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Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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Eric E. Hockersmith, William D. Muir,
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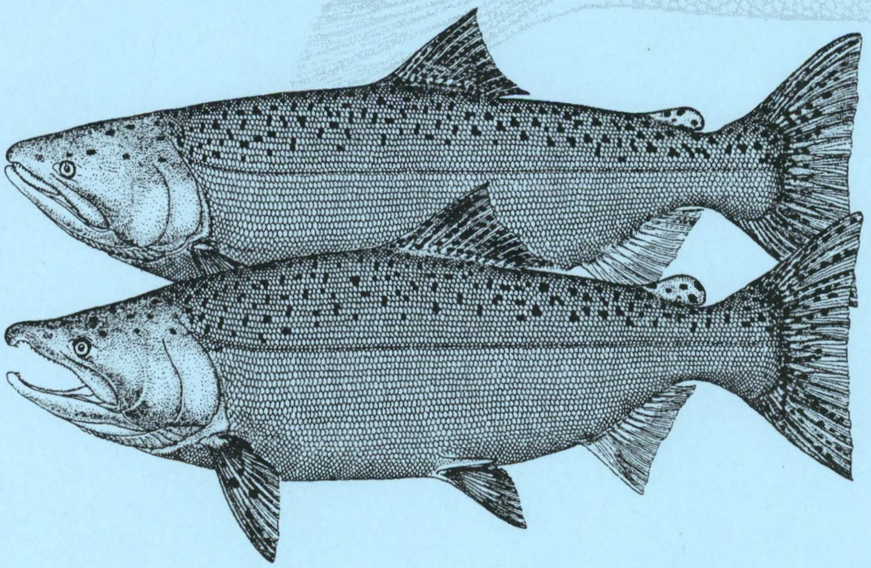
October 2000



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EXECUTIVE SUMMARY

In 1999, the National Marine Fisheries Service estimated relative survival for river-run hatchery yearling chinook salmon passing through two sections of the bypass system at Lower Monumental Dam on the Snake River. Fish were collected and marked with PIT tags at the Lower Monumental Dam smolt collection facility. After a 16-hour holding period, groups of approximately 740 marked fish were released at each of three locations: the bypass system downstream from the primary dewatering facility during collection/bypass mode, the bypass system downstream from the primary dewatering facility during primary bypass mode, and the tailrace 1-2 km below Lower Monumental Dam.

Survival was estimated from detections of individual PIT-tagged fish at juvenile collection/detection facilities at McNary, John Day, and Bonneville Dams from 16 ternary releases made daily from 4 to 19 May. Differences among detection percentages relative to tailrace release groups were evaluated by analysis of variance (ANOVA). Relative survival for release groups varied between release dates, with survival and travel times generally decreasing over time. Overall, relative survival was similar between fish released during collection/bypass mode (0.958, s.e. 0.010) and primary bypass mode (0.977, s.e. 0.010). ANOVA showed no significant differences among treatments ($F = 1.67$, $P = 0.215$).

CONTENTS

INTRODUCTION

The National Marine Fisheries Service and the Northwest Power Planning Council have set interim performance standards of 80% fish passage efficiency and 95% juvenile salmon passage survival at each dam on the lower Snake and Columbia Rivers. In an effort to improve smolt survival during downstream migration and to help reach these standards, juvenile bypass systems have been constructed at each lower Snake River and most Columbia River projects. During the spring migration, 50% or more of migrants passing each dam typically pass through these bypass systems, depending on the level of spill at each project.

After construction, each juvenile collection/bypass system at Snake and Columbia River dams was evaluated to ensure that the facility performed as designed. These evaluations typically involved releases of marked smolts within the system and an examination of the fish recaptured in the smolt monitoring facility, where they were evaluated for descaling, injury, mortality, and stress (Monk et al. 1992; Marsh et al. 1995, 1996a,b; Gessel et al. 1997). These studies demonstrated that smolts could pass through the new bypass systems safely, although some problem areas were identified.

After the modifications to identified problem areas were completed, there were few follow-up evaluations. Recently, analysis has focused on adult return rates of fish marked with passive integrated transponder (PIT) tags as juveniles that migrated inriver using different routes of passage (turbine, bypass, or spill) (Sandford and Smith, in prep.). This analysis indicates that during some years, smolts that passed through multiple bypass systems had lower adult returns than those passing via spill or turbine (fish that pass via the spill or turbine cannot be distinguished since they are not detected through either route of passage), although this conclusion is based on relatively small numbers of returning adults. These results raise concerns about the efficacy of juvenile bypass systems to safely pass smolts downstream.

Furthermore, estimates of survival through the hydropower system are based on detections of PIT-tagged fish that are bypassed at Snake and Columbia River dams and routed back to the river through the PIT-tag diversion systems. It is important to determine if passage through these systems is affecting survival of fish to ensure that survival estimates obtained are unbiased. Moreover, outfall release sites at several juvenile fish facilities were not completely evaluated after construction due to logistical difficulties of fish recovery (Marsh 1996b). At the time of construction, this unknown was an acceptable risk because fish collected at the facility were destined for transportation. However, with recent changes in salmon management, more fish are being returned to the river, and optimal locations for bypass outfall pipes are being reconsidered at Lower Monumental and McNary Dams. A more complete understanding of the rate of survival or injury caused by passage through these modified systems is needed.

In 1999, we evaluated survival through the bypass system at Lower Monumental Dam downstream from the primary dewatering facility using PIT-tagged fish passing during collection/bypass and primary bypass modes of operation. This evaluation provided estimates of survival for the bypass system downstream from the primary dewatering facility, including the primary bypass pipe and bypass outfall. It did not include evaluation of bypass survival upstream from the primary dewatering facility or provide data on mortality associated with the submersible traveling screens, the gatewells, orifices, or the collection channel. This study addressed research needs outlined in MPE-W-98-10 of the U.S. Army Corps of Engineers, North Pacific Division, Anadromous Fish Evaluation Program.

