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Fish Ecology Division

Northwest Fisheries Science Center

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Seattle, Washington

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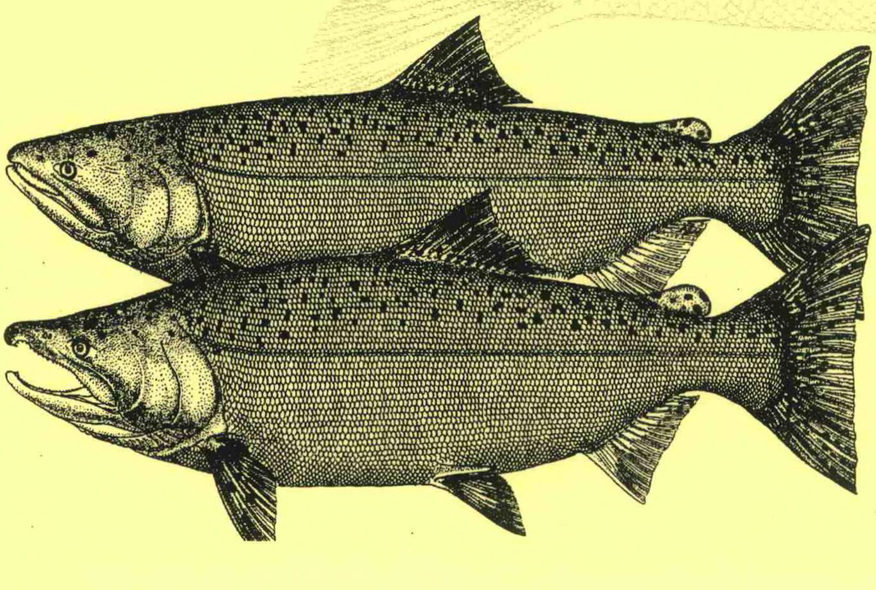
December 2009



Transportation of Juvenile Salmonids on the Snake River, 2007: Final Report for the 2003 Fall Chinook salmon Juvenile Migration

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Report of research by

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EXECUTIVE SUMMARY

The National Marine Fisheries Service began annual studies in 2001 to evaluate the efficacy of transporting Snake River fall Chinook salmon smolts from Lower Snake River hydropower projects. From 2001 through 2003, we tagged hatchery subyearling fall Chinook salmon *Oncorhynchus tshawytscha* at Lyons Ferry Hatchery and released them in the Snake River 81 km above Lower Granite Dam at river kilometer 254. Here we report the final results for fish tagged in 2003. We also report adult returns from fall Chinook salmon collected, tagged, and transported from Lower Granite Dam during September and October 2003 to develop an index of adult returns from fish transported in fall.

Our original study was designed to compare the smolt-to-adult return rate (SAR) of fish transported as juveniles from Lower Granite Dam with that of fish released to migrate inriver and not detected at any collector dam. However, recent data has shown that the method used to estimate numbers of non-detected yearling Chinook migrants cannot produce unbiased estimates of non-detected Snake River fall Chinook salmon. The method assumes equal probabilities of downstream detection among fish from each cohort after release; however, we now know that a considerable proportion of fall Chinook overwinter within the migration corridor.

Subyearling fish may delay the downstream migration for several months, passing dams during winter when bypass systems are dewatered, or during the following spring. Thus, since at present there is no way to reliably estimate numbers of non-detected fish that survived to Lower Granite Dam, we report only the SARs of study fish with known juvenile passage histories. These include fish transported and bypassed as subyearlings in 2003, fish detected migrating the year following release (holdover fish), and fish from the fall transport index group.

From August to November 2007, we detected no fish from the Lyons Ferry releases. We did detect seven age-4-ocean adults marked for the transport index group of fall Chinook salmon juveniles in September/October 2003. Adults returning in 2007 completed adult returns from smolts tagged during the 2003 study year. Total adult returns from juveniles marked in 2003 at Lyons Ferry Hatchery and released above Lower Granite Dam were very poor; only 22 adults returned to Lower Granite Dam from all three treatment groups (transported, bypassed, and holdover fish), and all but one fish returned as either a jack or age-2-ocean adult.

The combined SAR (jacks through age-4-ocean fish) for Lyons Ferry Hatchery study groups was 0.09% (95% CI, 0.05-0.14%) for transported, 0.13% (0.02-0.24%) for bypassed, and 3.64% (0.00-8.68%) for holdover groups. The SAR for fall transport index fish was 3.84% (3.08-4.60%).

For study fish from Lyons Ferry Hatchery, the combined conversion rates between dams (Bonneville to McNary and McNary to Lower Granite) were 72.2% for transported (13 of 18 fish), 100% for bypassed (4 of 4 fish), and 100% for holdover fish (2 of 2 fish). For transport index fish marked in fall, the overall conversion rate was only 40% (84 of 209 fish), with large numbers failing to convert both from McNary to Lower Granite and from Bonneville to McNary Dam. The lower river stretch, from Bonneville to McNary Dam, encompasses the Zone 6 Native American fishery, and conversion rates were not adjusted for take in this fishery. Too few adults returned to make meaningful comparisons of conversion rates among transported, bypassed, and holdover migration histories.

Results from the small number of returning adults from 2003 releases do not change the conclusion of Williams et al. (2005) that "transportation appeared to neither greatly harm nor help" Snake River fall Chinook salmon. For the 2003 releases overall, the transported group had slightly lower SARs than the bypassed group, but the highest SARs were seen in holdover fish, or those that delayed migration. Fall transport index fish also had relatively high SARs.

CONTENTS

INTRODUCTION

In 2007, we continued studies to evaluate transportation of juvenile salmonids as a means to mitigate for downstream losses that result from passage through the lower Snake and Columbia River federal hydropower system. The primary objective of this study was to compare smolt-to-adult return rates (SARs) of juvenile Snake River fall Chinook salmon *Oncorhynchus tshawytscha* transported to a release site below Bonneville Dam to those of their cohorts allowed to migrate inriver. Detections of PIT-tagged smolts released to migrate inriver also provided data for short-term survival estimates between the point of release and downstream dams (Muir et al. 2001).

During transportation study years 1995-1996 and 1998-1999, we PIT-tagged (Prentice et al. 1990) wild and hatchery spring/summer yearling Chinook salmon smolts at Lower Granite Dam. After adult returns from these releases were complete, we compared the SARs of smolts transported and released below Bonneville Dam to those of smolts released to the tailrace of Lower Granite Dam to migrate inriver (Marsh et al. 1996, 1997, 2000). Migrating smolts detected at downstream dams were returned to the river to continue their migration.

However, in evaluating SARs from those years (and from fish PIT-tagged for other studies upstream from Lower Granite Dam during the same years), we found that smolts collected and bypassed at multiple dams during inriver migration often survived to adulthood at lower rates than those collected and bypassed only at Lower Granite Dam. Furthermore, study fish not detected at any dam (because they passed each dam via spillways or turbines or were not detected in juvenile bypass facilities), usually returned at higher rates than fish bypassed at downstream collector dams (Williams et al. 2005).

Thus, in hindsight, study designs from 1995 through 1999 did not provide sufficient information to compare returns of transported fish to those of fish that were not transported and also not detected at a collector dam. We therefore redesigned the study in 2000 to compare SARs of transported fish to those of inriver migrants with no detection history at a collector dam, including Lower Granite Dam.

We originally designed the transport study for fall Chinook salmon to compare SARs of fish transported from Lower Granite Dam with those of fish not detected at a collector dam. However, recent data (Conner et al. 2005) has shown that the model used to estimate numbers of non-detected spring migrants (Sanford and Smith 2002) is not appropriate for estimates of non-detected Snake River fall Chinook salmon. A critical assumption of the model used to estimate juvenile survival is violated when some fall Chinook delay downstream migration (Buchanan and Skalski 2006). Estimates of juvenile survival based on this model consider the joint probability of migration and survival; however, for fall Chinook salmon, the probability of migration is unknown. These juveniles may migrate throughout the year, but detection systems at the dams are not operated year-round; fish that migrate when detection systems are not operated have no possibility of detection, thus no data on migration probability is available (Buchanan and Skalski 2006).

Because at present there is no method to estimate the number of non-detected fall Chinook salmon, we report SARs only for fish with known passage histories. These include fish transported or bypassed in the year of their release (2003) and holdover fish, or those detected during migration in the year following release (2004). In a related effort, we also PIT-tagged groups of fall Chinook salmon collected at Lower Granite Dam during September and October 2003 and transported them along with non-tagged fish. We did not release cohort groups of PIT-tagged fish to the tailrace, so have no comparison to this transported population. Thus, this portion of the study just provides an index of SAR for fish transported in the fall.

The more complex life history of Snake River fall Chinook salmon also precluded us from making estimates of differential delayed mortality (*D*) because insufficient data is available to estimate survival to the tailrace of Bonneville Dam for Snake River fall Chinook; a value needed to estimate *D*.

Here we report final results from the 2003 Snake River fall Chinook salmon tagging year, which was completed with the recovery of adults in 2007. Information from ongoing adult returns of fall Chinook salmon tagged from 2004 through 2006 is also provided here (Appendix B). Adult returns are not yet available for Snake River fall Chinook salmon smolts PIT-tagged for transport studies during 2007. Data from these returns will be reported for fall Chinook beginning in 2008, and complete results will be reported when adult returns are complete in 2012.

METHODS

Juvenile Collection and Tagging

In 2003, wild Snake River fall Chinook salmon juveniles were not available in sufficient numbers for tagging to evaluate transportation strategies. Therefore, we used hatchery fish as surrogates for this study year. Previous survival studies of migrating juveniles (Smith et al. 2002) have shown that performance of hatchery subyearling fall Chinook salmon is similar to that of wild fish if the hatchery fish are raised to approximately the same size as wild fish (referred to as surrogate-sized, approximately 70 mm). Hatchery subyearling Chinook are commonly reared to a larger size (approximately 100 mm) because fish of this size tend to have higher survival rates. We used hatchery fish from Lyons Ferry Hatchery, located on the Snake River between Little Goose and Lower Monumental Dams. Unfortunately, we were unable to obtain surrogate-size fish, as we have in previous years (Marsh et al. 2008); fish available in 2003 were normal, production-size subyearlings.

