Transportation of Juvenile Salmonids on the Snake River, 2005:

Final Report for 2003 Steelhead Juveniles with Updates on Other Transport Studies

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Report of research by

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North Pacific Division
U.S. Army Corps of Engineers
201 North 3rd
Walla Walla, Washington 99362-1876
Delivery Order E86960099

July 2008

EXECUTIVE SUMMARY

The National Marine Fisheries Service began evaluating transportation of Snake River steelhead *Oncorhynchus mykiss* smolts in 1999. In 2001, we began transportation studies of subyearling fall Chinook salmon *O. tshawytscha* in the Snake River and at McNary Dam. Beginning in 2003, we also evaluated transportation of steelhead PIT-tagged at upper Columbia River hatcheries and transported from McNary Dam. Here we report transportation study activities on the Snake River during 2005-2006, including adult recoveries of age-2-ocean wild steelhead, which complete the wild steelhead adult returns from the 2003 tagging year.

In 2003, we tagged only wild fish in the Snake River and released them either into the Lower Granite Dam tailrace or onto a barge at Lower Granite Dam. For this analysis, we used two transport groups: one collected, tagged, and transported from Lower Granite Dam (LGR), and one collected and transported from Little Goose Dam (LGS). These groups were compared with an inriver-migrant group, which excluded any fish detected at Little Goose or Lower Monumental Dams. During the 2003 migration, inriver migrants experienced flows that were higher than average, particularly late in the migration season. Spill during 2003 was provided at Snake and Columbia River dams as prescribed by the National Marine Fisheries Service 2000 Biological Opinion.

From 1 July 2005 to 30 June 2006, we detected 149 wild age-2-ocean adults from groups tagged in 2003 at Lower Granite Dam. Past adult recovery data has shown that few, if any, age-3-ocean adults will return. Based on all 2003 steelhead returns combined (age-1-ocean through age-2-ocean fish), smolt-to-adult return rates (SARs) were 2.22 for LGR transported fish, 1.01 for LGS transported fish, and 0.27 for inriver-migrant fish. For comparison, the SAR for fish collected and bypassed at one or more collector dams below Lower Granite Dam was 0.20.

For our study fish, these SARs produced transport-to-in-river migrant ratios (T/Is) of 8.17 (95% CI, 5.95-13.03) for fish transported from Lower Granite Dam and 3.73 (95% CI, 2.76-5.50) for fish transported from Little Goose Dam. Based on these SARs, the ratio of LGR-transported to LGS-transported steelhead was 2.19. Annual differential delayed mortality, *D*, was estimated at 1.47.

In earlier transportation studies, we collected and tagged a relatively constant proportion of the population of fish 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 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 results 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 steelhead 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 rose from 2.22 to 2.38, while the SAR for inriver migrants dropped from 0.27 to 0.21. Thus, the T/I for fish transported from Lower Granite Dam rose from 8.17 to 11.11. Weighting also increased the estimate of annual differential delayed mortality, *D*, from 1.47 to 1.65.

Estimates of T/I and *D* from tagged steelhead were affected to an unknown degree by collection and transport in 2003 of an estimated 72.9% of the untagged wild steelhead population in the Snake River. For example, the PIT-tagged wild steelhead that remained in the river to migrate would have been exposed to predation by avian predators upstream from Bonneville Dam, while transported fish would not encounter these predators. In addition to exposure, low numbers of fish in the river could have increased the overall vulnerability of the migrant portion of the population. Thus, the T/I*s* and estimates of *D* reported here are likely higher than they would be had fewer steelhead been collected and transported.

While annual SAR and *D* values are central to evaluations of transportation benefit, more useful information is found in the pattern of these indices related to juvenile migration timing. As in previous years, transport SARs varied with timing of the juvenile migration, with the highest SARs for fish that arrived at the dam from the third week of April through the first week of May. An additional, smaller peak occurred for fish arriving at the end of May. As observed in previous years, SARs were highest for fish migrating as juveniles early in the season and gradually decreased for fish that migrated later. Delayed mortality, *D*, was at least 1.0 for all fish except those migrating in mid-May, with peaks in *D* occurring with the same juvenile timing as peaks in transport SARs. The highest peak was for fish that had migrated as juveniles at the end of May.

For fish transported from Lower Granite Dam in 2003, the wild steelhead tagged at the dam for NMFS transportation evaluations produced a higher T/I ratio (8.17) than that of wild steelhead tagged above the dam for other studies (3.68). However, for fish transported from Little Goose Dam in 2003, wild steelhead tagged at Lower Granite Dam for NMFS transport studies produced a T/I ratio of 3.73, which was similar to that of wild steelhead tagged above the dam for other studies (3.85). To evaluate these comparisons, consideration must be given to potential differences between studies, such as collection and handling techniques, timing, or numbers of fish tagged.

Of wild steelhead adults detected at Bonneville Dam, 81% of LGR-transported, 76% of LGS-transported, and 80% of migrant fish migrated successfully to Lower Granite Dam (not adjusted for take in the Zone 6 fishery). Median travel times from Bonneville to Lower Granite Dam for age-1-ocean fish were 47 d for LGR-transported, 44 d for LGS-transported, and 38 d for inriver migrant fish. Respective median travel time for age-2-ocean transported fish was 61 d for LGR and 47 d for LGS adults. These were 28 and 7% slower than their age-1 ocean counterparts, respectively. In contrast, age-2-ocean fish were 29% faster than their age-1-ocean cohorts, with a median travel time of 27 d. This is the first year wherein age-2-ocean adults were slower than age-1-ocean adults, likely a result of varying flow conditions between years.

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INTRODUCTION

In 2005, we continued studies to evaluate the transport and release of juvenile salmonids below Snake and Columbia River dams to mitigate for losses from lower Snake and Columbia River hydropower dams operated by the U.S. Army Corps of Engineers (USACE). Our primary objective is to compare adult returns of Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* PIT-tagged as smolts and transported to a release site below Bonneville Dam to those of their cohorts that migrate through the hydropower system under optimal conditions for inriver survival. Detections from PIT-tagged smolts released to migrate inriver also provide data for juvenile survival estimates between the point of release and Bonneville Dam tailrace (Muir et al. 2001).

In 1999, we PIT tagged hatchery and wild steelhead smolts at Lower Granite Dam to compare adult returns of smolts marked and transported to below Bonneville Dam vs. those of smolts released to the tailrace of Lower Granite Dam to migrate in the river. Migrating smolts collected at downstream dams were returned to the river to continue their migration, although they were excluded from adult evaluations.

In hindsight, the 1999 study design, which was based on spring/summer Chinook salmon studies conducted from 1995 through 1999, did not provide sufficient information to compare the returns of non-detected and non-transported fish to those of transported fish. Therefore, beginning in 2000, we altered the experimental design of transportation studies to provide comparison between these groups.

Here we report final results from the 2003 wild steelhead tagging year at Lower Granite Dam, with adult returns through 2005-2006. Updated information is also provided on juvenile steelhead tagged for transportation studies in 2005 (Appendix B); complete adult return data from steelhead tagged during 1995-2002 (Appendix C); and partial adult returns for subyearling Chinook tagged from 2001 to 2005 (Appendix C).

METHODS

Sampling and Tagging of Wild Steelhead Juveniles in 2003

As in past years, we collected and PIT tagged wild Snake River steelhead at Lower Granite Dam in 2003. The study design was the same as that used in 2002 and involved three study groups: two transport groups, one each from both Lower Granite and Little Goose Dams, and an inriver-migrant group. The first group was loaded into a barge at Lower Granite Dam (LGR transported), and all remaining tagged fish were released into Lower Granite Dam tailrace.

We set the separation-by-code system at Little Goose Dam to divert for transport 80% of the PIT-tagged study fish collected at the juvenile fish facility in order to create the second transport group (LGS-transport). The remaining 20% of fish collected were bypassed and returned to the river. Although detections of these fish were excluded from transportation evaluations, they were used to help develop survival estimates necessary to estimate differential delayed mortality, *D*, of transported fish. The inriver-migrant group was composed of fish not detected at either Little Goose or Lower Monumental Dam consistent with the general unmarked population of fish that migrated through the Snake River without being collected at a Snake River collector dam.

We calculated the number of fish needed for marking to test the null hypothesis that there was no difference between the SARs of transported vs. inriver-migrant fish, and the alternative hypothesis, that the ratio of transported to inriver-migrant SARs 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 required for tagging was determined as:

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

and

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

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:

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

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%, the sample sizes required at Lower Granite Dam were:

$$n = 142$$
$$N_T = 6{,}800$$
$$N_I = 9{,}520$$
$$\text{Total juveniles} = 16{,}320$$

Where N_T is the number of juveniles needed for the transport cohort and N_I is the number of fish needed for the in-river-migrant cohort (6,800 × 1.4).

