Transportation of Juvenile Salmonids on the Columbia and Snake Rivers, 2004: Final Report for 2002 Steelhead Juveniles with Updates on Other Transport Studies

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Report of research by

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201 North 3rd
Walla Walla, Washington 99362-1876
Delivery Order E86960099

December 2005

EXECUTIVE SUMMARY

Since 1999, the National Marine Fisheries Service has evaluated transportation of Snake River steelhead smolts. In 2001, we began transportation studies of subyearling fall Chinook salmon 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 during 2004, including adult recoveries of age-2-ocean wild steelhead, which complete the wild steelhead adult returns from the 2002 tagging year

In 2002, we tagged only wild fish 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 transported from Lower Granite Dam (LGR-transport), and one from fish collected and transported from Little Goose Dam (LGS-transport). These groups were compared with an inriver migrant group, which excluded any fish detected at Little Goose or Lower Monumental Dam.

From 1 July 2004 to 30 June 2005, we detected 278 wild age-2-ocean adults from the 2002 tagging at Lower Granite Dam. Past adult recovery data shows that few, if any, age-3-ocean adults will return. Based on all 2002 returns combined (age-1-ocean through age-2-ocean fish), the smolt-to-adult return rates (SARs) were 2.60 for LGR-transported, 1.84 for LGS-transported, and 0.78 for inriver migrant steelhead. These SARs resulted in an LGR-transport to inriver-migrant ratio of 3.32 (95% CI, 2.76-4.34) and an LGS-transport to inriver-migrant ratio of 2.34 (95% CI, 1.91-2.86). Based on these SARS, the ratio of LGR-transport to LGS-transport was 1.42. As in previous years, SARs varied with time of the juvenile migration, but did not follow the same pattern observed in 2000 and 2001. Overall differential delayed mortality (D) estimate was 0.75.

Of adults detected at Bonneville Dam, 70% of LGR-transport, 68% of LGS-transport, and 78% of inriver migrant groups migrated successfully to Lower Granite Dam (not adjusted for any take in the Zone 6 fishery). Median travel time from Bonneville Dam to Lower Granite Dam for age-1-ocean fish was 54.5, 51.5, and 48.0 d for LGR-transport, LGS-transport, and inriver migrants, respectively. Age-2-ocean fish were approximately 21-24% faster, averaging 41.5 d for LGR-transport, 40.5 d for LGS-transport, and 37.0 d for inriver migrant fish.

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INTRODUCTION

In 2004, we continued studies to evaluate transportation and release of juvenile fish 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 and steelhead 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 in-river survival. Detections from PIT-tagged smolts released to migrate 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 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.

In hindsight, the 1999 study design, which was based on spring/summer Chinook 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 2002 steelhead tagging year at Lower Granite Dam, with adult returns through 2004-2005. Updated information is also provided on juvenile steelhead tagged for transportation in 2004 (Appendix B); complete adult return data from steelhead tagged 1995-2001; and partial adult returns for subyearling Chinook tagged from 2001 to 2004 (Appendix C). These updates include adult return data from both Snake and Columbia River studies.

METHODS

Sampling and Tagging of Juveniles in 2002

As in past years, we collected and PIT tagged wild Snake River steelhead at Lower Granite Dam in 2002. However, one change was made to the study design established in 2000. Instead of releasing all tagged fish into the Lower Granite Dam tailrace and forming a single transport group at Little Goose Dam, two transport groups were formed. The first group was loaded into a barge at Lower Granite Dam (LGR-transported), and all remaining tagged fish were released into the Lower Granite Dam tailrace.

We set the separation-by-code system at Little Goose Dam to divert 80% of PIT-tagged fish collected at the juvenile fish facility in order to create the second transport study group (LGS-transported). The remaining 20% of fish collected were bypassed and 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:

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

and

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

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:

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

Therefore, if $\alpha = 0.05$ and $\beta = 0.20$, and if we wish to discern difference of 40% (T/I = 1.4), and we expect a transport SAR of at least 2.1% for each species, 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 inriver migrant 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 2002, 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 for the non-detected group required 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 an approximate 40% collection efficiency at Little Goose Dam, 19,400 (47,600 × 0.4) wild steelhead smolts would be collected for transport at that dam.

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 recirculating anesthetic water system, followed the methodology described by Marsh et al. (1996, 2001).

2002 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 11 July 2002, McNary Dam was in bypass mode with all tagged and untagged fish collected (except tagged fish from our Columbia River hatchery study) bypassed to the river after passing through PIT-tag detectors. Thus, we included fish detected at McNary Dam in the analysis. After this date, all non-tagged fish collected at the dam were transported, so we did not include any bypassed fish in the analysis. At Little Goose and Lower Monumental Dams, fish detected on coils leading to the raceways were assumed to have been transported, while fish detected on diversion system coils were assumed to have been returned to the river.

Adult Recoveries and Data Analysis

In 2004-2005, we completed the recovery of adults tagged in 2002 (very few age-3-ocean adults return). The procedures for data analysis described by Marsh et al. (1996) were modified as described in Sandford and Smith (2002) (a brief description is given in Appendix D) to determine the number of juvenile fish in the transport and inriver migrant groups.

To calculate 95% CIs for various T/Is, 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/Is applicable to the untagged population. The weighted mean T/Is and CIs were then constructed on the natural logarithm scale (i.e., such ratio data were assumed to be log-normally distributed) and back-transformed.

RESULTS

Sampling and Tagging of Juveniles in 2002

We PIT-tagged 48,874 wild steelhead smolts at Lower Granite Dam from 9 April through 12 June 2002 (Table 1). The number of fish tagged daily ranged from 167 to 2,714 (Appendix Table A1). Of the 48,874 wild steelhead tagged, 43,506 were released into the tailrace and 4,879 were transported in barges from Lower Granite Dam.

Based on mortality counts from the holding tanks, post-marking delayed mortality (24-hour) averaged 0.2% for inriver 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. Descaling and body injury seemed to have similar effects on post-tagging delayed mortality. For all fish tagged, 1.3% were descaled and 4.7% had a body injury, while the delayed mortality rates were 0.5 and 0.4% for the two respective groups.

Table 1. The number of wild steelhead smolts PIT-tagged and released for Lower Granite transport, Little Goose transport, and inriver migrant groups at Lower Granite Dam, 2002. Mean fork lengths are also shown.

	Number	Mean fork length (mm)
Inriver migrant		
Tagged	43,874	175.3
Released	43,506	175.3
LGR Transport		
Tagged	4,917	176.1
Released	4,879	176.1
LGS Transport		
Released	13,963	172.6

Inriver Juvenile Migration

As juvenile study fish continued their seaward migration, some were collected at dams downstream from Lower Granite Dam. Of the 43,506 wild steelhead released into Lower Granite Dam tailrace, 17,655 (40.6%) were not detected at a downstream Snake River dam. Of the remaining 25,851 (59.4%) fish that were detected, 12,730 were transported from Little Goose Dam, 8,198 were transported from Lower Monumental Dam (with 7,019 detected for the first time after tagging at Lower Granite Dam), and 5,154 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 14,036 wild steelhead in the LGS-transport group and 15,037 in the inriver migrant group. All SAR calculations were based on these numbers.

At Little Goose and Lower Monumental Dams, our initial goal was to transport 80% of the steelhead collected. However, the separation-by-code systems diverted only 77.2% of the steelhead detected at Little Goose Dam and 75.2% of the steelhead detected at Lower Monumental Dam (Table 2).

Table 2. Summary of PIT-tagged 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, 2002.

