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CRITFC

TECHNICAL REPORT 08-01

Estimation of mid-Columbia summer Chinook salmon escapement and age composition using PIT tags in 2007

Jeffrey K. Fryer

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ABSTRACT

In 2007, a total of 470 summer Chinook salmon (*Oncorhynchus tshawytscha)* were PIT tagged at Bonneville Dam between June 16 and July 13. An additional 763 spring Chinook salmon were PIT tagged between April 24 and June 15, while 194 fall Chinook were PIT tagged between September 13 and October 12. After adding previously tagged fish, and subtracting fish that likely shed PIT tags, a total of 764 spring Chinook, 470 summer Chinook, and 194 fall Chinook were tracked upstream.

Based on PIT tagged recoveries, 75.4% of summer Chinook salmon passed upstream of McNary Dam, 56.1% upstream of Rock Island Dam, 33.3% upstream of Wells Dam, and 15.6% upstream of Lower Granite. For spring Chinook salmon, 59.0% passed upstream of McNary Dam, 11.6% upstream of Rock Island Dam, and 36.2% upstream of Lower Granite Dam. For fall Chinook, 35.4% of fall Chinook salmon passed upstream of McNary Dam, 0.2% upstream of Rock Island Dam, and 11.1% upstream of Lower Granite Dam.

Between Bonneville and McNary dams, spring Chinook averaged 39.6 km/day, summer Chinook 39.8 km/day and fall Chinook 34.0 km/day. There was not a significant linear relationship between flow or water temperature and summer Chinook salmon migration rate downstream of McNary dam. However, there was a significant relationship between flow and water temperature and summer Chinook salmon migration rates upstream of McNary Dam.

Age composition estimates, based on scale pattern analysis, indicate that those summer Chinook salmon passing upstream of Ice Harbor Dam are predominantly yearling outmigrants (70.9% Age 1.1 and 18.4% Age 1.2), while those passing upstream of Rock Island Dam are a mixture of subyearling and yearling outmigrants (26.7% Age 1.1, 21.7% Age 1.3, 16.3% Age 0.4, and 12.5% Age 1.2 with smaller percentages from other age classes).

Mark-recapture techniques were used to estimate summer Chinook salmon abundance at upstream dams. These techniques estimated from 21.9% less to 6.5% more fish at McNary and mid-Columbia dams than visual fish counts from mainstem dam fish ladders.

ACKNOWLEDGMENTS

Bonneville field sampling was supervised by John Whiteaker and assisted by Bobby Begay of the Columbia River Inter-Tribal Fish Commission (CRITFC). The following individuals also assisted in this project: Ryan Branstetter, David Graves, Doug Hatch, Denise Kelsey, Marianne McClure, Richard McConville, Jack McCormack, Shawn Narum, Winfred Perez, and Rishi Sharma of CRITFC; Ben Hausmann, Tammy Mackey, and Jon Rerecich of the US Army Corps of Engineers; Steven Lee and Dennis Quaempts of the University of Idaho, David Marvin of the Pacific States Marine Fisheries Commission, and Bob Jateff, Travis Maitland, Andrew Murdoch, Charlie Snow and Rick Stillwater of WDFW.

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INTRODUCTION

Populations of summer Chinook *(Oncorhynchus tshawytscha)* salmon destined for the mid-Columbia River have declined dramatically from historical levels (WDFW et al. 1993). In the past, this Chinook salmon race was the most robust and heavily fished stocks of the Columbia River (Thompson 1951, Chapman 1986). Causes of the declines are many but are mainly attributed to overfishing, loss of habitat primarily from hydropower and storage dams (Mullan 1987, Chapman et al. 1994), and mortality on the upstream and downstream migration. The Pacific Salmon Commission (PSC) also considers mid-Columbia summer Chinook salmon an exploitation rate indicator stock for harvest evaluation, and poor stock performance can constrain ocean and terminal fisheries.

The Columbia River Inter-Tribal Fish Commission annually samples summer Chinook salmon, as well as spring and fall Chinook salmon, at Bonneville Dam to estimate age and length-at-age composition (Whiteaker and Fryer 2007). These fish have long comprised a mixed stock of unknown origin. Given the stock's importance and the it's uncertain run timing and upstream survival, in 2006 we proposed to the Pacific Salmon Commission Chinook Technical Committee to purchase a passive integrated transponder (PIT) tag detector for use at Bonneville Dam and supply funding to PIT tag most summer Chinook salmon sampled as well as some spring and fall Chinook salmon. The PIT tag detector allowed us to identify previously tagged fish, thereby giving us known age (and stock) fish for validation of ages assigned by scale pattern analysis. In addition, by PIT tagging each summer Chinook salmon sampled, we could track these fish upstream and estimate age and length-at-age composition at upstream sites, as well as migration and fallback rates and escapement. This technical report details the results of this study in 2007.

METHODS

Sampling

Spring, summer, and fall Chinook salmon were PIT tagged at the Bonneville Dam Adult Fish Facility, located adjacent to the Second Powerhouse at river km 235. This 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.

Chinook salmon selected for sampling were examined for tags, fin clips, wounds, condition, measured for length, and a tissue sample along with six scales were removed for later genetic and age analysis (Whiteaker and Fryer *in preparation*). PIT tags were inserted into the body cavity using standard techniques (CBFWA 1999). The fish were then scanned for the PIT tag number, which was recorded. If no tag was detected due to either the tag being shed or a malfunctioning tag, the fish was released. All PIT tag and sampling information was uploaded to www.ptagis.org.

Tagged Chinook salmon were detected by PIT Tag receiver arrays found in the 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, as well as at several tributaries and hatcheries in the Columbia Basin (Appendix 1). PIT tag detection data is uploaded to www.ptagis.org where it is accessible to registered users of the site.

Age analysis

Scale pattern analysis was used to determine spring and summer Chinook salmon age composition using techniques developed for the age and stock composition project (Whiteaker and Fryer 2007) The addition of PIT tag detection equipment allowed us to scan for PIT tags indicating known origin and age fish which could be used age and life history validation.

Escapement

Summer Chinook salmon escapement to McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams was estimated as:

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

with variance:

$$Var(N) = \sum_i \frac{Var(B_i) R_i^{\,2}}{T_i^{\,2}}$$

where N was the estimated escapement at a particular upstream dam, *i* was the week of the Chinook migration at Bonneville Dam during the period for which escapement is being estimated, 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.* For Var(B_i), it was assumed that counts at mainstem dams were within 5% of the true count at α=0.05 (Fryer 1995).

Estimated dam counts using PIT tag data were compared with mainstem dam counts made at fish ladder viewing windows at McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams. The dates used for the count were derived by taking the median upstream passage time from Bonneville Dam and adding that to June 16 and July 31 which are the start and end dates of summer Chinook salmon passage as estimated by the U.S. v. Oregon Technical Advisory Committee.

Detection Efficiencies

Any fish detected at an upstream dam should also be detected at lower dams (except at McNary Dam and Ice Harbor where it is possible that a fish could use the navigation locks The percentage of PIT tagged chinook 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.

Also compiled for placement in the appendix of this report was the efficiency of detection at the different sites at dam fish ladders. PIT tag detection antennas in fish ladders are always placed in at least two sites in relatively close

proximity. PIT tag interrogation maps (Appendix 1) indicate that these are placed at vertical slots, weirs, or pools. To simplify the nomenclature, these sites will all subsequently be referred to as weirs.

With two weirs per dam, if a fish is detected at one weir, 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 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 in that ladder.

Also calculated was the percentage of Chinook salmon using each ladder at the 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 statistical week as well as 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.

Upstream age and length-at-age composition estimates

Age and length-at-age composition was estimated for upstream locations where an upstream location was either a dam with PIT tag monitoring, or between dams where there was significant summer Chinook salmon spawning. Thus, these statistics were estimated for McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams as well as the Rock Island-Rocky Reach, and Rocky Reach-Wells turnoffs. 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 Chinook salmon 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.

The variance was estimated as

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

where

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

Night passage

Fish at Columbia Basin dams are not all counted using the same time period. Fish at Bonneville and McNary dams are counted by observers only from 0400 to 2000 Pacific Standard Time, while fish at Priest Rapids, Rock Island, Rocky Reach, and Wells dams are all counted off videotape 24 hours per day. Night passage rates (where night is defined as 2000 to 0400) were calculated by stock for all dams passed based on the last time Chinook salmon were detected in a fish ladder. The last time detected was used as an approximation for passage time as the upper most weir was closer to the fish counting window than the lower most weir (where the first detection would be made) at all weirs except at BO4 near the Washington shore fish counting facility (Figure A1). (And at BO4, the distance between the upper most and lower most weir is only about 25 meters.)

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 summer Chinook salmon was actually detected in the juvenile bypass system following upstream passage. However, on the Columbia River only Bonneville, John Day, and McNary dams have both juvenile bypass systems with PIT tag detection capability. Also, any Chinook salmon falling back over the spillway, navigation locks or through the turbines would not be detected in the bypass system. Therefore, Chinook salmon with a detection at an "upper" detection weir followed by a detection at a "lower" detection weir separated by more than 2

hours were also considered fallbacks. At McNary and Bonneville dam, the upper detection weir was at the fish counting window (which are believed to detect all PIT tagged fish passing) while the lower weirs were PIT tag detectors at lower weirs. At McNary and Bonneville dams, detection histories of individuals detected at multiple ladders were also reviewed (MC1 and MC2 for McNary and BO1 and BO4 for Bonneville, Appendix 1). 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. Note that this method only estimates fallback plus re-ascension. Fish that fall back but do not reascend are not included.

Finally, a third method of detecting fallback was ascertained by fish that passed the upstream PIT tag detector at a given dam, then was next observed at a downstream dam.

RESULTS

Sample Size

A total of 763 spring Chinook, 470 summer Chinook, and 194 fall Chinook salmon were tagged in 2007 (Table 1). After adding previously tagged fish which we would otherwise have tagged to our sample, and subtracting fish which were not detected after release (likely a result of the tags being shed), the sample of fish tracked upstream consisted of 764 spring Chinook, 470 summer Chinook, and 194 fall Chinook salmon (Table 1). High water temperatures prevented sampling any Chinook salmon from July 16 through September 10.

Table 1. Number of summer Chinook salmon PIT tagged and tracked at Bonneville Dam by date and statistical week in 2007.

Summer Chinook					
Dates	**Statistical Week**	**Tagged (n)**	**Previously Tagged**	**Probable tag shed**	**Tracked (n)**
4/24,26	17	64	0	0	64
5/1,2,3	18	117	3	2	118
5/7,8	19	78	2	2	78
5/16,18	20	78	2	2	78
5/21,24,25	21	117	0	1	116
5/29,30,31	22	104	2	0	106
6/4,6,7	23	113	3	4	112
6/11,13,14,15	24	92	2	2	92
Total		**763**	**14**	**13**	**764**
Summer Chinook					
6/18,20,22	25	100	2	1	101
6/25,27,29	26	118	2	4	116
7/2,4,6	27	113	2	0	115
7/9,10,11,13	28	139	1	2	138
Total		**470**	**7**	**7**	**470**
Fall Chinook					
9/13	37	39	0	0	39
9/20	38	40	0	0	40
9/27	39	38	0	0	38
10/4	40	39	0	0	39
10/12	41	38	0	0	38
Total		**194**	**0**	**0**	**194**

Age Analysis

A total of 53 Chinook salmon with ageable scales that had been previously PIT tagged were sampled, allowing the known age since release to be compared with that estimated using scale patterns. We correctly aged 24 out of 25 (96%)

of the spring Chinook salmon as well as all 20 of the summer Chinook salmon and 9 of the fall Chinook salmon. The sole incorrectly aged fish was a 57.5 cm fish aged as having spent one year in saltwater, but it actually had spent two years in saltwater.

