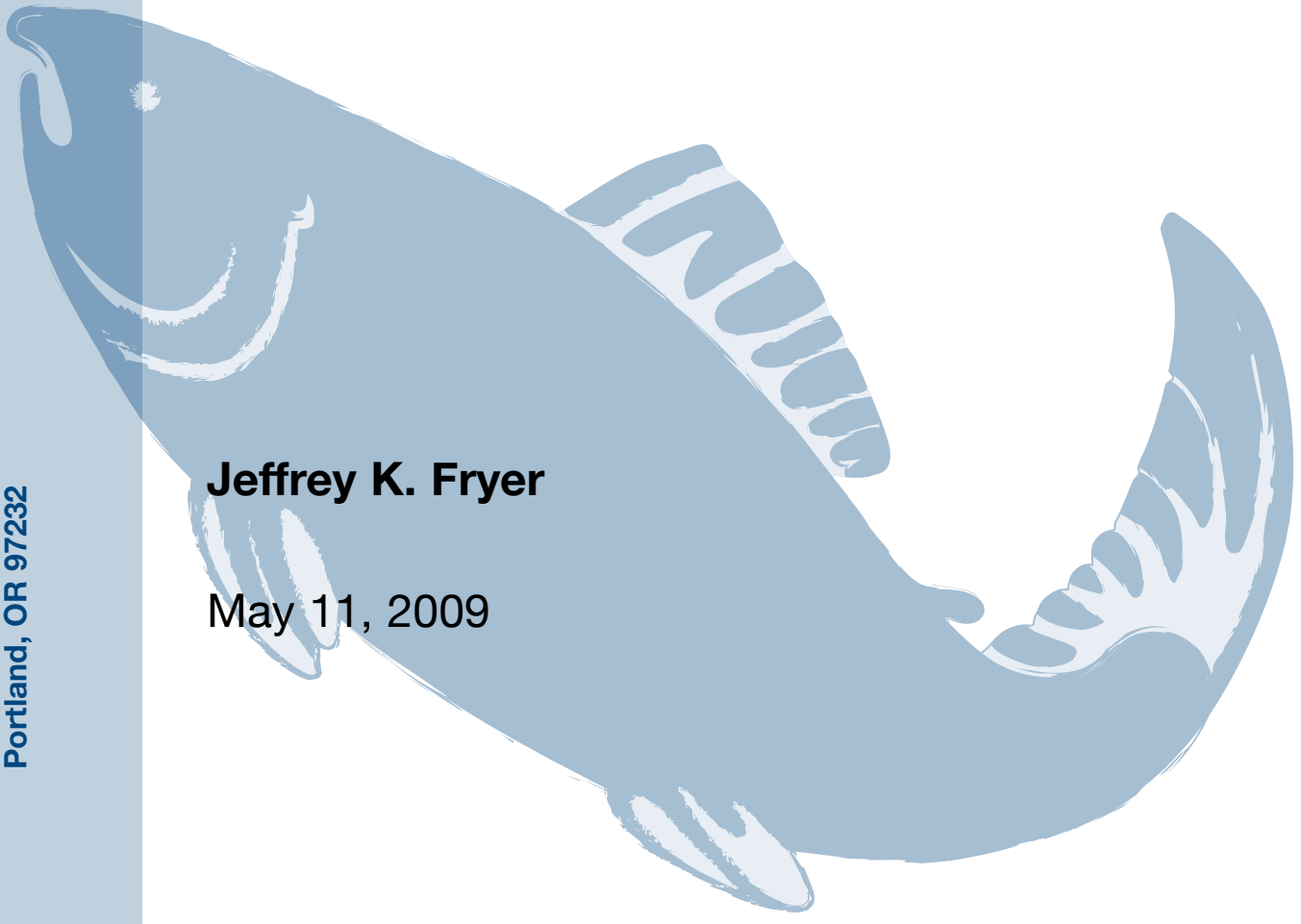
CRITFC

TECHNICAL REPORT 09-04

Estimation of mid-Columbia summer Chinook salmon escapement and age composition using PIT tags in 2008



Jeffrey K. Fryer

May 11, 2009

Columbia River Inter-Tribal Fish Commission
729 NE Oregon, Suite 200
Portland, OR 97232
503.238.0667
www.critfc.org

ABSTRACT

In 2008, a total of 644 spring, 904 summer, and 1280 fall Chinook salmon (*Oncorhynchus tshawytscha)* were tagged with 12.5 mm PIT tags at Bonneville Dam between April 15 and October 14. An additional 312 spring and 235 summer Chinook salmon were tagged with 8.5 mm PIT tags; however, poor detection at some dams (principally Priest Rapids, Rock Island, and Rocky Reach Dams where 64.3%, 41.9%, and 12.6% respectively were not detected) resulted in these data being ignored in calculating results. After adding previously tagged fish, and subtracting fish that likely shed PIT tags, a total of 663 spring Chinook, 913 summer Chinook, and 1285 fall Chinook were tracked upstream. Data collected from the upstream migration of these fish were used to (1) compare detection rates of different PIT tag models, (2) evaluate migration speed and timing, and (3) estimate abundance of different species.

Based on PIT tag detections, 63.6% of spring Chinook salmon passed upstream of McNary Dam, 9.9% upstream of Rock Island Dam, 3.3% upstream of Wells Dam, and 41.3% upstream of Lower Granite Dam. For summer Chinook salmon, 81.7% passed upstream of McNary Dam, 49.5% upstream of Rock Island Dam, and 26.1% upstream of Lower Granite Dam. For fall Chinook, 56.5% of fall Chinook salmon passed upstream of McNary Dam, 5.5% upstream of Rock Island Dam, and 15.3% upstream of Lower Granite Dam.

Between Bonneville and McNary Dams, spring Chinook averaged 34.2 km/day, summer Chinook 33.5 km/day and fall Chinook 37.6 km/day. There was not a significant linear relationship between flow or water temperature and migration rate between Bonneville and McNary Dams.

Age composition estimates, based on scale pattern analysis, indicate that those summer Chinook salmon passing upstream of Ice Harbor Dam are predominantly yearling outmigrants (58.0% Age 1.2 and 33.6% Age 1.1), while those passing upstream of Rock Island Dam are a mixture of subyearling and yearling outmigrants (31.8% Age 1.2, 26.8% Age 0.3, 15.2% Age 1.3, and 13.3% Age 0.2 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 12.6%

less to 13.0% more fish at mainstem dams upstream of Bonneville Dam than visual fish counts from fish ladders at those dams.

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, Shawn Narum, Winfred Perez, Rishi Sharma, and Charles Torbeck 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.

This report summarizes research funded by the Pacific Salmon Commission.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Populations of summer Chinook salmon *(Oncorhynchus tshawytscha)* 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 decline are many, but 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 (CRITFC) 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 2008). These fish have long comprised a mixed stock of unknown origin. Given the stock's importance, its uncertain run timing, and upstream survival, in 2006, CRITFC proposed to the PSC 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 CRITFC to identify previously tagged fish; thereby, giving CRITFC known age (and stock) fish for validation of ages assigned by scale pattern analysis. In addition, by PIT tagging each summer Chinook salmon sampled, CRITFC could track these fish upstream and estimate age and length-at-age composition at upstream sites, as well as migration, fallback rates, and escapement. This technical report details the results of this study in 2008.

METHODS

Sampling

Spring, summer, and fall Chinook salmon were PIT tagged throughout the run from April through October, 2008 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 migrate back to the Washington Shore Fish Ladder above the picket weir.

Chinook salmon selected for sampling were examined for tags, fin clips, wounds, and condition. They were measured for length and a tissue sample along with six scales were removed for later genetic and age analysis (Whiteaker and Fryer, *in preparation*). Standard techniques were used to inject PIT tags through a needle that penetrates the fish between the posterior tip of the pectoral fin and the anterior point of the pelvic girdle (CBFWA 1999). The fish were scanned for the PIT tag code, 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. To test the effectiveness of the newer 8.5 mm PIT tags (model TX148511B) at adult fish ladders, initially one in every three fish sampled was tagged with this tag, and the remaining two-thirds tagged with 12.5 mm PIT tags (model TX1411SST).

Tagged Chinook salmon were detected by PIT tag receivers found in the adult fish ladders at the following locations: 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 in several tributaries and hatcheries in the Columbia Basin (Appendix 1). PIT tag detection data was uploaded to www.ptagis.org, and is accessible to registered users of the site.

Age analysis

Scale pattern analysis was used to determine spring, summer, and fall 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 CRITFC to scan for PIT tags indicating origin and age of fish, which could be used in age and life history validation.

Escapement

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

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

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.* 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.

Detection Efficiencies

Any fish detected at an upstream dam should also be detected at lower dams (with the exception of Bonneville, McNary, Ice Harbor, and Lower Granite Dams where it is possible that a fish could use the navigation locks). 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. The detection efficiency for the two tags was used mid-season to evaluate how effectively the two tags were detected at mainstem dams. At the end of the season, a test comparing the proportions of independent samples (Snedecor and Cochrane, 1980) was used to evaluate whether similar proportions of Chinook salmon tagged with the two tag types was observed at mainstem dams and weirs with PIT tag detection.

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 were 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:

$$Pi = \frac{N_i}{T}$$

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

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 the same dam.

Upstream age and length-at-age composition estimates

Age and length-at-age composition was estimated for upstream locations at dams with PIT tag monitoring. 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.*

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 PST) 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). This method was used at all weirs except at the BO4 site at Bonneville Dam near the Washington shore fish counting facility where the distance between the upper most and lower most weir is about 25 meters (Figure A1).

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, at any dam a Chinook salmon with detection at an "upper" detection weir followed by detection at a "lower" detection weir separated by more than 2 hours were also considered fallbacks. At McNary and Bonneville Dams, the upper detection weir was at the fish counting window (which are believed to detect all passing PIT tagged fish) while the lower weirs were the PIT tag detectors furthest downstream in the fish ladder. 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. A Chinook salmon classified as a fallback by any of the three methods was considered a fallback.

RESULTS

Sample Size

A total of 644 spring Chinook, 904 summer Chinook, and 1280 fall Chinook salmon were tagged with 12.5 mm PIT tags in 2008 (Table 1). An additional 547 spring and summer Chinook were tagged with 8.5 mm PIT tags; however, these were ultimately excluded from further analysis due to poor detection at some sites. After adding previously tagged fish which, we would otherwise have tagged to our sample, and subtracting fish that were not detected after release (likely a result of the tags being shed), the sample of fish tracked upstream consisted of 663 spring Chinook, 913 summer Chinook, and 1285 fall Chinook salmon (Table 1).

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

Spring Chinook						
Dates	**Statistical Week**	**8.5 mm tagged (n)**	**12.5 mm tagged (n)**	**Previously Tagged**	**Probable tag shed**	**12.5 mm Tracked (n)**
4/15,16,18	16	13	26	0	0	26
4/22,23,25	17	38	78	0	0	78
4/29,30,5/2	18	51	103	2	0	105
5/6,7,8	19	56	112	6	0	118
5/12,13,14,15	20	81	170	6	0	176
5/19,20,21,22,24	21	28	58	2	0	60
5/26,27,28,29	22	45	97	4	1	100
Total		**312**	**644**	**20**	**1**	**663**
Summer Chinook						
6/3,4,5,6	23	58	124	3	1	126
6/9,10,11,12,13,14	24	32	66	4	0	70
6/15,16,17,18,19	25	38	71	1	0	72
6/23,24,25,26,27	26	54	102	1	1	102
6/30,7/1,7/2,7/3	27	14	61	1	1	61
7/6,7,8,9,10	28	16	161	0	0	161
7/14,15,16,17,18	29	23	205	3	1	207
7/21,22,23,24	30	0	86	1	0	87
7/28,29,30	31	0	28	0	1	27
Total		**235**	**904**	**14**	**5**	**913**
Fall Chinook						
8/1	31	0	10	0	0	10
8/4,5,6,7	32	0	48	0	1	47
8/11,12,13,14	33	0	11	0	1	10
8/18,21,226	34	0	53	1	0	54

8/25,26,27,28,	35	0	98	1	0	99
9/2,3,4,5	36	0	182	2	2	182
9/7,8,9,10,11	37	0	279	3	1	281
9/14,15,16,17,18	38	0	223	3	1	225
9/22,23,24,25,26	39	0	201	3	1	203
9/29,30,10/1,2	40	0	89	0	0	89
10/6,7,8,9,14	41-42	0	86	0	1	85
Total		**0**	**1280**	**13**	**8**	**1285**

Effectiveness of 8.5 mm tags

A preliminary assessment of detections of 8.5 and 12.5 mm tags in early July 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 Chinook salmon tagged with 8.5 mm tags was reduced from 33% to 10% of the total sample with no 8.5 mm tags used after July 18. Post-season analysis confirmed that Chinook and sockeye salmon tagged with 8.5 mm tags were less likely to be detected at some dams, particularly Priest Rapids, Rock Island, and Rocky Reach, than those tagged with 12.5 mm tags (Table 2). The percentage of PIT tagged sockeye missed by PIT tag antennas could not be estimated at Wells Dam due to the lack of a significant number of detections at upstream sites.