Last coil observation	Final disposition	Detected at Little Goose Dam
Excluded from transportation study		
Diversion or river return	River	3,685
Raceway	River*	0
Separator	Unknown	70
PIT-tagged fish included in study		
Raceway	Loaded to barge/truck and transported	12,499
SMP sample	Smolt monitoring program sample	231
Totals		
Observed		16,485
Transport group		12,730
Returned to river		3,685

* 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.

We made preliminary estimates of survival based upon PIT-tag detections at John Day and Bonneville Dams and on estuary detections in the pair-trawl system. We estimated survival for wild juvenile steelhead of 56.8% (SE 0.089%) from Lower Granite Dam tailrace to McNary Dam tailrace, and 19.5% (SE 0.056%) from Lower Granite tailrace to Bonneville Dam tailrace.

Adult Recoveries and Data Analysis

At Lower Granite Dam, we began recovering age-1-ocean adults in 2003 and finished with age-2-ocean adults in June 2005 (Table 3). Unlike Chinook salmon, steelhead can return to the ocean after spawning and return to spawn again (kelts). Several kelts were observed from the fish tagged for this study, complicating the counting of returning adults. While we did detect adults heading back to the ocean, none returned to Lower Granite Dam a second time.

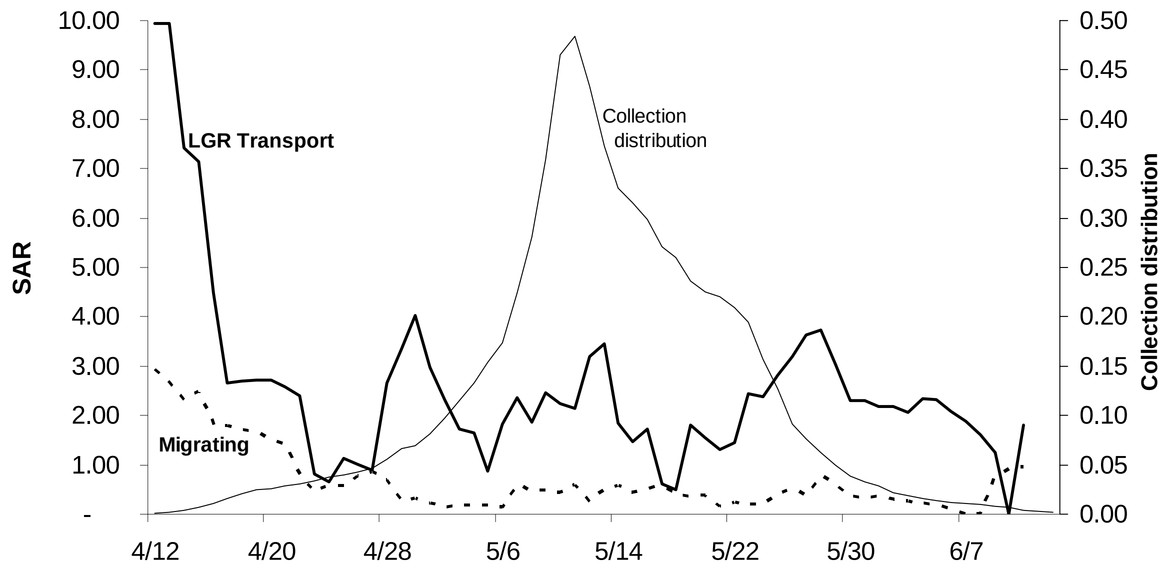
Table 3. Wild steelhead returns by study group and age-class, with juvenile numbers adjusted as described by Sandford and Smith (2002) for fish tagged at Lower Granite Dam in 2002.

	Juvenile numbers	Returns by age-class: 1-ocean	2-ocean	3-ocean	SAR	T/I	95% CI	LGR/LGS
Inriver migrant	15,037	70	48	0	0.78			
LGR transport	4,879	76	51	0	2.60	3.32	2.76-4.34	1.42
LGS transport	14,036	146	112	0	1.84	2.34	1.91-2.86	

Relationship between Juvenile Migration Timing and SARs

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). However, the timing pattern completely contradicted those observed in 2000 and 2001. For releases from the 2000 and 2001 study years, SARs were extremely high for fish tagged early in the juvenile migration season for both transported and inriver migrant fish, but dropped suddenly for fish tagged mid-season, with very few fish (from either test group) tagged after 9 May returning as adults.

For the 2002 study year, temporal SARs were similar to those observed for the 1999 study year: early juvenile inriver migrants showed very high SARs followed by a sharp drop. Inriver migrant SARS stayed low, and even decreased somewhat, over the remainder of the juvenile migration. For fish transported from Lower Granite Dam, there was a dramatic transition to higher SARs around 27 April. This date falls within the mid-April to early-May time period when such changes have been observed for spring/summer Chinook salmon transport studies (one coded-wire study year even suggested a late May transition).



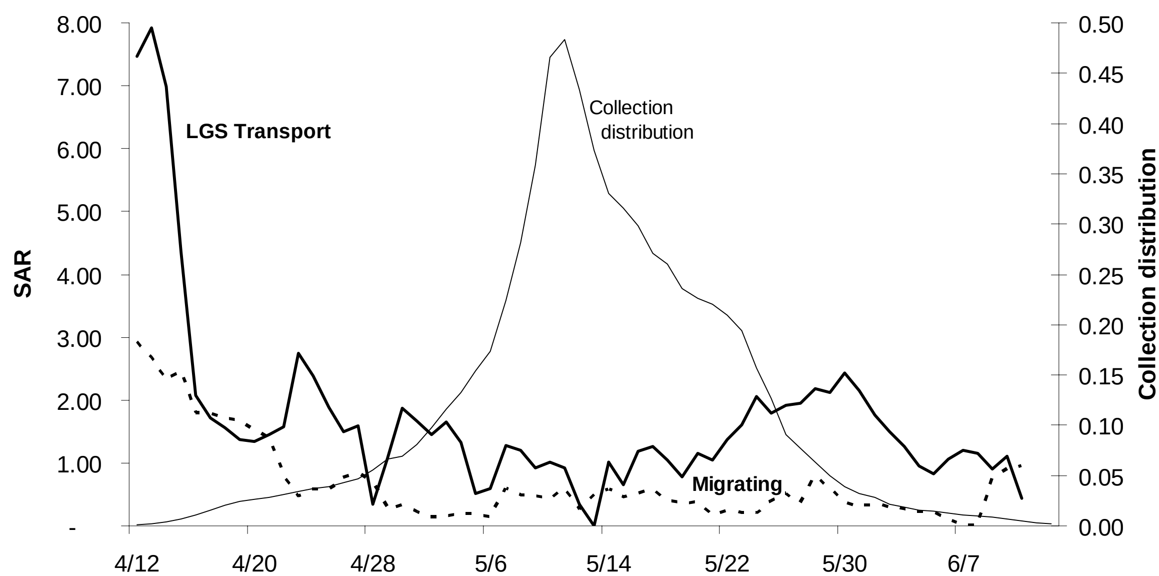


Figure 1. Smolt-to-adult return rates by juvenile tagging date for steelhead smolts transported from Lower Granite (LGR transport, above) and Little Goose Dam (LGS transport, below) compared with SARs of their inriver migrant cohorts in 2002. Also shown is the distribution of juvenile fish collected at these dams in 2002.

Delayed Mortality

The differential delayed mortality (D) also showed seasonal variation (Figure 2), as would be expected given the temporal changes in both transport and inriver migrant SARs. The overall 'D' (nonweighted) for 2002 was 0.75, but varied from 0.36 to 2.82, generally increasing (approaching 1.0) as the juvenile migration progressed. The overall D, weighted to represent the general population of steelhead was 0.78. The difference in 'D' between the nonweighted and general population was due to the later population, which had a higher 'D' value, being underrepresented by the tagging (Figure 2).

