Research Related to Transportation of Juvenile Salmonids on the Columbia River, 2005: Final report for the 2002 Hatchery Spring Chinook Salmon Juvenile Migration

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EXECUTIVE SUMMARY

Since 1995, the National Marine Fisheries Service has evaluated transportation of Snake River spring/summer Chinook salmon smolts. Beginning in 2002, spring Chinook salmon transportation was also evaluated from McNary Dam using fish PIT-tagged at upper Columbia River hatcheries.

From March through August 2005, we recovered age-3-ocean spring/summer Chinook salmon adults from smolts tagged in 2002, completing adult returns from that study year. In 2002, we tagged and released fish from Leavenworth (267,531), Entiat (59,401), and Winthrop (19,968) hatcheries. Study fish collected at McNary Dam were diverted to transportation, while the general population of fish collected at McNary Dam was returned to the river through the facility bypass pipes (the full-flow bypass pipe was not utilized in 2002). In 2005 we detected 2 age-3-ocean transported fish and 26 age-3-ocean migrant fish from the 2002 tagging. Based on all 2002 returns combined (jacks through age-3-ocean fish), the smolt-to-adult return rates (SAR) of transported and migrant fish were 0.33 and 0.35, respectively, resulting in a transport-to-migrant ratio (T/I) of 0.94 (95% confidence interval 0.78, 1.13).

Of adults detected at Bonneville Dam, 84% of transported fish and 85% of migrant fish successfully migrated to McNary Dam (not adjusted for any take in the Zone 6 fishery). Travel time from Bonneville Dam to McNary Dam was approximately 10 d for both transported and migrant age-2-ocean fish, while age-3-ocean fish were a little slower, averaging approximately 13 and 12 d for transported and migrant fish, respectively.

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INTRODUCTION

In 2005, we continued a study to evaluate transportation of juvenile fish as a means to mitigate for downstream losses that result from the lower Snake and Columbia River federal hydropower system. The primary objective of our study was to compare adult returns of yearling Chinook salmon 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 survival estimates between the point of release and Bonneville Dam tailrace (Muir et al. 2001).

Here we report on adult returns from 2005, which complete returns from transportation study releases of hatchery spring Chinook salmon at McNary Dam in 2002. Information on transportation studies from McNary Dam is also provided for juveniles tagged in 2005 (Appendix B) and on adult returns to date from juveniles tagged in 2003 and 2004 (Appendix C).

In 1995-1996 and 1998-1999, we PIT tagged yearling Chinook salmon smolts at Lower Granite Dam to compare adult returns of marked smolts transported to below Bonneville Dam versus 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 in the same years upstream of Lower Granite Dam), 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 not detected at dams (fish that passed via spillways, passed through turbines, or were not detected at juvenile fish facilities) 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 with the 2000 Lower Granite Dam transportation study, we altered our study design to provide better comparison between these groups, and it was this study design we used for the McNary Dam evaluation.

The last spring Chinook salmon transport studies conducted at McNary Dam were 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 recover PIT-tagged study fish on adult return was lacking in the lower river. However, by 2003, the adult ladders at Bonneville and McNary Dams were to be equipped with PIT-tag interrogation systems. Therefore, we began transport evaluations on anadromous salmonid juveniles migrating through McNary Dam beginning in spring 2002.

METHODS

Juvenile Collection and Tagging

To provide a holistic approach to evaluations of SARs and T/Is for fish originating only in the Columbia River upstream of McNary Dam, we PIT-tagged and released yearling Chinook salmon that originated in hatcheries in this area. We set the numbers of fish to tag at each hatchery to approximate the proportion that hatchery represented in the general population. Transport and migrating 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 80% of the fish collected at the juvenile fish facility to transportation. The remaining 20% of bypassed fish were used to help develop survival estimates necessary to estimate differential delayed mortality (‘D’) of transported fish. The number of fish in the migrating group will be estimated using the procedures developed by Sandford and Smith (2002).

