Estimation of mid-Columbia summer Chinook salmon escapement and age composition using PIT tags in 2006.

Technical Report 07-02

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ABSTRACT

A total of 633 summer Chinook salmon were PIT tagged at Bonneville Dam and tracked upstream between June 16 and July 26, 2006 using the PIT tag detection array system at mainstem dam fish ladders. Seventeen previously PIT tagged summer Chinook salmon were added to our sample. An additional 99 fall Chinook salmon were PIT tagged between September 8 and September 22, 2006.

Based on PIT tagged recoveries, 75.3% of summer Chinook salmon passed upstream of McNary Dam, 69.3% upstream of Rock Island Dam, 33.3% upstream of Wells Dam, and 4.5% upstream of Lower Granite. Over the three weeks of fall Chinook salmon tagging, 47.5% of those fish tagged passed McNary Dam, 5.1% passed Ice Harbor Dam, and 1.0% passed Rock Island Dam.

Summer Chinook salmon averaged 37.4 km/day between Bonneville and McNary dams while fall Chinook salmon averaged 39.1 km/day. No significant relationship was found between flow or water temperature and migration rate.

Age composition estimates, based on scale pattern analysis, indicate that those summer Chinook salmon passing upstream of Ice Harbor Dam are predominantly yearling outmigrants (68.2% Age 1.2 and 24.2% Age 1.1), while those passing upstream of Rock Island Dam are a mixture of subyearling and yearling outmigrants (36.1% Age 0.4, 20.6% Age 1.3, 19.8% Age 0.3, and 9.2% 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 13.0 to 44.8% more fish at McNary and mid-Columbia dams than visual fish counts from mainstem dam fish ladders.

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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 et al. 2006). These fish have comprised a mixed stock of unknown origin as, until 2006, we had no way of knowing what stock these fish belonged to. Therefore we proposed to the Pacific Salmon Commission Chinook Technical Committee to purchase a passive integrated transponder (PIT) tag detector for use at Bonneville Dam as well as sufficient tags to allow us to PIT tag all summer Chinook salmon sampled as well as some spring and fall Chinook salmon. The PIT tag scanner allowed us to scan for 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 2006.

METHODS

Sampling

Summer 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.

Summer Chinook salmon selected for sampling were examined for tags, fin clips, wounds, and condition, measured for length, and six scales removed for later age analysis (Whiteaker et al. 2007). 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, another tag was implanted. All PIT tag and sampling information was uploaded to www.ptagis.org.

Tagged Chinook salmon were detected by detection 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 summer Chinook salmon age composition using techniques developed for the age and stock composition project (Whiteaker et al. 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

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, 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 are assumed to be 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 15 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 where it is possible that a fish could use the navigation locks). For example the percentage missed at Rocky Reach Dam was calculated as:

$$P = \frac{W_m}{W_d + W_m}$$

where W_m was the number of fish detected at Wells Dam (the next dam with detection upstream of Rocky Reach Dam) which were not detected at Rocky Reach Dam and W_d was the number of fish detected passing Wells 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 summer 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 where 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 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 and PIT tag detection capability. Also, any Chinook salmon falling back over the spillway or through the turbines would not be detected in the bypass system.

Therefore, I also considered as fallbacks Chinook salmon with a detection at an "upper" detection weir followed by a detection at a "lower" detection weir separated by more than 12 hours. 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, I also reviewed detection histories of individuals detected at multiple ladders (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 I designated these two weirs as the upper and lower detection weirs. Note that this method only estimates fallback plus reascension. 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 633 summer Chinook salmon were PIT tagged between June 16, 2006 and July 24, 2006, while an additional 17 previously PIT tagged fish were detected and added to our study (Table 1). Two fish were not detected after tagging, and therefore these fish were assumed to have shed their tags. The number of summer Chinook salmon tracked upstream was 648. No (spring) Chinook were PIT prior to June 16 as NOAA concurrence to PIT tag potentially ESA-listed spring and fall Chinook salmon was not received until after the spring migration ended on June 15. High water temperatures prevented sampling any Chinook salmon from July 26 through September 1 but an additional 99 fall Chinook salmon were PIT tagged between September 5 and September 20, 2006.

Table 1. Number of summer Chinook salmon PIT tagged, and number of PIT tagged summer Chinook salmon tracked, at Bonneville Dam by date and statistical week in 2006.

Summer Chinook			
Dates	**Statistical Week**	**Tagged (n)**	**Tracked (n)**
6/16	24	24	24
6/20,21,23	25	141	141
6/26,28,30	26	169	178
7/5,6,7	27	174	180
7/10,12	28	95	97
7/17,19,21	29	16	16
7/24,26	30	12	12
Total		**631**	**648**
Fall Chinook			
Dates	**Statistical Week**	**Tagged (n)**	**Tracked (n)**
9/8,11	36	30	30
9/13,15	37	36	36
9/18,22	38	33	33
Total		**99**	**99**

Age Analysis

Of the 17 summer Chinook salmon sampled that had been previously PIT tagged, 13 fish had scales readable for ageing. Of these 13 fish, we correctly aged 12 (one each of Age 1.1 and 0.3, six of Age 1.2, and five of Age 1.3). The sole exception was a 61.5 cm fish sampled on June 30, 2006 that definitely had one saltwater annulus but had a second saltwater check that was not judged

strong enough to call it an annulus. However, the PIT tag indicated that it was Age 1.2, rather than Age 1.1 as it was originally aged.

Upstream Recoveries, mortality, and escapement

Data on tag detections was downloaded from www.ptagis.org on January 12, 2007. Of the 650 summer Chinook salmon in our study, a total of 648 fish were detected subsequent to release, so we assumed that 2 fish shed their tags prior to release. Most of the fish that were not detected at Rock Island Dam were lost between Bonneville and McNary dams (Figure 1, Table 2).

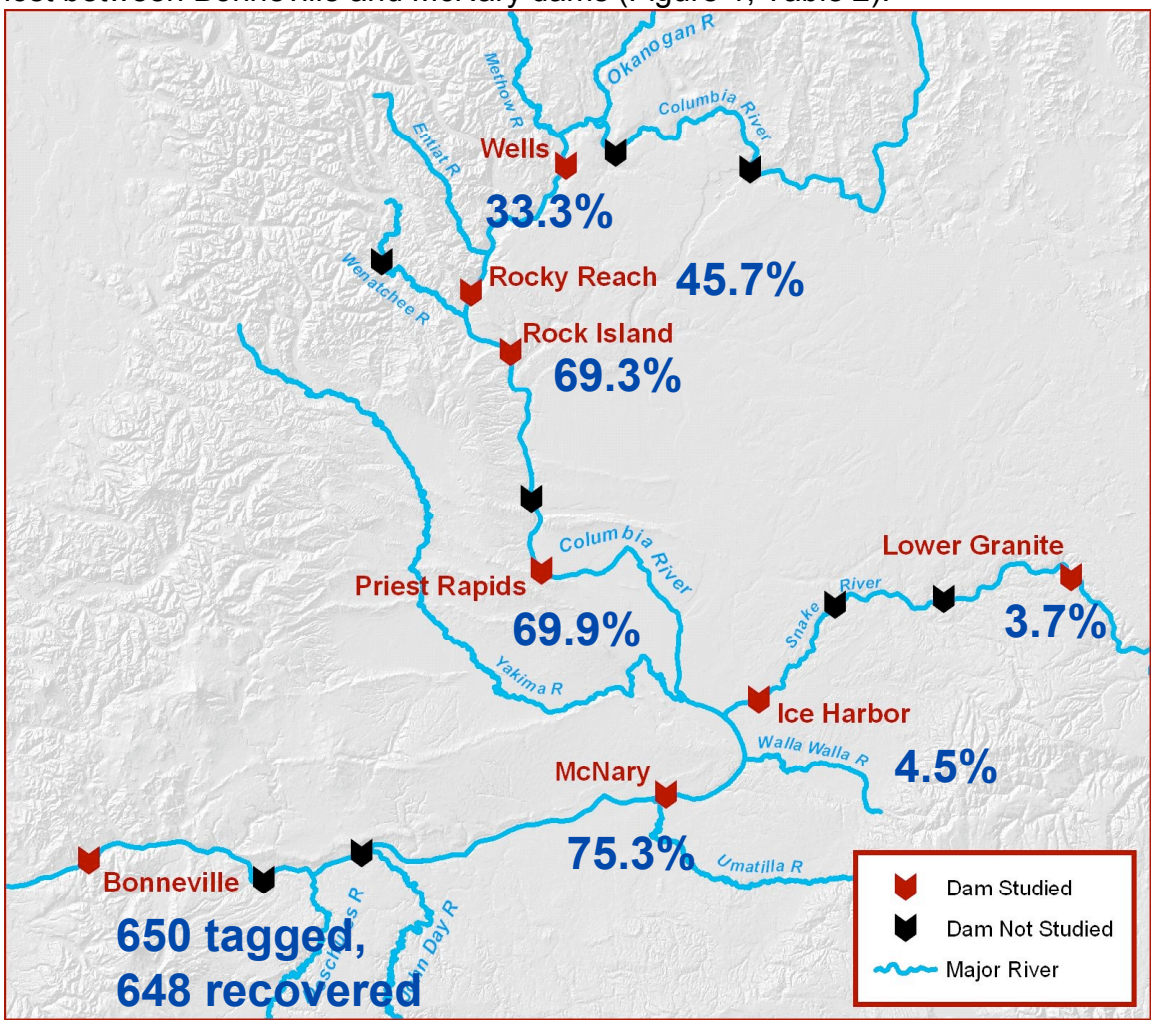

Figure 1. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of summer Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2006.

