--	--
Unknown[f]	6.1	11.6	15.8	--	--	--	8.1	--	--

The median time between first detection and last detection was six minutes or less at all dams except for Bonneville and Lower Granite dams (Table 38).

Table 38. Sockeye salmon median passage time from time of first detection at a dam to last detection at a dam and the percentage of sockeye salmon taking greater than 12 hours between first detection and last detection in 2011.

Dam	Median Passage Time (Minutes)	Taking More Than 12 Hours (%)
Bonneville	56	3.0%
McNary	0	5.9%
Priest Rapids	6	1.9%
Rock Island	4	2.4%
Rocky Reach	1	3.7%
Wells	3	5.5%
Tumwater	6	12.6%
Ice Harbor	3	0.0%
Lower Granite	262	16.7%

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

At Bonneville Dam, many sockeye were detected in underwater orifices just upstream and downstream of the fish trap where sampling occurred, inflating the median passage time. At Lower Granite Dam, all fish pass through the adult fish trap which likely results in increased passage times.

Night Passage

At dams with more than six detections, Okanagan stock sockeye salmon passed dams at night (2000-0400 hours) at a higher rate than Wenatchee stock sockeye salmon (Table 39). The Bonneville Dam estimate of nighttime passage is likely biased low because tagging occurred between about 0800 and 1300 hours, and with a median passage time of 56 minutes from tagging to final detection at Bonneville Dam (Table 38), fish would be expected to pass the counting window prior to 2000 hours.

Table 39. Estimated sockeye salmon nighttime passage (2000-0400 standard time) in 2011 at dams passed as estimated by PIT tag detections.

Dam	All Sockeye (includes unknown)	Okanagan Stock	Wenatchee Stock	Snake Stock
Bonneville	0.3%	0.0%	0.0%	0.0%
McNary-Oregon Shore	3.4%	3.7%	2.4%	0.0%
McNary-Washington Shore	5.9%	6.0%	5.8%	0.0%
Priest Rapids	1.9%	2.5%	0.0%	NA
Rock Island	4.1%	5.0%	0.0%	NA
Rocky Reach	4.2%	4.3%	0.0% [a]	NA
Wells	11.7%	11.6%	0.0% [a]	NA
Tumwater	9.7%	NA	9.7%	NA
Ice Harbor	16.7%	NA	NA	16.7% [a]
Lower Granite	0.0%	NA	NA	0.0% [a]
Mean of McNary, Priest Rapids and Rock Island	3.6%	4.1%	1.4%	NA

a - Based on six or fewer detections.

Stock Composition Estimates

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=0.85, Table 40). The overall stock composition estimate was 21.9% Wenatchee, 76.8% Okanagan, and 1.3% Snake River.

Six sockeye salmon were detected at both Wells and Tumwater dams. In all cases, these fish first passed Wells Dam, then moved downstream through both Wells and Rocky Reach dams, before being detected passing Tumwater Dam.

Table 40. Weekly and composite sockeye salmon stock composition at Bonneville Dam as estimated by PIT tags in 2011 and a comparison to stock composition estimates estimated using visual dam counts.

Statistical Week and Dates	Run Size	PIT Tag Sample Size	Percent Wenatchee	Percent Okanagan	Percent Snake River
24 (June 6-10)	1,048	19	0.0%	100.0%	0.0%
25 (June 13-17)	9,304	78	15.7%	84.3%	0.0%
26 (June 20-23)	34,753	125	24.4%	75.6%	0.0%
27 (June 27-July 1)	60,531	206	29.0%	68.8%	2.2%
28 (July 5-8)	53,023	173	16.4%	81.9%	1.7%
29 (July 11-14)	21,521	122	14.1%	84.8%	1.1%
30 (July 18-19)	5,616	24	25.0%	75.0%	0.0%
Composite	**185,796**	**747**	**21.9%**	**76.8%**	**1.3%**

A total of 43 adipose clipped sockeye salmon were PIT tagged[g]. Of these, 5 were last detected in the Snake Basin (2 of which had ventral fin clips in addition to an adipose fin clip), 12 were last detected in the Wenatchee Basin, 5 were last detected at or upstream of Rocky Reach Dam (1 in the Twisp River), and 21 were last detected at a Columbia River dam between Bonneville and Rock Island dams. We had 2 additional fish with ventral fin clips, 1 left and 1 right, which were last detected at OKC.

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

Age 1.2 sockeye salmon predominated in both our Wells and Tumwater samples (Tables 41 and 42). At Wells Dam, Age 1.1 sockeye increased through the migration while Age 1.3 sockeye decreased, with Age 1.2 fish staying relatively constant. The age distribution of males had a much higher percentage of Age 1.1 and 1.3 fish, and a lower percentage of Age 1.2 fish than females. After weighting the weekly sex composition by run size, males comprised an estimated 63.8% of the run at Wells Dam.

The Wenatchee sockeye run at Tumwater Dam overwhelmingly passed during Statistical Week 32 and consisted almost entirely of Age 1.2 and 1.3 sockeye. An estimated 61.2% of the run at Tumwater Dam was female and, like at Wells Dam, females were more likely to be Age 1.2 and less likely to be Age 1.3.

[g] Juvenile sockeye salmon are adipose clipped in Snake River and Lake Wenatchee hatchery programs.

Table 41. Age composition by week and sex for sockeye salmon sampled at Wells Dam in 2011.

Stat Week	Sampling Dates	Run Size	N	N Ageable	1.1	1.2	1.3	2.1	2.2	2.3
≤28	7/6,7/7	5,501	21	20	0.0%	45.0%	35.0%	10.0%	10.0%	0.0%
29	7/11,7/12	27,615	117	114	5.3%	38.6%	38.6%	2.6%	13.2%	1.8%
30	7/18,7/19	44,039	175	173	13.9%	49.1%	31.8%	1.2%	4.0%	0.0%
31	7/25,26,27	26,038	213	209	32.5%	46.9%	14.8%	2.4%	3.3%	0.0%
≥32	8/1,2,3	8,315	77	76	39.5%	40.8%	9.2%	5.3%	5.3%	0.0%
Composite		**111,508**	**603**	**592**	**17.3%**	**45.2%**	**28.0%**	**2.6%**	**6.5%**	**0.4%**
Variance					**1.4%**	**2.2%**	**2.0%**	**0.7%**	**1.1%**	**0.3%**
Males			392	385	21.7%	37.4%	32.3%	3.7%	4.6%	0.4%
Females			211	207	8.5%	60.1%	20.4%	1.0%	9.4%	0.5%

Table 42. Age composition by week and sex for sockeye salmon sampled at Tumwater Dam in 2011.

Stat Week	Sampling Dates	Run Size	N	N Ageable	1.1	1.2	1.3	2.1	2.2	2.3
≤32	8/1,8/2,8/3	13,969	209	207	--	77.3%	19.8%	--	2.9%	--
33	8/8,8/9,8/10	3,321	144	143	--	96.5%	2.1%	--	1.4%	--
≥34	8/15	1,344	6	6	--	83.3%	16.7%	--	0.0%	--
Composite		**18,634**	**359**	**356**	**--**	**81.2%**	**16.4%**	**--**	**2.4%**	--
Std. Dev.						**2.5%**	**2.4%**		**0.9%**	
Males			142	141	--	76.0%	21.9%	--	2.2%	--
Females			216	214	--	84.8%	12.6%	--	2.6%	--

The estimated Wenatchee sockeye age composition estimate (Wenatchee-Tumwater sample Stock-Method, (Table 43) was very similar to that estimated from sockeye salmon PIT tagged at Bonneville Dam that were subsequently detected at Tumwater Dam (Wenatchee-PIT tag Stock-Method, Table 43). In contrast, the estimated age composition at Wells Dam estimated from sampling differed considerably from that estimated from sockeye salmon PIT tagged at Bonneville Dam that were subsequently detected at Wells Dam. Wells sampling estimated more Age 1.3 sockeye and fewer Age 1.1 and Age 1.2 sockeye. This is consistent with past years where we have observed that the Wells Dam fish traps appear selective for larger sockeye (Fryer et al. 2011).

Wenatchee length at-age-composition estimates were similar using the two different methodologies; with mean length estimates differing by less than 2 cm for a given age class (Table 44). Okanagan length-at-age composition estimates were more variable, differing by up to 3.4 cm for Age 2.2. For both stocks, the mean length for fish sampled at upstream dams was greater than that of mean length at tagging for Bonneville tagged fish passing through the dam in question. Morphological changes caused by maturation between the time the fish were sampled at Bonneville Dam and the upstream dams, along with a trap bias at Wells Dam, are likely explanations for this difference.

Table 43. Age composition (%) of Columbia Basin sockeye salmon stocks as estimated by PIT tag recoveries as well as by sampling at Tumwater and Wells dams in 2011. Standard deviations are in parentheses.

Stock-Method	Ageable Sample Size	Age 1.1	1.2	1.3	2.1	2.2	2.3
Bonneville-sample	727	18.0 (1.4)	64.9 (1.8)	10.8 (1.2)	2.1 (0.5)	4.2 (0.8)	0.1 (0.1)
Wenatchee-PIT tag estimate	103	--	81.1 (3.5)	14.4 (3.3)	--	4.5 (2.1)	--
Wenatchee-Tumwater sample	395	--	81.2 (2.8)	16.4 (1.1)	--	2.4 (2.7)	0.2 (2.0)
Okanagan- PIT tag estimate	394	26.1 (2.3)	59.2 (2.6)	7.7 (1.4)	3.1 (0.9)	3.7 (1.0)	0.2 (0.2)
Okanagan-Wells sample	592	17.3 (1.4)	45.2 (2.1)	28.0 (2.0)	2.6 (0.7)	4.3 (0.3)	1.9 (0.6)
Snake River PIT tag estimate	5	18.4	81.6	--	--	--	--

Table 44. Length-at-age composition of Wenatchee and Okanagan stock sockeye salmon estimated by PIT tag detection and sampling at Tumwater and Wells dams in 2011.

Stock	Statistic	Age 1.1	1.2	1.3	2.1	2.2	2.3
Bonneville-Mixed stock	Mean	39.8	50.8	56.9	42.2	51.2	57.5
	St. Dev.	1.7	2.3	2.2	1.8	2.1	--
	N	131	475	83	17	30	1
Okanagan-PIT tags	Mean	39.9	50.2	56.5	42.1	50.7	57.5
	St. Dev.	1.7	2.4	2.4	1.9	1.8	--
	N	101	232	32	14	16	1
Okanagan-Wells Sampling[h]	Mean	40.1	52.3	57.5	44.1	54.1	58.0
	St. Dev.	2.0	2.2	2.4	2.0	3.4	4.2
	N	128	267	144	16	35	2
Wenatchee-PIT tags	Mean	--	51.3	57.4	--	52	--
	St. Dev.	--	2.0	1.3	--	2.4	--
	N	--	81	15	--	4	--
Wenatchee-Tumwater Sampling	Mean	--	53.0	58.7	--	53.8	60.5
	St. Dev.	--	2.6	3.5	--	3.5	--
	N	--	300	44	--	8	1

[h] The estimated Okanagan stock age composition determined from otoliths collected on the spawning ground (n=335) was .1.1=18.2%, 1.2=66.4%, 2.1=4.3%, 1.3=7.1%, 2.2 =4.0% (Margot Stockwell, personal communication).

Fallback

The highest fallback-reascension rates for sockeye salmon was at Lower Granite dam; however this rate was only based on six fish (Table 45). Fallback rates elsewhere were low, ranging from 0% at Ice Harbor to 4.1% at Rocky Reach Dam.

Table 45. Estimated fallback rates for sockeye salmon at dams in 2011.

Dam	Percent Fallback%
Bonneville	0.5%
McNary	0.9%
Priest Rapids	2.6%
Rock Island	1.7%
Rocky Reach	4.1%
Wells	2.7%
Tumwater	1.0%
Ice Harbor	0.0%
Lower Granite	16.7%

DISCUSSION

This study sampled and PIT tagged over 5100 salmonids at Bonneville Dam in 2011 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. The year 2011 marked the 6th year we have been tagging sockeye salmon, the 5th year we have tagged Chinook and the 3rd year we have PIT tagged steelhead at Bonneville Dam. Over this time, the number of PIT tag detection sites has continually increased, allowing us to learn more about the movement of tagged salmonids through the Columbia Basin.

