Transportation of Juvenile Salmonids on the Columbia River, 2006: Final report for the 2003 Juvenile Migration of Hatchery Yearling Spring Chinook Salmon

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EXECUTIVE SUMMARY

Since 1995, the National Marine Fisheries Service has evaluated transportation of spring/summer Chinook salmon smolts from Lower Granite Dam on the Snake River. In 2002, we began evaluations of transporting spring Chinook salmon from McNary Dam on the Columbia River. Fish were PIT-tagged at upper Columbia River hatcheries for these evaluations, and in 2006, we continued with the fifth year of this work.

From March through August 2006, we recovered age-3-ocean spring/summer Chinook salmon adults from smolts tagged in 2003, completing adult returns from that study year. In 2003, we tagged and released fish from Leavenworth (237,491), Entiat (59,251), Methow (34,923), and Winthrop (19,962) hatcheries. On alternate days in 2003, all juvenile fish collected at McNary Dam were diverted either back to the river through the full-flow bypass pipe (with study fish forming our bypass group) or across the separator. Study fish that crossed the separator were diverted to raceways for transport, while the general population of fish was returned to the river through the juvenile bypass system. Thus, we had three groups of study fish: transported, full-flow bypassed, and inriver migrant (fish that were never collected or detected at McNary Dam).

Numbers of juveniles in the transported and bypassed groups were known from detection data, while the number of juveniles in the inriver migrant group was estimated (since there were no detections of these fish). In 2006 we detected 15 transported, 10 bypassed, and 78 inriver migrant age-3-ocean adults from the 2003 tagging. Based on all 2003 returns combined (jacks through age-3-ocean adults), the smolt-to-adult return rates (SARs) were 0.32 for transported, 0.27 for bypassed, and 0.43 for inriver migrant fish. These SARs translated to a transport-to-inriver migrant ratio (T/I) of 0.74 (95% CI, 0.60-0.92), a bypass-to-inriver migrant ratio (B/I) of 0.62 (95% CI, 0.50-0.76), and a transport-to-bypass ratio (T/B) of 1.20 (95% CI, 0.91-1.60).

Of adults detected at Bonneville Dam, 79% of transported fish, 80% of bypassed fish, and 82% of inriver migrant fish successfully migrated to McNary Dam (not adjusted for any take in the Zone 6 fishery). Median travel time from Bonneville to McNary Dam was 6 d for age-2-ocean adults from all three groups, while age-3-ocean adults were a little slower, averaging 7.0, 9.0, and 7.0 d for transported, bypassed, and inriver migrant fish, respectively.

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INTRODUCTION

In 2006, we continued a study to evaluate transportation of juvenile fish as a means to mitigate for losses that result from downstream passage through the Columbia River federal hydropower system. The primary objective of our study was to compare adult returns of yearling spring Chinook salmon *Oncorhynchus tshawytscha* PIT-tagged as smolts and transported to a release site below Bonneville Dam to their cohorts allowed to migrate through the river under optimal conditions for in-river survival. Detections from PIT-tagged migrating smolts also provide data for short-term juvenile survival estimates between the point of release and Bonneville Dam tailrace (Muir et al. 2001).

Here we report 2006 adult returns, which complete returns from the hatchery spring Chinook salmon study conducted at McNary Dam in 2003. Information is also provided on complete and incomplete adult returns for 2002 and 2004 McNary Dam transport releases (Appendix B).

In 1995-1996 and 1998-1999, we PIT tagged spring/summer Chinook salmon smolts at Lower Granite Dam to compare adult returns of marked smolts transported to below Bonneville Dam vs. those of smolts released to the tailrace of Lower Granite Dam to migrate in-river. Migrating smolts collected at downstream dams were returned to the river to continue their migration.

Based on adult returns from those years (and from fish PIT tagged upstream from Lower Granite Dam in the same years), we found that smolts bypassed and returned to the river at downstream dams survived to adulthood at lower, rather than higher, rates than those bypassed only at Lower Granite Dam. Further, fish that were never detected at dams (because they passed via spillways, turbines, or were missed by PIT-tag monitors in juvenile fish facilities) usually returned at higher rates than fish bypassed at downstream collector dams (Williams et al. 2005).

Thus, in hindsight, the study designs from 1995 through 1999 did not provide sufficient information to compare the returns of non-detected and non-transported fish to returns of transported fish. Beginning in 2000, we altered our study design at Lower Granite Dam to provide better comparison between these groups, and it was this study design we used for the McNary Dam evaluation.

Prior to this study, the last transportation evaluations of spring Chinook salmon at McNary Dam were conducted in the 1980s. In 1994, a new smolt collection and transportation facility became operational at McNary Dam. Transportation research has not been conducted from this new facility because the capability to detect returning PIT-tagged adults was lacking in the lower river. We began the present transportation evaluations of anadromous salmonids at McNary Dam with juveniles migrating in spring 2002. These fish would begin returning as adults in 2003, the year when adult PIT tag interrogation systems were to be installed in the fish ladders at Bonneville and McNary Dam.

METHODS

Juvenile Collection and Tagging

To provide a holistic approach to evaluations of smolt-to-adult return rates (SARs) and transport-to-inriver migrant ratios (T/I) for fish originating only in the Columbia River upstream of McNary Dam, we PIT-tagged and released yearling spring Chinook salmon that originated in upper Columbia River hatcheries. We set numbers of fish to tag at each hatchery to approximate the proportions of fish that each hatchery represented in the general population.

Transport, bypass, and inriver migrant groups were established when the fish passed McNary Dam. To create the transport study group, we set the separation-by-code PIT-tag diversion system at McNary Dam to divert 100% of the study fish that passed over the separator to transportation. Full-flow bypassed fish were used to help develop the survival estimates necessary to estimate differential delayed mortality (*D*) of the transported fish. The number of fish in the inriver migrant group was estimated using the procedures discussed in Appendix C.

