Transportation of Juvenile Salmonids on the Snake River, 2006: Final report for the 2003 Wild Spring/Summer Chinook Salmon Juvenile Migration

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EXECUTIVE SUMMARY

The National Marine Fisheries Service began annual studies in 1995 to evaluate the efficacy of transporting Snake River spring/summer Chinook salmon *Oncorhynchus tshawytscha* smolts from Lower Snake River hydropower projects. From March to August 2006, we recovered 24 age-3-ocean spring/summer Chinook salmon adults, completing adult returns from smolts tagged during the 2003 study year.

In 2003, we tagged only wild fish and either released them into the Lower Granite Dam tailrace or loaded them into a barge at Lower Granite Dam. For analysis, the inriver migrant group was compared with two transport groups: one tagged and transported from Lower Granite Dam (LGR) and a second collected and transported from Little Goose Dam (LGS). The inriver migrant group excluded any fish detected at a Snake River dam after collection and tagging at LGR. During 2003, inriver migrants experienced higher-than-average flows, particularly late in the migration season. Spill during 2003 was provided at Snake and Columbia River dams as prescribed by the National Marine Fisheries Biological Opinion.

Based on all 2003 returns combined (jacks through age-3-ocean fish), the smolt-to-adult return rates (SARs) were 0.34 for fish transported from Lower Granite Dam, 0.20 for those transported from Little Goose Dam, and 0.13 for fish released to migrate in the river. For comparison, we also estimated the SAR of fish collected and returned to the river (bypassed) at one or more collector dams below Lower Granite Dam. The SAR for these bypassed fish was 0.10 (95% CI, 0.05-0.15).

For our study fish, these results produced transport-to-in-river migrant ratios (T/Is) of 2.64 (95% CI, 1.88-4.27) for fish transported from Lower Granite Dam and 1.60 (95% CI, 0.96-2.77) for fish transported from Little Goose Dam. We also observed a ratio of 1.65 for Lower Granite Dam to Little Goose Dam transport groups. As in previous years, SARs varied with timing of the juvenile migration. The estimate of annual differential delayed mortality, *D*, was 0.99.

While annual estimates of SAR and *D* are a main objective of transportation studies, the most useful information in recent years has been the discovery of temporal patterns in these indices. As in previous years, transport SARs in 2006 varied according to timing of the juvenile migration: there was a slight rise in SARs for fish that migrated early in the 2003 season, followed by a drop, and then a strong surge upward in mid-May. In a pattern similar to that observed in recent years, SARs for inriver migrants were highest for fish that migrated as juveniles early in the season and gradually

decreased for later-migrating juveniles. Because delayed mortality, *D*, is driven by the transport SAR pattern, peaks in *D* occurred at the same time as peaks in transport SARs, with the highest peak occurring at the end of May.

In transportation studies from 1995 to 2001, we collected and tagged a relatively constant proportion of the population arriving at Lower Granite Dam. Thus a majority of study fish were collected during the peak of the juvenile migration, with far fewer being tagged early or late in the season. After observing the marked differences in SARs related to juvenile migration timing, we redesigned the study to tag more fish in the early and late segments of the migration season. This tagging design provided more accurate data with which to examine relationships between SARs and juvenile migration timing.

However, as a result of this tagging plan, the passage distribution of the general population of migrating wild spring/summer Chinook salmon at Lower Granite Dam was slightly different from that of our tagged sample. When we weighted the results according to passage distribution of the general population, the SAR for fish transported from Lower Granite Dam dropped from 0.34 to 0.25, while the SAR for inriver migrants remained at 0.13. Thus, the T/I for fish transported from Lower Granite Dam dropped from 2.64 to 1.96. Weighting also decreased the estimate of annual differential delayed mortality, *D*, from 0.99 to 0.90.

Among wild spring/summer Chinook transported from Lower Granite Dam in 2003, fish tagged at the dam for NMFS transportation studies produced higher T/I ratios (2.64) than fish tagged above the dam for other studies (0.62). Also, for wild spring/summer Chinook salmon transported from Little Goose Dam, fish tagged at Lower Granite for NMFS transportation evaluations produced a higher T/I ratio (1.60) than fish tagged above Lower Granite Dam for other research (0.77).

Conversion rates (the percentage of adults that successfully migrated from Bonneville Dam to Lower Granite Dam) varied widely among the three groups, perhaps in part due to the low number of adults. Respective overall conversion rates were 80.0 for groups transported from Lower Granite, 87.5 for those transported from Little Goose, and 96.0 % for inriver migrants (numbers were not adjusted for take in the Zone 6 fishery). Age-2-ocean adults had higher conversion rates, in general, than age-3-ocean adults. Median travel times of age-2-ocean adults ranged from 17 to 109% shorter than those of age-3-ocean adults.

CONTENTS

INTRODUCTION

In 2006, 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 our studies was to compare adult returns of wild yearling spring/summer Chinook salmon *Oncorhynchus tshawytscha* with different migration histories. Study fish were PIT-tagged as smolts and transported to a release site below Bonneville Dam, while their cohorts were allowed to migrate under optimal conditions for inriver survival. Detections of PIT-tagged smolts released to migrate in the river also provide data for short-term juvenile survival estimates between the point of release and Bonneville Dam tailrace (Muir et al. 2001).

Here we report final results from the 2003 Snake River wild spring/summer Chinook salmon tagging year at Lower Granite Dam, which was completed with the recovery of age-3-ocean adults in 2006. Information is also provided on tagging for the juvenile transportation study during 2006 (Appendix B), complete adult returns from the 1995-2002 tagging years, and incomplete adult returns from the 2004-2005 tagging years (Appendix C).

During transportation study years 1995-1996 and 1998-1999, we PIT-tagged wild and hatchery spring/summer Chinook salmon smolts at Lower Granite Dam. Adult returns of these smolts were compared between fish transported to below Bonneville Dam and those released to the tailrace of Lower Granite Dam to migrate in the river. Study fish collected at downstream dams were returned to the river to continue migration.

However, in evaluating adult returns from those years (and from fish PIT-tagged in the same years upstream of Lower Granite Dam), we found that smolts bypassed and returned to the river at downstream dams usually survived to adulthood at lower rates than those bypassed only at Lower Granite Dam. Furthermore, fish not detected at dams usually returned at higher rates than fish bypassed at downstream collector dams (Williams et al. 2005). These fish may have passed the dams via spillways or turbines, or they may have passed through juvenile fish facilities without being detected.

Thus, in hindsight, the study designs from 1995 through 1999 did not provide sufficient information to compare the returns of non-detected/non-transported fish to those of fish that were transported. We therefore revised the study design in 2000 to compare smolt-to-adult return rates (SARs) of transported fish only to those of inriver migrants with no detection history on the Snake River other than initial collection and tagging. In addition, the study was modified to use only wild fish, since these are the populations of most concern.

METHODS

Sampling and Tagging of Juveniles

We PIT-tagged fish at Lower Granite Dam to develop the following three treatments: Lower Granite transport, Little Goose transport, and inriver migrant. To form the Lower Granite transport group, we loaded fish directly onto barges after tagging (n = 6,800). We released the remaining fish into the tailrace of Lower Granite Dam (n = 47,600). At Little Goose Dam, 80% of the study fish collected were diverted to transport barges to form the Little Goose transport group. The remaining 20% were returned to the river.

The inriver migrant group included only fish that were never detected at a Snake River collector dam. In other words, fish were excluded from the inriver migrant group if they were detected at either Little Goose Dam or at Lower Monumental Dam, even if they were returned to the river to continue downstream migration. Fish returned to the river at Little Goose Dam were used to help develop survival estimates necessary to estimate differential delayed mortality, *D*. We estimated delayed mortality as:

$$D = (S_M)(\mathrm{T/I})/S_T$$

where S_M was the estimated inriver survival from Lower Granite Dam tailrace to Bonneville Dam tailrace and S_T was survival during barge transport (assumed to be 0.98).

To determine release-group sizes at Lower Granite Dam, we calculated the number of fish required to test the null hypothesis, that there is no real difference between the SARs of transported and migrant fish. The alternate hypothesis was that the difference was real, with a long-term survival advantage of at least 40% for transported fish (i.e., that ratio of transported to inriver migrant SARs (T/I) was ≥1.4) 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

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

and

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

where n is the number of adult returns per treatment (for either n_T transport or n_I migrant groups).