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Data on tag detections was downloaded from www.ptagis.org on November 29, 2007. Those spring Chinook salmon that traveled upstream of McNary Dam were bound primarily for the Snake River (Figures 1, 4) while summer Chinook were bound primarily for the Columbia River upstream of Priest Rapids Dam (Figures 2, 4). Fall Chinook were bound primarily for areas downstream of Ice Harbor and Priest Rapids dams (Figures 3, 4). Most of the fish that were not detected at Rock Island Dam were lost between Bonneville and McNary dams (Figure 1, Table 2). Over the spring/summer portion of the run, the proportion of Chinook salmon passing Priest Rapids dam steadily increased, while those not passing McNary Dam steadily decreased (Figure 4). The proportion of Snake River fish passing Ice Harbor was relatively consistent until Statistical Week 25 and then declined.

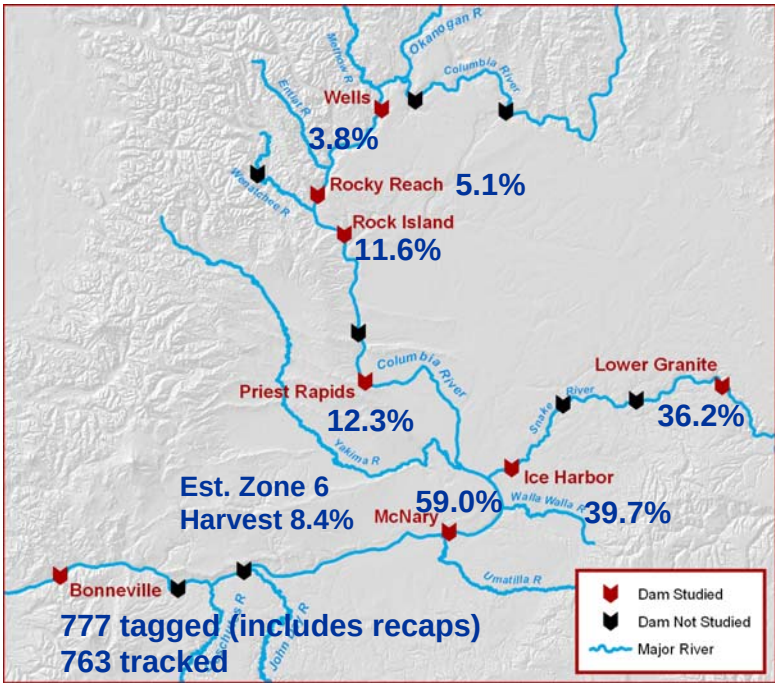

Figure 1. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of spring Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2007.

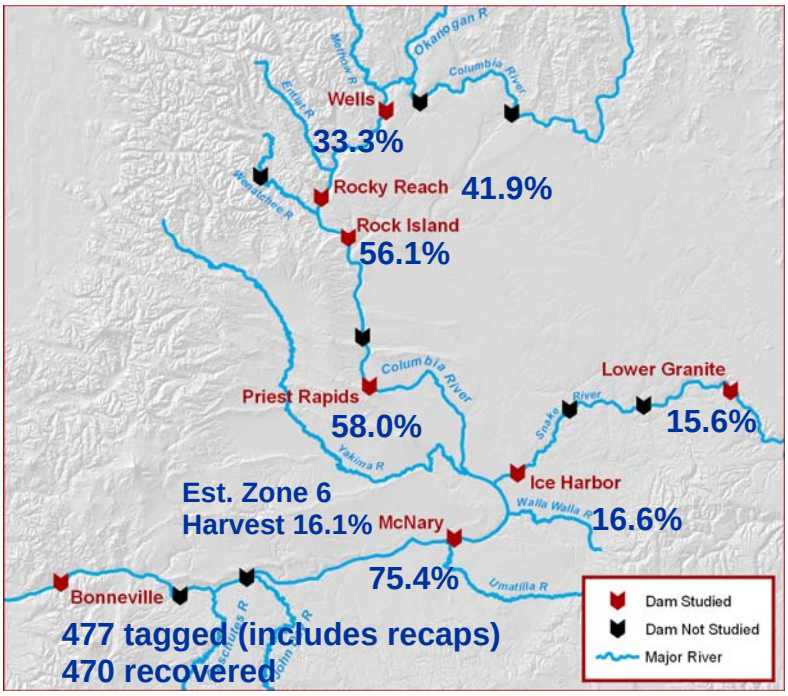

Figure 2. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of summer Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2007.

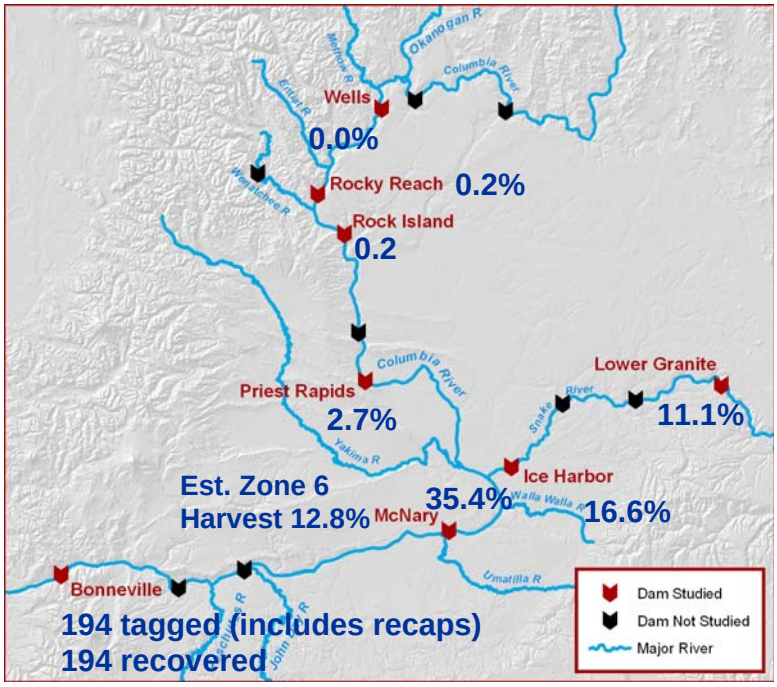

Figure 3. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fall Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2007.

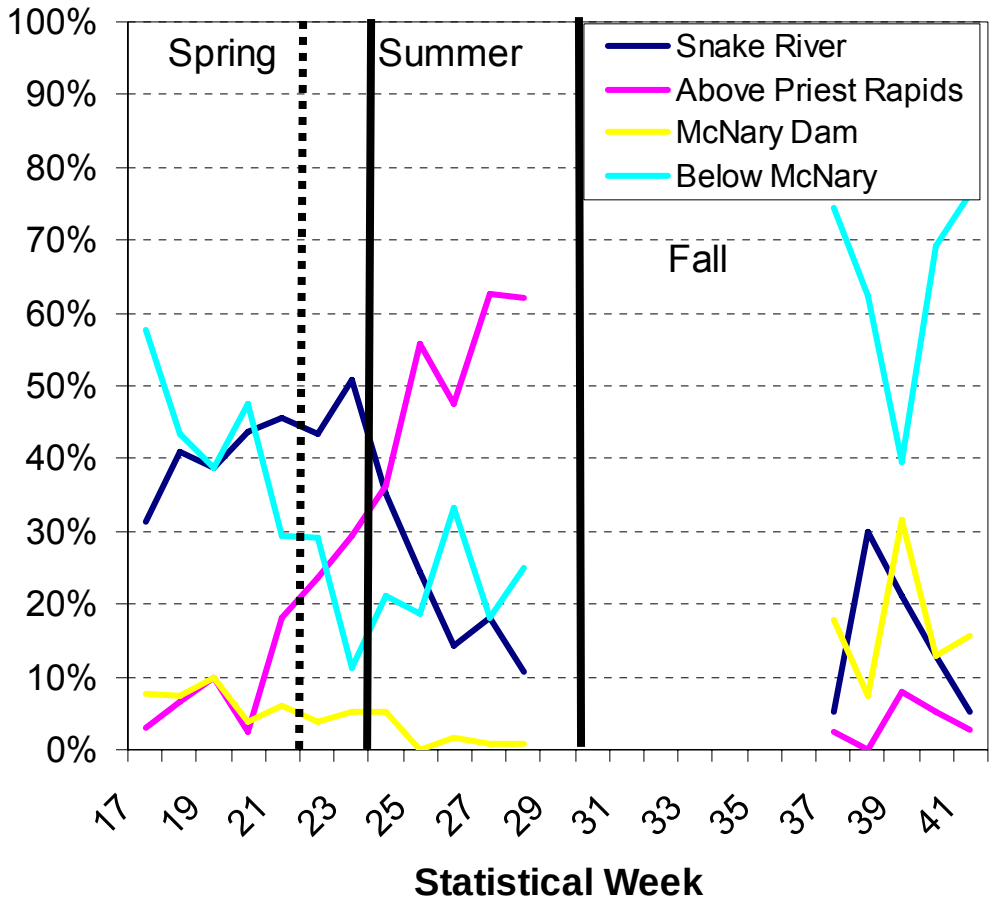

Figure 4. Distribution of final detection site by Statistical Week for Chinook salmon that were PIT tagged at Bonneville Dam. The solid lines denote June 16 and August 1, while the dashed line denotes June 1.

Table 2. Percentage of spring, summer, and fall Chinook salmon tracked from Bonneville Dam detected at upstream dams and the percentage "lost" between dams in 2007.

	Spring Chinook		Summer Chinook		Fall Chinook	
Dam	Estimated percentage reaching dam	Percent lost from previous dam	Estimated percentage reaching dam	Percent lost from previous dam	Estimated percentage reaching dam	Percent lost from previous dam
Bonneville	100.0		100.0		100.0	
McNary	60.6	39.4	77.2	22.8	55.4	44.6
Priest Rapids	12.4	79.6	58.3	24.4	2.4	95.6
Rock Island	11.7	5.8	56.4	3.3	0.2	93.4
Rocky Reach	5.2	55.5	42.1	25.3	0.2	0
Wells	3.9	25.6	33.5	20.4	0.0	100.0
Ice Harbor	39.9	60.1	36.9	83.1	16.6	83.4
Lower Granite	36.3	8.9	15.6	7.5	11.1	32.8

The percentage of Chinook salmon passing a dam undetected was generally under 1% (Table 3). The primary exception was at Ice Harbor Dam

where navigation locks provide a plausible reason as to how fish could pass undetected. (Navigation locks are also located at Lower Granite, McNary, and Bonneville dams.) No estimate could be made for Wells Dam or Lower Granite dams since there were no detection sites upstream, however all 32 Chinook salmon detected at the South Fork Salmon weir were detected at Lower Granite Dam. Data on the detection efficiency of individual weirs within ladders is found in Table A1, while data on the distribution of fish between ladders is found in Table A2.

