

March 2000

**SURVIVAL ESTIMATES FOR THE PASSAGE
OF JUVENILE SALMONIDS THROUGH SNAKE
& COLUMBIA RIVER DAMS & RESERVOIRS, 1998**

Annual Report 1998



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EXECUTIVE SUMMARY

In 1998, the National Marine Fisheries Service and the University of Washington completed the sixth year of a study to estimate survival of juvenile salmonids (*Oncorhynchus* spp.) passing through dams and reservoirs on the Snake and Columbia Rivers. Actively migrating steelhead smolts (*O. mykiss*) were collected at Lower Granite Dam, tagged with passive integrated transponder (PIT) tags, and released to continue their downstream migration. Steelhead (hatchery and wild) were PIT tagged and released in proportion to the number arriving at the dam. We did not PIT tag any yearling chinook salmon (*O. tshawytscha*) in 1998 because sufficient numbers for survival estimation were PIT-tagged and released from Lower Granite Dam for the Transportation Evaluation Study and from Snake River Basin hatcheries. PIT-tagged smolts were detected at interrogation facilities at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams. PIT-tagged smolts were also detected using the PIT-tag trawl operated in the Columbia River estuary, and PIT tags were recovered from bird colonies in the Columbia River estuary. Survival estimates were calculated using the Single-Release (SR) Model. At McNary Dam, we evaluated post-detection bypass survival for yearling chinook salmon (a test of a SR Model assumption).

Research objectives in 1998 were 1) to estimate reach and project survival in the Snake River throughout the steelhead and yearling chinook salmon migrations, 2) to evaluate the survival-estimation models under prevailing operational and environmental conditions in the Snake River, and 3) to estimate post-detection bypass survival for yearling chinook salmon at McNary Dam.

This report provides reach survival and travel time estimates for PIT-tagged hatchery and wild juvenile steelhead and yearling chinook salmon in the Snake and Columbia Rivers during 1998. Estimates of post-detection bypass survival for yearling chinook salmon at McNary Dam are also reported. Results are reported primarily in the form of data tables and figures with minimal description of methods and analysis. Detailed information on the methodology and statistical models used for this report is provided in five previous annual reports on this study, which are cited here.

Precise survival estimates for most of the 1998 steelhead and yearling chinook salmon migrations were obtained. Hatchery fish (78% of steelhead in the analysis and 83% of yearling chinook salmon) and wild fish (22% of steelhead and 17% of yearling chinook salmon) were combined in the analyses. Estimated survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam averaged 93.0% for steelhead and 99.1% for yearling chinook salmon. From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 88.9% and 85.3% for steelhead and yearling chinook salmon, respectively. From Lower Monumental Dam tailrace to McNary Dam tailrace, estimated survival averaged 79.7% and 91.5% for steelhead and yearling chinook salmon, respectively; and from McNary Dam tailrace to John Day Dam tailrace, estimated survival averaged 83.1% and 82.2% for steelhead and yearling chinook salmon, respectively. From John Day Dam tailrace to Bonneville Dam tailrace, estimated survival averaged 93.5% for steelhead. Survival could not be estimated below

John Day Dam for yearling chinook salmon because detections in the lower river were not sufficient. The overall estimate of steelhead survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 50.0%.

At McNary Dam, post-detection bypass survival for yearling chinook salmon was 94.8% (s.e. 2.65).

Analyses of relationships among survival probabilities, travel times, and environmental factors will be published at a later date, primarily in peer-reviewed journals.

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INTRODUCTION

Survival estimates for juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers are essential to develop effective strategies for recovering depressed stocks. Many current management strategies, however, rely on outdated estimates of system survival (Raymond 1979, Sims and Ossiander 1981) that lacked statistical precision and that were derived in a river system considerably different from today's (Williams and Matthews 1995). Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions, and under conditions projected for the future, are necessary to develop strategies that will optimize smolt survival during migration.

From 1993 through 1997, the National Marine Fisheries Service (NMFS) and the University of Washington (UW) demonstrated the feasibility of using three statistical models to estimate survival of juvenile salmonids tagged with passive integrated transponder (PIT) tags passing through Snake River dams and reservoirs (Iwamoto et al. 1994; Muir et al. 1995, 1996; Smith et al. 1998, Hockersmith et al. 1999). Evaluation of assumptions for these models indicated that all were generally satisfied, and accurate and precise survival estimates were obtained.

In 1998, NMFS and UW completed the sixth year of the study. Research objectives were 1) to estimate reach and project survival in the Snake River throughout the yearling chinook salmon and steelhead migrations, 2) to evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions in the Snake River, and 3) to estimate post-detection bypass survival for yearling chinook salmon at McNary Dam.

METHODS

Experimental Design

The Single-Release (SR) Model was used to estimate survival for releases of PIT-tagged yearling chinook salmon and steelhead from Snake River Basin hatcheries, traps, and from Lower Granite Dam in 1998 (Cormack 1964, Jolly 1965, Seber 1965). Iwamoto et al. (1994) presents background information and underlying statistical theory for the use of these methods in these settings.

During the 1998 migration season, automatic PIT-tag detectors (Prentice et al. 1990a,b,c) were operational in the juvenile bypass systems at Lower Granite (RKm 695), Little Goose (RKm 635), Lower Monumental (RKm 589), McNary (RKm 470), John Day (RKm 347) and Bonneville (RKm 234) Dams (Fig. 1). Further, the majority of PIT-tagged fish detected at dams below Lower Granite Dam were diverted back to the river by slide gates (rather than being barged or trucked downstream), which allowed for the possibility of detection of a particular fish at more than one downstream site. (Most PIT-tagged fish detected at Lower Granite Dam were transported for the multi-state comparative survival study in 1998).

We used records of downstream PIT-tag detections in the SR Model to estimate survival in the following reaches: from the point of release to Lower Granite Dam tailrace, from Lower Granite Dam tailrace to Little Goose Dam tailrace, from Little Goose Dam tailrace to Lower Monumental Dam tailrace, from Lower Monumental Dam tailrace to McNary Dam tailrace, from McNary Dam tailrace to John Day Dam tailrace, and (for steelhead) from John Day Dam tailrace to Bonneville Dam tailrace.

Lower Granite Dam Tailrace Release Groups

During 1998, steelhead were collected in the juvenile collection facility at Lower Granite Dam, PIT tagged, and released to the tailrace. Methods for collecting, tagging, and releasing steelhead were the same as used in past years of this study (Iwamoto et al. 1994; Muir et al. 1995, 1996; Smith et al. 1998; Hockersmith et al. 1999). Steelhead (both hatchery and wild) were PIT tagged in approximate proportion to their arrival at Lower Granite Dam throughout the migration season. No yearling chinook salmon were PIT tagged specifically for this study, because sufficient numbers were already tagged and released from Lower Granite Dam for the Transportation Evaluation Study and because large numbers were tagged for other studies upstream from Lower Granite Dam. Steelhead and yearling chinook salmon that were tagged above Lower Granite Dam, detected at Lower Granite Dam, and then returned to the tailrace were combined into daily “release groups” according to day of detection at Lower Granite Dam. These groups were then combined with the fish tagged and released each day at Lower Granite Dam. Daily tailrace release groups were then pooled into weekly groups. For these groups leaving Lower Granite Dam, we estimated survival from the Lower Granite Dam tailrace to McNary Dam tailrace.

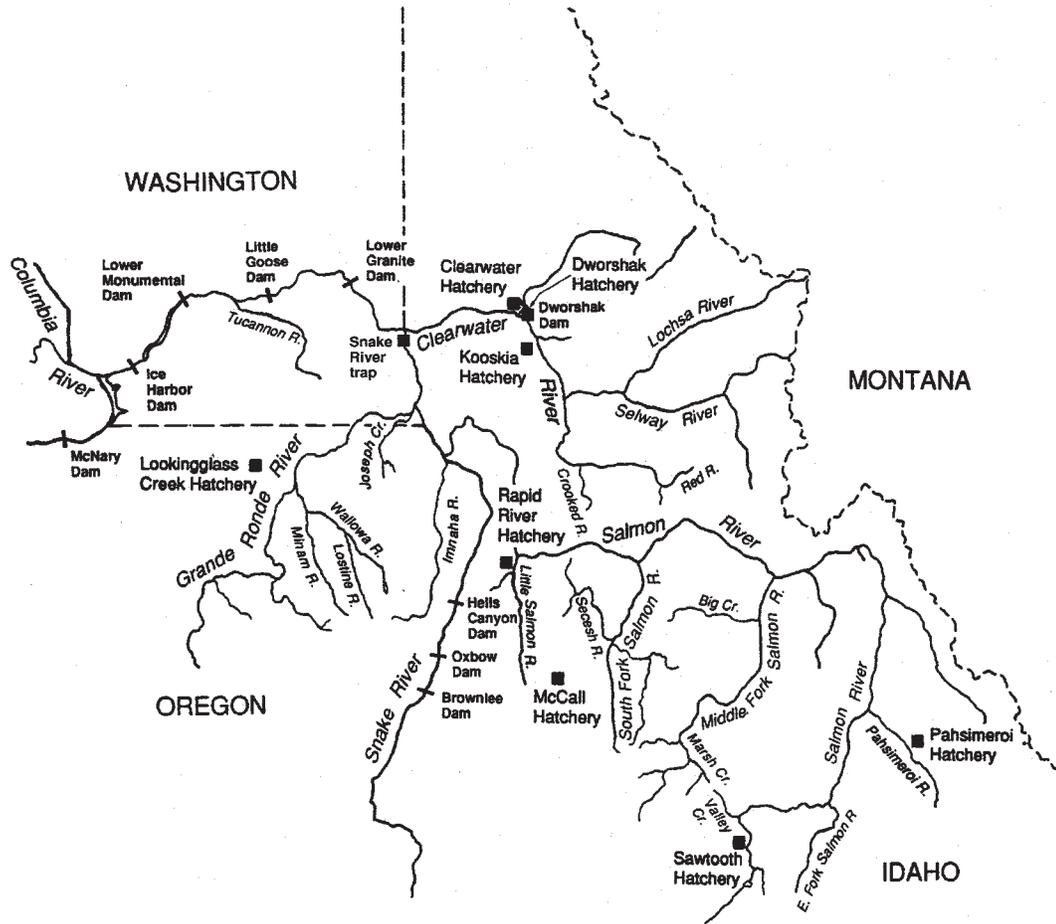


Figure 1. Study area showing release and detection sites.

McNary Dam Tailrace Release Groups

Steelhead and yearling chinook salmon that were tagged at any location above McNary Dam, detected at McNary Dam, and then returned to the tailrace were combined into daily “release groups” according to day of detection at McNary Dam. These daily tailrace release groups were then pooled into weekly groups. For weekly groups leaving McNary Dam, we estimated survival from McNary Dam tailrace to John Day Dam tailrace (both species), and from John Day Dam tailrace to Bonneville Dam tailrace (steelhead only, as yearling chinook salmon were not detected in sufficient numbers below John Day Dam to estimate survival).

Weighted mean estimates of steelhead survival from McNary Dam tailrace to Bonneville Dam tailrace were multiplied by the weighted mean estimate from Lower Granite Dam tailrace to McNary Dam tailrace to obtain an overall estimated mean survival probability from Lower Granite Dam tailrace to Bonneville Dam tailrace for steelhead.

Hatchery Releases

In 1998, most hatcheries in the Snake River Basin released PIT-tagged fish as part of research separate from the NMFS/UW survival study. We analyzed data from hatchery releases of PIT-tagged fish to provide estimates of survival for yearling chinook salmon from release to the tailrace of Lower Granite Dam and points downstream. In the course of characterizing the various hatchery releases, preliminary analyses were performed to determine whether data from multiple releases could be pooled to increase sample sizes. We neither intended nor attempted to analyze the experiments for which the hatchery releases were made.

For each hatchery, each set of releases was examined to determine suitability for survival analysis, and release groups were pooled where appropriate. The SR Model was applied to each resulting data set to estimate the same probabilities as for our Lower Granite Dam tailrace releases. Survival estimates were not calculated for releases of hatchery and wild chinook salmon PIT tagged as parr because release and detection numbers were not sufficient.

McNary Dam Post-detection Bypass Survival

To evaluate McNary Dam post-detection bypass survival (survival through the bypass system including outfall), we released a series of groups of PIT-tagged yearling chinook salmon between 2 May and 17 May. Both hatchery and wild yearling chinook salmon were collected at the McNary Dam juvenile collection system, sorted by Smolt Monitoring Program staff, and PIT tagged (Iwamoto et al. 1994). Fish handling methods such as water-to-water transfer and pre-anesthesia were used to minimize damage and stress to fish during the sorting and tagging process. Tagging personnel were rotated among tagging stations periodically to avoid handler bias. Tagged fish were passed through a water-filled pipe to 1,300-L holding tanks mounted on trucks. Holding tanks were aerated and supplied with flow-through water. Fish were held for a minimum of 24 hours for recovery and determination of post-tagging mortality. Holding density did not exceed 650 fish per tank.

On each release date, groups of tagged fish were released in two locations at McNary Dam: 1) into a gatewell (bypass release group); and 2) less than 1 km downstream from the dam to serve as a reference (tailrace release group). There were 15 replicates of yearling chinook salmon for each release location.

Bypass groups were released through a 10.2-cm-diameter hose that was 10 m in length. The hose was tethered so that fish entered the center of the gatewell, approximately 1 m below the surface. Thirteen groups were released into gatewell 9C, 1 into 9B, and 1 into 8C. All bypass groups were released between 0700 and 0800 PST.

During the majority of bypass releases, PIT-tagged fish sorted into the “A side” of the juvenile separator were returned to the river through the juvenile bypass pipe, while fish in the “B side” of the separator were returned to the river through the barge loading line, due to debris blockage in the B-side bypass pipe. During this operating mode, about 40% of the yearling chinook salmon were returned to the river through the bypass pipe and 60% through the barge loading line (Paul Hofarth, Washington Department of Fish and Wildlife, pers. comm., July 1998). During two releases (13 and 17 May), the system was operated in primary bypass mode for several hours, during which time all PIT-tagged fish were returned directly to the river without passing through the separator.

Fish released in the tailrace were trucked downstream to the Umatilla Marina, transferred via 10.2-cm-diameter hose to a partially filled 1,300-L tank mounted on a barge, and taken back upstream to within 1 km of the bypass outfall for release (Fig. 2). To maximize the probability of mixing of bypass and tailrace groups at downstream dams, tailrace groups were released from 4 to 7 hours after the bypass groups (between 1145 and 1340 PST) to compensate for the time required to traverse the bypass system for fish released into the gatewell.

Data Analysis

Tagging and detection data were retrieved from the PIT Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission.¹ Data were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated where appropriate, and all eliminated PIT-tag codes were recorded with the reasons for their elimination. For each remaining PIT-tag code, we constructed a record (detection history) indicating dams where the tagged fish was detected and those where it was not detected. Methods for data retrieval, database quality assurance/control, and construction of capture histories were the same as those used in past years (Iwamoto et al. 1994; Muir et al. 1995, 1996; Smith et al. 1998, Hockersmith et al. 1999).

¹ Pacific States Marine Fisheries Commission, PIT Tag Operations Center, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97207.

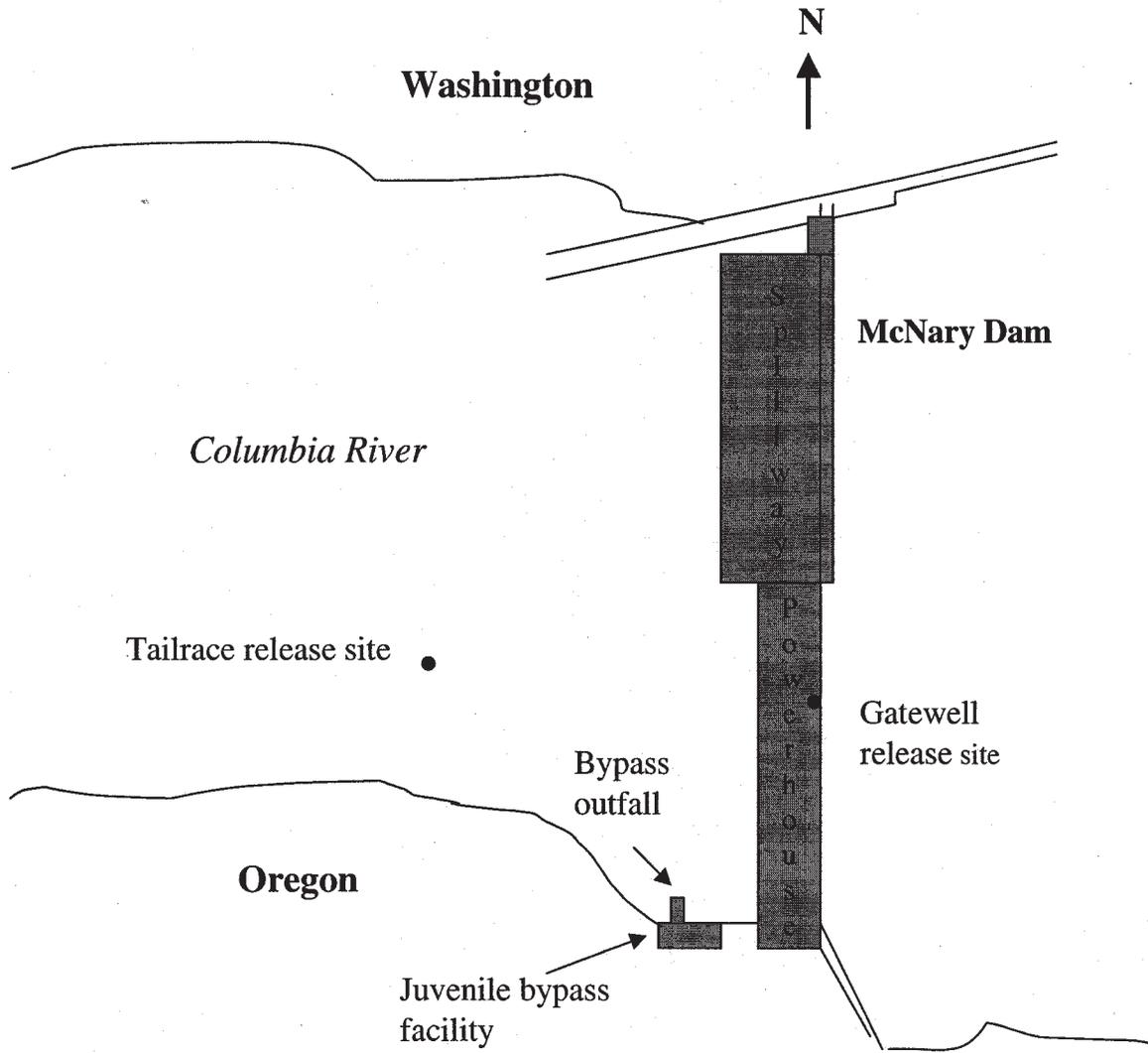


Figure 2. Diagram of McNary Dam showing locations of gatewell release site, bypass outfall, and tailrace release site.

Tests of Assumptions

As in past years, an important objective of the studies in 1998 was to test the statistical validity of the SR Model as applied to the data generated from PIT-tagged juvenile salmonids in the Snake and Columbia Rivers. Validity of the model was tested by evaluating critical assumptions and all were generally met during 1998.

Detection distributions of McNary Dam bypass and tailrace release groups were compared at John Day and Bonneville Dams using Chi-square tests of homogeneity to ensure that release groups had similar passage timing. When significant chi-square statistics were found, plots of the passage distributions were examined visually. Because the chi-square test is highly sensitive to violations of equal mixing, significant test statistics did not necessarily mean that the groups were not sufficiently mixed for valid survival estimation.

Survival Estimation

Estimates of survival probabilities under the SR Model are random variables, subject to sampling variability. When true survival probabilities are close to 1.0 and/or when sampling variability is high, it is possible for estimates of survival probabilities to exceed 1.0. For practical purposes, we considered estimates equal to 1.0 in these cases.