We calculated the number of fish needed for marking to test a null hypothesis that there is no difference between the SARs of transported and migrating fish, versus the alternative hypothesis that the ratio was 1.2 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 needed for tagging was determined as

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

and

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

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:

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

Therefore, if $\alpha = 0.05$ and $\beta = 0.20$, and we wish to discern a difference of 20% (T/I = 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 migrant cohort (47,300 × 1.2).

The above numbers are required at McNary Dam. Releasing tagged fish from hatcheries upstream of the dam will require increasing the numbers of fish tagged to provide sufficient numbers collected for transport at the dam.

To determine the number of fish that must be tagged at the hatcheries, we calculated survival from release to McNary dam and the probability of detection in the collection system at McNary dam for PIT-tagged fish released from Leavenworth Hatchery in spring 2000. These fish migrated through the McNary Dam project primarily in May and were almost completely past the dam by early June. During that period, spill at the dam averaged a relatively constant 40% of the total river flow. Estimated survival was 0.586 (s.e. 0.015) and the detection probability for fish arriving at McNary dam was 0.229 (s.e. 0.015). Therefore, we needed to release roughly 355,000 (47,300/0.586/0.229) PIT-tagged yearling Chinook salmon from hatcheries to obtain the number of study fish required in the transport group at McNary Dam.

Inriver Migration

Prior to 11 July 2002, McNary Dam was in bypass mode with all tagged and untagged fish collected bypassed to the river after passing through PIT-tag detectors, except tagged fish from this study. After this date, all non-tagged fish collected at the dam were transported. Study fish detected on coils leading to the 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.

Adult Recoveries and Data Analysis

In 2005, we completed the recovery of adults tagged as juveniles in 2002. The procedures for data analysis described by Marsh et al. (1996) were modified as described in Sandford and Smith (2002) to determine the number of juvenile fish in the migrating group.

Smolt-to-Adult Return Percentages (SARs) were calculated for transport, bypass, and not-detected cohorts as the number of adults returning in 2003-2005 and passing McNary Dam divided by the number of juveniles migrating past McNary Dam in 2002. Calculating the SARs for the transport and bypass groups was straightforward, based on actual detections of juveniles and adults at McNary Dam. Determining the juvenile number used in the SAR calculation for the not-detected group was more complicated. We estimated this number as:

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

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

Ratios of SARs were calculated for transport and bypass groups relative to the not-detected group. To test the null hypotheses of no difference between transport and not-detected fish or between bypass and not-detected fish, we calculated 95% confidence intervals for these ratios. If the value 1.0 was outside the interval, the two passage routes were considered to have significantly different SARs.

The confidence intervals 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 α = 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 D.

RESULTS

Juvenile Collection and Tagging

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

Table 1. Tag dates, releases dates, release numbers, and average tag lengths for yearling chinook salmon released from Columbia River hatcheries to evaluate transport from McNary Dam in 2002.

Hatchery	Tagging date	Release date	Release number	Average tag length (mm)
Winthrop	24-27 January 2002	15 April 2002	19,970	114.7
Entiat	5-13 February 2002	8 April 2002	59,401	124.3
Leavenworth	26 Feb-29 March 2002	24 April 2002	267,533	118.7
Total released			346,904	

Inriver Migration

Of 346,904 yearling spring Chinook salmon released, 67,903 (19.5%) were detected at McNary Dam. Final dispositions for the 346,904 fish released are shown in Table 2. Using the methods of Sandford and Smith (2002), the migration history data was analyzed resulting in an estimated 123,426 juvenile yearling Chinook salmon in the 2002 migrating group (Table 3). The SAR calculation for the migrating group is based on this number.

At McNary Dam, our initial goal was to transport 80% of the study fish collected. However, because of technology limitations, only 72.3% of the yearling Chinook salmon detected were transported from the dam during the smolt migration.

Based upon PIT-tag detections at John Day and Bonneville Dams, and on estuary detections in the pair-trawl system, we made estimates of survival for Winthrop, Entiat, and Leavenworth Hatcheries from release to the McNary Dam (50.6%, 53.8%, and 57.6%, respectively) and Bonneville Dam (42.0, 44.7, and 47.8%, respectively) tailraces.

Table 2. Final dispositions at McNary Dam for fish released from Columbia River hatcheries to evaluate transport from McNary Dam in 2002.