METHODS

Tagging and Release Procedures

In 1999, we collected and PIT-tagged river-run hatchery yearling chinook salmon at the Lower Monumental Dam smolt collection facility. Only fish clearly identifiable as hatchery yearling chinook salmon without PIT tags were used. Fish were preanesthetized with MS-222, sorted, and PIT-tagged using hypodermic syringes with 12-gauge needles. Sorting and tagging were done in a recirculating MS-222 anesthetic system. PIT-tagging syringes were soaked in ethyl alcohol for a minimum of 10 minutes for sanitization before reloading with PIT tags. Fish for all release groups were tagged simultaneously, and tagging personnel were periodically rotated among tagging stations. PIT-tagging at Lower Monumental Dam began in early May and continued into mid-May. Tagged fish were transferred from the smolt monitoring facility through a water-filled pipe to 712-L tanks mounted on trucks. Holding tanks were supplied with flow-through water during tagging and holding, and aerated with oxygen during transportation to release locations. Fish were held a minimum of 16 hours with flow-through water for recovery and determination of post-tagging mortality. Holding density did not exceed 800 fish per tank.

Sample sizes for releases were determined by evaluating data from PIT-tagged salmonids released from Snake River dams in 1997 and 1998 (Appendix A). The number of release groups per release location and number of fish per release group were calculated to maximize the ability to detect differences in passage survival through the bypass system, within constraints imposed by logistics of collecting, tagging, and transporting fish. For a given total number of fish used in the evaluation, similar statistical power could be attained with a range of combinations of total numbers of releases and numbers of fish per group. Based on marking and transport constraints, we designed the study to mark and release 16 groups of approximately 738 fish to each respective passage route for an approximate total of 11,800 fish released per location.

The release strategy for the study consisted of two treatments and a reference release (tailrace) of PIT-tagged fish at Lower Monumental Dam (Fig. 1). Both treatments were released at the same location, immediately below the primary dewatering facility, with the bypass system operated under two different modes (collection/bypass mode and primary bypass mode) (Fig. 2). The reference group was released mid-river 1-2 km downstream from the dam.

After a post-tagging recovery period of approximately 16 hours, fish were transported in recovery containers to the designated release areas. Fish were released from tanks into the bypass flume via 7.6-cm by 1.0-m hose. In order to provide mixing of treatment and reference groups, the collection/bypass group was released while the system was in collection/bypass mode approximately 15 minutes prior to the primary bypass release group to allow time for fish to pass through the facility. After approximately 15 minutes, the facility was switched to primary bypass operation mode by moving the facility bypass swing gate, and the primary bypass group was released. The reference release group was transferred to a small barge, transported to the release site, and released water-to-water approximately 5 minutes after the primary bypass release. Specific tailrace conditions (spill pattern, flow level, and powerhouse loading) were not standardized during the releases; however, passage conditions were similar throughout the study (Table 1). All releases were made between 0700 and 0830 during periods of no spill.

