Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs, 2010

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Report of research by

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EXECUTIVE SUMMARY

In 2010, the National Marine Fisheries Service (NMFS) completed the 18th year of a study to estimate survival and travel time of juvenile salmonids *Oncorhynchus* spp. passing through dams and reservoirs on the Snake and Columbia Rivers. All estimates were derived from detections of fish tagged with passive integrated transponder (PIT) tags. We PIT tagged and released a total of 17,602 hatchery steelhead *O. mykiss*, 12,860 wild steelhead, and 16,996 wild yearling Chinook salmon *O. tshawytscha* at Lower Granite Dam on the Snake River.

In addition, we utilized fish PIT tagged by NMFS and other agencies at traps and hatcheries upstream from the hydropower system and at sites within the hydropower system in both the Snake and Columbia Rivers. PIT-tagged smolts were detected at interrogation facilities at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville Dam, as well as in the PIT-tag detector trawl operated in the Columbia River estuary. Survival estimates were calculated using a statistical model for tag-recapture data from single release groups (the single-release model). Primary research objectives in 2010 were:

1) Estimate reach survival and travel time in the Snake and Columbia Rivers throughout the migration period of yearling Chinook salmon and steelhead
2) Evaluate relationships between survival estimates and migration conditions
3) Evaluate the survival estimation models under prevailing conditions

This report provides reach survival and travel time estimates for 2010 for PIT-tagged yearling Chinook salmon (hatchery and wild), hatchery sockeye salmon *O. nerka*, hatchery coho salmon *O. kisutch*, and steelhead (hatchery and wild) in the Snake and Columbia Rivers. Additional details on the methodology and statistical models used are provided in previous reports cited here.

Survival and detection probabilities were estimated precisely for most of the 2010 yearling Chinook salmon and steelhead migrations. Hatchery and wild fish were combined in some analyses. For Snake River fish, overall percentages by origin of the combined PIT-tagged release groups used in survival analyses were 72% hatchery-reared and 28% wild for yearling Chinook salmon and 66% hatchery-reared and 34% wild for steelhead. Based on smolt passage data at Lower Granite Dam collected by the Fish Passage Center, we estimate that 87% of the overall yearling Chinook salmon run in 2010 was of hatchery origin. We could not estimate this number for steelhead because separate collection counts for hatchery and wild fish are not available.

Estimated survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam averaged 0.962 for yearling Chinook salmon and 0.965 for steelhead. Reaches of river between dams were defined from tailrace to tailrace, and respective average survival estimates for yearling Chinook salmon and steelhead through the following reaches were:

	Yearling Chinook salmon	Steelhead
Little Goose to Lower Monumental Dam	0.973	0.984
Lower Monumental to McNary Dam[a]	0.851	0.876
McNary to John Day Dam	0.947	0.931
John Day to Bonneville Dam[b]	0.780	0.840

[a] A two-project reach, including Ice Harbor Dam and reservoir.
[b] A two-project reach, including The Dalles Dam and reservoir.

Combining average estimates from the Snake River smolt trap to Lower Granite Dam, from Lower Granite to McNary Dam, and from McNary to Bonneville Dam, estimated average survival through the entire hydropower system from the head of Lower Granite reservoir to the tailrace of Bonneville Dam (eight projects) was 0.551 (se 0.038) for Snake River yearling Chinook salmon and 0.618 (se 0.032) for steelhead during 2010.

For yearling spring Chinook salmon released in the Upper Columbia River basin, estimated survival from point of release to McNary Dam tailrace ranged from 0.830 for East Bank Hatchery fish released to Dryden Pond on the Wenatchee River to 0.204 for Yakima Hatchery fish released into the Natches River.

For steelhead released in the Upper Columbia River basin, estimated survival from point of release to McNary Dam tailrace ranged from 0.752 for fish from East Bank Hatchery released to the Wenatchee River in May to 0.317 for East Bank Hatchery fish released to the Wenatchee River in March.

During 2010, flows at Snake River dams were below the historic average for most of April and May, but spill percentages were high. Water temperatures in 2010 fluctuated above and below average through the migration season.

For Snake River yearling Chinook salmon, estimated survival through the entire hydropower system (Snake River trap to Bonneville Dam tailrace) in 2010 was above the average for the last 12 years. For Snake River steelhead, survival through the hydropower system in 2010 was also above average and was the second highest rate of survival estimated in the last 11 years (in 2004 and 2005 survival could not be estimated through the entire hydropower system).

Despite relatively lower flows and water velocities in 2010, yearling Chinook salmon and steelhead migration rates through the hydropower system were near average, and faster (i.e., travel times shorter) than those in years with similar levels of flow. Relatively high spill proportions and the use of surface collectors at most projects likely helped compensate for the lower water velocities by shortening fish travel times.

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INTRODUCTION

Accurate and precise survival estimates are needed for depressed stocks of juvenile Chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *O. nerka*, coho salmon *O. kisutch*, and steelhead *O. mykiss* that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers. To develop recovery strategies that will optimize smolt survival during migration, knowledge is needed of the magnitude, locations, and causes of smolt mortality. Such knowledge is necessary for strategies applied under present passage conditions as well as under conditions projected for the future (Williams and Matthews 1995; Williams et al. 2001).

From 1993 through 2009, the National Marine Fisheries Service (NMFS) estimated survival for these stocks using detections of PIT-tagged (Prentice et al. 1990a) juvenile salmonids passing through Snake River dams and reservoirs (Iwamoto et al. 1994; Muir et al. 1995, 1996, 2001a,b, 2003; Smith et al. 1998, 2000a,b, 2003, 2005, 2006; Hockersmith et al. 1999; Zabel et al. 2001, 2002; Faulkner et al. 2007, 2008, 2009). In 2010, NMFS completed the 18th year of the study.

Research objectives in 2010 were:

1) Estimate reach survival and travel time in the Snake and Columbia Rivers throughout the yearling Chinook salmon and steelhead migrations
2) Evaluate relationships between survival estimates and migration conditions
3) Evaluate the performance of survival-estimation models under prevailing operational and environmental conditions

SURVIVAL ESTIMATES FROM POINT OF RELEASE TO BONNEVILLE DAM

Methods

Experimental Design

The single-release (SR) model was used to estimate survival for groups of PIT-tagged yearling Chinook, sockeye, and coho salmon and steelhead (Cormack 1964; Jolly 1965; Seber 1965; Skalski 1998; Skalski et al. 1998; Muir et al. 2001a). Iwamoto et al. (1994) presented background information and underlying statistical theory pertaining to the SR model. In 2010, PIT-tagged fish used for survival estimates were released from hatcheries, traps, and Lower Granite Dam in the Snake River Basin, and from hatcheries and dams in the Upper Columbia River.

During the 2010 migration season, automatic PIT-tag detectors (Prentice et al. 1990a,b,c) were operated in juvenile bypass systems at the following seven dams: Lower Granite (rkm 695), Little Goose (rkm 635), Lower Monumental (rkm 589), Ice Harbor (rkm 538), McNary (rkm 470), John Day (rkm 347), and Bonneville (rkm 234; Figure 1).

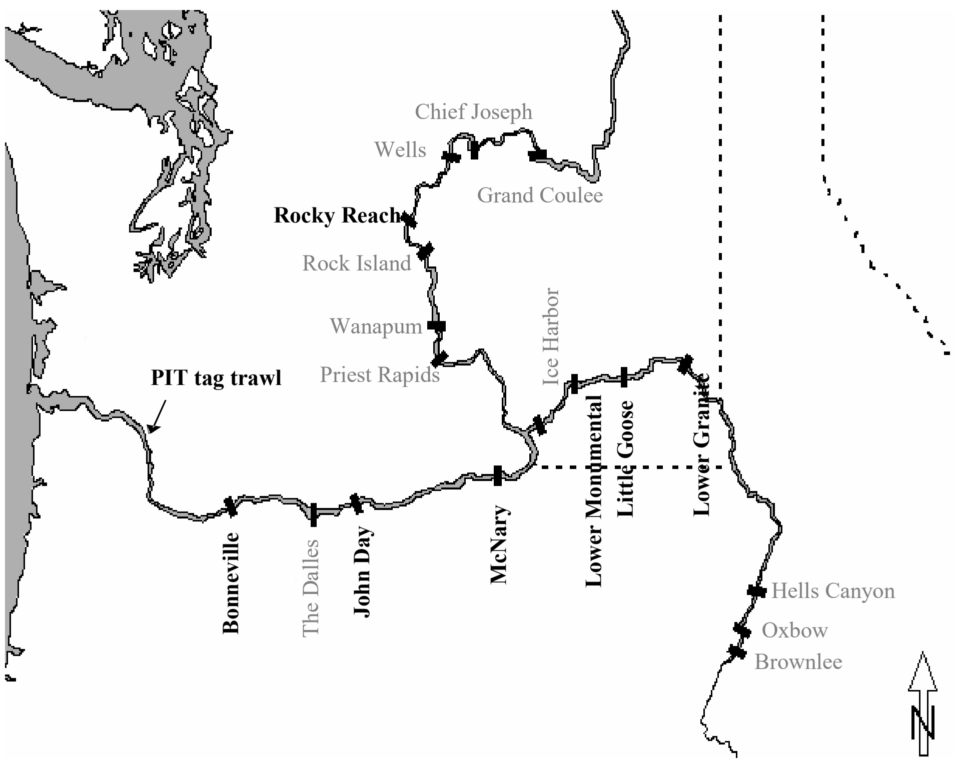

Figure 1. Study area showing sites with PIT-tag detection facilities (names in black), including dams and the PIT-tag trawl in the Columbia River estuary. Dams with names in gray do not have detection facilities.

The farthest downstream detection site was in the Columbia River estuary between rkm 65 and 84, where a pair trawl towed a PIT-tag detector (Ledgerwood et al. 2004). Since spring 2006, the corner collector at Bonneville Dam Second Powerhouse has been operated with a PIT-tag detection system. Detections at Bonneville Dam and in the pair trawl were sufficient to estimate survival from John Day tailrace to Bonneville Dam tailrace for yearling Chinook, coho and, sockeye salmon and steelhead in 2010.

A large proportion of PIT-tagged yearling Chinook salmon used in this analysis were released in the Snake River upstream from Lower Granite Dam for the multi-agency Comparative Survival Study (Schaller et al. 2007). In addition, we utilized about 122,360 yearling Chinook salmon PIT tagged at Lower Granite Dam as part of evaluation of latent mortality related to passage through Snake River dams (Marsh et al. 2006). Of these 122,360 fish, 74,523 were trucked and released to the tailrace of either Lower Granite (45,518) or Ice Harbor Dam (29,005). These latter groups were included in our McNary Dam release groups only if they were subsequently detected and returned to the river at McNary Dam (groups formed according to detection date at McNary Dam). The remaining 47,837 non-trucked (reference) fish were released to Lower Granite tailrace and used for our Lower Granite release groups.

Most PIT-tagged fish detected at dams below Lower Granite were diverted back to the river, which allowed for the possibility of detection of a particular fish at more than one downstream site (Marsh et al. 1999). For fish released in the Snake River Basin (upstream from Lower Granite Dam), we used records of downstream PIT-tag detections with the SR model to estimate survival in the following seven reaches:

- Point of release to Lower Granite Dam tailrace (various distances)
- Lower Granite Dam tailrace to Little Goose Dam tailrace (60 km)
- Little Goose Dam tailrace to Lower Monumental Dam tailrace (46 km)
- Lower Monumental Dam tailrace to Ice Harbor Dam tailrace (51 km)
- Ice Harbor Dam tailrace to McNary Dam tailrace (68 km)
- McNary Dam tailrace to John Day Dam tailrace (123 km)
- John Day Dam tailrace to Bonneville Dam tailrace (112 km)

The PIT-tag detection system in the Ice Harbor Dam juvenile bypass facility began operating in 2005. Because of the high level of spill at this dam, too few smolts were detected there to partition survival between Lower Monumental and McNary Dams in 2005. However, in 2006-2010 there were sufficient detections at Ice Harbor to partition survival through this reach.

For fish released in the Upper Columbia River, we estimated survival in the following three reaches:

- Point of release to the tailrace of McNary Dam (various distances)
- McNary Dam tailrace to John Day Dam tailrace (123 km)
- John Day Dam tailrace to Bonneville Dam tailrace (112 km)

Study Fish

Releases from Lower Granite Dam—During 2010, hatchery and wild steelhead and wild yearling Chinook salmon were collected at the Lower Granite Dam juvenile facility, PIT tagged, and released to the tailrace for the express purpose of estimating their subsequent survival. Fish were collected in approximate proportion to the numbers arriving at Lower Granite Dam during the migration season. However, in the early and late periods of the season, we tagged relatively more fish in order to provide sufficient numbers for analysis over these periods.

No hatchery yearling Chinook salmon were PIT tagged specifically for this study because none were needed: numbers released from Snake River Basin hatcheries, traps, and for other studies were sufficient for analysis downstream from Lower Granite Dam.

For both yearling Chinook salmon and steelhead, we created daily "release groups" from fish tagged upstream from Lower Granite Dam and subsequently detected at Lower Granite Dam on the same day. These groups were then combined with fish tagged and released each day at Lower Granite Dam. These daily release groups were then pooled into weekly groups, and we estimated survival probabilities in reaches between Lower Granite Dam tailrace and McNary Dam tailrace for both daily and weekly groups.

We PIT tagged and released 17,634 hatchery steelhead, 12,917 wild steelhead, and 17,076 wild yearling Chinook salmon from 14 April through 12 June at Lower Granite Dam for survival estimates (Table 1). Total mortalities of hatchery steelhead, wild steelhead, and yearling Chinook salmon were 22, 14, and 54, respectively. Each of these numbers represented well under 1% of the total fish handled.

During 2010, a total of 85,779 yearling Chinook salmon (61,703 hatchery origin, 24,076 wild) were detected and returned or PIT tagged and released to the river in the tailrace of Lower Granite Dam. A total of 42,290 (27,790 hatchery origin and 14,500 wild) steelhead were detected and returned or PIT tagged and released to the river in the tailrace of Lower Granite Dam.

Table 1. Number by date of PIT–tagged hatchery steelhead, wild steelhead, and yearling Chinook salmon released at Lower Granite Dam for survival estimates in 2010. Also included are tagging mortalities and lost tags.

	Hatchery Steelhead			**Wild Steelhead**			**Wild Yearling Chinook**		
Release date	Number released	Mortalities	Lost tags	Number released	Mortalities	Lost tags	Number released	Mortalities	Lost tags
14 Apr	61	-	-	59	-	3	7	-	-
15 Apr	30	-	-	50	-	1	26	-	1
21 Apr	292	1	1	177	-	1	59	-	-
22 Apr	378	-	-	230	3	1	65	-	-
24 Apr	379	-	-	347	-	-	185	-	-
27 Apr	875	-	-	621	-	6	497	6	-
28 Apr	676	1	-	734	1	-	1,259	2	-
29 Apr	1,041	-	-	430	1	-	1,129	2	-
30 Apr	783	2	-	566	1	-	1,874	2	4
1 May	201	-	-	463	-	6	1,243	7	-
4 May	736	-	-	613	-	2	826	1	-
5 May	736	-	-	473	2	1	969	5	-
6 May	734	1	-	468	-	1	714	6	2
7 May	775	-	-	484	-	1	721	2	2
8 May	693	1	-	278	-	2	540	2	1
11 May	667	1	-	624	-	4	435	1	-
12 May	558	1	-	374	-	-	801	2	-
13 May	887	1	-	179	-	-	362	-	1
14 May	605	-	-	207	-	-	627	2	-
15 May	602	-	-	132	-	-	264	-	-
18 May	494	-	-	444	2	1	642	-	1
19 May	490	1	1	531	1	3	766	2	3
20 May	488	-	2	491	1	3	926	2	2
21 May	492	1	-	475	-	-	884	5	4
22 May	491	-	-	584	-	3	327	1	1
25 May	353	-	1	601	-	2	219	-	2
26 May	352	-	-	299	-	-	94	1	1
27 May	348	2	-	342	1	1	159	1	-
28 May	349	1	-	280	-	-	171	2	1
29 May	348	1	1	260	-	-	205	-	-
2 Jun	261	1	-	175	-	1			
3 Jun	260	2	-	188	1	-			
5 Jun	523	1	1	198	-	-			
8 Jun	130	-	-	84	-	-			
9 Jun	129	-	1	168	-	-			
11 Jun	257	2	1	123	-	-			
12 Jun	128	1	1	108	-	-			
Totals	**17,602**	22	10	**12,860**	14	43	**16,996**	54	26

For both yearling Chinook and steelhead, some detections of fish that passed very early or very late in the season were excluded from analysis because sample sizes of these fish were too small to produce reliable estimates of either survival or travel time. Survival estimates for wild and hatchery fish combined were based predominantly on fish of hatchery origin (72% of yearling Chinook salmon and 66% of steelhead) during 2010. In comparison, we estimate that 80% of the overall yearling Chinook salmon run in 2010 was of hatchery origin, based on smolt passage data at Lower Granite Dam collected by the Fish Passage Center. We could not estimate this number for steelhead because separate collection counts for hatchery and wild fish were not available.

Releases from McNary Dam—For both yearling Chinook salmon and steelhead tagged at all locations in the Snake River Basin, and for fish tagged in the Upper Columbia River, we created daily "release groups" of fish according to the day of detection at McNary Dam. Daily groups consisted of fish detected and returned to the tailrace, and daily groups were pooled into weekly groups. For weekly groups leaving McNary Dam, we estimated survival from McNary Dam tailrace to John Day Dam tailrace and from John Day Dam tailrace to Bonneville Dam tailrace. (Data were too sparse to estimate survival for daily groups).

Releases from Hatcheries and Smolt Traps—In 2010, most hatcheries in the Snake River Basin released PIT-tagged fish as part of research separate from the NMFS survival study. We analyzed data from hatchery releases of PIT-tagged yearling Chinook salmon, sockeye salmon, coho salmon, and steelhead to provide survival estimates and detection probabilities from release to the tailrace of Lower Granite Dam and to points downstream.

For fish from the Upper Columbia River basin, we estimated survival to the tailrace of McNary Dam for yearling spring Chinook salmon released from Cle Elum, East Bank, Leavenworth, Methow, Ringold, Wells, Winthrop, and Yakima Hatcheries. We also estimated survival to McNary Dam for steelhead from East Bank and Winthrop Hatcheries, and for coho salmon from Cascade, Eagle Creek, Entiat, Willard, Winthrop, and Yakima Hatcheries. In the course of characterizing the various hatchery releases, we conducted preliminary analyses (not reported here) to determine whether data from related release groups could be pooled to increase sample sizes.

We estimated survival to Lower Granite Dam tailrace and points downstream for releases of wild and hatchery PIT-tagged yearling Chinook salmon and steelhead from the Salmon (White Bird), Snake, and Clearwater River traps, and many more smolt traps throughout the Snake River Basin.

Data Analysis

Tagging and detection data were downloaded on 12 October, 2010, from the Columbia Basin PIT Tag Information System (PTAGIS), a regional database maintained by the Pacific States Marine Fisheries Commission (PTAGIS 2010). 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. Very few records (<0.1%) were eliminated. For each remaining PIT-tag code, we constructed a record (detection history) indicating all locations at which the tagged fish was detected and all locations at which it was not detected. Methods for data retrieval, database quality assurance/control, and construction of detection histories were the same as those used in past years (see Iwamoto et al. 1994 for detail).

These analyses were conducted using the data available at this time. It is possible, for a variety of reasons, that data in the PTAGIS database may be updated in the future. Thus, future estimates provided by NMFS or employed in future analyses may differ slightly from those presented here.

Tests of Assumptions—As in past years, we evaluated assumptions of the SR model as applied to the data generated from PIT-tagged juvenile salmonids in the Snake and Columbia Rivers (Burnham et al. 1987). Evaluations of individual model assumptions are reported in Appendix A.

Chi-square contingency tests used to evaluate model assumptions for 2010 indicated more significant differences between observed and expected proportions of fish in different detection-history categories than would be expected by chance alone. In many cases, sample sizes were such that the tests had power to detect violations that had only minimal effect on survival estimates. We present a detailed discussion of the assumption tests, the extent of violations, possible reasons for the occurrence of the violations, and their implications in Appendix A.

Survival Estimates—Estimates of survival probability 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, these estimates should be considered equal to 1.0.

When estimates for a particular river section or passage route were available from more than one release group, the estimates were often combined using a weighted average (Muir et al. 2001a). Weights were inversely proportional to the respective 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. Consequently, lower survival estimates tend to have smaller estimated variance. Therefore, we did not use the inverse estimated absolute variance in weighting, because lower survival estimates would have disproportionate influence, and the resulting weighted mean would be biased toward the lower survival estimates.

All survival estimates presented are from point of release (or the tailrace of a dam) to the tailrace of a dam downstream. All survival and detection probability estimates were computed 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).

We estimated survival from point of release to the tailrace of Bonneville Dam (the last dam encountered by seaward-migrating juvenile salmonids) for various stocks from both the Snake and Upper Columbia Rivers. These estimates were obtained by first calculating weighted average survival estimated over shorter reaches for daily or weekly release groups using the weighting scheme described above. These average survival estimates were then multiplied to compute the estimated survival probabilities through the entire reach.

We pooled similar fish from different release sites when we re-formed release groups at downstream sites. For example, for Snake River yearling Chinook salmon, we multiplied the weighted mean survival estimate for daily groups from Lower Granite to McNary Dam by the weighted mean estimate for weekly groups from McNary to Bonneville Dam to obtain overall estimated mean survival probability from Lower Granite to Bonneville Dam. Finally, we multiplied this result by the estimated survival to Lower Granite Dam for fish released from the Snake River Trap to compute estimated survival from the head of Lower Granite reservoir to the tailrace of Bonneville Dam; essentially the entire eight-project hydropower system negotiated by juvenile salmonids from the Snake River Basin.

Results

Snake River Stocks

Yearling Chinook Salmon—Survival probabilities were estimated for weekly groups of yearling Chinook salmon released to the tailrace of Lower Granite Dam for 7 consecutive weeks, from 20 April through 7 June. Tailrace-to-tailrace survival estimates averaged 0.962 (se 0.011) from Lower Granite to Little Goose Dam, 0.973 (se 0.019) from Little Goose to Lower Monumental Dam, and 0.851 (se 0.017) from Lower Monumental to McNary Dam (Table 2). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, survival averaged 0.772 (se 0.012).

Table 2. Estimated survival probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled for weekly estimates. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated survival of yearling Chinook salmon			
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
20 Apr–26 Apr	10,880	0.990 (0.073)	1.022 (0.127)	0.841 (0.082)	0.851 (0.028)
27 Apr–03 May	27,916	0.979 (0.017)	1.007 (0.088)	0.769 (0.067)	0.758 (0.014)
04 May–10 May	20,692	0.920 (0.029)	0.936 (0.129)	0.830 (0.113)	0.714 (0.019)
11 May–17 May	15,880	0.935 (0.028)	1.033 (0.048)	0.827 (0.035)	0.799 (0.018)
18 May–24 May	7,518	0.941 (0.018)	0.926 (0.045)	0.900 (0.051)	0.784 (0.028)
25 May–31 May	1,376	0.993 (0.046)	0.952 (0.110)	0.814 (0.112)	0.769 (0.068)
01 Jun–07 Jun	769	0.867 (0.042)	0.979 (0.090)	0.963 (0.168)	0.817 (0.127)
Weighted mean*		**0.962 (0.011)**	**0.973 (0.019)**	**0.851 (0.017)**	**0.772 (0.012)**

* Weighted means of the independent estimates for daily groups (13 April–31 May), with weights inversely proportional to respective estimated relative variances (see Table 5).

We estimated survival probabilities for weekly groups of yearling Chinook salmon released in the tailrace at McNary Dam for five consecutive weeks from 27 April through 31 May. Tailrace-to-tailrace survival estimates averaged 0.947 (se 0.021) from McNary to John Day Dam and 0.780 (se 0.039) from John Day to Bonneville Dam, and 0.738 (se 0.039) for the combined reach from McNary to Bonneville Dam (Table 3).

Table 3. Estimated survival probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2010. Daily groups pooled for weekly estimates. Estimates based on the single-release model. Standard errors in parentheses.

		Estimated survival of yearling Chinook salmon		
Date at McNary Dam	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
27 Apr–03 May	10,832	0.991 (0.068)	0.791 (0.078)	0.784 (0.056)
04 May–10 May	21,719	0.957 (0.055)	0.666 (0.052)	0.637 (0.034)
11 May–17 May	17,397	0.910 (0.067)	0.831 (0.088)	0.756 (0.058)
18 May–24 May	28,313	0.959 (0.050)	0.856 (0.066)	0.821 (0.046)
25 May–31 May	4,627	0.816 (0.094)	0.775 (0.162)	0.632 (0.110)
Weighted mean*		**0.947 (0.021)**	**0.780 (0.039)**	**0.738 (0.039)**

* Weighted means of the independent estimates for weekly pooled groups (27 April–31 May), with weights inversely proportional to respective estimated relative variances.

The product of average estimates from Lower Granite to McNary and from McNary to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.569 (se 0.032). Estimated survival probability through Lower Granite reservoir and dam for Snake River wild and hatchery Chinook salmon released from the Snake River trap was 0.968 (se 0.040). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River yearling Chinook salmon was 0.551 (se 0.038).

We also calculated separate survival probability estimates for weekly groups of hatchery and wild yearling Chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace (Table 4). Weighted mean survival estimates were similar for hatchery and wild yearling Chinook salmon for the combined reach from the tailrace of Lower Granite Dam to the tailrace of McNary Dam in 2010.

Survival probabilities were estimated for daily groups composed of yearling Chinook salmon (hatchery and wild combined) either detected at Lower Granite Dam and returned to the tailrace or collected and tagged at the dam and released to the tailrace. These survival estimates were variable and did not show any consistent increase or decrease in survival through Snake River reaches during the 2010 migration season (Table 5; Figure 2).

Table 4. Estimated survival probabilities for Snake River hatchery and wild yearling Chinook salmon detected and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled for weekly estimates. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated survival			
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
		Hatchery yearling Chinook			
20 Apr–26 Apr	9,613	1.010 (0.084)	0.978 (0.131)	0.872 (0.089)	0.861 (0.030)
27 Apr–03 May	20,268	1.014 (0.024)	1.101 (0.135)	0.676 (0.083)	0.755 (0.017)
04 May–10 May	16,180	0.916 (0.035)	1.426 (0.366)	0.572 (0.147)	0.747 (0.025)
11 May–17 May	12,795	0.979 (0.038)	0.999 (0.060)	0.842 (0.045)	0.824 (0.022)
18 May–24 May	2,257	0.923 (0.048)	1.077 (0.163)	0.800 (0.129)	0.795 (0.059)
Weighted mean*		**0.980 (0.020)**	**1.032 (0.042)**	**0.818 (0.035)**	**0.790 (0.022)**
		Wild yearling Chinook			
20 Apr–26 Apr	1,266	0.930 (0.141)	1.339 (0.500)	0.639 (0.214)	0.796 (0.063)
27 Apr–03 May	7,644	0.968 (0.023)	0.884 (0.105)	0.899 (0.108)	0.769 (0.024)
04 May–10 May	4,509	0.968 (0.051)	0.714 (0.110)	0.932 (0.141)	0.645 (0.028)
11 May–17 May	3,084	0.905 (0.040)	1.104 (0.079)	0.731 (0.050)	0.730 (0.029)
18 May–24 May	5,257	0.966 (0.020)	0.905 (0.046)	0.891 (0.054)	0.779 (0.032)
25 May–31 May	1,201	1.038 (0.052)	0.910 (0.109)	0.799 (0.112)	0.754 (0.068)
01 Jun–07 Jun	603	0.891 (0.048)	0.953 (0.094)	1.057 (0.208)	0.897 (0.160)
Weighted mean*		**0.962 (0.013)**	**0.948 (0.042)**	**0.841 (0.037)**	**0.744 (0.021)**

* Weighted means of the independent estimates for weekly pooled groups (20 April–07 June), with weights inversely proportional to respective estimated relative variances.

Table 5. Estimated survival probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled as necessary to calculate estimates. Estimates based on the single-release model. Standard errors in parentheses.