As in previous years, fish were PIT tagged in a mobile tagging trailer set up at the end of the raceway containing the study fish. Dip nets were used to transfer fish from the end of the raceway to a live well in the trailer. Fish were then sorted to remove fish that were too small or showed signs of disease or other conditions that would have reduced post-tagging survival. After sorting, fish were sent to tagging stations, where each fish was injected with a PIT tag and measured (fork length). Unusual body conditions were also noted at the time of tagging. Tagged fish were transferred via gravity-fed pipes to an awaiting truck. Each day at the end of the tagging session, fish were transported by truck up the Snake River to Couse Creek (rkm 254), 81 km above Lower Granite Dam. Upon arrival at the release site, river water was slowly passed through the tank to gradually acclimate fish in order to avoid thermal shock from too great a temperature difference between tank and river water at release.

To determine release-group sizes in 2003, we calculated the number of fish required to test a null hypothesis, that there was no difference between the SARs of transported and inriver migrant fish, vs. the alternative hypothesis, that the T/I ratio was 1.4 or greater. For a given type I error rate ($t_{\alpha/2}$, rejection of a true null hypothesis) and type II error rate (t_{β}, acceptance of a false null hypothesis), the number of fish needed for tagging was determined as:

(1) $$\ln\left(\frac{\mathrm{T}}{\mathrm{I}}\right)-\left(t_{\frac{\alpha}{2}}+t_{\beta}\right)\times \mathrm{SE}\left(\ln\left(\frac{\mathrm{T}}{\mathrm{I}}\right)\right)\approx 0$$

and

(2)
$$SE\left(\ln\frac{T}{I}\right) = \sqrt{\left(\frac{1}{n_T}+\frac{1}{n_I}\right)} = \sqrt{\frac{2}{n}}$$

where n is the number of adult returns per treatment (for either n_T transport or n_I inriver migrant groups). The previous two statements imply that the sample of adults needed is:

(3)
$$n = \frac{2\left(t_{\frac{\alpha}{2}} + t_{\beta}\right)^2}{\left(\ln\left(\frac{T}{I}\right)\right)^2}$$

Therefore, if $\alpha = 0.05$ and $\beta = 0.20$, and if we wished to discern a difference of 100% (T/I = 2.0), and we expected a transport SAR of at least 1.0% for each species, the sample sizes needed at Lower Granite Dam were:

$$n = 34$$
$$N_T = 3{,}400$$
$$N_I = 6{,}800$$
$$\text{Total juveniles} = 10{,}200$$

Where N_T is the number of juveniles needed for the transport cohort and N_I is the number of fish needed for the inriver migrating cohort (3,400 × 2.0).

However, because we released fish upstream from Lower Granite Dam, a release number greater than N_I was needed. This is because not all fish released above the dam will survive to reach the dam, and of those that reach the dam, not all will be collected. Therefore, based on previous estimates from PIT-tag detections, we assumed 60% survival to Lower Granite Dam and an FGE of 50% at the dam. Thus to obtain N_I of 6,800 required the release of approximately 22,750 fish above the dam.

The inriver migrant reference group was comprised of fish that were never detected at a collector dam during a period when collection for transportation was occurring. Collector dams are Lower Granite, Little Goose, and Lower Monumental Dams on the Snake River and McNary Dam on the Columbia River. For the three Snake River dams, collection for transportation began prior to the fall Chinook salmon juvenile migration and continued until the facilities were closed in late fall. Therefore, any inriver migrant study fish detected at one of these facilities was likely collected and transported, and was therefore excluded from the study.

At McNary Dam, collection for transportation began on 27 June 2003 and continued until the facility closed in fall. During the period before collection started at McNary Dam, all tagged and non-tagged fish were returned to the river. For this period, detected fish in the inriver migrant group were treated the same as the general population. Therefore, detection at McNary Dam prior to 27 June was not an exclusion criteria for the inriver migrant group. As at the Snake River dams, detection after the beginning of collection for transportation resulted in exclusion from the study.

In 2004, collection for transportation at McNary Dam began on 23 June. Again, detection of an inriver migrant study fish prior to this date did not result in exclusion from the study. Detection at bypass dams that do not collect for transportation (i.e., Ice Harbor, John Day, and Bonneville) also did not result in exclusion from the study, since all fish detected at these facilities are returned to the river, along with the general population of non-tagged fish.

Based upon previous PIT-tag detections, we estimated that 15-30% of the subyearling Chinook salmon that passed Lower Granite Dam without being detected would never be subsequently detected at a collector dam downstream. Therefore, to provide an adequate number of inriver migrant fish that would never be detected, we needed to release roughly 150,000 (22,712/0.15) PIT-tagged fish above the dam. This sample size also provided transport fish to be collected at Lower Granite Dam in numbers well in excess of study design requirements. We decided to return excess fish collected at Lower Granite Dam to the river to be used for evaluations of inriver survival to below John Day Dam. At the time, we believed this would provide data to begin the process for calculating post-transport delayed mortality.

A transport group was created at Lower Granite Dam by setting the separation-by-code system to divert 80% of PIT-tagged study fish collected to transportation raceways. The remaining fish were diverted back to the river to aid in creating reach survival estimates.

Inriver Migration

At all four collector dams (Lower Granite, Little Goose, Lower Monumental, and McNary Dams), fish detected on coils leading to the raceways were assumed to have been transported (unless records showed otherwise), while fish detected on diversion system coils were assumed to have been returned to the river. The only time fish passing through the McNary Dam juvenile fish facility were detected on coils leading to the raceways was after collection for transportation began on 27 June 2003.

Fall Transport Index Tagging

For a separate, but related evaluation, we PIT-tagged river-run subyearlings at Lower Granite Dam in September and October 2003 to develop an index of SARs for subyearling fish transported in fall. These fish were taken from the daily smolt monitoring sample. After tagging, we combined these fish with the general population collected at the facility for transport by truck to a release site below Bonneville Dam. We observed no mortality or tag loss from these fish, although post-tagging holding time was very short (< 1 h). This evaluation was needed to provide an index of SARs for fish collected and transported in fall because detections of study fish migrating this time of year (from our upstream releases) were insufficient for a precise estimate of SARs.

Adult Recoveries and Data Analysis

In 2007, we completed recoveries of adults tagged as juveniles in 2003 with the return of age-4-ocean fish; we expect very few, if any, age-5-ocean adults from these juveniles (none returned from 2001 releases) . Therefore, we completed the analyses for 2003 releases of fall Chinook salmon transportation studies after these age-4-ocean adults returned. Analyses were based on the SARs of juveniles observed (or tagged) at Lower Granite dam that subsequently returned as adults to Lower Granite Dam.

RESULTS

Juvenile Collection and Tagging

From 28 May through 5 June 2003, we PIT tagged a total of 53,714 subyearling Chinook salmon at Lyons Ferry Hatchery. Of these fish, 53,579 were released to the Snake River above Lower Granite Dam at rkm 254 (Table 1; Appendix Table A1). The target sample size was reduced to 50,000, about one-third of that originally planned (150,000) for two reasons. First, there were unexpected budget constraints that limited the scope of the study. Second, the hatchery could not provide surrogate-sized fish (~70 mm), so we tagged production-size fish instead (~100 mm). Since these larger fish have shown a considerably higher rate of downstream survival, fewer fish were needed to satisfy the study design. Based on mortality counts, post-marking delayed mortality (24-h) averaged 0.4% over the entire tagging season. In addition to the mortalities, there were 115 shed tags.

Table 1. Tag date, numbers tagged, and mean fork lengths of Lyons Ferry Hatchery subyearling fall Chinook salmon PIT-tagged and released as part of the Snake River fall Chinook salmon transportation study, 2003.

	Lyons Ferry Hatchery fall Chinook salmon		
Tagging date	Tag number	Release number*	Mean fork length (mm)
28 May 2003	8,748	8,728	100.1
30 May 2003	8,741	8,707	98.0
2 Jun 2003	11,559	11,544	100.9
3 Jun 2003	8,613	8,596	99.4
5 Jun 2003	16,053	16,004	100.2

* Release numbers adjusted for mortality and tag loss.

Inriver Migration

Flows at Lower Granite Dam were below average during summer 2003, and no summer spill was provided. As Lyons Ferry Hatchery study fish migrated seaward in 2003, 64.5% were detected at dams downstream from their release site. Of the 53,579 hatchery subyearling fall Chinook salmon tagged and released above Lower Granite Dam, 19,034 (35.5%) were never detected at a collector dam after release and 34,545 (64.5%) were detected after release. Of the detected fish, 30,349 were transported, with 16,085 transported from Lower Granite, 9,428 transported from Little Goose, 3,355 transported from Lower Monumental, and 1,481 transported from McNary Dam.

Of the remaining 4,196 detected fish, 3,962 were detected and returned to the river at one or more collector dam, with 7 detected as subyearlings during summer and fall 2003 and subsequently detected as yearlings during spring 2004, 48 were detected migrating only in spring 2004, and the remaining 179 fish had an unknown disposition. (Table 2 and Appendix Tables A3-A6).

Table 2. Summary of detection histories of PIT-tagged fall Chinook salmon smolts used for transportation evaluation, 2003.

Migration history	Total number	Number of detections			
		One	Two	Three	Four
		Released above Lower Granite Dam (n = 53,579)			
Not detected at a collector dam	19,034	--	--	--	--
Bypassed and returned to river at a collector dam	3,962	2,537	1,275	142	8
		Transported in spring 2003			
Transported from Lower Granite Dam	16,085	16,085	--	--	--
Transported from Little Goose Dam	9,428	7,849	1,579	--	--
Transported from Lower Monumental Dam	3,355	2,372	857	126	--
Transported from McNary Dam	1,481	867	494	113	7
Unknown disposition	179	115	57	7	0
		Holdovers (detected as yearlings in spring 2004)			
Not detected at a collector dam	10	8	2	0	0
Bypassed and returned to river at a collector dam in 2003	36	16	17	3	0
Bypassed and returned to river at a collector dam in 2003 and 2004	7	0	6	1	0
Transported from Lower Granite Dam	1	1	--	--	--
Transported from Lower Monumental Dam	1	1	0	0	--

As has been observed in various other studies, the passage distribution at Lower Granite Dam of production-sized juveniles from Lyons Ferry Hatchery was very compressed and much earlier than the distribution and timing of natural-origin fish (or surrogate-size fish in previous years). Figure 1 shows passage distribution at Lower Granite Dam for the production-size fish released in 2003 vs. that of the surrogate-size fish released in 2002.

