Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs, 2013

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EXECUTIVE SUMMARY

In 2013, we completed the 21st 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 tagged and released a total of 17,384 hatchery steelhead *O. mykiss*, 7,521 wild steelhead, and 11,517 wild yearling Chinook salmon *O. tshawytscha* at Lower Granite Dam on the Snake River.

In addition, we used detections of fish tagged by other researchers at traps and hatcheries upstream from Lower Granite Dam and at other sites on the Snake and Columbia Rivers. Detection sites were the smolt collection facilities at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville Dam, as well as the Bonneville Dam corner collector and 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 2013 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

In 2013, we estimated reach survival and travel time for PIT-tagged yearling Chinook salmon (hatchery and wild), hatchery sockeye salmon *O. nerka*, hatchery coho salmon *O. kisutch*, and steelhead (hatchery and wild). During most of the 2013 migration season, detections of yearling Chinook salmon and steelhead were sufficient for daily or weekly estimates of survival and detection probability.

Hatchery and wild study fish were combined in some analyses. For PIT-tagged fish detected or released at Lower Granite Dam, the respective overall percentages of hatchery and wild fish were 55 and 45% for yearling Chinook and 76 and 24% for steelhead. Based on counts at Lower Granite Dam by the Fish Passage Center, and on our own estimates of daily detection probability, we estimated that 88.0% of the overall yearling Chinook salmon run in 2013 was of hatchery origin. We could not calculate this number for steelhead because separate collection counts for hatchery and wild fish were not available.

All estimates of survival in reaches of river between dams were calculated from tailrace to tailrace. Estimates of average survival in 2013 through these reaches are listed below for combined groups of wild and hatchery yearling Chinook salmon and steelhead (standard errors in parenthesis):

	Yearling Chinook salmon	Steelhead
Lower Granite to Little Goose Dam	0.922 (0.012)	0.921 (0.020)
Little Goose to Lower Monumental Dam	0.983 (0.014)	0.977 (0.020)
Lower Monumental to McNary Dam[a]	0.904 (0.022)	0.739 (0.031)
Lower Monumental to Ice Harbor	0.952 (0.037)	0.996 (0.032)
Ice Harbor to McNary	0.938 (0.048)	0.763 (0.033)
McNary to John Day Dam	0.931 (0.054)	0.799 (0.025)
John Day to Bonneville Dam[b]	0.823 (0.036)	1.026 (0.154)

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

For combined groups of wild and hatchery yearling Chinook and steelhead from the Snake River Basin, we also estimated average survival from the Snake River smolt trap at the head of Lower Granite reservoir to the tailrace of Bonneville Dam (eight projects). These estimates were the product of average survival estimates through three reaches: Snake River smolt trap to Lower Granite Dam, Lower Granite to McNary Dam, and McNary to Bonneville Dam. During 2013, estimated survival for the entire hydropower system was 0.525 (95% CI 0.432-0.612) for Snake River yearling Chinook salmon and 0.501 (0.354-0.648) for Snake River steelhead.

For both Snake River yearling Chinook salmon and steelhead, estimated survival through the entire hydropower system in 2013 was higher than the average of estimates over the last 15 years, but was lower than the estimates in 2012. However, differences between 2012 and 2013 estimates were not statistically significant.

We also estimated survival to McNary Dam tailrace for groups of hatchery yearling Chinook salmon released from individual locations in the Upper Columbia River. These estimates ranged from 0.776 (0.075) for East Bank Hatchery fish released to Dryden Pond on the Wenatchee River to 0.288 (0.015) for Cle Elum Hatchery fish released to Easton Pond on the Yakima River. Similar estimates for Upper Columbia River steelhead ranged from 0.518 (0.081) for Wells Hatchery fish released to the Methow River to 0.303 (0.075) for East Bank Hatchery fish released into Nason Creek on the Wenatchee River.

Estimates of survival from Snake River hatcheries to Lower Granite Dam suggested substantial mortality upstream from the Snake and Clearwater River confluence. Continued development of instream PIT-detection systems for use in tributaries will be necessary if the sources of mortality in these upstream areas are to be identified.

Estimated proportions of transported fish (wild and hatchery combined) in 2013 were 34% for yearling Chinook and 38% for steelhead. These estimates were higher than the record low estimated in 2012, but were still among the lowest estimates for 1993-2013. By the time transportation began at Lower Granite Dam on 27 April, about 26% of the yearling Chinook and 26% of the steelhead had already passed. Other factors contributing to the higher percentage of inriver migrants in 2013 were the use of surface-bypass structures at multiple dams and periods of relatively high spill. Fish that pass dams via the spillways cannot enter the juvenile fish facility to be collected for transportation.

We calculated travel time 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 times through the entire hydropower system were shorter than the long-term average (faster migration) for both yearling Chinook and steelhead for the majority of the migration.