In 2011, we tested the performance of 9mm tags at upstream PIT tag arrays. These tags were developed primarily for use in juvenile salmon tagging studies where tag size can be a limiting factor in the size of juveniles which can be tagged. As part of the development process, these tags are tested to ensure adequate detection at juvenile detection systems at Snake and Columbia River mainstem dams. Their detection efficiency at adult fish ladders as well as in-stream detection arrays is unknown. Therefore tests, such as what we carried out in 2011, are valuable in determining how well these new tags will be detected at these sites when juveniles with these tags return as adults. Based on the results of this study, we recommend using the traditional 12.5 mm tags wherever possible, especially if detection at in-river antennas is important.

Excluding Rock Island Dam, which will be discussed later, the rate of fish not detected at dams was relatively small (generally under 3%) the undetectable rate for 9 mm tagged fish averaged two to four times that of 12.5 mm tagged fish (over all dams, 3.0% vs. 1.4% for Chinook, 0.4% vs. 1.2% for steelhead, and 2.6% vs. 8.2% for sockeye). Although 9 mm tagged fish were consistently detected at lower rates than 12.5 mm tagged fish at mainstem dam fish ladders, the only locations other than Rock Island Dam where there was a significant difference in detection rate were at in-stream antenna arrays. For sockeye salmon, we found the 9 mm tags were detected at a significantly lower rate at in-river antennas in the Okanagan River and on the White River in the Wenatchee system (the latter had power outages in 2011 which could have influenced this result).

At Rock Island Dam, rates of missed tagged fish were high, especially for those tagged with 9 mm tags compared to 12.5 mm tagged fish (33.0% vs. 11.0% for Chinook, 60.0% vs. 15.0% for steelhead, and 39.1% vs. 5.5% for sockeye). Rock Island Dam is known for having lower rates of detection than other mainstem dams due to electrical interference (Fryer et al. 2011) and it is likely that 9 mm tags are more adversely affected than 12.5 mm tags. In 2011, a lightning strike did disable PIT tag detection on the left ladder of Rock Island Dam from May 31 to June 29. However, visual counts indicate that only 19.9% of the Chinook run, 0.5% of the sockeye run, and less than 0.1% of the steelhead passed during this period and an even smaller fraction would have used the left ladder compared to the right or center ladders.

At McNary Dam, 12.6% of 12.5 mm tagged sockeye and 24.7% of 9 mm tagged sockeye were not detected. At this dam, it is likely that sockeye are using the navigation locks which are located on the north side of the dam just downstream from the Snake River (which enters the Columbia River from the south side). Corroborating evidence for this hypothesis is that the visual count of sockeye salmon at McNary Dam was 21.5% less than that at Priest Rapids Dam. However, the rate of missed Chinook and steelhead at McNary Dam was less than 2%.

All detection rates were lower than expected given the high probability of detection estimated at individual weirs (Tables A1-A3). At all fish ladders, the estimated probability of detecting 9 mm or 12.5 mm tagged Chinook or steelhead was 98% or higher. For sockeye, the probability of detection was 97.6% or higher at all dams except at the Rock Island Dam right ladder (96.9% for 12.5 mm tagged and 88.0% for 9 mm tagged sockeye) and Rocky Reach where the probability of detection was 93.4% for 9 mm tagged sockeye. This suggests that some tagged fish have some characteristic (e.g. the way the fish passes through the antenna or a malfunctioning or poorly placed PIT tag), that allows them to escape detection at multiple weirs at a given dam.

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 2011 the percentage of Chinook salmon at Bonneville Dam which ultimately passed Ice Harbor Dam peaked at 47.3% of the run for the week starting May 30, declining to 4.5% for the week starting June 10. The portion of the run bound for upstream of Priest Rapids Dam over the same period increased from 8.5% to 67.2%. These results suggest that in 2011, as in 2010, the run at Bonneville Dam transitioned over the month of June from being primarily Snake River spring/summer to being primarily mid-Columbia summer Chinook.

As at Bonneville Dam, Chinook runs passing dams upstream of Bonneville Dam are differentiated based on the date they pass, and these dates per dam are based on fixed migration rates assumed by managers. For instance, spring Chinook transition to summer Chinook on June 1 at Bonneville Dam, June 11 at Ice Harbor Dam and June 13 at Priest Rapids Dam. This means that the same Chinook could be classified differently at different dams. For instance, a “spring” Chinook passing Bonneville Dam on May 31 would be a “summer” Chinook passing Priest Rapids Dam on June 13. Using PIT tag data, this study found that 23.0% of spring, 0.4% of the summer, and 8.3% of the fall Chinook at Bonneville Dam were classified differently (Table 8). Misclassified Bonneville spring Chinook were all classified as summers, misclassified summers were all classified as falls, and the only incorrectly classified fall Chinook was classified as a summer Chinook at Priest Rapids Dam. This study found that 11.3% of spring, 0.4% of the summer, and 0.6% of the fall Chinook at Bonneville Dam were classified differently at Ice Harbor Dam. Incorrectly classified Bonneville Dam spring Chinook were classified as summers at Ice Harbor Dam, incorrectly classified summer Chinook were classified as fall Chinook, while the sole incorrectly classified fall Chinook was classified as a summer Chinook at Ice Harbor Dam.

Escapement estimates using PIT tag data for mainstem dam passage varied from the traditional methods (i.e. visual counts) and ranged from -6.1% to +17.6% for the entire Chinook salmon run; however there was considerably greater variation when looking at individual runs. Escapement estimates for sockeye salmon at Columbia River dams differ between the methods by -22.2% to 24.0%. Many factors can cause these discrepancies including inaccuracies of visual or video counts, fallback/reascension rates, tagging effects, and a biased sample 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.

The number of kelt steelhead returning in 2011 estimated by this project (3.1% of the run) was a decrease from the 4.8% estimated in 2009 and 5.2% in 2010. Also declining over 2010, but not 2009, was the percentage of B-run steelhead which comprised 11.4% of the run. This compares to 18.0% in 2010 and 8.0% in 2009.

The overall number of fish tagged in 2011 was similar to that in 2010 (Table 46). We tagged approximately 0.4% of the run for all three species in 2011. With few sampling days impacted by high temperatures our sample distribution was relatively similar to the run distribution with the exception of the steelhead and fall Chinook peaks when we cannot sample sufficient hours to sample proportionally.

Table 46. Total number of Chinook and sockeye PIT tags deployed by year (includes recpatures of previously PIT tagged fish).

	Total Tagged				Percent of run tagged			
Year	Chinook	Steelhead	Sockeye	Total	Chinook	Steelhead	Sockeye	Total
2009	2968	2485	838	6291	0.42%	0.41%	0.47%	0.42%
2010	2579	1741	913	5233	0.29%	0.42%	0.24%	0.31%
2011	3253	1377	763	5393	0.38%	0.37%	0.41%	0.38%

From 2008 through 2010 this study documented delays in sockeye salmon passage at Tumwater Dam that was likely attributable to 24 hour operation of the trap at that facility (Table 47). The median delay reported was up to 4.6 days (in 2008) and PIT tag detection records suggested that up to 33.3% (in 2010) of sockeye salmon reaching Tumwater Dam never passed over it. Trap operations were changed in 2011 so that passage through the fish ladder was not blocked 24 hours per day. The result was that the median delay dropped to 6 minutes in

2011 and it was likely that all sockeye detected at Tumwater Dam successfully passed over it. There was only one sockeye (9 mm tag) that was last detected at the lower antenna at Tumwater Dam; however this tag generated so few detections on its upstream migration that the tag was likely defective.

Table 47. Sockeye salmon delays at Tumwater Dam 2008-2011.

Year	N	Run Size	% last detected at downstream antenna	% taking more than 12 hours to pass	Median Delay (minutes)
2008	96	28034	8.3%	62.1%	4554
2009	87	16034	26.4%	41.4%	158
2010	111	35821	33.3%	72.1%	8494
2011	103	18634	1.0%	12.6%	6

Chinook salmon still were delayed at Tumwater Dam, with a median passage time at that site of over 20 hours (20:17) for spring Chinook and 9 hours for summer Chinook. For spring Chinook, 2 of 19 (10.5%) and 1 of 45 (2.2%) summer Chinook were last detected at the downstream antenna suggesting that these fish may not have passed over the dam.

REFERENCES

Busby, P.J. T. C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, R. W. Waknitz, and I.V. Lagomarsino. 1996. Status review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-27. http://www.nwfsc.noaa.gov/publications/techmemos/tm27.

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

Fish Passage Center (FPC). 2010. Adult fish counts online at www.fpc.org..

Fryer, J.K. 2008. Use of PIT tags to determine upstream migratory timing and survival of Columbia Basin sockeye salmon in 2007. Columbia River Inter-Tribal Fish Commission Technical Report 08-02.

Fryer, J. K. 2009. Use of PIT tags to determine upstream migratory timing and survival of Columbia Basin sockeye salmon in 2008. Columbia River Inter-Tribal Fish Commission Technical Report 09-03.

Fryer, J.K. 2010. Studies into factors limiting the abundance of Okanagan and Wenatchee sockeye salmon. Columbia River Inter-Tribal Fish Commission Technical Report

Fryer, J.K., H. Wright, S. Folks, K. Hyatt. 2011. Studies into Factors Limiting the Abundance of Okanagan and Wenatchee Sockeye Salmon in 2010. U.S. Dept. of Energy Bonneville Power Administration Report Project #2008-503-00.

Koo, T.S.Y. 1962. Age designation in salmon. Pages 37-48 *in* T.S.Y. Koo (editor). Studies of Alaska Red Salmon. University of Washington Press, Seattle, Washington.

Kelsey D., J. Mainord, J. Whiteaker, and J.K. Fryer. 2011. Age and length composition of Columbia Basin Chinook and sockeye salmon and steelhead at Bonneville Dam in 2009. Columbia River Inter-Tribal Fish Commission Technical Report.

Whiteaker J., and J.K. Fryer. 2008. Age and length composition of Columbia Basin Chinook and sockeye salmon and steelhead at Bonneville Dam in 2007. Columbia River Inter-Tribal Fish Commission Technical Report.

APPENDIX

Table A1. Probability of tag detection at PIT tag detectors by weir at Columbia Basin fish ladders, and the overall probability of detection, for Chinook salmon in 2011. Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank.

Dam, Site, Tag Type, and Number		Weir and Probability of Detection at Weir										Overall Detection Probability
Bonneville	**N**	**1**	**2**	**3**	**4**							
BO1 12.5 mm	51	100.0	96.3	94.4	96.3							100.0
BO1 9 mm	8	87.5	100.0	100.0	100.0							
BO4 12.5 mm	2602	95.4	97.1	98.5	97.8							100.0
BO4 9 mm	550	68.7	78.7	89.6	48.4							
McNary	**N**	**1**	**2**	**288**	**287**	**286**	**284**	**283**	**282**	**280**	**279**	
MC1 12.5 mm	999	97.1	98.7	92.0	43.5	89.9	91.3	52.4	91.8	91.7	91.4	100.0
MC1 9 mm	255	93.3	91.0	90.6	43.1	90.2	90.6	48.2	91.0	86.3	91.0	99.4
	N	**1**	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**303**	**302**	
MC2 12.5 mm	565	96.8	99.5	98.6	81.1	41.8	36.1	81.4	82.3	82.8	82.7	100.0
MC2 9 mm	130	96.2	97.7	97.7	82.3	40.8	35.4	77.7	81.5	83.1	83.8	100.0
Priest Rapids	**N**	**3**	**7**									
East 12.5 mm	293	97.6	100.0									100.0
East 9 mm	75	54.7	100.0									100.0
	N	**3**	**5**									
West 12.5 mm	75	77.5	100.0									100.0
West 9 mm	41	53.8	100.0									100.0
Rock Island	**N**	**1-2**	**3-4**									
Left (east) 12.5 mm	88	98.9	100.0									100.0
Left (east) 9 mm	15	86.7	93.3									99.1
	N	**5-6**	**7-8**									
Middle 12.5 mm	30	96.6	100.0									100.0
Middle 9 mm	5	60.0	100.0									100.0
	N	**09-0A**	**0B-0C**									
Right (west) 12.5 mm	178	97.8	86.5									99.7
Right (west) 9 mm	25	92.0	76.0									98.1
	N	**1-2**	**3-4**									
Rocky Reach 12.5 mm	205	99.5	95.6									100.0
Rocky Reach 9 mm	54	92.6	87.0									99.0
Wells	**N**	**1-2**	**3-4**									

Left (east) 12.5 mm	120	94.2	100.0									100.0
Left (east) 9 mm	33	93.9	97.0									99.8
	N	**5-6**	**7-8**									
Right (west) 12.5 mm	79	94.9	96.2									99.8
Right (west) 9 mm	15	100.0	93.3									100.0
Ice Harbor	**N**	**438**	**437**	**436**	**435**							
South 12.5 mm	548	98.9	99.3	99.8	99.6							100.0
South 9 mm	142	98.6	97.2	99.3	99.3							100.0
North 12.5 mm	123	85.4	95.9	91.9	96.7							100.0
North 9 mm	32	68.8	93.8	90.6	84.4							100.0
	N	**733**	**732**	**731**	**730**							
Lower Granite 12.5 mm	625	99.5	99.4	99.4	99.7							100.0
Lower Granite 9 mm	163	99.4	99.4	98.8	98.2							100.0
	N	**A1**	**A2**									
Tumwater 12.5 mm	53	100.0	100.0									100.0
Tumwater 9 mm	11	100.0	100.0									100.0

Table A2. Probability of tag detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for steelhead in 2011. Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank.