Hatchery	Transported	Bypassed	Unknown	Not detected
Winthrop	2,499	888	8	16,575
Entiat	8,704	3,364	41	47,292
Leavenworth	37,172	17,538	131	212,692
Totals	48,375	21,790	180	276,559

Table 3. Estimated number of migrating hatchery yearling Chinook salmon arriving at the McNary Dam tailrace in 2002 for the McNary Dam transport evaluation.

Hatchery	Number released	Estimated survival to McNary Dam	Estimated number arriving at McNary Dam	Transported (n)	Returned to the river (n)	Estimated number of migrating fish
Winthrop	19,970	0.5022	10,029	2,499	888	6,634
Entiat	59,401	0.5353	31,797	8,704	3,364	19,692
Leavenworth	267,533	0.5679	151,932	37,172	17,538	97,100
Totals	346,904		193,771	48,375	21,790	123,426

Adult Recoveries and Data Analysis

At McNary Dam, we began recovering jacks in 2003 and finished with age-3-ocean adults in August 2005. Returns by study group and age-class are shown Table 4, with juvenile numbers adjusted as described by Sandford and Smith (2002).

Table 4. Returns by study group and age-class of hatchery yearling Chinook salmon from McNary Dam transport study releases in 2002.

	Juvenile numbers	Returns by Age-class Jack	2-ocean	3-ocean	SAR	T/I	95% C.I.
Transport	48,375	10	148	2	0.33	0.94	(0.78, 1.13)
Bypassed	21,790	3	74	3	0.37	1.04	(0.82, 1.33)
Migrant	123,426	23	386	26	0.35		

By definition, migrant fish were those not detected at McNary Dam. Therefore, since we tagged and released our study fish above McNary Dam, we were unable to determine a temporal SAR for migrant fish because we do not know when each migrant adult passed McNary Dam as a juvenile. We were able to create temporal SARs for transport and bypass fish.

Unlike the seasonal trends observed with Snake River spring/summer Chinook salmon, where transported fish start out with low SARs then at a point in late April to mid May dramatically increase and remain at high levels, temporal patterns observed with hatchery yearling Chinook salmon at McNary Dam were less apparent (Figure 1). Each wave of rising and falling SARs lasted about 14 days for bypassed fish and 10 days for transported fish, without much of a change in amplitude in either direction.

The SARs of the bypassed and transported groups seemed out-of-phase, with high points in transport SARs coinciding with troughs in bypass SARs, although differences were generally small. Transport SARs were lower than for bypassed fish at the beginning of the migration, similar to results from the Snake River.