At Lower Granite, Little Goose and Lower Monumental Dams, our goal was to transport 80% of the subyearling Chinook salmon collected. Proportions of subyearling Chinook salmon collected and diverted for transportation were 78.4, 78.3 and 75.2% at Lower Granite, Little Goose and Lower Monumental Dam, respectively.

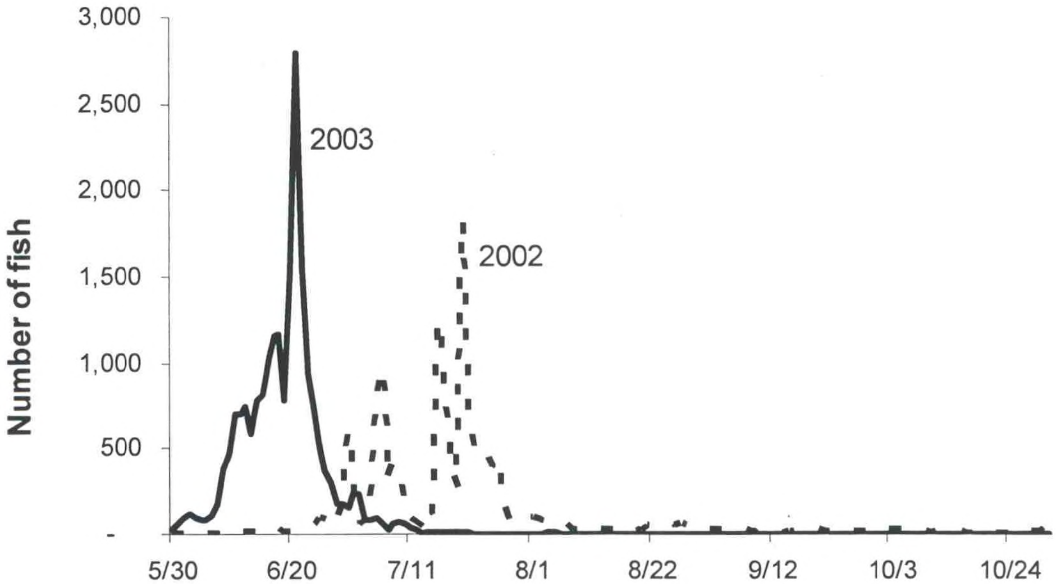

Figure 1. Passage patterns for fish passing Lower Granite Dam in 2003 and 2002. Fish released in 2003 were larger production-sized fish (~100 mm) while the fish released in 2002 were the smaller, surrogate-sized fish (~70 mm).

Fall Transport Index Tagging

In September and October 2003, an additional 2,552 river-run fall Chinook salmon were collected at Lower Granite Dam to develop a fall-transport index of SARs. These fish were PIT-tagged and transported by truck for release below Bonneville Dam along with transportation study fish (Table 3 and Appendix Table A2). All fish marked for the fall SARs index group were transported and thus were not detected again as juveniles after tagging at Lower Granite Dam.

Table 3. Tag date, numbers tagged, and mean fork lengths of fish PIT-tagged at and transported from Lower Granite Dam in September/October 2003 to determine a fall-transport index of SARs for Snake River fall Chinook salmon.

	Lower Granite Dam fall Chinook salmon	
Tag date	Number tagged	Mean fork length (mm)
5 Sep 2003	206	150.6
9 Sep 2003	205	154.5
11 Sep 2003	201	154.4
17 Sep 2003	127	158.5
19 Sep 2003	188	161.5
23 Sep 2003	102	169.8
25 Sep 2003	258	172.3
1 Oct 2003	211	178.1
3 Oct 2003	154	177.8
7 Oct 2003	150	180.1
9 Oct 2003	150	182.2
15 Oct 2003	99	187.5
17 Oct 2003	100	187.2
21 Oct 2003	101	187.4
23 Oct 2003	100	187.4
29 Oct 2003	100	189.8
31 Oct 2003	100	190.6

Adult Recoveries and Data Analysis

We began recovering jacks from the 2003 releases at Lower Granite Dam in 2004. In November 2007, we completed recoveries from this release year with the collection of age-4-ocean adults. Because very few, if any, age-5-ocean adults will return, we considered the study complete with the return of age-4-ocean adults. Final results by study group and age-class are shown in Table 4. Considerably more fish returned from the fall transportation index group (Table 5)

Table 4. Returns of hatchery fall Chinook salmon by juvenile migration history and age-class (with juvenile numbers) for fish released for Lower Granite Dam transport studies in 2003.

	Returns by age-class					SAR	
Juvenile numbers	Jack	2-ocean	3-ocean	4-ocean	5-ocean	(%)	95% CI
	Transported from Lower Granite Dam						
16,085	6	9	0	0	-	0.09	(0.05-0.14)
	Bypassed at collector dams						
5,210	3	2	0	0	-	0.13	(0.02-0.24)
	All holdovers (transports and migrants)						
55	1	0	1	0	-	3.64	(0.00-8.68)

Table 5. Fall Chinook salmon returns for fish PIT-tagged at Lower Granite Dam in September/October 2003 to provide and index SAR for fall transported fish.

	Returns by age-class					SAR	
Juvenile numbers	Jack	2-ocean	3-ocean	4-ocean	5-ocean	(%)	95% CI
2,552	34	28	29	7	-	3.84	(3.08-4.60)

Smolt-to-Adult Returns (SARs)

Study fish tagged in 2003 were much larger than those tagged in 2001 and 2002, but adult returns from fish tagged in 2003 were very poor nonetheless, with only 5 bypassed and 15 transported adults. Given these considerations, we believe that a valid comparison cannot be made between SARs from releases in 2003 and those from releases in the previous two years. However, we can report the following general observations. First, nearly all fish tagged at Lyons Ferry Hatchery returned as jacks or age-2-ocean adults. Only two adults returned after more than 2 years at sea. Second, adult return numbers mirrored the juvenile passage pattern, with virtually all adults returning from fish that passed Lower Granite Dam early in the juvenile migration period prior to 29 June (Figure 2). The high SARs of mid-August shown in Figure 2 were the result of one adult that returned from juvenile releases over a 5-day block in which 0 to 1 juveniles passed the dam per day. Only 5 bypassed adults returned, so we were unable to establish any temporal pattern related to juvenile passage timing for this group. For river-run fall Chinook salmon tagged for a fall transport index during September and October 2003, SARs ranged from 2.0 to 6.0% (Figure 3). Overall, SARs varied little in relation to the juvenile tagging period of fall 2003.

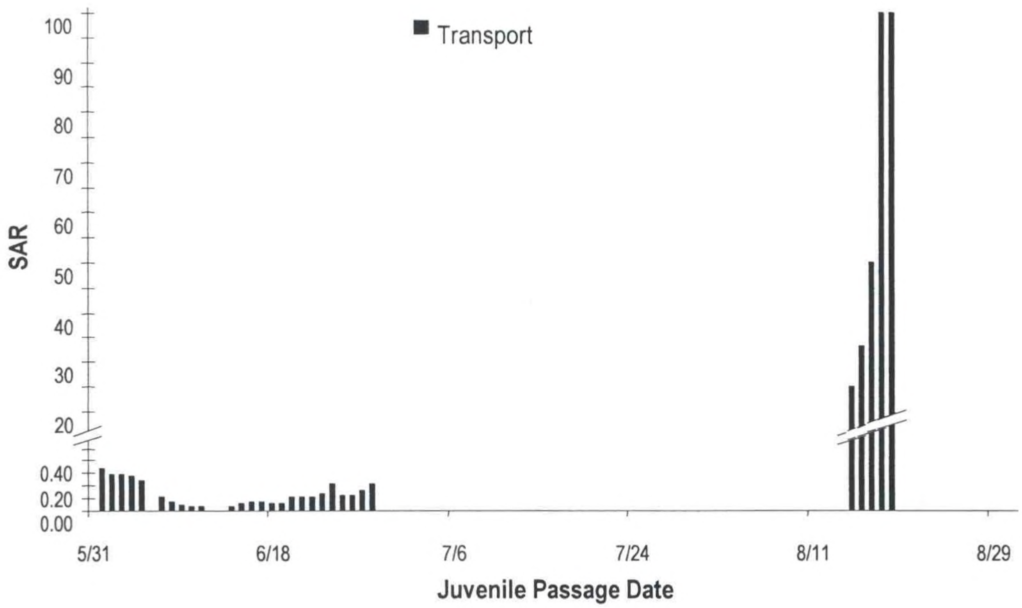

Figure 2. Smolt-to-adult return (SAR) rates by juvenile passage date at Lower Granite Dam for subyearling Chinook smolts tagged in 2003 at Lyons Ferry Hatchery and released above Lower Granite Dam. Data are 5-day running averages of daily juvenile releases.