Table 2. Percentage of summer Chinook salmon tracked at Bonneville Dam detected at upstream dams, the percentage "lost" between dams, and the percentage missed at each dam as determined by upstream detections in 2006.

Dam	Percent passing dam	Lost from previous dam (%)	"Missed" by PIT tag detectors at dam (%)	Sockeye missed (%)
Bonneville	100.0		0.2	0.2
McNary	75.3	24.7	0.2	3.1
Priest Rapids	69.9	1.2[1]	0.2	0.0
Rock Island	69.3	0.9	0.7	1.3
Rocky Reach	45.7	34.2	9.5	12.3
Wells	33.3	26.8	NA	NA
Ice Harbor	4.5	1.2[1]	0.0	NA
Lower Granite	3.7	17.2	NA	NA

We did have two tag codes with detections that we could not explain. The first, 3D9.257C6A7DAA, was not detected after Bonneville Dam except for a single detection at one weir at Rocky Reach Dam. The second, 3D9.257C6A4162, was not detected after release until recovery at Wells Hatchery. We speculate that either the tags were misread or were not functioning correctly which led us to eliminate these two upstream detections from our database.

Over the period of the migration, the percentage of summer Chinook salmon destined for above Priest Rapids Dam decreased, while the percentage last detected at Bonneville Dam steadily increased (Figure 2), however neither linear relationship is significant at α=0.05 (p=0.10 and 0.09, respectively). The percentage of summer Chinook salmon last observed in the Snake River was never more than 8% of the run in any week.

All 99 fall Chinook salmon tagged were subsequently detected at Bonneville Dam. However, only 47.5% were detected at McNary Dam, and only 7.1% at Priest Rapids Dam (Figure 3)[2]. Two additional (2.0%) were detected at Three Mile Dam on the Umatilla River and one fish (1.0%) at Prosser Dam on the Yakima River.

[1] Percent lost is the number lost between McNary and Priest Rapids and Ice Harbor dams combined.

[2] The low percentage of fall Chinook salmon detected at Priest Rapids Dam is not surprising as the primary spawning location for fall Chinook salmon is in the Hanford Reach, between McNary and Priest Rapids dams.

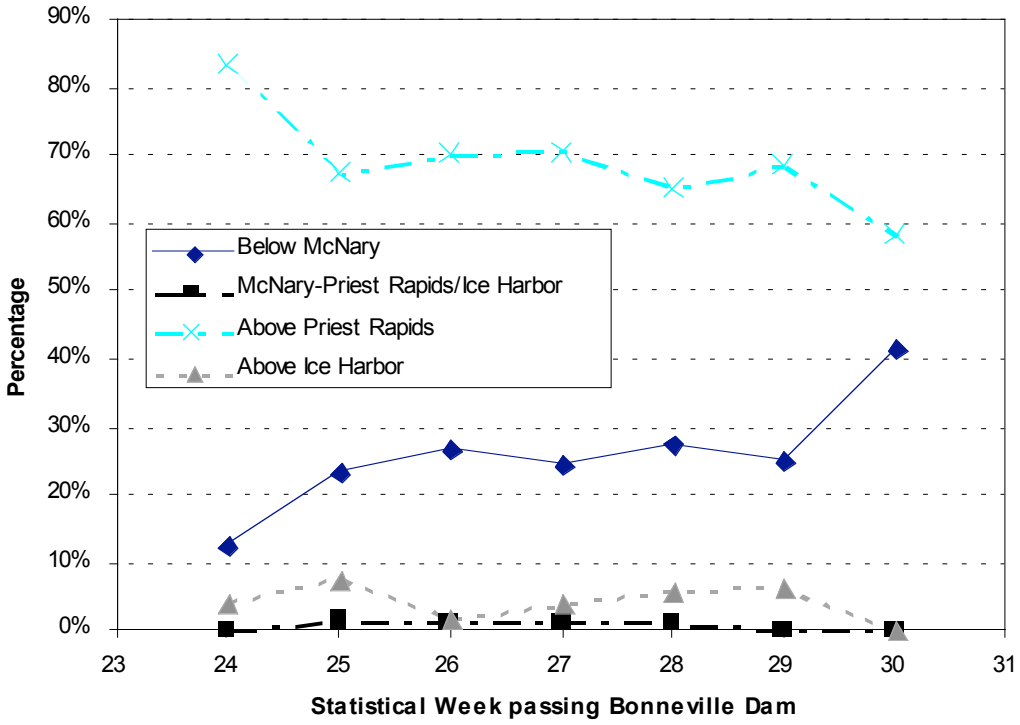

Figure 2. Final detection site by statistical week for summer Chinook salmon PIT tagged at Bonneville Dam in 2006.

Our three week PIT tagging effort for fall Chinook salmon was too short to discern trends in timing of the components of the run (Figure 4). However, in comparison to summer Chinook salmon, the percentage detected above Priest Rapids Dam was substantially less, while the percentage last observed below McNary and between McNary and Priest Rapids or Ice Harbor was far greater.

The highest rate of fish passing upstream at a dam without being detected was at Rocky Reach Dam (Table 2). No estimate could be made for Wells Dam or Lower Granite dams since there were no detection sites upstream. 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.

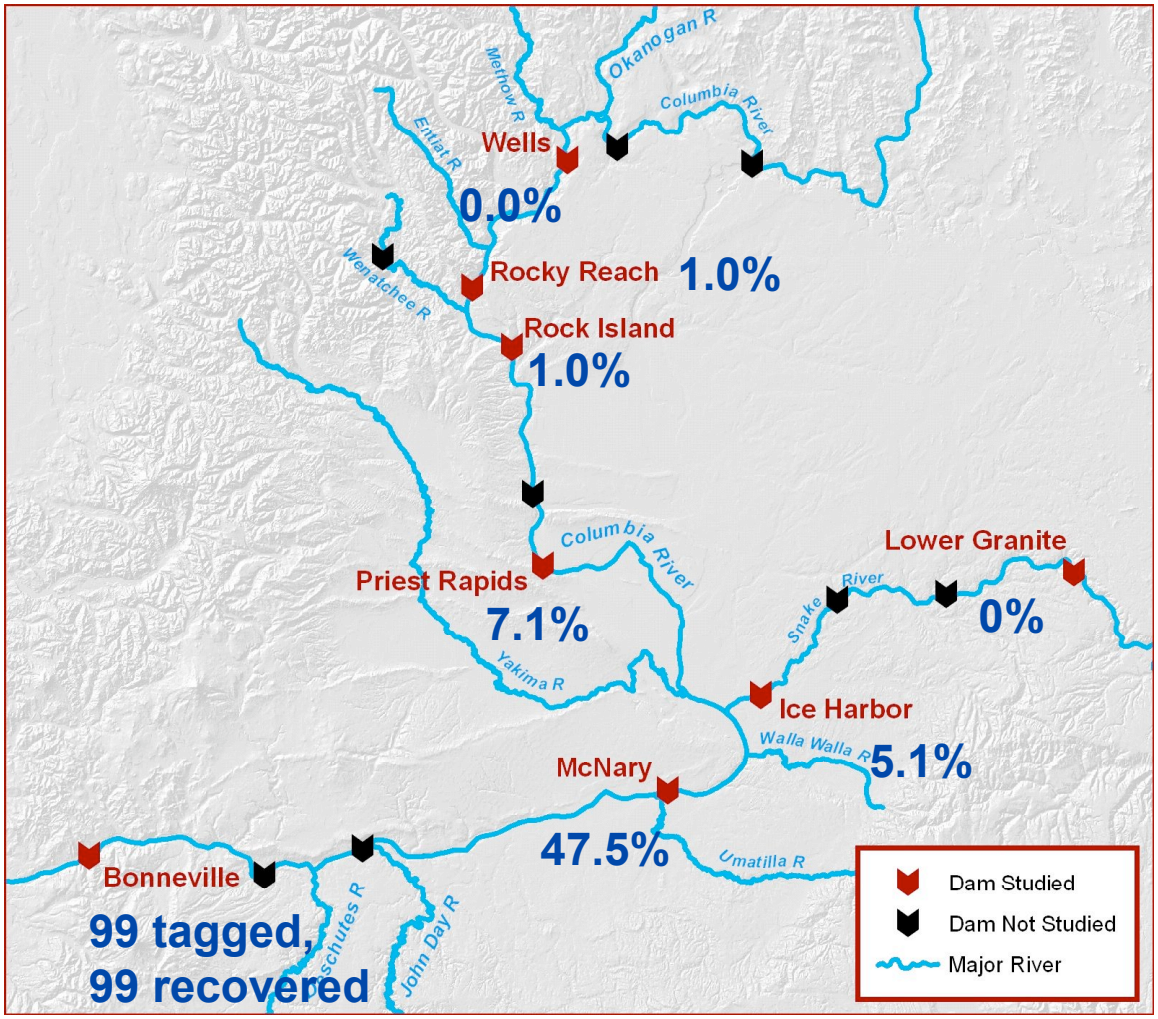

Figure 3. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fall Chinook salmon PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass upstream dams in 2006.