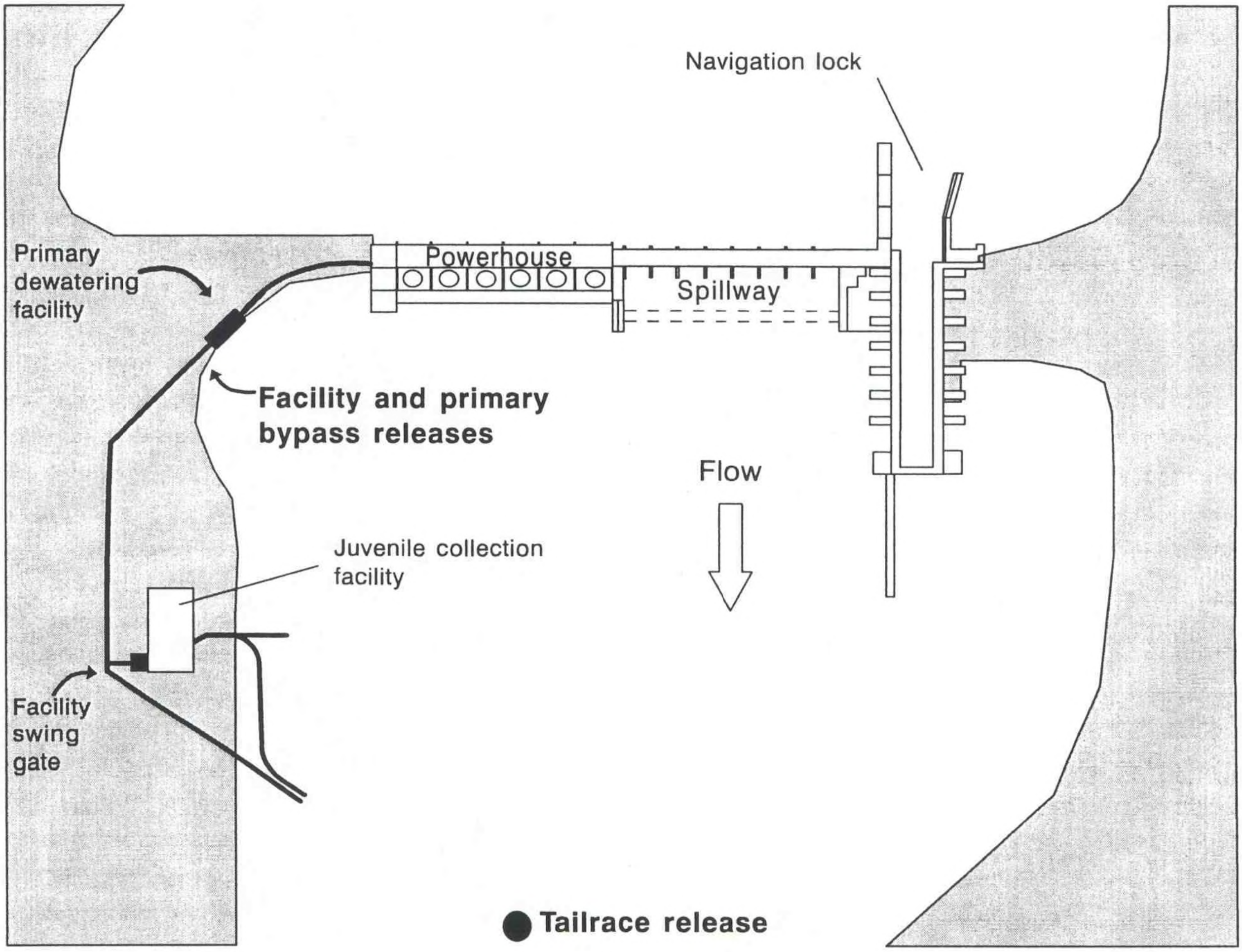

Figure 1. Schematic of Lower Monumental Dam, Snake River, showing release locations in 1999.

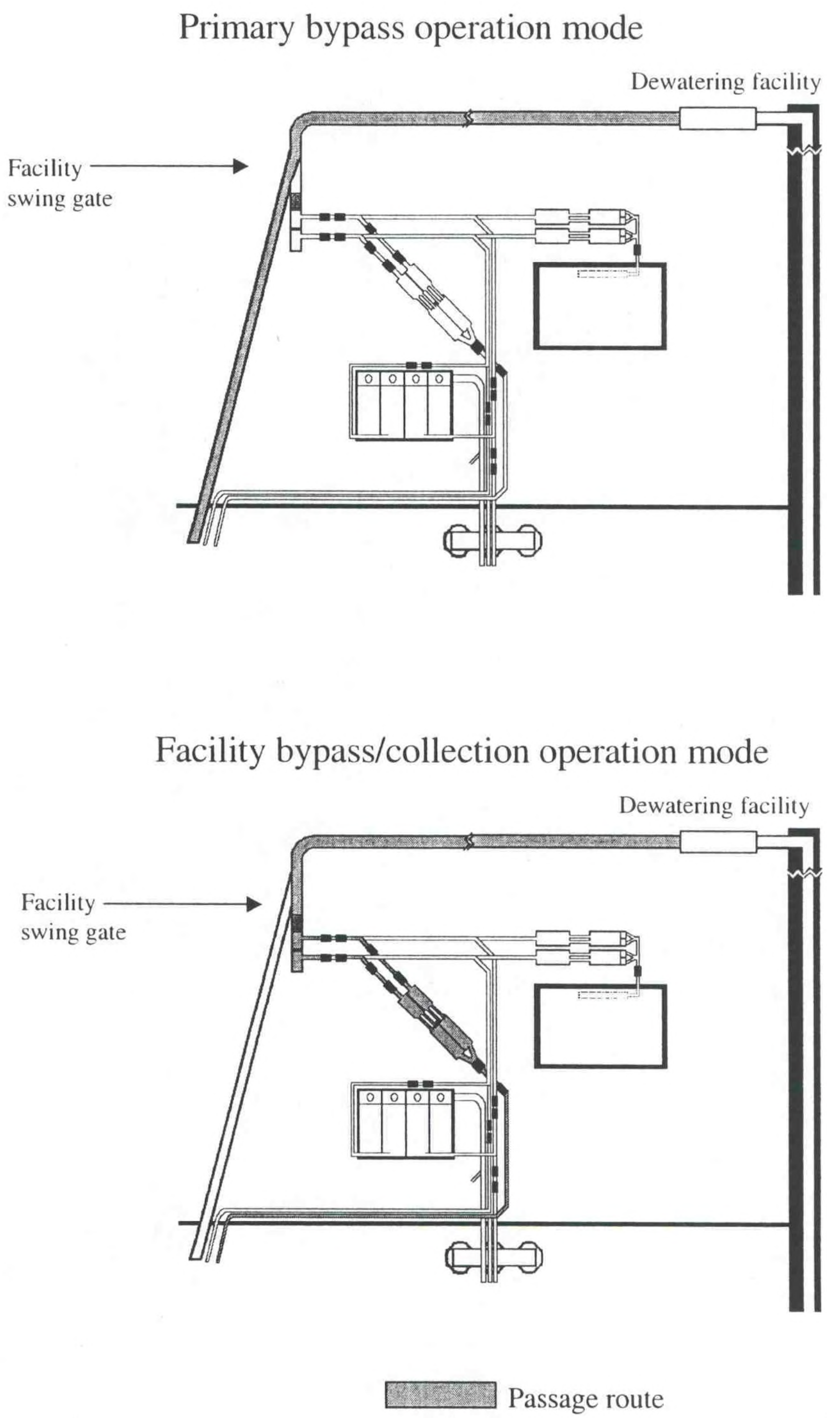

Figure 2. Schematics of Lower Monumental Dam bypass system showing the locations of the primary dewatering facility, facility swing gate, and routes of passage for fish passing through the bypass system during collection/bypass and primary bypass modes of operation.

Table 1. Lower Monumental Dam operations and discharge conditions during 1999 bypass survival evaluation.