The previous two statements imply that the sample of adults needed was:

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

Therefore, if α = 0.05 and β = 0.20, and if we wish to discern a difference of 40% (T/I = 1.4), and we expect a transport SAR of at least 2.1% for each species, the sample sizes needed at Lower Granite Dam were:

n =	142
N_T =	6,800
N_I =	9,520
Total juveniles =	16,320

Where NT is the number of juveniles needed for the transport cohort and NI is the number of fish needed for the migrating cohort (6,800 × 1.4).

In 1995, 29.7% of the spring/summer Chinook salmon smolts that we released into the Lower Granite Dam tailrace were never again detected. Based in part on this outcome, we conservatively estimated that at least 20% of the wild spring/summer Chinook salmon smolts released into the Lower Granite Dam tailrace would not be detected thereafter. Therefore, to provide 9,520 fish for the non-detected group would require a release of approximately 47,600 fish (9,520/0.2) into the Lower Granite Dam tailrace.

This number also provided sufficient smolts for collection at Little Goose Dam to form a transport test group. For example, assuming a collection efficiency at Little Goose Dam of approximately 40%, we would expect 19,400 (47,600 × 0.4) wild spring/summer Chinook salmon smolts to be collected for transport at that dam. The Lower Granite Dam transport group required an additional 6,800 fish.

Marked fish were held an average of 24 h before transport or release into the Lower Granite Dam tailrace, with tailrace releases made in the early morning. Basic collection and handling followed the methodology described by Marsh et al. (1996, 2001). We continued using the re-circulating anesthetic water system described in Marsh et al. (2001).

We tagged larger numbers of fish at the beginning and end of the migration season, when fewer fish were arriving at the dam. These larger releases were intended to compensate for the loss of statistical power due to low numbers of fish early and late in the season (an issue which we encountered in previous study years).

Inriver Juvenile Migration

During migration, inriver study fish were tracked by PIT-tag detection systems as they passed through the collection systems at dams downstream from Lower Granite Dam (Marsh et al. 1996). Prior to 27 June 2003, the juvenile collection facility at McNary Dam was in "bypass mode," meaning all tagged and untagged fish collected (except tagged fish from our Columbia River hatchery study) were bypassed to the river after passing through PIT-tag detectors.

Thus, fish from our releases that passed McNary Dam prior to 27 June experienced conditions identical to those of the general population of migrants, and thus were included in the study (as inriver migrants). Beginning at 0700 on 27 June 2003, all non-tagged fish collected at McNary Dam were transported; therefore, any study fish bypassed after this date was excluded from analysis. At Little Goose and Lower Monumental Dams, fish detected on coils leading to the raceways were assumed to have been transported, while fish detected on diversion system coils were assumed to have been returned to the river.

Adult Recoveries and Data Analysis

In 2006, we completed the recovery of adults tagged as juveniles in 2003. To estimate the number of juvenile fish in the Little Goose Dam (LGS) transport group and in the inriver migrant group, we used the procedures of Sandford and Smith (2002). A brief explanation of these procedures can be found in Appendix D.

To calculate 95% CIs for various T/Is, release days were pooled until a minimum of two adults returned in both transport and migrant categories. Empirical variance estimates were calculated using these temporal replicates. Daily (or multiple-day pooled) facility collection numbers were used to weight the replicates to provide weighted seasonal T/Is applicable to the untagged population. The weighted mean T/Is and CIs were then constructed on the natural logarithm scale (i.e., such ratio data were assumed to be log-normally distributed) and back-transformed.

RESULTS

Sampling and Tagging of Juveniles

We PIT-tagged 50,535 wild yearling spring/summer Chinook salmon from 8 April through 6 June 2003 (Table 1 and Appendix Table A1). The number of fish tagged daily ranged from 35 to 1,762. Of the 50,535 fish tagged, 43,098 were released into the tailrace, and 7,114 were transported in barges from Lower Granite Dam. Of the 43,098 wild fish released into the tailrace of Lower Granite Dam, 13,720 were first detected, collected, and transported from Little Goose Dam and 2,069 from Lower Monumental Dam (An additional 588 were transported from Lower Monumental Dam but were first detected at Little Goose Dam.).

Table 1. Numbers, mean fork length, mean weight, and mean condition factor (Ricker 1975) of wild juvenile spring/summer Chinook salmon smolts PIT-tagged and released as part of the Lower Granite Dam transportation study, 2003.

	Spring/summer Chinook salmon			
		Mean		
	Number	Fork length (mm)	Weight (g)	Condition factor
Transported from Lower Granite Dam				
Tagged	7,114	105.5	13.0	1.13
Released	7,114	105.5	13.0	1.13
Released into the Lower Granite Dam tailrace				
Tagged	43,421	108.2	12.4	0.98
Released*	43,098	108.2	12.4	0.98
Transported from Little Goose Dam				
Released	13,720	108.0	12.5	0.98
Bypassed at one or more dams				
Released	6,543	108.0	12.5	0.99

* Release numbers adjusted for mortality and tag loss.

Based on mortality counts from the holding tanks at Lower Granite Dam, 24-h post-marking delayed mortality averaged 0.4% for spring/summer Chinook salmon over the entire tagging season. Only a few fish that were either severely injured or exhibited gross symptoms of bacterial kidney disease were rejected for tagging.

By tracking the unique PIT-tag code of each mortality, we determined the body condition recorded when each fish was tagged. Unlike previous years (Marsh et al. 1996, 1997, 2000), where we found that descaling affected post-marking delayed mortality for spring/summer Chinook salmon, no correlation could be determined between any particular body condition and delayed mortality in 2003.

We recorded fork length for all fish and weight for 50% of the fish during tagging. To minimize tagging spring/summer Chinook salmon of hatchery origin that had partial or no fin clips (identifying them as hatchery fish), we set the maximum fork length for a fish to be considered wild at 124 mm. Based on previous analyses of known wild fish collected and measured during their juvenile migration (Marsh et al. 2001), this limited the number of hatchery fish marked while keeping to a minimum the number of wild fish inadvertently excluded.

Inriver Juvenile Migration

As inriver study fish continued their seaward migration, some were detected at dams downstream from Lower Granite Dam. Of the 43,098 wild spring/summer Chinook salmon tagged and released to the tailrace of Lower Granite Dam as inriver migrants, 17,593 (40.8%) were never detected in the Snake River after tagging. Of the 25,505 (59.2%) migrants detected, 13,720 were transported from Little Goose Dam, 2,657 were transported from Lower Monumental Dam (2,069 of the 2,657 were detected for the first time after tagging at Lower Granite Dam), and 8,977 were detected and returned to the river at one or more Snake River dams (Table 2 and Appendix Tables A2-A5). Analysis of SARs from the 2003 juvenile migration were based on estimates of 14,708 juvenile fish in the Little Goose transport group and 18,778 in the inriver migrant group. An additional 6,050 juvenile fish were included in a bypassed group for SAR calculations. Although a bypassed group had not been part of the original study design, we calculated SARs for these fish in response to requests for this data.

Table 2. Summary of PIT-tagged wild spring/summer Chinook salmon smolts included in transportation evaluation and final disposition of fish released at Lower Granite Dam and subsequently detected at Little Goose Dam in spring, 2003.

Last coil observation	Final disposition	Number detected at Little Goose Dam
Excluded from transportation study		
Diversion or river return	River	4,301
Raceway	River*	0
Separator	Unknown	85
Total returned to river		4,386
PIT-tagged fish included in study		
Raceway	Loaded to barge/truck and transported	13,057
SMP sample	Smolt Monitoring Program sample	663
Total transported		13,720
Total observed at Little Goose Dam		**18,106**

* Because fish cannot be held in transportation loading raceways longer than 48 h, these raceways must be emptied into the river in cases of delayed loading.

Our initial goal was to transport 80 and 50% of the yearling Chinook salmon collected at Little Goose and Lower Monumental Dams, respectively. The actual proportions of yearling Chinook collected that were diverted to transportation barges were 75.8% at Little Goose and 50.8% at Lower Monumental Dam.

During the 2003 migration season, flows were higher than average, particularly late in the season, and spill was provided at Snake and Columbia River dams as prescribed by the National Marine Fisheries Service Biological Opinion (NMFS 2000). Based upon PIT-tag detections at John Day and Bonneville Dams and on estuary detections in the pair-trawl system (Ledgerwood et al. 2004) we made preliminary estimates of survival from Lower Granite Dam tailrace to McNary and Bonneville Dam tailraces. For wild spring/summer Chinook salmon smolts, we estimated survival of 72.9 and 53.1% over the two respective reaches.

