Transportation of juvenile salmonids on the Columbia and Snake Rivers, 2003: final report for 2000 and 2001 steelhead juveniles

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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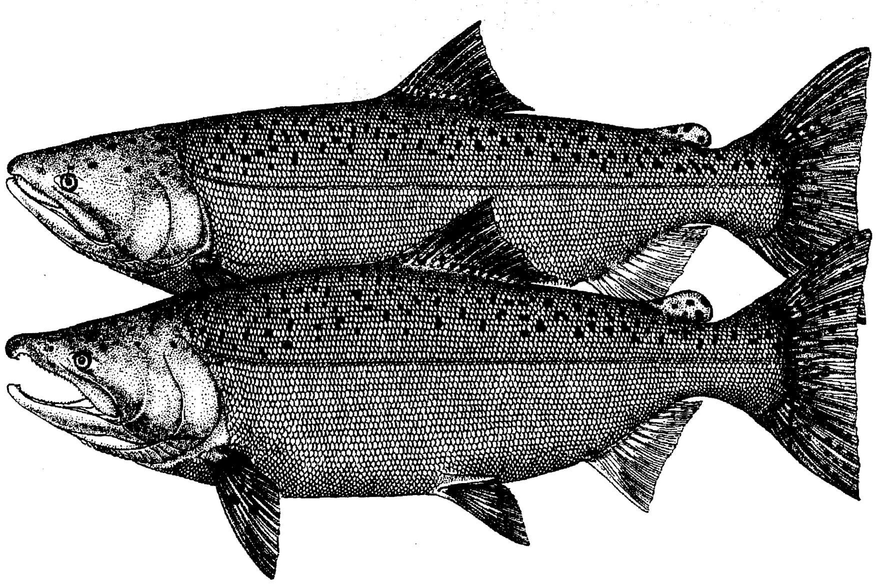
December 2004



Transportation of Juvenile Salmonids on the Columbia and Snake Rivers, 2003: Final report for 2000 and 2001 Steelhead Juveniles

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Report of research by

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for

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

December 2004

EXECUTIVE SUMMARY

Since 1999, the National Marine Fisheries Service has evaluated transportation of Snake River steelhead smolts. Beginning in 2003, transportation from McNary Dam was also evaluated for steelhead PIT-tagged at upper Columbia River hatcheries. In 2001, subyearling fall chinook salmon studies began in the Snake River and at McNary Dam.

Steelhead Tagged as Juveniles in 2000

From 1 July 2003 to 30 June 2004, we recovered age-3-ocean steelhead adults from smolts tagged in 2000, completing adult returns from that study year. In 2000, we tagged only wild fish and released them into the Lower Granite Dam tailrace. For analysis, the transport group included only fish collected and transported from Little Goose Dam and the "inriver" comparison group excluded any fish detected at Little Goose and Lower Monumental Dams. During this period we detected no new wild age-3-ocean adults from the 2000 tagging at Lower Granite Dam; the only age-3-ocean adult detected was a returning kelt that had been counted when it returned as an age-2-ocean adult. Based on all 2000 returns combined (age-1-ocean through age-3-ocean fish), the smolt-to-adult return rates (SARs) of transported and inriver fish were 3.98 and 1.85, respectively, resulting in a transport-to-inriver (T/I) ratio of 2.15 (95% CI, 1.99-2.40).

As in 1999, SARs varied with the seasonal timing of juvenile migration, but had a different pattern. While SARs from the 1999 study year were generally higher for fish migrating later in the season, SARs from fish marked in 2000 were higher for earlier migrants, with few adult returns of fish marked after early May. Overall differential delayed mortality (D) was 0.95.

Of adults detected at Bonneville Dam, 71% of transported and 81% of inriver groups migrated successfully to Lower Granite Dam (not adjusted for harvest in the Zone 6 fishery). Respective median travel times for transported and inriver age-1-ocean adults from Bonneville Dam to Lower Granite Dam were 48 and 58 d. Age-2-ocean fish were approximately 40-50% faster, averaging 30 and 31 d for transported and inriver fish, respectively.

Steelhead Tagged as Juveniles in 2001

From 1 July 2003 to 30 June 2004, we recovered age-2-ocean steelhead adults from smolts tagged in 2001, virtually completing adult returns from that study year. In 2001, we tagged only wild fish, and because of record low flows, released all fish into barges at Lower Granite Dam; thus there was no "inriver" comparison group for the 2001 juvenile migration. During the adult recovery period, we detected 156 wild age-2-ocean adults tagged as juveniles in 2001 at Lower Granite Dam.

Because no age-3-ocean adults have returned since tagging began in 1999, we expected few, if any, detections of age-3-ocean adults from the 2001 tagging. Therefore we calculated the final smolt-to-adult return rate (SAR) for 2001 based on returns of age-1 and age-2-ocean fish in 2002 and 2003. For fish transported in 2001, the SAR was 2.33 (95% CI, 2.11-2.55).

For fish from the 2001 juvenile migration year, SARs again varied depending on the seasonal timing of their migration as juveniles. The pattern of variation was similar to that seen in 2000, with SARs generally higher for fish that migrated early in the season and few returns of fish marked after early May.

Of adults detected at Bonneville Dam, 68% migrated successfully to Lower Granite Dam (not adjusted for any take in the Zone 6 fishery). Median travel time from Bonneville to Lower Granite Dam was 54 d for age-1-ocean adults and 43 d for age-2-ocean adults.

CONTENTS

INTRODUCTION

In 2003, we continued annual studies to evaluate transportation of juvenile fish to below Snake and Columbia River dams to mitigate losses that result from the lower Snake and Columbia River hydropower system operated by the U.S. Army Corps of Engineers (USACE). The primary objective of our studies is to compare adult returns of chinook salmon and steelhead transported below Bonneville Dam to those of their cohorts allowed to migrate inriver under optimal conditions for survival. Detections from PIT-tagged smolts released to migrate inriver will also provide data for short-term survival estimates between the point of release and Bonneville Dam tailrace (Iwamoto et al. 1994; Smith et al. 1999).

Between July 2003 and June 2004, we completed the recovery of adults tagged in 2000 and 2001 (no age-3-ocean adults returned from 2000 and we expect few to none from the 2001 marking). Each age-class of steelhead adults enters the Columbia River from mid-summer through fall; therefore, not all adults complete their upstream migration before water temperatures decrease to a level that stops their migration. Once this occurs, the adults overwinter in the mainstem rivers and continue their upstream migration the following spring, when water temperatures begin increasing. So, unlike chinook salmon adult age-classes (which run within a single calendar year), steelhead studies to Lower Granite Dam count adults from 1 July to 30 June as one age-class.

Here we report adult returns of fish tagged at Lower Granite Dam during the 2000 and 2001 juvenile steelhead migrations. Total adult detections of these fish between July 2003 and June 2004 are combined with detections from previous return years, and analysis of complete returns for steelhead marked in 2000 and 2001 are presented.

Information is also provided on fall Chinook and steelhead tagged for transportation evaluations during the 2003 juvenile migration (Appendix C); adult returns to date of fall Chinook salmon marked during the 2001 and 2002 juvenile migrations; and a summary of adult returns to date from steelhead marked during the juvenile migrations of 1999-2002 (Appendix D).

JUVENILE STEELHEAD TAGGED IN 2000

Methods

Fish Collection and Tagging

As in past years, we collected and PIT tagged wild Snake River steelhead at Lower Granite Dam. All tagged fish were released to the tailrace and allowed to migrate down river. To create the transport study group, we set the separation-by-code PIT-tag diversion system at Little Goose Dam to divert 80% of bypassed fish to transportation collection raceways. The remaining 20% of bypassed fish were not used for transportation evaluations, but were used to help develop estimates of survival and of differential delayed mortality ('D') for transported fish. Differential delayed mortality is defined as the ratio between transported fish that survived to adulthood and inriver fish that survived past Bonneville Dam as juveniles and also survived to adulthood.

The inriver migrant group was composed only of fish not detected at either Little Goose or Lower Monumental Dam. These fish were selected because fish not detected at a Snake River collector dam are thought to be more representative of their respective general unmarked populations than fish that are collected and bypassed during migration. All ratios of return rates for transported vs. inriver migrants (T/I ratios) were calculated using non-bypassed inriver migrants (fish never detected at a dam on the Snake River).

Study Design

We calculated the number of fish needed for marking by finding the numbers needed for an accurate statistical test of the null hypothesis that there is no difference in smolt-to-adult return ratios (SARs) between transported and inriver migrant fish (versus the alternative, that the T/I ratio is at least 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

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

and

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

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

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

Therefore, with $\alpha = 0.05$ and $\beta = 0.20$, a detection differential set at 40% (T/I = 1.4), and an expected transport SAR of at least 2.1%, the sample sizes needed 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 inriver cohort (6,800 × 1.4).

In 1995, 29.7% of the yearling chinook salmon smolts that we released into the Lower Granite Dam tailrace were never again detected. In 2000, 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, to provide the 9,520 fish needed 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 rate at Little Goose Dam of only 40%, approximately 19,400 (47,600 × 0.4) wild steelhead smolts could be collected for transport from a release of this size.

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

Inriver Migration

Marsh et al. (1996) provided details on how inriver study fish were tracked as they passed through the collection systems at dams downstream from Lower Granite Dam during this study. Prior to 20 June 2000, McNary Dam was in bypass mode, meaning all tagged and untagged fish collected (except tagged fish from our Columbia River hatchery study) were returned to the river after passing through PIT-tag detectors. Thus, we included these fish in the study. After 20 June 2000, all non-tagged fish collected at the dam were transported, so we did not include any bypassed fish in the study. At Little Goose and Lower Monumental Dams, fish detected on coils leading to the transportation holding raceways were assumed to have been transported, while fish detected on diversion system coils were assumed to have been returned to the river.