In 1995, 29.7% of the yearling Chinook salmon smolts that we released into Lower Granite Dam tailrace were never again detected. Based on this proportion, we conservatively estimated that at least 20% of the wild steelhead smolts released into the Lower Granite Dam tailrace would not be detected thereafter. Therefore, we needed to release 47,600 fish into Lower Granite Dam tailrace to provide the 9,520 needed for the non-detected in-river group (9,520/0.2). This number also provided sufficient smolts for collection at Little Goose Dam to form a transport test group. For example, assuming an approximate 40% collection efficiency at Little Goose Dam, 19,400 (47,600 × 0.4) wild steelhead smolts would be collected for transport.

Throughout the entire juvenile migration season, we PIT tagged a relatively constant proportion of fish collected at Lower Granite Dam. Marked fish were held an average of 24 h before release into Lower Granite Dam tailrace, with releases made in the early morning. Basic collection and handling, including the use of the re-circulating anesthetic water system, followed the methodology described by Marsh et al. (1996, 2001).

2003 Inriver Migration

Details on how migrating study fish are tracked as they pass through the collection systems at dams downstream from Lower Granite Dam are described by Marsh et al. (1996). Prior to 27 June 2003, McNary Dam was in bypass mode, meaning all tagged and non-tagged fish were collected and bypassed to the river after passing through PIT-tag detectors (excluding fish tagged for our Columbia River hatchery study). Thus, we included fish detected at McNary Dam in the analysis. After 27 June, all non-tagged fish collected at the dam were transported, so we excluded from the analysis any fish collected at McNary Dam after this date. 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 2005-2006, we completed the recovery of adults tagged in 2003 (few if any age-3-ocean adult returns are expected). The procedures for data analysis described by Marsh et al. (1996) were modified as described in Sandford and Smith (2002) to determine the number of juvenile fish in the transport and in-river-migrant groups (a brief description of these methods is given in Appendix D).

To calculate 95% CIs for various T/I*s*, release days were pooled until a minimum of two adults returned in both transport and in-river 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/I*s* applicable to the untagged population. The weighted mean T/I*s* 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.

We estimated delayed mortality (*D*):

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

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

RESULTS

Sampling and Tagging of Wild Steelhead Juveniles in 2003

We PIT-tagged 36,327 wild steelhead smolts at Lower Granite Dam from 9 April through 6 June 2003 (Table 1). The number of fish tagged daily ranged from 547 to 5,173 (Appendix Table A1). Of the 36,327 wild steelhead tagged, 31,535 were released into the tailrace and 3,381 were transported in barges from Lower Granite Dam.

Based on mortality counts from the holding tanks, post-marking delayed mortality (24-h) averaged 0.3% for in-river-migrant steelhead over the entire tagging season. This value was exceptionally low, considering that we tagged virtually every fish sampled. Only a few fish that were either severely injured or exhibited gross symptoms of bacterial kidney disease were not tagged. By tracking the unique PIT-tag code of each mortality, we determined the condition recorded when the live fish was tagged. Unlike in past years, in 2003 we were unable to attribute delayed mortality to any pre-existing condition.

Table 1. Numbers of wild steelhead smolts PIT-tagged and released for Lower Granite transport, Little Goose transport, and inriver-migrant groups at Lower Granite Dam, 2003. Mean fork length, weight, and fish condition are also shown.

		Mean		
	Number	Fork length (mm)	Weight (g)	Fish condition
Transported from Lower Granite Dam				
Tagged	3,538	171.5	50.6	0.97
Released*	3,381	171.5	50.6	0.97
Released into the Lower Granite Dam tailrace				
Tagged	32,789	172.9	49.2	0.91
Released*	31,535	172.9	49.2	0.91
Transported from Little Goose Dam				
Released	12,272	170.9	47.1	0.91
Bypassed at one or more dams				
Released	5,869	172.2	49.0	0.91

* Release numbers adjusted for mortality and tag loss

Inriver Juvenile Migration

As juvenile study fish continued their seaward migration, some were collected at dams downstream from Lower Granite Dam. Of the 31,535 wild steelhead released into Lower Granite Dam tailrace, 10,505 (33.3%) were not detected at a downstream Snake River dam. Of the remaining 21,030 (66.7%) fish that were detected, 12,272 were transported from Little Goose Dam, and 2,857 were transported from Lower Monumental Dam (with 2,127 detected for the first time after tagging at Lower Granite Dam). The remaining 5,869 detected fish were bypassed at one or more Snake River dams. Numbers of fish released to Lower Granite Dam tailrace were adjusted using the methods of Sandford and Smith (2002), resulting in estimates of 12,843 wild steelhead in the LGS transport group, 9,579 in the inriver-migrant group, and 5,449 in the bypass group. All SAR calculations were based on these numbers.

At Little Goose and Lower Monumental Dams, our initial goal was to transport 80 and 50% of the wild steelhead collected, respectively. However, the separation-by-code systems were able to divert only 74.7% of the steelhead collected at Little Goose Dam and 45.8% of the steelhead collected at Lower Monumental Dam (Table 2).

Table 2. Summary of PIT-tagged wild steelhead 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	Detected at Little Goose Dam
Excluded from transportation study		
Diversion or river return	River	3,659
Raceway	River*	27
Separator	Unknown	76
PIT-tagged fish included in study		
Raceway	Loaded to barge/truck and transported	11,973
SMP sample	Smolt monitoring program sample	299
Totals		
Observed		16,034
Transport group		12,272
Returned to river		3,686

* 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.

During the 2003 migration, flows were higher than average, particularly late in the migration season, and spill was provided at Snake and Columbia River dams as prescribed by the National Marine Fisheries Service Biological Opinion (NMFS 2000). Preliminary estimates of inriver survival in 2003 were based upon PIT-tag detections at Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams, and on estuary detections in the pair-trawl system. We estimated survival for wild juvenile steelhead of 59.7% (SE 1.3%) from Lower Granite Dam tailrace to McNary Dam tailrace, and 30.9% (SE 1.1%) from Lower Granite tailrace to Bonneville Dam tailrace.

Adult Recoveries and Data Analysis

At Lower Granite Dam, we began recovering age-1-ocean wild steelhead adults in 2004 and finished with age-2-ocean adults in June 2006 (Table 3). Unlike Chinook salmon, steelhead can return to the ocean after spawning and return to spawn again (kelts). Several kelts were observed from fish tagged for this study, complicating the counting of returning adults. We did detect adults returning to the ocean, one of which returned to Lower Granite Dam a second time.

In addition to the main study groups, we also looked at the SAR of fish that migrated to the ocean and were bypassed at one or more dams below Lower Granite Dam (5,449 juveniles). From these fish, 11 adults returned for a SAR of 0.20 (95% CI, 0.08-0.32).

Table 3. Wild adult steelhead returns by study group and age-class, with juvenile numbers adjusted as described by Sandford and Smith (2002) for fish tagged at Lower Granite Dam in 2003.

Juvenile numbers	Returns by age-class			SAR	T/I	95% CI	LGR/LGS
	1-ocean	2-ocean	3-ocean				
Inriver migrant							
9,579	11	15	0	0.27			
Transported from Lower Granite Dam							
3,381	36	39	0	2.22	8.17	5.95-13.03	2.19
Transported from Little Goose Dam							
12,843	54	76	0	1.01	3.73	2.76-5.50	
Bypassed at one or more dams*							
5,449	4	7	0	0.20	10.99	8.46-14.26	

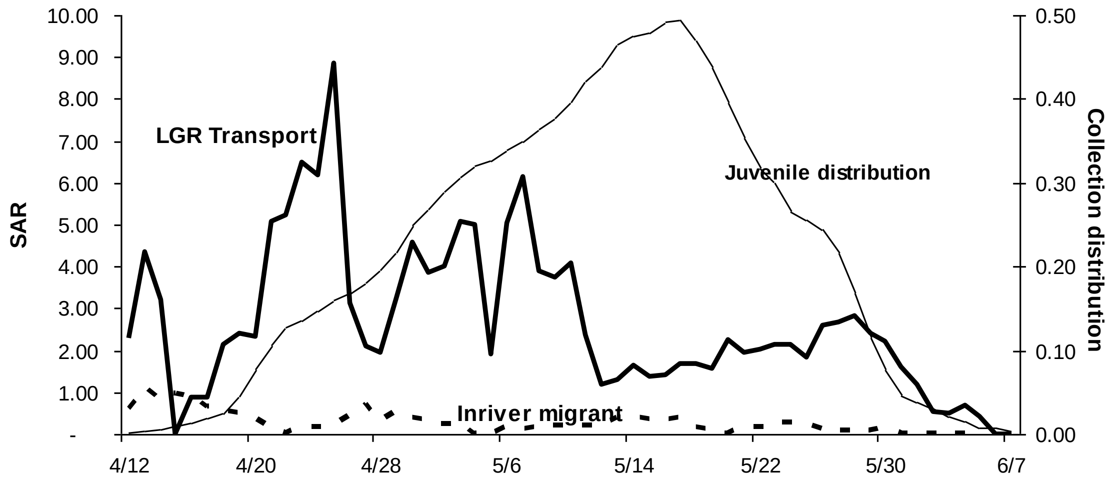
* The T/I shown for this group is (transported from Lower Granite Dam)/(bypassed at one or more dams).