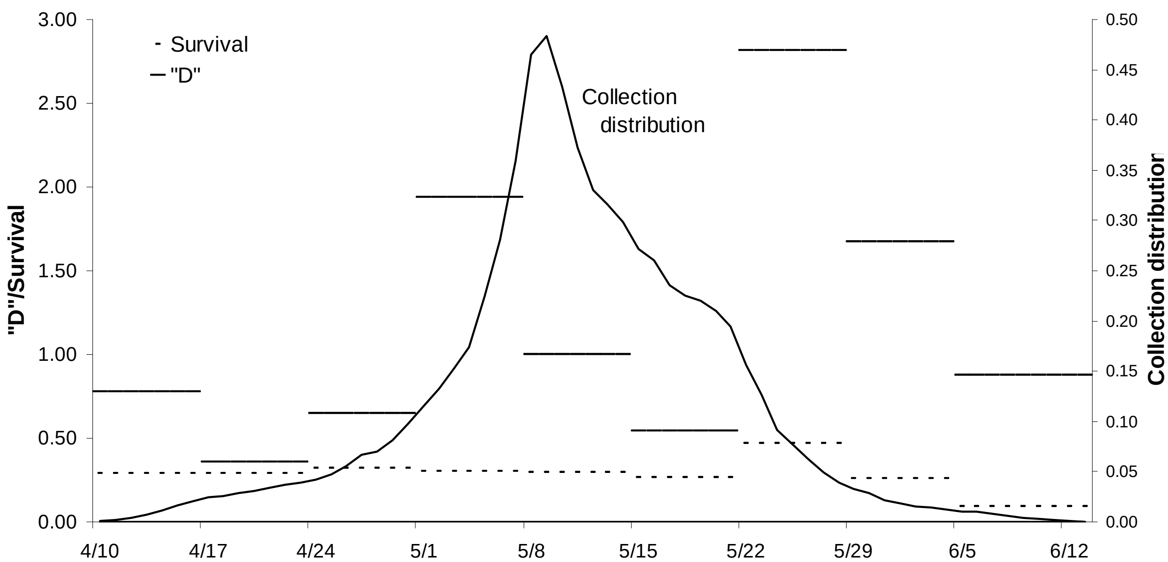


Figure 2. Estimates of differential delayed mortality (D) over time for steelhead smolts tagged at Lower Granite Dam in 2002. Grouping is based on having adequate numbers of smolts to estimate in-river survival between Lower Granite and McNary Dams and between McNary and Bonneville Dams. Overall 'D' of the tagged fish for the year was 0.75, while the overall 'D' for the general population was 0.78.

Conversion Rate

The proportion of returning adults observed at Bonneville Dam and subsequently observed at Lower Granite Dam (conversion rate) was higher for the inriver migrant group than for either transport group (Table 4). Most adults that did not successfully migrate from Bonneville Dam to Lower Granite Dam did not pass McNary Dam (Table 5).

Table 4. Percentage of adult wild steelhead observed at Bonneville Dam that were subsequently observed at Lower Granite Dam (the conversion rate) from 2002 releases.

Age class		Observed at Bonneville Dam	Observed at Lower Granite Dam	Conversion rate
Age-1-ocean	Inriver migrant	87	66	75.86
	LGR Transport	101	70	69.31
	LGS Transport	201	138	68.66
Age-2-ocean	Inriver migrant	55	45	81.82
	LGR Transport	70	50	71.43
	LGS Transport	156	106	67.95
Totals	Inriver migrant	142	111	78.17
	LGR Transport	171	120	70.18
	LGS Transport	357	244	68.35
		670	475	70.90

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 2002.

Reach		Seen at first dam	Subsequently seen at second dam	Survival (%)
Age-1-ocean				
BON to MCN	Inriver migrant	87	68	78.16
	LGR Transport	101	79	78.22
	LGS Transport	201	152	75.62
MCN to LGR	Inriver migrant	72	70	97.22
	LGR Transport	84	76	90.48
	LGS Transport	158	143	90.51
Age-2-ocean				
BON to MCN	Inriver migrant	55	45	81.82
	LGR Transport	70	53	75.71
	LGS Transport	156	114	73.08
MCN to LGR	Inriver migrant	48	48	100.00
	LGR Transport	54	50	92.59
	LGS Transport	119	110	92.44
Totals				
BON to MCN	Inriver migrant	142	113	79.58
	LGR Transport	171	132	77.19
	LGS Transport	357	266	74.51
MCN to LGR	Inriver migrant	120	118	98.33
	LGR Transport	138	126	91.30
	LGS Transport	277	253	91.34

Straying

In 2003, with the addition of detection capabilities at dams on the Columbia River above the confluence with the Snake River, we were able to observe where straying occurred. Seven adults from the 2002 tagging year were detected at Priest Rapids Dam (Table 6). Of these seven, two were subsequently detected at Rock Island Dam, and two at Wells Dam (one had been detect at both Priest Rapids and Rock Island, the other only at Rock Island). Six of the seven strays were eventually detected at Lower Granite Dam. Of these six, one fish migrated inriver, three had been transported from Little Goose Dam, and two transported from Lower Monumental Dam. The one stray adult that was never detected at Lower Granite Dam had been one of the two detected at Wells Dam and had been transported as a smolt from Little Goose Dam.

Table 6. Juvenile migration history and adult detection data of individual wild steelhead strays tagged for transportation studies in 2002.

	Adult detection at Columbia River dams				Adult detection at Snake River dams	
Tag code	McNary	Priest Rapids	Rock Island	Wells	Ice Harbor	Lower Granite
Inriver migrant						
3D9.1BF1121146	7/10/04	8/3/04			10/5/04	10/10/04
Transported from Little Goose Dam						
3D9.1BF11DA9BD	7/13/04	7/25/04			10/22/04	11/3/04
3D9.1BF11D309E	7/20/03	8/1/03			8/17/03	8/24/03
3D9.1BF11E0B0C	7/15/04	8/25/04	9/6/04		3/5/05	3/25/05
3D9.1BF11CB93C	8/19/04	8/23/04	9/1/04	9/10/04		
Transported from Lower Monumental Dam						
3D9.1BF11DA75E	7/22/03	8/4/03			10/2/03	10/9/03
3D9.1BF11D172A	7/30/03	8/7/03		8/29/03	11/7/03	3/5/04

Travel Time

Median travel times from Bonneville Dam to Lower Granite Dam ranged from 37 to 54.5 d (Table 7). As we have observed in the past, median travel time was less for age-2-ocean adults than for age-1-ocean adults. Differences in median travel time between the two age classes occurred in the Bonneville-to-McNary Dam region of the river. The median travel time between McNary and Lower Granite Dams was the same for both age classes.

Table 7. Median travel times from Bonneville Dam to McNary Dam, McNary Dam to Lower Granite Dam, and Bonneville Dam to Lower Granite Dam for adult wild steelhead PIT tagged in 2002 as juveniles at Lower Granite Dam.

		Median travel time (days)		
Age class		Bonneville to McNary Dam	McNary to Lower Granite Dam	Bonneville to Lower Granite Dam
Age-1-ocean	Inriver migrant	40	8	48
	LGR Transport	46	8	54.5
	LGS Transport	40.5	9	51.5
Age-2-ocean	Inriver migrant	23	7.5	37
	LGR Transport	27	8	41.5
	LGS Transport	39	8	40.5

Kelts

Unlike salmon, steelhead may overwinter during their adult migration through the hydropower system, resuming migration the following spring. We have noted that the majority of steelhead adults passing Lower Granite Dam in spring are from transport groups. Of the 44 adults from the 2002 tagging year that returned in spring, one was an inriver migrant fish, two had been migrating juveniles that were removed from the study, and 41 were transported from either Lower Granite (6), Little Goose (23), or Lower Monumental (12) Dams.