We calculated the number of fish needed for marking to test the null hypothesis that there is no difference between the SARs of transported and inriver migrant fish (i.e., the true T/I = 1) vs. the alternative hypothesis that the difference was at least 20% (the true T/I $\geq$ 1.2). 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

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

and

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

where n is the number of adult returns per treatment (for either n_T transport or n_I in-river 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, if $\alpha = 0.05$ and $\beta = 0.20$, and we wish to discern a difference of 20% or more ($T/I \geq 1.2$), and we expect a transport SAR of at least 1.0%, the sample sizes needed at McNary Dam were:

$$n = 473$$
$$N_T = 47{,}300$$
$$N_I = 56{,}760$$
$$\text{Total juveniles} = 104{,}060$$

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 (47,300 × 1.2).

These calculations determined the numbers of fish needed for release above McNary Dam. However, the release of fish from hatcheries upstream from the dam required greater numbers of tagged fish than needed to evaluate SARs because of the small proportions of these fish that would be subsequently collected at the dam.

To determine the number of fish we needed to tag at the hatcheries, we calculated the probability of survival from release to McNary Dam and the probability of detection in the collection system at McNary Dam. For these calculations, we used survival estimates from PIT-tagged fish released from Leavenworth Hatchery in spring 2000. Most of these fish had arrived at McNary Dam in May, and nearly all had passed the dam by early June 2000. During this passage period, spill at the dam averaged a relatively constant 40% of total river flow. Estimated survival was 0.586 (SE = 0.015), and the probability of detection was 0.229 (SE = 0.015). Therefore, we needed to release roughly 355,000 (47,300/0.586/0.229) PIT-tagged spring Chinook salmon from hatcheries to obtain the number of study fish required for the transport group at McNary Dam.

Juvenile Inriver Migrant Groups

Prior to 27 June 2003, the full flow bypass system at McNary Dam was operated every other day (Figure 1). On alternate days, PIT-tagged study fish were routed through the separator and collected in raceways for transportation, while the general population was returned to the river. The full-flow bypass system monitors PIT-tagged fish and returns them to the river (along with the general population) without the dewatering process required by the separator. Bypass groups were created by grouping detections of fish in the full-flow system by day of detection. After 27 June, all non-tagged fish collected at the dam were transported. Study fish detected on coils leading to raceways were assumed to have been transported, while fish detected on return-to-river or diversion system coils were assumed to have been returned to the river. The latter were excluded from analysis, since the inriver migrant cohort included only non-detected fish.

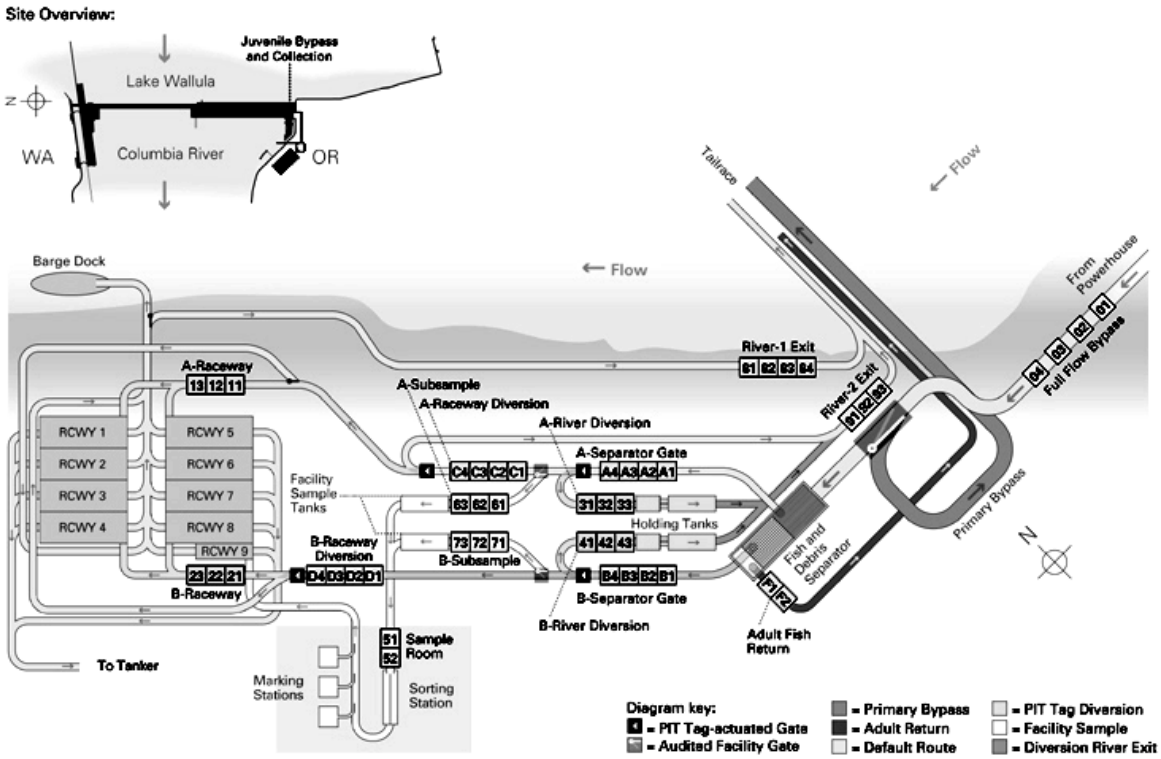

Figure 1. McNary Dam site configuration showing fish collection routes to full-flow bypass system and separator. Diagram courtesy of Pacific States Marine Fisheries Commission, PTAGIS.