When estimates for a particular river section or passage route were available from more than one release group or pair of release groups, the estimates were typically summarized using a weighted average. The weight for each estimate was equal to the inverse of the corresponding estimated relative variance (coefficient of variation squared). The variance of an estimated survival probability from the SR Model is a function of the estimate itself, that is, lower survival estimates tend to have smaller estimated variance. Consequently, if inverse estimated absolute variance is used in weighting, lower survival estimates tend to have disproportionate influence, and the resulting weighted mean is biased toward the lower survival estimates.

All survival analyses were performed using the statistical computer program SURPH (“Survival with Proportional Hazards”) for analyzing release-recapture data, developed at the University of Washington (Skalski et al. 1993, Smith et al. 1994).

For McNary Dam bypass survival, the number of unique PIT-tag detections from bypass and tailrace release groups recorded from John Day Dam, Bonneville Dam, the PIT-tag trawl operated in the Columbia River Estuary, and PIT-tag recoveries from bird colonies in the Columbia River estuary were combined into a detection proportion for each release group. Relative survival of the bypass release group was estimated as the ratio of the detection proportion for the bypass group to that of the tailrace release group. The series of relative survival estimates was averaged using the geometric mean.

Travel Time

Travel times were calculated for steelhead and yearling chinook salmon for the following reaches 1) Lower Granite Dam to Little Goose Dam, 2) Little Goose Dam to Lower Monumental Dam, 3) Lower Monumental Dam to McNary Dam, 4) Lower Granite Dam to McNary Dam, and 5) Lower Granite Dam to Bonneville Dam. Travel time between any two dams was calculated for each fish detected at both dams as the number of days between last detection at the upstream dam and first detection at the downstream dam. Travel time included the time required to move through the reservoir to the forebay of the downstream dam and any delay associated with residence in the forebay before entry into the bypass system.

To facilitate comparisons among the five river sections, rate of migration in each section (kilometers per day) was also calculated. Lengths of the river sections are 60 km from Lower Granite Dam to Little Goose Dam, 46 km from Little Goose Dam to Lower Monumental Dam, 119 km from Lower Monumental to McNary Dam, 225 km from Lower Granite to McNary Dam, and 461 km from Lower Granite to Bonneville Dam. Rate of migration through a river section was calculated as the length of the section (km) divided by the travel time (days) (which included any delay at dams as noted above). For each group, the 20th percentile, median, and 80th percentile travel times and migration rates were determined from the distributions of travel times for individual fish.

The true complete set of travel times for a release group includes travel times of both detected and undetected fish. However, travel time cannot be determined for a fish that traverses a river section unless it is detected at both ends of the section. Therefore, travel time statistics are computed from travel times for detected fish only, and represent a sample of the complete set. During 1998, substantial spill volumes occurred at all dams, resulting in lower detection rates. From some release groups fish passed detector dams both before and after large spill volumes began. For these groups, the faster migrants were sampled more heavily than the slower migrants because faster migrants arrived at the dam during the earlier period of lighter spill, when detection rates were higher. Thus, the distributions of observed travel times for these groups were biased toward shorter travel times, or faster migration rates.

RESULTS

Tagging at Lower Granite Dam

Steelhead were PIT tagged at Lower Granite Dam from 6 April to 5 June (Table 1). A total of 23,320 hatchery steelhead and 6,844 wild steelhead were handled. Mortality from handling and tagging averaged less than 0.3%. An additional 15,525 steelhead (12,363 hatchery origin, 3,247 wild, 15 unknown) that were PIT tagged and released above Lower Granite Dam were detected and returned to the Snake River by the slide gates at Lower Granite Dam between 4 April and 12 June. Also between 4 April and 12 June, a total of 98,503 yearling chinook salmon (81,893 hatchery origin, 16,606 wild, and 4 unknown) that were PIT tagged and released upstream were detected and returned to the river or PIT tagged and released to the tailrace for the Transportation Evaluation Study at Lower Granite Dam.

Survival Estimation -- Lower Granite and McNary Dam Tailrace Release Groups

Survival probabilities were estimated for weekly groups of steelhead released in the tailrace at Lower Granite Dam for 10 consecutive weeks from 6 April through 14 June (including hatchery and wild steelhead PIT-tagged and released above Lower Granite Dam). Survival estimates (average of estimates for daily groups weighted by inverse estimated relative variance) from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.930 (s.e. 0.004) (Table 2). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.889 (s.e. 0.006). From Lower Monumental Dam tailrace to McNary Dam tailrace, estimated survival averaged 0.797 (s.e. 0.018). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, survival averaged 0.649 (s.e. 0.013). From McNary Dam tailrace to John Day Dam tailrace, estimated survival (weighted average of 6 weekly groups of fish detected and returned to McNary Dam tailrace) averaged 0.831 (s.e. 0.031) (Table 3). The weighted average survival estimate for steelhead from John Day Dam tailrace to Bonneville Dam tailrace was 0.935 (s.e. 0.103). The product of the average estimates from Lower Granite Dam to McNary Dam and from McNary Dam to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.500 (s.e. 0.054).

Survival probability estimates from Lower Granite Dam tailrace to McNary Dam tailrace were also calculated separately for hatchery and wild steelhead (Tables 4 and 5), and were found to be similar. Estimated survival probabilities for daily Lower Granite Dam release groups of steelhead (hatchery and wild combined) detected and returned to the river or PIT tagged and released into the tailrace of Lower Granite Dam are given in Appendix Table 1. Detection probability estimates for the weekly groups were also calculated (Tables 6 through 9).

Survival probability estimates were obtained for 10 consecutive weekly groups, 6 April through 14 June, of yearling chinook salmon (hatchery and wild combined) from Lower Granite Dam. Survival estimates (average of estimates for daily groups weighted by inverse estimated relative variance) from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.991 (s.e. 0.006) (Table 10). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.853 (s.e. 0.009). From Lower Monumental Dam tailrace to

Table 1. Numbers of steelhead handled (N) and mortalities while PIT-tagging at Lower Granite Dam for survival studies in 1998. Overall percent mortality is also shown.

Tag Date	<u>Hatchery steelhead</u>		<u>Wild steelhead</u>	
	N	Mortalities	N	Mortalities
06 Apr	68	0	31	0
07 Apr	86	0	13	0
08 Apr	79	0	21	0
09 Apr	84	0	20	0
10 Apr	83	2	18	0
11 Apr	80	2	19	0
12 Apr	79	0	20	0
13 Apr	74	0	26	0
14 Apr	81	2	19	0
15 Apr	77	0	23	0
16 Apr	77	0	21	0
17 Apr	74	0	24	0
18 Apr	66	0	34	0
19 Apr	74	0	28	0
20 Apr	257	0	148	0
21 Apr	308	1	94	1
22 Apr	298	0	106	0
23 Apr	270	1	134	0
24 Apr	245	0	156	1
25 Apr	233	0	173	0
26 Apr	260	0	144	2
27 Apr	505	0	347	0
28 Apr	431	0	423	0
29 Apr	588	0	263	0
30 Apr	402	1	450	0
01 May	1,049	1	228	0
02 May	1,082	4	193	0
04 May	1,061	0	107	0
05 May	961	0	207	0
06 May	909	2	254	1
07 May	857	0	312	0
08 May	943	4	224	0
09 May	941	3	229	3
11 May	875	1	176	0
12 May	1,092	3	219	0
13 May	1,112	3	200	1
14 May	994	2	320	0
15 May	965	2	350	0
18 May	582	6	120	0

Table 1. Continued.

Tag Date	<u>Hatchery steelhead</u>		<u>Wild steelhead</u>	
	N	Mortalities	N	Mortalities
19 May	621	2	80	0
20 May	600	3	107	1
21 May	498	1	205	1
22 May	590	1	112	2
26 May	463	2	66	0
27 May	447	1	78	0
28 May	456	2	69	0
29 May	435	1	91	0
01 Jun	187	1	23	0
02 Jun	180	3	30	1
03 Jun	177	1	33	1
04 Jun	186	1	24	0
05 Jun	178	2	32	1
Total	23,320	61	6,844	16
Percent		0.26%		0.23%

Table 2. Estimated survival probabilities for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to LMO	LGR to MCN
06 Apr - 12 Apr	758	0.859 (0.083)	0.731 (0.105)	0.892 (0.155)	0.628 (0.066)	0.560 (0.079)
13 Apr - 19 Apr	996	0.846 (0.055)	0.768 (0.066)	0.987 (0.142)	0.650 (0.038)	0.642 (0.086)
20 Apr - 26 Apr	3,794	0.936 (0.019)	0.867 (0.033)	0.793 (0.053)	0.812 (0.026)	0.643 (0.038)
27 Apr - 03 May	10,249	0.936 (0.007)	0.896 (0.012)	0.842 (0.031)	0.839 (0.009)	0.706 (0.025)
04 May - 10 May	11,694	0.930 (0.006)	0.889 (0.011)	0.782 (0.028)	0.827 (0.009)	0.646 (0.023)
11 May - 17 May	8,842	0.912 (0.008)	0.892 (0.015)	0.753 (0.038)	0.814 (0.012)	0.613 (0.030)
18 May - 24 May	5,341	0.936 (0.023)	0.806 (0.036)	0.919 (0.083)	0.754 (0.028)	0.693 (0.057)
25 May - 31 May	2,675	0.945 (0.023)	0.934 (0.041)	0.684 (0.047)	0.883 (0.032)	0.604 (0.035)
01 Jun - 07 Jun	1,230	0.804 (0.042)	0.924 (0.103)	0.755 (0.309)	0.743 (0.073)	0.561 (0.223)
08 Jun - 14 Jun	102	0.726 (0.095)	0.794 (0.153)	0.679 (0.538)	0.576 (0.095)	0.391 (0.307)
Weighted Mean ^a	44,349	0.930 (0.004)	0.889 (0.006)	0.797 (0.018)	0.825 (0.007)	0.649 (0.013)

^a Weighted means of the independent estimates for daily groups (6 April-31 May), with weights inversely proportional to respective estimated relative variances (see Appendix Table 1).

Table 3. Estimated survival probabilities for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of McNary Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	MCN to JDA	JDA to BON	MCN to BON
27 Apr - 03 May	388	0.789 (0.128)	0.924 (0.304)	0.729 (0.211)
04 May - 10 May	1,058	0.797 (0.053)	1.0 ^a (0.207)	0.804 (0.157)
11 May - 17 May	1,359	0.819 (0.057)	0.792 (0.135)	0.648 (0.101)
18 May - 24 May	1,249	0.875 (0.079)	1.0 ^a (0.404)	1.0 ^a (0.336)
25 May - 31 May	749	0.789 (0.070)	1.0 ^a (0.302)	0.867 (0.227)
01 Jun - 07 Jun	317	1.0 ^a (0.160)	0.535 (0.162)	0.580 (0.153)
Weighted Mean ^b	5,120	0.831 (0.031)	0.935 (0.013)	0.770 (0.081)

^a Model-based estimate greater than 1.0.

^b Weighted means of the independent estimates for weekly pooled groups (27 April-7 Jun), with weights inversely proportional to respective estimated relative variances.

Table 4. Estimated survival probabilities for juvenile hatchery steelhead detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to LMO	LGR to MCN
06 Apr - 12 Apr	602	0.828 (0.080)	0.747 (0.109)	0.896 (0.165)	0.619 (0.067)	0.555 (0.086)
13 Apr - 19 Apr	770	0.875 (0.063)	0.789 (0.075)	0.863 (0.128)	0.690 (0.044)	0.596 (0.082)
20 Apr - 26 Apr	2,364	0.902 (0.022)	0.927 (0.041)	0.778 (0.062)	0.837 (0.032)	0.651 (0.046)
27 Apr - 03 May	7,270	0.936 (0.008)	0.909 (0.013)	0.830 (0.034)	0.851 (0.011)	0.707 (0.028)
04 May - 10 May	9,595	0.928 (0.007)	0.894 (0.012)	0.776 (0.031)	0.829 (0.010)	0.644 (0.025)
11 May - 17 May	7,229	0.901 (0.008)	0.887 (0.016)	0.738 (0.040)	0.799 (0.013)	0.589 (0.030)
18 May - 24 May	4,363	0.930 (0.025)	0.789 (0.039)	0.871 (0.084)	0.733 (0.030)	0.639 (0.056)
25 May - 31 May	2,320	0.937 (0.025)	0.931 (0.043)	0.684 (0.050)	0.872 (0.033)	0.596 (0.037)
01 Jun - 07 Jun	1,082	0.790 (0.044)	0.937 (0.111)	0.725 (0.296)	0.741 (0.077)	0.537 (0.211)
08 Jun - 14 Jun	97	0.747 (0.096)	0.816 (0.166)	0.515 (0.384)	0.610 (0.108)	0.314 (0.230)
Weighted Mean ^a	35,692	0.921 (0.007)	0.896 (0.008)	0.785 (0.017)	0.825 (0.012)	0.644 (0.015)

^a Weighted means of the independent estimates for weekly pooled groups (6 April-14 Jun), with weights inversely proportional to respective estimated relative variances.

Table 5. Estimated survival probabilities for juvenile wild steelhead detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to LMO	LGR to MCN
06 Apr - 12 Apr	156	1.0 ^a (0.545)	0.588 (0.335)	0.691 (0.357)	0.777 (0.299)	0.536 (0.182)
13 Apr - 19 Apr	226	0.735 (0.108)	0.689 (0.137)	1.0 ^a (0.769)	0.507 (0.072)	0.888 (0.376)
20 Apr - 26 Apr	1,427	0.996 (0.038)	0.775 (0.056)	0.812 (0.099)	0.772 (0.047)	0.627 (0.067)
27 Apr - 03 May	2,973	0.935 (0.014)	0.866 (0.022)	0.886 (0.067)	0.809 (0.018)	0.717 (0.053)
04 May - 10 May	2,095	0.938 (0.015)	0.866 (0.025)	0.817 (0.075)	0.813 (0.020)	0.664 (0.059)
11 May - 17 May	1,612	0.964 (0.018)	0.922 (0.038)	0.844 (0.117)	0.889 (0.033)	0.750 (0.099)
18 May - 24 May	977	0.958 (0.057)	0.887 (0.102)	1.0 ^a (0.312)	0.850 (0.084)	1.0 ^a (0.243)
25 May - 31 May	355	1.0 ^a (0.069)	0.953 (0.124)	0.683 (0.139)	0.958 (0.104)	0.654 (0.112)
01 Jun - 07 Jun	148	0.913 (0.143)	0.819 (0.280)	NA NA	0.748 (0.222)	NA NA
08 Jun - 14 Jun	5	NA NA	NA NA	NA NA	NA NA	NA NA
Weighted Mean ^b	9,974	0.947 (0.008)	0.870 (0.013)	0.861 (0.048)	0.820 (0.018)	0.698 (0.030)

^a Model-based estimate greater than 1.0.

^b Weighted means of the independent estimates for weekly pooled groups (6 April-7 Jun), with weights inversely proportional to respective estimated relative variances.

Table 6. Estimated detection probabilities for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	758	0.213 (0.026)	0.232 (0.031)	0.200 (0.034)
13 Apr - 19 Apr	996	0.231 (0.021)	0.422 (0.030)	0.167 (0.027)
20 Apr - 26 Apr	3,794	0.394 (0.011)	0.357 (0.014)	0.186 (0.013)
27 Apr - 03 May	10,249	0.485 (0.006)	0.626 (0.008)	0.156 (0.007)
04 May - 10 May	11,694	0.534 (0.006)	0.678 (0.008)	0.187 (0.008)
11 May - 17 May	8,842	0.529 (0.007)	0.613 (0.010)	0.150 (0.009)
18 May - 24 May	5,341	0.318 (0.010)	0.287 (0.013)	0.088 (0.009)
25 May - 31 May	2,675	0.351 (0.013)	0.362 (0.016)	0.191 (0.015)
01 Jun - 07 Jun	1,230	0.351 (0.023)	0.419 (0.044)	0.055 (0.024)
08 Jun - 14 Jun	102	0.378 (0.071)	0.724 (0.118)	0.289 (0.236)

Table 7. Estimated detection probabilities for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of McNary Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	JDA	BON
27 Apr - 03 May	388	0.219 (0.042)	0.258 (0.079)
04 May - 10 May	1,058	0.415 (0.032)	0.184 (0.038)
11 May - 17 May	1,359	0.354 (0.028)	0.199 (0.034)
18 May - 24 May	1,249	0.278 (0.028)	0.085 (0.025)
25 May - 31 May	749	0.370 (0.038)	0.105 (0.030)
01 Jun - 07 Jun	317	0.329 (0.055)	0.196 (0.058)

Table 8. Estimated detection probabilities for juvenile hatchery steelhead detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	602	0.241 (0.030)	0.253 (0.035)	0.191 (0.036)
13 Apr - 19 Apr	770	0.224 (0.023)	0.429 (0.033)	0.174 (0.030)
20 Apr - 26 Apr	2,364	0.397 (0.014)	0.373 (0.018)	0.182 (0.016)
27 Apr - 03 May	7,270	0.487 (0.007)	0.636 (0.010)	0.163 (0.008)
04 May - 10 May	9,595	0.536 (0.006)	0.676 (0.009)	0.189 (0.009)
11 May - 17 May	7,229	0.528 (0.008)	0.625 (0.011)	0.157 (0.010)
18 May - 24 May	4,363	0.324 (0.011)	0.297 (0.014)	0.093 (0.010)
25 May - 31 May	2,320	0.352 (0.014)	0.369 (0.018)	0.195 (0.016)
01 Jun - 07 Jun	1,082	0.352 (0.025)	0.414 (0.046)	0.059 (0.026)
08 Jun - 14 Jun	97	0.386 (0.072)	0.703 (0.125)	0.379 (0.286)

Table 9. Estimated detection probabilities for juvenile wild steelhead detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	156	0.092 (0.043)	0.133 (0.060)	0.248 (0.095)
13 Apr - 19 Apr	226	0.265 (0.051)	0.394 (0.068)	0.134 (0.062)
20 Apr - 26 Apr	1,427	0.389 (0.020)	0.326 (0.024)	0.194 (0.024)
27 Apr - 03 May	2,973	0.481 (0.012)	0.600 (0.016)	0.137 (0.013)
04 May - 10 May	2,095	0.525 (0.014)	0.685 (0.019)	0.173 (0.019)
11 May - 17 May	1,612	0.531 (0.016)	0.561 (0.024)	0.120 (0.019)
18 May - 24 May	977	0.295 (0.023)	0.245 (0.028)	0.064 (0.017)
25 May - 31 May	355	0.345 (0.035)	0.320 (0.043)	0.164 (0.037)
01 Jun - 07 Jun	148	0.340 (0.066)	0.464 (0.145)	NA NA
08 Jun - 14 Jun	5	NA NA	NA NA	NA NA

Table 10. Estimated survival probabilities for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to LMO	LGR to MCN
06 Apr - 12 Apr	9,518	1.0 ^a (0.016)	0.804 (0.019)	0.886 (0.026)	0.829 (0.014)	0.734 (0.019)
13 Apr - 19 Apr	19,410	1.0 ^a (0.010)	0.777 (0.013)	0.907 (0.022)	0.830 (0.011)	0.752 (0.016)
20 Apr - 26 Apr	26,437	0.998 (0.007)	0.901 (0.013)	0.880 (0.022)	0.899 (0.011)	0.791 (0.017)
27 Apr - 03 May	19,964	0.969 (0.006)	0.855 (0.012)	0.964 (0.033)	0.828 (0.011)	0.798 (0.026)
04 May - 10 May	15,657	0.965 (0.006)	0.873 (0.011)	0.959 (0.028)	0.843 (0.009)	0.808 (0.023)
11 May - 17 May	4,939	1.0 ^a (0.013)	0.858 (0.026)	0.948 (0.074)	0.866 (0.023)	0.821 (0.061)
18 May - 24 May	1,418	0.905 (0.039)	0.834 (0.077)	0.977 (0.180)	0.755 (0.061)	0.737 (0.123)
25 May - 31 May	489	0.998 (0.088)	0.748 (0.095)	0.848 (0.180)	0.746 (0.067)	0.632 (0.123)
01 Jun - 07 Jun	122	0.863 (0.199)	0.955 (0.302)	0.790 (0.395)	0.824 (0.173)	0.651 (0.296)
08 Jun - 14 Jun	114	0.910 (0.110)	1.0 ^a (0.310)	NA NA	1.0 ^a (0.256)	NA NA
Weighted Mean ^b	98,412	0.991 (0.006)	0.853 (0.009)	0.915 (0.011)	0.846 (0.006)	0.770 (0.009)

^a Model-based estimate greater than 1.0.