Size at Tagging

Inriver migrant fish that returned as both age-1- and age-2-ocean adults were larger at the time of tagging than the corresponding 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 in earlier study years.

Table 8. Average length at tagging by year class of wild steelhead PIT tagged as juveniles at Lower Granite Dam in 2002 and returning as adults in 2003 and 2004.

Age class		Average length at tagging (mm)
Age-1-ocean	Inriver migrant	215.7
	LGR transport	200.6
	LGS transport	193.6
	Total	199.9
Age-2-ocean	Inriver migrant	194.6
	LGR transport	179.1
	LGS transport	179.3
	Total	182.4

DISCUSSION

Adult returns of both inriver migrant and transported steelhead began increasing in the late 1990s. These large numbers of returning adults have provided higher return rates, which allow 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 temporal changes in SARs.

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

Calculating the statistics for groups of fish by the period when they were marked as smolts 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 were much lower for fish tagged and transported as smolts 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 of 1999: low SARs for fish tagged as smolts early in the juvenile migration, with a dramatic surge in transport SARs of fish tagged in the last week of April. This latter pattern is typical of that observed in transportation studies of spring/summer Chinook salmon.

These dichotomies in adult return rates within years were peculiar and unexpected, and after four years of observation, we have an even split in the pattern between juvenile migration timing and SARs.

Survival of adults from Bonneville Dam to Lower Granite Dam was greatest for the inriver migrant group. To understand why, we looked at arrival timing of both the inriver migrant and transported adults at both Bonneville and Lower Granite Dam. For steelhead tagged as smolts in 2002, the arrival at Bonneville Dam of age-1-ocean adult inriver 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).

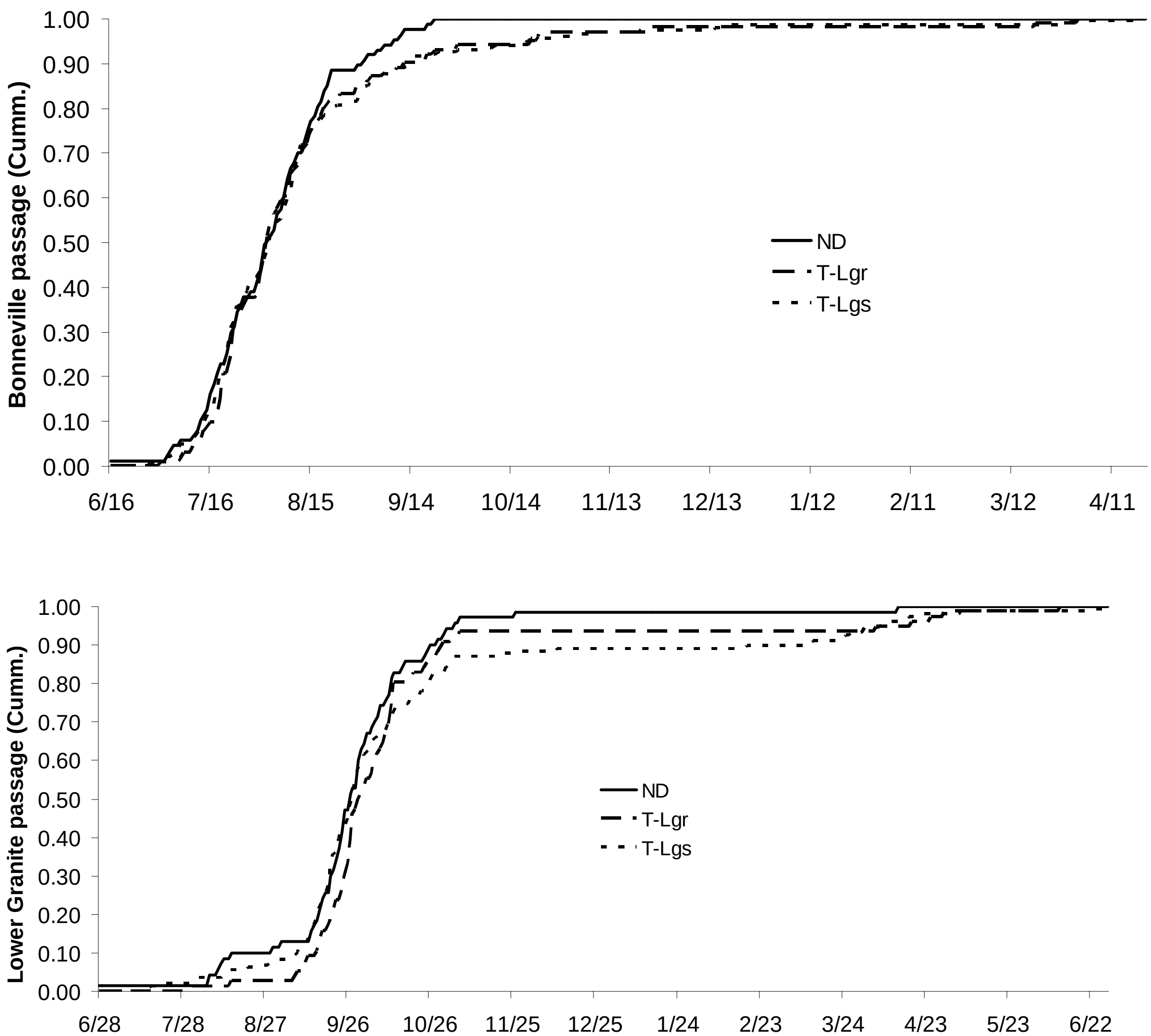


Figure 3. Distribution of age-1-ocean adult wild steelhead tagged as smolts in 2002 and detected passing Bonneville (above) and Lower Granite Dam (below) in 2003.

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

We have noticed that most adults that pass over Lower Granite Dam in the spring are from the transported group. While we did see straying of Snake River 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 straying rates were low (1.1% for all transported fish and 0.8% for inriver migrant fish), and only one adult did not eventually pass over Lower Granite Dam. Because of this, we believe the transported fish may stray more below the Snake River than inriver migrant adults.

When we parsed 2002 adult survival data into the smaller reaches of Bonneville to McNary Dam and McNary to Lower Granite Dam, we found that more fish (from both 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 12 and 20%. Since 2001, the Zone 6 fishery has taken between 8.1 and 12.5% of the 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.

As was observed for the 2000 and 2001 study years, travel time between Bonneville Dam and Lower Granite Dam for the 2002 study year was considerably less for age-2-ocean adults than for age-1-ocean adults. This may be explained by the run type. The majority of age-1-ocean adults are A-run fish (ca. 80%), which tend to enter the Columbia River earlier, and are therefore exposed to less desirable migration conditions that exist through the late summer. These migration conditions retard the adult migration, and may prevent adults from even entering the Snake River until it begins to cool in the fall. The majority of age-2-ocean adults are B-run fish (ca. 80%) which tend to enter the river later, meaning they encounter better migration conditions. These better migration conditions, coupled with the fact that B-run fish tend to be larger than A-run fish, allow them to move more quickly through the FCRPS.

When we compared the number of adults in each age class to whether the fish had been transported or not, we did not see the large differences observed in 2000 and 2001. We hypothesized that the large difference in both 2000 and 2001 implied that A-run and B-run fish are not collected at the same rate (Marsh et al. 2004). If our explanation were true, the results from the 2002 tagging year would indicate that there was no difference in the rate A- and B-run fish were collected in 2002.