Adult Recoveries and Data Analysis

In 2006, we completed the recovery of adult Chinook salmon tagged as juveniles in 2003. The procedures for data analysis described by Marsh et al. (1996) were modified as described in Appendix C to determine the number of juvenile fish in the inriver migrant group.

Smolt-to-adult return rates were calculated for transported, bypassed, and non-detected (inriver migrant) cohorts. These SARs were calculated by dividing the number of fish that passed the dam as adults in 2004-2006 by the number fish that passed as juveniles in 2003. Calculation of SARs for the transport and bypass groups was straightforward, since it was based on actual detections of juveniles and adults at McNary Dam. However, because fish in the inriver migrant group were never detected as juveniles after tagging, the number of juveniles in the inriver migrant group had to be estimated in order to calculate SARs for the cohort. This estimate was derived as follows:

$$\hat{N}_{nd} = N \cdot \hat{S} \cdot \left(1 - \hat{p}\right)$$

where N was the release number at Mid-Columbia hatcheries; S was survival from release to McNary Dam; and p was the probability of detection at McNary Dam. (The "hats" indicate the pertinent quantity was estimated).

Ratios of SARs were then calculated for transported and bypassed groups relative to the inriver migrant (non-detected) group. To test the null hypotheses, that there was no difference between the SARs of transported and inriver-migrant fish (T/I) or between the SARs of bypassed and inriver-migrant fish (B/I), we calculated 95% confidence intervals for each of these ratios. If the value 1.0 was outside the confidence interval, then SARs for the two passage routes were considered to have been significantly different.

Confidence intervals around the T/I and B/I ratios were constructed by natural-log transforming the estimates, calculating the interval on the transformed scale as ±1.96 standard errors (1.96 = the z-value for $\alpha = 0.05$), and back-transforming the endpoints. This was done because the ratios were assumed to be log-normally distributed. The derivation of the standard errors is shown in Appendix C.

RESULTS

Tagging of Juveniles

Study fish were PIT tagged and released at Winthrop, Methow, Entiat, and Leavenworth Hatcheries (Table 1).

Table 1. Tag dates, releases dates, release numbers, and average fish lengths at tagging for spring Chinook salmon released from Columbia River hatcheries to evaluate transportation from McNary Dam in 2003.

Hatchery	Tag date	Release date	Release number	Average length at release (mm)
Winthrop	7-8 Jan 2003	14 Apr 2003	19,962	116.8
Methow	4-7 Sep 2002	14 Apr 2003	34,923	96.1
Entiat	16-24 Oct 2002	10 Apr 2003	59,251	87.6
Leavenworth	17 Oct-5 Nov 2002	21 Apr 2003	237,491	117.4
Total released			351,627	

Inriver Migration

Of 351,627 spring Chinook salmon smolts released, 71,782 (20.2%) were detected at McNary Dam. Final dispositions for the 351,627 fish released are shown in Table 2.

Table 2. Final dispositions at McNary Dam for fish released from Columbia River hatcheries to evaluate transportation from McNary Dam in 2003.

Hatchery	Transported	Bypassed	Unknown	Not detected
Winthrop	1,879	2,216	0	15,867
Methow	1,953	2,748	0	30,222
Entiat	6,181	7,094	7	45,969
Leavenworth	21,316	28,395	3	187,777
Totals	31,329	40,453	10	279,835

Migration history data was analyzed using the methods of Sandford and Smith (2002). These analyses resulted in estimates of 149,775 juvenile spring Chinook salmon in the 2003 inriver migrant group (Table 3). The SAR calculation for inriver migrants was based on this number.

Table 3. The estimated number of migrating hatchery spring Chinook salmon arriving at the McNary Dam tailrace in 2003 for the McNary Dam transport evaluation.

Hatchery	Number released	Estimated rate of survival to McNary Dam	Estimated arriving at McNary (n)	Transported (n)	Full-flow bypassed (n)	Estimated inriver migrant (n)
Winthrop	19,962	0.551	11,005	1,879	2,216	6,910
Methow	34,923	0.516	18,020	1,953	2,748	13,319
Entiat	59,251	0.662	29,241	6,181	7,094	25,959
Leavenworth	237,491	0.646	153,425	21,316	28,395	103,711
Totals	351,627	0.630	221,567	31,329	40,453	149,775

Our initial goal was to transport 100% of the study fish collected at McNary Dam on alternate days. However, because of limitations to the separation-by-code system, only 91.3% of the study fish were actually transported.

Survival estimates from release to McNary Dam tailrace and release to Bonneville Dam tailrace were based on PIT-tag detections at John Day and Bonneville Dams and on detections in the pair-trawl system in the upper estuary. Respective estimates of survival from release to McNary and Bonneville tailraces were 0.551 and 0.440 for Winthrop, 0.516 and 0.518 for Methow, 0.662 and 0.464 for Entiat, and 0.646 and 0.474 for Leavenworth Hatchery.

Adult Recoveries and Data Analysis

At McNary Dam, we began adult recoveries from the 2003 releases with jacks returning in 2004 and finished with age-3-ocean adults returning through August 2006. Returns by study group and age-class are shown Table 4, with juvenile numbers adjusted as described in Appendix C.

Table 4. Returns by study group and age-class of hatchery spring Chinook salmon released in 2003 for McNary Dam transportation studies.