Results

Fish Collection and Tagging

We PIT tagged fish from 30 March through 20 June 2000. During this period, we tagged 71,107 wild steelhead (Appendix Table 1), or 1.6% of the total steelhead collected at Lower Granite Dam in 2000. The number of fish tagged daily ranged from 4 to 4,525. Of the 71,107 wild steelhead tagged, 70,711 were released to the tailrace.

	Number of fish	Mean fork length (mm)
Tagged	71,107	184.4
Released	70,711	184.4

Based on mortality counts from the recovery holding tank for inriver migrants, post-marking delayed mortality (24-hour) averaged 0.2% for steelhead over the entire tagging season. We tagged virtually every fish sampled and rejected only a few fish that were either severely injured or exhibited gross symptoms of bacterial kidney disease. By tracking the unique PIT-tag code of each mortality, we determined the body condition recorded when the live fish was tagged.

Descaling and body injury seemed to have similar impacts on post-tagging delayed mortality. For all fish tagged, 0.4% were descaled and 2.3% had a body injury; for these two groups, delayed mortality was 1.2 and 7.9%, respectively.

Inriver Migration

As inriver study fish continued their seaward migration, some were re-collected at dams downstream from Lower Granite Dam: of the 70,711 wild steelhead released, 43,692 (61.8%) were detected at least once at a downstream collector dam. Final dispositions for the 70,711 fish released were as follows: 21,788 were transported from Little Goose Dam (Table 1; Appendix Tables A2, A6-A8), 27,019 were not detected at a Snake River dam, and 21,906 were bypassed at one or more Snake River dam. This migration history data was analyzed using the methods of Sandford and Smith (2002), which resulted in estimates of 24,744 and 23,506 juvenile fish in the 2000 transport and inriver groups, respectively. All SAR calculations were based on these numbers.

Although we set the separation-by-code system at Little Goose Dam to divert 80% of bypassed steelhead for transport, only 73.4% of these fish were actually transported from the dam during the 2000 juvenile migration. This was partly a result of lower separation efficiencies than expected at Little Goose Dam. Because fish can be held in transportation loading raceways for a maximum of 48 h, collected fish must be returned to the river if delays in loading exceed this time. However, no steelhead from the untagged population were returned to the river from the transportation holding raceways at Little Goose and Lower Monumental Dams in 2000.

Based upon PIT-tag detections at John Day and Bonneville Dams and on estuary detections in the pair-trawl system, we made preliminary estimates of juvenile survival from the Lower Granite Dam tailrace to the McNary Dam and Bonneville Dam tailraces. Estimates were made using the single-release model (Iwamoto et al. 1994; Smith et al. 1999). For wild steelhead, estimated survival was 0.708 from Lower Granite to McNary Dam tailrace and 0.510 from Lower Granite to Bonneville Dam tailrace.

Table 1. Summary of fish included in transportation evaluation study and final disposition of PIT-tagged steelhead smolts released at Lower Granite Dam and subsequently detected at Little Goose Dam in spring 2000.

Last coil observation	Final disposition	Number detected at Little Goose Dam
Excluded from transportation study		
Diversion or river-return	River	7,335
Raceway	River*	0
SMP sample	Smolt Monitoring Program sample	479
Separator	Unknown	92
PIT-tagged fish included in study		
Raceway	Loaded to barge/truck and transported	21,788
Totals		
Observed		29,694
Transport group		21,788
Returned to river		7,335

* 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.

Adult Recoveries and Data Analysis

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 transport and inriver groups.

To calculate 95% CIs for various T/Is, release days were pooled until a minimum of two adults returned in both transport and inriver 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.

At Lower Granite Dam, we began recovering age-1-ocean adults in 2001 and age-2-ocean adults in 2002. We continued to recover age-2-ocean fish through June 2003. However, we did not recover any age-3-ocean fish from July 2003 through June 2004. Returns by study group and age-class are shown below, with juvenile numbers adjusted as described above (Sandford and Smith 2002).

	Juvenile	Returns by age-class				
	numbers	1-ocean	2-ocean	3-ocean	SAR	T/I (95% CI)
Transport	24,744	557	428	0	3.98	2.15 (1.99-2.40)
Inriver	23,506	281	154	0	1.85	

Unlike chinook salmon, steelhead can return to the ocean after spawning and return to spawn again. Fish that display this life-cycle characteristic are called kelts. Several kelts were observed amongst the fish tagged for this study, potentially complicating the count of adult returns. We decided to count adults only the first time they were detected at Lower Granite Dam. Most kelts were detected in the year following their first adult detection; however, one did not return until the second year after its first detection as an adult.

As in previous years, differences in SARs were seen to vary with the seasonal timing of juvenile migration in both transported and inriver fish (Figure 1). However, the patterns observed were exactly the opposite of those seen previously. In previous study years, early juvenile migrants showed lower SARs than later migrating fish. The transition between early and later transported fish has been very dramatic and has varied from mid-April to early May (one coded-wire study even suggested it could be late May).

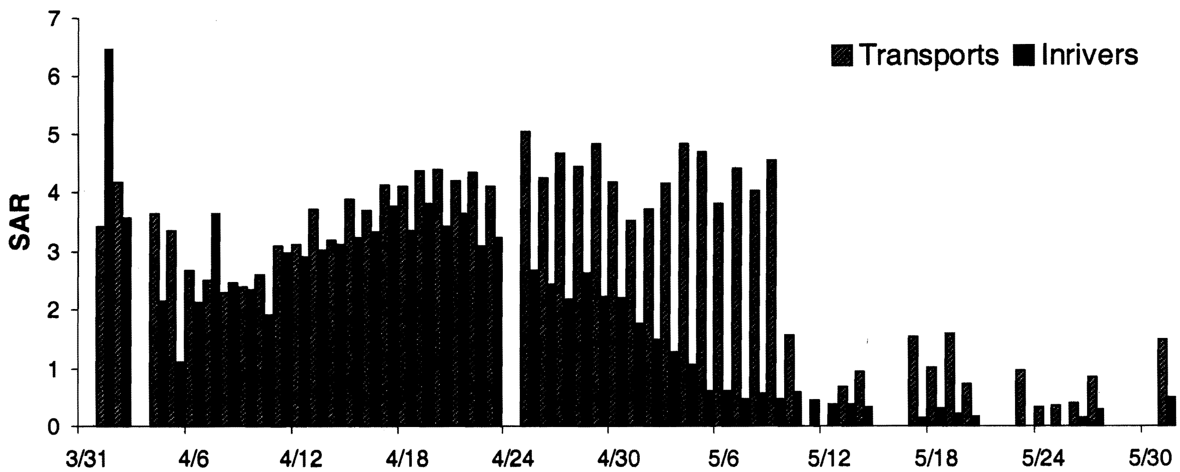

Figure 1. Smolt-to-adult return rates by release date for transported and inriver migrant steelhead smolts tagged at Lower Granite Dam in 2000. Data presented as 3-day running averages of daily releases and juvenile release numbers adjusted proportionally to daily collection numbers. Overall transport/inriver ratio was 2.15.

In 2000, SARs were extremely high for steelhead that migrated early as juveniles in both transported and inriver groups. But very few fish (from either test group) tagged after 9 May 2000 (20.1% of total tagging) returned as adults (1.9% of total adults).

Differential delayed mortality (D) varied according to the seasonal timing of juvenile migration (Figure 2), as would be expected given the similar pattern of variation observed in both transport and inriver SARs. Overall D for fish migrating as juveniles in 2000 was 0.95 (range, 0.19-3.55), but generally increased (approached 1.0) for late-season juvenile migrants. By weighting tagged groups according to the distribution of unmarked steelhead, overall D for the general unmarked population of steelhead was estimated at 1.28. The difference in D between tagged fish and the general population was due to larger numbers of fish in weighted groups with high D (late migrant juveniles; Figure 2).

The number of returning PIT-tagged adults detected at Bonneville Dam and subsequently detected at Lower Granite Dam (the conversion rate) was higher for the inriver group than for the transport group (Table 3). During each return year from the 2000 juvenile migration, more dams were being equipped with PIT tag detection systems for adults. When the age-1-ocean adults returned in 2001, only Bonneville and Lower Granite Dams were equipped with adult detection systems. McNary Dam was equipped in 2002, when the age-2-ocean adults returned, and by 2003, Ice Harbor, Priest Rapids, Rock Island, and Wells Dams had each been equipped with adult detection systems.

Most adults that did not successfully migrate from Bonneville to Lower Granite Dam also did not pass McNary Dam in 2002 (Table 4). Because of this detection pattern, and because the Zone 6 fishery is located in the reach between Bonneville and McNary Dams, we surmised that most of these adults were lost to harvest.

Median travel times from Bonneville to Lower Granite Dam ranged from 30 to 58 d (Table 5) and decreased for age-2-ocean fish. Median travel time between Bonneville and McNary Dam was roughly 10 days longer than the travel time between McNary and Lower Granite Dam for both transported and inriver age-2-ocean adults. Unlike salmon, steelhead adults may overwinter during their migration through the hydropower system, resuming their migration the following spring. We have noted that the majority of adults passing Lower Granite Dam in spring are from the transport group.

Inriver adults of both age classes were larger at tagging than their transported cohorts (Table 6), and age-1-ocean adults were larger at tagging than age-2-ocean adults. Because bypass systems may selectively collect smaller fish, while larger fish pass undetected (Williams et al. 2004), these results may indicate that transported and non-transported fish were not random samples of the population released at Lower Granite Dam.