As in other recent years, rates of PIT-tag detection continued to be relatively low in 2013 because of high rates of spill and the use of surface-bypass structures (removable and temporary spillway weirs, or RSWs and TSWs). Consequently, the precision of estimates based on PIT-tagged fish was impaired. We believe there is now an urgent need to develop PIT-tag detection capability in the TSW and RSW bypass structures or in normal spill bays to improve overall detection rates. As we have suggested in recent years, higher rates of detection are necessary if we are to maintain or enhance the precision of survival estimates based on data gathered from PIT-tagged smolts.

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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 2013, 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, 2011, 2012, 2013). In 2013, NMFS completed the 21st year of the study.

Research objectives in 2013 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.

During the 2013 migration season, fish used for these 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. Study fish were detected using automatic PIT-tag monitors (Prentice et al. 1990a,b,c) 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).

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 2013, detections at Bonneville Dam and in the pair trawl were sufficient to estimate survival from John Day tailrace to Bonneville Dam tailrace for some stocks, but not all. We estimated survival in this reach for groups of Snake and 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).

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

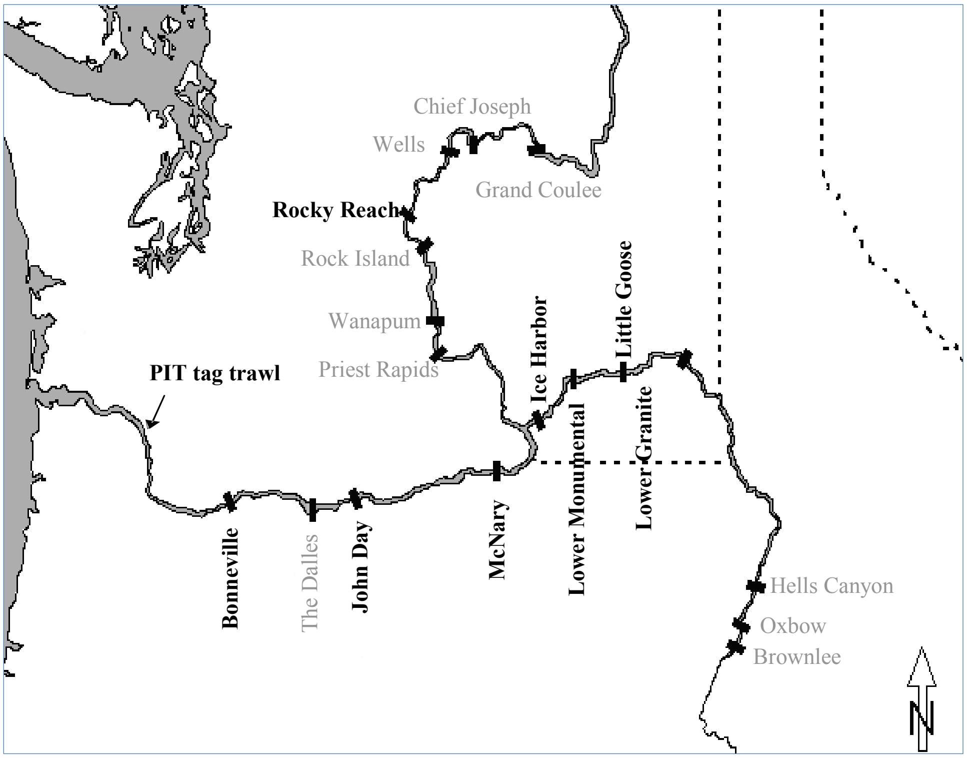


Figure 1. Study area showing sites with PIT-tag detection facilities (names in black), including dams and the PIT-tag trawl in the Columbia River estuary. Dams with names in gray do not have detection facilities.

- 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. In each year from 2006-2013, there have been sufficient detections at Ice Harbor to partition survival through this reach. However, low detection rates at Lower Monumental and Ice Harbor often result in survival estimates with poor precision.

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 2013, hatchery and wild steelhead and wild yearling Chinook salmon were collected at the Lower Granite Dam juvenile facility. These 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 to provide sufficient numbers for analysis over these periods.

No hatchery yearling Chinook salmon were tagged specifically for this study because sufficient numbers of these fish were PIT tagged and released from Snake River Basin hatcheries and traps by other researchers. Data from these fish were used for estimates of detection probability, survival, and travel time.

For both yearling Chinook salmon and steelhead tagged and released upstream from Lower Granite Dam, we created virtual daily "release groups" of fish according to date of detection at the dam. Each daily release group was combined with fish tagged and released at the dam on the same date. Daily release groups were then pooled into weekly groups, and we estimated survival probabilities for individual reaches between Lower Granite Dam tailrace and McNary Dam tailrace for both daily and weekly groups. Our analyses using weekly release groups excluded some daily groups of both yearling Chinook and steelhead that were detected at the dam during weeks early or late in the season when sample sizes were too small to produce reliable estimates of either survival or travel time.

At Lower Granite Dam, we PIT tagged and released 17,384 hatchery steelhead, 7,521 wild steelhead, and 11,517 wild yearling Chinook salmon from 26 April through 16 June 2013 (Table 1). Total mortalities of hatchery steelhead, wild steelhead, and wild yearling Chinook salmon were 9, 6, and 27, respectively. Each of these numbers represented well under 1% of the total fish handled. A total of 37,731 yearling Chinook salmon (20,678 hatchery origin, 17,053 wild) were either detected and returned to the tailrace of Lower Granite Dam or collected and PIT tagged at the dam and released to the tailrace. A total of 42,395 steelhead (32,138 hatchery origin and 10,257 wild) were similarly returned or released to the tailrace of Lower Granite Dam.

