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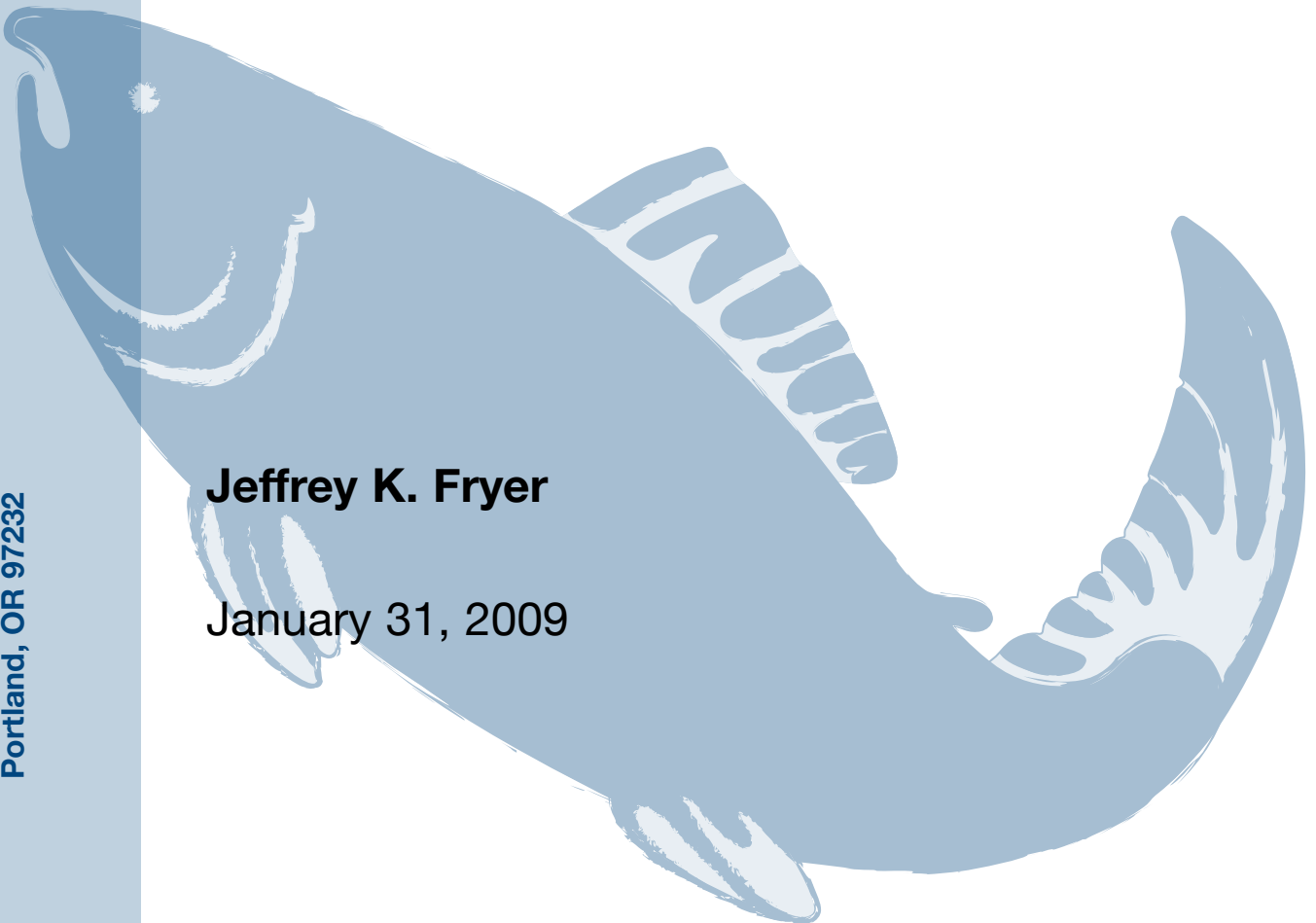
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## **Use of PIT tags to determine upstream migratory timing and survival of Columbia Basin sockeye salmon in 2008**

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## ABSTRACT

A total of 1133 sockeye salmon, *Oncorhynchus nerka*, were PIT-tagged at Bonneville Dam in 2008, 824 with 12.5 mm PIT tags (model TX1411SST) and 309 with 8.5 mm PIT tags (model TXP148511B). These fish were tracked upstream using detections within fish ladders at Bonneville, McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, Ice Harbor, Lower Granite, and Tumwater Dams. Results indicated that 8.5 mm PIT tags were commonly not detected by fish ladder antennas at several dams and thus excluded 8.5 mm tag data from further analysis. Based on 12.5 mm tag detections, upstream survival steadily declined as the migration progressed; Bonneville-Rock Island survival declined from as much as 90% for sockeye salmon passing Bonneville Dam during June to less than 80% during the first two weeks of July. There was also a significant linear relationship between decreasing survival and increasing water temperature. The estimated stock composition of sockeye salmon passing Bonneville Dam was 87.4% Okanogan 12.3% Wenatchee, and 0.4% Snake.

Sockeye salmon mean travel time between Bonneville and Rock Island Dams was 14.0 days, indicating a mean travel speed of 35.1 km per day. Fish passing Bonneville Dam later in the migration traveled upstream faster than those earlier in the migration.

Mark-recapture techniques were used to estimate sockeye salmon abundance at upstream dams. These techniques estimated up to 29.9% more fish at McNary Dam than visual counts but estimates at other Columbia River dams were within 6.4% of visual counts. At Tumwater Dam, mark-recapture techniques estimated 29.1% fewer fish than visual counts. The mean time required from first detection to last detection for the same fish at Tumwater Dam was more than four days, compared with less than 10 minutes at mainstem dams other than Bonneville Dam (103 minutes) and Lower Granite Dam (490 minutes). Estimated rates of sockeye salmon falling back over the dams after ascending and then reascending (where  $n > 10$ ) ranged from 0.5% at Bonneville Dam to 4.0% at Rocky Reach Dam.

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## INTRODUCTION

Sockeye salmon, *Oncorhynchus nerka*, is one of the species of Pacific salmon native to the Columbia River Basin. Prior to white settlement of the region, it is estimated the Columbia Basin supported an annual sockeye salmon run averaging over three million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, this sockeye salmon population has severely declined, reaching a low of fewer than 9200 fish in 1995 before rebounding in recent years. The 2008 estimate of 213,607 sockeye at Bonneville Dam was the highest since 1959, with a mean escapement for the most recent four year period (2005-2008) of 87,000 fish (DART 2008, Fish Passage Center 2008).

The Columbia Basin sockeye salmon run was once composed of at least eight principal stocks (Fulton 1970, Fryer 1995). Today, only two major stocks remain (Figure 1); the first originating in the Wenatchee River-Lake Wenatchee



**Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, mainstem dams, and the two major sockeye salmon production areas.**



System (Wenatchee stock) and second in the Okanogan River-Osoyoos Lake System (Okanogan stock). A third remnant stock, comprising well under 0.1% of the run, returns to Snake River-Redfish Lake (Snake stock) and is listed under the Endangered Species Act.

The Okanogan run is the Columbia Basin's sole remaining transboundary stock. The fish spawn in the Canadian portion of the Okanogan River, then rear in Osoyoos Lake, through which runs the border between the United States and Canada. This run has persisted despite one of the longest, most difficult migrations of any salmon stock in the world. The stock migrates 986 km between the spawning grounds and the ocean through one dam and a series of irrigation control structures on the Okanogan River as well as nine mainstem Columbia River dams. The production of this run is believed to be limited by upstream and downstream migration survival as well as habitat factors in the spawning and rearing areas (Fryer 1995).

The Wenatchee stock spawns in tributaries to Lake Wenatchee and rears in the lake. This stock migrates 842 km through two Wenatchee River dams and seven mainstem Columbia River dams. Since the spawning grounds and lake are relatively pristine, the production of this run is believed limited by upstream and downstream survival as well as the low productivity of the oligotrophic Lake Wenatchee (Fryer 1995).

Since both stocks are believed to be limited, at least in part, by upstream survival, this study was proposed to begin in 2006 to examine upstream survival and timing by inserting Passive Integrated Transponder (PIT) tags in sockeye sampled at Bonneville Dam as part of the annual Pacific Salmon Commission (PSC)-funded sockeye stock identification project<sup>1</sup>. These PIT tagged fish were then detected at upstream dam fish ladders with detection capability (McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells Dams on the Columbia River and Ice Harbor and Lower Granite Dams on the Snake River). In 2006 and 2007, the PIT tags used for this project were standard TX1411SST tags which measured 12.5 mm by 2.07 mm. These tags, and their similar sized predecessors, have long been the standard for both juvenile and adult research in the Columbia Basin. However, in the past two years, increasing numbers of

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<sup>1</sup> In 2006-2008 we were also funded by the PSC to PIT tag Chinook salmon (Fryer 2007a, 2008a, 2009)

juvenile salmon have been tagged with TXP148511B tags which measure 8.5 mm by 2.12 mm (Fryer 2008c). The smaller tags allow for smaller juvenile fish to be tagged. Although, detection of these tags at Columbia Basin smolt passage facilities at Bonneville, John Day, and McNary Dams appears adequate (Fryer 2008c), detection rates at adult fish ladders are unknown. To evaluate detection rates within the adult ladders, the U.S. Fish and Wildlife Service provided CRITFC with TX148511B tags to increase the number of sockeye salmon tagged.

The fact that there are only two significant Columbia Basin sockeye salmon stocks passing through multiple Columbia River dams with PIT tag detection makes the species ideal for a PIT tag study. Determination of migration timing and mortality for other salmon and steelhead species is difficult since most tributaries are without detection facilities meaning that fish can escape undetected. The run timing of the adult Columbia Basin sockeye salmon migration is of particular interest because the migration timing has shifted to earlier in the year over the past 70 years (Fryer 1995, Quinn et al. 1997), while a 1997 radio-tagging study found high mortality of the latter portion of the run (Naughton 2005) as well as no difference in stock-specific migration timing. The radio tag study was conducted in an unusually high flow year that may not be typical of other years. Results of this study from 2006 and 2007 (Fryer 2007c, Fryer 2008b) concurred with Naughton (2005) regarding higher mortality during the latter portion of the run, but differed in that this study, unlike Naughton (2005), did find different stock-specific migration timing.

## METHODS

### ***Sampling***

Sockeye salmon were sampled and tagged at the Adult Fish Facility located adjacent to the Second Powerhouse at Bonneville Dam (river km 235) in conjunction with the sampling of steelhead (*O. mykiss*) and summer Chinook salmon (*O. tshawytscha*). Sampling and tagging typically occurred between 0900 and 1500 four to five days per week. The facility uses a picket weir to divert fish ascending the Washington Shore fish ladder into the adult sampling facility collection pool. An attraction flow is used to draw fish through a false weir where they then can be selected for sampling. Fish not selected and fish that have recovered from sampling then migrate back to the Washington Shore fish ladder above the picket weir.