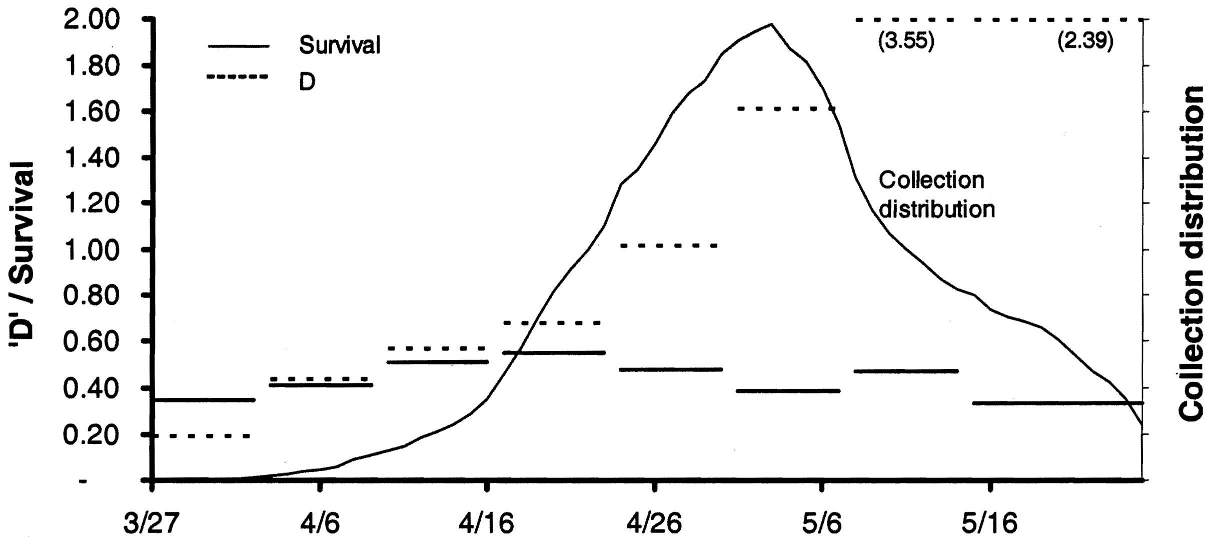

Figure 2. Estimates of differential delayed mortality (D) over time for steelhead smolts tagged at Lower Granite Dam in 2000. Grouping is based on having adequate numbers of smolts to estimate inriver survival between Lower Granite and McNary Dams and between McNary and Bonneville Dams. Overall 'D' of the tagged fish for the year was 0.95, while the overall 'D' for the general population was 1.28.

Table 3. Percentage of adult steelhead PIT-tagged as juveniles in 2000 detected at Bonneville Dam that were subsequently detected at Lower Granite Dam (the conversion rate) (not adjusted for Zone 6 harvest).

Age class		Detected at Bonneville Dam	Detected at Lower Granite Dam	Conversion rate
Age-1-ocean	Inriver	235	195	82.98
	Transport	549	376	68.49
Age-2-ocean	Inriver	194	149	76.80
	Transport	589	414	70.29
Totals	Inriver	429	344	80.19
	Transport	1,138	790	68.42

Table 4. Percentage of adult steelhead PIT-tagged as juveniles in 2000 detected at Bonneville Dam subsequently detected at McNary (not adjusted for Zone 6 harvest) and Lower Granite Dams for age-2-ocean fish.

Reach		Detected at first dam	Subsequently detected at second dam	Percentage
BON to MCN	Inriver	194	155	79.90
	Transport	589	444	75.38
MCN to LGR	Inriver	161	155	96.27
	Transport	454	425	93.61

Table 5. Median travel times from Bonneville Dam to Lower Granite Dam for adult steelhead PIT tagged in 2000.

Age class		Median travel time from Bonneville Dam to Lower Granite Dam (days)
Age-1-ocean	Inriver	48
	Transport	58
Age-2-ocean	Inriver	30
	Transport	30.5

Table 6. Average length at tagging in 2000 for successful returning adult steelhead.

Age class		Average tagging length of returning adults
Age-1-ocean	Inriver	213.8
	Transport	199.4
	Total	205.0
Age-2-ocean	Inriver	192.8
	Transport	183.2
	Total	185.5

JUVENILE STEELHEAD TAGGED IN 2001

Methods

Fish Collection and Tagging

As in past years, we collected and PIT tagged wild Snake River steelhead at Lower Granite Dam. However, due to record low flows, all fish were placed on barges for transport from Lower Granite Dam. No fish were released into the Lower Granite Dam tailrace; therefore, no inriver-migrant cohort was formed or evaluated for the 2001 juvenile steelhead migration.

Study Design

The number of PIT-tagged fish required for a transport index group at Lower Granite Dam was expressed as

$$N = \left(\frac{2\alpha}{2}\right)^2 \times SAR \times \frac{1 - SAR}{w^2}$$

where N is the number of PIT-tagged juveniles required for a transport index group, SAR is the expected smolt-to-adult return rate, and w is one-half the width of a 95% confidence interval for the SAR.

We set $\alpha = 0.05$, w at 0.002 (0.2%), and assumed an SAR for transported fish of 0.01 (1.0%). This produced N = 10,000; therefore, we proposed to tag a minimum of 10,000 for the steelhead transport index group in spring 2001. Basic collection and handling of juveniles followed the methodology described by Marsh et al. (1996, 2001). We continued using the recirculating anesthetic water system described by Marsh et al. (2001).

Results

Fish Collection and Tagging

From 10 April through 8 June 2001, we tagged 15,982 wild steelhead (Appendix Table B) at Lower Granite Dam. The number of fish tagged daily ranged from 2 to 1,833. Of the 15,982 wild steelhead tagged, 15,273 were placed into barges at Lower Granite Dam.

Number tagged	Number released	Mean fork length (mm)
15,982	15,273	183.3

Because all tagged fish were returned to transport raceways, we were unable to determine delayed mortality. The number of juveniles actually released was 15,978; however, two groups had to be discarded because of factors beyond our control. On 18 May 2001, the barge carrying fish marked on 17 May (592 wild steelhead) was forced to release fish above Ice Harbor Dam because its internal screens became clogged with juvenile lamprey. On 24 May, a hydraulic oil spill in one of the gatewells caused a layer of oil to cover all the raceways. Tagging was stopped immediately, and all fish that had been tagged (113 wild steelhead) were removed from the study.

Adult Recoveries and Data Analysis

At Lower Granite Dam, we recovered age-1-ocean adults in 2002 and age-2-ocean adults from July 2003 through June 2004. Based on past results, we did not expect any age-3-ocean adults to return. Returns by age-class are shown below.

	Adult steelhead returns by age-class			
Juvenile numbers	1-ocean	2-ocean	3-ocean	SAR (95% CI)
15,273	200	156	---	2.33 (2.11-2.55)

As in previous years, temporal differences were seen in the SARs of transported fish, although the pattern was more similar to the 2000 steelhead studies than the 1999 study (Figure 3). As with the 2000 study, SARs of early transported fish were higher than later in the season, although the decrease in SARs was not as dramatic as observed in the 2000 study. For the 2001 tagging, 28% of the fish were tagged after 7 May 2001, but

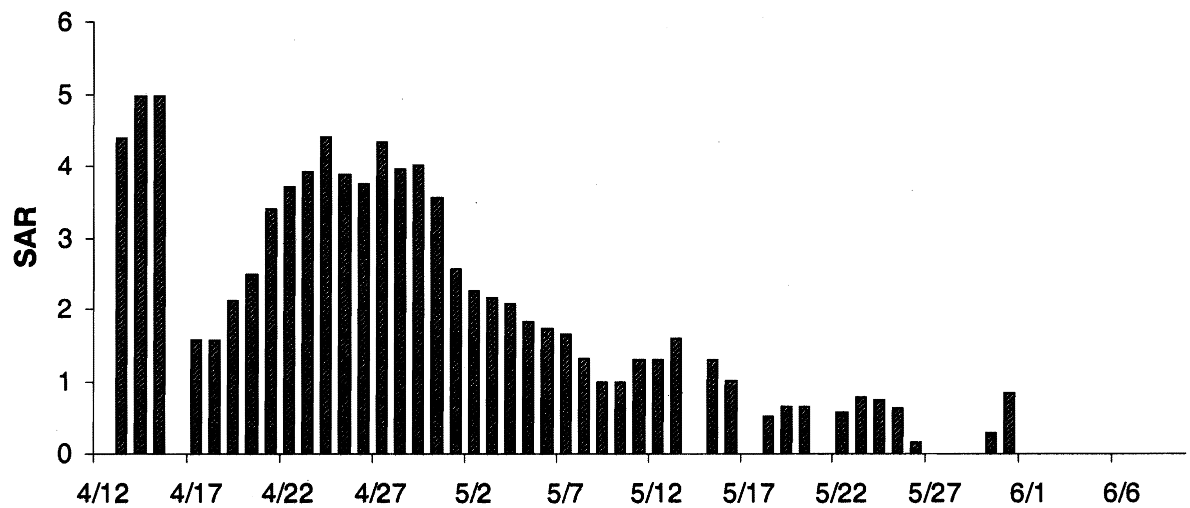

Figure 3. Smolt-to-adult return rates by release date for transported steelhead smolts tagged at Lower Granite Dam in 2001. Data presented as 3-day running averages of daily releases and juvenile release numbers adjusted proportionally to daily collection numbers.

only 10% of adult returns came from fish tagged after that date, compared to the 2000 tagging where 20% of the fish were tagged after 9 May 2000, but only 2% of the adult returns were from fish tagged during that time.

The number of returning PIT-tagged adults detected at Bonneville Dam and subsequently detected at Lower Granite Dam (the conversion rate) was similar to what we observed from the 2000 study fish (Table 6). When age-1-ocean adults from 2001 returned in 2002, Bonneville, McNary, and Lower Granite Dams were equipped with adult detection systems. Ice Harbor, Priest Rapids, Rock Island, and Wells Dams were equipped with adult detection systems prior to the age-2-ocean returns. Most adults that did not successfully migrate from Bonneville Dam to Lower Granite Dam did not pass McNary Dam, a pattern similar to that seen in returns from the 2000 tagging (Table 7). In 2003, with the addition of detection capabilities at dams on the Columbia River above the confluence with the Snake River, we observed no straying of study fish into the upper Columbia River.

