Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs, 2011

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EXECUTIVE SUMMARY

In 2011, the National Marine Fisheries Service (NMFS) completed the 19th year of a study to estimate survival and travel time of juvenile salmonids *Oncorhynchus* spp. passing 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 22,010 hatchery steelhead *O. mykiss*, 17,999 wild steelhead, and 16,023 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 2011 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 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 during 2011. Complete details on the methodology and statistical models used are provided in previous reports from this study.

Survival and detection probabilities were estimated for groups of PIT-tagged fish during most of the 2011 migration period for yearling Chinook salmon and steelhead. Hatchery and wild fish were combined in some analyses: for Snake River combined groups, the respective overall percentages of hatchery and wild fish were 57 and 43% for yearling Chinook and 74 and 26% for steelhead. Smolt population estimates were calculated using passage data at Lower Granite Dam collected by the Fish Passage Center and estimates of daily detection probabilities. Based on these population estimates, 87% of the overall yearling Chinook salmon run in 2011 was of hatchery origin. We could not

estimate this number for steelhead because separate collection counts for hatchery and wild fish were not available.

Survival in reaches of river between dams was calculated from tailrace to tailrace. Estimates of average survival in 2011 through reaches between dams are listed below for yearling Chinook salmon and steelhead (standard errors in parenthesis):

	Yearling Chinook salmon	Steelhead
Lower Granite to Little Goose Dam	0.919 (0.007)	0.955 (0.004)
Little Goose to Lower Monumental Dam	0.966 (0.007)	0.948 (0.010)
Lower Monumental to McNary Dam[a]	0.845 (0.012)	0.772 (0.014)
Lower Monumental to Ice Harbor	0.912 (0.025)	0.928 (0.016)
Ice Harbor to McNary	0.914 (0.020)	0.839 (0.021)
McNary to John Day Dam	0.893 (0.026)	0.960 (0.043)
John Day to Bonneville Dam[b]	0.766 (0.080)	0.858 (0.051)

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

For yearling Chinook and steelhead, we also estimated average survival through the entire hydropower system from the head of Lower Granite reservoir to the tailrace of Bonneville Dam (eight projects). To derive these estimates, we multiplied the average survival estimates of the combined groups through three reaches: from the Snake River smolt trap to Lower Granite Dam, from Lower Granite to McNary Dam, and from McNary to Bonneville Dam. During 2011, estimated survival for the entire hydropower system was 0.483 (95% CI 0.392-0.574) for Snake River yearling Chinook salmon and 0.592 (0.533-0.651) for steelhead.

For Snake River yearling Chinook salmon, estimated survival through the entire hydropower system in 2011 was below the average for the last 13 years. In contrast, estimated survival for Snake River steelhead through the entire hydropower system was above the 13-year average in 2011, but was lower than estimated in 2009 and 2010.

We also estimated survival to McNary Dam tailrace for groups of yearling Chinook salmon released from individual hatcheries and locations in the Upper Columbia River. These estimates ranged from 0.718 (se 0.102) for East Bank Hatchery fish released in the Similkameen River to 0.245 (se 0.012) for Cle Elem Hatchery fish released from Jack Creek Pond. Similar estimates for Upper Columbia River steelhead ranged from 0.604 (se 0.046) for fish from East Bank Hatchery released into the Wenatchee River to 0.330 (se 0.014) for Winthrop Hatchery fish released into the Methow River. Estimates of survival from hatcheries to Lower Granite Dam suggest that substantial mortality is occurring upstream from the Snake and Clearwater River confluence. Continued development of instream PIT-detection systems for use in tributaries will be necessary if these areas of upstream mortality are to be identified.

For both yearling Chinook salmon and steelhead, a significant negative correlation was seen during 1998-2011 between estimated survival from Lower Monumental to McNary Dam and percentage of PIT tags recovered on avian colonies. The smaller proportion of smolts taken by birds during 2006-2011 was likely due to an increase in the total number of smolts (tagged and untagged) remaining in the river.

This increase in total numbers of inriver migrant smolts was partly due to the decrease in estimated percentages of fish transported from Snake River dams in 2011. Proportions of transported fish (wild and hatchery combined) were among the lowest estimated since 1995, averaging 39% for yearling Chinook and 37% for steelhead. This was partially explained by the late timing of the transportation program in 2011. When transportation began at Lower Granite Dam, about 28% of the yearling Chinook and 36% of the steelhead had already passed the dam. Other factors contributing to the higher number of inriver migrants in 2011 were the use of surface bypass structures during periods of high spill, a powerhouse outage at Little Goose Dam, and closures of the juvenile collection systems due to debris accumulation.

Travel time was also calculated for yearling Chinook salmon and steelhead over individual reaches between dams and over the entire hydropower system from Lower Granite to Bonneville Dam (461 km). Travel time through the hydropower system during 2011 was among the fastest of all years of our study for both yearling Chinook salmon and steelhead. During 2011, flows at Snake River dams were above the historic average (1994-2010) and increased to high levels during May. These high flows resulted in increased water velocity and relatively high spill percentages due to forced spill. Travel time was likely shortened by these high levels of flow and spill and by the use of surface bypass structures at most projects during 2011.

High rates of spill and the use of surface-bypass structures (RSWs, TSWs) in recent years have resulted in low PIT-tag detection rates and consequently reduced precision of survival estimates. Development of PIT-tag detection capability in the TSW and RSW bypass structures or any normal spillway bays would improve detection rates and greatly enhance knowledge of juvenile salmonid survival.

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INTRODUCTION

Accurate and precise estimates of survival 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, information is needed on 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 2010, 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, 2010). In 2011, NMFS completed the 19th year of the study.

Research objectives in 2011 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 and detection probabilities 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 2011, 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 2011 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).

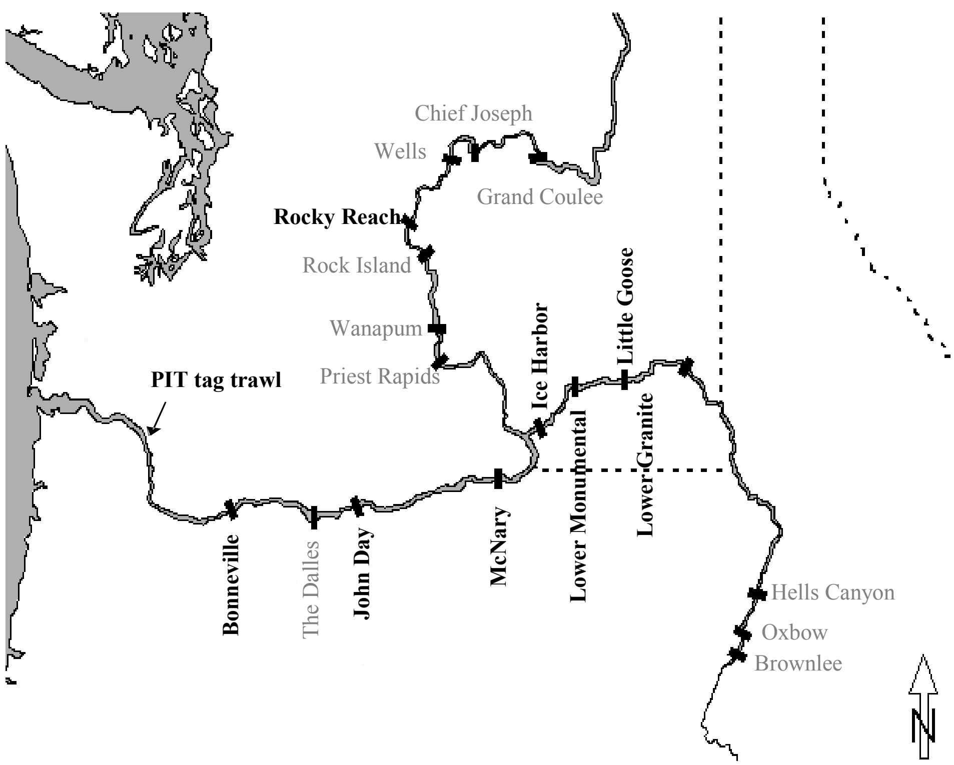

Figure 1. Study area showing sites with PIT-tag detection facilities (names in black), including dams and the PIT-tag trawl in the Columbia River estuary. Dams with names in gray do not have detection facilities.

The farthest downstream detection site for PIT-tagged fish was in the Columbia River estuary (rkm 65-84), where a pair-trawl detection system was operated (Ledgerwood et al. 2004). Since spring 2006, a PIT-tag detection system has been operated in the corner collector at Bonneville Dam Second Powerhouse. In 2011, detections at Bonneville Dam and in the pair trawl were sufficient to estimate survival from John Day tailrace to Bonneville Dam tailrace. We estimated survival in this reach for groups of Columbia River steelhead and yearling Chinook, coho, and sockeye salmon. Detections of sockeye salmon released in the Snake River were not sufficient to estimate survival through this reach.

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 used about 74,791 yearling Chinook salmon PIT tagged at Lower Granite Dam as part of an evaluation of latent mortality related to passage through Snake River dams (Marsh et al. 2006). These fish were trucked and released to the tailrace of either Lower Granite (45,734) or Ice Harbor Dam (29,057). We included these fish in McNary Dam "release" groups if they were subsequently detected and returned to the river at McNary Dam (groups formed according to detection date at McNary Dam).

Most PIT-tagged fish detected at dams downstream of Lower Granite Dam were diverted back to the river, which allowed for the possibility of detection 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 was first operated 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 2006-2011 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 2011, hatchery and wild steelhead and wild yearling Chinook salmon were collected at the Lower Granite Dam juvenile facility. Fish were 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 except during the early and late periods of the migration season, when 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 of hatchery yearling Chinook that were PIT tagged and released from Snake River Basin hatcheries and traps for other studies were sufficient for analysis of survival downstream from Lower Granite Dam.

For both yearling Chinook salmon and steelhead tagged and released upstream from Lower Granite Dam, we created virtual "release groups" of fish according to date of detection at the dam. Each daily virtual release group was combined with fish tagged and released on the same date at Lower Granite Dam. 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 22,010 hatchery steelhead, 17,999 wild steelhead, and 16,023 wild yearling Chinook salmon from 5 April through 17 June 2011 at Lower Granite Dam for survival estimates (Table 1). Total mortalities of hatchery steelhead, wild steelhead, and wild yearling Chinook salmon were 23, 15, and 68, respectively. Each of these numbers represented well under 1% of the total fish handled. A total of 69,084 yearling Chinook salmon (39,615 hatchery origin, 29,469 wild) were detected and returned or PIT tagged and released to the tailrace of Lower Granite Dam. A total of 81,090 steelhead (56,949 hatchery origin and 21,441 wild) were detected and returned or PIT tagged and released to 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 2011. Also included are tagging mortalities and lost tags.

	Hatchery Steelhead			**Wild Steelhead**			**Wild Yearling Chinook**		
Release date	Number released	Mort-alities	Lost tags	Number released	Mort-alities	Lost tags	Number released	Mort-alities	Lost tags
6 Apr	301	1	-	323	2	2	791	2	3
7 Apr	306	-	-	619	1	3	408	2	3
13 Apr	503	-	-	563	-	5	562	2	4
14 Apr	699	2	-	448	-	2	958	2	2
20 Apr	1,191	5	2	254	-	-	600	3	-
21 Apr	1,203	3	-	472	-	-	726	5	-
23 Apr	1,195	2	1	-	-	-	-	-	-
26 Apr	1,200	-	-	-	-	-	-	-	-
27 Apr	600	-	-	465	-	4	813	2	-
28 Apr	600	-	-	553	2	-	795	1	-
30 Apr	1,273	-	-	-	-	-	-	-	-
3 May	666	-	-	455	-	2	1,428	9	1
4 May	666	-	1	229	-	-	664	4	-
5 May	667	-	-	241	-	1	605	4	-
6 May	666	1	-	451	1	1	866	6	-
7 May	665	1	-	434	-	-	888	7	1
10 May	665	1	-	570	-	2	645	2	-
11 May	666	-	-	309	1	1	397	2	-
12 May	662	-	-	389	-	-	302	-	-
13 May	668	-	-	713	-	1	498	-	-
14 May	664	-	-	611	-	2	448	1	1
17 May	817	3	1	750	1	3	583	1	-
19 May	822	-	2	429	-	2	210	3	-
20 May	399	-	1	863	-	-	196	-	-
21 May	401	1	1	568	-	1	319	1	-
24 May	352	-	-	960	2	1	785	1	-
25 May	354	-	-	1,208	1	-	502	2	2
26 May	349	-	1	522	-	1	432	-	-
27 May	352	-	1	1,033	-	-	362	3	1
28 May	349	1	-	569	-	-	210	3	-
1 Jun	261	1	-	433	1	-	30	-	-
2 Jun	262	1	1	169	-	-			
3 Jun	261	-	2	130	-	-			
4 Jun	259	-	1	175	-	-			
7 Jun	169	-	1	248	1	-			
8 Jun	170	-	1	177	-	1			
9 Jun	99	-	1	487	1	-			
10 Jun	104	-	1	487	-	-			
11 Jun	104	-	-	189	-	-			
13 Jun	80	-	-	135	-	1			
15 Jun	80	-	-	111	-	1			
16 Jun	80	-	1	96	1	-			
17 Jun	80	-	-	111	-	-			
18 Jun	80	-	-	50	-	-			
Totals	22,010	23	20	17,999	15	37	16,023	68	18

For both yearling Chinook and steelhead, some detections of fish that passed Lower Granite Dam 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 (57% of yearling Chinook salmon and 74% of steelhead) during 2011. In comparison, we estimate that 87% of the overall yearling Chinook salmon run in 2011 was of hatchery origin. This estimate was based on smolt population estimates derived from passage data at Lower Granite Dam collected by the Fish Passage Center and daily detection probability estimates at Lower Granite Dam. 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 yearling Chinook salmon and steelhead tagged at all locations in the Snake River Basin, and in the Upper Columbia River, we created virtual "release groups" of fish according to 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, we estimated tailrace-to-tailrace survival from McNary to John Day Dam and from John Day to Bonneville Dam. (Data were too sparse to estimate survival for daily groups).

Releases from Hatcheries and Smolt Traps—In 2011, 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 , sockeye, and 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, Entiat, Leavenworth, Methow, Ringold, Wells, and Winthrop Hatcheries. We also estimated survival to McNary Dam for steelhead from Chelan, East Bank, Turtle Rock, and Winthrop Hatcheries, and for coho salmon from Cascade and Winthrop Hatcheries.

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 1 October 2011 from the Columbia Basin PIT Tag Information System (PTAGIS), a regional database maintained by the Pacific States Marine Fisheries Commission (PTAGIS 1996-present). 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 potential detection locations and whether the tagged fish was detected or not detected at each. Methods for data retrieval, database quality assurance/control, and construction of detection histories were the same as those used in past years and were described in detail by Iwamoto et al. (1994).

The analyses reported here were conducted using the data available as of this writing. 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—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). Chi-square contingency tests used to evaluate model assumptions for 2011 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. This results in lower survival estimates having disproportionate influence, and the weighted mean being biased toward the lower estimates. Therefore, we used the inverse of estimated *relative* variance rather than *absolute* variance in weighting.

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. This program was 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 mean survival estimates over shorter reaches for virtual daily or weekly release groups, using the weighting procedure described above. We pooled similar fish from different release sites to form virtual release groups at downstream sites.

The weighted mean survival estimates were then multiplied to estimate survival probabilities through the entire reach. 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 This provided an 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. This product was the estimate of 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.

The powerhouse at Little Goose Dam was shut down for maintenance and repairs from 24 May through 2 June 2011. Fish could not enter the juvenile bypass system at Little Goose Dam during this time, and thus no tagged fish could be detected. The resulting lack of data precluded estimates of survival in reaches that included Little Goose Dam during that period. However, no fish was removed for transportation or sampled from the bypass system during the shutdown period. Therefore, it was possible to estimate survival from Lower Granite to Lower Monumental Dam by simply ignoring Little Goose Dam as a detection site. This allowed estimates of survival from Lower Granite to McNary Dam during the shutdown. Seasonal mean survival estimates affected by the lack of estimates during the shutdown were those from Lower Granite to Little Goose and from Little Goose to Lower Monumental Dam; those not affected were from Lower Monumental to McNary and from Lower Granite to McNary Dam.

Results

Snake River Yearling Chinook Salmon

Estimates of Survival—Survival probabilities were estimated for weekly groups of yearling Chinook salmon from the tailrace of Lower Granite Dam through multiple reaches of the Snake River for 10 consecutive weeks during 23 March-31 May. Mean tailrace-to-tailrace survival estimates were 0.919 (se 0.007) from Lower Granite to Little Goose Dam, 0.966 (0.007) from Little Goose to Lower Monumental, and 0.845 (0.012) from Lower Monumental to McNary Dam (Table 2). For the combined reach from Lower Granite to McNary Dam, mean survival was 0.746 (0.010).

Table 2. Estimated survival probabilities for weekly groups of 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 2011. Daily groups were pooled for weekly estimates, and weighted mean is of independent estimates for daily groups. Standard errors in parentheses.

		Estimated survival of yearling Chinook salmon from Lower Granite Dam			
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
23 Mar–29 Mar	469	0.876 (0.041)	0.916 (0.081)	0.892 (0.155)	0.715 (0.114)
30 Mar–5 Apr	1,775	0.911 (0.022)	0.936 (0.040)	0.943 (0.066)	0.805 (0.050)
6 Apr–12 Apr	4,714	0.872 (0.011)	0.952 (0.020)	0.848 (0.028)	0.704 (0.021)
13 Apr–19 Apr	5,729	0.877 (0.009)	0.973 (0.018)	0.851 (0.026)	0.726 (0.019)
20 Apr–26 Apr	8,305	0.911 (0.009)	0.955 (0.019)	0.868 (0.024)	0.754 (0.017)
27 Apr–3 May	15,581	0.932 (0.008)	1.008 (0.020)	0.824 (0.022)	0.775 (0.014)
4 May–10 May	12,810	0.947 (0.010)	1.022 (0.024)	0.688 (0.034)	0.666 (0.029)
11 May–17 May	12,224	1.019 (0.018)	0.914 (0.026)	0.787 (0.052)	0.733 (0.046)
18 May–24 May	3,789	0.841 (0.035)	1.131 (0.068)	0.964 (0.132)	0.917 (0.118)
25 May–31 May	2,465	0.866 (0.041)[a]		1.185 (0.203)	1.026 (0.169)
Weighted mean[b]		**0.919 (0.007)**	**0.966 (0.007)**	**0.845 (0.012)**	**0.746 (0.010)**

a Estimate for Lower Granite to Lower Monumental Dam during shutdown at Little Goose Dam.
b Weighted mean estimates for daily groups (24 Mar–31 May; see Table 5), except weighted means for Lower Granite to Little Goose and for Little Goose to Lower Monumental do not include daily estimates from 22-31 May.

We estimated survival probabilities for weekly groups of yearling Chinook salmon from the tailrace at McNary Dam through multiple reaches of the Columbia River for five consecutive weeks during 27 April-24 May. Tailrace-to-tailrace survival estimates averaged 0.893 (se 0.026) from McNary to John Day, 0.766 (0.080) from John Day to Bonneville, and 0.687 (0.065) for the combined reach from McNary to Bonneville Dam (Table 3).

Table 3. Estimated survival probabilities for weekly groups of Snake River yearling Chinook salmon (hatchery and wild combined) detected and returned to the tailrace of McNary Dam in 2011. Daily groups were pooled for weekly estimates, and weighted means are of weekly estimates. Standard errors in parentheses.

	Estimated survival of yearling Chinook salmon from McNary Dam			
Date at McNary Dam	Number Released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
20 Apr–26 Apr	2,954	0.876 (0.064)	0.837 (0.320)	0.734 (0.275)
27 Apr–3 May	10,242	0.838 (0.041)	0.891 (0.219)	0.747 (0.180)
4 May–10 May	28,353	0.908 (0.032)	0.801 (0.094)	0.728 (0.081)
11 May–17 May	14,193	1.012 (0.081)	0.299 (0.093)	0.302 (0.090)
18 May–24 May	3,986	0.773 (0.122)	0.473 (0.466)	0.366 (0.355)
Weighted mean		**0.893 (0.026)**	**0.766 (0.080)**	**0.687 (0.065)**

The product of average estimates from Lower Granite to McNary and from McNary to Bonneville Dam provided an overall survival estimate from Lower Granite tailrace to Bonneville Dam tailrace of 0.513 (se 0.049) for Snake River hatchery and wild yearling Chinook salmon combined . For these combined yearling Chinook, estimated survival probability from the Snake River trap through Lower Granite reservoir and dam was 0.943 (0.009). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River yearling Chinook salmon was 0.483 (se 0.046).

We also estimated survival probabilities separately for weekly groups of hatchery and wild yearling Chinook salmon from Lower Granite 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 2011.

Table 4. Estimated survival probabilities for weekly groups of Snake River hatchery and wild yearling Chinook salmon detected and released to the tailrace at Lower Granite Dam in 2011. Daily groups were pooled for weekly estimates, and weighted means are of weekly estimates. Standard errors in parentheses.

		Estimated survival from Lower Granite Dam			
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			
23 Mar–29 Mar	417	0.858 (0.043)	0.904 (0.085)	0.896 (0.167)	0.695 (0.118)
30 Mar–5 Apr	1,260	0.909 (0.031)	0.897 (0.051)	0.918 (0.080)	0.748 (0.057)
6 Apr–12 Apr	2,068	0.822 (0.020)	0.953 (0.039)	0.858 (0.050)	0.672 (0.032)
13 Apr–19 Apr	3,014	0.894 (0.016)	0.988 (0.033)	0.824 (0.041)	0.727 (0.029)
20 Apr–26 Apr	5,485	0.925 (0.014)	0.939 (0.028)	0.882 (0.035)	0.766 (0.024)
27 Apr–3 May	9,564	0.932 (0.012)	1.013 (0.031)	0.844 (0.033)	0.796 (0.021)
4 May–10 May	7,547	0.941 (0.016)	1.063 (0.038)	0.683 (0.050)	0.683 (0.045)
11 May–17 May	7,902	1.043 (0.025)	0.916 (0.036)	0.736 (0.064)	0.703 (0.057)
18 May–24 May	1,284	0.853 (0.075)	1.185 (0.151)	0.977 (0.280)	0.987 (0.266)
25 May–31 May	496	0.814 (0.097)[a]		1.254 (0.528)	1.027 (0.408)
Weighted mean		**0.923 (0.017)**[b]	**0.976 (0.019)**[b]	**0.839 (0.021)**	**0.753 (0.016)**
		Wild yearling Chinook			
30 Mar–5 Apr	515	0.953 (0.031)	0.996 (0.062)	0.992 (0.119)	0.942 (0.101)
6 Apr–12 Apr	2,646	0.919 (0.013)	0.944 (0.023)	0.840 (0.035)	0.729 (0.027)
13 Apr–19 Apr	2,715	0.877 (0.011)	0.965 (0.020)	0.860 (0.033)	0.728 (0.025)
20 Apr–26 Apr	2,820	0.916 (0.012)	0.972 (0.025)	0.837 (0.033)	0.745 (0.025)
27 Apr–3 May	6,017	0.954 (0.011)	1.000 (0.026)	0.792 (0.028)	0.756 (0.020)
4 May–10 May	5,263	0.978 (0.012)	0.975 (0.030)	0.694 (0.045)	0.662 (0.039)
11 May–17 May	4,322	1.001 (0.025)	0.914 (0.036)	0.855 (0.086)	0.782 (0.076)
18 May–24 May	2,505	0.843 (0.040)	1.112 (0.076)	0.959 (0.148)	0.899 (0.132)
25 May–31 May	1,969	0.876 (0.045)[a]		1.174 (0.221)	1.028 (0.186)
Weighted mean		**0.934 (0.014)**[b]	**0.970 (0.012)**[b]	**0.826 (0.020)**	**0.743 (0.015)**

a Estimate for Lower Granite to Lower Monumental Dam during shutdown at Little Goose Dam.

b Weighted mean does not include estimate for week of 25-31 May.