Escapement estimates derived from PIT tag detections result in escapement estimate estimates that are higher than mainstem dam counts by 13.0 to 44.8% (Table 3). The dates in the dam count estimates were those estimated by the median travel time from Bonneville Dam to upstream dams (Table 4).

Table 3. 2006 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 difference between the two estimates.

Site	Estimate	Standard Deviation	Dam Count Dates	Dam Count	Difference
MCN	68,814	598	6/22-8/6	47,184	44.8%
PRD	64,411	557	6/27-8/11	48,860	29.5%
RIS	64,150	555	6/30-8/14	52,044	20.7%
RRH	43,848	330	7/1-8/15	36,151	13.0%
WEL	31,477	248	7/7-8/21	21,325	41.8%

Table 4. Median summer Chinook salmon migration time and travel rates between mainstem dams as estimated as estimated by PIT tag recoveries in 2006.

Dam pair	Distance (km)	Median time (days)	Median travel rate (km/day)	Sockeye median km/day
Bonneville-McNary	231	6.2	37.4	46.1
McNary-Priest Rapids	167	3.9	42.8	37.2
Priest Rapids-Rock Island	89	3.7	28.6	22.6
Rock Island-Rocky Reach	33	2.8	29.0	24.4
Rocky Reach-Wells	65	12.0	11.9	22.7
Bonneville-Rock Island	487	13.8	35.3	34.9
Bonneville-Wells	585	15.1	28.1	32.2
McNary-Ice Harbor	67	1.6	42.0	NA
Ice Harbor-Lower Granite	156	4.7	33.1	NA

Migration Timing and Passage Time

The highest between-dam travel rate was between McNary and Priest Rapids and between McNary and Ice Harbor dams (Table 4). The lowest rate was between Rocky Reach and Wells dams. Fall Chinook salmon had a median travel rate of 39.1 km/day between Bonneville and McNary dams. For all other dam pairs fall Chinook sample sizes were too small to provide a meaningful estimate. For all dam pairs for summer Chinook salmon, there was no significant linear relationship between statistical week passing Bonneville Dam and median travel rate. There also was no significant linear relationship between water temperature or flow at Priest Rapids or The Dalles dams and median travel rate.

Bonneville Dam had the greatest median time between first PIT tag detection and last PIT tag detection for both summer and fall Chinook salmon (Table 5). There are likely two contributing factors; the first being that it is likely that sampled fish take some time to recover from tagging prior to resuming their upstream migration. And second, there are both more, and more widely spaced detectors at Bonneville (and McNary) dams than at any other dam studied. Lower Granite and Rock Island dams had the highest percentage of summer Chinook salmon taking more than 12 hours to pass.

Table 5. Summer Chinook salmon median travel times from time of first detection at a dam to last detection at a dam and the percentage taking greater than 12 hours between first detection and last detection in 2006. Sites with fewer than three fish were excluded.

	Median Passage Time (Minutes)		Percent taking more than 12 hours to pass dam		
Dam	Summer Chinook	Fall Chinook	Summer Chinook	Fall Chinook	Sockeye
Bonneville	87	96	1.0	10.1	6.8
McNary	70	80	0.6	4.3	3.2
Priest Rapids	6	7	2.7	0	2.4
Rock Island	42		13.0		1.8
Rocky Reach	2		3.7		2.7
Wells	1		3.7		4.8
Ice Harbor	3	2	6.9	0	
Lower Granite	84		20.8		

Upstream age and length-at-age composition

The percentage of yearling outmigrant (i.e. Age 1.x) summer Chinook salmon passing upstream of Ice Harbor into the Snake River is much greater than that 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 0.4, and a smaller percentage of Age 1.2, than that at any other site. Mean length-at-age composition estimates at these sites are given in Table 7.

Table 6. 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 2006.

		Brood Year and Age Class							
		2004	2003		2002		2001		2000
Dam	Statistic	0.1	1.1	0.2	1.2.	0.3	1.3	0.4	1.4
Priest Rapids	Mean	3.4	5.3	1.0	9.4	19.9	20.9	35.5	4.4
	Std Dev.	1.2	1.3	0.5	1.6	2.2	2.2	2.5	1.0
Rock Island	Mean	3.4	5.3	1.1	9.2	19.8	20.6	36.1	4.5
	Std Dev.	1.2	1.3	0.5	1.5	2.2	2.2	2.6	1.0
Rock Island - Rocky Reach	Mean	1.3	3.2	1.2	4.4	11.7	20.7	53.3	4.1
	Std Dev.	0.9	1.4	0.8	1.5	1.7	3.2	3.7	1.7
Rocky Reach	Mean	4.1	5.9	1.3	11.9	25.2	19.2	27.7	4.6
	Std Dev.	1.5	1.7	0.8	2.1	2.9	2.7	2.9	1.3
Rocky Reach - Wells	Mean	0.0	14.1	0.0	19.6	11.9	14.6	33.6	6.2
	Std Dev.	0.0	4.7	0.0	5.0	3.8	4.0	6.4	3.2
Wells	Mean	5.5	2.9	1.9	8.9	30.2	21.2	25.4	3.9
	Std Dev.	1.9	1.3	1.1	2.2	3.5	3.2	3.1	1.4
Ice Harbor	Mean	3.8	24.2	0.0	68.2	2.2	1.7	0.0	0.0
	Std Dev.	2.5	4.3	0.0	4.7	2.0	1.5	0.0	0.0

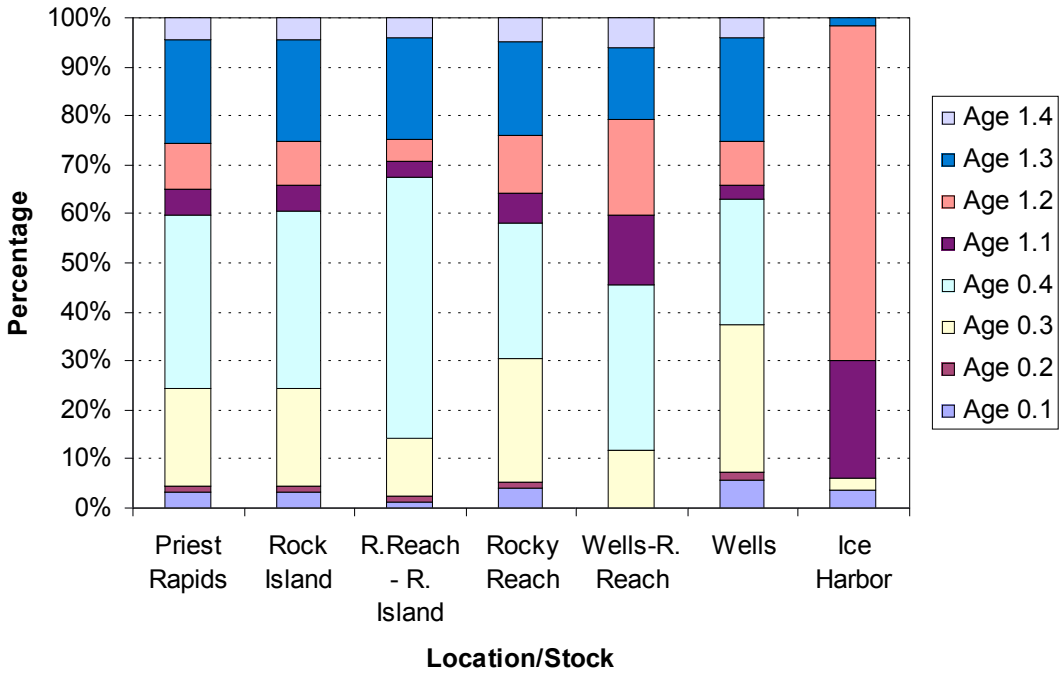

Figure 4. Age composition of Snake River summer Chinook salmon at Ice Harbor and mid-Columbia Chinook salmon upstream of Priest Rapids Dam estimated using PIT tags in 2006

Table 7. 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 2006.

		Brood Year and Age Class							
		2004	2003		2002		2001		2000
Dam	**Statistic**	**0.1**	**0.2**	**1.1**	**0.3**	**1.2**	**0.4**	**1.3**	**1.4**
Rock Island	Mean	43.9	63.4	50.1	82.0	71.9	90.7	85.9	88.8
	Std. Dev	4.5	7.3	12.9	6.9	7.2	6.2	7.4	6.3
	N	11	5	20	83	41	144	84	19
R. Island – R. Reach Difference	Mean	42.8	69.5	54.6	82.4	69.1	91.1	88.5	91.9
	Std. Dev	8.4	4.9	3.8	7.3	5.8	6.1	8.5	5.5
	N	3	2	6	22	10	81	37	7
Rocky Reach	Mean	44.3	59.3	49.2	81.8	73.0	90.2	83.7	87.1
	Std. Dev	2.7	5.8	16.1	6.7	7.4	6.3	5.7	6.0
	N	8	3	13	62	32	63	49	13
R.Reach - Wells Difference	Mean			53.8	82.3	75.5	90.0	84.0	90.3
	Std. Dev			8.2	7.0	6.0	6.6	6.8	5.6
	N			8	10	15	22	13	4
Wells	Mean			54.4	82.3	75.5	89.7	83.4	90.3
	Std. Dev			8.7	7.0	6.0	6.6	6.5	5.6
	N			7	10	15	21	15	4
Ice Harbor	Mean	40.8		49.6	90.5	75.2		89.5	
	Std. Dev	4.6		6.6		4.8			
	N	2		6	1	17		1	

Fallback

Estimated fallback-reascension rates based on summer Chinook salmon reascending fish ladders ranged from 0.4% at Bonneville to 8.3% at Lower Granite Dam (Table 8). 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 17 fish tagged by this study and recovered at Wells Hatchery (Charlie Snow, WDFW, October 17, 2006 e-mail, personal communication), three 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 three fish were included in the percentage of fallback estimated at Wells Dam in Table 8.) Fall Chinook salmon fell back at higher rates at Bonneville and McNary Dam than did summer Chinook salmon.