We estimated that 88.0% of the overall run of yearling Chinook salmon in 2013 was of hatchery origin. This estimate was based on counts of the run at large (both tagged and untagged fish) by the Fish Passage Center and our own estimates of daily detection probability at Lower Granite Dam (based on tagged fish only). We could not estimate the proportion of hatchery steelhead in the run at large because separate counts for hatchery and wild fish were not available. Proportions of hatchery fish in the combined groups used to estimate survival were 55% for yearling Chinook salmon and 76% for steelhead.

Releases from McNary Dam—For yearling Chinook salmon and steelhead tagged at all locations in the Snake River Basin and Upper Columbia River, we created virtual daily "release groups" 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. We estimated tailrace-to-tailrace survival from McNary to John Day and from John Day to Bonneville Dam for weekly groups only, as data were too sparse to estimate survival for daily groups.

Releases from Hatcheries and Smolt Traps—In 2013, most hatcheries in the Snake and Upper Columbia River Basins 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 (for fish originating in the Snake River Basin) or McNary Dam (for fish originating in the Upper Columbia River Basin) and to points downstream.

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 from other smolt traps throughout the Snake River Basin.

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 2013. 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
26 Apr	1,969	--	1	67	--	--	465	1	--
27 Apr	1,408	--	--	158	--	--	135	1	--
30 Apr	911	--	3	239	--	3	563	5	--
1 May	661	1	2	83	--	--	1,200	2	--
2 May	1,326	--	1	375	--	2	795	1	--
3 May	1,067	1	2	203	--	1	337	--	--
4 May	309	1	--	250	1	--	553	--	1
7 May	691	--	--	448	--	5	172	--	--
8 May	670	--	1	399	--	2	588	1	--
9 May	861	--	--	246	--	--	632	2	--
10 May	1,021	1	1	168	--	1	550	1	2
11 May	135	--	--	375	--	--	423	1	4
14 May	548	1	--	713	--	11	817	1	1
15 May	566	--	1	505	1	4	827	2	4
16 May	536	--	1	516	--	1	1,262	3	2
17 May	748	--	3	447	--	13	783	--	1
18 May	77	--	--	185	--	7	72	1	--
22 May	556	--	8	307	--	4	286	--	--
23 May	600	2	1	325	1	7	535	4	2
24 May	567	1	2	270	2	13	362	1	--
25 May	42	--	--	67	--	2	160	--	--
29 May	349	--	--	202	--	--			
30 May	303	--	1	209	--	1			
31 May	302	--	--	122	--	--			
1 Jun	99	--	--	69	--	--			
4 Jun	187	--	--	143	--	--			
5 Jun	160	1	--	92	1	--			
7 Jun	280	--	--	117	--	--			
8 Jun	30	--	--	40	--	--			
11 Jun	82	--	--	42	--	--			
12 Jun	90	--	--	52	--	--			
13 Jun	90	--	--	39	--	--			
14 Jun	99	--	--	25	--	--			
15 Jun	44	--	--	23	--	--			
Totals	17,384	9	28	7,521	6	77	11,517	27	17

Data Analysis

Tagging and detection data were downloaded on 5 August 2013 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 downloaded on the date indicated above. 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 detection-history data generated from PIT-tagged juvenile salmonids in the Snake and Columbia Rivers (Burnham et al. 1987). Chi-square contingency tests were used to evaluate model assumptions, with assumption violations indicated by significant differences between observed and expected proportions of fish in different detection-history categories. In many cases, sample sizes were large enough that these tests had sufficient power to detect small deviations from model assumptions that had only marginal effect on survival estimates. Appendix A contains a detailed discussion of these tests of assumption, the extent of assumption violations, and the implications of and possible reasons for these violations.

Survival Estimates—All survival estimates presented here were calculated from the tailrace of a dam to the tailrace of a downstream dam or from a release point upstream from the hydropower system to the tailrace of a downstream dam. 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) for analyses using the single-release model.

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 of survival through a particular river section or passage route were available for more than one release group, those estimates were combined to produce a weighted average (Muir et al. 2001a). For each group, weights were inversely proportional to their respective estimated relative variances (coefficient of variation squared). We used the inverse of estimated *relative* variance rather than *absolute* variance in weighting because 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, which results in lower survival estimates having disproportionate influence. Use of the inverse relative variance prevented the weighted mean from being biased toward the lower estimates.

For various stocks from both the Snake and Upper Columbia Rivers, we estimated survival from point of release to the tailrace of Bonneville Dam (the final dam encountered by seaward-migrating juvenile salmonids). For extended reaches like this, estimates were derived as the product of appropriate estimates from the shorter component reaches.