We estimated survival probabilities for daily groups of yearling Chinook salmon (hatchery and wild combined) either detected and returned to the tailrace at Lower Granite Dam or collected and tagged at the dam and released to the tailrace. These estimates were variable and did not show any consistent increase or decrease in survival through Snake River reaches during the 2011 migration season (Table 5; Figure 2).

Table 5. Estimated survival probabilities for daily groups of 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 2011. Daily groups were pooled as needed for sufficient sample size on the dates indicated. Weighted means are of estimates of daily groups. Standard errors in parentheses.

		Estimated survival of yearling Chinook salmon from Lower Granite Dam			
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
24–29 Mar	469	0.876 (0.041)	0.916 (0.081)	0.892 (0.155)	0.715 (0.114)
30 Mar	276	0.935 (0.055)	0.881 (0.087)	0.990 (0.189)	0.815 (0.144)
31 Mar	182	0.948 (0.090)	0.889 (0.124)	1.154 (0.312)	0.973 (0.247)
1 Apr	144	0.958 (0.101)	0.850 (0.131)	1.024 (0.239)	0.834 (0.177)
2 Apr	154	0.982 (0.082)	1.053 (0.186)	0.977 (0.286)	1.010 (0.250)
3 Apr	295	0.910 (0.049)	1.115 (0.121)	0.669 (0.106)	0.679 (0.085)
4 Apr	472	0.836 (0.039)	0.942 (0.072)	0.987 (0.127)	0.778 (0.089)
5 Apr	252	0.943 (0.062)	0.824 (0.095)	1.018 (0.186)	0.791 (0.130)
6 Apr	1,244	0.863 (0.019)	0.990 (0.036)	0.836 (0.051)	0.714 (0.038)
7 Apr	873	0.900 (0.026)	0.933 (0.047)	0.776 (0.056)	0.652 (0.040)
8 Apr	524	0.908 (0.037)	0.860 (0.057)	0.942 (0.091)	0.736 (0.064)
9 Apr	541	0.798 (0.028)	1.014 (0.058)	0.866 (0.083)	0.701 (0.059)
10 Apr	603	0.895 (0.032)	0.988 (0.066)	1.047 (0.126)	0.926 (0.098)
11 Apr	439	0.847 (0.037)	0.958 (0.073)	0.658 (0.070)	0.534 (0.047)
12 Apr	490	0.891 (0.038)	0.871 (0.068)	0.935 (0.118)	0.726 (0.082)
13 Apr	1,114	0.847 (0.019)	0.970 (0.037)	0.823 (0.053)	0.676 (0.038)
14 Apr	1,373	0.858 (0.016)	0.977 (0.031)	0.895 (0.053)	0.750 (0.040)
15 Apr	616	0.885 (0.029)	1.008 (0.063)	0.794 (0.073)	0.708 (0.053)
16 Apr	515	0.954 (0.039)	0.873 (0.062)	0.865 (0.089)	0.720 (0.064)
17 Apr	669	0.902 (0.028)	1.024 (0.059)	0.820 (0.072)	0.757 (0.054)
18 Apr	733	0.907 (0.030)	0.920 (0.056)	0.903 (0.087)	0.754 (0.064)
19 Apr	709	0.873 (0.027)	1.009 (0.063)	0.823 (0.079)	0.724 (0.057)
20 Apr	1,282	0.881 (0.022)	0.934 (0.040)	0.813 (0.052)	0.669 (0.037)
21 Apr	1,633	0.911 (0.018)	0.951 (0.035)	0.894 (0.056)	0.774 (0.042)

Table 5. Continued.

		Estimated survival of yearling Chinook salmon from Lower Granite Dam			
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
22 Apr	851	0.919 (0.027)	1.003 (0.058)	0.803 (0.067)	0.740 (0.049)
23 Apr	849	0.926 (0.031)	0.903 (0.060)	0.966 (0.093)	0.808 (0.064)
24 Apr	1,031	0.916 (0.029)	0.945 (0.060)	0.914 (0.077)	0.792 (0.051)
25 Apr	1,423	0.887 (0.024)	0.999 (0.058)	0.866 (0.065)	0.768 (0.042)
26 Apr	1,236	0.973 (0.032)	0.883 (0.057)	0.878 (0.070)	0.754 (0.043)
27 Apr	2,934	0.907 (0.017)	1.032 (0.044)	0.835 (0.046)	0.782 (0.030)
28 Apr	3,324	0.913 (0.017)	0.978 (0.037)	0.853 (0.041)	0.762 (0.026)
29 Apr	2,609	0.948 (0.022)	1.002 (0.051)	0.815 (0.052)	0.775 (0.034)
30 Apr	2,417	0.938 (0.022)	0.969 (0.054)	0.926 (0.070)	0.842 (0.044)
1 May	1,247	0.976 (0.037)	0.968 (0.080)	0.905 (0.102)	0.854 (0.072)
2 May	835	0.924 (0.039)	1.127 (0.112)	0.704 (0.094)	0.732 (0.070)
3 May	2,215	0.935 (0.018)	0.986 (0.049)	0.710 (0.052)	0.654 (0.038)
4 May	1,627	0.954 (0.024)	0.997 (0.056)	0.710 (0.064)	0.675 (0.050)
5 May	1,451	0.961 (0.027)	0.998 (0.062)	0.656 (0.068)	0.629 (0.054)
6 May	1,929	0.946 (0.027)	0.978 (0.058)	0.784 (0.085)	0.726 (0.069)
7-8 May	3,524	0.934 (0.021)	1.083 (0.058)	0.888 (0.124)	0.898 (0.118)
9 May	1,652	0.958 (0.031)	0.941 (0.065)	0.935 (0.199)	0.842 (0.172)
10 May	2,627	0.964 (0.019)	0.960 (0.044)	0.700 (0.110)	0.648 (0.098)
11 May	2,737	0.997 (0.027)	0.972 (0.047)	0.664 (0.083)	0.644 (0.076)
12 May	1,895	1.056 (0.053)	0.912 (0.068)	0.682 (0.116)	0.658 (0.106)
13 May	1,733	1.028 (0.054)	0.903 (0.069)	0.748 (0.112)	0.694 (0.097)
14-15 May	2,554	1.083 (0.051)	0.841 (0.057)	1.041 (0.157)	0.947 (0.136)
16-18 May	3,748	1.013 (0.033)	0.875 (0.047)	0.958 (0.142)	0.850 (0.121)
19 May	403	0.989 (0.072)	0.983 (0.127)	0.657 (0.200)	0.639 (0.183)
20 May	393	0.911 (0.069)	1.069 (0.153)	0.845 (0.314)	0.823 (0.289)
21 May	512	0.902 (0.072)	0.944 (0.113)	0.782 (0.224)	0.666 (0.181)
22-24 May	2,038	0.999 (0.075)[a]		0.971 (0.198)	0.970 (0.184)
25-31 May	2,465	0.866 (0.041)[a]		1.185 (0.203)	1.026 (0.169)
Weighted mean		**0.919 (0.007)**[b]	**0.966 (0.007)**[b]	**0.845 (0.012)**	**0.746 (0.010)**

a Estimate for Lower Granite to Lower Monumental Dam during shutdown at Little Goose Dam.
b Weighted mean does not include estimates for daily groups from 22-31 May.

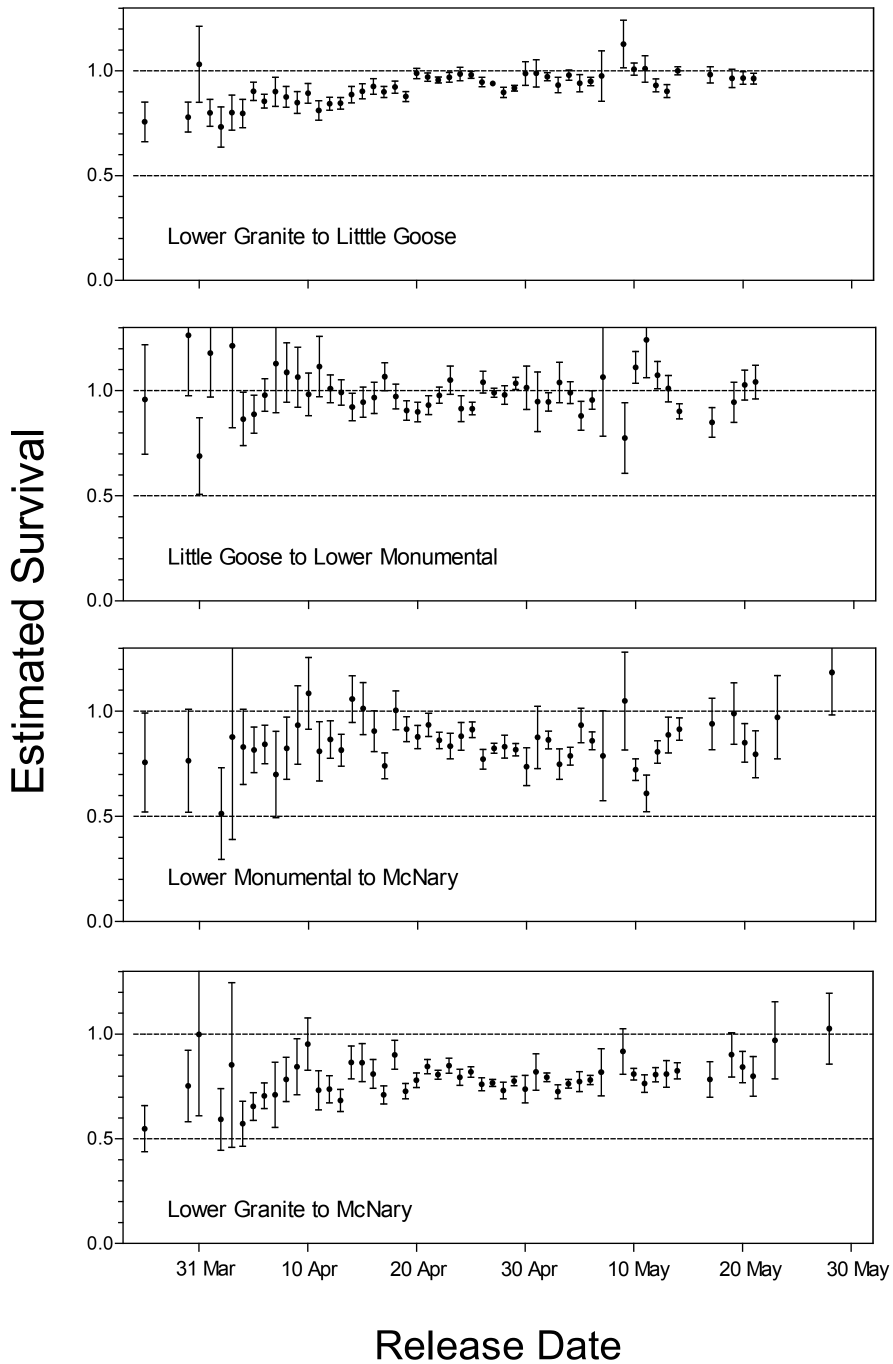

Figure 2. Estimated survival through various reaches by release date at Lower Granite Dam for daily groups of Snake River yearling Chinook salmon (hatchery and wild combined), 2011. Bars extend one standard error above and below point estimates.

Detection Probabilities—For most weekly groups of yearling Chinook salmon, estimates of detection probability varied throughout the season with changing flow volumes, spill levels, and degrees of smoltification (Tables 6-8). High levels of flow and spill during May resulted in very low detection rates at McNary and Bonneville Dams. Detection probabilities were generally highest at Little Goose and Lower Monumental Dams. Detection probabilities were consistently higher for wild fish than for hatchery fish released from Lower Granite Dam during the same time period (Table 8).

Table 6. Estimated detection probabilities for weekly groups of Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2011. Daily groups were pooled for weekly estimates. Standard errors in parentheses.

	Estimated detection probability of yearling Chinook salmon from Lower Granite Dam release groups			
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
23 Mar–29 Mar	469	0.472 (0.032)	0.410 (0.040)	0.210 (0.040)
30 Mar–5 Apr	1,775	0.399 (0.015)	0.390 (0.018)	0.309 (0.023)
6 Apr–12 Apr	4,714	0.466 (0.009)	0.433 (0.011)	0.430 (0.015)
13 Apr–19 Apr	5,729	0.499 (0.008)	0.424 (0.010)	0.466 (0.014)
20 Apr–26 Apr	8,305	0.440 (0.007)	0.309 (0.008)	0.475 (0.012)
27 Apr–3 May	15,581	0.404 (0.005)	0.218 (0.005)	0.423 (0.009)
4 May–10 May	12,810	0.418 (0.006)	0.344 (0.008)	0.130 (0.007)
11 May–17 May	12,224	0.233 (0.006)	0.388 (0.009)	0.077 (0.006)
18 May–24 May	3,789	0.135 (0.008)	0.340 (0.017)	0.081 (0.012)
25 May–31 May	2,465	NA	0.406 (0.024)	0.088 (0.017)

Table 7. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace of McNary Dam in 2011. Daily groups were pooled for weekly estimates. Standard errors in parentheses.

	Estimated detection probability of yearling Chinook salmon from McNary Dam release groups		
Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
20 Apr–26 Apr	2,954	0.345 (0.027)	0.126 (0.048)
27 Apr–3 May	10,242	0.282 (0.015)	0.110 (0.027)
4 May–10 May	28,353	0.190 (0.007)	0.129 (0.014)
11 May–17 May	14,193	0.261 (0.021)	0.065 (0.020)
18 May–24 May	3,986	0.332 (0.053)	0.021 (0.020)

Table 8. Estimated detection probabilities for Snake River hatchery and wild yearling Chinook salmon detected and released to the tailrace of Lower Granite Dam in 2011. Daily groups were pooled to form weekly estimates. Standard errors in parentheses.

Estimated detection probability for Lower Granite Dam release groups				
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
	Hatchery Yearling Chinook			
23 Mar–29 Mar	417	0.475 (0.034)	0.412 (0.043)	0.204 (0.042)
30 Mar–5 Apr	1,260	0.359 (0.018)	0.372 (0.022)	0.311 (0.028)
6 Apr–12 Apr	2,068	0.418 (0.015)	0.348 (0.017)	0.427 (0.024)
13 Apr–19 Apr	3,014	0.437 (0.012)	0.331 (0.013)	0.451 (0.020)
20 Apr–26 Apr	5,485	0.397 (0.009)	0.254 (0.009)	0.456 (0.016)
27 Apr–3 May	9,564	0.348 (0.007)	0.189 (0.007)	0.394 (0.012)
4 May–10 May	7,547	0.351 (0.008)	0.304 (0.011)	0.108 (0.008)
11 May–17 May	7,902	0.218 (0.007)	0.355 (0.012)	0.073 (0.007)
18 May–24 May	1,284	0.115 (0.014)	0.294 (0.030)	0.063 (0.018)
25 May–31 May	496	NA	0.423 (0.055)	0.088 (0.038)
	Wild Yearling Chinook			
30 Mar–5 Apr	515	0.477 (0.027)	0.423 (0.032)	0.304 (0.039)
6 Apr–12 Apr	2,646	0.497 (0.012)	0.490 (0.014)	0.431 (0.019)
13 Apr–19 Apr	2,715	0.559 (0.012)	0.515 (0.014)	0.479 (0.019)
20 Apr–26 Apr	2,820	0.510 (0.012)	0.403 (0.013)	0.502 (0.019)
27 Apr–3 May	6,017	0.483 (0.008)	0.257 (0.008)	0.461 (0.014)
4 May–10 May	5,263	0.499 (0.009)	0.394 (0.013)	0.156 (0.011)
11 May–17 May	4,322	0.255 (0.009)	0.440 (0.015)	0.082 (0.009)
18 May–24 May	2,505	0.144 (0.010)	0.358 (0.020)	0.090 (0.014)
25 May–31 May	1,969	NA	0.406 (0.024)	0.088 (0.017)

Snake River Steelhead

Estimates of Survival—We estimated survival probabilities for weekly groups of steelhead from the tailrace of Lower Granite Dam to multiple downstream sites for 13 consecutive weeks during 23 March-21 June. Average tailrace-to-tailrace survival was estimated at 0.955 (se 0.004) from Lower Granite to Little Goose Dam, 0.948 (0.010) from Little Goose to Lower Monumental Dam, and 0.772 (0.014) from Lower Monumental to McNary Dam (Table 9). For the combined reach from Lower Granite to McNary Dam tailrace, estimated survival averaged 0.693 (0.013).

Table 9. Estimated survival probabilities for weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from the tailrace of Lower Granite Dam in 2011. Daily groups were pooled for weekly estimates, and weighted mean is of independent estimates for daily groups. Standard errors in parentheses.

		Estimated survival of steelhead from Lower Granite Dam			
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
23 Mar–29 Mar	225	0.969 (0.018)	0.966 (0.049)	0.779 (0.110)	0.729 (0.098)
30 Mar–5 Apr	4,335	0.974 (0.008)	0.906 (0.018)	0.676 (0.025)	0.596 (0.020)
6 Apr–12 Apr	3,219	0.935 (0.010)	0.923 (0.022)	0.755 (0.037)	0.651 (0.029)
13 Apr–19 Apr	5,576	0.935 (0.010)	0.909 (0.020)	0.844 (0.036)	0.717 (0.027)
20 Apr–26 Apr	11,711	0.961 (0.007)	0.955 (0.017)	0.773 (0.022)	0.710 (0.017)
27 Apr–3 May	9,830	0.958 (0.012)	0.966 (0.030)	0.815 (0.036)	0.754 (0.026)
4 May–10 May	9,076	0.966 (0.012)	0.950 (0.026)	0.771 (0.043)	0.708 (0.036)
11 May–17 May	15,265	0.924 (0.011)	1.022 (0.020)	0.772 (0.045)	0.730 (0.040)
18 May–24 May	8,002	0.914 (0.016)	0.975 (0.025)	0.933 (0.092)	0.832 (0.081)
25 May–31 May	6,519	0.880 (0.026)[a]		0.793 (0.095)	0.698 (0.081)
1 Jun–7 Jun	2,916	0.858 (0.026)	1.004 (0.060)	0.988 (0.166)	0.851 (0.136)
8 Jun–14 Jun	2,247	0.932 (0.023)	1.071 (0.067)	0.609 (0.104)	0.608 (0.098)
15 Jun–21 Jun	753	0.859 (0.037)	0.846 (0.094)	0.735 (0.249)	0.534 (0.172)
Weighted mean[b]		**0.955 (0.004)**	**0.948 (0.010)**	**0.772 (0.014)**	**0.693 (0.013)**

a Estimate for Lower Granite to Lower Monumental Dam during shutdown at Little Goose Dam.
b Weighted mean of estimates for daily groups (23 Mar–31 May; see Table 12), except weighted means for Lower Granite to Little Goose and for Little Goose to Lower Monumental do not include daily estimates from 24-31 May.

We estimated survival probabilities for weekly groups of steelhead from the tailrace of McNary Dam to multiple sites downstream for 5 consecutive weeks during 6 April-10 May. The first two weekly release groups, which started on 6 and 13 April, had to be pooled due to low detection numbers. Mean estimated tailrace-to-tailrace survival was 0.960 (se 0.043) from McNary to John Day Dam, 0.858 (se 0.051) from John Day to Bonneville Dam, and 0.866 (se 0.038) for the combined reach from McNary to Bonneville Dam tailrace (Table 10).

Table 10. Estimated survival probabilities for weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from McNary Dam in 2011. Daily groups were pooled for weekly estimates, and weighted means are of weekly estimates. Standard errors in parentheses. Note that the 6-19 April group covered 2 weeks of daily group estimates.

	Estimated survival of steelhead from McNary Dam			
Date at McNary Dam	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
6 Apr–19 Apr	2,121	0.858 (0.066)	0.776 (0.520)	0.666 (0.444)
20 Apr–26 Apr	1,823	0.931 (0.095)	0.930 (0.442)	0.866 (0.401)
27 Apr–3 May	4,601	0.981 (0.068)	0.969 (0.241)	0.951 (0.227)
4 May–10 May	4,412	1.063 (0.087)	0.784 (0.153)	0.834 (0.147)
Weighted mean		**0.960 (0.043)**	**0.858 (0.051)**	**0.866 (0.038)**

The product of mean estimates from Lower Granite to McNary Dam and from McNary to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.600 (se 0.029). Estimated survival probability through Lower Granite reservoir and dam for Snake River wild and hatchery steelhead released from the Snake River trap was 0.986 (0.017). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River steelhead was 0.592 (0.030).

Separate survival probabilities were estimated for weekly groups of hatchery and wild steelhead (Table 11). Tailrace-to-tailrace survival estimates through most individual and combined reaches were similar between wild and hatchery steelhead.

Table 11. Estimated survival probabilities for weekly groups of juvenile Snake River hatchery and wild steelhead from the tailrace of Lower Granite Dam, 2011. Daily groups were pooled for weekly estimates, and weighted means are of weekly estimates. Standard errors in parentheses.

		Estimated survival for Lower Granite Dam releases			
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		
23 Mar–29 Mar	212	0.980 (0.018)	0.956 (0.050)	0.751 (0.104)	0.704 (0.092)
30 Mar–5 Apr	4,190	0.975 (0.008)	0.902 (0.019)	0.667 (0.025)	0.586 (0.020)
6 Apr–12 Apr	2,093	0.936 (0.013)	0.920 (0.030)	0.726 (0.046)	0.625 (0.035)
13 Apr–19 Apr	4,365	0.950 (0.011)	0.904 (0.022)	0.842 (0.040)	0.723 (0.031)
20 Apr–26 Apr	10,594	0.960 (0.008)	0.960 (0.018)	0.760 (0.024)	0.700 (0.018)
27 Apr–3 May	7,971	0.942 (0.013)	0.991 (0.034)	0.798 (0.040)	0.745 (0.029)
4 May–10 May	6,609	0.956 (0.014)	0.938 (0.029)	0.802 (0.055)	0.719 (0.045)
11 May–17 May	11,389	0.927 (0.013)	1.016 (0.024)	0.759 (0.051)	0.715 (0.046)
18 May–24 May	4,958	0.919 (0.025)	0.955 (0.037)	1.018 (0.153)	0.894 (0.132)
25 May–31 May	3,058	0.878 (0.044)[a]		0.619 (0.112)	0.543 (0.094)
1 Jun–7 Jun	1,684	0.836 (0.035)	1.070 (0.088)	0.802 (0.160)	0.718 (0.133)
8 Jun–14 Jun	747	1.011 (0.053)	1.016 (0.123)	0.580 (0.182)	0.597 (0.175)
15 Jun–21 Jun	374	0.789 (0.048)	0.869 (0.130)	0.817 (0.423)	0.560 (0.279)
Weighted mean		**0.954 (0.007)[b]**	**0.948 (0.013)[b]**	**0.759 (0.019)**	**0.686 (0.018)**
			Wild steelhead		
30 Mar–5 Apr	145	0.957 (0.036)	1.012 (0.091)	1.080 (0.300)	1.046 (0.277)
6 Apr–12 Apr	1,126	0.938 (0.015)	0.932 (0.031)	0.782 (0.060)	0.684 (0.049)
13 Apr–19 Apr	1,211	0.882 (0.021)	0.931 (0.045)	0.832 (0.078)	0.683 (0.058)
20 Apr–26 Apr	1,117	0.972 (0.023)	0.916 (0.049)	0.865 (0.076)	0.771 (0.058)
27 Apr–3 May	1,859	1.022 (0.028)	0.867 (0.061)	0.847 (0.083)	0.751 (0.056)
4 May–10 May	2,466	0.991 (0.023)	0.996 (0.055)	0.690 (0.069)	0.681 (0.059)
11 May–17 May	3,876	0.918 (0.020)	1.034 (0.039)	0.794 (0.088)	0.753 (0.080)
18 May–24 May	3,044	0.940 (0.020)	0.981 (0.034)	0.869 (0.114)	0.801 (0.102)
25 May–31 May	3,461	0.892 (0.033)[a]		0.927 (0.148)	0.827 (0.129)
1 Jun–7 Jun	1,232	0.887 (0.040)	0.928 (0.079)	1.412 (0.440)	1.163 (0.352)
8 Jun–14 Jun	1,500	0.906 (0.026)	1.088 (0.078)	0.616 (0.126)	0.607 (0.116)
15 Jun–21 Jun	379	0.931 (0.057)	0.827 (0.136)	0.669 (0.300)	0.515 (0.217)
Weighted mean		**0.942 (0.012)[b]**	**0.968 (0.017)[b]**	**0.814 (0.032)**	**0.730 (0.024)**

a Estimate for Lower Granite to Lower Monumental Dam during shutdown at Little Goose Dam.
b Weighted mean does not include weekly estimate for 25-31 May.