Adult Recoveries and Data Analysis

We began recovering jacks from the 2003 releases at Lower Granite Dam in 2004, and in August 2006, we completed recoveries from this release year with the collection of age-3-ocean adults. Returns by study group and age-class are shown in Table 3. We included the "bypassed at one or more dams" group for comparison with the migrant group; however, it was not used in the discussions that follow. The percentage of wild age-3-ocean adults in 2006 (from our tagging) was similar to that of the average from the previous 7 years (Table 4).

Table 3. Wild spring/summer Chinook salmon returns by study group and age-class, with number of juveniles adjusted as described by Sandford and Smith (2002) for fish tagged at Lower Granite Dam in 2003.

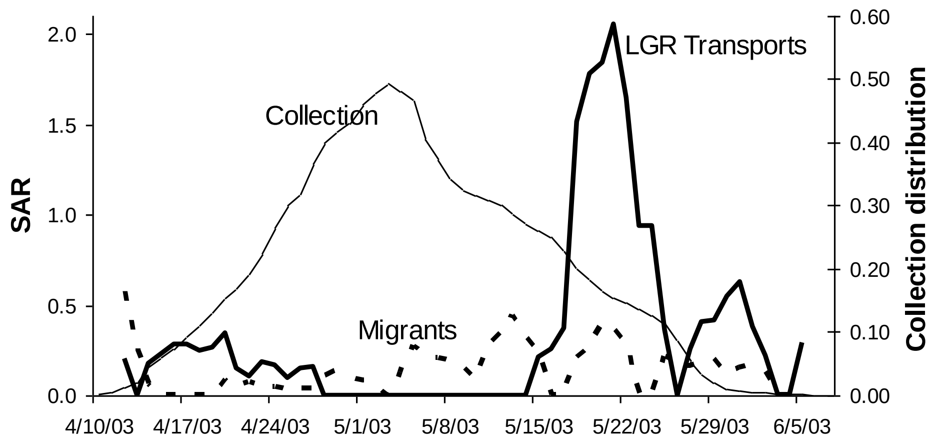
Juvenile numbers	Returns by age-class: Jack	2-ocean	3-ocean	SAR	T/I	95% C.I.	LGR/LGS
Inriver migrants							
18,778	0	19	5	0.13			
Transported from Lower Granite Dam							
7,114	0	14	10	0.34	2.64	(1.88-4.30)	1.65
Transported from Little Goose Dam							
14,708	2	22	6	0.20	1.60	(0.96-2.77)	
Bypassed at one or more dams*							
6,050	0	3	3	0.10	3.40	(1.83-7.46)	

* T/I shown for this group is (Transported from Lower Granite Dam)/(Bypassed at one or more dams).

Table 4. Age-class distribution of returning adults by study year for Snake River wild spring/summer Chinook salmon transportation studies.

Study year	Jacks (%)	2-ocean adults (%)	3-ocean adults (%)	Total adults
1995	1.94	63.23	34.84	55
1996	6.25	62.50	31.25	16
1998	6.90	70.11	22.99	87
1999	4.27	81.10	14.63	328
2000	3.83	40.37	55.80	832
2001	13.21	71.07	15.72	159
2002	8.49	72.60	18.90	365
2003	2.30	68.97	28.74	87

As in previous years, the SARs of transported and migrant groups differed with timing of the juvenile release (Figure 1). The timing of the major increase in transport SARs occurred at roughly the same time as in 2002, around 14 May. A robust examination of temporal SAR trends was made difficult by the generally low adult return rate. For example, for fish tagged from 26 April to 16 May, we observed a 21-d period when no adults returned from fish transported from Lower Granite Dam. Similarly, for fish tagged from 24 April to 15 May, only one adult returned that had been transported from Little Goose Dam. For inriver migrant fish, SARs were erratic, ranging from zero to 0.5% and back multiple times.



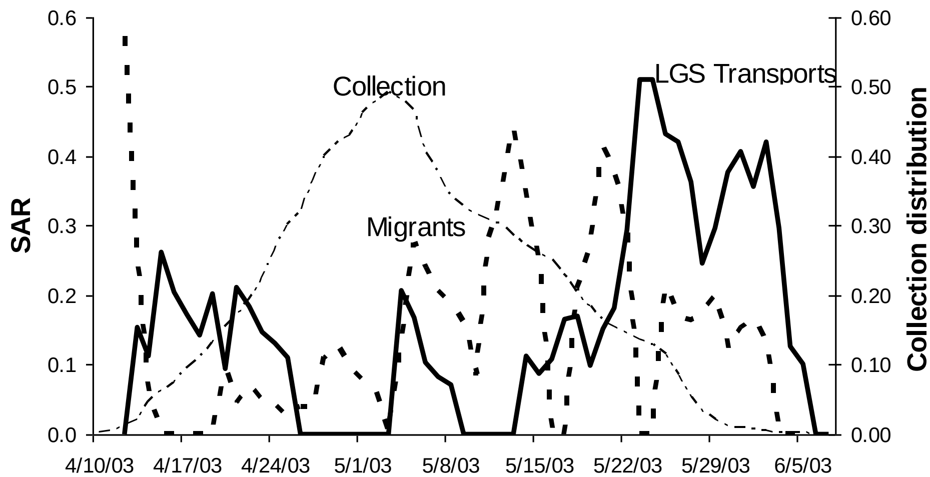


Figure 1. Smolt-to-adult return rates by release date for wild spring/summer Chinook salmon smolts tagged in 2003 and transported from Lower Granite Dam (upper chart) or Little Goose Dam (lower chart) vs. fish released to migrate in the river. Data are 5-d running averages of daily juvenile releases, and numbers are adjusted proportional to daily collection numbers at the dams in 2003. The overall transport/migrant ratios were 2.64 at Lower Granite and 1.60 at Little Goose Dam.

In transportation studies from 1995 to 2001, we collected and tagged a relatively constant proportion of the population arriving at Lower Granite Dam. Thus a majority of study fish were collected during the peak of the juvenile migration, with far fewer being tagged early or late in the season. After observing the marked differences in SARs related to juvenile migration timing, we redesigned the study to tag more fish in the early and late segments of the migration season. This tagging design provided more accurate data with which to examine relationships between SARs and juvenile migration timing.

However, because we tagged larger numbers of fish at the beginning and end of the migration season in 2003, the arrival distribution of study fish did not emulate that of the general population at Lower Granite Dam. When we weighted the results according to passage distribution of the general population, the SAR for fish transported from Lower Granite Dam dropped from 0.34 to 0.25, while the SAR for inriver migrants remained at 0.13. Thus, the T/I for fish transported from Lower Granite Dam dropped from 2.64 to 1.96. Weighting also decreased the estimate of annual differential delayed mortality, *D*, from 0.99 to 0.90 (Figure 2).

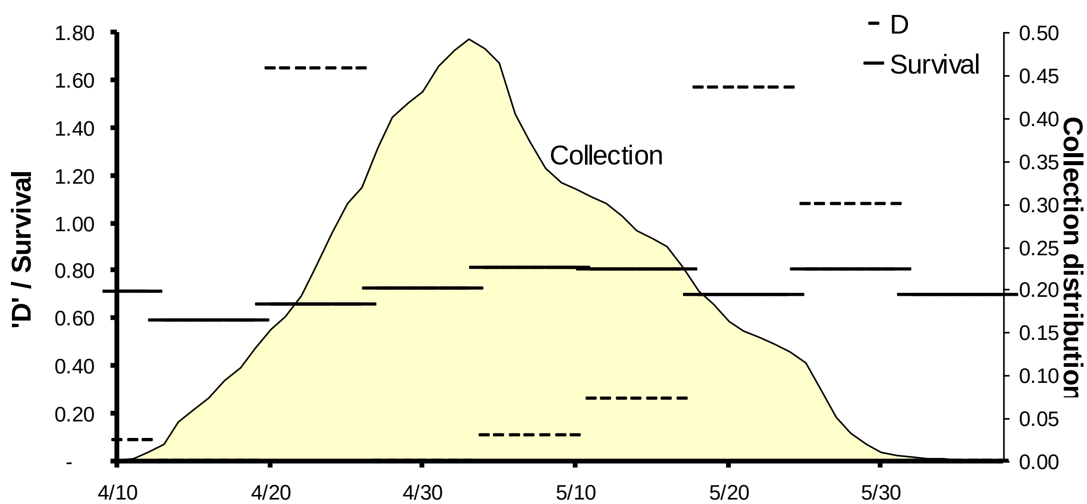


Figure 2. Estimates of differential delayed mortality (*D*) and in-river survival between Lower Granite and McNary Dams over time for wild spring/summer Chinook salmon smolts tagged at Lower Granite Dam in 2003. Overall *D* of the tagged fish for the year was 0.99, while the overall *D* for the general population was 0.90.