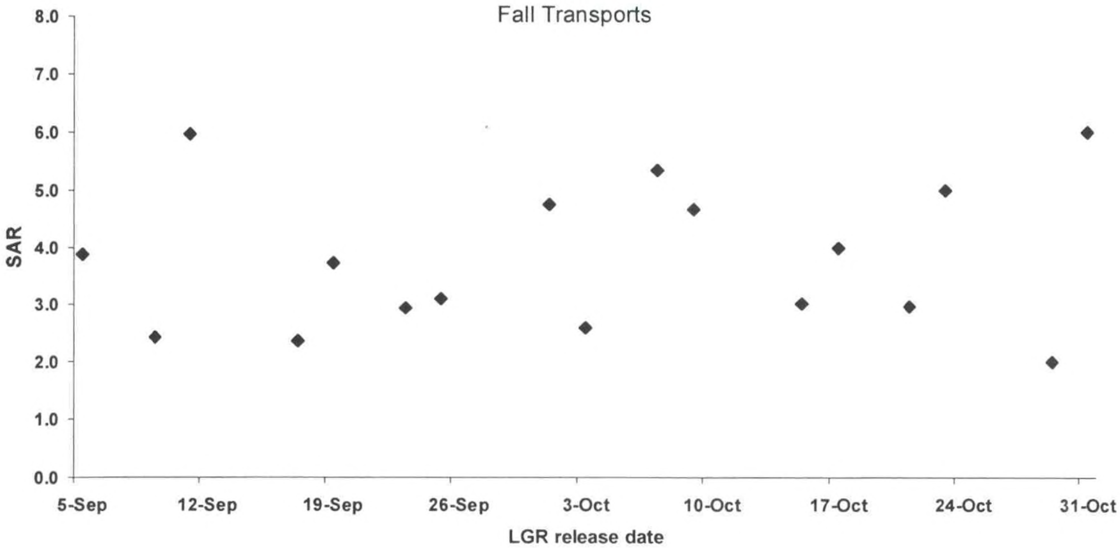

Figure 3. Smolt-to-adult return rates by juvenile release date for river-run subyearling Chinook smolts tagged for a fall transport index in 2003 at Lower Granite Dam and transported by truck to below Bonneville Dam. Data are daily SARs.

Conversion Rates

Meaningful comparisons of conversion rates among the 3 migration history categories was not possible for fish released in 2003 because of the low number of adult returns (Table 6). As in 2002, we observed unusually low conversion rates for the fall transportation index group of 2003 (Table 7), with a conversion rate between Bonneville and McNary Dam lower than that between McNary and Lower Granite Dam (Table 8). Interestingly, the older (and hence larger) fish had lower conversion rates between Bonneville and Lower Granite Dams.

Table 6. Adult conversion rates (percentage) of adult Lyons Ferry Hatchery fall Chinook salmon PIT-tagged in 2003 that were observed at Bonneville Dam and subsequently detected at Lower Granite Dam (not adjusted for Zone 6 harvest).

Detection history	Number seen at Bonneville Dam	Number seen at Lower Granite Dam	Conversion rate
	Jacks		
Bypass	2	2	100.0
Transport	5	4	80.0
Holdover	1	1	100.0
	Age-2-ocean adults		
Bypass	2	2	100.0
Transport	12	9	75.0
Holdover	0	0	--
	Age-3-ocean adults		
Bypass	0	0	--
Transport	0	0	--
Holdover	1	1	100.0
	Age-4-ocean adults		
Bypass	0	0	--
Transport	0	0	--
Holdover	0	0	--
	Totals		
Bypass	4	4	100.0
Transport	18	13	72.2
Holdover	2	2	100.0

Table 7. Adult conversion rates (percent) from Bonneville to Lower Granite Dam for river-run fall Chinook salmon PIT-tagged in September-October 2003 to develop a SARs index for fish transported in fall (not adjusted for Zone 6 harvest).

Age class	Number seen at Bonneville Dam	Number seen at Lower Granite Dam	Conversion rate
Jacks	30	20	66.7
Age-2-ocean adults	56	28	50.0
Age-3-ocean adults	91	29	31.9
Age-4-ocean adults	32	7	21.9
Totals	209	84	40.2

Table 8. Adult conversion rates (percent) from Bonneville to McNary and from McNary to Lower Granite Dam for river-run fall Chinook salmon PIT-tagged in September-October 2003 to develop a SARs index for fish transported in fall (not adjusted for Zone 6 harvest).

	Bonneville to McNary Dam			McNary to Lower Granite Dam		
Age class	Seen at Bonneville (n)	Subsequently seen at McNary (n)	Conversion rate	Seen at McNary (n)	Subsequently seen at Lower Granite (n)	Conversion rate
Jacks	30	26	86.7	41	34	82.9
Age-2-ocean	56	45	80.4	45	28	62.2
Age-3-ocean	91	35	38.5	35	29	82.9
Age-4-ocean	32	11	34.4	11	7	63.6
Totals	209	117	56.0	132	98	74.2

To understand the lower conversion rate of fall transport adults, we examined straying. We found that five returning fish strayed above Priest Rapids Dam: one jack, one age-2-ocean, two age-3-ocean, and one age-4-ocean adult (Table 9). One of the two age-3-ocean adults and the age-4-ocean adult passed above Rock Island Dam, and the age-4-ocean adult continued upstream and crossed Wells Dam. Three of these straying fish, the jack and both age-3-ocean adults, returned to the Snake River and eventually crossed Ice Harbor Dam. Only the jack finally crossed Lower Granite Dam, 13 days after crossing Priest Rapids Dam. These low detection numbers of straying fish, however, were not sufficient to explain what happened to fish that did not convert.

Table 9. Adult detection data showing the location of fish that strayed past the confluence of the Snake and Columbia Rivers. Returns were river-run fall Chinook salmon PIT-tagged in September-October 2003 to develop a SARs index for fish transported in fall.

	Fall transport index fish that strayed					
	Adult detection at Columbia River dams				Adult detection at Snake River dams	
Tag code	McNary	Priest Rapids	Rock Island	Wells	Ice Harbor	Lower Granite
3D9.1BF1BB963A	12 Sep 04	17 Sep 04			26 Sep 04	30 Sep 04
3D9.1BF1BCCCAA	18 Sep 05	10 May 05				
3D9.1BF1BD0180	12 Jul 06	21 Jul 06	11 Aug 06		13 Jul 06	
3D9.1BF1BE5B31	29 Sep 06	31 Oct 06			4 Oct 06	
3D9.1BF1BC78D0	29 Jun 07	3 Jul 07		12 Jul 07		

We also looked at median travel time as a possible reason for the differences in conversion rates between transportation study fish from Lyons Ferry Hatchery and river-run fish tagged at Lower Granite Dam for the fall transport index group. Total median travel times of the three study groups and the index groups (all age classes combined) ranged from 11.5 to 15 d (Tables 10 and 11). We concluded that a difference of only 1.5 to 3.5 d would not explain the difference in conversion rates.

Table 10. Travel times from Bonneville Dam to Lower Granite Dam for adult hatchery fall Chinook salmon PIT-tagged as juveniles for transportation studies in 2003.

Age class	Migration history	Number of adults	Travel time from Bonneville to Lower Granite Dam (d)
Jacks	Bypass	2	11.0
	Transport	4	11.5
	Holdover	1	12.0
Age-2-ocean	Bypass	2	18.0
	Transport	9	13.0
	Holdover	0	--
Age-3-ocean	Bypass	0	--
	Transport	0	--
	Holdover	1	15.0
Age-4-ocean	Bypass	0	--
	Transport	0	--
	Holdover	0	--
Total/mean	Bypass	4	11.5
	Transport	13	13.0
	Holdover	2	13.5

Table 11. Travel times from Bonneville to Lower Granite Dam for adult river-run fall Chinook salmon PIT-tagged as juveniles for an index of fall transport in 2003.

Age class	Migration history	Number of adults	Travel time from Bonneville to Lower Granite Dam (d)
Jacks	Fall transport index	20	12.5
Age-2-ocean	Fall transport index	28	14.0
Age-3-ocean	Fall transport index	29	18.0
Age-4-ocean	Fall transport index	7	21.0
Total/mean	Fall transport index	84	15.0

Length at Tagging

As found in previous study years, we saw a difference among migration histories in the size at tagging juveniles that subsequently produced adult returns. Of study fish that returned as adults, the average size of juveniles at tagging was smaller for fish that were bypassed and returned to the river than for their cohorts that were transported (Table 12). However, no pattern related to length at tagging was discerned among age classes.

Table 12. Average length at tagging of adult hatchery fall Chinook salmon PIT-tagged as juveniles at Lyons Ferry Hatchery in 2003.

Age class	Migration history	Number of adults	Average length as juveniles at tagging (mm)
Jacks	Bypass	3	101.0
	Transport	6	108.3
	Holdover	1	113.0
Age-2-ocean	Bypass	2	91.0
	Transport	9	105.7
	Holdover	0	--
Age-3-ocean	Bypass	0	--
	Transport	0	--
	Holdover	1	95.0
Age-4-ocean	Bypass	0	--
	Transport	0	--
	Holdover	0	--

DISCUSSION

We began transportation studies of Snake River fall Chinook salmon in 2001 under the assumption that the migration behavior of these fish was similar to that of spring migrants (i.e., migration to the ocean was completed during the year of tagging and release). Based on this assumption, our study design for fall Chinook salmon was similar to those used for spring migrants (Marsh et al. 1997, 2000, 2001, 2004b, 2005, 2006). As with the spring studies, we released a transport group, intending to compare SARs of that group to those of "non-detected" cohorts that migrate as juveniles without being detected at a collector dam (i.e., a dam with transportation facilities, meaning Lower Granite, Little Goose, Lower Monumental, or McNary Dam).

We originally intended to use the methods of Sandford and Smith (2002) to estimate the number of juveniles in the "non-detected" migrant group for transport studies of fall Chinook salmon from 2001 to 2004 (Marsh et al. 2003, 2004a). Since fall Chinook salmon can return as adults up to 5 years after entering the ocean, adult returns of these fish would be completed from 2006 to 2009.

However, as we began to observe adult returns from the 2001-2004 releases, we obtained new information about Snake River fall Chinook salmon behavior and their complex life history strategies. An important new finding was in regard to the timing of juvenile migration for Snake River fall Chinook salmon. We now know that these fish migrate year-round, often stopping for months at a time before moving farther downstream (Connor et al. 2005; Marsh et al. 2007; Marsh et al. in prep.). The consequence of this behavior in terms of our study is that our present methods cannot distinguish between probabilities of detection, mortality, and delayed migration in the non-detected fish group. Thus a transportation study of Snake River fall Chinook salmon cannot be based on a study design appropriate for transportation studies of spring migrants (spring/summer Chinook salmon and steelhead *O. mykiss*) (Buchanan and Skalski 2006).