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 2011 migration season (Table 12; Figure 3).

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 2011. Daily groups pooled as needed for sufficient sample size on the dates indicated. Weighted means are of estimates of daily groups. Standard errors in parentheses.

Estimated survival of steelhead daily groups from Lower Granite Dam					
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
23-29 Mar	225	0.969 (0.018)	0.966 (0.049)	0.779 (0.110)	0.729 (0.098)
30 Mar	153	0.939 (0.029)	0.983 (0.074)	0.650 (0.115)	0.600 (0.098)
31 Mar	266	0.970 (0.022)	1.011 (0.058)	0.897 (0.136)	0.880 (0.124)
1 Apr	636	1.002 (0.021)	0.913 (0.052)	0.653 (0.068)	0.598 (0.056)
2 Apr	1,565	0.991 (0.014)	0.912 (0.032)	0.605 (0.035)	0.546 (0.027)
3 Apr	905	0.950 (0.018)	0.857 (0.039)	0.671 (0.055)	0.547 (0.040)
4 Apr	436	0.915 (0.027)	0.934 (0.061)	0.716 (0.092)	0.612 (0.070)
5 Apr	374	1.020 (0.035)	0.849 (0.059)	0.886 (0.143)	0.767 (0.117)
6 Apr	1,037	0.970 (0.018)	0.893 (0.038)	0.774 (0.070)	0.671 (0.056)
7 Apr	1,138	0.913 (0.014)	0.977 (0.034)	0.769 (0.064)	0.686 (0.053)
8 Apr	245	0.942 (0.040)	0.864 (0.076)	0.752 (0.110)	0.612 (0.080)
9 Apr	300	0.956 (0.037)	0.850 (0.068)	0.746 (0.105)	0.606 (0.076)
10 Apr	196	0.915 (0.061)	0.924 (0.124)	0.671 (0.153)	0.567 (0.114)
11 Apr	163	0.951 (0.058)	1.012 (0.162)	0.530 (0.123)	0.510 (0.091)
12 Apr	140	0.926 (0.051)	0.782 (0.091)	0.991 (0.247)	0.718 (0.170)
13 Apr	1,209	0.900 (0.022)	0.867 (0.041)	0.801 (0.063)	0.625 (0.043)
14 Apr	1,362	0.932 (0.018)	0.912 (0.039)	0.833 (0.073)	0.708 (0.057)
15 Apr	224	0.988 (0.057)	0.762 (0.104)	1.090 (0.379)	0.820 (0.271)
16 Apr	495	0.941 (0.034)	0.890 (0.074)	1.113 (0.235)	0.932 (0.188)
17 Apr	852	0.928 (0.023)	1.059 (0.065)	0.765 (0.091)	0.751 (0.078)
18 Apr	747	0.946 (0.028)	0.921 (0.049)	0.931 (0.103)	0.812 (0.083)
19 Apr	687	0.969 (0.027)	0.877 (0.050)	0.850 (0.089)	0.722 (0.068)
20 Apr	2,334	0.961 (0.014)	0.928 (0.033)	0.783 (0.046)	0.699 (0.035)
21 Apr	3,105	0.958 (0.014)	0.979 (0.032)	0.777 (0.040)	0.729 (0.031)
22 Apr	1,036	0.958 (0.023)	0.968 (0.054)	0.854 (0.090)	0.792 (0.074)
23 Apr	1,788	0.989 (0.020)	0.967 (0.044)	0.729 (0.055)	0.697 (0.044)
24 Apr	845	0.959 (0.028)	0.878 (0.060)	0.869 (0.108)	0.731 (0.080)
25 Apr	830	0.932 (0.029)	0.903 (0.066)	1.031 (0.142)	0.868 (0.105)
26 Apr	1,773	0.954 (0.022)	1.032 (0.063)	0.629 (0.055)	0.620 (0.042)

Table 12. Continued.

Estimated survival of steelhead daily groups from Lower Granite Dam					
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
27 Apr	1,720	0.972 (0.027)	0.957 (0.064)	0.805 (0.080)	0.749 (0.058)
28 Apr	2,305	0.955 (0.026)	0.905 (0.057)	0.783 (0.068)	0.676 (0.044)
29 Apr	1,359	0.959 (0.034)	1.175 (0.127)	0.640 (0.092)	0.722 (0.069)
30 Apr	2,338	0.972 (0.024)	0.931 (0.056)	0.898 (0.083)	0.813 (0.060)
1 May	493	0.911 (0.049)	0.838 (0.103)	0.942 (0.179)	0.719 (0.111)
2-3 May	1,615	0.941 (0.026)	1.055 (0.083)	0.816 (0.097)	0.810 (0.074)
4 May	1,275	0.952 (0.028)	0.949 (0.068)	0.886 (0.117)	0.800 (0.092)
5 May	1,160	0.980 (0.030)	0.910 (0.064)	0.790 (0.102)	0.705 (0.080)
6 May	1,575	0.963 (0.026)	0.989 (0.066)	0.713 (0.088)	0.679 (0.073)
7 May	1,569	1.000 (0.032)	0.858 (0.053)	0.716 (0.081)	0.614 (0.062)
8-9 May	1,095	0.994 (0.054)	0.950 (0.090)	0.707 (0.160)	0.668 (0.142)
10 May	2,402	0.933 (0.024)	1.004 (0.051)	0.705 (0.117)	0.660 (0.105)
11 May	2,532	0.921 (0.021)	0.949 (0.040)	0.607 (0.075)	0.531 (0.063)
12 May	2,499	0.893 (0.026)	1.050 (0.050)	0.744 (0.126)	0.698 (0.115)
13 May	2,335	0.872 (0.036)	1.039 (0.059)	0.851 (0.135)	0.770 (0.118)
14 May	2,156	1.109 (0.067)	0.750 (0.054)	0.902 (0.127)	0.750 (0.102)
15 May	773	0.913 (0.064)	1.020 (0.098)	1.050 (0.219)	0.978 (0.194)
16 May	1,471	0.988 (0.049)	1.034 (0.091)	0.582 (0.095)	0.595 (0.086)
17-18 May	4,064	0.953 (0.016)	1.086 (0.040)	0.886 (0.114)	0.917 (0.113)
19 May	1,514	1.069 (0.070)	0.822 (0.062)	0.967 (0.221)	0.849 (0.192)
20 May	1,492	0.946 (0.015)	0.979 (0.036)	0.848 (0.155)	0.784 (0.141)
21-23 May	2,513	0.951 (0.035)	0.917 (0.049)	0.871 (0.165)	0.759 (0.141)
24-25 May	4,104	0.852 (0.032)[a]		0.920 (0.141)	0.784 (0.117)
26-27 May	2,953	0.903 (0.039)[a]		0.880 (0.167)	0.795 (0.146)
28-31 May	1,380	0.918 (0.050)[a]		0.613 (0.134)	0.563 (0.118)
Weighted mean		**0.955 (0.004)[b]**	**0.948 (0.010)[b]**	**0.772 (0.014)**	**0.693 (0.013)**

a Estimate for Lower Granite to Lower Monumental Dam during shutdown at Little Goose Dam.
b Weighted mean does not include estimates for daily groups from 24–31 May.

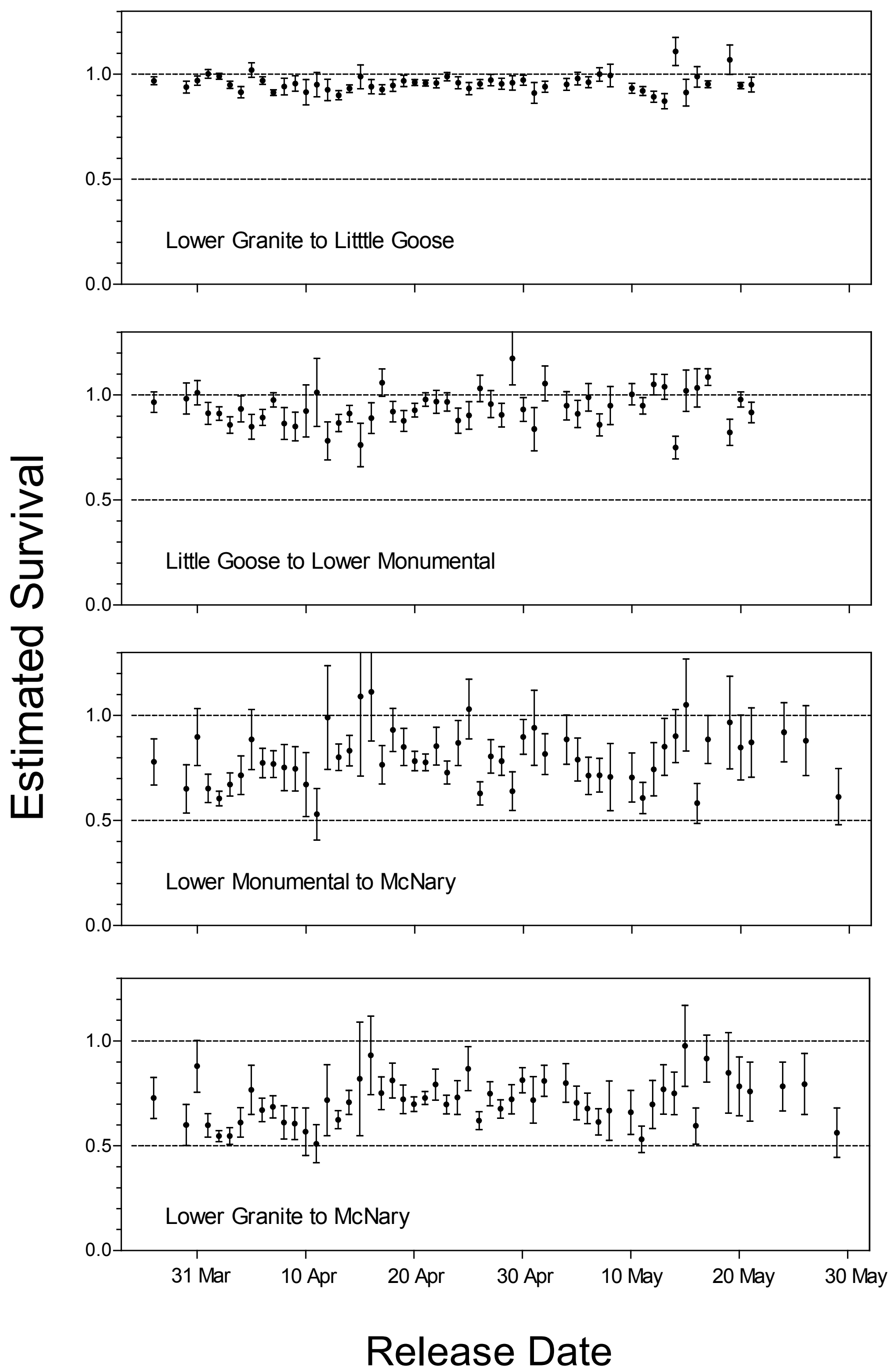

Figure 3. Estimated survival through various reaches versus release date at Lower Granite Dam for daily release groups of Snake River steelhead (hatchery and wild combined), 2011. Bars extend one standard error above and below point estimates.

Detection Probabilities—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). High flow and spill levels during May caused sharp a decrease in detection at McNary Dam. Detection probability estimates were generally highest at Little Goose and Lower Monumental Dams and lowest at McNary and Bonneville Dams. 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) from the tailrace of Lower Granite Dam, 2011. Weekly estimates from pooled daily groups. Standard errors in parentheses.

Estimated detection probability of steelhead from Lower Granite Dam				
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
23 Mar–29 Mar	225	0.830 (0.028)	0.640 (0.045)	0.173 (0.037)
30 Mar–5 Apr	4,335	0.648 (0.009)	0.550 (0.013)	0.318 (0.014)
6 Apr–12 Apr	3,219	0.639 (0.011)	0.534 (0.015)	0.292 (0.016)
13 Apr–19 Apr	5,576	0.553 (0.009)	0.451 (0.011)	0.273 (0.012)
20 Apr–26 Apr	11,711	0.530 (0.006)	0.353 (0.007)	0.309 (0.009)
27 Apr–3 May	9,830	0.448 (0.007)	0.208 (0.007)	0.241 (0.010)
4 May–10 May	9,076	0.411 (0.007)	0.322 (0.009)	0.101 (0.006)
11 May–17 May	15,265	0.278 (0.005)	0.405 (0.008)	0.049 (0.003)
18 May–24 May	8,002	0.227 (0.006)	0.526 (0.012)	0.047 (0.005)
25 May–31 May	6,519	NA	0.485 (0.020)	0.068 (0.012)
1 Jun–7 Jun	2,916	0.317 (0.013)	0.346 (0.020)	0.074 (0.013)
8 Jun–14 Jun	2,247	0.415 (0.015)	0.384 (0.024)	0.085 (0.016)
15 Jun–21 Jun	753	0.525 (0.029)	0.437 (0.049)	0.092 (0.033)

Table 14. Estimated detection probabilities for weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from the tailrace of McNary Dam, 2011. Weekly estimates from pooled daily groups with 2-weeks pooled during 6-19 April due to low detection numbers. Standard errors in parentheses.

Estimated detection probability of steelhead from McNary Dam			
Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
6 Apr–19 Apr	2,121	0.498 (0.040)	0.100 (0.067)
20 Apr–26 May	1,823	0.277 (0.030)	0.122 (0.057)
27 Apr–3 May	4,601	0.220 (0.016)	0.123 (0.030)
4 May–10 May	4,412	0.156 (0.014)	0.150 (0.027)

Table 15. Estimated detection probabilities for juvenile Snake River hatchery and wild steelhead from the tailrace at Lower Granite Dam, 2011. Daily groups pooled weekly. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Estimated detection probability of steelhead from Lower Granite Dam		
		Hatchery steelhead		
23 Mar–29 Mar	212	0.833 (0.029)	0.654 (0.046)	0.184 (0.039)
30 Mar–5 Apr	4,190	0.648 (0.009)	0.549 (0.013)	0.323 (0.014)
6 Apr–12 Apr	2,093	0.627 (0.014)	0.502 (0.019)	0.316 (0.022)
13 Apr–19 Apr	4,365	0.550 (0.010)	0.457 (0.013)	0.266 (0.014)
20 Apr–26 Apr	10,594	0.530 (0.006)	0.353 (0.008)	0.304 (0.009)
27 Apr–3 May	7,971	0.446 (0.008)	0.213 (0.008)	0.229 (0.010)
4 May–10 May	6,609	0.399 (0.009)	0.335 (0.011)	0.091 (0.007)
11 May–17 May	11,389	0.276 (0.006)	0.402 (0.009)	0.046 (0.004)
18 May–24 May	4,958	0.191 (0.008)	0.497 (0.015)	0.037 (0.006)
25 May–31 May	3,058	NA	0.450 (0.024)	0.069 (0.014)
1 Jun–7 Jun	1,684	0.307 (0.018)	0.316 (0.026)	0.086 (0.018)
8 Jun–14 Jun	747	0.353 (0.026)	0.342 (0.041)	0.070 (0.024)
15 Jun–21 Jun	374	0.532 (0.041)	0.468 (0.071)	0.081 (0.045)
		Wild steelhead		
30 Mar–5 Apr	145	0.656 (0.046)	0.555 (0.063)	0.186 (0.059)
6 Apr–12 Apr	1,126	0.658 (0.017)	0.584 (0.023)	0.260 (0.024)
13 Apr–19 Apr	1,211	0.566 (0.019)	0.429 (0.024)	0.304 (0.030)
20 Apr–26 Apr	1,117	0.529 (0.020)	0.355 (0.022)	0.361 (0.031)
27 Apr–3 May	1,859	0.459 (0.017)	0.189 (0.016)	0.303 (0.025)
4 May–10 May	2,466	0.442 (0.014)	0.287 (0.017)	0.129 (0.014)
11 May–17 May	3,876	0.283 (0.010)	0.414 (0.015)	0.056 (0.007)
18 May–24 May	3,044	0.275 (0.010)	0.563 (0.018)	0.060 (0.009)
25 May–31 May	3,461	NA	0.485 (0.020)	0.068 (0.012)
1 Jun–7 Jun	1,232	0.330 (0.020)	0.388 (0.032)	0.057 (0.018)
8 Jun–14 Jun	1,500	0.444 (0.018)	0.406 (0.030)	0.094 (0.020)
15 Jun–21 Jun	379	0.519 (0.041)	0.407 (0.068)	0.103 (0.049)

Survival and Detection from Hatcheries and Smolt Traps

Snake River 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 dams further downstream. 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 ranged from 0.833 (se 0.022) for fish from the Nez Perce Tribal Hatchery to 0.264 (0.015) for fish from McCall Hatchery released into Johnson Creek. For steelhead, estimated survival from release to Lower Granite Dam tailrace ranged from 0.877 (0.017) for fish from Magic Valley Hatchery released at the Pahsimeroi Trap, to 0.614 (0.018) for fish from Magic Valley Hatchery released into Squaw Creek. For sockeye salmon PIT-tagged and released in spring, estimated survival to Lower Granite Dam tailrace ranged from 0.780 (0.023) for fish from Oxbow Hatchery released at Redfish Lake Creek Trap to 0.724 (0.008) for fish from Sawtooth Hatchery released at Redfish Lake Creek Trap.

Snake River 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.

Upper Columbia River Hatchery Release Groups—Survival probabilities were estimated for PIT-tagged hatchery yearling Chinook, coho salmon, and steelhead from release at Upper Columbia River hatcheries to the tailrace of McNary Dam and to dams further downstream. Estimates of survival varied among hatcheries and release locations (Appendix Table B9), as did detection probability estimates (Appendix Table B10). For yearling Chinook released in the Upper Columbia River, estimated survival from release to McNary Dam tailrace ranged from 0.718 (se 0.102) for East Bank Hatchery fish released into the Similkameen River to 0.245 (0.012) for Cle Elem Hatchery fish released from Jack Creek Pond.

For Upper Columbia River steelhead, estimated survival from release to McNary Dam tailrace ranged from 0.604 (0.046) for fish from East Bank Hatchery released into the Wenatchee River to 0.330 (0.014) for Winthrop Hatchery fish released into the Methow River. For Upper Columbia River coho salmon, estimated survival from release to McNary Dam tailrace ranged from 0.416 (0.036) for fish from Winthrop Hatchery released into the Methow River, to 0.339 (0.026) for fish from Cascade Hatchery released into the Wenatchee River at Leavenworth Hatchery.

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 2006-2011 to partition survival estimates through the individual reaches from Lower Monumental to Ice Harbor and from Ice Harbor to McNary Dam (Table 16). In 2011, estimated mean survival from tailrace to tailrace for yearling Chinook salmon was 0.912 (se 0.025) from Lower Monumental to Ice Harbor Dam and 0.914 (0.020) from Ice Harbor to McNary Dam. For steelhead, estimated mean survival through these reaches was 0.928 (0.016) and 0.839 (0.021), respectively.

Table 16. Estimated survival and detection probabilities from Lower Granite to Ice Harbor Dam for Snake River yearling Chinook salmon and steelhead (hatchery and wild combined), 2011. Daily groups were pooled for weekly estimates and weighted means. Standard errors in parentheses.

Date at Lower Granite	Number released	**Estimated survival probability** Lower Monumental to Ice Harbor Dam	Ice Harbor to McNary Dam	**Detection probability Ice Harbor Dam**
		Hatchery and wild yearling Chinook salmon		
23 Mar–29 Mar	469	1.032 (0.209)	0.848 (0.210)	0.099 (0.024)
30 Mar–5 Apr	1,775	0.825 (0.051)	1.141 (0.091)	0.175 (0.014)
6 Apr–12 Apr	4,714	0.957 (0.035)	0.894 (0.039)	0.166 (0.008)
13 Apr–19 Apr	5,729	1.004 (0.038)	0.854 (0.037)	0.132 (0.007)
20 Apr–26 Apr	8,305	0.973 (0.032)	0.909 (0.033)	0.125 (0.006)
27 Apr–3 May	15,581	0.905 (0.024)	0.924 (0.026)	0.142 (0.004)
4 May–10 May	12,810	0.808 (0.030)	0.852 (0.046)	0.166 (0.007)
11 May–17 May	12,224	0.800 (0.032)	0.946 (0.068)	0.164 (0.007)
18 May–24 May	3,789	0.883 (0.065)	1.103 (0.159)	0.181 (0.014)
25 May–31 May	2,465	1.040 (0.079)	1.082 (0.192)	0.242 (0.019)
Weighted mean[a]		**0.912 (0.025)**	**0.914 (0.020)**	**0.149 (0.007)**
		Hatchery and wild steelhead		
23 Mar–29 Mar	225	1.000 (0.124)	0.811 (0.144)	0.210 (0.038)
30 Mar–5 Apr	4,335	0.910 (0.033)	0.736 (0.034)	0.239 (0.011)
6 Apr–12 Apr	3,219	0.956 (0.053)	0.789 (0.054)	0.146 (0.010)
13 Apr–19 Apr	5,576	0.972 (0.054)	0.880 (0.057)	0.090 (0.006)
20 Apr–26 Apr	11,711	0.967 (0.035)	0.821 (0.034)	0.103 (0.005)
27 Apr–3 May	9,830	0.913 (0.038)	0.909 (0.044)	0.137 (0.006)
4 May–10 May	9,076	0.905 (0.034)	0.849 (0.051)	0.191 (0.008)
11 May–17 May	15,265	0.872 (0.026)	0.887 (0.054)	0.179 (0.006)
18 May–24 May	8,002	0.919 (0.040)	1.012 (0.107)	0.184 (0.009)
25 May–31 May	6,519	1.020 (0.058)	0.806 (0.103)	0.212 (0.013)
1 Jun–7 Jun	2,916	1.169 (0.125)	0.868 (0.163)	0.124 (0.014)
Weighted mean[b]		**0.928 (0.016)**	**0.839 (0.021)**	**0.145 (0.014)**

a Weighted means of the independent estimates for weekly pooled groups (23 March-31 May).
b Weighted means of the independent estimates for weekly pooled groups (23 March-7 June).

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 only for fish detected at both dams. Travel time was defined as the number of days between last detection at the upstream dam and first detection at the downstream dam. Generally, the last detection an upstream dam was on a PIT-tag detector close enough to the outfall site that fish would arrive in the tailrace within minutes of detection. Thus, travel time included the time required to move through the tailrace of the upstream dam, the reservoir, and the forebay of the downstream dam. This encompassed any delay associated with residence in the forebay, gatewells, or collection channel of the downstream dam prior to detection in the juvenile bypass system.