Sockeye selected were examined for: tags (including scanning for existing PIT tags); fin clips; wounds; and condition. They were measured for length, had and four scales removed for later age analysis and measurement for a stock identification project (Fryer 2007b). Data was recorded on to datasheets. PIT tags were inserted into the body cavity of the sockeye salmon using standard techniques (CBFWA 1999). The fish were scanned for the PIT tag number which was recorded both on the data sheet as well as stored in the Destron Fearing FS 2001 PIT tag reader. If no tag was detected due to either the tag being shed or a malfunctioning tag then no effort was made to implant another tag to eliminate the possibility of double tagging. Sockeye salmon were allowed to recover prior to release in a small recovery tank which was checked daily for shed tags. All PIT tag and sampling information was uploaded to the Columbia Basin PIT tag information system (PTAGIS) database ([www.ptagis.org](http://www.ptagis.org)).

Sampling was recorded to a video file using the Salmonsoft FishTick software running on a desktop computer. This software imprints the PIT tag number on the video file allowing for later review of proper tagging technique as well as to ensure that the proper PIT tag number was recorded.

PIT-tagged sockeye salmon were detected by existing PIT tag detection arrays in adult fish ladders at 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, and Tumwater Dam on the Wenatchee River (Appendix 1). PIT tag detection data from these arrays is automatically uploaded

several times daily to the PTAGIS database, where it is immediately accessible to registered users of the site. If a tag was not detected after the fish was released, we considered it as a shed tag and removed it from further analysis.

We also supplied a PIT tag reader to the Okanogan National Alliance to use during their Okanogan River spawning ground surveys and brood stock collection activities.

### ***Stock classification***

Sockeye salmon stock determinations were made by last detection point. For example, those individuals last observed at Rocky Reach or Wells Dams were classified as being Okanogan stock, those last observed at Rock Island Dam (but not observed at Rocky Reach or Wells Dams) were classified as Wenatchee stock, while those last observed downstream of Rock Island were considered as unknown and were also considered mortalities (note that this will overestimate the proportion of the Wenatchee stock since any mortality of Okanogan-stock fish that occurs between Rock Island and Rocky Reach Dams will be considered as a Wenatchee-stock sockeye salmon). The sole exception to this rule were those fish never detected after release, which were considered to have shed their tags and were subtracted from the number of fish tagged for subsequent analysis.

### ***Escapement***

Escapement to McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells Dams was estimated as:

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

where  $N$  was the estimated escapement at a particular upstream dam,  $B_i$  is the weekly visual count passing Bonneville Dam in week  $i$  (DART 2008, Fish Passage Center 2008),  $T_i$  is the number of fish PIT tagged at Bonneville Dam in week  $i$ , and  $R_i$  is the number of PIT tag detections at the dam where escapement is being estimated of those fish tagged in week  $i$ .

### ***Mortality***

PIT-tagged sockeye salmon that were lost on the upstream migration (with the exception of those “lost” between Rock Island and Rocky Reach Dams, which were considered to be Wenatchee stock) were recorded as mortalities. Mortality rates were computed by week of passage at Bonneville Dam between

dams with detection capabilities and correlated with temperatures and flows at The Dalles Dam (for Bonneville to McNary mortality) and Priest Rapids Dam (for McNary to Rock Island mortality).

### ***Detection Efficiencies***

Any fish detected at an upstream dam should also be detected at lower dams (except at Bonneville, McNary, and Ice Harbor Dams where it is possible that a fish could use the navigation locks). The percentage of PIT tagged sockeye salmon missed at each dam with PIT tag detection arrays was calculated; for example the percentage missed at Rocky Reach Dam was calculated as:

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

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

Compiled for placement in the appendix of this report was the probability of detection at the different sites, hereafter referred to as weirs, at dam fish ladders. PIT tag detection antennas in fish ladders are always located at a minimum of two weirs in relatively close proximity. Therefore, if a fish is detected at one weir, it should also be detected at the rest of the weirs in that same ladder. This allows a probability of detection at the individual weirs to be calculated by comparing it with other weirs in that same ladder. Detection probabilities were calculated as:

$$Pi = \frac{N_i}{Max(N_i)}$$

where  $N_i$  is the number of fish detected at a given weir and  $Max(N_i)$  is the total number of fish detected by any weir in that ladder.

Also calculated was the percentage of sockeye salmon using each ladder at dams with multiple ladders.

### ***Migration timing and passage time***

Run timing was estimated using the date and time of detection at the different dams. Migration rates were calculated between dam pairs as the time between the last detection at the lower dam and the first detection at the upper dam and correlated with temperatures and flows at The Dalles Dam (for

Bonneville to McNary migration rates) and Priest Rapids Dam (for McNary to Wells migration rates).

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 a dam.

### ***Bonneville Stock composition estimates using PIT tag recoveries***

The overall stock composition,  $P_i$ , for stock  $i$  (where  $i$  denotes the Wenatchee or Okanogan stock) at Bonneville Dam was estimated as:

$$P_i = \sum_j W_j * S_{ij}$$

where  $W_j$  is the proportion of the run passing Bonneville Dam in week  $j$ , and  $S_{ij}$  is the percentage of the run estimated in week  $i$  estimated to belong to stock  $i$  based on upstream recoveries.

The stock composition estimated by PIT tag recoveries was compared with that estimated by scale pattern analysis, visual interpretation of scale patterns, as well as by visual fish counts at dam fish ladders. Two visual counts are available, the first estimating the Wenatchee stock abundance as the difference between the Rock Island and Rocky Reach Dam counts and the second using Tumwater Dam visual count to estimate the Wenatchee stock abundance.

### ***Okanogan and Wenatchee age and length-at-age composition***

The age composition for the Okanogan and Wenatchee stocks was estimated as:

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

where  $T_{i,j}$  was the estimate for stock  $i$  and age group  $j$ ,  $A_{i,j,k}$  was the percentage of sockeye for stock  $i$  and age group  $j$  in week  $k$  (such that  $\sum_j A_{i,j,k} = 1$ ) and  $W_k$  was the percentage of the run that passed Bonneville Dam in week  $k$ .

The variance was estimated as

$$Var(T_{i,j}) = \sum_k Var(A_{i,j,k}) * W_k^2$$

where

$$Var(A_{i,j}) = \frac{\sum_k A_{i,j,k} (1 - A_{i,j,k})}{n_{i,k}}$$

### ***Night passage***

Fish at Columbia Basin dams are not always counted using the same time period. Fish at Bonneville and McNary Dam fish ladders are counted by observers only from 0400 to 2000 Pacific Standard Time for 50 minutes of each hour and the counts expanded by a factor of 1.2. Fish passing Priest Rapids, Rock Island, Rocky Reach, and Wells Dams are recorded 24 hours per day and the video later reviewed. In this study, night passage rates (where night is defined as 2000 to 0400) were calculated by stock for all dams passed based on the last detection time for a given fish ladder. The last time at the uppermost weir was used as an approximation for passage time as this weir was closer to the fish counting window than the lower most weir (where the first detection would be made). This was the case at all weirs except at BO4 near the Washington shore fish counting facility at Bonneville Dam (Figure A1), and at BO4, the distance between the upper most and lower most weirs is only about 25 meters.

### ***Fallback***

There were two methods of determining fallback for the study. Fallback is defined as a fish that ascends a fish ladder into the reservoir above the dam, then “falls back” to the tailrace of the dam either over the spillway or through the turbines. The first determination of fallback was the detection of an adult sockeye salmon in a juvenile bypass system. However, on the Columbia River only Bonneville, John Day, and McNary Dams have both juvenile bypass systems and PIT tag detection capability in those facilities. Also, any sockeye salmon falling back over the spillway or through the turbines would not be detected. Therefore, the sockeye salmon that had detection at an “upper” detection weir followed by detection at a “lower” detection weir that was separated by more than 2 hours as fallbacks were also considered. At McNary and Bonneville Dams, the upper weir was at the fish counting window, which is believed to detect all PIT-tagged fish passing, while the lower weirs have lower passage efficiency for sockeye salmon<sup>2</sup>. At Priest Rapids, Rock Island, Rocky Reach, and Wells Dams, there are only two weirs with PIT tag detectors in each

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<sup>2</sup> Appendix 1 gives PIT tag detection array configurations for all mainstem Columbia Basin dams except Rocky Reach Dam. This information is also available at [www.ptagis.org](http://www.ptagis.org).

fish ladder, so these two weirs were designated as the upper and lower detection weirs.



## RESULTS

### **Sample Size**

A total of 1,162 sockeye salmon were sampled between June 3, 2008 and August 1, 2008 as part of the age composition study (Whiteaker and Fryer, 2009). Of these fish, a total of 1,133 sockeye salmon were released with working PIT tags (Table 1). The difference of 29 fish includes those fish that were not PIT tagged, or were PIT tagged but the tags were not detected when scanned. In addition, PIT tags from two tagged fish were subsequently found in the recovery tank. The fish that shed these tags were also excluded from the total number of PIT tagged fish released. PIT tag detection data was downloaded from [www.ptagis.org](http://www.ptagis.org) on November 10, 2008.

**Table 1. Number of PIT tagged sockeye salmon tracked at Bonneville Dam by date and statistical week in 2008.**

Sampling Dates	Statistical Week	Sampled (n)	Number Tagged		Number Tracked	
			12.5 mm tags	8.5 mm tags	12.5 mm tags	8.5 mm tags
6/3,4,5,6	23	11	7	4	7	4
6/10,11,12,13,14,	24	180	118	55	116	53
6/15,16,17,18,19	25	363	236	116	235	113
6/23,24,25,26,27	26	250	168	77	167	75
6/30,7/1,2,3	27	200	153	43	150	40
7/5,6,7,8,9,10	28	116	103	12	100	12
7/14,15,16,17,18	29	37	34	2	33	2
7/21,22,23,24	30	4	4	0	4	0
7/28,29,30,8/1	31	1	1	0	1	0
	Total	1162	824	309	813	299

### **Effectiveness of 8.5 mm tags**

A preliminary assessment of detections of 8.5 and 12.5 mm tags in late June found that both Chinook and sockeye salmon with 8.5 mm tags were being detected at much lower rates than 12.5 mm tags at some dams. Therefore, during the week of June 30, the percentage of sockeye salmon tagged with 8.5 mm tags was reduced from 33% to 10% of the total sample. Post-season analysis confirmed that sockeye salmon tagged with 8.5 mm tags were less likely to be detected at all sites than those tagged with 12.5 mm tags (Table 2). Over all dams, the percentage of 12.5 mm PIT tagged fish missed in 2008 was similar to that in the 2006 and 2007 studies. The percentage of missed 8.5 mm tagged fish was greater than 18% at all dams except for Bonneville Dam. By comparison, only for Rock Island and McNary Dams was the percentage of missed 12.5 mm tagged fish in 2008 greater than 0.4%. The percentage of PIT

tagged sockeye missed by PIT tag detectors could not be estimated at Lower Granite, Wells, and Tumwater Dams given the lack of detection sites further upstream. Based on detection data from individual weirs within each fish ladder (Table A1), it is likely that detection of 8.5 mm tagged fish at Tumwater and Wells is far less than that for 12.5 mm tagged fish.