Relationship between Juvenile Migration Timing and Smolt-to-Adult Returns

As in previous years, a definite pattern of differences in SARs corresponding with time of the juvenile migration was observed for both transported and inriver-migrant fish (Figure 1). For LGR-transported fish, this pattern was a mixture of the two patterns observed in the past. In a trend similar to that of study fish from 2000 and 2001, SARs were high for fish that migrated as juveniles through April and early May, averaging nearly 4% before dropping dramatically in the second week of May. However, unlike the trend for 2000 and 2001 study fish, where after the second week of May virtually no adults returned from fish marked, and SARs dropped to zero, SARs from 2003 study fish dropped to 1% and then slowly increased to nearly 3%. This was similar to the pattern observed in 1999 and 2002, where SARs were highest for late-season juvenile migrants. For 2003 inriver-migrant fish, SARs started low, at just over 1%, and gradually decreased with later juvenile migration timing.

Delayed Mortality

Differential delayed mortality, *D*, also varied with juvenile migration timing (Figure 2), as would be expected given the variation seen in SARs of both transported and inriver-migrant study fish. The annual estimate of *D* (non-weighted) for 2003 was 1.47, but varied from 0.36 to 2.82, generally increasing (approaching 1.0) with later juvenile migration. The annual estimate of *D*, weighted to represent the general population of steelhead for 2004 was 1.65. The difference in *D* between the non-weighted and weighted estimates was due to the later segment of the juvenile population, which had a higher *D* value, being underrepresented during tagging (Figure 2).



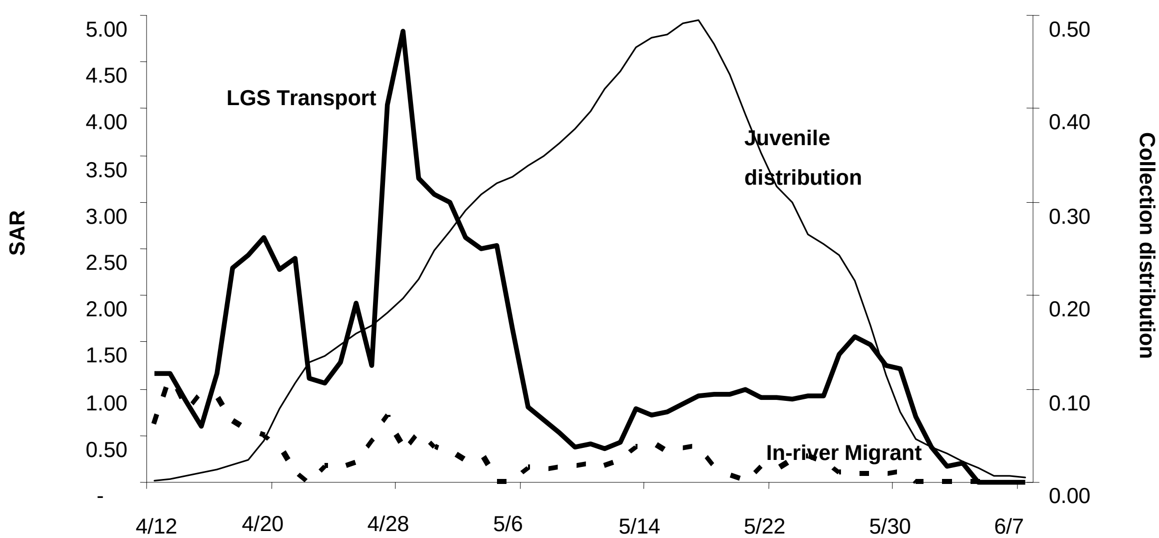


Figure 1. Smolt-to-adult return rates by juvenile tagging date for wild steelhead smolts transported from Lower Granite (LGR transport, above) and Little Goose Dams (LGS transport, below) compared with SARs of their inriver-migrant cohorts in 2003. Also shown is the distribution of juvenile fish collected at Lower Granite Dam in 2003.

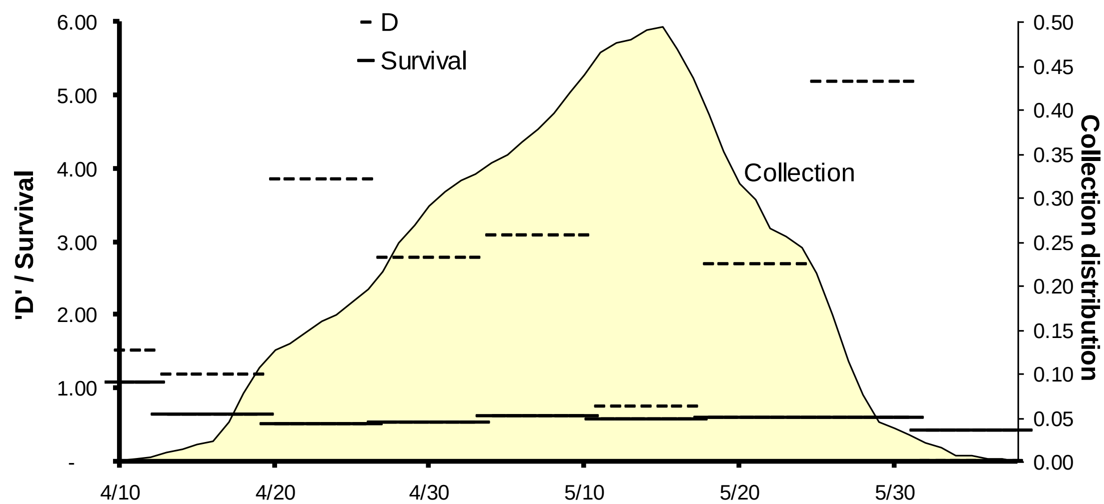


Figure 2. Estimates of differential delayed mortality, *D*, over time for wild steelhead smolts tagged at Lower Granite Dam in 2003. Grouping is based on having adequate numbers of smolts to estimate in-river survival between Lower Granite and McNary Dam and between McNary and Bonneville Dam. Overall *D* of the tagged fish for the year was 1.47, while the overall *D* for the general population was 1.65.

Conversion Rate

In past years, the proportion of returning steelhead adults observed at Bonneville Dam and subsequently observed at Lower Granite Dam (conversion rate) has been higher for the inriver-migrant group than for either transport group. However, overall conversion rates for fish marked in 2003 were similar for all three study groups (Table 4). We did observe that for age-1-ocean fish, inriver-migrants had a lower conversion rate than transported fish from either group, but for age-2-ocean fish, inriver-migrants had a higher conversion rate than transported fish. Conversion rates of age-1-ocean fish from the two transport groups were similar, while the conversion rate of age-2-ocean adults from the LGS transport group was lower than that of the LGR transport group. In general, most adults that did not successfully migrate from Bonneville to Lower Granite Dam also did not pass McNary Dam (Table 5). However, this did not hold true for the age-2-ocean inriver and LGR transport groups, where losses were evenly divided between the two reaches.

Table 4. Percentage of adult wild steelhead observed at Bonneville Dam that were subsequently observed at Lower Granite Dam (the conversion rate) from 2003 releases.

	Number observed at Bonneville Dam	Number observed at Lower Granite Dam	Conversion rate (%)
	Age-1-ocean		
Migrant	13	9	69.2
LGR transport	39	32	82.0
LGS transport	57	49	86.0
Bypass	6	6	100.0
	Age-2-ocean		
Migrant	17	15	88.2
LGR transport	47	38	80.8
LGS transport	108	76	70.4
Bypass	11	8	72.7
	Subtotals		
Migrant	30	24	80.0
LGR transport	86	70	81.4
LGS transport	165	125	75.8
Bypass	17	14	82.4
	Totals		
	281	219	77.9

Table 5. Adult survival (percent) from Bonneville Dam to McNary Dam and from McNary Dam to Lower Granite Dam for wild steelhead PIT-tagged and released from Lower Granite Dam in 2003.