Migration rate through a river section was calculated as the length of the reach (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 individual fish within a release group includes travel times of both detected and non-detected fish. However, travel time based on PIT-tag detections cannot be determined for a fish that traverses a reach of river without being detected at both ends of the reach. Therefore, travel time statistics are computed only from the travel times of detected fish, and thus they represent a subsample of the complete release group. 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 was estimated for yearling Chinook salmon and juvenile steelhead from the tailrace of Lower Granite and McNary Dams to multiple downstream sites. Estimated travel time varied throughout the migration 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 were among the shortest observed in recent years (2004-2010) during most of the 2011 season (Figure 4).

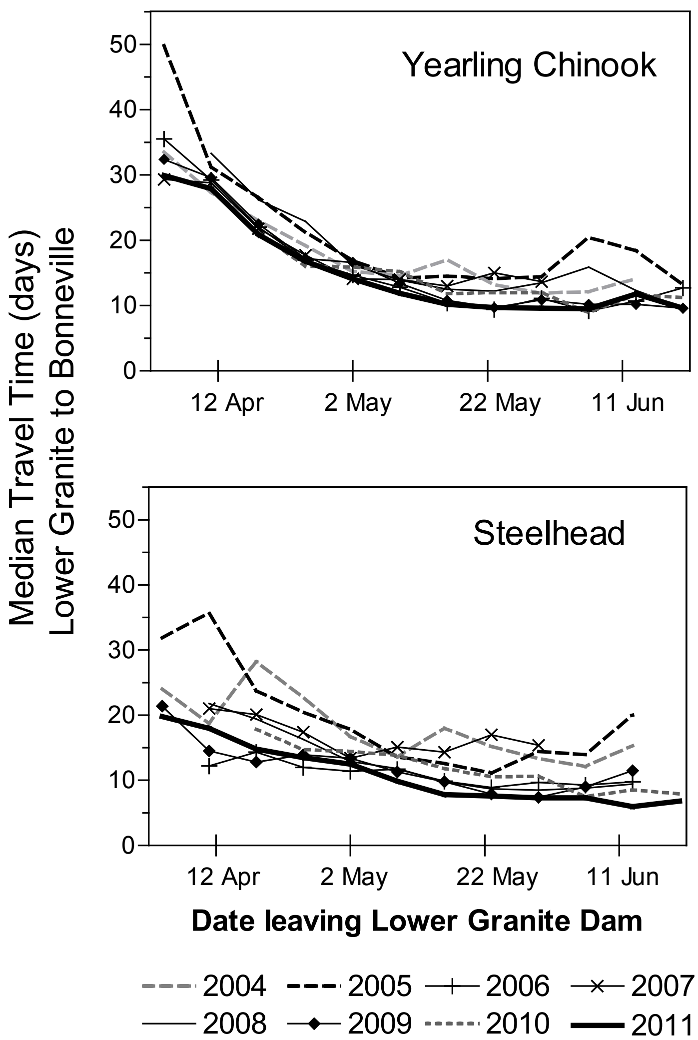

Figure 4. Median travel time (days) from Lower Granite Dam to Bonneville Dam for weekly release groups of Snake River yearling Chinook salmon and steelhead from Lower Granite Dam, 2004-2011.

The observed decreases in travel times 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).

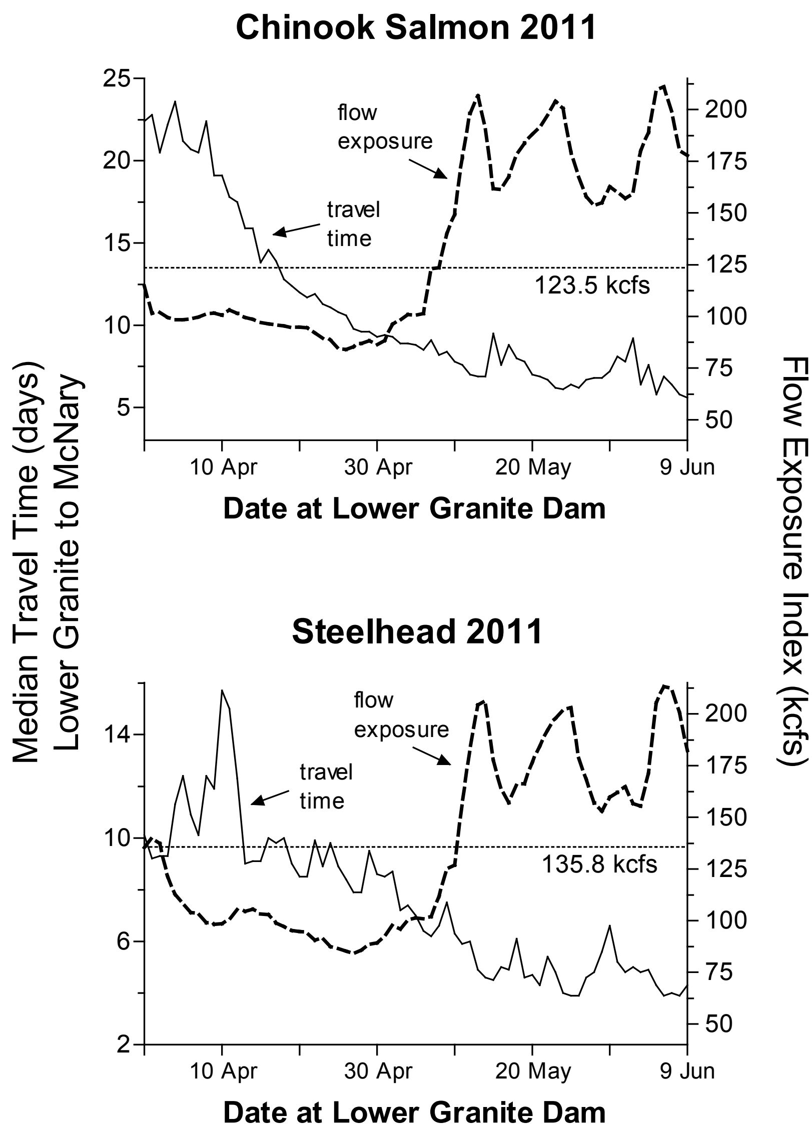

Figure 5. Travel time (days) for yearling Chinook salmon and steelhead from Lower Granite Dam to McNary Dam and index of flow exposure at Lower Monumental Dam (kcfs) for daily groups of PIT-tagged fish during 2011. Dashed horizontal lines represent the annual average flow exposure index, weighted by 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 2011. Weekly estimates from pooled daily groups.

Travel time of yearling Chinook salmon from Lower Granite Dam (d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam				Little Goose to Lower Monumental				Lower Monumental to McNary Dam			
	N	20%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
23 Mar–29 Mar	194	3.1	5.0	12.9	78	1.5	2.1	4.3	26	3.0	4.2	6.3
30 Mar–5 Apr	645	4.4	8.4	16.3	214	1.8	2.7	4.7	154	3.8	5.5	7.9
6 Apr–12 Apr	1,918	5.4	8.6	15.6	697	2.2	2.9	4.2	588	4.2	5.4	7.2
13 Apr–19 Apr	2,508	4.3	6.1	9.9	983	1.9	2.4	3.1	749	3.8	4.7	6.2
20 Apr–26 Apr	3,331	3.6	4.8	6.8	922	1.7	2.1	2.7	850	3.4	4.1	5.4
27 Apr–3 May	5,870	3.3	4.1	5.4	1,197	1.6	1.9	2.4	911	3.1	3.7	4.6
4 May–10 May	5,066	2.8	3.4	4.6	1,730	1.3	1.6	2.0	358	2.7	3.4	4.1
11 May–17 May	2,904	2.3	2.9	3.8	859	1.0	1.3	1.7	212	2.3	3.0	4.1
18 May–24 May	431	2.6	2.9	3.8	170	1.1	1.3	1.7	79	2.1	2.7	3.7
25 May–31 May	44	2.8	3.0	4.0	12	1.0	1.4	1.9	81	2.2	2.7	3.6
1 Jun–7 Jun	83	2.0	2.7	2.9	22	1.0	1.3	1.6	6	2.1	3.8	4.7
8 Jun–14 Jun	106	1.9	2.7	3.0	29	0.9	1.3	1.5	8	2.2	3.0	3.5
15 Jun–21 Jun	61	2.1	2.9	3.0	12	1.0	1.2	1.6	3	2.5	3.1	3.9
22 Jun–28 Jun	31	1.9	2.9	3.0	8	0.7	1.1	1.6	1	3.4	3.4	3.4

Date at Lower Granite Dam	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
23 Mar–29 Mar	68	14.2	23.6	36.9	14	15.7	28.0	45.6
30 Mar–5 Apr	414	15.8	22.7	32.2	83	25.4	29.9	36.5
6 Apr–12 Apr	1,338	14.8	19.9	26.8	260	23.2	27.9	32.8
13 Apr–19 Apr	1,816	11.0	14.5	19.5	344	17.4	20.9	25.5
20 Apr–26 Apr	2,799	9.5	11.2	13.9	484	14.8	16.8	19.3
27 Apr–3 May	4,793	8.4	9.6	11.2	754	12.9	14.1	15.6
4 May–10 May	1,053	7.5	8.7	10.1	119	10.4	11.9	13.3
11 May–17 May	636	6.2	7.5	9.5	75	8.9	10.2	11.8
18 May–24 May	274	5.7	6.9	8.5	25	9.2	9.7	11.6
25 May–31 May	209	5.7	6.6	8.1	28	8.5	9.6	11.3
1 Jun–7 Jun	24	5.7	7.0	8.0	8	7.7	9.5	10.1
8 Jun–14 Jun	25	5.5	6.2	7.5	3	8.7	11.8	12.1
15 Jun–21 Jun	9	6.4	8.5	9.1	7	8.3	9.6	10.5
22 Jun–28 Jun	12	6.6	7.9	9.9	14	9.5	10.3	11.6

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 2011. Weekly estimates from pooled daily groups.

Migration rate of yearling Chinook salmon from Lower Granite Dam (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%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
23 Mar–29 Mar	194	4.7	12.0	19.0	78	10.7	21.9	30.5	26	19.0	28.3	39.9
30 Mar–5 Apr	645	3.7	7.2	13.6	214	9.7	17.2	26.1	154	15.1	21.8	31.5
6 Apr–12 Apr	1,918	3.8	7.0	11.2	697	11.1	15.7	20.9	588	16.5	22.0	28.4
13 Apr–19 Apr	2,508	6.1	9.9	13.9	983	14.8	19.3	24.3	749	19.3	25.3	31.6
20 Apr–26 Apr	3,331	8.9	12.6	16.4	922	17.2	21.9	26.6	850	22.2	28.8	34.7
27 Apr–3 May	5,870	11.1	14.7	18.2	1,197	19.1	24.1	29.1	911	26.0	32.4	37.9
4 May–10 May	5,066	13.1	17.4	21.1	1,730	22.5	28.9	36.5	358	28.8	35.2	43.9
11 May–17 May	2,904	15.6	20.8	26.5	859	27.4	35.4	45.1	212	29.2	39.9	52.4
18 May–24 May	431	15.6	20.5	23.3	170	27.1	34.6	41.8	79	32.4	44.4	56.9
25 May–31 May	44	15.0	20.2	21.6	12	24.3	32.6	46.5	81	32.8	44.4	54.8
1 Jun–7 Jun	83	20.5	22.3	29.9	22	28.2	35.1	45.1	6	25.4	31.4	56.7
8 Jun–14 Jun	106	20.0	21.9	32.1	29	30.9	36.5	48.9	8	33.5	40.1	53.8
15 Jun–21 Jun	61	19.9	21.0	28.6	12	29.7	39.3	48.4	3	30.2	38.1	48.6
22 Jun–28 Jun	31	20.3	21.0	31.2	8	29.1	42.6	68.7	1	34.7	34.7	34.7

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
23 Mar–29 Mar	68	6.1	9.5	15.9	14	10.1	16.4	29.3
30 Mar–5 Apr	414	7.0	9.9	14.3	83	12.6	15.4	18.2
6 Apr–12 Apr	1,338	8.4	11.3	15.3	260	14.0	16.5	19.9
13 Apr–19 Apr	1,816	11.5	15.5	20.5	344	18.1	22.1	26.6
20 Apr–26 Apr	2,799	16.2	20.1	23.7	484	23.8	27.4	31.2
27 Apr–3 May	4,793	20.2	23.5	26.9	754	29.5	32.7	35.8
4 May–10 May	1,053	22.3	26.0	29.9	119	34.7	38.6	44.2
11 May–17 May	636	23.6	30.0	36.5	75	39.0	45.3	52.0
18 May–24 May	274	26.5	32.7	39.7	25	39.9	47.3	50.3
25 May–31 May	209	27.8	33.9	39.6	28	40.6	48.2	54.2
1 Jun–7 Jun	24	28.1	32.4	39.4	8	45.5	48.3	60.0
8 Jun–14 Jun	25	30.1	36.1	41.1	3	38.2	39.0	53.2
15 Jun–21 Jun	9	24.7	26.5	35.2	7	43.7	47.9	55.2
22 Jun–28 Jun	12	22.8	28.3	33.9	14	39.6	44.8	48.4

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 2011.

	Hatchery and wild yearling Chinook salmon from McNary Dam											
Date at	McNary to John Day Dam				John Day to Bonneville Dam				McNary to Bonneville Dam			
McNary Dam	N	20%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
	Travel time (d)											
6 Apr–12 Apr	25	3.4	4.4	7.9	2	2.0	2.1	2.1	6	6.8	9.8	15.8
13 Apr–19 Apr	209	4.4	6.4	8.9	16	1.9	2.3	3.0	43	6.2	8.7	11.3
20 Apr–26 Apr	893	4.2	5.4	7.7	96	2.0	2.3	2.9	271	6.3	7.7	10.0
27 Apr–3 May	2,422	3.9	4.7	5.9	227	1.9	2.0	2.3	839	5.6	6.3	7.6
4 May–10 May	4,881	3.4	3.9	4.8	478	1.6	1.8	2.1	2,647	4.8	5.4	6.0
11 May–17 May	3,744	2.9	3.2	4.0	65	1.2	1.4	1.7	278	3.9	4.4	4.9
18 May–24 May	1,023	2.4	3.0	3.6	11	1.1	1.3	1.4	30	3.5	4.1	4.7
25 May–31 May	226	2.2	2.9	3.9	2	1.3	1.4	1.5	10	3.7	4.0	4.6
1 Jun–7 Jun	42	2.4	2.9	4.0	2	1.0	1.0	1.1	8	3.4	3.9	4.3
8 Jun–14 Jun	24	2.0	2.6	3.3	1	1.3	1.3	1.3	4	2.7	3.1	3.6
	Migration rate (km/d)											
6 Apr–12 Apr	25	15.6	28.0	36.1	2	53.8	54.9	55.9	6	14.9	24.2	34.8
13 Apr–19 Apr	209	13.9	19.3	28.2	16	37.0	48.9	59.5	43	20.8	27.3	38.4
20 Apr–26 Apr	893	15.9	22.8	29.1	96	39.0	48.5	57.4	271	23.6	30.7	37.7
27 Apr–3 May	2,422	20.9	26.3	31.7	227	48.3	55.1	59.5	839	31.0	37.3	42.2
4 May–10 May	4,881	25.5	31.3	36.1	478	52.6	61.1	69.3	2,647	39.3	43.9	48.7
11 May–17 May	3,744	30.7	38.3	42.7	65	68.1	81.3	93.4	278	48.1	54.0	60.5
18 May–24 May	1,023	34.3	41.3	50.8	11	77.9	87.6	99.1	30	50.0	57.8	66.7
25 May–31 May	226	31.7	41.8	56.7	2	74.8	81.3	88.3	10	51.3	58.6	63.4
1 Jun–7 Jun	42	31.0	42.1	51.7	2	106.6	109.7	114.1	8	55.0	61.1	69.0
8 Jun–14 Jun	24	37.2	46.6	60.6	1	85.6	85.6	85.6	4	65.7	76.6	87.7

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 2011.

Travel time of juvenile steelhead from Lower Granite Dam (d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam				Little Goose to Lower Monumental				Lower Monumental to McNary Dam			
	N	20%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
23 Mar–29 Mar	181	2.8	3.1	4.2	112	1.2	1.8	3.3	16	2.4	3.5	6.3
30 Mar–5 Apr	2,736	2.1	2.8	3.6	1,140	1.2	1.9	3.7	415	3.0	3.8	5.9
6 Apr–12 Apr	1,923	2.2	2.8	3.8	866	1.5	2.2	6.1	314	3.0	3.7	5.5
13 Apr–19 Apr	2,884	2.6	2.9	3.9	1,055	2.0	3.0	6.0	463	3.0	3.6	4.7
20 Apr–26 Apr	5,964	2.0	2.8	3.8	1,831	1.9	3.0	5.9	866	3.0	3.6	4.9
27 Apr–3 May	4,218	2.1	2.9	3.8	785	1.8	2.8	5.5	314	2.9	3.3	4.3
4 May–10 May	3,601	2.0	2.2	3.0	1,052	1.3	1.9	3.8	162	2.3	2.8	3.4
11 May–17 May	3,926	1.6	1.9	2.4	1,344	0.9	1.2	1.9	202	1.7	2.0	2.4
18 May–24 May	1,658	1.5	1.7	1.9	760	0.8	1.1	1.8	148	1.5	1.8	2.5
25 May–31 May	22	2.0	2.1	2.6	7	0.9	1.1	2.1	127	1.6	1.8	2.4
1 Jun–7 Jun	793	1.5	1.8	1.9	294	0.8	1.0	1.5	71	1.6	2.0	2.7
8 Jun–14 Jun	870	1.2	1.3	1.6	354	0.7	0.8	1.2	44	1.4	1.7	2.1
15 Jun–21 Jun	340	1.3	1.4	1.8	112	0.7	0.9	1.1	18	1.4	1.6	1.8
22 Jun–28 Jun	40	1.2	1.8	2.0	10	0.6	0.8	1.0	1	3.2	3.2	3.2

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
23 Mar–29 Mar	28	8.8	10.9	15.0	9	11.0	12.0	22.1
30 Mar–5 Apr	727	7.1	9.7	20.8	171	12.5	19.8	33.5
6 Apr–12 Apr	576	7.5	10.9	20.2	156	13.5	18.0	27.4
13 Apr–19 Apr	1,026	7.8	9.2	14.9	419	12.3	14.8	21.3
20 Apr–26 Apr	2,413	7.0	8.9	12.8	994	11.6	13.5	16.9
27 Apr–3 May	1,718	6.9	8.1	10.3	776	10.9	12.5	14.4
4 May–10 May	623	6.0	6.8	8.3	290	8.8	9.9	11.3
11 May–17 May	491	4.3	5.1	6.5	256	7.0	7.8	8.8
18 May–24 May	297	3.9	4.6	6.1	100	6.6	7.6	9.6
25 May–31 May	291	3.7	4.1	5.6	77	5.9	7.3	8.9
1 Jun–7 Jun	178	3.9	4.7	5.8	59	6.4	7.3	8.9
8 Jun–14 Jun	111	3.3	3.9	4.8	71	5.6	6.0	6.9
15 Jun–21 Jun	33	3.5	4.2	5.3	21	5.8	6.8	7.9
22 Jun–28 Jun	4	4.8	5.3	5.5	4	7.5	8.0	12.1

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 2011.

Migration rate of juvenile steelhead from Lower Granite Dam (km/d)

Date at Lower Granite Dam	Lower Granite to Little Goose Dam N	20%	Median	80%	Little Goose to Lower Monumental N	20%	Median	80%	Lower Monumental to McNary Dam N	20%	Median	80%
23 Mar–29 Mar	181	14.4	19.3	21.4	112	13.8	25.0	37.4	16	19.0	33.7	49.6
30 Mar–5 Apr	2,736	16.6	21.8	28.4	1,140	12.3	24.2	37.4	415	20.3	31.0	40.3
6 Apr–12 Apr	1,923	15.6	21.5	27.6	866	7.6	21.0	31.1	314	21.6	31.9	39.8
13 Apr–19 Apr	2,884	15.3	20.4	23.0	1,055	7.6	15.1	23.1	463	25.3	33.0	39.9
20 Apr–26 Apr	5,964	15.9	21.1	29.3	1,831	7.8	15.6	24.7	866	24.2	33.3	40.1
27 Apr–3 May	4,218	16.0	20.9	29.0	785	8.3	16.5	25.7	314	27.8	36.3	41.0
4 May–10 May	3,601	19.9	26.8	30.5	1,052	12.3	23.7	35.9	162	34.7	43.0	52.7
11 May–17 May	3,926	25.1	31.1	36.6	1,344	24.0	37.7	48.9	202	49.0	60.4	71.3
18 May–24 May	1,658	31.1	34.7	39.7	760	24.9	43.0	56.1	148	48.6	67.2	79.3
25 May–31 May	22	22.8	28.7	29.9	7	21.9	41.8	51.7	127	50.0	64.3	74.8
1 Jun–7 Jun	793	31.4	34.3	41.1	294	30.1	45.1	56.1	71	43.4	60.4	72.1
8 Jun–14 Jun	870	36.8	45.1	51.3	354	39.3	58.2	69.7	44	57.2	70.8	85.0
15 Jun–21 Jun	340	33.1	41.4	47.2	112	41.4	52.3	63.0	18	66.5	76.3	82.6
22 Jun–28 Jun	40	30.8	33.7	48.0	10	47.9	57.5	71.9	1	36.7	36.7	36.7

Date at Lower Granite Dam	Lower Granite to McNary Dam N	20%	Median	80%	Lower Granite to Bonneville Dam N	20%	Median	80%
23 Mar–29 Mar	28	15.0	20.5	25.7	9	20.8	38.5	42.1
30 Mar–5 Apr	727	10.8	23.3	31.6	171	13.7	23.2	36.9
6 Apr–12 Apr	576	11.1	20.5	30.2	156	16.8	25.6	34.2
13 Apr–19 Apr	1,026	15.1	24.3	28.7	419	21.7	31.2	37.4
20 Apr–26 Apr	2,413	17.6	25.4	32.0	994	27.3	34.0	39.9
27 Apr–3 May	1,718	21.7	27.7	32.4	776	32.0	37.0	42.3
4 May–10 May	623	27.0	32.9	37.6	290	40.8	46.6	52.2
11 May–17 May	491	34.7	44.5	52.0	256	52.7	59.3	65.9
18 May–24 May	297	36.9	48.7	58.1	100	47.9	60.4	69.7
25 May–31 May	291	40.3	54.5	61.5	77	51.8	63.2	78.7
1 Jun–7 Jun	178	38.5	48.4	57.3	59	51.5	63.1	72.1
8 Jun–14 Jun	111	46.7	58.3	67.4	71	66.9	76.6	82.2
15 Jun–21 Jun	33	42.8	53.4	65.0	21	58.5	67.6	78.8
22 Jun–28 Jun	4	41.2	42.5	47.0	4	38.1	57.3	61.8

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 2011.