		Estimated survival of yearling Chinook salmon			
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
13–22 Apr	2,118	1.128 (0.241)	1.098 (0.448)	0.649 (0.222)	0.804 (0.054)
23-25 Apr	8,601	0.959 (0.082)	1.026 (0.141)	0.869 (0.089)	0.855 (0.032)
26-28 Apr	6,416	1.002 (0.026)	1.139 (0.207)	0.707 (0.130)	0.807 (0.030)
29 Apr	9,484	0.987 (0.031)	0.990 (0.152)	0.776 (0.119)	0.758 (0.025)
30 Apr	2,579	0.929 (0.043)	0.957 (0.206)	0.894 (0.195)	0.795 (0.049)
01-02 May	9,193	1.038 (0.041)	0.928 (0.156)	0.743 (0.123)	0.715 (0.024)
03-04 May	7,052	0.910 (0.044)	0.873 (0.187)	0.932 (0.198)	0.740 (0.034)
05 May	1,456	0.970 (0.097)	1.076 (0.529)	0.594 (0.290)	0.620 (0.051)
06 May	6,171	1.046 (0.077)	0.736 (0.194)	0.943 (0.244)	0.727 (0.041)
07-09 May	6,360	0.853 (0.045)	1.067 (0.278)	0.791 (0.205)	0.720 (0.033)
10-12 May	5,777	0.922 (0.044)	1.071 (0.126)	0.765 (0.087)	0.755 (0.026)
13 May	4,409	0.918 (0.066)	1.059 (0.109)	0.916 (0.083)	0.891 (0.045)
14 May	1,150	1.049 (0.117)	0.865 (0.116)	0.971 (0.112)	0.882 (0.079)
15-16 May	4,467	0.964 (0.052)	0.992 (0.075)	0.798 (0.054)	0.762 (0.033)
17-18 May	1,515	0.908 (0.030)	0.954 (0.075)	0.854 (0.080)	0.739 (0.046)
19 May	1,535	0.906 (0.041)	1.081 (0.116)	0.869 (0.115)	0.850 (0.076)
20 May	1,990	0.973 (0.040)	0.876 (0.085)	0.984 (0.112)	0.838 (0.061)
21 May	1,693	1.012 (0.047)	0.919 (0.117)	0.823 (0.116)	0.765 (0.058)
22-24 May	1,101	0.918 (0.048)	0.870 (0.141)	0.884 (0.163)	0.706 (0.074)
25-27 May	775	1.001 (0.058)	1.072 (0.233)	0.717 (0.169)	0.769 (0.082)
28-31 May	601	0.900 (0.072)	0.839 (0.122)	0.918 (0.176)	0.692 (0.106)
Weighted mean*		**0.962 (0.011)**	**0.973 (0.019)**	**0.851 (0.017)**	**0.772 (0.012)**

* Weighted means of the independent estimates for daily groups (13 April –31 May), with weights inversely proportional to respective estimated relative variances.

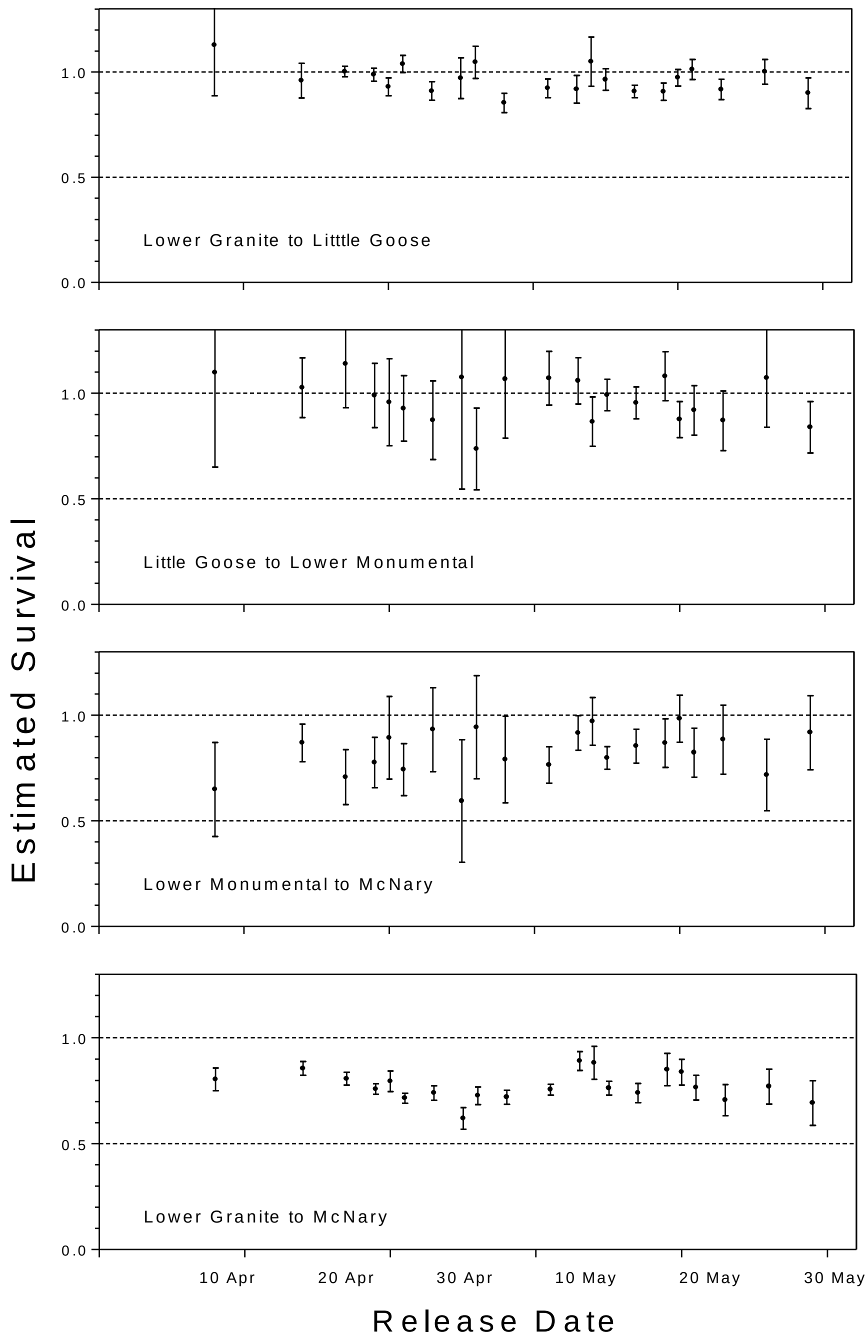

Figure 2. Estimated survival through various reaches vs. release date at Lower Granite Dam for daily release groups of Snake River yearling Chinook salmon, 2010. Bars extend one standard error above and below point estimates.

Estimates of detection probability varied throughout the season for most weekly groups of yearling Chinook salmon as flow volumes, spill levels, and degrees of smoltification changed (Tables 6-8). Detection probabilities were generally highest at and McNary Dam and Bonneville Dam, and lowest at Lower Monumental Dam and John Day Dam. Detection probabilities for wild fish were consistently greater than those for hatchery fish released from Lower Granite Dam during the same time period (Table 8), with the greatest differences occurring at Little Goose Dam and McNary Dam.

Table 6. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled weekly. Estimates based on the single–release model. Standard errors in parentheses.

	Estimated detection probability of yearling Chinook salmon			
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
20 Apr–26 Apr	10,880	0.136 (0.010)	0.019 (0.002)	0.259 (0.009)
27 Apr–03 May	27,916	0.184 (0.004)	0.009 (0.001)	0.308 (0.006)
04 May–10 May	20,692	0.102 (0.004)	0.006 (0.001)	0.258 (0.008)
11 May–17 May	15,880	0.083 (0.003)	0.072 (0.003)	0.331 (0.008)
18 May–24 May	7,518	0.326 (0.008)	0.096 (0.006)	0.338 (0.014)
25 May–31 May	1,376	0.335 (0.020)	0.110 (0.014)	0.276 (0.028)
01 Jun–07 Jun	769	0.381 (0.026)	0.312 (0.031)	0.172 (0.031)

Table 7. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2010. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

	Estimated detection probability of yearling Chinook salmon		
Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
27 Apr–03 May	10,832	0.057 (0.004)	0.278 (0.020)
04 May–10 May	21,719	0.045 (0.003)	0.328 (0.018)
11 May–17 May	17,397	0.045 (0.004)	0.217 (0.017)
18 May–24 May	28,313	0.048 (0.003)	0.220 (0.013)
25 May–31 May	4,627	0.074 (0.010)	0.234 (0.042)

Table 8. Estimated detection probabilities for Snake River hatchery and wild yearling Chinook salmon detected and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled to form weekly estimates. Estimates based on the single–release model. Standard errors in parentheses.

		Detection probability		
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Hatchery Yearling Chinook		
20 Apr–26 Apr	9,613	0.127 (0.011)	0.019 (0.002)	0.246 (0.010)
27 Apr–03 May	20,268	0.148 (0.004)	0.007 (0.001)	0.288 (0.008)
04 May–10 May	16,180	0.091 (0.004)	0.003 (0.001)	0.226 (0.008)
11 May–17 May	12,795	0.069 (0.004)	0.059 (0.003)	0.300 (0.009)
18 May–24 May	2,257	0.218 (0.015)	0.041 (0.007)	0.273 (0.023)
18 May–24 May	2,257	0.127 (0.011)	0.019 (0.002)	0.246 (0.010)
		Wild Yearling Chinook		
20 Apr–26 Apr	1,266	0.196 (0.032)	0.013 (0.005)	0.360 (0.030)
27 Apr–03 May	7,644	0.270 (0.008)	0.014 (0.002)	0.358 (0.013)
04 May–10 May	4,509	0.137 (0.009)	0.016 (0.003)	0.370 (0.018)
11 May–17 May	3,084	0.130 (0.009)	0.118 (0.009)	0.460 (0.021)
18 May–24 May	5,257	0.364 (0.010)	0.117 (0.007)	0.367 (0.016)
25 May–31 May	1,201	0.326 (0.021)	0.116 (0.016)	0.290 (0.030)
01 Jun–07 Jun	603	0.361 (0.028)	0.329 (0.034)	0.159 (0.033)

Steelhead—We estimated survival probabilities for weekly groups of steelhead from the tailrace of Lower Granite Dam for eight consecutive weeks from 20 April through 14 June. Average tailrace-to-tailrace survival was estimated at 0.965 (se 0.028) from Lower Granite to Little Goose Dam, 0.984 (se 0.044) from Little Goose to Lower Monumental Dam, and 0.876 (se 0.032) from Lower Monumental to McNary Dam (Table 9). For the combined reach from Lower Granite to McNary Dam tailrace, estimated survival averaged 0.770 (se 0.020).

Table 9. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled weekly. Estimates based on the single–release model. Standard errors in parentheses.

	Estimated survival of steelhead				
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
20 Apr–26 Apr	4,249	0.997 (0.073)	0.873 (0.119)	0.902 (0.105)	0.785 (0.048)
27 Apr–03 May	9,080	1.091 (0.031)	0.818 (0.069)	0.858 (0.075)	0.766 (0.030)
04 May–10 May	7,811	0.935 (0.036)	0.905 (0.145)	0.837 (0.138)	0.709 (0.040)
11 May–17 May	5,994	0.926 (0.034)	0.974 (0.084)	0.918 (0.101)	0.827 (0.064)
18 May–24 May	8,679	0.920 (0.026)	1.089 (0.087)	0.788 (0.077)	0.789 (0.050)
25 May–31 May	4,345	0.972 (0.040)	1.107 (0.154)	0.866 (0.158)	0.932 (0.115)
01 Jun–07 Jun	1,582	0.994 (0.046)	0.866 (0.088)	0.623 (0.095)	0.536 (0.067)
08 Jun–14 Jun	156	1.037 (0.054)	0.789 (0.094)	0.717 (0.192)	0.587 (0.148)
Weighted mean*		**0.965 (0.028)**	**0.984 (0.044)**	**0.876 (0.032)**	**0.770 (0.020)**

* Weighted means of the independent estimates for daily groups (13 April–31 May), with weights inversely proportional to respective estimated relative variances (see Table 14).

We estimated survival probabilities for weekly groups of steelhead released in the tailrace of McNary Dam for five consecutive weeks from 27 April through 31 May. Estimated tailrace-to-tailrace survival averaged 0.931 (se 0.051) from McNary to John Day Dam, 0.840 (se 0.038) from John Day to Bonneville Dam, and 0.789 (se 0.027) for the combined reach from McNary to Bonneville Dam tailrace (Table 10).

Table 10. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2010. Daily groups pooled weekly. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated survival of steelhead		
Date at McNary Dam	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
27 Apr–03 May	3,002	0.846 (0.054)	0.941 (0.124)	0.796 (0.092)
04 May–10 May	5,537	1.012 (0.064)	0.783 (0.084)	0.793 (0.069)
11 May–17 May	2,441	0.809 (0.102)	0.893 (0.178)	0.723 (0.112)
18 May–24 May	2,426	1.173 (0.201)	0.772 (0.189)	0.906 (0.158)
25 May–31 May	1,698	0.922 (0.194)	0.746 (0.224)	0.688 (0.148)
Weighted mean*		**0.931 (0.051)**	**0.840 (0.038)**	**0.789 (0.027)**

* Weighted means of the independent estimates for weekly pooled groups (27 April–31 May), with weights inversely proportional to respective estimated relative variances.

The product of 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 0.608 (se 0.026). Estimated survival probability through Lower Granite reservoir and dam for Snake River wild and hatchery steelhead released from the Snake River trap was 1.017 (se 0.030). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River steelhead was 0.618 (se 0.032).

Separate survival probabilities were estimated for weekly groups of hatchery and wild steelhead from Lower Granite Dam tailrace to McNary Dam tailrace (Table 11). Survival estimates through most individual reaches and the reaches combined were similar for wild and hatchery steelhead.

Estimated survival probabilities for daily release groups of steelhead (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam did not show any consistent increase or decrease through Snake River reaches during the 2010 migration season (Table 12; Figure 3).

Table 11. Estimated survival probabilities for juvenile Snake River hatchery and wild steelhead detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled weekly. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated survival			
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
		Hatchery steelhead			
20 Apr–26 Apr	3,089	0.960 (0.070)	0.930 (0.134)	0.893 (0.112)	0.798 (0.053)
27 Apr–03 May	5,835	1.124 (0.040)	0.831 (0.089)	0.812 (0.089)	0.758 (0.034)
04 May–10 May	5,203	0.897 (0.042)	1.036 (0.214)	0.768 (0.163)	0.713 (0.048)
11 May–17 May	4,123	0.898 (0.038)	1.059 (0.107)	0.888 (0.119)	0.845 (0.082)
18 May–24 May	5,409	0.914 (0.034)	1.172 (0.124)	0.717 (0.090)	0.768 (0.059)
25 May–31 May	2,441	0.980 (0.057)	1.048 (0.200)	0.803 (0.192)	0.825 (0.128)
01 Jun–07 Jun	1,279	0.984 (0.052)	0.842 (0.092)	0.689 (0.123)	0.570 (0.086)
08 Jun–14 Jun	147	1.048 (0.057)	0.778 (0.094)	0.679 (0.179)	0.554 (0.138)
Weighted mean[a]		**0.980 (0.033)**	**0.956 (0.053)**	**0.802 (0.029)**	**0.759 (0.021)**
		Wild steelhead			
20 Apr–26 Apr	1,160	1.345 (0.342)	0.624 (0.236)	0.920 (0.262)	0.772 (0.112)
27 Apr–03 May	3,245	1.032 (0.048)	0.796 (0.110)	0.972 (0.144)	0.798 (0.060)
04 May–10 May	2,608	0.990 (0.065)	0.720 (0.180)	0.980 (0.258)	0.698 (0.074)
11 May–17 May	1,871	1.007 (0.077)	0.773 (0.129)	0.978 (0.190)	0.761 (0.095)
18 May–24 May	3,270	0.917 (0.039)	0.980 (0.118)	0.896 (0.140)	0.805 (0.087)
25 May–31 May	1,904	0.965 (0.058)	1.173 (0.241)	0.949 (0.267)	1.074 (0.216)
01 Jun–07 Jun	303	1.030 (0.102)	1.030 (0.281)	0.424 (0.142)	0.450 (0.097)
Weighted mean[b]		**0.981 (0.023)**	**0.895 (0.060)**	**0.918 (0.051)**	**0.773 (0.041)**

[a] Weighted means of the independent estimates for weekly pooled groups (20 April –14 June), with weights inversely proportional to respective estimated relative variances.

[b] Weighted means of the independent estimates for weekly pooled groups (20 April–07 June), with weights inversely proportional to respective estimated relative variances.

Table 12. Estimated survival probabilities for daily groups of Snake River juvenile steelhead (hatchery and wild combined) detected and released or PIT tagged and released to the tailrace of Lower Granite Dam in 2010. Daily groups pooled as necessary to calculate estimates. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated survival of steelhead			
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
13–22 Apr	1,825	1.023 (0.185)	0.823 (0.232)	0.880 (0.158)	0.741 (0.075)
23-25 Apr	2,270	0.953 (0.080)	0.985 (0.167)	0.866 (0.138)	0.813 (0.067)
26-27 Apr	2,443	1.068 (0.077)	0.839 (0.140)	0.842 (0.131)	0.755 (0.057)
28 Apr	1,798	1.052 (0.053)	0.975 (0.172)	0.735 (0.136)	0.754 (0.059)
29 Apr	1,877	1.145 (0.065)	0.811 (0.166)	0.896 (0.192)	0.833 (0.073)
30 Apr-02 May	3,037	1.080 (0.060)	0.687 (0.099)	0.984 (0.148)	0.730 (0.052)
03-05 May	3,566	0.972 (0.051)	1.290 (0.348)	0.520 (0.143)	0.653 (0.048)
06 May	1,454	0.868 (0.073)	0.764 (0.219)	1.143 (0.362)	0.757 (0.120)
07-09 May	2,864	0.992 (0.072)	0.712 (0.204)	1.088 (0.319)	0.768 (0.074)
10-11 May	1,734	0.930 (0.066)	0.821 (0.182)	0.964 (0.237)	0.737 (0.096)
12 May	1,037	1.098 (0.209)	0.681 (0.207)	0.806 (0.228)	0.602 (0.093)
13-15 May	3,110	0.948 (0.048)	0.999 (0.107)	1.030 (0.156)	0.976 (0.115)
16-18 May	1,589	0.830 (0.022)	1.160 (0.110)	0.892 (0.152)	0.859 (0.124)
19 May	1,448	0.936 (0.057)	1.059 (0.186)	0.968 (0.229)	0.959 (0.163)
20 May	2,033	1.111 (0.110)	1.172 (0.290)	0.725 (0.196)	0.944 (0.137)
21 May	1,881	1.341 (0.163)	1.003 (0.339)	0.555 (0.190)	0.746 (0.099)
22 May	1,597	1.082 (0.090)	0.967 (0.246)	0.604 (0.165)	0.632 (0.082)
23-25 May	1,627	1.216 (0.090)	0.676 (0.162)	1.056 (0.322)	0.869 (0.176)
26-27 May	1,671	0.937 (0.060)	1.524 (0.449)	0.690 (0.246)	0.986 (0.207)
28-31 May	1,560	0.827 (0.054)	1.231 (0.228)	0.781 (0.198)	0.796 (0.146)
Weighted mean*		**0.965 (0.028)**	**0.984 (0.044)**	**0.876 (0.032)**	**0.770 (0.020)**

* Weighted means of the independent estimates for daily groups (13 April–31 May), with weights inversely proportional to respective estimated relative variances.

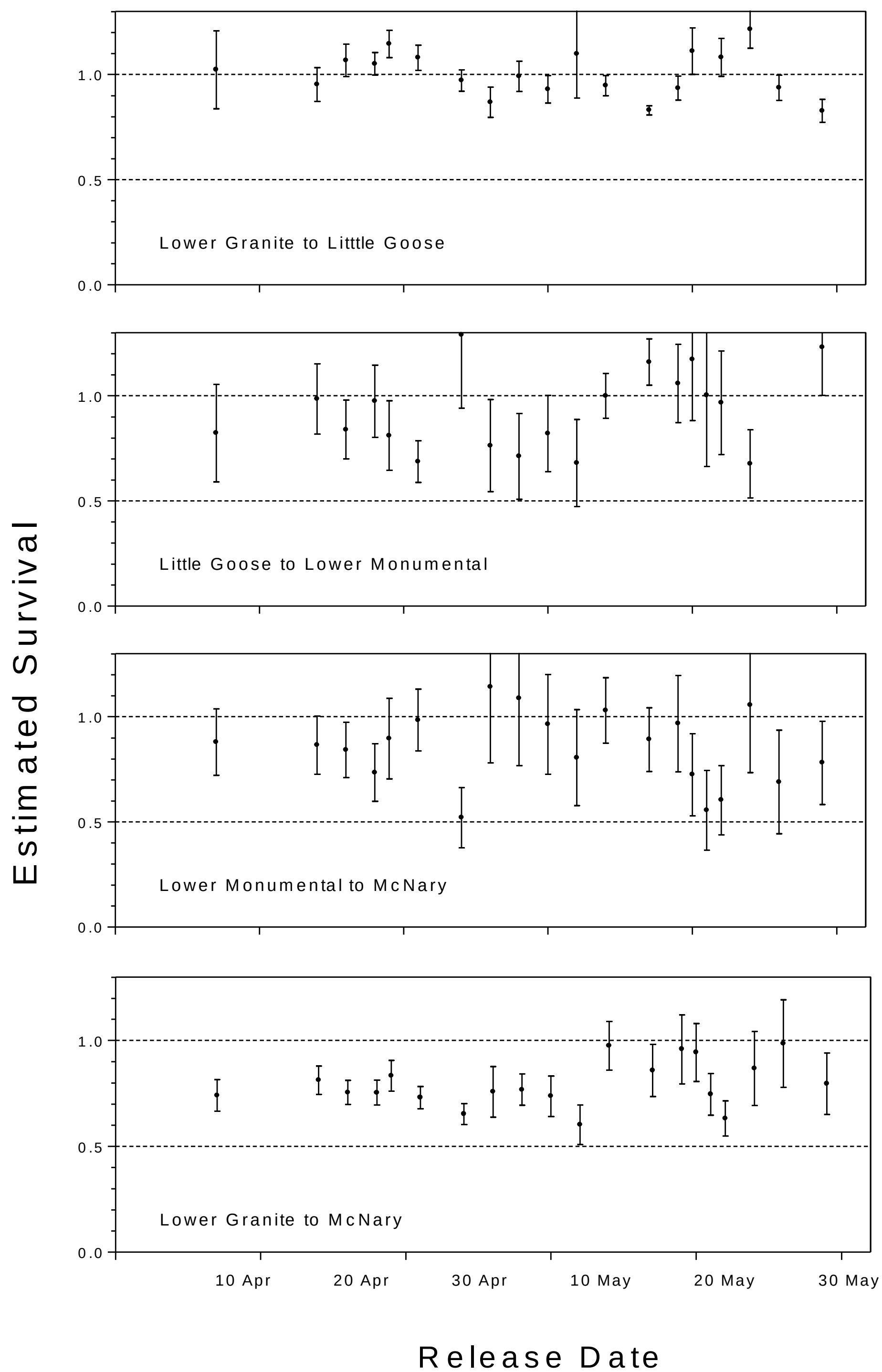

Figure 3. Estimated survival through various reaches versus release date at Lower Granite Dam for daily release groups of Snake River steelhead, 2010. Bars extend one standard error above and below point estimates.

Estimates of detection probability at Snake River dams for weekly groups of steelhead varied throughout the season as flow volumes, spill levels, and degrees of smoltification changed (Tables 13-15). Detection probability estimates were generally highest at Little Goose and Bonneville Dam and lowest at Lower Monumental and John Day Dam. Detection probability estimates did not show consistent differences between hatchery and wild fish (Table 15).

Table 13. Estimated detection probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Weekly estimates from pooled daily groups. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated detection probability of steelhead		
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
20 Apr–26 Apr	4,249	0.236 (0.019)	0.041 (0.006)	0.138 (0.010)
27 Apr–03 May	9,080	0.237 (0.008)	0.034 (0.003)	0.175 (0.008)
04 May–10 May	7,811	0.191 (0.009)	0.015 (0.003)	0.127 (0.008)
11 May–17 May	5,994	0.204 (0.009)	0.067 (0.006)	0.083 (0.008)
18 May–24 May	8,679	0.258 (0.009)	0.061 (0.005)	0.107 (0.008)
25 May–31 May	4,345	0.285 (0.014)	0.052 (0.008)	0.087 (0.012)
01 Jun–07 Jun	1,582	0.343 (0.020)	0.206 (0.021)	0.124 (0.019)
08 Jun–14 Jun	156	0.600 (0.050)	0.590 (0.072)	0.341 (0.097)

Table 14. Estimated detection probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2010. Daily groups pooled for weekly estimates. Estimates based on the single–release model. Standard errors in parentheses.

	Estimated detection probability of steelhead		
Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
27 Apr–03 May	3,002	0.134 (0.011)	0.381 (0.045)
04 May–10 May	5,537	0.087 (0.007)	0.391 (0.034)
11 May–17 May	2,441	0.054 (0.008)	0.407 (0.064)
18 May–24 May	2,426	0.039 (0.008)	0.275 (0.049)
25 May–31 May	1,698	0.040 (0.010)	0.333 (0.073)

Table 15. Estimated detection probabilities for juvenile Snake River hatchery and wild steelhead detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled weekly. Estimates based on the single–release model. Standard errors in parentheses.

		Estimated detection probability of steelhead		
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Hatchery steelhead		
20 Apr–26 Apr	3,089	0.267 (0.021)	0.044 (0.006)	0.144 (0.012)
27 Apr–03 May	5,835	0.224 (0.010)	0.032 (0.004)	0.183 (0.010)
04 May–10 May	5,203	0.182 (0.010)	0.013 (0.003)	0.126 (0.010)
11 May–17 May	4,123	0.208 (0.011)	0.068 (0.008)	0.071 (0.008)
18 May–24 May	5,409	0.233 (0.010)	0.055 (0.006)	0.102 (0.009)
25 May–31 May	2,441	0.274 (0.018)	0.049 (0.010)	0.088 (0.015)
01 Jun–07 Jun	1,279	0.336 (0.022)	0.219 (0.024)	0.107 (0.020)
08 Jun–14 Jun	147	0.590 (0.052)	0.608 (0.074)	0.356 (0.100)
		Wild steelhead		
20 Apr–26 Apr	1,160	0.133 (0.035)	0.031 (0.010)	0.118 (0.020)
27 Apr–03 May	3,245	0.261 (0.014)	0.039 (0.006)	0.157 (0.014)
04 May–10 May	2,608	0.211 (0.016)	0.020 (0.006)	0.130 (0.016)
11 May–17 May	1,871	0.193 (0.017)	0.065 (0.012)	0.116 (0.017)
18 May–24 May	3,270	0.302 (0.015)	0.071 (0.009)	0.118 (0.014)
25 May–31 May	1,904	0.300 (0.021)	0.055 (0.012)	0.086 (0.018)
01 Jun–07 Jun	303	0.372 (0.046)	0.154 (0.044)	0.196 (0.053)

Hatchery Release Groups—Survival probabilities were estimated for PIT-tagged hatchery yearling Chinook, sockeye salmon, and steelhead from release at Snake River Basin hatcheries to the tailrace of Lower Granite Dam and to downstream dams. These estimates varied among hatcheries and release locations (Appendix Tables B1-B3), as did estimated detection probabilities among detection sites (Appendix Tables B4-B6). For yearling Chinook salmon, estimated survival from release to Lower Granite Dam tailrace was highest for fish from Dworshak Hatchery released into the North Fork Clearwater River (0.898) and lowest for fish from McCall Hatchery released into Johnson Creek (0.269).

For steelhead, estimated survival from release to Lower Granite Dam tailrace ranged from 0.980 for fish from Niagara Springs Hatchery released into the Little Salmon River, to 0.650 for fish from Hagerman Hatchery released into the Salmon River. For sockeye salmon PIT-tagged and released in spring, estimated survival to Lower Granite Dam tailrace ranged from 0.146 from Redfish Lake Creek trap to 0.246 from Sawtooth trap. Estimated survival was generally lower for sockeye salmon PIT-tagged and released in fall 2009 (0.089-0.157).