Table 8. Estimated summer Chinook salmon fallback and reascension at mainstem Columbia River dams in 2006 as estimated by PIT tags with sockeye estimates for comparison purposes. Note sample sizes are very small for fall Chinook salmon upstream of McNary Dam.

Dam	Summer Chinook (%)	Fall Chinook (%)	Sockeye (%)
Bonneville	0.9	3.0	0.2
McNary	0.4	2.1	1.5
Priest Rapids	0.9	0	0.5
Rock Island	0.4	0	0.8
Rocky Reach	1.7	0	1.0
Wells	5.1	NA	3.3
Ice Harbor	6.9	0	NA
Lower Granite	8.3	0	NA

Several summer Chinook salmon fell back over multiple dams. (By comparison, no sockeye or fall Chinook salmon fell back over multiple dams.) Individual fish fell back over Ice Harbor and McNary dams (tag code 3D9.257C665326) and Lower Granite and Ice Harbor dams (3D9.257C669D81), while two fish fell back over Wells and Rocky Reach dams (3D9.257C6A3FE4 and 3D9.257C6ABC3E). One fish (3D9.257C6A7295) ascended the Rock Island Dam right fish ladder on July 10, then descended the same fish ladder on July 16, then fell back over both Wanapum and Priest Rapids dams before entering the Priest Rapids west shore fish ladder on July 23. This fish did not pass over this ladder until July 29 and proceeded through a Rock Island Dam fish ladder on August 1, and passed Rocky Reach Dam on August 10.

Night Passage

Night (2000-0400) passage ranged from 0.7% at Bonneville Dam to 4.2% at Lower Granite Dam (Table 9). The Bonneville Dam estimate of night passage is likely biased low due to the fact that tagging occurred between about 0900 and 1500. No PIT tagged fall Chinook salmon passed at night.

Table 9. Estimated summer chinook salmon night passage (2000-0400) in 2006 at mainstem Columbia River dams as estimated by PIT tags with sockeye estimates for comparison purposes.

Dam	Summer Chinook (%)	Sockeye (%)
Bonneville	0.7	0.2
McNary-OR Shore	1.5	10.0
McNary-WA Shore	4.0	7.1
Priest Rapids	1.3	6.6
Rock Island	3.8	3.4
Rocky Reach	1.5	11.7
Wells	3.7	15.1
Ice Harbor	3.4	NA

DISCUSSION

This study demonstrated the feasibility of PIT tagging summer Chinook salmon at Bonneville Dam and then tracking them upstream and used 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. Adult ladders at John Day and The Dalles dams are scheduled to be added in 2008. Ultimately, it seems likely all dams in the Columbia Basin with upstream upstream passage facilities will be wired with PIT tag detectors.

One drawback with PIT tag detectors, when compared to radio tags, is the low number of weirs with PIT tag interrogation coils in the fish ladders (only two for Priest Rapids, Rock Island, Rocky Reach, and Wells dams) at all dams but Bonneville and McNary. This makes it impossible to estimate total passage time at the ladders and can raise questions about the direction of movement if detection is not 100% at all weirs. It would be far easier to determine ladder passage time and direction of movement, and thereby more accurately estimate fallback, if there were detectors at the lower and upper ends of these ladders.

Summer Chinook salmon PIT tag detection rates at mainstem dams in 2006 were close to 100% at dams except for Rocky Reach dam where 9.5% of summer Chinook salmon detected at Wells Dam were not detected passing Rocky Reach. A similar percentage (12.3%) of sockeye salmon were also missed at Rocky Reach. PIT tag detection was installed at Rocky Reach Dam prior to the beginning of the 2006 migration season and it appears there were equipment problems in 2006 that should be addressed for 2007 (Thad Mosey, Chelan PUD, January 19, 2007 e-mail, personal communication).

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, this study estimated that the percentage of Snake River fish at Bonneville Dam ranged from 2% to 6% between mid-June and mid-July. Our age composition study estimated that 19% and 26% of Chinook salmon passing Bonneville Dam in the first two weeks of June were subyearling outmigrants which means they are likely 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.)

Different summer Chinook salmon migration dates at mid-Columbia dams lead to very different dam count estimates. Upstream dam count estimates based on dates determined by median migration rates differed from those estimated by PIT tags by 13.0 to 44.8% (Table 3). Other possible dam count estimates, plus those presented in Table 3, are found in Table 10. These estimates are based on traditional dates, new TAC dates, and TAC dates with an additional 15 day lag in the start of the run at Priest Rapids, Rock Island, Rocky Reach, and Wells Dam (to be consistent with McNary and Bonneville dams). Our estimate of escapement to mid-Columbia River dams is consistently higher than that provided by dam counts. The estimates most comparable to our estimates are those based on traditional dates at upstream dams. The most likely explanation for our higher estimates is that the summer Chinook salmon migration is distributed over a longer period in the mid-Columbia than that assumed by the dates used to differentiate races; i.e. summer Chinook salmon are actually being counted as spring or fall Chinook salmon. However, among

the fish we PIT tagged, the only dam where more than 4.1% passed outside the dates assumed in Table 3 was Wells Dam at 10.7%.

Table 10. Summer Chinook salmon escapement to Bonneville, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams as estimated using PIT tags, using traditional dates, TAC dates, and traditional dates plus a 15 day lag in the starting date.

Dam	Bonne-ville	McNary	Priest Rapids	Rock Island	Rocky Reach	Wells
PIT Tag Estimate	NA	68,814	64,411	64,150	43,848	31,477
Median upstream migration rate Estimate (from Table 4)	NA	47,184	48,860	52,044	36,151	21,325
Traditional Dates	6/1-7/31	6/9-8/8	6/14-8/13	6/18-8/17	6/20-8/19	6/29-8/28
	101,874	63,872	57,792	62,950	42,978	27,615
TAC Dates	6/15-7/31	6/24-8/8	6/14-8/13	6/18-8/17	6/20-8/19	6/29-8/28
	90,554	42,559	57,792	62,950	42,978	27,615
TAC dates with 15 day lag upstream	6/15-7/31	6/24-8/8	6/29-8/13	7/2-8/17	7/4-8/19	7/13-8/28
	90,554	42,559	45,249	46,089	32,855	15,726

This project willcontinue in 2007. One addition in 2007 is that we do plan to PIT tag approximately 200 late spring/early summer Chinook salmon between May 20 and June 15 to better account for the transition between spring and summer Chinook salmon runs. Based on PIT tag recoveries, we hope to better differentiate the two runs and thereby provide better upstream abundance estimates.

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Whiteaker J., J.K. Fryer, and A. Stillinger. 2007. Age and length composition of Columbia Basin Chinook and sockeye salmon and steelhead at Bonneville Dam in 2006. 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 summer Chinook salmon in 2006.

Dam and site	Weir (bolded) and probability of detection at weir											Overall detection probability
Bonne-ville	**N**	**1**	**2**	**3**	**4**							
BO4	586	99.5	99.5	99.5	99.3							100.0
BO1	4	100.0	100.0	100.0	100.0							100.0
McNary	**N**	**1**	**2**	**312**	**311**	**309**	**308**	**306**	**305**	**303**	**302**	
MC1	130	98.5	99.2	60.8	67.7	60.8	43.1	11.5	100.0	69.2	40.0	100.0
	N	**1**	**2**	**3**	**312**	**311**	**309**	**308**	**306**	**303**	**302**	
MC2	341	99.7	100.0	100.0	65.7	62.2	62.5	62.2	61.9	67.2	64.2	100.0
Priest Rapids	**N**	**3**	**7**									
East	353	89.6[3]	100.0									100.0
	N	**3**	**5**									
West	43	72.1	100.0									100.0
Rock Island	**N**	**1-2**	**3-4**									
Left	102	100.0	100.0									100.0
	N	**5-6**	**7-8**									
Middle	30	96.7	98.8									100.0
	N	**09-0A**	**0B-0C**									
Right	253	98.8	69.1									99.6
	N	**1-2**	**3-4**									
Rocky Reach	257	79.3	70.0									93.8
Wells	**N**	**1-2**	**3-4**									
Left	113	100.0	100.0									100.0
	N	**5-6**	**7-8**									
Right	99	100.0	100.0									100.0
Ice Harbor	**N**	**438**	**437**	**436**	**435**							
South	18	100.0	100.0	100.0	100.0							100.0
North	10	60.0	100.0	100.0	100.0							100.0
Lower Granite	**N**	**733**	**732**	**731**	**730**							
	23	100.0	100.0	100.0	100.0							100.0