	Juvenile numbers	Returns by age-class			SAR	T/I	95% C.I.
		Jack	2-ocean	3-ocean			
Transport	31,329	11	74	15	0.32	0.74	(0.60-0.92)
Bypassed	37,331	13	76	10	0.27	0.61	(0.50-0.76)
Inriver migrant	149,775	82	486	78	0.43		

By definition, inriver-migrant fish for this study were those fish tagged and released above McNary Dam but never detected during their downstream migration. Therefore, we were unable to examine variations in SARs based on juvenile migration timing, since no data on timing was available (i.e., if fish were not detected as juveniles, we do not know whether they passed McNary Dam earlier or later in the season). However, we were able to correlate SARs with juvenile migration timing for transported and bypassed fish (Figure 2).

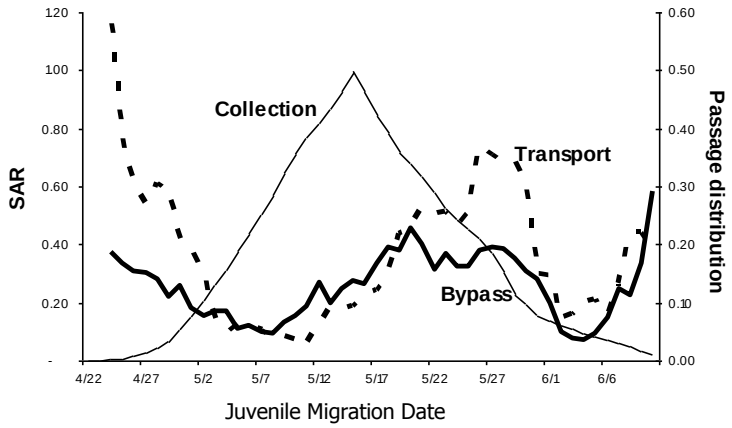

Figure 2. Smolt-to-adult return rates by detection date at McNary Dam for transported and bypassed spring Chinook salmon smolts tagged at Winthrop, Methow, Entiat, and Levanworth Hatcheries in 2003. Data presented are 5-day running averages of daily detection numbers. Overall transport/bypass ratio was 1.20.

Trends between SARs and juvenile migration timing for fish released in 2003 were different from those observed for fish released in 2002. The temporal variation in SARs from the 2002 study year showed multiple rises and falls over the course of the juvenile migration season.

In contrast, the temporal variation in SARs observed from the 2003 releases was similar to that observed from Snake River spring/summer Chinook salmon: SARs for transported fish that migrated as juveniles early in the season were similar to those of fish that migrated inriver to the ocean (in this case the bypassed fish). This was followed by a dramatic increase in transport SARs in late April to mid-May where they remained for some time. The one difference here compared to the Snake River temporal SAR pattern is the increase in bypass SARs at roughly the same time as the transport SARs, although they did not rise as high.

Because we could not calculate temporal SARs for inriver migrant fish, we were unable to determine a temporal differential delayed mortality (*D*) between transported and inriver migrant fish. We were, however, able to calculate *D* between the transport and bypass fish. As with SARs, there was some variation in *D* corresponding with juvenile migration timing (Figure 3.

The overall *D* value for 2003 was 0.87, but varied from 0.69 to 1.54, generally decreasing (dropping further from 1.0) as the juvenile migration progressed.

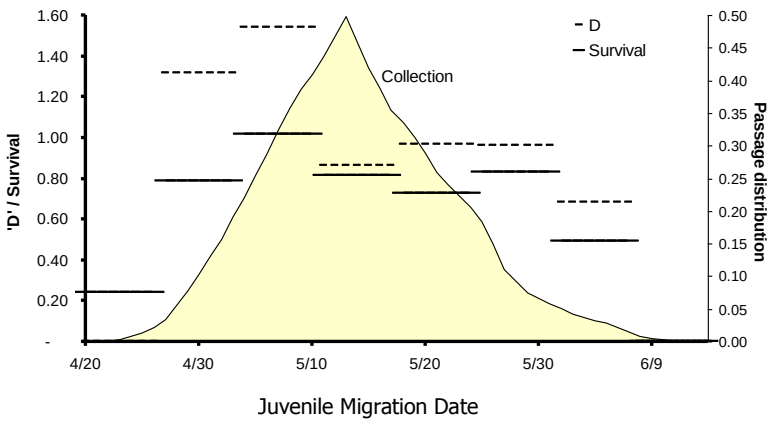

Figure 3. Estimates of survival and differential delayed mortality (*D*) over time for spring Chinook salmon smolts tagged at Winthrop, Methow, Entiat, and Leavenworth Hatcheries in 2003. Survival rates are from McNary Dam tailrace to Bonneville Dam tailrace. Groupings are based on having adequate numbers of smolts to estimate in-river survival between McNary and Bonneville Dams. Overall *D* for the year was 0.87.

Overall, the percentage of returning adults observed at Bonneville Dam and subsequently observed at McNary Dam (the conversion rate) was similar for all three groups (Table 5). Although differences by age class were observed, the patterns were inconsistent. For example, transported age-2-ocean adults converted at the lowest rate of the three groups, while age-3-ocean transported adults converted at the highest rate. We do not know if the Zone 6 harvest differentially affected return rates of different study groups or age classes.

Table 5. The numbers and percentages of adult spring Chinook salmon PIT tagged in 2003 that were detected at Bonneville Dam and subsequently detected at McNary Dam (the conversion rate).