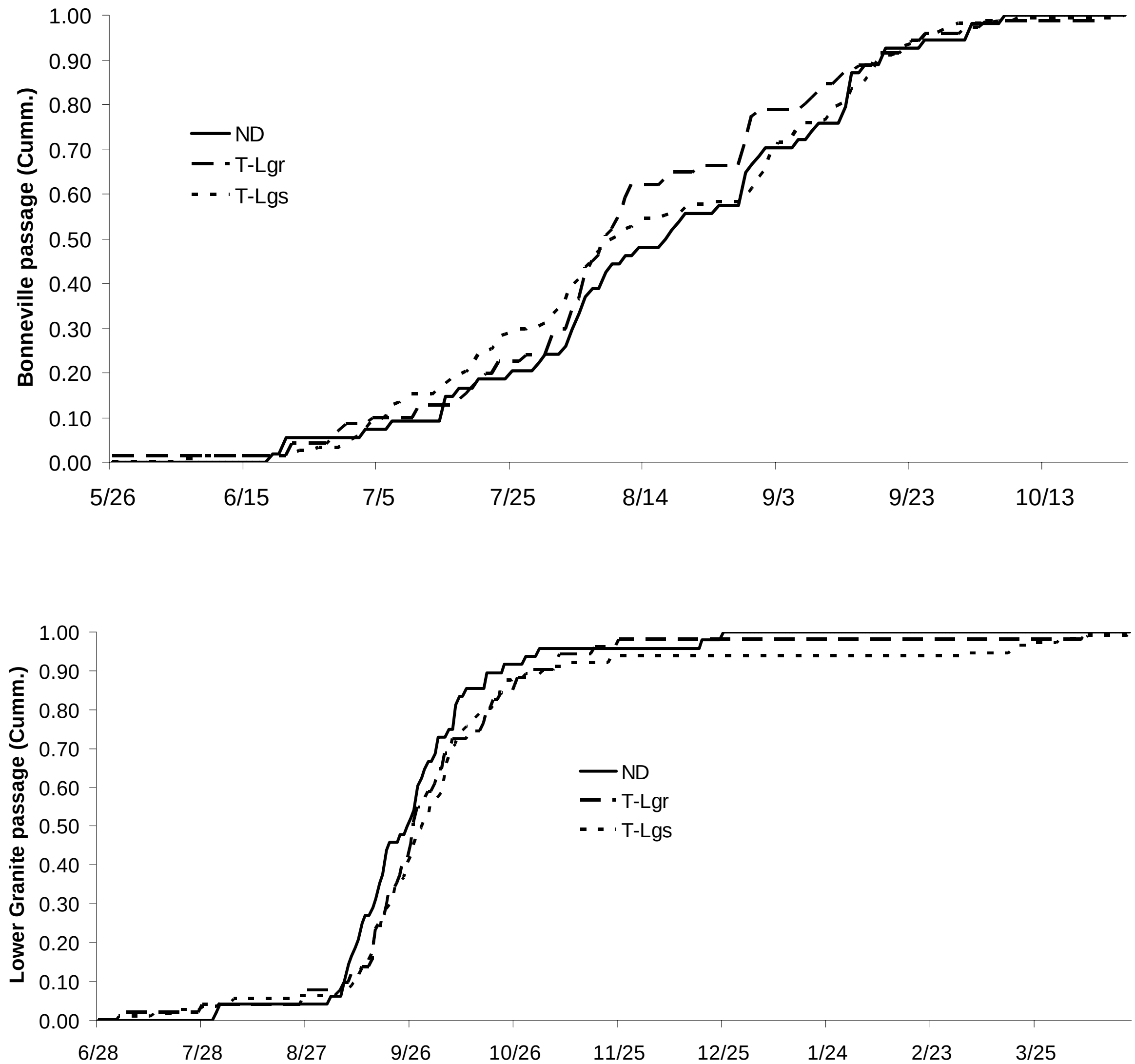


Figure 4. Distribution of age-2-ocean adult wild steelhead tagged as smolts in 2002 and detected passing Bonneville (above) and Lower Granite Dam (below) in 2004.

REFERENCES

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaska and west coast pacific salmon. Fisheries 24(1):6-14.

Hargreaves, B. N. 1997. Early ocean survival of salmon off British Columbia and impacts of the 1983 and 1991-1995 El Nino events. Proceedings of the workshop on estuarine and early ocean survival of northeastern pacific salmon. NOAA Technical Memorandum NMFS-NWFSC-29.

Marsh, D. M., J. R. Harmon, K. W. McIntyre, K. L. Thomas, N. N. Paasch, B. P. Sandford, D. J. Kamikawa, and G. M. Matthews. 1996. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1995. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2004. Transportation of juvenile salmonids on the Columbia and Snake Rivers, 2003: final report for 2000 and 2001 steelhead juveniles. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2001. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 2000. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2000. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1998. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 1997. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1996. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Matthews, G. M. and R. S. Waples. 1991. Status review for Snake River Spring and Summer Chinook Salmon. NOAA Technical Memorandum NMFS F/NWC-200.

Muir, W. D., S. G. Smith, J. G. Williams, E. E. Hockersmith, and J. R. Skalski. 2001. Survival estimates for migrant yearling chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia Rivers, 1993-1998. North American Journal of Fisheries Management 21:269-282.

Sandford, B. P., and S. G. Smith. 2002. Estimation of smolt-to-adult return percentages for Snake River Basin anadromous salmonids, 1990-1997. Journal of Agricultural Biological, and Environmental Statistics 7:243-263.

Raymond, H. L. 1988. Effects of hydropower development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8:1-24.

APPENDIX A

Juvenile Data from the 2002 Steelhead Tagging Year

Appendix Table A1. Total wild steelhead tagged at Lower Granite Dam in spring 2002.

Release date	Transport released LGR	Transport released LGS*	Inriver migrant Tagged	Inriver migrant Released*	Inriver migrant Delayed mortality	Inriver migrant Lost tags
4/10	40	100	289	153	1	0
4/11	-	77	217	113	0	1
4/12	103	235	649	323	0	0
4/15	-	217	447	160	3	1
4/16	48	-	-	-	3	0
4/17	-	-	-	-	1	2
4/18	78	163	753	507	3	7
4/19	-	260	867	507	1	5
4/22	186	202	799	490	0	3
4/23	-	479	1,901	1,196	1	1
4/24	367	368	1,061	506	3	4
4/25	-	-	-	-	0	1
4/26	-	-	-	-	0	0
4/29	59	114	520	292	2	0
4/30	73	154	729	323	3	2
5/1	115	134	877	252	7	1
5/2	54	61	429	159	0	2
5/3	55	118	456	179	1	2
5/6	-	-	-	-	1	1
5/7	-	-	-	-	2	0
5/8	42	119	354	90	1	0
5/9	52	136	406	104	3	0
5/10	30	66	290	119	0	1
5/13	44	100	442	140	1	0
5/14	49	96	884	311	0	1
5/15	25	66	466	246	1	2
5/16	34	133	633	300	3	0
5/17	28	168	635	268	25	2

Appendix Table A1. Continued.

Release date	Transport released LGR	Transport released LGS*	Inriver migrant Tagged	Inriver migrant Released*	Inriver migrant Delayed mortality	Inriver migrant Lost tags
5/18	38	292	873	253	1	1
5/19	39	291	764	149	0	0
5/20	62	653	1,278	272	4	2
5/21	222	755	1,675	192	0	2
5/22	89	183	687	209	0	1
5/23	198	612	1,507	366	0	0
5/24	186	485	1,507	248	1	5
5/25	534	1,002	2,380	508	1	0
5/26	-	738	1,499	171	2	2
5/27	220	900	1,634	225	1	3
5/28	-	-	-	-	1	3
5/29	128	496	983	1706	0	1
5/30	-	578	1,070	190	1	2
5/31	376	665	1,819	400	3	1
6/1	275	400	2,127	933	1	4
6/2	-	610	1,897	846	2	1
6/3	402	424	1,259	503	0	0
6/4	-	165	976	425	0	0
6/5	194	66	497	306	0	1
6/6	-	196	514	187	0	0
6/7	93	116	280	51	1	0
6/8	-	122	241	37	1	0
6/9	32	-	-	-	0	0
6/10	-	-	-	-	1	0
6/11	35	94	231	45	0	0
6/12	-	55	147	27		
6/13	44	80	186	33		

* 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, 2002.