Date at McNary Dam	Hatchery and wild juvenile steelhead from McNary Dam											
	McNary to John Day Dam				John Day to Bonneville Dam				McNary to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
	Travel time (d)											
6 Apr–12 Apr	586	3.8	4.9	12.2	38	1.4	1.6	2.0	70	5.0	6.5	16.8
13 Apr–19 Apr	321	4.0	5.1	10.9	28	1.4	1.6	1.8	70	5.5	6.3	7.5
20 Apr–26 Apr	471	3.8	4.8	8.8	53	1.5	1.6	1.7	191	4.8	5.7	7.0
27 Apr–3 May	994	3.9	5.0	9.0	107	1.5	1.6	1.8	536	4.7	5.4	6.3
4 May–10 May	731	3.5	4.6	6.9	75	1.3	1.4	1.6	549	4.3	4.8	5.5
11 May–17 May	603	2.5	3.2	4.3	13	1.0	1.1	1.2	107	3.3	3.7	4.4
18 May–24 May	611	2.3	2.9	4.7	5	0.9	1.0	1.5	20	3.1	3.5	4.1
25 May–31 May	127	2.0	2.9	4.6	1	1.0	1.0	1.0	13	3.0	3.5	4.2
1 Jun–7 Jun	70	2.1	2.9	4.7	4	1.0	1.1	1.4	8	3.4	3.5	4.1
8 Jun–14 Jun	57	2.1	2.9	4.1	5	0.9	1.0	1.0	21	2.6	3.0	3.6
	Migration rate (km/d)											
6 Apr–12 Apr	586	10.1	25.3	32.0	38	56.8	70.2	80.1	70	14.1	36.2	47.1
13 Apr–19 Apr	321	11.3	24.0	30.8	28	61.1	70.6	77.9	70	31.7	37.2	43.3
20 Apr–26 Apr	471	13.9	25.4	32.0	53	64.9	70.2	76.4	191	33.8	41.6	49.3
27 Apr–3 May	994	13.7	24.8	31.9	107	64.2	72.0	77.4	536	37.6	43.9	50.1
4 May–10 May	731	17.8	26.8	34.7	75	72.9	82.5	87.6	549	42.6	49.5	54.6
11 May–17 May	603	28.5	38.4	48.8	13	93.4	98.3	113.0	107	54.0	63.3	70.9
18 May–24 May	611	26.2	41.8	53.9	5	74.3	115.3	122.8	20	57.7	67.4	75.4
25 May–31 May	127	26.9	43.0	60.3	1	115.3	115.3	115.3	13	55.7	68.0	80.0
1 Jun–7 Jun	70	25.9	42.7	59.7	4	83.1	104.6	115.3	8	57.3	67.2	70.0
8 Jun–14 Jun	57	30.3	42.7	59.7	5	108.7	115.3	121.5	21	65.7	78.9	91.5

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 that enters a collection system is detected; thus, the probability of detecting a PIT-tagged fish on a given day is the de facto probability of the fish entering the collection system on that day.

3. For each day, divide the daily collection count by the detection probability estimate for that day to get an estimate of the total number of fish (tagged and untagged) that passed Lower Granite Dam on that day. This also gives rise to estimates for that day of the total number of fish in the Lower Granite Dam collection system and the number of fish that passed via other routes (i.e., "non-detected" or "non-bypassed").

4. For each daily group of PIT-tagged fish leaving Lower Granite Dam (i.e. detected and returned to the river), tabulate the number 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. Translate these counts into "Lower Granite equivalents" (an "equivalent" is a count at a downstream dam that is adjusted upward to account for mortality that occurred between release and that downstream site, i.e., the number of fish that had to have left Lower Granite Dam in order to realize the downstream counts at Little Goose and Lower Monumental Dam).

5. Assume that for the group of untagged fish arriving at Lower Granite Dam on a given day, the proportion of Lower Granite-equivalents first collected at Lower Granite, Little Goose, and Lower Monumental Dams is the same as that of the group of PIT-tagged fish arriving on that day. (The number of PIT-tagged fish that arrived but were not detected at Lower Granite is estimated from steps 2 and 3.)

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), and travel time distribution changes throughout the season (e.g., fish that arrive earlier at Lower Granite Dam tend to take longer to get to the downstream dams).

7. For each daily group of the run-at-large, calculate the product of three quantities:
   i. Estimated number of fish in the group passing Lower Granite Dam that day (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 2011, smolt transportation began on 1 May at Lower Granite Dam, 5 May at Little Goose Dam, and 8 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 2011 season were 35.2% for wild fish and 40.7% for hatchery fish. For non-tagged steelhead, estimated percentages transported were 36.1 and 37.8% 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 2011 estimated transport proportions for hatchery steelhead and wild steelhead were only slightly higher than those of 2010, which were the lowest estimates observed for 1995-2009 (Figure 6; Table 23).

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 provided 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, less than half of the non-tagged populations at large 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.

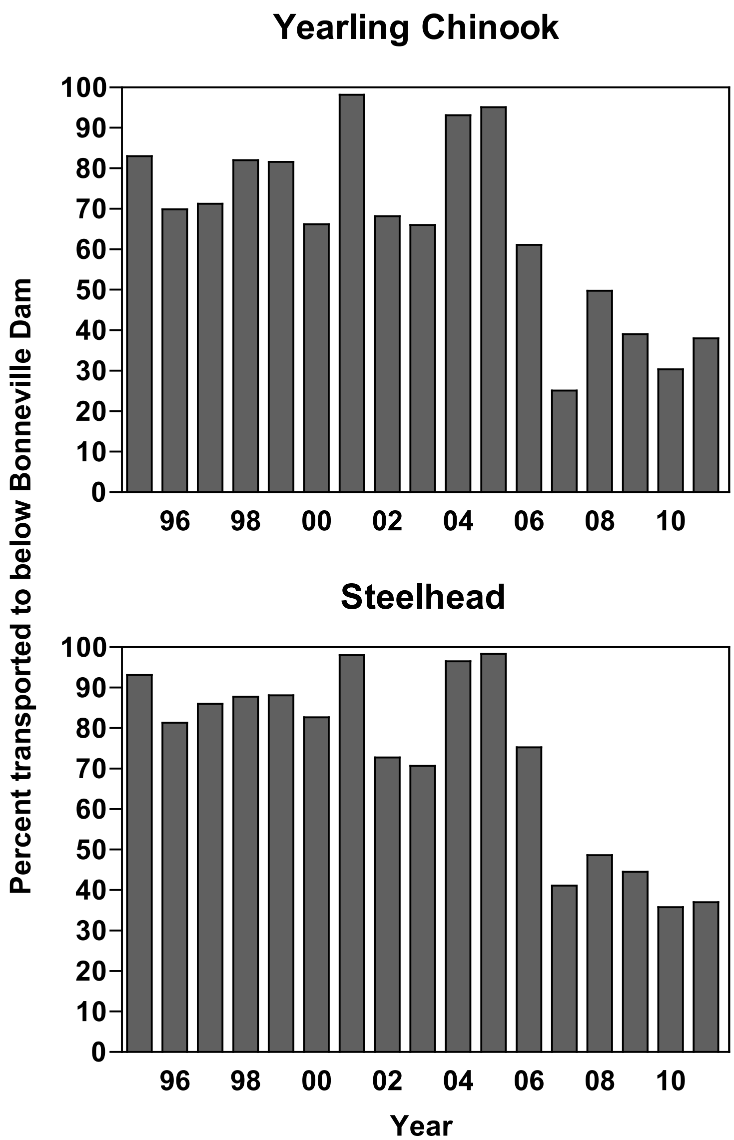

Figure 6. Estimated percent of yearling Chinook salmon and steelhead (hatchery and wild combined) transported to below Bonneville Dam by year (1995-2011).

Table 23. Annual estimated percentages of migrating Snake River yearling Chinook salmon and steelhead that were transported (1993-2011). Estimates are shown for hatchery and wild fish separately. Arithmetic means are shown for the hatchery and wild estimates separately across years and combined within years.

	Transported fish (%)					
	Yearling Chinook Salmon			Juvenile Steelhead		
Year	Hatchery	Wild	Mean	Hatchery	Wild	Mean
1993	88.1	88.5	88.3	94.7	93.2	94.0
1994	84.0	87.7	85.9	82.2	91.3	86.8
1995	79.6	86.4	83.0	94.3	91.8	93.1
1996	68.7	71.0	69.9	82.9	79.8	81.4
1997	71.5	71.1	71.3	84.5	87.5	86.0
1998	81.4	82.5	82.0	87.3	88.2	87.8
1999	77.3	85.9	81.6	88.5	87.6	88.1
2000	61.9	70.4	66.2	81.5	83.9	82.7
2001	97.3	99.0	98.2	96.7	99.3	98.0
2002	64.2	72.1	68.2	70.4	75.2	72.8
2003	61.5	70.4	66.0	68.4	72.9	70.7
2004	92.9	93.2	93.1	97.3	95.7	96.5
2005	95.0	95.1	95.1	98.0	98.7	98.4
2006	62.3	59.9	61.1	76.0	74.6	75.3
2007	25.4	24.8	25.1	41.1	41.1	41.1
2008	45.3	54.3	49.8	46.6	50.5	48.6
2009	38.3	40.4	39.4	42.7	46.1	44.4
2010	22.6	38.2	30.4	34.8	36.8	35.8
2011	40.7	35.2	38.0	37.8	36.1	37.0
Mean	**66.2**	**69.8**	**68.0**	**74.0**	**75.3**	**74.7**

The transportation start dates in 2011 were later than those in 2010 (23 April at Lower Granite Dam, 1 May at Little Goose Dam, and 3 May at Lower Monumental Dam). However, detection rates at the collector dams were higher in 2011 than in 2010. When transportation began at Lower Granite on 1 May, approximately 28% of the yearling Chinook salmon and 36% of the steelhead had already passed the dam. Some hatchery releases of steelhead occurred earlier than in previous years and resulted in a spike in passage in the first week of April. For steelhead, approximately 50% of the run had passed Lower Granite Dam by 10 May, and approximately 80% had passed by 18 May. For yearling Chinook, approximately 50% had passed by 8 May and approximately 80% had passed by 14 May.

Transportation at Lower Granite and Lower Monumental Dams was suspended from 16-18 May due to high flow and again from 22-28 May due to high flow and repair of the lock at The Dalles, which impeded barge passage. Transportation from Little Goose was suspended from 24 May through 1 June while the powerhouse was serviced. Throughout the migration season, high spill percentages, in combination with surface bypass collection at each of the collector dams on the Snake River, resulted in low collection rates due to fewer fish entering juvenile bypass systems. These relatively low collection rates, the late start in collection relative to run timing, and the temporary suspensions of transportation resulted in relatively low proportions of fish being transported in 2011.

COMPARISONS BETWEEN STOCKS AND AMONG YEARS

Comparison of Annual Survival Estimates Among Years

We made two comparisons of annual survival estimates from 2011 to those obtained in previous years of the NMFS survival study. First, we compared migration distance to survival estimates to Lower Granite Dam for releases from specific hatcheries. Second, we compared season-wide survival estimates for specific reaches across years.

Snake River Stocks

Yearling Chinook Salmon and Steelhead—For yearling Chinook salmon from most Snake River Basin hatcheries, estimates of survival to Lower Granite Dam tailrace in 2011 were similar to those made in recent years. Mean survival of fish from these hatcheries in 2011 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 the distance of a release site to Lower Granite Dam and estimated survival . For yearling Chinook from Snake River hatcheries from 1998 to 2011, there has been a significant negative linear correlation between migration distance and average estimated survival (Figure 7; $R^2 = 0.874$, $P = 0.002$).

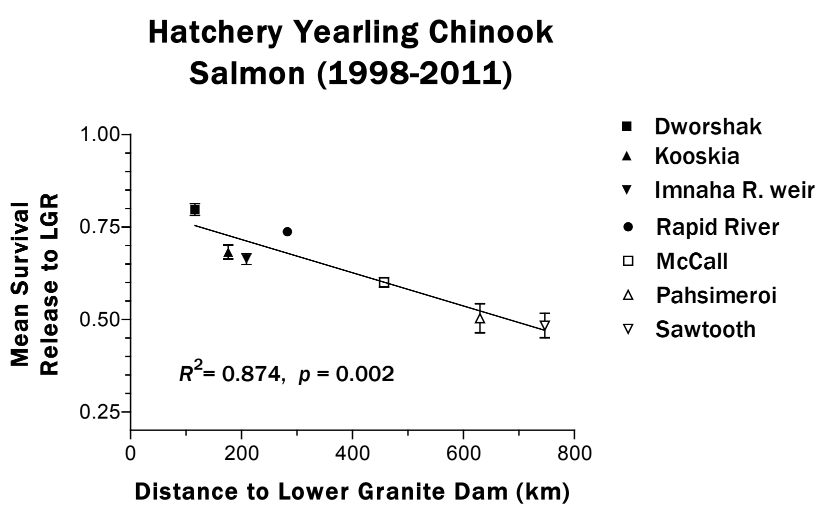

Figure 7. Estimated survival from release at Snake River Basin hatcheries to Lower Granite Dam tailrace, 1998-2011 vs. distance (km) to Lower Granite Dam. The squared correlation between survival and migration distance is also shown, along with a *P*-value for a test of the null hypothesis of zero correlation. 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, 1993–2011. 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)	NA	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)
2011	0.722 (0.006)	0.729 (0.014)	0.572 (0.009)	0.766 (0.006)	0.631 (0.007)	0.498 (0.005)	0.521 (0.007)	0.634 (0.041)
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)	0.610 (0.014)

* Released at Imnaha River Weir.

For yearling Chinook salmon (hatchery and wild combined), mean survival estimated for 2011 was lower than that estimated for 2010 for both the Lower Granite to McNary Dam reach and the McNary to Bonneville Dam reach (Tables 25 and 27; Figures 8 and 9). For yearling Chinook salmon in 2011, mean estimated survival was 0.746 (95% CI 0.726-0.766) from Lower Granite tailrace to McNary tailrace and 0.687 (0.560-0.814) from McNary tailrace to Bonneville tailrace.

For yearling Chinook salmon (hatchery and wild combined) migrating in 2011, estimated survival through the entire hydrosystem (Snake River Trap to Bonneville tailrace) was 0.483 (0.392-0.574; Table 27). This estimate was lower than either the annual mean of 0.551 estimated for 2010 or the 14-year mean of 0.493 estimated for 1998-2011. The difference between the 2011 and 2010 estimates was not statistically significant ($P = 0.26$); however, the power of this significance test was low. For wild yearling Chinook salmon alone, the mean estimate for 2011 through the entire hydrosystem was 0.677 (Table 27). This was higher than the estimate for hatchery and wild Chinook combined, but imprecise, as evidenced by the wide confidence interval (0.402-0.952).

For steelhead (hatchery and wild combined) migrating in 2011, mean estimated survival was 0.693 (95% CI 0.668-0.718) through the reach from Lower Granite to McNary Dam and 0.866 (0.792-0.941) through the reach from McNary to Bonneville Dam. The former estimate was the lowest since 2005, while the latter was the highest recorded over the past 13 years (Table 28; Figures 8 and 9).

For steelhead (hatchery and wild combined) migrating in 2011, estimated survival through the entire hydrosystem (Snake River Trap to Bonneville tailrace) was 0.592 (0.533-0.651; Table 28). This estimate was lower than the annual mean estimate for either 2009 or 2010, although neither difference was statistically significant (P-values for pairwise comparisons were 0.56 for 2009 and 0.20 for 2010). For wild steelhead alone, estimated survival through the hydrosystem was 0.474 (0.277-0.670; Table 28).

Table 25. Annual weighted means of survival probability estimates for yearling Chinook salmon (hatchery and wild combined), 1993–2011. 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 wild and hatchery 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 and Ice Harbor to McNary	McNary to John Day Dam	John Day to Bonneville Dam *	John Day to The Dalles and 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
2011	0.943 (0.009)	0.919 (0.007)	0.966 (0.007)	0.845 (0.012)	0.919	0.893 (0.026)	0.766 (0.080)	0.875
Mean	**0.939 (0.009)**	**0.927 (0.008)**	**0.917 (0.011)**	**0.855 (0.014)**	**0.924**	**0.878 (0.021)**	**0.789 (0.034)**	**0.886**

Table 26. Annual weighted means of survival probability estimates for steelhead (hatchery and wild combined), 1993–2011. 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 wild and hatchery 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 and Ice Harbor to McNary	McNary to John Day Dam	John Day to Bonneville Dam*	John Day to The Dalles and 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
2011	0.986 (0.017)	0.955 (0.004)	0.948 (0.010)	0.772 (0.014)	0.879	0.960 (0.043)	0.858 (0.051)	0.926
Mean	**0.953 (0.009)**	**0.917 (0.011)**	**0.903 (0.015)**	**0.753 (0.036)**	**0.862**	**0.807 (0.053)**	**0.758 (0.033)**	**0.868**

Table 27. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River hatchery and wild yearling Chinook salmon 1997–2011. 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)
2011	0.943 (0.009)	0.746 (0.010)	0.687 (0.065)	0.513 (0.049)	0.483 (0.046)
Mean	**0.939 (0.009)**	**0.730 (0.016)**	**0.696 (0.026)**	**0.519 (0.027)**	**0.493 (0.026)**
			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)
2011	0.954 (0.010)	0.743 (0.015)	0.955 (0.197)	0.710 (0.147)	0.677 (0.140)
Mean	**0.928 (0.010)**	**0.732 (0.019)**	**0.653 (0.040)**	**0.480 (0.034)**	**0.446 (0.083)**

Table 28. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River steelhead, 1997–2011. 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)
2011	0.986 (0.017)	0.693 (0.013)	0.866 (0.038)	0.600 (0.029)	0.592 (0.030)
Mean	**0.947 (0.013)**	**0.636 (0.038)**	**0.635 (0.047)**	**0.431 (0.046)**	**0.418 (0.047)**
			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)
2011	0.983 (0.037)	0.730 (0.024)	0.660 (0.136)	0.482 (0.101)	0.474 (0.100)
Mean	**0.958 (0.011)**	**0.635 (0.046)**	**0.598 (0.050)**	**0.416 (0.048)**	**0.402 (0.048)**

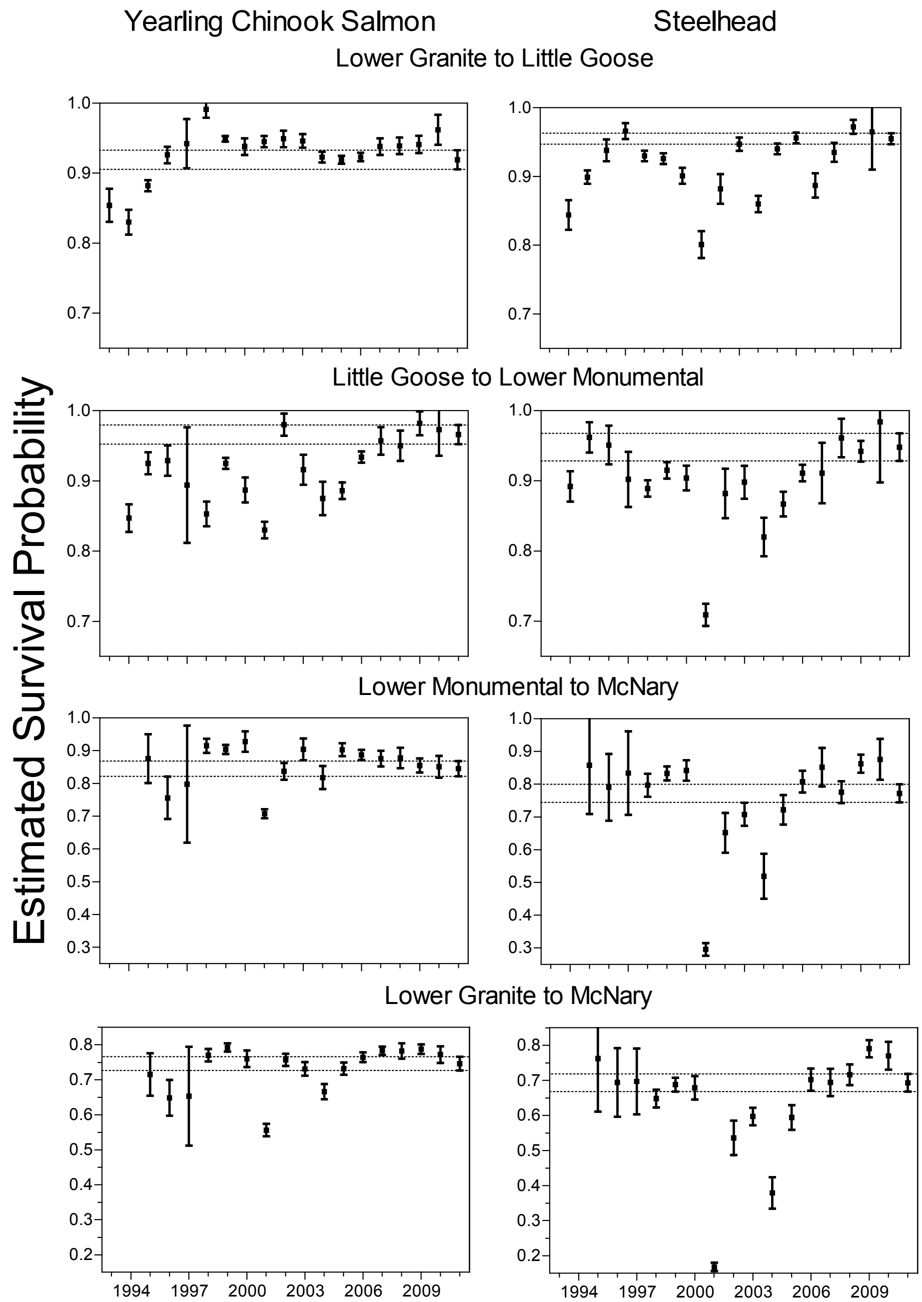

Figure 8. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead (hatchery and wild combined) through Snake River reaches, 1993-2011. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2011 estimates.

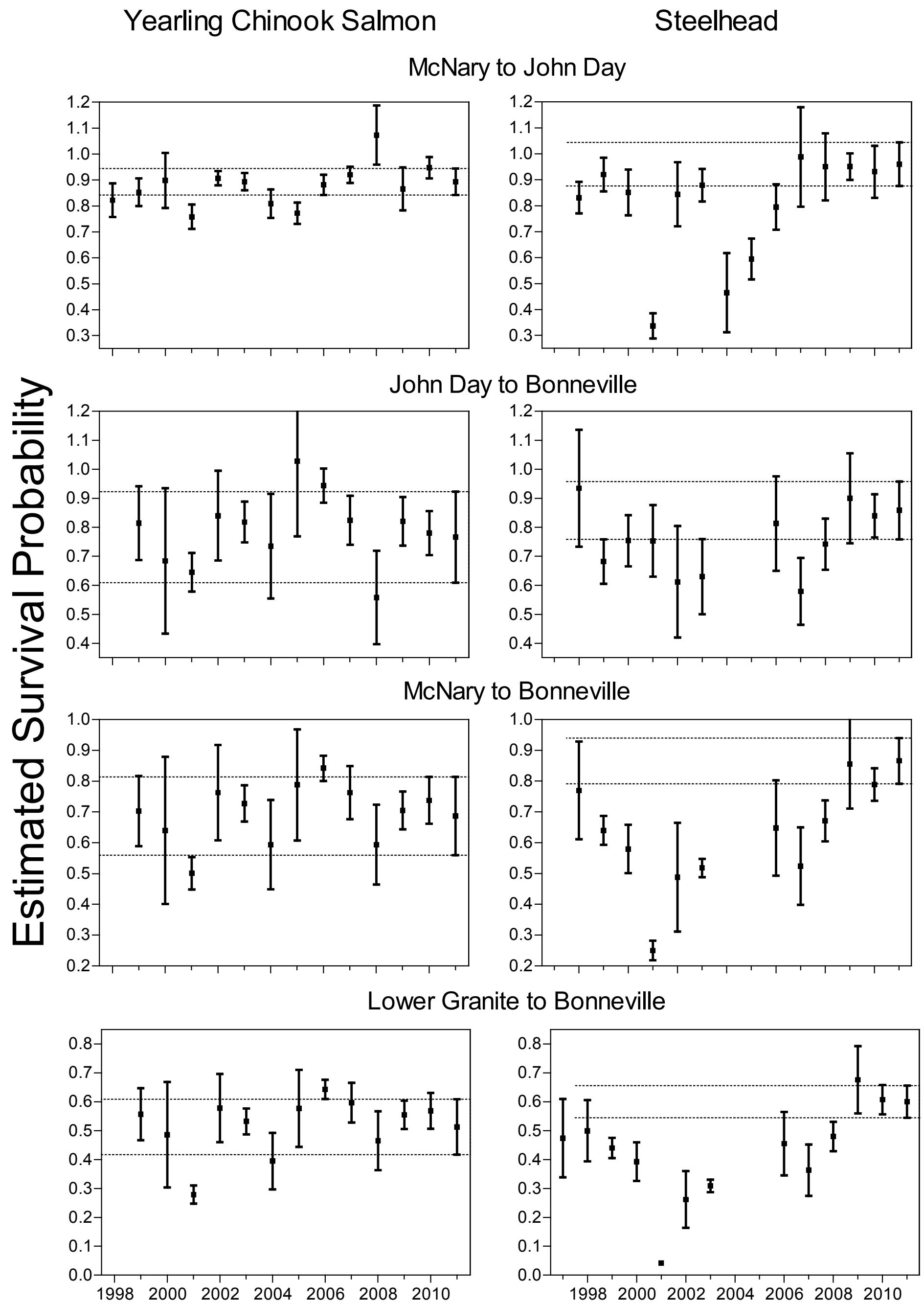

Figure 9. Annual average survival estimates for PIT-tagged Snake River yearling Chinook salmon and steelhead (hatchery and wild combined) through Columbia River reaches and from Lower Granite Dam to Bonneville Dam, 1993-2011. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2011 estimates.