The fundamental problem is in estimating the number of fish that arrive at Lower Granite Dam but are not detected (the non-detected group). These estimates are based on the single-release model, which relies on the assumption that after release, all fish have an equal probability of detection downstream. However, Snake River fall Chinook salmon that pass detection sites during winter, when detection systems are shut down, have no chance of detection; thus a critical assumption of the model is violated. Unless or until we are able to determine the number of fish that migrate during this time period, we are unlikely to find appropriate adjustments to the model to produce reasonably accurate estimates.

Without the ability to reliably estimate the number of fish in the non-detected group, we can neither calculate nor estimate a reliable SAR for this group, nor can we compare SARs of this group to those of a transport group, as is commonly done in transportation evaluations of spring/summer Chinook salmon and steelhead.

Another important finding was the trend of higher adult returns in subyearling Chinook that ceased migration during winter and were detected the following spring (after detection systems were watered up). These "holdover" fish returned at much higher rates (18-30 times higher) than fish that migrated during summer in the same year they were released. Thus, in addition to being unable to estimate the number of non-detected fish (which forms the inriver migrant group for comparison), fish from this same group are adding disproportionately to the total number of returning adults. When we consider that adult returns of detected subyearlings are higher for fish that migrated as juveniles later in the year, our estimate of the total number of non-detected juvenile migrants is even less meaningful, since we lack any knowledge of juvenile migration timing for "non-detected" adults.

Despite these complexities, we can still viably compare the SARs of fish returned to the river following detection at Lower Granite Dam to those of transported fish. Fish detected and bypassed are known to have passed during the transportation "window" at the dam. Thus, they provide a basis for comparison to fish collected and transported from the same dam. This comparison can address the important question of whether or not to transport fish after they have been collected. However, it does not address other potential effects of transportation or how transportation compares with other mitigation strategies (i.e., spill and RSWs) on the entire population, since it excludes the substantial number of fish that are never detected within the hydropower system.

In addition, it could be argued that detections of the bypass group at Lower Granite Dam do not constitute an unbiased data set for comparison with transported fish because we do not know whether these fish continued to migrate downstream after detection. We have evidence of the cessation of migration from our 2002 and 2003 study years: a number of fish were detected as subyearlings during their expected juvenile migration year but were subsequently detected as yearlings the following year. These detections indicate that fish may delay migration anywhere along the migration corridor. For example, one fish was detected as a subyearling at Lower Granite Dam in June 2002 and then as a yearling the following spring at Little Goose Dam; thus it remained in the upper Snake River for months after detection.

In response to this new information, we changed our study design in 2005 (Connor et al. 2008). However, for fish released during transport studies prior to the redesign (2001-2004), we can estimate SARs only for fish groups known to have passed Lower Granite Dam. These include the transport group (transported from the dam), a "bypass" group (detected and bypassed at the dam), and a "holdover" group (detected at or below the dam in the spring following release).

To evaluate if fall transport by truck had any obvious detrimental effects to fish, we also PIT-tagged fish during September and October 2003 for an index of fall transportation. However, as we did not concurrently release inriver migrant groups with these fish, we have no data with which to directly compare their SARs with those of any other group. Thus we cannot evaluate the potential alternative of returning collected fish to the tailrace.

Survival from release to Lower Granite Dam of production-sized fish is generally higher than for wild and surrogate-sized fish (Conner et al. 2004, 2008). Assuming a survival of 79% and FGE of 50%, we would have expected to collect around 40% of the fish released in 2003, and we came close, collecting 38.3% of the fish tagged and released in 2003.

Production-sized hatchery fall Chinook salmon also have a compressed, early juvenile migration distribution. Therefore, we expected to detect very few of these fish migrating in the spring following their expected outmigration year, and that is what we observed. Juveniles detected migrating in 2004 accounted for only 0.10% of all fish released, the lowest level of holdovers for study years 2001 through 2005 (Table 13).

Table 13. Number and percent of juvenile hatchery fall Chinook salmon migrating the year after release from releases above Lower Granite Dam, 2001-2005.

Study	Number	Detected migrating downstream the year after release	
Year	released	Number	Percent
2001	74,245	496	0.67
2002	97,916	1,219	1.24
2003	53,579	55	0.10
2004	48,913	180	0.37
2005	170,177	630	0.37

Comparisons of SARs from transported and bypassed groups released in 2003 did nothing to alter the conclusion of Williams et al. (2005), that "transportation appeared to neither greatly harm nor help" Snake River fall Chinook salmon. Transported fish had slightly lower SARs than bypassed fish, although the number of adults in both groups was too small to determine whether this comparison had either statistical or biological significance. Among fish released during summer, the highest SARs were observed in the holdover group. However, the small number of adults in this group pushed the lower end of the 95% confidence interval below zero, and we expected holdover fish to have higher SARs because they were substantially larger as juveniles than their cohorts that migrated during summer/fall the previous year.

We also expected that conversion rates from Bonneville to Lower Granite Dam would be lower, in general, for fall Chinook than for spring/summer Chinook adults due to the higher harvest rate of fall Chinook salmon. However, even considering this expectation, we were surprised at the extremely low conversion rate of adults tagged to develop an index of fall transportation. The overall conversion rate for the 2003 fall index group was even lower than that observed for the 2002 fall transport adults.

During fall 2005, 2006, and 2007, returning adults from the 2002 and 2003 transportation study years were captured at Lower Granite Dam trap (Harmon 2003) as part of a life-history study (Marsh et al. 2007; in prep). Fish were diverted to the trap using the separation-by-code PIT-tag diversion system (Marsh et al. 1999; Downing et al. 2001). Lengths of returning adults from the fall transport index group of the 2002 study year (Table 14) supported the idea that fall transport adults are larger than the other groups. However, adults from the fall transport index group of 2003 did not show this.

One confounding issue when discussing size at the juvenile migration and of returning adults is whether fish enter the ocean as a subyearling or as a yearling. One would expect that adults from the holdover group would also be larger adults because they were larger when they migrated as juveniles, and if ocean age was assigned based on time at sea, that would be the case. However, in transportation studies, we assign ocean age based on brood year. Therefore, adults that delayed migration until the spring following release have actually spent one less year at sea than their cohorts of the same age class.

Nevertheless, we continue to assign ages in this manner, and our reason for doing so is based on another surprising finding from the life history study: Analysis of scales taken from returning adults has shown that a large proportion of the fall transport group overwintered in freshwater areas below Bonneville Dam after being transported. These fish entered the ocean as yearlings, as did fish in the holdover group. If we based age assignment on time at sea instead of brood year, we would need two fall transport groups: one that entered the ocean as subyearlings, and a second that entered as yearlings/holdovers.

Table 14. Average lengths of adult hatchery and river-run fall Chinook salmon PIT-tagged as juveniles for transport studies in 2002 and 2003 and re-captured at Lower Granite Dam during fall of 2005, fall 2006, and fall 2007. Because of the low number of adults from the 2003 study year, the groups are broken into holdover, fall transport, and bypass/transport combined.

Age class		Number of adults	Average length of returning adults at Lower Granite Dam (mm)
	2002 Study year		
Age-3-ocean	Bypass	4	733.3
	Transport	23	739.3
	Holdover	12	712.5
	Fall transport index	24	748.5
Age-4-ocean	Bypass	2	805.0
	Transport	8	840.0
	Holdover	1	820.0
	Fall transport index	9	848.8
Age-5-ocean	Bypass	0	--
	Transport	0	--
	Holdover	0	--
	Fall transport index	1	830.0
	2003 Study year		
Age-2-ocean	Bypass/transport	9	667.8
	Holdover	0	--
	Fall transport index	15	652.7
Age-3-ocean	Bypass/transport	2	820.0
	Holdover	1	780.0
	Fall transport index	14	840.0
Age-4-ocean	Bypass/transport	2	950.0
	Holdover	0	--
	Fall transport index	5	880.0

In fact, as Table 15 shows, the fall transport group is not the only group from the 2002 and 2003 study years that have a mixture of subyearling and yearling ocean entrants, and would require this treatment. However, to avoid confusion we will continue to assign ocean age based on brood year until such time as a rigorous method of analysis that accounts for this overwintering behavior is developed.

Table 15. Age at ocean entry for adult hatchery and river-run fall Chinook salmon PIT-tagged as juveniles at for transport studies in 2002 and 2003 and re-captured at Lower Granite Dam during fall of 2005 and fall 2006.

Age class		Age at ocean entry		
		Subyearling	Yearling	Unknown
		2002 Study year		
Age-3-ocean	Bypass	3	0	0
	Transport	7	5	3
	Holdover	0	8	0
	Fall transport index	1	9	3
Age-4-ocean	Bypass	0	2	0
	Transport	3	3	0
	Holdover	0	1	0
	Fall transport index	1	6	1
		2003 Study year		
Age-2-ocean	Bypass	1	1	0
	Transport	4	0	0
	Holdover	0	0	0
	Fall transport index	7	6	2
Age-3-ocean	Bypass	0	0	0
	Transport	0	0	0
	Holdover	0	0	0
	Fall transport index	7	6	5

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APPENDIX A

Juvenile Data from the 2003 Fall Chinook Salmon Tagging Year

Appendix Table A1. Total hatchery fall Chinook salmon tagged at Lyons Ferry Hatchery and released above Lower Granite Dam in 2003.

	Released above Granite Dam tailrace			
Tag Date	Tagged	Mortalities	Lost tags	Released
28 May 03	8,748	3	17	8,728
30 May 03	8,741	5	29	8,707
2 Jun 03	11,559	6	9	11,544
3 Jun 03	8,613	2	15	8,596
5 Jun 03	16,053	4	45	16,004

Appendix Table A2. Total river-run fall Chinook salmon PIT-tagged at Lower Granite Dam during fall 2003.