Median travel times from Bonneville Dam to Lower Granite Dam ranged from 43 to 50 d (Table 8). Median travel times decreased with each age class. For age-1-ocean adults, median travel time between Bonneville and McNary Dam was 29 d, while median travel time between McNary and Lower Granite Dam was only 11 d. An even larger difference was observed with age-2-ocean adults, with median travel times of 27 d between Bonneville and McNary Dam vs. 8 d between McNary and Lower Granite Dam.

Table 6. Percentage of adult steelhead PIT-tagged as juveniles in 2001 detected at Bonneville Dam and subsequently detected at Lower Granite Dam (conversion rate; not adjusted for Zone 6 harvest).

Age class		Detected at Bonneville Dam	Detected at Lower Granite Dam	Conversion rate
Age-1-ocean	Transport	299	192	64.21
Age-2-ocean	Transport	203	149	73.40
Totals	Transport	502	341	67.93

Table 7. Percentage of adult steelhead PIT-tagged as juveniles in 2001 detected at Bonneville Dam subsequently detected at McNary (not adjusted for Zone 6 harvest) and Lower Granite Dams.

Reach		Detected at first dam	Subsequently detected at second dam	Percentage
Age-1-ocean	BON to MCN	299	221	73.91
	MCN to LGR	227	192	84.58
Age-2-ocean	BON to MCN	203	157	77.34
	MCN to LGR	160	145	90.63
Totals	BON to MCN	502	378	75.30
	MCN to LGR	387	337	87.08

Table 8. Median travel times from Bonneville Dam to Lower Granite Dam for adult spring/summer chinook salmon PIT tagged in 2000.

Age class		Travel time from Bonneville Dam to Lower Granite Dam (days)
Age-1-ocean	Transport	54
Age-2-ocean	Transport	43

DISCUSSION

It is of utmost importance that we continue to gather as much data as possible on the relationship between salmon populations and the Federal Columbia River Power System (FCRPS) during this period of high post-Bonneville-Dam survival. The inriver and transport SARs for steelhead began to increase in the late 1990s. These higher return rates have provided us with large numbers of returning adults, which lead to smaller standard errors than originally presumed for our SAR estimates. The large numbers of returning adults also present us with opportunities to examine other potentially important trends in the data.

Transportation studies of steelhead smolts PIT-tagged at Lower Granite Dam since 1999 have shown that T/Is and SARs vary considerably in relation to the seasonal timing of juvenile migration (Marsh et al. 2000, 2001; Muir et al. 2001). 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.

Results from the 1999 steelhead study showed annual T/Is that were lower than expected, primarily because SARs for transported fish were much lower for fish tagged as smolts early in the migration season. However, results from the 2000 and 2001 study years show that the relatively few fish tagged in early in the juvenile migration season (late March/early April) had the highest SARs. In both these years, as fish numbers increased, SARs of transported fish dropped in early April, rose to a peak near the end of April, and then steadily decreased in early May. Few fish marked after 10 May returned. We did not notice this lack of returns in late May from fish tagged in 1999. Also, T/Is from the 2000 study year were generally greater than 1.0 even in the early part of the juvenile migration (the 2001 study year had no inriver fish; therefore, no T/Is).

During the 2000 juvenile migration, approximately 15,000 wild steelhead were PIT-tagged above Lower Granite Dam in natal streams and at smolt traps for other studies unrelated to transportation. Detections of these fish allowed us to compare SARs of our marked fish with those of fish marked upstream to look for any effects (positive or negative) of marking at the dam. Overall SARs and T/Is for our study fish, both in groups transported from Little Goose Dam and in groups not detected on the Snake River, were higher than those of fish tagged above the dam. However, some of this difference may be due to the small numbers of both migrating juveniles and returning adults in each detection-history category from the fish tagged above Lower Granite Dam.

The default action for PIT-tag diversion systems at collector dams is to return PIT-tagged fish to the river, so very few are transported. Also, because steelhead have higher FGE than do chinook salmon, very few fish marked above the dam make it through the Snake River without being detected at one or more collector dams. For example, while our marking at Lower Granite Dam produced 24,738 fish transported from Little Goose Dam and 23,506 fish that were not detected in the Snake River, the tagging above Lower Granite Dam produced 130 transported and 2,017 not detected respectively.

Survival of adults from Bonneville to Lower Granite Dam has been greatest for the inriver groups. To understand why, we looked at arrival timing of both inriver and transported adults at Bonneville and Lower Granite Dam. The 2000 study year is the only year where we had enough wild steelhead tagged to make any inferences (in 2001 all tagged fish were transported). For age-1-ocean adults, arrival timing at Bonneville Dam was nearly identical for the two groups, but the transported adults slowed as they continued through the FCRPS toward Lower Granite Dam (Figures 4 and 5).

For age-2-ocean adults, arrival timing at Bonneville Dam was earlier for the inriver group than for the transported group, and the transported group slowed as it continued toward Lower Granite Dam, similar to the slowing seen for age-1-ocean fish (Figures 6 and 7). We have noticed that most adult steelhead that pass over Lower Granite Dam in the spring are from the transported group. While we did not observe straying of Snake River adults (from the 2001 study year) above the confluence of the Columbia and Snake Rivers (Priest Rapids, Rock Island, and Wells Dams had PIT tag detection systems in 2003), transported fish may stray more below the Snake River than inriver adults.

Because McNary Dam was equipped with adult PIT-tag detectors in 2002, we were able to parse adult survival of age-2-ocean adults tagged in 2000 into smaller reaches. We examined detections of fish at Bonneville Dam subsequently detected at McNary Dam and detections at McNary Dam of adults subsequently detected at Lower Granite Dam. We found that a higher proportion of inriver adults successfully migrated through both reaches and that a higher proportion of both transported and inriver adults did not successfully migrate through the lower reach (although transported fish were slightly less successful in the lower reach). This was possibly due to more straying in the lower Columbia River or to harvest in the Zone 6 fishery.

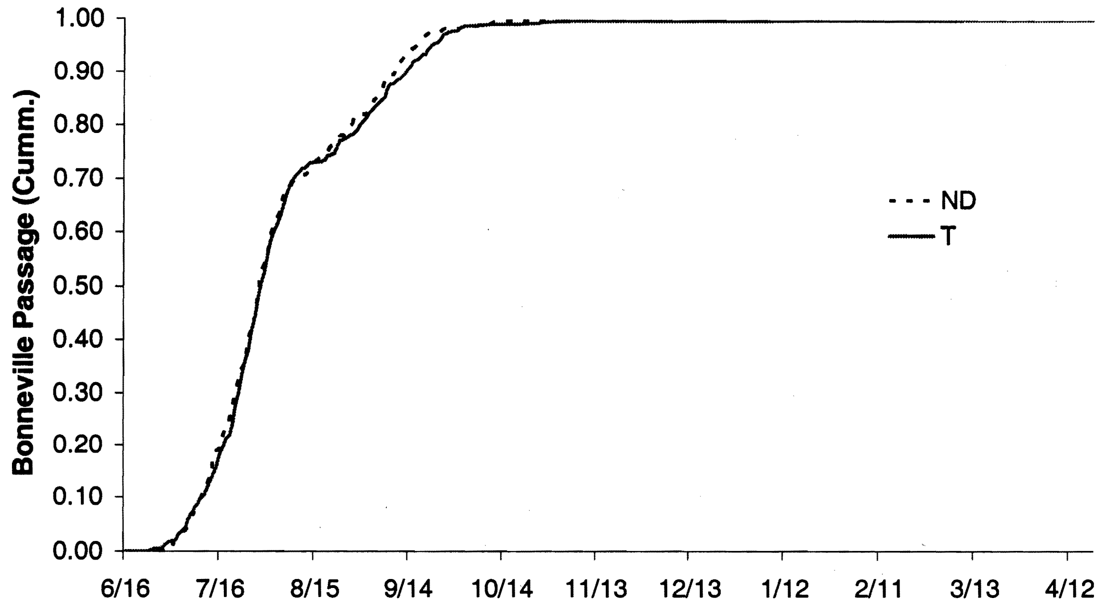

Figure 4. Distribution of age-1-ocean adult steelhead returns over Bonneville Dam from the 2000 tagging year. ND = never detected in the Snake River; T = transported from Little Goose Dam.

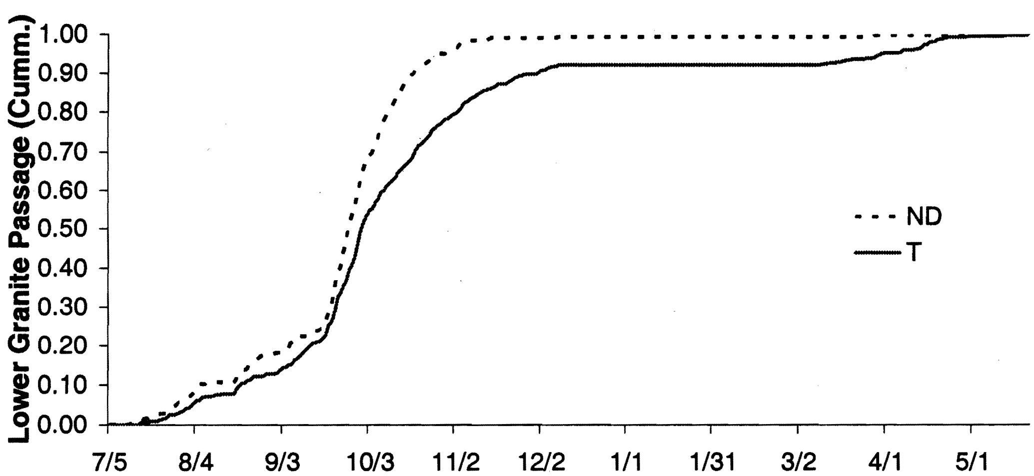

Figure 5. Distribution of age-1-ocean adult steelhead returns over Lower Granite Dam from the 2000 tagging year. ND = never detected in the Snake River; T = transported from Little Goose Dam.