Table 3. Percentage of Chinook salmon passing a dam undetected that were subsequently detected at an upstream dam in 2007.

Dam	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville	0.5%	0.6%	0.0%
McNary	0.6%	0.5%	0.0%
Priest Rapids	0.8%	0.4%	0.0%
Rock Island	0.8%	0.4%	0.0%
Rocky Reach	1.8%	0.0%	100.0%[a]
Ice Harbor	1.2%	2.4%	0.0%

Escapement estimates derived from PIT tag detections result in estimates differing from those estimated by visual counts by -21.9% to +6.4% (Table 4).

Table 4. 2007 summer Chinook salmon escapement at McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams as estimated from both PIT tag recoveries and dam counts and the differences between the two estimates. Note that the dates used were June 16-July 31 at Bonneville Dam with upstream dates lagged by the median summer Chinook passage time to that dam.

Site	Estimate	Standard Deviation	Dam Count Dates (estimated by Median Travel Time	Dam Count	Difference
McNary	33,078	598	6/21-8/5	31,057	6.5%
Priest Rapids	25,370	577	6/26-8/10	25,765	-1.5%
Rock Island	24,519	579	6/30-8/14	28,256	-13.3%
Rocky Reach	18,254	589	7/1-8/15	23,369	-21.9%
Wells	14,535	597	7/5-8/19	13,655	6.4%

Migration Timing and Passage Time

The fastest travel time between dams, as measured in kilometers per day, was between McNary and Ice Harbor for summer and fall Chinook salmon and between Bonneville and McNary dams for spring Chinook salmon (Table 5). The slowest travel time for both spring and summer Chinook salmon was between Rocky Reach and Wells dams (Table 5). For Chinook salmon migrating through

[a] The only PIT tagged fall Chinook salmon detected at Wells Dam was not detected at Rocky Reach Dam.

Bonneville Dam between statistical weeks 17 and 28, there was a significant linear relationship between statistical week and median travel rate for McNary to Priest Rapids Dam (p=0.016), McNary to Rock Island Dam (p=0.008), Priest Rapids to Rock Island Dam (p=0.001), and McNary to Ice Harbor Dam (p=0.043). Linear relationships between these median travel rates and Priest Rapids flow and temperature also tend to be significant as flow and temperature are highly correlated with statistical week (ρ=-0.8 and 0.98 respectively).

Table 5. Chinook salmon migration rate between mainstem dams as estimated by PIT tag detections in 2007 (Sample sizes were too small to estimate fall Chinook rates above McNary Dam.)

		Median travel rate (km/day)		
Dam pair	Distance (km)	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville-McNary	231	39.6	39.8	34.0
McNary-Priest Rapids	167	30.7	39.3	
Priest Rapids-Rock Island	89	23.7	30.0	
Rock Island-Rocky Reach	33	18.5	22.8	
Rocky Reach-Wells	65	9.4	12.8	
Bonneville-Rock Island	487	28.9	34.7	
Bonneville-Wells	585	23.2	30.6	
McNary-Ice Harbor	67	38.3	43.5	34.8
Ice Harbor-Lower Granite	156	32.7	34.1	31.3

Bonneville, McNary, and Lower Granite dams had the greatest median time between the first PIT tag detection and last PIT tag detection for spring, summer, and fall Chinook salmon (Table 5). However, it should be noted that at both Bonneville and McNary dams, there is a much greater distance between the furthest downstream and furthest upstream PIT tag detection antennas. (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 some time to recover from sampling. (All fish are trapped and sampled at Lower Granite Dam, while our sample consists of fish trapped and sampled at Bonneville Dam.)

Table 6. Median travel times from time of first detection at a dam to time of last detection and the percentage taking more than 12 hours between first detection and last detection. Data representing fewer than three fish are excluded.

	Median Passage Time (minutes)			Percentage with more than 12 hours between first detection and last detection at a dam		
Dam	Spring Chinook	Summer Chinook	Fall Chinook	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville	77	95	89	4.4	3.4	8.2

McNary	115	92	85	16.4	8.4	7.2
Priest Rapids	5	5		0	1.8	
Rock Island	53	54		16.1	13.7	
Rocky Reach	12	1		13.3	7.6	
Wells	1	1		14.0	6.4	
Ice Harbor	2	2	3	7.4	13.0	0
Lower Granite	81	81	71	7.0	13.7	4.5

Upstream age and length-at-age composition

The percentage of yearling juvenile life history (i.e. Age 1.x) summer Chinook salmon passing upstream of Ice Harbor into the Snake River is much greater than the percentage passing upstream of Priest Rapids Dam into the mid-Columbia River (Table 6, Figure 5). In the mid-Columbia River, those Chinook salmon which turn off between Rock Island and Rocky Reach (which is assumed to represent Wenatchee summer Chinook salmon) have a higher percentage of the older Age 0.5 salmon than that at any other site. Mean length-at-age composition estimates at these sites are given in Table 7.

Table 7. Age composition estimates (%) with standard deviations (%), as estimated by PIT tag recoveries of fish aged using scale pattern analysis at Bonneville Dam, for summer Chinook salmon at Priest Rapids, Rock Island, Rocky Reach, Wells, and Ice Harbor dams as well as for the turnoff between Rock Island and Rocky Reach and between Wells and Rocky Reach dams in 2007.

		Brood Year and Age Class								
		2005	2004		2003		2002		2001	
Dam	Statistic	0.1	1.1	0.2	1.2.	0.3	1.3	0.4	1.4	0.5
Priest Rapids	Mean	3.9	26.1	7.1	12.5	2.3	22.1	15.8	6.8	3.5
	Std Dev.	1.2	3.1	1.8	2.4	1.0	3.0	2.4	1.9	1.5
Rock Island	Mean	3.6	26.7	6.1	12.5	2.4	21.7	16.3	7.0	3.6
	Std Dev.	1.3	3.2	1.6	2.5	1.0	3.1	2.5	1.9	1.5
Rock Island - Rocky Reach	Mean	1.4	26.9	4.6	14.4	2.9	21.9	10.7	7.6	9.6
	Std Dev.	1.1	5.3	2.4	5.3	2.0	5.9	4.7	4.1	4.6
Rocky Reach	Mean	4.4	25.8	7.6	11.8	2.0	21.7	18.4	6.8	1.5
	Std Dev.	1.7	3.8	2.2	2.7	1.2	3.6	2.9	2.2	1.1
Rocky Reach - Wells	Mean	2.6	22.8	2.6	17.5	2.1	42.2	7.6	2.6	0.0
	Std Dev.	2.7	6.5	2.7	5.9	1.6	7.8	4.6	2.7	0.0
Wells	Mean	4.8	27.4	9.0	9.5	2.3	15.9	21.0	8.2	2.0
	Std Dev.	2.0	4.6	2.9	2.7	1.6	3.8	3.4	2.8	1.5
Ice Harbor	Mean	1.4	70.9	3.6	18.4	0.0	5.6	0.0	0.0	0.0
	Std Dev.	1.1	5.9	2.9	4.8	0.0	2.9	0.0	0.0	0.0

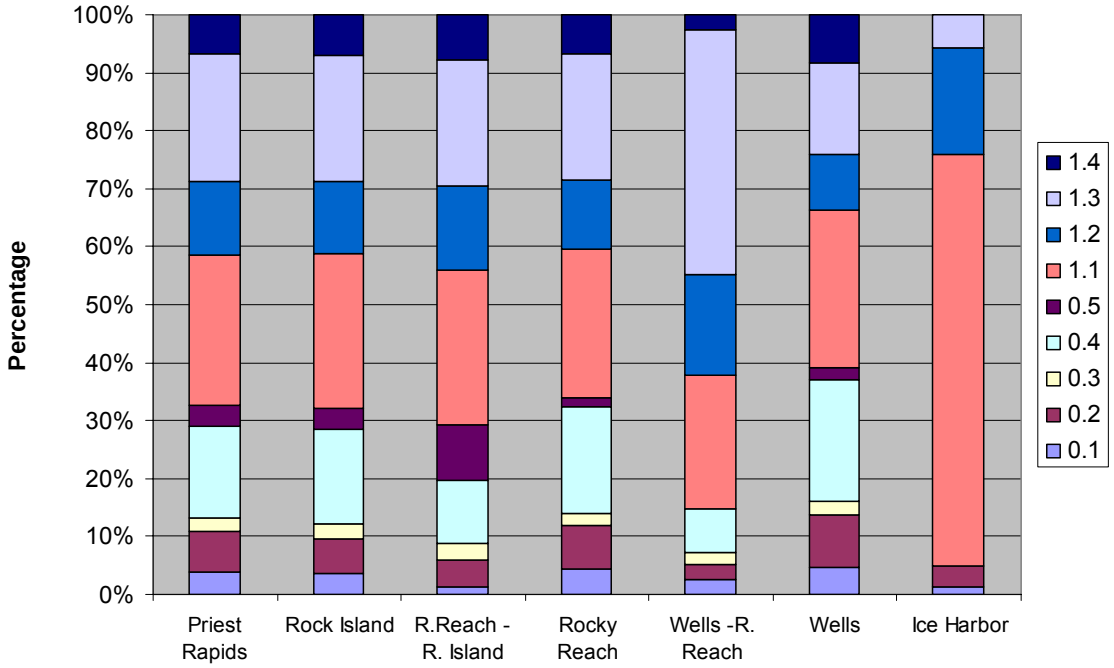

Figure 5. Age composition of Snake River summer Chinook salmon at Ice Harbor and mid-Columbia Chinook salmon upstream of Priest Rapids Dam estimated using PIT tags in 2007

Table 8. Length-at-age composition, as estimated by PIT tag recoveries of fish aged using scale pattern analysis at Bonneville Dam, for summer Chinook salmon at Priest Rapids, Rock Island, Rocky Reach, Wells, and Ice Harbor dams as well as for the turnoff between Rock Island and Rocky Reach and Rocky Reach and Wells Dams in 2007.

		Brood Year and Age Class								
		2005	2004		2003		2002		2001	
Dam	**Statistic**	**0.1**	**1.1**	**0.2**	**1.2.**	**0.3**	**1.3**	**0.4**	**1.4**	**0.5**
Rock Island	Mean	46.1	53.3	64.2	73.6	79.3	87.2	93.0	90.7	91.0
	Std. Dev	5.0	4.7	8.3	6.7	5.3	6.9	5.3	8.3	7.0
	N	10	64	18	30	6	51	41	15	8
R. Island – R. Reach Difference	Mean	44.5	55.3	62.2	71.6	79.3	87.6	95.8	92.5	89.7
	Std. Dev		4.2	7.3	5.7	0.4	4.5	8.3	3.3	8.5
	N	1	19	3	8	2	13	6	4	5
Rocky Reach	Mean	46.2	52.5	64.6	74.3	79.3	87.1	92.5	90.0	93.2
	Std. Dev	5.3	4.7	8.6	7.0	6.9	7.6	4.6	9.5	3.9
	N	9	45	15	22	4	38	35	11	3
R.Reach - Wells Difference	Mean	46.0	54.1	67.0	78.9	83.5	90.0	87.2	90.0	
	Std. Dev		4.4		6.8		6.1	4.5		
	N	1	9	1	6	1	16	3	1	
Wells	Mean	46.3	52.1	64.4	72.6	77.8	85.0	93.0	90.0	93.2
	Std. Dev	5.7	4.7	8.9	6.4	7.7	8.0	4.4	10.0	3.9
	N	8	36	14	16	3	22	32	10	3
Ice Harbor	Mean	49.5	55.2	63.5	78.1		87.8			
	Std. Dev		4.0	2.1	5.7		3.2			
	N	1	49	2	15		4			

Fallback

Estimated fallback-reascension rates based on Chinook salmon reascending fish ladders ranged from 0% at Priest Rapids for spring Chinook to 12.7% for summer Chinook at Ice Harbor Dam (Table 10). These rates likely underestimate true fallback rates as it does not include any fish that ascended a dam, fell back, and then either never reascended or were not detected at downstream dams or hatcheries. Data from tag recoveries at Wells Hatchery indicates that fallback with no reascension does occur. Of the 16 fish tagged by this study and recovered at Wells Hatchery, 10 ascended fish ladders at Wells Dam and were last detected at the upstream weir before presumably falling back over Wells Dam and entering Wells Hatchery. (These fish were not included in Table 10 with the exception of a single summer Chinook salmon that ascended the east bank ladder, likely fell back, and then ascended the west bank ladder before falling back to enter the hatchery.) None of the 48 Chinook detected at Tumwater Dam passed Rocky Reach, suggesting fallback.