The conversion rate, or number of returning adults observed at Bonneville Dam and subsequently observed at Lower Granite Dam (number not adjusted for harvest in the Zone 6 fishery) varied greatly between study groups and age classes (Table 5). Most adults that did not successfully migrate from Bonneville Dam to Lower Granite Dam were lost between Bonneville and McNary Dams (Table 6). There were differences in passage timing among groups through the reach from Bonneville to McNary Dam (Table 7). Depending on how the Zone 6 fishery was managed, these timing differences may explain some of the conversion rate differences.

Table 5. Percentage of adult wild spring/summer Chinook salmon PIT-tagged in 2003 that were observed at Bonneville Dam and subsequently detected at Lower Granite Dam (the conversion rate).

Migration history	Number seen at Bonneville Dam	Number seen at Lower Granite Dam	Conversion rate
	Jacks		
Inriver migrant	0	0	--
LGR Transport	0	0	--
LGS Transport	2	2	100.00
Bypass	1	0	0.00
	Age-2-ocean adults		
Inriver migrant	17	16	94.12
LGR Transport	16	14	87.50
LGS Transport	21	20	95.24
Bypass	9	8	88.89
	Age-3-ocean adults		
Inriver migrant	3	3	100.00
LGR Transport	14	10	71.43
LGS Transport	9	6	66.67
Bypass	5	5	100.00
	Totals		
Inriver migrant	20	19	95.00
LGR Transport	30	24	80.00
LGS Transport	32	28	87.50
Bypass	15	13	86.67

Table 6. Adult conversion rates (percent) from Bonneville Dam to McNary Dam and from McNary Dam to Lower Granite Dam for wild spring/summer Chinook salmon PIT-tagged and released from Lower Granite Dam in 2003.

Reach	Migration history	Seen at first dam (n)	Subsequently seen at second dam (n)	Conversion rate
		Jacks		
BON to MCN	Inriver migrant	0	0	--
	LGR Transport	0	0	--
	LGS Transport	2	2	100.00
	Bypass	1	0	0.00
MCN to LGR	Inriver migrant	0	0	--
	LGR Transport	0	0	--
	LGS Transport	2	2	100.00
	Bypass	0	0	--
		Age-2-ocean adults		
BON to MCN	Inriver migrant	17	16	94.12
	LGR Transport	16	14	87.50
	LGS Transport	21	21	100.00
	Bypass	9	8	88.89
MCN to LGR	Inriver migrant	16	16	100.00
	LGR Transport	14	14	100.00
	LGS Transport	23	22	95.65
	Bypass	8	8	100.00
		Age-3-ocean adults		
BON to MCN	Migrant	3	3	100.00
	LGR Transport	14	11	78.57
	LGS Transport	9	6	66.67
	Bypass	5	5	100.00
MCN to LGR	Migrant	3	3	100.00
	LGR Transport	11	10	90.91
	LGS Transport	6	6	100.00
	Bypass	8	5	62.50
		Totals		
BON to MCN	Migrant	20	19	95.00
	LGR Transport	30	25	83.33
	LGS Transport	32	29	90.63
	Bypass	15	13	86.67
MCN to LGR	Migrant	19	19	100.00
	LGR Transport	25	24	96.00
	LGS Transport	31	30	96.77
	Bypass	16	13	81.25

Table 7. Median adult passage date through Bonneville and McNary Dams. Also shown are the tenth and ninetieth percentiles.

Age class		Number of adults	Passage date: Median	10th Percentile	90th Percentile
			Bonneville Dam		
Jacks	LGS Transport	2	6/22/04	6/7/04	7/8/04
	Bypass	1	8/29/04	---	---
Age-2-ocean adults	Inriver migrant	17	5/31/05	4/24/05	7/9/05
	LGR Transport	16	5/21/05	4/27/05	6/15/05
	LGS Transport	21	5/22/05	4/28/05	6/19/05
	Bypass	9	5/30/05	4/25/05	6/17/05
Age-3-ocean adults	Inriver migrant	3	5/12/06	4/27/06	5/15/06
	LGR Transport	14	5/19/06	5/5/06	6/15/06
	LGS Transport	9	5/15/06	5/7/06	6/14/06
	Bypass	5	5/16/06	5/2/06	5/21/06
			McNary Dam		
Jacks	LGS Transport	2	6/27/04	6/12/04	7/13/04
Age-2-ocean adults	Inriver migrant	16	6/6/05	4/28/05	7/22/05
	LGR Transport	14	5/27/05	5/3/05	6/29/05
	LGS Transport	23	5/27/05	5/2/05	6/25/05
	Bypass	8	6/5/05	4/30/05	6/28/05
Age-3-ocean adults	Inriver migrant	3	5/18/06	5/6/06	5/21/06
	LGR Transport	11	5/20/06	5/11/06	6/28/06
	LGS Transport	6	5/21/06	5/12/06	6/18/06
	Bypass	5	5/28/06	5/10/06	6/5/06

In 2003, with the addition of adult detection capabilities at dams on the Columbia River above the confluence with the Snake River, we were able to observe whether straying occurred. No adults from the 2003 study strayed above the Snake/Columbia River confluence.

Upstream travel time from Bonneville to Lower Granite Dam ranged from 11.0 to 23.0 d (Table 8). Travel time increased with each age class, and within age classes, travel times were roughly the same between Bonneville and McNary Dam as between McNary and Lower Granite Dam. There were differences between treatment groups which varied with age class. Age-2-ocean migrant adults were faster than both transport groups, but age-3-ocean migrant adults were slower. Fish transported from Little Goose Dam were faster as adults than those transported from Lower Granite Dam.

Table 8. Travel times from Bonneville Dam to Lower Granite Dam for adult wild spring/summer Chinook salmon PIT-tagged as juveniles in 2003.

Age class	Migration history	Travel time from Bonneville Dam to Lower Granite Dam (d)
Jacks	Inriver migrant	--
	Transported LGR	--
	Transported LGS	11.0
	Bypass	--
Age-2-ocean	Inriver migrant	11.0
	Transported LGR	14.5
	Transported LGS	13.0
	Bypass	11.5
Age-3-ocean	Inriver migrant	23.0
	Transported LGR	17.0
	Transported LGS	19.5
	Bypass	19

For adults transported from both dams, average tagging length decreased with an increase in age of the returning adults. The exception was for jacks transported from Little Goose Dam: these fish were smaller than age-2-ocean adults, but larger than age-3-ocean adults (Table 9). Inriver migrant age-2-ocean adults were smaller than the age-3-ocean adults.

Table 9. Average tagging lengths, weights, and condition factors of adult wild spring/summer Chinook salmon PIT-tagged as juveniles at Lower Granite Dam in 2003.

Age class		Number of adults	Average values as juveniles at tagging of returning adults		
			Tag length (mm)	Tag weight (g)	Condition factor
Jacks	Inriver migrant	0	--	--	--
	LGR Transport	0	--	--	--
	LGS Transport	2	110.0	14.7	0.97
	Bypass	0	--	--	--
	Total	2	110.0	14.7	0.97
Age-2-ocean	Inriver migrant	19	112.1	13.0	0.95
	LGR Transport	14	112.0	14.4	1.01
	LGS Transport	22	114.2	15.2	0.99
	Bypass	4	103.3	15.5	1.02
	Total	59	112.3	14.3	0.99
Age-3-ocean	Inriver migrant	5	115.8	11.8	0.89
	LGR Transport	10	107.5	14.4	1.16
	LGS Transport	6	106.5	12.7	1.08
	Bypass	3	112.0	12.4	1.01
	Total	24	109.5	13.8	1.11

DISCUSSION

For most transport studies conducted of spring/summer Chinook salmon smolts since 1995, annual T/Is, while indicating a transport benefit, have been lower than expected compared with concurrent estimates of in-river survival (Marsh et al. 2000, 2001; Muir et al. 2001). In contrast to coded-wire tag studies prior to 1995, contemporary study designs and the use of PIT tags allow for a more refined analysis of SARs and T/I*s* than a simple calculation of an annual average.