Reach	Migration history	Number seen at first dam	Number subsequently seen at second dam	Survival (%)
		Age-1-ocean		
BON to MCN	Inriver-migrant	13	8	61.5
	LGR transport	39	33	84.6
	LGS transport	57	50	87.7
	Bypass	6	6	100.0
MCN to LGR	Inriver-migrant	9	9	100.0
	LGR transport	37	36	97.3
	LGS transport	54	53	98.1
	Bypass	6	6	100.0
		Age-2-ocean		
BON to MCN	Inriver-migrant	17	16	94.1
	LGR transport	47	42	89.4
	LGS transport	108	80	74.1
	Bypass	11	8	72.7
MCN to LGR	Inriver-migrant	16	15	93.7
	LGR transport	43	39	90.7
	LGS transport	80	76	95.0
	Bypass	8	8	100.0
		Totals		
BON to MCN	Inriver-migrant	30	24	80.0
	LGR transport	86	75	87.2
	LGS transport	165	130	78.8
	Bypass	17	14	82.4
MCN to LGR	Inriver-migrant	25	24	96.0
	LGR transport	80	75	93.7
	LGS transport	134	129	96.3
	Bypass	14	14	100.0

Straying

In 2003, with adult detection capabilities available at dams on the Columbia River above the confluence with the Snake River, we were able to observe if straying occurred into the upper Columbia River. Only one wild steelhead adult from the 2003 tagging year was detected at a Columbia River dam above McNary Dam (Priest Rapids Dam; Table 6). That adult, from the LGR transport group, was eventually detected at Lower Granite Dam.

Table 6. Juvenile migration history and adult detection data of the only wild steelhead stray tagged for transportation studies in 2003.

	Adult detection at Columbia River dams				Adult detection at Snake River dams	
Tag code	McNary	Priest Rapids	Rock Island	Wells	Ice Harbor	Lower Granite
Transported from Lower Granite Dam						
3D9.1BF1BE78B5	7/22/05	8/4/05			10/15/05	10/22/05

Travel Time

Median travel time from Bonneville Dam to Lower Granite Dam ranged from 27 to 61 d (Table 7). Unlike in the past, where median travel time for all study groups was consistently shorter for age-2-ocean adults than for age-1-ocean adults, only inriver-migrant adults showed this pattern from fish migrating in 2003. Age-2-ocean adults from the 2003 inriver-migrant group were 29% faster than their age-1-ocean counterparts, while age-2-ocean adults from the LGR and LGS transport groups were 28 and 7% slower, respectively, than their age-1-ocean cohorts. Another difference between the 2003 study year and previous study years was that differences in median travel time between the two age classes occurred in both the Bonneville-to-McNary Dam and McNary-to-Lower Granite Dam reaches of the river instead of only in the reach from Bonneville to McNary Dam.

The longer median travel time for inriver-migrants between Bonneville and McNary Dam, compared with travel time between Bonneville and Lower Granite Dam, was due to two issues: small numbers of adults in each group, and two fish that were not detected at McNary Dam. These two fish were the second and third fastest fish between Bonneville and Lower Granite Dam, and their omission from the timing evaluation pulled the median down for the entire group. Had these two fish been detected at McNary Dam, the median travel time between Bonneville and McNary Dams would have been 19.5 d, more in line with the 38-d travel time between Bonneville and Lower Granite Dams.

Unlike salmon, steelhead may overwinter during their adult migration through the hydropower system, resuming migration the following spring. We have noted in past years the majority of steelhead adults passing Lower Granite Dam in spring are from transport groups. Of the 21 adults from the 2003 tagging year that returned in spring, one had been a migrating juvenile that was removed from the study, and 20 were transported from either Lower Granite (6), Little Goose (13), or Lower Monumental (1) Dams.

Table 7. Median travel times from Bonneville to McNary Dam, McNary to Lower Granite Dam, and Bonneville to Lower Granite Dam for adult wild steelhead PIT tagged as juveniles in 2003 at Lower Granite Dam.

Age class	Migration history group	Number of adults	Travel time (d) Range	Median
Bonneville to McNary Dam				
Age-1-ocean	Inriver migrant	8	5-70	43.0
	LGR Transport	32	6-250	31.5
	LGS Transport	49	5-260	31.0
	Bypass	4	6-79	28.0
Age-2-ocean	Inriver migrant	15	6-81	19.0
	LGR Transport	42	5-250	36.0
	LGS Transport	77	5-301	23.0
	Bypass	7	6-20	8.0
McNary to Lower Granite Dam				
Age-1-ocean	Inriver migrant	9	5-25	8.0
	LGR Transport	35	6-91	9.0
	LGS Transport	52	4-153	8.0
	Bypass	4	4-9	8.5
Age-2-ocean	Inriver migrant	14	4-25	7.0
	LGR Transport	39	5-228	11.0
	LGS Transport	74	5-236	11.5
	Bypass	7	6-10	9.0
Bonneville to Lower Granite Dam				
Age-1-ocean	Inriver migrant	10	12-80	35.5
	LGR Transport	32	14-281	47.5
	LGS Transport	49	10-268	44.0
	Bypass	4	10-87	37.0
Age-2-ocean	Inriver migrant	15	13-88	27.0
	LGR Transport	38	12-264	61.0
	LGS Transport	75	13-277	47.0
	Bypass	7	12-27	18.0

Kelts

Unlike salmon, steelhead may return to the ocean after spawning. Over the course of the study, we detected one kelt returning upriver to spawn for a second time as an age-3-ocean adult.

Size at Tagging

Inriver-migrant fish that returned as both age-1- and age-2-ocean adults were larger on average at the time of tagging than transported fish (Table 8). Also, fish that returned as age-1-ocean adults were larger at the time of tagging than fish that returned as age-2-ocean adults. These results are similar to those from earlier study years.

Table 8. Average length at tagging by year class of wild steelhead PIT tagged as juveniles at Lower Granite Dam in 2003 and returning as adults in 2004-2005 and 2005-2006.

Age class	Migration history	Average length at tagging (mm)
Age-1-ocean	Inriver migrant	214.9
	LGR transport	194.7
	LGS transport	196.8
	Bypass	197.8
	Total	198.4
Age-2-ocean	Inriver migrant	198.3
	LGR transport	185.0
	LGS transport	186.0
	Bypass	186.7
	Total	187.6

DISCUSSION

Adult returns of both inriver migrant and transported steelhead began increasing in the late 1990s (Williams et al. 2005). These large numbers of returning adults have provided higher return rates, which result in smaller standard errors than originally presumed for our SAR estimates. The large numbers of returning adults present us with opportunities to examine other potentially important trends in the data, such as changes in SARs related to timing of the juvenile migration.

For transport studies conducted on steelhead smolts since 1999, annual T/I*s* have shown a transport benefit, although SARs have varied with juvenile migration timing (Marsh et al. 2000, 2001, 2004, 2005). In contrast to previous studies, contemporary study designs and the use of PIT tags has allowed for rigorous analysis of SARs and T/I*s*.

Calculating the statistics for groups of adult fish by the period when they were marked as smolts has revealed clear but differing trends in adult return data. Adult returns from steelhead tagged in 1999 showed annual T/I*s* that were lower than expected, primarily because SARs were much lower for fish tagged and transported early in the juvenile migration season than for those transported later. However, results from the 2000 and 2001 study years showed high SARs for fish tagged as smolts early in the juvenile migration season, but very low SARs for those tagged after the first 7-9 days of May. Adult returns of fish tagged in 2002 show a pattern similar to that in 1999: lower SARs for fish tagged as smolts early in the juvenile migration with a dramatic surge in SARs for transported fish tagged in the last week of April. This latter pattern was typical of that observed in transportation studies of spring/summer Chinook salmon (Williams et al. 2005).

These dichotomies in wild steelhead adult return rates within years were unexpected, and after four years of observation, we have an even split in the pattern between juvenile migration timing and SARs. Results from 2003 did nothing to tip the scale one way or the other, as the temporal pattern was a mix of the two previously observed patterns. For the 2003 study year, SARs for fish that migrated as juveniles in April and early May were similar to those for juveniles with the same timing in 2000 and 2001. However, SARs for juveniles migrating in mid-to-late May were similar to those observed for juveniles that migrated during this period in 1999 and 2002.

For fish transported from Lower Granite Dam in 2003, the wild steelhead tagged at the dam for NMFS transportation evaluations produced a higher T/I ratio (8.17) than that of wild steelhead tagged above the dam for other studies (3.68). However, for fish transported from Little Goose Dam in 2003, wild steelhead tagged at Lower Granite Dam for NMFS transport studies produced a T/I ratio of 3.73, which was similar to that of wild steelhead tagged above the dam for other studies (3.85).