Table 9. Estimated Chinook salmon fallback and reascension at mainstem Columbia River dams in 2007 as estimated by PIT tags with sockeye estimates for comparison purposes. Fish falling back multiple times are only counted once.

Dam	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	3.8	1.9	1.5
McNary	5.6	1.9	2.7
Priest Rapids	0	1.5	0.0
Rock Island	0.8	1.1	
Rocky Reach	6.7	7.1	
Wells	11.6	3.2	
Ice Harbor	8.3	12.7	0.0
Lower Granite	0.3	1.4	0.0

A total of eight PIT tagged Chinook salmon fell back over multiple dams. All of these salmon likely were Snake River fish as these fish all were last detected at Ice Harbor or Lower Granite with the exception of one fish (3D9.1C2C507149) that fell back from above Ice Harbor down to below McNary, then ascended above Ice Harbor then fell back over Ice Harbor and McNary Dam and whose final detection was at Three Mile Dam in the Umatilla River

Night Passage

Night (2000-0400) passage was under 2% except for summer Chinook at Lower Granite and spring Chinook at Wells Dam (Table 11). The Bonneville Dam estimate of night passage is likely biased low due to the fact that tagging

occurred between about 0800 and 1500.

Table 10. Estimated summer Chinook salmon night passage (2000-0400) in 2007 at mainstem Columbia River dams as estimated by PIT tags.

Dam	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	0.4	0.2	0.5
McNary-	1.9	0.6	1.8
Priest Rapids	0.0	0.4	
Rock Island	0.0	0.8	
Rocky Reach	1.7	1.5	
Wells	2.3	1.9	
Ice Harbor	1.3	1.4	0.0
Lower Granite	1.2	3.9	0.0

Detection in terminal areas

Escapement estimates for four sites with more than 15 detections are found in Table 11 with comparisons to visual or trap counts. The PIT tag estimate from the site with the largest number of detections, Tumwater Dam, only differed by 13%. However, the PIT tag estimate differed from the estimates at other sites by 25 to 60%. The largest difference was for Prosser Dam and is likely a result of the high concentration of Prosser-bound spring Chinook the first week we PIT tagged (April 22-28) when the number of Chinook salmon we PIT tagged was small (64), Bonneville fish counts were high, and a relatively large proportion of the 64 fish PIT tagged were detected at Prosser Dam (Figure 6). A greater number of PIT tagged Chinook early in the run would likely result in better escapement estimates at Prosser Dam as well as at the other sites.

Less than 1% of the spring Chinook tagged were detected at sites on the Walla Walla River, the Tucannon River, sites other than Three Mile Dam in the Umatilla River, and Valley Creek in the Salmon Basin.

Table 11. Estimated 2007 Chinook salmon escapement, as estimated using PIT tag detections, to Tumwater, Three Mile, and Prosser dams and the South Fork Salmon Weir.

Location	Number of detections	Escapement Estimate from trap or visual counts	Estimated Escapement using PIT tags	% difference
Tumwater Dam	48	5513	4796	-13%
South Fork	32	2514	3745	+49%

Salmon Weir				
Three Mile Dam	17	3552[b]	4436	+25%
Prosser Dam	38	4293[c]	6867	+60%

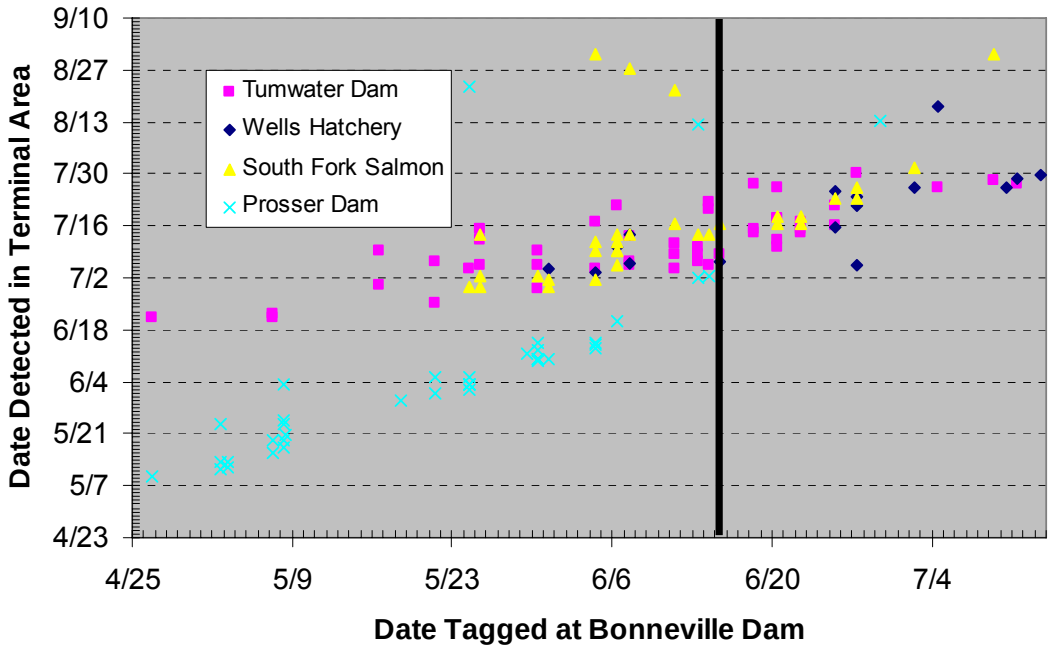

Figure 6. Figure showing the date PIT tagged fish were detected passing upstream dams or weirs versus the date fish was PIT tagged at Bonneville Dam in 2007.

[b] Personal Communication, Preston Bronsan, Confederated Tribes of the Umatilla Indian Reservation e-mail 12/13/07

[c] Personal communication, Bill Boche, Yakama Indian Nation e-mail 12/4/07

DISCUSSION

This study demonstrates the feasibility of PIT tagging summer Chinook salmon at Bonneville Dam tracking these fish upstream, and using the resulting upstream detections to estimate upstream escapement, age composition, length composition, and migration rates.

PIT tags provide an easier, much cheaper, and less intrusive method of monitoring the upstream migration than radio tags used in past studies. However, PIT tags do not always provide as much data as 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. The adult ladder at Tumwater Dam on the Wenatchee River is scheduled to have PIT tag detectors installed in 2008. In addition, Washington Department of Fish and Wildlife should have detectors installed in the Wenatchee and Methow rivers in 2008. Ultimately, it seems likely that all dams in the Columbia Basin with upstream passage facilities as well as many rivers will be wired with PIT tag detectors in the near future which will greatly improve the technology's capabilities. A drawback with PIT tags, when compared to radio tags, is the low number of detection antennas at Columbia River dams upstream of McNary Dam which makes total ladder passage time estimates impossible, and fallback estimates less certain.

One question that has troubled fish managers is the definition of what is a summer Chinook salmon. Traditionally, spring Chinook salmon have been those migrating past Bonneville Dam through May 31, with summer Chinook salmon passing from June 1 through July 31, while fall Chinook salmon pass on or after August 1. Dates upstream were lagged to take into account passage times. However, for management purposes, the spring-summer differentiation at Bonneville Dam was recently moved from June 1 to June 16 because fishery managers believed that the Chinook salmon migrating in early June are mostly Snake River spring/summer Chinook salmon (many of which are listed as endangered under ESA), while those migrating in late June are mid-Columbia summer Chinook salmon. (However, the most recent data from genetics studies suggest that spring-summer transition date would be better set as June 1 [Narum et al. 2007].) It is likely that the date that differentiates the two stocks, if it in fact exists, differs from year to year. In 2006, when we began tagging on June 16,

this study estimated that the percentage of Snake River fish at Bonneville Dam ranged from 2% to 6% between mid-June and mid-July (Fryer 2007). Our 2007 age composition study estimated that 19% and 26% of Chinook salmon passing Bonneville Dam in the first two weeks of June were subyearling outmigrants suggesting that they likely were from upstream of Priest Rapids Dam. (Virtually all Snake River spring/summer Chinook salmon are yearling outmigrants, while mid-Columbia summer Chinook salmon are commonly considered subyearling outmigrants, though many do outmigrate as yearlings.) In 2007, we PIT tagged spring/summer Chinook salmon from late April through early July. We found that the proportion of mid-Columbia Chinook salmon at Bonneville Dam increased from less than 10% of the run prior to May 27 to over 50% of the run June 24 (Figure 4). Meanwhile, the percentage of Snake River spring/summer Chinook decreased from 50% of the run prior to June 1 to less than 20% of the run after July 1. These trends suggest that, in 2007 at least, no one date can be selected to differentiate Snake River spring/summer from mid-Columbia summer Chinook salmon; rather the entire month of June is a transition period between the two stocks and life histories.

The dates used to separate spring from summer, and summer from fall, Chinook salmon at dams upstream of Bonneville Dam are lagged by the approximate migration time as the fish move upstream (Table 12). Therefore, it is possible for a Chinook salmon to be a summer Chinook at Bonneville Dam, then quickly migrate upstream so that it is a spring Chinook at McNary Dam, then slow down and become a summer Chinook at Priest Rapids Dam. If June 1 is used as the first day of the summer Chinook migration at Bonneville Dam, and June 14 (13 days being the median passage time from Bonneville to Priest Rapids Dam as estimated in this report) as the first day of summer Chinook at Priest Rapids Dam, then 63% of Bonneville spring Chinook are correctly classified at Priest Rapids Dam, while 37% are misclassified as summer Chinook salmon. All summer Chinook at Bonneville dam are correctly classified at Priest Rapids Dam. Using the U.S. v. Oregon Technical Advisory Committee date of June 16 as the first day of the summer migration at Bonneville Dam, and June 29 as the first day of the summer migration at Priest Rapids Dam, then 91% of Bonneville spring Chinook salmon are correctly classified at Priest Rapids Dam (with 9% misclassified as summer Chinook), while 97% of Bonneville summer Chinook salmon are correctly classified (with 3% misclassified as spring Chinook). Other dates could also be tested to minimize the misclassification rate as Chinook salmon move upstream. However, the lowest misclassification rate

does not necessarily indicate the best date for differentiating spring Chinook from summer Chinook salmon at Bonneville Dam.