Calculating the statistics for groups of fish by the period when they were marked as smolts has revealed an interesting time trend in the data. Recent annual T/I*s* have been lower than expected, primarily because transport SARs were much lower for fish tagged as smolts earlier in the migration season than for those tagged later. The timing of rather abrupt increases in transport SARs for smolts that migrated later has been inconsistent among study years. In general, transport benefits are equivocal early in the season and at roughly expected levels later in the season. As a result, when averaged over the entire juvenile migration season, overall T/I*s* have been lower than expected.

As shown below, the transition date from low to high transport SARs for wild spring/summer Chinook salmon has varied during previous study years. Transition dates have ranged from 22 April to 16 May (Marsh et al. 2000, 2003, 2004a,b, 2005, 2006). The transition date of the 2003 juvenile migration was 14 May, and this was the second latest date observed in the current sequence of studies.

Study year	Transition date of rise in SARs for transported fish
1995	5 May
1998	25 April
1999	22 April
2000	6 May
2001	26 April
2002	16 May
2003	14 May

Among wild spring/summer Chinook transported from Lower Granite Dam in 2003, fish tagged at the dam for NMFS transportation studies produced higher T/I ratios (2.64) than fish tagged above the dam for other studies (0.62). Also, for wild spring/summer Chinook salmon transported from Little Goose Dam, fish tagged at Lower Granite for NMFS transportation evaluations produced a higher T/I ratio (1.60) than fish tagged above Lower Granite Dam for other research (0.77).

A comparison of these T/Is should consider any substantial differences between the two studies, such as study population, collection and handling techniques, timing of collections, or numbers of fish tagged. For example, of fish PIT-tagged above Lower Granite Dam in 2003, over 50% arriving at the dam were from either the Imnaha or Snake River trap. In contrast, fish tagged at the dam were collected over the course of the juvenile migration season, and thus represented populations from several streams with different possible migration timing. Study fish collected over a longer period would thus more likley provide a representative sample of the entire spring/summer Chinook salmon population migrating out of Idaho and northeastern Oregon.

However, fish were also tagged at the dam in greater numbers during the early and late passage distribution periods to examine trends in SARs related to juvenile migration timing. Thus, the annual T/I estimate was affected by this sampling design. Weighting the SARs of NMFS study fish based on distribution of the general population decreased the T/I for fish transported from Lower Granite Dam from 2.64 to 1.96. Several factors can substantially influence SARs and T/Is from different studies, and it is important that such factors not be overlooked in comparisons of these results.

The observed within-year changes in SARs were unexpected. To the best of our knowledge, the rather abrupt within-year increases in transport SARs were not related to any environmental or biological factor that has been examined during the freshwater phase. A rather significant, post-release phenomenon appears to have affected the survival of transported fish during most of April, and even into early May in some years, and then has dissipated quickly. The SARs of inriver migrants PIT-tagged and released in April may not have been similarly affected because the great majority of these fish would have arrived below Bonneville Dam 2-3 weeks later than transported fish (Muir et al. 2006). Furthermore, the arrival timing distribution in the estuary is more protracted for the inriver migrant cohort. Therefore, inriver migrant juveniles likely enter the ocean under varying conditions, depending on time of arrival. This attenuates any clear "signal" that might be evaluated during the freshwater phase of juvenile migration.

We have not observed any temporal differences in migration behavior, physiology, disease, or transport methodologies that might explain the abrupt and sustained seasonal changes in SARs of transported fish. We believe the pattern relates to arrival timing of smolts in the estuary and near-ocean environments in recent years. Conditions that might vary annually in these areas include predator abundance and dynamics (birds, fish, and marine mammals), alternative prey availability for those predators (anchovies, herring, and sand lance), and abundance of prey for juvenile salmon (enhanced survival of fast-growing, robust smolts) (Emmett and Brodeur 2000; Emmett et al. 2006). Changes in predator/prey dynamics coincidental with the

1976/1977 oceanic regime shift (Hare et al. 1999), particularly during early ocean residence (Hargreaves 1997), likely play a major role in determining annual SARs and high within- and between-year variation in SARs.

Muir et al. (2006) theorized that size-related predation is a cause of post-hydropower system delayed mortality, particularly for wild spring/summer Chinook salmon. The growth that migrant fish experience during their 2-3 week journey to the estuary allows them to reach a large enough size that fewer piscivorous predators can consume them. Early season transported fish lack the opportunity for growth, thereby, reaching the estuary at a size that makes them more vulnerable to predation.

For example, in 2003, while nearly the same percentages (between 61-63%) of both early transported and early migrant wild yearling Chinook salmon were susceptible to northern pikeminnow predation based on size, 33% of early transported fish were susceptible to Pacific hake predation compared to only 12% of their migrant cohorts (Muir et al. 2006).

Conversion rates and travel times of adults from Bonneville Dam to Lower Granite Dam varied wildly between treatment groups. The wide range of rates was most likely due to the poor overall adult return rate, which, in turn, resulted in very small numbers of adults in some age classes (3-22 adults). As we have seen in the past, more fish were lost between Bonneville and McNary Dams than between McNary and Lower Granite Dams. However, when the Zone 6 fishery is factored in, the conversion rates are virtually the same. For example, the average conversion rate for all age-2-ocean adults from this study (in 2005) between Bonneville and McNary Dams was 92.2%, without accounting for the Zone 6 fishery. The Zone 6 fishery's estimated take in 2005 was 6.8%. Adjusting the Bonneville Dam to McNary Dam conversion rate for the fishery yields a conversion rate of 99.0%, virtually matching the McNary Dam to Lower Granite Dam conversion rate of 98.4%.

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APPENDIX A

Juvenile Data from the 2003 Spring/Summer Chinook Salmon Tagging Year

Appendix Table A1. Total wild spring/summer Chinook salmon tagged at Lower Granite Dam in spring 2003.

	Transported from Lower Granite Dam		Released into Lower Granite Dam tailrace			
Tag Date	Tagged	Released	Tagged	Mortalities	Lost tags	Released
4/8/03	265	265	0	0	0	0
4/9/03	84	82	440	4	1	435
4/10/03	93	93	543	2	1	540
4/11/03	46	46	337	1	0	336
4/12/03	-	-	-	-	-	-
4/13/03	-	-	-	-	-	-
4/14/03	225	215	1,317	3	0	1,311
4/15/03	219	218	1,479	9	0	1,469
4/16/03	158	158	1,086	4	0	1,082
4/17/03	114	114	715	10	0	704
4/18/03	110	109	679	5	2	670
4/19/03	-	-	-	-	-	-
4/20/03	-	-	-	-	-	-
4/21/03	196	196	1,245	13	0	1,229
4/22/03	363	358	2,306	10	0	2,295
4/23/03	255	255	1,656	6	0	1,650
4/24/03	275	274	1,771	4	0	1,767
4/25/03	131	129	848	1	0	848
4/26/03	-	-	-	-	-	-
4/27/03	-	-	-	-	-	-
4/28/03	229	229	1,334	6	0	1,327
4/29/03	91	91	572	2	0	570
4/30/03	53	53	355	0	0	355
5/1/03	117	117	766	0	0	766
5/2/03	124	123	743	1	0	742
5/3/03	-	-	-	-	-	-
5/4/03	-	-	-	-	-	-

Appendix Table A1. Continued.