Table 2. Percentage of Chinook and sockeye salmon tagged with 8.5 mm and 12.5 mm PIT missed at Columbia Basin dams with PIT tag detection in 2008.

	Chinook Salmon		Sockeye Salmon	
Dam	12.5 mm tagged	8.5 mm tagged	12.5 mm tagged	8.5 mm tagged
Bonneville	0.1%	3.7%	0.4%	1.7%
McNary	0.9%	0.8%	10.1%	18.2%
Priest Rapids	0.1%	64.3%	0.3%	33.7%
Rock Island	2.5%	41.9%	6.9%	57.7%
Rocky Reach	0.0%	12.6%	0.2%	28.3%
Ice Harbor	1.4%	1.0%	0.0%	33.3%[1]
Lower Granite	4.1%	3.6%	NA	NA
Mean	1.3%	18.3%	3.0%	28.8%

A test comparing the proportions of 8.5 and 12.5 mm tagged fish at upstream sites found a significant difference at Bonneville-4 (Washington shore counting station), Priest Rapids Dam, and Rock Island Dam (Table 3). In all cases, 8.5

[1] One of three sockeye salmon were not detected. This fish could also have gone through the navigation locks.

mm tagged fish were significantly less likely to be detected than 12.5 mm tagged fish. Additional data would likely make other results significant as four other sites, South Fork Salmon Weir, Rocky Reach, Three Mile Dam, and Wells Dam, had lower percentages of 8.5 mm tagged fish relative to 12.5 mm tagged fish than did Bonneville Dam-4. Only at six sites, Bonneville Dam 1 and 2, John Day River Weir, Prosser Dam, Roza Dam, and Tumwater Dam were higher percentages of 8.5 mm tagged fish relative to 12.5 mm tagged fish observed and at all these sites the total number of detections was 81 or less.

Table 3. Total detections at upstream sites of Chinook salmon PIT tagged between April 15 and June 30, 2009, the percentage tagged with 8.5 mm PIT tags, and the P-value for a test comparing the proportion of fish of the two tag types detected. Significant results (α=0.10) are in bold.

Site	Total Detections	Percent 8.5 mm	P-value
Bonneville Dam-1	60	38.3	0.836
Bonneville Dam-2	25	36.0	0.959
Bonneville Dam-3	1417	32.3	0.948
Bonneville Dam-4	**1432**	**28.8**	**0.000**
Lower Granite Dam	618	31.4	0.682
Ice Harbor Dam-	641	31.7	0.760
John Day River Weir	10	70.0	0.841
South Fork Salmon River Weir at Krasse Creek	93	19.1	0.507
McNary Dam	1119	31.4	0.266
Priest Rapids Dam	**275**	**13.1**	**0.023**
Prosser Dam	75	36.0	0.876
Rock Island Dam	**276**	**20.3**	**0.087**
Rocky Reach Dam	188	28.2	0.664
Roza Dam	60	35.0	0.929
Three Mile Dam	11	18.2	0.944
Tumwater Dam	81	35.8	0.873
Wells Dam	150	28.0	0.721
Warm Springs Hatchery Weir	26	26.9	0.942
Sample size for Chinook tagged through June 30, 2008:	1555	32.3%	

Given the high percentage of missed 8.5 mm tagged fish at some dams and that 8.5 mm tags were not used later in the run, only data from 12.5 mm tags is used in the rest of this report.

Age Analysis

A total of 38 Chinook salmon with ageable scales that had been previously PIT tagged were sampled, allowing us to validate age estimates derived from scale patterns. We correctly aged all 18 spring Chinook and all 8 fall Chinook salmon but only 9 out of 12 (75%) of the summer Chinook salmon. Two of the incorrectly aged fish were relatively short (76.5 and 77.0) Age 1.3 Chinook with resorbed scales sampled in early June that were aged as Age 1.2; while the third was a very rare Age 2.2 Chinook sampled on June 4, 2008 which, was aged as being of Age 1.2. Only one other Chinook sampled since our sampling program began in 1987 has been aged as having spent two years in freshwater.

Mainstem Dam Recoveries, Mortality, and Escapement Estimates

Data on tag detections was downloaded from www.ptagis.org on January 15, 2009. Those spring Chinook salmon that traveled upstream of McNary Dam were bound primarily for the Snake River (Table 4, Figures 1, 4) while summer Chinook were bound primarily for the Columbia River upstream of Priest Rapids Dam (Table 4, Figures 2, 4). Fall Chinook were bound primarily for areas downstream of Ice Harbor and Priest Rapids Dams (Table 4, Figures 3, 4). Over the spring/summer portion of the run, the proportion of Chinook salmon passing Priest Rapids Dam steadily increased, while those apparently destined for points downstream of McNary Dam steadily decreased (Figure 4). The proportion of Chinook that ultimately passed Ice Harbor Dam rose through the early part of the run before dropping after Statistical Week 24.

Table 4. Percentage of spring, summer, and fall Chinook salmon tracked from Bonneville Dam detected at upstream dams and the percentage "lost" between dams in 2008.

	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	63.6	36.4	81.7	18.3	56.2	43.8
Priest Rapids	10.3	83.8	51.0	37.5	11.9	78.8
Rock Island	9.9	4.0	49.5	3.1	5.5	53.5
Rocky Reach	3.4	65.3	37.7	23.7	4.5	18.2
Wells	3.3	3.0	26.5	29.7	1.8	59.4
Ice Harbor	43.2	32.0	27.5	66.4	15.8	71.9
Lower Granite	41.3	4.6	26.1	5.0	13.6	14.1

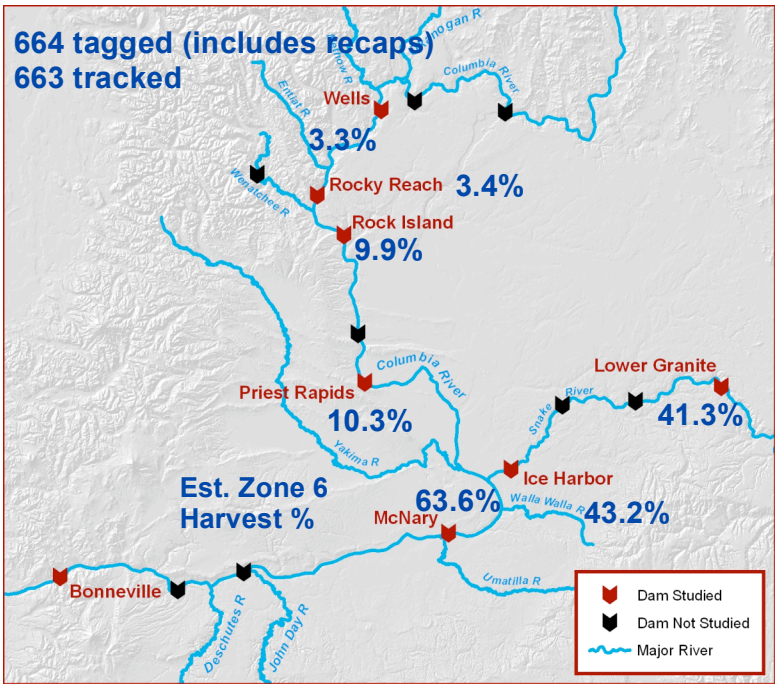


Figure 1. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite Dams showing the number of spring Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2008.

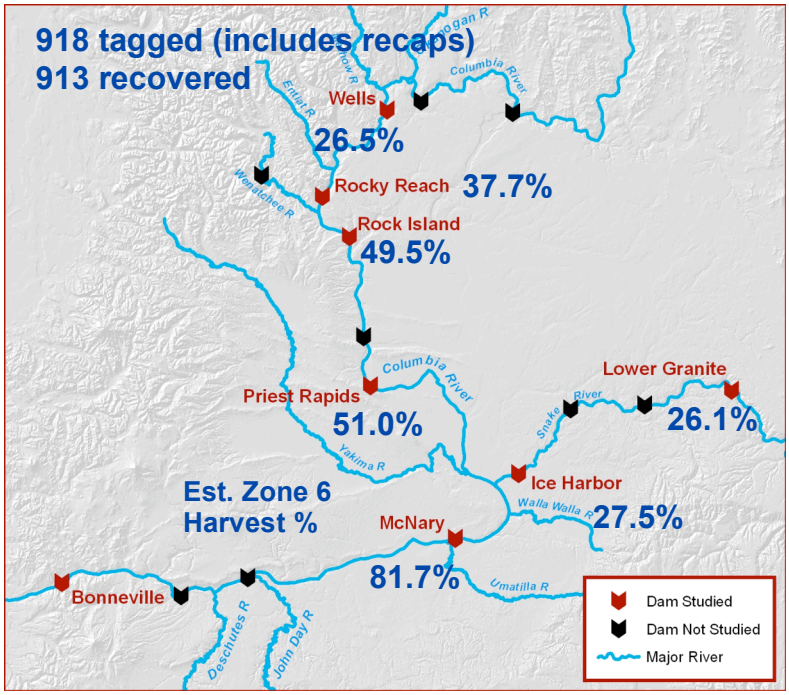


Figure 2. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite Dams showing the number of summer Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2008.

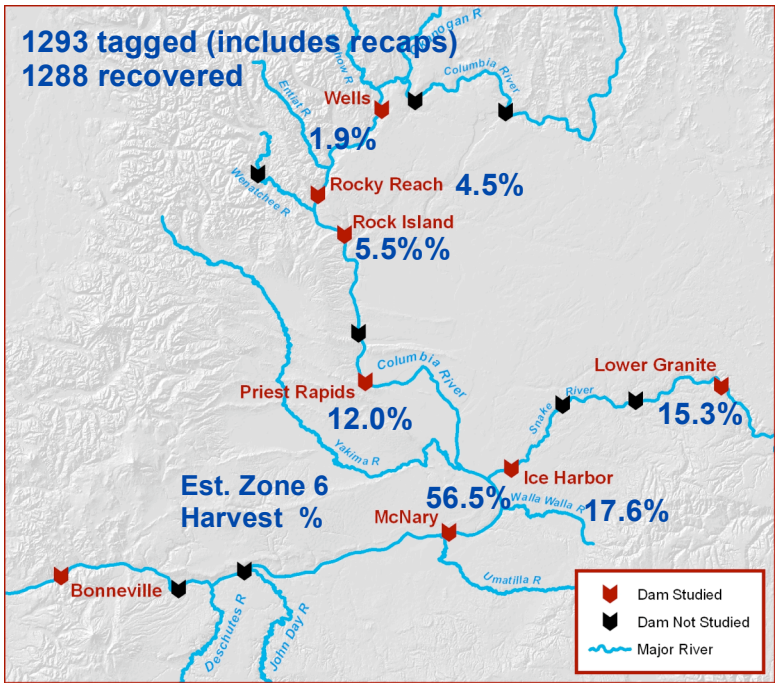


Figure 3. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite Dams showing the number of fall Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2008.

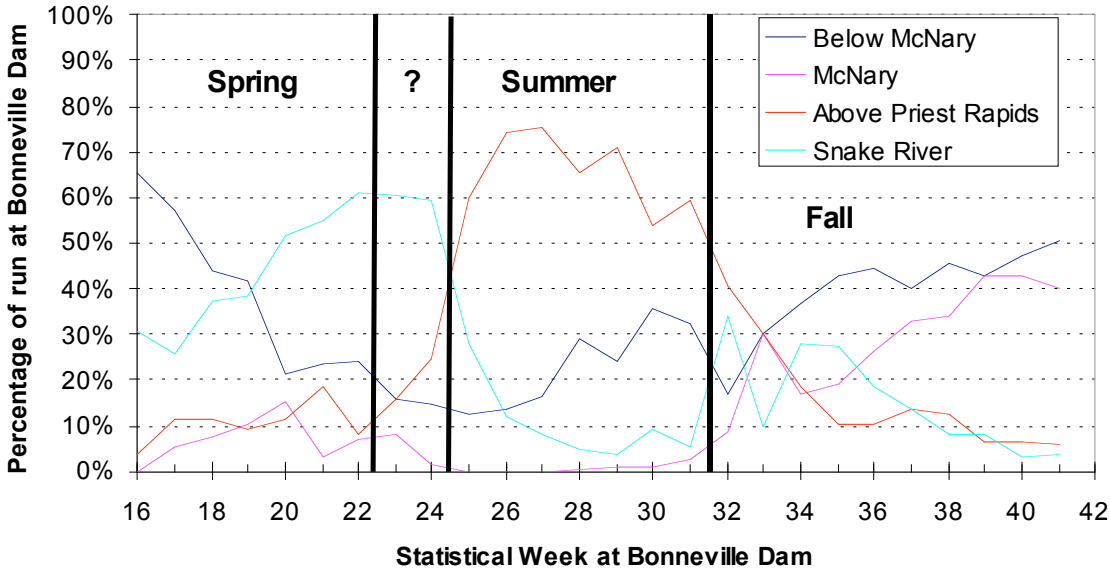


Figure 4. Distribution of final detection site by Statistical Week for Chinook salmon that were PIT tagged at Bonneville Dam in 2008. The solid lines denote June 1, June 16, and August 1.