Age class	Migration history	Detected at Bonneville Dam (n)	Detected at McNary Dam (n)	Conversion rate (%)
Jacks	Transport	10	10	100.0
	Bypassed	11	11	100.0
	Inriver migrant	74	68	91.9
Age-2-ocean	Transport	94	72	76.6
	Bypassed	91	72	79.1
	Inriver migrant	574	470	81.9
Age-3-ocean	Transport	17	14	82.4
	Bypassed	14	10	71.4
	Inriver migrant	92	72	78.3
Totals	Transport	121	96	79.3
	Bypassed	116	93	80.2
	Inriver migrant	740	610	82.4

Travel times from Bonneville to McNary Dam ranged from 5 to 9 d (Table 6). Travel times increased with each age class, but were similar between treatment groups for jacks and age-2-ocean adults. The difference between travel times of inriver migrant and transported age-3-ocean adults was due to only 2 age-3-ocean transported adults returning. The travel times for the 2 age-3-ocean transported adults was 5 and 13 days, while the range of travel times for the 24 age-3-ocean inriver migrant adults was 5 to 20 days. With adult detection capabilities at dams above McNary Dam on the Columbia and Snake Rivers, we would have observed any straying that might have occurred; however, none was observed.

Table 6. Median travel times from Bonneville Dam to McNary Dam for adult spring Chinook salmon PIT tagged as juveniles in 2003 for McNary Dam transport evaluation.

Age class	Migration history	Number of adults	Median travel time from Bonneville to McNary Dam (d)
Jacks	Transport	10	6.0
	Bypassed	11	6.0
	Inriver migrant	68	5.0
Age-2-ocean	Transport	72	6.0
	Bypassed	72	6.0
	Inriver migrant	470	6.0
Age-3-ocean	Transport	14	7.0
	Bypassed	10	9.0
	Inriver migrant	72	7.0

DISCUSSION

Since 1995, T/Is from most transportation studies of Snake River spring/summer Chinook salmon smolts have indicated a transport benefit. However, this benefit has been lower than expected when compared to later estimates of in-river survival, which excluded fish detected at downstream dams (Marsh et al. 2000, 2001; Muir et al. 2001).

As one moves down-river, any transport benefit should decrease proportional to the remaining number of dams and distance to the ocean. McNary Dam, being the last transport dam and only three dams above the point of release for transported fish should have lower annual T/Is than the Snake River dams. This premise was supported by results from the 2002 and 2003 study years, both of which show no transport benefit from McNary Dam when compared to fish passing the dam through spillways and turbines.

While awaiting the final year of a three-year series of releases, we can only make preliminary observations against which to compare further results. Comparisons with concurrent Snake River transport studies are only marginally informative, since hatchery fish were used here, while wild fish were used in the Snake River. However, we can compare trends between this study and a similar transport study at McNary Dam using hatchery steelhead (Marsh et al., in prep.).

Similar to the results from this study of steelhead (Marsh et al. in prep), SARs from spring Chinook salmon migrating as juveniles in 2003 indicate that full-flow bypassed fish were the poorest performing group at McNary Dam. This was surprising, as we would have expected performance of full-flow bypassed fish to be similar to that of inriver migrants. Except for the method of passing the dam, the full-flow and inriver migrant groups experienced the same migration conditions.

Another surprising result observed was in contrast to the results for steelhead from Marsh et al. (in prep.). Steelhead that were returned to the river in 2003 after crossing the separator (facility bypassed fish) had a lower SAR than those returned via the full-flow bypass facility. Yet the 2003 spring Chinook salmon that returned to the river via the juvenile fish facility (2,982 juveniles) had a higher SAR (0.40) than their cohorts that returned through the full-flow bypass (SAR = 0.27).

During the 2003 steelhead study, only one adult returned from 766 juveniles that returned to the river after reaching the separator through the adult return pipe. This result indicated that using the adult return pipe was a poor way to return juvenile fish to the river. For spring Chinook salmon, only 155 juveniles used this return route, and none of

these fish returned as adults. Thus there is little data with which to draw conclusions regarding the efficacy of this passage route for spring Chinook salmon.

Results from the first two years of this study indicate that at McNary Dam, fish passage through spillways and turbines returns more fish than transportion. However, the question of whether it is better to transport fish once they enter the bypass system or return them to the river is harder to answer. The full-flow bypass route did not have PIT-tag detection capabilities in 2002, so the 2003 study year was the first with a full-flow bypass group. Based on results from the 2003 study year, it may be better to transport fish than to send them back to the river through the full-flow bypass pipe. However, fish that crossed the separator and returned to the river via the facility bypass pipes returned at higher rates than transported fish for both the 2002 and 2003 study years (the results were not significant).

The SARs of fish that passed via the full-flow bypass in 2003 were significantly lower than those of their counterparts that passed via the facility bypass: the ratio of full-flow to facility bypass SARs was 0.66 (95% CI, 0.50-0.88). These results indicate that for yearling Chinook salmon, a problem may exist with the full-flow bypass system at or below the facility gate. This potential problem has not been observed in similar steelhead studies.

We were not able to calculate ratios of SARs for transported and bypassed fish to those of inriver migrants based on juvenile migration timing because we do not know when inriver migrants passed the dam as juveniles. The best we can do is monitor temporal patterns in both the transport and full-flow bypass groups.

Snake River transportation studies have generally shown large shifts in SARs related to the juvenile migration timing of yearling Chinook salmon. In contrast, trends in SARs from the 2002 and 2003 study years at McNary Dam have been mixed for both transport and bypass groups. From the 2002 study at McNary Dam, the pattern between juvenile migration timing and SARs showed multiple rises and falls in SARs of both groups, with a gradual decrease as the juvenile migration progressed. For 2003, the pattern was similar to that observed in Snake River studies of fish released the same year.

This lack of major differences in SARs between transported and bypassed groups with different juvenile migration timing is unlike any of the patterns observed in studies of Snake River spring/summer Chinook salmon (Williams et al. 2005, Muir et al. 2006). This is probably due to the similar arrival timing of the two groups below Bonneville Dam. The distance traveled for both transported and bypassed groups is far less from McNary Dam than from any Snake River location studied. Therefore, the time between

transported and bypassed group arrivals below Bonneville Dam may vary by only a few days. In contrast, the time between arrivals of these same two groups from Snake River dams has differed by 2 to 4 weeks (Williams et al. 2005; Muir et al. 2006).