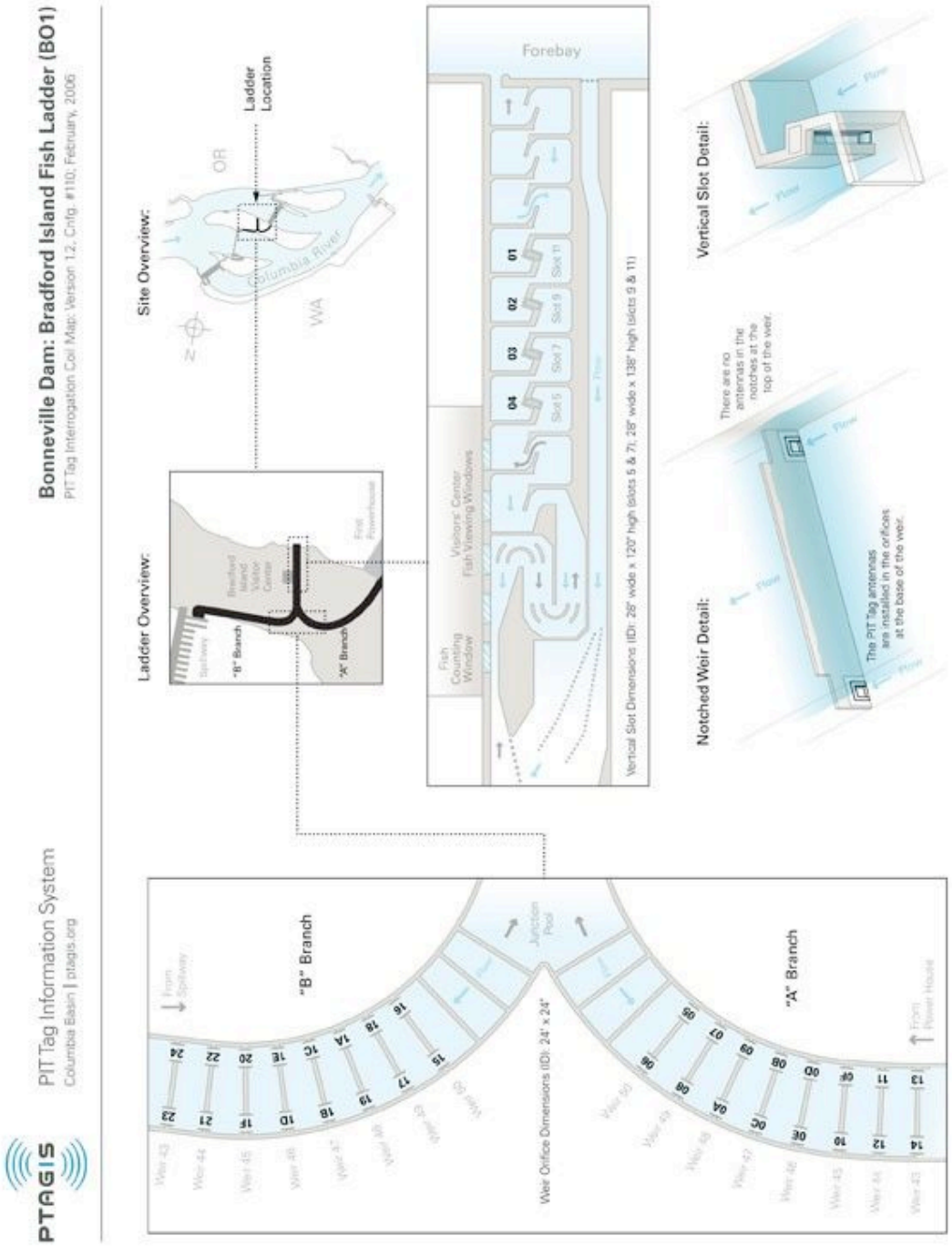
[3] Fish bypass this weir when the Priest Rapids adult fish trap is in operation.

Table A2. Distribution of summer Chinook salmon passage by fish ladder for dams with multiple fish ladders as estimated by PIT tag detections in 2006.

Dam	Right Bank[4]	Left Bank	Center
Bonneville	99.3%	0.7%	
McNary	72.4%	27.6%	
Priest Rapids	10.8%	89.2%	
Rock Island	65.7%	26.5%	7.8%
Wells	46.7%	53.3%	
Ice Harbor	35.6%	64.4%	

[4] 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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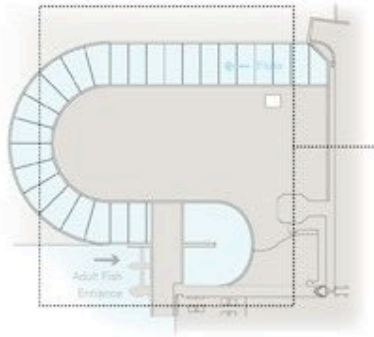
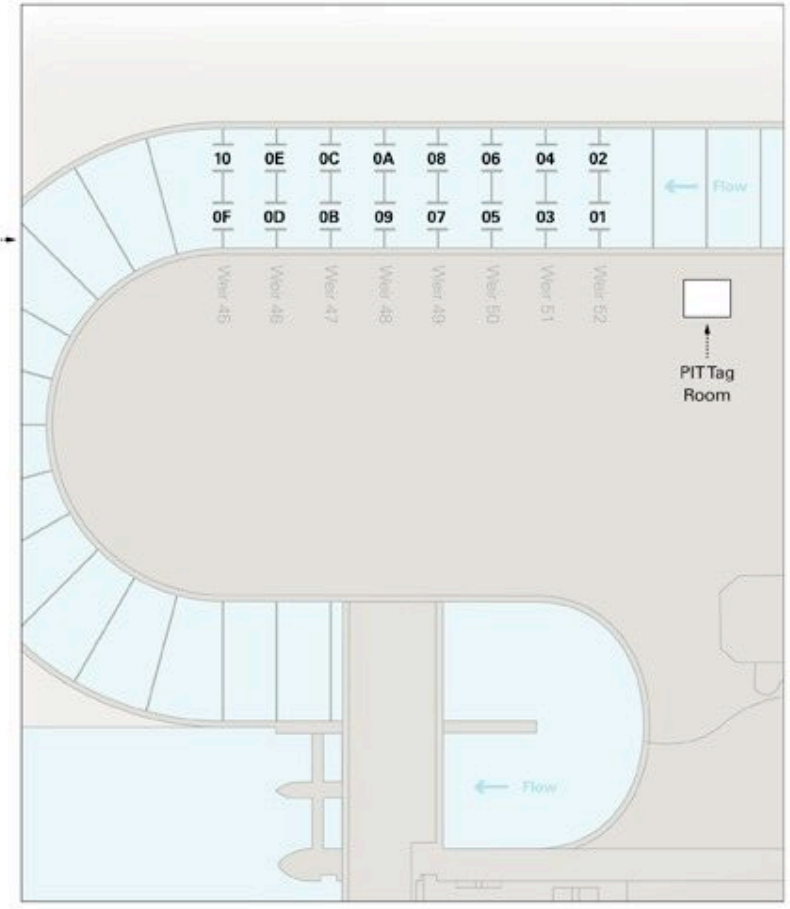
Bonneville Dam: Cascades Island Fish Ladder (BO2)

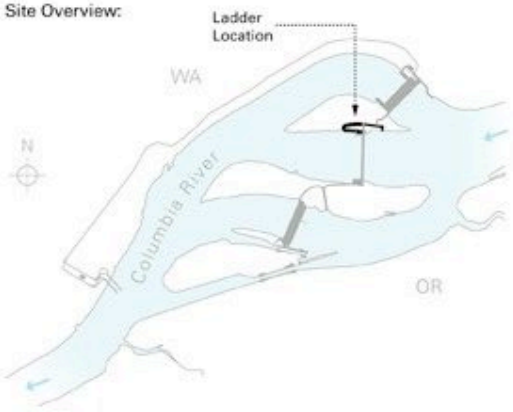
PIT Tag Interrogation Coil Map: Version 1.1, Cnfg. #100; February, 2002
Orifice Dimensions: 24" wide x 24" high

Ladder Overview:





Site Overview:



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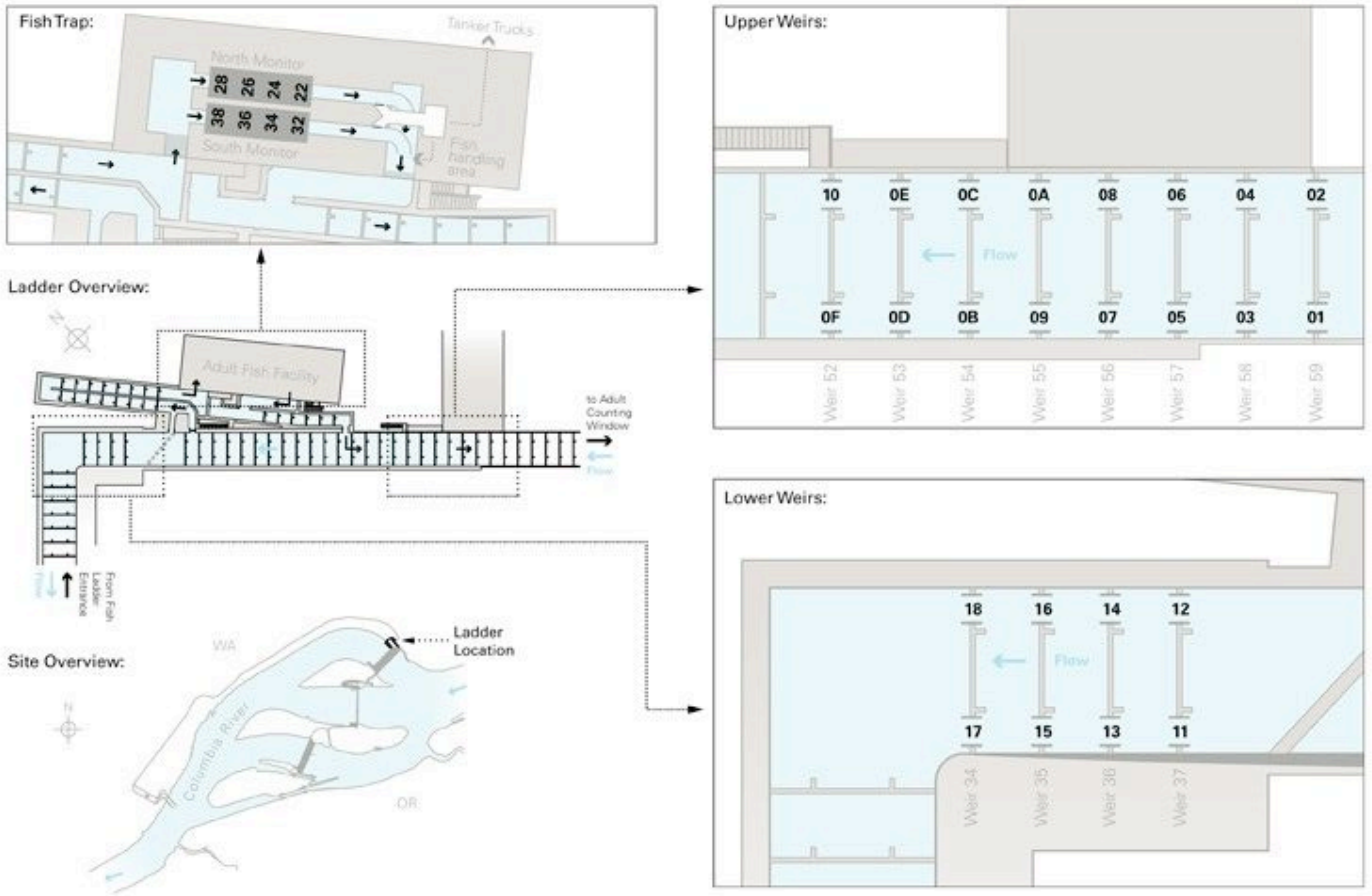
Bonneville Dam: Washington Shore Fish Ladder and AFF (BO3)

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

Orifice Dimensions: 18" wide x 18" high



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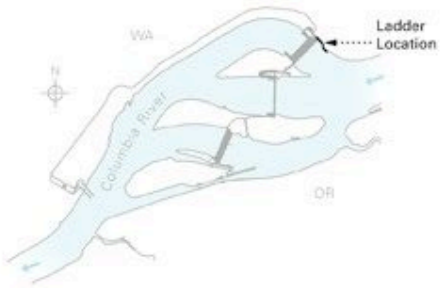
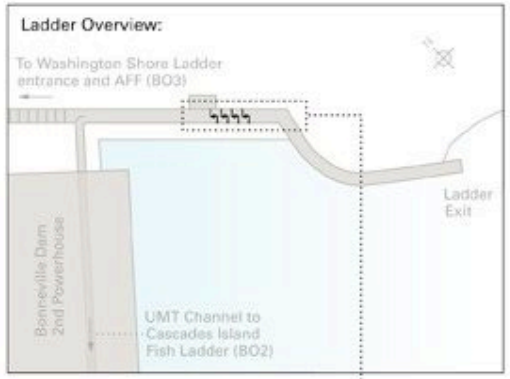
Bonneville Dam: Washington Shore Ladder Vertical Slots (BO4)

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)

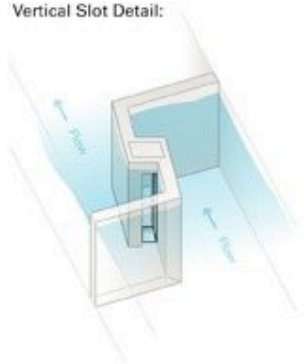
Site Overview:



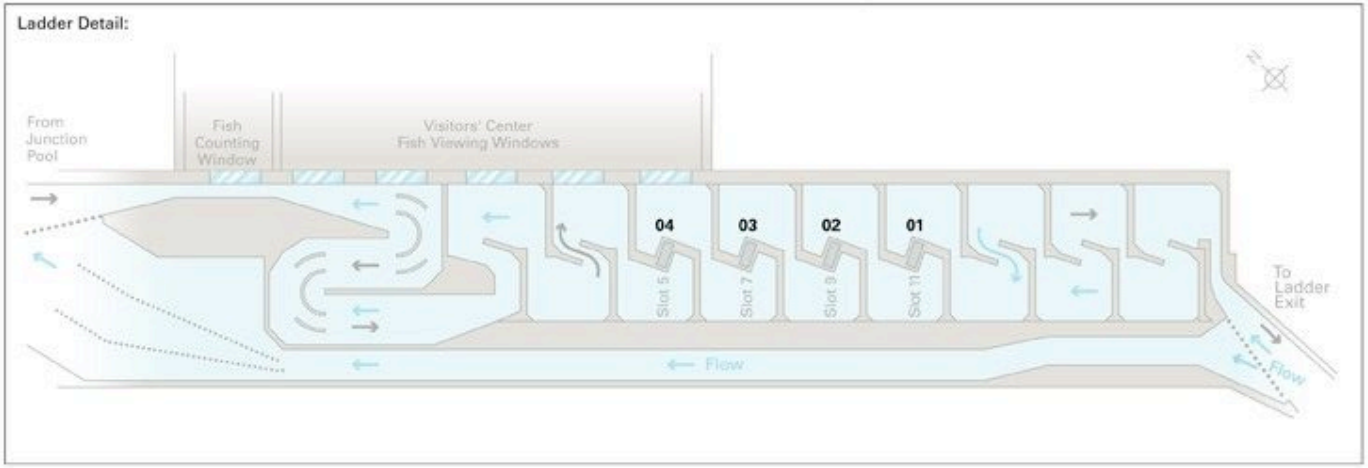
Ladder Overview:



Vertical Slot Detail:



Ladder Detail:



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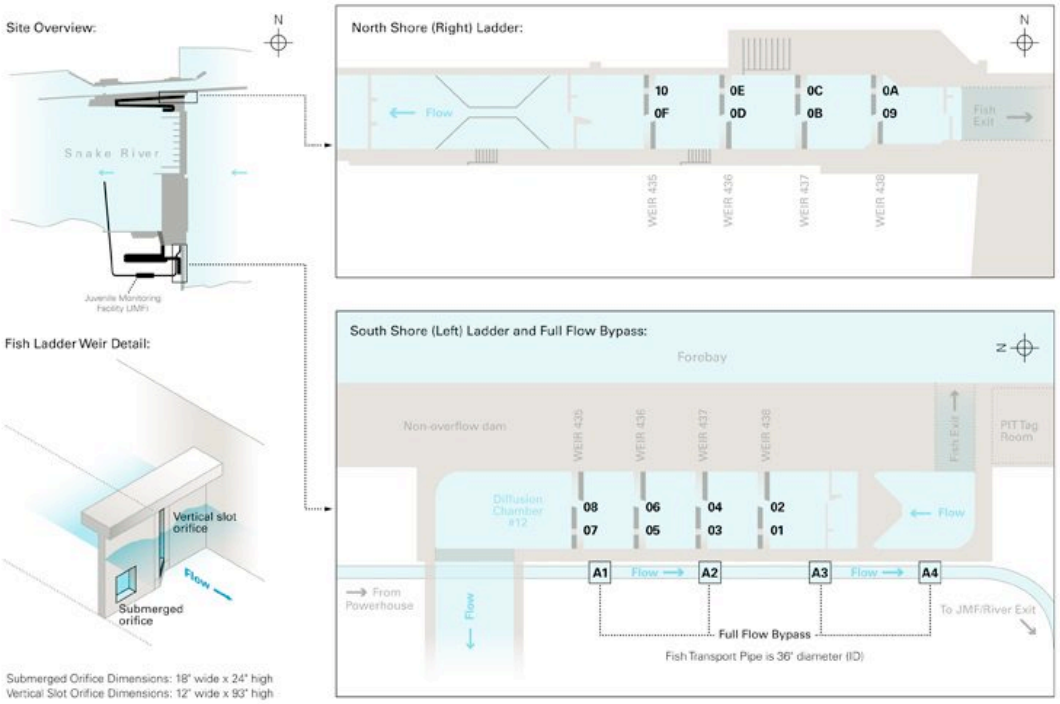
Ice Harbor Dam Fish Ladders and Full Flow Bypass (ICH)