The percentage of Chinook salmon passing a dam undetected was generally under 1% (Table 5). Two exceptions were McNary and Ice Harbor Dams where navigation locks provide a plausible explanation as to how fish

could pass undetected (navigation locks are also located at Bonneville Dam). The dams with the highest percentage passing undetected are Rock Island Dam which, is known to have problems with detection due to the antenna size and noise (D. Marvin, Pacific States Marine Fisheries Commission, personal communication). 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.

Table 5. Percentage of Chinook salmon passing a dam undetected that were subsequently detected at an upstream dam in 2008 (12 mm tags only).

Dam	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville	0.2%	0.1%	0.1%
McNary	0.7%	1.5%	0.4%
Priest Rapids	0.0%	0.2%	0.0%
Rock Island	4.3%	2.2%	2.6%
Rocky Reach	0.0%	0.0%	0.0%
Ice Harbor	2.7%	0.6%	0.0%
Lower Granite	0.0%	0.0%	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 6).

Table 6. Total and Summer Chinook salmon escapement at Columbia Basin mainstem upstream of Bonneville Dam estimated from both PIT tag recoveries and dam counts and the differences between the two estimates. Note that the dates used for summer Chinook escapement were June 1-July 31 at Bonneville Dam with upstream dates lagged by the median summer Chinook passage time to that dam.

	All Chinook Salmon			Summer Chinook			
Site	Viewing Window Count	PIT Tag estimate	Percent Difference	Viewing Window Count	Viewing Window Count Dates	PIT Tag estimate	Difference
McNary	267984	294111	9.7%	65974	6/8-8/7	74558	13.0%
Priest Rapids	103967	89834	-13.6%	42660	6/12-8/11	46793	9.7%
Rock Island	68061	72672	6.8%	41267	6/16-8/15	45177	9.5%
Rocky Reach	48113	49846	3.6%	31802	6/17-8/16	34398	8.2%
Wells	31992	34114	6.6%	22435	6/20-8/19	24829	10.7%
Ice Harbor	122994	128722	4.7%	28657	6/11-8/09	26288	-8.3%
Lower Granite	115630	115630	2.4%	27684	6/15-8/14	24186	-12.6%

Migration Timing and Passage Time

The fastest travel time between dams, as measured in kilometers per day, was between Bonneville and McNary Dams for spring and fall Chinook salmon and McNary and Priest Rapids Dams for summer Chinook salmon (Table 7). The slowest travel time for both spring and summer Chinook salmon was between Rocky Reach and Wells Dams (Table 7). No significant relationships were found between migration rates and statistical week and mean weekly flow and temperature at Priest Rapids and The Dalles Dams.

Table 7. Chinook salmon migration rate between mainstem dams as estimated by PIT tag detections in 2008.

		Median travel rate (km/day)		
Dam pair	Distance (km)	Spring Chinook	Summer Chinook	Fall Chinook
Bonneville-McNary	231	34.2	33.5	37.6
McNary-Priest Rapids	167	32.2	40.5	27.9
Priest Rapids-Rock Island	89	23.0	29.1	25.3
Rock Island-Rocky Reach	33	24.5	30.3	23.5
Rocky Reach-Wells	65	20.8	20.1	17.8
Rock Island-Tumwater	73	3.7	5.1	No data
Bonneville-Rock Island	487	27.5	33.3	32.7
Bonneville-Wells	585	25.8	30.5	27.6
McNary-Ice Harbor	67	32.7	36.2	36.7
Ice Harbor-Lower Granite	156	26.6	35.9	31.9

Tumwater Dam on the Wenatchee River had by far the greatest median time between the time a PIT tagged fish was first detected and the time it was last detected, with a median time of over 16 days for spring Chinook salmon (Table 8). Bonneville, McNary, and Lower Granite Dams had the greatest median time among mainstem Columbia Basin dams. 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 8. 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 in 2008.

	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	74	85	92	7.4	5.5	9.8
McNary-OR shore	120	113	96	8.7	7.1	4.4
McNary-WA shore	96	52	6	2.6	2.0	2.1
Priest Rapids	5	6	4	3.6	1.4	11.4
Rock Island	28	37	78	13.5	12.5	23.0
Rocky Reach	20	11	14	3.1	6.6	5.2
Wells	1	1	1	0.0	4.4	0.0
Ice Harbor	3	3	3	5.1	5.1	2.3
Lower Granite	97	77	73	14.7	8.9	5.6
Tumwater	23168	1294	NA	80.0	57.1	NA

Upstream age and length-at-age composition

The percentage of subyearling juvenile life history (i.e. Age 0.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 9, Figure 6). In the mid-Columbia River, those Chinook salmon that 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 Tables 10-12.

Table 9. Age composition estimates (%) as estimated by PIT tag recoveries of fish aged using scale pattern analysis at Bonneville Dam, for spring, summer, and fall Chinook salmon at Priest Rapids, Rock Island, Rocky Reach, Wells, Tumwater, Ice Harbor, and Lower Granite Dams in 2008.

	% Age	Brood Year and Age Class										
		2006	2005		2004		2003			2002		2001
Run and site	0.x	0.1	0.2	1.1	0.3	1.2	0.4	2.2	1.3	0.5	1.4	1.5
Spring												
Priest Rapids	1.1	0.0	0.0	7.0	0.6	77.5	0.0	0.0	14.3	0.0	0.6	0.0
Rock Island	1.2	0.0	0.0	7.3	0.6	76.8	0.0	0.0	14.6	0.0	0.6	0.0
Rocky Reach	0.0	0.0	0.0	9.1	0.0	77.9	0.0	0.0	11.3	0.0	1.7	0.0
Wells	0.0	0.0	0.0	0.0	0.0	84.9	0.0	0.0	13.1	0.0	2.0	0.0
Tumwater	0.0	0.0	0.0	10.4	0.0	87.6	0.0	0.0	2.0	0.0	0.0	0.0
Ice Harbor	0.0	0.0	0.0	24.2	0.0	71.8	0.0	0.0	4.0	0.0	0.0	0.0
Lower Granite	0.0	0.0	0.0	23.8	0.0	72.4	0.0	0.0	3.8	0.0	0.0	0.0
Summer												
Priest Rapids	41.5	1.6	13.0	7.4	26.6	31.9	1.3	0.0	15.2	0.2	2.5	0.3
Rock Island	42.1	1.4	13.3	7.0	26.8	31.8	1.3	0.0	15.2	0.2	2.6	0.3
Rocky Reach	36.8	1.4	16.1	7.1	21.9	35.7	0.4	0.0	14.3	0.3	2.5	0.4
Wells	39.5	1.0	16.6	8.5	23.8	33.4	0.7	0.0	13.6	0.5	2.1	0.0
Tumwater	62.3	3.1	7.2	12.7	48.3	17.2	2.6	0.0	6.2	0.0	2.6	0.0
Ice Harbor	2.5	0.2	0.6	33.6	1.2	58.0	0.4	0.5	5.7	0.0	0.3	0.0
Lower Granite	2.7	0.2	0.6	33.7	1.1	58.4	0.4	0.5	5.2	0.0	0.0	0.0
Fall												
Priest Rapids	95.4	10.9	60.7	0.0	15.8	4.4	8.0	0.0	0.3	0.0	0.0	0.0
Rock Island	91.2	20.6	41.0	0.0	21.2	8.2	8.3	0.0	0.6	0.0	0.0	0.0
Rocky Reach	91.2	22.5	42.1	0.0	16.6	8.8	10.0	0.0	0.0	0.0	0.0	0.0
Wells	77.3	26.2	15.3	0.0	32.3	22.7	3.5	0.0	0.0	0.0	0.0	0.0
Tumwater		-	-	-	-	-	-	-	-	-	-	-
Ice Harbor	68.0	8.7	52.6	17.4	5.8	13.4	0.4	0.0	0.5	0.6	0.0	0.0
Lower Granite	74.0	9.4	57.5	12.2	6.6	13.3	0.4	0.0	0.5	0.0	0.0	0.0

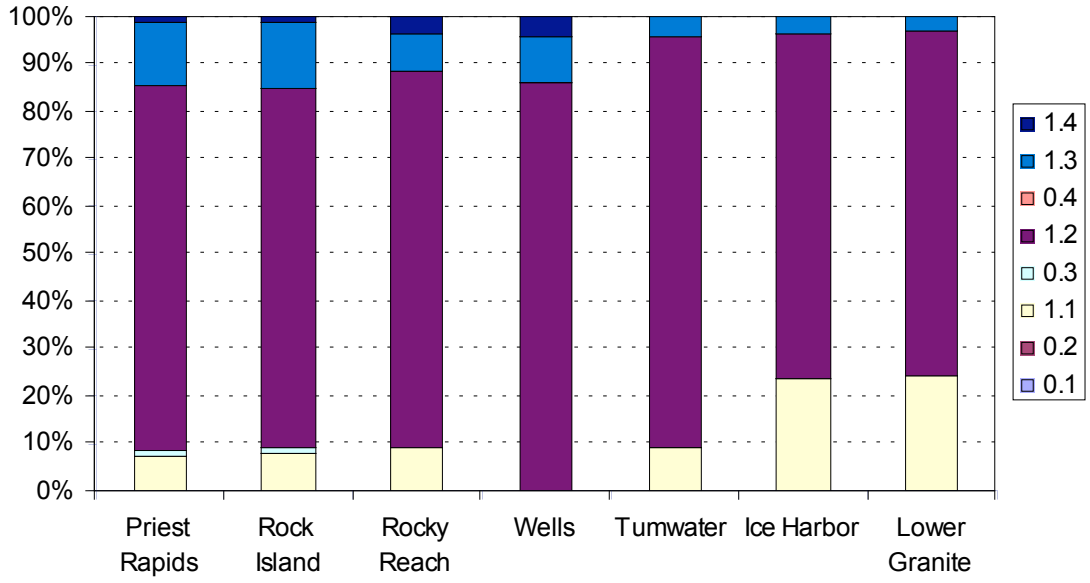


Figure 5. Spring Chinook age composition at Columbia Basin dams upstream of McNary Day estimated using PIT tags in 2008 (age classes comprising less than 1% of the run for all races at all dams are excluded).

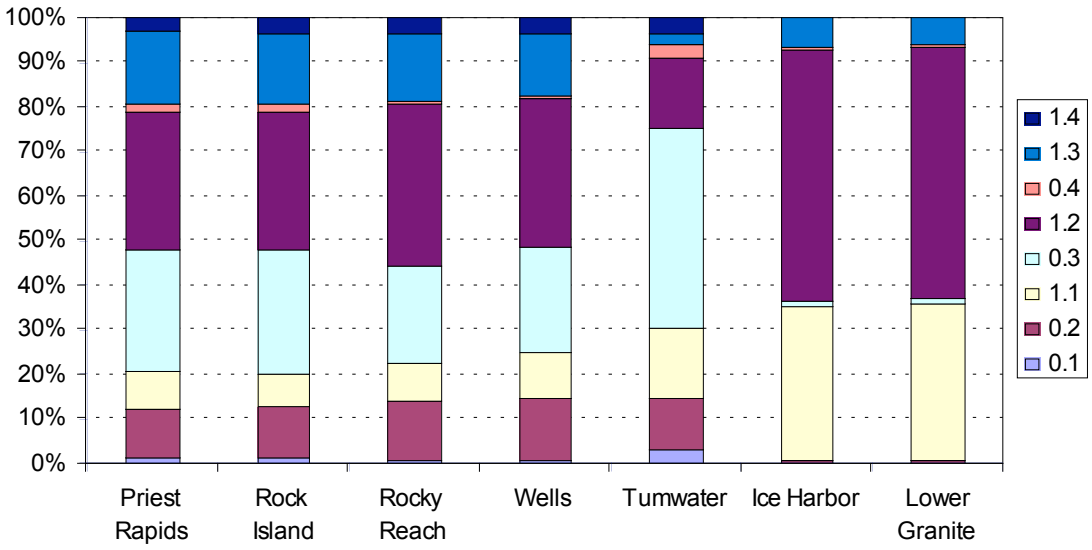


Figure 6. Summer Chinook age composition at Columbia Basin dams upstream of McNary Day estimated using PIT tags in 2008 (age classes comprising less than 1% of the run for all races at all dams are excluded).