Release date	Release times	Powerhouse (kcfs)	Spill (kcfs)	Total discharge (kcfs)
4 May	0810 - 0820	121.1	0	121.1
5 May	0755 - 0800	94.1	0	94.1
6 May	0730 - 0755	100.5	0	100.5
7 May	0740 - 0805	87.3	0	87.3
8 May	0730 - 0745	84.8	0	84.8
9 May	0720 - 0740	78.3	0	78.3
10 May	0727 - 0743	96.0	0	96.0
11 May	0728 - 0745	84.9	0	84.9
12 May	0714 - 0748	77.4	0	77.4
13 May	0750 - 0803	67.8	0	67.8
14 May	0737 - 0755	83.9	0	83.9
15 May	0735 - 0750	72.8	0	72.8
16 May	0720 - 0735	82.4	0	82.4
17 May	0750 - 0805	85.2	0	85.2
18 May	0740 - 0754	111.2	0	111.2
19 May	0805 - 0821	75.3	0	75.3

Statistical Analysis

Survival estimation was based on detections of individual PIT-tagged fish at the juvenile collection/detection facilities at McNary, John Day, and Bonneville Dams. Relative survival for treatment releases was estimated as the ratio of treatment recovery proportions to tailrace recovery proportions. Ratios between the geometric mean relative survival estimates of the two treatment release groups were evaluated using a weighted two-factor ANOVA with release day as a random (blocking) factor and treatment as a fixed factor. The weights were the inverses of the respective sample variances. The analysis was done on the natural log scale to normalize the relative survivals and the log-scale means were back-transformed. Residuals were examined to assess the performance of the analysis. To evaluate mixing of the release groups at downstream dams, we used contingency table tests (chi-square goodness-of-fit) to test for differences between distributions of daily detections at McNary Dam. At present, no formal analysis of adult returns of PIT-tagged fish used in this study is anticipated.

RESULTS

Tagging and Release Procedures

Hatchery yearling chinook salmon were PIT tagged daily at Lower Monumental Dam from 3 through 18 May. Tagging began after 25% of the hatchery yearling chinook salmon had passed Lower Monumental Dam and was completed when 79% of these fish had passed. In total, 96,237 juvenile salmonids were handled during this study in order to PIT tag 35,895 hatchery yearling chinook salmon (Tables 2 and 3). Tagging and handling mortality was less than 1.0% (Table 2), with overall tagging mortality and tag loss at 0.86 and 0.11%, respectively (Table 3). The majority of handling and tagging mortality during the study occurred on 5 May due to a combination of a higher composition of steelhead in the sample and anesthesia dosage. The anesthesia dosage was increased in order to handle the high numbers of steelhead resulting in some of the sample being over anesthetized.

Statistical Analysis

The collection/bypass release group sizes were adjusted by removing fish that were diverted to the raceways or to the Smolt Monitoring Program daily sample. We also removed fish that were detected at the separator but not detected again at Lower Monumental Dam and fish that were never detected at Lower Monumental Dam (Table 4). The majority (90.4%) of fish from the collection/bypass release groups passed through the bypass system, exited the bypass pipe to the river, and were included in the analysis.

Passage distributions at McNary Dam were similar among the three groups, which were released on the same day from various locations at Lower Monumental Dam, in 12 of 16 ternary

Table 2. Numbers of fish handled (N) and mortalities (Morts) during PIT tagging of hatchery yearling chinook salmon at Lower Monumental Dam for bypass survival evaluation studies during 1999. Overall percent mortality is also shown.

	Hatchery yearling chinook		Wild yearling chinook		Hatchery fall chinook		Wild fall chinook		Hatchery steelhead		Wild steelhead		Sockeye		Coho	
Date	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts
3 May	2,708	15	766	0	527	0	0	0	2,504	1	241	0	15	0	7	0
4 May	3,833	7	881	0	472	0	0	0	4,810	1	396	0	10	0	5	0
5 May	1,059	173	366	0	201	0	0	0	5,519	1	305	1	4	0	2	0
6 May	2,335	13	479	0	294	0	0	0	3,909	1	175	0	10	0	7	0
7 May	3,085	12	484	0	399	0	0	0	4,954	1	195	0	5	0	11	0
8 May	3,304	8	620	0	328	0	0	0	2,862	1	161	0	6	0	11	0
9 May	3,542	12	533	0	289	0	0	0	2,987	1	192	0	10	0	14	0
10 May	2,550	10	339	0	167	0	0	0	1,754	2	133	0	7	0	12	0
11 May	3,455	13	489	0	214	0	0	0	1,802	0	133	0	6	0	20	0
12 May	2,775	5	286	0	131	0	0	0	1,609	1	94	0	2	0	7	0
13 May	2,792	15	304	0	134	0	0	0	926	1	52	0	7	0	21	0
14 May	2,132	12	168	0	127	0	0	0	1,257	1	77	0	6	0	19	0
15 May	2,403	14	229	0	77	0	0	0	1,111	1	103	0	3	0	12	0
16 May	2,173	9	144	0	62	0	0	0	910	1	62	0	7	0	17	0
17 May	2,083	12	180	0	53	0	0	0	1,338	2	129	0	3	0	19	0
18 May	3,832	8	396	0	36	0	0	0	868	1	113	0	12	0	23	0
Total	44,061	338	6,664	0	3,511	0	0	0	39,120	17	2,561	1	113	0	207	0
% Mort		0.8		0.0		0.0		0.0		0.0		0.0		0.0		0.0

Table 3. Numbers of hatchery yearling chinook salmon PIT tagged, tagging mortality (Morts), tag loss, and numbers released (N) at Lower Monumental Dam for bypass survival evaluation studies during 1999.

Tag date	Tailrace				Collection bypass				Primary bypass				Overall tagging and release			
	Tagged	Morts	Tag loss	N	Tagged	Morts	Tag loss	N	Tagged	Morts	Tag loss	N	Tagged	Morts	Tag loss	N
3 May	742	1	0	741	748	11	2	735	748	2	2	744	2,238	14	4	2,220
4 May	601	2	0	599	617	3	1	613	621	0	1	620	1,839	5	2	1,832
5 May	745	79	0	666	722	49	0	673	717	43	0	674	2,184	171	0	2,013
6 May	672	5	1	666	688	0	0	688	686	6	3	677	2,046	11	4	2,031
7 May	771	3	2	766	771	5	0	766	776	3	3	770	2,318	11	5	2,302
8 May	772	4	1	767	776	0	1	775	774	3	0	771	2,322	7	2	2,313
9 May	771	2	0	769	776	4	0	772	773	3	0	770	2,320	9	0	2,311
10 May	770	6	0	764	776	2	0	774	773	0	2	771	2,319	8	2	2,309
11 May	768	0	1	767	775	7	1	767	774	3	0	771	2,317	10	2	2,305
12 May	767	1	0	766	776	2	1	773	774	0	0	774	2,317	3	1	2,313
13 May	774	4	2	768	773	5	1	767	775	5	2	768	2,322	14	5	2,303
14 May	732	3	1	728	739	4	2	733	743	2	5	736	2,214	9	8	2,197
15 May	771	0	0	771	774	11	0	763	774	0	0	774	2,319	11	0	2,308
16 May	738	0	1	737	742	5	0	737	744	3	0	741	2,224	8	1	2,215
17 May	771	3	1	767	777	6	1	770	774	0	0	774	2,322	9	2	2,311
18 May	755	1	0	754	761	4	2	755	758	2	1	755	2,274	7	3	2,264
Total	11,920	114	10	11,796	11,991	118	12	11,861	11,984	75	19	11,890	35,895	307	41	35,547
%		0.96	0.08			0.98	0.10			0.63	0.16			0.86	0.11	