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 mm	1115	97.1	96.5	99.1	98.2							100.0
BO4-9 mm	214	75.2	82.2	94.4	93.5							
BO1 12.5 mm	42	92.3	100.0	100.0	100.0							
BO1 9 mm	3	100.0	100.0	33.3	100.0							100.0
McNary	**N**	**1**	**2**	**288**	**287**	**286**	**284**	**283**	**282**	**280**	**279**	
MC1 12.5 mm	633	98.3	99.7									
MC1 9 mm	119	97.5	91.6	94.4	93.5	94.4	95.1	52.8	95.5	94.9	95.2	100.0
	N	**1**	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**303**	**302**	
MC2 12.5 mm	137	99.3	98.5	99.3								
MC2 9 mm	33	84.8	90.9	87.9	89.1	51.5	40.6	81.5	83.0	48.8	85.5	100.0
Priest Rapids	**N**	**3**	**7**									
East 12.5 mm	38	100.0	100.0									
East 9 mm	10	60.0	90.0									100.0
	N	**3**	**5**									
West 12.5 mm	12	100.0	100.0									
West 9 mm	3	33.3	100.0									100.0
Rock Island	**N**	**1-2**	**3-4**									
Left (east) 12.5 mm	3	100.0	100.0									
Left (east) 9 mm	0											
	N	**5-6**	**7-8**									
Middle12.5 mm	1	100	100									
Middle 9 mm	0											
	N	**09-0A**	**0B-0C**									
Right (west) 12.5 mm	37	100.0	81.1									
Right (west) 9 mm	4	100.0	75.5									99.3
	N	**1-2**	**3-4**									
Rocky Reach 12.5 mm	40	100.0	97.5									
Rocky Reach 9 mm	8	100.0	87.5									99.7
Wells	**N**	**1-2**	**3-4**									
Left (east) 12.5 mm	22	100	100									
Left (east) 9 mm	2	100	100									100.0
	N	**5-6**	**7-8**									

Right (west) 12.5 mm	14	100	100									
Right (west) 9 mm	6	100	100									100.0
Ice Harbor	**N**	**438**	**437**	**436**	**435**							
South 12.5 mm	567	100.0	99.6	99.8	99.5							
South 9 mm	68	95.9	95.9	100.0	100.0							
North 12.5 mm	82	100.0	100.0	100.0	100.0							100.0
North 9 mm	11	100.0	90.9	100.0	100.0							100.0
	N	**733**	**732**	**731**	**730**							
Lower Granite 12.5 mm	563	93.1	91.7	90.1	95.9							100.0
Lower Granite 9 mm	109	94.5	90.8	87.2	91.7							100.0

Table A3. Probability of tag detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for sockeye salmon in 2011.

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	596	97.1	96.1	98.5	96.1	100.0
BO4-9	129	85.3	72.1	92.2	52.7	99.8
BO1-12.5	6	100.0	100.0	100.0	100.0	100.0
BO1-9	2	100.0	100.0	100.0	100.0	100.0
McNary	**N**	**1**	**2**	**3**		
MC1-12.5	201	96.5	95.5			99.8
MC1-9	37	94.6	94.6			99.7
MC2-12.5	203	93.1	99.5	94.9		100.0
MC1-9	32	84.2	100.0	97.4		100.0
Priest Rapids	**N**	**3**	**7**			
East-12.5	428	88.3	97.4			98.9
East 9	**70**	61.4	97.1			97.6
	N	**3**	**5**			
West 12.5	93	93.5	88.2			97.7
West-9	16	81.3	87.5			99.2
Rock Island	**N**	**1-2**	**3-4**			
Left-12.5	75	98.7	70.7			99.6
Left-9	22	90.9	77.3			97.9
	N	**5-6**	**7-8**			
Middle-12.5	52	76.9	98.1			99.6
Middle-9	6	33.3	100.0			100.0
	N	**09-0A**	**0B-0C**			
Right-12.5	261	84.3	80.5			96.9
Right-9	25	80.0	40.0			88.0
Rocky Reach	**N**	**1-2**	**3-4**			
12.5	344	85.2	88.1			98.2
9	60	71.2	76.7			93.4
Wells	**N**	**1-2**	**3-4**			
Left-12.5	224	98.2	96.9			100.0
Left 9	43	95.3	97.7			99.9
	N	**5-6**	**7-8**			
Right-12.5	104	99.0	98.0			100.0
Right 9	100.0	100.0	100.0			100.0
Tumwater	**N**					
12.5	81	100.0	100.0			100.0
9	9	95.5	90.9			99.6

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

Table A4. List of PTAGIS interrogation sites (three letter code, name, and description).

Site Code	Site Name	Description
ACB	Asotin Creek ISA at Cloverland Bridge	Instream detectors at the Cloverland Bridge, Asotin Creek rkm 4.6.
ACM	Asotin Creek ISA at Mouth	Instream detectors on Asotin Creek at the mouth, 50m upstream of Hwy 129 bridge.
B2J	Bonneville Dam PH2 Juvenile Bypass System	Bonneville Dam PH2 Juvenile Bypass and Sampling Facility
BBT	Touchet River at Bolles Bridge	Instream detectors on the Touchet River above Bolles Bridge at rkm 65.2
BCC	Bonneville Dam PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel
BGM	Burlingame Diversion Dam	Burlingame Diversion Dam, lower Walla Walla River
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.
CCA	Charley Creek ISA at rkm 0.5	Instream detectors on Charley Creek at rkm 0.5.
CHL	Lower Chiwawa River	Instream MUX at Chiwawa River rkm 1
CHU	Upper Chiwawa River	Instream MUX at Chiwawa River rkm 12, between the FR-62 bridge and Alder Creek
CHW	Chiwaukum Creek	Chiwaukum Creek PIT Tag Detection Site, rkm 0.4, near Tumwater Campground
CRW	Chewuch River above Winthrop	In-stream array on the Chewuch River above Winthrop, WA.
DWL	Dworshak NFH adult trap	Dworshak National Fish Hatchery Adult Trap
ENA	Upper Entiat River at rkm 17.1	Instream antenna array on Entiat river at rkm 17.1, above Mad River
ENF	Upper Entiat River Instream at rkm 40.6	Instream detectors near USFS property boundary, Entiat River rkm 40.6.
ENL	Lower Entiat River	Instream MUX at Entiat River rkm 2, immediately upstream of Entiat, WA.
ENM	Middle Entiat River	Instream MUX at Entiat River rkm 26, below the McKenzie Diversion Dam
ENS	Upper Entiat River at rkm 35.7	Instream antenna array on Entiat River rkm 35.7, above Stormy Creek
ESS	East Fk South Fk Salmon River at Parks Cr.	Instream MUX on the East Fk South Fk Salmon River (rkm 21) at Parks Creek
FDC	Feed Canal, Umatilla River	Feed Canal, Umatilla River
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 Adult Fishway and Fish Trap
GRJ	Lower Granite Dam Juvenile Bypass System	Lower Granite Dam Juvenile Fish Bypass/Transportation Facility
ICH	Ice Harbor Dam Fishways and Juvenile Bypass	Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass
ICL	Lower Icicle Creek at rkm 0.4	Lower Icicle Creek Instream PIT Tag Detection Site, rkm 0.4
IR1	Lower Imnaha River ISA at river km 7	Instream 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.
IR3	Upper Imnaha River ISA at rm 41	Instream detectors on the Upper Imhaha River at river km 41
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	Potlatch River near Juliaetta
KRS	SF Salmon River at Krassel Cr.	Instream MUX on the South Fork Salmon River (rkm 65) near Krassel Creek
LC1	Upper Lolo Creek (ID) at river km 25	Instream site on Lolo Creek 25km upstream of confluence with Clearwater River.
LC2	Lower Lolo Creek (ID) at river km 21	Instream site on Lolo Creek 21km upstream of confluence with Clearwater River.
LFF	Lyle Falls Fishway and Adult Wet Lab	Lyle Falls Fishway

Table A4. Continued.

Site Code	Site Name	Description
LMJ	Lower Monumental Dam Juvenile Bypass System	Lower Monumental Dam Juvenile Fish Bypass/Transportation Facility
LMR	Lower Methow River near Pateros	Instream MUX on the lower Methow River immediately upstream of Pateros
LTR	Lower Tucannon River,near the river mouth	Instream detectors on the lower Tucannon River below Starbuck, WA.
LWE	Lower Wenatchee River	Instream MUX at Wenatchee River rkm 2
LWL	Little White Salmon NFH adult fish ladder	Adult Fishway at Little White Salmon National Fish Hatchery
MAD	Mad River,Entiat River Basin	Instream MUX at Mad River rkm 1, at Ardenvoir, WA.
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
MCJ	McNary Dam Juvenile Bypass System	McNary Dam Juvenile Fish Bypass/Transportation Facility
MRW	Methow River array at Winthrop	In-stream array on the Methow River at Winthrop, WA.
NAL	Lower Nason Creek	Instream MUX at Nason Creek rkm 1, located within Lake Wenatchee State Park
NAU	Upper Nason Creek	Instream MUX at Nason Creek rkm 19
NBA	Nursery Bridge Diversion Dam Fishways	Nursery Bridge Dam Fishways (both), Walla Walla River at Milton-Freewater
OKC	Okanagan Channel at VDS-3	Okanagan Channel VDS-3, at Okanogan River km 149 upstream of Osoyoos Lake
ORB	Oasis Road Bridge, lower Walla Walla River	Instream detectors at Oasis Road Bridge, lower Walla Walla River
PES	Peshastin Creek	Instream MUX at Peshastin River rkm 3, below the bridge at Smithson's property
PRA	Priest Rapids Dam Adult Fishways	Priest Rapids Dam Adult Fishways (both)
PRO	Prosser Dam Fishways and screened Diversion	Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam
RCL	Rock Creek (WA) near Yakima Nation Longhouse	Instream detection system on Rock Creek (WA) near the Yakama Nation Longhouse
RCS	Rock Creek (WA) at Squaw Creek	Instream detection system on Rock Creek (WA) at Squaw Creek
RIA	Rock Island Dam Adult Fishways	Rock Island Dam Adult Fishways (all three)
ROZ	Roza Dam Juvenile Diversion	Roza Diversion Dam Spillway and Adult Fishway detectors
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway
RRJ	Rocky Reach Dam Juvenile Bypass System	Rocky Reach Dam (Chelan Co. PUD) Juvenile Fish Bypass System
SC1	Lower SF Clearwater R at rkm 0.9	Instream site on South Fork Clearwater River 0.9 km upstream of mouth
SC2	Lower SF Clearwater R at rkm 2	Instream site on South Fork Clearwater River 2 km upstream of mouth
SCL	Spring Creek NFH Adult Ladder	Adult Fishway at Spring Creek National Fish Hatchery
SCP	Spring Creek Acc. Pond behind Winthrop NFH	Instream array on Spring Creek/Foghorn Diversion below Winthrop NFH.
SFG	SF Salmon River near Guard Station Rd. Bridge	Instream MUX on the SF Salmon River (rkm 30) at the Guard Station Road Bridge
STL	Sawtooth Hatchery Adult Trap	Sawtooth Hatchery Adult Trap
STR	SF Salmon Satellite Facility	South Fork Salmon Satellite Facility downstream of Knox Bridge
TAY	Big Creek (Idaho) at Taylor Ranch	Instream detectors centered around the bridge at Taylor Ranch, Big Creek, ID
TMF	Three Mile Falls Dam Fishway and Diversion	Adult Fishway and Juvenile Bypass/subsampling facility at Three Mile Falls Dam
TUF	Tumwater Dam Adult Fishway	Adult Fishway at Tumwater Dam
TWR	Lower Twisp River near MSRF Ponds	Instream MUX on the lower Twisp River adjacent to the MSRF ponds
TWX	Estuary Towed Array (Experimental)	Columbia River Estuary Trawl Detector, operated by NOAA-Fisheries
VC1	Valley Creek,in-river at Stanley, ID	Instream detectors in Valley Creek at Stanley, ID
VC2	Valley Creek,in-river below Stanley, ID	Instream detectors in Valley Creek downstream of Stanley, ID
WEA	Wells Dam Adult Fishways	Wells Dam (Douglas Co. PUD) Adult Fishways (both)
WFC	Wolf Creek In-stream Array, Chewuck River	Instream detector on Wolf Creek, Methow River Basin
WSH	Adult fishway at Warm Springs NFH	Adult Fishway at Warm Springs National Fish Hatchery
WTL	White River,Wenatchee Basin	Instream MUX at White River rkm 4, at the old fish weir site
ZEN	Secesh River near Zena Creek Ranch	In-stream array on the Secesh River near Zena Creek Ranch
ZSL	Zosel Dam Adult Fishways	Adult Fishways at Zosel Dam, Okanogan River below Osoyoos Lake