^b Weighted means of the independent estimates for daily groups (2 April-31 May), with weights inversely proportional to respective estimated relative variances (see Appendix Table 1).

McNary Dam tailrace, estimated survival averaged 0.915 (s.e. 0.011). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, survival averaged 0.770 (s.e. 0.009). From McNary Dam tailrace to John Day Dam tailrace, estimated survival (weighted average of 7 weekly groups of fish detected and returned to McNary Dam tailrace) averaged 0.822 (s.e. 0.033) (Table 11). There were not enough detections or recoveries of tags below Bonneville Dam to estimate survival of yearling chinook salmon to Bonneville Dam tailrace.

Survival probabilities were estimated separately for hatchery and wild yearling chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace (Tables 12 and 13), and found to be similar. Estimated survival probabilities for daily release groups of yearling chinook salmon (hatchery and wild combined), detected and returned to the river or PIT-tagged and released into the tailrace of Lower Granite Dam, are given in Appendix 2. Detection probability estimates for the weekly groups were also calculated (Tables 14 through 17).

Survival Estimation -- Hatchery and Fish Trap Release Groups

For PIT-tagged hatchery yearling chinook salmon and steelhead released from Snake River Basin hatcheries in 1998, we estimated survival probabilities to the Snake River trap at the head of Lower Granite Reservoir and downstream dams (Tables 18 and 19) and detection probabilities at the detection sites (Tables 20 and 21). Survival probability estimates for juvenile salmonids PIT tagged and released from Snake River Basin traps in 1998 are shown in Table 22.

Travel Time

Travel time statistics for juvenile steelhead and yearling chinook salmon released in the tailrace of Lower Granite Dam are given in Tables 23 through 26. For both species, migration rates were highest in the lower river sections. Migration rates generally increased over time as flows, water temperatures, and levels of spill increased and, presumably, as fish became more smolted.

McNary Dam Post-detection Bypass Survival

Yearling chinook salmon were PIT tagged at McNary Dam for bypass survival evaluation from 1 to 16 May (Table 27). Overall, a total of 56,234 juvenile salmonids were collected to provide sufficient numbers of yearling chinook salmon for PIT tagging, resulting in an overall mortality rate of 1.5% (Table 27). Mortality for yearling chinook salmon from collection, handling, and PIT-tagging averaged 1.2% (Table 27). Spill levels during the releases ranged from 0% of total discharge during the first release to over 50% (Table 28). Of the total 17,873 yearling chinook salmon PIT tagged, 17,061 were released and used in the final analysis (Table 29). Fish were removed from the analysis if they were recaptured by the Smolt Monitoring Program at McNary Dam after release in the gatewell or if they died prior to release.

Of the 17,061 yearling chinook salmon released from McNary Dam, 16.4% were detected at John Day Dam, 9.6% were detected at Bonneville Dam, 1.4% were detected by the PIT tag trawl, and 1.6% were recovered on Rice Island (some were detected at more than one location).

Table 11. Estimated survival probabilities for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of McNary Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam.

Date at MCN	Number released	MCN to JDA
20 Apr - 26 Apr	1,868	0.694 (0.094)
27 Apr - 03 May	14,154	0.815 (0.056)
04 May - 10 May	9,741	0.889 (0.062)
11 May - 17 May	7,295	0.762 (0.042)
18 May - 24 May	4,977	0.976 (0.098)
25 May - 31 May	982	0.898 (0.210)
01 Jun - 07 Jun	166	0.614 (0.188)
Weighted Mean ^b	39,183	0.822 (0.033)

^a Model-based estimate greater than 1.0.

^b Weighted means of the independent estimates for weekly pooled groups (27 April-7 Jun), with weights inversely proportional to respective estimated relative variances.

Table 12. Estimated survival probabilities for hatchery yearling chinook salmon detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to LMO	LGR to MCN
06 Apr - 12 Apr	6,821	1.0 ^a (0.021)	0.783 (0.023)	0.882 (0.031)	0.825 (0.017)	0.728 (0.022)
13 Apr - 19 Apr	16,147	1.0 ^a (0.012)	0.779 (0.014)	0.894 (0.024)	0.836 (0.012)	0.747 (0.017)
20 Apr - 26 Apr	22,820	1.0 ^a (0.008)	0.894 (0.014)	0.891 (0.024)	0.895 (0.012)	0.797 (0.019)
27 Apr - 03 May	17,400	0.972 (0.007)	0.858 (0.014)	0.938 (0.035)	0.835 (0.012)	0.783 (0.027)
04 May - 10 May	13,424	0.967 (0.007)	0.879 (0.012)	0.957 (0.031)	0.850 (0.010)	0.814 (0.025)
11 May - 17 May	4,029	1.0 ^a (0.015)	0.878 (0.030)	0.939 (0.084)	0.881 (0.027)	0.827 (0.070)
18 May - 24 May	880	0.899 (0.056)	0.858 (0.119)	1.0 ^a (0.346)	0.771 (0.096)	0.883 (0.244)
25 May - 31 May	167	1.0 ^a (0.205)	0.661 (0.166)	0.895 (0.383)	0.740 (0.123)	0.663 (0.263)
01 Jun - 07 Jun	51	0.608 (0.282)	0.700 (0.385)	0.571 (0.414)	0.425 (0.134)	0.243 (0.168)
08 Jun - 14 Jun	43	0.767 (0.141)	1.0 ^a (0.380)	NA NA	0.837 (0.267)	NA NA
Weighted Mean ^b	81,782	0.994 (0.012)	0.855 (0.015)	0.910 (0.011)	0.853 (0.009)	0.773 (0.012)

^a Model-based estimate greater than 1.0.

^b Weighted means of the independent estimates for weekly pooled groups (6 April-14 Jun), with weights inversely proportional to respective estimated relative variances.

Table 13. Estimated survival probabilities for wild yearling chinook salmon detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to LMO	LGR to MCN
06 Apr - 12 Apr	2,697	0.990 (0.025)	0.847 (0.034)	0.896 (0.049)	0.838 (0.025)	0.751 (0.035)
13 Apr - 19 Apr	3,263	1.0 ^a (0.021)	0.768 (0.027)	0.964 (0.052)	0.807 (0.022)	0.778 (0.037)
20 Apr - 26 Apr	3,615	0.989 (0.015)	0.935 (0.033)	0.817 (0.050)	0.925 (0.029)	0.755 (0.039)
27 Apr - 03 May	2,564	0.955 (0.014)	0.836 (0.028)	1.117 (0.105)	0.798 (0.024)	0.892 (0.080)
04 May - 10 May	2,233	0.961 (0.015)	0.842 (0.025)	0.962 (0.069)	0.809 (0.020)	0.779 (0.054)
11 May - 17 May	909	1.0 ^a (0.028)	0.792 (0.048)	0.967 (0.157)	0.822 (0.043)	0.795 (0.123)
18 May - 24 May	538	0.926 (0.056)	0.830 (0.101)	0.864 (0.197)	0.769 (0.081)	0.664 (0.135)
25 May - 31 May	321	0.950 (0.095)	0.783 (0.114)	0.831 (0.202)	0.744 (0.079)	0.618 (0.137)
01 Jun - 07 Jun	71	1.0 ^a (0.274)	1.0 ^a (0.428)	0.873 (0.562)	1.0 ^a (0.315)	0.992 (0.569)
08 Jun - 14 Jun	71	1.0 ^a (0.163)	1.0 ^a (0.497)	NA NA	1.0 ^a (0.458)	NA NA
Weighted Mean ^b	16,282	0.985 (0.011)	0.842 (0.018)	0.927 (0.029)	0.829 (0.017)	0.771 (0.015)

^a Model-based estimate greater than 1.0.

^b Weighted means of the independent estimates for weekly pooled groups (6 April-42 Jun), with weights inversely proportional to respective estimated relative variances.

Table 14. Estimated detection probabilities for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	9,518	0.266 (0.006)	0.320 (0.007)	0.486 (0.013)
13 Apr - 19 Apr	19,410	0.349 (0.005)	0.303 (0.005)	0.453 (0.010)
20 Apr - 26 Apr	26,437	0.442 (0.004)	0.303 (0.005)	0.329 (0.008)
27 Apr - 03 May	19,964	0.532 (0.005)	0.438 (0.007)	0.198 (0.007)
04 May - 10 May	15,657	0.515 (0.005)	0.520 (0.007)	0.265 (0.008)
11 May - 17 May	4,939	0.517 (0.010)	0.441 (0.014)	0.179 (0.015)
18 May - 24 May	1,418	0.394 (0.022)	0.268 (0.025)	0.123 (0.023)
25 May - 31 May	489	0.238 (0.029)	0.401 (0.043)	0.156 (0.037)
01 Jun - 07 Jun	122	0.171 (0.054)	0.365 (0.090)	0.136 (0.073)
08 Jun - 14 Jun	114	0.328 (0.060)	0.421 (0.113)	NA NA

Table 15. Estimated detection probabilities for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of McNary Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviation: JDA-John Day Dam.

Date at MCN	Number released	JDA
20 Apr - 26 Apr	1,868	0.125 (0.019)
27 Apr - 03 May	14,154	0.088 (0.007)
04 May - 10 May	9,741	0.134 (0.010)
11 May - 17 May	7,295	0.228 (0.014)
18 May - 24 May	4,977	0.129 (0.014)
25 May - 31 May	982	0.137 (0.034)
01 Jun - 07 Jun	166	0.353 (0.116)

Table 16. Estimated detection probabilities for hatchery yearling chinook salmon detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	6,821	0.249 (0.007)	0.314 (0.009)	0.490 (0.016)
13 Apr - 19 Apr	16,147	0.340 (0.005)	0.296 (0.006)	0.454 (0.011)
20 Apr - 26 Apr	22,820	0.430 (0.005)	0.300 (0.005)	0.327 (0.008)
27 Apr - 03 May	17,400	0.519 (0.005)	0.429 (0.007)	0.202 (0.008)
04 May - 10 May	13,424	0.509 (0.006)	0.508 (0.008)	0.264 (0.009)
11 May - 17 May	4,029	0.511 (0.011)	0.424 (0.015)	0.180 (0.017)
18 May - 24 May	880	0.377 (0.029)	0.226 (0.032)	0.089 (0.027)
25 May - 31 May	167	0.198 (0.047)	0.401 (0.078)	0.133 (0.062)
01 Jun - 07 Jun	51	0.161 (0.098)	0.571 (0.187)	0.167 (0.152)
08 Jun - 14 Jun	43	0.364 (0.103)	0.500 (0.177)	NA NA

Table 17. Estimated detection probabilities for wild yearling chinook salmon detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	2,697	0.306 (0.012)	0.336 (0.014)	0.478 (0.024)
13 Apr - 19 Apr	3,263	0.390 (0.012)	0.336 (0.013)	0.452 (0.023)
20 Apr - 26 Apr	3,615	0.513 (0.011)	0.325 (0.013)	0.337 (0.020)
27 Apr - 03 May	2,564	0.614 (0.013)	0.493 (0.018)	0.173 (0.018)
04 May - 10 May	2,233	0.549 (0.013)	0.593 (0.018)	0.272 (0.022)
11 May - 17 May	909	0.544 (0.022)	0.509 (0.031)	0.175 (0.031)
18 May - 24 May	538	0.415 (0.033)	0.322 (0.040)	0.165 (0.039)
25 May - 31 May	321	0.259 (0.036)	0.405 (0.052)	0.168 (0.046)
01 Jun - 07 Jun	71	0.175 (0.064)	0.301 (0.099)	0.125 (0.083)
08 Jun - 14 Jun	71	0.308 (0.074)	0.364 (0.145)	NA

Table 18. Estimated survival probabilities for PIT-tagged yearling chinook salmon released from hatcheries in 1998. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; SNT-Snake River Trap; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Number released	Rel to SNT	SNT to LGR	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Clearwater	2,010	NA	NA	0.701 (0.016)	0.970 (0.034)	0.883 (0.051)	1.0 ^a (0.151)	0.643 (0.086)
Clearwater	499	NA	NA	0.585 (0.030)	0.938 (0.059)	0.917 (0.092)	0.895 (0.184)	0.450 (0.086)
Clearwater	500	NA	NA	0.754 (0.031)	0.935 (0.060)	0.919 (0.106)	0.820 (0.200)	0.531 (0.119)
Clearwater	500	NA	NA	0.696 (0.031)	0.930 (0.056)	0.907 (0.093)	0.723 (0.160)	0.424 (0.087)
Clearwater	300	NA	NA	0.725 (0.044)	1.0 ^a (0.092)	0.667 (0.077)	0.883 (0.174)	0.449 (0.086)
Kooskia	1,001	NA	NA	0.652 (0.024)	0.946 (0.050)	0.805 (0.065)	1.0 ^a (0.205)	0.638 (0.014)
Dworshak	47,704	0.688 (0.002)	1.0 ^a (0.008)	0.836 (0.006)	1.0 ^a (0.015)	0.761 (0.013)	0.928 (0.023)	0.528 (0.020)
Rapid R.	48,192	0.663 (0.025)	0.995 (0.038)	0.660 (0.004)	1.0 ^a (0.010)	0.850 (0.011)	0.979 (0.030)	0.543 (0.097)
McCall	47,460	0.629 (0.034)	0.930 (0.050)	0.585 (0.004)	0.987 (0.011)	0.847 (0.012)	0.945 (0.031)	0.487 (0.015)
Lookingglass ^b	19,169	0.667 (0.041)	1.0 ^a (0.063)	0.682 (0.006)	0.978 (0.015)	0.845 (0.016)	0.937 (0.038)	0.463 (0.014)
Lookingglass ^c	43,939	0.782 (0.045)	0.900 (0.052)	0.704 (0.005)	0.973 (0.012)	0.826 (0.014)	0.860 (0.029)	0.294 (0.075)
Pahsimeroi	993	NA	NA	0.428 (0.021)	1.0 ^a (0.075)	0.839 (0.117)	0.765 (0.215)	0.552 (0.016)
Sawtooth	499	NA	NA	0.601 (0.033)	0.931 (0.073)	0.875 (0.099)	1.0 ^a (0.273)	0.512 (0.127)

^a Model-based estimate greater than 1.0.

^b Released at Innaha River Weir

^c Released at Lookingglass Hatchery.

Table 19. Estimated survival probabilities for PIT-tagged juvenile steelhead released from hatcheries in 1998. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Clearwater	302	0.674 (0.031)	1.0 ^a (0.058)	0.909 (0.082)	0.950 (0.238)	0.593 (0.144)
Clearwater	300	0.690 (0.035)	0.943 (0.058)	0.975 (0.090)	0.667 (0.199)	0.423 (0.123)
Clearwater	4,495	0.491 (0.010)	0.962 (0.022)	0.949 (0.036)	0.706 (0.072)	0.316 (0.031)
Dworshak	1,997	0.869 (0.011)	0.929 (0.021)	0.943 (0.035)	0.769 (0.075)	0.585 (0.055)
Dworshak	500	0.683 (0.026)	0.999 (0.047)	0.845 (0.065)	0.660 (0.120)	0.381 (0.067)
Dworshak	501	0.772 (0.025)	1.0 ^a (0.048)	0.810 (0.062)	0.680 (0.127)	0.426 (0.077)
Dworshak	499	0.921 (0.019)	0.943 (0.031)	0.953 (0.049)	0.902 (0.143)	0.747 (0.115)

Table 20. Estimated detection probabilities for PIT-tagged yearling chinook salmon released from hatcheries in 1998. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: SNT-Snake River Trap; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Number released	SNT	LGR	LGO	LMO	MCN
Clearwater	2,010	NA	0.479 (0.016)	0.419 (0.018)	0.430 (0.025)	0.175 (0.026)
Clearwater	499	NA	0.463 (0.033)	0.494 (0.039)	0.462 (0.051)	0.290 (0.063)
Clearwater	500	NA	0.515 (0.031)	0.460 (0.037)	0.425 (0.051)	0.233 (0.058)
Clearwater	500	NA	0.462 (0.031)	0.519 (0.037)	0.486 (0.053)	0.237 (0.056)
Clearwater	300	NA	0.368 (0.037)	0.450 (0.047)	0.578 (0.059)	0.266 (0.063)
Kooskia	1,001	NA	0.437 (0.023)	0.457 (0.028)	0.451 (0.037)	0.219 (0.043)
Dworshak	47,704	0.00015 (0.00007)	0.383 (0.004)	0.358 (0.004)	0.315 (0.005)	0.350 (0.008)
Rapid R.	48,192	0.00260 (0.00030)	0.508 (0.004)	0.487 (0.005)	0.464 (0.006)	0.242 (0.008)
McCall	47,460	0.00258 (0.00032)	0.469 (0.004)	0.485 (0.005)	0.487 (0.007)	0.219 (0.008)
Lookingglass ^b	19,169	0.00235 (0.00045)	0.446 (0.006)	0.517 (0.007)	0.470 (0.009)	0.267 (0.011)
Lookingglass ^c	43,939	0.00256 (0.00031)	0.487 (0.004)	0.469 (0.005)	0.417 (0.007)	0.262 (0.009)
Pahsimeroi	993	NA	0.437 (0.028)	0.445 (0.036)	0.358 (0.050)	0.206 (0.058)
Sawtooth	499	NA	0.464 (0.035)	0.398 (0.039)	0.457 (0.052)	0.199 (0.055)

^a Released at Imnaha River Weir.

^b Released at Lookingglass Hatchery.

Table 21. Estimated detection probabilities for PIT-tagged juvenile steelhead released from hatcheries in 1998. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: SNT-Snake River Trap; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Number released	LGR	LGO	LMO	MCN
Clearwater	302	0.614 (0.037)	0.439 (0.042)	0.595 (0.055)	0.156 (0.047)
Clearwater	300	0.503 (0.039)	0.449 (0.042)	0.661 (0.062)	0.140 (0.051)
Clearwater	4,495	0.469 (0.012)	0.463 (0.014)	0.538 (0.021)	0.139 (0.016)
Dworshak	1,997	0.613 (0.013)	0.475 (0.016)	0.668 (0.023)	0.178 (0.021)
Dworshak	500	0.556 (0.030)	0.492 (0.034)	0.635 (0.048)	0.192 (0.044)
Dworshak	501	0.582 (0.028)	0.473 (0.033)	0.659 (0.047)	0.208 (0.047)
Dworshak	499	0.618 (0.025)	0.521 (0.028)	0.663 (0.037)	0.175 (0.034)

Table 22. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 1998. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to LMO	Rel to MCN
<u>Hatchery chinook salmon</u>								
Snake	25 Mar - 23 May	2,303	0.928 (0.013)	0.992 (0.025)	0.855 (0.037)	0.944 (0.090)	0.788 (0.030)	0.744 (0.066)
Salmon	17 Mar - 05 May	3,025	0.740 (0.012)	0.995 (0.023)	0.917 (0.041)	0.951 (0.094)	0.676 (0.027)	0.642 (0.059)
Imnaha	07 Apr - 23 Apr	2,000	0.761 (0.016)	0.994 (0.031)	0.853 (0.047)	0.809 (0.079)	0.645 (0.032)	0.522 (0.045)
<u>Wild chinook salmon</u>								
Snake	25 Mar - 23 May	961	0.915 (0.019)	1.0 ^a (0.040)	0.869 (0.057)	1.0 ^a (0.207)	0.818 (0.045)	1.0 ^a (0.160)
Salmon	17 Mar - 01 May	1,416	0.926 (0.016)	1.0 ^a (0.035)	0.813 (0.047)	0.963 (0.100)	0.769 (0.038)	0.740 (0.069)
Imnaha	27 Feb - 20 May	3,956	0.854 (0.010)	1.0 ^a (0.020)	0.846 (0.028)	0.982 (0.064)	0.740 (0.021)	0.727 (0.043)
<u>Hatchery steelhead</u>								
Snake	30 Mar - 23 May	4,274	0.926 (0.010)	0.910 (0.019)	0.876 (0.030)	0.833 (0.063)	0.739 (0.022)	0.615 (0.044)
Salmon	20 Apr - 22 May	1,117	0.879 (0.016)	0.920 (0.030)	1.0 ^a (0.062)	0.794 (0.117)	0.809 (0.046)	0.642 (0.088)
Imnaha	21 Apr - 16 Jun	3,859	0.831 (0.012)	0.924 (0.023)	0.840 (0.034)	0.937 (0.096)	0.645 (0.023)	0.605 (0.059)
<u>Wild steelhead</u>								
Snake	25 Mar - 23 May	1,088	0.919 (0.017)	0.934 (0.037)	0.841 (0.056)	0.920 (0.168)	0.722 (0.042)	0.665 (0.116)
Salmon	25 Mar - 22 May	112	0.892 (0.070)	0.871 (0.138)	0.766 (0.171)	1.0 ^a (1.143)	0.595 (0.109)	0.790 (0.667)
Imnaha	10 Mar - 11 Jun	3,106	0.856 (0.011)	1.0 ^a (0.025)	0.821 (0.035)	0.944 (0.093)	0.705 (0.026)	0.666 (0.061)

^a Model-based estimate greater than 1.0.