Table 4. Detection history of collection bypass releases and adjusted collection bypass release numbers due to fish not detected, detected but history unknown, diverted into a raceway, or diverted to the Smolt Monitoring Program (SMP) daily sample for PIT-tagged hatchery yearling chinook salmon released at Lower Monumental Dam, 1999.

Release date	Number released	Not detected	Unknown	Raceway	SMP daily sample	Adjusted released size
4 May	735	59	11	7	115	543
5 May	613	38	2	2	26	545
6 May	673	61	3	5	14	590
7 May	688	14	1	29	38	606
8 May	766	15	5	1	12	733
9 May	775	28	8	157	57	525
10 May	772	18	0	5	5	744
11 May	774	21	1	3	1	748
12 May	767	39	0	12	14	702
13 May	773	34	0	8	0	731
14 May	767	57	2	5	0	703
15 May	733	16	1	7	4	705
16 May	763	24	0	4	2	733
17 May	737	82	0	5	5	645
18 May	770	10	0	7	4	749
19 May	755	20	0	7	2	726
Total	11,861	536	32	264	299	10,728

releases (Table 5 and Appendix B Figs. B1-B4). Four sets of groups had significantly different passage distributions at downstream dams; however, their arrival timing generally varied by less than a day. The four groups experienced similar passage conditions at downstream dams, and the small difference in timing most likely had little effect on the survival estimates. Because the distributions appeared to differ only slightly, we concluded that the homogeneity test was sensitive enough to pick up differences that were too small to actually affect the survival analyses of treatment effects.

Estimated relative survival was similar between fish released during collection/bypass (0.958, s.e. 0.010) and primary bypass modes (0.977, s.e. 0.010) (Table 6). ANOVA showed no significant differences among treatments ($F = 1.67$, $P = 0.215$) (Appendix C). Given the sample size used and the observed variability, a true difference in survival of 4.1% ($\alpha = 0.05$ and $\beta = 0.20$) could be detected.

Table 5. Tests of homogeneity of McNary Dam passage distributions for groups of PIT-tagged hatchery yearling chinook salmon released into the tailrace, the bypass system downstream from the primary dewatering screen during collection/bypass mode, and the bypass system downstream from the primary dewatering screen during primary bypass mode at Lower Monumental Dam. P values calculated using a Monte Carlo approximation of the exact method. Shaded cells indicate significant differences in passage timing among tests (significance level $\alpha = 0.10$).

Release Date	χ^2	Degrees of freedom	P value
4 May	26.27	26	0.4452
5 May	21.10	24	0.6685
6 May	29.46	26	0.2480
7 May	27.74	24	0.2258
8 May	25.15	22	0.2522
9 May	33.09	22	0.0328
10 May	20.64	24	0.7225
11 May	34.37	24	0.0333
12 May	31.54	20	0.0321
13 May	22.02	18	0.1963
14 May	23.90	20	0.2243
15 May	20.65	18	0.2720
16 May	17.12	20	0.6892
17 May	17.72	14	0.2098
18 May	25.18	16	0.0326
19 May	16.01	18	0.6441

Table 6. Complete release and detection data for bypass survival study including numbers released (N), numbers (Det.) and proportions (Prop.) detected, and proportion detected relative to tailrace reference group (Rel. to tailrace) for PIT-tagged hatchery yearling chinook salmon released at Lower Monumental Dam, 1999.

	Tailrace			Primary bypass				Collection bypass			
Release Date	N	Det.	Prop.	N	Det.	Prop.	Rel. to tailrace	N	Det.	Prop.	Rel. to tailrace
4 May	741	435	0.587	744	440	0.591	1.01	543	300	0.552	0.94
5 May	599	321	0.536	620	367	0.592	1.10	545	295	0.541	1.01
6 May	666	354	0.532	674	336	0.499	0.94	590	301	0.510	0.96
7 May	666	345	0.518	677	350	0.517	1.00	606	314	0.518	1.00
8 May	766	394	0.514	770	397	0.516	1.00	733	370	0.505	0.98
9 May	767	443	0.578	771	423	0.549	0.95	525	303	0.577	1.00
10 May	769	476	0.619	770	494	0.642	1.04	744	435	0.585	0.94
11 May	764	460	0.602	771	425	0.551	0.92	748	425	0.568	0.94
12 May	767	418	0.545	771	398	0.516	0.95	702	364	0.519	0.95
13 May	766	346	0.452	774	353	0.456	1.01	731	350	0.479	1.06
14 May	768	373	0.486	768	342	0.445	0.92	703	294	0.418	0.86
15 May	728	361	0.496	736	335	0.455	0.92	705	345	0.489	0.99
16 May	771	369	0.479	774	372	0.481	1.00	733	328	0.447	0.93
17 May	737	363	0.493	741	369	0.498	1.01	645	289	0.448	0.91
18 May	767	418	0.545	774	401	0.518	0.95	749	397	0.530	0.97
19 May	754	332	0.440	755	298	0.395	0.90	726	275	0.379	0.86
Overall	11,796	6,208	0.526	11,890	6,100	0.513	0.977*	10,728	5,385	0.502	0.958*

* Pooled estimates are unweighted averages of the independent estimates.