Sockeye Salmon—For pooled groups of wild and hatchery sockeye salmon originating in the Snake River basin, estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace in 2011 was 0.659 (95% CI 0.597-0.723; Table 29). This estimate was higher than the average survival of 0.602 estimated for 1996-2011. Survival downstream of McNary Dam could not be estimated for sockeye salmon in 2011 due to poor detection at McNary and Bonneville Dams.

Table 29. Estimated survival for sockeye salmon (hatchery and wild combined) from Lower Granite Dam tailrace to Bonneville Dam tailrace 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, 1996–2011. Standard errors in parentheses. All available data for sockeye are shown; estimates are provided regardless of precision. Estimates to Bonneville tailrace were of poor quality in many 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)
2011	0.659 (0.033)	NA	NA
Mean	**0.602 (0.040)**	**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)
2011	0.742 (0.088)	0.691 (0.676)	0.513 (0.498)
Mean	**0.647 (0.034)**	**0.780 (0.112)**	**0.520 (0.076)**

Upper Columbia River Stocks

Yearling Chinook Salmon and Steelhead—For pooled groups of wild and hatchery yearling Chinook salmon from Upper Columbia River hatcheries, estimated survival from McNary tailrace to Bonneville tailrace in 2011 was 0.637 (95% CI 0.503-0.807). This estimate was below the 1999-2011 average of 0.752 for that reach (Table 30).

For pooled groups of wild and hatchery steelhead from Upper Columbia hatcheries, estimated survival from McNary tailrace to Bonneville tailrace in 2011 was 0.651 (0.456-0.929). This estimate was lower than the mean survival of 0.715 estimated over the same reach for 2003-2011 (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 tailrace to McNary tailrace in 2011 was 0.742 (0.589-0.935; Table 29). Although survival estimates are shown in Table 29 for these fish from McNary to Bonneville and from Rock Island to Bonneville Dam, low detection rates at McNary and Bonneville Dam in 2011 made precision of these estimates very poor.

Table 30. Estimated survival and standard error (se) through reaches of the lower Columbia River hydropower system for hatchery yearling Chinook salmon (1999–2011) and steelhead (2003–2011) originating in the upper Columbia River. Steelhead estimates were not possible prior to 2003. Multiple release sites were used in each year and not all release sites occurred consistently among years. 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)
2011	0.534 (0.010)	1.042 (0.047)	0.612 (0.077)	0.637 (0.077)
Mean	**0.552 (0.016)**	**0.904 (0.032)**	**0.819 (0.052)**	**0.752 (0.034)**
	Hatchery steelhead			
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)
2011	0.435 (0.012)	1.201 (0.064)	0.542 (0.101)	0.651 (0.119)
Mean	**0.438 (0.014)**	**0.919 (0.051)**	**0.798 (0.063)**	**0.715 (0.035)**

Comparison of Annual Survival Estimates Among Snake and Columbia River Stocks

For spring/summer Chinook salmon, estimated survival from McNary to Bonneville Dam tailrace was higher for Snake River (0.687, se 0.065) was than for Upper Columbia River fish migrating in 2011 (0.584, se 0.061; Table 31), although the difference was not statistically significant ($P = 0.25$). For steelhead, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was higher for Snake River (0.866, se 0.038) than for Upper Columbia River fish (0.668, se 0.115), although the difference was not statistically significant ($P = 0.10$). For sockeye salmon, estimated survival from McNary tailrace to John Day tailrace was higher for Snake River fish (0.867, se 0.091) than for Upper Columbia River fish (0.666, se 0.166), but again, the difference was not statistically significantly different ($P = 0.29$).

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 2011. 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.

Stock	Release location	Number released	Survival estimates (standard errors) McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
Snake R Chinook (Sp/Su)*	McNary Dam tailrace	59,728*	0.893 (0.026)	0.766 (0.080)	0.687 (0.065)
Upper Columbia Chinook (Sp/Su)	Upper Columbia sites[a]	138,102	1.020 (0.041)	0.572 (0.063)	0.584 (0.061)
Upper Columbia Chinook (Sp/Su)	Yakima River sites[b]	70,210	0.876 (0.047)	0.781 (0.186)	0.684 (0.160)
Upper Columbia Coho	Upper Columbia sites	41,079	NA	NA	NA
Upper Columbia Coho	Yakima River sites	23,954	0.912 (0.111)	1.001 (0.571)	0.913 (0.512)
Snake River Sockeye	Snake River sites[c]	58,951	0.867 (0.091)	NA	NA
Upper Columbia Sockeye	Upper Columbia sites	2,977	0.666 (0.166)	1.038 (1.032)	0.691 (0.676)
Snake River Steelhead*	McNary Dam Tailrace	12,957*	0.960 (0.043)	0.858 (0.051)	0.866 (0.038)
Upper Columbia Steelhead	Upper Columbia sites	91,596	1.206 (0.059)	0.554 (0.097)	0.668 (0.115)

[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 upstream of Lower Granite Dam on the Snake River or its tributaries.

DISCUSSION

Estimated survival for Snake River yearling Chinook salmon and steelhead through the entire hydrosystem (Snake River trap to Bonneville tailrace) was lower in 2011 than in the previous 2 years. For yearling Chinook, the 2011 estimated total hydrosystem survival was 48.3%, which was nearly equal to the long-term (1999-2011) average of 49.3%, but lower than the 2010 estimate of 55.1% (though not significantly different $P = 0.26$). For steelhead, estimated survival through the hydrosystem in 2011 was 59.2%, which was higher than the long-term average of 41.8%, but lower than the 2010 estimate of 61.8% (though not significantly different; $P = 0.20$)

Snake River flow volume in 2011 was higher than in recent years for most of the migration period, and increased sharply in mid-May. These high flows resulted in increased debris loads in the river, which in turn caused problems for juvenile fish bypass systems at several projects. For example, at Little Goose Dam the gatewell orifices became clogged with debris on 19 May, resulting in smolt mortalities. At Bonneville Dam, problems with debris necessitated removal of the bypass screens from several turbine units. These screens were removed on 19 May and were not reinstalled until 12 July. In addition, the PIT-tag detection trawl system in the estuary experienced problems from high flow and debris, resulting in less sampling time and restricted sampling areas compared to previous years.

Removal of the bypass screens at Bonneville Dam resulted in greater numbers of fish passing the dam through turbines, which likely resulted in lower survival than would have occurred otherwise. At the same time, screen removal resulted in an extreme reduction in PIT-tag detections, which meant that survival could not be estimated during that period. Therefore, any annual average survival estimate for Chinook or steelhead migrating in 2001 that included the reach from John Day to Bonneville Dam could be an overestimate of the actual survival of the population.

Seasonal indices of smolts passing John Day Dam in 2011 indicated that on 19 May, when the screens were first removed at Bonneville Dam, approximately 40% of the Chinook population and 45% of steelhead population had not yet passed. However, preliminary estimates of dam survival at Bonneville Dam from acoustic tag studies comparing survival before and after the high flow event in late May only varied by about 1% (G. Ploskey, personal communication, November 30, 2011).

In addition to problems related to flow, on 20 May 2011, a transformer at Little Goose Dam was damaged, resulting in a shutdown of the powerhouse for several hours. On 24 May, the powerhouse at Little Goose Dam was shut down again to repair the transformer, and normal operations did not resume until 2 June. A limited amount of discharge (5 kcfs) was passed through the powerhouse during that time for on-site power usage. One consequence of this shutdown was an elimination of PIT-tag detections. During the shutdown, we could not estimate survival for daily groups from Lower Granite to Little Goose tailrace. However, because there were no removals for transportation or smolt sampling at Little Goose Dam during the shutdown, we were able to estimate survival from Lower Granite to Lower Monumental by simply ignoring Little Goose Dam as a detection site.

Another consequence of the powerhouse shutdown at Little Goose was an increase in the amount of discharge forced through the spillways. During a period of high flow, this increase in spilled water resulted in high levels of total dissolved gas in the tailrace of Lower Monumental Dam. Thus supersaturation may have increased smolt mortality for both yearling Chinook salmon and steelhead in 2011.

Estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams in 2011 were similar to those in 2010, and were among the lowest seen from 1995-2009. The low transportation rates are partially explained by the timing of the start of transportation. When transportation began at Lower Granite Dam on 1 May, about 28% of the yearling Chinook and 36% of the steelhead had already passed the dam. Other factors contributing to low rates of transportation were the use of surface bypass structures and the periods of high spill percentages, both of which increase spillway passage and reduce numbers of collected fish in the juvenile bypass systems. Furthermore, the temporary halt of transportation due to high flow, the repair of the lock at The Dalles, and the Little Goose powerhouse outage also reduced transportation rates.

The high estimated survival of steelhead through the entire hydrosystem from 2009 through 2011 is particularly noteworthy. In all reaches, mean estimated survival of steelhead was higher in these years than in previous years. Reaches with unusually high mean estimated survival for steelhead in 2011 were those from McNary to John Day tailrace and from John Day to Bonneville tailrace. High estimated survival in these and other reaches resulted in a total hydrosystem survival estimate greater than 59% for steelhead in 2011.

Also in 2011, new avian predator deterrent wires were installed in John Day tailrace, and a new spillway wall was constructed at The Dalles Dam. Both of these improvements appeared to contribute to higher smolt survival in the reaches from McNary to John Day and John Day to Bonneville Dam. Preliminary estimates of survival from McNary to John Day Dam were 96.8 and 98.7% for acoustic-tagged yearling Chinook salmon and steelhead, respectively (J. Hughes, Pacific Northwest National Laboratory, personal communication). Respective preliminary estimates of yearling Chinook salmon and steelhead survival were 96.0 and 99.5% through The Dalles Dam (J. Skalski, University of Washington, personal communication) and 96.0 and 96.5% through Bonneville Dam (G. Ploskey, Pacific Northwest National Laboratory, personal communication).

With the addition in 2009 of a temporary spillway weir (TSW) at Little Goose Dam, the total number of Snake and Columbia River dams with surface bypass structures has increased to seven. These include 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 surface bypass structures can have direct positive effects on survival, as well as indirect positive effects associated with decreased travel times. Measures of absolute survival through surface passage structures are often similar to those through juvenile bypass systems or unaltered spillways. However, travel time may decrease for fish that pass through surface bypass structures because these structures help reduce delay in the forebay. For steelhead, less time spent in the reservoir and forebay of a dam means decreased travel time and reduced exposure to predators.

Exposure to high water temperatures is also potentially decreased with faster travel times. Higher water temperatures can trigger reversion to parr and suspended downstream migration in steelhead smolts. 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. Once migration ceases, a PIT-tagged smolt will not be detected at any further downstream dams. For purposes of the survival-estimation model, such an event cannot be distinguished from mortality. Thus, estimated survival should be higher for steelhead with shorter travel time. Cooler-than-normal water temperatures during the migration period also likely contributed to high survival of steelhead in 2011.

Predation is another 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 intensively monitored (Ryan et al. 2001, 2003; Roby et al. 2008). In Lake Wallula (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 in this area include the American white pelican *Pelecanus erythrorhynchos,* cormorant *Phalacrocorax auritus*, egret *Ardea alba*, and herons *A. herodias* and *Nycticorax nycticorax.*

Steelhead smolts have been found 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.

As indexed by the percentage of PIT-tags detected at Lower Monumental Dam that are subsequently detected on bird colonies (Table 32), the proportion of PIT-tagged steelhead lost to piscivorous birds Lake Wallula was lower during 2006-2011 than during 2001-2005. Steelhead survival between Lower Monumental and McNary Dams was, correspondingly, lower during 2001-2005 and higher during 2006-2011.

For both yearling Chinook salmon and steelhead, a significant negative correlation was seen during 1998-2011 between estimated survival from Lower Monumental to McNary Dam and percentage of PIT tags recovered on avian colonies (Figure 10). The smaller proportion of smolts taken by birds during 2006-2011 was due in part to an increase in the total number of smolts (tagged and untagged) remaining in the river. This higher number of inriver migrant smolts in turn resulted from increased spill, expanded use of surface passage structures at Snake River dams (all 4 dams in 2011), and delayed initiation of the smolt transportation program.

The estimated percentage of steelhead (hatchery and wild combined) transported in 2011 was 37%; this estimate was the second lowest of all years during 1993-2011. Similar to 2009 and 2010, the low rate of transport left a large number of steelhead migrating in-river in 2011. As we have previously demonstrated (cf. Faulkner et al. 2008), 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 fish taken by predators decreases.

Table 32. Percentage of PIT–tagged smolts (wild and hatchery combined) detected at Lower Monumental Dam and later detected on avian predator colonies in McNary pool bird colonies, 1998-2011. Note that these estimates are not adjusted for detection efficiency on individual colonies.

	Proportion of fish detection at Lower Monumental Dam that were subsequently detected on an avian colony (%)	
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
2003[a]	1.06	3.71
2004[b]	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
2011	1.03	3.37

[a] Only Crescent Island Caspian tern colony sampled.
[b] Only Crescent Island and Foundation Island colonies sampled.

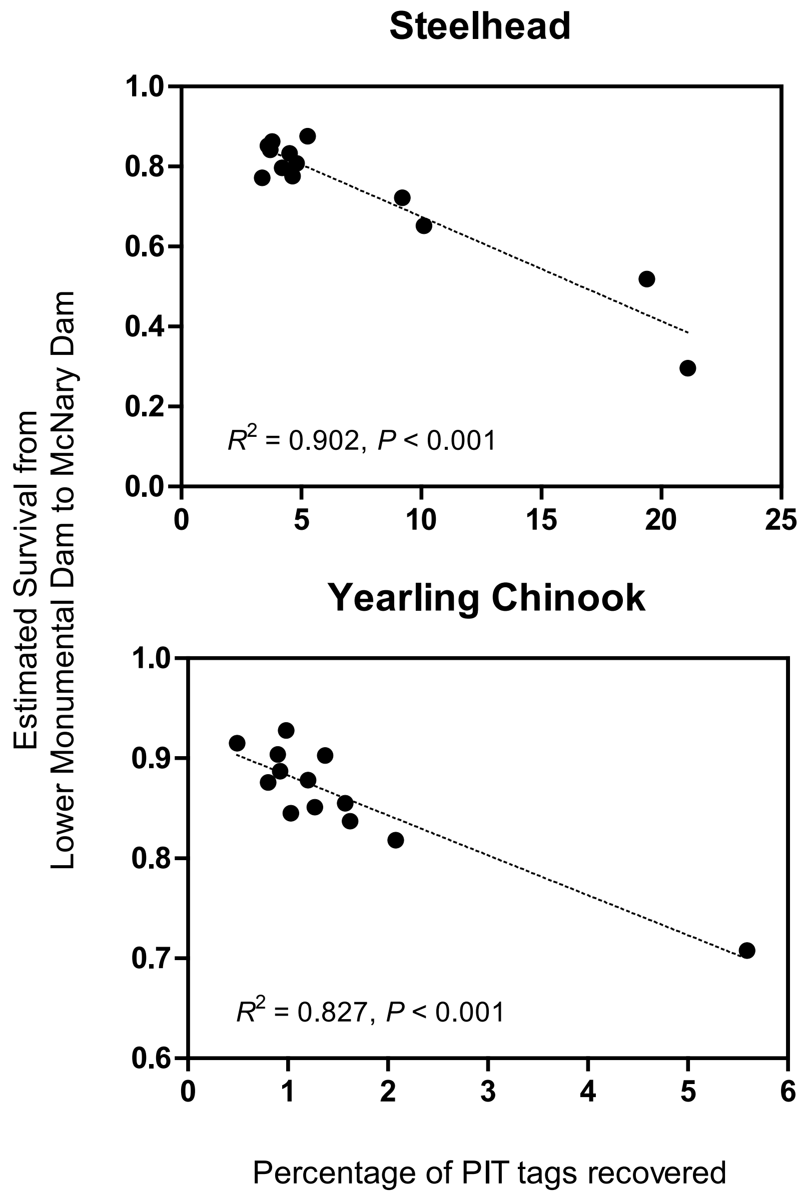

Figure 10. Estimated survival between Lower Monumental and McNary Dams vs. percentage of Lower Monumental Dam-detected PIT tags recovered on bird colonies, 1998-2011 (excluding 2003, which had incomplete recovery effort).

CONCLUSIONS AND RECOMMENDATIONS

Results from the 2011 studies provide estimates of survival only during the downstream-migration portion of the anadromous life-cycle. These data will be analyzed in conjunction with adult return data over the next 3 years. Such analyses will help determine whether variations in spill, flow, temperature, and passage route result in patterns of smolt-to-adult survival consistent with those observed for juvenile survival during the downstream migration. Based on results of survival studies to date, we recommend the following:

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 is occurring upstream from the Snake and Clearwater River confluence. Continued development of instream PIT-detection systems for use in tributaries will be necessary if these areas of upstream mortality are to be identified.

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

4) High rates of spill and the use of surface-bypass structures (RSWs, TSWs) in recent years have resulted in low PIT-tag detection rates and consequently reduced precision of survival estimates. Development of PIT-tag detection capability in the spillways would improve detection rates and greatly enhance knowledge of juvenile salmonid survival.

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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 2011 (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 2011 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 9 weekly groups of yearling Chinook salmon. For these, the overall sum of the χ^2 test statistics was significant 3 times (33%). For 12 steelhead groups, the overall test was significant 4 times (33%). Counting all individual component tests (i.e., 2.C2, 3.SR3, etc.), 6 tests of 45 (13%) were significant for yearling Chinook salmon and 11 of 60 (18%) 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. Twelve of the 17 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 than fish not previously detected. The direction of the relationship was not consistent, going either way with nearly equal frequency for both yearling Chinook salmon and steelhead.

For weekly groups from McNary Dam, significant contingency table test results were more common than expected for both yearling Chinook and steelhead (Appendix Tables A4-A6). For yearling Chinook salmon, there was one (11%) significant test out of the 9 individual component tests, and for steelhead 2 (29%) of the 7 component tests were significant. All 3 of the significant component tests for both yearling Chinook and steelhead were for Test 2.C2, and each of those indicated fish detected at John Day Dam were less likely to be detected again at Bonneville Dam 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 2011, 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 2011 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 Lower 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 concludethat a reasonable amount of heterogeneity in the survival and detection process occurred, but did not seriously affect the performance of estimators of survival (see also Burnham et al. 1987 on effects of small amount of heterogeneity).

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, 2011.

	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	9	4	9	0	9	0	9	1	9	1	9	4	9	2	9	3
Steelhead	12	3	12	5	12	2	12	0	12	1	12	4	12	2	12	4
Total	21	7	21	5	21	2	21	1	21	2	21	8	21	4	21	7

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 2011.

Release	Overall		Test 2		Test 2.C2		Test 2.C3	
	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
23 Mar–29 Mar	8.10	0.231	5.69	0.128	5.45	0.065	0.24	0.624
30 Mar–5 Apr	7.51	0.277	4.12	0.249	3.71	0.157	0.41	0.522
6 Apr–12 Apr	9.31	0.157	6.61	0.085	3.50	0.174	3.12	0.078
13 Apr–19 Apr	10.48	0.106	10.40	**0.015**	10.33	**0.006**	0.07	0.789
20 Apr–26 Apr	17.41	**0.008**	8.47	**0.037**	6.01	**0.050**	2.46	0.117
27 Apr–3 May	3.68	0.719	0.53	0.912	0.21	0.900	0.32	0.573
4 May–10 May	15.08	**0.020**	9.05	**0.029**	8.09	**0.017**	0.96	0.327
11 May–17 May	9.83	0.132	4.42	0.220	0.64	0.727	3.78	0.052
18 May–24 May	18.16	**0.006**	9.91	**0.019**	7.30	**0.026**	2.61	0.106
Total (df)	99.56 (54)		59.20 (27)		45.23 (18)		13.97 (9)	

Release	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
23 Mar–29 Mar	2.41	0.492	1.04	0.307	0.32	0.571	1.05	0.307
30 Mar–5 Apr	3.39	0.335	0.14	0.704	0.00	0.992	3.25	0.072
6 Apr–12 Apr	2.70	0.441	0.44	0.509	2.26	0.133	0.01	0.945
13 Apr–19 Apr	0.08	0.994	0.00	0.994	0.00	0.964	0.08	0.781
20 Apr–26 Apr	8.94	**0.030**	0.51	0.477	5.01	**0.025**	3.42	0.064
27 Apr–3 May	3.15	0.368	0.13	0.714	0.00	0.957	3.02	0.082
4 May–10 May	6.03	0.110	0.69	0.406	3.73	0.054	1.61	0.204
11 May–17 May	5.42	0.144	3.11	0.078	0.53	0.466	1.77	0.183
18 May–24 May	8.24	**0.041**	0.42	0.519	2.91	0.088	4.91	**0.027**
Total (df)	40.35 (27)		6.48 (9)		14.77 (9)		19.10 (9)	

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 2011.

Release	Overall		Test 2		Test 2.C2		Test 2.C3	
period	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
23 Mar–29 Mar	8.08	0.232	1.71	0.635	0.94	0.624	0.77	0.382
30 Mar–5 Apr	8.39	0.211	8.03	**0.045**	3.47	0.176	4.56	**0.033**
6 Apr–12 Apr	4.87	0.561	3.97	0.265	2.86	0.239	1.11	0.293
13 Apr–19 Apr	8.53	0.202	5.23	0.156	4.70	0.096	0.53	0.466
20 Apr–26 Apr	10.33	0.111	5.84	0.120	0.06	0.970	5.78	**0.016**
27 Apr–3 May	17.62	**0.007**	7.48	0.058	6.22	**0.045**	1.26	0.262
4 May–10 May	19.09	**0.004**	13.06	**0.005**	5.17	0.075	7.90	**0.005**
11 May–17 May	11.67	0.070	9.77	**0.021**	7.07	**0.029**	2.70	0.101
18 May–24 May	15.72	**0.015**	1.18	0.759	0.84	0.658	0.34	0.560
1 Jun–7 Jun	22.46	**0.001**	22.00	**<0.001**	16.38	**<0.001**	5.62	**0.018**
8 Jun–14 Jun	7.97	0.240	1.67	0.643	0.97	0.615	0.70	0.403
15 Jun–21 Jun	6.90	0.330	4.26	0.235	0.08	0.960	4.18	**0.041**
Total (df)	141.64 (72)		84.20 (36)		48.76 (24)		35.43 (12)	

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
23 Mar–29 Mar	6.37	0.095	1.46	0.227	3.04	0.081	1.87	0.172
30 Mar–5 Apr	0.36	0.949	0.32	0.570	0.00	0.980	0.03	0.859
6 Apr–12 Apr	0.90	0.825	0.01	0.922	0.15	0.694	0.74	0.391
13 Apr–19 Apr	3.31	0.347	0.67	0.413	2.63	0.105	0.01	0.927
20 Apr–26 Apr	4.49	0.213	0.05	0.821	0.21	0.646	4.23	**0.040**
27 Apr–3 May	10.14	**0.017**	7.18	**0.007**	0.16	0.690	2.80	0.094
4 May–10 May	6.03	0.110	3.48	0.062	2.55	0.110	0.00	0.984
11 May–17 May	1.90	0.593	0.00	0.949	1.38	0.240	0.51	0.473
18 May–24 May	14.55	**0.002**	13.61	**<0.001**	0.35	0.553	0.58	0.445
1 Jun–7 Jun	0.47	0.926	0.22	0.638	0.20	0.654	0.04	0.833
8 Jun–14 Jun	6.30	0.098	1.74	0.187	3.77	0.052	0.79	0.375
15 Jun–21 Jun	2.64	0.450	0.01	0.919	0.24	0.623	2.39	0.122
Total (df)	57.45 (36)		28.76 (12)		14.70 (12)		13.99 (12)	

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, 2011.