Tag group	Total observed	Number transported	Percent transported
DMM02099.IR1	191	146	76.4
DMM02100.IR1	224	175	78.1
DMM02101.IR1	316	241	76.3
DMM02101.IR2	208	155	74.5
DMM02102.IR1	254	193	76.0
DMM02102.IR3	263	205	77.9
DMM02105.IR1	269	207	77.0
DMM02105.IR3	278	213	76.6
DMM02106.IR1	362	282	77.9
DMM02106.IR3	287	214	74.6
DMM02107.IR1	118	92	78.0
DMM02107.IR2	276	197	71.4
DMM02108.IR1	337	256	76.0
DMM02108.IR2	582	436	74.9
DMM02109.IR1	296	228	77.0
DMM02109.IR2	417	320	76.7
DMM02112.IR1	167	124	74.3
DMM02112.IR2	74	56	75.7
DMM02113.IR1	138	111	80.4
DMM02113.IR2	175	140	80.0
DMM02114.IR1	340	268	78.8
DMM02114.IR2	158	123	77.8
DMM02115.IR1	328	254	77.4
DMM02115.IR2	64	51	79.7
DMM02116.IR1	614	452	73.6
DMM02116.IR2	68	56	82.4
DMM02119.IR1	185	130	70.3
DMM02119.IR2	140	106	75.7
DMM02120.IR1	129	93	72.1
DMM02120.IR2	157	113	72.0

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM02121.IR1	161	115	71.4
DMM02121.IR2	79	56	70.9
DMM02122.IR1	225	157	69.8
DMM02122.IR2	115	86	74.8
DMM02123.IR1	135	100	74.1
DMM02123.IR2	77	58	75.3
DMM02126.IR1	104	70	67.3
DMM02126.IR2	30	25	83.3
DMM02127.IR1	161	114	70.8
DMM02128.IR1	392	272	69.4
DMM02129.IR1	208	139	66.8
DMM02129.IR2	133	98	73.7
DMM02130.IR1	270	202	74.8
DMM02133.IR1	133	93	69.9
DMM02133.IR2	159	109	68.6
DMM02134.IR1	180	132	73.3
DMM02134.IR2	94	69	73.4
DMM02135.IR1	190	147	77.4
DMM02135.IR2	145	110	75.9
DMM02136.IR1	128	99	77.3
DMM02136.IR2	218	155	71.1
DMM02137.IR1	275	203	73.8
DMM02137.IR2	346	265	76.6
DMM02138.IR1	865	640	74.0
DMM02139.IR1	1,290	960	74.4
DMM02139.IR2	78	61	78.2
DMM02140.IR1	515	386	75.0
DMM02140.IR2	710	562	79.2
DMM02141.IR1	466	353	75.8
DMM02141.IR2	209	163	78.0
DMM02142.IR1	1,220	974	79.8

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM02142.IR2	35	28	80.0
DMM02143.IR1	931	735	78.9
DMM02143.IR2	55	45	81.8
DMM02144.IR1	1,232	962	78.1
DMM02144.IR2	446	349	78.3
DMM02145.IR1	1,026	795	77.5
DMM02145.IR2	495	394	79.6
DMM02146.IR1	664	526	79.2
DMM02146.IR2	883	655	74.2
DMM02148.IR1	927	731	78.9
DMM02148.IR2	11	10	90.9
DMM02149.IR1	1,010	777	76.9
DMM02149.IR2	10	6	60.0
DMM02150.IR1	971	764	78.7
DMM02150.IR2	55	39	70.9
DMM02151.IR1	867	664	76.6
DMM02151.IR2	32	24	75.0
DMM02152.IR1	851	664	78.0
DMM02152.IR2	132	99	75.0
DMM02153.IR1	586	470	80.2
DMM02154.IR1	252	208	82.5
DMM02154.IR2	6	6	100.0
DMM02155.IR1	215	173	80.5
DMM02156.IR1	410	317	77.3
DMM02157.IR1	251	204	81.3
DMM02158.IR1	156	128	82.1
DMM02161.IR1	89	78	87.6
DMM02162.IR1	48	35	72.9
DMM02163.IR1	78	63	80.8

Appendix Table A3. Locations of observations (detections) of PIT-tagged wild steelhead within the Little Goose Dam juvenile fish facility (GOJ), 2002.

					Detected on separator and one additional coil (coil location)		
GOJ date	Separator	Diversion	Raceway	Sample	Diversion	Raceway	Sample
4/12/2002	-	-	-	-	2	4	1
4/13/2002	-	-	-	-	9	27	2
4/14/2002	2	-	-	-	31	123	7
4/15/2002	-	-	1	-	49	189	10
4/16/2002	-	-	-	-	27	96	-
4/17/2002	-	-	-	-	15	48	4
4/18/2002	-	-	-	-	41	144	3
4/19/2002	1	-	-	-	55	151	4
4/20/2002	1	-	-	-	35	103	5
4/21/2002	-	-	-	-	74	185	7
4/22/2002	2	-	-	-	57	205	2
4/23/2002	3	1	2	-	115	261	9
4/24/2002	2	-	-	-	38	121	2
4/25/2002	-	-	-	-	17	89	2
4/26/2002	-	-	-	-	20	77	3
4/27/2002	-	-	-	-	32	106	1
4/28/2002	-	-	-	-	21	85	1
4/29/2002	-	-	-	-	34	109	3
4/30/2002	-	-	-	-	20	83	2
5/1/2002	-	-	-	-	16	91	1
5/2/2002	-	-	-	-	17	48	1
5/3/2002	1	-	-	-	38	102	1
5/4/2002	-	-	-	-	56	150	1
5/5/2002	-	-	-	-	32	68	-
5/6/2002	2	-	-	-	24	75	-
5/7/2002	1	-	-	-	9	49	-
5/8/2002	-	-	-	-	6	25	-
5/9/2002	-	-	-	-	3	5	-
5/10/2002	-	-	1	-	4	11	-
5/11/2002	1	-	-	-	8	25	1

Appendix Table A3. Continued.

GOJ date	Separator	Diversion	Raceway	Sample	Detected on separator and one additional coil (coil location)		
					Diversion	Raceway	Sample
5/12/2002	-	-	-	-	16	54	2
5/13/2002	-	1	-	-	27	74	1
5/14/2002	-	-	-	-	27	74	-
5/15/2002	-	-	1	-	28	88	-
5/16/2002	-	-	-	-	10	45	1
5/17/2002	-	-	-	-	41	81	1
5/18/2002	-	-	1	-	30	77	-
5/19/2002	1	-	1	-	42	121	1
5/20/2002	2	-	-	-	108	302	1
5/21/2002	3	-	-	-	107	331	2
5/22/2002	2	-	2	-	198	627	3
5/23/2002	-	-	2	-	193	691	3
5/24/2002	3	-	-	-	57	202	1
5/25/2002	3	-	1	-	69	278	2
5/26/2002	1	-	-	-	90	351	6
5/27/2002	4	-	-	-	132	493	5
5/28/2002	1	1	1	-	124	499	11
5/29/2002	6	-	2	-	241	794	11
5/30/2002	5	-	2	-	187	620	12
5/31/2002	4	-	-	1	159	646	7
6/1/2002	4	-	2	-	227	716	4
6/2/2002	4	-	1	-	129	487	6
6/3/2002	3	-	1	1	145	585	10
6/4/2002	-	-	1	-	122	411	4
6/5/2002	4	-	-	-	76	314	4
6/6/2002	1	-	-	-	28	105	3
6/7/2002	2	-	-	-	24	99	5
6/8/2002	-	-	-	-	49	135	12
6/9/2002	-	-	-	-	29	109	7
6/10/2002	-	-	-	-	19	67	5
6/11/2002	-	-	-	-	3	12	-

Appendix Table A3. Continued.