Table 23. Travel time statistics for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

Date at LGR	LGR to LGO (days)			LGO to LMO (days)			LMO to MCN (days)			LGR to MCN (days)						
	N	20%	80%	N	20%	80%	N	20%	80%	N	20%	80%				
06 Apr - 12 Apr	139	6.5	10.0	16.4	29	2.7	3.8	4.9	18	3.3	4.3	5.5	81	12.5	16.2	21.7
13 Apr - 19 Apr	195	5.6	7.9	11.3	65	2.7	3.6	5.5	50	3.6	4.3	5.3	101	12.0	14.6	17.7
20 Apr - 26 Apr	1,401	3.4	4.2	5.8	407	2.0	3.0	5.2	152	2.9	3.5	4.3	436	8.9	10.5	13.0
27 Apr - 03 May	4,655	3.3	4.0	5.7	2,372	1.8	2.8	4.7	634	2.3	2.8	3.7	1,022	7.7	9.6	13.1
04 May - 10 May	5,805	2.8	3.7	5.2	2,926	1.8	2.7	4.4	860	2.5	3.0	3.8	1,229	7.6	9.6	12.3
11 May - 17 May	4,265	2.7	3.4	4.5	2,208	1.7	2.4	4.1	473	2.3	2.8	3.3	747	7.0	8.5	10.6
18 May - 24 May	1,590	2.7	3.5	4.7	355	1.2	1.8	2.7	81	1.9	2.3	2.8	304	5.8	7.0	8.9
25 May - 31 May	887	2.0	2.2	3.1	270	1.0	1.4	2.3	111	1.8	2.2	2.8	295	4.4	5.3	6.6
01 Jun - 07 Jun	346	2.5	2.8	3.1	108	1.4	1.9	2.4	15	2.5	2.8	4.5	33	6.4	8.5	10.8
08 Jun - 14 Jun	28	2.8	3.1	4.5	14	1.4	2.2	3.0	8	2.1	2.7	3.4	11	7.0	7.8	8.8

Date at LGR	LGR to BON (days)		
	N	20%	80%
06 Apr - 12 Apr	101	20.5	24.8
13 Apr - 19 Apr	130	17.4	19.5
20 Apr - 26 Apr	393	13.9	16.5
27 Apr - 03 May	1,036	12.4	14.5
04 May - 10 May	872	12.4	14.6
11 May - 17 May	623	12.0	14.1
18 May - 24 May	364	9.4	10.9
25 May - 31 May	188	7.8	8.9
01 Jun - 07 Jun	28	9.4	11.5
08 Jun - 14 Jun	1	13.5	13.5

Table 24. Migration rate statistics for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

Date at LGR	LGR to LGO (km/day)				LGO to LMO (km/day)				LMO to MCN (km/day)				LGR to MCN (km/day)			
	N	20%	Med.	80%												
06 Apr - 12 Apr	139	3.7	6.0	9.2	29	9.3	12.0	16.8	18	21.7	27.8	35.8	81	10.4	13.9	18.1
13 Apr - 19 Apr	195	5.3	7.6	10.7	65	8.4	12.7	17.1	50	22.6	27.7	33.5	101	12.7	15.4	18.7
20 Apr - 26 Apr	1,401	10.4	14.2	17.5	407	8.8	15.2	22.7	152	27.7	33.7	41.0	436	17.3	21.4	25.4
27 Apr - 03 May	4,655	10.5	15.1	18.5	2,372	9.9	16.3	25.4	634	32.6	42.8	51.5	1,022	17.1	23.4	29.3
04 May - 10 May	5,805	11.5	16.2	21.6	2,926	10.6	17.4	25.8	860	31.6	40.3	48.0	1,229	18.2	23.3	29.6
11 May - 17 May	4,265	13.4	17.7	22.0	2,208	11.1	18.9	27.7	473	35.7	43.0	51.1	747	21.2	26.6	32.2
18 May - 24 May	1,590	12.7	17.4	22.0	355	16.8	25.4	38.0	81	42.5	52.2	63.0	304	25.2	32.2	38.5
25 May - 31 May	887	19.7	26.8	30.8	270	20.4	33.1	47.9	111	42.5	54.6	65.7	295	34.0	42.9	50.9
01 Jun - 07 Jun	346	19.1	21.6	24.3	108	19.3	24.2	32.2	15	26.5	42.3	47.6	33	20.8	26.4	35.1
08 Jun - 14 Jun	28	13.4	19.6	21.7	14	15.2	20.7	32.2	8	35.3	44.6	56.1	11	25.6	28.9	32.0

Date at LGR	LGR to BON (km/day)			
	N	20%	Med.	80%
06 Apr - 12 Apr	101	16.3	18.6	22.5
13 Apr - 19 Apr	130	19.7	23.7	26.4
20 Apr - 26 Apr	393	22.6	28.0	33.2
27 Apr - 03 May	1,036	24.9	31.9	37.3
04 May - 10 May	872	26.0	31.5	37.1
11 May - 17 May	623	27.9	32.8	38.6
18 May - 24 May	364	35.4	42.2	48.9
25 May - 31 May	188	40.3	51.8	59.3
01 Jun - 07 Jun	28	34.7	40.0	49.1
08 Jun - 14 Jun	1	34.2	34.2	34.2

Table 25. Travel time statistics for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

Date at LGR	LGR to LGO (days)			LGO to LMO (days)			LMO to MCN (days)			LGR to MCN (days)		
	N	20%	Med. 80%	N	20%	Med. 80%	N	20%	Med. 80%	N	20%	Med. 80%
06 Apr - 12 Apr	2,606	11.5	14.9 20.1	680	2.1	2.9 4.1	983	4.1	5.0 6.2	3,265	17.0	20.2 23.5
13 Apr - 19 Apr	7,233	7.2	9.4 12.3	1,561	2.1	2.7 3.7	1,851	3.8	4.8 5.9	6,398	13.4	15.9 18.9
20 Apr - 26 Apr	11,676	5.3	6.7 9.1	3,008	2.0	2.6 3.5	1,767	3.3	4.0 5.0	6,497	10.9	12.4 14.8
27 Apr - 03 May	10,279	5.0	6.3 8.0	3,487	1.6	2.1 3.0	1,154	2.9	3.7 5.0	2,846	10.2	12.3 15.3
04 May - 10 May	7,787	4.4	5.4 7.0	3,044	1.5	2.1 3.0	1,562	3.2	3.9 5.0	3,038	9.8	11.5 13.9
11 May - 17 May	2,578	4.8	6.2 8.2	938	1.5	2.0 3.0	283	2.8	3.6 4.8	692	9.9	11.5 13.7
18 May - 24 May	505	4.2	5.2 6.9	108	1.1	1.5 2.2	36	2.0	2.8 3.4	123	7.3	8.9 11.0
25 May - 31 May	116	3.2	4.6 5.8	35	1.0	1.5 2.1	21	2.0	2.3 3.1	47	6.8	8.5 10.6
01 Jun - 07 Jun	18	4.0	4.9 5.8	3	2.3	2.6 2.8	3	4.0	4.5 6.5	10	9.6	11.5 13.0
08 Jun - 14 Jun	26	3.9	4.8 6.0	12	1.6	1.9 2.7	2	2.5	2.6 2.6	8	8.1	10.0 10.7

Date at LGR	LGR to BON (days)		
	N	20%	Med. 80%
06 Apr - 12 Apr	789	23.9	26.5 30.0
13 Apr - 19 Apr	1,357	19.4	22.0 25.6
20 Apr - 26 Apr	1,772	16.0	18.4 21.8
27 Apr - 03 May	1,445	15.0	17.4 20.5
04 May - 10 May	1,172	14.4	16.5 18.9
11 May - 17 May	301	13.9	15.7 17.6
18 May - 24 May	66	10.5	11.7 14.4
25 May - 31 May	32	9.8	12.1 14.8
01 Jun - 07 Jun	8	12.2	13.4 15.7
08 Jun - 14 Jun	3	12.6	12.9 13.0

Table 26. Migration rate statistics for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT tagged and released into the tailrace of Lower Granite Dam in 1998. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

Date at LGR	LGR to LGO (km/day)			LGO to LMO (km/day)			LMO to MCN (km/day)			LGR to MCN (km/day)						
	N	20% Med.	80%	N	20% Med.	80%	N	20% Med.	80%	N	20% Med.	80%				
06 Apr - 12 Apr	2,606	3.0	4.0	5.2	680	11.1	15.8	21.7	983	19.1	23.8	29.3	3,265	9.6	11.1	13.2
13 Apr - 19 Apr	7,233	4.9	6.4	8.3	1,561	12.4	17.0	22.4	1,851	20.1	24.9	31.0	6,398	11.9	14.2	16.8
20 Apr - 26 Apr	11,676	6.6	8.9	11.3	3,008	13.0	18.0	23.4	1,767	23.7	29.5	35.8	6,497	15.2	18.1	20.6
27 Apr - 03 May	10,279	7.5	9.5	12.0	3,487	15.2	21.9	29.3	1,154	23.9	32.2	40.6	2,846	14.7	18.4	22.1
04 May - 10 May	7,787	8.5	11.2	13.6	3,044	15.2	22.2	30.5	1,562	23.7	30.2	37.7	3,038	16.2	19.6	22.9
11 May - 17 May	2,578	7.3	9.7	12.4	938	15.2	22.9	30.5	283	24.6	32.9	42.5	692	16.4	19.6	22.7
18 May - 24 May	505	8.7	11.5	14.2	108	21.1	31.7	43.0	36	35.2	41.9	59.2	123	20.5	25.3	30.7
25 May - 31 May	116	10.4	13.0	18.9	35	22.3	30.7	45.1	21	38.6	52.9	60.4	47	21.3	26.4	33.2
01 Jun - 07 Jun	18	10.3	12.2	15.0	3	16.6	17.7	20.2	3	18.3	26.6	29.8	10	17.4	19.6	23.5
08 Jun - 14 Jun	26	10.0	12.6	15.5	12	17.0	23.7	28.4	2	45.1	46.5	48.0	8	20.9	22.5	27.7

Date at LGR	LGR to BON (km/day)			
	N	20% Med.	80%	
06 Apr - 12 Apr	789	15.3	17.4	19.3
13 Apr - 19 Apr	1,357	18.0	21.0	23.7
20 Apr - 26 Apr	1,772	21.2	25.0	28.9
27 Apr - 03 May	1,445	22.5	26.5	30.7
04 May - 10 May	1,172	24.3	27.9	31.9
11 May - 17 May	301	26.2	29.3	33.1
18 May - 24 May	66	32.1	39.4	43.7
25 May - 31 May	32	31.1	38.1	46.9
01 Jun - 07 Jun	8	29.5	34.4	37.8
08 Jun - 14 Jun	3	35.4	35.6	36.5

Table 27. Numbers of salmonids handled during PIT tagging for bypass survival evaluation at McNary Dam during 1998. Mortalities (handling and tagging) are in parenthesis.

Tag date	Yearling chinook			Subyearling chinook			Steelhead			Coho			Sockeye		Total
	Hatchery	Unknown	Wild	Unknown	Wild	Hatchery	Hatchery	Wild	Hatchery	Unknown	Hatchery	Wild	Hatchery	Wild	
1 May	571 (15)	310 (3)	13 (0)	1 (0)	13 (0)	213 (2)	101 (0)	6 (0)	32 (0)	4 (0)	147 (4)	1,398			
2 May	1,866 (18)	1,327 (17)	30 (0)	8 (1)	30 (0)	391 (2)	204 (2)	17 (0)	80 (0)	26 (0)	714 (8)	4,663			
3 May	1,110 (10)	992 (9)	7 (1)	2 (0)	7 (1)	132 (2)	98 (2)	9 (0)	57 (0)	38 (0)	866 (8)	3,311			
4 May	1,592 (13)	1,549 (4)	2 (0)	3 (0)	2 (0)	182 (2)	207 (0)	29 (0)	127 (1)	65 (2)	1,047 (13)	4,803			
5 May	880 (20)	989 (14)	4 (0)	0 (0)	4 (0)	170 (0)	148 (2)	15 (0)	124 (2)	41 (1)	871 (27)	3,242			
6 May	585 (10)	646 (5)	12 (0)	6 (0)	12 (0)	194 (0)	114 (0)	19 (0)	131 (2)	42 (0)	611 (33)	2,360			
7 May	940 (15)	1,142 (13)	44 (0)	12 (0)	44 (0)	338 (2)	190 (1)	15 (0)	214 (0)	108 (0)	1,274 (60)	4,277			
8 May	525 (10)	753 (13)	31 (1)	22 (0)	31 (1)	267 (4)	91 (0)	23 (0)	142 (2)	141 (1)	1,342 (73)	3,337			
9 May	915 (13)	1,041 (7)	100 (1)	33 (1)	100 (1)	394 (1)	142 (1)	22 (0)	198 (2)	226 (4)	1,791 (34)	4,862			
10 May	1,040 (17)	1,099 (10)	143 (2)	87 (1)	143 (2)	375 (2)	109 (0)	19 (0)	178 (2)	172 (1)	1,724 (27)	4,946			
11 May	688 (18)	638 (3)	34 (1)	20 (1)	34 (1)	136 (0)	60 (0)	6 (0)	54 (0)	58 (0)	532 (18)	2,226			
12 May	1,639 (21)	1,563 (11)	41 (1)	56 (1)	41 (1)	497 (2)	126 (1)	16 (0)	126 (1)	125 (0)	1,550 (33)	5,739			
13 May	561 (10)	507 (3)	10 (0)	16 (0)	10 (0)	124 (0)	44 (2)	5 (0)	31 (0)	34 (0)	839 (9)	2,171			
14 May	927 (18)	869 (7)	30 (2)	43 (0)	30 (2)	256 (2)	89 (0)	8 (0)	63 (2)	47 (1)	534 (30)	2,866			
15 May	841 (16)	733 (11)	43 (0)	44 (1)	43 (0)	307 (1)	82 (0)	11 (0)	60 (1)	31 (0)	787 (27)	2,939			
16 May	990 (8)	865 (8)	39 (0)	30 (1)	39 (0)	267 (1)	95 (0)	9 (1)	55 (0)	28 (0)	716 (19)	3,094			
Total	15,670 (232)	15,023 (138)	583 (9)	383 (7)	583 (9)	4,243 (23)	1,900 (11)	229 (1)	1,672 (15)	1,186 (10)	15,345 (423)	56,234 (869)			

Table 28. Conditions at McNary Dam during juvenile bypass evaluation releases in 1998.
 Conditions measured two hours after bypass release.

Release date	Time	Total discharge (kcfs)	Spill (kcfs)	Turbine discharge (kcfs)	Tailrace elevation (ft)
2 May	1000	164.4	0.0	159.7	266.0
3 May	1100	252.3	90.9	156.7	267.0
4 May	1100	240.4	99.3	136.4	266.8
5 May	1100	287.4	136.3	146.4	267.4
6 May	1100	325.5	170.7	150.1	268.2
7 May	1100	338.9	165.0	169.2	268.6
8 May	1100	340.5	165.6	170.2	268.6
9 May	1000	378.8	205.5	168.6	269.0
10 May	1000	350.6	175.7	170.2	268.3
11 May	1000	258.1	99.0	154.4	267.0
12 May	1000	307.6	129.3	173.6	268.5
13 May	1000	314.6	150.0	159.9	267.9
15 May	1000	345.2	165.4	175.1	268.3
16 May	1000	307.9	129.3	173.9	267.9
17 May	1000	252.6	75.4	172.5	267.3

Table 29. Relative survival estimates for PIT-tagged yearling chinook salmon released at McNary Dam in 1998. The weighted geometric mean relative survival estimate used weights that were inversely proportional to the relative variances (i.e., coefficients of variation squared) of the individual estimates. The number of fish released, numbers detected, and median travel time to John Day Dam are also shown.

Release Date	Release Location	Release Number	John Day		Bonneville		Rice Island	Total	Detection Proportion	Relative Survival (%)	Median Travel Time to John Day Dam (days)
			Dam	Detections	Dam	Detections					
5/2/98	Forebay	600	58	62	6	132	0.220	120.9	3.9		
5/2/98	Tailrace	533	36	51	4	97	0.182		3.6		
5/3/98	Forebay	608	74	38	12	121	0.199	90.7	3.9		
5/3/98	Tailrace	538	53	47	13	118	0.219		4.0		
5/4/98	Forebay	610	58	41	12	112	0.184	91.1	3.8		
5/4/98	Tailrace	546	64	39	10	110	0.201		3.8		
5/5/98	Forebay	623	93	51	12	155	0.249	115.1	4.2		
5/5/98	Tailrace	546	65	34	9	118	0.216		4.1		
5/6/98	Forebay	548	89	38	12	133	0.243	89.3	3.9		
5/6/98	Tailrace	537	78	53	9	146	0.272		4.0		
5/7/98	Forebay	591	96	62	3	155	0.262	100.3	4.5		
5/7/98	Tailrace	547	80	63	8	143	0.261		4.8		
5/8/98	Forebay	548	82	57	9	138	0.252	113.6	4.6		
5/8/98	Tailrace	546	77	45	8	121	0.222		4.9		
5/9/98	Forebay	535	95	49	9	145	0.271	92.0	4.9		
5/9/98	Tailrace	567	109	63	13	167	0.295		4.5		
5/10/98	Forebay	561	109	64	8	177	0.316	101.1	4.9		
5/10/98	Tailrace	567	114	69	8	177	0.312		4.9		
5/11/98	Forebay	572	131	55	7	175	0.306	94.6	4.9		
5/11/98	Tailrace	569	121	70	10	184	0.323		4.9		
5/12/98	Forebay	573	108	52	7	154	0.269	87.0	5.6		
5/12/98	Tailrace	563	113	65	7	174	0.309		5.2		
5/13/98	Forebay	595	110	52	8	162	0.272	89.2	4.7		
5/13/98	Tailrace	567	101	74	8	173	0.305		5.0		
5/15/98	Forebay	573	98	55	11	155	0.271	81.2	5.0		
5/15/98	Tailrace	570	130	65	10	190	0.333		5.2		
5/16/98	Forebay	613	106	62	17	168	0.274	87.8	4.9		
5/16/98	Tailrace	570	129	46	13	178	0.312		4.9		
5/17/98	Forebay	613	112	63	10	164	0.268	93.0	4.9		
5/17/98	Tailrace	532	104	59	8	153	0.288		3.7		
Total		17,061	2,793	1,644	281	4,495	0.258	94.8 (s.e. 2.65)			

Median travel times to John Day Dam for individual release groups ranged from 3.6 to 5.6 days (Table 29). Passage distributions of bypass and tailrace release groups were significantly different for 5 of the 15 releases at John Day Dam and 2 of the 15 releases at Bonneville Dam (Tables 30 and 31). However, passage distributions did not appear to differ sufficiently to affect the resulting estimates of survival for any of the paired groups (Figures A1-A15). Estimated survival of fish released into the bypass system (into the gatewell) relative to survival of fish released into the tailrace averaged 94.8% (s.e. 2.65) (geometric mean) with a 95% confidence interval from 89.3 to 100.7% (Table 29).