Smolt Trap Release Groups—Survival probability estimates for juvenile salmonids PIT tagged and released from Snake River Basin smolt traps were generally inversely related to distance of the traps from Lower Granite Dam (Appendix Table B7). Estimated detection probabilities were similar among release groups of the same species and rearing type from different traps (Appendix Table B8). However, for yearling Chinook salmon, estimated detection probabilities for wild fish were consistently higher than those for hatchery fish released from the same locations (i.e., Grande Ronde, Salmon, and Snake River traps). Detection probability estimates were not consistently different between hatchery and wild steelhead released from the same locations.

Partitioning Survival Between Lower Monumental and Ice Harbor Dam—A PIT-tag detection system became operational at Ice Harbor Dam in 2005, and sufficient detections occurred in 2006-2010 to partition survival estimates through the individual reaches (Table 16). In 2010, estimated mean survival from tailrace to tailrace for yearling Chinook salmon was 0.949 (se 0.021) from Lower Monumental to Ice Harbor Dam and 0.907 (se 0.011) from Ice Harbor to McNary Dam. For steelhead, estimated mean survival through these reaches was 0.979 (se 0.061) and 0.881 (se 0.047), respectively.

Table 16. Estimated survival and detection probabilities for Snake River yearling Chinook salmon and steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Daily groups pooled for weekly estimates. Estimates based on the single–release model. Standard errors in parentheses.

Date at Lower Granite	Number released	Survival probability: Lower Monumental to Ice Harbor Dam	Survival probability: Ice Harbor to McNary Dam	**Detection probability Ice Harbor Dam**
		Hatchery and wild yearling Chinook salmon		
20 Apr–26 Apr	10,880	0.949 (0.098)	0.869 (0.054)	0.052 (0.004)
27 Apr–03 May	27,916	0.828 (0.074)	0.918 (0.036)	0.045 (0.002)
04 May–10 May	20,692	0.911 (0.124)	0.937 (0.055)	0.034 (0.002)
11 May–17 May	15,880	0.967 (0.062)	0.874 (0.051)	0.030 (0.002)
18 May–24 May	7,518	0.986 (0.054)	0.923 (0.049)	0.113 (0.006)
25 May–31 May	1,376	0.942 (0.120)	0.854 (0.107)	0.138 (0.016)
01 Jun–07 Jun	769	0.971 (0.147)	0.935 (0.191)	0.136 (0.023)
Weighted mean[a]		**0.949 (0.021)**	**0.907 (0.011)**	**0.042 (0.007)**
		Hatchery and wild steelhead		
20 Apr–26 Apr	4,249	1.156 (0.146)	0.838 (0.091)	0.051 (0.006)
27 Apr–03 May	9,080	0.982 (0.080)	0.882 (0.051)	0.102 (0.006)
04 May–10 May	7,811	0.999 (0.164)	0.779 (0.071)	0.063 (0.005)
11 May–17 May	5,994	1.218 (0.249)	0.777 (0.160)	0.012 (0.003)
18 May–24 May	8,679	0.810 (0.069)	0.984 (0.082)	0.096 (0.006)
25 May–31 May	4,345	0.814 (0.104)	1.210 (0.176)	0.120 (0.011)
01 Jun–07 Jun	1,582	1.119 (0.136)	0.619 (0.100)	0.153 (0.019)
08 Jun–14 Jun	156	1.638 (0.546)	0.459 (0.192)	0.130 (0.050)
Weighted mean[b]		**0.979 (0.061)**	**0.881 (0.047)**	**0.046 (0.015)**

a Weighted means of the independent estimates for weekly pooled groups (20 April –07 June), with weights inversely proportional to respective estimated relative variances.

b Weighted means of the independent estimates for weekly pooled groups (20 April –14 June), with weights inversely proportional to respective estimated relative variances.

Upper Columbia River Hatchery Release Groups

Survival probability estimates for PIT-tagged hatchery yearling Chinook, coho salmon, and steelhead from release at Upper Columbia River hatcheries to the tailrace of McNary Dam and dams downstream varied among hatcheries and release locations (Appendix Table B12), as did detection probability estimates (Appendix Table B13). For yearling Chinook released in the Upper Columbia River, estimated survival from release to McNary Dam tailrace ranged from 0.830 (se 0.051) for East Bank Hatchery fish released from Dryden Pond on the Wenatchee River to 0.204 (se 0.013) for Yakima Hatchery fish released into the Natches River.

For Upper Columbia River steelhead, estimated survival from release to McNary Dam tailrace ranged from 0.752 (se 0.095) for fish from East Bank Hatchery released into the Wenatchee River in May to 0.317 (se 0.034) for East Bank Hatchery fish released into the Wenatchee River in March. For Upper Columbia River coho salmon, estimated survival from release to McNary Dam tailrace ranged from 0.750 (se 0.103) for fish from Cascade Hatchery released from Leavenworth Hatchery, to 0.196 (se 0.034) for fish from Yakima Hatchery released from Stiles Pond in the Yakima River Basin.

TRAVEL TIME AND MIGRATION RATES

Methods

We calculated travel times of yearling Chinook salmon and steelhead for the following eight reaches:

- Lower Granite Dam to Little Goose Dam (60 km)
- Little Goose Dam to Lower Monumental Dam (46 km)
- Lower Monumental Dam to McNary Dam (119 km)
- Lower Granite Dam to McNary Dam (225 km)
- Lower Granite Dam to Bonneville Dam (461 km)
- McNary Dam to John Day Dam (123 km)
- John Day Dam to Bonneville Dam (113 km)
- McNary Dam to Bonneville Dam (236 km)

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 (generally at a PIT-tag detector close enough to the outfall site that fish arrived in the tailrace within minutes after detection) 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, gatewells, or collection channel prior to detection in the juvenile bypass system.

Migration rate through a river section was calculated as the length of the section (km) divided by the travel time (d), 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.

The true complete set of travel times for a release group includes travel times of both detected and non-detected fish. However, using PIT tags, travel time cannot be determined for a fish that traverses a river section but is not detected at both ends of the section. Travel time statistics are computed only from travel times for detected fish, which represent a sample of the complete set. Non-detected fish pass dams via turbines and spill; thus, their time to pass a dam is typically minutes to hours shorter than that of detected fish, which pass the dam via the juvenile bypass system.

Results

Travel time estimates for yearling Chinook salmon and juvenile steelhead released in the tailraces of Lower Granite and McNary Dams varied throughout the season (Tables 17-22). For both species, estimated migration rates were generally highest in the lower river sections. Estimated travel times from Lower Granite to Bonneville Dam for yearling Chinook salmon and steelhead in 2010 were near the average observed for recent years (2003-2009) for most of the season, and were lower than average (migration rates increased) later in the season (Figure 4).

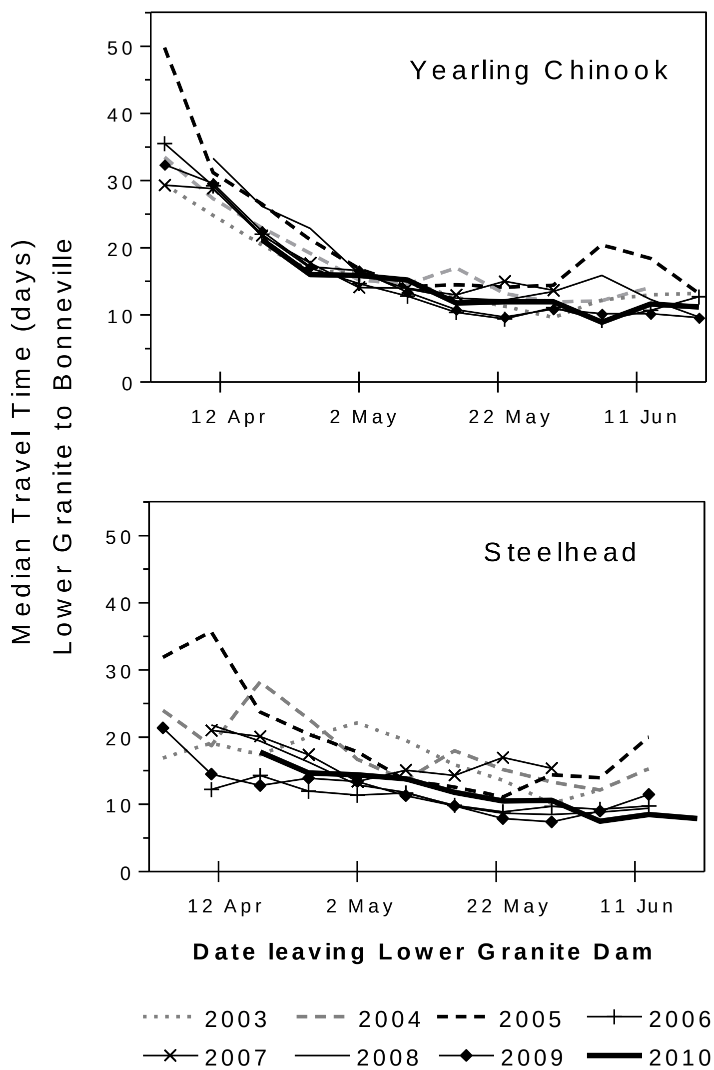

Figure 4. Median travel time (days) from Lower Granite Dam to Bonneville Dam for weekly release groups of Snake River yearling Chinook salmon and steelhead from Lower Granite Dam, 2003-2010.

Travel times throughout the season for steelhead in 2010 were faster than expected based on flow alone when compared to years with similar flow, such as 2004 and 2007. The observed increases in migration rates for yearling Chinook salmon and steelhead later in the season generally coincided with increases in flow, and presumably with increased levels of smoltification (Figure 5).

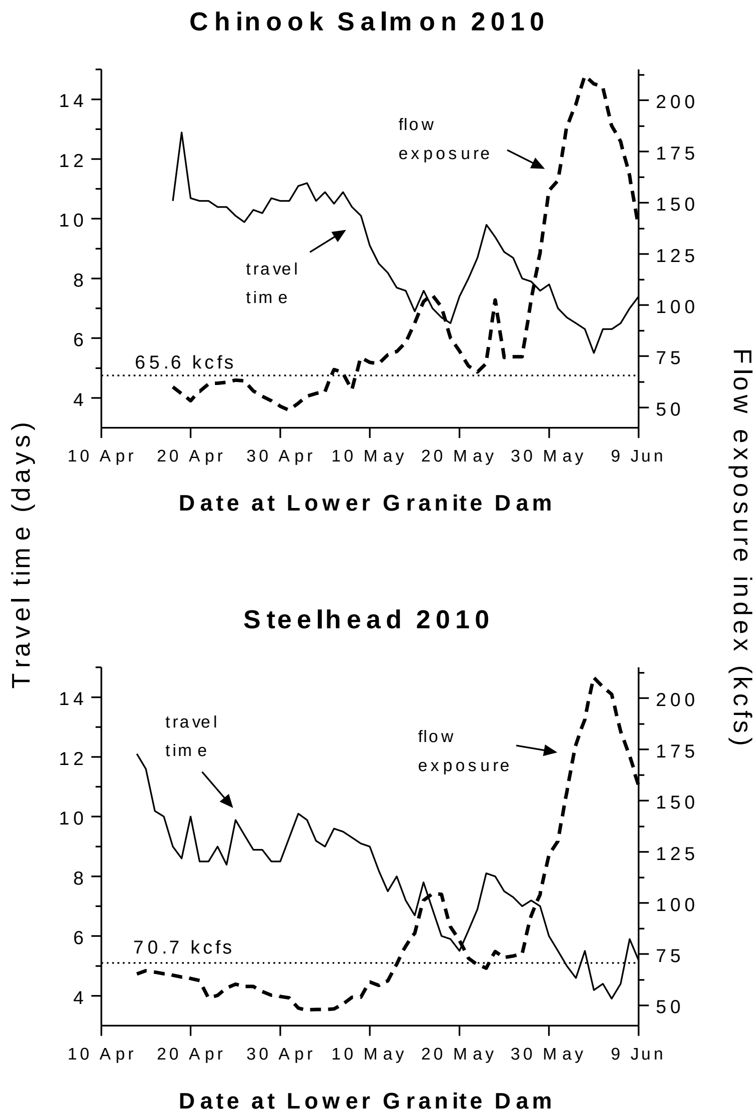

Figure 5. Travel time (days) for yearling Chinook salmon and steelhead from Lower Granite Dam to McNary Dam and index of flow exposure at Lower Monumental Dam (kcfs) for daily groups of PIT-tagged fish during 2010. Dashed horizontal lines represent the annual average flow exposure index, weighted by the number of PIT-tagged fish in each group.

Table 17. Travel time statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at Lower Granite Dam in 2010. Weekly estimates from pooled daily groups. Abbreviations: N–Number of fish on which statistics are based; Med.–Median.

Travel time of yearling Chinook salmon (d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam				Little Goose to Lower Monumental				Lower Monumental to McNary Dam			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	17	5.9	7.3	9.2	0	NA	NA	NA	0	NA	NA	NA
20 Apr–26 Apr	1,463	4.0	5.0	6.0	1	2.3	2.3	2.3	29	3.4	3.9	4.6
27 Apr–03 May	5,037	3.0	3.9	4.9	34	2.1	2.8	5.0	57	3.5	4.6	5.6
04 May–10 May	1,950	3.6	4.1	5.0	15	1.7	2.6	3.3	22	2.9	3.6	4.1
11 May–17 May	1,227	2.7	3.1	3.8	141	1.5	1.9	2.5	303	2.7	3.2	4.0
18 May–24 May	2,302	1.9	2.3	3.0	204	1.1	1.5	2.1	195	3.0	3.6	4.3
25 May–31 May	458	2.7	3.1	3.8	50	1.3	1.6	2.1	22	2.4	3.0	3.8
01 Jun–07 Jun	254	1.8	2.2	2.9	75	0.8	1.0	1.2	30	2.3	3.1	4.4
08 Jun–14 Jun	95	2.0	2.8	3.3	33	1.1	1.4	1.8	12	2.7	2.9	4.0
15 Jun–21 Jun	55	2.1	2.9	3.4	4	1.1	1.3	1.6	3	3.1	3.2	3.6
22 Jun–28 Jun	22	2.1	2.9	3.1	0	NA	NA	NA	2	2.8	3.2	3.6

Date at Lower Granite Dam	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	28	11.1	15.6	18.2	17	16.0	21.2	23.3
20 Apr–26 Apr	2,114	9.2	10.5	12.3	1,678	14.2	16.0	18.4
27 Apr–03 May	6,411	9.2	10.6	12.7	3,893	14.5	15.9	18.3
04 May–10 May	3,795	9.4	10.5	12.4	2,118	13.9	15.2	16.7
11 May–17 May	4,182	6.9	7.8	8.8	2,051	10.8	11.8	13.2
18 May–24 May	1,960	6.4	7.5	9.0	799	10.8	12.0	13.6
25 May–31 May	283	7.4	8.4	9.5	108	10.9	12.0	13.4
01 Jun–07 Jun	103	5.3	6.1	7.3	77	7.8	8.9	10.2
08 Jun–14 Jun	31	6.2	7.3	9.6	15	10.2	11.6	12.7
15 Jun–21 Jun	24	6.6	7.6	9.6	17	10.2	11.2	12.7
22 Jun–28 Jun	23	6.3	7.2	8.7	15	9.7	10.4	11.7

Table 18. Migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at Lower Granite Dam in 2010. Weekly estimates from pooled daily groups. Abbreviations: N–Number of fish observed; Med–Median.

Migration rate of yearling Chinook salmon (km/d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam				Little Goose to Lower Monumental				Lower Monumental to McNary Dam			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	17	6.5	8.3	10.2	0	NA	NA	NA	0	NA	NA	NA
20 Apr–26 Apr	1,463	10.0	11.9	15.1	1	20.0	20.0	20.0	29	25.8	30.4	35.4
27 Apr–03 May	5,037	12.2	15.4	19.9	34	9.1	16.7	22.0	57	21.1	26.1	33.5
04 May–10 May	1,950	11.9	14.6	16.8	15	14.1	17.5	26.7	22	28.9	32.6	41.3
11 May–17 May	1,227	15.7	19.6	22.1	141	18.8	23.7	30.9	303	29.5	37.0	44.1
18 May–24 May	2,302	19.7	25.9	31.1	204	22.2	30.5	40.4	195	27.5	33.2	39.9
25 May–31 May	458	15.8	19.2	22.3	50	21.6	28.2	35.4	22	30.9	40.3	50.2
01 Jun–07 Jun	254	21.0	27.3	33.7	75	36.8	46.0	57.5	30	27.3	38.3	52.7
08 Jun–14 Jun	95	18.3	21.5	30.5	33	25.0	32.2	41.4	12	30.1	41.2	44.7
15 Jun–21 Jun	55	17.9	20.8	28.7	4	29.1	34.3	40.4	3	33.3	37.4	38.4
22 Jun–28 Jun	22	19.2	20.4	28.2	0	NA	NA	NA	2	33.1	37.4	43.1

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	28	12.4	14.4	20.2	17	19.8	21.8	28.7
20 Apr–26 Apr	2,114	18.2	21.5	24.5	1,678	25.1	28.8	32.5
27 Apr–03 May	6,411	17.7	21.2	24.5	3,893	25.2	29.0	31.9
04 May–10 May	3,795	18.2	21.4	23.8	2,118	27.6	30.4	33.1
11 May–17 May	4,182	25.5	28.9	32.8	2,051	35.0	38.9	42.8
18 May–24 May	1,960	25.1	30.0	35.2	799	33.8	38.3	42.6
25 May–31 May	283	23.6	26.9	30.2	108	34.3	38.3	42.1
01 Jun–07 Jun	103	30.7	36.6	42.1	77	45.1	52.0	59.3
08 Jun–14 Jun	31	23.4	30.7	36.6	15	36.2	39.8	45.0
15 Jun–21 Jun	24	23.6	29.8	33.9	17	36.2	41.1	45.2
22 Jun–28 Jun	23	25.8	31.3	35.5	15	39.4	44.5	47.8

Table 19. Travel time and migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2010. Abbreviations: N–number of fish on which statistics are based; Med.-median.

Date at McNary Dam	Hatchery and wild yearling Chinook salmon											
	McNary to John Day Dam				John Day to Bonneville Dam				McNary to Bonneville Dam			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
	Travel time (d)											
20 Apr–26 Apr	9	3.9	5.1	5.1	0	NA	NA	NA	33	5.7	6.3	7.1
27 Apr–03 May	612	4.0	4.9	6.6	133	1.9	2.1	2.4	2,357	5.5	6.3	7.5
04 May–10 May	930	4.4	5.2	6.3	204	1.9	2.1	2.3	4,527	5.8	6.5	7.3
11 May–17 May	708	3.7	4.5	5.4	119	1.7	1.9	2.1	2,846	5.2	5.7	6.4
18 May–24 May	1,309	3.1	3.8	4.7	243	1.7	1.9	2.1	5,112	4.4	4.9	5.5
25 May–31 May	278	3.7	4.3	5.2	52	1.7	1.9	2.2	685	4.8	5.4	6.0
01 Jun–07 Jun	149	2.9	3.2	3.8	11	1.5	1.5	1.6	102	4.2	4.5	5.1
08 Jun–14 Jun	79	2.9	3.1	3.9	10	1.4	1.6	1.9	60	3.9	4.2	4.9
15 Jun–21 Jun	35	2.9	3.0	3.3	4	1.4	1.5	1.6	15	3.8	4.3	4.6
22 Jun–28 Jun	16	2.7	2.9	3.2	1	1.2	1.2	1.2	7	3.5	3.7	3.8
29 Jun–05 Jul	15	2.1	3.2	3.4	3	1.4	1.5	1.5	27	3.8	3.9	4.4
	Migration rate (km/d)											
20 Apr–26 Apr	9	24.0	24.3	31.2	0	NA	NA	NA	33	33.2	37.2	41.3
27 Apr–03 May	612	18.6	24.9	30.7	133	47.7	54.3	60.4	2,357	31.6	37.3	43.1
04 May–10 May	930	19.6	23.6	27.8	204	49.3	54.9	59.2	4,527	32.1	36.6	40.8
11 May–17 May	708	22.9	27.5	33.0	119	52.6	59.8	66.9	2,846	36.6	41.8	45.6
18 May–24 May	1,309	25.9	32.5	39.0	243	53.8	60.1	66.9	5,112	42.6	48.2	54.0
25 May–31 May	278	23.9	28.9	33.3	52	50.2	59.2	65.3	685	39.1	43.8	48.9
01 Jun–07 Jun	149	31.9	38.6	42.1	11	68.9	73.9	75.8	102	46.4	51.9	55.9
08 Jun–14 Jun	79	31.2	39.4	42.4	10	58.5	72.4	81.9	60	48.2	55.5	61.0
15 Jun–21 Jun	35	37.0	41.6	42.7	4	69.8	73.9	80.7	15	51.2	55.3	62.1
22 Jun–28 Jun	16	37.8	42.6	46.1	1	93.4	93.4	93.4	7	62.3	63.4	67.0
29 Jun–05 Jul	15	36.5	38.4	58.9	3	76.9	77.4	81.9	27	53.4	60.2	62.9

Table 20. Travel time statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Abbreviations: N-Number of fish on which statistics are based; Med.–Median.

Travel time of juvenile steelhead (d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam				Little Goose to Lower Monumental				Lower Monumental to McNary Dam			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	65	4.3	5.3	6.1	0	NA	NA	NA	1	4.5	4.5	4.5
20 Apr–26 Apr	1,001	2.1	2.9	3.8	8	2.7	3.0	3.6	20	3.8	4.0	5.3
27 Apr–03 May	2,347	2.8	3.0	3.8	44	1.9	2.8	5.2	42	3.6	4.0	4.6
04 May–10 May	1,396	2.9	3.1	3.9	32	2.0	3.0	3.9	11	3.2	3.8	4.2
11 May–17 May	1,133	2.1	2.9	3.2	82	1.4	1.8	2.4	30	2.5	2.9	3.5
18 May–24 May	2,057	1.9	2.0	2.4	242	1.0	1.2	1.6	50	2.4	3.0	3.4
25 May–31 May	1,205	2.1	2.9	3.4	72	1.0	1.4	2.0	20	1.8	2.8	3.2
01 Jun–07 Jun	539	1.6	1.9	2.1	96	0.7	1.0	1.2	15	1.6	2.0	2.2
08 Jun–14 Jun	97	1.6	1.8	2.1	43	0.8	1.1	1.6	17	1.8	2.1	2.4

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	20	10.1	11.4	12.3	43	16.1	17.8	19.6
20 Apr–26 Apr	369	7.9	8.9	10.5	838	12.8	14.7	16.9
27 Apr–03 May	1,145	7.9	8.9	10.5	1,697	12.9	14.4	15.9
04 May–10 May	696	8.4	9.3	10.9	1,268	12.8	13.8	15.4
11 May–17 May	406	6.9	7.5	8.4	1,041	10.6	11.8	12.8
18 May–24 May	725	5.2	6.1	7.2	1,343	9.6	10.5	11.6
25 May–31 May	349	6.4	7.2	8.3	328	9.6	10.6	11.3
01 Jun–07 Jun	101	3.9	4.4	5.1	137	6.7	7.5	8.3
08 Jun–14 Jun	30	4.6	5.2	6.1	8	7.9	8.5	10.9

Table 21. Migration rate statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2010. Abbreviations: N-Number of fish on which statistics are based; Med.–Median.

Migration rate of juvenile steelhead (km/d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam N	20%	Med.	80%	Little Goose to Lower Monumental N	20%	Med.	80%	Lower Monumental to McNary Dam N	20%	Med.	80%
13 Apr–19 Apr	65	9.8	11.4	14.1	0	NA	NA	NA	1	26.4	26.4	26.4
20 Apr–26 Apr	1,001	16.0	20.6	28.0	8	12.6	15.3	16.8	20	22.2	29.6	31.7
27 Apr–03 May	2,347	15.6	19.9	21.1	44	8.8	16.3	24.0	42	26.1	30.0	32.6
04 May–10 May	1,396	15.3	19.2	20.6	32	11.7	15.5	23.5	11	28.3	30.9	37.1
11 May–17 May	1,133	19.0	20.7	29.1	82	19.6	25.3	33.6	30	34.4	41.3	47.0
18 May–24 May	2,057	24.9	29.9	31.7	242	28.0	38.3	45.1	50	34.8	40.3	49.2
25 May–31 May	1,205	17.7	20.4	28.6	72	22.7	31.9	44.7	20	37.5	42.5	64.7
01 Jun–07 Jun	539	28.2	31.9	37.5	96	38.0	47.4	66.7	15	53.1	60.1	72.6
08 Jun–14 Jun	97	28.8	34.1	38.5	43	28.8	43.4	54.8	17	49.2	56.1	66.1

Date at Lower Granite Dam	Lower Granite to McNary Dam N	20%	Med.	80%	Lower Granite to Bonneville Dam N	20%	Med.	80%
13 Apr–19 Apr	20	18.4	19.7	22.4	43	23.5	26.0	28.7
20 Apr–26 Apr	369	21.5	25.1	28.4	838	27.3	31.5	35.9
27 Apr–03 May	1,145	21.4	25.3	28.6	1,697	29.0	32.1	35.8
04 May–10 May	696	20.7	24.2	26.9	1,268	30.0	33.3	36.1
11 May–17 May	406	26.7	29.8	32.7	1,041	35.9	39.2	43.3
18 May–24 May	725	31.3	36.8	43.3	1,343	39.7	43.7	48.0
25 May–31 May	349	27.2	31.3	35.2	328	40.6	43.7	48.2
01 Jun–07 Jun	101	44.3	51.0	57.1	137	55.7	61.5	68.7
08 Jun–14 Jun	30	36.9	43.6	49.2	8	42.1	54.3	58.1

Table 22. Travel time and migration rate statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at McNary Dam in 2010. Abbreviations: N–Number of fish on which statistics are based; Med.–Median.

Date at McNary Dam	Hatchery and wild juvenile steelhead											
	McNary to John Day Dam				John Day to Bonneville Dam				McNary to Bonneville Dam			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
	Travel time (d)											
20 Apr–26 Apr	26	4.5	5.1	8.3	6	2.0	2.1	2.3	41	6.1	6.6	8.9
27 Apr–03 May	340	4.0	4.9	6.6	119	1.9	2.1	2.3	909	5.5	6.4	7.8
04 May–10 May	487	4.1	5.2	6.5	145	1.8	2.0	2.3	1,712	5.5	6.0	7.0
11 May–17 May	106	3.3	4.1	5.6	32	1.6	1.8	2.1	715	4.7	5.0	5.8
18 May–24 May	111	3.1	3.5	4.4	18	1.5	1.7	1.9	603	3.9	4.7	5.3
25 May–31 May	62	3.0	3.5	4.4	16	1.4	1.6	1.9	389	4.5	4.9	5.5
01 Jun–07 Jun	163	2.0	2.8	3.4	21	1.1	1.2	1.3	120	3.4	3.7	4.0
08 Jun–14 Jun	132	2.1	3.0	3.6	20	1.1	1.2	1.6	58	3.3	3.8	4.3
15 Jun–21 Jun	46	2.1	2.9	3.5	7	1.3	1.4	1.8	26	3.4	3.7	4.6
	Migration rate (km/d)											
20 Apr–26 Apr	26	14.7	24.2	27.3	6	49.8	52.6	55.4	41	26.5	35.6	38.6
27 Apr–03 May	340	18.6	25.0	30.8	119	48.3	53.1	59.8	909	30.4	37.0	43.2
04 May–10 May	487	18.8	23.6	30.2	145	48.7	56.5	62.8	1,712	33.6	39.4	43.0
11 May–17 May	106	21.9	30.1	37.4	32	53.6	62.1	68.9	715	40.3	47.6	50.6
18 May–24 May	111	28.0	34.6	40.2	18	59.5	66.5	74.3	603	44.8	50.5	60.7
25 May–31 May	62	27.7	35.4	40.7	16	60.8	68.5	79.0	389	42.7	48.3	52.9
01 Jun–07 Jun	163	36.5	43.8	60.9	21	84.3	93.4	102.7	120	59.6	63.8	68.8
08 Jun–14 Jun	132	34.4	41.6	58.3	20	68.5	94.2	106.6	58	54.3	61.8	72.0
15 Jun–21 Jun	46	35.2	42.0	57.2	7	62.8	77.9	87.6	26	51.0	63.1	69.6

ESTIMATES OF THE PROPORTION TRANSPORTED FROM SPRING MIGRANT POPULATIONS

Methods

To estimate the proportion of non-tagged fish that were transported, we proceeded through the following steps:

1. Compile daily collection counts at Lower Granite Dam from the Smolt Monitoring Program (fpc.org).

2. Use PIT-tag data to derive daily estimates of detection probability at Lower Granite Dam using the methods of Sandford and Smith (2002). Virtually every PIT-tagged fish in the collection system is detected; thus, the probability of detecting a PIT-tagged fish on a given day is equivalent to the probability of entering the collection system.