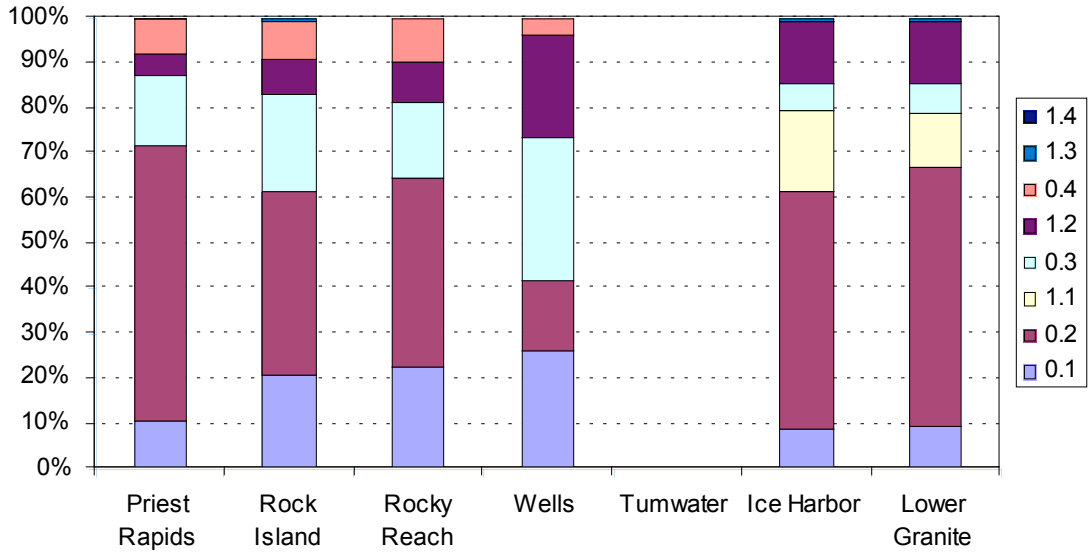


Figure 7. Fall Chinook age composition at Columbia Basin dams upstream of McNary Day estimated using PIT tags in 2008 (age classes comprising less than 1% of the run for all races at all dams are excluded).

Table 10. Spring Chinook salmon length-at-age composition, as estimated by PIT tag recoveries of fish aged using scale pattern analysis that passed Bonneville Dam prior to June 1, 2008, at Columbia Basin dams upstream of McNary Dam in 2008.

		Brood Year and Age Class										
	Stat-	2006	2005		2004		2003			2002		2001
Dam	istic	0.1	0.2	1.1	0.3	1.2	0.4	1.3	2.2	0.5	1.4	1.5
Priest Rapids	μ	52.9	84	75.0		87.6			83.5	52.9		
	s	3.8	-	5.1		6.5			-	3.8		
	n	5	1	55		8			1	5		
Rock Island	μ	54.5	84	75.65		87.8				54.5		
	s	4.2	-	3.8		3.3				4.2		
	n	2	1	10		5				2		
Rocky Reach	μ	53.0		70.6		87.3			83.5	53.0		
	s	-		4.7		15.9			-	-		
	n	1		18		2			1	1		
Wells	μ			70.6		87.3			83.5			
	s			4.7		15.9			-			
	n			18		2			1			
Tumwater	μ	51.3		77.9		87.0			81.5	51.3		
	s	5.3		3.4		-			7.8	5.3		
	n	2		26		1			2	2		
Ice Harbor	μ	51.8		74.6		88.1			73.3	51.8		
	s	4.0		4.1		5.5			13.1	4.0		
	n	90		224		13			29	90		
Lower Granite	μ	51.6		74.5		89.4			73.6	51.6		
	s	4.0		4.1		5.0			13.3	4.0		
	n	83		215		11			28	83		

Table 11. Summer Chinook salmon length-at-age composition, as estimated by PIT tag recoveries of fish aged using scale pattern analysis that passed Bonneville Dam June 1-July 31,2008, at Columbia Basin dams upstream of McNary Dam in 2008.

		Brood Year and Age Class										
	Stat-	2006	2005		2004		2003			2002		2001
Dam	istic	0.1	0.2	1.1	0.3	1.2	0.4	1.3	2.2	0.5	1.4	1.5
Priest Rapids	μ	40.2	65.9	51.3	82.1	73.0	92.8	85.4		94.5	93.1	88.0
	s	10.3	5.0	5.0	5.6	7.9	3.8	5.5		-	6.2	-
	n	19	79	45	133	184	6	77		1	12	1
Rock Island	μ	39.9	65.9	51.2	82.2	73.0	93.1	85.3		94.5	93.1	88.0
	s	10.5	5.0	5.1	5.6	7.9	4.1	5.5		-	6.2	-
	n	18	78	42	130	179	5	75		1	12	1
Rocky Reach	μ	39.2	65.8	50.8	82.3	72.3	90.0	85.5		94.5	94.9	88.0
	s	12.3	4.8	5.2	5.8	8.1	-	5.1		-	4.4	-
	n	13	72	33	90	158	1	55		1	9	1
Wells	μ	35.4	65.7	50.6	82.3	71.7	90.0	85.9		94.5	95.8	
	s	15.7	5.2	4.8	5.7	8.9	-	4.6		-	4.8	
	n	7	57	25	68	110	1	39		1	4	
Tumwater	μ	42.8	70.8	51.7	83.2	79.7	88.0	83.7			78.0	
	s	2.9	2.4	4.9	4.8	2.4	-	6.8			-	
	n	4	3	7	20	15	1	7			1	
Ice Harbor	μ	47.0	65.3	56.6	75.8	76.8	95.3	85.8	76.5			
	s	-	7.0	7.8	8.6	4.9	2.5	7.2	-			
	n	1	4	74	3	120	2	13	1			
Lower Granite	μ	47.0	65.3	56.5	80.8	77.0	95.3	85.8	76.5			
	s	-	7.0	8.1	1.8	4.7	2.5	7.5	-			
	n	1	4	69	2	115	2	12	1			

Table 12. Fall Chinook salmon length-at-age composition, as estimated by PIT tag recoveries of fish aged using scale pattern analysis that passed Bonneville, for fall Chinook salmon at Columbia Basin dams upstream of McNary Dam in 2008.

		Brood Year and Age Class										
	Stat-	2006	2005		2004		2003			2002		2001
Dam	istic	0.1	0.2	1.1	0.3	1.2	0.4	1.3	2.2	0.5	1.4	1.5
Priest Rapids	μ	47.1	68.1		79.1	73.2	90.9					
	s	3.2	5.3		6.2	6.8	3.9					
	n	12	92		21	12	8					
Rock Island	μ	47.0	68.2		79.1	73.7	93.5					
	s	3.4	6.5		7.8	6.8	0.5					
	n	9	31		11	11	3					
Rocky Reach	μ	47.1	67.8		82.0	73.4	93.5					
	s	3.5	6.9		3.5	7.1	0.5					
	n	7	24		7	10	3					
Wells	μ	44.6	66.1		81.3	73.6	94.0					
	s	1.1	4.4		3.8	7.5	-					
	n	4	7		5	9	1					
Tumwater	μ											
	s											
	n											
Ice Harbor	μ	47.8	65.3	56.0	80.8	72.2	89.3					
	s	5.1	5.9	4.3	4.2	6.6	6.7					
	n	14	70	23	9	26	2					
Lower Granite	μ	47.8	65.2	56.0	80.8	71.0	89.3					
	s	5.1	5.9	4.7	4.2	6.0	6.7					
	n	14	68	12	9	20	2					

Fallback

Estimated fallback-reascension rates based on Chinook salmon reascending fish ladders ranged from 0% at Wells Dam for spring and fall Chinook to 21.7% for spring Chinook at Tumwater Dam (Table 13). 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 30 fish tagged by this study and recovered at Wells Hatchery, 16 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 as fallbacks in Table 13).

Table 11. Estimated Chinook salmon fallback and reascension at mainstem Columbia River dams in 2008 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 (%)
McNary	4.0	1.7	1.5
Priest Rapids	4.2	1.6	13.9
Rock Island	2.9	6.8	14.5
Rocky Reach	4.3	8.3	10.2
Wells	0.0	6.7	0.0
Tumwater	21.7	7.1	
Ice Harbor	5.7	8.9	2.3
Lower Granite	17.3	9.5	9.1

A total of nine PIT tagged Chinook salmon fell back over multiple dams with adult fish tag detection. Unlike 2007 when all but one of eight multiple-dam fallbacks were likely Snake River fish, in 2008, all nine fish were likely destined for areas upstream of Rock Island Dam. Eight Chinook salmon fell back over both Wells and Rocky Reach Dams, while one fell back over Ice Harbor and McNary Dams before heading up the Columbia River and being last detected at Tumwater Dam.

Night Passage

Night (2000-0400 Pacific Standard Time) passage was under 6% at all mainstem dams (Table 14). Tributary dam and weir night passage was higher, ranging to over 50% at the South Fork Salmon weir. The Bonneville Dam estimate of night passage is likely biased low due to the fact that tagging occurred between about 0700 and 1400 PST.

Table 12. Estimated summer Chinook salmon night passage (2000-0400) in 2008 at mainstem Columbia River dams as estimated by PIT tags.

Site	Spring Chinook (%)	Summer Chinook (%)	Fall Chinook (%)
Bonneville	0.5	0.3	0.2
McNary-	0.5	1.7	1.2
Priest Rapids	0.0	1.7	2.5
Rock Island	1.4	1.8	4.1
Rocky Reach	3.1	2.2	8.6
Wells	3.6	5.4	3.4
Ice Harbor	1.1	1.1	0.6
Lower Granite	1.9	1.2	2.8
Prosser	3.9	0.0	9.1
Roza	29.7	22.2	0.0
Tumwater	16.0	9.5	-
Three Mile	9.1	0.0	25.0
South Fork Salmon weir	55.2	60.8	-

Detection in terminal areas

Escapement estimates for five sites with more than 15 detections are found in Table 11 with comparisons to visual or trap counts. These PIT tag estimates differed from visual or trap counts by a much greater percentage than at mainstem dams (Table 15). This likely is a result of smaller sample sizes of PIT tagged fish.

The largest proportions of tributary-bound Chinook passed Bonneville Dam between May and July (Figure 7). 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 13. Estimated 2008 Chinook salmon escapement, as estimated using PIT tag detections, to Tumwater, Three Mile, Prosser, and Roza Dams and the South Fork Salmon Weir.

Location	Number of detections	Escapement Estimate from trap or visual counts	Estimated Escapement using PIT tags	Difference between estimates
Tumwater Dam, Wenatchee River	91	8450	9644	+14%
South Fork Salmon R river Weir	96	6504	4978	-16%
Three Mile Dam, Umatilla River	18	2004	2506	+16%
Prosser Dam, Yakima River	87	10921	14449	+32%
Roza Dam, Yakima River	53	5475	7203	+39%

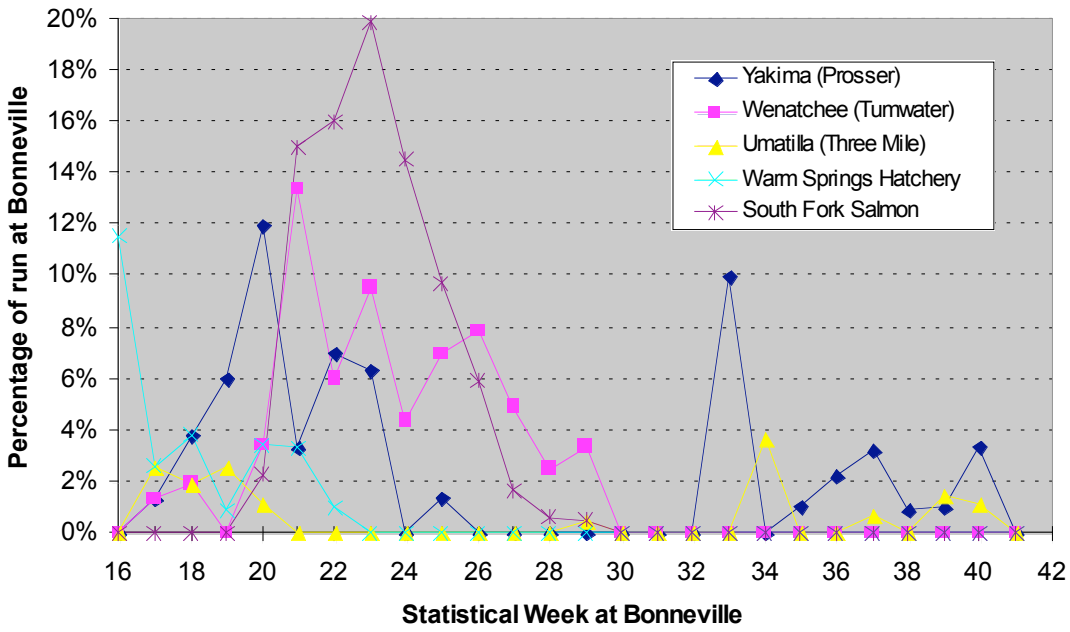


Figure 6. Percentage of Chinook salmon by Statistical Week passing Bonneville Dam destined for the Yakima, Wenatchee, Umatilla, and South Fork Salmon rivers as well as Warm Springs Hatchery based on upstream PIT tag detections at Prosser, Tumwater and Three Mile Dams and a PIT tag detection weir at rkm 65 of the South Fork Salmon River.