	Tagged at, and transported from, Lower Granite Dam				
Tag Date	Tagged	Mortalities	Lost tags	Duplicates	Released
05 Sep 03	206	-	-	-	206
09 Sep 03	205	-	-	-	205
11 Sep 03	201	-	-	-	201
17 Sep 03	127	-	-	-	127
19 Sep 03	188	-	-	-	188
23 Sep 03	102	-	-	-	102
25 Sep 03	258	-	-	-	258
01 Oct 03	211	-	-	-	211
03 Oct 03	154	-	-	-	154
07 Oct 03	150	-	-	-	150
09 Oct 03	150	-	-	-	150
15 Oct 03	99	-	-	-	99
17 Oct 03	100	-	-	-	100
21 Oct 03	101	-	-	-	101
23 Oct 03	100	-	-	-	100
29 Oct 03	100	-	-	-	100
31 Oct 03	100	-	-	-	100

Appendix Table A3. Locations of observations (detections) of PIT-tagged juvenile fall Chinook salmon within the Lower Granite Dam juvenile fish facility, 2003 study year.

Detection date	Detected once at Lower Granite Dam (coil location)				Detected on separator and at least one additional coil (coil location)			
	Separator	Diversion	Sample	Raceway	Diversion	Sample	Raceway	Sample raceway
30 May 03	-	-	-	1	6	-	17	-
31 May 03	-	-	-	-	12	-	47	-
1 Jun 03	-	-	-	2	19	-	65	-
2 Jun 03	-	-	-	-	21	-	89	-
3 Jun 03	-	-	-	1	21	2	69	-
4 Jun 03	-	-	-	-	19	2	62	-
5 Jun 03	-	-	-	1	19	-	63	-
6 Jun 03	-	-	-	-	21	1	77	-
7 Jun 03	-	-	-	1	37	5	131	-
8 Jun 03	-	-	-	2	90	9	276	-
9 Jun 03	1	1	-	1	109	9	354	-
10 Jun 03	4	1	-	5	175	12	504	-
11 Jun 03	13	1	-	4	149	13	514	-
12 Jun 03	-	-	-	4	159	13	563	-
13 Jun 03	-	1	-	3	128	14	437	-
14 Jun 03	-	-	-	2	157	22	594	-
15 Jun 03	1	1	-	5	174	17	613	-
16 Jun 03	3	-	-	2	223	36	756	-
17 Jun 03	2	-	-	3	229	45	877	-
18 Jun 03	1	-	-	2	250	43	872	-
19 Jun 03	-	-	-	-	151	25	604	-
20 Jun 03	2	-	1	4	312	60	1,126	1
21 Jun 03	2	1	-	9	602	100	2,079	-
22 Jun 03	-	1	-	6	334	27	1,188	-
23 Jun 03	-	-	-	1	182	24	735	-
24 Jun 03	1	-	-	-	142	12	557	-
25 Jun 03	2	-	-	1	124	7	402	-
26 Jun 03	1	-	-	1	74	4	290	-
27 Jun 03	-	-	-	1	65	14	222	-
28 Jun 03	-	-	-	2	34	2	130	-
29 Jun 03	-	1	-	1	32	2	141	-
30 Jun 03	-	-	-	-	30	3	118	-
1 Jul 03	4	-	-	2	34	4	183	-
2 Jul 03	1	-	-	-	46	9	171	-
3 Jul 03	-	-	-	-	14	3	58	-
4 Jul 03	-	-	-	-	13	3	62	-
5 Jul 03	-	-	-	-	17	4	73	-
6 Jul 03	-	-	-	-	9	2	50	-
7 Jul 03	-	-	-	-	3	1	14	-
8 Jul 03	-	-	-	-	10	4	44	-
9 Jul 03	-	-	-	-	7	4	53	-
10 Jul 03	-	-	-	-	12	3	39	-
11 Jul 03	-	-	-	-	8	1	23	-
12 Jul 03	-	-	-	-	2	3	13	-

Appendix Table A3. Continued.

Detection date	Detected once at Lower Granite Dam (coil location)				Detected on separator and at least one additional coil (coil location)			
	Separator	Diversion	Sample	Raceway	Diversion	Sample	Raceway	Sample raceway
13 Jul 03	-	-	-	-	1	2	2	-
14 Jul 03	-	-	-	-	1	2	10	-
15 Jul 03	-	-	-	-	1	-	12	-
16 Jul 03	-	-	-	1	2	-	10	-
17 Jul 03	-	-	-	-	3	1	9	-
18 Jul 03	-	-	-	-	4	-	12	-
19 Jul 03	-	-	-	-	3	2	12	-
20 Jul 03	-	-	-	-	1	1	8	-
21 Jul 03	-	-	-	-	2	1	5	-
22 Jul 03	-	-	-	-	1	1	3	-
23 Jul 03	-	-	-	-	1	-	2	-
24 Jul 03	-	-	-	-	-	-	3	-
25 Jul 03	-	-	-	-	-	-	1	-
27 Jul 03	-	-	-	-	2	-	1	-
29 Jul 03	-	-	-	-	-	-	1	-
30 Jul 03	-	-	-	-	-	1	1	-
31 Jul 03	-	-	-	-	-	-	1	-
1 Aug 03	-	-	-	-	1	-	1	-
2 Aug 03	-	-	-	-	1	-	3	-
3 Aug 03	-	-	-	-	-	1	2	-
4 Aug 03	-	-	-	-	1	3	7	-
5 Aug 03	-	-	-	-	2	2	4	-
6 Aug 03	-	-	-	-	1	-	2	-
7 Aug 03	-	-	-	-	-	-	2	-
8 Aug 03	-	-	-	-	1	-	-	-
9 Aug 03	-	-	-	-	-	1	1	-
11 Aug 03	-	-	-	-	1	-	1	-
12 Aug 03	-	-	-	-	-	-	3	-
13 Aug 03	-	-	-	-	1	-	1	-
14 Aug 03	-	-	-	-	-	-	1	-
15 Aug 03	-	-	-	-	-	-	1	-
17 Aug 03	-	-	-	-	-	-	1	-
22 Aug 03	-	-	-	-	1	-	-	-
24 Aug 03	-	-	-	-	1	-	-	-
25 Aug 03	-	-	-	-	-	-	1	-
7 Sep 03	-	-	-	-	-	1	-	-
14 Sep 03	-	-	-	-	-	1	-	-
16 Sep 03	-	-	-	-	-	1	-	-
27 Sep 03	-	-	-	-	-	2	-	-
29 Sep 03	-	-	-	-	-	1	-	-
5 Oct 03	-	-	-	-	1	-	-	-
12 Oct 03	-	-	-	-	-	1	-	-
15 Oct 03	-	-	-	-	-	1	-	-
23 Oct 03	-	-	-	-	-	1	-	-

Appendix Table A3. Continued.

Detection date	Detected once at Lower Granite Dam (coil location)				Detected on separator and at least one additional coil (coil location)			
	Separator	Diversion	Sample	Raceway	Diversion	Sample	Raceway	Sample raceway
30 Mar 04	-	-	-	-	2	-	-	-
6 Apr 04	-	-	-	-	-	1	-	-
9 Apr 04	-	-	-	-	1	-	-	-
24 Apr 04	-	-	-	-	2	-	-	-
26 Apr 04	-	-	-	-	3	-	-	-

Appendix Table A4. Locations of observations (detections) of PIT-tagged juvenile fall Chinook salmon within the Little Goose Dam juvenile fish facility, 2003 study year.

Detection date	Detected once at Little Goose Dam (coil location)			Detected on separator and one additional coil (coil location)		
	Separator	Diversion	Raceway	Diversion	Sample	Raceway
1 Jun 03	-	-	-	1	-	-
2 Jun 03	1	-	-	8	-	18
3 Jun 03	1	-	-	21	-	71
4 Jun 03	-	-	-	25	1	94
5 Jun 03	-	-	-	37	-	122
6 Jun 03	-	-	-	34	1	110
7 Jun 03	1	-	-	17	-	82
8 Jun 03	-	-	-	29	1	93
9 Jun 03	-	-	-	13	1	44
10 Jun 03	1	-	-	75	7	253
11 Jun 03	-	-	-	110	6	356
12 Jun 03	1	-	-	124	13	406
13 Jun 03	1	-	2	75	9	302
14 Jun 03	-	-	-	29	3	127
15 Jun 03	-	1	-	72	3	262
16 Jun 03	1	-	1	74	9	262
17 Jun 03	-	-	-	63	14	214
18 Jun 03	1	-	-	33	7	130
19 Jun 03	1	-	-	109	6	373
20 Jun 03	3	-	1	181	24	680
21 Jun 03	7	1	3	292	23	1,074
22 Jun 03	3	-	-	201	15	733
23 Jun 03	1	-	1	143	14	500
24 Jun 03	3	-	2	128	12	421
25 Jun 03	2	-	-	99	7	372
26 Jun 03	-	-	-	49	4	181
27 Jun 03	1	-	-	28	2	125
28 Jun 03	1	-	-	29	5	120
29 Jun 03	1	-	1	83	6	300
30 Jun 03	3	-	-	42	11	159
1 Jul 03	-	-	-	40	5	120
2 Jul 03	-	-	-	22	6	114
3 Jul 03	-	-	-	35	9	117
4 Jul 03	-	-	-	24	4	102
5 Jul 03	1	-	-	36	9	151
6 Jul 03	-	-	-	22	5	89
7 Jul 03	-	-	-	9	6	41
8 Jul 03	-	-	-	10	5	42
9 Jul 03	-	-	-	11	3	37
10 Jul 03	-	-	-	3	4	15

Appendix Table A4. Continued.