	Transported from Lower Granite Dam		Released into Lower Granite Dam tailrace			
Tag Date	Tagged	Released	Tagged	Mortalities	Lost tags	Released
5/5/03	146	142	914	1	0	911
5/6/03	197	193	1,216	3	0	1,213
5/7/03	325	324	2,103	15	0	2,085
5/8/03	187	183	1,268	3	0	1,265
5/9/03	105	102	616	6	0	610
5/10/03	-	-	-	-	-	-
5/11/03	-	-	-	-	-	-
5/12/03	93	92	606	8	0	598
5/13/03	119	118	767	15	0	752
5/14/03	68	67	447	2	0	445
5/15/03	79	79	474	3	1	470
5/16/03	121	121	693	6	0	687
5/17/03	-	-	-	-	-	-
5/18/03	-	-	-	-	-	-
5/19/03	134	132	854	7	0	847
5/20/03	198	197	1,172	6	0	1,165
5/21/03	161	159	903	6	0	897
5/22/03	97	97	603	3	0	600
5/23/03	146	145	967	2	2	963
5/24/03	131	130	912	2	0	910
5/25/03	-	-	-	-	-	-
5/26/03	459	453	2,739	10	0	2,729
5/27/03	119	118	712	4	0	708
5/28/03	88	88	556	4	0	551
5/29/03	331	330	2,002	13	2	1,986
5/30/03	218	213	1,347	8	2	1,335
5/31/03	162	161	1,007	5	0	1,002
6/1/03	-	-	-	-	-	-
6/2/03	80	79	489	5	0	484
6/3/03	62	60	502	3	1	498
6/4/03	52	52	351	1	0	350
6/5/03	76	76	495	0	0	495
6/6/03	73	72	453	0	0	453

Appendix Table A2. Observations (detections) and transportation numbers at Little Goose Dam of wild spring/summer Chinook salmon released into the Lower Granite Dam tailrace, 2003.

File name	Total observed	Number transported	Percent transported
DMM03099.IR1	176	133	75.6
DMM03100.IR1	221	176	79.6
DMM03101.IR1	125	108	86.4
DMM03104.IR1	407	321	78.9
DMM03105.IR1	502	365	72.7
DMM03106.IR1	453	354	78.1
DMM03107.IR1	362	290	80.1
DMM03108.IR1	327	258	78.9
DMM03111.IR1	549	427	77.8
DMM03112.IR1	803	599	74.6
DMM03113.IR1	635	492	77.5
DMM03114.IR1	492	353	71.7
DMM03115.IR1	288	224	77.8
DMM03118.IR1	360	273	75.8
DMM03119.IR1	135	105	77.8
DMM03120.IR1	83	58	69.9
DMM03121.IR1	191	145	75.9
DMM03122.IR1	217	169	77.9
DMM03125.IR1	190	137	72.1
DMM03126.IR1	315	240	76.2
DMM03127.IR1	598	463	77.4
DMM03128.IR1	328	243	74.1
DMM03129.IR1	200	160	80.0
DMM03132.IR1	251	195	77.7
DMM03133.IR1	390	290	74.4
DMM03134.IR1	268	192	71.6
DMM03135.IR1	224	152	67.9
DMM03136.IR1	285	228	80.0
DMM03139.IR1	345	277	80.3
DMM03140.IR1	555	421	75.9
DMM03140.IR2	1	1	100.0
DMM03141.IR1	734	549	74.8

Appendix Table A2. Continued.

File name	Total observed	Number transported	Percent transported
DMM03142.IR1	449	325	72.4
DMM03143.IR1	485	377	77.7
DMM03144.IR1	582	444	76.3
DMM03146.IR1	1,734	1,294	74.6
DMM03147.IR1	217	158	72.8
DMM03148.IR1	254	191	75.2
DMM03149.IR1	936	681	72.8
DMM03150.IR1	724	544	75.1
DMM03151.IR1	549	423	77.0
DMM03153.IR1	251	183	72.9
DMM03154.IR1	229	169	73.8
DMM03155.IR1	179	148	82.7
DMM03156.IR1	267	211	79.0
DMM03157.IR1	240	174	72.5

Appendix Table A3. Locations of observations (detections) of PIT-tagged wild juvenile spring/summer Chinook salmon within the Little Goose Dam juvenile fish facility, 2003.

	Detected once at Little Goose Dam (coil location)				Detected on separator and one additional coil (coil location)		
Detection date	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
12-Apr	-	-	-	-	1	-	-
13-Apr	-	-	-	-	6	16	4
14-Apr	-	-	-	-	20	63	19
15-Apr	-	1	-	-	50	186	21
16-Apr	-	2	-	-	27	114	18
17-Apr	-	-	-	-	21	83	12
18-Apr	-	-	-	1	33	125	9
19-Apr	-	-	-	1	47	157	11
20-Apr	-	-	-	-	62	212	14
21-Apr	-	-	-	-	95	342	15
22-Apr	-	1	-	1	119	437	7
23-Apr	-	-	-	3	179	577	17
24-Apr	-	-	-	4	75	256	3
25-Apr	-	-	-	1	199	677	9
26-Apr	-	-	-	2	264	802	3
27-Apr	-	1	-	2	129	447	4
28-Apr	-	-	-	4	103	264	79
29-Apr	-	-	-	2	62	137	50
30-Apr	-	-	-	-	37	94	18
1-May	-	-	-	1	23	56	10
2-May	-	1	-	2	70	182	48
3-May	-	-	-	1	49	152	1
4-May	-	-	-	-	43	133	2
5-May	-	-	-	1	68	177	27
6-May	-	1	1	-	72	211	23
7-May	-	-	-	-	18	54	8
8-May	-	-	-	1	29	95	20
9-May	-	-	-	-	28	83	10
10-May	-	1	-	1	57	188	1
11-May	-	-	-	1	66	244	1
12-May	-	-	-	3	114	340	56
13-May	-	-	-	10	144	368	123
14-May	-	-	-	1	55	164	26
15-May	-	-	-	1	57	189	8
16-May	-	2	-	3	148	460	30
17-May	-	1	-	1	152	509	4
18-May	1	1	-	2	191	412	1
19-May	-	-	-	17	105	422	87
20-May	-	-	-	3	55	158	17
21-May	-	-	-	-	11	40	3

Appendix Table A3. Continued.

	Detected once at Little Goose Dam (coil location)				Detected on separator and one additional coil (coil location)		
Detection date	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
22-May	-	-	-	1	31	97	18
23-May	-	-	-	1	97	326	17
24-May	1	1	-	11	536	1,851	19
25-May	3	7	-	17	819	2,393	15
26-May	2	3	-	6	678	2,072	11
27-May	-	1	-	4	197	698	5
28-May	1	2	-	7	351	1,063	3
29-May	1	1	-	6	437	1,321	8
30-May	-	1	-	3	165	577	2
31-May	-	2	-	12	285	884	3
1-Jun	3	4	-	7	300	913	5
2-Jun	-	1	-	6	234	713	3
3-Jun	1	-	-	1	103	342	1
4-Jun	-	-	-	1	54	204	3
5-Jun	-	-	-	1	77	272	5
6-Jun	-	1	-	1	87	353	2
7-Jun	-	-	-	2	89	307	6
8-Jun	-	-	-	2	88	326	3
9-Jun	-	2	-	-	82	282	3
10-Jun	-	1	-	1	79	235	4
11-Jun	-	-	-	-	27	104	2
12-Jun	-	-	-	-	10	34	1
13-Jun	-	-	-	-	4	16	-
14-Jun	-	-	-	-	1	3	-
15-Jun	-	-	-	-	1	-	-
16-Jun	-	-	-	-	1	5	-
17-Jun	-	-	-	1	-	4	1
19-Jun	-	-	-	-	1	-	-
20-Jun	-	-	-	-	2	5	-
21-Jun	-	-	-	-	1	6	-
22-Jun	-	-	-	-	-	2	-
23-Jun	-	-	-	-	-	1	-
24-Jun	-	-	-	-	-	1	-
26-Jun	-	-	-	-	-	1	-
29-Jun	-	-	-	-	1	1	-
30-Jun	-	-	-	-	-	-	1
1-Jul	-	-	-	-	-	2	-
5-Jul	-	-	-	-	-	-	1
9-Jul	-	-	-	-	-	1	-
12-Jul	-	-	-	-	-	1	-
19-Jul	-	-	-	-	-	1	-
8-Aug	-	-	-	-	-	1	-

Appendix Table A4. Locations of observations (detections) of PIT-tagged wild spring/summer Chinook salmon within the Lower Monumental Dam juvenile fish facility, 2003.