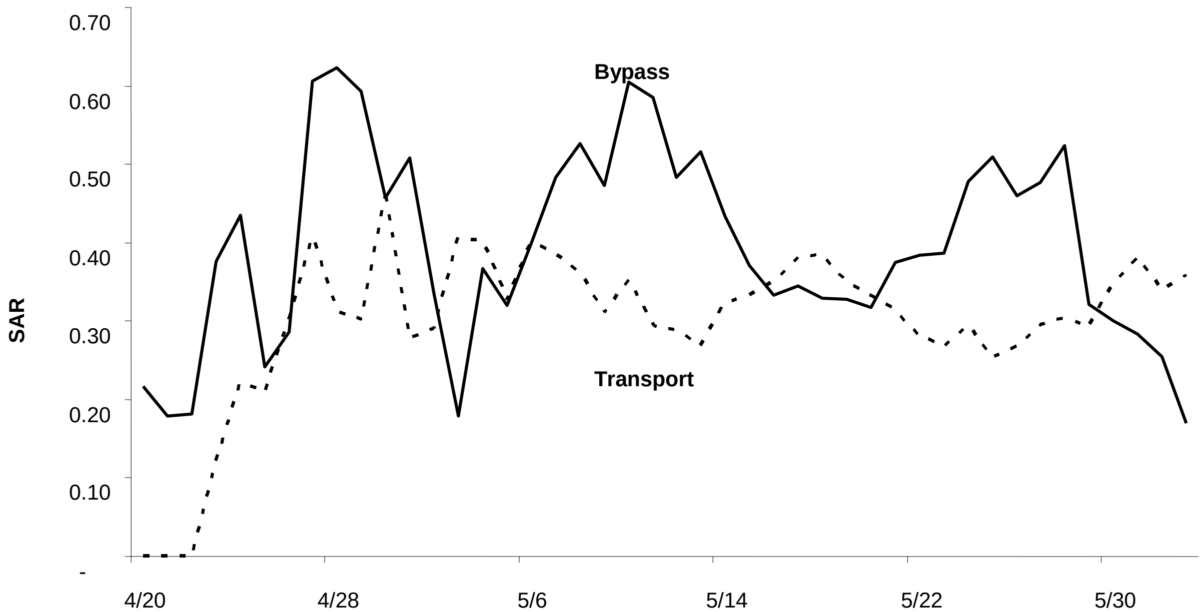

Figure 1. Smolt-to-adult return rates by detection date at McNary Dam for transported and bypassed yearling Chinook salmon smolts tagged at Winthrop, Entiat, and Levanworth Hatcheries in 2002. Data presented are 5-day running averages of daily detection numbers. Overall transport/bypass ratio was 0.90.

Because we could not calculate temporal SARs for migrant fish, we were unable to determine a temporal differential delayed mortality (D) between transported and migrant fish. We were, however, able to calculate D between the transport and bypass fish. Despite no obvious pattern in temporal SARs, there was some seasonal variation in D (Figure 2). The overall D value for 2002 was 1.00, but varied from 0.69 to 1.38, generally increasing (approaching 1.0) as the juvenile migration progressed.

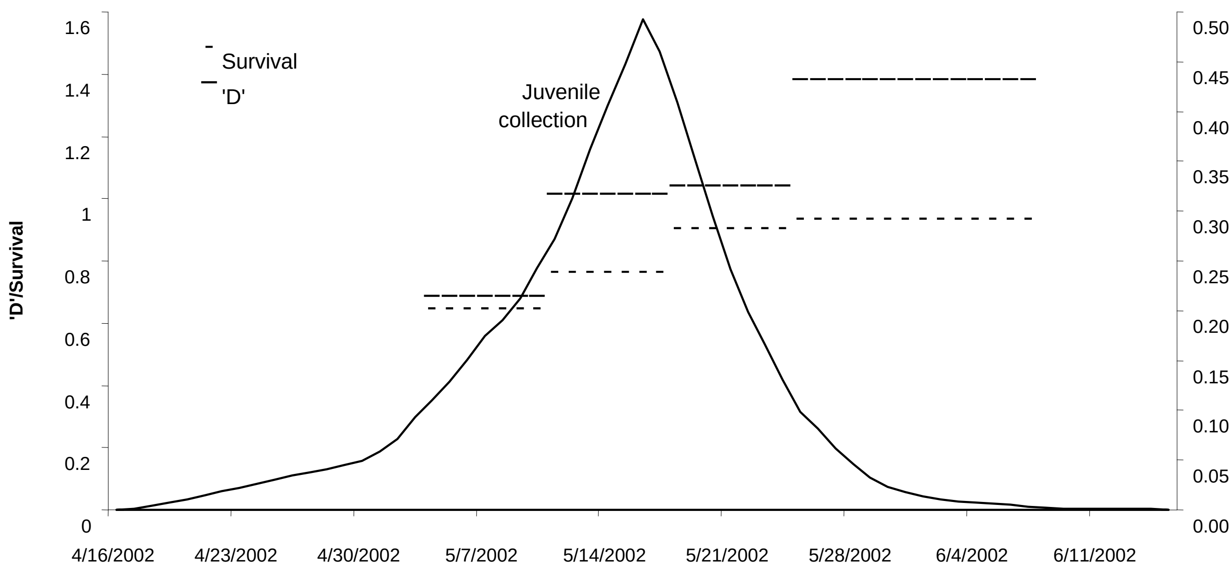

Figure 2. Estimates of differential delayed mortality (D) over time for yearling Chinook salmon smolts tagged at Winthrop, Entiat, and Leavenworth Hatcheries in 2002. Grouping are based on having adequate numbers of smolts to estimate in-river survival between release and McNary Dam and between McNary and Bonneville Dams. The percentages shown represent the percent of the outmigration each bar represents?. Overall 'D' of both the tagged fish and the general population (who are these fish, where is this info? for the year was 1.00. Need axis label on 2nd Y