DISCUSSION

Juvenile bypass systems were first utilized to divert salmonid smolts around hydroelectric facilities on the lower Snake River in the 1970s (Marsh et al. 1995). However, Lower Monumental Dam was constructed without a collection channel, and therefore did not have a bypass system. During 1991, a collection channel was mined through Lower Monumental Dam, and a bypass system became operational in 1992. In 1993, a wet separator, sampling facility, transportation collection and holding components, and PIT-tag detection system were added to the bypass system. This new facility was evaluated by Marsh et al. (1995, 1996b) for acute mortality, descaling, and injuries during 1993-94. Although no major problems were discovered, the primary bypass pipe could not be throughly evaluated due to logistical difficulties of fish recovery.

Based on the results of our study, survival of juvenile chinook salmon was not significantly different between fish passing through the bypass system during collection/bypass mode and those passing during primary bypass mode. Estimated survival through the facility operating in collection/bypass mode (0.958) was slightly lower than during primary bypass mode (0.977) indicating that passage through the remainder of the facility (secondary dewaterer, fish separator, and PIT-tag detectors) may be contributing to mortality. However, the estimated difference in survival was small (0.019) and was not statistically significant. Furthermore, survival was not evaluated upstream from the primary dewatering facility; therefore, we could not evaluate mortality associated with the submersible traveling screens, gatewells, orifices, or collection channel. In addition, because all releases were made in the morning during periods of no spill, we could not evaluate bypass survival during spill conditions. Spill can cause the current to head back upstream near the bypass outfall at Lower Monumental Dam, and this could affect mortality in juvenile passage.

Among previously conducted studies of survival through bypass systems, Gilbreath et al. (1993) reported that the overall recovery percentage for bypass-released groups of juvenile chinook salmon was 7.6% less than for turbine-released groups and 8.3% less than for tailrace-released groups at Bonneville Dam Second Powerhouse. At Little Goose Dam, survival during 1994 was 0.994 (s.e. 0.023) for PIT-tagged hatchery yearling chinook salmon and 1.000 (s.e. 0.097) for hatchery steelhead. In 1995, survival was 0.979 (s.e. 0.031) for fish released into the Little Goose Dam collection channel (Muir et al. 1995, 1996). At Lower Monumental Dam, survival for PIT-tagged hatchery yearling chinook salmon was 0.936 (s.e. 0.033) in 1994 and 0.954 (s.e. 0.034) in 1995, and survival for hatchery steelhead released into the collection channel was 0.977 (s.e. 0.025) in 1994 and 0.929 (s.e. 0.060%) in 1995 (Muir et al. 1995, 1996). At Little Goose Dam in 1997, Muir et al. (1998) estimated survival for hatchery steelhead passing through the entire bypass system at 0.953 (s.e. 0.016)(fish were released in front of the trashrack and guided into the bypass system by an extended bar screen). None of these studies compared the survival of fish passing through the bypass system during collection/bypass vs. primary bypass modes of operation.

Estimates of bypass survival from this study are similar to estimates from earlier studies of survival through bypass systems at Lower Monumental (Muir et al. 1995, 1996) and Little Goose Dams (Muir et al. 1998), with survival slightly lower than previously found (bypass survival has been generally assumed to be 98-100%). Since little mortality is found within the facility during routine smolt monitoring, the most likely location of substantial mortality is near the bypass outfall.

RECOMMENDATIONS

The results of this study do not indicate the need for additional evaluation of survival for juvenile salmonids within the bypass system downstream from the primary dewatering facility at Lower Monumental Dam. However, juvenile salmonid survival within the bypass system upstream from the dewatering facility was not evaluated, nor was bypass survival evaluated during periods of spill.

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APPENDIX A:

Sample Size Estimation

Sample sizes were determined by evaluating data of detections of PIT-tagged hatchery chinook salmon at Snake and Columbia river dams during 1997 and 1998. Detection probabilities for PIT-tagged hatchery yearling chinook salmon known to have survived to the tailrace of Lower Monumental Dam, and detected at least once at McNary, John Day, or Bonneville Dams were 43% and 58% in 1997 and 1998, respectively. For sample size calculations, we used two alternative recovery percentages, 58% representing expected recovery rates in a low-flow, relatively low-spill year similar to 1998, and 43% representing a typical high-spill year similar to 1997. Using releases of 700 fish per location, then

$$b = \frac{8 * 2 * MSE}{d^2 * p^2}$$

where **b** = the number of 700-fish release groups.

8 = the square of the sum of the t-values corresponding to $\alpha = 0.05$ and $\beta = 0.20$.

MSE = the expected mean squared error term of the ANOVA.

d = the desired detectable difference (proportional change in recovery percentage).

p = the overall mean recovery proportion.