Detection date	Detected once at Lower Monumental Dam (coil location)			Detected on separator and one additional coil (coil location)			
	Diversion	Raceway	Separator	Diversion	River	Raceway	Sample
14-Apr	-	-	-	4	-	3	-
15-Apr	-	-	-	13	-	8	1
16-Apr	-	-	-	13	-	14	2
17-Apr	-	-	-	12	-	12	-
18-Apr	-	-	-	13	-	16	2
19-Apr	-	-	-	4	-	5	1
20-Apr	-	-	-	14	-	11	6
21-Apr	-	-	-	19	-	18	3
22-Apr	-	-	-	60	-	53	5
23-Apr	-	-	1	49	-	48	6
24-Apr	-	-	-	50	-	50	2
25-Apr	-	2	-	56	-	55	3
26-Apr	-	-	-	37	-	35	5
27-Apr	-	-	-	86	-	81	2
28-Apr	-	-	1	43	-	47	9
29-Apr	-	-	-	44	-	43	6
30-Apr	-	-	-	22	-	24	1
1-May	-	-	-	9	-	9	-
2-May	-	-	-	6	-	3	-
3-May	-	-	-	7	-	7	-
4-May	-	-	-	12	-	14	1
5-May	-	-	-	26	-	25	-
6-May	-	-	-	47	-	46	-
7-May	-	-	-	27	-	31	2
8-May	-	-	-	14	-	14	3
9-May	-	-	-	16	-	11	-
10-May	-	-	-	24	-	22	4
11-May	-	-	-	26	-	26	3
12-May	-	-	-	48	-	44	6
13-May	-	-	-	32	-	32	1
14-May	-	-	-	56	-	53	2
15-May	-	-	-	89	-	85	6
16-May	-	-	-	64	-	65	1
17-May	-	-	-	79	-	67	6
18-May	-	-	-	49	-	51	4
19-May	-	-	-	45	-	45	4
20-May	-	-	-	40	-	37	3
21-May	-	1	-	74	-	71	9
22-May	-	-	-	30	-	23	4
23-May	-	-	-	19	-	18	1
24-May	-	-	-	77	-	77	5
25-May	-	-	2	529	-	485	50
26-May	1	1	1	712	-	627	51
27-May	-	-	-	668	28	576	25

Appendix Table A4. Continued.

Detection date	Detected once at Lower Monumental			Detected on separator and one additional coil			
	Diversion	Raceway	Separator	Diversion	River	Raceway	Sample
28-May	-	-	-	182	-	179	10
29-May	-	1	-	126	-	112	11
30-May	-	-	2	231	-	203	29
31-May	1	1	3	241	-	248	34
1-Jun	-	-	2	245	-	229	23
2-Jun	-	-	2	193	1	191	17
3-Jun	-	-	1	159	-	161	12
4-Jun	-	-	-	95	-	93	9
5-Jun	-	-	-	55	-	49	2
6-Jun	-	-	-	54	-	54	2
7-Jun	-	-	-	80	-	78	2
8-Jun	-	-	-	98	-	100	3
9-Jun	-	-	-	84	-	80	6
10-Jun	-	-	-	92	-	102	4
11-Jun	-	-	-	57	-	50	5
12-Jun	-	-	-	33	-	30	3
13-Jun	-	-	-	14	-	15	-
14-Jun	-	-	-	12	-	11	-
15-Jun	-	-	-	3	-	3	-
16-Jun	-	-	-	3	-	1	1
17-Jun	-	-	-	1	-	2	-
18-Jun	-	-	-	5	-	2	-
19-Jun	-	-	-	-	-	1	-
20-Jun	-	-	-	3	-	1	-
21-Jun	-	-	-	4	-	4	-
22-Jun	-	-	-	1	-	1	1
23-Jun	-	-	-	-	-	-	1
24-Jun	-	-	-	2	-	-	1
25-Jun	-	-	-	1	-	-	1
26-Jun	-	-	-	-	-	-	1
27-Jun	-	-	-	1	-	-	-
28-Jun	-	-	-	1	-	-	1
29-Jun	-	-	-	1	-	-	1
1-Jul	-	-	-	-	-	-	1
3-Jul	-	-	-	1	-	-	-
21-Jul	-	-	-	1	-	-	-
29-Jul	-	-	-	-	-	-	1

Appendix Table A5. Locations of observations (detections) of PIT-tagged wild spring/summer Chinook salmon within the McNary Dam juvenile fish facility, 2003.

			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	Bypass	Raceway Transport	Bypass	Diversion	Raceway	Raceway Bypass	Raceway Transport	Sample	Sample Bypass	Transport	Bypass	Raceway Bypass
17-Apr	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Apr	1	-	-	-	-	-	-	-	11	-	-	1	-	-	-
19-Apr	8	-	-	-	-	-	-	-	1	-	-	1	-	-	-
20-Apr	3	-	-	-	-	-	-	-	10	-	-	-	-	-	-
21-Apr	11	-	-	-	-	-	-	-	1	-	-	-	-	-	-
22-Apr	5	-	-	-	-	-	-	-	16	1	-	-	-	-	-
23-Apr	45	-	-	-	-	-	-	-	1	-	-	-	-	-	-
24-Apr	7	-	-	-	-	-	-	-	36	-	-	2	-	-	-
25-Apr	77	-	-	-	-	-	-	-	12	-	-	-	-	-	-
26-Apr	22	-	-	-	-	-	-	-	236	1	-	6	-	-	-
27-Apr	220	-	-	-	-	-	-	2	40	-	-	-	-	-	-
28-Apr	41	-	-	-	-	1	-	-	193	7	-	1	-	-	-
29-Apr	219	-	-	-	-	-	-	-	38	3	-	-	-	-	-
30-Apr	39	-	-	-	-	-	-	-	232	7	-	1	-	-	-
1-May	496	-	-	-	2	-	-	-	48	1	-	-	-	-	-
2-May	65	-	-	-	-	2	-	-	339	9	-	3	-	-	-
3-May	363	-	-	-	-	-	-	-	27	-	-	-	-	-	-
4-May	50	-	-	-	-	-	-	-	277	9	-	3	-	-	-
5-May	238	-	-	-	-	-	-	-	32	1	-	1	-	-	-
6-May	7	-	-	-	-	-	-	-	89	3	-	2	-	-	-
7-May	101	-	-	-	-	-	-	-	15	-	-	-	-	-	-
8-May	25	-	-	-	-	-	-	-	161	12	-	-	-	1	-
9-May	181	-	-	-	-	-	-	-	38	1	-	-	-	-	-
10-May	42	-	-	-	-	-	-	-	126	8	-	1	-	-	1
11-May	104	-	-	-	-	-	-	-	16	2	-	-	-	-	-
12-May	10	-	-	-	-	-	-	-	83	2	-	1	-	-	-
13-May	59	-	-	-	-	-	-	1	10	-	-	-	-	-	-
14-May	16	-	-	-	-	-	-	-	71	8	-	2	-	-	-
15-May	197	-	-	-	-	-	-	-	22	-	-	-	-	-	-
16-May	74	-	-	-	-	1	-	1	250	12	-	2	1	-	-

Appendix Table A5. 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	Bypass	Raceway Transport	Bypass	Diversion	Raceway	Raceway Bypass	Raceway Transport	Sample	Sample Bypass	Transport	Bypass	Raceway Bypass
17-May	270	-	-	-	-	-	-	-	86	4	-	-	-	-	-
18-May	63	3	-	-	-	-	-	-	170	6	-	1	-	-	-
19-May	119	-	-	-	-	-	-	-	20	1	-	-	-	-	-
20-May	27	-	-	-	-	-	-	-	82	1	-	-	-	-	-
21-May	87	-	-	-	-	-	-	-	8	-	-	-	-	-	-
22-May	25	-	-	-	-	-	-	-	112	9	-	-	-	-	-
23-May	174	-	-	-	-	-	-	-	36	2	-	-	-	-	-
24-May	59	-	3	-	-	-	-	-	179	7	-	-	-	-	1
25-May	122	-	2	-	-	-	-	-	72	-	-	1	-	-	-
26-May	58	-	1	-	-	-	-	-	98	3	-	-	-	-	1
27-May	248	-	-	-	-	-	-	-	52	1	-	-	-	-	1
28-May	114	-	-	-	-	-	-	-	240	20	-	1	-	-	1
29-May	191	-	-	-	-	-	-	-	113	8	-	1	-	-	-
30-May	31	-	1	-	-	-	-	-	64	2	-	-	-	-	1
31-May	97	-	-	-	-	-	-	-	15	2	-	-	-	-	-
1-Jun	36	-	2	1	-	-	-	-	140	6	-	2	-	-	-
2-Jun	144	-	-	-	-	-	-	-	62	2	-	-	-	-	1
3-Jun	58	-	3	-	-	-	-	-	128	6	-	2	-	-	1
4-Jun	120	-	-	-	-	-	-	-	80	3	-	-	-	-	2
5-Jun	84	-	3	-	-	-	-	-	78	1	-	-	-	-	1
6-Jun	84	-	1	-	-	-	-	-	41	1	-	-	-	-	-
7-Jun	25	-	3	-	-	-	-	-	35	-	-	-	-	-	-
8-Jun	43	-	-	-	-	-	-	-	23	-	-	-	-	-	-
9-Jun	22	-	3	-	-	-	-	-	42	2	-	-	-	-	1
10-Jun	52	-	-	-	-	-	-	-	23	1	-	-	-	-	-
11-Jun	28	-	-	-	-	-	-	-	16	-	-	-	-	-	-
12-Jun	39	-	-	-	-	-	-	-	7	-	-	-	-	-	-
13-Jun	21	-	-	-	-	-	-	-	42	-	-	1	-	-	-
14-Jun	40	-	-	-	-	-	-	1	12	-	-	-	-	-	-
15-Jun	7	-	-	-	-	-	-	-	19	-	-	-	-	-	-
16-Jun	31	-	-	-	-	-	-	-	4	-	-	-	-	-	-