	Test 2.C2		Test 3.SR3		Test 2 + 3	
Species	No.	sig.	No.	sig.	No.	sig.
Chinook	5	1	4	0	5	0
Steelhead	4	2	3	0	4	0
Total	9	3	7	0	9	0

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 2011.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
20 Apr–26 Apr	2.08	0.354	2.08	0.149	0.00	0.972
27 Apr–3 May	2.70	0.259	1.20	0.273	1.49	0.222
4 May–10 May	4.70	0.096	4.25	**0.039**	0.44	0.506
11 May–17 May	2.39	0.303	2.31	0.129	0.08	0.776
18 May–24 May	0.31	0.578	0.31	0.578	NA	NA
Total (df)	12.17 (9)		10.15 (5)		2.02 (4)	

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 2011.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
27 Apr–3 May	2.43	0.119	2.43	0.119	NA	NA
4 May–10 May	1.75	0.418	0.17	0.684	1.58	0.209
11 May–17 May	5.66	0.059	5.21	**0.023**	0.46	0.499
25 May–31 May	5.75	0.056	5.69	**0.017**	0.07	0.796
Total (df)	15.59 (7)		13.49 (4)		2.10 (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 2011. Estimates based on the single-release model. Standard errors in parentheses.

	Yearling Chinook salmon					
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	17,092	0.784 (0.008)	0.913 (0.013)	0.985 (0.020)	0.922 (0.027)	0.650 (0.015)
Crooked River	25,488	0.524 (0.007)	0.915 (0.017)	1.004 (0.027)	0.811 (0.031)	0.390 (0.012)
Powell Pond	17,089	0.753 (0.010)	0.930 (0.019)	1.042 (0.032)	0.836 (0.036)	0.610 (0.020)
Red River Pond	17,060	0.319 (0.008)	1.039 (0.042)	0.980 (0.058)	0.852 (0.078)	0.276 (0.021)
Selway River	17,082	0.749 (0.008)	0.914 (0.014)	1.010 (0.023)	0.913 (0.029)	0.631 (0.015)
Dworshak Hatchery						
NF Clearwater River	51,753	0.722 (0.006)	0.915 (0.012)	0.963 (0.018)	0.803 (0.020)	0.511 (0.010)
Kooskia Hatchery						
Clear Creek	13,932	0.729 (0.014)	0.876 (0.027)	1.057 (0.050)	0.803 (0.057)	0.542 (0.029)
Lookingglass Hatchery						
Catherine Creek Pond	20,837	0.300 (0.007)	0.934 (0.037)	1.039 (0.060)	0.782 (0.080)	0.228 (0.020)
Grande Ronde Pond	1,967	0.434 (0.019)	1.101 (0.077)	0.953 (0.106)	0.849 (0.226)	0.386 (0.097)
Imnaha Weir	20,755	0.572 (0.009)	0.940 (0.024)	1.064 (0.040)	0.742 (0.050)	0.424 (0.025)
Lookingglass Hatchery	1,994	0.652 (0.019)	1.037 (0.048)	1.035 (0.085)	0.727 (0.119)	0.509 (0.075)
Lostine Pond	1,992	0.490 (0.022)	1.000 (0.070)	0.832 (0.074)	1.004 (0.245)	0.409 (0.097)
Nez Perce Tribal Hatchery						
Nez Perce Tribal H.	5,900	0.833 (0.022)	0.847 (0.036)	0.957 (0.062)	0.958 (0.092)	0.647 (0.048)
McCall Hatchery						
Johnson Creek	4,165	0.264 (0.015)	0.994 (0.082)	1.022 (0.111)	0.827 (0.210)	0.222 (0.053)
Knox Bridge	51,875	0.631 (0.007)	0.967 (0.019)	1.055 (0.028)	0.730 (0.031)	0.469 (0.018)
Pahsimeroi Hatchery						
Pahsimeroi Pond	21,131	0.498 (0.005)	0.914 (0.013)	0.975 (0.021)	0.836 (0.027)	0.371 (0.010)
Rapid River Hatchery						
Rapid River Hatchery	51,730	0.766 (0.006)	0.942 (0.014)	1.051 (0.022)	0.703 (0.024)	0.533 (0.016)
Sawtooth Hatchery						
Sawtooth Hatchery	18,938	0.521 (0.007)	0.958 (0.023)	1.077 (0.043)	0.690 (0.052)	0.370 (0.024)
Yankee Fork	2,395	0.329 (0.023)	0.931 (0.124)	0.802 (0.140)	0.561 (0.134)	0.138 (0.029)

Appendix Table B2. Estimated survival probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2011. Estimates based on the single-release model. Standard errors in parentheses.

	Juvenile steelhead					
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	33,822	0.794 (0.005)	0.971 (0.010)	0.986 (0.016)	0.795 (0.024)	0.605 (0.015)
			Dworshak Hatchery			
Clear Creek	4,933	0.691 (0.009)	0.962 (0.014)	0.952 (0.025)	0.741 (0.038)	0.469 (0.022)
Clearwater R.	17,503	0.796 (0.005)	0.964 (0.008)	0.914 (0.013)	0.719 (0.020)	0.504 (0.012)
Eldorado Creek	756	0.739 (0.045)	0.848 (0.096)	1.108 (0.190)	1.711 (1.152)	1.188 (0.779)
S.F. Clearwater R.	7,008	0.720 (0.008)	0.960 (0.015)	0.966 (0.024)	0.723 (0.036)	0.483 (0.022)
			Hagerman Hatchery			
East Fork Salmon R.	6,981	0.813 (0.023)	0.929 (0.055)	0.919 (0.062)	1.130 (0.206)	0.784 (0.139)
Sawtooth Hatchery (4/15)	6,747	0.816 (0.017)	1.030 (0.038)	0.857 (0.046)	0.858 (0.074)	0.618 (0.044)
Sawtooth Hatchery (4/27)	6,662	0.834 (0.021)	0.966 (0.044)	0.889 (0.052)	0.875 (0.129)	0.626 (0.087)
Yankee Fork	8,212	0.756 (0.017)	0.918 (0.042)	0.968 (0.056)	0.840 (0.128)	0.564 (0.082)
			Irrigon Hatchery			
Big Canyon Fac. (4/13)	4,352	0.806 (0.018)	1.074 (0.045)	0.861 (0.048)	1.016 (0.115)	0.757 (0.080)
Big Canyon Fac. (4/26)	4,389	0.819 (0.020)	1.038 (0.046)	0.888 (0.059)	0.815 (0.098)	0.615 (0.065)
Little Sheep Facility	21,900	0.704 (0.008)	0.983 (0.023)	0.950 (0.029)	0.830 (0.059)	0.546 (0.036)
Wallowa Hatchery (4/10)	9,950	0.740 (0.010)	1.012 (0.024)	0.904 (0.033)	1.003 (0.070)	0.679 (0.043)
Wallowa Hatchery (4/24)	3,495	0.825 (0.022)	0.976 (0.047)	0.871 (0.064)	0.992 (0.133)	0.696 (0.082)
			Lyons Ferry Hatchery			
Cottonwood Pond	6,000	0.830 (0.013)	0.993 (0.027)	0.941 (0.048)	0.759 (0.061)	0.589 (0.038)

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
	Juvenile steelhead					
	Magic Valley Hatchery					
E. F. Salmon R.	4,983	0.733 (0.022)	0.846 (0.041)	1.053 (0.062)	0.820 (0.155)	0.536 (0.098)
Little Salmon R.	7,659	0.844 (0.011)	1.009 (0.025)	0.910 (0.033)	0.897 (0.076)	0.696 (0.055)
Pahsimeroi R. Trap	7,166	0.877 (0.017)	0.928 (0.033)	0.933 (0.043)	0.964 (0.147)	0.732 (0.108)
Salmon R. (rkm 347)	1,599	0.770 (0.029)	0.870 (0.053)	1.012 (0.085)	0.921 (0.160)	0.624 (0.097)
Salmon R. (rkm 385)	2,081	0.758 (0.023)	1.019 (0.063)	0.870 (0.072)	1.006 (0.196)	0.676 (0.124)
Salmon R. (rkm 476)	2,095	0.711 (0.023)	0.965 (0.058)	0.989 (0.083)	0.919 (0.167)	0.623 (0.104)
Salmon R. (rkm 506)	2,093	0.866 (0.031)	0.984 (0.069)	0.887 (0.083)	1.087 (0.226)	0.821 (0.159)
Squaw Creek	5,076	0.614 (0.018)	0.990 (0.056)	0.923 (0.067)	0.717 (0.128)	0.402 (0.068)
	Niagara Springs Hatchery					
Hells Canyon Dam	8,234	0.704 (0.008)	0.972 (0.017)	0.956 (0.027)	0.840 (0.050)	0.550 (0.030)
Little Salmon R.	6,922	0.762 (0.011)	0.977 (0.025)	0.958 (0.036)	0.838 (0.074)	0.597 (0.049)
Pahsimeroi Trap	12,840	0.746 (0.012)	1.038 (0.034)	0.883 (0.038)	0.969 (0.102)	0.662 (0.066)

Appendix Table B3. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2011. Estimates based on the single-release model. Standard errors in parentheses.

	Juvenile sockeye salmon							
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	12 May 11	9,975	0.780 (0.023)	0.991 (0.062)	0.776 (0.056)	0.735 (0.106)	0.565 (0.079)	0.441 (0.060)
			Sawtooth Hatchery					
Redfish L. Cr. Trap	12 May 11	51,672	0.724 (0.008)	0.833 (0.022)	1.010 (0.028)	0.793 (0.045)	0.667 (0.037)	0.483 (0.026)

Appendix Table B4. Estimated detection probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2011. Estimates based on the single-release model. Standard errors in parentheses.

	Yearling Chinook salmon				
Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Clearwater Hatchery			
Clear Creek	17,092	0.300 (0.005)	0.375 (0.006)	0.260 (0.006)	0.382 (0.010)
Crooked River	25,488	0.291 (0.005)	0.366 (0.006)	0.280 (0.008)	0.308 (0.010)
Powell Pond	17,089	0.281 (0.005)	0.332 (0.007)	0.250 (0.008)	0.272 (0.010)
Red River Pond	17,060	0.283 (0.009)	0.262 (0.011)	0.272 (0.014)	0.167 (0.014)
Selway River	17,082	0.284 (0.005)	0.345 (0.006)	0.234 (0.006)	0.375 (0.010)
		Dworshak Hatchery			
NF Clearwater R.	51,753	0.254 (0.003)	0.348 (0.004)	0.262 (0.005)	0.290 (0.006)
		Kooskia Hatchery			
Clear Creek	13,932	0.277 (0.007)	0.352 (0.009)	0.284 (0.013)	0.228 (0.014)
		Lookingglass Hatchery			
Catherine Cr. Pond	20,837	0.334 (0.009)	0.289 (0.011)	0.317 (0.016)	0.126 (0.013)
Grande Ronde Pond	1,967	0.315 (0.020)	0.269 (0.022)	0.318 (0.033)	0.085 (0.024)
Imnaha Weir	20,755	0.321 (0.006)	0.330 (0.008)	0.327 (0.012)	0.131 (0.009)
Lookingglass H.	1,994	0.365 (0.016)	0.335 (0.018)	0.297 (0.025)	0.124 (0.021)
Lostine Pond	1,992	0.320 (0.019)	0.235 (0.020)	0.428 (0.033)	0.071 (0.019)
		McCall Hatchery			
Johnson Creek	4,165	0.211 (0.016)	0.204 (0.018)	0.300 (0.030)	0.067 (0.018)
Knox Bridge	51,875	0.259 (0.004)	0.235 (0.004)	0.297 (0.007)	0.120 (0.005)
		Nez Perce Tribal Hatchery			
Nez Perce Tribal H.	5,900	0.294 (0.010)	0.387 (0.014)	0.325 (0.019)	0.262 (0.021)
		Pahsimeroi Hatchery			
Pahsimeroi Pond	21,131	0.381 (0.006)	0.436 (0.007)	0.300 (0.008)	0.420 (0.012)
		Rapid River Hatchery			
Rapid River H.	51,730	0.326 (0.004)	0.291 (0.004)	0.316 (0.006)	0.157 (0.005)
		Sawtooth Hatchery			
Sawtooth H.	18,938	0.386 (0.007)	0.360 (0.008)	0.340 (0.013)	0.148 (0.011)
Yankee Fork	2,395	0.311 (0.026)	0.274 (0.035)	0.372 (0.049)	0.155 (0.040)

Appendix Table B5. Estimated detection probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2011. Estimates based on the single-release model. Standard errors in parentheses.

		Juvenile steelhead			
Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Clearwater Hatchery			
S.F. Clearwater	33,822	0.382 (0.004)	0.395 (0.004)	0.347 (0.006)	0.184 (0.006)
		Dworshak Hatchery			
Clear Creek	4,933	0.489 (0.009)	0.599 (0.011)	0.500 (0.015)	0.258 (0.015)
Clearwater R.	17,503	0.404 (0.005)	0.576 (0.006)	0.482 (0.008)	0.277 (0.008)
Eldorado Creek	756	0.365 (0.029)	0.291 (0.034)	0.372 (0.057)	0.032 (0.022)
S.F. Clearwater R.	7,008	0.420 (0.008)	0.520 (0.010)	0.475 (0.013)	0.240 (0.013)
		Hagerman Hatchery			
East Fork Salmon R.	6,981	0.261 (0.009)	0.162 (0.010)	0.351 (0.016)	0.028 (0.006)
Sawtooth Hatch. (4/15)	6,747	0.290 (0.008)	0.280 (0.010)	0.268 (0.014)	0.130 (0.011)
Sawtooth Hatch. (4/27)	6,662	0.281 (0.009)	0.281 (0.012)	0.376 (0.018)	0.042 (0.007)
Yankee Fork	8,212	0.304 (0.009)	0.191 (0.009)	0.416 (0.018)	0.047 (0.008)
		Irrigon Hatchery			
Big Canyon Fac. (4/13)	4,352	0.296 (0.010)	0.259 (0.012)	0.345 (0.016)	0.078 (0.010)
Big Canyon Fac. (4/26)	4,389	0.307 (0.010)	0.282 (0.013)	0.286 (0.018)	0.085 (0.011)
Little Sheep Facility	21,900	0.347 (0.005)	0.235 (0.006)	0.388 (0.010)	0.059 (0.005)
Wallowa Hatch. (4/10)	9,950	0.328 (0.007)	0.334 (0.009)	0.306 (0.011)	0.113 (0.008)
Wallowa Hatch. (4/24)	3,495	0.324 (0.012)	0.293 (0.014)	0.267 (0.019)	0.094 (0.013)
		Lyons Ferry Hatchery			
Cottonwood Pond	6,000	0.373 (0.009)	0.373 (0.011)	0.243 (0.013)	0.167 (0.013)
		Magic Valley Hatchery			
E. F. Salmon R.	4,983	0.288 (0.011)	0.270 (0.013)	0.421 (0.021)	0.034 (0.008)
Little Salmon R.	7,659	0.403 (0.008)	0.326 (0.009)	0.430 (0.014)	0.094 (0.009)
Pahsimeroi R. Trap	7,166	0.322 (0.008)	0.292 (0.010)	0.402 (0.015)	0.028 (0.005)
Salmon R. (rkm 347)	1,599	0.361 (0.019)	0.360 (0.022)	0.380 (0.031)	0.126 (0.024)
Salmon R. (rkm 385)	2,081	0.380 (0.016)	0.285 (0.019)	0.416 (0.029)	0.074 (0.016)
Salmon R. (rkm 476)	2,095	0.392 (0.017)	0.283 (0.019)	0.376 (0.029)	0.092 (0.018)
Salmon R. (rkm 506)	2,093	0.336 (0.016)	0.281 (0.019)	0.346 (0.028)	0.062 (0.014)
Squaw Creek	5,076	0.320 (0.012)	0.238 (0.014)	0.389 (0.022)	0.040 (0.009)
		Niagara Springs Hatchery			
Hells Canyon Dam	8,234	0.408 (0.008)	0.432 (0.009)	0.443 (0.013)	0.166 (0.011)
Little Salmon R.	6,922	0.408 (0.008)	0.342 (0.010)	0.434 (0.015)	0.102 (0.010)
Pahsimeroi Trap	12,840	0.336 (0.007)	0.246 (0.008)	0.366 (0.012)	0.044 (0.005)

Appendix Table B6. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2011. Estimates based on the single-release model. Standard errors in parentheses.

	Juvenile sockeye salmon						
Release site	Release date	Number released	Lower Granite	Little Goose	Lower Monumental	McNary
			Oxbow Hatchery			
Redfish L Cr Trap	12 May 2011	9,975	0.252 (0.009)	0.107 (0.007)	0.364 (0.018)	0.088 (0.013)
			Sawtooth Hatchery			
Redfish L Cr Trap	12 May 2011	51,672	0.247 (0.003)	0.062 (0.002)	0.464 (0.008)	0.117 (0.007)

Appendix Table B7. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2011. 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	23 Mar-31 May	597	0.475 (0.056)	0.995 (0.217)	0.598 (0.141)	1.912 (1.233)	0.540 (0.338)
Catherine Creek	22 Feb-28 May	430	0.400 (0.043)	0.748 (0.111)	1.617 (0.493)	0.383 (0.187)	0.185 (0.069)
Crooked River	22 Mar-29 May	996	0.665 (0.046)	0.768 (0.092)	NA	NA	NA
Grande Ronde	07 Mar-24 May	3,377	0.890 (0.014)	0.960 (0.027)	0.964 (0.041)	0.925 (0.068)	0.761 (0.049)
Imnaha	01 Feb-29 May	3,215	0.821 (0.014)	0.925 (0.024)	0.944 (0.035)	0.869 (0.058)	0.623 (0.037)
Johnson Creek	02 Mar-31 May	1,447	0.552 (0.023)	0.972 (0.066)	0.935 (0.083)	0.884 (0.186)	0.444 (0.089)
Knox Bridge	05 Mar-3 May	624	0.583 (0.043)	0.899 (0.116)	0.785 (0.114)	1.783 (0.793)	0.734 (0.321)
Lemhi River	09 Mar-30 May	684	0.726 (0.038)	1.226 (0.168)	0.781 (0.147)	1.013 (0.330)	0.704 (0.209)
Lookingglass Cr.	26 Jan-3 May	324	0.499 (0.040)	1.019 (0.110)	0.934 (0.159)	0.835 (0.236)	0.397 (0.099)
Lostine River	31 Jan-12 May	1,732	0.573 (0.019)	0.969 (0.053)	1.081 (0.091)	0.737 (0.108)	0.442 (0.057)
Lw. S.F. Salmon	02 Mar-22 Mar	1,034	0.528 (0.024)	0.932 (0.060)	0.986 (0.094)	0.787 (0.150)	0.382 (0.067)
Minam	01 Mar-13 May	1,092	0.590 (0.032)	0.903 (0.086)	0.996 (0.127)	1.009 (0.263)	0.536 (0.129)
Pahsimeroi	26 Feb-25 May	313	0.577 (0.058)	0.970 (0.166)	NA	NA	NA
Red River	09 Apr-30 May	655	0.335 (0.038)	0.943 (0.182)	NA	NA	NA
Salmon	08 Mar-08 May	6,023	0.854 (0.009)	0.957 (0.017)	0.940 (0.025)	0.854 (0.037)	0.656 (0.024)
Sawtooth	19 Mar-16 May	2,055	0.534 (0.028)	0.837 (0.082)	1.010 (0.124)	1.069 (0.285)	0.482 (0.121)
Snake	25 Mar-12 May	8,247	0.943 (0.009)	0.913 (0.013)	0.954 (0.020)	0.832 (0.027)	0.683 (0.019)
U. Grande Ronde	11 Mar-31 May	673	0.449 (0.032)	0.903 (0.091)	0.981 (0.149)	0.852 (0.305)	0.339 (0.114)
			Wild Sockeye Salmon				
Pettit Lake Cr	11 May-28 May	413	0.380 (0.111)	0.638 (0.234)	0.716 (0.224)	1.862 (1.739)	0.324 (0.297)
Redfish Lake Cr	12 Apr-22 Jun	1,279	0.401 (0.037)	0.839 (0.130)	0.876 (0.163)	1.128 (0.530)	0.332 (0.150)

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	01 Feb-31 May	2,618	0.641 (0.017)	0.992 (0.044)	0.838 (0.057)	0.988 (0.127)	0.526 (0.061)
Crooked River	22 Mar-26 May	103	0.653 (0.069)	0.818 (0.130)	1.108 (0.278)	0.278 (0.106)	0.164 (0.049)
Grande Ronde	16 Mar-24 May	1,023	0.944 (0.028)	0.932 (0.044)	1.140 (0.090)	0.811 (0.125)	0.814 (0.111)
Imnaha	07 Feb-31 May	2,268	0.800 (0.018)	1.034 (0.045)	1.037 (0.079)	0.732 (0.106)	0.628 (0.080)
Lookingglass Cr.	26 Jan-06 May	199	0.495 (0.052)	1.094 (0.150)	0.778 (0.174)	0.990 (0.605)	0.417 (0.245)
Lostine River	01 Feb-13 May	596	0.278 (0.023)	1.247 (0.167)	0.970 (0.219)	0.521 (0.181)	0.175 (0.052)
Minam River	15 Mar-10 May	615	0.682 (0.036)	0.960 (0.085)	1.079 (0.160)	0.993 (0.335)	0.701 (0.219)
Rapid River	23 Apr-31 May	317	0.857 (0.056)	0.872 (0.126)	1.087 (0.208)	1.058 (0.512)	0.860 (0.395)
Salmon	17 Mar-08 May	112	0.902 (0.094)	0.775 (0.120)	1.285 (0.399)	NA	NA
Snake	31 Mar-12 May	515	0.983 (0.037)	0.932 (0.069)	0.971 (0.120)	0.848 (0.217)	0.754 (0.176)
U. Grande Ronde	11 Mar-31 May	617	0.486 (0.031)	1.097 (0.107)	0.969 (0.141)	0.633 (0.168)	0.327 (0.079)
			Hatchery Chinook Salmon				
Grande Ronde	27 Mar-14 May	1,403	0.812 (0.028)	0.911 (0.047)	1.099 (0.098)	0.864 (0.178)	0.703 (0.134)
Salmon	14 Mar-28 Apr	3,995	0.796 (0.015)	0.952 (0.029)	1.096 (0.055)	0.714 (0.062)	0.593 (0.045)
Snake	25 Mar-12 May	3,262	0.930 (0.018)	0.929 (0.027)	0.967 (0.042)	0.778 (0.049)	0.649 (0.034)
			Hatchery Sockeye Salmon				
Redfish Lake Cr	09 May-22 Jun	1,174	0.505 (0.031)	0.982 (0.097)	0.937 (0.131)	0.880 (0.271)	0.409 (0.118)
			Hatchery Steelhead				
Grande Ronde	12 Apr-24 May	2,880	0.924 (0.018)	1.007 (0.033)	0.911 (0.048)	0.901 (0.095)	0.762 (0.073)
Salmon	17 Mar-08 May	877	0.857 (0.031)	0.924 (0.052)	0.927 (0.082)	0.701 (0.131)	0.514 (0.088)
Snake	01 Apr-12 May	1,835	0.985 (0.019)	0.965 (0.034)	0.923 (0.053)	0.741 (0.084)	0.650 (0.066)

Appendix Table B8. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2011. 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	23 Mar-31 May	597	0.321 (0.045)	0.233 (0.048)	0.492 (0.080)	0.069 (0.047)
Catherine Creek	22 Feb-28 May	430	0.401 (0.052)	0.430 (0.061)	0.300 (0.096)	0.222 (0.098)
Crooked River	22 Mar-29 May	996	0.335 (0.029)	0.260 (0.031)	0.366 (0.055)	0.038 (0.026)
Grande Ronde	7 Mar-24 May	3,377	0.415 (0.011)	0.384 (0.013)	0.383 (0.017)	0.277 (0.020)
Imnaha	1 Feb-29 May	3,215	0.416 (0.011)	0.446 (0.014)	0.421 (0.017)	0.293 (0.020)
Johnson Creek	2 Mar-31 May	1,447	0.363 (0.021)	0.236 (0.020)	0.438 (0.034)	0.110 (0.025)
Knox Bridge	5 Mar-3 May	624	0.379 (0.036)	0.293 (0.040)	0.537 (0.059)	0.083 (0.040)
Lemhi River	9 Mar-30 May	684	0.395 (0.028)	0.210 (0.032)	0.357 (0.050)	0.130 (0.043)
Lookingglass Cr.	26 Jan-3 May	324	0.389 (0.044)	0.385 (0.052)	0.367 (0.066)	0.290 (0.082)
Lostine River	31 Jan-12 May	1,732	0.414 (0.019)	0.312 (0.021)	0.371 (0.031)	0.204 (0.031)
Lw. S.F. Salmon	2 Mar-22 Mar	1,034	0.410 (0.026)	0.345 (0.028)	0.401 (0.039)	0.185 (0.037)
Minam	1 Mar-13 May	1,092	0.366 (0.026)	0.252 (0.027)	0.370 (0.042)	0.129 (0.035)
Pahsimeroi	26 Feb-25 May	313	0.327 (0.045)	0.289 (0.054)	0.345 (0.083)	0.040 (0.039)
Red River	09 Apr-30 May	655	0.319 (0.045)	0.285 (0.055)	0.204 (0.073)	0.042 (0.041)
Salmon	08 Mar-08 May	6,023	0.436 (0.008)	0.461 (0.010)	0.411 (0.012)	0.384 (0.016)
Sawtooth	19 Mar-16 May	2,055	0.329 (0.021)	0.213 (0.022)	0.378 (0.037)	0.100 (0.027)
Snake	25 Mar-12 May	8,247	0.395 (0.008)	0.506 (0.010)	0.415 (0.012)	0.442 (0.016)
U. Grande Ronde	11 Mar-31 May	673	0.384 (0.036)	0.324 (0.039)	0.370 (0.056)	0.103 (0.040)
			Wild Sockeye Salmon			
Pettit Lake Cr	11 May-28 May	413	0.127 (0.045)	0.209 (0.062)	0.417 (0.105)	0.091 (0.087)
Redfish Lake Cr	12 Apr-22 Jun	1,279	0.259 (0.029)	0.161 (0.027)	0.358 (0.054)	0.095 (0.045)

Appendix Table B8. Continued.