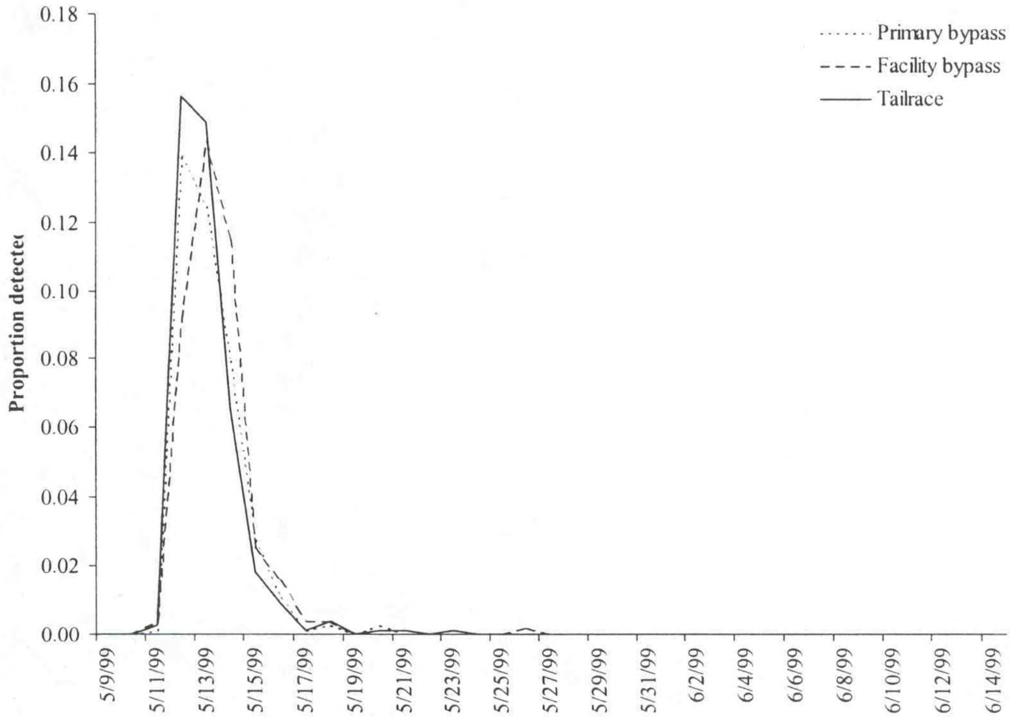
For detectable differences of 0.03, 0.04, or 0.05, the required number of 700-fish release groups under high spill is 43 (42.5 rounded to 43), 24 (23.9 rounded to 24), and 16 (15.3 rounded to 16), respectively (Table 1), using an expected ***MSE*** of 0.000442 (based on 1997 and 1998 data). To detect a 0.05 difference in recovery proportion between the release sites under high spill (and to detect a 0.04 difference under low spill), approximately 11,200 fish will be needed per release site, for a total of 33,600 hatchery yearling chinook salmon.

Appendix Table A1. The number of release groups (700 hatchery chinook/group) required per location and the total number of fish required (3 locations) for Lower Monumental Dam bypass survival evaluation.

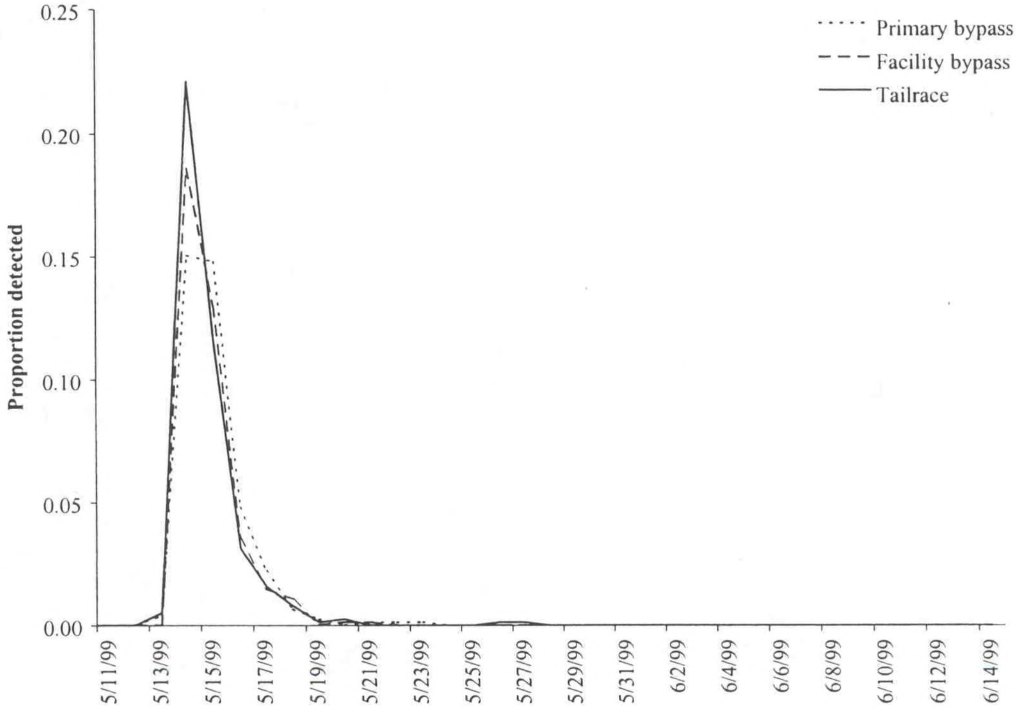
Detectable difference	Recovery proportion	Number of release groups	Total number of fish required
3%	0.58	23.4	50,400
4%	0.58	13.1	29,400
5%	0.58	8.4	18,900
3%	0.43	42.5	90,300
4%	0.43	23.9	50,400
5%	0.43	15.3	33,600

APPENDIX B:

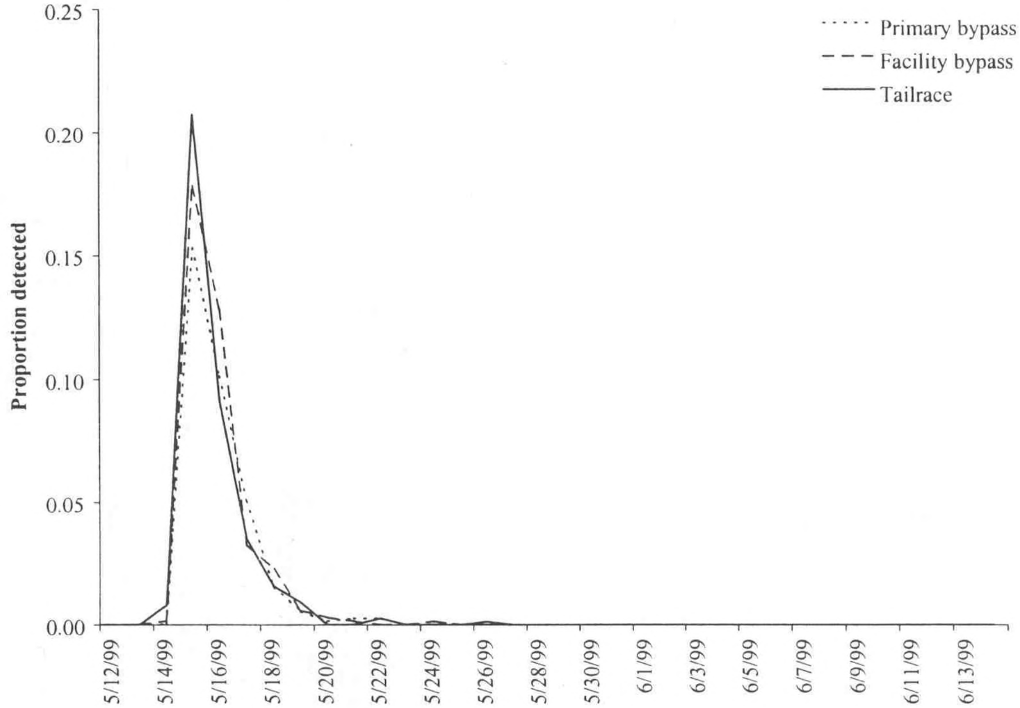
McNary Dam Passage Distributions for Release Groups with Significantly Different Passage Timing



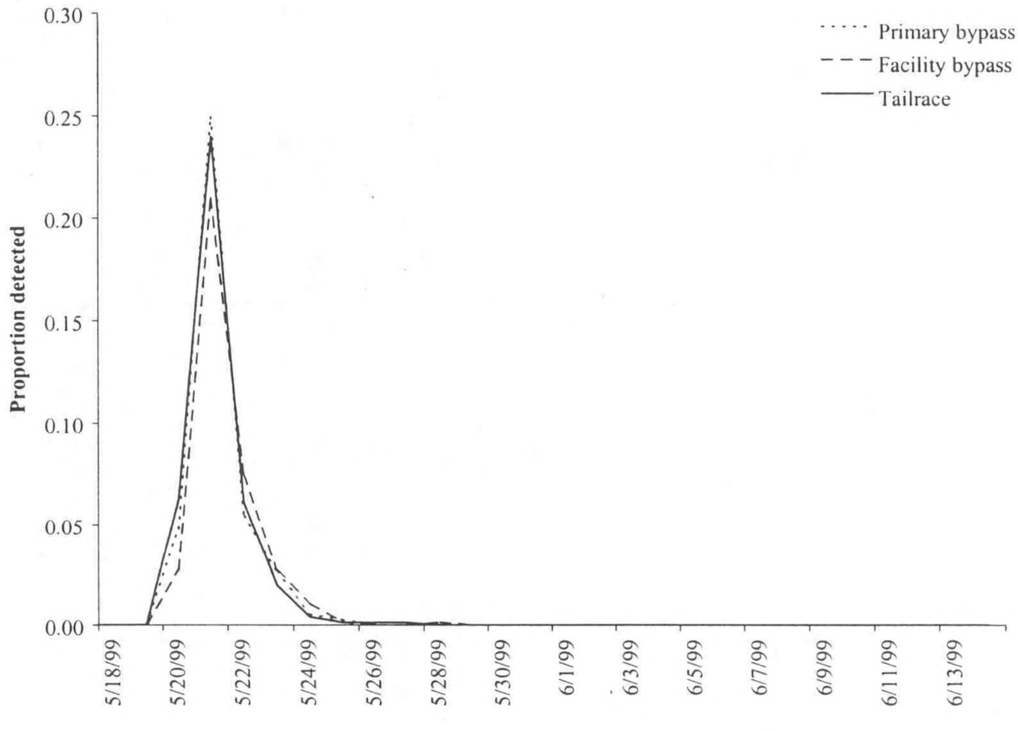
Appendix Figure B1. Passage distribution at McNary Dam for PIT-tagged hatchery yearling chinook salmon released at Lower Monumental Dam on 9 May 1999.



Appendix Figure B2. Passage distribution at McNary Dam for PIT-tagged hatchery yearling chinook salmon released at Lower Monumental Dam on 11 May 1999.



Appendix Figure B3. Passage distribution at McNary Dam for PIT-tagged hatchery yearling chinook salmon released at Lower Monumental Dam on 12 May 1999.



Appendix Figure B4. Passage distribution at McNary Dam for PIT-tagged hatchery yearling chinook salmon released at Lower Monumental Dam on 18 May 1999.

APPENDIX C:

ANOVA for Estimated Relative Survival of Treatment Groups

Appendix Table C1. Relative collection bypass and primary bypass weighted survival estimates (weights inverse of the respective sample variances) on the natural log scale (to normalize the relative survivals) and the back transformed means.

Release date	Log scale mean	Back transformed mean
4 May	-0.02	0.98
5 May	0.06	1.06
6 May	-0.05	0.95
7 May	0.00	1.00
8 May	-0.01	0.99
9 May	-0.03	0.97
10 May	-0.01	0.99
11 May	-0.07	0.93
12 May	-0.05	0.95
13 May	0.03	1.03
14 May	-0.12	0.89
15 May	-0.05	0.95
16 May	-0.03	0.97
17 May	-0.04	0.96
18 May	-0.04	0.96
19 May	-0.13	0.88
Overall		
Primary bypass	-0.03	0.97
Collection bypass	-0.04	0.96

Appendix Table C2. Weighted two-factor ANOVA of collection bypass and primary bypass survival estimates with release date as a random (blocking) factor and treatment as a fixed factor.

Source	Degrees of freedom	Adjusted sum of squares	Adjusted mean square	F	P
Release date	15	22.725	1.515	2.28	0.061
Treatment	1	1.112	1.112	1.67	0.215
Error	15	9.972	0.665		
Total	31	33.903			