An important instance of estimated survival through an extended reach is that for fish released from the Snake River trap to Bonneville Dam tailrace. This trap is located near the head of Lower Granite reservoir, so the survival estimate is over essentially the entire eight-project hydropower system negotiated by juvenile salmonids from the Snake River Basin. For yearling Chinook salmon (hatchery and wild combined), we constructed the estimate for the extended reach from three components:

1) Survival from Snake River trap to Lower Granite Dam for pooled hatchery and wild fish tagged at and released from the trap.
2) Weighted mean estimated survival from Lower Granite Dam to McNary Dam for daily virtual groups of fish released from Lower Granite Dam.
3) Weighed mean estimated survival from McNary Dam to Bonneville Dam for weekly virtual groups of fish released from McNary Dam.

Our methods for constructing the virtual groups and for calculating weighted means of estimates are described above.

Results

Snake River Yearling Chinook Salmon

Estimates of Survival—For weekly groups of yearling Chinook salmon, survival probabilities from Lower Granite to multiple Snake River dams were estimated over 8 consecutive weeks during 30 March-24 May. Mean survival estimates were 0.922 (se 0.012) from Lower Granite to Little Goose, 0.983 (0.014) from Little Goose to Lower Monumental, and 0.781 (0.016) from Lower Monumental to McNary Dam (Tables 2 and 5). For the combined reach from Lower Granite to McNary Dam, mean estimated survival was 0.781 (0.016).

Table 2. Estimated survival probabilities for weekly groups of Snake River yearling Chinook salmon (hatchery and wild combined) detected and returned or tagged and released to the tailrace at Lower Granite Dam in 2013. Daily groups were pooled for weekly estimates, and weighted means are 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
30 Mar–5 Apr	363	0.964 (0.113)	0.760 (0.174)	0.788 (0.183)	0.578 (0.079)
6 Apr–12 Apr	1,934	0.920 (0.038)	0.911 (0.100)	0.875 (0.108)	0.733 (0.052)
13 Apr–19 Apr	2,400	0.849 (0.033)	0.971 (0.106)	0.934 (0.114)	0.769 (0.053)
20 Apr–26 Apr	2,736	0.852 (0.038)	1.038 (0.103)	0.893 (0.097)	0.790 (0.049)
27 Apr–3 May	6,949	0.954 (0.048)	0.972 (0.092)	0.802 (0.075)	0.744 (0.034)
4 May–10 May	10,298	0.845 (0.015)	1.036 (0.038)	1.008 (0.063)	0.883 (0.047)
11 May–17 May	10,685	0.968 (0.013)	0.987 (0.033)	0.815 (0.041)	0.778 (0.031)
18 May–24 May	1,721	0.934 (0.064)	1.173 (0.203)	0.776 (0.140)	0.849 (0.073)
Weighted mean[a]		**0.922 (0.012)**	**0.983 (0.014)**	**0.904 (0.022)**	**0.781 (0.016)**

a Weighted mean estimates for daily groups (24 Mar–31 May; see Table 5)

For weekly groups of yearling Chinook salmon, we estimated survival probabilities from McNary Dam to multiple dams on the Columbia River for six consecutive weeks during 20 April-31 May. Survival estimates averaged 0.931 (se 0.054) from McNary to John Day, 0.823 (0.036) from John Day to Bonneville, and 0.796 (0.064) 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 2013. Daily groups were pooled for weekly estimates, and weighted means are of independent estimates for weekly groups. 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	921	0.695 (0.079)	0.781 (0.273)	0.542 (0.180)
27 Apr–3 May	5,317	0.937 (0.086)	0.872 (0.219)	0.818 (0.191)
4 May–10 May	23,049	1.048 (0.068)	0.849 (0.112)	0.889 (0.103)
11 May–17 May	12,032	0.915 (0.082)	0.867 (0.199)	0.793 (0.168)
18 May–24 May	2,868	0.922 (0.136)	0.750 (0.268)	0.691 (0.225)
25 May–31 May	1,615	0.719 (0.117)	0.554 (0.195)	0.399 (0.124)
Weighted mean		**0.931 (0.054)**	**0.823 (0.036)**	**0.796 (0.064)**

We calculated the product of average estimates from Lower Granite to McNary and from McNary to Bonneville Dam to provide an overall estimate of survival from Lower Granite to Bonneville Dam. This produced an overall survival estimate of 0.622 (se 0.052) from Lower Granite to Bonneville Dam. For wild and hatchery yearling Chinook salmon released from the Snake River trap, estimated survival was 0.845 (0.031) from release to the tailrace of Lower Granite Dam. Thus, estimated survival probability through all eight hydropower projects encountered by Snake River yearling Chinook salmon was 0.525 (se 0.048).

We also estimated separate probabilities of survival from Lower Granite to McNary Dam for weekly groups of hatchery and wild yearling Chinook salmon (Table 4). Weighted mean survival estimates for Lower Granite to McNary Dam tailrace were similar between hatchery and wild groups.