3. For each day, divide the collection count by the detection probability to get an estimate of the total number of fish passing Lower Granite Dam that day. This also gives rise to estimates of the number of fish in the Lower Granite Dam collection system and the number of fish that passed via other routes that day.

4. For each daily group of PIT-tagged fish leaving Lower Granite Dam (i.e. detected and returned to the river), estimate the number of "Lower Granite equivalents" that were next detected (i.e. next entered a collection system) at Little Goose Dam and the number that passed Little Goose undetected and next entered a collection system at Lower Monumental Dam. These estimates were based on estimated arrival distributions (i.e., travel time distributions) for each daily group. Travel time distributions varied across groups to take into account that earlier fish generally travel more slowly than later fish.

5. Assume that for the group of untagged fish arriving at Lower Granite Dam on a given day, the proportions of fish first collected at Lower Granite, Little Goose, and Lower Monumental Dam are the same as those for the group of PIT-tagged fish arriving on that day. (The number of PIT-tagged fish that arrived at Lower Granite but were not detected is estimated from daily detection probability estimates from step 2.)

6. For each daily group of fish arriving at Lower Granite Dam, estimate the proportion of those that entered the collection system at each collector dam and were transported from that dam. For groups arriving at Lower Granite Dam after the transport starting date at a collector dam, the proportion transported is 100%. For

groups arriving before the starting date, the estimated proportion of the daily Lower Granite Dam group transported depends on the travel time distribution (i.e., a certain percentage of each group arrived before transport began).

7. For each daily group of the run-at-large, calculate the product of three quantities:
   i. Estimated number of fish in the group (step 3)
   ii. Estimated proportion of fish first entering the collection system at each dam (steps 4-5)
   iii. Estimated proportion of fish entering the collection system that were transported (step 6)

   This gives the estimated total equivalents from each group at Lower Granite Dam that were transported from each dam.

8. Sum all estimated numbers transported and divide by the total population estimate to derive the estimated percentage transported for the season.

Results

In 2010, smolt transportation began on 23 April at Lower Granite Dam, 1 May at Little Goose Dam, and 3 May at Lower Monumental Dam. Until these dates, smolts collected at Snake River dams were bypassed back to the river. Estimated percentages of non-tagged spring/summer Chinook salmon smolts that were transported during the entire 2010 season were 38.2% for wild fish and 22.6% hatchery fish. For non-tagged steelhead, estimated percentages transported were 36.8 and 34.8% for wild and hatchery smolts, respectively. These estimates represent the proportion of smolts that arrived at Lower Granite Dam and were subsequently transported from either Lower Granite or one of the downstream collector dams. The 2010 estimated transport proportions for wild Chinook salmon, hatchery steelhead, and wild steelhead were all the lowest estimates observed for 1995-2010 (Figure 6; Table 23). Only hatchery Chinook salmon had a lower estimate in another year (2007).

Survival estimates presented in this report are based on PIT-tagged fish that remained in-river. These fish either passed through turbines or spillways (including surface passage structures), or were intentionally returned to the river after detection in bypass systems. (PIT-tagged fish that were transported provide survival information up until the point of transport, but not downstream from that point).

When considering the implications of in-river survival probability for populations of Snake River salmonids, it is important to remember that in recent years, around half of non-tagged fish were removed from the river for transport. In years before 2007, well over half of the populations at large were transported. Only fish that remained in the river were subject to the reach survival probabilities presented in this report; survival of transported fish is affected by entirely different factors.

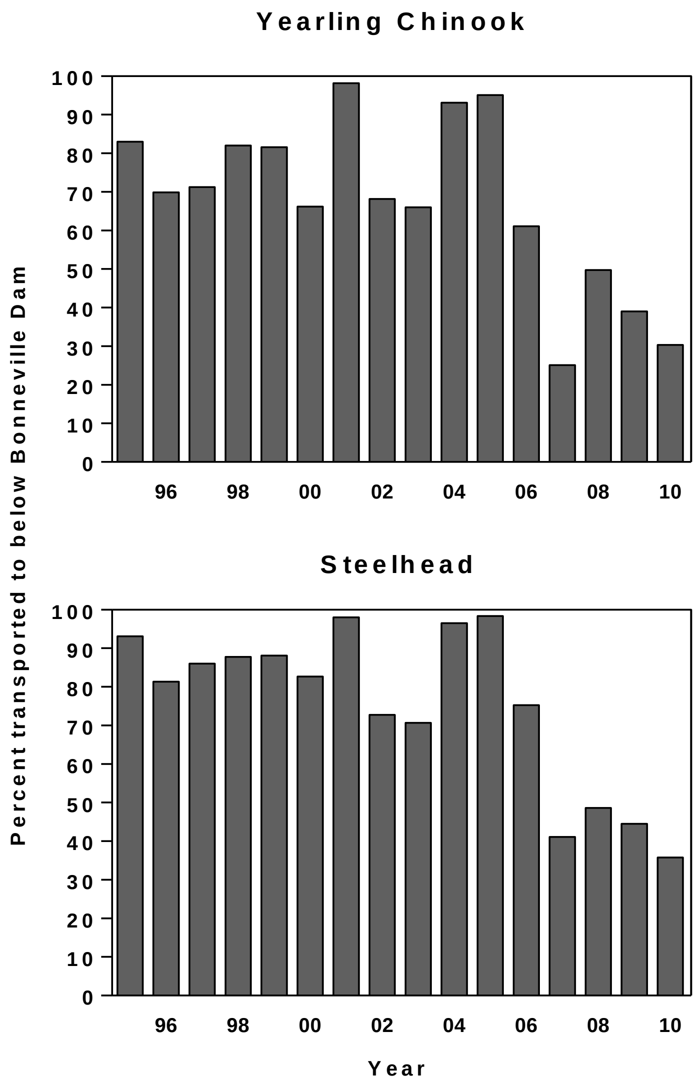

Figure 6. Estimated percent of yearling Chinook salmon and steelhead (hatchery and wild combined) transported to below Bonneville Dam by year (1995-2010).

Table 23. Annual estimated percentages of migrating Snake River yearling Chinook salmon and steelhead that were transported (1993-2010). Estimates are shown for hatchery and wild fish separately. Arithmetic means of hatchery and wild estimates within and across years are shown.

	Yearling Chinook Salmon			**Juvenile Steelhead**		
Year	Hatchery	Wild	Mean	Hatchery	Wild	Mean
1993	88.5	88.1	88.3	93.2	94.7	94.0
1994	87.7	84.0	85.9	91.3	82.2	86.8
1995	86.4	79.6	83.0	91.8	94.3	93.1
1996	71.0	68.7	69.9	79.8	82.9	81.4
1997	71.1	71.5	71.3	87.5	84.5	86.0
1998	82.5	81.4	82.0	88.2	87.3	87.8
1999	85.9	77.3	81.6	87.6	88.5	88.1
2000	70.4	61.9	66.2	83.9	81.5	82.7
2001	99.0	97.3	98.2	99.3	96.7	98.0
2002	72.1	64.2	68.2	75.2	70.4	72.8
2003	70.4	61.5	66.0	72.9	68.4	70.7
2004	93.2	92.9	93.1	95.7	97.3	96.5
2005	95.1	95.0	95.1	98.7	98.0	98.4
2006	59.9	62.3	61.1	74.6	76.0	75.3
2007	24.8	25.4	25.1	41.1	41.1	41.1
2008	54.3	45.3	49.8	50.5	46.6	48.6
2009	40.4	38.3	39.4	46.1	42.7	44.4
2010	38.2	22.6	30.4	36.8	34.8	35.8
Mean	**71.7**	**67.6**	**69.7**	**77.5**	**76.0**	**76.7**

Estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams were among the lowest seen from 1995-2009. High spill percentages, in combination with surface passage structures at each of the collector dams on the Snake River, resulted in low proportions of fish entering juvenile bypass systems. In 2010, respective estimated percentages entering the bypass systems at Lower Granite Dam, Little Goose Dam, and Lower Monumental Dam were 26, 26, and 8 for wild yearling Chinook, and 16, 12, and 2 for hatchery yearling Chinook, respectively. The transport percentage was lower for hatchery than for wild Chinook salmon because of the difference in percentages entering bypass systems.

In 2010, the respective estimated percentages entering the bypass systems at Lower Granite, Little Goose, and Lower Monumental were 23, 22, and 6 for wild steelhead, and 20, 23, and 6 for hatchery steelhead, respectively. These bypass percentages are among the lowest estimated from 1995 to 2009 for both yearling Chinook salmon and steelhead.

Smolt transportation began on 23 April at Lower Granite Dam, 1 May at Little Goose Dam, and 3 May at Lower Monumental Dam. These start dates were earlier than in 2009 (1 May at Lower Granite, 5 May at Little Goose, and 8 May at Lower Monumental). However, yearling Chinook salmon and steelhead smolts arrived later at Lower Granite Dam in 2010 than in 2007-2009. When transportation began at Lower Granite on 23 April, only about 2% of the yearling Chinook salmon and 1% of the steelhead had already passed the dam. However, the cumulative passage distribution for yearling Chinook salmon climbed rapidly, and approximately 50% of the run had passed Lower Granite by 3 May. The steelhead run was a little more protracted; 50% of the run had passed by 11 May. Despite the earlier transport start dates and relatively later run-timing in 2010 than in 2009, the higher spill percentages and consequent lower collection rates resulted in lower percentages of fish transported.

COMPARISON BETWEEN STOCKS AND AMONG YEARS

Comparison of Annual Survival Estimates Among Years

We made two comparisons of 2010 results to those obtained in previous years of the NMFS survival study. First, we related migration distance to survival estimates from release at specific hatcheries to Lower Granite Dam. Second, we compared season-wide survival estimates for specific reaches across years.

Snake River Stocks

Yearling Chinook Salmon and Steelhead—For yearling Chinook salmon, estimates of survival in 2010 from most Snake River Basin hatcheries to Lower Granite Dam tailrace were similar to those made in recent years. The mean of the hatchery estimates for 2010 was a little higher than the long-term mean (Table 24). Over the years of the study, we have consistently observed an inverse relationship between migration distance from the release site to Lower Granite Dam and estimated survival through that reach (Figure 7). From 1998 to 2010, there has been a significant negative linear correlation between migration distance and average estimated survival ($R^2 = 0.880$, $P = 0.002$).

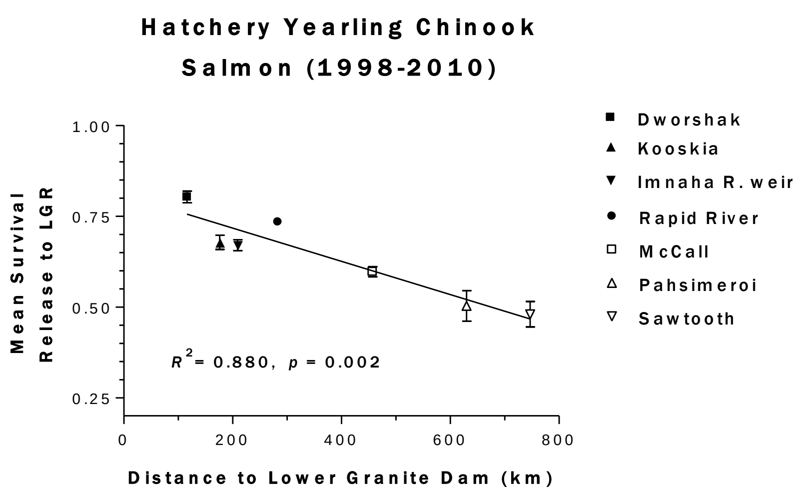

Figure 7. Estimated survival from release at Snake River Basin hatcheries to Lower Granite Dam tailrace, 1998-2010 vs. distance (km) to Lower Granite Dam. The squared correlation between survival and migration distance is also shown, along with a P-value for a test of the null hypothesis of zero correlation. Whiskers show standard errors.

Table 24. Estimated survival for yearling Chinook salmon from selected Snake River Basin hatcheries to the tailrace of Lower Granite Dam, 1993–2010. Distance (km) from each hatchery to Lower Granite Dam in parentheses in header. Standard errors in parentheses following each survival estimate. Simple arithmetic means across all years are given.

	Estimated Survival of hatchery yearling Chinook salmon							
Year	Dworshak (116)	Kooskia (176)	Lookingglass* (209)	Rapid River (283)	McCall (457)	Pahsimeroi (630)	Sawtooth (747)	Mean
1993	0.647 (0.028)	0.689 (0.047)	0.660 (0.025)	0.670 (0.017)	0.498 (0.017)	0.456 (0.032)	0.255 (0.023)	0.554 (0.060)
1994	0.778 (0.020)	0.752 (0.053)	0.685 (0.021)	0.526 (0.024)	0.554 (0.022)	0.324 (0.028)	0.209 (0.014)	0.547 (0.081)
1995	0.838 (0.034)	0.786 (0.024)	0.617 (0.015)	0.726 (0.017)	0.522 (0.011)	0.316 (0.033)	0.230 (0.015)	0.576 (0.088)
1996	0.776 (0.017)	0.744 (0.010)	0.567 (0.014)	0.588 (0.007)	0.531 (0.007)	—	0.121 (0.017)	0.555 (0.096)
1997	0.576 (0.017)	0.449 (0.034)	0.616 (0.017)	0.382 (0.008)	0.424 (0.008)	0.500 (0.008)	0.508 (0.037)	0.494 (0.031)
1998	0.836 (0.006)	0.652 (0.024)	0.682 (0.006)	0.660 (0.004)	0.585 (0.004)	0.428 (0.021)	0.601 (0.033)	0.635 (0.046)
1999	0.834 (0.011)	0.653 (0.031)	0.668 (0.009)	0.746 (0.006)	0.649 (0.008)	0.584 (0.035)	0.452 (0.019)	0.655 (0.045)
2000	0.841 (0.009)	0.734 (0.027)	0.688 (0.011)	0.748 (0.007)	0.689 (0.010)	0.631 (0.062)	0.546 (0.030)	0.697 (0.035)
2001	0.747 (0.002)	0.577 (0.019)	0.747 (0.003)	0.689 (0.002)	0.666 (0.002)	0.621 (0.016)	0.524 (0.023)	0.653 (0.032)
2002	0.819 (0.011)	0.787 (0.036)	0.667 (0.012)	0.755 (0.003)	0.592 (0.006)	0.678 (0.053)	0.387 (0.025)	0.669 (0.055)
2003	0.720 (0.008)	0.560 (0.043)	0.715 (0.012)	0.691 (0.007)	0.573 (0.006)	0.721 (0.230)	0.595 (0.149)	0.654 (0.028)
2004	0.821 (0.003)	0.769 (0.017)	0.613 (0.004)	0.694 (0.003)	0.561 (0.002)	0.528 (0.017)	0.547 (0.018)	0.648 (0.044)
2005	0.823 (0.003)	0.702 (0.021)	0.534 (0.004)	0.735 (0.002)	0.603 (0.003)	0.218 (0.020)	0.220 (0.020)	0.549 (0.092)
2006	0.853 (0.007)	0.716 (0.041)	0.639 (0.014)	0.764 (0.004)	0.634 (0.006)	0.262 (0.024)	0.651 (0.046)	0.645 (0.071)
2007	0.817 (0.007)	0.654 (0.015)	0.682 (0.010)	0.748 (0.004)	0.554 (0.007)	0.530 (0.038)	0.581 (0.015)	0.652 (0.040)
2008	0.737 (0.011)	0.631 (0.015)	0.694 (0.008)	0.801 (0.004)	0.578 (0.007)	0.447 (0.011)	0.336 (0.012)	0.603 (0.062)
2009	0.696 (0.007)	0.633 (0.012)	0.699 (0.009)	0.728 (0.005)	0.513 (0.005)	0.510 (0.006)	0.367 (0.007)	0.592 (0.050)
2010	0.898 (0.017)	0.744 (0.030)	0.682 (0.025)	0.786 (0.019)	0.566 (0.014)	0.384 (0.023)	0.427 (0.018)	0.641 (0.072)
Mean	0.781 (0.019)	0.680 (0.021)	0.659 (0.012)	0.691 (0.024)	0.572 (0.015)	0.479 (0.035)	0.420 (0.038)	0.612 (0.013)

* Released at Imnaha River Weir.

For yearling Chinook salmon (hatchery and wild combined), mean survival estimated in 2010 was similar to that estimated in 2009 from Lower Granite to McNary Dam, but was higher from McNary to Bonneville Dam (Tables 25 and 27; Figures 8 and 9). For yearling Chinook salmon in 2010, mean estimated survival was 0.772 (95% CI 0.748-0.796) from Lower Granite tailrace to McNary tailrace and 0.738 (95% CI 0.662-0.814) from McNary tailrace to Bonneville tailrace, with the latter estimate higher than the 10-year average.

Estimated survival through the entire hydropower system (Snake River Trap to Bonneville tailrace) for yearling Chinook salmon (hatchery and wild combined) in 2010, was 0.551 (Table 27; 95% CI 0.476-0.626), which was the fourth highest of our data series. The same estimate for only wild yearling Chinook salmon was 0.374 (Table 27; 95% CI 0.285-0.463), which was significantly lower than that for hatchery and wild combined. The estimate for wild fish was affected by a lower-than-average survival estimate of 0.821 from the Snake Trap to Lower Granite tailrace.

For steelhead (hatchery and wild combined) in 2010, mean estimated survival from tailrace to tailrace was 0.770 (95% CI 0.731-0.809) for Lower Granite to McNary Dam and 0.789 (95% CI 0.736-0.842) from McNary to Bonneville Dam. These estimates were the highest among those recorded over the past 12 years for these reaches except those of 2009 (Tables 28; Figures 8 and 9).

Estimated hydropower system survival for steelhead (hatchery and wild combined) in 2010 was 0.618 (Table 28; 95% CI 0.554-0.681), which was the second highest in our data series (1997-2003, 2006-2009). Estimated hydropower system survival for wild steelhead was 0.571 (Table 28; 95% CI 0.385-0.756).

Table 25. Annual weighted means of survival probability estimates for yearling Chinook salmon (hatchery and wild combined), 1993–2010. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root (i.e., geometric mean) of the two–project estimate to facilitate comparison with other single-project estimates. Simple arithmetic means across all years are given.

Annual survival estimates for yearling Chinook salmon								
Year	Trap to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam*	L Monumental to Ice Harbor to McNary	McNary to John Day Dam	John Day to Bonneville Dam *	John Day to The Dalles to Bonneville Dam
1993	0.828 (0.013)	0.854 (0.012)						
1994	0.935 (0.023)	0.830 (0.009)	0.847 (0.010)					
1995	0.905 (0.010)	0.882 (0.004)	0.925 (0.008)	0.876 (0.038)	0.936			
1996	0.977 (0.025)	0.926 (0.006)	0.929 (0.011)	0.756 (0.033)	0.870			
1997	NA	0.942 (0.018)	0.894 (0.042)	0.798 (0.091)	0.893			
1998	0.925 (0.009)	0.991 (0.006)	0.853 (0.009)	0.915 (0.011)	0.957	0.822 (0.033)		
1999	0.940 (0.009)	0.949 (0.002)	0.925 (0.004)	0.904 (0.007)	0.951	0.853 (0.027)	0.814 (0.065)	0.902
2000	0.929 (0.014)	0.938 (0.006)	0.887 (0.009)	0.928 (0.016)	0.963	0.898 (0.054)	0.684 (0.128)	0.827
2001	0.954 (0.015)	0.945 (0.004)	0.830 (0.006)	0.708 (0.007)	0.841	0.758 (0.024)	0.645 (0.034)	0.803
2002	0.953 (0.022)	0.949 (0.006)	0.980 (0.008)	0.837 (0.013)	0.915	0.907 (0.014)	0.840 (0.079)	0.917
2003	0.993 (0.023)	0.946 (0.005)	0.916 (0.011)	0.904 (0.017)	0.951	0.893 (0.017)	0.818 (0.036)	0.904
2004	0.893 (0.009)	0.923 (0.004)	0.875 (0.012)	0.818 (0.018)	0.904	0.809 (0.028)	0.735 (0.092)	0.857
2005	0.919 (0.015)	0.919 (0.003)	0.886 (0.006)	0.903 (0.010)	0.950	0.772 (0.029)	1.028 (0.132)	1.014
2006	0.952 (0.011)	0.923 (0.003)	0.934 (0.004)	0.887 (0.008)	0.942	0.881 (0.020)	0.944 (0.030	0.972
2007	0.943 (0.028)	0.938 (0.006)	0.957 (0.010)	0.876 (0.012)	0.936	0.920 (0.016)	0.824 (0.043)	0.908
2008	0.992 (0.018)	0.939 (0.006)	0.950 (0.011)	0.878 (0.016)	0.937	1.073 (0.058)	0.558 (0.082)	0.750
2009	0.958 (0.010)	0.940 (0.006)	0.982 (0.009)	0.855 (0.011)	0.925	0.866 (0.042)	0.821 (0.043)	0.906
2010	0.968 (0.040)	0.962 (0.011)	0.973 (0.019)	0.851 (0.017)	0.922	0.947 (0.021)	0.780 (0.039)	0.883
Mean	**0.939 (0.010)**	**0.928 (0.009)**	**0.914 (0.011)**	**0.856 (0.015)**	**0.925**	**0.877 (0.023)**	**0.791 (0.036)**	**0.887**

Table 26. Annual weighted means of survival probability estimates for steelhead (hatchery and wild combined), 1993–2010. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root (i.e., geometric mean) of the two–project estimate to facilitate comparison with other single-project estimates. Simple arithmetic means across all years are given.

Annual survival estimates for steelhead								
Year	Trap to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam*	L Monumental to Ice Harbor to McNary	McNary to John Day Dam	John Day to Bonneville Dam*	John Day to The Dalles to Bonneville Dam
1993	0.905 (0.006)							
1994	NA	0.844 (0.011)	0.892 (0.011)					
1995	0.945 (0.008)	0.899 (0.005)	0.962 (0.011)	0.858 (0.076)	0.926			
1996	0.951 (0.015)	0.938 (0.008)	0.951 (0.014)	0.791 (0.052)	0.889			
1997	0.964 (0.015)	0.966 (0.006)	0.902 (0.020)	0.834 (0.065)	0.913			
1998	0.924 (0.009)	0.930 (0.004)	0.889 (0.006)	0.797 (0.018)	0.893	0.831 (0.031)	0.935 (0.103)	0.967
1999	0.908 (0.011)	0.926 (0.004)	0.915 (0.006)	0.833 (0.011)	0.913	0.920 (0.033)	0.682 (0.039)	0.826
2000	0.964 (0.013)	0.901 (0.006)	0.904 (0.009)	0.842 (0.016)	0.918	0.851 (0.045)	0.754 (0.045)	0.868
2001	0.911 (0.007)	0.801 (0.010)	0.709 (0.008)	0.296 (0.010)	0.544	0.337 (0.025)	0.753 (0.063)	0.868
2002	0.895 (0.015)	0.882 (0.011)	0.882 (0.018)	0.652 (0.031)	0.807	0.844 (0.063)	0.612 (0.098)	0.782
2003	0.932 (0.015)	0.947 (0.005)	0.898 (0.012)	0.708 (0.018)	0.841	0.879 (0.032)	0.630 (0.066)	0.794
2004	0.948 (0.004)	0.860 (0.006)	0.820 (0.014)	0.519 (0.035)	0.720	0.465 (0.078)	NA	NA
2005	0.967 (0.004)	0.940 (0.004)	0.867 (0.009)	0.722 (0.023)	0.850	0.595 (0.040)	NA	NA
2006	0.920 (0.013)	0.956 (0.004)	0.911 (0.006)	0.808 (0.017)	0.899	0.795 (0.045)	0.813 (0.083)	0.902
2007	1.016 (0.026)	0.887 (0.009)	0.911 (0.022)	0.852 (0.030)	0.923	0.988 (0.098)	0.579 (0.059)	0.761
2008	0.995 (0.018)	0.935 (0.007)	0.961 (0.014)	0.776 (0.017)	0.881	0.950 (0.066)	0.742 (0.045)	0.861
2009	1.002 (0.011)	0.972 (0.005)	0.942 (0.008)	0.863 (0.014)	0.929	0.951 (0.026)	0.900 (0.079)	0.949
2010	1.017 (0.030)	0.965 (0.028)	0.984 (0.044)	0.876 (0.032)	0.936	0.931 (0.051)	0.840 (0.038)	0.907
Mean	**0.951 (0.009)**	**0.915 (0.012)**	**0.900 (0.015)**	**0.752 (0.038)**	**0.861**	**0.795 (0.056)**	**0.749 (0.035)**	**0.862**

Table 27. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River hatchery and wild yearling Chinook salmon 1997–2010. Standard errors in parentheses. Simple arithmetic means are given.

Year	Trap to Lower Granite Dam	Lower Granite to McNary Dam	McNary to Bonneville Dam	Lower Granite to Bonneville Dam	Trap to Bonneville Dam
			Hatchery and wild yearling Chinook		
1997	NA	0.653 (0.072)	NA	NA	NA
1998	0.924 (0.011)	0.770 (0.009)	NA	NA	NA
1999	0.940 (0.009)	0.792 (0.006)	0.704 (0.058)	0.557 (0.046)	0.524 (0.043)
2000	0.929 (0.014)	0.760 (0.012)	0.640 (0.122)	0.486 (0.093)	0.452 (0.087)
2001	0.954 (0.015)	0.556 (0.009)	0.501 (0.027)	0.279 (0.016)	0.266 (0.016)
2002	0.953 (0.022)	0.757 (0.009)	0.763 (0.079)	0.578 (0.060)	0.551 (0.059)
2003	0.993 (0.023)	0.731 (0.010)	0.728 (0.030)	0.532 (0.023)	0.528 (0.026)
2004	0.893 (0.009)	0.666 (0.011)	0.594 (0.074)	0.395 (0.050)	0.353 (0.045)
2005	0.919 (0.015)	0.732 (0.009)	0.788 (0.093)	0.577 (0.068)	0.530 (0.063)
2006	0.952 (0.011)	0.764 (0.007)	0.842 (0.021)	0.643 (0.017)	0.612 (0.018)
2007	0.943 (0.028)	0.783 (0.006)	0.763 (0.044)	0.597 (0.035)	0.563 (0.037)
2008	0.992 (0.018)	0.782 (0.011)	0.594 (0.066)	0.465 (0.052)	0.460 (0.052)
2009	0.958 (0.010)	0.787 (0.007)	0.705 (0.031)	0.555 (0.025)	0.531 (0.025)
2010	0.968 (0.040)	0.772 (0.012)	0.738 (0.039)	0.569 (0.032)	0.551 (0.038)
Mean	**0.948 (0.008)**	**0.736 (0.018)**	**0.697 (0.028)**	**0.519 (0.029)**	**0.493 (0.028)**
			Wild yearling Chinook		
1998	0.915 (0.019)	0.771 (0.015)			
1999	0.951 (0.011)	0.791 (0.014)	0.620 (0.099)	0.490 (0.079)	0.466 (0.075)
2000	0.955 (0.023)	0.775 (0.014)	0.575 (0.156)	0.446 (0.121)	0.425 (0.116)
2001	0.921 (0.058)	0.525 (0.034)	0.437 (0.041)	0.230 (0.026)	0.211 (0.028)
2002	0.985 (0.038)	0.768 (0.026)	0.469 (0.120)	0.360 (0.093)	0.355 (0.092)
2003	0.943 (0.033)	0.729 (0.020)	0.757 (0.059)	0.552 (0.046)	0.520 (0.047)
2004	0.862 (0.013)	0.667 (0.023)	0.566 (0.164)	0.377 (0.110)	0.325 (0.095)
2005	0.964 (0.034)	0.661 (0.017)	0.681 (0.243)	0.450 (0.161)	0.434 (0.156)
2006	0.929 (0.019)	0.754 (0.010)	0.827 (0.085)	0.623 (0.064)	0.579 (0.061)
2007	0.903 (0.062)	0.773 (0.013)	0.780 (0.088)	0.603 (0.069)	0.544 (0.072)
2008	0.955 (0.036)	0.786 (0.020)	0.607 (0.127)	0.477 (0.101)	0.456 (0.098)
2009	0.940 (0.012)	0.765 (0.018)	0.606 (0.068)	0.464 (0.053)	0.436 (0.050)
2010	0.821 (0.047)	0.744 (0.021)	0.612 (0.063)	0.455 (0.049)	0.374 (0.045)
Mean	**0.926 (0.012)**	**0.731 (0.021)**	**0.628 (0.034)**	**0.461 (0.031)**	**0.427 (0.029)**

Table 28. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River steelhead, 1997–2010. Standard errors in parentheses; simple arithmetic means are given.