It is important to note that a comparison of these T/Is should consider any substantial differences between the two studies, such as collection or handling techniques or numbers of fish tagged. For example, among fish transported from Lower Granite Dam, 3,381 were tagged at the dam and 1,309 above the dam. Among fish transported from Little Goose Dam, 12,272 were tagged at Lower Granite Dam and 938 were tagged above the dam.

In addition, the passage distribution of the general population of wild steelhead at Lower Granite Dam was slightly different from our tagging distribution. Weighting the annual SARs of our study fish to match the general population's passage distribution changes the annual T/I for fish transported from Lower Granite Dam from 8.17 to 11.11, based on weighted SARs of 2.38 and 0.21 for transported from Lower Granite Dam and inriver-migrant fish, respectively.

A possible explanation for the differences observed between fish tagged at Lower Granite Dam and those tagged above is the population each represents. Of the PIT-tagged fish arriving at Lower Granite Dam in 2003, over 60% were from either the Imnaha or Clearwater Rivers. At Lower Granite Dam, fish are tagged over the course of the juvenile migration. This likely provides a more representative sample of the entire steelhead population migrating out of Idaho and northeastern Oregon.

During the 2003 migration, an estimated 72.9% of non PIT-tagged wild steelhead were collected and transported from Snake River dams (Williams et al. 2005), while the inriver PIT-tagged group used in our study were left inriver to migrate. As a result, fewer non-tagged wild steelhead smolts were available to avian predators near the Snake and Columbia River confluence, which increased their mortality to an unknown degree. Thus, the T/Is and estimates of *D* reported here are likely higher than they would be had fewer steelhead been collected and transported.

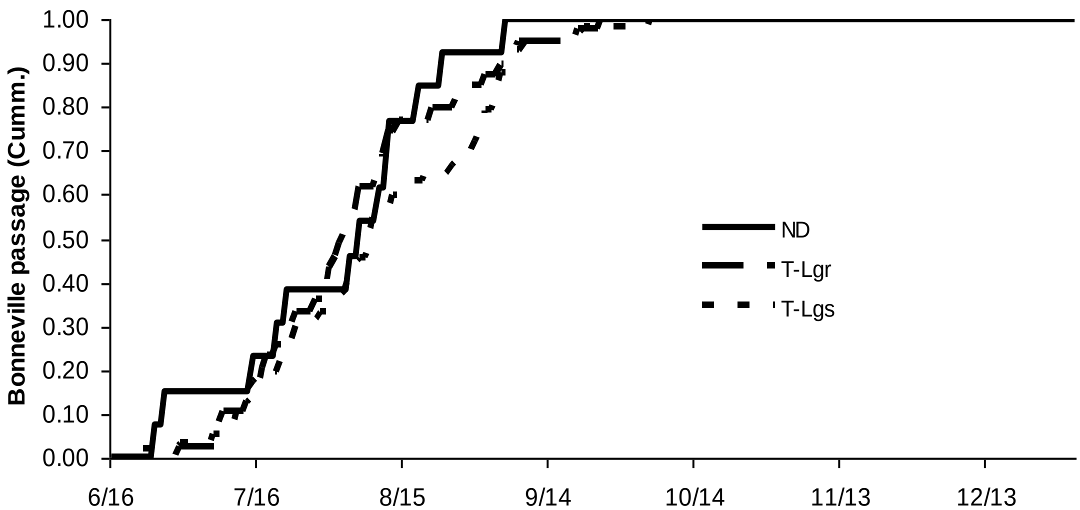
While overall survival of steelhead adults from Bonneville Dam to Lower Granite Dam was similar for all three groups, we did observe differences in both the age-1- and age-2-ocean adults individually. To understand why, we looked at arrival timing of both the migrant and transported adults at both Bonneville and Lower Granite Dam. For steelhead tagged as smolts in 2003, the arrival at Bonneville Dam of age-1-ocean adult migrants was slightly ahead of transported fish from the same year class. The timing difference increased as they moved through the FCRPS toward Lower Granite Dam (Figure 3).

Arrival timing of age-2-ocean adults at Bonneville Dam was unusually protracted, with both transported groups slightly ahead of the migrant adults. However, arrivals at Lower Granite Dam showed a normal pattern, with the migrant group arriving earlier than the transport adults (Figure 4).

When we parsed 2003 adult survival data into the smaller reaches of Bonneville to McNary Dam and McNary to Lower Granite Dam, we found that more fish (from all three groups, although transported fish were slightly higher) were lost in the first reach. The difference in survival between the Bonneville Dam to McNary Dam reach and the McNary Dam to Lower Granite Dam reach was between 7 and 19%. Since 2001, the Zone 6 fishery has taken between 8.1 and 12.5% of the steelhead adults passing between Bonneville and McNary Dams, which accounts for a large portion of the difference. The rest of the difference could be due to higher straying rates below McNary Dam.

While we did see straying of Snake River steelhead adults from the 2002 study year above the confluence of the Columbia and Snake Rivers (Priest Rapids, Rock Island, and Wells Dams had PIT-tag detection in 2003, the first year adults returned from the 2002 study year), the straying rates were low (1.1% for all transported fish and 0.8% for migrant fish), and only one adult did not eventually pass over Lower Granite Dam. Only one adult (a LGR Transport fish) strayed over Priest Rapids Dam from the 2003 study year. That adult did eventually pass over Lower Granite Dam.

We have noticed that most adults that pass over Lower Granite Dam in the spring are from the transported group. This may be due to transported adults wondering and delaying more than migrant adults on their journey up the Columbia and Snake Rivers.



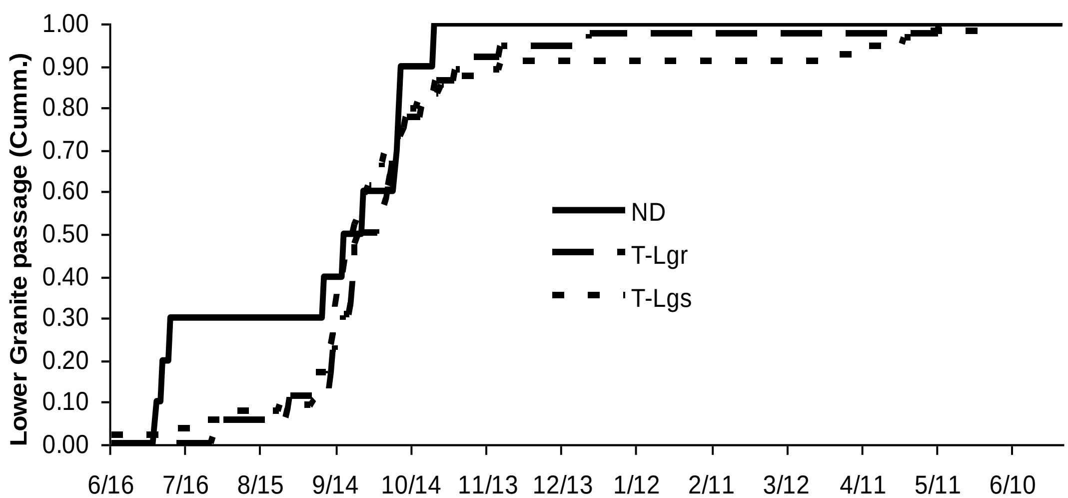
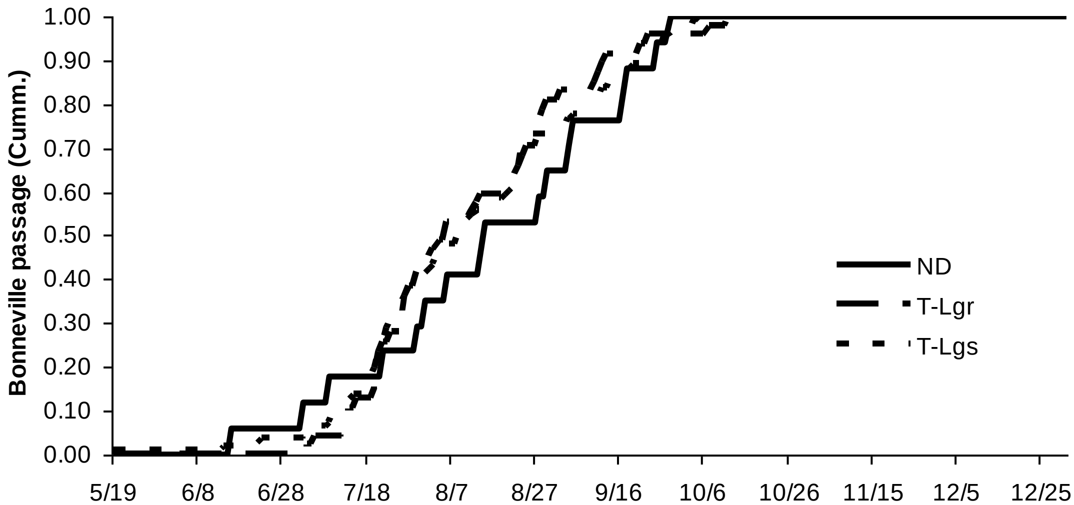


Figure 3. Distribution of age-1-ocean adult wild steelhead tagged as smolts in 2003 and detected passing Bonneville (above) and Lower Granite Dam (below) in 2004-05.