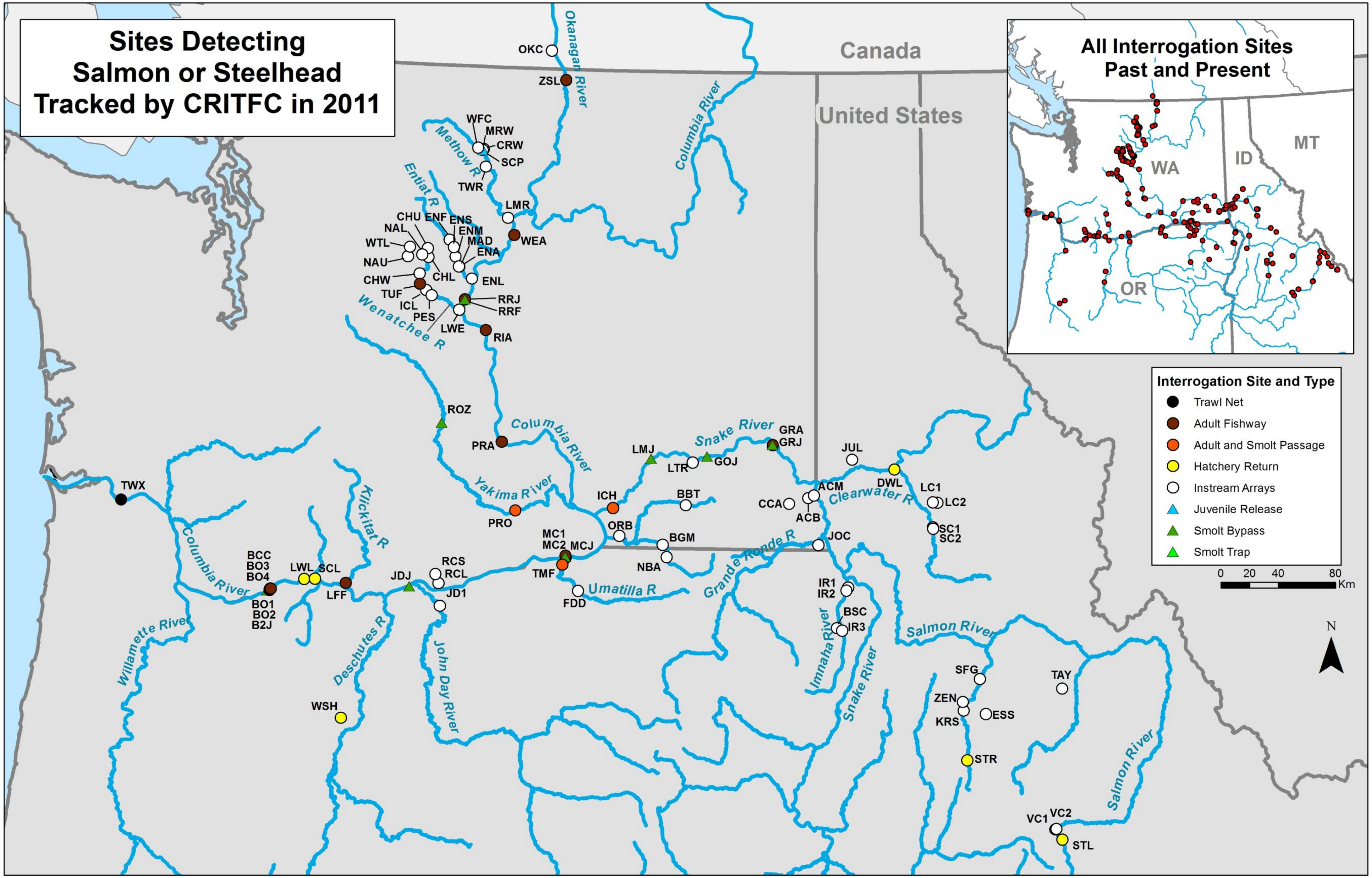

Figure A1. Map of Columbia River interrogation sites that detected Chinook and sockeye salmon, and steelhead in 2011. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

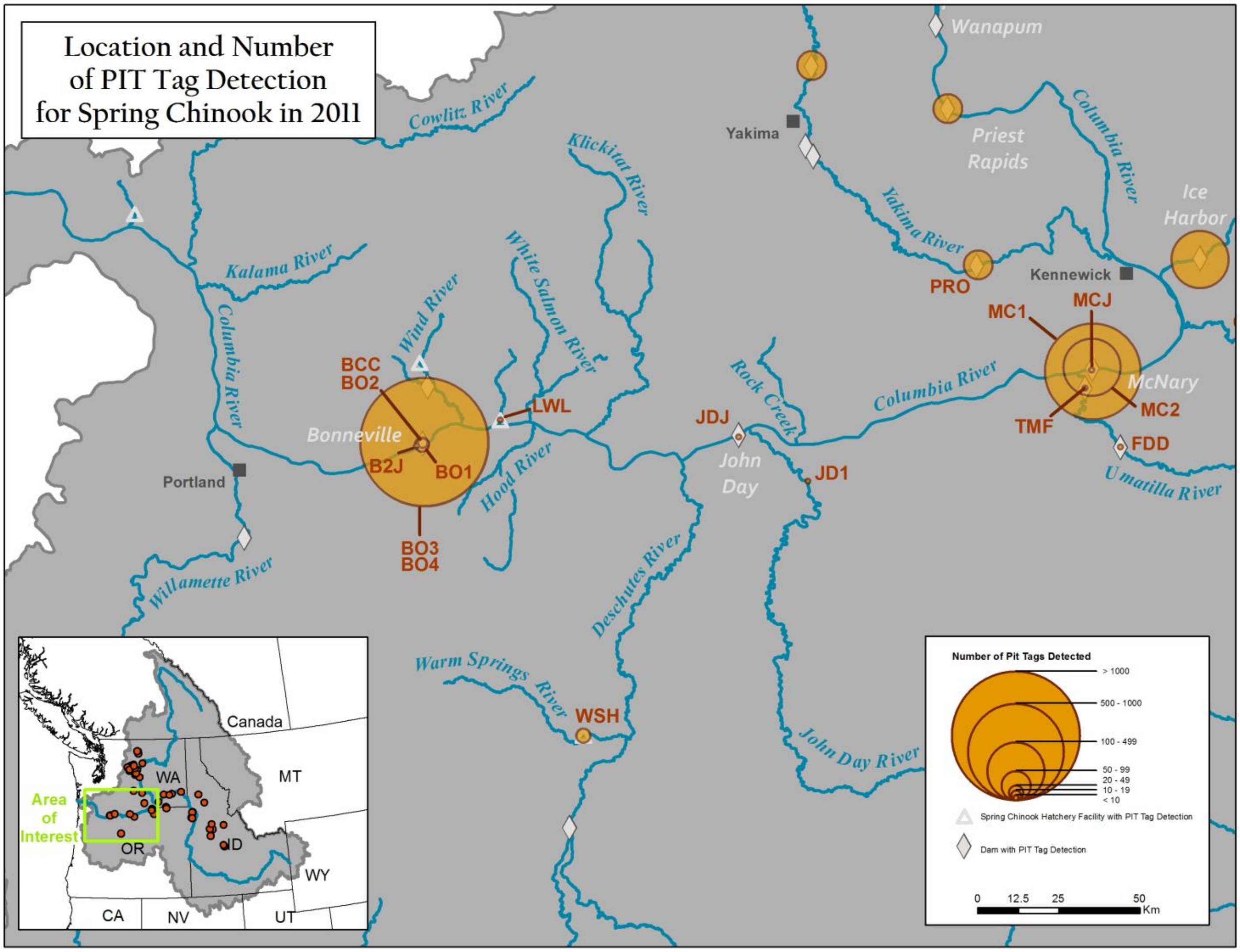

Figure A2. Map of Lower Columbia River detections sites and number of spring Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

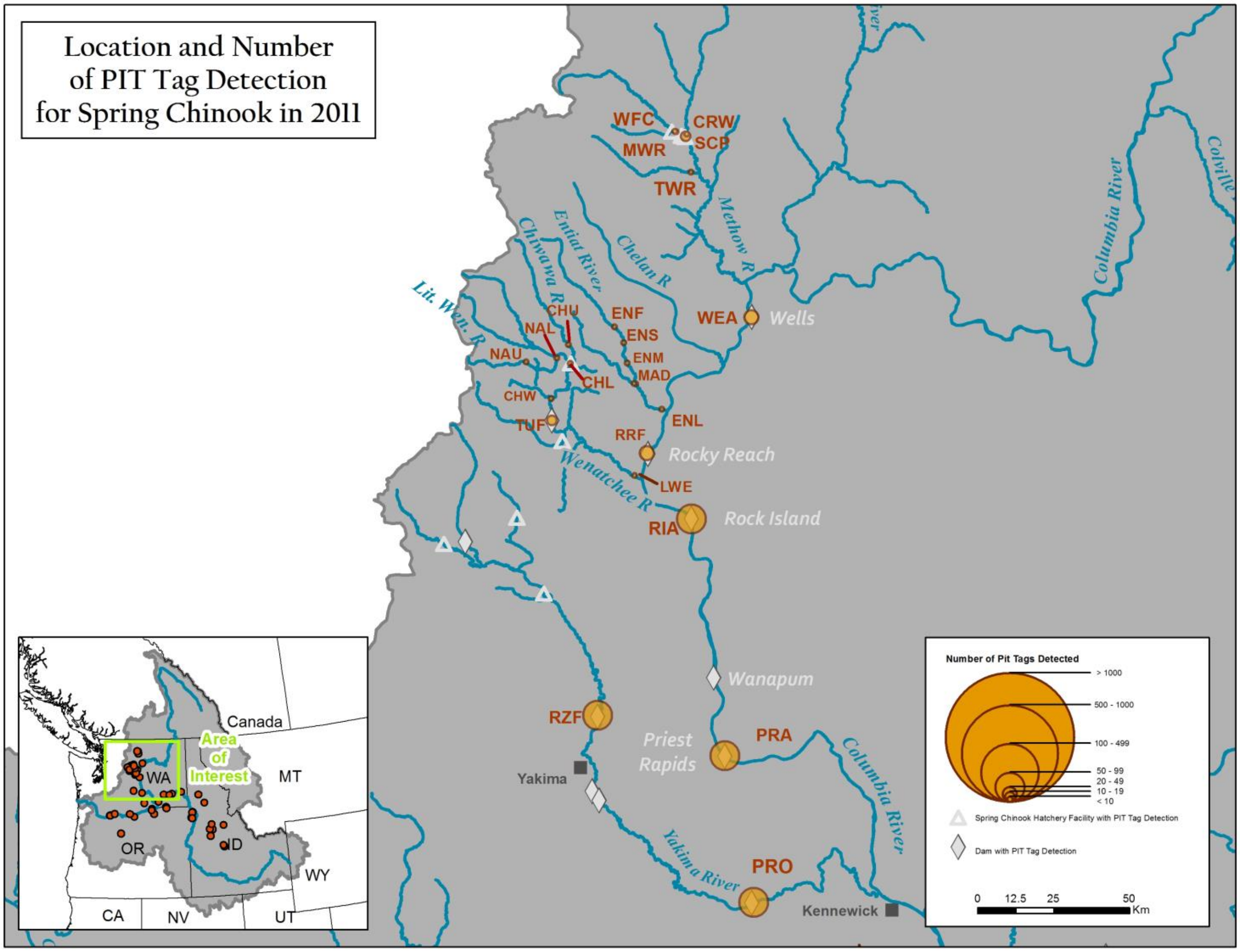

Figure A3. Map of Upper Columbia River detections sites and number of spring Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