Table 4. Estimated survival probabilities for weekly groups of Snake River hatchery and wild yearling Chinook salmon detected and returned or tagged and released to the tailrace at Lower Granite Dam in 2013. Daily groups were pooled for weekly estimates, and weighted means are of independent estimates for weekly groups. 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			
30 Mar–5 Apr	239	1.078 (0.212)	0.557 (0.162)	0.880 (0.216)	0.529 (0.082)
6 Apr–12 Apr	1,398	0.923 (0.051)	0.866 (0.122)	0.924 (0.142)	0.739 (0.064)
13 Apr–19 Apr	1,771	0.841 (0.042)	0.876 (0.110)	1.101 (0.158)	0.811 (0.071)
20 Apr–26 Apr	1,969	0.861 (0.054)	1.022 (0.137)	0.892 (0.125)	0.784 (0.059)
27 Apr–3 May	3,272	0.964 (0.086)	0.890 (0.147)	0.894 (0.141)	0.767 (0.058)
4 May–10 May	6,825	0.873 (0.026)	0.967 (0.052)	1.098 (0.096)	0.926 (0.069)
11 May–17 May	4,719	0.948 (0.023)	1.001 (0.058)	0.859 (0.080)	0.816 (0.063)
Weighted mean		**0.909 (0.018)**	**0.961 (0.027)**	**0.970 (0.044)**	**0.799 (0.033)**
		Wild yearling Chinook			
6 Apr–12 Apr	536	0.946 (0.056)	0.984 (0.173)	0.780 (0.158)	0.726 (0.086)
13 Apr–19 Apr	629	0.891 (0.052)	1.206 (0.257)	0.649 (0.152)	0.698 (0.075)
20 Apr–26 Apr	767	0.874 (0.055)	1.043 (0.153)	0.881 (0.152)	0.804 (0.089)
27 Apr–3 May	3,677	0.971 (0.058)	1.015 (0.118)	0.746 (0.086)	0.736 (0.042)
4 May–10 May	3,473	0.885 (0.019)	1.073 (0.053)	0.883 (0.079)	0.838 (0.064)
11 May–17 May	5,966	0.994 (0.015)	0.966 (0.040)	0.816 (0.048)	0.784 (0.036)
18 May–24 May	1,535	0.901 (0.063)	1.189 (0.208)	0.787 (0.145)	0.844 (0.076)
Weighted mean		**0.950 (0.021)**	**1.019 (0.025)**	**0.817 (0.021)**	**0.778 (0.018)**

We estimated survival probabilities for daily groups of yearling Chinook salmon (hatchery and wild combined) either detected and returned or PIT-tagged and released to the tailrace of Lower Granite Dam. These estimates were variable and showed no consistent increase or decrease in survival through Snake River reaches during the 2013 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 returned or PIT tagged and released to the tailrace at Lower Granite Dam in 2013. Daily groups were pooled as needed for sufficient sample size on the dates indicated. Weighted means are 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 Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
24 Mar–3Apr	306	0.797 (0.110)	0.627 (0.148)	1.113 (0.296)	0.557 (0.114)
4–6 Apr	350	0.878 (0.084)	1.019 (0.237)	0.722 (0.185)	0.646 (0.094)
7–9 Apr	986	0.927 (0.054)	0.795 (0.112)	0.987 (0.154)	0.728 (0.069)
10 Apr	284	1.159 (0.162)	0.861 (0.335)	0.624 (0.257)	0.622 (0.125)
11–12 Apr	462	0.888 (0.071)	1.093 (0.274)	0.820 (0.226)	0.796 (0.111)
13 Apr	259	0.805 (0.080)	0.962 (0.248)	1.112 (0.350)	0.862 (0.179)
14–15 Apr	804	0.829 (0.050)	1.028 (0.222)	0.823 (0.195)	0.701 (0.080)
16 Apr	415	0.830 (0.072)	0.987 (0.264)	1.075 (0.337)	0.881 (0.160)
17–18 Apr	574	0.880 (0.075)	0.967 (0.192)	0.840 (0.179)	0.715 (0.084)
19 Apr	348	0.949 (0.136)	0.872 (0.298)	1.152 (0.460)	0.954 (0.244)
20–21 Apr	858	0.812 (0.066)	1.131 (0.213)	0.985 (0.205)	0.904 (0.109)
22 Apr	349	0.850 (0.127)	0.936 (0.248)	0.793 (0.209)	0.631 (0.098)
23–24 Apr	539	1.004 (0.127)	1.181 (0.341)	0.634 (0.188)	0.752 (0.110)
25–26 Apr	990	0.832 (0.054)	0.944 (0.136)	0.992 (0.161)	0.779 (0.078)
27 Apr	346	0.983 (0.152)	1.002 (0.474)	0.896 (0.441)	0.883 (0.174)
28 Apr	157	0.993 (0.308)	0.667 (0.338)	1.044 (0.502)	0.692 (0.192)
29 Apr	856	0.740 (0.099)	1.119 (0.304)	0.920 (0.244)	0.763 (0.090)
30 Apr	1,320	1.122 (0.142)	0.759 (0.154)	0.799 (0.142)	0.680 (0.056)
1 May	1,702	0.874 (0.076)	1.066 (0.210)	0.796 (0.157)	0.741 (0.065)
2–3 May	2,568	1.023 (0.098)	0.930 (0.154)	0.816 (0.136)	0.776 (0.076)
4–7 May	4,184	0.867 (0.031)	1.003 (0.074)	1.046 (0.111)	0.910 (0.077)
8 May	1,791	0.852 (0.047)	1.028 (0.114)	1.092 (0.206)	0.957 (0.154)
9 May	2,172	0.819 (0.029)	1.047 (0.074)	0.912 (0.114)	0.782 (0.084)
10 May	2,151	0.915 (0.025)	1.013 (0.058)	0.983 (0.118)	0.911 (0.099)
11 May	1,830	0.931 (0.027)	0.955 (0.057)	0.826 (0.097)	0.735 (0.077)
12 May	1,473	0.961 (0.036)	1.002 (0.090)	0.908 (0.152)	0.874 (0.127)
13 May	1,479	0.996 (0.038)	0.957 (0.092)	0.750 (0.108)	0.716 (0.082)
14 May	1,691	0.976 (0.028)	0.974 (0.080)	1.048 (0.149)	0.996 (0.119)
15 May	1,603	0.984 (0.033)	0.864 (0.076)	0.934 (0.114)	0.794 (0.073)
16 May	1,633	0.951 (0.033)	0.988 (0.105)	0.770 (0.098)	0.724 (0.057)
17-21 May	1,414	1.010 (0.054)	1.089 (0.161)	0.674 (0.110)	0.741 (0.064)
22-31 May	1,559	0.831 (0.062)	1.131 (0.191)	0.945 (0.172)	0.888 (0.087)
Weighted mean		**0.922 (0.012)**	**0.983 (0.014)**	**0.904 (0.022)**	**0.781 (0.016)**