**Table 2. Percentage of PIT tagged fish by tag type not detected at dam detection sites as estimated from upstream detections in 2008 with comparison data for 2006-2007.**

Dam	2008 results			2006 (12.5 mm tags)	2007 (12.5 mm tags)
	All tags	12.5 mm tagged	8.5 mm tagged		
Bonneville	0.7%	0.4%	1.7%	0.2%	2.1%
McNary	12.3%	10.1%	18.2%	3.1%	6.5%
Priest Rapids	9.4%	0.3%	33.7%	0.0%	0.8%
Rock Island	20.4%	6.9%	57.7%	1.3%	6.8%
Rocky Reach	7.4%	0.2%	28.3%	12.3%	0.7%
Ice Harbor	16.7%	0.0%	33.3%		
Mean	11.2%	3.0%	28.8%	3.4%	3.4%

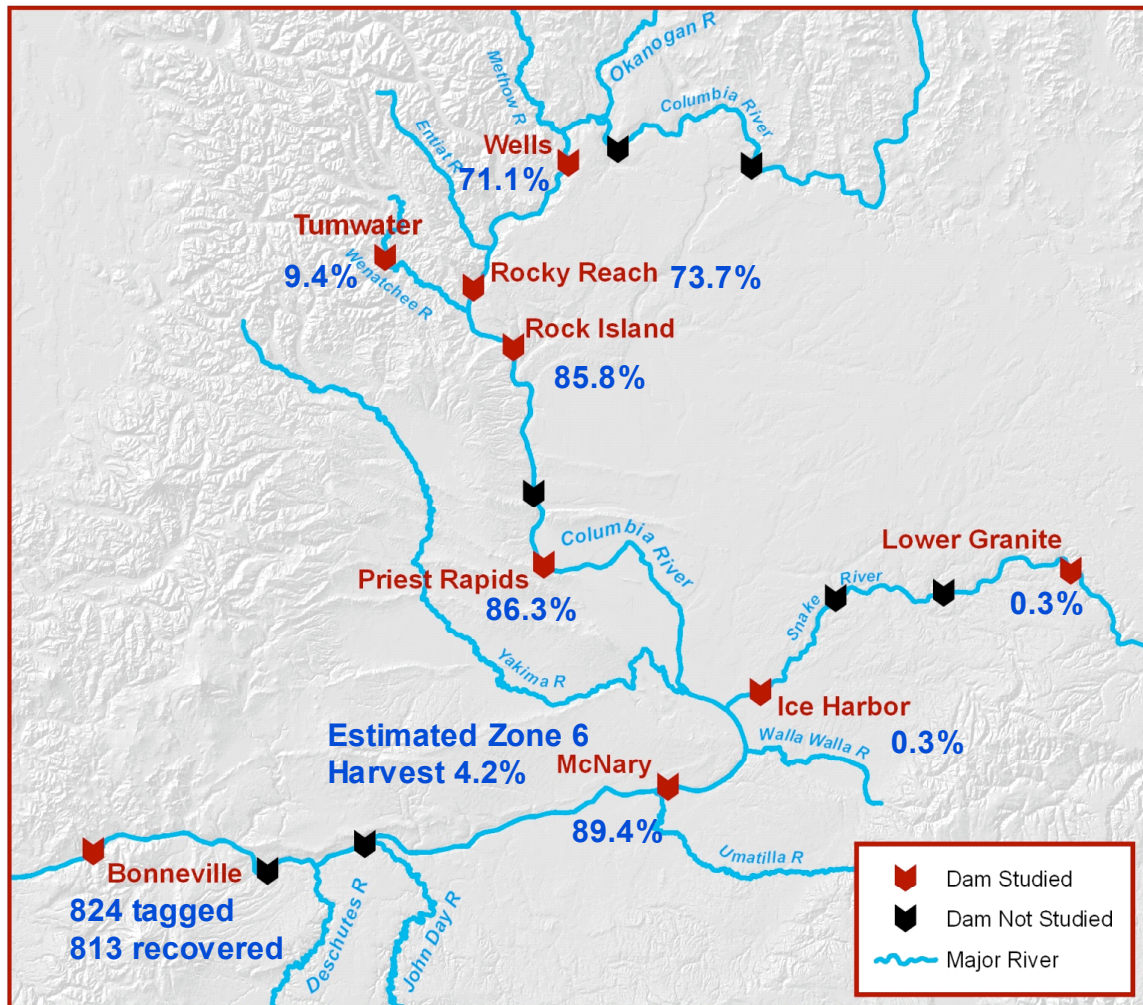
Given the high percentage of sockeye salmon missed at dams for fish tagged with 8.5mm tags, only data from 12.5 mm tags will be used in the rest of this report.

#### ***Upstream Recoveries, mortality, and escapement:***

Of the total 12.5mm PIT tag sample size of 824, 813 fish were detected subsequent to release. The remaining 11 fish shed their tags prior to detection at the Bonneville Dam, did not pass Bonneville Dam, or passed via the Bonneville Dam navigation locks and were not subsequently detected at upstream dams. Most of the tagged sockeye salmon that were not detected at Rock Island Dam were lost before reaching McNary Dam (Table 3, Figure 2). This reach of river is where the Zone 6 tribal fishery occurs, which was estimated to harvest 9,017 sockeye salmon (Table A2). A total of six PIT-tagged sockeye salmon, out of approximately 1000 scanned, were detected by the Okanogan Nation Alliance in Okanogan River brood stock collection and spawning ground survey activities. All of these fish were tagged with 12.5 mm tags.

**Table 3. Percentage of PIT-tagged sockeye salmon detected subsequent to tagging at upstream dams, estimated escapement from both PIT tags and visual means, and the difference between the PIT tag and visual escapement estimate in 2008.**

Dam	Estimated percentage reaching dam	Estimated escapement using PIT tag data	Visual Dam count	Difference between PIT tag and visual estimate
Bonneville	100.0		213,504	
McNary	89.4	190,867	146,924	29.9%
Priest Rapids	86.3	184,343	196,864	-6.4%
Rock Island	85.8	183,363	193,739	-5.5%
Rocky Reach	73.7	163,502	161,343	1.3%
Wells	71.1	160,408	165,334	-3.0%
Tumwater	9.4	20,081	28,340	-29.1%
Ice Harbor	0.3	607	539	12.6%
Lower Granite	0.3	607	937	-35.2%



**Figure 2. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite Dams showing the number of fish PIT-tagged at Bonneville Dam, and the percentage of the run estimated to pass McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, Ice Harbor, and Lower Granite Dams in 2008.**

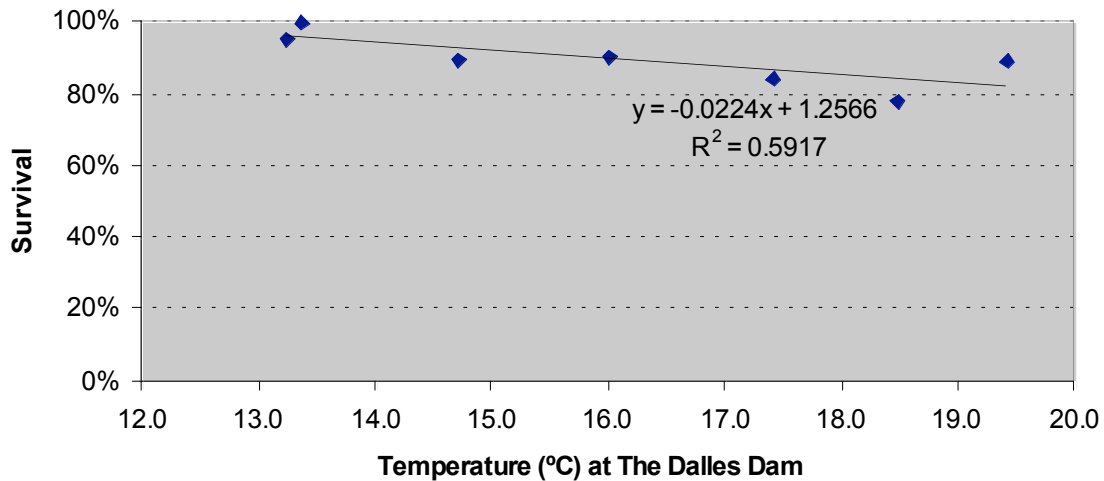
Using PIT tag detections to estimate escapement at mainstem dams results in estimates that are within 6.4% of the visual count at Priest Rapids, Rock Island, Rocky Reach, and Wells Dams. The PIT tag escapement method estimated 29.9% more sockeye estimated passing McNary Dam than visual count method estimates. At McNary Dam, as at Bonneville, Ice Harbor, and Lower Granite Dams, it is possible that sockeye salmon pass through the navigation locks where they would not be counted by visual observers nor would they be detected by PIT tag antennas. This likely happened to a greater extent in 2008 than in 2007 and 2006 as is reflected in the percentage of 12.5 mm PIT tagged sockeye missed at McNary Dam in the three years (Table 2).

The 2008 results were similar to 2006 and 2007, where there was a significant linear relationship between survival from Bonneville to McNary ( $p=0.04$ ) and from Bonneville and Rock Island ( $p=0.03$ ) and statistical week tagged with sockeye tagged later in the migration having a lower survival rate (Table 4). There was not a significant linear relationship between statistical week tagged at Bonneville Dam and survival from Bonneville to Priest Rapids ( $p=0.06$ ) and Rocky Reach to Wells Dams ( $p=0.10$ ).

**Table 4. Sockeye salmon survival through selected reaches by Statistical Week as estimated by PIT tag detections in 2008.**

<b>Statistical Week at Bonneville Dam</b>	<b>Bonneville- McNary</b>	<b>Bonneville- Priest Rapids</b>	<b>Bonneville- Rock Island</b>	<b>Rocky Reach- Wells</b>
23	100.0%	85.7%	85.7%	100.0%
24	95.6%	92.1%	90.4%	99.0%
25	89.8%	86.4%	86.0%	97.8%
26	90.4%	88.0%	88.0%	97.7%
27	84.6%	81.2%	79.9%	100.0%
28	78.0%	77.0%	75.0%	97.2%
29-31	89.5%	81.6%	78.9%	96.4%
Composite	89.4%	86.3%	85.8%	98.1%

Bonneville to McNary survival significantly decreases with increasing temperatures ( $p=0.04$ , Figure 3) but not with increasing flow ( $p=0.13$ ). All three variables are highly correlated with absolute correlation coefficients ranging from 0.93-0.99. McNary to Rock Island survival shows no significant relationship with statistical week passing McNary Dam ( $p=0.37$ ), Priest Rapids Dam flow ( $p=0.52$ ) or temperature ( $p=0.44$ ).



**Figure 3. Figure showing the linear relationship between the survival of PIT-tagged sockeye salmon from Bonneville to McNary Dam and mean water temperature at The Dalles Dam by statistical week in 2008.**

### ***Migration Timing and Passage Time***

Sockeye salmon travel quickly upstream, with a median travel time between Bonneville and Rock Island Dam of 14.0 days (Table 5). Sockeye salmon passing Bonneville Dam later in the migration travel upstream faster than those earlier in the migration. There is a significant ( $\alpha=0.05$ ) linear relationship between statistical week passing Bonneville Dam and passage time from Bonneville Dam to McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams. The mean difference in travel time between the two stocks of sockeye salmon was less than one day to all upstream dams (Table 6).