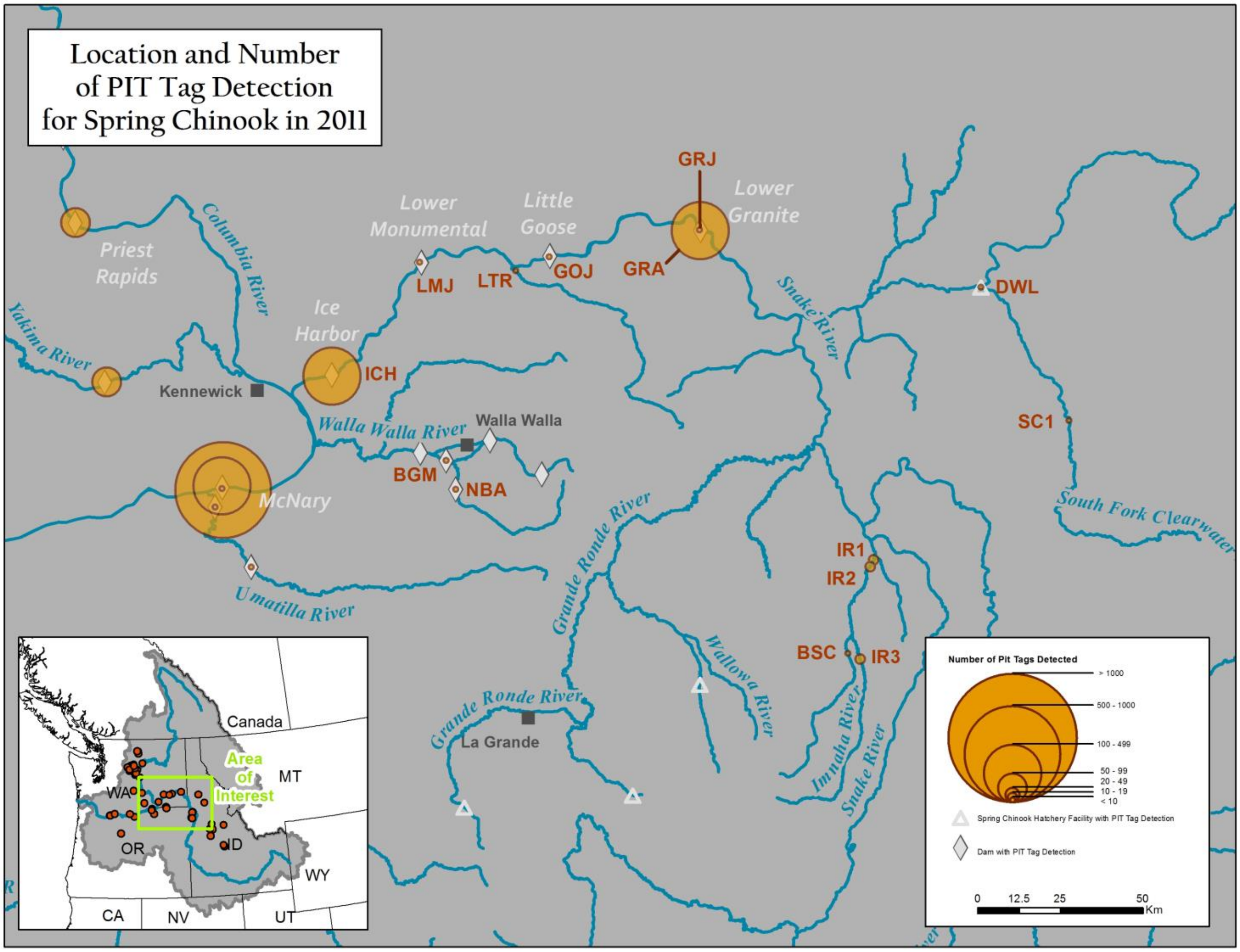

Figure A4. Map of Lower Snake River detections sites and number of spring Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

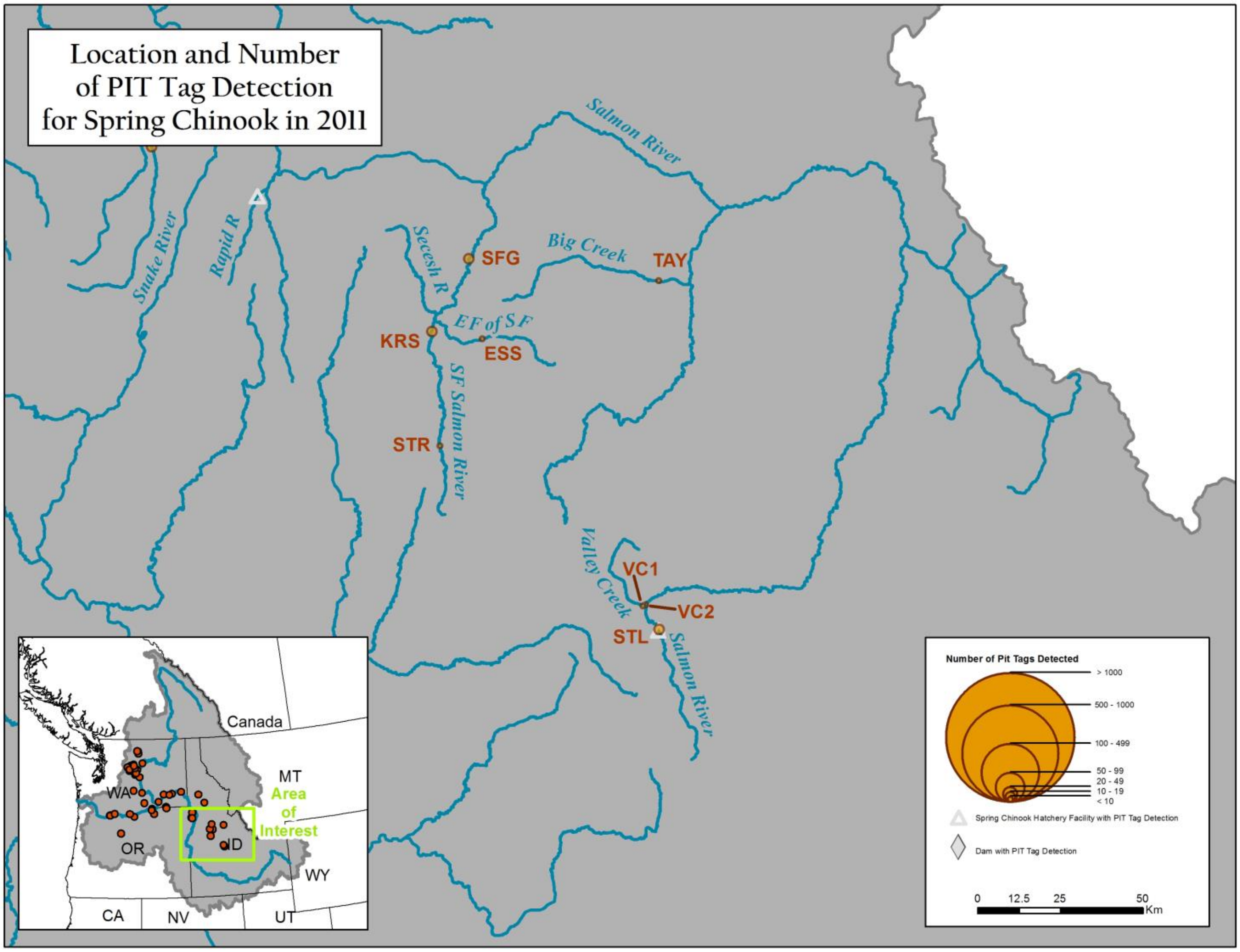

Figure A5. Map of Salmon River detections sites and number of spring Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

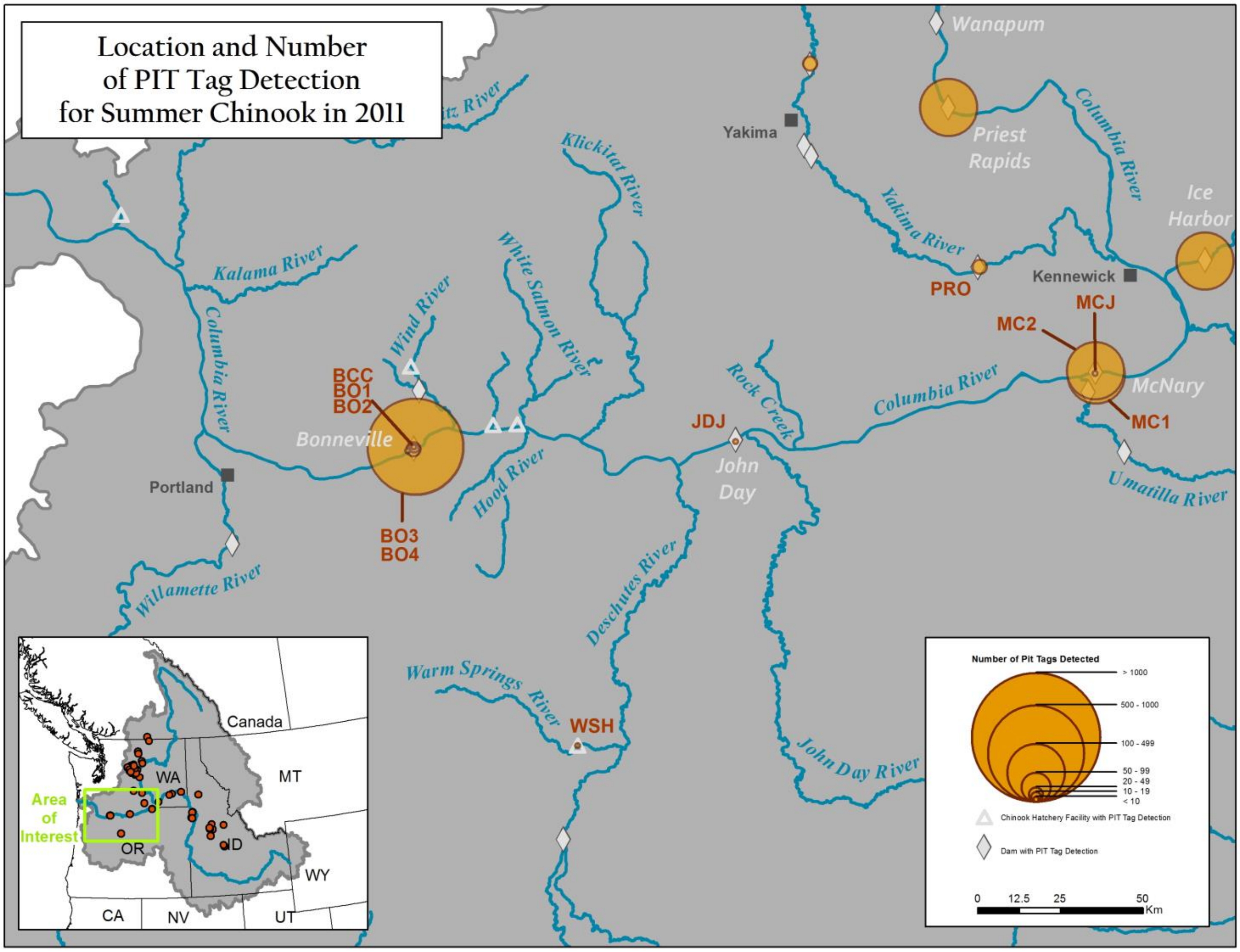

Figure A6. Map of Lower Columbia River detections sites and number of summer Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