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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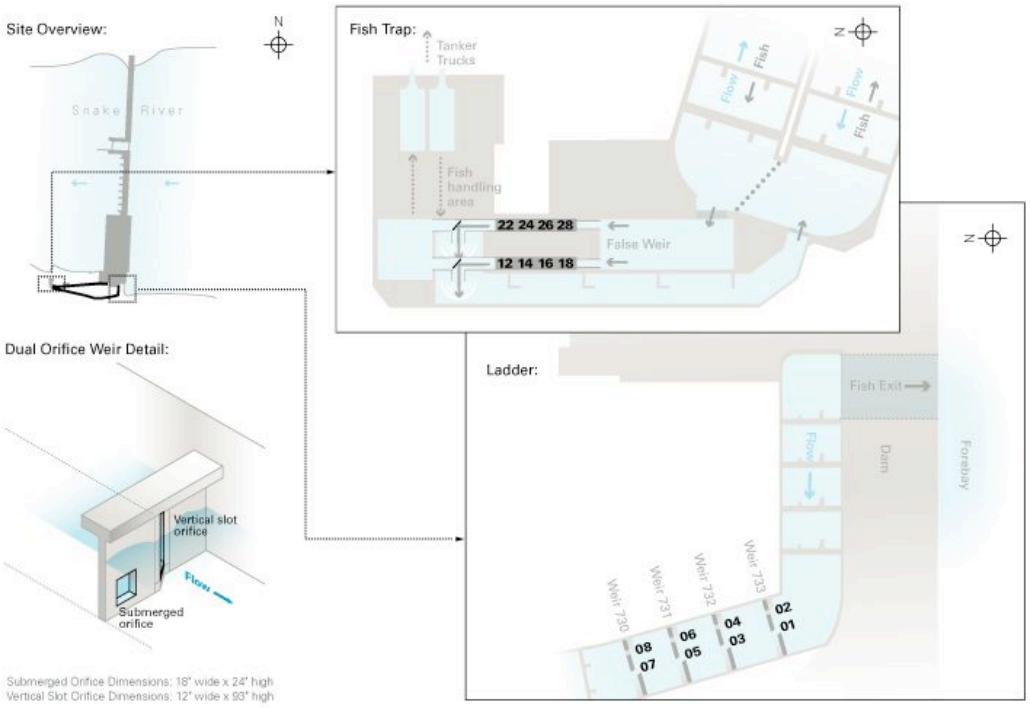
Lower Granite Dam Fish Ladder and Trap (GRA)

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



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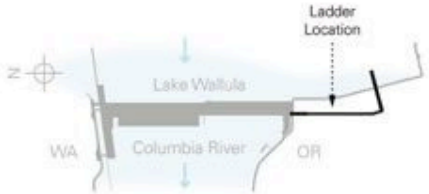
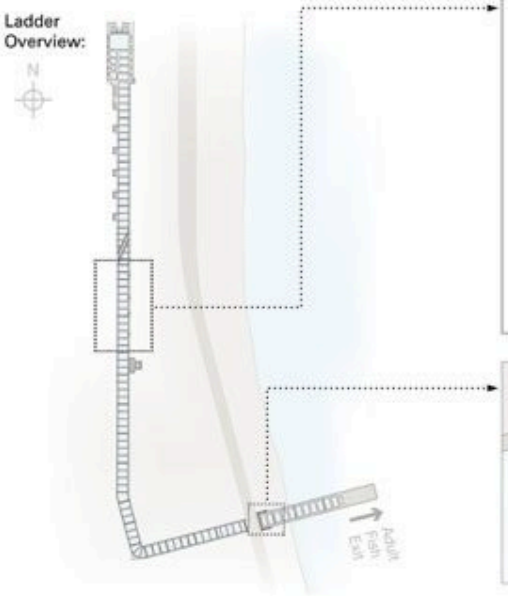
McNary Dam: Oregon Shore Ladder (MC1)

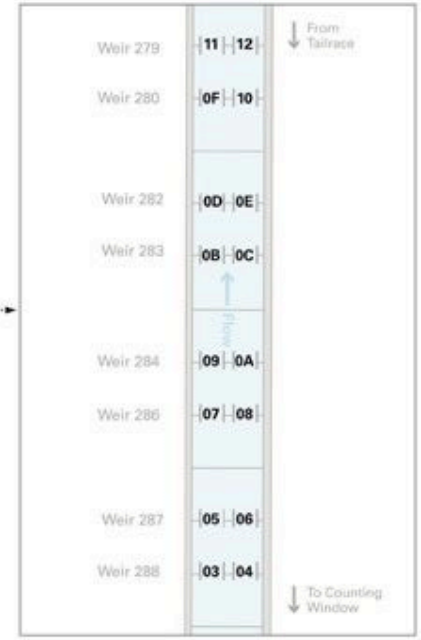
PIT Tag Interrogation Coil Map: Version 1.2, Cnfg. #100; February 2002

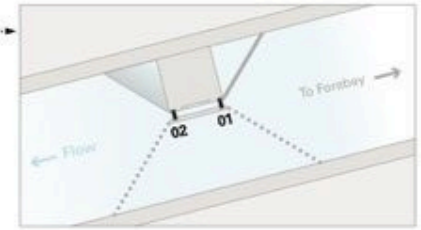
Site Overview:



Ladder Overview:

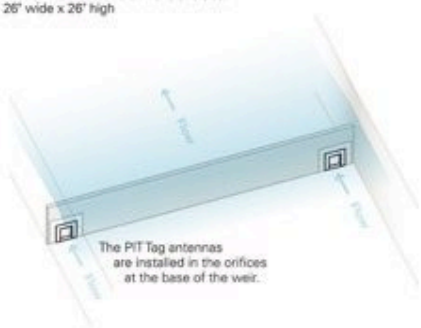






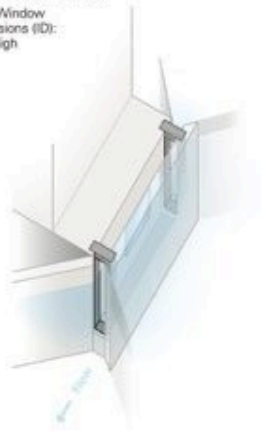
Overflow Weir Detail:

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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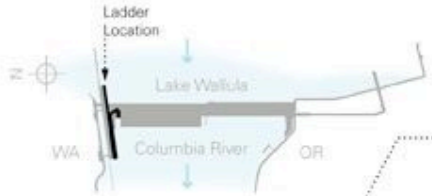
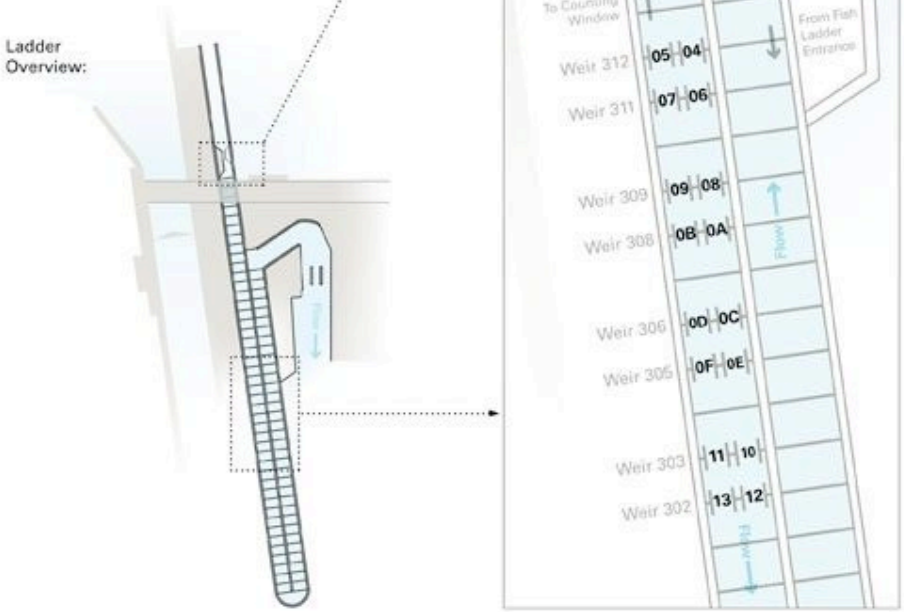
McNary Dam: Washington Shore Ladder (MC2)

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

Site Overview:

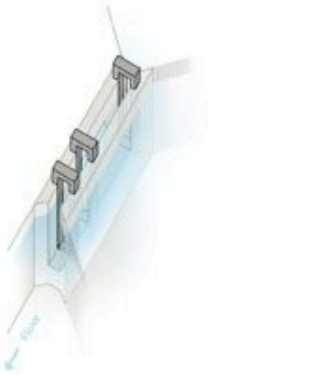


Ladder Overview:



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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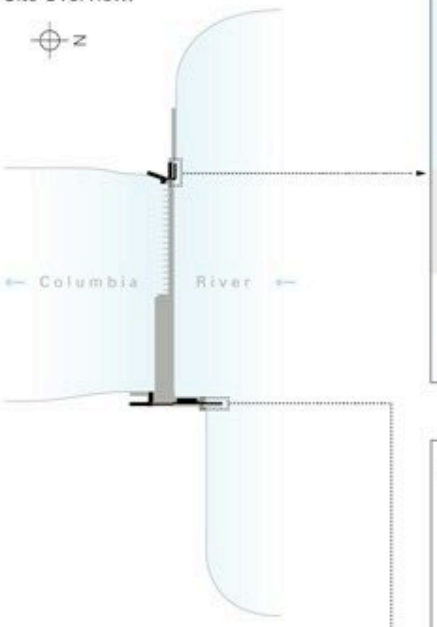
Columbia Basin