Comparison of Survival Estimates, 1993-1998

Estimates of survival from Snake River Basin hatcheries to Lower Granite Dam tailrace were higher in 1998 than in 1997, and were similar to those obtained in earlier years. Over the years of this study, we have observed a consistent inverse relationship between the migration distance from the release site to Lower Granite Dam and the estimated survival through that reach (Fig. 3). For 1993-1998 estimates, the negative linear correlation between migration distance and estimated survival was significant ($R^2 = 61.1\%$, $P < 0.0001$).

For yearling chinook salmon, survival was slightly higher in 1998 than in previous years through most reaches, while for steelhead, survival was slightly lower in 1998 than in previous years through most reaches investigated (Fig. 4). From Lower Granite Dam tailrace to McNary Dam tailrace, average estimated survival for yearling chinook salmon was the highest obtained from 1995 to 1998, while for steelhead, it was the lowest over the same time period.

Average per-project survival (one "project" is one reservoir/dam combination) was estimated for each year of the study (2 to 5 projects, depending on the year). Estimated per-project survival was lowest in 1993 and 1994, the first 2 years of the study, and higher in later years after the spill program began (Fig. 5).

Table 30. Tests of homogeneity of John Day Dam passage distributions for PIT-tagged yearling chinook salmon released into the bypass or tailrace of McNary Dam in 1998. P values calculated using Monte Carlo approximation of the exact method.

Release Date	χ^2	Degrees of Freedom	P value
5/2/98	11.61	10	0.290
5/3/98	17.99	13	0.109
5/4/98	15.27	12	0.189
5/5/98	8.43	16	0.985
5/6/98	11.34	12	0.529
5/7/98	14.21	15	0.534
5/8/98	7.13	11	0.853
5/9/98	20.19	12	0.040
5/10/98	12.35	14	0.622
5/11/98	10.88	13	0.663
5/12/98	21.61	11	0.016
5/13/98	11.54	13	0.606
5/15/98	22.85	12	0.015
5/16/98	22.58	10	0.005
5/17/98	26.45	12	0.003

Table 31. Tests of homogeneity of Bonneville Dam passage distributions for PIT-tagged spring/summer chinook salmon released into the bypass or tailrace of McNary Dam in 1998. P values calculated using Monte Carlo approximation of the exact method.

Release Date	χ^2	Degrees of Freedom	P value
5/2/98	9.13	8	0.285
5/3/98	8.82	9	0.482
5/4/98	11.42	12	0.552
5/5/98	11.21	15	0.855
5/6/98	11.21	12	0.554
5/7/98	4.72	10	0.962
5/8/98	9.88	9	0.359
5/9/98	7.00	11	0.863
5/10/98	14.47	12	0.250
5/11/98	16.11	11	0.112
5/12/98	10.63	11	0.497
5/13/98	9.55	11	0.617
5/15/98	18.88	11	0.040
5/16/98	17.90	8	0.010
5/17/98	12.55	11	0.291

DISCUSSION

Results of the 1998 NMFS/UW survival study satisfied the research objectives: 1) to estimate reach and project survival in the Snake River throughout the yearling chinook and steelhead migrations, 2) to evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions in the Snake River, and 3) to estimate yearling chinook salmon post-detection bypass survival at McNary Dam.

Survival estimates throughout the 6 years of this study have generally been higher than estimates of survival obtained in the 1970s. Those studies used less sophisticated methods in a river system substantially different from today's (Williams and Matthews 1995). Management strategies should not rely on outdated system survival estimates. Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions and under conditions projected for the future is essential to develop strategies for optimizing smolt survival during migration.

Accurate and precise estimates of system survival from upstream release sites in the Snake River Basin to the tailraces of Lower Granite, Little Goose, Lower Monumental, or McNary Dams can be made using the SR, Modified Single Release (MSR), and Paired Release (PR) methodologies with the PIT-tag diversion systems in place and with sufficient release numbers. Estimates of survival can extend to the tailrace of John Day and Bonneville dams with sufficient sample sizes and PIT-tag interrogation at Bonneville Dam and other downstream locations such as the PIT-tag trawl and the Rice Island bird colony. Estimating survival over longer reaches will permit further exploration of relationships among smolt survival, smolt travel time, smolt quality, and environmental conditions encountered during migration. Such investigations are in progress, and the results will be published at a later date, primarily in peer-reviewed journals. Data collected in the first 6 years of this study provide valuable baseline information for evaluation of future management strategies.

CONCLUSIONS

1) Precise survival estimates were obtained for steelhead (hatchery and wild combined) from Lower Granite Dam to the tailraces of Little Goose, Lower Monumental, McNary, John Day and Bonneville dams. Estimated survival was 93% from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, 89% from Little Goose Dam tailrace to Lower Monumental Dam tailrace, 80% from Lower Monumental Dam tailrace to McNary Dam tailrace, 83% from McNary Dam tailrace to John Day Dam tailrace, and 94% from John Day Dam tailrace to Bonneville Dam tailrace.

2) Precise survival estimates were obtained for yearling chinook salmon (hatchery and wild combined) from their release points (hatcheries and traps) to Lower Granite Dam, and from Lower Granite Dam to the tailraces of Little Goose, Lower Monumental, McNary, and John Day Dams. For yearling chinook salmon released from the tailrace of Lower Granite Dam, estimated survival was 99% from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, 85% from Little Goose Dam tailrace to Lower Monumental Dam tailrace, 92% from Lower Monumental Dam tailrace to McNary Dam tailrace, and 82% from McNary Dam tailrace to John Day Dam tailrace.

3) Survival for yearling chinook salmon passing through the McNary Dam juvenile bypass system was 94.8% (s.e. 2.65).

4) Survival and travel time data collected during this study can be used as baseline data for evaluation of future reservoir drawdowns or other management strategies.

RECOMMENDATIONS

Successful validation of field and statistical methodologies in 1998 formed the basis for the following recommendations for 1999 and future years:

1) The SR (MSR when appropriate) and PR methodologies should be adopted for survival estimation. Future protocols should be designed to evaluate the effects of seasonal and environmental variation, differing capture and release protocols, expanded study areas, and additional salmonid stocks.

2) Hatcheries should be provided with minimum release-size requirements for their PIT-tag studies so that survival estimates from hatcheries to detection sites at dams can be made with known precision.

3) Future survival studies should continue to be coordinated with other projects to maximize the data-collection effort and minimize study effects on salmonid resources.

4) Improved statistical precision should be accomplished by maximizing the return of PIT-tagged juveniles to the river through increased detector and diverter efficiency.

5) To date, little mortality has been found in Lower Granite and other reservoirs investigated. Estimates of survival from hatcheries to Lower Granite Dam indicate that substantial mortality occurs upstream from the Snake and Clearwater River confluence. Efforts should continue to identify where this mortality occurs.

6) Increasing the number of detection facilities in the Columbia River Basin will improve survival investigations. We recommend installation of detectors and diversion systems at The Dalles, Bonneville, and Priest Rapids Dams. The development of flat-plate detector technology in bypass systems and portable streambed flat-plate detectors for use in tributaries would greatly enhance survival estimation capabilities.

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APPENDIX TABLES

Appendix Table 1. Estimated survival probabilities for juvenile steelhead (hatchery and wild combined) detected and returned to or PIT-tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled as necessary to calculate estimates. Estimates based on the Single-Release Model. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; Rel.-Release; Est.-Estimate; s.e.-standard error.

Survival Estimates															
Rel. Date	LGR-LGO		LGO-LMO		LGR-LMO		LMO-MCN		LGR-MCN		Rel. Date	Est.	s.e.		
	Est.	s.e.													
06 Apr 98	0.792	0.247	1.029	0.574	0.814	0.378	0.917	0.600	0.746	0.357	06 Apr 98	0.917	0.600	0.746	0.357
07 Apr 98	1.402	0.493	0.604	0.279	0.846	0.246	1.155	0.652	0.978	0.471	07 Apr 98	1.155	0.652	0.978	0.471
08 Apr 98	1.218	0.358	1.137	0.643	1.385	0.656	0.500	0.306	0.692	0.258	08 Apr 98	0.500	0.306	0.692	0.258
09 Apr 98	0.861	0.221	0.775	0.440	0.667	0.335	0.637	0.382	0.425	0.125	09 Apr 98	0.637	0.382	0.425	0.125
10 Apr 98	0.664	0.139	0.808	0.255	0.536	0.132	1.091	0.526	0.585	0.251	10 Apr 98	1.091	0.526	0.585	0.251
11 Apr 98	0.692	0.145	0.725	0.213	0.502	0.112	0.884	0.360	0.444	0.162	11 Apr 98	0.884	0.360	0.444	0.162
12 Apr 98	0.717	0.156	0.582	0.163	0.417	0.074	0.885	0.262	0.369	0.101	12 Apr 98	0.885	0.262	0.369	0.101
13 Apr 98	1.298	0.441	0.667	0.331	0.865	0.298	0.513	0.340	0.444	0.253	13 Apr 98	0.513	0.340	0.444	0.253
14 Apr 98	0.762	0.107	0.958	0.203	0.730	0.127	3.606	3.384	2.632	2.436	14 Apr 98	3.606	3.384	2.632	2.436
15 Apr 98	0.839	0.134	0.808	0.176	0.678	0.103	1.146	0.464	0.777	0.298	15 Apr 98	1.146	0.464	0.777	0.298
16 Apr 98	0.880	0.188	0.718	0.187	0.632	0.092	0.706	0.217	0.447	0.126	16 Apr 98	0.706	0.217	0.447	0.126
17 Apr 98	1.022	0.204	0.719	0.184	0.735	0.112	1.046	0.359	0.769	0.241	17 Apr 98	1.046	0.359	0.769	0.241
18 Apr 98	0.695	0.082	0.891	0.154	0.619	0.090	0.847	0.269	0.524	0.155	18 Apr 98	0.847	0.269	0.524	0.155
19 Apr 98	0.854	0.145	0.601	0.120	0.514	0.057	0.966	0.250	0.496	0.128	19 Apr 98	0.966	0.250	0.496	0.128
20 Apr 98	0.937	0.075	0.846	0.134	0.793	0.110	0.750	0.231	0.595	0.166	20 Apr 98	0.750	0.231	0.595	0.166
21 Apr 98	1.055	0.066	0.715	0.088	0.754	0.079	0.755	0.152	0.570	0.099	21 Apr 98	0.755	0.152	0.570	0.099
22 Apr 98	0.939	0.054	0.847	0.095	0.795	0.078	0.954	0.212	0.758	0.153	22 Apr 98	0.954	0.212	0.758	0.153
23 Apr 98	0.849	0.050	1.058	0.121	0.899	0.091	0.654	0.119	0.587	0.089	23 Apr 98	0.654	0.119	0.587	0.089
24 Apr 98	0.888	0.051	0.885	0.091	0.786	0.068	0.818	0.145	0.643	0.101	24 Apr 98	0.818	0.145	0.643	0.101
25 Apr 98	0.970	0.048	0.974	0.101	0.945	0.086	0.615	0.092	0.581	0.069	25 Apr 98	0.615	0.092	0.581	0.069
26 Apr 98	0.912	0.034	0.847	0.052	0.773	0.039	0.928	0.122	0.717	0.088	26 Apr 98	0.928	0.122	0.717	0.088
27 Apr 98	0.925	0.026	0.860	0.040	0.795	0.031	0.864	0.085	0.687	0.064	27 Apr 98	0.864	0.085	0.687	0.064
28 Apr 98	0.941	0.024	0.897	0.037	0.844	0.029	0.989	0.112	0.835	0.091	28 Apr 98	0.989	0.112	0.835	0.091
29 Apr 98	0.921	0.020	0.900	0.033	0.829	0.026	0.929	0.108	0.770	0.087	29 Apr 98	0.929	0.108	0.770	0.087
30 Apr 98	0.937	0.017	0.910	0.031	0.853	0.026	0.903	0.102	0.770	0.085	30 Apr 98	0.903	0.102	0.770	0.085

Appendix Table 1. Continued.

Survival Estimates											
Rel. Date	<u>LGR-LGO</u>		<u>LGO-LMO</u>		<u>LGR-LMO</u>		<u>LMO-MCN</u>		<u>LGR-MCN</u>		
	Est.	s.e.									
01 May 98	0.928	0.018	0.905	0.032	0.840	0.026	0.828	0.098	0.695	0.080	
02 May 98	0.974	0.017	0.870	0.026	0.848	0.020	0.729	0.054	0.618	0.044	
03 May 98	0.920	0.014	0.905	0.023	0.833	0.018	0.822	0.061	0.685	0.049	
04 May 98	0.940	0.021	0.956	0.041	0.899	0.033	0.717	0.084	0.645	0.071	
05 May 98	0.952	0.015	0.935	0.030	0.891	0.025	0.665	0.055	0.592	0.047	
06 May 98	0.913	0.017	0.905	0.032	0.826	0.024	0.890	0.099	0.736	0.080	
07 May 98	0.905	0.016	0.866	0.028	0.783	0.022	0.911	0.095	0.713	0.073	
08 May 98	0.950	0.015	0.849	0.024	0.807	0.020	0.839	0.071	0.677	0.056	
09 May 98	0.936	0.014	0.877	0.025	0.821	0.021	0.769	0.067	0.631	0.054	
10 May 98	0.915	0.015	0.869	0.026	0.795	0.021	0.707	0.070	0.562	0.055	
11 May 98	0.946	0.045	0.755	0.063	0.714	0.049	0.662	0.138	0.473	0.095	
12 May 98	0.937	0.019	0.878	0.034	0.823	0.028	0.751	0.088	0.618	0.070	
13 May 98	0.913	0.014	0.927	0.027	0.846	0.023	0.717	0.075	0.606	0.061	
14 May 98	0.920	0.014	0.926	0.031	0.851	0.026	0.658	0.067	0.560	0.054	
15 May 98	0.915	0.020	0.863	0.037	0.789	0.030	0.850	0.119	0.671	0.091	
16 May 98	0.911	0.023	0.862	0.041	0.785	0.033	0.934	0.129	0.733	0.097	
17 May 98	0.911	0.059	0.846	0.102	0.771	0.080	0.542	0.132	0.418	0.093	
18 May 98	0.891	0.076	0.708	0.108	0.631	0.080	1.004	0.378	0.633	0.226	
19 May 98	0.998	0.049	0.867	0.088	0.865	0.076	1.099	0.298	0.951	0.243	
20 May 98	0.928	0.061	0.723	0.090	0.671	0.071	0.600	0.125	0.403	0.072	
21 May 98	1.014	0.068	0.669	0.077	0.678	0.063	1.281	0.321	0.869	0.202	
22 May 98	0.890	0.067	0.844	0.107	0.751	0.077	0.919	0.207	0.691	0.138	
23 May 98	0.908	0.052	0.942	0.093	0.855	0.068	0.886	0.161	0.757	0.124	
24 May 98	0.917	0.061	0.791	0.108	0.726	0.087	0.838	0.220	0.608	0.145	
25 May 98	1.074	0.092	0.840	0.153	0.902	0.143	0.637	0.172	0.574	0.126	
26 May 98	0.874	0.088	0.813	0.141	0.710	0.106	0.965	0.273	0.685	0.173	
27 May 98	0.963	0.057	0.938	0.084	0.903	0.060	0.752	0.104	0.679	0.083	
28 May 98	0.893	0.035	1.041	0.095	0.929	0.078	0.587	0.078	0.546	0.056	
29 May 98	0.981	0.072	0.964	0.119	0.946	0.093	0.628	0.116	0.594	0.092	
30 May 98	0.930	0.048	0.854	0.070	0.794	0.053	0.719	0.105	0.581	0.077	
31 May 98	0.985	0.166	1.429	0.800	1.407	0.750					
Weighted Mean	0.930	0.004	0.889	0.006	0.825	0.007	0.797	0.018	0.649	0.013	

Appendix Table 2. Estimated survival probabilities for yearling chinook salmon (hatchery and wild combined) detected and returned to or PIT-tagged and released into the tailrace of Lower Granite Dam in 1998. Daily groups pooled as necessary to calculate estimates. Estimates based on the Single-Release Model. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-MCNary Dam; Rel.-Release; Est.-Estimate; s.e.-standard error.

Survival Estimates												
Rel. Date	LGR-LGO		LGO-LMO		LGR-LMO		Rel. Date	LMO-MCN		LGR-MCN		
	Est.	s.e.	Est.	s.e.	Est.	s.e.		Est.	s.e.	Est.	s.e.	
02 Apr 98	0.718	0.072	1.938	0.726	1.392	0.540	02 Apr 98	0.818	0.468	1.139	0.449	
03 Apr 98	0.818	0.124	1.073	0.259	0.878	0.173	03 Apr 98	1.099	0.361	0.965	0.258	
04 Apr 98	0.976	0.115	0.823	0.140	0.803	0.095	04 Apr 98	0.967	0.246	0.777	0.180	
05 Apr 98	1.129	0.137	0.834	0.156	0.941	0.126	05 Apr 98	0.713	0.146	0.672	0.103	
06 Apr 98	0.992	0.055	0.855	0.074	0.849	0.055	06 Apr 98	0.811	0.086	0.688	0.059	
07 Apr 98	1.075	0.131	1.071	0.239	1.151	0.210	07 Apr 98	0.637	0.172	0.733	0.142	
08 Apr 98	1.154	0.084	0.663	0.067	0.765	0.049	08 Apr 98	0.947	0.110	0.724	0.074	
09 Apr 98	0.937	0.042	0.906	0.064	0.849	0.047	09 Apr 98	0.950	0.103	0.807	0.076	
10 Apr 98	1.059	0.036	0.801	0.039	0.848	0.029	10 Apr 98	0.861	0.051	0.730	0.036	
11 Apr 98	0.985	0.031	0.836	0.040	0.823	0.028	11 Apr 98	0.891	0.054	0.733	0.038	
12 Apr 98	1.067	0.033	0.757	0.034	0.808	0.025	12 Apr 98	0.911	0.052	0.736	0.037	
13 Apr 98	1.073	0.041	0.785	0.046	0.842	0.035	13 Apr 98	0.915	0.074	0.771	0.055	
14 Apr 98	1.033	0.022	0.818	0.028	0.846	0.022	14 Apr 98	0.918	0.045	0.776	0.033	
15 Apr 98	1.071	0.029	0.836	0.038	0.896	0.032	15 Apr 98	0.901	0.060	0.807	0.046	
16 Apr 98	1.040	0.035	0.729	0.039	0.758	0.030	16 Apr 98	0.863	0.064	0.654	0.042	
17 Apr 98	1.030	0.025	0.849	0.038	0.875	0.032	17 Apr 98	0.951	0.073	0.832	0.057	
18 Apr 98	1.138	0.035	0.688	0.035	0.782	0.030	18 Apr 98	0.847	0.058	0.663	0.039	
19 Apr 98	1.075	0.019	0.742	0.025	0.798	0.022	19 Apr 98	0.929	0.047	0.741	0.032	
20 Apr 98	1.031	0.025	0.805	0.040	0.830	0.035	20 Apr 98	0.918	0.073	0.762	0.053	
21 Apr 98	1.021	0.022	0.859	0.039	0.877	0.034	21 Apr 98	0.822	0.054	0.721	0.039	
22 Apr 98	0.982	0.015	0.891	0.027	0.875	0.023	22 Apr 98	0.869	0.042	0.761	0.031	
23 Apr 98	1.016	0.015	0.893	0.029	0.907	0.025	23 Apr 98	0.872	0.045	0.791	0.034	
24 Apr 98	0.969	0.019	0.946	0.038	0.916	0.032	24 Apr 98	0.924	0.070	0.846	0.057	
25 Apr 98	0.973	0.015	0.965	0.034	0.939	0.030	25 Apr 98	0.905	0.066	0.850	0.056	
26 Apr 98	1.022	0.022	0.806	0.037	0.823	0.033	26 Apr 98	0.949	0.101	0.782	0.078	
27 Apr 98	0.967	0.018	0.851	0.037	0.823	0.032	27 Apr 98	1.075	0.126	0.885	0.099	
28 Apr 98	0.973	0.013	0.855	0.027	0.832	0.024	28 Apr 98	0.921	0.071	0.766	0.055	
29 Apr 98	0.959	0.016	0.822	0.031	0.788	0.027	29 Apr 98	1.040	0.102	0.819	0.076	
30 Apr 98	0.961	0.017	0.928	0.041	0.892	0.036	30 Apr 98	0.831	0.084	0.741	0.069	

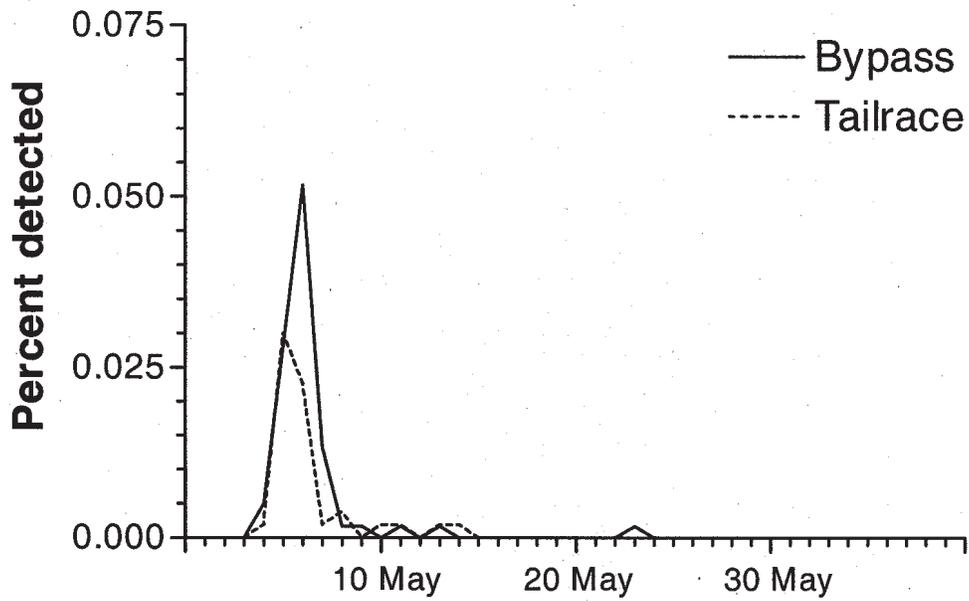
Appendix Table 2. Continued.