DISCUSSION

This study again demonstrated 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 detection is not installed at all mainstem dams, nor is it present in many tributaries. However, new detection sites, particularly in tributaries, are continually being added. For instance, new sites in 2008 included Tumwater Dam on the Wenatchee River, Roza Dam on the Yakima River, and PIT tag detection antennas on the South Fork Salmon as well as the John Day River. 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.

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 Bonneville (although the percentage of 8.5 mm tagged fish missed at Bonneville is relatively small), Wells, Prosser, and Tumwater Dams although, detection appears good at Roza Dam.

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 behavior), that allows them to escape detection at multiple weirs at a given dam.

One question of interest to fish managers is the definition of 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, varies 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). In 2007, we found that 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 while the percentage of mid-Columbia Chinook salmon increased from less than 10% of the run prior to May 27 to over 50% of the run June 24. This suggested the entire month of June is a transition period between the two stocks and life histories. Results from 2008 were similar to 2007 with the percentage of Snake River spring/summer Chinook at Bonneville Dam steadily decreasing through June (Statistical weeks 23-26, Figure 7) from 53.0% to 9.5% while the percentage passing Priest Rapids Dam increased from 14.8% to 66.7%.

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 16 as the first day of summer Chinook at Priest Rapids Dam which, is currently used by TAC, then in 2008 90% of Bonneville spring Chinook are correctly classified at Priest Rapids Dam, while 10% are misclassified as summer Chinook salmon. Ninety-nine percent of the 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 lagging this date the same 15 days to arrive at June 29 as the first day of the summer migration at Priest Rapids Dam, then 96% of Bonneville spring Chinook salmon in 2008 are similarly classified at Priest Rapids Dam (with 9% misclassified as summer Chinook), while 95% of Bonneville summer Chinook salmon are similarly classified (with 3% misclassified as spring Chinook). Using TAC dates to differentiate summer and fall Chinook salmon (Table 16), 100% of fall Chinook are similarly classified at both Bonneville and Priest Rapids Dams, while 95% of summer Chinook at Bonneville Dam are similarly classified at Priest Rapids Dam.

Table 14. 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 2008).

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

Escapement estimates for dam passage and terminal areas varied from the traditional methods (i.e. visual counts) ranging from -12.6% to +13.0% for mainstem dam passage and -16% to +39% 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.

When sampling at Bonneville Dam, we typically assign gender based on morphometric characteristics to all fish sampled including those we PIT tag. When these PIT tagged fish return to hatcheries and data is uploaded to PTAGIS, gender is typically noted allowing us to validate the assigned genders. In 2008, we correctly identified the gender 76.7% of the spring Chinook salmon (n=43) and 70.7% of summer Chinook salmon (n=41). Although, 16 fall Chinook we PIT tagged were subsequently recovered, for none of them was the gender reported. Our relatively low accuracy is the result of fish not expressing their gender specific spawning characteristics so soon after entering freshwater. More training and/or the use of tools such as ultrasound machines could boost the accuracy of gender determination.

In 2008, when water temperatures exceeded 70.0 F (21.1 C), sampling at the Bonneville Dam Adult Fish Facility was restricted to four mornings per week from 6 AM to 10 AM. Fish typically take 1.0 to 1.5 hours to reach the sampling area from the time the trapping commences which gives us 3 to 3.5 hours of actual sampling to sample both steelhead and fall Chinook salmon. These restrictions continue until water temperatures drop below 20.8 C (69.5º F). In 2008, we were under these restrictions from Statistical Week 31 into 36. Only relatively small numbers of Chinook passed Bonneville Dam until temperatures started dropping in Statistical Week 35. During Statistical Weeks 35 and 36, almost 40% of the run passed; however, due to sampling restrictions continuing until temperatures dropped to 20.8C, only 21% (Figure 8) of our sample (totaling 256 fish) was collected.

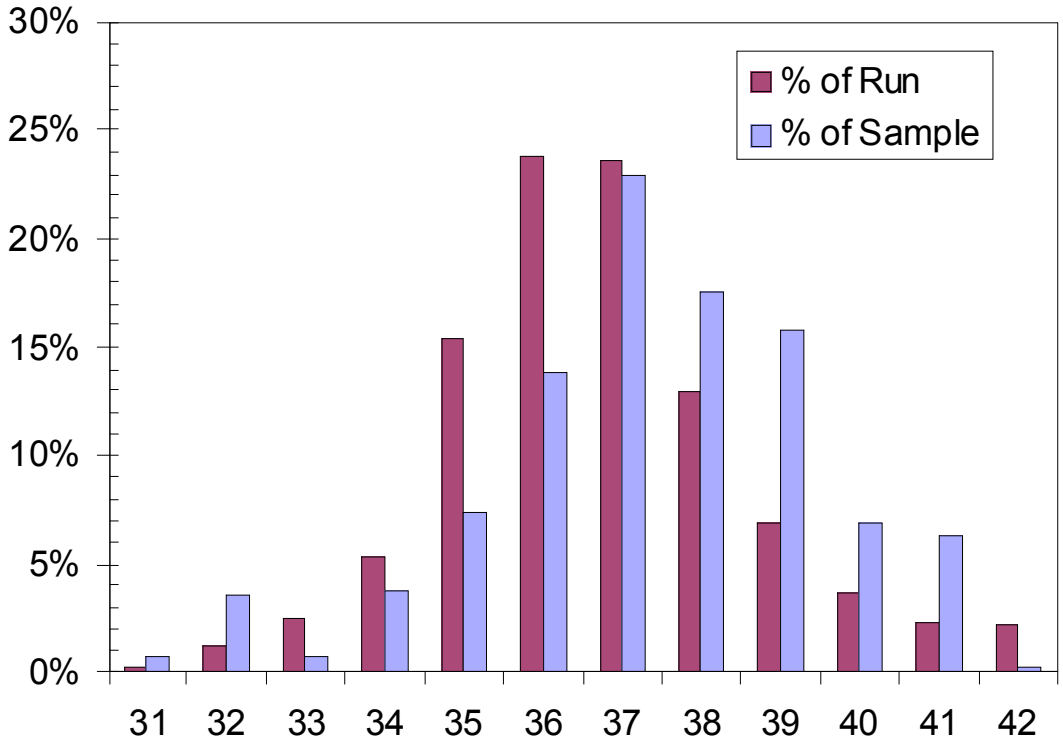


Figure 7. Comparison of the proportions of the fall Chinook run at Bonneville Dam and the weekly sample of those fish 2008.

One problem noted in our 2007 study (Fryer 2008) did not recur in 2008. In 2007, 1.4% of Chinook salmon PIT tagged were not detected after release compared to 0.5% in 2006. A similar trend was noted with our sockeye salmon PIT tagging program, where the percentage increased from 2.0% to 7.6%. In 2008, only 0.3% of Chinook salmon and 1.3% of sockeye salmon PIT tagged with 12.5 mm tags were not detected after release.

One question raised regarding our project has been the impact of sampling Chinook salmon at the Adult Fish Facility on possibly increasing Bonneville Dam passage time and/or upstream survival. Of the 534 Chinook salmon detected in the Adult Fish Facility trap in 2008, we sampled 57. Median time from detection in the trap to last detection at Bonneville Dam was 3.0 hours for sampled Chinook compared with 2.2 hours for unsampled Chinook. The percentage detected at McNary, Priest Rapids, and Ice Harbor Dams for

sampled Chinook salmon was 78.9%, 4.3% and 66.7% respectively compared to 57.2%, 2.7% and 40.9%. No explanation is apparent for why sampled Chinook salmon are detected at a higher rate upstream than unsampled Chinook salmon. This same trend did not hold for Steelhead as detection rates for sampled and unsampled Steelhead at these sites did not vary by more than 1.8 percentage points.

In 2008, we tested the use of a computerized video system to record our 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 is scanned after tagging. We had planned this 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 was the extent of both sockeye and Chinook salmon delays in passing Tumwater Dam with the median delay of 16.1 days for spring Chinook, 0.9 days for summer Chinook, and 4.7 days for sockeye. This was likely attributable to 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 this was causing significant delays.

This project will continue in 2009 as a Columbia Basin Fish Accords project (http://www.critfc.org/cbp). The project will focus on PIT tagging Steelhead, Chinook salmon, and sockeye salmon sampled at the Bonneville Dam Adult Fish facility.

REFERENCES

Chapman, D.W. 1986. Salmon and steelhead abundance in the Columbia River in the nineteenth century. Transactions of the American Fisheries Society 115: 662-670.

Chapman, D.W., A. Giorgi, T. Hillman, D. Deppert, M. Erho, S. Hays, C. Peven, B. Suzumoto, and R. Klinge. 1994. Status of summer/fall Chinook salmon in the Mid-Columbia Region. Don Chapman Consultants Inc., Boise, ID, 412 p.

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

Fryer, J.K. 1995. Columbia Basin sockeye salmon: causes of their past decline, factors contributing to their present low abundance, and the future outlook. PhD dissertation. University of Washington, Seattle. 272 pp.

Fryer, J. K. 2007. Estimation of mid-Columbia summer Chinook salmon escapement and age composition using PIT tags in 2006**.** Columbia River Inter-Tribal Fish Commission Technical Report 07-02.

Mullan, J.W. 1987. Status and propagation of chinook salmon in the mid-Columbia River through 1985. U.S. Fish and Wildlife Service, Biological Report (87)3, Leavenworth, Washington, 111 p.

Narum, S.R., D. Hatch, and J. Whiteaker. 2007. Genetic stock identification of Chinook salmon mixtures at Bonneville Dam. Final Report to the Pacific Salmon Commission. Columbia River Inter-Tribal Fish Commission, Portland.

Snedecor, G.W. and W. Cochrane. 1980. Statistical Methods. Iowa state University Press, Ames, Iowa.

Thompson, W.F. 1951. An outline for salmon research in Alaska. University of Washington, Fisheries Research Institute Circular 18, Seattle, Washington, 49 p.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. Washington State salmon and steelhead stock inventory 1992. Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes, Olympia, Washington.

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

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 2008. Columbia River Inter-Tribal Fish Commission Technical Report.

APPENDIX

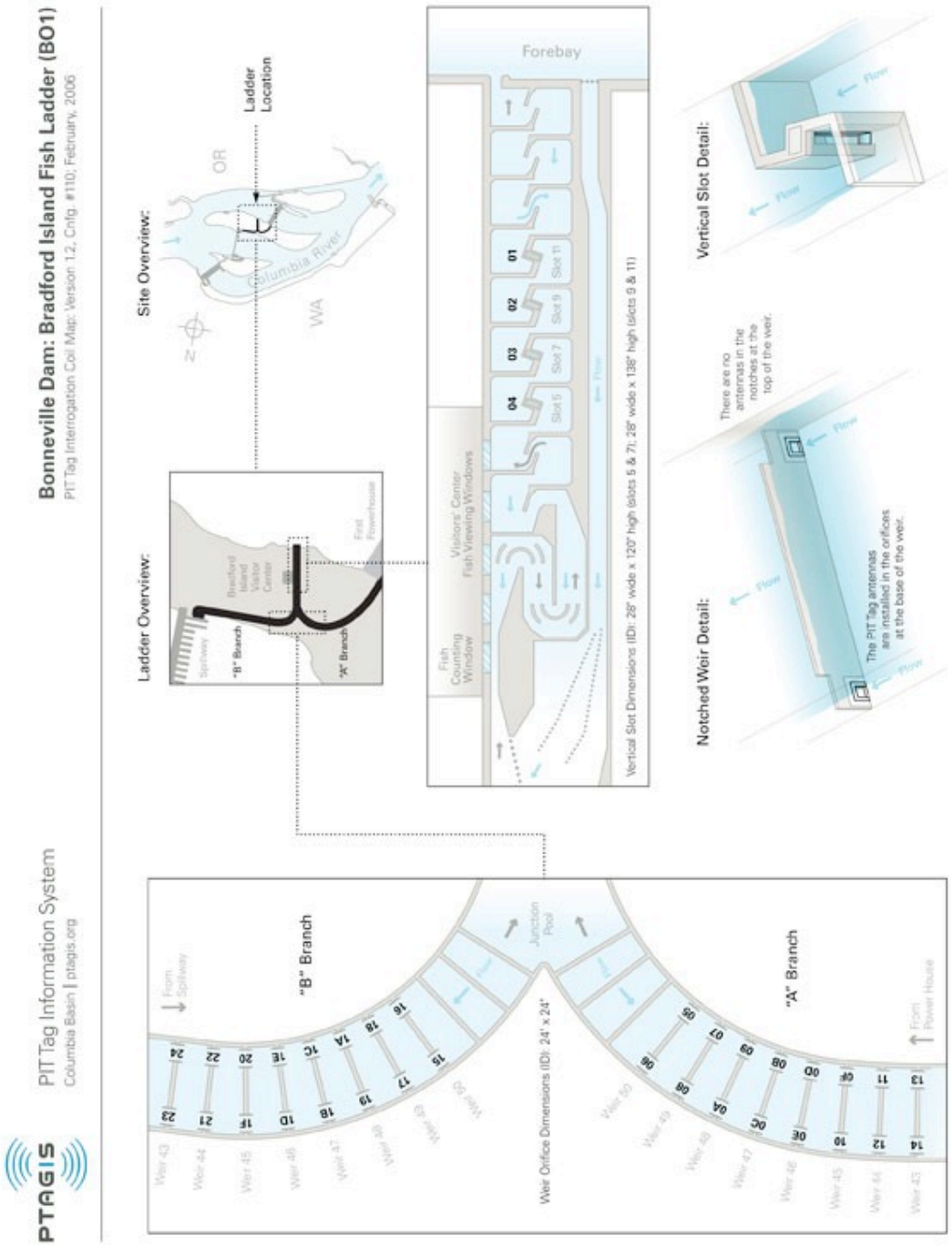
Table A1. Probability of detection at PIT tag detectors by weir at mainstem Columbia Basin fish ladders, and the overall probability of detection, for spring and summer Chinook salmon in 2008.