Table 12. Dates used by the U.S. Army Corps of Engineers to differentiate adult Chinook salmon races at Columbia and Snake river dams as well as Prosser Dam on the Yakima River (DART 2007).

Dam	Spring	Summer	Fall
Bonneville	3/15-5/31	6/1-7/31	8/1-11/15
The Dalles	4/1-6/3	6/4-8/3	8/4-10/31
John Day	4/1-6/5	6/6-8/5	8/6-10/31
McNary	4/1-6/8	6/9-8/8	8/9-10/31
Priest Rapids	4/15-6/13	6/14-8/13	8/14-11/15
Rock Island	4/14-6/17	6/18-8/17	8/18-11/14
Rocky Reach	4/16-6/19	6/20-8/19	8/20-11/14
Wells	5/1-6/28	6/29-8/28	8/29-11/15
Ice Harbor	4/1-6/11	6/12-8/11	8/12-12/15
Lower Monumental	4/1-6/13	6/14-8/13	8/14-10/31
Little Goose	4/15-6/15	6/16-8/15	8/16-10/31
Lower Granite	3/1-6/17	6/18-8/17	8/18-12/15
Prosser	3/1-8/15	None	8/16-2/29

Estimated fallback and reascension rates were variable for Columbia River Chinook ranging from 0 to 12.7%, though these estimates are likely low because they do not include fish that fall back and are not detected again. Likewise, night time migration is generally low at less than 2% although these numbers may be confounded if there is an affect of tagging only fish that migrate during the day at Bonneville Dam.

Escapement estimates for dam passage and terminal areas varied widely from the traditional methods (i.e. visual counts) ranging from 6.5 to -21.9% for dam passage and -13 to 60% for terminal areas. Many factors can cause these discrepancies including inaccuracies of visual or video counts, fallback/reascension rates, and PIT tag sample sizes. If sample sizes are significantly increased through fish being tagged as juveniles and tagged as adults passing through Bonneville Dam, along with more terminal areas being wired for PIT tag detection, improved accuracy of stock specific escapement and survival estimates are likely.

Having a PIT tag detector funded by this project to scan fish PIT tagged as juveniles did provide a measure of validation of ages, with 53 out of 54 (98.1%) agreement on total age. However, normally fish are PIT tagged at hatcheries so all that is known from the tag is the total age and not necessarily the freshwater/saltwater age split. For instance, if a 2007 return has a tag indicating that it was tagged and released in 2004 from the 2003 brood; possible ages could be 0.3 or 1.2. (It is extremely rare that a Chinook salmon will spend more than two years in freshwater, which would make it Age 2.1.) On the other hand, if a 2007 return has a tag indicating that it was released in 2004 from the 2002 brood, then it is reasonably certain that this fish is Age 1.3.

When sampling at Bonneville Dam, we typically assign gender to all fish sampled, including those we PIT tag, based on morphometric characteristics. When these PIT tagged fish return to hatcheries and data is uploaded to PTAGIS, gender is typically noted allowing us to validate our ability to determine gender. In 2007, we correctly identified the gender only 53.7% of the spring Chinook salmon (n=41) and 77.8% of summer Chinook salmon (n=18). This is likely the result of fish not expressing their gender specific spawning characteristics so this low in the system. This is especially true for spring Chinook who migrate much further upstream but gender identification accuracy does improve with stocks that spawn lower in the system such as ocean type summer and fall Chinook. More training and/or the use of tools such as ultrasound machines could boost the accuracy of gender determination.

Our sampling at the Bonneville Dam Adult Fish Facility is currently restricted to steelhead sampling one day per week when water temperatures exceed 21.1C. While the impact on our summer Chinook salmon sampling and tagging, and likely our results, is typically minor, the impact on our fall Chinook salmon sampling can be significant. Due to this restriction, in 2007 we were unable to sample 14% of the summer Chinook and 48% of the fall Chinook salmon run. By comparison, in 2006 high water temperatures resulted in us being unable to sample 3% of the summer Chinook and 17% of the fall Chinook salmon run. We are seeking permit modifications and changes in Adult Fish Facility procedures to allow us to conduct at least limited sampling and tagging at temperatures above 21.1C in 2008.

The percentage of Chinook salmon passing dams undetected (Table 3), though small, was higher than expected given the high detection rate estimated at individual weirs (Table A1). At all fish ladders, the estimated probability of detection was 100% with the exception of the Rock Island right ladder at 99.8%. This suggests that a small number Chinook salmon have some characteristic (e.g. a malfunctioning or poorly placed PIT tag or some behavior), that allows them to escape detection at multiple weirs at a given dam.

In 2007 there was an increase in the number of Chinook salmon that were PIT tagged and never detected again. In 2006, there was one such fish while in 2007 there were 20. However, after we noted the problem in mid-July and retrained our technicians, no additional fish that were tagged but not detected after release. In 2008, we intend to more closely monitor detection data to detect possible tagging problems earlier. We also intend to set up a computerized video system (FishTick by Salmonsoft) to record our sampling, including the PIT tagging. FishTick will accept as input the PIT tag signal and imprint this on the video when the fish is scanned after tagging. For any fish that is not detected after release, we will then be able to review archived video to ensure that proper tagging technique was applied.

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Whiteaker J and J.K. Fryer. *In preparation*. 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 detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for spring and summer Chinook salmon in 2007.

Dam and site	Weir (bolded) and probability of detection at weir											Overall detection probability
Bonne-ville	**N**	**1**	**2**	**3**	**4**							
BO4	1207	99.3	99.3	99.4	99.5							100.0
BO1	36	100.0	100.0	100.0	100.0							100.0
McNary	**N**	**1**	**2**	**288**	**287**	**286**	**284**	**283**	**282**	**280**	**279**	
MC1	130	98.5	99.2	84.2	85.0	76.7	86.6	87.7	85.1	87.5	86.8	100.0
	N	**1**	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**303**	**302**	
MC2	341	99.7	100.0	100.0	73.8	73.5	74.0	67.8	74.6	75.6	75.8	100.0
Priest Rapids	**N**	**3**	**7**									
East	388	98.5[d]	99.5									100.0
	N	**3**	**5**									
West	18	94.4	100.0									100.0
Rock Island	**N**	**1-2**	**3-4**									
Left	85	100.0	98.8									100.0
	N	**5-6**	**7-8**									
Middle	30	100.0	100.0									100.0
	N	**09-0A**	**0B-0C**									
Right	305	99.3	73.1									99.8
	N	**1-2**	**3-4**									
Rocky Reach	257	99.2	96.5									100.0
Wells	**N**	**1-2**	**3-4**									
Left	156	98.7	100.0									100.0
	N	**5-6**	**7-8**									
Right	38	100.0	100.0									100.0
Ice Harbor	**N**	**438**	**437**	**436**	**435**							
South	295	100.0	99.7	99.7	100.0							100.0
North	122	100.0	100.0	100.0	100.0							100.0
Lower Granite	**N**	**733**	**732**	**731**	**730**							
	371	100.0	100.0	100.0	100.0							100.0

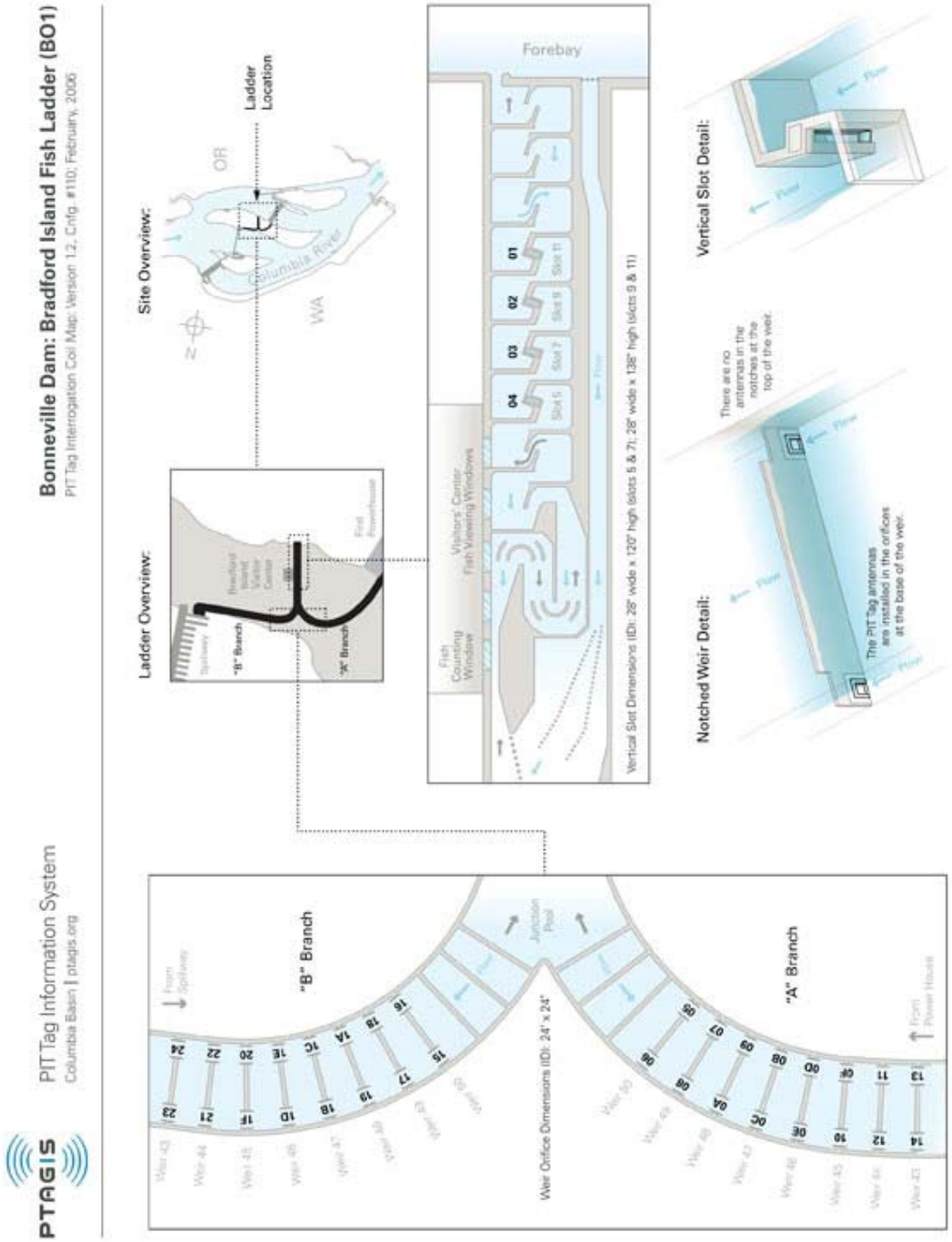
[d] Fish bypass this weir when the Priest Rapids adult fish trap is in operation.

Table A2. Distribution of summer Chinook salmon passage by fish ladder for dams with multiple fish ladders as estimated by PIT tag detections in 2007.