**Table 5. Median sockeye salmon migration time and travel rates between mainstem dams as estimated by PIT tag recoveries in 2008.**

<b>Dam pair</b>	<b>Distance (km)</b>	<b>Median time (days)</b>	<b>Median travel time (km/day)</b>
Bonneville-McNary	231	5.7	40.3
McNary-Priest Rapids	167	4.6	36.4
Priest Rapids-Rock Island	89	3.2	28.2
Rock Island-Rocky Reach	33	1.1	30.7
Rocky Reach-Wells	65	2.2	29.3
Rock Island-Tumwater	73	11.6	6.3
Bonneville-Rock Island	487	14.0	34.7
Bonneville-Tumwater	560	26.8	20.9
Bonneville-Wells	585	15.2	32.5

**Table 6. Median adult sockeye salmon travel 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 2008.**

Statistical Week at Bonneville Dam	Bonneville-McNary	Bonneville-Priest Rapids	Bonneville-Rock Island	Bonneville-Rocky Reach	Bonneville-Wells	Bonneville-Tumwater	McNary-Rock Island	Rock Island-Rocky Reach	Rocky Reach-Wells
23	8.2	16.1	19.3	20.6	23.2		8.9	1.6	3.3
24	7.9	13.2	16.9	18.1	21.1	33.2	8.9	1.2	2.3
25	5.8	11.7	15.7	16.5	19.1	28.8	9.1	1.1	2.4
26	5.7	10.1	13.7	14.3	16.9	26.0	7.9	1.0	2.1
27	4.9	9.2	12.8	13.8	15.9	22.7	7.6	1.0	2.1
28	5.2	9.7	12.8	13.9	16.2	20.2	6.9	1.0	2.1
29-31	4.9	9.0	11.8	13.0	15.3	22.5	6.9	1.1	2.1
P-value	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.06	0.06
<b>Stock</b>									
Okanogan	5.7	10.8	14.0	15.2	18.0	NA	3.4	1.6	2.3
Wenatchee	5.3	10.1	14.7	15.7	17.7	26.8	4.3	NA	NA
Snake River	5.7	NA	NA	NA	NA	NA	NA	NA	NA
Unknown <sup>3</sup>	5.9	12.3	24.0	NA	NA	NA	NA	NA	NA

The median time between first detection and last detection was six minutes or less at all dams except for Bonneville, Lower Granite, and Tumwater Dams (Table 7). At Bonneville Dam, many sockeye were detected in underwater orifices just upstream and downstream of the fish trap where sampling occurred. If these detections are excluded, the median time drops to 10 minutes. At Lower Granite Dam, all fish were trapped which likely resulted in increased passage times. At Tumwater Dam, all fish were trapped during the sockeye migration, likely resulting in delays.

**Table 7. Sockeye salmon median travel 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 2008.**

Dam	Median Passage Time (Minutes)	Taking more than 12 hours- (%)
Bonneville	76	6.9
McNary	0	1.4
Priest Rapids	6	0.6
Rock Island	3	0.3
Rocky Reach	2	1.0
Wells	2	0.8
Tumwater	6690	62.1
Ice Harbor	3	0.0
Lower Granite	490.0	0.0

<sup>3</sup> Unknown stock sockeye salmon are those that were not detected at Rock Island Dam and are likely mortalities on the upstream migration.

### Stock composition estimates

The percentage of Okanogan stock sockeye salmon at Bonneville Dam steadily increased as the run progressed while the Wenatchee portion of the run decreased (Table 8). The overall stock composition estimate of 14.7% Wenatchee and 85.3% Okanogan was similar to that estimated using dam counts (Table 8). There was not a significant linear relationship between weekly stock composition and statistical week ( $p=0.50$ ).

A total of nine adipose clipped sockeye salmon were PIT tagged with 12.5 mm tags; of these fish: one was not detected after release; two were not detected after Bonneville Dam; two were last detected at Lower Granite Dam; three were last detected at Tumwater Dam; and one was last detected at Wells Dam<sup>4</sup>.

**Table 8. Weekly and composite sockeye salmon stock composition at Bonneville Dam as estimated by PIT tags in 2008 and a comparison to stock composition estimates estimated using visual dam counts.**

Statistical Week	Run Size	PIT Tag sample size	Percent Wenatchee	Percent Okanogan	Percent Snake River
22-23	1181	6	0.0	100.0	0.0
24	14849	84	7.1	92.9	0.0
25	77562	175	10.9	89.1	0.0
26	81214	132	14.4	85.6	0.0
27	30135	119	15.1	82.4	2.5
28	6367	75	5.3	94.7	0.0
29	2256	29	6.9	93.1	0.0
Composite	213564	620	12.3	87.4	0.4
Standard Deviation			1.5	1.5	0.2
Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach for Wenatchee estimate)			16.7	83.3	
Visual Fish Counts at dams (Tumwater count as Wenatchee estimate)			14.9	85.1	

### Okanogan and Wenatchee age and length-at-age composition

The age composition estimate for the predominant age class (1.2) was similar for the two stocks (Table 9). One-ocean sockeye salmon (age 1.1 and 2.1) were found solely in the Okanogan stock, while the Wenatchee stock had a higher percentage of five and six-year-old fish (ages 2.2, 1.3, and 2.3). For the

<sup>4</sup> Juvenile sockeye salmon are adipose clipped in Snake River, Lake Wenatchee, and Skaha Lake (Okanogan Basin) hatchery programs.

Wenatchee stock, the age composition was similar whether estimated by PIT tag or by sampling at Tumwater Dam. In 2008, no sampling was conducted to estimate the Okanogan stock age composition at Wells Dam because in 2007 the trap was found to be highly selective against smaller fish (Fryer 2008b). Length-at-age estimates are found in Table 10.

**Table 9. Age composition (%) of Wenatchee and Okanogan sockeye salmon as estimated by PIT tag recoveries as well as by sampling at Tumwater Dam. Standard deviations are in parentheses.**

Stock/method	Sample Size	Age					
		1.1	1.2	1.3	2.1	2.2	2.3
Bonneville sample	1162	7.1 (0.8)	87.4 (1.1)	0.5 (0.2)	1.7 (0.5)	3.1 (0.6)	0.1 (0.1)
Wenatchee PIT tag estimate	64		87.7 (4.4)	4.8 (2.9)		5.5 (3.2)	2.0 (1.5)
Wenatchee-Tumwater sample	392		90.3 (1.8)	1.0 (0.6)		8.6 (1.7)	0.1 (0.1)
Okanogan- PIT tag estimate	598	7.4 (1.0)	86.4 (1.4)	0.7 (0.4)	2.3 (0.7)	3.2 (0.8)	

**Table 10. Length-at-age composition of Wenatchee and Okanogan stock sockeye salmon estimated by PIT tag detection and sampling at Tumwater and Wells dam in 2008.**

Stock	Statistic	Age					
		1.1	1.2	1.3	2.1	2.2	2.3
Bonneville mixed stock	Mean	39.9	49.5	56.9	42.5	50.4	56.5
	St. Dev.	1.9	2.7	2.9	1.9	3.1	2.1
	N	84	663	4	16	24	2
Okanogan (PIT tags)	Mean	39.9	49.3	55.5	43.1	49.8	
	St. Dev.	1.9	2.7	-	1.6	3.1	
	N	71	488	1	18	16	
Wenatchee (PIT tags)	Mean		50.7	57.3	13	51.2	56.5
	St. Dev.		2.4	3.3		2.5	2.1
	N		56	3		3	2
Wenatchee (Tumwater Sampling)	Mean		52.7	57.2		53.0	60.0
	St. Dev.		2.3	2.57		2.6	-
	N		358	3		30	1

### ***Fallback***

Estimated fallback (and reascension) rates for sockeye salmon ranged from 0% at Ice Harbor Dam to 33.3% at Lower Granite Dam (Table 11). However, the Lower Granite estimate is based on only three fish. Five 12.5 mm PIT tagged sockeye salmon fell back through the John Day juvenile bypass system, while one sockeye fell back through at the Bonneville Dam juvenile bypass system. Two sockeye last seen at Tumwater Dam and therefore, assumed to be Wenatchee stock passed Rocky Reach Dam (upstream of the



Wenatchee River confluence) prior to reaching Tumwater Dam. Another sockeye salmon passed both Rocky Reach and Wells Dams before falling back downstream and was last detected at Tumwater Dam. This was the only sockeye salmon in this study that PIT tag detections indicate fell back over multiple dams.

**Table 11. Estimated sockeye salmon fallback at mainstem Columbia River dams in 2008 as estimated by PIT tag detections.**

<b>Dam</b>	<b>Sockeye (%)</b>
Bonneville	0.5
McNary	1.1
Priest Rapids	1.6
Rock Island	1.0
Rocky Reach	4.0
Wells	0.7
Tumwater	1.5
Ice Harbor	0.0
Lower Granite	33.3

### ***Night Passage***

Okanogan stock sockeye salmon passed dams at night (2000-0400) at a higher rate than Wenatchee stock sockeye salmon (Table 12). The Bonneville Dam estimate of night time passage is likely biased low due because tagging occurred between about 0900 and 1500 and, with a median passage time of 76 minutes (Table 7) would be expected to pass the counting window prior to 2000.

**Table 12. Estimated sockeye salmon nighttime passage (2000-0400 standard time) in 2008 at mainstem Columbia River dams as estimated by PIT tag detections**

<b>Dam</b>	<b>All Sockeye (includes unknown)</b>	<b>Okanogan Stock</b>	<b>Wenatchee Stock</b>
Bonneville	2.9	2.8	1.5
McNary-Oregon Shore	6.4	6.0	3.3
McNary-Washington Shore	5.8	5.2	8.8
Priest Rapids	5.4	5.9	1.5
Rock Island	4.3	4.4	3.2
Rocky Reach	8.5	8.3	33.3 <sup>5</sup>
Wells	7.1	7.1	0.0 <sup>6</sup>
Tumwater	6.1	NA	6.1
Mean McNary, Priest Rapids and Rock Island	5.3	5.3	3.6

<sup>5</sup> Only three Wenatchee stock sockeye salmon passed upstream of Rocky Reach Dam and then fell back downstream to migrate up the Wenatchee River to Tumwater Dam.

<sup>6</sup> Only one Wenatchee stock sockeye salmon passed upstream of Wells Dam and then fell back downstream to migrate up the Wenatchee River to Tumwater Dam.

## DISCUSSION

This study demonstrated the feasibility of using PIT tags to assess the following: adult sockeye salmon migration; timing; escapement; Wenatchee and Okanogan stock age and length-at-age composition; mortality; fallback rates; and the weekly and total stock composition at Bonneville Dam.

Stock composition estimates produced by this study were consistent with those estimated using upstream dam counts. However, both estimates do not allow classification of stock for sockeye salmon at Bonneville Dam that do not pass Rock Island or Ice Harbor Dams. These fish are considered mortalities and made up of 14.2% of the run. The estimate of 12.3% Wenatchee, 87.4% Okanogan, and 0.4% Snake is based on upstream detections; to extrapolate this estimate to Bonneville Dam assumes that these presumed mortalities have a similar classification. Scale pattern studies that have been conducted in the past (e.g. Fryer 2007b) do offer stock composition estimates at Bonneville Dam unaffected by this potential bias; however, scale pattern analysis suffers from insufficient sample size of some age classes and high variance in stock composition estimates.