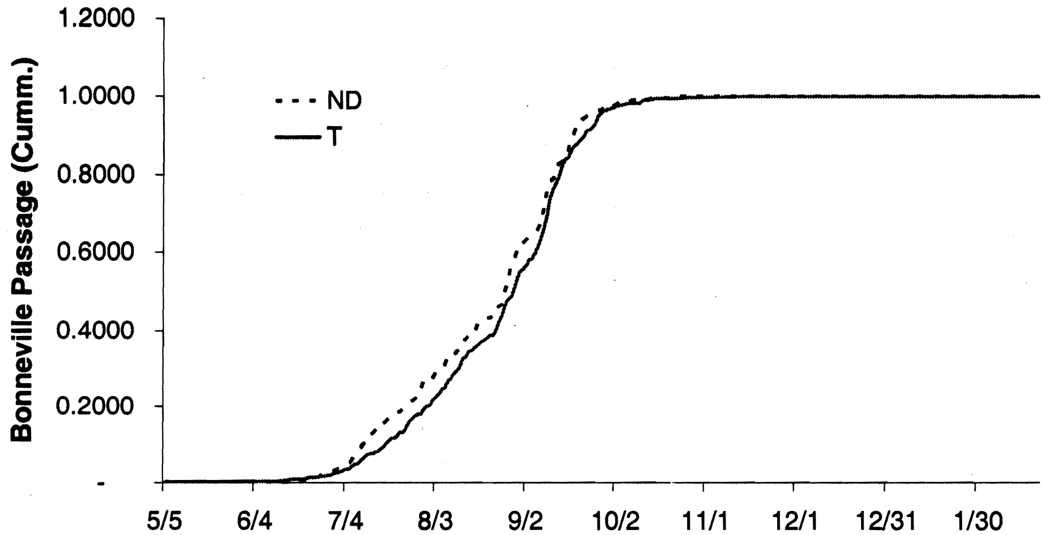

Figure 6. Distribution of age-2-ocean adult steelhead returns over Bonneville Dam from the 2000 tagging year. ND = never detected in the Snake River; T = transported from Little Goose Dam.

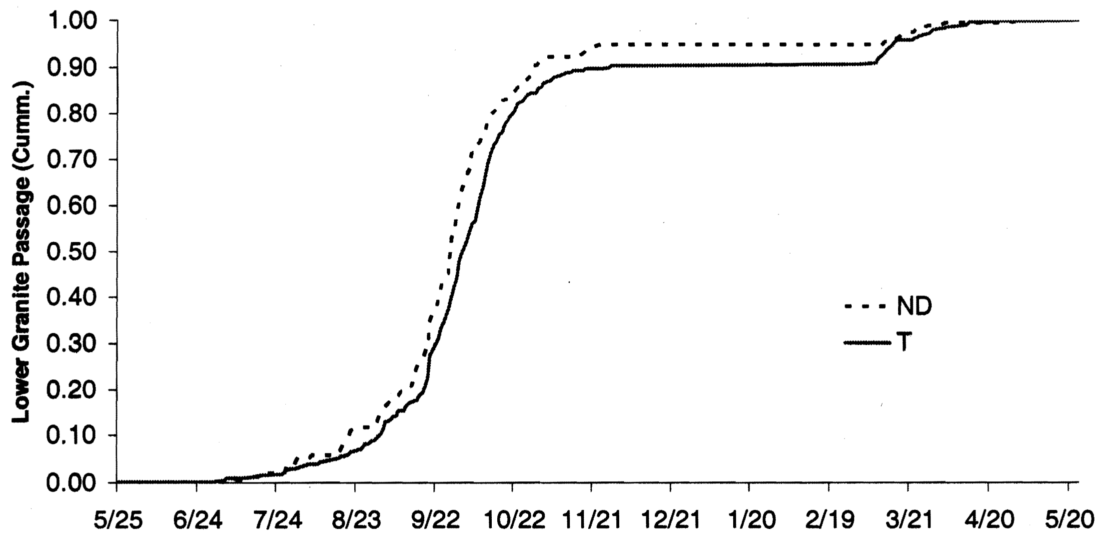

Figure 7. Distribution of age-2-ocean adult steelhead returns over Lower Granite Dam from the 2000 tagging year. ND = never detected in the Snake River; T = transported from Little Goose Dam.

One explanation for differences in adult arrival timing at Bonneville Dam and subsequent migration times to Lower Granite may be size. Inriver adults were larger as juveniles than transported adults. If this size difference continued to adulthood, inriver adults would have an advantage in migrating through the rivers. There is some data from radio tagging studies at Bonneville Dam (Chris Peery, University of Idaho, personal communication) to support this size difference continuing into adulthood, but it is inconsistent.

For the past several years researchers from the University of Idaho have radio-tagged a portion of our transportation study fish. We collected adult length data from these fish, divided the data into four groups based on age class and study year, and compared length among juvenile migration histories. Of the 4 groups, two showed that the larger size of inriver juveniles continued into adulthood, one showed the opposite pattern (transported adults were larger), and one showed virtually identical adult lengths.

For both the 2000 and 2001 study years, travel time between Bonneville Dam and Lower Granite Dam was considerably less for age-2-ocean adults than for age-1-ocean adults (the opposite of what has been observed with spring/summer chinook). This difference may be due to size: fish that spend 2 years in the ocean are considerably larger than those that spend one year. Another factor that may influence travel time relates to run type. About 80% of age-1-ocean adults are A-run fish, which tend to enter the Columbia River earlier and are therefore exposed to higher temperature conditions during late summer. Higher water temperatures may cause adults to delay entering the Snake River until it begins to cool in the fall. During upstream migration in the lower river, adults may temporarily dip into cooler tributaries, such as the Deschutes River, to avoid warmer water in the reservoirs. The majority of age-2-ocean adults are B-run fish (ca. 80%) which tend to enter the river later, after water temperatures have cooled.

The percentage of age-2-ocean adult returns was also higher for transported fish (43.5%) than for inriver fish (35.4%) tagged in 2000, another possible run-related trend. In fact, the age-class break down of transported fish tagged in 2001 was virtually identical to that of fish tagged in 2000. Given that age-2-ocean returns are predominantly B-run fish, it would seem that transported adult groups may have a larger percentage of B-run fish than inriver groups. This would imply that B-run fish receive more of a benefit from transportation than do A-run fish.

One way to determine if this is true is to look for possible morphological differences between A-run and B-run juveniles. Because we recorded fork lengths of all fish tagged for transportation studies, we were able to examine this data to determine if any inferences could be made. However, we found the average length at tagging for all inriver and transported fish was identical.

We also examined juvenile length at tagging and length of returning adults. Fish that returned as age-1-ocean adults were 10% larger as juveniles than were fish that returned as age-2-ocean adults, indicating that B-run fish may be smaller as juveniles than A-run fish. We parsed this data based on whether fish were transported or migrated inriver and found that the average inriver migrant that returned as an adult was 5-7% larger than the average transported adult, regardless of age at return.

These observations, along with the observation that transported adults had a higher percentage of age-2-ocean adults, would indicate that B-run fish may be smaller as juveniles and that they benefit more from transportation than A-run fish. In summary, these evaluations indicated that if juvenile size relates to subsequent adult returns (Zabel and Williams 2002), a comparison of transported fish to non-transported fish should involve more than just an evaluation of effects of transportation. The ability to fully evaluate the degree to which transportation can mitigate loss through the FCRPS may be more complicated than presumed.

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APPENDIX A

Juvenile Data from the 2000 Steelhead Tagging Year

Appendix Table A1. Total wild steelhead tagged at Lower Granite Dam in spring 2000.

Tag date	Tagged	Released	Post-tagging mortality	Lost tags
30-Mar	15	15	0	0
31-Mar	86	86	0	0
1-Apr	125	123	0	2
3-Apr	189	185	0	4
4-Apr	327	323	0	4
5-Apr	143	143	0	0
6-Apr	416	414	0	2
7-Apr	716	706	9	1
8-Apr	296	295	1	0
9-Apr	377	376	0	1
10-Apr	1,179	1,158	9	12
11-Apr	939	929	3	7
12-Apr	1,677	1,634	16	27
13-Apr	926	909	1	16
14-Apr	1,951	1,896	28	27
15-Apr	2,359	2,345	5	9
16-Apr	3,460	3,437	10	13
17-Apr	4,502	4,485	16	1
18-Apr	4,129	4,114	7	8
19-Apr	2,023	2,008	2	13
20-Apr	4,388	4,368	2	18
21-Apr	3,641	3,626	1	14
22-Apr	2,644	2,635	2	7
24-Apr	1,185	1,183	2	0
25-Apr	1,525	1,519	2	4
26-Apr	1,633	1,625	3	5
27-Apr	3,191	3,185	3	3
28-Apr	2,751	2,731	4	16
29-Apr	2,175	2,169	3	3
30-Apr	1,529	1,522	3	4
1-May	1,593	1,592	0	1
2-May	2,244	2,243	1	0
3-May	1,996	1,993	3	0

Appendix Table A1. Continued.