Dam	Right Bank[e]	Left Bank	Center
Bonneville	97.2%	2.8%	
McNary	41.4%	58.6%	
Priest Rapids	4.4%	95.6%	
Rock Island	72.6%	20.2%	7.1%
Wells	19.6%	80.4%	
Ice Harbor	29.3%	70.7%	

[e] 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, Ice Harbor, Lower Granite, 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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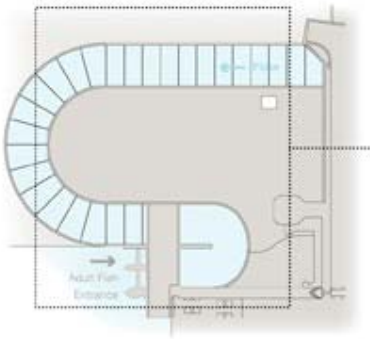
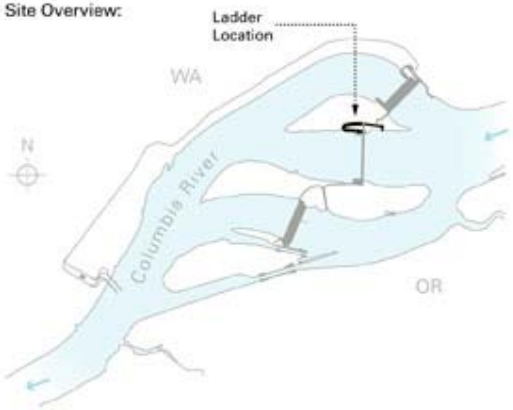
Bonneville Dam: Cascades Island Fish Ladder (BO2)

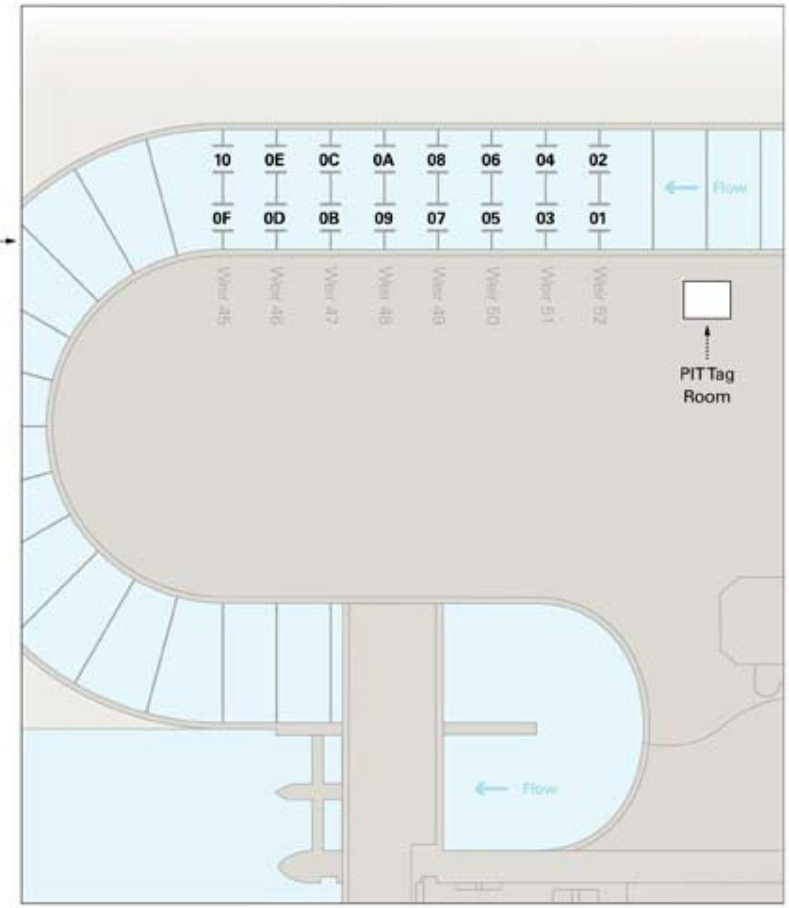
PIT Tag Interrogation Coil Map: Version 1.1, Cnfg. #100; February, 2002
Orifice Dimensions: 24" wide x 24" high

Ladder Overview:



Site Overview:





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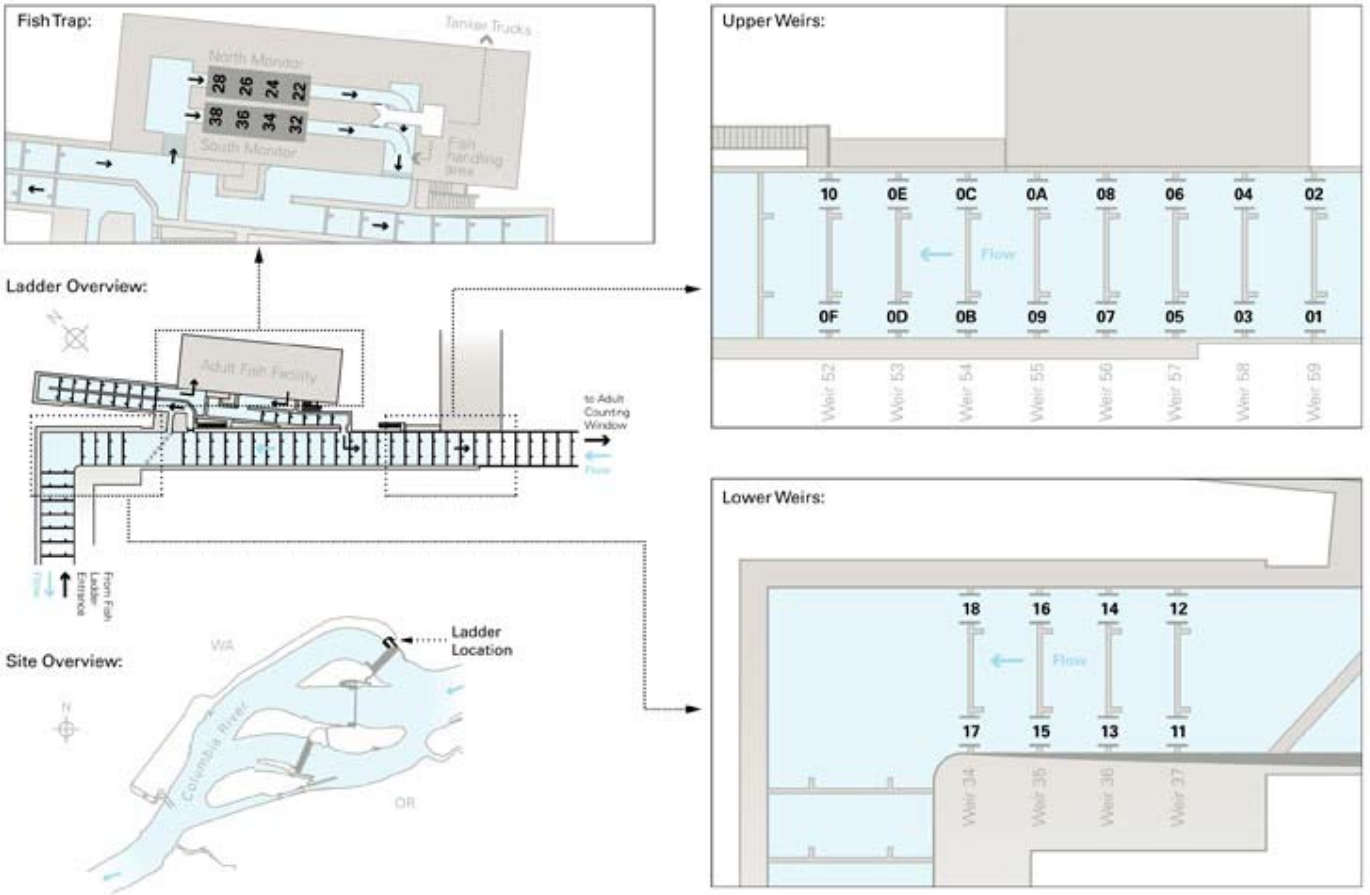
Bonneville Dam: Washington Shore Fish Ladder and AFF (BO3)

PIT Tag Interrogation Coil Map: Version 1.2, Cnfg. #110; Revised December, 2003

Orifice Dimensions: 18" wide x 18" high



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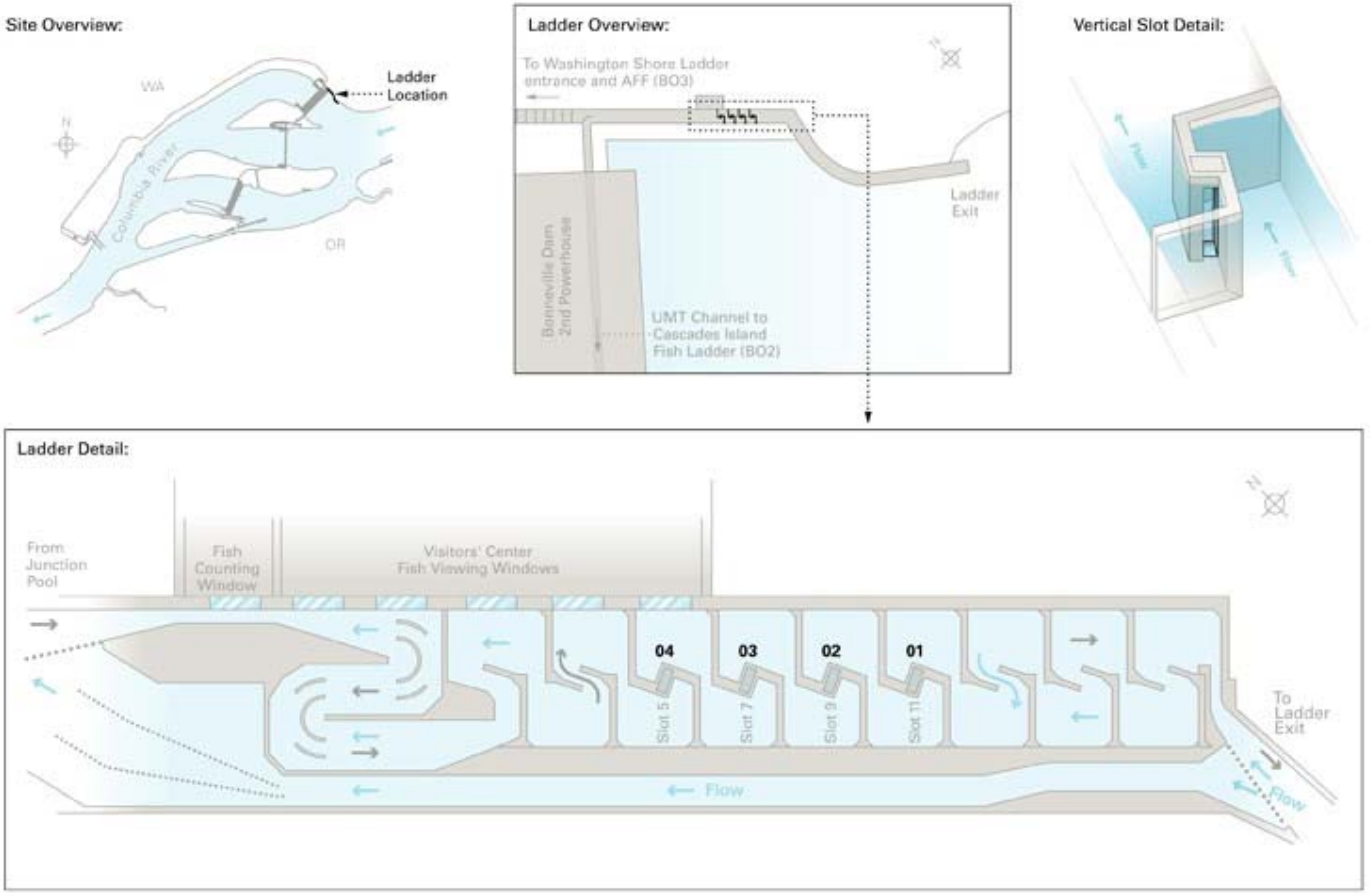
Bonneville Dam: Washington Shore Ladder Vertical Slots (BO4)