Survival Estimates

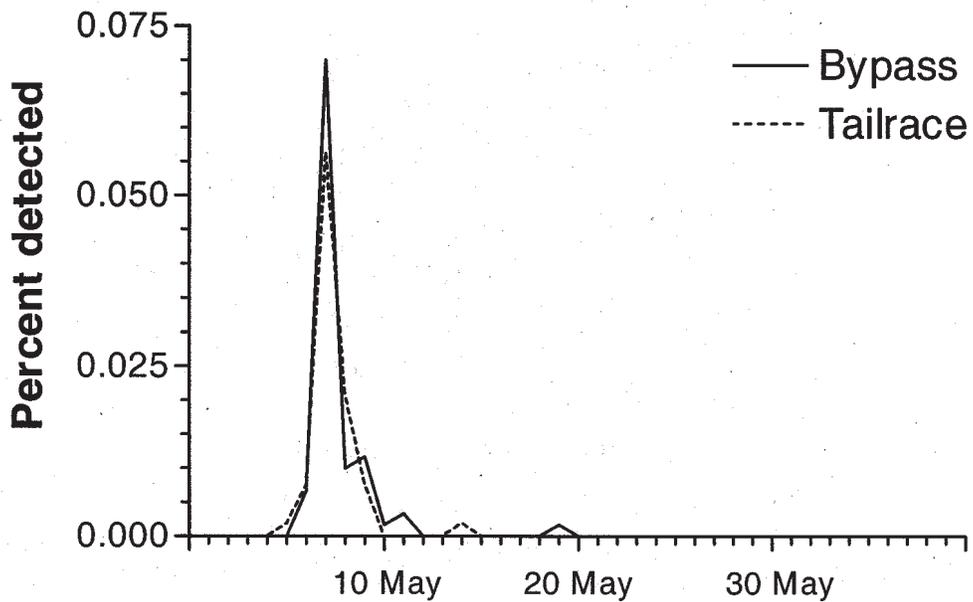
Rel. Date	<u>LGR-LGO</u>		<u>LGO-LMO</u>		<u>LGR-LMO</u>		Rel. Date	<u>LMO-MCN</u>		<u>LGR-MCN</u>	
	Est.	s.e.	Est.	s.e.	Est.	s.e.		Est.	s.e.	Est.	s.e.
01 May 98	0.983	0.014	0.850	0.027	0.835	0.023	01 May 98	0.959	0.072	0.801	0.056
02 May 98	0.961	0.018	0.884	0.035	0.849	0.030	02 May 98	1.028	0.099	0.873	0.078
03 May 98	0.954	0.021	0.813	0.035	0.776	0.028	03 May 98	0.990	0.097	0.768	0.071
04 May 98	0.950	0.019	0.878	0.036	0.835	0.029	04 May 98	0.938	0.093	0.783	0.073
05 May 98	0.954	0.015	0.939	0.033	0.895	0.027	05 May 98	0.963	0.077	0.863	0.065
06 May 98	0.955	0.012	0.873	0.021	0.834	0.017	06 May 98	0.958	0.054	0.799	0.042
07 May 98	0.965	0.016	0.886	0.028	0.855	0.023	07 May 98	1.035	0.079	0.885	0.065
08 May 98	0.980	0.018	0.838	0.027	0.822	0.022	08 May 98	0.917	0.065	0.754	0.051
09 May 98	0.994	0.016	0.835	0.027	0.830	0.023	09 May 98	0.967	0.073	0.803	0.058
10 May 98	0.974	0.027	0.931	0.062	0.906	0.055	10 May 98	0.869	0.157	0.788	0.135
11 May 98	1.000	0.017	0.877	0.036	0.877	0.032	11 May 98	0.937	0.103	0.822	0.085
12 May 98	1.012	0.035	0.860	0.072	0.870	0.065	12 May 98	0.817	0.173	0.711	0.142
13 May 98	1.017	0.028	0.840	0.056	0.854	0.051	13 May 98	1.028	0.199	0.878	0.162
14 May 98	1.086	0.044	0.855	0.079	0.929	0.075	14 May 98	0.849	0.177	0.789	0.151
15 May 98	1.037	0.077	0.877	0.145	0.909	0.133	15 May 98	2.391	1.638	2.174	1.454
16 May 98	1.003	0.093	0.807	0.132	0.810	0.109	16 May 98	2.156	1.425	1.746	1.132
17 May 98	1.065	0.142	1.173	0.497	1.249	0.498	17 May 98	0.333	0.173	0.416	0.132
18 May 98	0.935	0.097	0.706	0.136	0.661	0.107	18 May 98	1.384	0.616	0.915	0.383
19 May 98	0.920	0.130	0.686	0.169	0.631	0.128	19 May 98	1.393	0.707	0.878	0.417
20 May 98	0.933	0.083	0.831	0.154	0.775	0.126	20 May 98	0.808	0.270	0.626	0.183
21 May 98	0.958	0.160	0.769	0.247	0.737	0.201	21 May 98	0.881	0.484	0.649	0.311
22 May 98	0.981	0.103	0.850	0.207	0.834	0.183	22 May 98	0.511	0.210	0.426	0.148
23 May 98	0.948	0.109	0.947	0.250	0.898	0.213	23 May 98	2.330	2.223	2.094	1.935
24 May 98	0.677	0.073	1.414	0.494	0.958	0.340	24 May 98	1.359	1.247	1.301	1.102
25 May 98	0.816	0.120	1.165	0.367	0.951	0.274	25 May 98	0.380	0.163	0.362	0.116
26 May 98	1.043	0.182	0.563	0.122	0.587	0.073	26 May 98	2.593	1.649	1.523	0.962
27 May 98	1.108	0.232	0.813	0.239	0.901	0.180	27 May 98	0.909	0.399	0.818	0.320
28 May 98	1.329	0.381	0.469	0.168	0.623	0.120	28 May 98	0.675	0.195	0.421	0.102
29 May 98	1.015	0.298	2.670	2.531	2.712	2.443	29-31 May 98	0.310	0.247	0.315	0.220
30-31 May 98	0.598	0.188	0.727	0.305	0.435	0.137					
Weighted Mean	0.991	0.006	0.853	0.009	0.846	0.006		0.915	0.011	0.770	0.009

APPENDIX FIGURES

John Day Dam

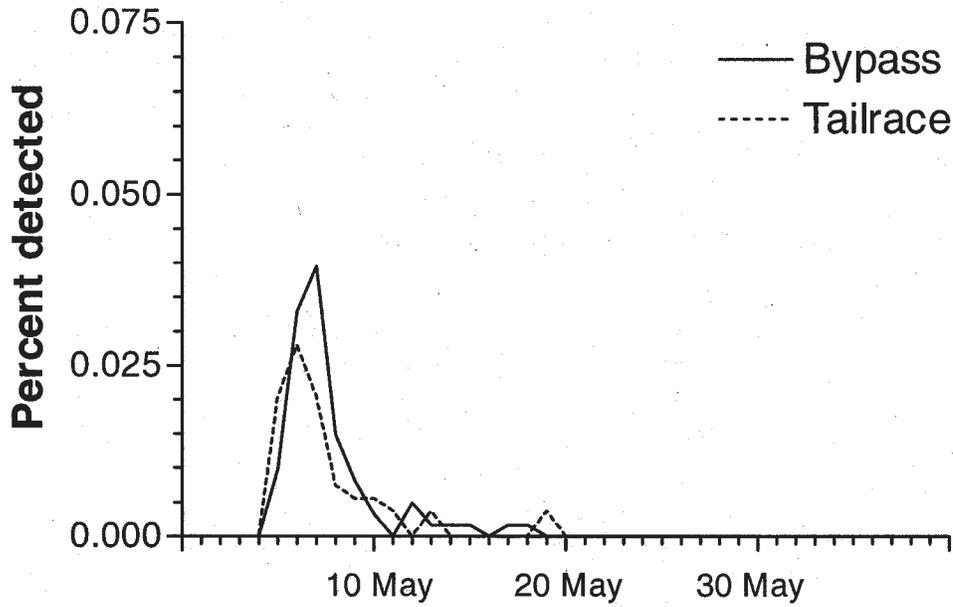


Bonneville Dam

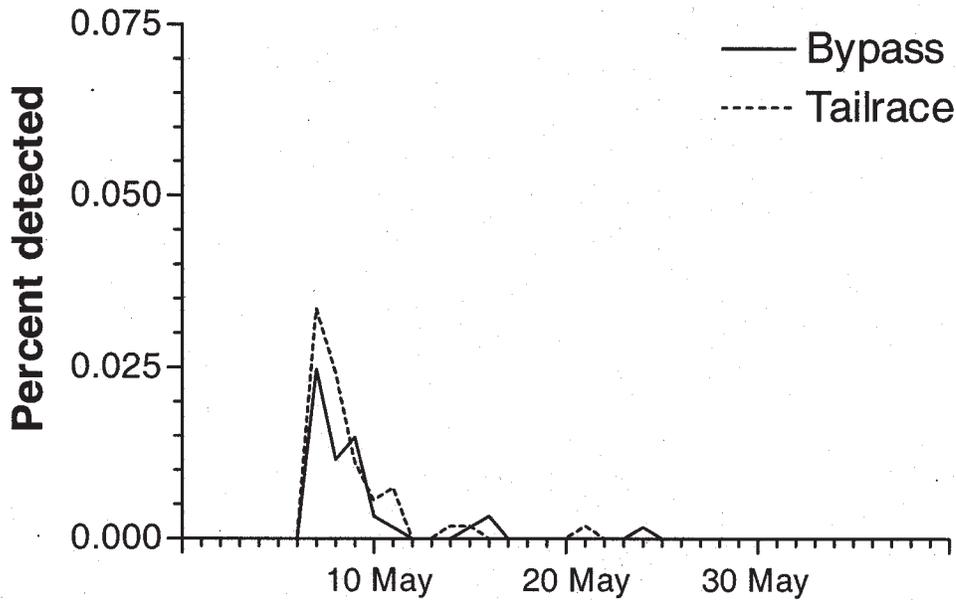


Appendix Figure 1. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 2 May, 1998.

John Day Dam

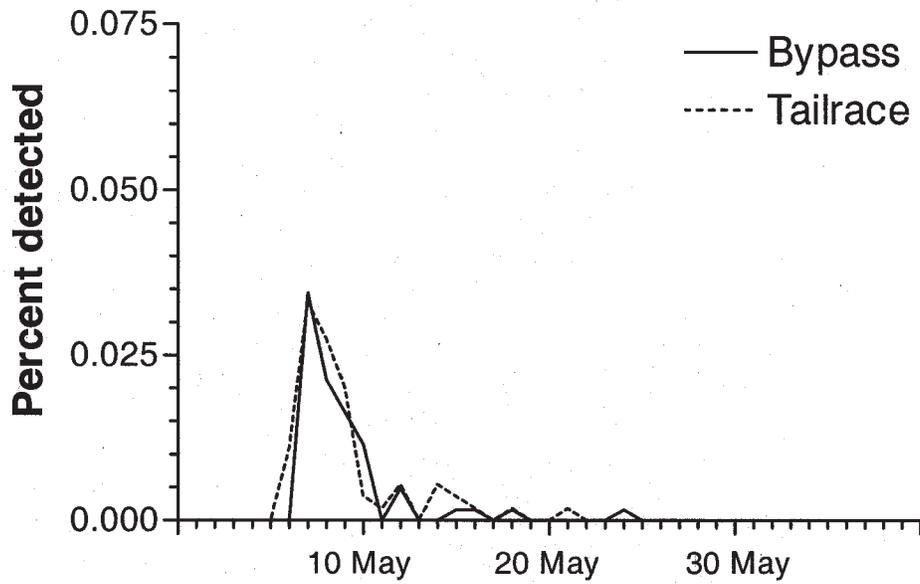


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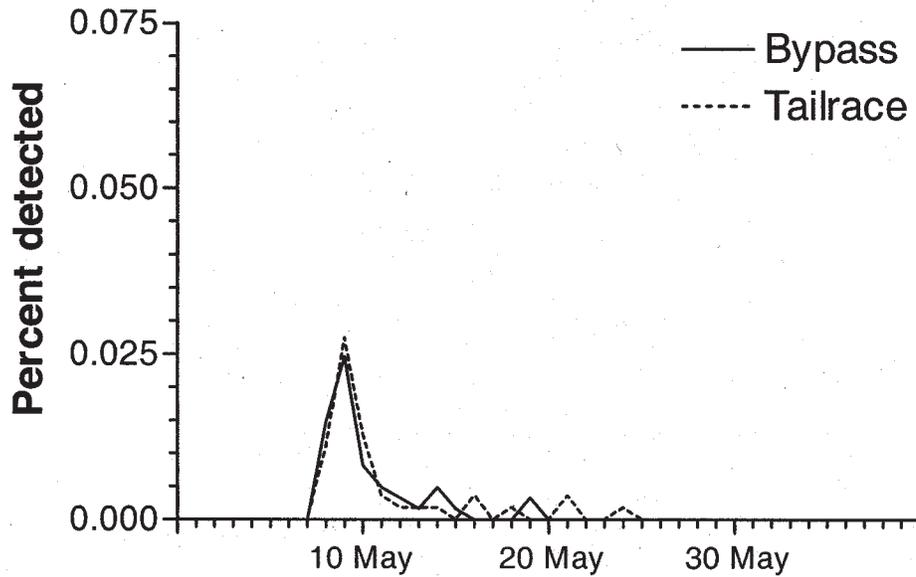


Appendix Figure 2. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 3 May, 1998.

John Day Dam

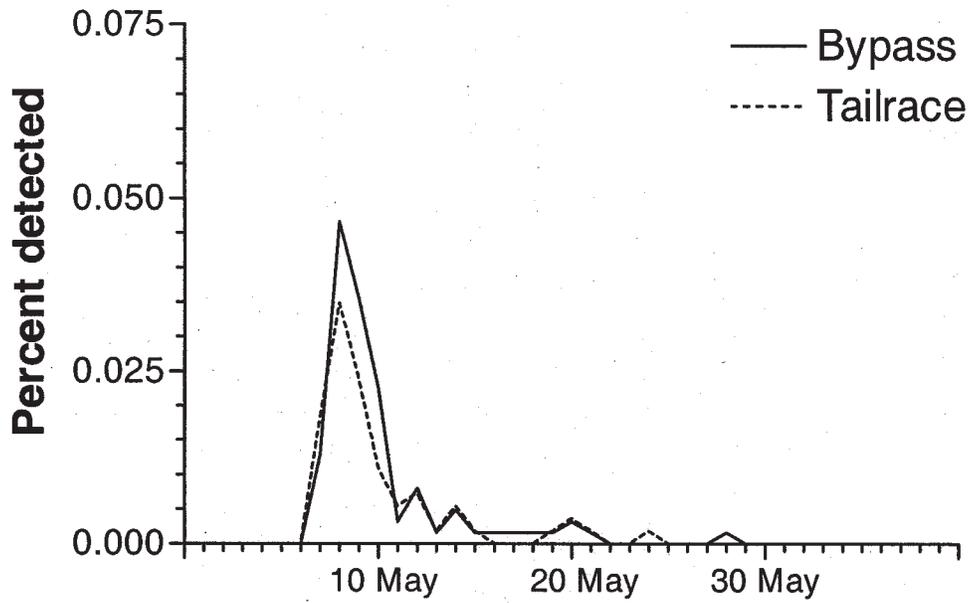


Bonneville Dam

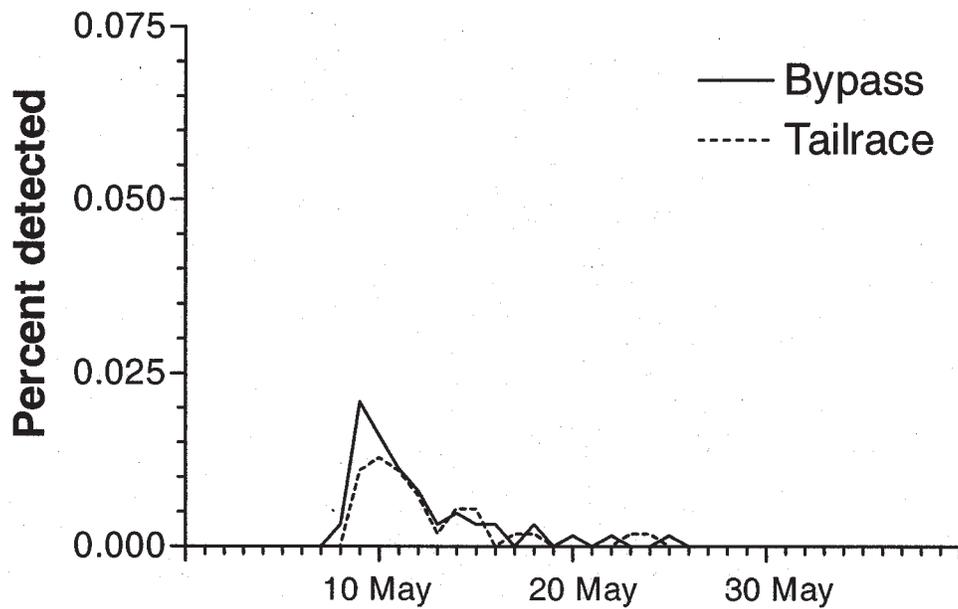


Appendix Figure 3. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 4 May, 1998.