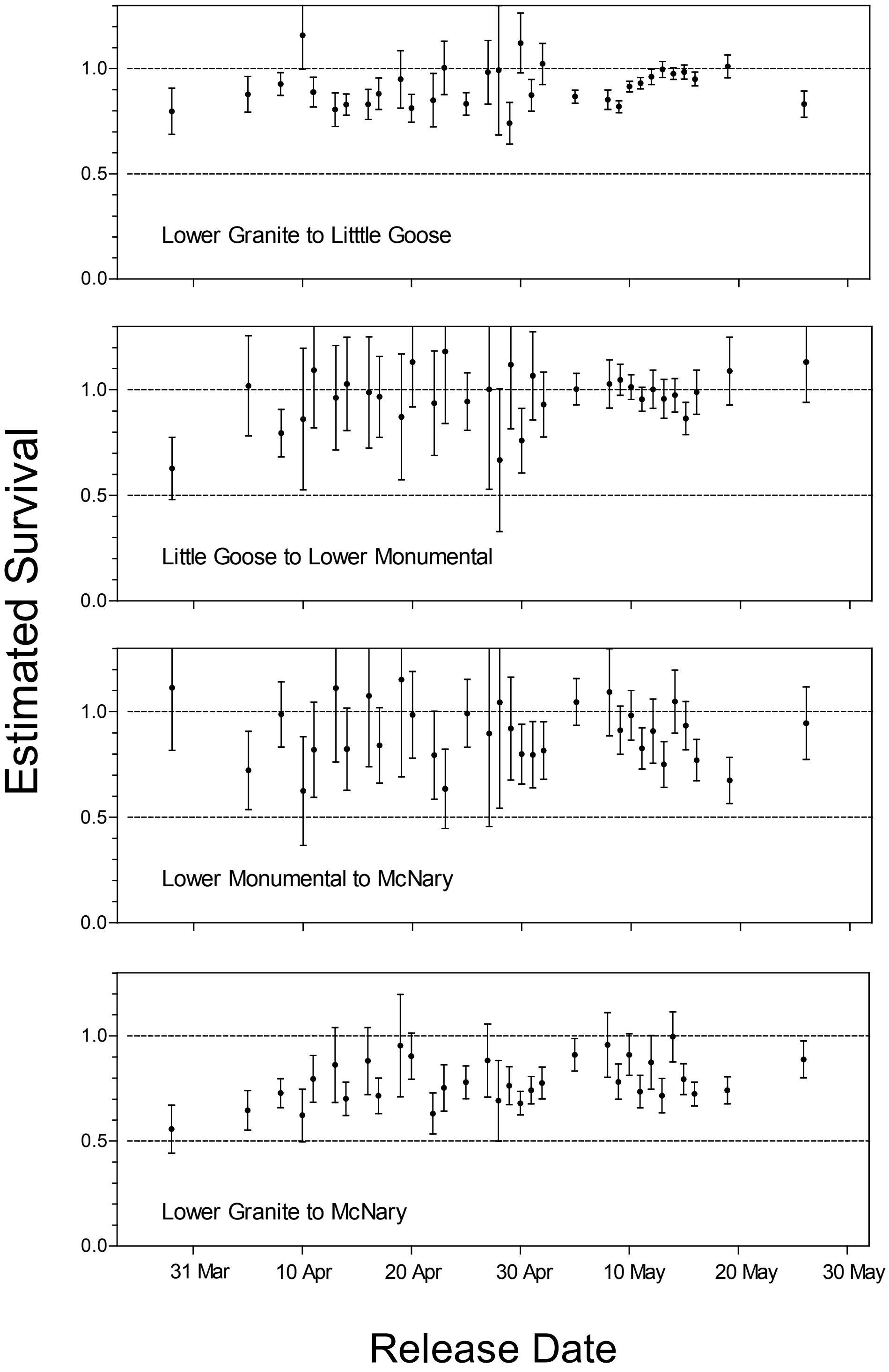


Figure 2. Estimated survival probabilities through various reaches by release date at Lower Granite Dam for daily groups of Snake River yearling Chinook salmon (hatchery and wild combined), 2013. Bars extend one standard error above and below point estimates.

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). Detection probability estimates were generally higher at Little Goose and McNary Dams and lower at Lower Monumental, John Day, and Bonneville Dams. Detection probability estimates were typically higher for wild than for hatchery fish released during the same period (Table 8).

Table 6. Estimated detection probabilities for weekly groups of Snake River yearling Chinook salmon (hatchery and wild combined) detected and returned or PIT tagged and released to the tailrace of Lower Granite Dam in 2013. 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
30 Mar–5 Apr	363	0.271 (0.040)	0.116 (0.030)	0.355 (0.057)
6 Apr–12 Apr	1,934	0.336 (0.018)	0.079 (0.011)	0.334 (0.026)
13 Apr–19 Apr	2,400	0.311 (0.016)	0.067 (0.009)	0.335 (0.025)
20 Apr–26 Apr	2,736	0.214 (0.013)	0.073 (0.008)	0.327 (0.023)
27 Apr–3 May	6,949	0.103 (0.006)	0.048 (0.005)	0.268 (0.014)
4 May–10 May	10,298	0.308 (0.007)	0.205 (0.008)	0.150 (0.009)
11 May–17 May	10,685	0.417 (0.007)	0.192 (0.007)	0.216 (0.010)
18 May–24 May	1,721	0.158 (0.014)	0.040 (0.008)	0.337 (0.031)

Table 7. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and returned or released to the tailrace of McNary Dam in 2013. 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	921	0.358 (0.044)	0.167 (0.058)
27 Apr–3 May	5,317	0.160 (0.016)	0.090 (0.022)
4 May–10 May	23,049	0.081 (0.006)	0.082 (0.010)
11 May–17 May	12,032	0.102 (0.010)	0.079 (0.017)