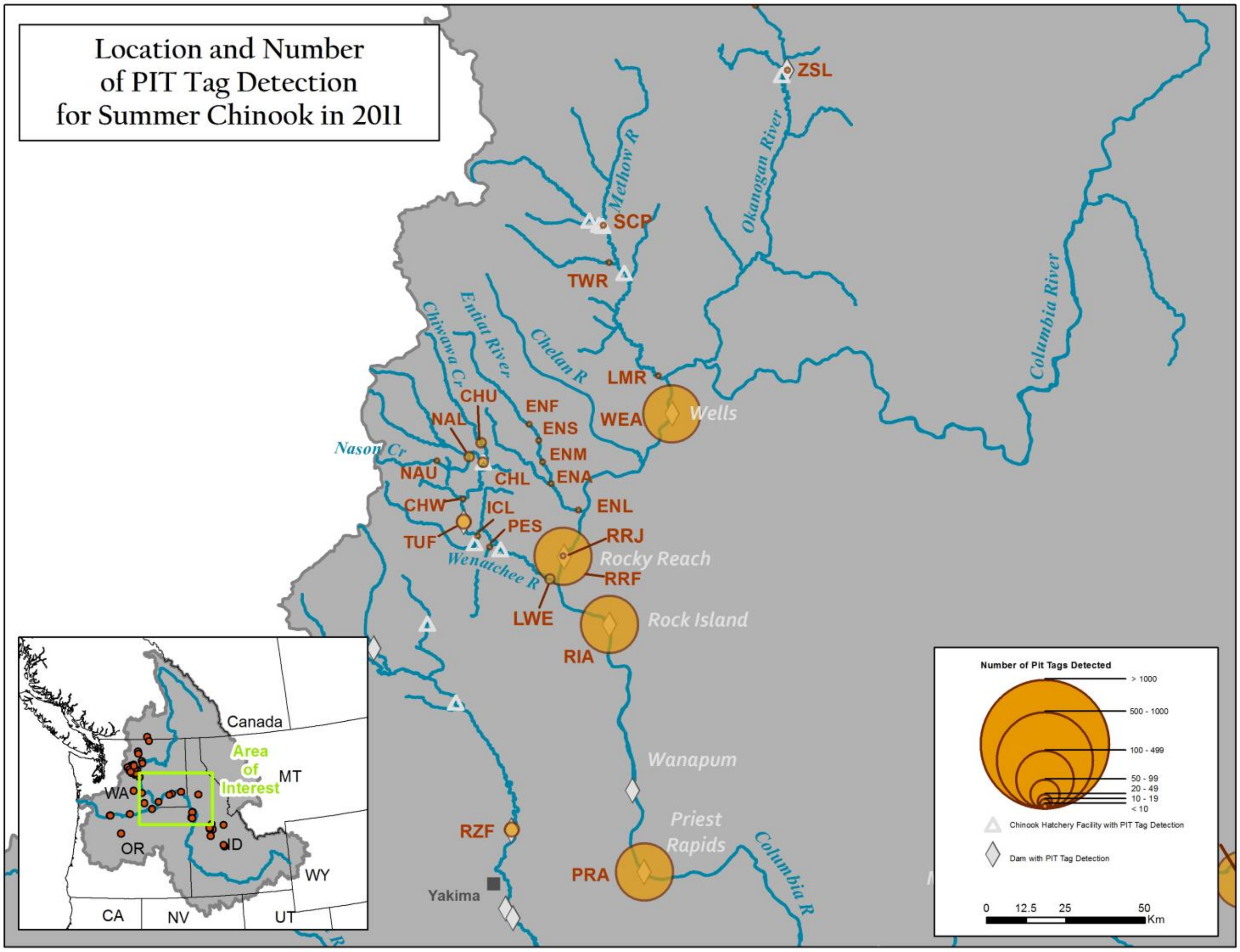

Figure A7. Map of Upper Columbia River detections sites and number of summer Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

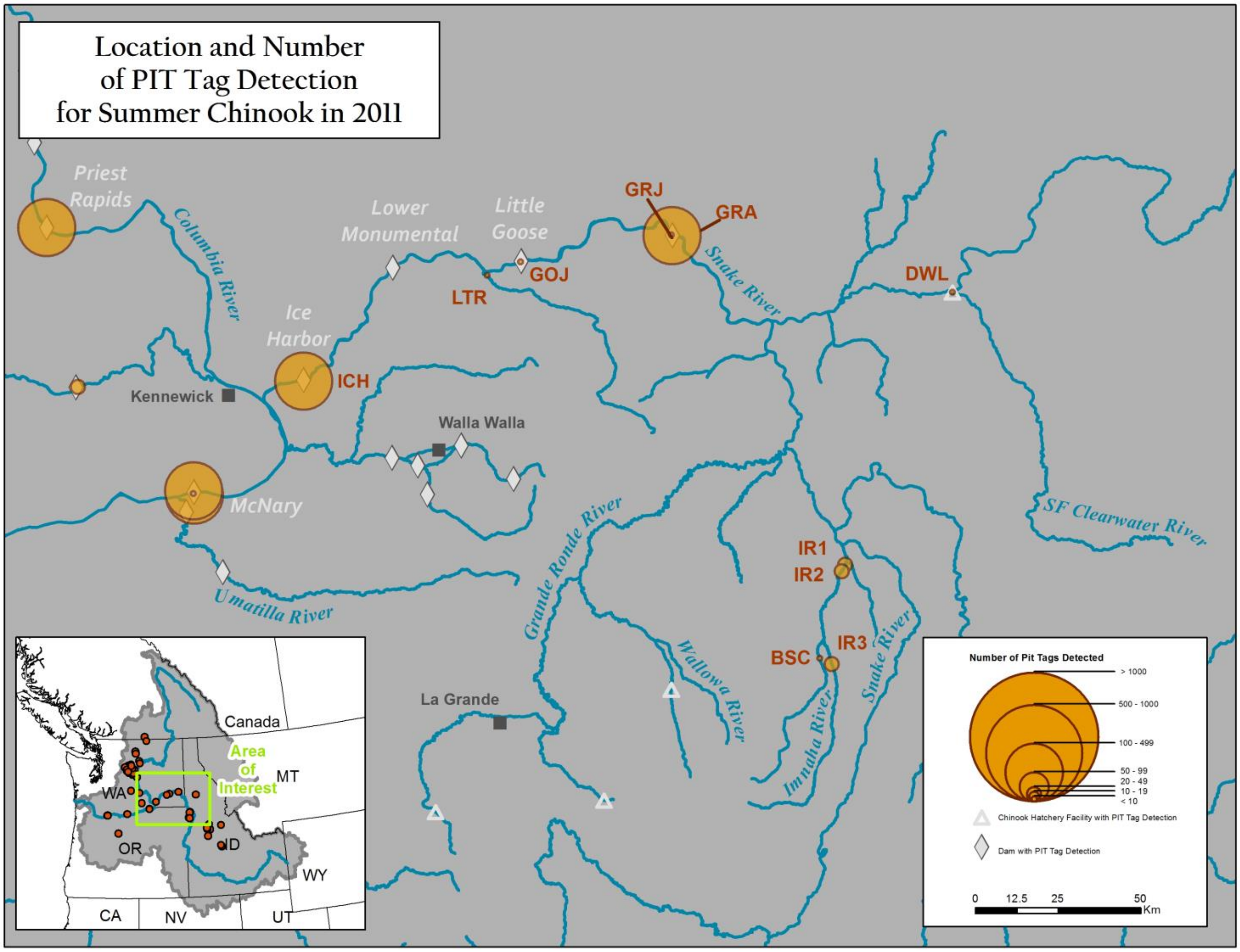

Figure A8. Map of Lower Snake River detections sites and number of summer Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

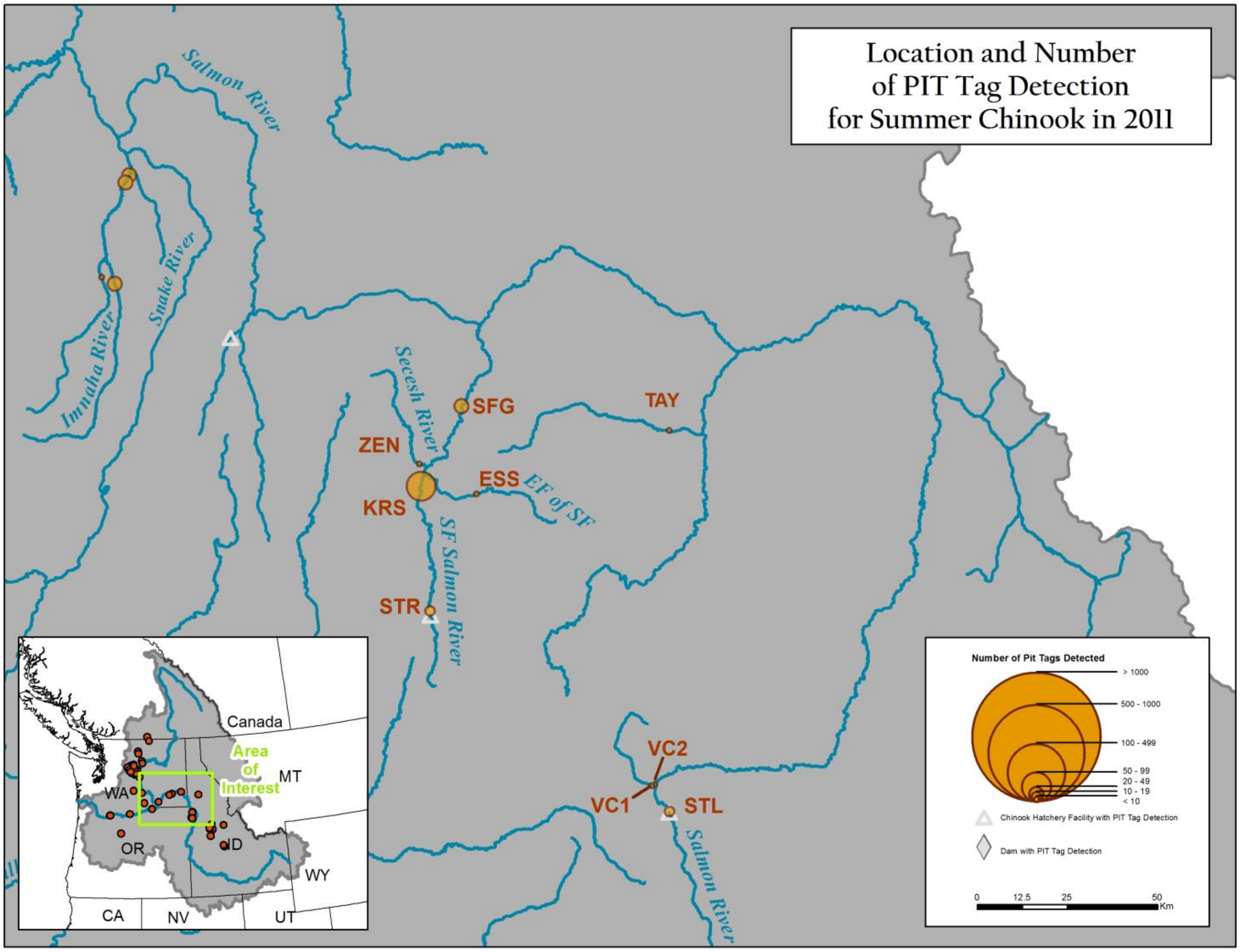

Figure A9. Map of Salmon River detections sites and number of summer Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