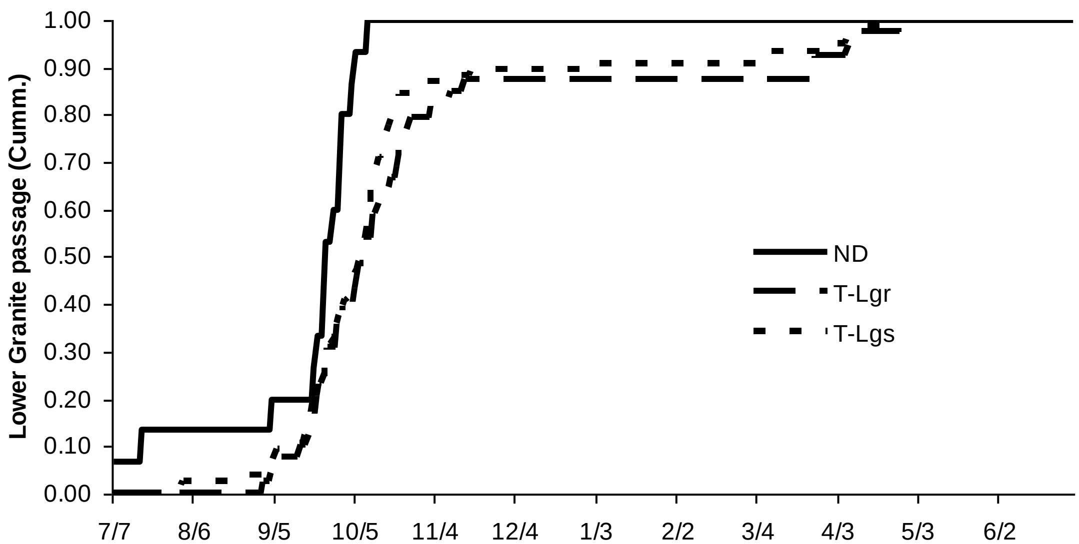


Figure 4. Distribution of age-2-ocean adult wild steelhead tagged as smolts in 2003 and detected passing Bonneville (above) and Lower Granite Dam (below) in 2005-06.

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APPENDIX A

Juvenile Data from the 2003 Wild Steelhead Tagging Year

Appendix Table A1. Wild steelhead tagged at Lower Granite Dam in spring 2003.

Release date	Transport released LGR	LGS*	Tagged	Migrant Released*	Delayed mortality	Lost tags
10-Apr	541	128	860	174	5	1
11-Apr	-	86	877	184	3	1
12-Apr	208	128	663	133	1	1
13-Apr	-	-	-	-	-	-
14-Apr	-	-	-	-	-	-
15-Apr	-	45	1,437	50	3	-
16-Apr	458	57	1,654	72	10	-
17-Apr	-	67	1,413	195	4	-
18-Apr	360	175	1,225	232	11	-
19-Apr	-	482	1,793	379	6	2
20-Apr	229	-	-	-	-	-
21-Apr	-	-	-	-	-	-
22-Apr	246	181	1,695	175	51	1
23-Apr	405	129	2,761	252	10	1
24-Apr	268	48	1,855	110	8	-
25-Apr	287	22	1,889	75	5	1
26-Apr	135	10	908	38	1	-
27-Apr	-	-	-	-	-	-
28-Apr	-	-	-	-	-	-
29-Apr	258	43	1,582	162	6	-
30-Apr	107	30	747	114	2	-
1-May	70	50	547	104	-	1
2-May	142	72	1,038	149	-	-
3-May	140	38	918	100	1	-
4-May	-	-	-	-	-	-
5-May	-	-	-	-	-	-
6-May	160	48	1,126	134	1	-
7-May	210	35	1,398	107	3	-
8-May	388	165	2,858	425	15	-
9-May	198	53	1,470	101	4	-

Appendix Table A1. Continued.

Release date	Transport released		Migrant			
	LGR	LGS*	Tagged	Released*	Delayed mortality	Lost tags
10-May	219	267	1,670	525	8	-
11-May	-	-	-	-	-	-
12-May	-	-	-	-	-	-
13-May	172	240	1,532	502	10	1
14-May	175	196	1,446	317	16	2
15-May	158	321	1,440	490	4	1
16-May	159	211	1,279	430	6	1
17-May	245	227	1,876	709	19	-
18-May	-	-	-	-	-	-
19-May	-	-	-	-	-	-
20-May	718	1,157	5,173	681	18	-
21-May	-	419	913	157	2	2
22-May	393	1,464	3,250	179	6	3
23-May	354	1,331	2,854	183	9	2
24-May	304	768	2,510	224	2	4
25-May	232	359	1,696	150	2	4
26-May	-	-	-	-	-	-
27-May	639	977	4,492	364	15	-
28-May	213	299	1,623	299	4	-
29-May	195	362	1,595	285	10	3
30-May	400	388	2,709	147	14	5
31-May	295	387	2,189	139	19	5
1-Jun	215	294	1,475	30	5	-
2-Jun	-	-	-	-	-	-
3-Jun	127	257	949	55	5	2
4-Jun	-	253	1,015	62	3	3
5-Jun	210	186	762	58	1	1
6-Jun	-	198	1,000	75	1	-
7-Jun	244	193	854	54	-	-

* Numbers shown in these categories were adjusted using the methods of Sandford and Smith (2002).

Appendix Table A2. Observations (detections) and transportation numbers at Little Goose Dam of wild steelhead smolts released into the Lower Granite Dam tailrace, 2003.

Tag group	Total observed	Number transported	Percent transported
DMM03099.IR1	338	262	77.5
DMM03100.IR1	367	294	80.1
DMM03101.IR1	257	216	84.0
DMM03104.IR1	456	362	79.4
DMM03105.IR1	559	407	72.8
DMM03106.IR1	550	430	78.2
DMM03107.IR1	569	452	79.4
DMM03108.IR1	868	683	78.7
DMM03111.IR1	726	573	78.9
DMM03112.IR1	960	714	74.4
DMM03113.IR1	709	546	77.0
DMM03114.IR1	519	375	72.3
DMM03115.IR1	307	238	77.5
DMM03118.IR1	415	314	75.7
DMM03119.IR1	192	148	77.1
DMM03120.IR1	142	105	73.9
DMM03121.IR1	276	213	77.2
DMM03122.IR1	281	213	75.8
DMM03125.IR1	246	187	76.0
DMM03126.IR1	355	271	76.3
DMM03127.IR1	778	600	77.1
DMM03128.IR1	386	290	75.1
DMM03129.IR1	520	408	78.5
DMM03132.IR1	576	443	76.9
DMM03133.IR1	637	474	74.4
DMM03134.IR1	700	527	75.3
DMM03135.IR1	467	342	73.2
DMM03136.IR1	597	481	80.6
DMM03139.IR1	929	727	78.3

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM03139.IR2	297	229	77.1
DMM03140.IR1	1,039	795	76.5
DMM03140.IR2	556	406	73.0
DMM03141.IR1	1,876	1,420	75.7
DMM03141.IR2	663	517	78.0
DMM03142.IR1	1,334	973	72.9
DMM03142.IR2	795	608	76.5
DMM03143.IR1	1,442	1,104	76.6
DMM03144.IR1	1,042	781	75.0
DMM03144.IR2	15	8	53.3
DMM03146.IR1	2,198	1,638	74.5
DMM03146.IR2	773	586	75.8
DMM03147.IR1	590	437	74.1
DMM03148.IR1	769	582	75.7
DMM03149.IR1	1,131	837	74.0
DMM03149.IR2	285	224	78.6
DMM03150.IR1	968	734	75.8
DMM03150.IR2	237	183	77.2
DMM03151.IR1	918	700	76.3
DMM03151.IR2	14	9	64.3
DMM03153.IR1	578	431	74.6
DMM03154.IR1	553	416	75.2
DMM03155.IR1	390	308	79.0
DMM03156.IR1	518	409	79.0
DMM03157.IR1	477	362	75.9

Appendix Table A3. Locations of observations (detections) of PIT-tagged wild steelhead within the Little Goose Dam juvenile fish facility (GOJ), 2003.