Tag date	Tagged	Released	Post-tagging mortality	Lost tags
4-May	2,016	2,013	3	0
5-May	1,395	1,392	3	0
6-May	2,151	2,140	4	7
7-May	1,559	1,558	0	1
8-May	1,335	1,335	0	0
9-May	631	631	0	0
10-May	812	810	1	1
11-May	634	631	2	1
12-May	547	547	0	0
13-May	491	491	0	0
15-May	407	405	2	0
16-May	344	344	0	0
17-May	231	230	1	0
18-May	215	215	0	0
19-May	290	289	1	0
22-May	235	235	0	0
23-May	347	346	1	0
24-May	193	193	0	0
25-May	211	209	2	0
26-May	199	196	3	0
30-May	105	105	0	0
31-May	86	86	0	0
1-Jun	27	27	0	0
2-Jun	41	41	0	0
5-Jun	30	30	0	0
6-Jun	37	37	0	0
7-Jun	60	55	5	0
8-Jun	44	44	0	0
9-Jun	19	19	0	0
12-Jun	25	25	0	0
13-Jun	4	4	0	0
14-Jun	21	21	0	0
15-Jun	7	7	0	0
16-Jun	13	13	0	0
19-Jun	15	15	0	0

Appendix Table A2. Observations (detections) and transportation numbers at Little Goose Dam of wild steelhead smolts released into the Lower Granite Dam tailrace, 2000.

Tag group	Total observed	Number transported	Percent transported
DMM00090.CS1	13	9	69.2
DMM00091.CS1	69	49	71
DMM00092.CS1	84	58	69
DMM00094.CS1	147	98	66.7
DMM00095.CS1	240	154	64.2
DMM00096.CS1	100	71	71.0
DMM00097.CS1	242	158	65.3
DMM00098.CS1	222	155	69.8
DMM00099.CH1	--	--	--
DMM00099.SH1	107	79	73.8
DMM00100.CH1	--	--	--
DMM00100.SH1	197	140	71.1
DMM00101.CH1	37	32	86.5
DMM00101.SH1	581	447	76.9
DMM00101.SH2	68	47	69.1
DMM00102.CH1	--	--	--
DMM00102.SH1	416	307	73.8
DMM00102.SH2	156	123	78.8
DMM00103.CH1	--	--	--
DMM00103.CH2	--	--	--
DMM00103.SH1	608	464	76.3
DMM00103.SH2	280	213	76.1
DMM00104.CH1	--	--	--
DMM00104.CH2	--	--	--
DMM00104.SH1	293	114	38.9
DMM00104.SH2	158	90	57.0
DMM00105.CH1	--	--	--
DMM00105.CH2	--	--	--
DMM00105.SH1	625	471	75.4
DMM00105.SH2	352	266	75.6
DMM00106.CH1	1	0	0
DMM00106.CH2	--	--	--
DMM00106.SH1	853	626	73.4
DMM00106.SH2	790	607	76.8
DMM00107.CH1	--	--	--
DMM00107.CH2	3	3	100.0
DMM00107.SH1	1,158	822	71.0
DMM00107.SH2	965	729	75.5
DMM00108.CH1	4	2	50.0
DMM00108.CH2	4	3	75.0

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM00108.SH1	1,285	951	74.0
DMM00108.SH2	759	577	76.0
DMM00109.CH1	23	15	65.2
DMM00109.CH2	12	8	66.7
DMM00109.SH1	1,014	760	75.0
DMM00109.SH2	607	435	71.7
DMM00110.CH1	--	--	--
DMM00110.SH1	536	381	71.1
DMM00110.SH2	170	121	71.2
DMM00111.CH1	12	7	58.3
DMM00111.CH2	--	--	--
DMM00111.SH1	1,135	841	74.1
DMM00111.SH2	224	155	69.2
DMM00111.SH3	37	27	73.0
DMM00112.CH1	5	4	80.0
DMM00112.CH2	--	--	--
DMM00112.SH1	1,630	1,178	72.3
DMM00112.SH2	137	89	65
DMM00113.CH1	--	--	--
DMM00113.CH2	--	--	--
DMM00113.SH1	543	400	73.7
DMM00113.SH2	470	343	73.0
DMM00115.CH1	--	--	--
DMM00115.CH2	--	--	--
DMM00115.SH1	605	450	74.4
DMM00116.CH1	--	--	--
DMM00116.SH1	883	669	75.8
DMM00117.CH1	--	--	--
DMM00117.CH2	--	--	--
DMM00117.SH1	914	675	73.9
DMM00118.CH1	20	16	80.0
DMM00118.CH2	23	19	82.6
DMM00118.SH1	1,571	1,142	72.7
DMM00119.CH1	1	1	100.0
DMM00119.CH2	--	--	--
DMM00119.SH1	1,529	1,123	73.4
DMM00120.CH1	--	--	--
DMM00120.CH2	--	--	--
DMM00120.SH1	1,159	860	74.2
DMM00121.CH1	--	--	--
DMM00121.CH2	--	--	--
DMM00121.SH1	811	583	71.9
DMM00122.CH1	--	--	--

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM00122.CH2	--	--	--
DMM00122.SH1	610	450	73.8
DMM00123.CH1	--	--	--
DMM00123.SH1	827	609	73.6
DMM00124.CH1	--	--	--
DMM00124.SH1	702	530	75.5
DMM00125.CH1	--	--	--
DMM00125.SH1	540	397	73.5
DMM00126.CH1	--	--	--
DMM00126.SH1	324	257	79.3
DMM00127.CH1	--	--	--
DMM00127.SH1	443	338	76.3
DMM00128.CH1	--	--	--
DMM00128.SH1	405	308	76.0
DMM00129.CH1	--	--	--
DMM00129.SH1	190	139	73.2
DMM00130.CH1	--	--	--
DMM00130.SH1	64	50	78.1
DMM00131.CH1	--	--	--
DMM00131.SH1	66	50	75.8
DMM00132.CH1	--	--	--
DMM00132.SH1	42	30	71.4
DMM00133.CH1	--	--	--
DMM00133.SH1	39	29	74.4
DMM00134.CH1	--	--	--
DMM00134.CH2	--	--	--
DMM00134.SH1	55	42	76.4
DMM00136.CH1	--	--	--
DMM00136.SH1	50	40	80.0
DMM00137.CH1	--	--	--
DMM00137.SH1	49	40	81.6
DMM00138.CH1	--	--	--
DMM00138.SH1	33	26	78.8
DMM00139.CH1	--	--	--
DMM00139.SH1	33	24	72.7
DMM00140.CH1	--	--	--
DMM00140.SH1	49	37	75.5
DMM00143.CH1	--	--	--
DMM00143.SH1	36	30	83.3
DMM00144.CH1	--	--	--
DMM00144.SH1	69	59	85.5
DMM00145.CH1	--	--	--
DMM00145.SH1	42	32	76.2

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM00146.CH1	--	--	--
DMM00146.SH1	46	35	76.1
DMM00147.CH1	--	--	--
DMM00147.SH1	43	33	76.7
DMM00151.CH1	--	--	--
DMM00151.SH1	7	4	57.1
DMM00152.CH1	--	--	--
DMM00152.SH1	8	6	75.0
DMM00153.CH1	--	--	--
DMM00153.SH1	3	3	100.0
DMM00154.CH1	--	--	--
DMM00154.SH1	10	7	70.0
DMM00157.CH1	--	--	--
DMM00157.SH1	6	5	83.3
DMM00158.CH1	--	--	--
DMM00158.SH1	7	4	57.1
DMM00159.CH1	--	--	--
DMM00159.SH1	2	2	100
DMM00160.CH1	--	--	--
DMM00160.SH1	1	1	100
DMM00161.CH1	--	--	--
DMM00161.SH1	1	1	100.0
DMM00164.CS1	1	1	100.0
DMM00165.CH1	--	--	--
DMM00166.CH1	--	--	--
DMM00166.SH1	2	1	50.0
DMM00167.CS1	--	--	--
DMM00168.CS1	--	--	--
DMM00171.CS1	1	1	100
	29,694	21,788	73.4

Appendix Table A3. Locations of observations (detections) of PIT-tagged wild steelhead within the Little Goose Dam juvenile fish facility (GOJ), 2000.

Detection date at GOJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
02-Apr-00	-	-	-	-	-	4	1
03-Apr-00	-	-	-	-	-	6	1
04-Apr-00	-	-	-	-	-	12	3
05-Apr-00	-	1	-	-	7	18	5
06-Apr-00	-	-	-	-	11	38	7
07-Apr-00	-	-	-	-	16	74	14
08-Apr-00	-	-	-	4	25	106	32
09-Apr-00	-	-	-	3	21	87	35
10-Apr-00	-	1	1	5	28	109	23
11-Apr-00	-	-	-	-	34	111	18
12-Apr-00	-	-	-	-	20	84	9
13-Apr-00	-	-	-	2	63	237	21
14-Apr-00	-	1	-	1	117	459	27
15-Apr-00	-	2	-	2	160	559	20
16-Apr-00	-	2	-	-	213	435	15
17-Apr-00	-	2	-	-	208	607	17
18-Apr-00	2	3	-	4	361	1,125	19
19-Apr-00	6	3	-	20	438	1,241	16
20-Apr-00	-	2	-	5	424	1,491	12
21-Apr-00	8	4	1	8	593	1,518	16
22-Apr-00	1	2	-	7	357	1,051	14
23-Apr-00	4	7	-	5	437	1,232	13
24-Apr-00	4	-	-	4	385	927	10
25-Apr-00	2	4	-	1	212	593	9
26-Apr-00	-	-	-	-	70	225	-
27-Apr-00	-	-	-	-	82	283	3
28-Apr-00	2	3	-	1	214	546	5
29-Apr-00	2	2	-	1	200	716	8

Appendix Table A3. Continued.