Dam and site	Tag Type	Weir (bolded) and probability of detection at weir											Overall detection probability
Bonneville		**N**	**1**	**2**	**3**	**4**							
BO4	12.5	2747	99.1	95.1	99.5	99.6							
	8.5	297	67.5	71.8	50.7	77.5							100.0
BO1	12.5	98	89.8	91.8	92.9	94.9							
	8.5	22	86.4	59.1	81.8	77.3							100.0
McNary		**N**	**1**	**2**	**288**	**287**	**286**	**284**	**283**	**282**	**280**	**279**	
MC1	12.5	1097	0.97	0.98	88.2	88.8	81.5	91.1	89.2	89.7	90.0	89.7	99.9
	8.5	240	0.72	0.88	84.6	86.3	80.8	92.1	91.3	72.9	85.4	82.9	96.7
		N	**1**	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**303**	**302**	
MC2	12.5		98.6	99.2	99.5	84.3	63.5	36.3	77.5	79.5	78.9	77.6	100.0
	8.5	341	49.5	88.9	81.2	76.4	75.0	34.7	77.1	76.4	73.6	64.6	98.9
Priest Rapids		**N**	**3**	**7**									
East	12.5	631	99.2[2]	99.8									100.0
	8.5	38	31.6	78.9									85.6
		N	**3**	**5**									
West	12.5	123	0.0	100.0									100.0
	8.5	4	95.6	100.0									100.0
Rock Island		**N**	**1-2**	**3-4**									
Left	12.5	241	95.9	93.8									98.9
	8.5	43	93.7	90.7									99.7
		N	**5-6**	**7-8**									
Middle	12.5	117	100.0	100.0									100.0
	8.5	21	81.0	95.2									99.1
		N	**09-0A**	**0B-0C**									
Right	12.5	318	99.7	86.5									100.0
	8.5	13	92.3	15.4									93.5
		N	**1-2**	**3-4**									
Rocky Reach	12.5	489	100.0	97.8									100.0
	8.5	76	82.9	71.1									95.0
Wells		**N**	**1-2**	**3-4**									
Left	12.5	95	81.1	100.0									100.0
	8.5	23	69.6	78.3									93.4
		N	**5-6**	**7-8**									
Right	12.5	242	100.0	100.0									100.0
	8.5	33	81.8	66.7									93.9
Ice Harbor		**N**	**438**	**437**	**436**	**435**							

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

South	12.5	564	99.6	99.6	99.5	99.8							100.0
	8.5	169	94.1	94.7	95.9	98.8							100.0
North	12.5	84	100.0	100.0	100.0	100.0							100.0
	8.5	38	100.0	100.0	94.7	94.7							100.0
Lower Granite		**N**	**733**	**732**	**731**	**730**							
	12.5	558	99.8	99.5	100.0	99.6							100.0
	8.5	196	97.4	100.0	100.0	99.0							100.0
Tumwater		**N**	**A1**	**A2**									
	12.5	65	100.0	100.0									100.0
	8.5	29	96.6	93.1									99.8
Prosser		**N**	**1**	**2**									
Left	12.5	37	100.0	100.0									100.0
	8.5	17	94.4	66.7									98.1
		N	**3**	**4**									
Middle	12.5	25	100.0	100.0									100.0
	8.5	9	100.0	88.9									88.9
		N	**5**	**6**									
Right	12.5	9	100.0	100.0									100.0
	8.5	0	NA	NA									NA
Roza		**N**	**1**	**2**	**3**								
	12.5	39	100.0	100.0	100.0								100.0
	8.5	21	100.0	100.0	100.0								100.0

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.



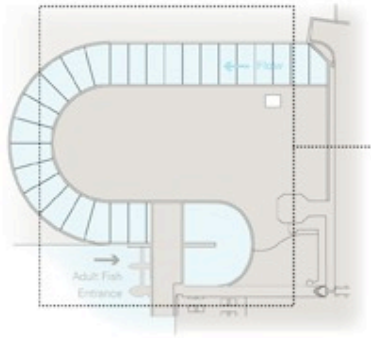
PTAGIS

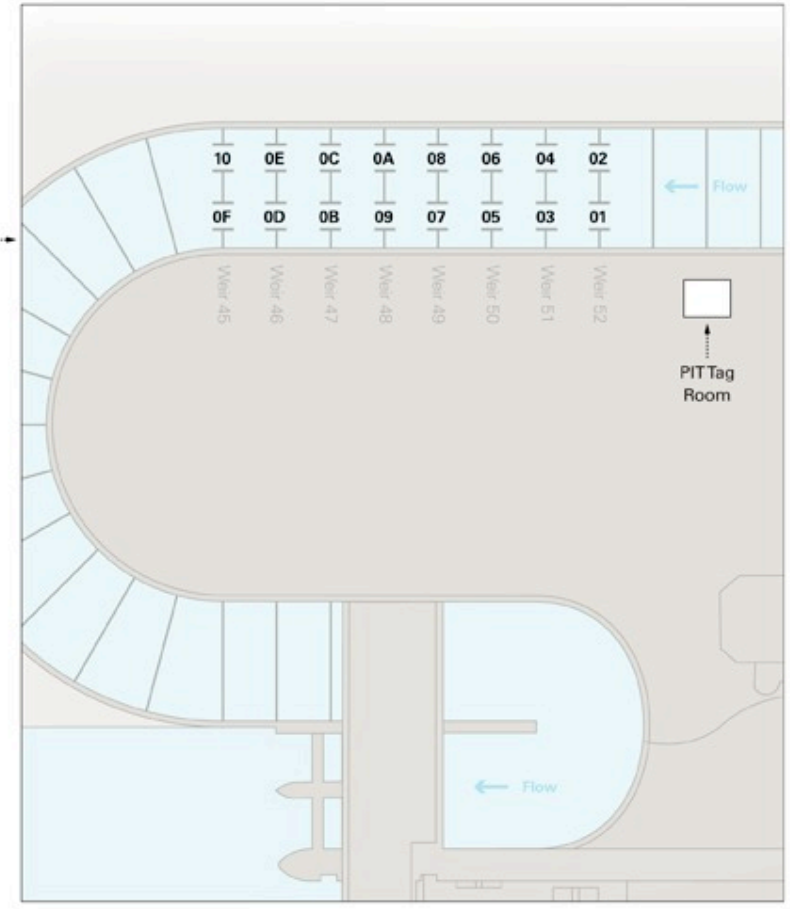
PIT Tag Information Systems
Columbia Basin | ptagis.org

Bonneville Dam: Cascades Island Fish Ladder (BO2)

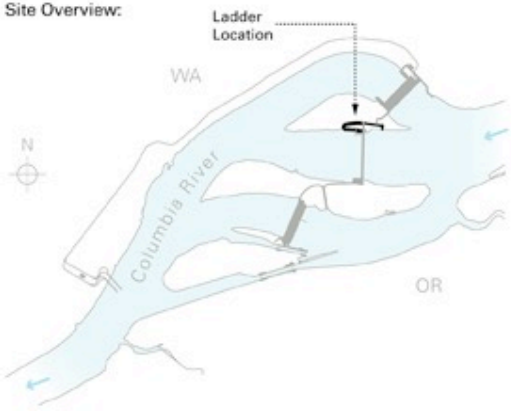
PIT Tag Interrogation Coil Map: Version 1.1, Cnfg. #100; February, 2002
Orifice Dimensions: 24" wide x 24" high

Ladder Overview:





Site Overview:



PTAGIS

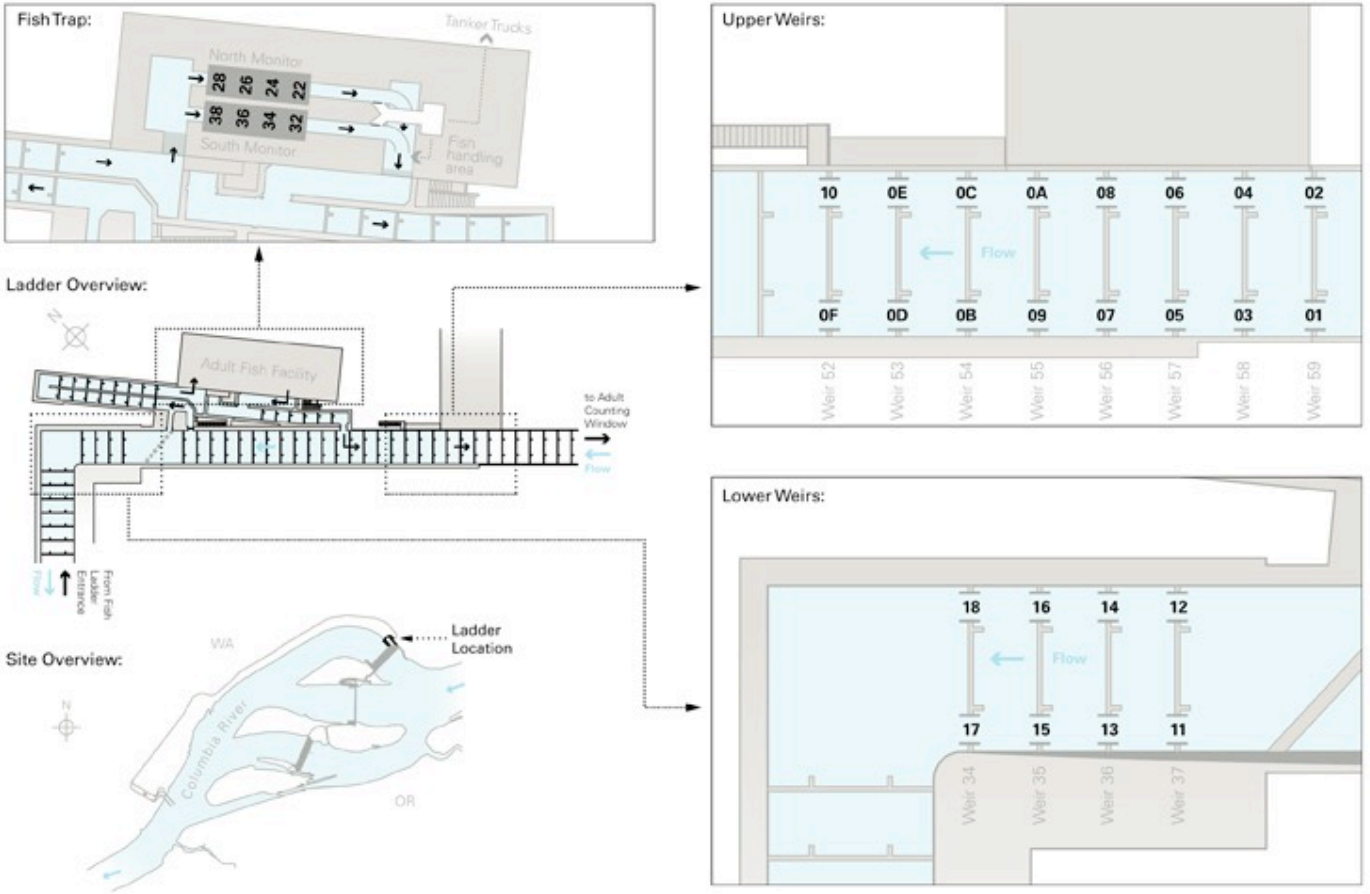
PIT Tag Information Systems

Columbia Basin | ptagis.org

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

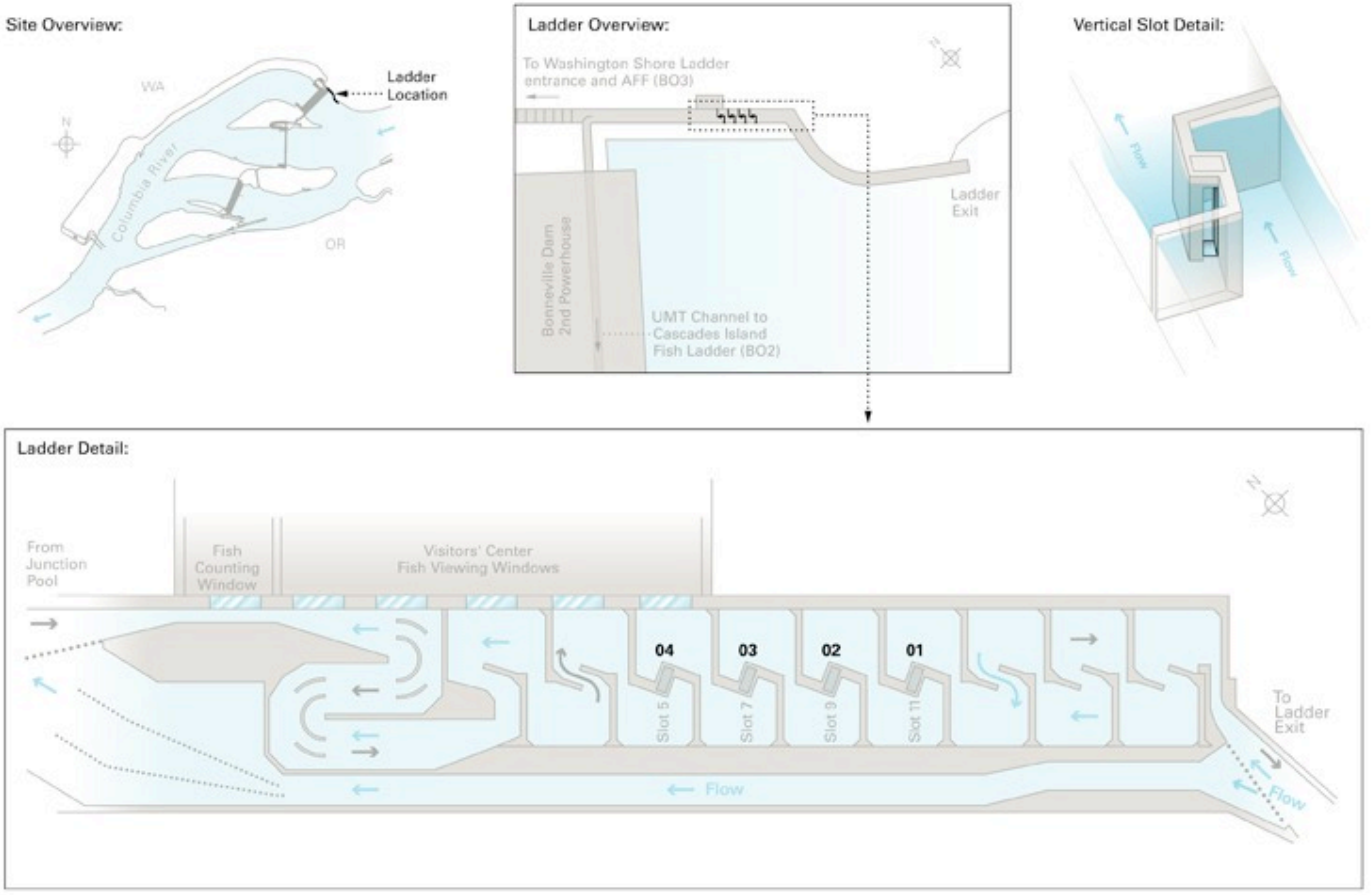


PTAGIS

PIT Tag Information Systems
Columbia Basin | ptagis.org

Bonneville Dam: Washington Shore Ladder Vertical Slots (BO4)

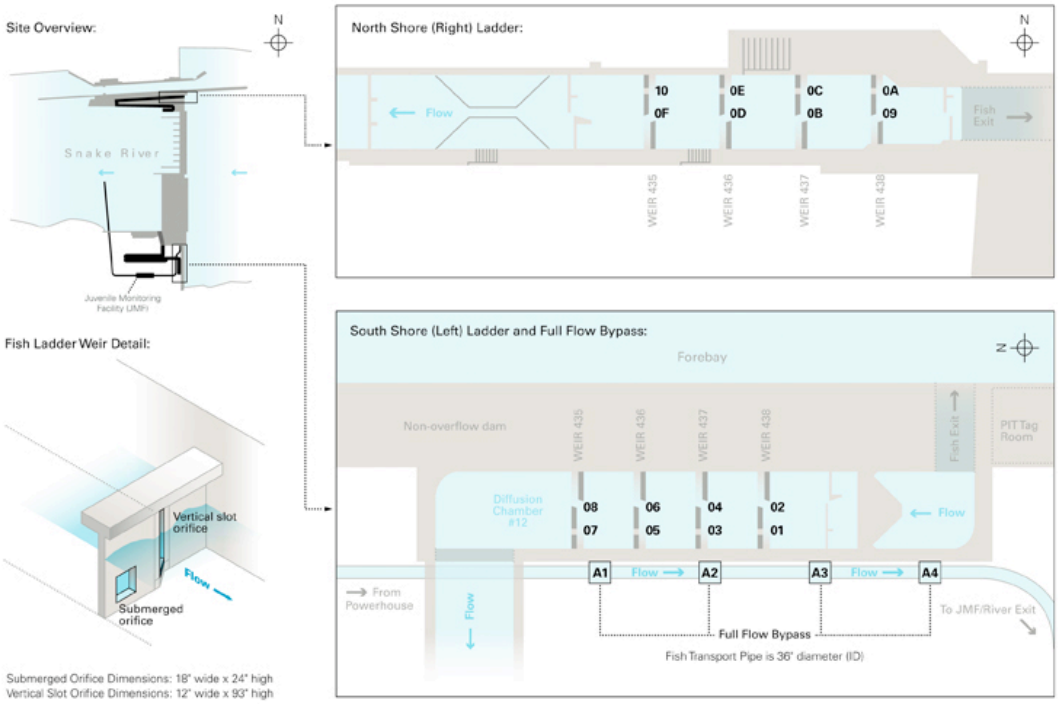
PIT Tag Interrogation Coil Map: Version 1.0, Cnfg. #100; Created March, 2005
Antenna Dimensions (ID): 28" wide x 120" high (slots 5 & 7); 28" wide x 138" high (slots 9 & 11)



PTAGIS PIT Tag Information Systems
Columbia Basin | ptagis.org

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

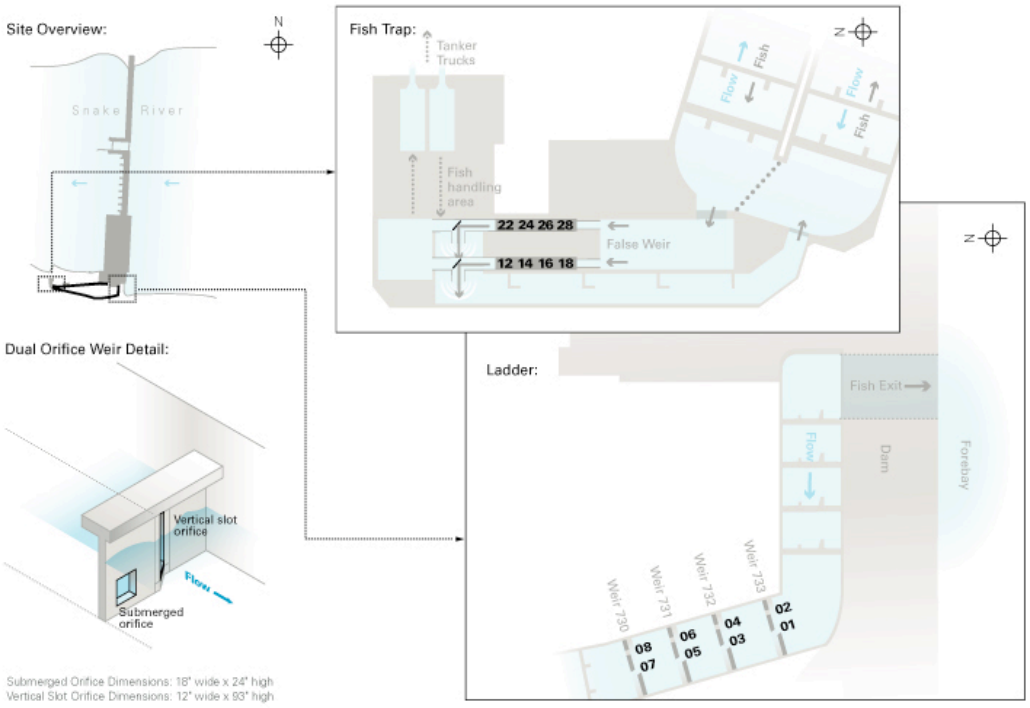
PIT Tag Interrogation Coil Map: Version 1.0, Cnfg. #100; Created April, 2005
This supercedes the previous IHA (fish ladders only) installation.



PTAGIS PIT Tag Information Systems
Columbia Basin | ptagis.org

Lower Granite Dam Fish Ladder and Trap (GRA)

PIT Tag Interrogation Coil Map: Version 4.1, Cnfg. #140; Revised December, 2003



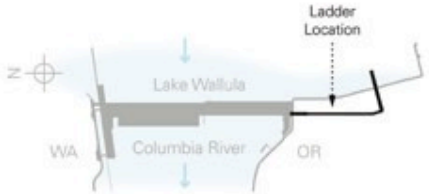
PTAGIS

PIT Tag Information System
Columbia Basin | ptagis.org

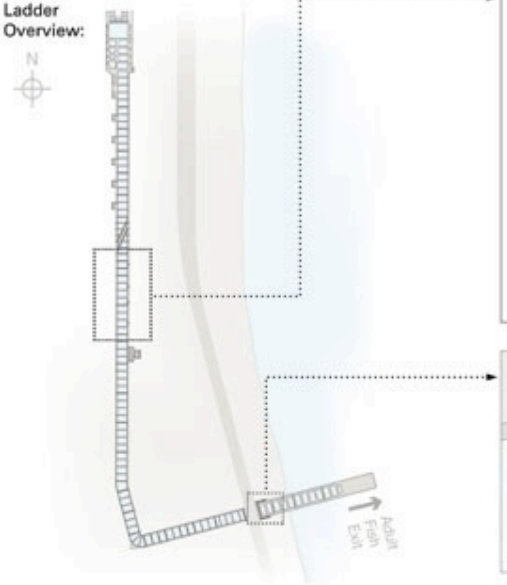
McNary Dam: Oregon Shore Ladder (MC1)

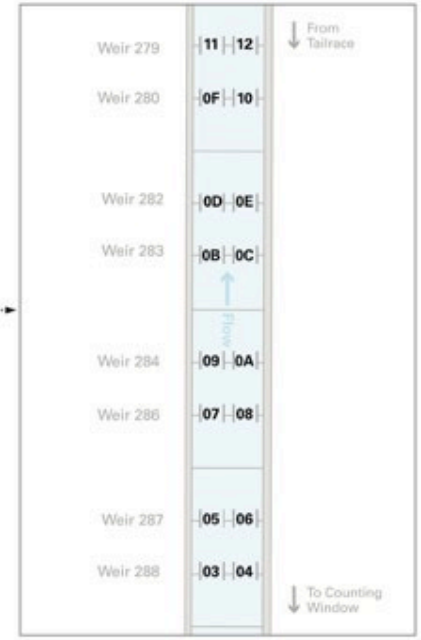
PIT Tag Interrogation Coil Map: Version 1.2, Cnfg. #100; February 2002

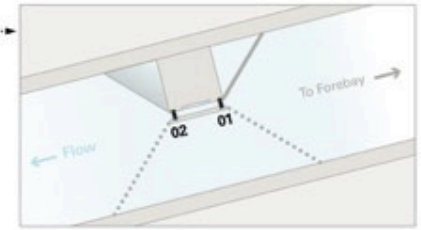
Site Overview:



Ladder Overview:

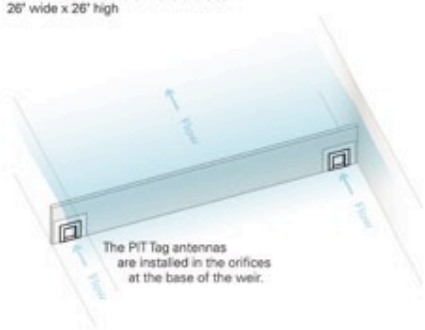






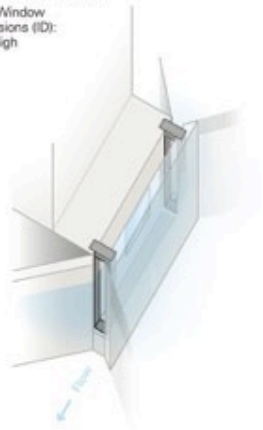
Overflow Weir Detail:

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



Counting Window Detail:

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



PTAGIS

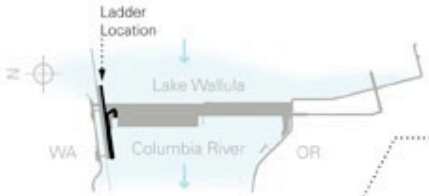
PIT Tag Information System

Columbia Basin | ptagis.org

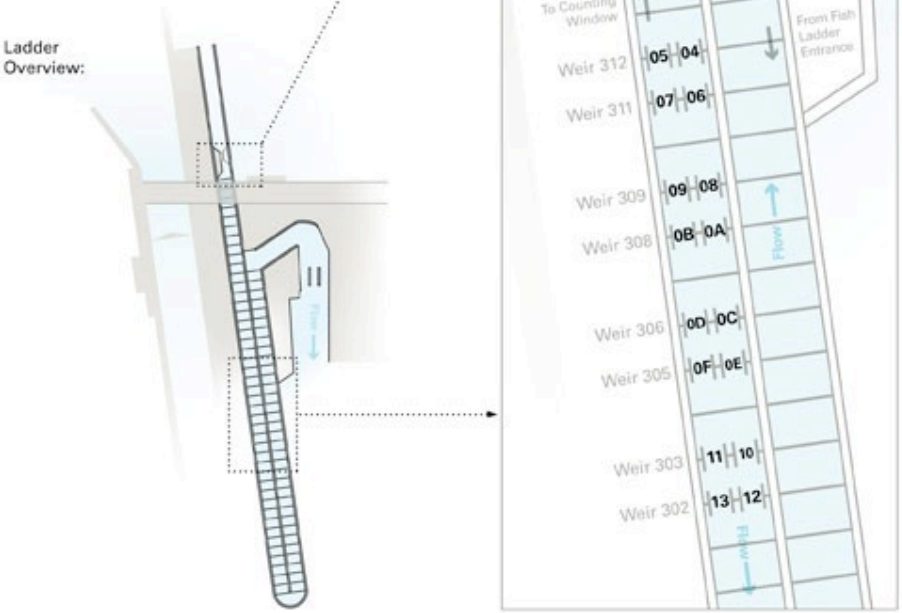
McNary Dam: Washington Shore Ladder (MC2)

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

Site Overview:

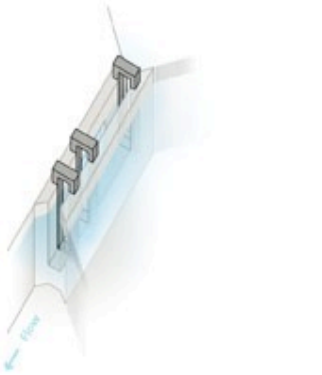


Ladder Overview:



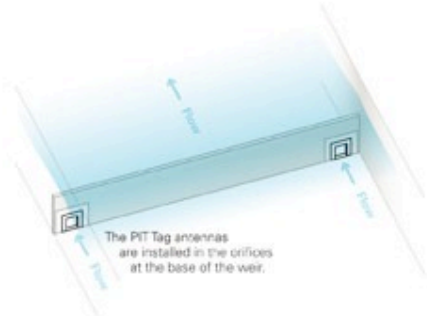
Counting Window Detail:

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



Overflow Weir Detail:

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



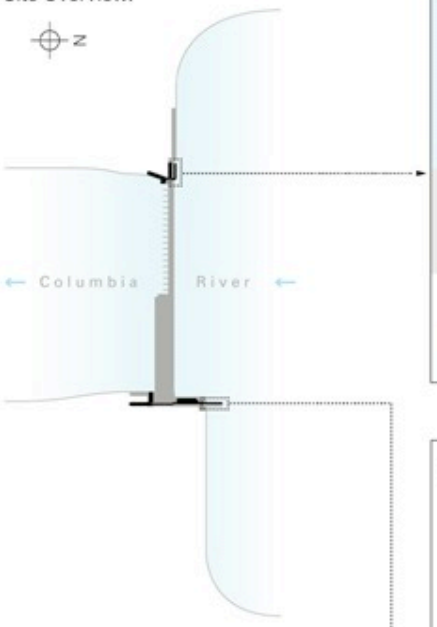
PTAGIS

PIT Tag Information Systems
Columbia Basin

Priest Rapids Dam Fish Ladders (PRA)

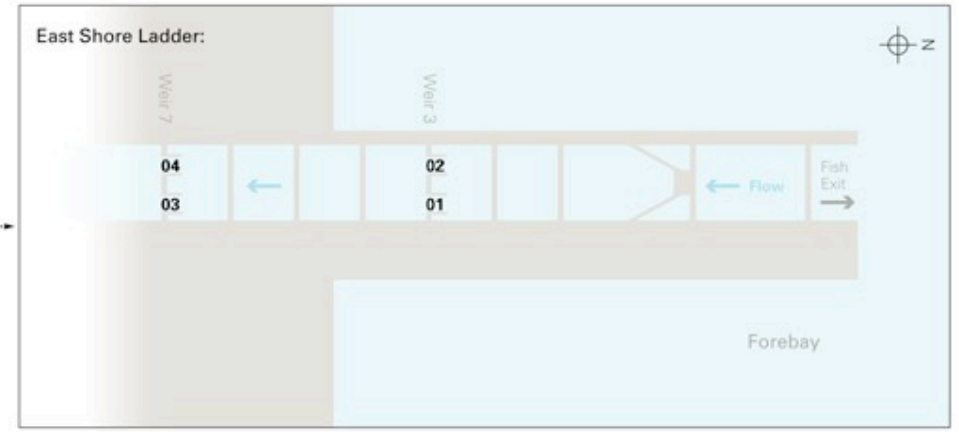
Interrogation Coil Map Revised: May, 2003 v.1.0, Cnfg. #100

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)

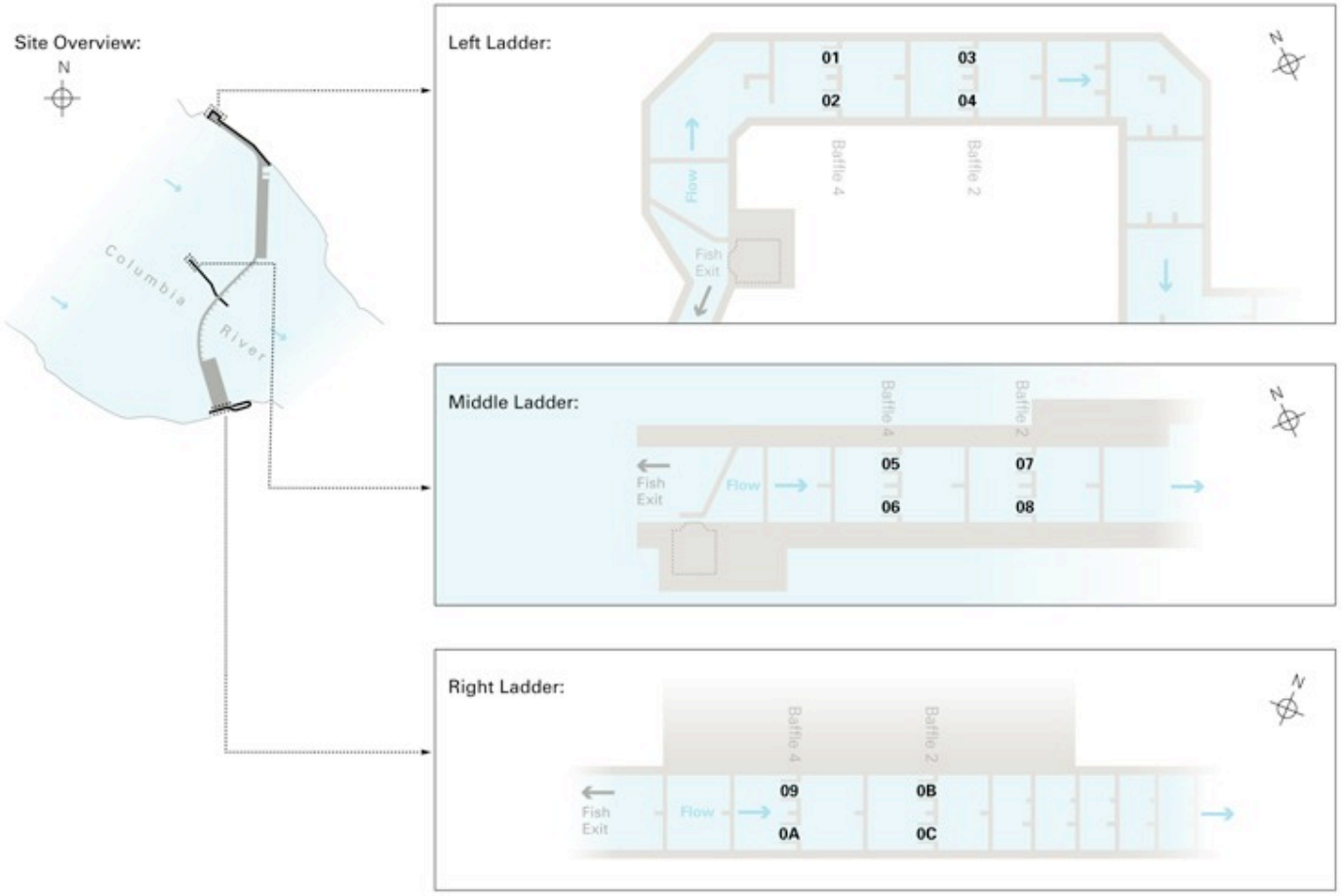
East Shore (Left) Ladder
- Weir 3: 24.0" wide x 55.0" high (ID)
- Weir 7: 24.5" wide x 45.0" high (ID)

PTAGIS

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)



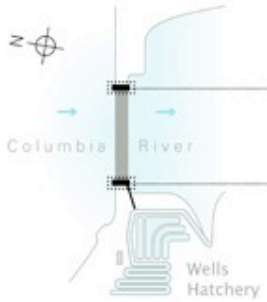
PTAGIS

PIT Tag Information Systems
Columbia Basin

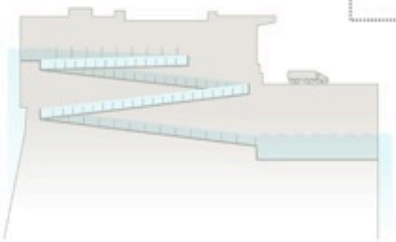
Wells Dam Fish Ladders (WEA)

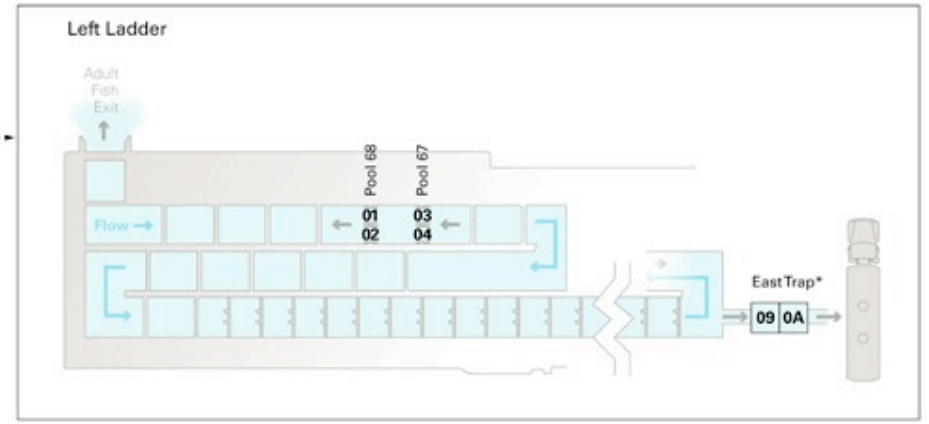
PIT Tag Interrogation Map: Version 1.1, Cnfg. #110; Revised June, 2004
Ladder Orifice Dimensions: 21" wide x 34.5" high

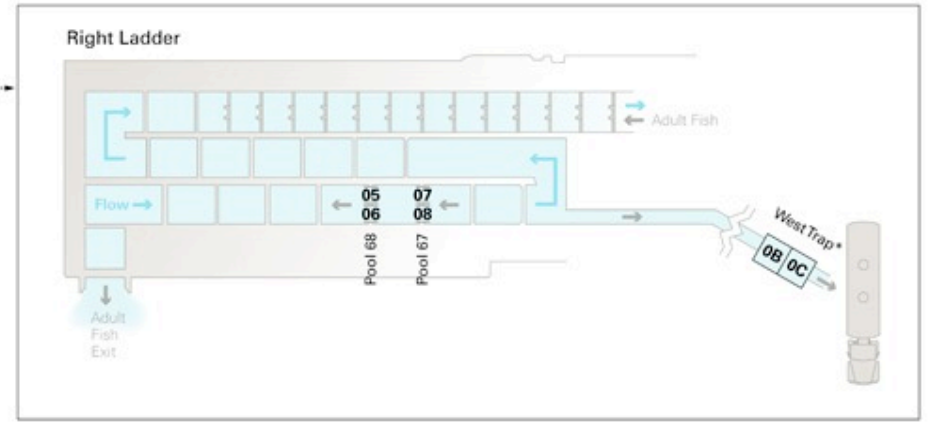
Site Overview:



Elevation View:







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