Year	Snake River Trap to Lower Granite Dam	Lower Granite to McNary Dam	McNary to Bonneville Dam	Lower Granite to Bonneville Dam	Trap to Bonneville Dam
			Hatchery and wild steelhead		
1997	1.020 (0.023)	0.728 (0.053)	0.651 (0.082)	0.474 (0.069)	0.484 (0.072)
1998	0.924 (0.009)	0.649 (0.013)	0.770 (0.081)	0.500 (0.054)	0.462 (0.050)
1999	0.908 (0.011)	0.688 (0.010)	0.640 (0.024)	0.440 (0.018)	0.400 (0.017)
2000	0.964 (0.013)	0.679 (0.016)	0.580 (0.040)	0.393 (0.034)	0.379 (0.033)
2001	0.911 (0.007)	0.168 (0.006)	0.250 (0.016)	0.042 (0.003)	0.038 (0.003)
2002	0.895 (0.015)	0.536 (0.025)	0.488 (0.090)	0.262 (0.050)	0.234 (0.045)
2003	0.932 (0.015)	0.597 (0.013)	0.518 (0.015)	0.309 (0.011)	0.288 (0.012)
2004	0.948 (0.004)	0.379 (0.023)	NA	NA	NA
2005	0.967 (0.004)	0.593 (0.018)	NA	NA	NA
2006	0.920 (0.013)	0.702 (0.016)	0.648 (0.079)	0.455 (0.056)	0.418 (0.052)
2007	1.016 (0.026)	0.694 (0.020)	0.524 (0.064)	0.364 (0.045)	0.369 (0.047)
2008	0.995 (0.018)	0.716 (0.015)	0.671 (0.034)	0.480 (0.027)	0.478 (0.028)
2009	1.002 (0.011)	0.790 (0.013)	0.856 (0.074)	0.676 (0.059)	0.678 (0.060)
2010	1.017 (0.030)	0.770 (0.020)	0.789 (0.027)	0.608 (0.026)	0.618 (0.032)
Mean	**0.958 (0.012)**	**0.621 (0.045)**	**0.615 (0.047)**	**0.417 (0.048)**	**0.404 (0.049)**
			Wild steelhead		
1998	0.919 (0.017)	0.698 (0.030)	NA	NA	NA
1999	0.910 (0.024)	0.746 (0.019)	0.634 (0.113)	0.473 (0.085)	0.430 (0.078)
2000	0.980 (0.027)	0.714 (0.028)	0.815 (0.102)	0.582 (0.076)	0.570 (0.076)
2001	0.958 (0.011)	0.168 (0.010)	0.209 (0.046)	0.035 (0.008)	0.034 (0.008)
2002	0.899 (0.023)	0.593 (0.039)	0.574 (0.097)	0.341 (0.062)	0.306 (0.056)
2003	0.893 (0.026)	0.597 (0.022)	0.500 (0.042)	0.299 (0.027)	0.267 (0.026)
2004	0.936 (0.007)	0.383 (0.029)	NA	NA	NA
2005	0.959 (0.008)	0.562 (0.046)	NA	NA	NA
2006	0.976 (0.036)	0.745 (0.040)	0.488 (0.170)	0.363 (0.128)	0.355 (0.125)
2007	1.050 (0.056)	0.730 (0.027)	0.524 (0.064)	0.383 (0.049)	0.402 (0.056)
2008	0.951 (0.029)	0.692 (0.029)	0.713 (0.093)	0.493 (0.068)	0.469 (0.066)
2009	0.981 (0.019)	0.763 (0.029)	0.727 (0.073)	0.555 (0.060)	0.544 (0.059)
2010	1.003 (0.049)	0.773 (0.041)	0.736 (0.110)	0.569 (0.090)	0.571 (0.095)
Mean	**0.956 (0.011)**	**0.628 (0.049)**	**0.592 (0.055)**	**0.409 (0.052)**	**0.395 (0.052)**

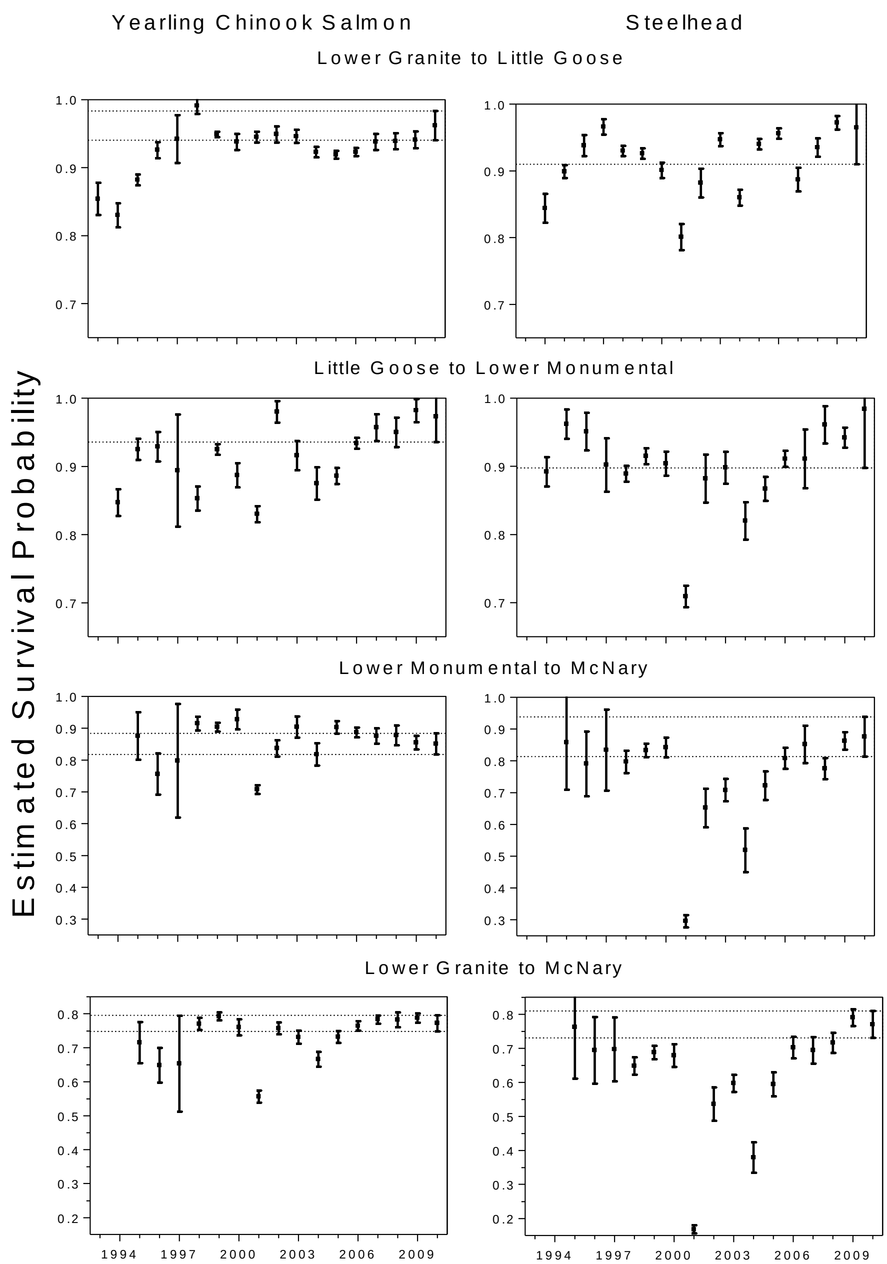

Figure 8. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead (hatchery and wild combined) through Snake River reaches, 1993-2010. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2010 estimates.

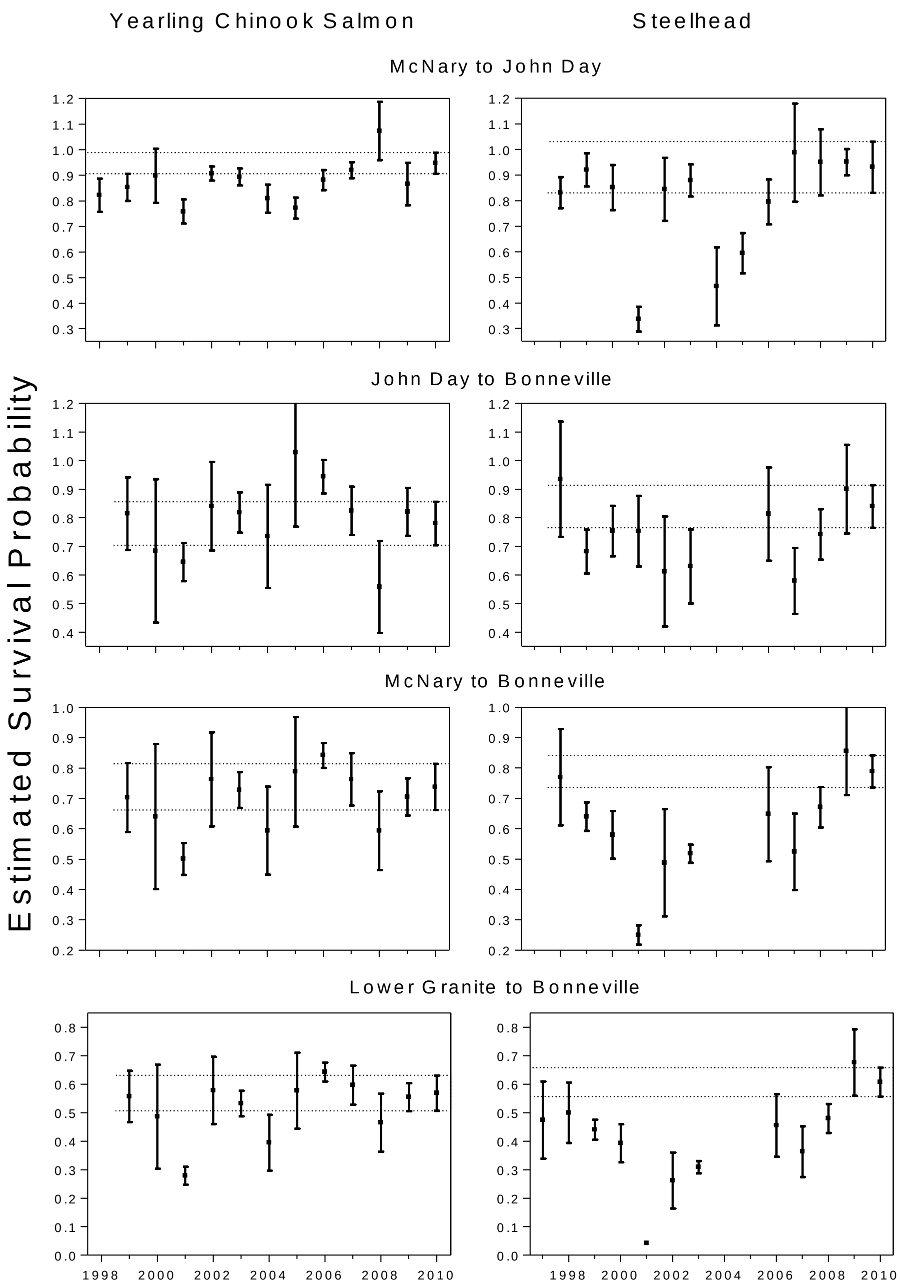

Figure 9. Annual average survival estimates for PIT-tagged Snake River yearling Chinook salmon and steelhead (hatchery and wild combined) through Columbia River reaches and from Lower Granite Dam to Bonneville Dam, 1993-2010. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2010 estimates.

Sockeye Salmon—For pooled groups of sockeye salmon (hatchery and wild combined) originating in the Snake River basin, estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace in 2010 was 0.723 (95% CI 0.650-0.804; Table 29). This estimate was above the average estimated survival of 0.598 for 1996-2009, and was the fourth highest estimate over that 13-year period. Estimated survival for Snake River sockeye from Lower Granite Dam tailrace to Bonneville Dam tailrace in 2010 was 0.544 (95% CI 0.413-0.717). Large releases of hatchery sockeye in 2010 allowed for a relatively precise estimate of survival from Lower Granite Dam to Bonneville Dam. Comparison of estimates from Lower Granite to Bonneville from previous years is limited by the large sampling errors resulting from typically small release sizes.

Table 29. Estimated survival and standard errors for sockeye salmon (hatchery and wild combined) from Lower Granite Dam tailrace to Bonneville Dam tailrace. Data shown for fish originating in the Snake River and from Rock Island Dam tailrace to Bonneville Dam tailrace for fish originating in the upper Columbia River, 1996–2010. All available data for sockeye are shown; estimates were provided regardless of the size of their associated standard errors. Estimates to Bonneville tailrace were of questionable quality in several cases due to small sample sizes and low detection probabilities.

	Annual survival estimates Snake River sockeye		
Year	Lower Granite to McNary	McNary to Bonneville Dam	Lower Granite to Bonneville Dam
1996	0.283 (0.184)	NA	NA
1997	NA	NA	NA
1998	0.689 (0.157)	0.142 (0.099)	0.177 (0.090)
1999	0.655 (0.083)	0.841 (0.584)	0.548 (0.363)
2000	0.679 (0.110)	0.206 (0.110)	0.161 (0.080)
2001	0.205 (0.063)	0.105 (0.050)	0.022 (0.005)
2002	0.524 (0.062)	0.684 (0.432)	0.342 (0.212)
2003	0.669 (0.054)	0.551 (0.144)	0.405 (0.098)
2004	0.741 (0.254)	NA	NA
2005	0.388 (0.078)	NA	NA
2006	0.630 (0.083)	1.113 (0.652)	0.820 (0.454)
2007	0.679 (0.066)	0.259 (0.084)	0.272 (0.073)
2008	0.763 (0.103)	0.544 (0.262)	0.404 (0.179)
2009	0.749 (0.032)	0.765 (0.101)	0.573 (0.073)
2010	0.723 (0.039)	0.752 (0.098)	0.544 (0.077)
Mean	**0.598 (0.048)**	**0.542 (0.099)**	**0.388 (0.069)**
	Annual survival estimates upper Columbia River sockeye		
	Rock Island to McNary Dam	McNary to Bonneville Dam	Rock Island to Bonneville Dam
1996	NA	NA	NA
1997	0.397 (0.119)	NA	NA
1998	0.624 (0.058)	1.655 (1.617)	1.033 (1.003)
1999	0.559 (0.029)	0.683 (0.177)	0.382 (0.097)
2000	0.487 (0.114)	0.894 (0.867)	0.435 (0.410)
2001	0.657 (0.117)	NA	NA
2002	0.531 (0.044)	0.286 (0.110)	0.152 (0.057)
2003	NA	NA	NA
2004	0.648 (0.114)	1.246 (1.218)	0.808 (0.777)
2005	0.720 (0.140)	0.226 (0.209)	0.163 (0.147)
2006	0.793 (0.062)	0.767 (0.243)	0.608 (0.187)
2007	0.625 (0.046)	0.642 (0.296)	0.401 (0.183)
2008	0.644 (0.094)	0.679 (0.363)	0.437 (0.225)
2009	0.853 (0.076)	0.958 (0.405)	0.817 (0.338)
2010	0.778 (0.063)	0.627 (0.152)	0.488 (0.111)
Mean	**0.640 (0.035)**	**0.788 (0.122)**	**0.520 (0.083)**

Upper Columbia River Stocks

Yearling Chinook Salmon and Steelhead—For pooled groups of yearling Chinook salmon from Upper Columbia River hatcheries, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace in 2010 was 0.735 (95% CI 0.666-0.811). This estimate was below the 1999-2010 average of 0.765 for that reach (Table 30).

For pooled groups of steelhead from Upper Columbia hatcheries, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace in 2010 was 0.626 (95% CI 0.565-0.694), which was below the 2003-2010 average of 0.724 for that reach (Table 30).

Sockeye Salmon—For sockeye salmon originating in the Upper Columbia River basin that were captured and tagged at Rock Island Dam and returned to the river, estimated survival from Rock Island Dam tailrace to McNary Dam tailrace in 2010 was 0.778 (95% CI 0.664-0.912; Table 29). This was the third highest estimate observed among those from 1997 to 2010. Note that Table 29 provides survival estimates to Bonneville Dam tailrace from the tailraces of Lower Granite, McNary, and Rock Island Dams for all years in which data were sufficient to calculate estimates. However, small release sizes and poor detection probabilities resulted in estimates to Bonneville which were of poor quality for many of the years shown. We presented all available estimates, regardless of quality, in an effort to represent all of the available data on sockeye. The uncertainty in the estimates must be taken into account if used for inference.

Table 30. Estimated survival and standard error (se) through reaches of the lower Columbia River hydropower system for hatchery yearling Chinook salmon and steelhead originating in the upper Columbia River, 1999–2010. Simple arithmetic means across all years are given.

Annual survival estimates upper Columbia River				
Year	Release site to McNary Dam	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
	Hatchery yearling Chinook salmon			
1999	0.572 (0.014)	0.896 (0.044)	0.795 (0.129)	0.712 (0.113)
2000	0.539 (0.025)	0.781 (0.094)	NA	NA
2001	0.428 (0.009)	0.881 (0.062)	NA	NA
2002	0.555 (0.003)	0.870 (0.011)	0.940 (0.048)	0.817 (0.041)
2003	0.625 (0.003)	0.900 (0.008)	0.977 (0.035)	0.879 (0.031)
2004	0.507 (0.005)	0.812 (0.019)	0.761 (0.049)	0.618 (0.038)
2005	0.545 (0.012)	0.751 (0.042)	NA	NA
2006	0.520 (0.011)	0.954 (0.051)	0.914 (0.211)	0.871 (0.198)
2007	0.584 (0.009)	0.895 (0.028)	0.816 (0.091)	0.730 (0.080)
2008	0.582 (0.019)	1.200 (0.085)	0.522 (0.114)	0.626 (0.133)
2009	0.523 (0.013)	0.847 (0.044)	1.056 (0.143)	0.895 (0.116)
2010	0.660 (0.014)	0.924 (0.040)	0.796 (0.046)	0.735 (0.037)
Mean	**0.553 (0.017)**	**0.893 (0.033)**	**0.842 (0.052)**	**0.765 (0.035)**
	Hatchery steelhead			
1999				
2000				
2001				
2002				
2003	0.471 (0.004)	0.997 (0.012)	0.874 (0.036)	0.871 (0.036)
2004	0.384 (0.005)	0.794 (0.021)	1.037 (0.112)	0.823 (0.088)
2005	0.399 (0.004)	0.815 (0.017)	0.827 (0.071)	0.674 (0.057)
2006	0.397 (0.008)	0.797 (0.026)	0.920 (0.169)	0.733 (0.134)
2007	0.426 (0.016)	0.944 (0.064)	0.622 (0.068)	0.587 (0.059)
2008	0.438 (0.015)	NA	NA	NA
2009	0.484 (0.018)	0.809 (0.048)	0.935 (0.133)	0.756 (0.105)
2010	0.512 (0.017)	0.996 (0.054)	0.628 (0.038)	0.626 (0.033)
Mean	**0.439 (0.016)**	**0.879 (0.036)**	**0.835 (0.059)**	**0.724 (0.039)**

Comparison of Annual Survival Estimates Among Snake and Columbia River Stocks

In 2010, we compared estimated survival to the tailrace of McNary Dam among yearling spring Chinook salmon released from two hatcheries in the Upper Columbia River and one in the Snake River. These groups migrated similar distances and passed a similar number of dams (Appendix Tables B1 and B9). Average estimated survival to McNary Dam for these yearling Chinook is shown below:

Hatchery	River	Release date	Migration distance (rkm)	Projects passed	Estimated survival (se)
East Bank	Wenatchee	14 April	363	4	0.638 (0.039)
East Bank	Methow	15 April	431	6	0.781 (0.058)
Dworshak	Clearwater	31 March	341	5	0.780 (0.014)
Lookingglass	Imnaha	7 April	434	5	0.563 (0.017)

In a similar comparison, survival estimates for steelhead from Upper Columbia hatcheries to the tailrace of McNary Dam was generally lower than for their counterparts from Snake River Basin hatcheries that migrated similar distances and passed a similar number of dams (shown below and in Appendix Tables B2 and B9).

Hatchery	River	Release date	Migration distance (rkm)	Projects passed	Estimated survival (se)
East Bank	Nason Cr.	3 May	390	4	0.505 (0.043)
Winthrop	Methow	19 April	454	6	0.523 (0.034)
Dworshak	Clearwater	1 Feb	341	5	0.562 (0.015)
Clearwater	S.F. Clearwater	19 April	458	5	0.632 (0.035)

From McNary Dam tailrace to Bonneville Dam tailrace, estimated survival of spring/summer Chinook salmon from the Snake River (0.738, se 0.039) was nearly equal to that of spring/summer Chinook from the Upper Columbia River (0.725, se 0.026; Table 31). For steelhead, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was higher for Snake River (0.789, se 0.027) than for Upper Columbia River fish (0.619, se 0.030).

Estimated survival from McNary Dam tailrace to Bonneville Dam tailrace for Snake River sockeye salmon (0.754, se 0.098) was lower than that for Upper Columbia River sockeye salmon (0.841, se 0.157). Note that the comparisons of survival estimates in this section are not based on formal statistical tests, and if they were, the differences would not be statistically significant in most cases due to the size of the associated sampling errors.

Table 31. Average survival estimates (with standard errors in parentheses) from McNary Dam tailrace to Bonneville Dam tailrace for various spring–migrating salmonid stocks (hatchery and wild combined) in 2010. For each reach, the survival estimate represents either a weighted average of weekly estimates (indicated by *), or a single seasonal estimate for pooled release cohorts. Numbers released for pooled estimates (no asterisk) are from points upstream of McNary Dam. Abbreviations: Sp/Su, spring/summer.

			Survival estimates (standard errors)		
Stock	Release location	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
Snake R Chinook (Sp/Su)*	McNary Dam tailrace	82,888*	0.947 (0.021)	0.780 (0.039)	0.738 (0.039)
U Columbia Chinook (Sp/Su)	Upper Columbia sites[a]	205,083	0.963 (0.031)	0.753 (0.033)	0.725 (0.026)
U Columbia Chinook (Sp/Su)	Yakima River sites[b]	76,208	0.820 (0.039)	0.826 (0.072)	0.677 (0.053)
Upper Columbia Coho	Upper Columbia sites	21,592	0.999 (0.095)	0.878 (0.143)	0.877 (0.136)
Upper Columbia Coho	Yakima River sites	20,298	1.134 (0.188)	0.565 (0.110)	0.640 (0.093)
Snake River Sockeye	Snake River sites[c]	68,361	0.995 (0.136)	0.758 (0.134)	0.754 (0.098)
Upper Columbia Sockeye	Upper Columbia sites	13,531	0.876 (0.087)	0.961 (0.195)	0.841 (0.157)
Snake River Steelhead*	McNary Dam Tailrace	15,104*	0.931 (0.051)	0.840 (0.038)	0.789 (0.027)
Upper Columbia Steelhead	Upper Columbia sites	91,950	1.010 (0.049)	0.613 (0.034)	0.619 (0.030)

a Upper Columbia sites include any release sites on the Columbia River or its tributaries that are upstream of the confluence with the Yakima River.

b Yakima River sites include any release sites on the Yakima River or its tributaries.
c Snake River sites include any release sites ups tream of Lower Granite Dam on the Snake River or its tributaries.

DISCUSSION

Estimated survival for Snake River yearling Chinook salmon and steelhead through the hydropower system (Snake River trap to Bonneville tailrace) in 2010 was relatively high compared to recent years. Estimated hydropower system survival for yearling Chinook was 55.1%, which was higher than the 12-year average of 49.3% (1999-2010; Table 27) and higher than the 2009 estimate of 53.1%. However, there was no significant difference in yearling Chinook hydropower system survival between 2009 and 2010 ($P = 0.67$). For steelhead, the 2010 estimated hydropower system survival was 61.8%, which was higher than the average of 40.4% for 1997-2003 and 2006-2010 (Table 28), but lower than the 2009 estimate of 67.8%. There was no significant difference in steelhead hydropower system survival between 2009 and 2010 ($P = 0.38$).

Estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams were among the lowest seen from 1995-2009. High spill percentages, in combination with surface passage structures at each collector dam on the Snake River, resulted in low proportions of fish entering juvenile bypass systems. In 2010, respective estimated percentages entering the bypass systems at Lower Granite, Little Goose, and Lower Monumental Dam were 26, 26, and 8% for wild yearling Chinook, and 16, 12, and 2% for hatchery yearling Chinook. The transport percentage was lower for hatchery than for wild Chinook salmon because of the difference in percentages entering bypass systems. Respective estimated percentages entering the bypass systems at Lower Granite, Little Goose, and Lower Monumental were 23, 22, and 6% for wild steelhead, and 20, 23, and 6% for hatchery steelhead. These 2010 bypass percentages were among the lowest estimated from 1995 to 2009 for both yearling Chinook salmon and steelhead.

Smolt transportation began on 23 April at Lower Granite Dam, 1 May at Little Goose Dam, and 3 May at Lower Monumental Dam. These start dates were earlier than in 2009 (1 May at Lower Granite, 5 May at Little Goose, and 8 May at Lower Monumental). However, yearling Chinook salmon and steelhead smolts arrived later at Lower Granite Dam in 2010 than in 2007-2009. When transportation began at Lower Granite on 23 April, only about 2% of the yearling Chinook salmon and 1% of the steelhead had already passed the dam. However, the cumulative passage distribution for yearling Chinook salmon climbed rapidly, and approximately 50% of the run had passed Lower Granite by 3 May. The steelhead run was a little more protracted; 50% of the run had passed by 11 May. Despite the earlier transport start dates and relatively later run-timing in 2010 than in 2009, the higher spill percentages and consequently lower collection rates resulted in lower percentages of transported fish.

The high estimated survival of steelhead through the hydropower system in both 2009 and 2010 is particularly noteworthy. Mean estimated survival of steelhead in 2009 and 2010 was relatively high in all reaches in comparison to previous years. For steelhead in 2010, the reaches with unusually high mean estimated survival were Lower Granite to Little Goose Dam tailrace and John Day to Bonneville Dam tailrace. High annual estimated survival in these reaches, combined with high estimated survival in other reaches, resulted in a hydropower system survival estimate of almost 62% for steelhead.

One possible contributing factor in the higher steelhead survival in the Lower Granite Dam tailrace to Little Goose Dam tailrace reach is the new temporary spillway weir (TSW) at Little Goose Dam. Although passage survival for steelhead at Little Goose Dam was not significantly different between the TSW and standard spillbays in 2009, estimated passage survival through both routes was high (> 99%; Beeman et al. 2010). If steelhead is disproportionately attracted to the TSW as a passage route, the result would be an increase in survival at Little Goose Dam. Estimated survival between the tailraces of Lower Granite and Little Goose Dams in 2009 and 2010 were the highest we have recorded, which suggests the TSW contributed. However, before the effect of the TSW on overall dam passage survival can be estimated, a detailed investigation is needed of the effect of the TSW on overall spillway passage probability after accounting for other factors, such as spill percentage.