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



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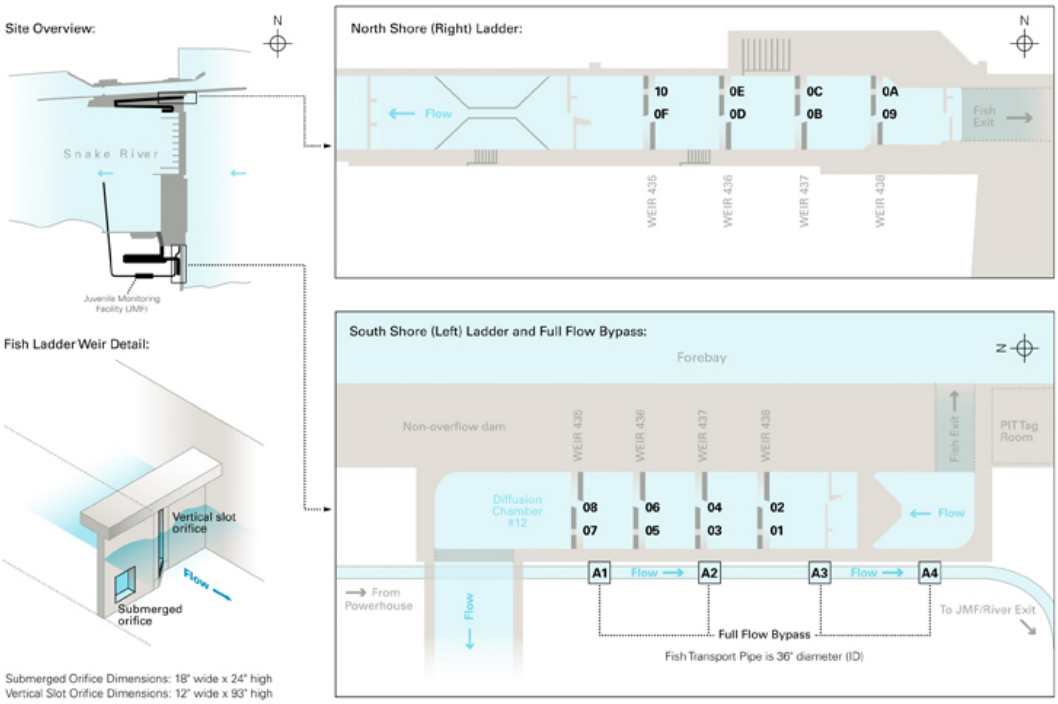
Ice Harbor Dam Fish Ladders and Full Flow Bypass (ICH)

PIT Tag Interrogation Coil Map: Version 1.0, Cnfg. #100; Created April, 2005
This supercedes the previous IHA (fish ladders only) installation.



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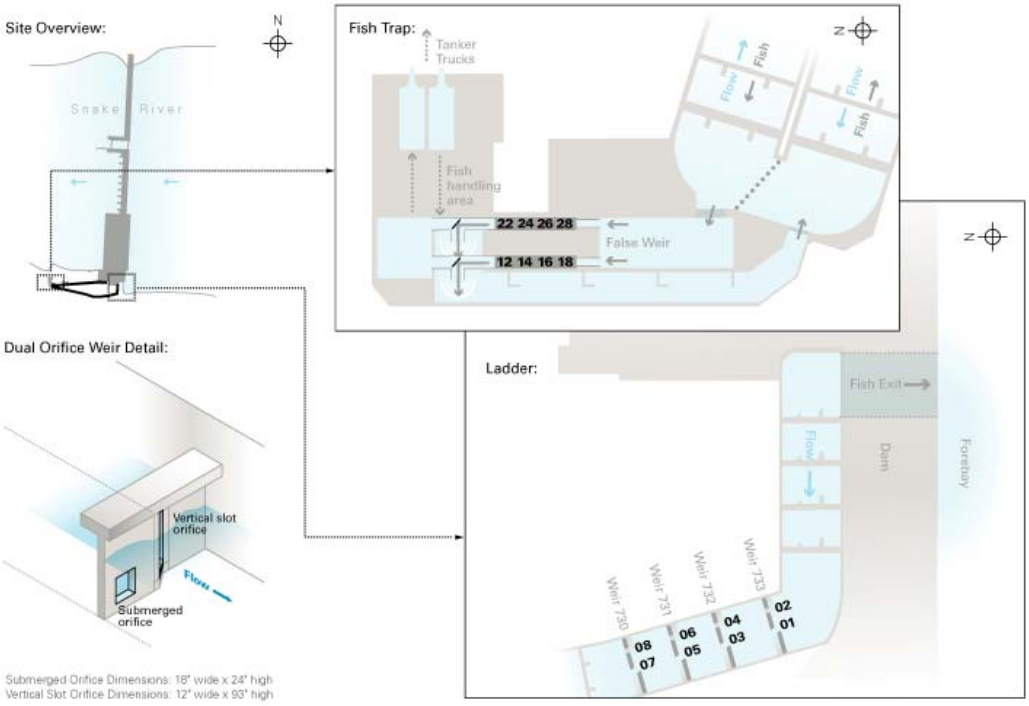
Lower Granite Dam Fish Ladder and Trap (GRA)
PIT Tag Interrogation Coil Map: Version 4.1, Cnfg. #140; Revised December, 2003



Submerged Orifice Dimensions: 18" wide x 24" high
Vertical Slot Orifice Dimensions: 12" wide x 93" high

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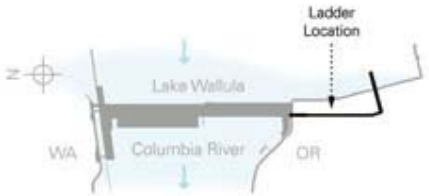
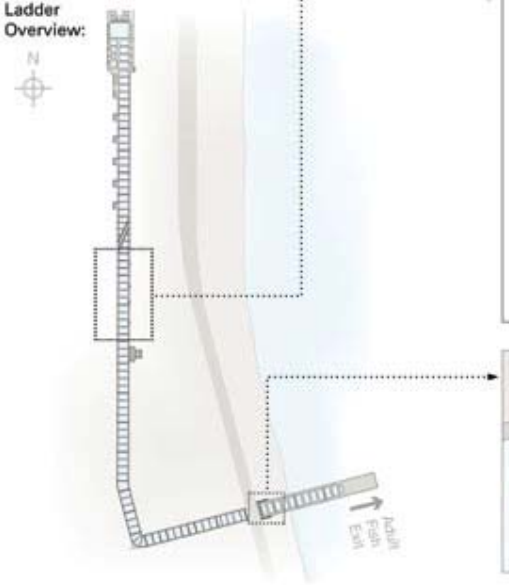
McNary Dam: Oregon Shore Ladder (MC1)

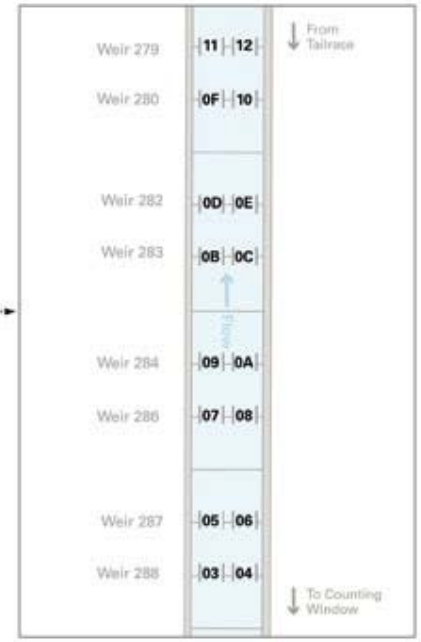
PIT Tag Interrogation Coil Map: Version 1.2, Cnfg. #100; February 2002

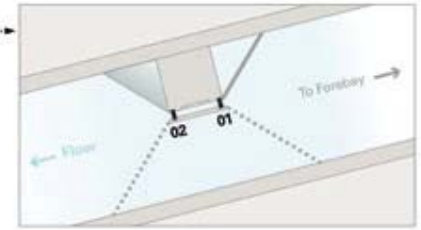
Site Overview:



Ladder Overview:

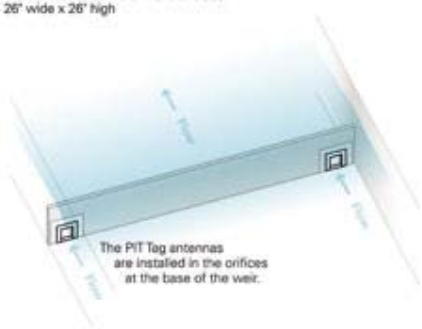






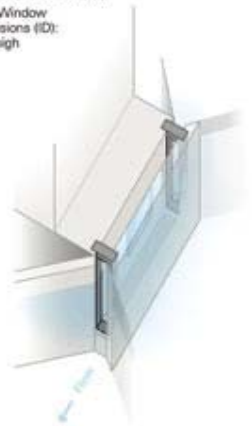
Overflow Weir Detail:

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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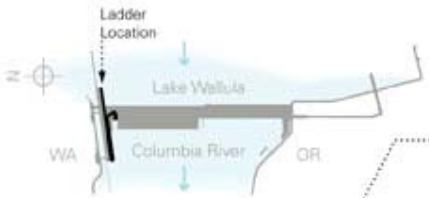
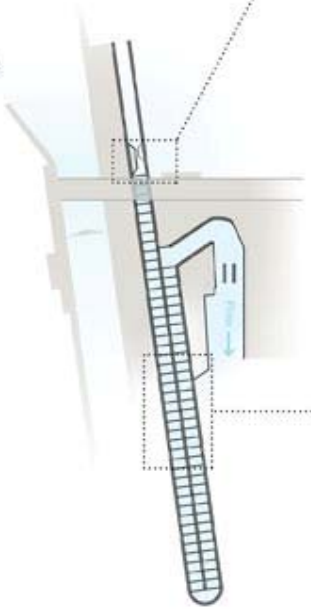
McNary Dam: Washington Shore Ladder (MC2)

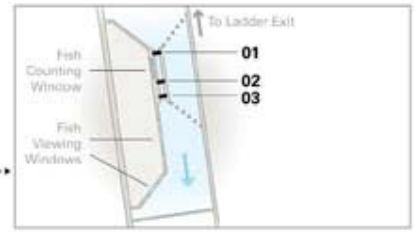
PIT Tag Interrogation Coil Map: Version 1.1, Cnfg. #120; Revised March, 2006