Detection date	Detected once at Little Goose Dam (coil location)			Detected on separator and one additional coil (coil location)		
	Separator	Diversion	Raceway	Diversion	Sample	Raceway
11 Jul 03	-	-	-	13	2	44
12 Jul 03	-	-	-	14	5	58
13 Jul 03	-	-	-	4	1	18
14 Jul 03	-	-	-	7	-	18
15 Jul 03	1	-	-	1	-	7
16 Jul 03	-	-	-	1	1	8
17 Jul 03	-	-	-	4	1	15
18 Jul 03	-	-	-	2	1	14
19 Jul 03	-	-	-	3	2	9
20 Jul 03	-	-	-	4	1	10
21 Jul 03	-	-	-	1	-	3
22 Jul 03	-	-	-	2	-	8
23 Jul 03	-	-	-	2	1	9
24 Jul 03	-	-	-	1	4	4
25 Jul 03	-	-	-	1	-	4
26 Jul 03	-	-	-	1	1	3
27 Jul 03	-	-	-	2	4	5
28 Jul 03	-	-	-	2	1	8
29 Jul 03	-	-	-	2	-	9
30 Jul 03	-	-	-	3	5	7
31 Jul 03	-	-	-	2	-	11
1 Aug 03	-	-	-	2	3	3
2 Aug 03	-	-	-	2	1	8
3 Aug 03	-	-	-	2	-	6
4 Aug 03	-	-	-	1	1	2
5 Aug 03	-	-	-	-	1	2
6 Aug 03	-	-	-	-	1	1
7 Aug 03	-	-	-	1	-	1
8 Aug 03	-	-	-	-	2	3
9 Aug 03	-	-	-	1	1	3
10 Aug 03	-	-	-	-	1	-
16 Aug 03	-	-	-	-	3	-
17 Aug 03	-	-	-	1	4	-
18 Aug 03	-	-	-	1	2	-
19 Aug 03	-	-	-	-	4	-
20 Aug 03	-	-	-	2	-	-
22 Aug 03	-	-	-	1	-	-
23 Aug 03	-	-	-	-	2	1
24 Aug 03	-	-	-	-	1	-
29 Aug 03	-	-	-	-	1	-

Appendix Table A4. Continued.

Detection date	Detected once at Little Goose Dam (coil location)			Detected on separator and one additional coil (coil location)		
	Separator	Diversion	Raceway	Diversion	Sample	Raceway
2 Sep 03	-	-	-	1	1	-
3 Sep 03	-	-	-	-	1	-
4 Sep 03	-	-	-	-	1	-
5 Sep 03	-	-	-	-	-	2
6 Sep 03	-	-	-	1	-	2
8 Sep 03	-	-	-	-	-	1
9 Sep 03	-	-	-	1	-	1
16 Sep 03	-	-	-	-	1	-
21 Sep 03	-	-	-	-	1	-
3 Apr 04	-	-	-	1	-	-
8 Apr 04	-	-	-	1	-	-
9 Apr 04	-	-	-	1	-	-
15 Apr 04	-	-	-	1	-	-
16 Apr 04	-	-	-	1	-	-
19 Apr 04	-	-	-	1	-	-
20 Apr 04	-	-	-	1	-	-
21 Apr 04	-	-	-	2	-	-
23 Apr 04	-	-	-	1	-	-
24 Apr 04	-	-	-	1	-	-
26 Apr 04	-	-	-	3	-	-
27 Apr 04	-	-	-	2	-	-
28 Apr 04	-	-	-	1	-	-
29 Apr 04	-	-	-	1	-	-
30 Apr 04	-	-	-	1	-	-
1 May 04	-	-	-	2	-	-
2 May 04	-	-	-	1	-	-
4 May 04	-	-	-	1	-	-

Appendix Table A5. Locations of observations (detections) of PIT-tagged juvenile fall Chinook salmon within the Lower Monumental Dam juvenile fish facility, 2003 study year.

Detection date	Detected once at Lower Monumental Dam (coil location)			Detected on separator and one additional coil (coil location)		
	Separator	Sample	Raceway	Diversion	Sample	Raceway
3 Jun 03	-	-	-	2	-	1
4 Jun 03	-	-	-	5	2	17
5 Jun 03	-	-	-	6	1	16
6 Jun 03	-	-	1	8	1	24
7 Jun 03	-	-	-	7	1	36
8 Jun 03	-	-	-	11	1	32
9 Jun 03	-	-	-	4	3	8
10 Jun 03	-	-	-	10	-	25
11 Jun 03	1	-	-	24	8	55
12 Jun 03	-	-	-	28	5	107
13 Jun 03	1	-	-	33	4	93
14 Jun 03	-	-	-	20	1	71
15 Jun 03	-	-	-	11	3	41
16 Jun 03	-	-	-	16	2	57
17 Jun 03	-	-	-	21	7	60
18 Jun 03	-	-	-	12	5	47
19 Jun 03	-	-	-	7	1	19
20 Jun 03	-	-	-	69	12	212
21 Jun 03	-	-	-	113	24	355
22 Jun 03	5	-	-	68	84	190
23 Jun 03	4	-	-	46	112	50
24 Jun 03	13	-	-	65	223	-
25 Jun 03	12	1	-	32	100	-
26 Jun 03	4	-	-	54	144	-
27 Jun 03	3	-	-	22	72	-
28 Jun 03	8	-	-	30	105	-
29 Jun 03	6	-	-	30	89	-
30 Jun 03	-	-	-	8	34	-
1 Jul 03	2	-	-	17	48	-
2 Jul 03	7	-	-	46	88	-
3 Jul 03	2	-	-	10	38	5
4 Jul 03	-	-	-	6	3	19
5 Jul 03	1	-	-	10	8	42
6 Jul 03	-	-	-	12	15	25
7 Jul 03	-	-	-	4	21	-
8 Jul 03	1	-	-	4	18	-
9 Jul 03	2	-	-	8	29	-
10 Jul 03	-	-	-	9	26	-
11 Jul 03	-	-	-	17	47	-
12 Jul 03	3	-	-	11	42	5
13 Jul 03	-	-	-	3	3	11
14 Jul 03	-	-	-	4	-	12
15 Jul 03	-	-	-	1	4	5
16 Jul 03	1	-	-	5	5	12
17 Jul 03	-	-	-	8	3	26
18 Jul 03	-	-	-	4	7	15

Appendix Table A5. Continued.

Detection date	Detected once at Lower Monumental Dam (coil location)			Detected on separator and one additional coil (coil location)		
	Separator	Sample	Raceway	Diversion	Sample	Raceway
19 Jul 03	-	-	-	3	3	10
20 Jul 03	-	-	-	5	7	20
21 Jul 03	-	-	-	1	3	11
22 Jul 03	-	-	-	4	1	7
23 Jul 03	-	-	-	5	4	15
24 Jul 03	-	-	-	1	2	4
25 Jul 03	-	-	-	2	2	8
26 Jul 03	-	-	-	1	-	6
27 Jul 03	-	-	-	1	3	6
28 Jul 03	-	-	-	-	1	2
29 Jul 03	-	-	-	3	2	4
30 Jul 03	-	-	-	1	1	3
31 Jul 03	-	-	-	2	1	2
1 Aug 03	-	-	-	-	-	5
2 Aug 03	-	-	-	1	1	2
3 Aug 03	-	1	-	2	1	3
4 Aug 03	-	-	-	2	-	4
5 Aug 03	-	-	-	1	4	3
6 Aug 03	-	-	-	1	1	7
7 Aug 03	-	-	-	3	-	1
8 Aug 03	-	-	-	-	-	2
9 Aug 03	-	-	-	1	1	3
10 Aug 03	-	-	-	-	-	3
11 Aug 03	-	-	-	-	1	3
15 Aug 03	-	-	-	1	-	-
17 Aug 03	-	-	-	1	2	-
18 Aug 03	-	-	-	1	1	-
19 Aug 03	-	-	-	-	3	-
20 Aug 03	-	-	-	2	5	-
21 Aug 03	-	-	-	1	6	-
22 Aug 03	-	-	-	1	2	-
23 Aug 03	-	-	-	1	3	-
24 Aug 03	1	-	-	-	-	-
25 Aug 03	-	-	-	-	3	-
26 Aug 03	1	-	-	1	1	-
27 Aug 03	-	-	-	-	3	-
28 Aug 03	-	-	-	1	1	-
29 Aug 03	-	-	-	-	1	-
30 Aug 03	-	-	-	1	2	-
31 Aug 03	-	-	-	-	5	-
1 Sep 03	1	-	-	1	-	-
3 Sep 03	-	-	-	-	2	-
6 Sep 03	-	-	-	1	-	-
7 Sep 03	-	-	-	-	1	-
8 Sep 03	-	-	-	-	2	-
10 Sep 03	-	-	-	-	1	-

Appendix Table A5. Continued.

Detection date	Detected once at Lower Monumental Dam (coil location)			Detected on separator and one additional coil (coil location)		
	Separator	Sample	Raceway	Diversion	Sample	Raceway
12 Sep 03	-	-	-	-	1	-
15 Sep 03	-	-	-	-	1	-
18 Sep 03	-	-	-	1	-	-
20 Sep 03	-	-	-	-	1	-
28 Sep 03	-	-	-	1	-	-
1 Apr 04	-	-	-	1	-	-
14 Apr 04	-	-	-	1	-	-
17 Apr 04	-	-	-	1	-	-
18 Apr 04	-	-	-	1	-	-
19 Apr 04	-	-	-	1	-	-
23 Apr 04	-	-	-	1	-	-
24 Apr 04	-	-	-	3	-	-
25 Apr 04	-	-	-	3	-	-
26 Apr 04	-	-	-	1	-	-
27 Apr 04	-	-	-	1	-	-
29 Apr 04	-	-	-	1	-	-
30 Apr 04	-	-	-	1	-	-
10 May 04	-	-	-	1	-	-
15 May 04	-	-	-	1	-	-

Appendix Table A6. Locations of observations (detections) of PIT-tagged fall Chinook salmon within the McNary Dam juvenile fish facility, 2003 study year.