In the reach from John Day to Bonneville Dam, new avian predation deterrent wires in John Day tailrace and the completion of a spillway wall at The Dalles Dam both appeared to contribute to improved smolt survival. Preliminary estimates of survival from the upstream face through the tailrace of John Day Dam were 94.7 and 96.1% for acoustic-tagged yearling Chinook salmon and steelhead, respectively (Weiland et al. 2010). Respective preliminary estimates of yearling Chinook salmon and steelhead survival were 96.4 and 95.3% through The Dalles Dam (Skalski et al. 2010) and 96.3 and 95.6% through Bonneville Dam (Ploskey et al. 2010).

With the addition of a TSW at Little Goose Dam in 2009, the total number of dams with surface collectors on the lower Snake and lower Columbia Rivers increased to seven. This includes removable spillway weirs (RSWs) at Lower Granite, Lower Monumental, and Ice Harbor Dam; TSWs at Little Goose, McNary, and John Day Dam; and the corner collector at Bonneville Dam. Operation of these surface bypass devices can have direct effects on survival, as well as indirect effects associated with decreased travel times. Although absolute measures of surface-passage survival are often similar to those for the bypass system or unaltered spillways, travel times may decrease when fish pass through surface routes because delay in the forebay is decreased. Decreased travel times mean steelhead spend less time in the reservoirs and forebays of dams, which decreases exposure to predators.

Exposure to potentially high water temperatures generally also decreases with faster travel times. Exposure to higher water temperatures can trigger steelhead smolts to revert to parr and cease active migration. Zaugg and Wagner (1973) found that gill Na^+K^+-ATPase (an indicator of migratory readiness) and migratory urge declined at water temperatures of 13°C and above. Reversion to parr was thought to be a factor during a period of higher water temperatures in 2001, when longer travel times were observed later in the season (see Zabel et al. 2002). If a steelhead smolt travels quickly through the hydropower system, it should be less likely to revert to parr and cease migration. A PIT-tagged smolt that ceases migration will not be detected at subsequent dams, and for the purposes of the survival-estimation model, this cannot be distinguished from mortality. Thus estimated survival for steelhead should increase with shorter travel time.

Predation is one factor that unquestionably directly affects survival of migrating smolts (Collis et al. 2002). Avian piscivores are abundant along the Columbia River downstream from its confluence with the Snake River, and bird population sizes and consumption rates are well monitored (Ryan et al. 2001, 2003; Roby et al. 2008). In the McNary Dam reservoir, Crescent Island harbors the second largest Caspian tern *Hydroprogne caspia* colony in North America (about 500 breeding pairs annually on average in the last 10 years), as well as large populations of gulls *Larus* spp. Other avian piscivores reside within the McNary pool, including the American white pelican *Pelecanus erythrorhynchos,* cormorant *Phalacrocorax auritus*, egret *Ardea alba*, and herons *A. herodias* and *Nycticorax nycticorax.* Steelhead smolts are particularly susceptible to predation by birds. For example, Collis et al. (2001) reported over 15% of the tags from PIT-tagged steelhead detected at Bonneville Dam in 1998 were later found on estuarine bird colonies, while only 2% of the tags from PIT-tagged yearling Chinook salmon were found.

Between Lower Monumental and McNary Dams, steelhead survival was depressed during 2001-2005, but higher during 2006-2010. Accordingly, the proportion of PIT-tagged steelhead lost to piscivorous birds in McNary pool was lower during 2006-2010 than during 2001-2005 (indexed by the percentage of PIT-tags detected at Lower Monumental Dam and subsequently on bird colonies; Table 32). The decreased proportion of smolts taken by birds in 2006-2010 was due in part to an increase in the total number of smolts (tagged and untagged) remaining in the river. This increase in turn resulted from increased spill, a greater number of Snake River dams using surface passage structures (all 4 dams in 2010), and a delayed initiation of the smolt transportation program. A negative and significant correlation was found between estimated survival from Lower Monumental to McNary Dam tailrace and the percentage of PIT tags recovered from both yearling Chinook salmon and steelhead (Figure 10).

Table 32. Percentage of PIT–tagged smolts (wild and hatchery combined) detected at Lower Monumental Dam later detected on McNary pool bird colonies, 1998-2010.

Year	Yearling Chinook Salmon	Steelhead
1998	0.49	4.20
1999	0.90	4.51
2000	0.98	3.66
2001	5.59	21.06
2002	1.62	10.09
2003a	1.06	3.71
2004b	2.08	19.42
2005	1.37	9.15
2006	0.92	4.81
2007	0.80	3.59
2008	1.20	4.63
2009	1.57	3.78
2010	1.27	5.26

[a] Only Crescent Island Caspian tern colony sampled.

[b] Only Crescent Island and Foundation Island colonies sampled.

The estimated percentage of steelhead (hatchery and wild combined) that were transported in 2010 was 36%, the lowest percentage estimated from 1993 through 2010. Similar to 2009, this low transport rate left a large number of steelhead migrating in-river in 2010. As we have previously demonstrated, if the total number of fish lost to predation remains relatively constant between years, years with more fish migrating in the river will lead to higher survival estimates, as the proportion of PIT-tagged fish taken by predators decreases (Faulkner et al. 2008).

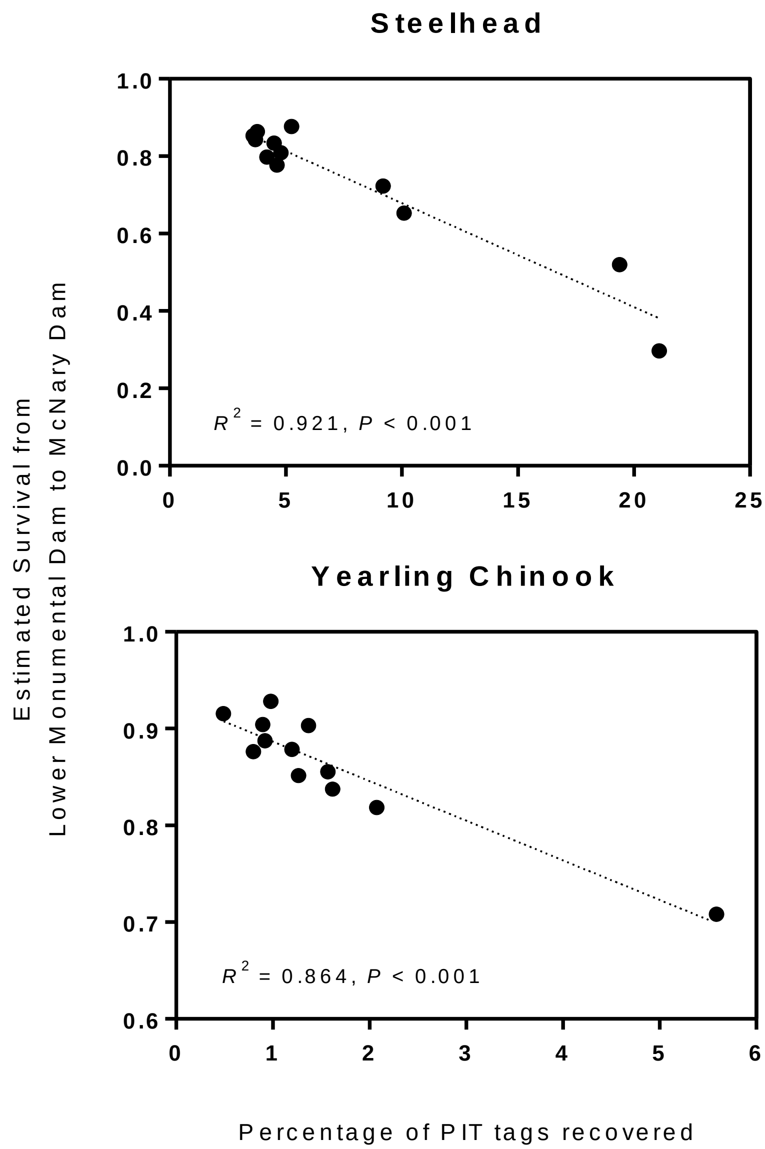

Figure 10. Estimated survival between Lower Monumental and McNary Dams versus percentage of Lower Monumental Dam-detected PIT tags recovered on bird colonies, 1998-2010 (excluding 2003, which had incomplete recovery effort).

CONCLUSIONS AND RECOMMENDATIONS

Results from the 2010 studies provide estimates of survival only during the downstream portion of the migration. Analyses of these data in conjunction with adult return data over the next 3 years will help determine whether variations in spill, flow, temperature, and passage-route produce patterns in smolt-to-adult survival consistent with those observed during the downstream migration phase.

1) Coordination of future survival studies with other projects should continue in order to maximize the data-collection effort and minimize study effects on salmonid resources.

2) Estimates of survival from hatcheries to Lower Granite Dam suggest that substantial mortality occurs upstream from the Snake and Clearwater River confluence. Efforts should continue to identify where this mortality occurs.

3) Increasing the number of PIT-tag detection facilities in the Columbia River Basin will improve survival estimates. We recommend installation of PIT-tag detectors and diversion systems at The Dalles Dam and at upper Columbia River dams.

4) Although there is now a PIT-tag detection system in the juvenile bypass facility at Ice Harbor Dam, because of the high rate of spill and use of a removable spillway weir (RSW) to pass fish, too few fish are detected for survival estimation in some years. Development of PIT-tag detection capability in the RSW would greatly enhance knowledge of juvenile salmonid survival.

5) Survival estimates indicate substantial mortality upstream from Lower Granite Dam. Continued development of instream PIT-detection systems for use in tributaries will be necessary if these areas of upstream mortality are to be identified.

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APPENDIX A

Evaluation of Model Assumptions

Background

Using the Cormack-Jolly-Seber (CJS), or single-release (SR) model, the passage of a single PIT-tagged salmonid through the hydropower system is modeled as a sequence of events. Examples of such events are detection at Little Goose Dam or survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam. Each event has an associated probability of occurrence (technically, these probabilities are "conditional," as they are defined only if a certain condition is met, for example "probability of detection at Little Goose Dam *given* that the fish survived to Little Goose Dam").

The detection history is thus a record of the outcome of a series of events. (although detection history is an imperfect record of outcomes, since it cannot always distinguish between mortality and survival without detection). The SR model represents detection history data for a group of tagged fish as a multinomial distribution; each multinomial cell probability (detection history probability) is a function of the underlying survival and detection event probabilities. Three key assumptions lead to the multinomial cell probabilities used in the SR model:

A1) Fish in a single group of tagged fish have common event probabilities (each conditional detection or survival probability is common to all fish in the group).

A2) Event probabilities for each individual fish are independent from those for all other fish.

A3) Each event probability for an individual fish is conditionally independent from all other probabilities.

For a migrating PIT-tagged fish, assumption A3 implies that detection at any particular dam does not affect (or give information regarding) probabilities of subsequent events. For the group as a whole, this means that detected and nondetected fish at a given dam have the same probability of survival in downstream reaches and have the same conditional probability of detection at downstream dams.

Methods

We used the methods presented by Burnham et al. (1997; pp 71-77) to assess the goodness-of-fit of the SR model to observed detection history data. In these tests, we compiled a series of contingency tables from detection history data for each group of tagged fish, and used χ^2 tests to identify systematic deviations from what was expected if the assumptions were met. We applied the tests to weekly groups of yearling Chinook salmon and steelhead (hatchery and wild combined) leaving Lower Granite and McNary Dam in 2010 (Snake River-origin fish only, i.e., the fish used for survival estimates reported in Tables 2-3 and 9-10).

If goodness-of-fit tests for a series of release groups resulted in more significant tests than expected by chance, we compared observed and expected tables to determine the nature of the violation. While consistent patterns of violations in the assumption testing do not unequivocally pinpoint the cause of the violation, they can be suggestive, and some hypothesized causes may be ruled out.

Potential causes of assumption violations include inherent differences between individuals in survival or detection probability (e.g., propensity to be guided by bypass screens); differential mortality between the passage route that is monitored for PIT tags (juvenile collection system) and those that are not (spillways and turbines); behavioral responses to bypass and detection; and differences in passage timing for detected and non-detected fish if such differences result in exposure to different conditions downstream. However, inherent differences and behavioral responses cannot be distinguished using detection information alone.

Conceptually, we make the distinction that inherent traits are those that characterized the fish before any hydrosystem experience, while behavioral responses occur as a result of particular hydrosystem experiences. For example, developing a preference for a particular passage route is a behavioral response, while size-related differences in passage-route selection are inherent. Of course, response to passage experience may also depend on inherent characteristics.

To describe each test we conducted, we follow the nomenclature of Burnham et al. (1987). For release groups from Lower Granite Dam, we analyzed 4-digit detection histories indicating status at Little Goose, Lower Monumental, and McNary Dams, and the final digit for detection anywhere below McNary Dam. The first test for Lower Granite Dam groups was Burnham et al. (1997) Test 2.C2, which was based on the following contingency table:

Test 2.C2	First site detected below Little Goose		
df = 2	Lower Monumental	MCN	John Day or below
Not detected at Little Goose	n_{11}	n_{12}	n_{13}
Detected at Little Goose	n_{21}	n_{22}	n_{23}

In this table, all fish detected somewhere below Little Goose Dam were cross-classified according to their detection history at Little Goose Dam and according to their first detection site below Little Goose Dam. For example, n_{11} is the classification of fish not detected at Little Goose Dam that were first detected downstream at Lower Monumental Dam. If all SR model assumptions are met, counts of fish detected at Little Goose should be in constant proportion to those of fish not detected (i.e., n_{11}/n_{21}, n_{12}/n_{22}, and n_{13}/n_{23} should be equal). Because this table counted only fish detected below Little Goose (i.e., all fish survived passage at Goose), differential *direct* mortality for fish detected and not detected at Little Goose will not cause violations of Test 2.C2 by itself.

However, differential *indirect* mortality related to Little Goose passage could cause violations if differences are not expressed until fish are below LMO. Behavioral response to guidance at Little Goose could cause violations of Test 2.C2: if fish detected at Little Goose become more likely to be detected downstream, then they will tend to have more first downstream detections at LMO. If detected fish at Little Goose become less likely to be detected downstream, then they will have fewer first detections at LMO. Inherent differences among fish could also cause violations of Test 2.C2, and would be difficult to distinguish from behavioral responses.

The second test for Lower Granite Dam groups was Test 2.C3, based on the contingency table:

Test 2.C3	First site detected below Lower Monumental	
df = 1	MCN	John Day or below
Not detected at Lower Monumental	n_{11}	n_{12}
Detected at Lower Monumental	n_{21}	n_{22}

This table and corresponding implications are similar to those of Test 2.C2. All fish that were detected somewhere below Lower Monumental are cross-classified according to their history at Lower Monumental and according to their first detection site below Lower Monumental. If the respective counts for fish first detected at McNary are not in the same proportion as those first detected at John Day or below, it could indicate behavioral response to detection at Lower Monumental, inherent differences in detectability (i.e., guidability) among tagged fish in the group, or long-term differential mortality caused by different passage routes at Lower Monumental.

The next series of tests for Lower Granite Dam groups is called Test 3. The first in the series is called Test 3.SR3, based on the contingency table:

Test 3.SR3	Detected again at McNary or below?	
df = 1	YES	NO
Detected at Lower Monumental, not detected at Little Goose	n_{11}	n_{12}
Detected at Lower Monumental, detected at Little Goose	n_{21}	n_{22}

In this table, all fish detected at Lower Monumental are cross-classified according to their status at Little Goose and whether or not they were detected again downstream from Lower Monumental. As with the Test 2 series, differential mortality in different passage routes at Little Goose will not be detected by this test if all the mortality is expressed before the fish arrive at Lower Monumental. Differences in mortality expressed below McNary could cause violations, however, as could behavioral responses (possibly somewhat harder to detect because of the conditioning on detection at Lower Monumental) or inherent differences in detectability or survival between fish detected at Little Goose and those not detected there.

The second test in the Test 3 series is Test 3.Sm3, based on the contingency table:

Test 3.Sm3	Site first detected below Lower	
df = 1	McNary	John Day
Detected at Lower Monumental, not detected at Little Goose	n_{11}	n_{12}
Detected at Lower Monumental, detected at Little Goose	n_{21}	n_{22}

This test is sensitive to the same sorts of differences as Test 3.SR3, but tends to have somewhat less power. Because the table classifies only fish detected somewhere below Lower Monumental, it is not sensitive to differences in survival between Lower Monumental and McNary.

The final test for Lower Granite Dam groups is Test 3.SR4, based on the contingency table:

Test 3.SR4	Detected at John Day or below?	
df = 1	Yes	No
Detected at McNary, not detected previously	n_{11}	n_{12}
Detected at McNary, also detected previously	n_{21}	n_{22}

This table classifies all fish detected at McNary according to whether they had been detected at least once at Little Goose and Lower Monumental and whether they were detected again below McNary. A significant test indicates that some below-McNary parameter(s) differ between fish detected upstream of McNary and those not detected. The cause of such an assumption violation could be differences in indirect survival associated with detection at Little Goose and/or Lower Monumental (mortality expressed between McNary and the estuary PIT-trawl), inherent differences in survival or detection probabilities, or behavioral responses.

We did not include any contingency table tests when any of the expected cells of the table were less than 1.0, as the test statistic does not sufficiently approximate the asymptotic χ^2 distribution in these cases. (For Test 2.C2, when the expected values in the "Lower Monumental" and "McNary" columns were all greater than 1.0, but one or two of the expected values in the "John Day or below" column were less than 1.0, we collapsed the "McNary" and "John Day or below" and calculated a one-degree-of-freedom test of the resulting 2-by-2 table). We combined the two test statistics in the Test 2 series and the three in the Test 3 series and then all tests together in a single overall χ^2 test statistic.

For release groups from McNary Dam, we analyzed 3-digit detection histories indicating status at John Day Dam, Bonneville Dam, and the estuary PIT-trawl.

Only two tests are possible for 3-digit detection histories. The first of these was Test 2.C2, based on the contingency table:

Test 2.C2	First site detected below John Day	
df = 1	BON	Trawl
Not detected at John Day	n_{11}	n_{12}
Detected at John Day	n_{21}	n_{22}

and the second is Test 3.SR3, based on the contingency table:

Test 3.SR3	Detected at Trawl	
df = 1	Yes	No
Detected at Bonneville, not detected at John Day	n_{11}	n_{12}
Detected at Bonneville, detected at John Day	n_{21}	n_{22}

These tests are analogous to Tests 2.C3 and 3.SR4, respectively, for the Lower Granite Dam release groups. Potential causes of violations of the tests for McNary Dam groups are the same as those for Lower Granite Dam groups.

Results

For weekly Lower Granite Dam release groups in 2010 there were more significant ($\alpha = 0.05$) tests than expected by chance alone for both yearling Chinook salmon and steelhead (Appendix Table A1). There were 7 weekly groups of yearling Chinook salmon. For these, the overall sum of the χ^2 test statistics was significant 2 times. For 8 steelhead groups, the overall test was significant 2 times. Counting all individual component tests (i.e., 2.C2, 3.SR3, etc.), 4 tests of 33 (12%) were significant for yearling Chinook salmon and 4 of 40 (10%) were significant for steelhead (Appendix Tables A1-A3).

We diagnosed the patterns in the contingency tables that led to significant tests and results were similar to those we reported in past years. All but one of the 8 significant individual component tests for Lower Granite groups of yearling Chinook salmon and steelhead were for component tests of Test 2. This provides evidence that fish previously detected were either more or less likely to be detected again at downstream dams as compared to fish not previously detected. Although the direction of the relationship was not consistent, in the majority of significant individual Test 2 component tests (3 of 4 tests for yearling Chinook salmon and 2 of 3 for steelhead), fish previously detected were more likely to be detected again at downstream dams.

For weekly groups from McNary Dam, significant contingency table test results were more common than expected for steelhead, but not for yearling Chinook salmon (Appendix Tables A4-A6). For yearling Chinook salmon, there were no significant tests out of the 10 individual component tests, and for steelhead 2 (25%) of the 8 component tests were significant. Both of the significant component tests for steelhead were for Test 2.C2, and both of those indicated fish detected at John Day Dam were less likely to be detected again downstream than those not detected at John Day Dam.

Discussion

We believe that inherent differences in detectability (guidability) of fish within a release group are the most likely cause of the patterns we observed in the contingency table tests in 2010, as in previous years. Zabel et al. (2002) provided evidence of inherent differences related to length of fish at tagging, and similar observations were made in 2010 data. Fish size probably does not explain all inherent differences, but it appears to explain some. The relationship between length at tagging and detection probability at Little Goose Dam, the first dam encountered after release by fish in these data sets (all fish in the data set were detected at Lower Granite Dam; Little Goose Dam is the first encountered after leaving Lowr Granite Dam), suggests that the heterogeneity is inherent, and not a behavioral response

Another possibility is that correlated changes in spill levels at adjacent dams during passage of a cohort resulted in correlated detection probabilities within subsets of the cohort. For example, suppose that spill is high (spill passage high and detection probability low) at both Little Goose Dam and Lower Monumental Dam while the first half of a cohort is passing those dams, and then spill is low (detection probability high) at both dams while the second half of the cohort passes. In this case, fish detected at Little Goose Dam will be more likely detected at Lower Monumental than those not detected at Little Goose Dam. Correlation among spill proportions across the season at the Snake River dams combined with greater propensity for steelhead to pass through spillways suggest that this phenomenon could help explain the frequent significant contingency table tests for steelhead in the Snake River.

Although the contingency table tests described here do well at detecting most violations of CJS model assumptions, there are instances where assumptions could be violated without resulting in significant tests. A specific example is that of acute differential post-detection mortality, where detected and nondetected fish have a difference in mortality in the period between the detection point of interest and the next detection point. This would violate assumption A3, but the violation is not detectable because all the tests described here condition on known fates of fish either at the site of interest or sites downstream. Detection of differential post-detection mortality requires knowledge of the fate of individual nondetected fish in the tailrace of the detection dam of interest and downstream. The fate of fish not detected at the site of interest is only known for those fish detected again downstream, and not for those never detected again. Therefore, none of the assumptions tests described here can detect differential post-detection mortality between two adjacent detection sites.

Results in previous years (e.g., Zabel et al. 2002) led us to conclude, as did Burnham et al. (1987), that a reasonable amount of heterogeneity in the survival and detection process did not seriously affect the performance of estimators of survival.

Appendix Table A1. Number of tests of goodness-of-fit to the single release model conducted for weekly release groups of yearling Chinook salmon and steelhead (hatchery and wild combined) from Lower Granite Dam, and number of significant ($\alpha = 0.05$) test results, 2010.

	Test 2.C2		Test 2.C3		Test 3.SR3		Test 3.Sm3		Test 3.SR4		Test 2 sum		Test 3 sum		Test 2 + 3	
Species	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.
Chinook	7	2	7	2	6	0	6	0	7	0	7	4	7	0	7	2
Steelhead	8	3	8	0	8	1	8	0	8	0	8	3	8	1	8	2
Total	15	5	15	2	14	1	14	0	15	0	15	7	15	1	15	4

Appendix Table A2. Results of tests of goodness of fit to the single release model for release groups of yearling Chinook salmon (hatchery and wild) from Lower Granite to McNary Dam in 2010.

Release	Overall χ^2	Overall *P* value	Test 2 χ^2	Test 2 *P* value	Test 2.C2 χ^2	Test 2.C2 *P* value	Test 2.C3 χ^2	Test 2.C3 *P* value
20 Apr–26 Apr	9.94	0.042	9.71	0.021	3.63	0.163	6.08	0.014
27 Apr–03 May	9.07	0.170	4.17	0.244	4.07	0.131	0.11	0.746
04 May–10 May	10.77	0.096	8.75	0.033	8.75	0.013	0.00	0.991
11 May–17 May	43.46	< 0.001	42.14	< 0.001	40.16	< 0.001	1.98	0.160
18 May–24 May	4.72	0.580	4.55	0.208	2.95	0.229	1.61	0.205
25 May–31 May	10.60	0.102	9.41	0.024	3.37	0.185	6.04	0.014
01 Jun–07 Jun	4.60	0.595	1.38	0.710	1.27	0.531	0.12	0.734
Total (df)	93.15 (40)		80.11 (21)		64.19 (14)		15.92 (7)	

Release	Test 3 χ^2	Test 3 *P* value	Test 3.SR3 χ^2	Test 3.SR3 *P* value	Test 3.Sm3 χ^2	Test 3.Sm3 *P* value	Test 3.SR4 χ^2	Test 3.SR4 *P* value
20 Apr–26 Apr	0.23	0.633	NA	NA	NA	NA	0.23	0.633
27 Apr–03 May	4.90	0.180	3.46	0.063	1.29	0.256	0.15	0.701
04 May–10 May	2.02	0.569	0.02	0.887	0.87	0.350	1.13	0.289
11 May–17 May	1.32	0.725	0.24	0.626	0.25	0.614	0.83	0.363
18 May–24 May	0.17	0.982	0.01	0.942	0.02	0.876	0.14	0.709
25 May–31 May	1.19	0.755	0.72	0.397	0.34	0.558	0.13	0.716
01 Jun–07 Jun	3.22	0.358	0.58	0.445	2.10	0.148	0.54	0.462
Total (df)	13.04 (19)		5.02 (6)		4.88 (6)		3.14 (7)	

Appendix Table A3. Results of tests of goodness of fit to the single release model for release groups of juvenile steelhead (hatchery and wild) from Lower Granite to McNary Dam in 2010.

Release period	Overall χ^2	Overall *P* value	Test 2 χ^2	Test 2 *P* value	Test 2.C2 χ^2	Test 2.C2 *P* value	Test 2.C3 χ^2	Test 2.C3 *P* value
20 Apr–26 Apr	5.67	0.462	4.19	0.241	1.57	0.456	2.62	0.105
27 Apr–03 May	10.60	0.102	8.93	0.030	8.02	0.018	0.91	0.340
04 May–10 May	19.93	0.003	17.83	< 0.001	17.43	< 0.001	0.39	0.532
11 May–17 May	10.51	0.105	5.85	0.119	4.88	0.087	0.97	0.324
18 May–24 May	175.70	< 0.001	166.08	< 0.001	163.68	< 0.001	2.40	0.121
25 May–31 May	1.97	0.923	1.62	0.655	0.62	0.732	1.00	0.318
01 Jun–07 Jun	5.42	0.491	4.74	0.192	2.68	0.261	2.05	0.152
08 Jun–14 Jun	0.85	0.991	0.38	0.945	0.23	0.891	0.15	0.702
Total (df)	230.62 (48)		209.62 (24)		199.12 (16)		10.49 (8)	

Release period	Test 3 χ^2	Test 3 *P* value	Test 3.SR3 χ^2	Test 3.SR3 *P* value	Test 3.Sm3 χ^2	Test 3.Sm3 *P* value	Test 3.SR4 χ^2	Test 3.SR4 *P* value
20 Apr–26 Apr	1.47	0.688	1.12	0.290	0.01	0.913	0.34	0.559
27 Apr–03 May	1.66	0.645	0.01	0.928	1.22	0.270	0.44	0.509
04 May–10 May	2.10	0.552	0.05	0.832	1.62	0.203	0.44	0.508
11 May–17 May	4.65	0.199	3.30	0.069	0.01	0.935	1.35	0.246
18 May–24 May	9.62	0.022	9.34	0.002	0.26	0.614	0.03	0.873
25 May–31 May	0.35	0.951	0.25	0.621	0.10	0.750	0.00	0.979
01 Jun–07 Jun	0.69	0.877	0.02	0.888	0.14	0.708	0.53	0.468
08 Jun–14 Jun	0.47	0.925	0.00	0.951	0.00	0.952	0.47	0.495
Total (df)	21.01 (24)		14.08 (8)		3.36 (8)		3.58 (8)	

Appendix Table A4. Number of tests of goodness of fit to the single release model conducted for weekly release groups of yearling Chinook salmon and steelhead (hatchery and wild combined) from McNary Dam, and number of significant ($\alpha = 0.05$) test results, 2010.