Detection date at GOJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
30-Apr-00	2	1	-	2	262	730	6
01-May-00	1	5	-	4	406	1,122	16
02-May-00	-	1	-	-	216	734	8
03-May-00	4	2	-	3	409	1,012	11
04-May-00	2	-	-	-	179	526	6
05-May-00	1	1	-	-	196	647	4
06-May-00	2	-	-	-	211	592	5
07-May-00	-	1	-	4	151	515	5
08-May-00	-	-	-	2	84	268	3
09-May-00	1	1	-	1	49	213	4
10-May-00	1	-	-	-	97	297	3
11-May-00	-	-	-	1	120	362	3
12-May-00	-	-	-	-	42	149	4
13-May-00	-	-	-	-	27	107	1
14-May-00	-	-	-	-	10	28	1
15-May-00	-	-	-	-	6	25	2
16-May-00	-	-	-	-	5	12	-
17-May-00	-	-	-	-	3	13	1
18-May-00	-	-	-	1	3	16	2
19-May-00	-	1	-	-	5	15	1
20-May-00	-	-	-	-	2	12	-
21-May-00	-	-	-	1	4	20	1
22-May-00	-	-	-	-	10	31	1
23-May-00	-	-	-	-	13	61	3
24-May-00	-	-	-	-	15	40	1
25-May-00	-	-	-	-	4	22	-
26-May-00	-	-	-	-	5	28	1
27-May-00	-	-	-	-	14	62	3
28-May-00	-	-	-	-	11	42	-

Appendix Table A3. Continued.

Detection date at GOJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
29-May-00	-	-	-	-	8	42	2
30-May-00	-	-	-	-	9	26	-
31-May-00	-	-	-	-	3	14	-
01-Jun-00	-	-	-	-	2	10	1
02-Jun-00	-	-	-	-	1	5	-
03-Jun-00	-	-	-	-	1	2	1
04-Jun-00	-	-	-	-	2	6	-
05-Jun-00	-	-	-	-	-	5	1
06-Jun-00	-	-	-	-	1	2	-
07-Jun-00	-	-	-	-	2	6	-
08-Jun-00	-	-	-	-	1	5	-
09-Jun-00	-	-	-	-	1	3	1
10-Jun-00	-	-	-	-	-	4	-
11-Jun-00	-	-	-	-	2	1	1
24-Jun-00	-	-	-	-	-	1	-
26-Jun-00	-	-	-	-	-	2	-
01-Jul-00	-	-	-	-	1	-	-
09-Jul-00	-	-	-	-	-	1	-
13-Jul-00	-	-	-	-	-	1	-
19-Jul-00	-	-	-	-	-	1	-
22-Jul-00	-	-	-	-	-	1	-
23-Jul-00	-	-	-	-	1	-	1
24-Jul-00	-	-	-	-	-	2	-
26-Jul-00	-	-	-	-	-	1	-

Appendix Table A4. Locations of observations (detections) of PIT-tagged wild steelhead within the Lower Monumental Dam juvenile fish facility (LMJ), 2000.

Detection date at LMJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
17-Apr-00	-	-	1	-	-	-	-
18-Apr-00	-	-	3	-	-	-	-
19-Apr-00	-	-	3	-	-	-	-
20-Apr-00	-	-	4	-	-	-	-
21-Apr-00	-	-	8	-	-	-	2
22-Apr-00	-	-	37	-	-	-	-
23-Apr-00	-	-	77	-	-	-	8
24-Apr-00	-	-	93	-	-	-	3
25-Apr-00	2	-	141	-	-	-	3
26-Apr-00	-	9	193	-	7	-	8
27-Apr-00	-	9	219	-	47	-	8
28-Apr-00	-	-	334	-	-	-	10
29-Apr-00	-	-	309	-	-	-	9
30-Apr-00	-	1	296	-	-	-	10
01-May-00	-	-	266	-	-	1	11
02-May-00	1	3	206	-	-	-	8
03-May-00	-	-	191	-	-	-	5
04-May-00	-	2	197	-	-	-	6
05-May-00	-	1	243	1	1	-	4
06-May-00	-	-	329	-	-	-	6
07-May-00	-	-	303	-	-	-	4
08-May-00	-	-	390	-	-	-	5
09-May-00	-	2	400	-	-	-	8
10-May-00	-	-	407	-	-	-	5
11-May-00	-	-	261	-	-	-	3
12-May-00	-	-	226	-	-	-	2
13-May-00	-	1	127	-	-	-	1

Appendix Table A4. Continued.

Detection date at LMJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
14-May-00	-	-	108	-	-	-	-
15-May-00	-	-	164	-	-	-	6
16-May-00	-	-	80	-	2	-	3
17-May-00	-	-	131	-	-	-	1
18-May-00	-	-	127	-	-	-	2
19-May-00	-	-	169	-	-	-	4
20-May-00	-	-	136	-	-	-	-
21-May-00	-	-	129	-	-	-	3
22-May-00	-	-	137	-	-	-	4
23-May-00	-	-	123	-	-	-	2
24-May-00	-	-	96	-	-	-	4
25-May-00	-	-	105	-	-	-	1
26-May-00	-	-	87	-	-	-	-
27-May-00	-	-	82	-	-	-	1
28-May-00	2	-	67	-	-	-	1
29-May-00	-	-	91	-	-	-	2
30-May-00	-	-	79	-	-	-	1
31-May-00	-	-	85	-	-	1	1
01-Jun-00	-	-	77	-	-	-	-
02-Jun-00	-	1	45	-	5	1	-
03-Jun-00	-	12	19	-	4	-	-
04-Jun-00	-	8	24	-	-	1	-
05-Jun-00	-	4	16	-	-	-	-
06-Jun-00	-	9	2	-	7	1	-
07-Jun-00	-	6	23	-	4	-	-
08-Jun-00	-	-	31	-	-	-	1
09-Jun-00	-	-	48	-	-	-	-
10-Jun-00	-	-	48	-	-	-	-
11-Jun-00	-	-	42	-	-	-	-

Appendix Table A4. Continued.

Detection date at LMJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
12-Jun-00	-	-	51	-	-	-	3
13-Jun-00	-	-	12	-	-	-	1
14-Jun-00	-	-	64	-	-	-	1
15-Jun-00	-	-	83	-	-	-	3
16-Jun-00	-	-	166	-	-	-	1
17-Jun-00	-	-	81	-	-	-	2
18-Jun-00	-	-	53	-	-	-	-
19-Jun-00	-	-	44	-	-	1	9
20-Jun-00	-	-	46	-	-	3	-
21-Jun-00	-	-	32	-	-	1	-
22-Jun-00	-	-	43	-	-	-	-
23-Jun-00	-	-	20	-	-	-	-
24-Jun-00	-	-	13	-	-	-	-
25-Jun-00	-	-	28	-	-	-	-
26-Jun-00	-	-	27	-	-	-	-
27-Jun-00	-	-	18	-	-	-	-
28-Jun-00	-	-	10	-	-	-	-
29-Jun-00	-	-	9	-	-	-	-
30-Jun-00	-	-	5	-	-	-	-
01-Jul-00	-	-	16	-	-	-	-
02-Jul-00	-	-	7	-	-	-	-
03-Jul-00	-	-	12	-	-	-	-
04-Jul-00	-	-	16	-	-	-	-
05-Jul-00	-	-	23	-	-	-	-
06-Jul-00	-	-	14	-	-	-	-
07-Jul-00	-	-	5	-	-	-	-
08-Jul-00	-	-	6	-	-	-	-
09-Jul-00	-	-	5	-	-	-	-
10-Jul-00	-	-	5	-	-	-	-

Appendix Table A4. Continued.

Detection date at LMJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
11-Jul-00	-	-	6	-	-	-	-
12-Jul-00	-	-	5	-	-	-	-
13-Jul-00	-	-	1	-	-	-	-
14-Jul-00	-	-	1	-	-	1	-
15-Jul-00	-	-	1	-	-	-	-
16-Jul-00	-	-	4	-	-	-	-
18-Jul-00	-	-	4	-	-	1	-
19-Jul-00	-	-	4	-	-	-	-
20-Jul-00	-	-	2	-	-	-	-
21-Jul-00	-	-	2	-	-	-	-
22-Jul-00	-	-	1	-	-	-	-
23-Jul-00	-	-	1	-	-	-	-
25-Jul-00	-	-	2	-	1	-	-
26-Jul-00	-	-	3	-	-	-	-
27-Jul-00	-	-	2	-	-	-	-
28-Jul-00	-	-	2	-	-	-	-
30-Jul-00	-	-	1	-	-	-	-
21-Aug-00	-	-	1	-	-	-	-
03-Sep-00	-	-	1	-	-	-	-

Appendix Table A5. Locations of observations (detections) of PIT-tagged wild steelhead within the McNary Dam juvenile fish facility (MCJ), 2000.

Detection date at MCJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
10-Apr-00	-	-	-	1	-	-	-
11-Apr-00	-	-	-	7	-	-	-
12-Apr-00	-	-	-	3	-	-	1
13-Apr-00	-	-	-	7	-	-	-
14-Apr-00	-	-	-	10	-	-	1
15-Apr-00	-	-	-	26	-	-	3
16-Apr-00	-	-	-	34	-	-	-
17-Apr-00	-	-	-	33	-	-	1
18-Apr-00	1	-	-	32	-	-	11
19-Apr-00	-	-	-	62	-	-	7
20-Apr-00	2	-	-	68	-	-	9
21-Apr-00	-	-	-	62	-	-	1
22-Apr-00	-	-	-	65	-	-	2
23-Apr-00	-	-	-	123	-	-	8
24-Apr-00	1	-	-	237	-	-	9
25-Apr-00	-	-	-	217	-	-	13
26-Apr-00	-	1	27	272	29	-	11
27-Apr-00	-	-	18	215	137	-	11
28-Apr-00	-	-	-	249	-	1	9
29-Apr-00	1	-	-	283	-	1	10
30-Apr-00	-	-	-	179	-	-	6
01-May-00	-	-	-	115	-	1	6
02-May-00	-	-	3	77	1	-	5
03-May-00	-	-	-	127	-	-	5
04-May-00	-	-	1	193	-	-	5
05-May-00	2	-	1	208	-	-	7
06-May-00	-	-	2	159	-	-	3
07-May-00	-	-	1	107	-	-	1

Appendix Table A5. Continued.