John Day Dam

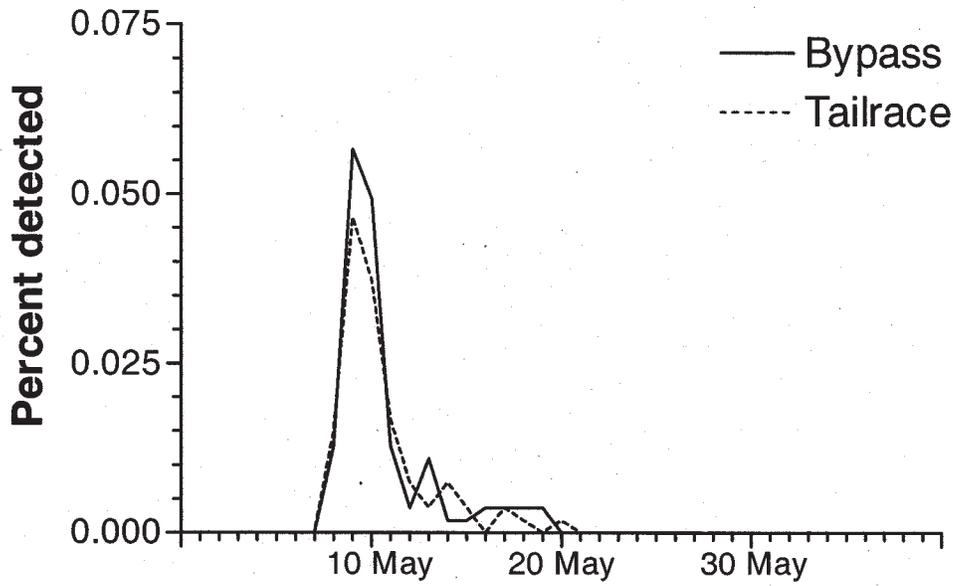


Bonneville Dam

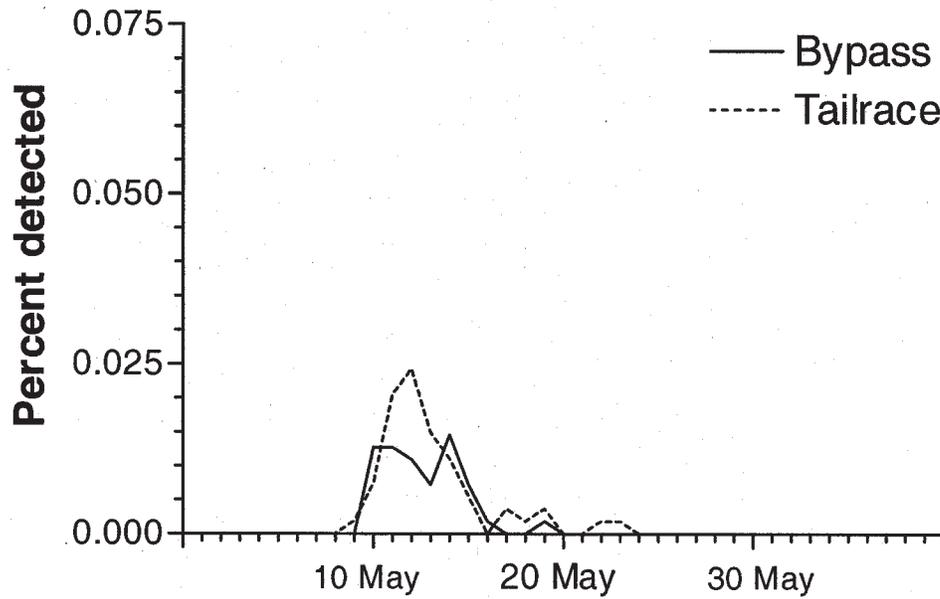


Appendix Figure 4. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 5 May, 1998.

John Day Dam

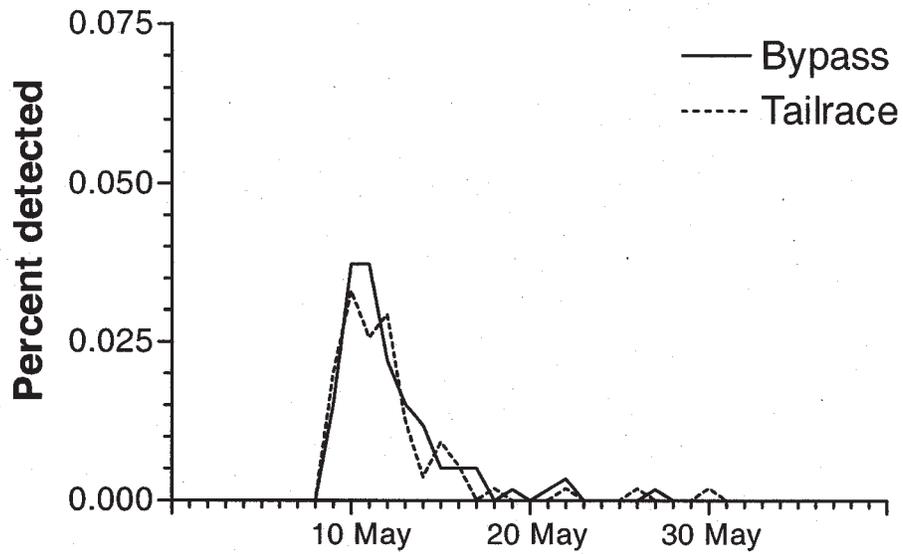


Bonneville Dam

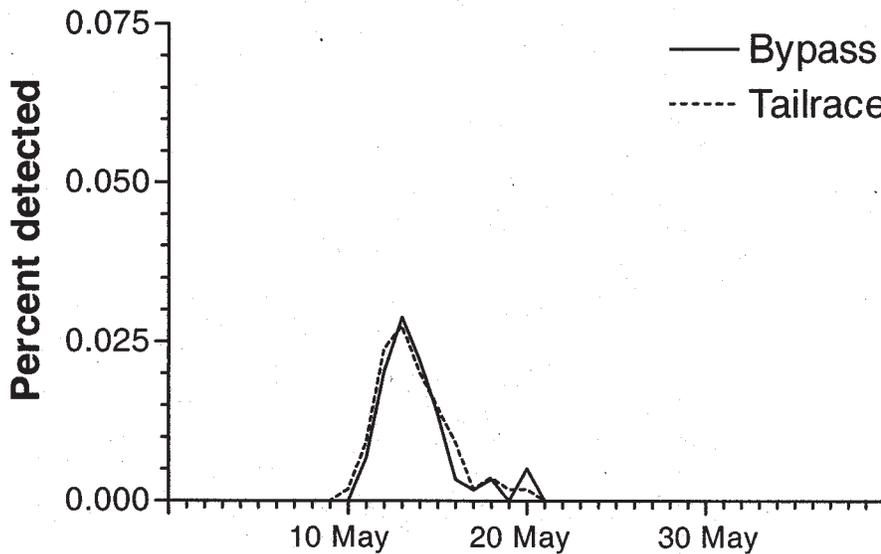


Appendix Figure 5. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 6 May, 1998.

John Day Dam

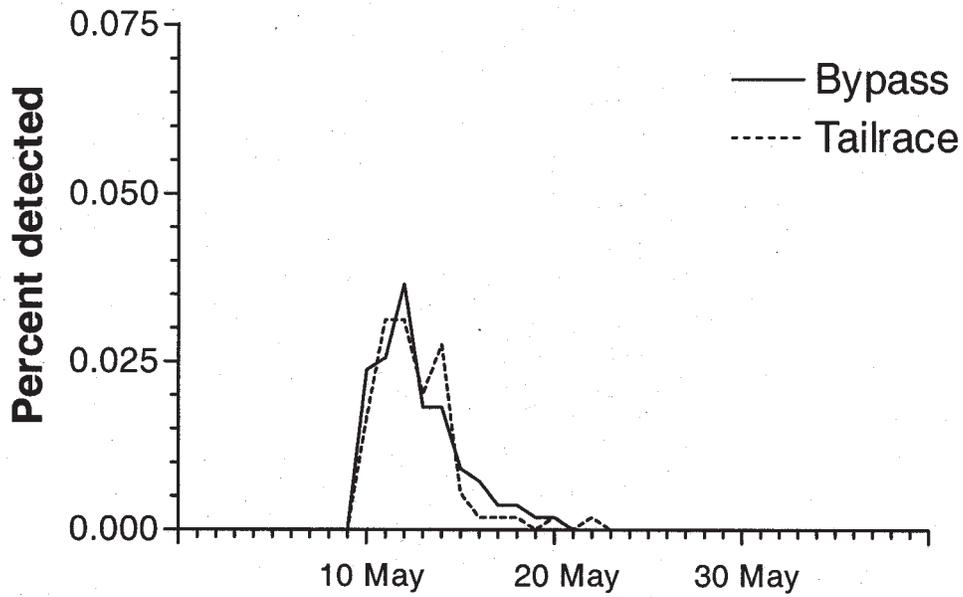


Bonneville Dam

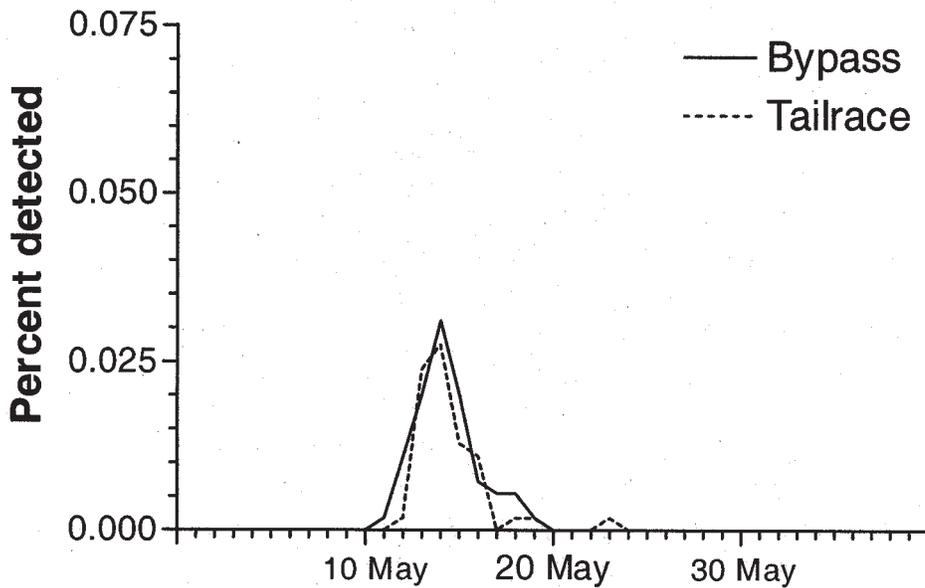


Appendix Figure 6. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 7 May, 1998.

John Day Dam

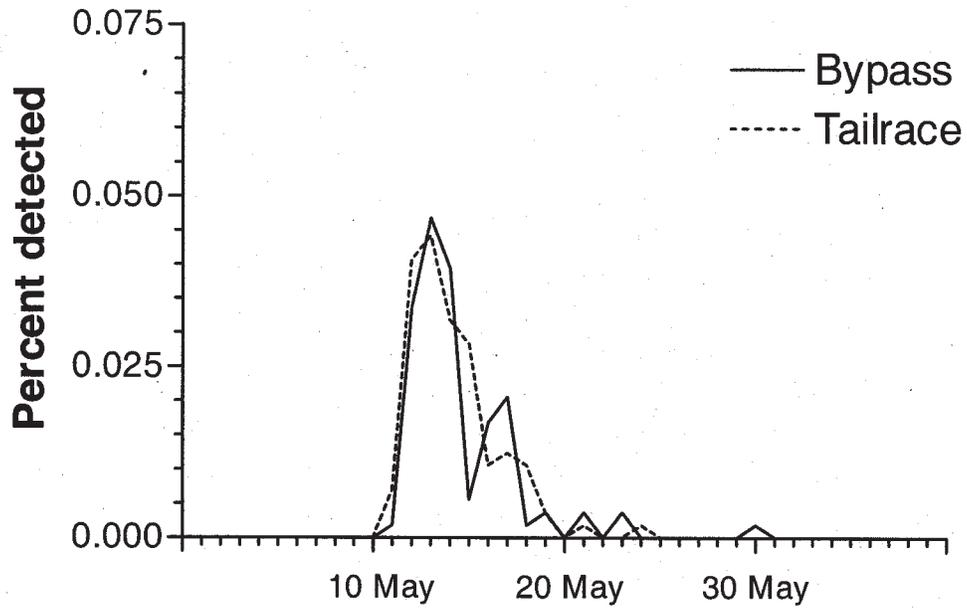


Bonneville Dam

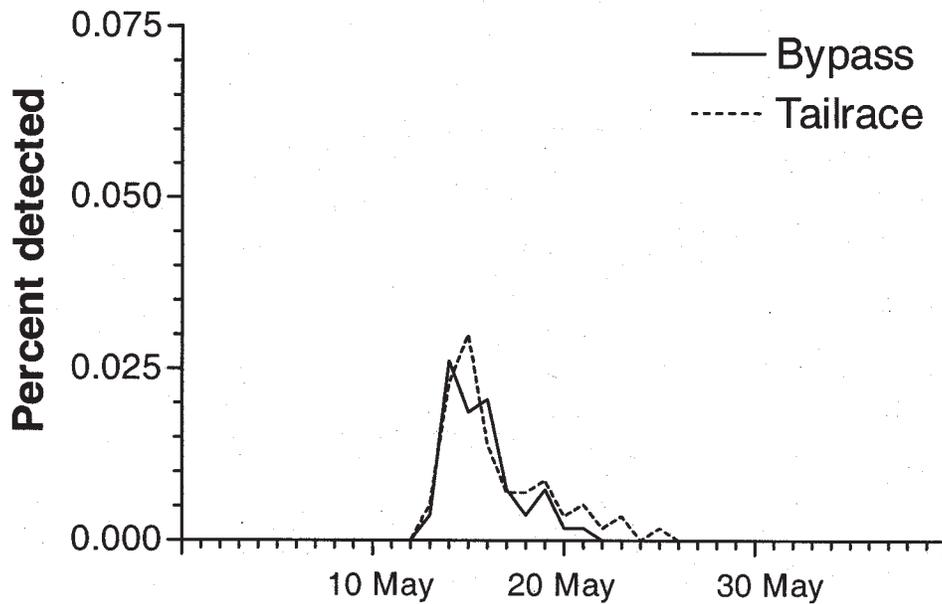


Appendix Figure 7. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 8 May, 1998.

John Day Dam

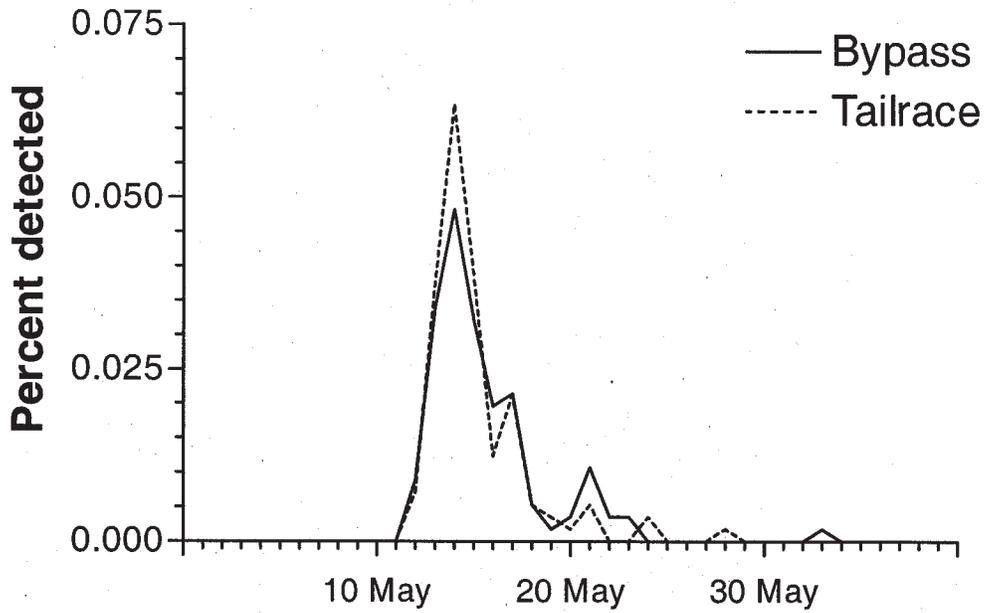


Bonneville Dam

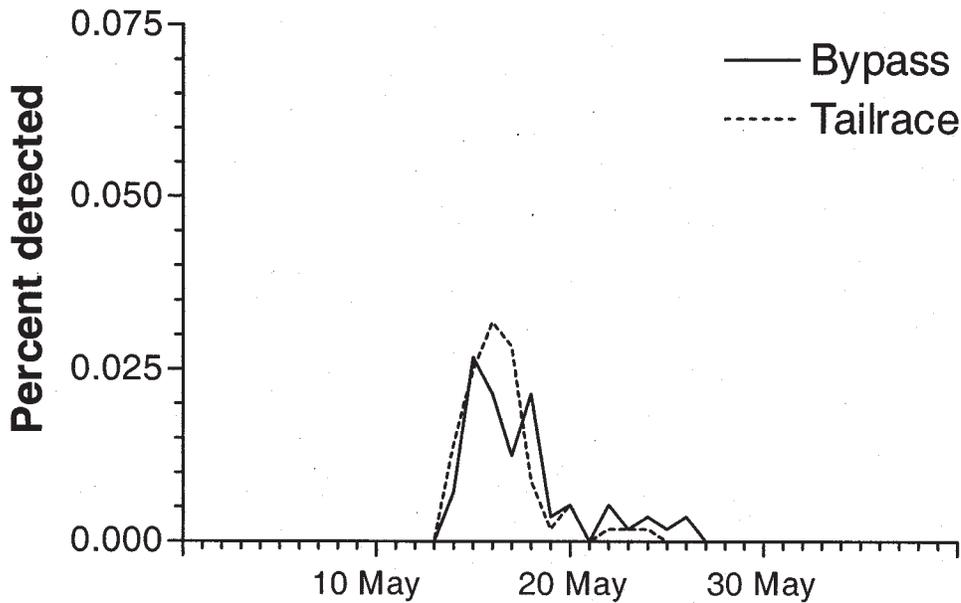


Appendix Figure 8. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 9 May, 1998.

John Day Dam

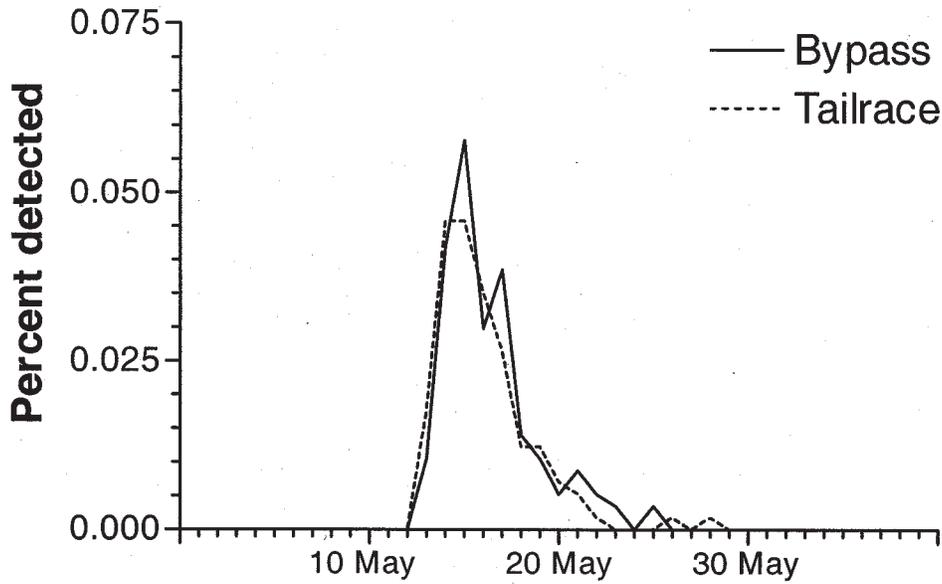


Bonneville Dam

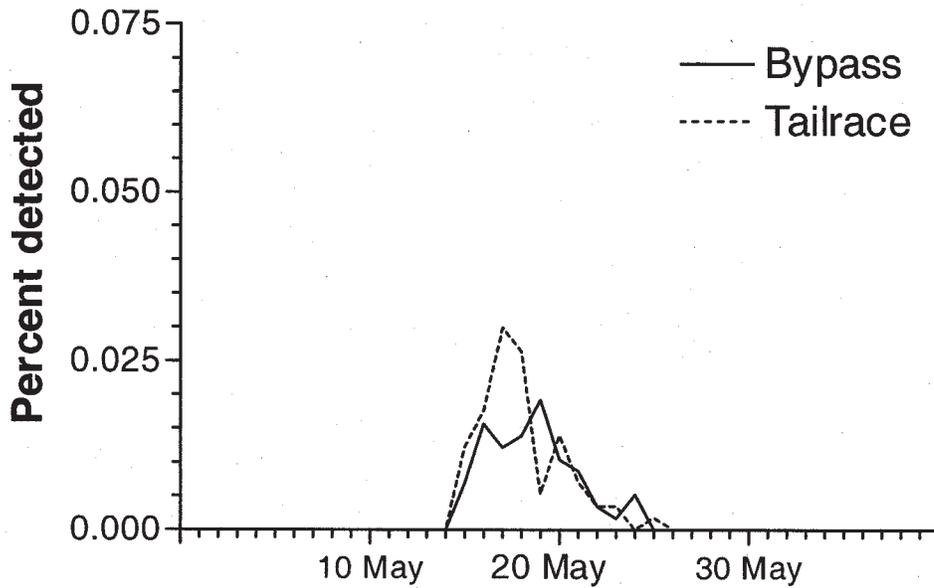


Appendix Figure 9. Detection distribution at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 10 May, 1998.