	Test 2.C2		Test 3.SR3		Test 2 + 3	
Species	No.	sig.	No.	sig.	No.	sig.
Chinook	5	0	5	0	5	0
Steelhead	5	2	3	0	5	2
Total	10	2	8	0	10	2

Appendix Table A5. Results of tests of goodness of fit to the single release model for release groups of yearling Chinook salmon (hatchery and wild) from McNary to Bonneville Dam in 2010.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
27 Apr–03 May	0.21	0.900	0.15	0.695	0.06	0.813
04 May–10 May	2.20	0.332	1.74	0.188	0.47	0.494
11 May–17 May	1.25	0.536	0.30	0.586	0.95	0.329
18 May–24 May	2.69	0.260	1.86	0.173	0.83	0.361
25 May–31 May	2.97	0.226	0.84	0.359	2.13	0.144
Total (df)	9.33 (10)		4.88 (5)		4.44 (5)	

Appendix Table A6. Results of tests of goodness of fit to the single release model for release groups of steelhead (hatchery and wild) from McNary to Bonneville Dam in 2010.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
27 Apr–03 May	2.50	0.287	0.28	0.598	2.22	0.136
04 May–10 May	0.23	0.892	0.18	0.674	0.05	0.818
11 May–17 May	7.71	0.021	6.85	0.009	0.86	0.354
18 May–24 May	11.02	0.001	11.02	0.001	NA	NA
25 May–31 May	1.20	0.274	1.20	0.274	NA	NA
Total (df)	22.66 (8)		19.52 (5)		3.14 (3)	

APPENDIX B

Survival and Detection Probability Estimates from Individual Hatcheries and Traps

Appendix Table B1. Estimated survival probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Release to McNary Dam
			Clearwater Hatchery			
Clear Creek	18,168	0.816 (0.031)	1.117 (0.128)	1.066 (0.189)	0.678 (0.095)	0.659 (0.020)
Powell Pond	18,176	0.674 (0.035)	0.947 (0.084)	0.830 (0.133)	1.028 (0.151)	0.545 (0.020)
Red River Pond	18,163	0.702 (0.030)	1.006 (0.077)	1.058 (0.176)	0.860 (0.137)	0.642 (0.025)
Selway River	18,183	0.793 (0.032)	0.929 (0.096)	1.002 (0.161)	0.817 (0.106)	0.604 (0.019)
			Dworshak Hatchery			
NF Clearwater River	51,403	0.898 (0.017)	1.014 (0.039)	0.934 (0.063)	0.917 (0.055)	0.780 (0.014)
			Kooskia Hatchery			
Clear Creek	14,543	0.744 (0.030)	1.101 (0.097)	0.840 (0.133)	0.906 (0.127)	0.624 (0.022)
			Lookingglass Hatchery			
Catherine Creek Pond	20,311	0.447 (0.020)	0.882 (0.065)	1.231 (0.177)	0.760 (0.106)	0.369 (0.015)
Grande Ronde Pond	2,482	0.422 (0.029)	1.115 (0.138)	0.633 (0.109)	1.196 (0.194)	0.356 (0.034)
Imnaha Weir	20,604	0.682 (0.025)	1.060 (0.068)	1.015 (0.120)	0.768 (0.086)	0.563 (0.017)
Lookingglass Hatchery	2,929	0.707 (0.039)	1.216 (0.134)	0.633 (0.104)	1.161 (0.174)	0.632 (0.047)
Lostine Pond	20,311	0.447 (0.020)	0.882 (0.065)	1.231 (0.177)	0.760 (0.106)	0.369 (0.015)
			McCall Hatchery			
Johnson Creek (Mar)	2,188	0.269 (0.024)	1.124 (0.164)	1.016 (0.291)	0.639 (0.188)	0.196 (0.028)
Johnson Creek (Apr)	2,224	0.373 (0.028)	0.918 (0.096)	1.345 (0.330)	0.570 (0.153)	0.263 (0.035)
Knox Bridge	51,785	0.566 (0.014)	1.011 (0.042)	1.014 (0.084)	0.797 (0.063)	0.462 (0.010)
			Pahsimeroi Hatchery			
Pahsimeroi Pond	21,375	0.384 (0.023)	0.850 (0.074)	1.165 (0.329)	0.667 (0.186)	0.254 (0.012)
			Rapid River Hatchery			
Rapid River Hatchery	51,905	0.786 (0.019)	1.010 (0.043)	0.969 (0.067)	0.866 (0.055)	0.666 (0.012)
			Sawtooth Hatchery			
Sawtooth Hatchery	16,999	0.427 (0.018)	0.994 (0.075)	0.930 (0.126)	0.807 (0.102)	0.318 (0.012)
Yankee Fork	4,285	0.514 (0.042)	0.893 (0.119)	1.535 (0.522)	0.550 (0.191)	0.388 (0.041)

Appendix Table B2. Estimated survival probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Release to McNary Dam
			Clearwater Hatchery			
S.F. Clearwater (rkm 31)	5,237	0.887 (0.043)	1.028 (0.090)	0.926 (0.133)	0.831 (0.108)	0.702 (0.039)
S.F. Clearwater (rkm 62)	4,968	0.891 (0.044)	1.063 (0.091)	0.822 (0.132)	0.812 (0.124)	0.632 (0.035)
S.F. Clearwater (rkm 84)	2,755	0.790 (0.053)	1.189 (0.157)	0.684 (0.147)	0.950 (0.189)	0.610 (0.056)
Crooked River	2,392	0.748 (0.061)	0.926 (0.131)	0.789 (0.197)	0.872 (0.228)	0.476 (0.070)
Kooskia Hatchery	4,079	0.929 (0.057)	1.043 (0.122)	0.635 (0.096)	1.232 (0.151)	0.758 (0.055)
Red River Pond	4,171	0.760 (0.047)	1.058 (0.114)	0.928 (0.209)	0.781 (0.175)	0.582 (0.052)
			Dworshak Hatchery			
Clearwater R. (Feb)	43,173	0.801 (0.013)	1.071 (0.033)	0.764 (0.039)	0.858 (0.042)	0.562 (0.015)
Clearwater R. (Apr)	1,481	0.808 (0.039)	1.591 (0.235)	0.593 (0.141)	0.695 (0.144)	0.529 (0.054)
			Hagerman Hatchery			
Salmon River	934	0.650 (0.069)	1.501 (0.400)	1.248 (0.698)	0.483 (0.250)	0.587 (0.087)
East Fork Salmon R.	6,804	0.713 (0.038)	0.846 (0.066)	1.181 (0.159)	0.588 (0.092)	0.419 (0.038)
Sawtooth Trap	12,936	0.759 (0.031)	1.021 (0.068)	0.922 (0.110)	0.792 (0.092)	0.566 (0.026)
Yankee Fork	7,258	0.721 (0.024)	0.966 (0.052)	0.791 (0.060)	0.921 (0.110)	0.507 (0.051)
			Irrigon Hatchery			
Big Canyon Fac. (4/14)	5,404	0.815 (0.041)	1.023 (0.085)	1.205 (0.196)	0.733 (0.128)	0.737 (0.066)
Big Canyon Fac. (4/27)	5,440	0.821 (0.046)	0.873 (0.078)	1.044 (0.172)	0.865 (0.160)	0.647 (0.068)
Big Sheep Creek	4,783	0.820 (0.042)	0.884 (0.075)	1.143 (0.186)	0.701 (0.122)	0.580 (0.054)
Little Sheep Facility	16,915	0.796 (0.021)	0.965 (0.042)	1.091 (0.093)	0.677 (0.064)	0.568 (0.030)
Wallowa Hatchery	12,249	0.824 (0.037)	0.903 (0.062)	1.322 (0.209)	0.671 (0.110)	0.660 (0.041)
			Lyons Ferry Hatchery			
Cottonwood Pond	5,998	0.818 (0.030)	1.072 (0.085)	0.871 (0.110)	0.898 (0.107)	0.686 (0.048)

Appendix Table B2. Continued.

Release site	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Release to McNary Dam
			Magic Valley Hatchery			
E. F. Salmon R.	5,576	0.721 (0.041)	0.933 (0.081)	1.515 (0.368)	0.454 (0.116)	0.463 (0.043)
Little Salmon R.	8,948	0.922 (0.032)	0.942 (0.056)	1.079 (0.129)	0.607 (0.072)	0.569 (0.028)
Pahsimeroi R. Trap	7,172	0.793 (0.046)	0.783 (0.062)	1.440 (0.261)	0.638 (0.127)	0.571 (0.054)
Salmon R. (rkm 347)	989	0.862 (0.126)	0.801 (0.185)	0.887 (0.293)	1.024 (0.323)	0.627 (0.105)
Salmon R. (rkm 385)	2,082	0.798 (0.064)	1.344 (0.233)	0.517 (0.154)	1.099 (0.296)	0.609 (0.067)
Salmon R. (rkm 476)	2,590	0.853 (0.057)	1.165 (0.157)	1.157 (0.326)	0.563 (0.150)	0.647 (0.056)
Salmon R. (rkm 506)	2,097	0.946 (0.101)	0.950 (0.164)	1.431 (0.667)	0.568 (0.272)	0.730 (0.122)
Squaw Creek	3,285	0.708 (0.055)	0.861 (0.099)	0.978 (0.199)	0.731 (0.168)	0.436 (0.060)
			Niagara Springs Hatchery			
Hells Canyon Dam	8,256	0.920 (0.036)	0.948 (0.060)	1.179 (0.125)	0.781 (0.091)	0.803 (0.052)
Little Salmon R.	6,974	0.980 (0.043)	0.925 (0.070)	0.981 (0.131)	0.823 (0.110)	0.732 (0.047)
Pahsimeroi Trap	12,897	0.945 (0.041)	0.936 (0.063)	0.803 (0.090)	0.930 (0.104)	0.660 (0.033)

Appendix Table B3. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2010. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Release date	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam	Release to McNary Dam
Oxbow Hatchery								
Redfish L. Cr. Trap	04 May 10	5,962	0.172 (0.025)	0.815 (0.166)	1.000 (0.399)	0.818 (0.343)	0.667 (0.161)	0.115 (0.023)
Sawtooth Trap	04 May 10	5,983	0.246 (0.039)	0.782 (0.148)	2.328 (1.107)	0.399 (0.198)	0.727 (0.169)	0.179 (0.031)
Sawtooth Hatchery								
Alturus Lake	07 Oct 09	1,018	0.157 (0.028)	0.816 (0.185)	1.419 (0.564)	0.385 (0.172)	0.446 (0.133)	0.070 (0.018)
Pettit Lake	07 Oct 09	1,018	0.089 (0.014)	0.995 (0.202)	1.611 (0.818)	0.955 (0.746)	1.530 (0.957)	0.136 (0.084)
Redfish Lake	07 Oct 09	1,016	0.123 (0.016)	1.423 (0.384)	0.459 (0.165)	1.232 (0.636)	0.805 (0.391)	0.099 (0.048)
Redfish L. Cr. Trap	04 May 10	25,853	0.146 (0.006)	0.961 (0.065)	0.996 (0.128)	0.679 (0.095)	0.650 (0.056)	0.095 (0.008)
Sawtooth Trap	04 May 10	25,831	0.164 (0.010)	0.719 (0.060)	1.076 (0.132)	0.830 (0.108)	0.642 (0.061)	0.105 (0.008)

Appendix Table B4. Estimated detection probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Clearwater Hatchery			
Clear Creek	18,168	0.118 (0.005)	0.056 (0.006)	0.008 (0.001)	0.213 (0.007)
Powell Pond	18,176	0.118 (0.007)	0.095 (0.007)	0.013 (0.002)	0.233 (0.010)
Red River Pond	18,163	0.139 (0.007)	0.102 (0.007)	0.018 (0.003)	0.225 (0.010)
Selway River	18,183	0.119 (0.006)	0.072 (0.007)	0.010 (0.002)	0.223 (0.008)
		Dworshak Hatchery			
NF Clearwater River	51,403	0.154 (0.003)	0.113 (0.004)	0.018 (0.001)	0.215 (0.004)
		Kooskia Hatchery			
Clear Creek	14,543	0.189 (0.008)	0.131 (0.010)	0.021 (0.003)	0.315 (0.012)
		Lookingglass Hatchery			
Catherine Creek Pond	20,311	0.159 (0.008)	0.135 (0.008)	0.038 (0.005)	0.248 (0.011)
Grande Ronde Pond	2,482	0.190 (0.017)	0.119 (0.016)	0.057 (0.012)	0.295 (0.031)
Imnaha Weir	20,604	0.149 (0.006)	0.113 (0.006)	0.035 (0.004)	0.258 (0.009)
Lookingglass Hatchery	2,929	0.156 (0.012)	0.089 (0.010)	0.037 (0.007)	0.224 (0.019)
Lostine Pond	20,311	0.172 (0.009)	0.141 (0.010)	0.039 (0.006)	0.249 (0.017)
		McCall Hatchery			
Johnson Creek (Mar)	2,188	0.199 (0.023)	0.169 (0.025)	0.052 (0.016)	0.304 (0.047)
Johnson Creek (Apr)	2,224	0.202 (0.020)	0.260 (0.026)	0.053 (0.014)	0.302 (0.043)
Knox Bridge	51,785	0.169 (0.005)	0.124 (0.004)	0.028 (0.002)	0.290 (0.007)
		Pahsimeroi Hatchery			
Pahsimeroi Pond	21,375	0.135 (0.009)	0.184 (0.012)	0.008 (0.002)	0.318 (0.015)
		Rapid River Hatchery			
Rapid River H.	51,905	0.130 (0.004)	0.094 (0.004)	0.034 (0.002)	0.235 (0.005)
		Sawtooth Hatchery			
Sawtooth H.	16,999	0.193 (0.009)	0.132 (0.009)	0.041 (0.006)	0.351 (0.014)
Yankee Fork	4,285	0.200 (0.018)	0.195 (0.021)	0.041 (0.014)	0.258 (0.029)

Appendix Table B5. Estimated detection probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Clearwater Hatchery			
SF Clearwater (rkm 31)	5,237	0.166 (0.010)	0.207 (0.016)	0.036 (0.005)	0.141 (0.010)
SF Clearwater (rkm 62)	4,968	0.180 (0.010)	0.217 (0.015)	0.033 (0.006)	0.171 (0.012)
SF Clearwater (rkm 84)	2,755	0.199 (0.016)	0.185 (0.022)	0.044 (0.010)	0.139 (0.016)
Crooked River	2,392	0.204 (0.019)	0.251 (0.029)	0.062 (0.016)	0.114 (0.020)
Kooskia Hatchery	4,079	0.158 (0.011)	0.182 (0.019)	0.044 (0.006)	0.131 (0.011)
Red River Pond	4,171	0.181 (0.013)	0.224 (0.020)	0.034 (0.008)	0.114 (0.012)
		Dworshak Hatchery			
Clearwater R. (Feb)	43,173	0.238 (0.004)	0.267 (0.007)	0.065 (0.003)	0.170 (0.005)
Clearwater R. (Apr)	1,481	0.241 (0.017)	0.156 (0.024)	0.054 (0.012)	0.197 (0.024)
		Hagerman Hatchery			
Salmon River	934	0.203 (0.027)	0.138 (0.035)	0.023 (0.012)	0.132 (0.025)
East Fork Salmon R.	6,804	0.187 (0.011)	0.307 (0.017)	0.098 (0.013)	0.106 (0.012)
Sawtooth Trap	12,936	0.154 (0.007)	0.187 (0.010)	0.039 (0.005)	0.119 (0.007)
Yankee Fork	7,258	0.247 (0.010)	0.366 (0.015)	0.254 (0.017)	0.105 (0.012)
		Irrigon Hatchery			
Big Canyon. (4/14)	5,404	0.184 (0.011)	0.201 (0.014)	0.049 (0.008)	0.080 (0.009)
Big Canyon. (4/27)	5,440	0.189 (0.012)	0.220 (0.016)	0.062 (0.010)	0.077 (0.010)
Big Sheep Creek	4,783	0.207 (0.012)	0.238 (0.017)	0.056 (0.009)	0.086 (0.010)
Little Sheep Facility	16,915	0.216 (0.007)	0.266 (0.009)	0.068 (0.006)	0.095 (0.006)
Wallowa Hatchery	12,249	0.153 (0.008)	0.192 (0.010)	0.029 (0.005)	0.078 (0.006)
		Lyons Ferry Hatchery			
Cottonwood Pond	5,998	0.197 (0.009)	0.203 (0.015)	0.054 (0.006)	0.094 (0.008)
		Magic Valley Hatchery			
East Fork Salmon R	5,576	0.183 (0.012)	0.278 (0.018)	0.042 (0.010)	0.116 (0.013)
Little Salmon River	8,948	0.209 (0.008)	0.251 (0.012)	0.049 (0.006)	0.152 (0.009)
Pahsimeroi R. Trap	7,172	0.154 (0.010)	0.289 (0.015)	0.040 (0.007)	0.074 (0.008)
Salmon R. (rkm 347)	989	0.156 (0.026)	0.209 (0.038)	0.050 (0.017)	0.119 (0.024)
Salmon R. (rkm 385)	2,082	0.186 (0.018)	0.159 (0.025)	0.029 (0.009)	0.132 (0.018)
Salmon R. (rkm 476)	2,590	0.190 (0.015)	0.176 (0.021)	0.027 (0.008)	0.140 (0.015)
Salmon R. (rkm 506)	2,097	0.151 (0.018)	0.197 (0.027)	0.025 (0.012)	0.084 (0.016)
Squaw Creek	3,285	0.180 (0.016)	0.321 (0.026)	0.080 (0.016)	0.100 (0.016)
		Niagara Springs Hatchery			
Hells Canyon Dam	8,256	0.178 (0.008)	0.198 (0.010)	0.064 (0.007)	0.078 (0.006)
Little Salmon R.	6,974	0.177 (0.009)	0.210 (0.013)	0.043 (0.006)	0.097 (0.008)
Pashimeroi Trap	12,897	0.149 (0.007)	0.174 (0.009)	0.039 (0.004)	0.092 (0.006)

Appendix Table B6. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2010. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Release date	Number released	Lower Granite	Little Goose	Lower Monumental	McNary
Oxbow Hatchery						
Redfish L Cr Trap	4 May 2010	5,962	0.096 (0.016)	0.120 (0.021)	0.021 (0.009)	0.087 (0.020)
Sawtooth Trap	4 May 2010	5,983	0.058 (0.011)	0.142 (0.018)	0.012 (0.006)	0.084 (0.017)
Sawtooth Hatchery						
Alturus Lake	7 Oct 2009	1,018	0.188 (0.044)	0.298 (0.060)	0.125 (0.052)	0.381 (0.106)
Pettit Lake	7 Oct 2009	1,018	0.254 (0.056)	0.371 (0.078)	0.103 (0.057)	0.125 (0.083)
Redfish Lake	7 Oct 2009	1,016	0.304 (0.052)	0.242 (0.069)	0.290 (0.082)	0.214 (0.110)
Redfish L Cr Trap	4 May 2010	25,853	0.226 (0.011)	0.175 (0.012)	0.057 (0.008)	0.199 (0.017)
Sawtooth Trap	4 May 2010	25,831	0.110 (0.008)	0.148 (0.010)	0.052 (0.007)	0.206 (0.017)

Appendix Table B7. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2010. 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.

Trap	Release dates	Number released	Release to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Release to MCN
			Wild Chinook Salmon				
American River	18 Mar-31 May	2,901	0.639 (0.036)	0.827 (0.068)	0.907 (0.084)	1.248 (0.197)	0.598 (0.083)
American River	01Jun-30 Jun	917	0.687 (0.106)	0.784 (0.183)	0.758 (0.217)	0.993 (0.288)	0.406 (0.076)
Catherine Creek	02 Mar-22 May	571	0.474 (0.059)	0.970 (0.202)	0.999 (0.345)	1.318 (0.642)	0.606 (0.231)
Clearwater	09 Mar-26 May	2,386	0.932 (0.041)	0.940 (0.080)	0.854 (0.115)	0.980 (0.136)	0.733 (0.058)
Crooked Fork Cr.	20 Mar-29 May	766	0.590 (0.052)	0.743 (0.096)	1.650 (0.463)	0.422 (0.141)	0.305 (0.051)
Crooked River	18 Mar-31 May	630	0.710 (0.070)	0.827 (0.113)	0.818 (0.132)	1.380 (0.394)	0.663 (0.169)
E. Fork Salmon	18 Mar-30 May	114	0.550 (0.180)	0.812 (0.340)	0.971 (0.514)	NA	NA
Grande Ronde	15 Mar-19 May	4,151	0.831 (0.030)	1.047 (0.081)	1.084 (0.169)	0.706 (0.104)	0.666 (0.032)
Imnaha	27 Feb-31 May	7,781	0.792 (0.024)	0.868 (0.045)	0.975 (0.090)	0.866 (0.079)	0.581 (0.023)
Johnson Creek	05 Mar-29 May	1,868	0.512 (0.024)	1.013 (0.070)	0.771 (0.079)	1.063 (0.151)	0.426 (0.050)
Knox Bridge	02 Mar-18 May	1,144	0.523 (0.041)	0.819 (0.098)	0.982 (0.173)	1.179 (0.278)	0.496 (0.088)
Lookingglass Cr.	01 Feb-10 May	565	0.614 (0.079)	0.822 (0.170)	1.000 (0.360)	0.969 (0.359)	0.489 (0.092)
Lostine River	04 Feb-17 May	1,085	0.698 (0.060)	0.953 (0.133)	0.871 (0.184)	0.997 (0.233)	0.578 (0.086)
Lw. S.F. Salmon	04 Mar-16 May	2,331	0.616 (0.022)	0.974 (0.054)	0.963 (0.099)	0.926 (0.110)	0.535 (0.041)
Marsh Creek	18 Mar-31 May	338	0.595 (0.097)	0.756 (0.157)	0.885 (0.175)	1.540 (0.603)	0.614 (0.216)
Minam	18 Feb-27 May	1,054	0.654 (0.048)	0.895 (0.103)	1.212 (0.276)	0.969 (0.258)	0.688 (0.112)
Pahsimeroi	27 Feb-31 May	548	0.613 (0.188)	1.010 (0.423)	0.679 (0.295)	0.982 (0.423)	0.413 (0.103)
Pahsimeroi	01 Jun-30 Jun	949	0.445 (0.055)	1.089 (0.254)	1.461 (0.763)	0.771 (0.441)	0.546 (0.154)
Red River	29 Mar-31 May	801	0.534 (0.074)	0.798 (0.161)	1.206 (0.381)	0.900 (0.375)	0.462 (0.136)
Salmon	10 Mar-28 May	6,731	0.925 (0.038)	0.884 (0.058)	0.774 (0.085)	1.047 (0.108)	0.663 (0.024)
Sawtooth	17 Mar-31 May	1,842	0.633 (0.060)	0.789 (0.104)	1.270 (0.281)	0.689 (0.175)	0.438 (0.060)
Snake	20 Apr-28 May	852	0.821 (0.047)	1.109 (0.137)	0.928 (0.248)	0.955 (0.257)	0.807 (0.092)
Spoolcart*	03 Mar-28 May	504	0.458 (0.037)	0.921 (0.101)	1.062 (0.195)	1.115 (0.297)	0.500 (0.108)
			Wild Sockeye Salmon				
Pettit Lake Cr	05 May-19 May	257	0.289 (0.110)	0.898 (0.520)	0.720 (0.507)	0.802 (0.616)	0.150 (0.084)
Redfish Lake Cr	13 Apr-15 Jun	692	0.309 (0.042)	0.658 (0.114)	0.986 (0.285)	0.593 (0.238)	0.119 (0.037)

Appendix Table B7. Continued.

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
				Wild Steelhead			
Asotin Creek	20 Apr-31 May	1,272	0.791 (0.052)	1.162 (0.251)	0.522 (0.197)	1.578 (0.559)	0.758 (0.169)
Catherine Creek	02 Mar-28 May	571	0.261 (0.054)	1.272 (0.524)	1.667 (1.614)	0.492 (0.501)	0.273 (0.130)
Crooked Fork Cr	25 Mar-29 May	398	1.000 (0.152)	1.174 (0.485)	0.530 (0.275)	1.393 (0.626)	0.867 (0.299)
Clearwater	09 Mar-24 May	1,528	0.850 (0.049)	1.205 (0.174)	0.812 (0.213)	1.151 (0.318)	0.958 (0.165)
Grande Ronde	26 Mar-24 May	977	1.060 (0.081)	0.793 (0.092)	2.415 (1.142)	0.324 (0.161)	0.658 (0.113)
Imnaha	26 Feb-31 May	5,996	0.866 (0.031)	0.963 (0.063)	0.922 (0.118)	0.806 (0.115)	0.620 (0.051)
Lookingglass Cr.	01 Mar-28 May	386	0.664 (0.162)	0.818 (0.314)	0.639 (0.402)	0.867 (0.563)	0.301 (0.114)
Lostine River	04 Feb-26 May	600	0.291 (0.078)	1.030 (0.494)	0.539 (0.317)	1.339 (0.987)	0.216 (0.131)
Minam River	11 Mar-29 May	473	0.377 (0.125)	0.539 (0.270)	NA	NA	NA
Pahsimeroi	05 Mar- 31 May	297	0.305 (0.095)	2.061 (1.807)	NA	NA	NA
Rapid River	08 Mar-30 May	255	1.288 (0.313)	0.665 (0.257)	1.364 (1.311)	0.416 (0.427)	0.486 (0.231)
Salmon	24 Mar-28 May	400	1.052 (0.138)	0.748 (0.158)	1.585 (0.844)	0.536 (0.301)	0.669 (0.166)
Snake	20 Apr-28 May	1,724	1.003 (0.049)	1.028 (0.097)	0.637 (0.115)	0.940 (0.178)	0.617 (0.064)
Spoolcart*	03 Mar-28 May	597	0.288 (0.040)	1.639 (0.500)	0.451 (0.189)	0.712 (0.272)	0.152 (0.039)
				Hatchery Chinook Salmon			
Grande Ronde	21 Mar-20 Apr	1,400	0.836 (0.062)	0.826 (0.106)	1.250 (0.400)	0.919 (0.296)	0.793 (0.090)
Salmon	10 Mar-25 May	4,703	0.835 (0.036)	0.988 (0.072)	1.009 (0.146)	0.754 (0.106)	0.627 (0.032)
Snake	19 Apr-28 May	1,783	0.997 (0.052)	0.882 (0.077)	0.964 (0.170)	0.878 (0.158)	0.744 (0.060)
				Hatchery Sockeye Salmon			
Alturas Lake Cr	04 May-02 Jun	126	0.432 (0.100)	0.933 (0.256)	1.016 (0.401)	1.231 (1.150)	0.505 (0.439)
Pettit Lake Cr	06 May-19 May	106	0.330 (0.121)	0.943 (0.426)	1.203 (0.742)	NA	NA
Redfish Lake Cr	20 Apr-15 Jun	589	0.298 (0.040)	0.969 (0.191)	0.682 (0.181)	1.370 (0.735)	0.270 (0.136)
				Hatchery Steelhead			
Grande Ronde	09 Apr-24 May	2,920	1.026 (0.052)	0.894 (0.070)	1.293 (0.240)	0.553 (0.111)	0.656 (0.063)
Salmon	05 Apr-28 May	2,647	0.830 (0.035)	0.953 (0.065)	1.462 (0.245)	0.550 (0.108)	0.636 (0.074)
Snake	20 Apr-28 May	3,430	1.019 (0.038)	0.988 (0.062)	0.799 (0.096)	0.957 (0.128)	0.769 (0.061)

* Upper Grande Ronde River

Appendix Table B8. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Trap	Release dates	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
			Wild Chinook Salmon			
American River	18 Mar-31 May	2,901	0.264 (0.018)	0.367 (0.022)	0.306 (0.026)	0.192 (0.029)
American River	01Jun-30 Jun	917	0.198 (0.034)	0.286 (0.048)	0.144 (0.038)	0.312 (0.062)
Catherine Creek	02 Mar-22 May	571	0.240 (0.038)	0.256 (0.050)	0.143 (0.048)	0.208 (0.083)
Clearwater	09 Mar-26 May	2,386	0.309 (0.017)	0.266 (0.020)	0.124 (0.017)	0.352 (0.030)
Crooked Fork Cr.	20 Mar-29 May	766	0.321 (0.034)	0.412 (0.042)	0.166 (0.049)	0.383 (0.071)
Crooked River	18 Mar-31 May	630	0.235 (0.030)	0.415 (0.043)	0.320 (0.051)	0.185 (0.053)
E. Fork Salmon	18 Mar-30 May	114	0.176 (0.073)	0.391 (0.113)	0.176 (0.102)	0.125 (0.117)
Grande Ronde	15 Mar-19 May	4,151	0.266 (0.012)	0.184 (0.014)	0.048 (0.008)	0.386 (0.021)
Imnaha	27 Feb-31 May	7,781	0.226 (0.009)	0.220 (0.010)	0.062 (0.006)	0.345 (0.016)
Johnson Creek	05 Mar-29 May	1,868	0.294 (0.019)	0.301 (0.023)	0.190 (0.021)	0.295 (0.038)
Knox Bridge	02 Mar-18 May	1,144	0.316 (0.030)	0.397 (0.038)	0.204 (0.038)	0.257 (0.051)
Lookingglass Cr.	01 Feb-10 May	565	0.234 (0.037)	0.214 (0.041)	0.055 (0.023)	0.292 (0.061)
Lostine River	04 Feb-17 May	1,085	0.230 (0.024)	0.243 (0.030)	0.107 (0.023)	0.266 (0.044)
Lw. S.F. Salmon	04 Mar-16 May	2,331	0.297 (0.015)	0.284 (0.018)	0.099 (0.012)	0.330 (0.028)
Marsh Creek	18 Mar-31 May	338	0.229 (0.046)	0.479 (0.060)	0.359 (0.077)	0.263 (0.101)
Minam	18 Feb-27 May	1,054	0.261 (0.025)	0.300 (0.031)	0.080 (0.020)	0.244 (0.043)
Pahsimeroi	27 Feb-31 May	548	0.149 (0.049)	0.226 (0.058)	0.122 (0.048)	0.312 (0.082)
Pahsimeroi	01 Jun-30 Jun	949	0.223 (0.033)	0.203 (0.044)	0.076 (0.038)	0.159 (0.048)
Red River	29 Mar-31 May	801	0.225 (0.036)	0.331 (0.049)	0.159 (0.049)	0.178 (0.057)
Salmon	10 Mar-28 May	6,731	0.187 (0.009)	0.224 (0.012)	0.045 (0.006)	0.395 (0.016)
Sawtooth	17 Mar-31 May	1,842	0.205 (0.022)	0.346 (0.030)	0.123 (0.027)	0.250 (0.038)
Snake	20 Apr-28 May	852	0.342 (0.026)	0.264 (0.032)	0.061 (0.018)	0.347 (0.044)
Spoolcart*	03 Mar-28 May	504	0.346 (0.039)	0.324 (0.042)	0.168 (0.037)	0.253 (0.060)

Appendix Table B8. Continued.