18 May–24 May	2,868	0.124 (0.019)	0.114 (0.038)
25 May–31 May	1,615	0.143 (0.025)	0.273 (0.086)

Table 8. Estimated detection probabilities for Snake River hatchery and wild yearling Chinook salmon detected and returned or released to the tailrace of Lower Granite Dam in 2013. 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		
30 Mar–5 Apr	239	0.194 (0.046)	0.132 (0.039)	0.365 (0.068)
6 Apr–12 Apr	1,398	0.298 (0.021)	0.069 (0.012)	0.314 (0.031)
13 Apr–19 Apr	1,771	0.281 (0.018)	0.067 (0.010)	0.302 (0.029)
20 Apr–26 Apr	1,969	0.178 (0.014)	0.061 (0.009)	0.318 (0.027)
27 Apr–3 May	3,272	0.083 (0.009)	0.040 (0.007)	0.239 (0.020)
4 May–10 May	6,825	0.234 (0.009)	0.178 (0.010)	0.140 (0.011)
11 May–17 May	4,719	0.359 (0.011)	0.194 (0.012)	0.168 (0.014)
		Wild Yearling Chinook		
6 Apr–12 Apr	536	0.418 (0.033)	0.104 (0.022)	0.382 (0.051)
13 Apr–19 Apr	629	0.382 (0.030)	0.067 (0.017)	0.418 (0.050)
20 Apr–26 Apr	767	0.295 (0.025)	0.101 (0.018)	0.351 (0.043)
27 Apr–3 May	3677	0.117 (0.009)	0.054 (0.006)	0.290 (0.019)
4 May–10 May	3473	0.417 (0.012)	0.248 (0.014)	0.164 (0.014)
11 May–17 May	5966	0.457 (0.010)	0.191 (0.009)	0.246 (0.013)
18 May–24 May	1535	0.161 (0.015)	0.042 (0.008)	0.345 (0.034)

Snake River Steelhead

Estimates of Survival—For weekly groups of steelhead, we estimated probabilities of survival from Lower Granite Dam to multiple downstream dams for 8 consecutive weeks during 6 April-31 May. Average estimated survival was 0.921 (se 0.020) from Lower Granite to Little Goose, 0.977 (0.020) from Little Goose to Lower Monumental, and 0.739 (0.031) from Lower Monumental to McNary Dam (Table 9). For the combined reach from Lower Granite to McNary Dam tailrace, estimated survival averaged 0.645 (0.026).