Appendix Table A5. 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	Bypass	Raceway Transport	Bypass	Diversion	Raceway	Raceway Bypass	Raceway Transport	Sample	Sample Bypass	Transport	Bypass	Raceway Bypass
17-Jun	18	-	1	-	-	-	-	-	27	-	-	-	-	-	-
18-Jun	15	-	-	-	-	-	-	-	6	-	-	-	-	-	-
19-Jun	4	-	-	-	-	-	-	-	7	-	-	-	-	-	-
20-Jun	9	-	-	-	-	-	-	-	4	-	-	-	-	-	-
21-Jun	6	-	-	-	-	-	-	-	15	-	-	-	-	-	-
22-Jun	17	-	-	-	-	-	-	-	4	-	-	-	-	-	-
23-Jun	1	-	-	-	-	-	-	-	13	-	-	-	-	-	-
24-Jun	8	-	-	-	-	-	-	-	2	-	-	-	-	-	-
25-Jun	2	-	1	-	-	-	-	-	5	-	-	-	-	-	-
26-Jun	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-
27-Jun	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Jun	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-
29-Jun	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
30-Jun	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Jul	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
2-Jul	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-Jul	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
4-Jul	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-
7-Jul	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
9-Jul	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
11-Jul	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
15-Jul	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
16-Jul	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
26-Jul	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
29-Jul	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-

APPENDIX B

Tagging Results for 2006 Transportation Studies

From 21 April through 26 May 2006, we PIT-tagged a total of 13,576 wild yearling spring/summer Chinook salmon smolts, all of which were loaded into barges at Lower Granite Dam. From 21 April through 16 June, we PIT-tagged 18,710 wild steelhead smolts at Lower Granite Dam, all of which were loaded into barges at the dam.

APPENDIX C

Adult Returns from Previous and In-progress Studies

Appendix Table C1. Snake River wild spring/summer Chinook salmon studies.

	Juvenile fish numbers			Returns by Age-class			SAR							Annual report containing final results
Tagging year	LGR Transport	LGS Transport	Migrant	1-ocean	2-ocean	3-ocean	LGR Transport	LGS Transport	Migrant	LGR T/I	LGS T/I	95% C.I. (LGR T/I) (LGS T/I)	Status	
2005	12,729	--	--	0	–	–	–	–	–	–	–	–	In-progress	Fall 2008
2004	11,208	--	--	2	25	–	–	–	–	–	–	–	In-progress	Fall 2007
2003 a	**7,114**	**14,709**	**18,778**	**2**	**55**	**21**	**0.34**	**0.20**	**0.13**	**2.64**	**1.60**	**(1.88, 4.27)** **(0.96, 2.77)**	**Completed**	**Current**
2002 a	4,963	10,569	11,842	25	183	52	1.25	1.02	0.76	1.64	1.34	(1.36, 1.97) (1.07, 1.60)	Completed	Current
2001	16,512	--	--	21	113	25	0.95	–	–	–	–	(0.84, 1.11)	Completed	2004
2000 a	--	17,367	26,329	16	263	355	–	1.47	1.44	–	1.02	(0.9, 1.1)	Completed	2003
1999 a	8,384	--	1,920	11	164	27	2.10	–	1.35	1.55	–	(1.0, 2.4)	Completed	2001
1998 a	5,689	--	2,932	6	42	14	0.60	–	0.95	0.63	–	(0.4, 1.0)	Completed	2001
1996 a	7,949	--	3,915	1	8	3	0.11	–	0.08	1.5	–	(0.5, 7.5)	Completed	1999
1995 a	24,066	--	6,794	1	70	36	0.38	–	0.22	1.7	–	(1.1, 2.6)	Completed	1998

a - Juvenile numbers have been adjusted by the technique described in Sandford and Smith (2002)

Appendix Table C2. Snake River hatchery spring/summer Chinook salmon studies.

Tagging year	Juvenile fish numbers		Returns by age-class			SAR					Annual report containing final results
	Transport	Migrant	Jack	2-ocean	3-ocean	Transport	Migrant	T/I	95% C.I.	Status	
1999	42,273	16,664	99	935	41	1.97	1.45	1.4	(1.2, 1.6)	Completed	2001
1998	39,596	23,552	48	297	34	0.62	0.57	1.1	(0.9, 1.4)	Completed	2001
1996	35,632	20,186	7	43	22	0.13	0.1	1.2	(0.8, 2.0)	Completed	1999
1995	83,064	25,757	34	444	70	0.54	0.32	1.7	(1.4, 2.1)	Completed	1998

APPENDIX D

Overview of Statistical Methodology

For each day of the migration season, we estimated numbers of fish passing each dam, developing a series of daily passage estimates. These daily estimates were used to estimate SARs according to the method of Sandford and Smith (2002). A brief synopsis of this method follows (shown here for Little Goose Dam).

1) Fish detected on day k at Lower Monumental Dam that had previously been detected at Little Goose Dam were grouped according to day of detection (passage) at Little Goose Dam.

2) Fish detected on day k at Lower Monumental Dam that had *not* previously been detected at Little Goose Dam were assigned a day of detection at Little Goose Dam based on the distribution at Little Goose Dam of fish detected at both dams. This step assumed that the passage distribution for non-detected fish at Little Goose Dam was proportionate to that of their cohorts detected at Little Goose Dam.

3) This process was repeated for each day of detection at Lower Monumental Dam during the juvenile migration season.

4) All fish detected at Lower Monumental Dam were assigned a passage day i at Little Goose Dam whether or not they had been detected at Little Goose Dam.

5) Probability (p) of detection at Little Goose Dam on day i was estimated by comparing the proportion of fish detected on day i to the total number of fish known to have arrived at the dam on day i. Numbers were adjusted for fish that had been transported from Little Goose Dam.

6) The total number of fish arriving at Little Goose Dam on day i (LGS_i) was estimated by dividing the total number detected at Little Goose Dam on day i (including bypassed and transported fish) by the estimated probability of detection on day i.

We then estimated SARs for various detection-history categories, in particular for fish transported from a dam, for fish bypassed back to the river at one or more dams, and for fish never detected at a Snake River dam. To do this, we developed daily passage estimates at Little Goose Dam using the following process:

7) For each group that passed Little Goose Dam on day *i* (LGS_i; see step 5 above), we estimated the probability of detection at Lower Monumental (LMO) and McNary (MCN) Dams using the Cormack-Jolly-Seber single-release model (Cormack 1964; Jolly 1965; Seber 1965).

8) We multiplied the group passing Little Goose Dam on day *i* by the detection and transport probabilities derived from step 7 to estimate numbers in each detection history category. For example, the detection-history category "not detected at Lower Monumental Dam and then bypassed at McNary Dam" would be expressed as

$$(LGS_i) \quad [1 - p\,(\text{LMO})] \quad [p\,(\text{MCN})] \quad [1 - p\,(\text{transport at MCN})].$$

9) We summed the products from step 8 for each day to arrive at the total number of smolts in each detection-history category.

Next we calculated SARs. For a given detection-history category, this was the ratio of the observed number of adults in the category to the estimated number of smolts in that category.

Finally, we estimated the precision of the estimated SARs. This was done using bootstrap methods wherein the individual fish information (i.e., detection history, detection dates, and adult return record) was resampled 1,000 times with replacement (Efron and Tibshirani 1993). Standard errors and confidence limits about the SARs were generated from these bootstrapped estimates.