GOJ date	Separator	Diversion	Raceway	Sample	Detected on separator and one additional coil (coil location)		
					Diversion	Raceway	Sample
6/12/2002	-	-	-	-	1	4	-
6/13/2002	-	-	-	-	2	8	2
6/14/2002	-	-	-	-	8	23	8
6/15/2002	1	-	-	-	9	32	6
6/16/2002	-	-	-	-	4	22	4
6/17/2002	-	-	-	-	3	7	3
6/18/2002	-	-	-	-	3	8	1
6/19/2002	-	-	-	-	2	9	-
6/20/2002	-	-	-	-	1	8	1
6/21/2002	-	-	-	-	2	2	-
6/22/2002	-	-	-	-	1	6	-
6/23/2002	-	-	-	-	1	2	-
6/24/2002	-	-	-	-	-	1	1
6/25/2002	-	-	-	-	1	2	-
6/26/2002	-	-	-	-	-	1	-
6/29/2002	-	-	-	-	1	-	-
6/30/2002	-	-	-	-	-	1	-
7/3/2002	-	-	-	-	-	1	-
7/15/2002	-	-	-	-	1	-	-

Appendix Table A4. Locations of observations (detections) of PIT-tagged wild steelhead within the Lower Monumental Dam juvenile fish facility (LMJ), 2002.

					Detected on separator and one additional coil (coil location)			
LMJ date	Separator	Diversion	Raceway	Sample	Diversion	Raceway	Sample	River
4/15/2002	-	-	-	-	-	-	1	-
4/18/2002	-	-	-	-	-	-	2	-
4/22/2002	-	-	-	-	-	-	8	-
4/25/2002	-	-	-	-	-	-	3	-
4/29/2002	-	-	-	-	-	-	1	-
4/30/2002	-	-	-	-	34	109	11	-
5/1/2002	4	-	-	-	62	256	30	-
5/2/2002	-	-	-	-	40	108	1	-
5/3/2002	-	-	-	-	12	41	10	-
5/4/2002	-	-	-	-	67	99	10	-
5/5/2002	-	-	-	-	24	68	1	-
5/6/2002	-	-	-	-	13	34	-	-
5/7/2002	-	-	-	-	61	132	2	-
5/8/2002	-	-	-	-	30	77	-	-
5/9/2002	-	-	-	-	19	52	5	-
5/10/2002	-	-	-	-	49	67	-	-
5/11/2002	-	-	-	-	32	16	-	-
5/12/2002	-	-	-	-	10	15	-	-
5/13/2002	-	-	-	-	20	51	2	-
5/14/2002	-	-	-	-	6	22	-	-
5/15/2002	-	-	-	-	17	61	3	-
5/16/2002	-	-	-	-	34	104	3	-
5/17/2002	-	-	-	-	37	78	1	-
5/18/2002	-	-	-	-	27	67	3	-
5/19/2002	-	-	-	-	100	241	3	-
5/20/2002	-	-	-	1	52	123	2	-
5/21/2002	-	1	-	-	73	172	4	-
5/22/2002	-	-	-	-	149	381	4	-
5/23/2002	-	-	-	-	56	204	-	-
5/24/2002	-	-	-	-	106	303	2	-
5/25/2002	-	-	-	-	69	258	2	-

Appendix Table A4. Continued.

LMJ date	Separator	Diversion	Raceway	Sample	Detected on separator and one additional coil (coil location)			
					Diversion	Raceway	Sample	River
5/26/2002	-	-	-	-	30	136	1	-
5/27/2002	-	-	-	-	15	49	10	-
5/28/2002	-	-	1	-	108	387	33	-
5/29/2002	-	-	-	-	98	330	2	-
5/30/2002	-	-	-	-	215	558	42	-
5/31/2002	1	-	1	1	223	536	47	19
6/1/2002	1	-	-	-	72	223	32	-
6/2/2002	1	-	1	-	36	119	22	-
6/3/2002	3	-	-	1	199	586	103	-
6/4/2002	1	-	-	-	132	428	6	-
6/6/2002	-	-	-	-	58	188	-	-
6/7/2002	-	-	-	-	72	269	13	-
6/8/2002	-	-	-	-	44	142	1	-
6/9/2002	-	1	-	-	48	176	8	-
6/10/2002	-	-	-	-	18	59	3	-
6/11/2002	-	-	-	-	16	88	-	-
6/12/2002	-	-	-	-	12	49	3	-
6/13/2002	-	-	-	-	13	57	-	-
6/14/2002	-	-	-	-	10	30	-	-
6/15/2002	-	-	-	-	8	19	1	-
6/16/2002	-	-	-	-	2	10	-	-
6/17/2002	-	-	-	-	3	15	-	-
6/18/2002	-	-	-	-	10	28	-	-
6/19/2002	-	-	-	-	7	26	-	-
6/20/2002	-	-	-	-	5	23	-	-
6/21/2002	-	-	-	-	4	12	-	-
6/22/2002	-	-	-	-	-	8	-	-
6/23/2002	-	-	-	-	2	4	-	-
6/24/2002	-	-	-	-	-	4	-	-
6/25/2002	-	-	-	-	1	2	-	-
6/26/2002	-	-	-	-	-	2	1	-
6/28/2002	-	-	-	-	-	-	1	-
6/29/2002	-	-	-	-	3	1	6	-

Appendix Table A4. Continued.

LMJ date	Separator	Diversion	Raceway	Sample	Detected on separator and one additional coil (coil location)			
					Diversion	Raceway	Sample	River
6/30/2002	-	-	-	-	-	1	2	-
7/1/2002	-	-	-	-	-	1	1	-
7/2/2002	-	-	-	-	1	-	1	-
7/3/2002	-	-	-	-	-	-	2	-
7/4/2002	-	-	-	-	1	-	-	-
7/5/2002	-	-	-	-	-	-	1	-
7/7/2002	1	-	-	-	-	-	-	-
7/8/2002	-	-	-	-	-	-	1	-
7/10/2002	-	-	-	-	-	2	-	-
7/11/2002	-	-	-	-	1	-	-	-
7/14/2002	-	-	-	-	-	1	-	-
7/23/2002	-	-	-	-	-	2	-	-
7/24/2002	-	-	-	-	-	1	-	-
7/25/2002	-	-	-	-	-	-	-	-
7/26/2002	-	-	-	-	-	1	-	-
7/28/2002	-	-	-	-	-	1	-	-
7/30/2002	-	-	-	-	-	1	-	-
7/31/2002	-	-	-	-	1	-	-	-
8/2/2002	-	-	-	-	-	1	-	-
8/4/2002	-	-	-	-	-	1	-	-
8/11/2002	-	-	-	-	-	2	-	-
8/12/2002	-	-	-	-	1	-	-	-
8/14/2002	-	-	-	-	-	2	-	-
8/17/2002	-	-	-	-	-	-	2	-
8/20/2002	-	-	-	-	1	-	-	-
8/21/2002	-	-	-	-	-	-	1	-
8/22/2002	-	-	-	-	-	-	2	-
8/25/2002	-	-	-	-	1	-	-	-
8/28/2002	-	-	-	-	1	-	1	-
8/29/2002	-	-	-	-	-	-	1	-
8/31/2002	-	-	-	-	-	-	3	-
9/5/2002	-	-	-	-	2	-	-	-
9/25/2002	-	-	-	-	-	-	1	-
10/12/2002	-	-	-	-	1	-	-	-

Appendix Table A5. Locations of observations (detections) of PIT-tagged wild steelhead within the McNary Dam juvenile fish facility, 2002.