Unlike years 2006 and 2007, there was not a significant linear relationship between run timing and stock composition. In those years, as well as in most years of the past sockeye stock identification study (e.g. Fryer 1995, 2006) using scale pattern analysis, there was a significant relationship between run timing and stock composition, with a higher percentage of the Wenatchee stock migrating in the early portion of the run and a higher percentage of the Okanogan stock migrating in the latter portion of the run. The 2008 data agrees with a 1997 radio tag study, Naughton (2005) which found that there was no difference in run timing between the two stocks.

PIT tags provide an easier, much cheaper, and less intrusive method of monitoring the upstream migration than radio tags used in past studies (e.g. Naughton (2005)). However, PIT tags may not provide the same data that can be collected in a radio tag study. For example, PIT tag detectors are not installed at all mainstem dams, nor are they present in many tributaries. However, new detection sites, particularly at dams, are continually being added. Ultimately, it seems likely all dams in the Columbia Basin with upstream passage facilities will

be wired with PIT tag detectors in the near future. In 2008, PIT tag detection was added at Tumwater Dam and CRITFC is presently working towards funding detection at key sites in the Okanogan basin. PIT tag detection in the Okanogan Basin would allow mortality to be estimated between Wells Dam and the spawning grounds, which is believed to be high.

This study was the first to examine whether 8.5 mm PIT tags, increasingly used in juvenile tagging studies, perform as well as 12.5 mm PIT tags at adult fish ladders. The results indicate that 8.5 mm tags perform poorly at McNary, Priest Rapids, Rock Island, and Rocky Reach Dams. This conclusion is based on lower detection rates at individual weirs (Table A1) as well as the percentage of fish not detected at dams with detection antennas but detected further upstream (Table 2). Individual weir detection rates also suggest lower detection rates for 8.5 mm tags compared to 12.5 mm tags at Wells, Tumwater, and Bonneville Dams although, the percentage of 8.5 mm tagged fish missed at Bonneville is relatively small. There is insufficient data at Ice Harbor and Lower Granite Dam to make any conclusions.

As was the case in 2006 and 2007, the percentage sockeye salmon passing dams undetected (Table 2) was generally higher than it should have been given the high detection rate estimated at individual weirs (Table A1). This was the case for both 8.5 and 12.5 mm tagged sockeye salmon. At most fish ladders, overall detection based on individual weirs was 100% for 12.5 mm tagged fish; the exceptions were the Rock Island left ladder at 97.3%, the Rock Island right ladder at 99.7%, and the Rocky Reach ladder at 97.4%. This suggests that sockeye salmon have some characteristic (e.g. a malfunctioning tag, a poorly placed PIT tag, or fish behavior), that allows them to escape detection at multiple weirs at a given dam.

The percentage of 12.5 mm tagged fish missed at McNary Dam increased to 10.1% in 2008 from 6.5% in 2007 and 3.1% in 2006. While it is possible some proportion of this is attributable to tagged fish being missed, it seems more likely that sockeye salmon are ascending via the navigation locks. The large disparity in visual dam counts, with McNary Dam estimating over 20% less passage than either Priest Rapids or Rock Island Dams (both of which are located upstream of McNary Dam), also points to significant lock passage as a likely possibility.

For the first time in the three years of this study, PIT tagged sockeye salmon were detected at Snake River Dams and these fish were presumed to be ESA-listed Snake River sockeye. All six of the fish detected in the Snake River were tagged at Bonneville Dam in Statistical Week 27 (two on June 30 and four on July 2). Of the six fish detected, one was unclipped, two were adipose clipped only, two had a right ventral clip in addition to an adipose clip, and one had a right pectoral fin clip in addition to an adipose clip. Three of these six fish were tagged with 8.5 mm tags, while the other three were tagged with 12.5 mm tags. Five of these sockeye salmon were detected at Ice Harbor Dam (one tagged with an 8.5 mm tag was not detected at both Ice Harbor and Bonneville Dams but was detected at McNary and Lower Granite Dams), all passed Ice Harbor Dam during Statistical Week 28 (one on July 6 and four on July 10). Five of the six fish detected at Lower Granite passed within 6 days of each other (two on July 10, two on July 14, and one on July 15) with the remaining sockeye salmon passed on August 3. The age composition of the six Snake River sockeye salmon was 66.7% Age 1.1, 16.7% Age 1.2, and 16.7% Age 2.2.

Two PIT tags from sockeye salmon tagged by this project in 2008 were recovered at the Badger Island Pelican Colony in the McNary Pool. The first sockeye salmon was a 48 cm fish that was tagged at Bonneville Dam on June 12 and the second was a 53 cm fish tagged on June 16.

Out of approximately 1,000 sockeye salmon scanned, six 12.5 mm PIT tagged sockeye salmon were recovered from October 10<sup>th</sup> to October 22<sup>nd</sup> by the Okanagan Nation Alliance during hatchery broodstock collection and spawning ground survey activities.

Most escapement estimates using PIT tags were within 6.4% of escapement methods estimated from visual methods at dams; the exceptions were McNary and Tumwater Dams (Table 3). At Tumwater, the PIT tag estimated escapement was 20,081, versus 28,340 obtained by counting sockeye salmon as they passed through a fish trap. This difference is surprising, and may be of great importance to the stock, as the escapement goal for this stock is 23,000 fish. Given that the Lake Wenatchee sport fishery harvested 4,849 sockeye salmon, using the trap count leaves an escapement to the spawning grounds of 23,491 while using the PIT tag estimate results in an escapement of 15,232 fish.

Two problems noted in the operation of the 2007 study (Fryer 2008b) did not recur in 2008. In 2007, there were four sockeye mortalities (all in one week) but in 2008 (as in 2006) there were none. Also, in 2007, 7.6% of tagged sockeye salmon were not detected after release, an increase over the 2.0% observed in 2006. In 2008, the percentage of 12.5 mm tagged fish not detected after release was 1.3%. These fish either lost their tags between tagging and detection, or swam downstream and either did not reascend or reascended through the Bonneville Dam navigation locks. In 2008, the team recovered two tags shed by sockeye salmon in the small tank where sockeye salmon were allowed to recover, indicating that tag loss prior to detection at the Bonneville Dam detection antennas was possible. In both 2006 and 2007, all fish were allowed to recover in a larger pool where recovery of shed tags was impossible.

In 2008, the use of a computerized video system was tested to record the sampling, including PIT tagging. The software, although designed for use in estimation of escapement at fish viewing windows such as those at dams and weirs, proved useful in accepting as input the PIT tag signal and imprinting this on the video when the fish was scanned after tagging. It was anticipated that the video would help to determine if proper tagging procedures were correctly applied in the case of mortalities or lost tags. Neither was a significant problem this year; however, the video file was useful for checking for incorrectly recorded fish lengths when the length did not agree with the age as determined from scales.

An unexpected result of this study was the discovery that sockeye salmon have a median delay of 4.6 days in passing Tumwater Dam. This was likely attributable to the 24 hour operation of the fish trap at Tumwater Dam. Fish were observed “stacking up” in the fish ladder below the trap (Keely Murdoch, Yakama Nation, personal communication), and it was evident that it was causing significant delays. It is possible that some sockeye salmon were not passing the Tumwater Dam due to the passage delays-7.6% of those sockeye salmon detected at Tumwater Dam were last detected at the lower detection site suggesting that these fish turned around and went downstream and were not detected again. Although these fish were last detected at the Tumwater Dam lower detection site and may not have passed Tumwater Dam, they were included in the Tumwater escapement estimates presented in Table 3.

This project will continue in 2009 as part of two Columbia Basin Fish Accords projects (<http://www.critfc.org/cbp>). The first project will focus on PIT tagging steelhead and salmon (including sockeye) that are sampled at the Bonneville Dam Adult Fish facility. The second project focuses on sockeye salmon and will initially feature installation of PIT tag detection in the Okanogan Basin to better estimate upstream survival for the Okanogan stock.

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## APPENDIX

**Table A1. Probability of detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for sockeye salmon in 2008.**

<b>Dam, site, and tag type<sup>1</sup></b>	<b>Weir and probability of detection at weir</b>											<b>Overall Detection Probability</b>
<b>Bonneville</b>	<b>N</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>							
BO4-12.5	762	99.7	99.7	98.3	99.9							100.0
BO4-8.5	262	78.2	74.4	48.5	69.5							99.1
BO1-12.5	44	100.0	100.0	100.0	100.0							100.0
BO1-8.5	18	72.2	61.1	61.1	83.3							99.3
<b>McNary</b>		<b>1</b>	<b>2</b>	<b>288</b>	<b>287</b>	<b>286</b>	<b>284</b>	<b>283</b>	<b>282</b>	<b>280</b>	<b>279</b>	
MC1-12.5	352	100.0	97.3	14.5	14.2	16.8	18.2	16.2	15.3	21.3	19.9	100.0 <sup>7</sup>
MC1-8.5	97	74.2	88.7	19.6	14.4	18.6	16.5	19.6	12.4	19.6	14.4	97.1 <sup>a</sup>
		<b>1</b>	<b>2</b>	<b>3</b>	<b>312</b>	<b>311</b>	<b>309</b>	<b>308</b>	<b>306</b>	<b>305</b>	<b>303</b>	
MC2-12.5	292	100.0	100.0	100.0	10.4	10.1	19.8	16.8	19.9	19.9	23.6	100.0 <sup>bb</sup>
MC2-8.5	122	86.1	92.6	66.4	14.8	8.2	10.7	19.7	18.9	11.5	18.0	100.0 <sup>b</sup>
<b>P. Rapids</b>		<b>3</b>	<b>7</b>									
East-12.5	625	95.5 <sup>9</sup>	100.0									100.0
East-8.5	147	20.4	92.5									90.4
		<b>3</b>	<b>5</b>									
West-12.5	<b>66</b>	100.0	100.0									100.0
West-8.5	<b>28</b>	75.0	78.6									94.6
<b>R. Island</b>		<b>1-2</b>	<b>3-4</b>									
Left-12.5	237	84.4	82.7									97.3
Left-8.5	49	57.1	75.6									89.5
		<b>5-6</b>	<b>7-8</b>									
Middle-12.5	101	100.0	100.0									100.0
Middle-8.5	40	40.0	90.0									94.0
		<b>09-0A</b>	<b>0B-0C</b>									
Right-12.5	304	99.0	73.7									99.7
Right 8.5	14	92.9	14.3									93.9
<b>R. Reach</b>		<b>1-2</b>	<b>3-4</b>									
12.5	579	87.2	80.0									97.4
8.5	53	73.6	47.2									86.0
<b>Wells</b>		<b>1-2</b>	<b>3-4</b>									
Left-12.5	323	99.7	100.0									100.0
Left-8.5	101	70.3	76.2									92.3
		<b>5-6</b>	<b>7-8</b>									
Right-12.5	285	100.0	100.0									100.0
Right-12.5	95	88.4	77.9									97.4
<b>Tumwater</b>		<b>161</b>	<b>162</b>									
12.5	66	100.0	100.0									100.0
8.5	30	96.7	90.0									99.7

<sup>7</sup> Overall detection probability is based solely on detection at counting station weirs (1 and 2)

<sup>8</sup> Overall detection probability is based solely on detection at counting station weirs (1, 2, and 3)

<sup>c</sup> Fish bypass this weir when the Priest Rapids adult fish trap is in operation.