Overall conversion rates from Bonneville to McNary Dam were similar for transported (79.3%), bypassed (80.2%), and inriver migrant adults (82.4%) from 2003 releases. However, these rates were lower than those of adults from the 2003 releases of spring/summer Chinook salmon for Snake River transportation studies (Marsh et al., in prep.). These rates do not include the Zone 6 fishery, which may or may not have a differential effect on the different groups or age classes. Harvest rates can vary over the course of the fishery. When we looked at median passage date at Bonneville Dam (Table 7), we found differences of several days between the three age classes, which could result in different levels of harvest for each age class. This would complicate any adjustment of the conversion rates based on harvest rate.

Table 7. The tenth, fiftieth, and ninetieth percentiles for Bonneville Dam passage dates of returning adults from the 2002 and 2003 study years.

			Percentile		
Age class	Study year	Adults	10th	50th	90th
Jacks	2003	96	3 May 04	13 May 04	21 May 04
Age-2-ocean	2003	770	22 Apr 05	29 Apr 05	12 May 05
Age-3-ocean	2003	125	27 Apr 06	8 May 06	18 May 06
Jacks	2002	24	1 May 03	12 May 03	22 May 03
Age-2-ocean	2002	692	15 Apr 04	22 Apr 04	4 May 04
Age-3-ocean	2002	31	17 Apr 05	25 Apr 05	5 May 05

Differences in median (50th percentile) passage date at Bonneville Dam between age classes was more likely due to year of return than age at return. During any calendar year, it generally appears that age-3-ocean adults return first, followed by age-2-ocean adults and then jacks. Median passage dates in Table 7 show that age-3-ocean adults generally returned later than age-2-ocean adults from both the 2002 and 2003 study years. However, a comparison of age-3-ocean adults from 2002 and age-2-ocean adults from 2003, both of which returned in 2005, shows that age-3-ocean adults arrived at Bonneville Dam 4 days earlier than age-2-ocean adults.

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APPENDIX A

Juvenile Data from the 2003 Spring Chinook Salmon Tagging Year

Appendix Table A1. Observations (detections), transportation, and bypass numbers at McNary Dam of PIT tagged spring Chinook salmon smolts released from Columbia River hatcheries above McNary Dam tailrace, 2003.

Tag group	Total observed	Number transported	Number bypassed
Winthrop	4,095	1,879	2,216
Methow	4,701	1,953	2,748
Entiat	13,282	6,181	7,094
Leavenworth	49,714	21,316	
Total	71,792	31,329	40,453

Appendix Table A2. Locations of observations (detections) of PIT-tagged spring Chinook salmon within the McNary Dam juvenile fish facility (MCJ), 2003.

					Detected on full-flow and additional coil(s) (coil location)			Detected on separator and additional coil(s) (coil location)								
MCJ date	Full-flow	Adult	Separator	Bypass	Adult	Separator	Raceway	Bypass	Bypass	Bypass Raceway	Sample	Sample Bypass	Raceway	Bypass	Sample Bypass	Raceway
4/22/03	-	-	-	-	-	1	-	-	-	-	-	-	8	-	-	-
4/23/03	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4/24/03	10	-	-	-	-	-	-	-	1	-	-	5	49	-	-	-
4/25/03	174	-	-	-	-	-	-	-	-	-	-	-	11	-	-	1
4/26/03	51	-	-	-	-	6	7	-	4	-	-	5	266	-	-	2
4/27/03	325	-	-	-	-	4	-	-	1	-	-	-	57	-	-	-
4/28/03	91	-	-	-	-	2	-	-	3	-	-	1	430	1	-	1
4/29/03	681	-	-	-	-	1	-	-	3	-	-	4	154	-	-	-
4/30/03	269	-	2	-	-	4	2	-	4	-	-	12	1,204	2	-	7
5/1/03	1,378	-	-	-	-	1	1	-	1	-	-	-	182	-	-	-
5/2/03	261	-	-	-	-	3	-	-	4	-	1	11	1,441	1	-	7
5/3/03	1,787	-	-	-	-	-	-	-	3	-	-	-	161	-	-	2
5/4/03	262	-	2	-	-	3	-	-	5	-	1	11	1,478	-	-	3
5/5/03	2,115	-	-	-	-	-	-	-	2	-	-	1	216	-	-	1
5/6/03	285	-	-	-	-	4	-	-	2	-	-	14	1,679	1	-	4
5/7/03	1,826	-	-	-	-	1	-	-	1	-	-	6	468	-	-	-
5/8/03	434	-	1	-	-	5	1	2	9	-	-	12	1,820	-	-	2
5/9/03	2,232	-	-	-	-	-	-	-	-	-	-	1	489	3	-	1
5/10/03	559	-	-	-	-	2	-	-	7	-	-	11	1,678	3	-	2
5/11/03	1,677	-	1	-	-	3	-	-	-	-	-	-	304	-	-	1
5/12/03	270	-	-	-	-	1	-	-	3	-	-	18	1,257	-	-	7
5/13/03	1,592	-	-	-	-	-	-	-	1	-	-	7	284	-	1	-
5/14/03	392	-	-	1	-	-	-	-	3	1	-	15	1,679	-	-	4
5/15/03	2,064	-	-	1	-	-	-	-	1	-	-	2	306	-	-	2
5/16/03	536	-	1	-	-	-	-	2	62	-	-	17	2,079	2	-	2
5/17/03	2,327	-	1	-	-	1	-	-	37	-	-	3	410	-	-	2

Appendix Table A2. Continued.