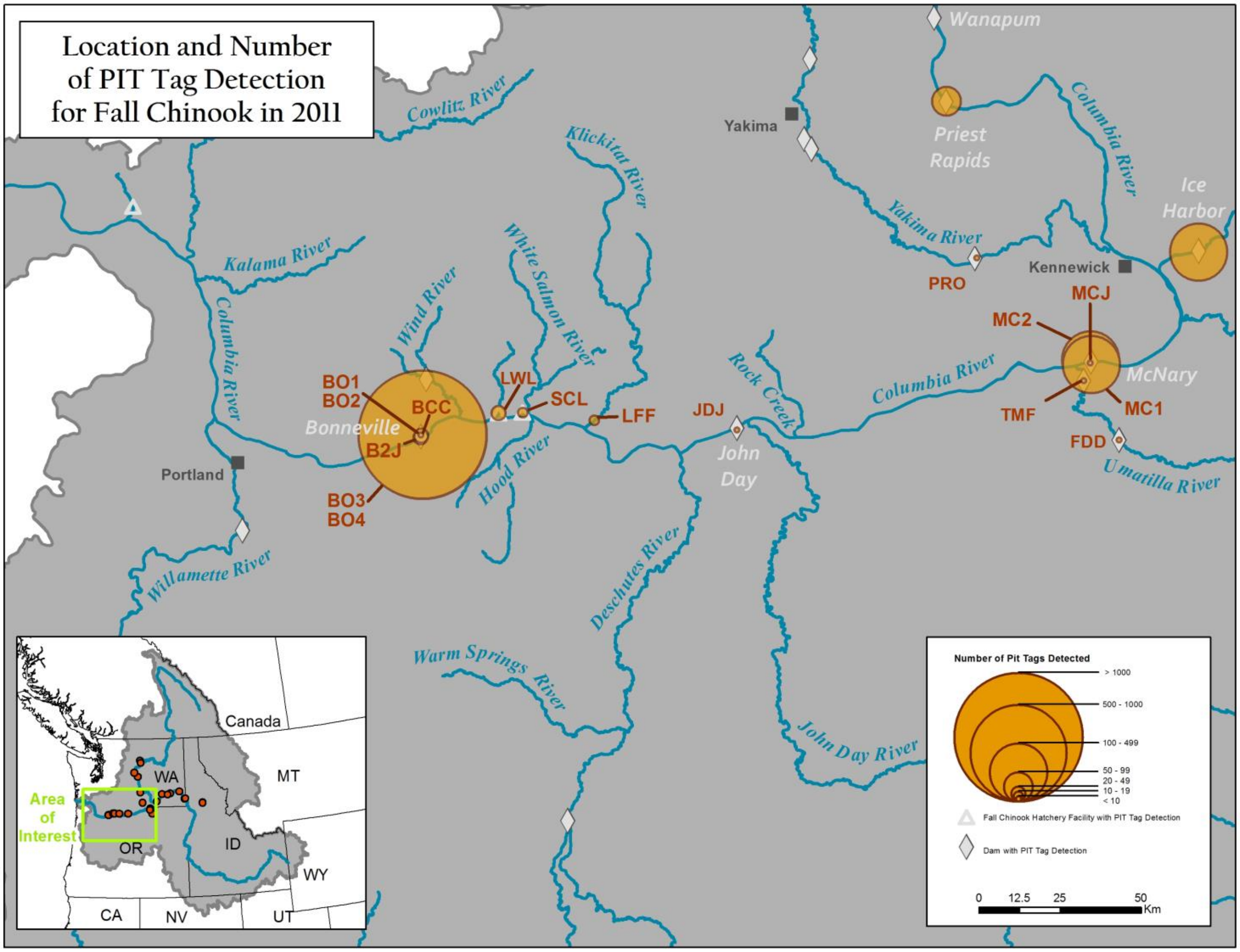

Figure A10. Map of Lower Columbia River detections sites and number of fall Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

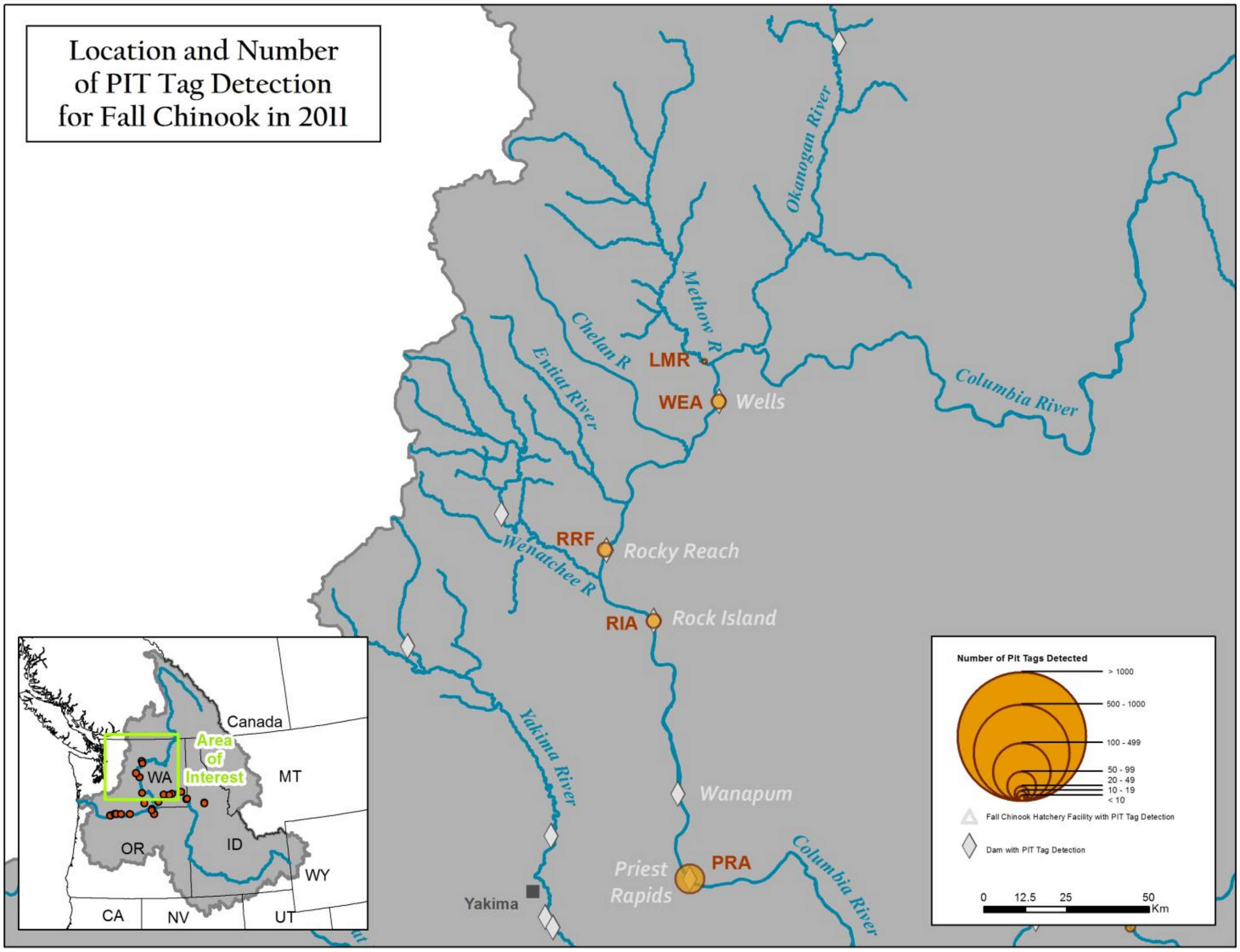

Figure A11. Map of Upper Columbia River detections sites and number of fall Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

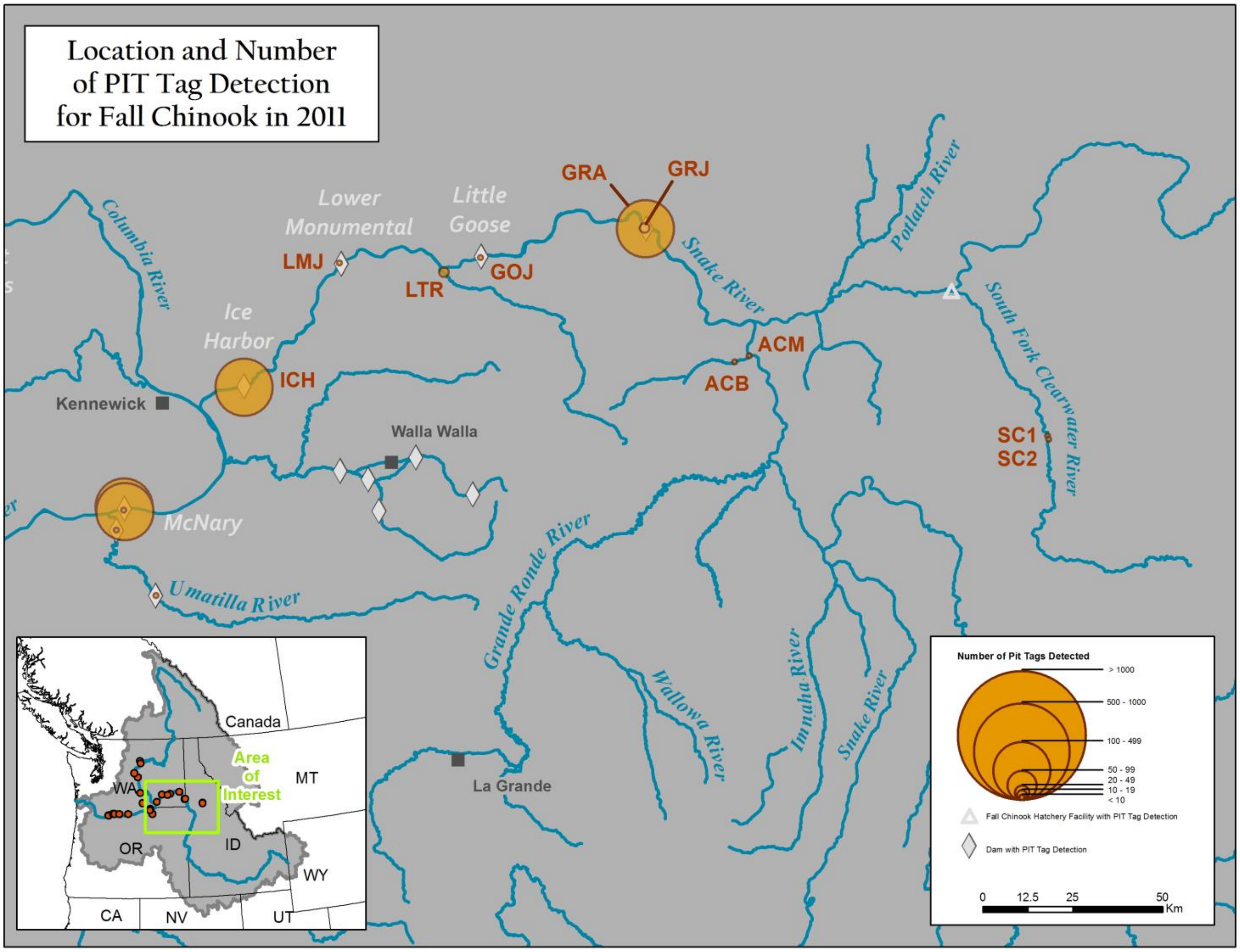

Figure A12. Map of Lower Snake River detections sites and number of fall Chinook detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

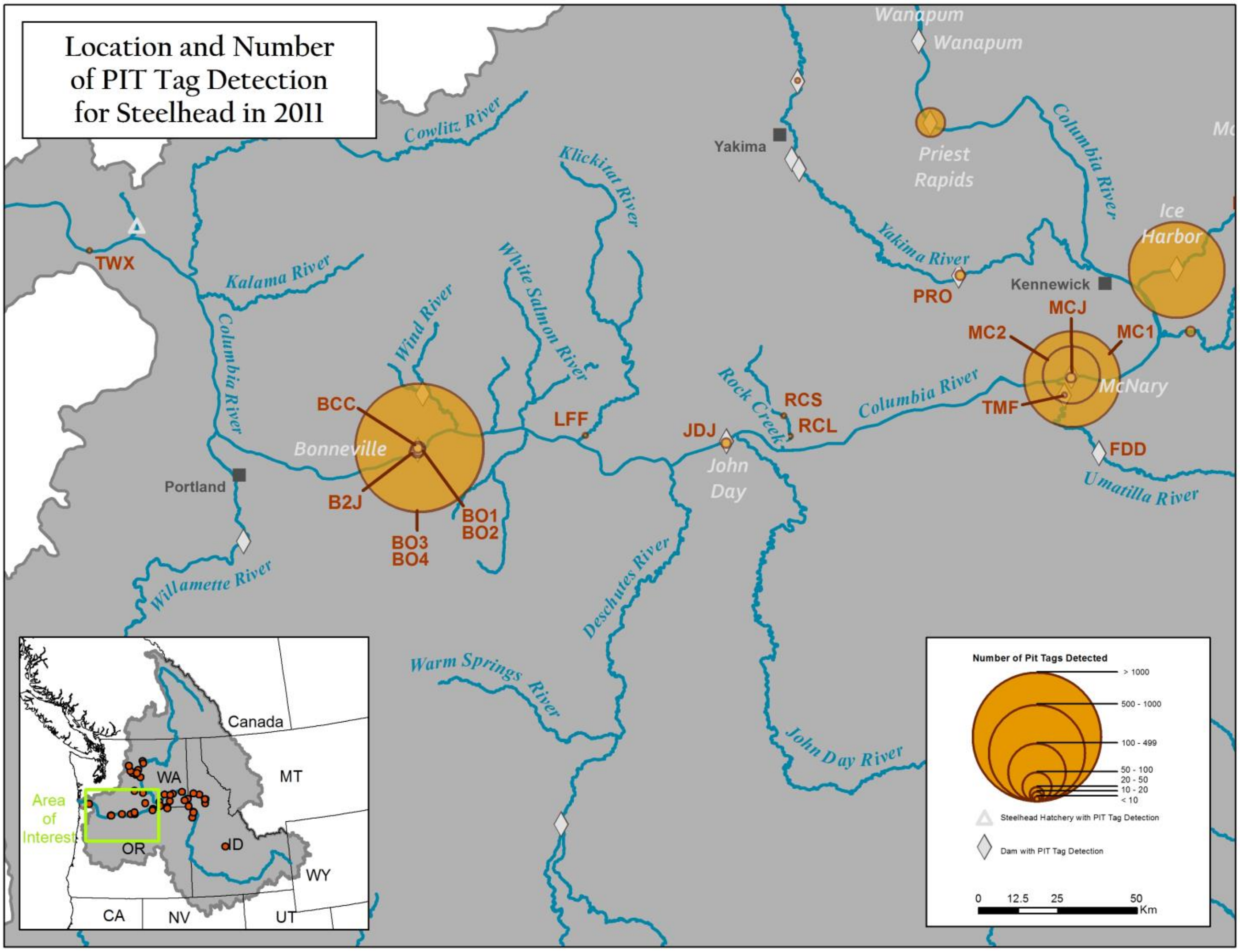

Figure A13. Map of Lower Columbia River detections sites and number of steelhead detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