			Detected on full-flow and additional coil(s) (coil location)									
				Detected on separator and additional coil(s) (coil location)								
MCJ date	Full-flow	Separator	Adult	Diversion	Sample	Raceway	Raceway bypass	Diversion bypass	Sample bypass	Raceway transport	Bypass	Raceway transport
7 Jun 03	1	-	-	-	-	-	-	-	-	-	-	-
8 Jun 03	3	-	-	-	-	-	-	-	-	1	-	-
9 Jun 03	-	-	1	-	-	-	1	-	-	-	-	-
10 Jun 03	11	-	-	-	-	-	3	-	-	-	-	-
11 Jun 03	1	-	-	-	-	-	7	-	-	1	-	-
12 Jun 03	6	-	-	-	-	-	2	-	-	2	-	-
13 Jun 03	3	-	-	-	-	-	15	-	1	2	-	-
14 Jun 03	20	-	-	-	-	-	3	-	-	1	-	-
15 Jun 03	4	-	-	-	-	-	27	-	-	5	-	-
16 Jun 03	58	-	-	-	-	-	13	-	-	2	-	-
17 Jun 03	60	-	-	-	-	1	94	-	1	20	-	-
18 Jun 03	93	-	1	-	-	-	27	-	-	5	-	-
19 Jun 03	60	1	1	-	-	-	131	-	1	27	-	1
20 Jun 03	132	-	-	-	-	-	35	-	-	8	-	-
21 Jun 03	168	-	5	-	-	-	308	-	1	69	1	-
22 Jun 03	364	-	-	-	-	-	56	-	1	13	-	-
23 Jun 03	75	-	-	-	-	-	158	-	2	33	-	-
24 Jun 03	387	-	1	-	-	-	58	-	1	10	-	-
25 Jun 03	79	-	-	-	-	-	270	-	3	47	-	-
26 Jun 03	149	-	1	-	-	-	42	-	1	12	-	-
27 Jun 03	16	-	-	-	-	-	-	20	-	58	-	-
28 Jun 03	-	-	-	1	-	-	-	28	-	59	-	-
29 Jun 03	-	-	2	-	-	-	-	18	-	51	-	-
30 Jun 03	17	-	1	4	5	-	-	54	-	138	-	1
1 Jul 03	11	1	2	2	1	-	-	34	-	93	-	-
2 Jul 03	17	-	-	-	-	-	-	7	-	33	-	-
3 Jul 03	1	-	2	1	1	-	-	20	-	54	-	-
4 Jul 03	-	-	2	1	-	-	-	30	-	84	-	-
5 Jul 03	14	-	4	1	-	-	-	20	-	54	-	-
6 Jul 03	-	-	2	-	-	-	-	10	-	29	-	-

Appendix Table A6. Continued.

			Detected on full-flow and additional coil(s) (coil location)									
				Detected on separator and additional coil(s) (coil location)								
MCJ date	Full-flow	Separator	Adult	Diversion	Sample	Raceway	Raceway bypass	Diversion bypass	Sample bypass	Raceway transport	Bypass	Raceway transport
7 Jul 03	-	-	1	-	3	-	-	26	-	54	-	-
8 Jul 03	-	-	2	-	-	-	-	8	-	35	-	-
9 Jul 03	-	-	-	-	-	-	-	7	-	14	-	-
10 Jul 03	9	-	1	-	1	-	-	8	-	23	-	-
11 Jul 03	-	-	-	-	-	-	-	14	-	32	-	-
12 Jul 03	-	-	3	1	-	-	-	6	-	31	-	-
13 Jul 03	-	-	-	2	-	-	-	4	-	23	-	-
14 Jul 03	5	-	-	-	1	-	-	10	-	22	-	-
15 Jul 03	-	-	-	2	1	-	-	14	-	46	-	-
16 Jul 03	-	-	-	1	-	-	-	5	-	26	-	-
17 Jul 03	-	-	-	-	-	-	-	8	-	24	-	-
18 Jul 03	-	-	-	-	-	-	-	2	-	8	-	-
19 Jul 03	1	-	-	-	1	-	-	3	-	10	-	-
20 Jul 03	-	-	2	-	1	-	-	7	-	20	-	-
21 Jul 03	-	-	-	-	1	-	-	5	-	17	-	-
22 Jul 03	-	-	2	-	-	-	-	5	-	18	-	-
23 Jul 03	-	-	-	-	-	-	-	4	-	20	-	-
24 Jul 03	3	-	1	-	-	-	-	2	-	12	-	-
25 Jul 03	-	-	-	-	-	-	-	5	-	12	-	-
26 Jul 03	3	-	-	-	-	-	-	5	-	10	-	-
27 Jul 03	-	-	-	-	-	-	-	3	-	6	-	-
28 Jul 03	-	-	1	-	2	-	-	1	-	12	-	-
29 Jul 03	-	-	-	-	1	-	-	2	-	10	-	-
30 Jul 03	-	-	-	-	-	-	-	1	-	8	-	-
31 Jul 03	-	-	1	-	-	-	-	2	-	9	-	-
1 Aug 03	-	-	-	-	-	-	-	1	-	1	-	-
2 Aug 03	-	-	-	-	-	-	-	-	-	4	-	-
3 Aug 03	-	-	-	-	-	-	-	1	-	2	-	-
4 Aug 03	-	-	1	-	-	-	-	-	-	1	-	-
5 Aug 03	-	-	-	-	-	-	-	2	-	2	-	-

Appendix Table A6. Continued.

MCJ date	Full-flow	Separator	Detected on full-flow and additional coil(s) (coil location): Adult	Diversion	Sample	Raceway	Raceway bypass	Diversion bypass	Sample bypass	Raceway transport	Detected on separator and additional coil(s) (coil location): Bypass	Raceway transport
6 Aug 03	-	-	-	-	-	-	-	-	-	5	-	-
7 Aug 03	-	-	-	-	-	-	-	1	-	3	-	-
8 Aug 03	-	-	-	-	-	-	-	2	-	3	-	-
9 Aug 03	-	-	-	-	-	-	-	-	-	4	-	-
10 Aug 03	-	-	-	-	-	-	-	-	-	2	-	-
11 Aug 03	-	-	-	-	-	-	-	-	-	5	-	-
12 Aug 03	1	-	-	-	-	-	-	-	-	-	-	-
14 Aug 03	-	-	-	-	-	-	-	1	-	1	-	-
15 Aug 03	-	-	-	-	-	-	-	1	-	1	-	-
16 Aug 03	-	-	-	-	-	-	-	-	-	1	-	-
17 Aug 03	-	-	-	-	-	-	-	1	-	1	-	-
18 Aug 03	-	-	-	-	-	-	-	1	-	-	-	-
19 Aug 03	-	-	1	-	-	-	-	1	-	3	-	-
20 Aug 03	-	-	-	-	-	-	-	-	-	2	-	-
21 Aug 03	-	-	-	-	-	-	-	-	-	2	-	-
22 Aug 03	-	-	-	-	-	-	-	1	-	-	-	-
23 Aug 03	-	-	-	-	-	-	-	-	-	1	-	-
24 Aug 03	1	-	-	-	-	-	-	-	-	1	-	-
25 Aug 03	1	-	-	-	-	-	-	-	-	-	-	-
26 Aug 03	1	-	-	-	-	-	-	1	-	-	-	-
27 Aug 03	-	-	-	-	-	-	-	-	-	1	-	-
29 Aug 03	-	-	-	-	-	-	-	-	-	3	-	-
2 Sep 03	-	-	-	-	-	-	-	1	-	-	-	-
17 Sep 03	-	-	-	-	-	-	-	-	-	1	-	-
18 Sep 03	-	-	-	-	-	-	-	-	-	1	-	-
3 Apr 04	-	-	-	-	-	-	1	-	-	-	-	-
12 Apr 04	-	-	-	-	-	-	-	-	1	-	-	-
18 Apr 04	-	-	-	-	-	-	1	-	-	-	-	-
19 Apr 04	1	-	-	-	-	-	-	-	-	-	-	-

Appendix Table A6. Continued.

MCJ date	Full-flow	Separator	Detected on full-flow and additional coil(s) (coil location)									
				Detected on separator and additional coil(s) (coil location)								
			Adult	Diversion	Sample	Raceway	Raceway bypass	Diversion bypass	Sample bypass	Raceway transport	Bypass	Raceway transport
21 Apr 04	2	-	-	-	-	-	-	-	-	-	-	-
25 Apr 04	1	-	-	-	-	-	-	-	-	-	-	-
28 Apr 04	-	-	1	-	-	-	1	-	-	-	-	-
2 May 04	-	-	-	-	-	-	2	-	-	-	-	-
3 May 04	-	-	-	-	-	-	1	-	-	-	-	-
4 May 04	-	-	-	-	-	-	1	-	-	-	-	-
6 May 04	-	-	-	-	-	-	1	-	-	-	-	-

APPENDIX B

Adult Returns from Complete and Ongoing Studies

Appendix Table B1. Snake River fall Chinook salmon transportation studies.

Tagging year	Juvenile fish numbers: Transport	Juvenile fish numbers: Fall Transport[a]	Juvenile fish numbers: Bypass	Returns by age-class: Jack	Returns by age-class: 2-ocean	Returns by age-class: 3-ocean	Returns by age-class: 4-ocean	Returns by age-class: 5-ocean	SAR: Transport	SAR: Fall Transport	SAR: Bypass	T/I	95 % C.I.	Status	Annual Report containing final results
2007	--na--	8,742	--na--	--	--	--	--	--	--	--	--	--	--	In-progress	2011
2006[b]	270,639	2,308	220,523	508	--	--	--	--	--	--	--	--	--	In-progress	2010
2005[b]	84,844	2,545	83,272	80	110	--	--	--	--	--	--	--	--	In-progress	2009
2004[c]	3,617	2,545	45,296	27	27	37	--	--	--	--	--	--	--	In-progress	2008
2003[d]	**16,085**	**2,552**	**3,962**	**45**	**39**	**30**	**7**	--	**0.09**	**3.84**	**0.13**	--	--	**Completed**	**2007**
2002[d]	12,344	2,500	3,990	101	159	64	20	1	0.98	4.88	0.66	--	--	Completed	2006
2001[d]	18,904	--na--	2,429	33	38	17	7	0	0.23	--	0.28	--	--	Completed	2006

[a] In 2007, fish tagged in the fall were split into transport (4,360 fish) and inriver (4,382 fish) groups, with inriver fish being released to the Lower Granite Dam tailrace.

[b] These fish were tagged at Dworshak Hatchery as part of a joint NOAA Fisheries/U. S. Fish and Wildlife Service study. Fish were assigned to either a "Transport" or "Bypass" group prior to release.

[c] These fish were tagged at Lower Granite Dam from 2 Jun to 30 July 2004.

[d] Juvenile "Bypass" numbers are raw numbers, not adjusted using the methodology of Sandford and Smith (2002).