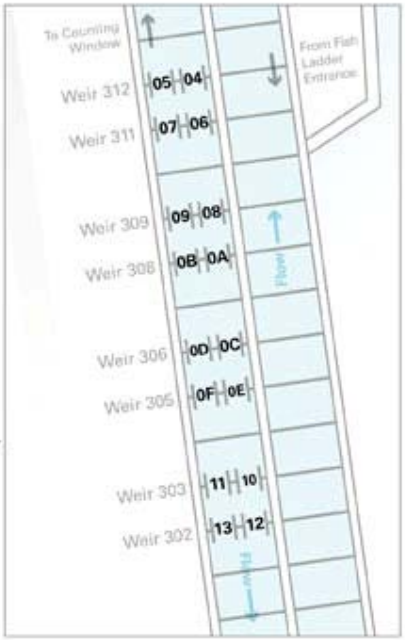
Site Overview:



Ladder Overview:

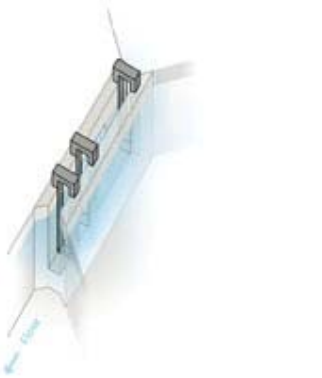






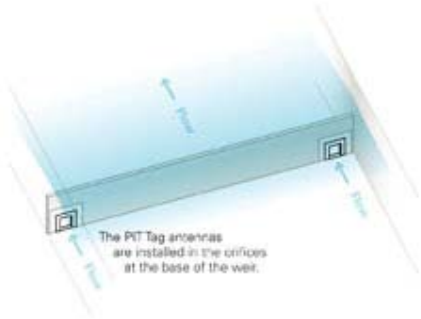
Counting Window Detail:

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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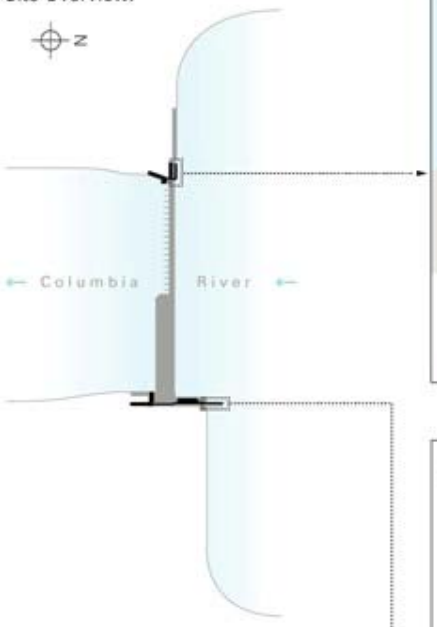
Columbia Basin

Priest Rapids Dam Fish Ladders (PRA)

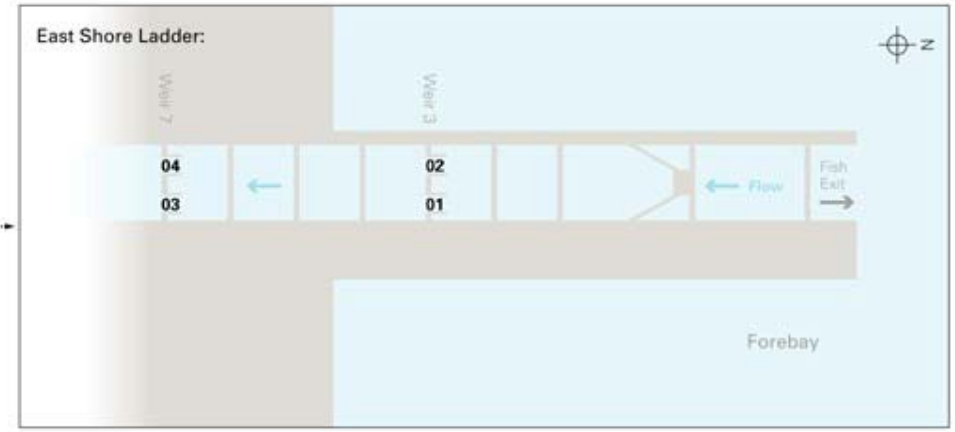
Interrogation Coil Map Revised: May, 2003 v.1.0, Cnfg. #100

Site Overview:



West Shore Ladder:

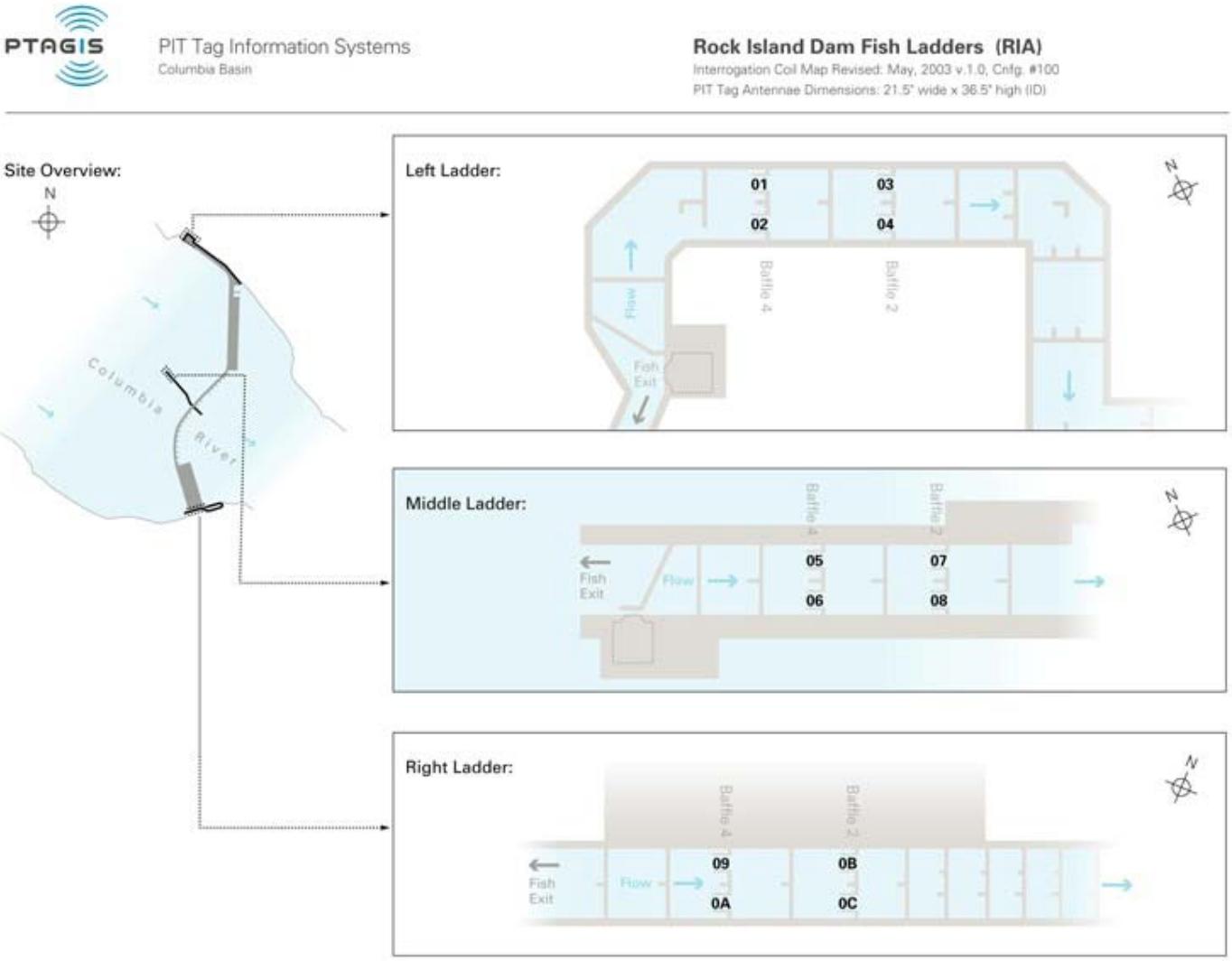
East Shore Ladder:



PIT Tag Antenna Dimensions
two antennas per weir

West Shore (Right) Ladder
- Weir 3: 22.5" wide x 43.0" high (ID)
- Weir 5: 22.0" wide x 50.0 high (ID)

East Shore (Left) Ladder
- Weir 3: 24.0" wide x 55.0" high (ID)
- Weir 7: 24.5" wide x 45.0" high (ID)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PIT Tag Information Systems
Columbia Basin
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)
Site Overview:
N
Columbia River
Left Ladder:
01
02
03
04
Baffle 4
Baffle 2
Flow
Fish Exit
Middle Ladder:
05
06
07
08
Right Ladder:
09
0A
0B
0C

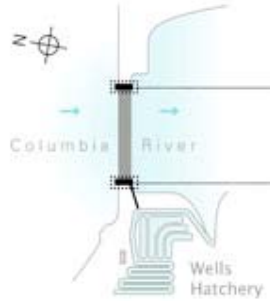
PTAGIS

PIT Tag Information Systems
Columbia Basin

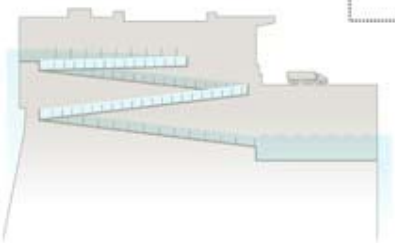
Wells Dam Fish Ladders (WEA)

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

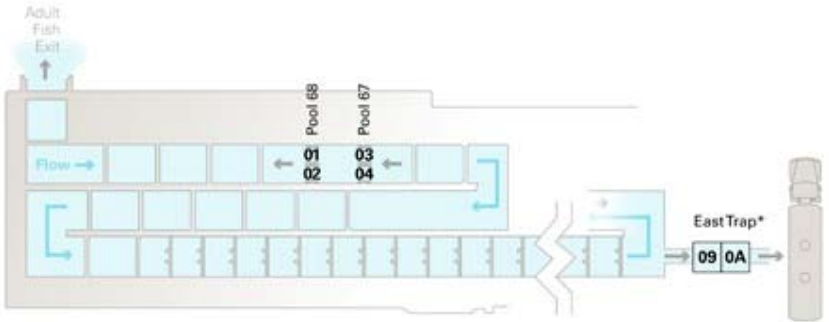
Site Overview:



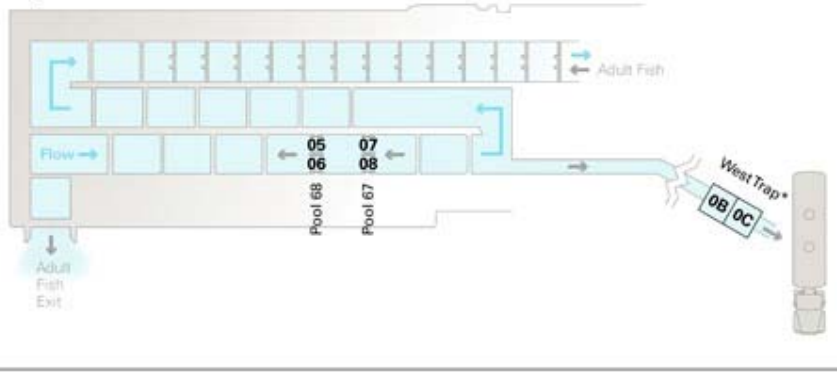
Elevation View:



Left Ladder



Right Ladder



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