Detection date at MCJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
08-May-00	-	-	-	186	-	-	3
09-May-00	-	-	-	184	-	-	2
10-May-00	-	-	-	136	-	-	2
11-May-00	-	-	-	184	-	-	2
12-May-00	-	-	-	169	-	-	2
13-May-00	-	-	1	86	-	-	-
14-May-00	-	-	-	72	-	-	1
15-May-00	-	-	-	76	-	1	-
16-May-00	-	-	2	49	3	-	4
17-May-00	-	-	-	73	-	-	2
18-May-00	-	-	-	37	-	-	1
19-May-00	1	-	-	28	-	-	-
20-May-00	-	-	-	28	-	-	-
21-May-00	-	-	-	42	-	-	1
22-May-00	1	-	-	28	-	-	1
23-May-00	-	-	-	23	-	-	-
24-May-00	-	-	-	19	-	-	-
25-May-00	-	-	-	11	-	-	2
26-May-00	-	-	-	18	-	-	-
27-May-00	-	-	-	22	-	-	-
28-May-00	1	-	-	20	-	-	-
29-May-00	-	-	-	12	-	-	-
30-May-00	-	-	-	11	-	-	-
31-May-00	-	-	-	16	-	-	-
01-Jun-00	-	-	-	23	-	-	-
02-Jun-00	-	-	-	6	-	-	-
03-Jun-00	-	-	5	1	-	-	-
04-Jun-00	-	-	6	-	-	-	-
05-Jun-00	-	-	6	2	-	-	-

Appendix Table A5. Continued.

Detection date at MCJ	Detected once (coil location)			Detected on separator and at least one additional coil (coil location)			
	Diversion	Raceway	Sample	Diversion	Raceway	Sample	Sample diversion
06-Jun-00	-	-	3	-	2	-	-
07-Jun-00	-	-	3	1	1	-	-
08-Jun-00	-	-	-	4	-	-	-
09-Jun-00	-	-	-	1	-	-	-
11-Jun-00	-	-	-	2	-	-	-
12-Jun-00	-	-	-	3	-	-	-
13-Jun-00	-	-	-	1	-	-	-
14-Jun-00	-	-	-	2	-	-	-
15-Jun-00	-	-	-	5	-	-	-
16-Jun-00	-	-	-	4	-	-	-
17-Jun-00	-	-	-	2	-	-	-
23-Jun-00	-	-	-	2	-	-	-
24-Jun-00	-	-	-	1	-	-	-
26-Jun-00	-	-	-	1	-	-	-

APPENDIX B

Juvenile Data from the 2001 Steelhead Tagging Year

Appendix Table B. Total wild steelhead tagged at Lower Granite Dam in spring 2000.

Tag date	Tagged	Transported
10-Apr	73	73
11-Apr	100	100
12-Apr	88	88
13-Apr	73	73
16-Apr	82	82
17-Apr	107	107
18-Apr	84	84
19-Apr	117	117
20-Apr	80	80
21-Apr	137	137
22-Apr	152	152
23-Apr	142	142
24-Apr	163	163
25-Apr	184	184
26-Apr	580	580
27-Apr	402	402
28-Apr	637	637
29-Apr	478	478
30-Apr	1,208	1,208
1-May	874	874
2-May	1,833	1,833
3-May	1,450	1,450
4-May	658	657
5-May	747	747
6-May	612	612
7-May	296	296
8-May	138	138
9-May	281	281
10-May	199	199
11-May	204	204
12-May	139	139

Appendix Table B. Continued.

Tag date	Tagged	Transported
14-May	114	114
15-May	156	156
17-May[a]	593	593
18-May	607	607
19-May	488	488
21-May	307	307
22-May	576	576
23-May	262	262
24-May[b]	113	113
25-May	87	87
29-May	64	64
30-May	50	50
31-May	35	35
1-Jun	39	39
4-Jun	8	8
5-Jun	2	2
6-Jun	11	11
7-Jun	59	59
8-Jun	95	95
Totals	15,984	15,983

a These fish had to be released above Ice Harbor Dam when all the internal barge screens became plugged with juvenile lamprey.

b These fish were removed from the study because a hydraulic oil leak in one of the gatewells caused a layer of oil to form on all raceways.

APPENDIX C

Tagging Results for 2003 Juvenile Transportation Studies

Snake River Spring/Summer Chinook Salmon and Steelhead

From 9 April through 6 June 2003, we PIT tagged a total of 51,261 wild yearling smolts, loaded 7,118 of these into barges at Lower Granite Dam and released 43,108 into the Lower Granite Dam tailrace. From 9 April through 12 June, we PIT tagged 36,291 wild steelhead smolts at Lower Granite Dam, with 3,384 loaded into barges at the dam and 31,544 released into the tailrace.

Based on mortality counts from the inriver-holding tanks, post-marking delayed mortality (24-hour) averaged 0.4% for spring/summer chinook salmon and 0.3% for steelhead over the entire tagging season.

Transport groups were also created at Little Goose and Lower Monumental Dams. The separation-by-code systems were set at 80% and 50% to transport at the respective dam. The remaining fish were diverted back to the river to aid in creating reach survival estimates.

Snake River Fall Chinook Salmon

From 28 May through 5 June 2003, we PIT tagged a total of 53,714 subyearling chinook salmon at Lyons Ferry State Hatchery, releasing 53,583 of these fish into the Snake River above Lower Granite Dam at River Kilometer 254.

Based on mortality counts, post-marking delayed mortality (24-hour) averaged 0.4% over the entire tagging season.

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

Columbia River Hatchery Spring Chinook Salmon and Steelhead

In 2003, we continued a transportation study from McNary Dam using upper Columbia River hatchery yearling spring chinook salmon and began a transportation study from McNary Dam using upper Columbia River hatchery steelhead. One additional group was added to the study, fish bypassed directly to the McNary Dam tailrace (without going through the juvenile collection facility).

Beginning in late-August 2002, the U.S. Fish and Wildlife Service and Biomark, Inc. began PIT-tagging hatchery yearling spring chinook salmon and steelhead. A total of 354,928 yearling spring chinook salmon were tagged at Winthrop (19,962 fish), Methow (34,925), Entiat (59,879 fish), and Leavenworth Fish Hatcheries (240,162 fish). A total of 486,368 steelhead tagged at Winthrop (49,947), Wells (246,052), Eastbank (62,036), Chelan (33,172), and Ringold Fish Hatcheries (95,161).

Fish that were guided into the collection channel in McNary Dam were either bypassed directly to the river or sent into the juvenile collection facility on an every-other-day basis. The SAR of fish transported from McNary Dam will be compared to the SAR of fish bypassed directly to the river (without entering the juvenile collection facility) and to the SAR of fish that were never detected at McNary Dam.

APPENDIX D

Adult Returns from Previous and In-progress Studies

Appendix Table D1. Snake River wild steelhead studies.

Tagging year	Juvenile fish numbers		Returns by Age-class			SAR					
	Transport	Inriver	1-ocean	2-ocean	3-ocean	Transport	Inriver	T/I	95% C.I.	Status	Report year of final results
2003[a]	3,384	31,544	–	–	–	–	–	–		In-progress	--
2002[b]	4,899	43,506	270	–	–	–	–	–		In-progress	--
2001	**15,273**	**--**	**200**	**156**	**–**	**2.33**	**–**	**–**	**(2.11, 2.55)**	**Completed**	**Current**
2000[b]	**24,744**	**23,506**	**839**	**581**	**0**	**3.98**	**1.85**	**2.15**	**(1.99, 2.40)**	**Completed**	**Current**
1999[b]	6,062	1,471	41	53	0	1.42	0.54	2.6	(1.6, 5.6)	Completed	2002

a Number of fish released for this detection history category. Fish from this group that are detected at a Snake River dam will be excluded from analysis.

b Juvenile numbers in this detection-history category were estimated using the methods of Sandford and Smith (2002). Fish detected at Snake River dams were excluded from the cohort.

Appendix Table D2. Snake River hatchery steelhead studies.

Tagging year	Juvenile fish numbers		Returns by age-class			SAR					
	Transport	Inriver*	1-ocean	2-ocean	3-ocean	Transport	Inriver	T/I	95% C.I.	Status	Report year of final results
1999	41,109	10,442	240	283	2	1.08	0.78	1.4	(1.2, 1.7)	Completed	2001

* Juvenile numbers in this detection-history category were estimated using the methods of Sandford and Smith (2002). Fish detected at Snake River dams were excluded from the cohort.

Appendix Table D3. Snake River hatchery fall chinook salmon studies.

Tagging year	Juvenile fish numbers: Transport	Juvenile fish numbers: Inriver	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	T/I	95% C.I.	Status	Report year of final results
2003	16,109	19,161	--	--	--	--	--	--	--	--	--	In-progress	--
2002	12,344	76,334	95	--	--	--	--	--	--	--	--	In-progress	--
2001	18,907	26,340	71	75	--	--	--	--	--	--	--	In-progress	--

Appendix Table D4. Columbia River fall chinook salmon tagged at McNary Dam studies.

Tagging year	Juvenile fish numbers: Transport	Juvenile fish numbers: Inriver	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	T/I	95% C.I.	Status	Report year of final results
2002	38,322	56,648	143	--	--	--	--	--	--	--	--	In-progress	--
2001	23,250	38,546	33	29	--	--	--	--	--	--	--	In-progress	--

APPENDIX E

Overview of Statistical Methodology

APPENDIX E

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

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

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.