					Detected on full-flow and additional coil(s) (coil location)											
								Detected on separator and additional coil(s) (coil location)								
MCJ date	Full-flow	Adult	Separator	Bypass	Adult	Separator	Raceway	Bypass	MCJ date	Full-flow	Adult	Separator	Bypass	Adult	Separator	Raceway
5/18/03	377	-	-	-	-	2	-	2	182	-	2	18	1,761	4	-	4
5/19/03	1,866	-	-	-	-	2	-	-	54	-	-	6	393	-	-	-
5/20/03	305	-	-	2	-	1	-	-	145	-	1	7	978	2	-	2
5/21/03	1,441	-	-	-	-	-	-	-	17	-	-	3	148	1	-	-
5/22/03	413	-	-	-	-	-	-	1	286	-	-	14	1,333	-	-	1
5/23/03	1,662	-	-	-	-	1	-	-	71	-	-	6	364	-	-	1
5/24/03	275	-	-	-	15	1	-	-	236	-	-	11	925	1	-	2
5/25/03	1,069	-	-	-	-	-	-	-	47	-	-	2	166	-	-	-
5/26/03	274	-	-	-	7	3	1	-	279	-	1	12	830	-	-	4
5/27/03	1,350	-	-	-	1	2	-	-	73	-	-	1	249	-	-	-
5/28/03	404	-	-	-	2	3	-	-	370	-	-	14	1,874	1	-	3
5/29/03	2,004	-	-	-	-	-	-	-	110	-	-	7	667	1	-	-
5/30/03	327	-	-	-	21	-	-	-	247	-	-	8	871	-	-	1
5/31/03	999	-	-	-	1	-	-	-	63	-	-	3	293	2	-	-
6/1/03	152	-	1	-	8	-	-	-	110	-	-	4	387	-	-	-
6/2/03	404	-	-	-	3	-	-	-	49	-	-	2	134	-	-	1
6/3/03	90	-	-	-	10	-	-	-	36	-	-	4	371	-	-	-
6/4/03	396	-	-	1	5	-	-	-	17	-	-	2	207	-	-	2
6/5/03	172	1	-	-	15	-	-	-	6	-	-	2	167	-	-	-
6/6/03	250	-	-	-	8	1	-	-	8	-	-	1	94	-	-	-
6/7/03	115	-	-	-	17	-	-	-	3	-	-	1	115	-	-	-
6/8/03	346	-	-	-	3	-	-	-	4	-	-	-	75	-	-	-
6/9/03	254	-	-	-	24	1	-	-	9	-	-	4	299	-	-	-
6/10/03	326	-	-	-	-	-	-	-	5	-	-	1	106	-	-	-
6/11/03	104	-	-	-	6	-	-	-	6	-	-	-	89	-	-	-
6/12/03	96	-	-	-	-	-	-	-	2	-	-	-	15	-	-	-
6/13/03	24	-	-	-	1	-	-	-	5	-	-	-	93	-		-

Appendix Table A2. Continued.

					Detected on full-flow and additional coil(s) (coil location)											
									Detected on separator and additional coil(s) (coil location)							
MCJ date	Full-flow	Adult	Separator	Bypass	Adult	Separator	Raceway	Bypass	MCJ date	Full-flow	Adult	Separator	Bypass	Adult	Separator	Raceway
6/14/03	57	-	-	1	-	-	-	-	2	-	-	-	23	-	-	-
6/15/03	8	-	-	-	3	-	-	-	1	-	-	-	25	-	-	-
6/16/03	15	-	-	-	1	-	-	-	1	-	-	-	9	-	-	-
6/17/03	20	-	-	-	1	-	-	-	1	-	-	-	18	-	-	-
6/18/03	27	-	-	-	1	-	-	-	1	-	-	-	5	-	-	-
6/19/03	8	-	-	-	-	-	-	-	1	-	-	-	7	-	-	-
6/20/03	5	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
6/21/03	10	-	-	-	-	-	-	-	1	-	-	-	5	-	-	-
6/22/03	9	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
6/23/03	2	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
6/24/03	11	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
6/25/03	3	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
6/26/03	5	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
6/27/03	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
6/28/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
6/29/03	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
6/30/03	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7/1/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
7/2/03	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7/3/03	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
7/5/03	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7/9/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
7/15/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
7/16/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
7/24/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
8/9/03	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-

APPENDIX B

Adult Returns from Studies in Progress

Appendix Table B1. Upper Columbia River hatchery spring Chinook salmon studies.

	Juvenile fish numbers			Returns by Age-class			SAR							
Tagging year	Transport	Bypass[a]	Inriver migrant	1-ocean	2-ocean	3-ocean	Transport	Bypass	Inriver migrant	T/I	B/I	95% C.I. (T/I) (B/I)	Status	Annual report containing final results
2004	24,266	24,544	--[b]	64	415	–	–	–	–	–	–	–	In-progress	Fall 2007
2003	**31,329**	**37,331**	**149,775**	**109**	**647**	**–**	**0.32**	**0.27**	**0.43**	**0.74**	**0.62**	**(0.60, 0.92) (0.50, 0.76)**	**Completed**	**Current**
2002	48,375	21,790	123,426	36	608	31	0.33	0.37	0.35	0.94	1.04	(0.78, 1.13) (0.82, 1.33)	Completed	2005

a In 2003 and 2004, "Bypass" fish were fish guided, then bypassed back to the river through the full-flow outfall pipe; they did not enter the collection facility. In 2002, "Bypass" fish entered crossed the separator and were returned to the river through the facility's bypass pipes.

b The "Inriver migrant" number has not been determined at this time.