					Detected on separator and one additional coil (coil location)		
GOJ date	Separator	Diversion	Raceway	Sample	Diversion	Raceway	Sample
4/12/03	-	-	-	-	1	-	-
4/13/03	-	-	-	-	6	16	4
4/14/03	-	-	-	-	20	63	19
4/15/03	-	-	1	-	50	186	21
4/16/03	-	-	2	-	27	114	18
4/17/03	-	-	-	-	21	83	12
4/18/03	1	-	-	-	33	125	9
4/19/03	1	-	-	-	47	157	11
4/20/03	-	-	-	-	62	212	14
4/21/03	-	-	-	-	95	342	15
4/22/03	1	-	1	-	119	437	7
4/23/03	3	-	-	-	179	577	17
4/24/03	4	-	-	-	75	256	3
4/25/03	1	-	-	-	199	677	9
4/26/03	2	-	-	-	264	802	3
4/27/03	2	-	1	-	129	447	4
4/28/03	4	-	-	-	103	264	79
4/29/03	2	-	-	-	62	137	50
4/30/03	-	-	-	-	37	94	18
5/1/03	1	-	-	-	23	56	10
5/2/03	2	-	1	-	70	182	48
5/3/03	1	-	-	-	49	152	1
5/4/03	-	-	-	-	43	133	2
5/5/03	1	-	-	-	68	177	27
5/6/03	-	-	1	1	72	211	23
5/7/03	-	-	-	-	18	54	8
5/8/03	1	-	-	-	29	95	20
5/9/03	-	-	-	-	28	83	10
5/10/03	1	-	1	-	57	188	1
5/11/03	1	-	-	-	66	244	1
5/12/03	3	-	-	-	114	340	56
5/13/03	10	-	-	-	144	368	123
5/14/03	1	-	-	-	55	164	26
5/15/03	1	-	-	-	57	189	8
5/16/03	3	-	2	-	148	460	30
5/17/03	1	-	1	-	152	509	4
5/18/03	2	1	1	-	191	412	1
5/19/03	17	-	-	-	105	422	87
5/20/03	3	-	-	-	55	158	17
5/21/03	-	-	-	-	11	40	3
5/22/03	1	-	-	-	31	97	18
5/23/03	1	-	-	-	97	326	17

Appendix Table A3. Continued.

					Detected on separator and one additional coil (coil location)		
GOJ date	Separator	Diversion	Raceway	Sample	Diversion	Raceway	Sample
5/24/03	11	1	1	-	536	1,851	19
5/25/03	17	3	7	-	819	2,393	15
5/26/03	6	2	3	-	678	2,072	11
5/27/03	4	-	1	-	197	698	5
5/28/03	7	1	2	-	351	1,063	3
5/29/03	6	1	1	-	437	1,321	8
5/30/03	3	-	1	-	165	577	2
5/31/03	12	-	2	-	285	884	3
6/1/03	7	3	4	-	300	913	5
6/2/03	6	-	1	-	234	713	3
6/3/03	1	1	-	-	103	342	1
6/4/03	1	-	-	-	54	204	3
6/5/03	1	-	-	-	77	272	5
6/6/03	1	-	1	-	87	353	2
6/7/03	2	-	-	-	89	307	6
6/8/03	2	-	-	-	87	326	3
6/9/03	-	-	2	-	82	282	3
6/10/03	1	-	1	-	79	235	4
5/12/03	3	-	-	-	114	340	56
6/11/03	-	-	-	-	27	104	2
6/12/03	-	-	-	-	10	34	1
6/13/03	-	-	-	-	4	16	-
6/14/03	-	-	-	-	1	3	-
6/15/03	-	-	-	-	1	-	-
6/16/03	-	-	-	-	1	5	-
6/17/03	1	-	-	-	-	4	1
6/19/03	-	-	-	-	1	-	-
6/20/03	-	-	-	-	2	5	-
6/21/03	-	-	-	-	1	6	-
6/22/03	-	-	-	-	-	2	-
6/23/03	-	-	-	-	-	1	-
6/24/03	-	-	-	-	-	1	-
6/26/03	-	-	-	-	-	1	-
6/29/03	-	-	-	-	1	1	-
6/30/03	-	-	-	-	-	-	1
7/1/03	-	-	-	-	-	2	-
7/5/03	-	-	-	-	-	-	1
7/9/03	-	-	-	-	-	1	-
7/12/03	-	-	-	-	-	1	-
7/19/03	-	-	-	-	-	1	-
8/8/03	-	-	-	-	-	1	-

Appendix Table A4. Locations of observations (detections) of PIT-tagged wild steelhead within the Lower Monumental Dam juvenile fish facility (LMJ), 2003.

					Detected on separator and one additional coil (coil location)			
LMJ date	Separator	Diversion	Raceway	Sample	Diversion	Raceway	Sample	River
4/14/03	-	-	-	-	4	3	-	-
4/15/03	-	-	-	-	13	8	1	-
4/16/03	-	-	-	-	13	14	2	-
4/17/03	-	-	-	-	12	12	-	-
4/18/03	-	-	-	-	13	16	2	-
4/19/03	-	-	-	-	4	5	1	-
4/20/03	-	-	-	-	14	11	6	-
4/21/03	-	-	-	-	19	18	3	-
4/22/03	-	-	-	-	60	53	5	-
4/23/03	1	-	-	-	49	48	6	-
4/24/03	-	-	-	-	50	50	2	-
4/25/03	-	-	2	-	56	55	3	-
4/26/03	-	-	-	-	37	35	5	-
4/27/03	-	-	-	-	86	81	2	-
4/28/03	1	-	-	-	43	47	9	-
4/29/03	-	-	-	-	44	43	6	-
4/30/03	-	-	-	-	22	24	1	-
5/1/03	-	-	-	-	9	9	-	-
5/2/03	-	-	-	-	6	3	-	-
5/3/03	-	-	-	-	7	7	-	-
5/4/03	-	-	-	-	12	14	1	-
5/5/03	-	-	-	-	26	25	-	-
5/6/03	-	-	-	-	47	46	-	-
5/7/03	-	-	-	-	27	31	2	-
5/8/03	-	-	-	-	14	14	3	-
5/9/03	-	-	-	-	16	11	-	-
5/10/03	-	-	-	-	24	22	4	-
5/11/03	-	-	-	-	26	26	3	-
5/12/03	-	-	-	-	48	44	6	-
5/13/03	-	-	-	-	32	32	1	-
5/14/03	-	-	-	-	56	53	2	-
5/15/03	-	-	-	-	89	85	6	-
5/16/03	-	-	-	-	64	65	1	-
5/17/03	-	-	-	-	79	67	6	-
5/18/03	-	-	-	-	49	51	4	-
5/19/03	-	-	-	-	45	45	4	-
5/20/03	-	-	-	-	40	37	3	-
5/21/03	-	-	1	-	74	71	9	-
5/22/03	-	-	-	-	30	23	4	-
5/23/03	-	-	-	-	19	18	1	-

Appendix Table A4. Continued.

					Detected on separator and one additional coil (coil location)			
LMJ date	Separator	Diversion	Raceway	Sample	Diversion	Raceway	Sample	River
5/24/03	-	-	-	-	77	77	5	-
5/25/03	2	-	-	-	529	485	50	-
5/26/03	1	1	1	-	712	627	51	-
5/27/03	-	-	-	-	668	576	25	28
5/28/03	-	-	-	-	182	179	10	-
5/29/03	-	-	1	-	126	112	11	-
5/30/03	2	-	-	-	231	203	29	-
5/31/03	3	1	1	-	241	248	34	-
6/1/03	2	-	-	-	245	229	23	-
6/2/03	2	-	-	-	193	191	17	1
6/3/03	1	-	-	-	159	161	12	-
6/4/03	-	-	-	-	95	93	9	-
6/5/03	-	-	-	-	55	49	2	-
6/6/03	-	-	-	-	54	54	2	-
6/7/03	-	-	-	-	80	78	2	-
6/8/03	-	-	-	-	98	100	3	-
6/9/03	-	-	-	-	84	80	6	-
6/10/03	-	-	-	-	92	102	4	-
6/11/03	-	-	-	-	57	50	5	-
6/12/03	-	-	-	-	33	30	3	-
6/13/03	-	-	-	-	14	15	-	-
6/14/03	-	-	-	-	12	11	-	-
6/15/03	-	-	-	-	3	3	-	-
6/16/03	-	-	-	-	3	1	1	-
6/17/03	-	-	-	-	1	2	-	-
6/18/03	-	-	-	-	5	2	-	-
6/19/03	-	-	-	-	-	1	-	-
6/20/03	-	-	-	-	3	1	-	-
6/21/03	-	-	-	-	4	4	-	-
6/22/03	-	-	-	-	1	1	1	-
6/23/03	-	-	-	-	-	-	1	-
6/24/03	-	-	-	-	2	-	1	-
6/25/03	-	-	-	-	1	-	1	-
6/26/03	-	-	-	-	-	-	1	-
6/27/03	-	-	-	-	1	-	-	-
6/28/03	-	-	-	-	1	-	1	-
6/29/03	-	-	-	-	1	-	1	-
7/1/03	-	-	-	-	-	-	1	-
7/3/03	-	-	-	-	1	-	-	-
7/21/03	-	-	-	-	1	-	-	-
7/29/03	-	-	-	-	-	-	1	-