Trap	Release dates	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
			Wild Steelhead			
Asotin Creek	1 Feb-31 May	2,618	0.428 (0.015)	0.419 (0.020)	0.413 (0.027)	0.207 (0.028)
Crooked River	22 Mar-26 May	103	0.550 (0.074)	0.444 (0.089)	0.615 (0.157)	0.111 (0.105)
Grande Ronde	16 Mar-24 May	1,023	0.364 (0.019)	0.377 (0.021)	0.306 (0.026)	0.160 (0.025)
Imnaha	7 Feb-31 May	2,268	0.433 (0.014)	0.332 (0.017)	0.334 (0.025)	0.117 (0.018)
Lookingglass Cr.	26 Jan-6 May	199	0.335 (0.054)	0.435 (0.070)	0.499 (0.106)	0.133 (0.088)
Lostine River	1 Feb-13 May	596	0.362 (0.041)	0.284 (0.049)	0.315 (0.066)	0.078 (0.038)
Minam River	15 Mar-10 May	615	0.403 (0.030)	0.350 (0.036)	0.322 (0.048)	0.088 (0.032)
Rapid River	23 Apr-31 May	317	0.449 (0.041)	0.254 (0.044)	0.364 (0.063)	0.054 (0.031)
Salmon	17 Mar-08 May	112	0.406 (0.063)	0.452 (0.074)	0.295 (0.099)	NA
Snake	31 Mar-12 May	515	0.464 (0.028)	0.340 (0.031)	0.321 (0.040)	0.119 (0.032)
U. Grande Ronde	11 Mar-31 May	617	0.360 (0.033)	0.267 (0.034)	0.342 (0.048)	0.102 (0.032)
			Hatchery Chinook Salmon			
Grande Ronde	27 Mar-14 May	1,403	0.332 (0.018)	0.364 (0.021)	0.302 (0.028)	0.104 (0.022)
Salmon	14 Mar-28 Apr	3,995	0.355 (0.010)	0.316 (0.012)	0.288 (0.015)	0.182 (0.016)
Snake	25 Mar-12 May	3,262	0.330 (0.010)	0.371 (0.012)	0.290 (0.014)	0.307 (0.018)
			Hatchery Sockeye Salmon			
Redfish Lake Cr	9 May-22 Jun	1,174	0.302 (0.025)	0.239 (0.026)	0.332 (0.043)	0.167 (0.051)
			Hatchery Steelhead			
Grande Ronde	12 Apr-24 May	2,880	0.352 (0.011)	0.355 (0.013)	0.297 (0.016)	0.110 (0.012)
Salmon	17 Mar-8 May	877	0.374 (0.022)	0.400 (0.026)	0.371 (0.034)	0.111 (0.024)
Snake	1 Apr-12 May	1,835	0.412 (0.014)	0.390 (0.016)	0.357 (0.021)	0.139 (0.017)

Appendix Table B9. Survival probabilities for PIT-tagged yearling Chinook, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2011. 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	0.354 (0.013)	0.844 (0.075)	0.523 (0.177)	0.442 (0.145)	0.156 (0.051)
Easton Pond	12,001	0.262 (0.013)	1.159 (0.177)	0.786 (0.550)	0.911 (0.625)	0.239 (0.164)
Jack Creek Pond	12,000	0.245 (0.012)	1.017 (0.133)	0.465 (0.202)	0.473 (0.198)	0.116 (0.048)
East Bank						
Carlton Pond	5,018	0.489 (0.038)	0.856 (0.135)	1.472 (0.847)	1.260 (0.710)	0.616 (0.344)
Chiwawa Pond	9,412	0.556 (0.045)	1.019 (0.184)	NA	NA	NA
Dryden Pond	29,925	0.666 (0.019)	1.002 (0.063)	0.624 (0.095)	0.626 (0.090)	0.417 (0.059)
Similkameen River	5,089	0.718 (0.102)	0.580 (0.146)	NA	NA	NA
Entiat						
Entiat Hatchery	9,960	0.536 (0.041)	1.320 (0.271)	0.481 (0.209)	0.635 (0.253)	0.340 (0.133)
Leavenworth						
Leavenworth NFH	14,873	0.432 (0.022)	0.967 (0.126)	0.362 (0.179)	0.350 (0.168)	0.151 (0.072)
Methow						
Methow Hatchery	7,998	0.485 (0.039)	1.133 (0.224)	0.886 (0.632)	1.004 (0.697)	0.486 (0.335)
Wolf Creek	7,999	0.412 (0.038)	0.995 (0.201)	0.637 (0.450)	0.634 (0.437)	0.261 (0.179)
Ringold						
Chelan River	5,011	0.602 (0.057)	1.121 (0.238)	0.407 (0.162)	0.456 (0.165)	0.274 (0.096)
Turtle Rock Hatchery	4,945	0.590 (0.057)	1.071 (0.200)	0.320 (0.094)	0.343 (0.091)	0.202 (0.050)
Wells						
Wells Hatchery	5,998	0.512 (0.073)	0.646 (0.218)	NA	NA	NA
Winthrop						
Winthrop NFH	3,993	0.529 (0.051)	1.177 (0.297)	0.638 (0.634)	0.751 (0.728)	0.397 (0.383)
Winthrop Back Channel	6,920	0.384 (0.032)	1.056 (0.220)	0.431 (0.302)	0.455 (0.309)	0.175 (0.118)

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			
Chelan						
Wenatchee River	10,028	0.405 (0.044)	0.848 (0.175)	0.371 (0.260)	0.315 (0.216)	0.128 (0.086)
East Bank						
Rolfing Pond	9,845	0.354 (0.032)	0.935 (0.148)	0.503 (0.347)	0.470 (0.321)	0.167 (0.113)
Wenatchee River	10,790	0.604 (0.046)	0.797 (0.105)	0.961 (0.673)	0.766 (0.533)	0.463 (0.320)
Turtle Rock						
Chiwawa River	4,226	0.588 (0.058)	1.039 (0.177)	NA	NA	NA
Nason Creek	5,256	0.551 (0.045)	1.098 (0.159)	0.350 (0.195)	0.384 (0.212)	0.212 (0.116)
Wenatchee River	8,506	0.585 (0.055)	1.033 (0.172)	1.131 (1.127)	1.169 (1.158)	0.684 (0.674)
Winthrop						
Winthrop NFH	29,580	0.330 (0.014)	1.549 (0.137)	0.555 (0.131)	0.860 (0.195)	0.284 (0.063)
			Coho Salmon			
Cascade						
Leavenworth NFH	11,158	0.339 (0.026)	1.018 (0.180)	0.985 (0.977)	1.003 (0.984)	0.340 (0.333)
Winthrop						
Winthrop NFH	6,994	0.416 (0.036)	1.578 (0.376)	0.786 (0.792)	1.241 (1.224)	0.516 (0.507)

Appendix Table B10. Estimated detection probabilities for PIT-tagged yearling Chinook salmon, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2011. 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	0.277 (0.011)	0.280 (0.024)	0.120 (0.040)
Cle Elum	Easton Pond	12,001	0.256 (0.015)	0.206 (0.030)	0.048 (0.033)
Cle Elum	Jack Creek Pond	12,000	0.265 (0.015)	0.251 (0.032)	0.106 (0.045)
East Bank	Carlton Pond	5,018	0.190 (0.016)	0.194 (0.028)	0.042 (0.024)
East Bank	Chiwawa Pond	9,412	0.109 (0.010)	0.160 (0.026)	NA
East Bank	Dryden Pond	29,925	0.172 (0.006)	0.162 (0.010)	0.083 (0.012)
East Bank	Similkameen River	5,089	0.087 (0.013)	0.178 (0.038)	NA
Entiat	Entiat Hatchery	9,960	0.145 (0.012)	0.087 (0.017)	0.041 (0.016)
Leavenworth	Leavenworth NFH	14,873	0.148 (0.008)	0.257 (0.032)	0.054 (0.026)
Methow	Methow Hatchery	7,998	0.146 (0.013)	0.135 (0.025)	0.033 (0.023)
Methow	Wolf Creek	7,999	0.121 (0.012)	0.182 (0.034)	0.037 (0.026)
Ringold	Chelan River	5,011	0.139 (0.015)	0.114 (0.022)	0.107 (0.038)
Ringold	Turtle Rock Hatcheryt	4,945	0.120 (0.013)	0.143 (0.024)	0.109 (0.028)
Wells	Wells Hatchery	5,998	0.131 (0.020)	0.118 (0.037)	NA
Winthrop	Winthrop NFH	3,993	0.165 (0.018)	0.140 (0.034)	0.059 (0.057)
Winthrop	Winthrop Back Channel	6,920	0.148 (0.014)	0.198 (0.039)	0.063 (0.043)
		Steelhead			
Chelan	Wenatchee River	10,028	0.068 (0.008)	0.240 (0.043)	0.043 (0.030)
East Bank	Rolfing Pond	9,845	0.073 (0.008)	0.305 (0.041)	0.058 (0.039)
East Bank	Wenatchee R.	10,790	0.075 (0.006)	0.287 (0.032)	0.026 (0.018)
Turtle Rock	Chiwawa River	4,226	0.064 (0.008)	0.351 (0.050)	NA
Turtle Rock	Nason Creek	5,256	0.069 (0.007)	0.355 (0.043)	0.077 (0.042)
Turtle Rock	Wenatchee R	8,506	0.058 (0.006)	0.244 (0.034)	0.017 (0.017)
Winthrop	Winthrop NFH	29,580	0.115 (0.006)	0.146 (0.012)	0.086 (0.019)
		Coho Salmon			
Cascade	Leavenworth NFH	11,158	0.128 (0.011)	0.201 (0.033)	0.031 (0.030)
Winthrop	Winthrop NFH	6,994	0.120 (0.012)	0.138 (0.031)	0.021 (0.021)

APPENDIX C

Environmental Conditions and Salmonid Passage Timing

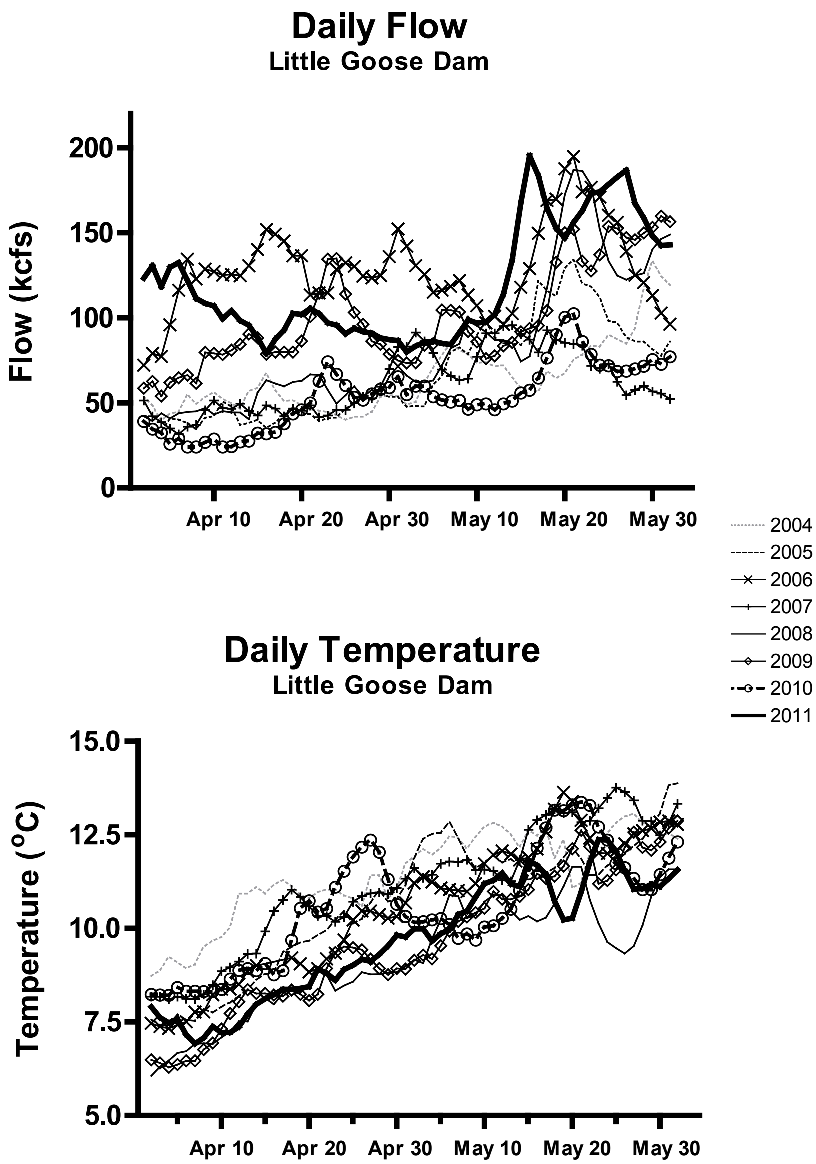
Methods

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 2011 from the Columbia River DART website on 25 August, 2011. We created plots to compare daily measures of flow, temperature, and spill at Little Goose Dam from 2011 to those from 2004-2010. We created plots and calculated cumulative passage proportions to compare daily estimates of numbers of smolts passing Lower Granite Dam in 2011 to those of 2008-2010.

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 shown in Figure 5).

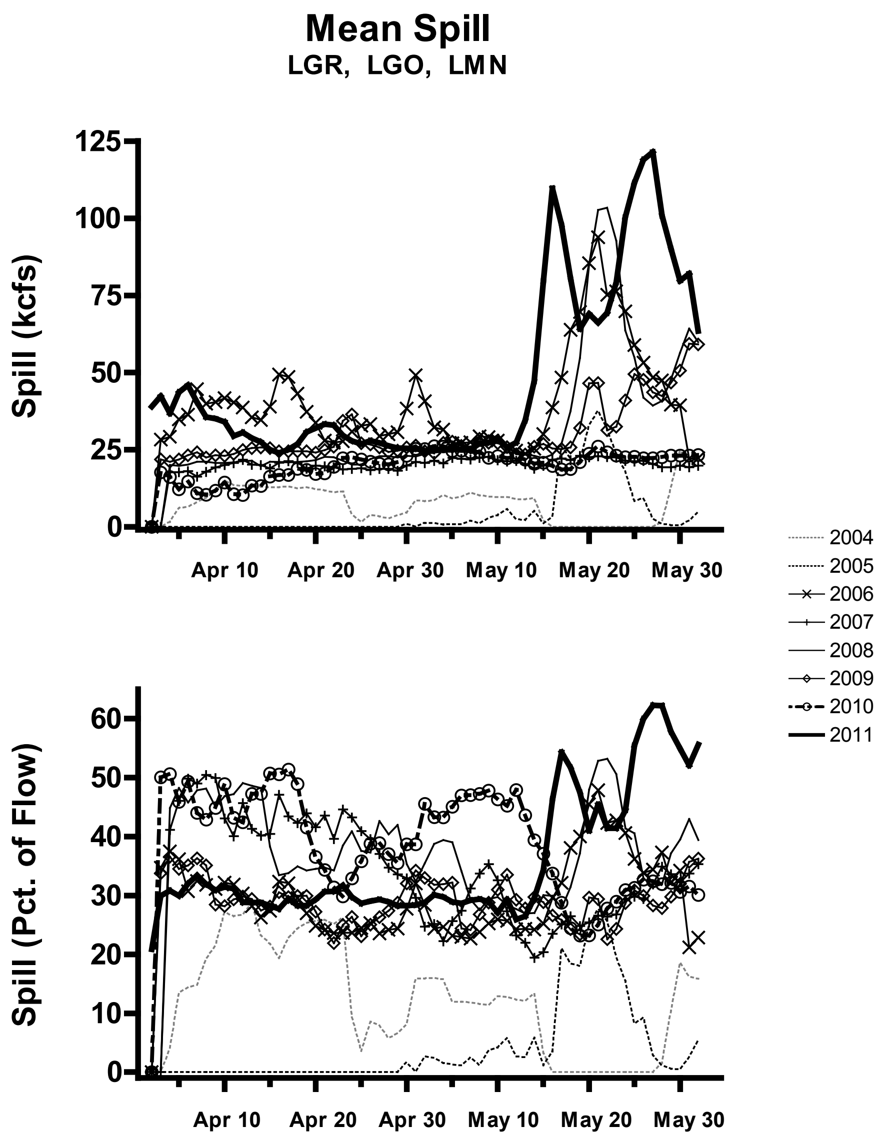
Results

Snake River flow volume in 2011 was higher than in recent years for most of the migration period (Appendix Figure C1). With the exception of higher flow in early April, the flow volume and pattern during April and early May in 2011 were most similar to 2009, while the volume and pattern during the remainder of May and June were more similar to 2006 and 2008. Snake River flow increased sharply starting around 10 May, rising from near 90 kcfs to over 200 kcfs on 16 May, and then stayed above 150 kcfs through the end of May.



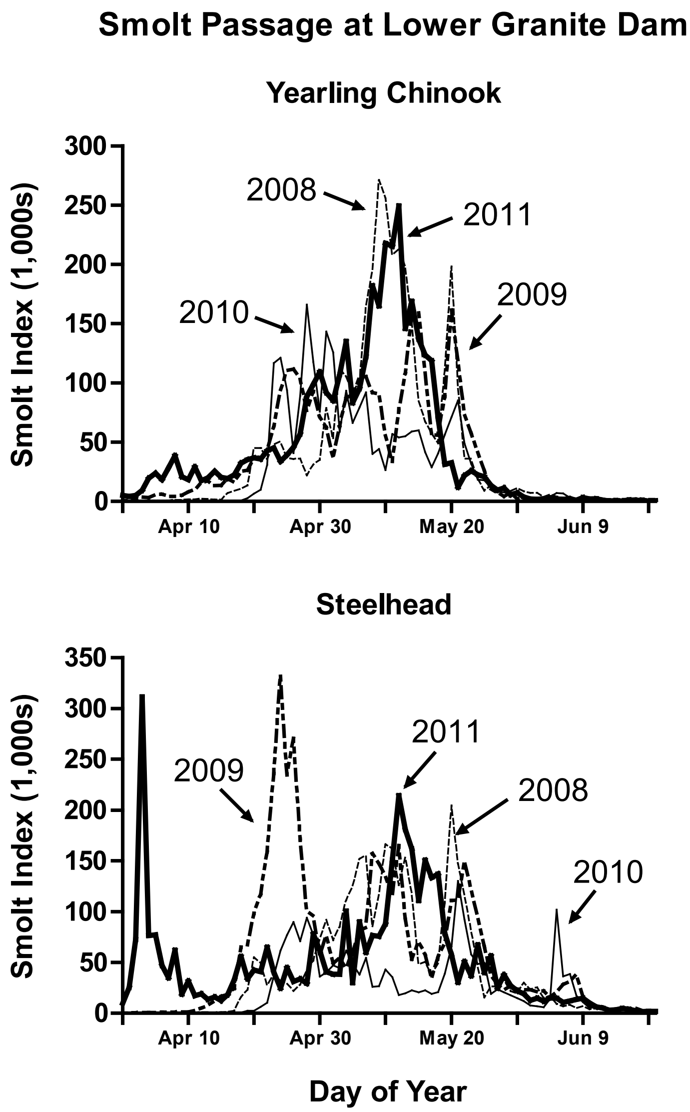
Appendix Figure C1. Daily Snake River flow (kcfs) and temperature (°C) measured at Little Goose Dam during April and May, 2004-2011.

Mean spill volume at the Snake River dams in 2011 was on the high end of average until about 15 May when high flow forced very high spill volumes (Appendix Figure C2). Average Snake River spill percentages in 2011 hovered around 30% until the flow increase in early May, when average spill percentages increased to levels higher than any seen in recent years (Appendix Figure C2). Water temperatures in the Snake River in 2011 were on the cool side of average for most of the season (Appendix Figure C1).



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, 2004-2011.

The first arrivals of yearling Chinook salmon and steelhead smolts at Lower Granite Dam in 2011 occurred earlier than in 2008-2010 (Appendix Figure C3). The early pulse of steelhead was the result of earlier-than-usual releases from some hatcheries. Despite the early initial arrivals, the bulk of the passage distributions and the peaks occurred at similar times as in previous years for both yearling Chinook and steelhead. The median day of passage at Lower Granite Dam for yearling Chinook salmon in 2011 was 8 May, while in 2010 it was 3 May. The median day of passage for steelhead was 10 May, while in 2010 it was 11 May.



Appendix Figure C3. Daily smolt passage index of yearling Chinook salmon and steelhead passing Lower Granite Dam, 2008-2011.