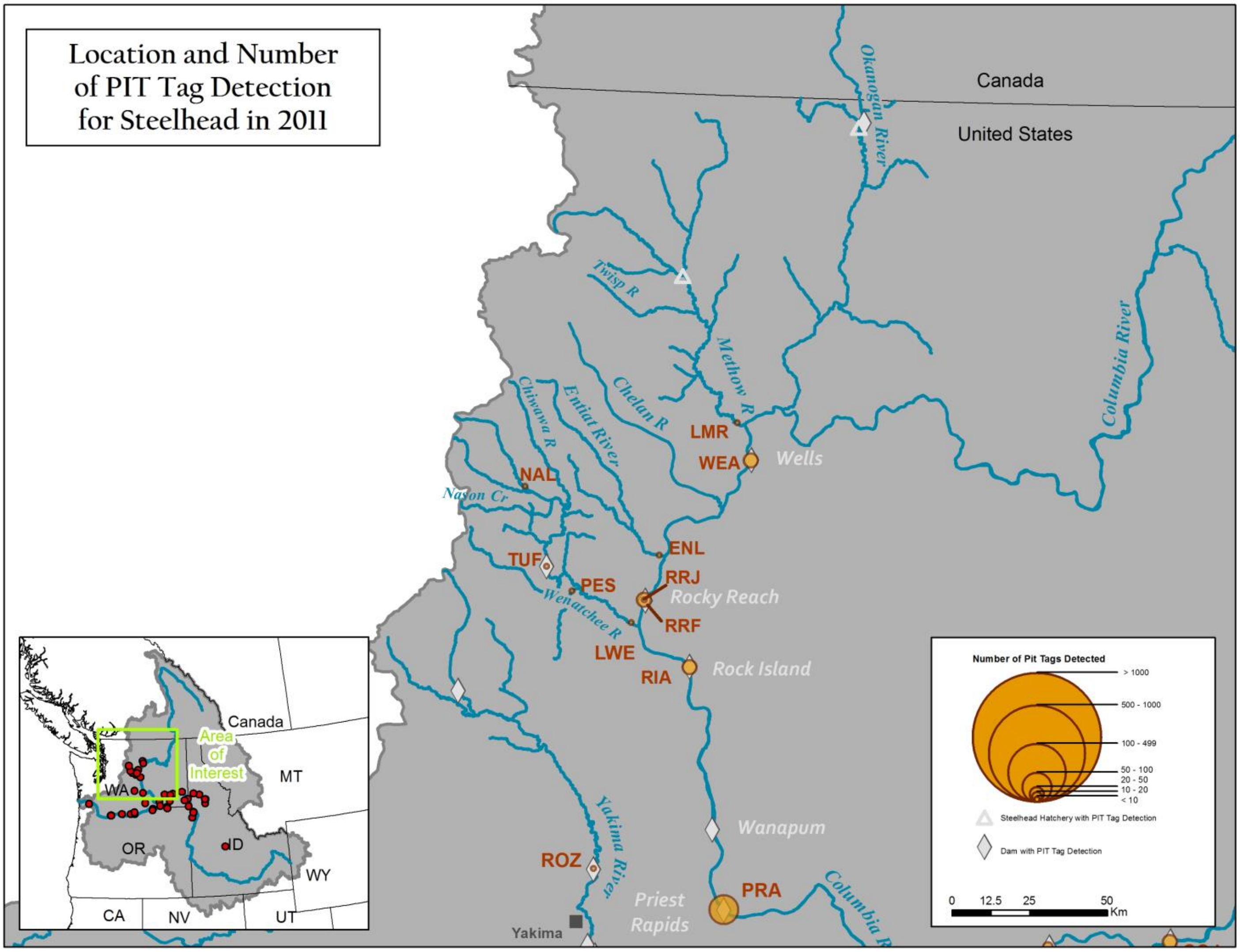

Figure A14. Map of Upper Columbia River detections sites and number of steelhead detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

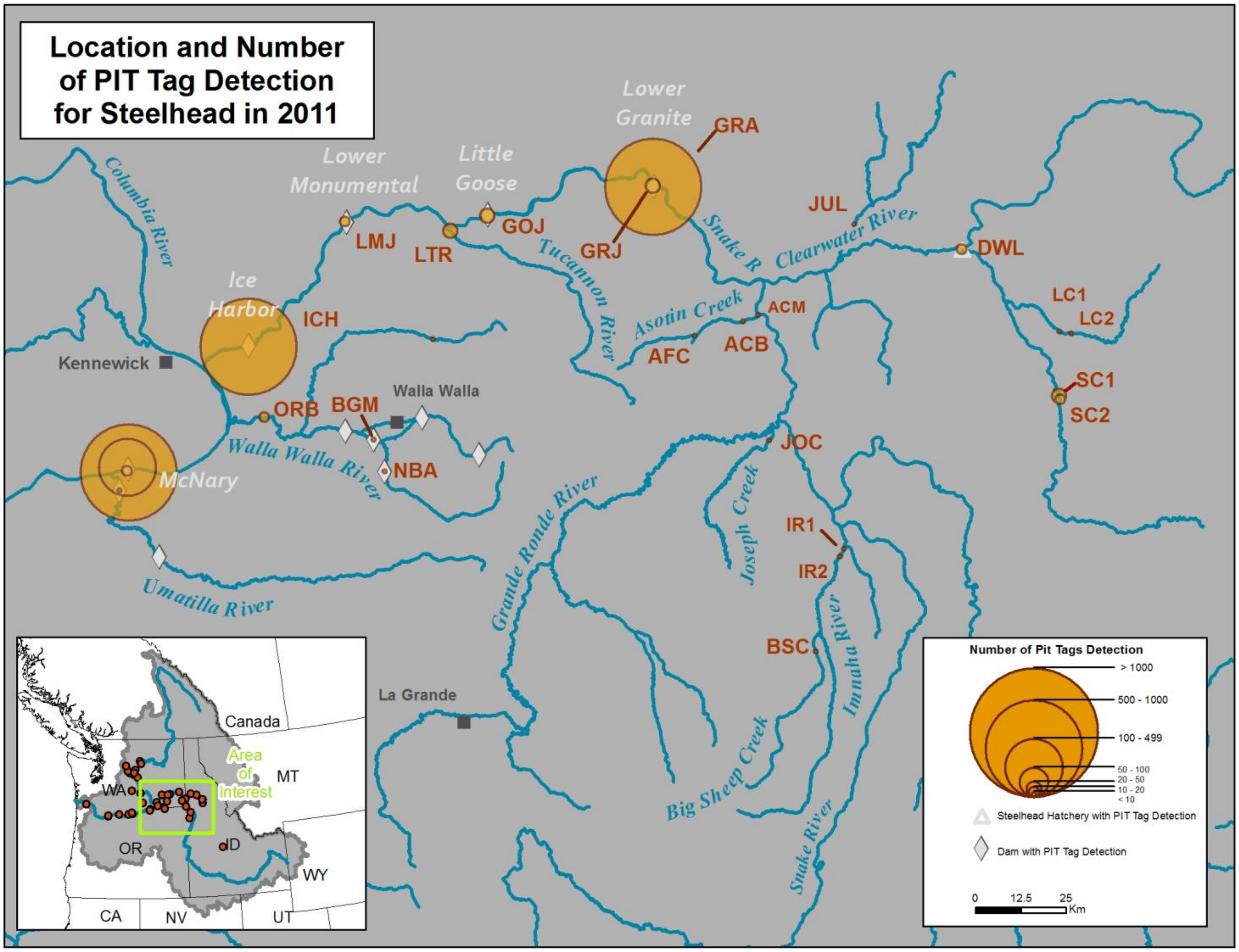

Figure A15. Map of Lower Snake River detections sites and number of steelhead detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.

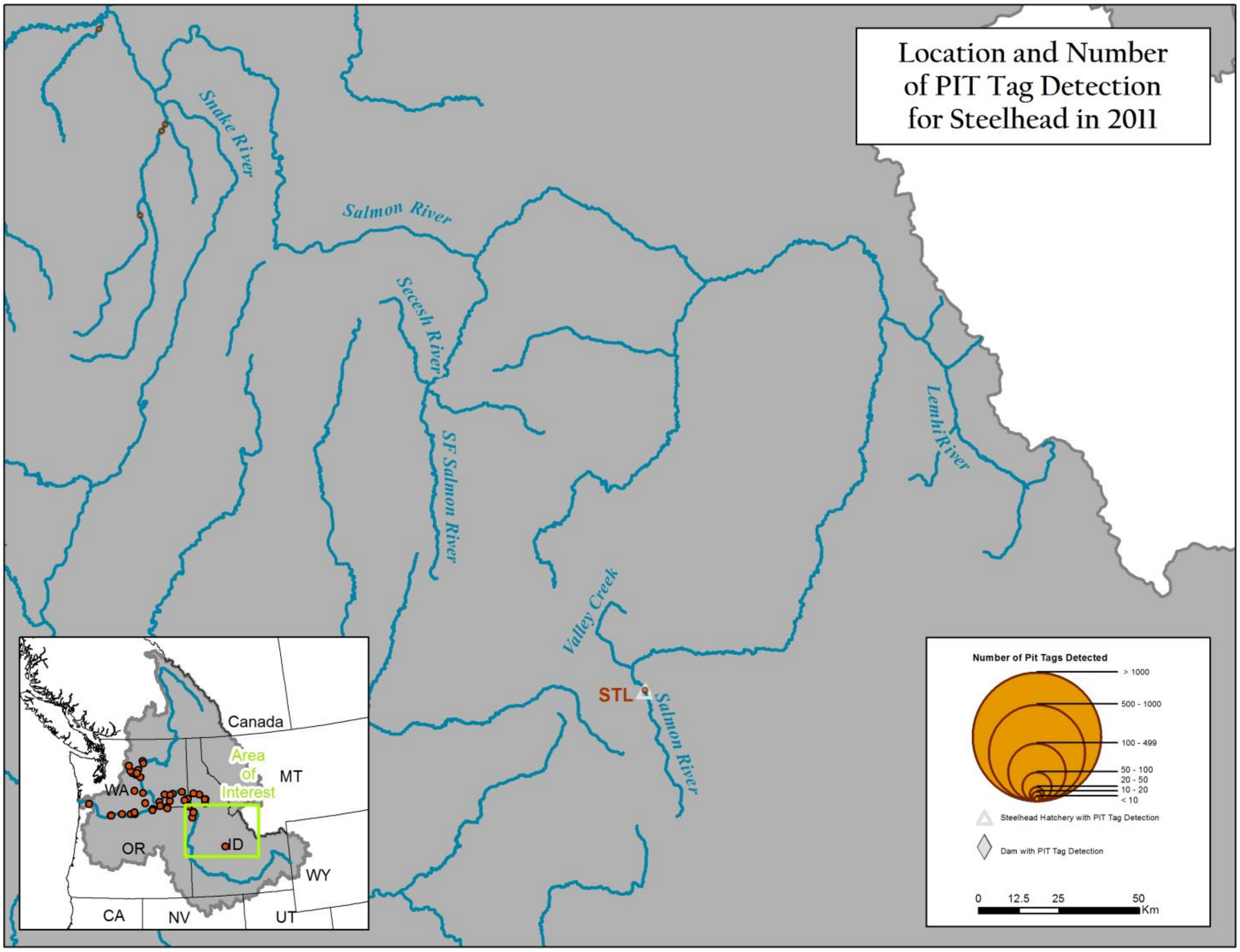

Figure A16. Map of Salmon River detections sites and number of steelhead detected. Table A4 in the Appendix lists the PTAGIS sites full name and the three-letter codes on this map.