**Table A2. Harvest by fishery for Columbia Basin sockeye salmon in 2008.**

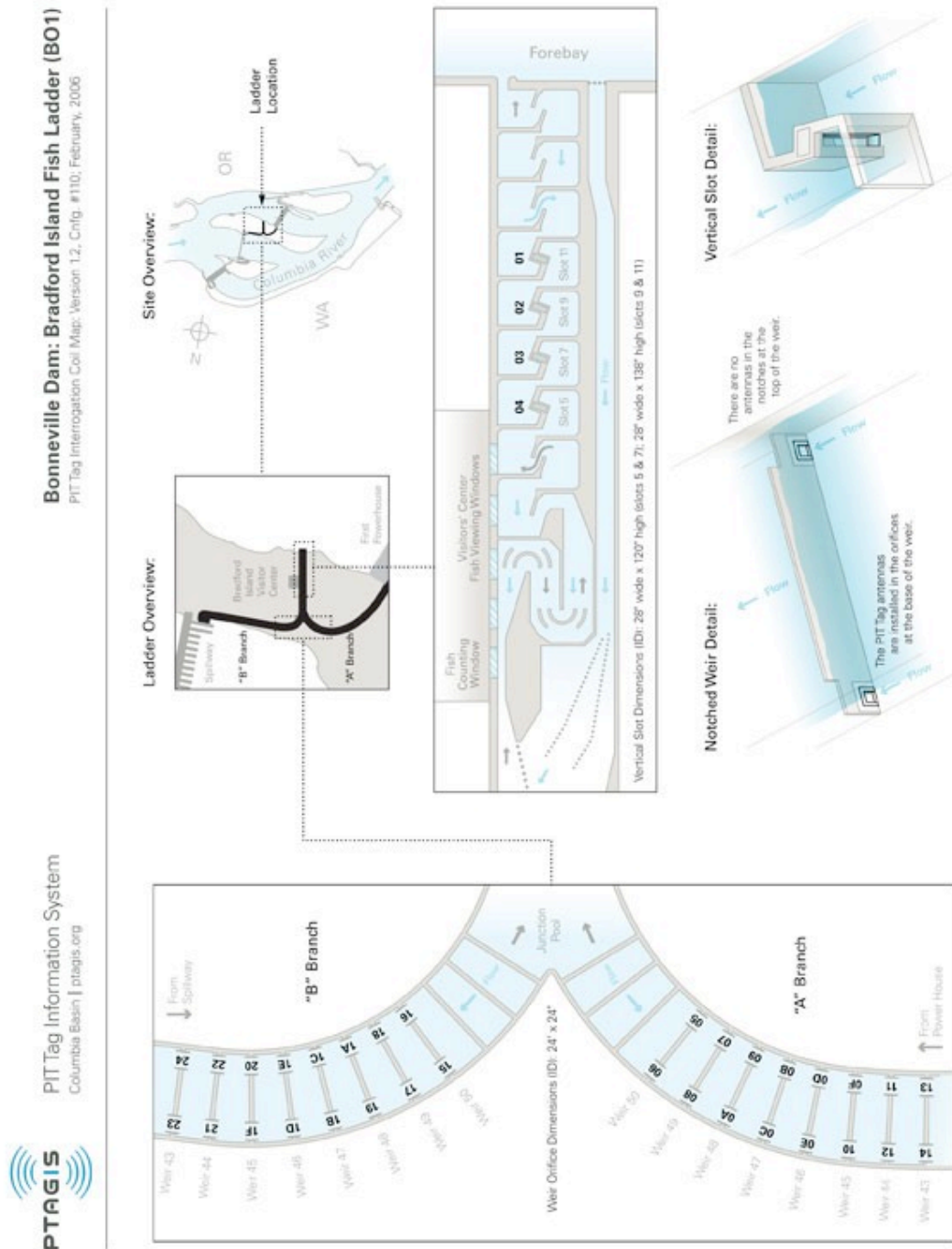
<b>Location</b>	<b>Fishery Type</b>	<b>Source</b>		<b>Totals</b>
Zone 1-5	Commercial	TAC	296	
	Sport	TAC	557	
	Non-retention mortality in shad fisheries	TAC	5	
				858
Zone 6	Commercial	TAC	3517	
	Ceremonial and Subsistence	TAC	5500	
				9017
Lake Wenatchee	Sport (5129 harvested, 280 released)	WDFW		4849
Priest Rapids-Wells Pool	Sport (456 harvested, 105 released)	WDFW		351
Colville	Okanogan River	CTCIR		
Colville	Chief Joseph tailrace	CTCIR		0
Upstream of Lake Osoyoos	Okanagan tribal	ONA		2852

**Table A3. Distribution of sockeye salmon by fish ladder for dams with multiple fish ladders as estimated by PIT tag detections in 2008.**

<b>Dam</b>	<b>Right Bank<sup>10</sup></b>	<b>Left Bank</b>	<b>Center</b>
<b>Bonneville</b>	94.5%	5.5%	
<b>McNary</b>	60.6%	39.4%	
<b>Priest Rapids</b>	90.4%	9.6%	
<b>Rock Island</b>	47.4%	36.9%	15.7%
<b>Wells</b>	46.9%	53.1%	

<sup>10</sup> Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank, at McNary it would be the Washington shore.

Figure A1. PIT Tag detection configurations in adult fish ladders at Bonneville, McNary, Priest Rapids, Rock Island, and Wells Dams. All images provided by PTAGIS (2007) and available at <http://www.ptagis.org>. Reprinted with permission.



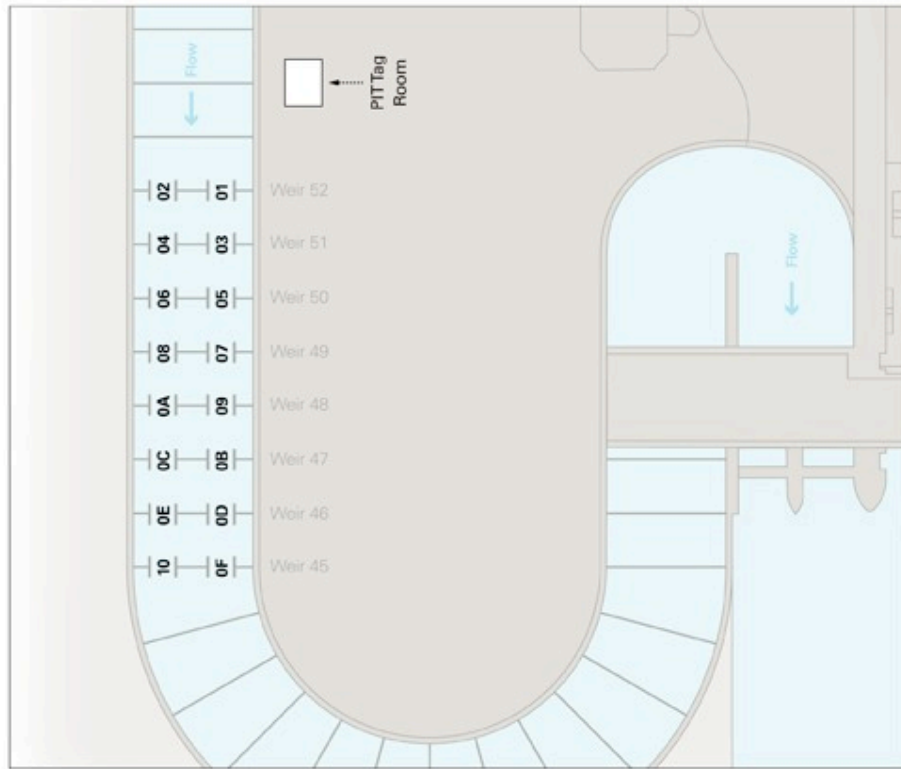
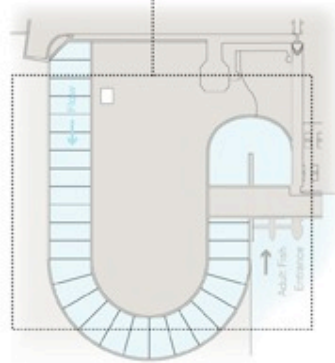


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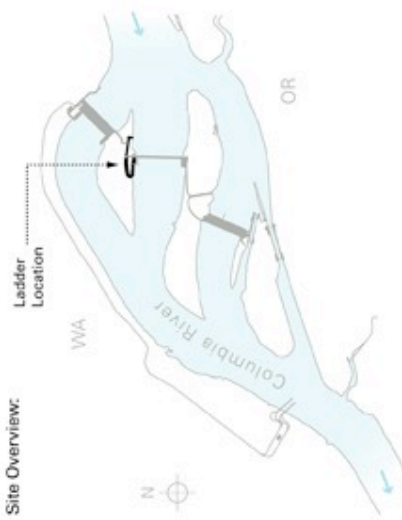
## Bonneville Dam: Cascades Island Fish Ladder (BO2)

PIT Tag Interrogation Coil Map: Version 1.1, Cnfg. #100; February, 2002  
Orifice Dimensions: 24" wide x 24" high

Ladder Overview:



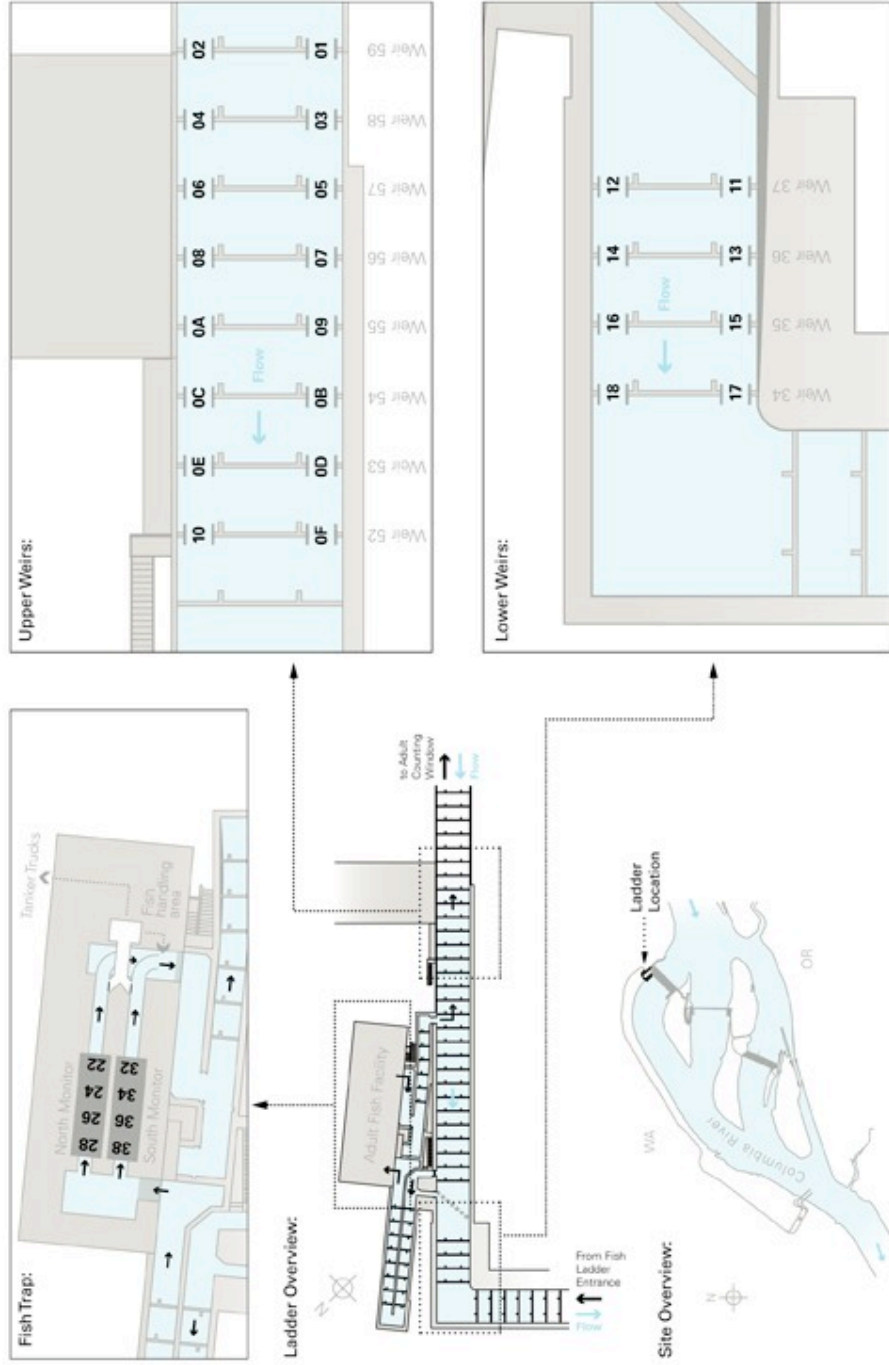
Site Overview:





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**Bonneville Dam: Washington Shore Fish Ladder and AFF (BO3)**  
PIT Tag Interrogation Coil Map: Version 1.2, Cnfig. #110; Revised December, 2003  
Orifice Dimensions: 18" wide x 18" high



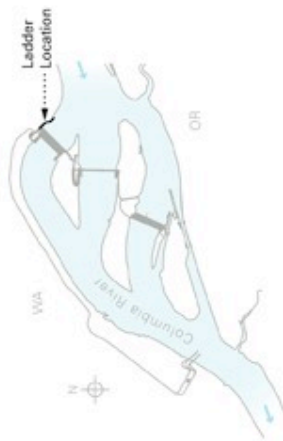


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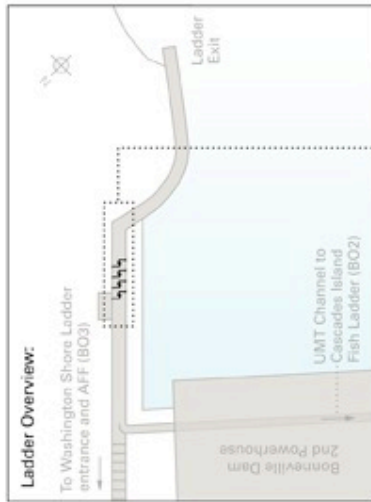
# Bonneville Dam: Washington Shore Ladder Vertical Slots (BO4)

PIT Tag Interrogation Coil Map: Version 1.0, Cnfig. #100; Created March, 2005  
Antenna Dimensions (ID): 28" wide x 120" high (slots 5 & 7); 28" wide x 138" high (slots 9 & 11)

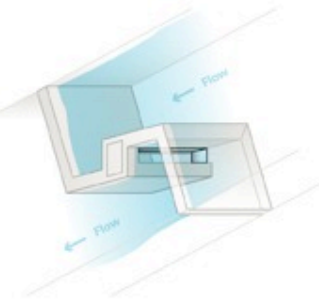
Site Overview:



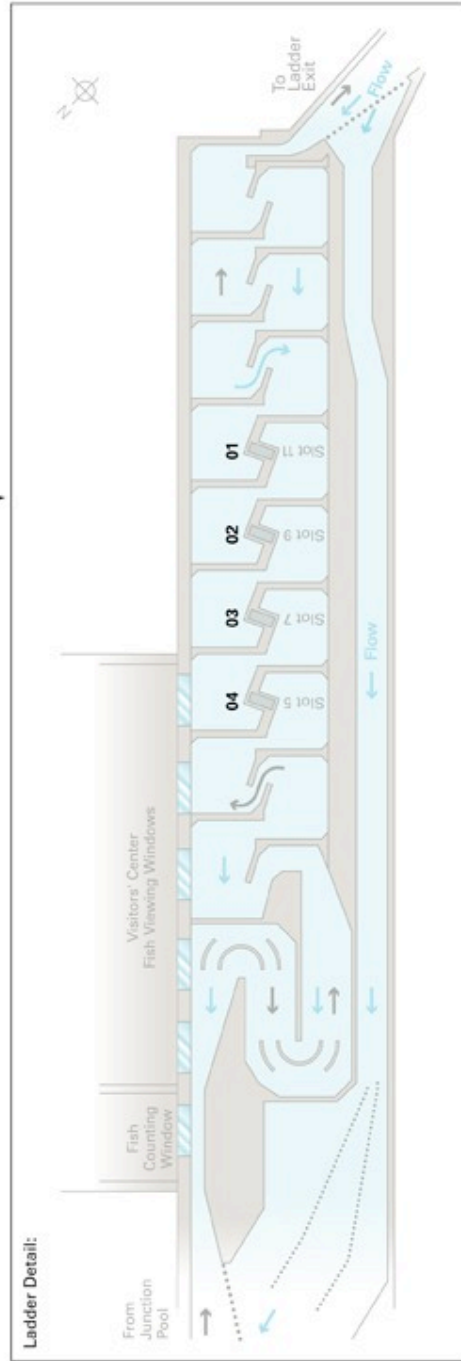
Ladder Overview:



Vertical Slot Detail:



Ladder Detail:

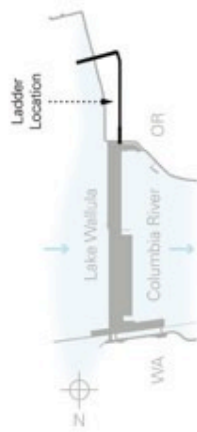




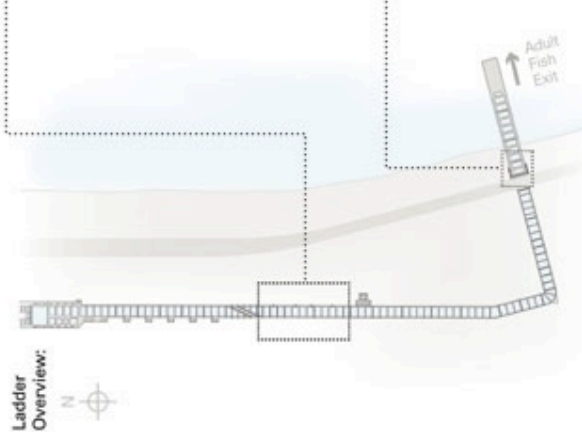
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McNary Dam: Oregon Shore Ladder (MC1)  
PIT Tag Interrogation Coil Map: Version 1.2, Cnfg. #100; February 2002

Site Overview:

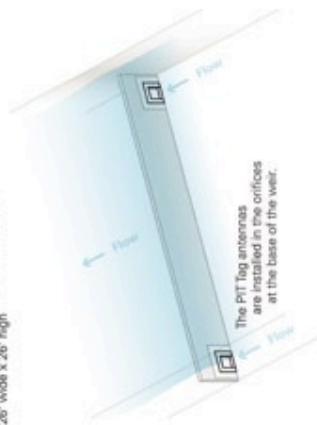


Ladder Overview:



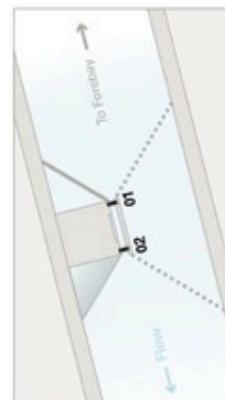
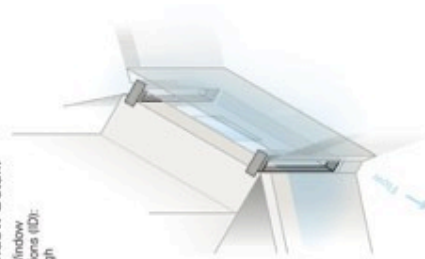
Overflow Weir Detail:

Weir Orifice Antenna Dimensions (ID):  
26" wide x 26" high



Counting Window Detail:

Adult Counting Window  
Antenna Dimensions (ID):  
20" wide x 62" high

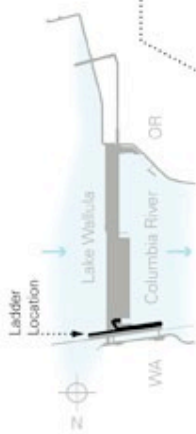




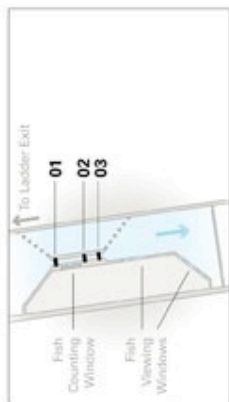
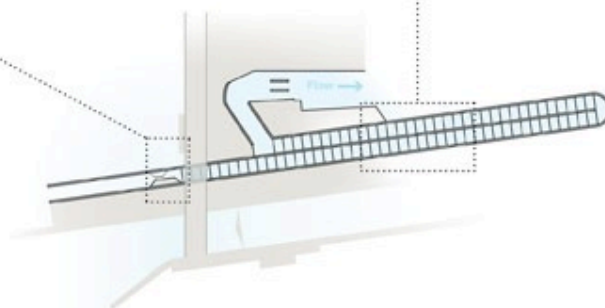
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**McNary Dam: Washington Shore Ladder (MC2)**  
PIT Tag Interrogation Cool Map: Version 1.1, Cnfg. #120; Revised March, 2006

#### Site Overview:

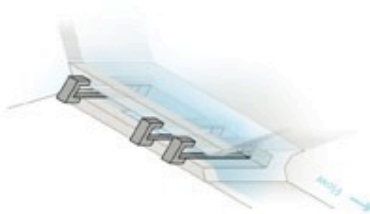


#### Ladder Overview:



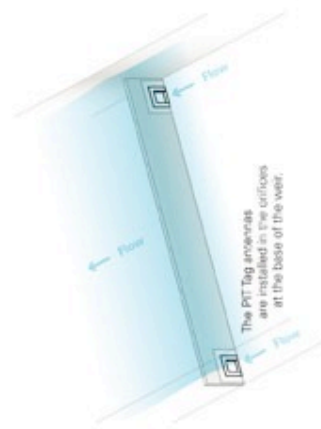
#### Counting Window Detail:

Adult Counting Window Antenna Dimensions (ID): 20" wide x 62" high



#### Overflow Weir Detail:

Weir Orifice Antenna Dimensions (ID): 21" wide x 23" high

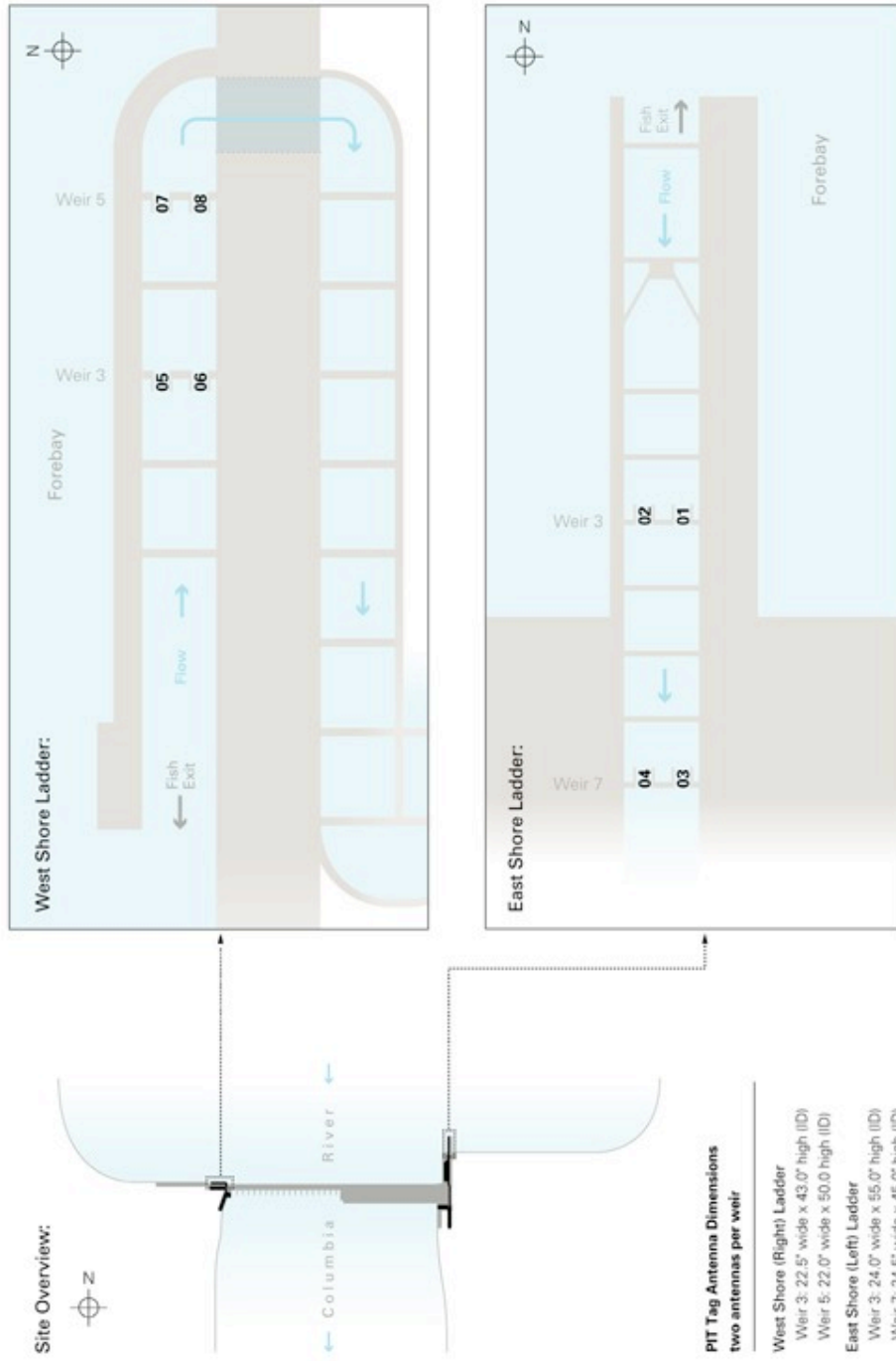






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**Priest Rapids Dam Fish Ladders (PRA)**  
Interrogation Coil Map Revised: May, 2003 v.1.0, Cnfg. #100

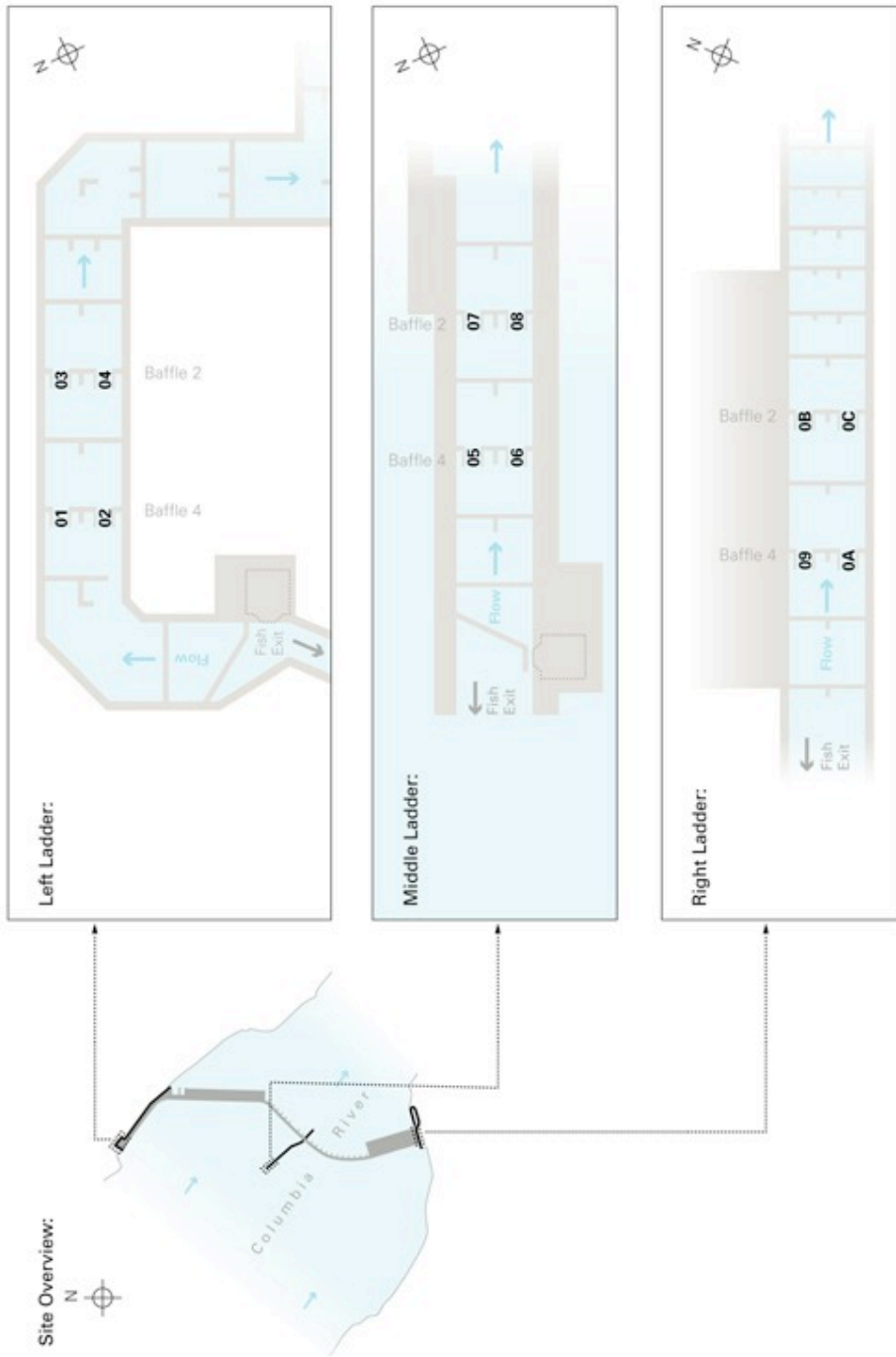




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### Rock Island Dam Fish Ladders (RIA)

Interrogation Coil Map Revised: May, 2003 v.1.0, Cnfg. #100  
PIT Tag Antennae Dimensions: 21.5" wide x 36.5" high (ID)



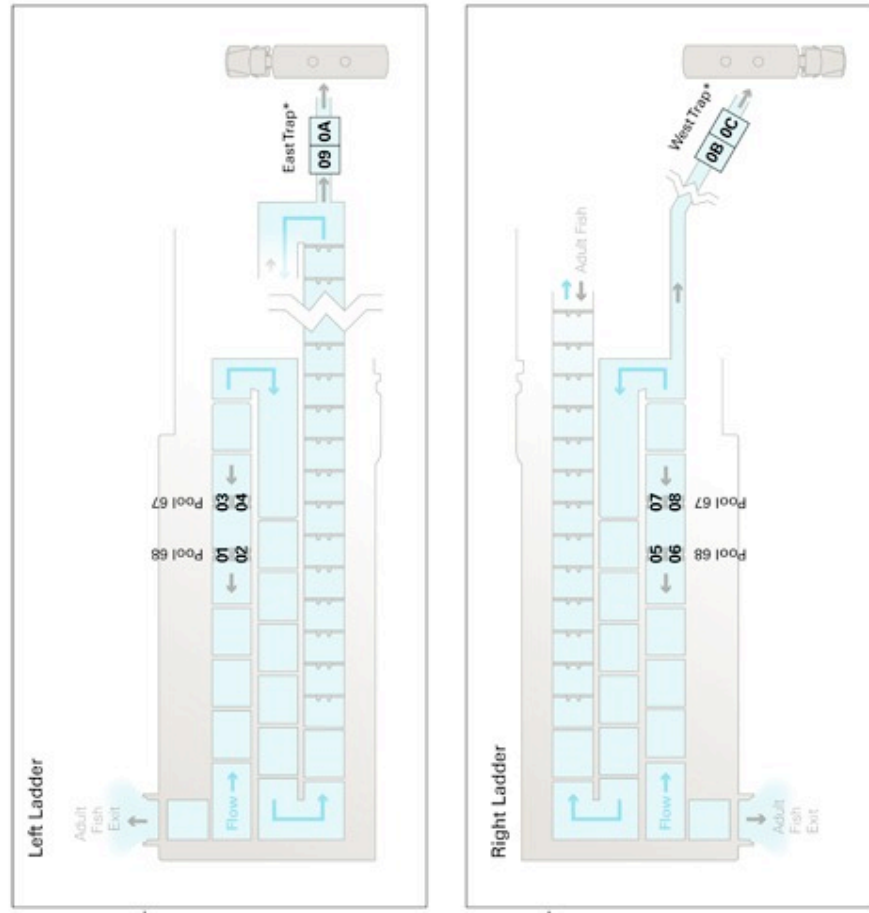
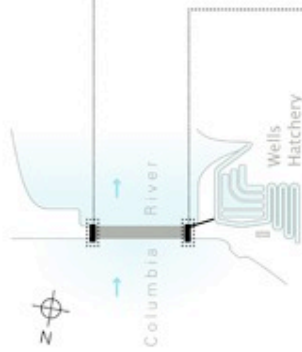


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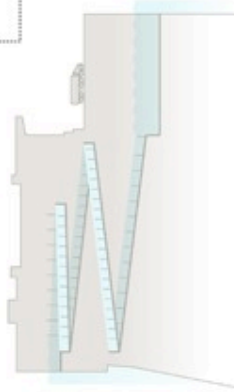
# Wells Dam Fish Ladders (WEA)

PIT Tag Interrogation Map, Version 1.1, Cnfg. #110, Revised June, 2004  
Ladder Office Dimensions: 21' wide x 34.5' high

Site Overview:



Elevation View:



\*Trap fish are removed to the hatchery or trucked off-site.