The number of returning adults observed at Bonneville Dam and subsequently observed at McNary Dam (the conversion rate) was similar for migrating and transport groups (Table 5). By the time jacks from this study began returning in 2003, Bonneville, McNary, Ice Harbor, Lower Granite, Priest Rapids, Rock Island, and Wells Dams had been equipped with adult detection systems.

Travel times from Bonneville to McNary Dam ranged from 5-9 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 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 migrant adults was 5 to 20 days. With 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.

On average, smaller smolts returned as older adults (Table 7). For example, age-3-ocean migrant fish were nearly 12% smaller as juveniles than migrant fish that returned as jacks.

Table 5. Percentage of adult spring Chinook salmon PIT tagged in 2002 that were detected at Bonneville Dam and subsequently detected at McNary Dam (the conversion rate).

Age class		Detected at Bonneville Dam	Detected at McNary Dam	Conversion rate
Jacks	Migrant	16	15	93.75
	Transport	6	6	100.00
	Bypassed	2	2	100.00
Age-2-ocean	Migrant	449	378	84.19
	Transport	174	145	83.33
	Bypassed	69	65	94.20
Age-3-ocean	Migrant	25	24	96.00
	Transport	2	2	100.00
	Bypassed	4	3	75.00
Totals	Migrant	490	417	85.10
	Transport	182	153	84.07
	Bypassed	75	70	93.33

Table 6. Median travel times from Bonneville Dam to McNary Dam for adult spring Chinook salmon PIT tagged as juveniles in 2002 for McNary Dam transport evaluation.

Age class		Number of adults	Median travel time from Bonneville Dam to McNary Dam (days)
Jacks	Migrant	15	6.0
	Transport	6	5.0
	Bypassed	2	6.0
Age-2-ocean	Migrant	378	6.0
	Transport	145	5.0
	Bypassed	65	5.0
Age-3-ocean	Migrant	24	7.0
	Transport	2	9.0
	Bypassed	3	9.0

Table 7. Average length at tagging of juvenile and adult yearling Chinook salmon by group and age class. Fish were PIT tagged as juveniles in 2002 for McNary Dam transport evaluation. Numbers of adults in parenthesis.

Group	Average length at juvenile tagging (mm)	Average adult length (mm) by age class		
		Jacks	Age-2-ocean	Age-3-ocean
Migrant	118.6	128.9 (12)	123.8 (171)	113.6 (16)
Transport	120.3	125.0 (1)	119.7 (63)	114.0 (2)
Bypassed	119.6	134.5 (2)	128.8 (30)	-

DISCUSSION

For most transport studies conducted on Snake River spring/summer Chinook salmon smolts since 1995, annual T/Is, while indicating a transport benefit, were lower than expected when compared to concurrent estimates of in-river survival (Marsh et al. 2000, 2001; Muir et al. 2001). As one moves down river, any transport benefit should decrease proportional to the remaining distance to the ocean. McNary Dam, being the last transportation dam, and located only three dams above the point of release for transported fish, should have lower annual T/Is than Snake River dams. The results from this year, which showed no benefit to fish from McNary transport, support this premise.

Being the first 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.

We are unable to calculate temporal transport and bypass to migrant ratios because we don't know when migrant fish passed the dam as juveniles. The best we can do is monitor temporal patterns in both the transport and bypass groups. Unlike Snake River studies, which show large temporal SAR shifts, trends of SARs for McNary Dam transport and bypass groups are less obvious, with multiple rises and falls, gradually decreasing as the outmigration progresses.

The lack of an obvious temporal trend in SARs for McNary Dam transport and bypass groups, like that observed for Snake River spring/summer Chinook (Williams et al. 2005), is likely do to their more similar time of arrival below Bonneville Dam. Because the distance traveled for both McNary transport and bypass groups is less than for Snake River transport and bypass groups, the arrival timing below Bonneville Dam for McNary transport and bypass groups only varies by a few days compared to weeks apart for Snake River transport and bypass groups (Williams et al. 2005.