MCJ date	Separator	Diversion	Raceway	Sample	Detected on separator and one additional coil (coil location)		
					Diversion	Raceway	Sample
4/17/2002	-	-	9	-	-	-	1
4/18/2002	-	-	12	-	-	-	1
4/19/2002	-	-	24	-	-	-	-
4/20/2002	-	-	24	-	-	-	-
4/21/2002	-	-	10	-	-	-	1
4/22/2002	-	-	15	1	-	-	-
4/23/2002	-	-	57	1	-	-	1
4/24/2002	-	-	45	2	-	-	1
4/25/2002	1	-	49	1	-	-	-
4/26/2002	-	-	60	1	-	-	-
4/27/2002	-	-	58	-	-	-	2
4/28/2002	-	-	81	1	-	-	4
4/29/2002	-	-	122	1	-	-	2
4/30/2002	1	1	79	-	-	-	2
5/1/2002	-	-	57	-	-	-	2
5/2/2002	-	-	70	-	-	-	2
5/3/2002	1	-	126	1	-	-	1
5/4/2002	-	-	100	2	-	-	1
5/5/2002	1	-	82	-	-	-	2
5/6/2002	-	-	67	1	-	-	-
5/7/2002	1	-	39	-	-	-	-
5/8/2002	-	-	46	1	-	-	1
5/9/2002	-	-	21	1	-	-	-
5/10/2002	-	-	20	-	-	-	1
5/11/2002	-	-	25	2	-	-	1
5/12/2002	-	-	15	1	-	-	-
5/13/2002	-	-	24	1	-	-	-
5/14/2002	-	-	13	-	-	-	1
5/15/2002	-	-	5	1	-	-	-
5/16/2002	-	-	11	-	-	-	-
5/17/2002	1	-	26	-	-	-	1
5/18/2002	-	-	25	-	-	-	1

Appendix Table A5. Continued.

MCJ date	Separator	Diversion	Raceway	Sample	Detected on separator and one additional coil (coil location)		
					Diversion	Raceway	Sample
5/19/2002	-	-	20	-	-	-	1
5/20/2002	-	-	40	1	-	-	1
5/21/2002	-	-	72	3	-	-	-
5/22/2002	-	-	68	1	-	-	-
5/23/2002	-	1	65	2	-	1	2
5/24/2002	-	-	23	1	-	-	-
5/25/2002	-	-	53	1	1	-	-
5/26/2002	-	-	41	1	-	-	1
5/27/2002	-	-	41	-	-	-	-
5/28/2002	-	-	27	1	-	-	-
5/29/2002	-	-	41	1	-	-	-
5/30/2002	-	-	39	-	-	-	-
5/31/2002	1	-	36	-	-	-	-
6/1/2002	-	-	38	-	-	-	-
6/2/2002	-	-	51	1	-	-	1
6/3/2002	-	-	78	-	1	-	4
6/4/2002	2	-	36	-	-	-	-
6/5/2002	-	-	10	-	-	-	-
6/6/2002	-	-	57	-	-	-	2
6/7/2002	-	-	75	-	-	-	4
6/8/2002	-	-	40	-	-	-	-
6/9/2002	-	1	13	-	-	-	-
6/13/2002	-	-	2	-	-	-	-
6/14/2002	-	-	4	-	-	-	-
6/15/2002	-	-	4	-	-	-	-
6/16/2002	-	-	5	-	-	-	-
6/18/2002	-	-	1	-	-	-	-
6/20/2002	1	-	1	-	-	-	-
6/23/2002	-	-	2	-	-	-	-
6/25/2002	-	-	1	-	-	-	-
6/26/2002	-	-	2	-	-	-	-
6/28/2002	-	-	2	-	-	-	-
10/5/2002	-	-	1	-	-	-	-

APPENDIX B

Tagging Results for 2004 Juvenile Transportation Studies

Snake River Spring/Summer Chinook Salmon and Steelhead

From 9 April through 10 June 2004, we PIT tagged a total of 11,208 wild yearling Chinook and 8,103 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 make post-marking delayed mortality (24-hour) estimates.

Snake River Fall Chinook Salmon

From 2 June through 30 July 2004, we PIT tagged a total of 49,287 subyearling Chinook salmon at Lower Granite Dam, releasing 3,617 of these fish into barges and 45,296 into the Lower Granite Dam tailrace. We also marked subyearling Chinook salmon at Lower Granite Dam in September and October for a transport index group.

Based on mortality counts, post-marking delayed mortality (24-hour) averaged 0.6% over the entire tagging season.

Other transport groups were created at downstream dams 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 2004, we continued transportation studies from McNary Dam using upper Columbia River hatchery yearling spring Chinook salmon and upper Columbia River hatchery steelhead. As in 2003, three study groups were formed at McNary Dam; fish that were either transported, not collected, or bypassed through the primary bypass directly to the McNary Dam tailrace.

Beginning in late August 2003, the U.S. Fish and Wildlife Service and Biomark, Inc. began PIT-tagging hatchery yearling spring Chinook salmon and steelhead. A total of 347,309 yearling spring Chinook salmon were tagged at Winthrop (19,900 fish), Methow (34,945), Entiat (59,707 fish), and Leavenworth Fish Hatcheries (232,757 fish).

A total of 478,854 steelhead were tagged at Winthrop (50,350), Wells (238,697), Eastbank (83,729), Chelan (9,584), and Ringold Fish Hatcheries (96,494).

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 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					95% CI		Annual
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	(LGR T/I) (LGS T/I)	Status	report containing final results
2004	8,103	--	--	–	–	–	–	–	–	–	–	–	In-progress	--
2003 a	3,381	12,843	9,579	100	–	–	–	–	–	–	–	–	In-progress	--
2002 a	4,879	14,036	15,037	292	211	–	2.60	1.84	0.78	3.32	2.34	(2.76, 4.34) (1.91, 2.86)	Completed	Current
2001	15,273	--	--	200	156	1	2.33	–	–	–	–	(2.11, 2.55)	Completed	2003
2000 a	24,744	--	23,506	839	581	0	3.98	–	1.85	2.15	–	(1.99, 2.40)	Completed	2003
1999 a	6,062	--	1,471	41	53	0	1.42	–	0.54	2.6	–	(1.6, 5.6)	Completed	2002

a - 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	Returns by Age-class: 1-ocean	Returns by Age-class: 2-ocean	Returns by Age-class: 3-ocean	SAR: Transport	SAR: Inriver	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	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
2004*	3,617	45,296	--	--	--	--	--	--	--	--	--	In-progress	--
2003	16,109	19,161	56	--	--	--	--	--	--	--	--	In-progress	--
2002	12,344	76,334	128	215	--	--	--	--	--	--	--	In-progress	--
2001	18,907	26,340	71	75	39	--	--	--	--	--	--	In-progress	--

* These 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					Annual report containing final results
Tagging year	Transport	Inriver migrant	Jack	2-ocean	3-ocean	4-ocean	5-ocean	Transport	Inriver migrant	T/I	95% C.I.	Status	
2002	38,322	56,648	143	212	--	--	--	--	--	--	--	In-progress	--
2001	23,250	38,546	33	29	63	--	--	--	--	--	--	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.