Appendix Table A5. Locations of observations (detections) of PIT-tagged wild steelhead 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	Adult return	Raceway	Raceway Bypass	Raceway Transport	Sample Bypass	Raceway Bypass
4/17/2003	3	-	-	-	-	-	-
4/18/2003	1	-	-	11	-	1	-
4/19/2003	8	-	-	1	-	1	-
4/20/2003	3	-	-	9	-	-	-
4/21/2003	11	-	-	1	-	-	-
4/22/2003	4	-	-	7	-	-	-
4/23/2003	4	-	-	-	-	-	-
4/24/2003	1	-	-	4	-	-	-
4/25/2003	10	-	-	4	-	-	-
4/26/2003	3	-	-	23	-	2	-
4/27/2003	18	-	-	10	-	-	-
4/28/2003	12	-	-	13	-	-	-
4/29/2003	25	-	-	4	1	-	-
4/30/2003	14	-	-	19	1	-	-
5/1/2003	31	-	-	8	-	-	-
5/2/2003	1	-	-	5	-	-	-
5/3/2003	8	-	-	2	-	-	-
5/4/2003	3	-	-	3	-	-	-
5/5/2003	4	-	-	-	-	-	-
5/6/2003	-	-	-	3	-	-	-
5/7/2003	7	-	-	-	-	-	-
5/8/2003	3	-	-	6	-	-	-
5/9/2003	7	-	-	4	-	-	-
5/10/2003	4	-	-	5	-	-	-
5/11/2003	4	-	-	-	-	-	-
5/12/2003	2	-	-	5	-	-	-
5/13/2003	1	-	-	1	-	-	-
5/14/2003	2	-	-	3	1	-	-
5/15/2003	12	-	-	3	-	-	-
5/16/2003	13	-	-	21	-	-	-
5/17/2003	17	-	-	17	2	-	-
5/18/2003	16	-	-	20	1	-	-
5/19/2003	18	-	-	5	-	-	-
5/20/2003	11	-	-	15	-	-	-
5/21/2003	16	-	-	5	-	-	-
5/22/2003	12	-	-	27	1	-	-
5/23/2003	83	-	-	14	2	-	-
5/24/2003	44	3	-	84	1	-	1

Appendix Table A5. Continued.

MCJ date	Full flow	Adult return	Detected on full-flow and additional coil(s) (coil location)		Detected on separator and additional coil(s) (coil location)		
			Raceway	Raceway Bypass	Raceway Transport	Sample Bypass	Raceway Bypass
5/25/2003	59	2	-	61	-	-	-
5/26/2003	46	-	-	48	-	-	-
5/27/2003	151	-	-	36	1	-	1
5/28/2003	81	-	-	129	8	1	1
5/29/2003	75	-	-	87	6	1	-
5/30/2003	14	-	-	9	-	-	1
5/31/2003	23	-	-	3	-	-	-
6/1/2003	16	2	-	36	3	2	-
6/2/2003	40	-	-	30	1	-	1
6/3/2003	27	1	-	26	-	-	-
6/4/2003	16	-	-	14	-	-	-
6/5/2003	5	2	-	12	-	-	-
6/6/2003	10	1	-	3	-	-	-
6/7/2003	1	1	-	7	-	-	-
6/8/2003	5	-	-	1	-	-	-
6/9/2003	6	2	-	9	1	-	1
6/10/2003	16	-	-	11	1	-	-
6/11/2003	7	-	-	5	-	-	-
6/12/2003	8	-	-	3	-	-	-
6/13/2003	7	-	-	8	-	-	-
6/14/2003	2	-	1	1	-	-	-
6/15/2003	1	-	-	-	-	-	-
6/16/2003	1	-	-	-	-	-	-
6/17/2003	1	-	-	1	-	-	-
6/21/2003	1	-	-	-	-	-	-

APPENDIX B

Tagging Results for 2005 Juvenile Transportation Studies

Snake River Steelhead

From 11 April through 10 June 2005, we PIT tagged a total of 10,477 wild steelhead smolts, and loaded them into barges at Lower Granite Dam. No fish were released to the river. Because it was not possible to remove all mortalities from the raceways, we were unable to estimate post-marking (24-h) delayed mortality.

Snake River Fall Chinook Salmon

In 2005, we began a joint NOAA Fisheries/U. S. Fish and Wildlife Service transportation study. The 2005 tagging year information is provided is a separate annual report.

Columbia River Hatchery Steelhead

The 2005 tagging year information is provided in a separate annual report detailing the final results of the 2003 Columbia River hatchery steelhead study year.

APPENDIX C

Adult Returns from Previous and In-progress Studies

Appendix Table C1. Snake River wild steelhead studies.

	Juvenile fish numbers			Returns by age-class			SAR							
Tagging year	LGR Transport	LGS Transport	Inriver migrant	1-ocean	2-ocean	3-ocean	LGR Transport	LGS Transport	Inriver migrant	LGR T/I	LGS T/I	95% CI (LGR T/I) (LGS T/I)	Status	Annual report containing final results
2005	10,477	--	--	–	–	–	–	–	–	–	–	–	In-progress	--
2004	8,103	--	--	37	–	–	–	–	–	–	–	–	In-progress	--
2003*	**3,381**	**12,843**	**9,579**	**101**	**130**	**–**	**2.22**	**1.01**	**0.27**	**8.17**	**3.73**	**(5.95, 13.03)** **(2.76, 5.50)**	**Completed**	**Current**
2002*	4,879	14,036	15,037	292	211	4	2.60	1.84	0.78	3.32	2.34	(2.76, 4.34) (1.91, 2.86)	Completed	2005
2001	15,273	--	--	200	156	1	2.33	–	–	–	–	(2.11, 2.55)	Completed	2003
2000*	--	24,744	23,506	839	581	0	–	3.98	1.85	–	2.15	(1.99, 2.40)	Completed	2003
1999*	6,062	--	1,471	41	53	0	1.42	–	0.54	2.6	–	(1.6, 5.6)	Completed	2002

* Juvenile numbers have been adjusted using the methods of Sandford and Smith (2002)

Appendix Table C2. Snake River hatchery steelhead studies.

Tagging year	Juvenile fish numbers: Transport	Juvenile fish numbers: Inriver migrant*	Returns by Age-class: 1-ocean	Returns by Age-class: 2-ocean	Returns by Age-class: 3-ocean	SAR: Transport	SAR: Inriver migrant	T/I	95% C.I.	Status	Annual report containing final results
1999	41,109	10,442	240	283	2	1.08	0.78	1.4	1.2-1.7	Completed	2001

* Juvenile numbers have been modified by Sandford and Smith (2002).

Appendix Table C3. Snake River hatchery fall Chinook salmon studies.

Tagging year	Juvenile fish numbers: Transport	Juvenile fish numbers: Inriver migrant (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: Inriver migrant	T/I	95% C.I.	Status	Annual report containing final results
2005[a]	84,844	83,272	--	--	--	--	--	--	--	--	--	In-progress	--
2004[b]	3,617	45,296	27	--	--	--	--	--	--	--	--	In-progress	--
2003	16,109	19,161	56	48	--	--	--	--	--	--	--	In-progress	--
2002	12,344	76,334	128	215	91	--	--	--	--	--	--	In-progress	--
2001	18,907	26,340	71	75	39	7	--	--	--	--	--	In-progress	--

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

b Fish were tagged at Lower Granite Dam from 2 June to 30 July 2004.

Appendix Table C4. Columbia River fall Chinook salmon tagged at McNary Dam studies.

	Juvenile fish numbers		Returns by age-class					SAR					
Tagging year	Transport	Inriver migrant	Jack	2-ocean	3-ocean	4-ocean	5-ocean	Transport	Inriver migrant	T/I	95% C.I.	Status	Annual report containing final results
2002	38,322	56,648	143	212	454	--	--	--	--	--	--	In-progress	--
2001	23,250	38,546	33	29	63	49	--	--	--	--	--	In-progress	--

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* (LGO_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* (LGO_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

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

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.