When we compared tagging lengths of juveniles that were bypassed, transported or passed McNary Dam without being diverted, the average fork-length of migrant fish was smaller than fish that were diverted. This is the opposite of what we have observed with Snake River spring/summer Chinook Salmon (Williams et al. 2005)

As with Snake River spring/summer Chinook salmon, the larger a juvenile is, the more likely it will return as a jack, and, the smaller a juvenile is, the more likely it will return as an age-3-ocean adult (Scheuerell 2005).

Conversion rates of adults from Bonneville Dam to McNary Dam were similar for the transport and migrant groups (84% and 85%, respectively), while higher for the bypass group (93%). These rates do not include the Zone 6 fishery. Problems with the Priest Rapids Dam's in-ladder PIT tag detectors in 2004 (when the bulk of the adults returned) prevent us from comparing conversion rates between Bonneville and McNary Dams with those between McNary and Priest Rapids Dams.

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APPENDIX A

Juvenile Data from the 2002 Spring Chinook Salmon Tagging Year

Appendix Table A1. Observations (detections), transportation, and bypass numbers at McNary Dam of spring Chinook salmon released from Columbia River hatcheries above McNary Dam tailrace, 2002.

Tag group	Total observed	Number transported	Number bypassed
Winthrop	3,387	2,499	888
Entiat	12,068	8,704	3,364
Leavenworth	54,710	37,172	17,538
Total	70,165	48,375	21,790

Appendix Table A2. Locations of observations (detections) of PIT-tagged spring Chinook salmon within the McNary Dam juvenile fish facility (MCJ), 2002.

MCJ detection date	Detected once (coil location)					If detected on separator, final coil (coil location)		
	Full-flow	Bypass	Transport	Sample	Separator	Bypass	Raceway	Sample
16-Apr-02	-	-	-	-	-	6	-	-
17-Apr-02	-	-	-	-	-	14	12	-
18-Apr-02	1	-	-	-	1	29	41	-
19-Apr-02	8	-	-	-	-	83	88	-
20-Apr-02	4	-	-	-	1	91	114	-
21-Apr-02	5	-	-	-	1	128	135	-
22-Apr-02	3	-	-	-	1	110	145	-
23-Apr-02	13	1	-	-	-	111	142	-
24-Apr-02	5	-	-	-	-	77	195	2
25-Apr-02	17	1	-	-	1	58	219	-
26-Apr-02	6	-	-	-	-	56	199	-
27-Apr-02	6	-	-	-	2	60	204	-
28-Apr-02	5	-	-	-	-	57	178	-
29-Apr-02	8	-	-	-	-	56	183	-
30-Apr-02	7	2	5	-	3	58	191	-
01-May-02	10	1	-	-	1	67	233	-
02-May-02	12	1	1	-	3	153	518	-
03-May-02	23	1	-	-	1	191	664	1
04-May-02	44	-	1	-	3	325	1,149	-
05-May-02	46	-	-	-	1	246	876	-
06-May-02	36	1	3	-	2	282	1,014	2
07-May-02	45	-	-	-	10	317	1,188	1
08-May-02	73	1	2	-	5	332	1,247	-
09-May-02	40	1	7	-	6	233	852	-
10-May-02	35	-	-	-	1	309	1,206	1
11-May-02	79	1	6	-	3	432	1,589	4
12-May-02	30	1	-	-	1	410	1,605	2
13-May-02	94	5	4	-	14	543	2,206	1
14-May-02	50	1	7	-	10	688	2,706	1

Appendix Table A2. Continued.