John Day Dam

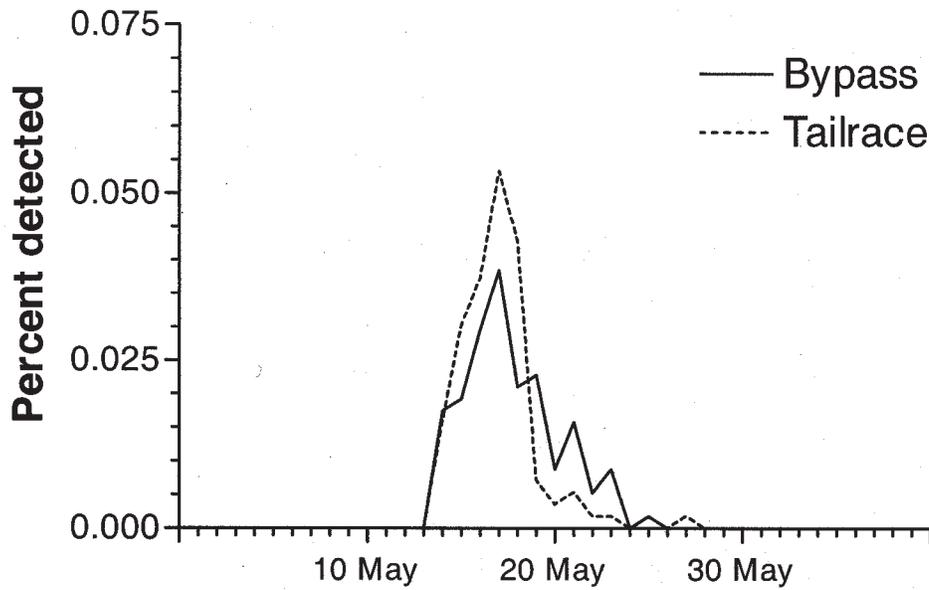


Bonneville Dam

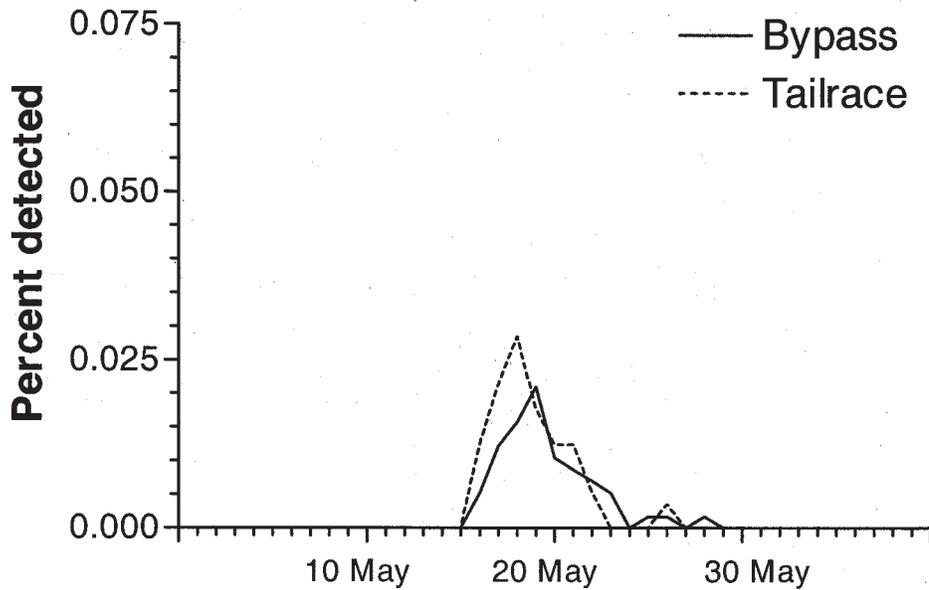


Appendix Figure 10. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 11 May, 1998.

John Day Dam

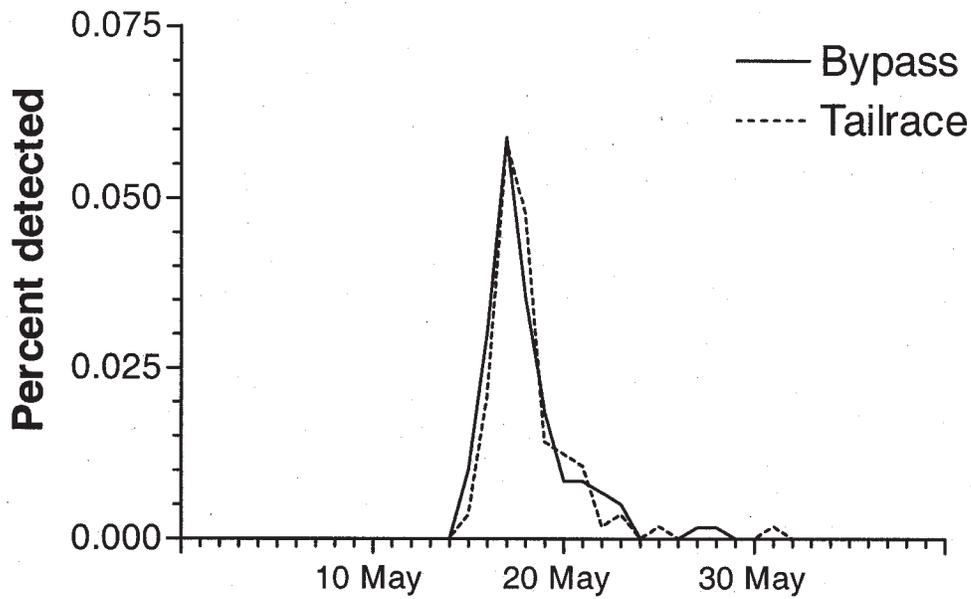


Bonneville Dam

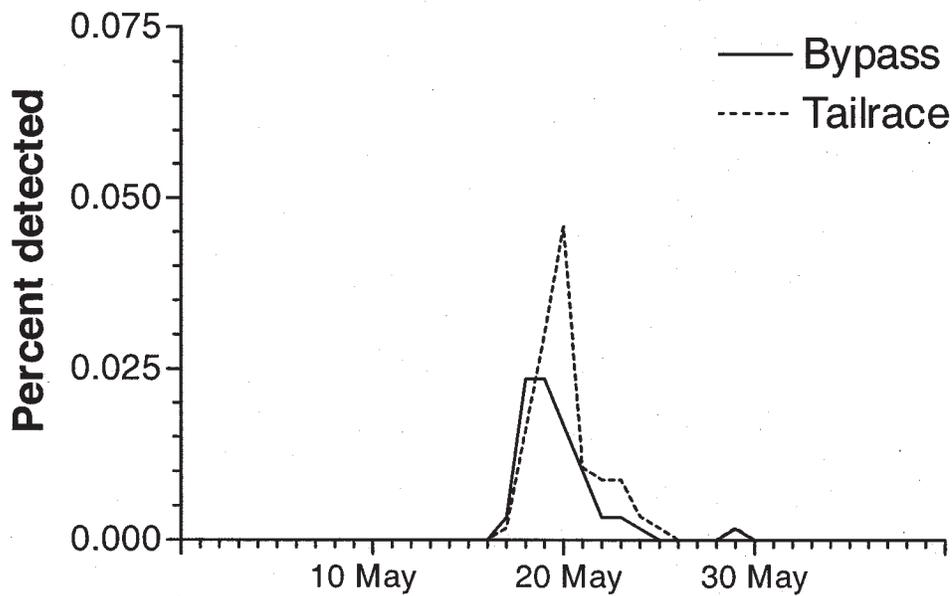


Appendix Figure 11. Detections distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 12 May, 1998.

John Day Dam

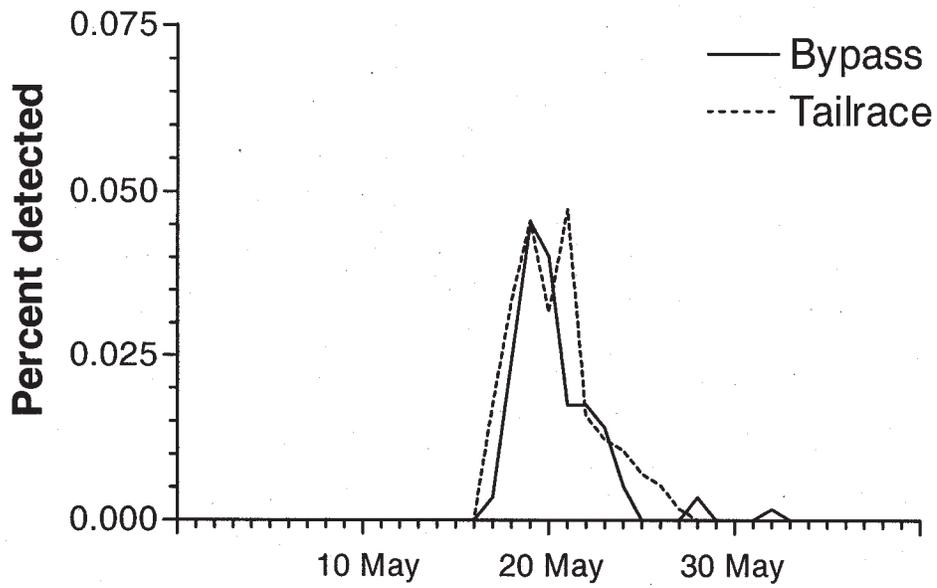


Bonneville Dam

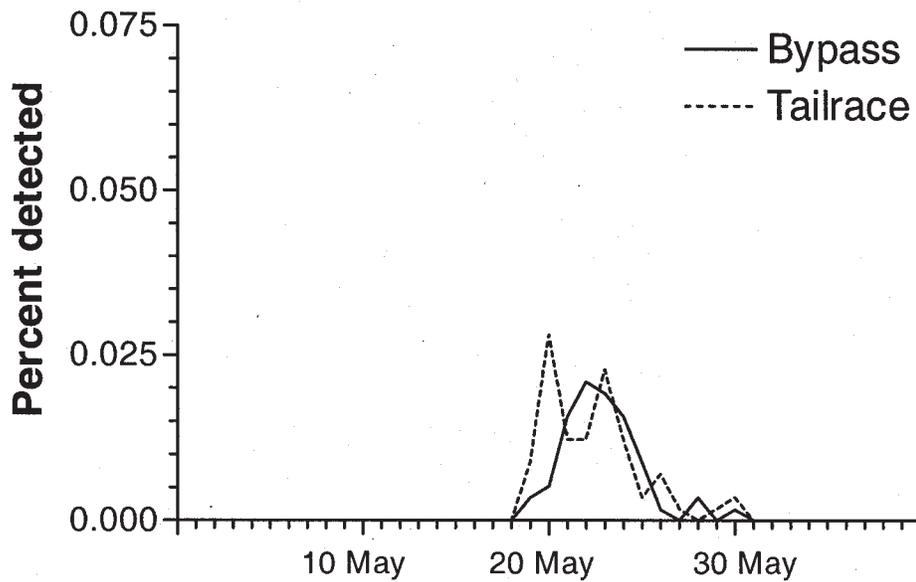


Appendix Figure 12. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 13 May, 1998.

John Day Dam

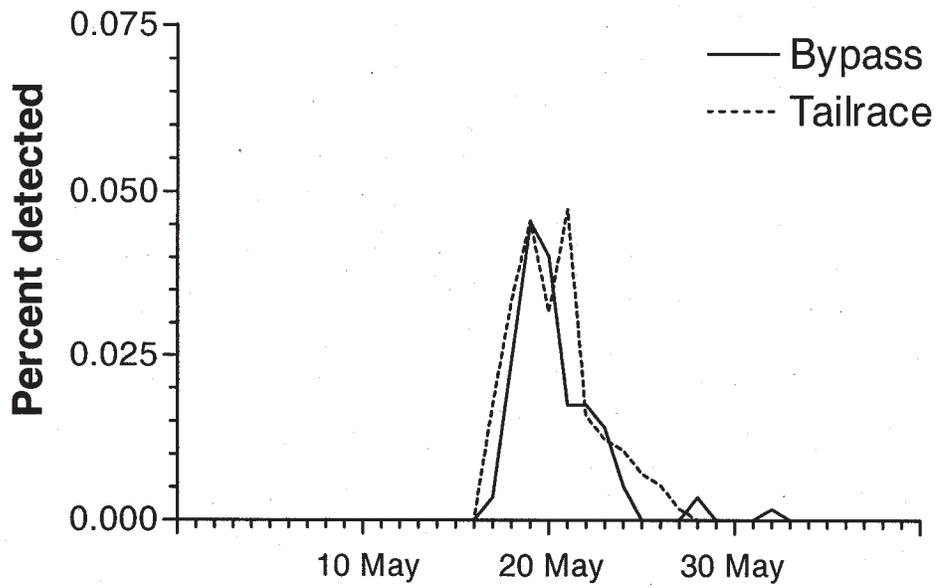


Bonneville Dam

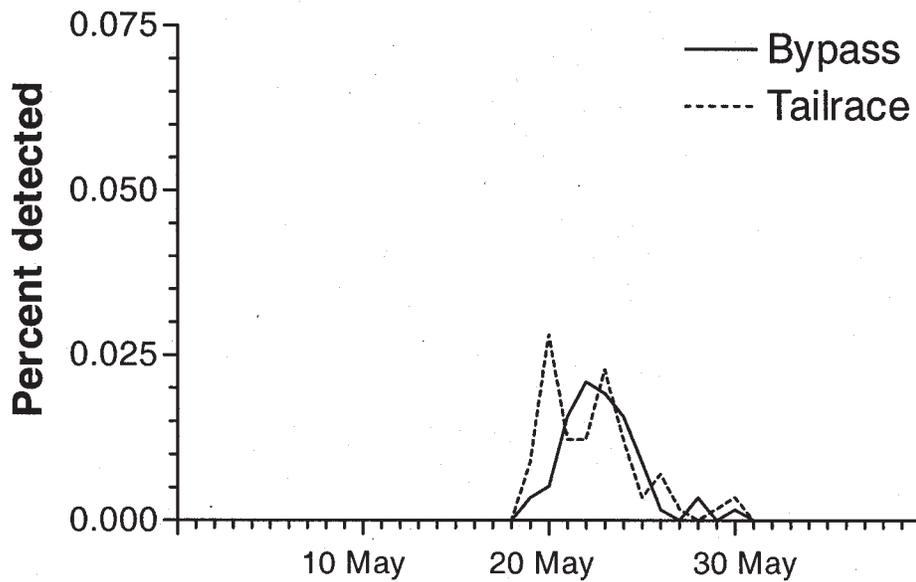


Appendix Figure 13. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 15 May, 1998.

John Day Dam

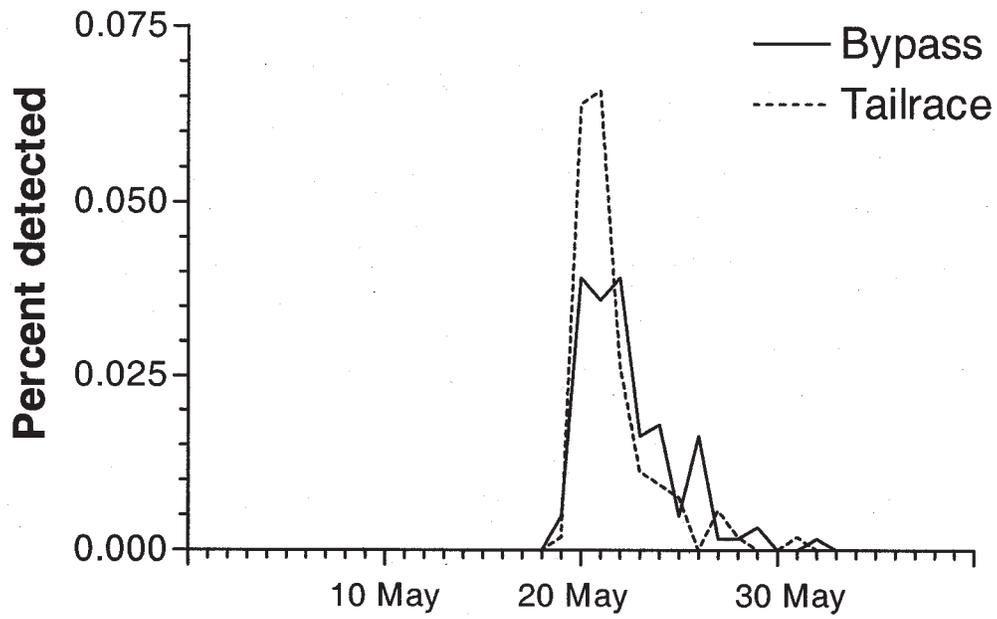


Bonneville Dam

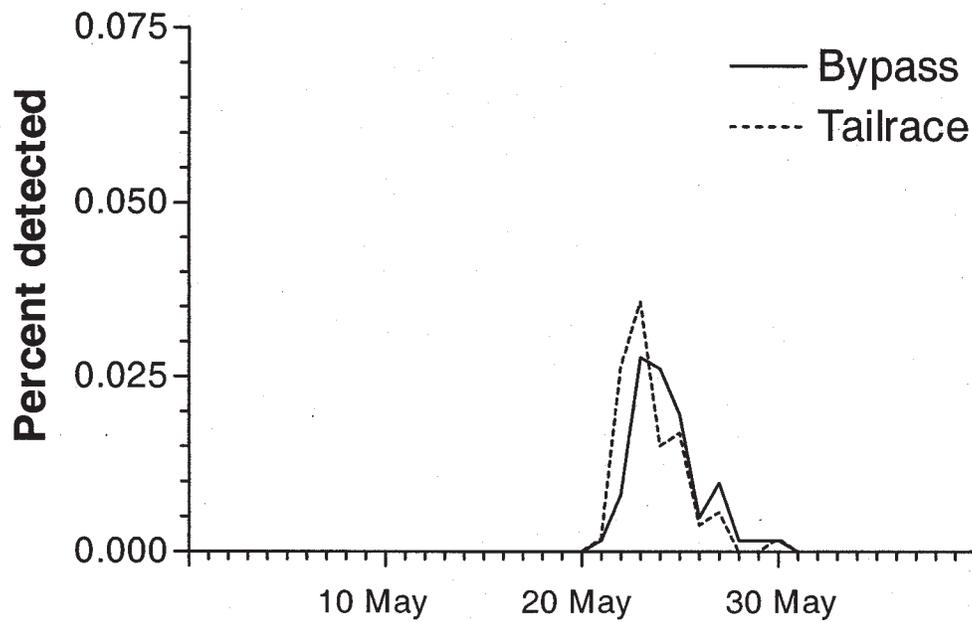


Appendix Figure 14. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 16 May, 1998.

John Day Dam



Bonneville Dam



Appendix Figure 15. Detection distributions at John Day and Bonneville Dams of PIT-tagged yearling chinook salmon released at McNary Dam on 17 May, 1998.