APPENDIX C

Overview of Methodology for Estimating Inriver Migrant Groups

Estimated Variance of Ratio of Smolt-to-Adult Return Proportions when one of the release numbers is estimated

From Mood et al. 1974, page 181, using the Delta Method for independent *x* and *y*,

$$V\left(\frac{x}{y}\right) \approx \left(\frac{\mu_x}{\mu_y}\right)^2 \left(\frac{V(x)}{\mu_x^{\,2}} + \frac{V(y)}{\mu_y^{\,2}}\right) \tag{1}$$

For $R = SAR_T/SAR_{ND}$ (for Transport vs Not-detected) or $R = SAR_B/SAR_{ND}$ (for Bypass vs Not-detected), and using estimated values, this becomes:

$$\hat{V}(\hat{R}) \approx \hat{R}^2\left(\frac{1}{n_T} - \frac{1}{N_T} + \frac{1}{n_{ND}} - \frac{1}{N_{ND}}\right)$$

where N_i (i = *T*, *B*, or *ND*) are numbers of juveniles and n_i are numbers of adults, since,

$$\frac{\hat{V}(S\hat{A}R_T)}{S\hat{A}R_T^{\,2}} = \frac{S\hat{A}R_T(1 - S\hat{A}R_T)}{N_T S\hat{A}R_T^{\,2}} = \frac{1 - S\hat{A}R_T}{N_T S\hat{A}R_T} = \frac{1}{n_T} - \frac{1}{N_T} \tag{2}$$

and similarly for SAR_B and SAR_{ND}.

If, however, N_{ND} is estimated from $NS(1\text{-}p)$ where *N* is the release number, *S* is survival from release to some location and *p* is probability of detection at that location, then:

$$\hat{V}(\hat{R}) \approx \hat{R}^2\left(\frac{1}{n_T} - \frac{1}{N_T} + \frac{\hat{V}(S\hat{A}R_{ND})}{S\hat{A}R_{ND}^{\,2}}\right) \tag{3}$$

from (1) and (2). Now,

$$\hat{V}(S\hat{A}R_{ND}) = \hat{V}\left(\frac{n_{ND}}{N_{ND}}\right) = \hat{V}\left(\frac{n_{ND}}{N\hat{S}(1-\hat{p})}\right) = \left(\frac{1}{N^2}\right)\hat{V}\left(\frac{n_{ND}}{\hat{S}(1-\hat{p})}\right)$$

$$\approx \left(\frac{1}{N^2}\right)\left(\frac{n_{ND}}{\hat{S}(1-\hat{p})}\right)^2\left(\frac{\hat{V}(n_{ND})}{n_{ND}^{\,2}} + \frac{\hat{V}(\hat{S}(1-\hat{p}))}{\hat{S}^2(1-\hat{p})^2}\right) \tag{4}$$

by (1) and,

$$S\hat{A}R_{ND}{}^{2} = \left(\frac{n_{ND}}{N_{ND}}\right)^{2} = \left(\frac{1}{N^{2}}\right)\left(\frac{n_{ND}}{\hat{S}(1-\hat{p})}\right)^{2} \tag{5}$$

So from (4) and (5),

$$\frac{\hat{V}(S\hat{A}R_{ND})}{S\hat{A}R_{ND}{}^{2}} \approx \frac{\hat{V}(n_{ND})}{n_{ND}{}^{2}} + \frac{\hat{V}(\hat{S}(1-\hat{p}))}{\hat{S}^{2}(1-\hat{p})^{2}} = \frac{1}{n_{ND}} - \frac{1}{N_{ND}} + \frac{\hat{V}(\hat{S}(1-\hat{p}))}{\hat{S}^{2}(1-\hat{p})^{2}} \tag{6}$$

Then from (3) and (6) and substituting the estimate for N_{ND},

$$\hat{V}(\hat{R}) \approx \hat{R}^{2}\left(\frac{1}{n_{T}} - \frac{1}{N_{T}} + \frac{1}{n_{ND}} - \frac{1}{N\hat{S}(1-\hat{p})} + \frac{\hat{V}(\hat{S}(1-\hat{p}))}{\hat{S}^{2}(1-\hat{p})^{2}}\right) \tag{7}$$

Now,

$$\hat{V}(\hat{S}(1-\hat{p})) \approx (1-\hat{p})^{2}\hat{V}(\hat{S}) + \hat{S}^{2}\hat{V}(\hat{p}) + 2(1-\hat{p})\hat{S}\hat{Cov}(\hat{S},1-\hat{p})$$

(Mood et al. 1974, page 180), and,

$$\hat{Cov}(\hat{S},1-\hat{p}) = -\hat{Cov}(\hat{S},\hat{p})$$

So,

$$\frac{\hat{V}(\hat{S}(1-\hat{p}))}{\hat{S}^{2}(1-\hat{p})^{2}} \approx \frac{\hat{V}(\hat{S})}{\hat{S}^{2}} + \frac{\hat{V}(\hat{p})}{(1-\hat{p})^{2}} - \frac{2\hat{Cov}(\hat{S},\hat{p})}{\hat{S}(1-\hat{p})} \tag{8}$$

Then from (7) and (8),

$$\hat{V}(\hat{R}) \approx \hat{R}^{2}\left(\frac{1}{n_{T}} - \frac{1}{N_{T}} + \frac{1}{n_{ND}} - \frac{1}{N\hat{S}(1-\hat{p})} + \frac{\hat{V}(\hat{S})}{\hat{S}^{2}} + \frac{\hat{V}(\hat{p})}{(1-\hat{p})^{2}} - \frac{2\hat{Cov}(\hat{S},\hat{p})}{\hat{S}(1-\hat{p})}\right)$$

Note that *S* and *p* were estimated using the single-release Cormack-Jolly-Seber model (Cormack 1964; Jolly 1965; Seber 1965) using the statistical software SURPH (Skalski et al. 1993; Smith et al. 1994).