MCJ detection date	Detected once (coil location)					If detected on separator, final coil (coil location)		
	Full-flow	Bypass	Transport	Sample	Separator	Bypass	Raceway	Sample
15-May-02	161	3	4	-	8	595	2,296	1
16-May-02	44	2	-	-	3	599	2,309	1
17-May-02	73	6	19	-	22	629	2,450	4
18-May-02	63	1	-	-	2	677	2,497	4
19-May-02	155	1	1	-	6	754	2,727	1
20-May-02	527	1	3	-	15	713	2,758	2
21-May-02	148	5	2	-	14	818	2,970	3
22-May-02	23	1	3	-	7	820	2,910	1
23-May-02	130	5	-	-	9	1,489	429	2
24-May-02	24	-	-	-	1	1,280	-	-
25-May-02	26	5	6	-	10	649	1,547	-
26-May-02	14	-	2	-	5	554	1,672	3
27-May-02	58	-	-	-	1	281	823	1
28-May-02	21	-	-	-	1	343	1,002	4
29-May-02	30	-	-	-	1	315	751	1
30-May-02	19	1	-	-	3	265	682	1
31-May-02	10	-	3	-	-	207	495	-
01-Jun-02	16	-	-	-	-	99	227	-
02-Jun-02	8	-	-	-	-	81	200	4
03-Jun-02	4	1	-	-	-	69	160	2
04-Jun-02	5	-	-	-	-	81	23	1
05-Jun-02	2	-	-	-	-	93	3	-
06-Jun-02	16	2	-	-	-	32	36	-
07-Jun-02	6	-	-	-	-	22	47	-
08-Jun-02	4	-	-	-	1	28	64	-
09-Jun-02	46	-	-	-	-	10	21	-
10-Jun-02	63	-	-	-	-	-	-	-
11-Jun-02	20	-	-	-	-	-	-	-
13-Jun-02	9	-	-	-	-	1	-	-
14-Jun-02	1	-	-	-	-	9	12	-
15-Jun-02	2	-	-	-	-	2	5	-
16-Jun-02	-	-	-	-	-	4	7	-

Appendix Table A2. Continued.

MCJ detection date	Detected once (coil location)					If detected on separator, final coil (coil location)		
	Full-flow	Bypass	Transport	Sample	Separator	Bypass	Raceway	Sample
17-Jun-02	-	-	-	-	-	4	9	-
18-Jun-02	-	-	-	-	-	1	5	-
19-Jun-02	-	-	-	-	-	-	2	-
20-Jun-02	-	-	-	-	-	1	-	-
21-Jun-02	1	-	-	-	-	-	-	-
26-Jun-02	-	-	-	-	-	1	1	-
27-Jun-02	-	-	-	-	-	-	1	-
28-Jun-02	1	-	-	-	-	-	-	-
11-Apr-03	-	1	-	-	-	-	-	-

APPENDIX B

Tagging Results for 2005 Juvenile Transportation Studies

No hatchery spring Chinook salmon were marked in Columbia River hatcheries above McNary Dam in 2005.

APPENDIX C

Adult Returns from In-Progress Studies

Appendix Table C1. Upper Columbia River hatchery spring Chinook salmon studies

	Juvenile fish numbers			Returns by Age-class			SAR					95% C.I.		Annual report of
	Transport	Bypass[a]	Migrant	1-ocean	2-ocean	3-ocean	Transport	Bypass	Migrant	T/I	B/I	(T/I, B/I)	Status	final results
2004	24,266	24,544	--[b]	64	–	–	–	–	–	–	–	–	In-progress	Fall 2007
2003	31,323	37,469	--[b]	109	647	–	–	–	–	–	–	–	In-progress	Fall 2006
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	Current

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 Number of "migrants" has not been determined at this time.

APPENDIX D

Overview of Statistical Methodology

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,

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

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

$$C\hat{o}v(\hat{S}, 1-\hat{p}) = -C\hat{o}v(\hat{S}, \hat{p})$$

So,

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

Then from (7) and (8),

$$\hat{V}(\hat{R}) \approx \hat{R}^2 \left(\frac{1}{n_T} - \frac{1}{N_T} + \frac{1}{n_{ND}} - \frac{1}{N\hat{S}(1-\hat{p})} + \frac{\hat{V}(\hat{S})}{\hat{S}^2} + \frac{\hat{V}(\hat{p})}{(1-\hat{p})^2} - \frac{2C\hat{o}v(\hat{S}, \hat{p})}{\hat{S}(1-\hat{p})} \right)$$

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).