Priest Rapids Dam Fish Ladders (PRA)

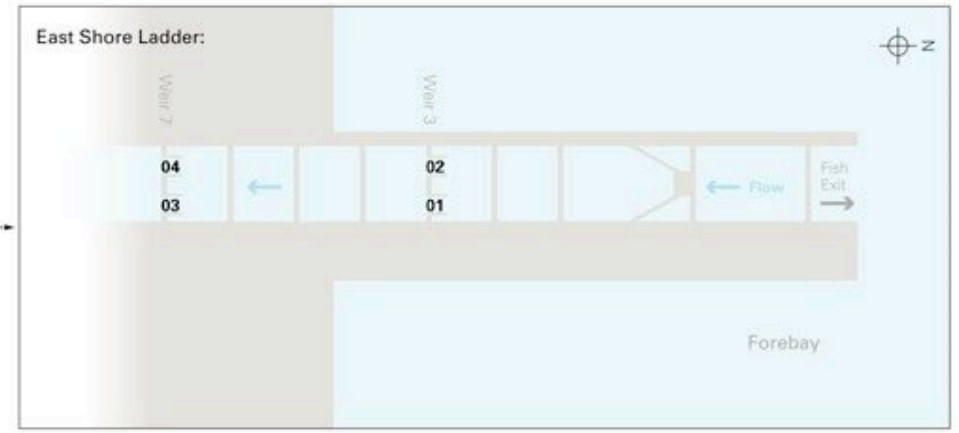
Interrogation Coil Map Revised: May, 2003 v.1.0, Cnfg. #100

Site Overview:



West Shore Ladder:

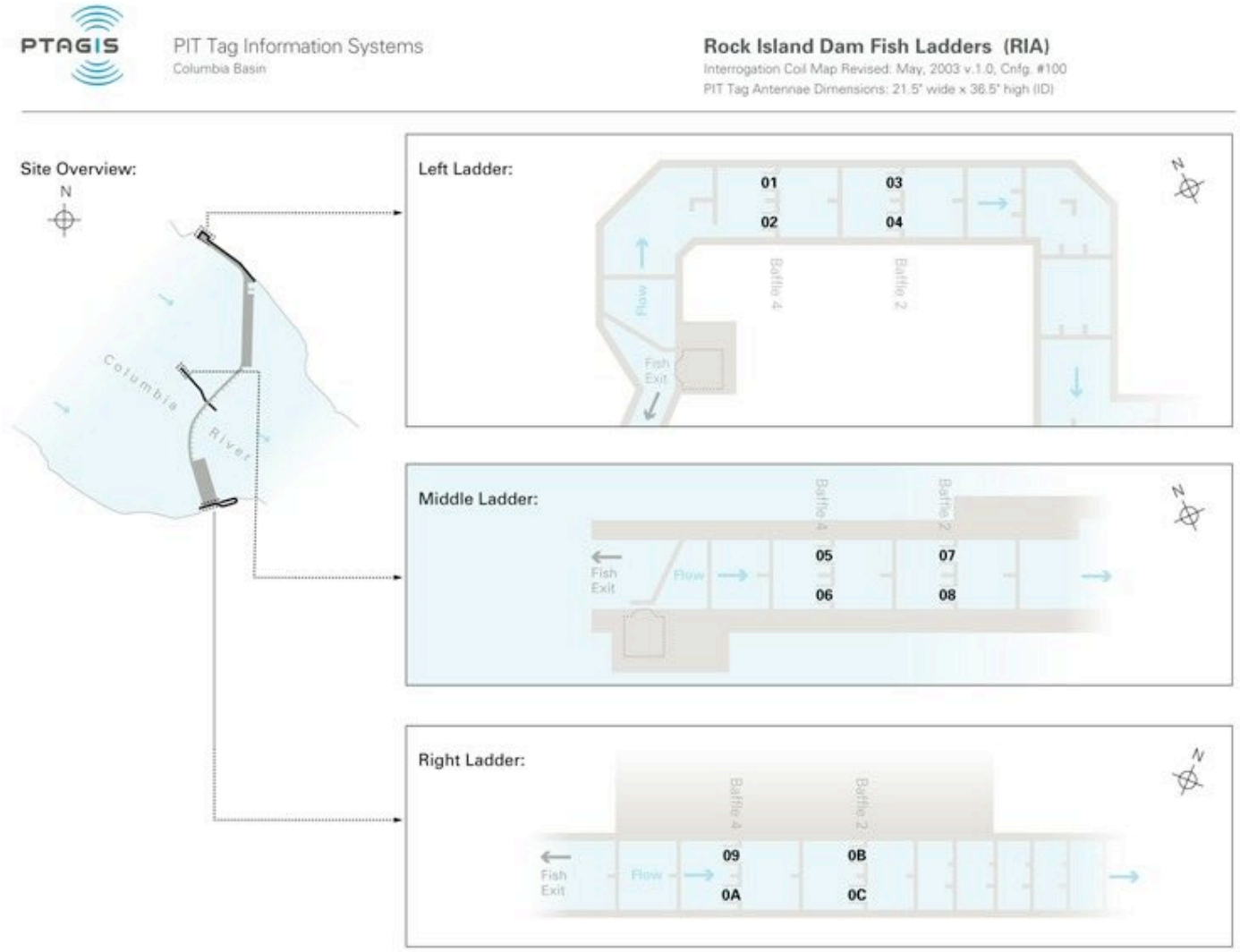
East Shore Ladder:



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

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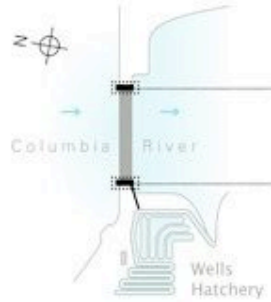
PIT Tag Information Systems
Columbia Basin

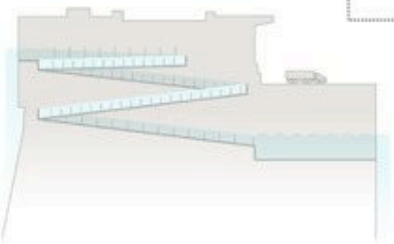
Wells Dam Fish Ladders (WEA)

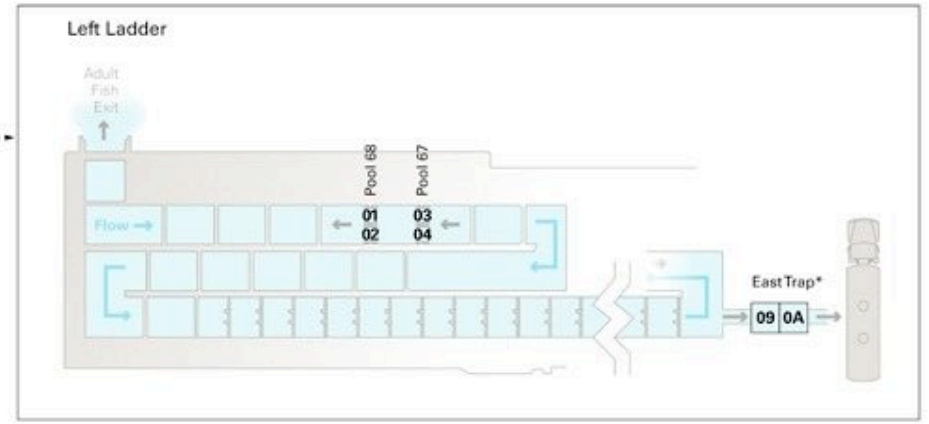
PIT Tag Interrogation Map: Version 1.1, Cnfg. #110; Revised June, 2004
Ladder Orifice Dimensions: 21" wide x 34.5" high

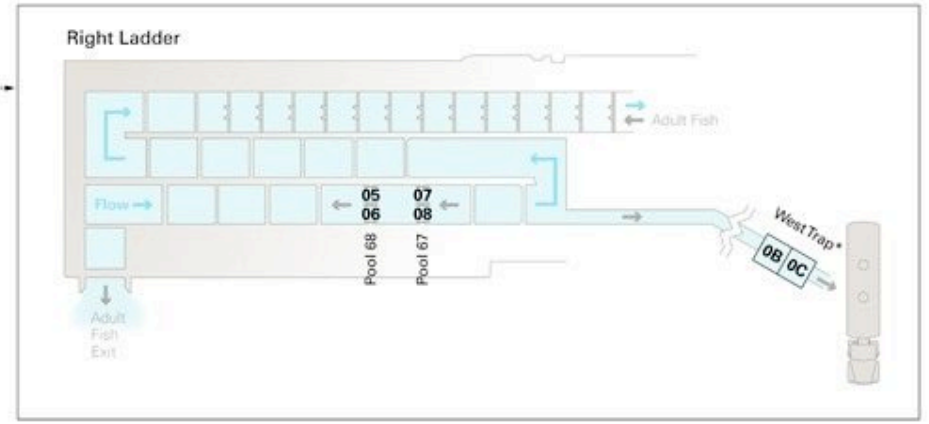
Site Overview:



Elevation View:







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