Trap	Release dates	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
			Wild Sockeye Salmon			
Pettit Lake Cr	05 May-19 May	257	0.148 (0.068)	0.150 (0.080)	0.125 (0.083)	0.286 (0.171)
Redfish Lake Cr	13 Apr-15 Jun	692	0.280 (0.046)	0.445 (0.065)	0.205 (0.065)	0.309 (0.104)
Wild Steelhead						
Asotin Creek	20 Apr-31 May	1,272	0.278 (0.023)	0.315 (0.065)	0.186 (0.050)	0.140 (0.032)
Catherine Creek	02 Mar-28 May	571	0.214 (0.053)	0.174 (0.068)	0.040 (0.038)	0.091 (0.050)
Crooked Fork Cr	25 Mar-29 May	398	0.239 (0.042)	0.158 (0.062)	0.075 (0.029)	0.100 (0.039)
Clearwater	09 Mar-24 May	1,528	0.292 (0.021)	0.215 (0.030)	0.062 (0.016)	0.109 (0.021)
Grande Ronde	26 Mar-24 May	977	0.193 (0.019)	0.281 (0.029)	0.019 (0.009)	0.141 (0.028)
Imnaha	26 Feb-31 May	5,996	0.242 (0.010)	0.242 (0.014)	0.074 (0.010)	0.146 (0.014)
Lookingglass Cr.	01 Mar-28 May	386	0.144 (0.041)	0.230 (0.072)	0.044 (0.031)	0.103 (0.049)
Lostine River	04 Feb-26 May	600	0.212 (0.064)	0.185 (0.076)	0.142 (0.071)	0.100 (0.067)
Minam River	11 Mar-29 May	473	0.180 (0.065)	0.318 (0.120)	NA	0.172 (0.108)
Pahsimeroi	05 Mar- 31 May	297	0.210 (0.076)	0.114 (0.095)	NA	0.105 (0.070)
Rapid River	08 Mar-30 May	255	0.168 (0.046)	0.278 (0.083)	0.039 (0.037)	0.125 (0.068)
Salmon	24 Mar-28 May	400	0.183 (0.030)	0.223 (0.043)	0.031 (0.017)	0.139 (0.040)
Snake	20 Apr-28 May	1,724	0.234 (0.015)	0.204 (0.019)	0.049 (0.010)	0.157 (0.020)
Spoolcart*	03 Mar-28 May	597	0.232 (0.043)	0.166 (0.052)	0.132 (0.050)	0.210 (0.066)
			Hatchery Chinook Salmon			
Grande Ronde	21 Mar-20 Apr	1,400	0.181 (0.017)	0.115 (0.016)	0.019 (0.007)	0.226 (0.028)
Salmon	10 Mar-25 May	4,703	0.145 (0.008)	0.127 (0.009)	0.027 (0.004)	0.292 (0.017)
Snake	19 Apr-28 May	1,783	0.203 (0.014)	0.173 (0.015)	0.038 (0.008)	0.295 (0.026)
			Hatchery Sockeye Salmon			
Alturas Lake Cr	04 May-02 Jun	126	0.202 (0.068)	0.429 (0.101)	0.267 (0.114)	0.167 (0.152)
Pettit Lake Cr	06 May-19 May	106	0.143 (0.076)	0.273 (0.112)	0.182 (0.116)	NA
Redfish Lake Cr	20 Apr-15 Jun	589	0.273 (0.046)	0.295 (0.058)	0.268 (0.069)	0.158 (0.084)
			Hatchery Steelhead			
Grande Ronde	09 Apr-24 May	2,920	0.156 (0.010)	0.198 (0.014)	0.030 (0.006)	0.094 (0.011)
Salmon	05 Apr-28 May	2,647	0.225 (0.013)	0.243 (0.016)	0.052 (0.009)	0.096 (0.013)
Snake	20 Apr-28 May	3,430	0.188 (0.010)	0.200 (0.012)	0.047 (0.006)	0.106 (0.010)

* Upper Grande Ronde River

Appendix Table B9. Survival probabilities for PIT-tagged yearling Chinook, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Hatchery/ Release site	Number released	Release to McNary Dam	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam	Release to Bonneville Dam
			Yearling Chinook Salmon			
Cle Elum						
Clark Flat Pond	16,000	0.343 (0.013)	0.866 (0.068)	0.887 (0.124)	0.768 (0.097)	0.264 (0.032)
Easton Pond	12,000	0.285 (0.014)	0.870 (0.106)	0.814 (0.163)	0.708 (0.122)	0.202 (0.034)
Jack Creek Pond	12,000	0.297 (0.015)	0.878 (0.101)	1.043 (0.250)	0.916 (0.202)	0.272 (0.059)
East Bank						
Carlton Pond	10,092	0.781 (0.058)	0.795 (0.104)	0.759 (0.113)	0.604 (0.076)	0.472 (0.048)
Chelan River	22,109	0.615 (0.028)	0.960 (0.081)	0.818 (0.097)	0.785 (0.082)	0.483 (0.046)
Chiwawa Pond	10,005	0.638 (0.039)	1.091 (0.156)	0.653 (0.118)	0.712 (0.099)	0.454 (0.057)
Dryden Pond	10,033	0.830 (0.051)	0.932 (0.093)	0.846 (0.113)	0.788 (0.098)	0.654 (0.071)
Leavenworth						
Leavenworth NFH	14,948	0.653 (0.028)	0.856 (0.081)	0.973 (0.156)	0.833 (0.119)	0.544 (0.074)
Methow						
Methow River	9,998	0.578 (0.052)	1.000 (0.200)	0.913 (0.248)	0.913 (0.204)	0.528 (0.108)
Methow Hatchery	9,999	0.612 (0.050)	1.002 (0.189)	0.700 (0.162)	0.701 (0.123)	0.429 (0.067)
Ringold						
Okanogan River	8,824	0.431 (0.038)	1.091 (0.240)	0.914 (0.340)	0.997 (0.325)	0.430 (0.135)
Wells						
Wells Hatchery	5,982	0.337 (0.042)	0.969 (0.274)	0.572 (0.406)	0.555 (0.374)	0.187 (0.124)
Winthrop						
Winthrop NFH	4,985	0.634 (0.069)	1.144 (0.305)	0.442 (0.138)	0.506 (0.113)	0.321 (0.062)
Yakima						
Natches River	29,865	0.204 (0.013)	0.577 (0.071)	1.089 (0.511)	0.628 (0.290)	0.128 (0.059)

Appendix Table B9. Continued.

Hatchery/ Release site	Number released	Release to McNary Dam	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam	Release to Bonneville Dam
			Steelhead			
East Bank						
Chiwawa River	4,874	0.583 (0.078)	0.763 (0.182)	1.007 (0.314)	0.768 (0.213)	0.448 (0.108)
Nason Creek	8,919	0.505 (0.043)	1.022 (0.158)	0.612 (0.113)	0.625 (0.098)	0.316 (0.042)
Wenatchee R (rkm 40; Mar)	2,184	0.317 (0.054)	1.117 (0.357)	0.483 (0.190)	0.540 (0.179)	0.171 (0.049)
Wenatchee R. (rkm 40; Apr)	8,100	0.323 (0.036)	1.274 (0.260)	0.421 (0.104)	0.536 (0.113)	0.173 (0.031)
Wenatchee R. (rkm 40; May)	9,044	0.752 (0.095)	0.586 (0.108)	0.624 (0.114)	0.365 (0.065)	0.275 (0.034)
Wenatchee R (rkm 77; May)	14,124	0.495 (0.036)	1.123 (0.150)	0.592 (0.088)	0.665 (0.081)	0.329 (0.032)
Winthrop						
Winthrop NFH	29,597	0.523 (0.026)	1.018 (0.077)	0.714 (0.060)	0.727 (0.057)	0.380 (0.024)
			Coho Salmon			
Cascade						
Butcher Creek Pond	2,987	0.300 (0.037)	1.506 (0.367)	0.905 (0.454)	1.363 (0.639)	0.409 (0.186)
Leavenworth NFH	3,895	0.750 (0.103)	0.555 (0.106)	1.875 (0.809)	1.041 (0.450)	0.780 (0.321)
Rolfing Pond	2,901	0.474 (0.058)	1.475 (0.356)	1.074 (0.495)	1.584 (0.678)	0.751 (0.308)
Eagle Creek						
Lost Creek Pond	2,522	0.300 (0.061)	0.982 (0.381)	0.336 (0.141)	0.330 (0.108)	0.099 (0.025)
Stiles Pond	2,582	0.259 (0.061)	0.488 (0.174)	1.229 (0.544)	0.601 (0.254)	0.156 (0.055)
Entiat						
Leavenworth NFH	5,483	0.655 (0.084)	0.974 (0.217)	0.851 (0.234)	0.829 (0.200)	0.543 (0.112)
Willard						
Butcher Creek Pond	2,904	0.496 (0.072)	1.121 (0.302)	0.459 (0.180)	0.514 (0.180)	0.255 (0.082)
Rolfing Pond	2,912	0.535 (0.101)	0.811 (0.222)	0.792 (0.382)	0.643 (0.308)	0.344 (0.152)
Winthrop NFH	5,993	0.513 (0.074)	0.997 (0.224)	0.633 (0.184)	0.631 (0.173)	0.324 (0.076)
Winthrop						
Winthrop NFH	5,957	0.645 (0.091)	0.974 (0.228)	0.786 (0.223)	0.765 (0.196)	0.493 (0.106)
Yakima						
Lost Creek Pond	2,505	0.306 (0.058)	1.258 (0.606)	0.450 (0.231)	0.565 (0.179)	0.173 (0.044)
Prosser Hatchery	1,371	0.616 (0.088)	0.970 (0.268)	1.083 (0.456)	1.050 (0.395)	0.647 (0.226)
Stiles Pond	2,501	0.196 (0.034)	2.046 (0.994)	0.326 (0.177)	0.668 (0.223)	0.131 (0.038)

Appendix Table B10. Estimated detection probabilities for PIT-tagged yearling Chinook salmon, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2010. Estimates based on the single-release model. Standard errors in parentheses.

Hatchery	Release site	Number released	McNary Dam	John Day Dam	Bonneville Dam
		Yearling Chinook Salmon			
Cle Elum	Clark Flat Pond	16,000	0.244 (0.011)	0.110 (0.009)	0.263 (0.033)
Cle Elum	Easton Pond	12,000	0.272 (0.015)	0.083 (0.011)	0.258 (0.044)
Cle Elum	Jack Creek Pond	12,000	0.258 (0.014)	0.099 (0.012)	0.187 (0.041)
East Bank	Carlton Pond	10,092	0.087 (0.007)	0.049 (0.006)	0.226 (0.024)
East Bank	Chelan River	22,109	0.111 (0.006)	0.067 (0.005)	0.181 (0.017)
East Bank	Chiwawa Pond	10,005	0.127 (0.009)	0.040 (0.006)	0.233 (0.030)
East Bank	Dryden Pond	10,033	0.085 (0.006)	0.072 (0.006)	0.223 (0.025)
Leavenworth	Leavenworth NFH	14,948	0.177 (0.008)	0.065 (0.006)	0.180 (0.025)
Methow	Methow River	9,998	0.094 (0.009)	0.032 (0.006)	0.135 (0.028)
Methow	Methow Hatchery	9,999	0.100 (0.009)	0.030 (0.006)	0.200 (0.032)
Ringold	Okanogan River	8,824	0.147 (0.014)	0.049 (0.010)	0.093 (0.030)
Wells	Wells Hatchery	5,982	0.153 (0.020)	0.093 (0.025)	0.111 (0.074)
Winthrop	Winthrop NFH	4,985	0.102 (0.012)	0.028 (0.007)	0.300 (0.059)
Yakima	Natches River	29,865	0.185 (0.013)	0.110 (0.013)	0.154 (0.071)
		Steelhead			
East Bank	Chiwawa River	4,874	0.071 (0.011)	0.037 (0.008)	0.217 (0.053)
East Bank	Nason Creek	8,919	0.081 (0.008)	0.044 (0.006)	0.339 (0.045)
East Bank	Wenatchee R. (rkm 40; Mar)	2,184	0.108 (0.022)	0.063 (0.019)	0.413 (0.120)
East Bank	Wenatchee R (rkm 40; Apr)	8,100	0.085 (0.011)	0.053 (0.010)	0.339 (0.062)
East Bank	Wenatchee R (rkm 40; May)	9,044	0.045 (0.006)	0.041 (0.006)	0.369 (0.047)
East Bank	Wenatchee R (rkm 77; May)	14,124	0.069 (0.006)	0.035 (0.004)	0.339 (0.034)
Winthrop	Winthrop NFH	29,597	0.057 (0.003)	0.050 (0.003)	0.354 (0.022)

Appendix Table B10. Continued.

Hatchery	Release Site	Number released	McNary Dam	John Day Dam	Bonneville Dam
			Coho Salmon		
Cascade	Butcher Creek Pond	2,987	0.133 (0.020)	0.079 (0.018)	0.160 (0.073)
Cascade	Leavenworth NFH	3,895	0.071 (0.011)	0.080 (0.012)	0.147 (0.061)
Cascade	Rolfing Pond	2,901	0.097 (0.014)	0.053 (0.012)	0.143 (0.059)
Eagle Cr	Lost Creek Pond	2,522	0.101 (0.023)	0.051 (0.019)	0.538 (0.138)
Eagle Cr	Stiles Pond	2,582	0.082 (0.022)	0.049 (0.018)	0.357 (0.128)
Entiat	Leavenworth NFH	5,483	0.056 (0.008)	0.032 (0.007)	0.220 (0.046)
Willard	Butcher Creek Pond	2,904	0.093 (0.015)	0.052 (0.013)	0.376 (0.121)
Willard	Rolfing Pond	2,912	0.069 (0.014)	0.085 (0.019)	0.211 (0.094)
Willard	Winthrop NFH	5,993	0.053 (0.009)	0.047 (0.009)	0.271 (0.064)
Winthrop	Winthrop NFH	5,957	0.043 (0.007)	0.028 (0.006)	0.250 (0.054)
Yakima	Lost Creek Pond	2,505	0.095 (0.021)	0.024 (0.012)	0.391 (0.102)
Yakima	Prosser Hatchery	1,371	0.114 (0.020)	0.051 (0.014)	0.250 (0.088)
Yakima	Stiles Pond	2,501	0.129 (0.026)	0.029 (0.014)	0.389 (0.115)

APPENDIX C

Environmental Conditions and Salmonid Passage Timing

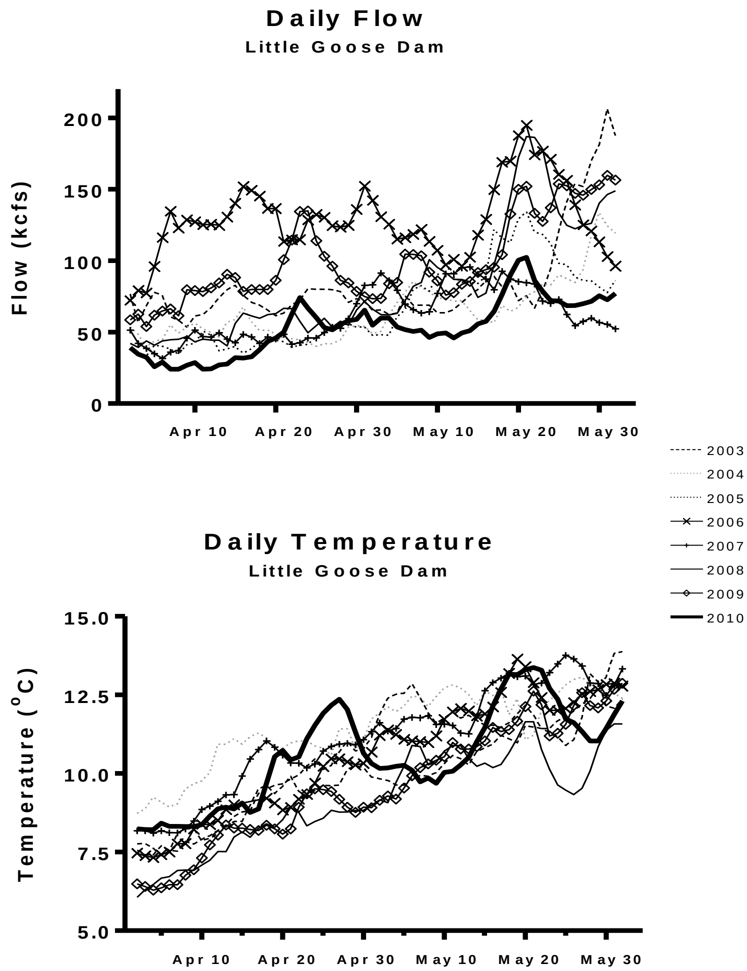
Methods

We obtained data on daily flow, temperature, and spill at Snake River dams and daily smolt passage index at Lower Granite Dam (yearling Chinook salmon and steelhead; hatchery and wild combined) in 2010 from the Columbia River DART website on 20 August, 2010. We created plots to compare daily measures of flow, temperature, and spill at Little Goose Dam from 2010 to those from 2003-2009. We created plots and calculated cumulative passage proportions to compare daily estimates of numbers of smolts passing Lower Granite Dam in 2010 to those of 2007-2009.

In addition, for each daily group of PIT-tagged yearling Chinook salmon and steelhead from Lower Granite Dam we calculated an index of Snake River flow exposure. For each daily group, the index was equal to the average daily flow at Lower Monumental Dam during the period between the 25th and 75th percentiles of PIT-tag detection at Lower Monumental Dam for the daily group. We then investigated the relationship between this index and estimates of travel time from Lower Granite Dam tailrace to McNary Dam tailrace.

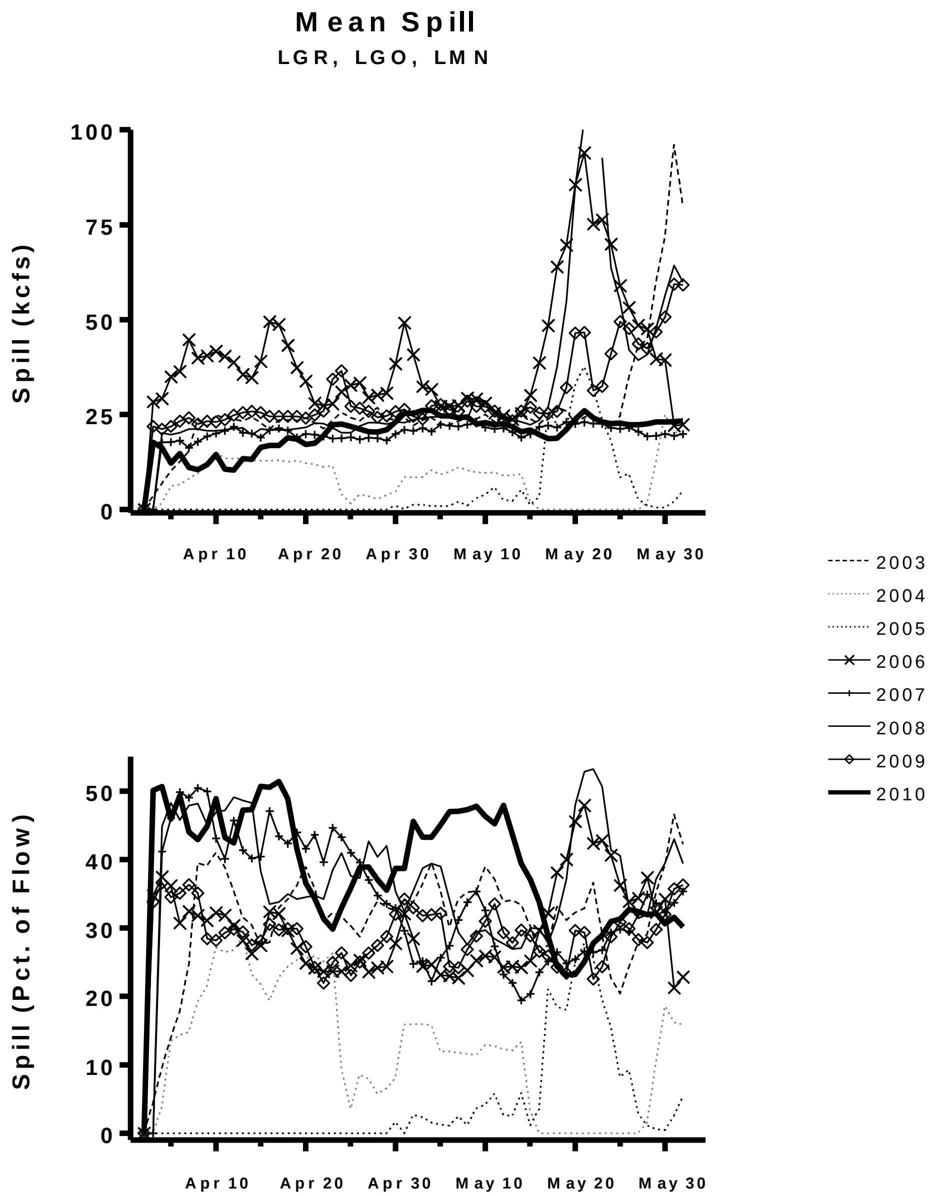
Results

Daily flow volume measured at Little Goose Dam in 2010 was below the average of recent years throughout April and May (Appendix Figure C1). However, flow increased rapidly in early June and was above average throughout June (this increase is not shown in Appendix Figure C1, but it can be seen in Figure 5). Flow in 2010 in April and May was similar to that of other low flow years during that time period (2001, 2002, 2004, 2005, and 2007). Although mean spill volume at the Snake River dams in 2010 was low to average when compared to recent years, mean spill as a percentage of flow was relatively high (Appendix Figure C2). Spill percentage in 2010 was much like those in 2007 and 2008 until mid-May, and then decreased with increasing flow. Spill percentage in 2010 was higher than in 2009 for most of the season. Water temperature in the Snake River in 2010 fluctuated, with peaks in late April and mid-May, and with the fluctuations nearly spanning the range of temperatures observed during recent years (Appendix Figure C1).

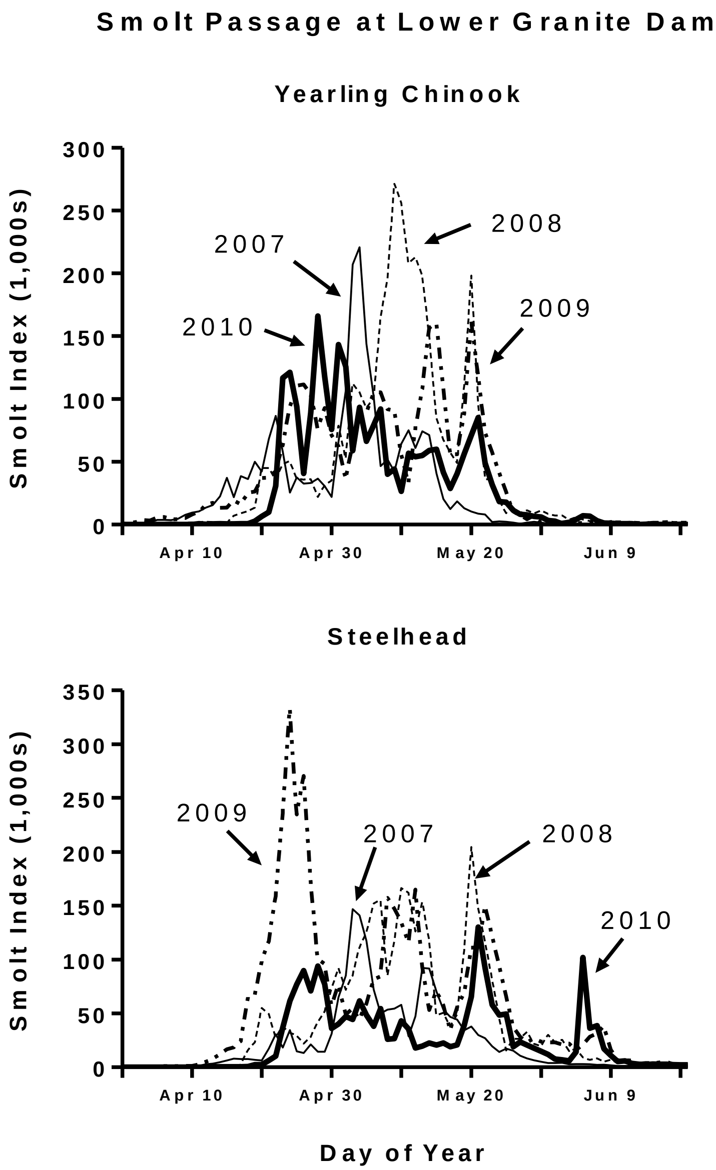


Appendix Figure C1. Daily Snake River flow (kcfs) and temperature (°C) measured at Little Goose Dam during April and May, 2003-2010.

The first arrivals of yearling Chinook salmon and steelhead smolts at Lower Granite Dam in 2010 occurred later than in 2007-2009 (Appendix Figure C3). The median day of passage for yearling Chinook salmon in 2010 was 3 May. When transportation began at Lower Granite on 23 April, only about 2% of the yearling Chinook salmon and 1% of the steelhead had already passed the dam. However, the cumulative passage distribution for Chinook climbed rapidly and approximately 50% of the run had passed Lower Granite by 3 May. The steelhead run was a little more protracted; 50% of the run had passed by 11 May.



Appendix Figure C2. Daily mean spill (top = kcfs; bottom = percentage of total flow) averaged across Lower Granite, Little Goose and Lower Monumental dams during April and May, 2003-2010.



Appendix Figure C3. Daily smolt passage index of yearling Chinook salmon and steelhead passing Lower Granite Dam, 2007-2010.