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 2013. Daily groups were pooled for weekly estimates, and weighted means are 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
6 Apr–12 Apr	903	0.893 (0.049)	0.779 (0.119)	0.858 (0.158)	0.597 (0.071)
13 Apr–19 Apr	2,275	0.920 (0.038)	1.069 (0.180)	0.758 (0.140)	0.746 (0.065)
20 Apr–26 Apr	5,570	0.911 (0.034)	1.049 (0.092)	0.709 (0.068)	0.677 (0.037)
27 Apr–3 May	7,732	0.978 (0.035)	0.935 (0.072)	0.808 (0.083)	0.739 (0.057)
4 May–10 May	7,334	0.926 (0.025)	0.901 (0.047)	0.764 (0.074)	0.638 (0.055)
11 May–17 May	10,693	0.912 (0.014)	1.000 (0.040)	0.746 (0.066)	0.680 (0.054)
18 May–24 May	3,728	0.974 (0.052)	0.905 (0.127)	0.517 (0.086)	0.456 (0.046)
25 May–31 May	1,787	1.114 (0.151)	0.879 (0.378)	0.405 (0.176)	0.396 (0.058)
Weighted mean[a]		**0.921 (0.020)**	**0.977 (0.020)**	**0.739 (0.031)**	**0.645 (0.026)**

a Weighted mean of estimates for daily groups (28 Mar–31 May; see Table 12)

For steelhead detected and returned to the tailrace of McNary Dam, we estimated probabilities of survival to multiple dams downstream for 8 consecutive weeks during 20 April-14 June. We had to create bi-weekly release groups to get sufficient numbers of fish to estimate survival due to very low detection rates at McNary, John Day, and Bonneville Dams. Mean estimated survival was 0.799 (se 0.025) from McNary to John Day, 1.026 (se 0.154) from John Day to Bonneville, and 0.798 (se 0.112) for the entire reach from McNary to Bonneville Dam (Table 10).

Table 10. Estimated survival probabilities for bi-weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from McNary Dam in 2013. Daily groups were pooled for bi-weekly estimates, and weighted means are of independent estimates for weekly groups. Standard errors in parentheses.

	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
20 Apr–3 May	4,860	0.812 (0.072)	0.833 (0.151)	0.677 (0.107)
4 May–17 May	5,316	0.826 (0.080)	1.217 (0.278)	1.005 (0.208)
18 May–31 May	1,562	0.698 (0.109)	1.563 (0.594)	1.090 (0.378)
1 Jun–14 Jun	775	0.741 (0.256)	0.677 (0.333)	0.501 (0.175)
Weighted mean		**0.799 (0.025)**	**1.026 (0.154)**	**0.798 (0.112)**

We calculated the product of mean estimates from Lower Granite to McNary and from McNary to Bonneville Dam. This product provided an overall survival estimate of 0.515 (se 0.075) from Lower Granite to Bonneville Dam. For wild and hatchery steelhead released from the Snake River trap, estimated survival probability to the tailrace of Lower Granite Dam was 0.973 (0.032). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River steelhead was 0.501 (0.075).

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 detected and returned or tagged and released to the tailrace of Lower Granite Dam, 2013. Daily groups were pooled for weekly estimates, and weighted means are of independent estimates for weekly groups. 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		
6 Apr–12 Apr	603	0.941 (0.066)	0.742 (0.134)	0.826 (0.175)	0.577 (0.079)
13 Apr–19 Apr	2,123	0.944 (0.041)	1.031 (0.176)	0.768 (0.144)	0.748 (0.067)
20 Apr–26 Apr	5,440	0.914 (0.034)	1.048 (0.094)	0.718 (0.071)	0.688 (0.038)
27 Apr–3 May	6,564	0.958 (0.035)	0.974 (0.081)	0.747 (0.084)	0.697 (0.058)
4 May–10 May	5,347	0.952 (0.033)	0.866 (0.055)	0.765 (0.093)	0.631 (0.069)
11 May–17 May	7,000	0.936 (0.020)	1.024 (0.055)	0.706 (0.081)	0.677 (0.070)
18 May–24 May	2,304	0.959 (0.068)	0.945 (0.189)	0.469 (0.108)	0.425 (0.056)
Weighted mean		**0.940 (0.005)**	**0.968 (0.033)**	**0.727 (0.027)**	**0.668 (0.031)**
			Wild steelhead		
6 Apr–12 Apr	300	0.806 (0.069)	0.871 (0.256)	0.854 (0.307)	0.599 (0.137)
13 Apr–19 Apr	152	0.647 (0.090)	1.929 (1.714)	0.554 (0.538)	0.691 (0.279)
20 Apr–26 Apr	130	0.821 (0.142)	1.040 (0.510)	0.477 (0.247)	0.408 (0.098)
27 Apr–3 May	1,168	1.184 (0.155)	0.662 (0.142)	1.173 (0.302)	0.919 (0.177)
4 May–10 May	1,987	0.885 (0.039)	0.974 (0.090)	0.756 (0.123)	0.652 (0.091)
11 May–17 May	3,693	0.880 (0.021)	0.969 (0.056)	0.801 (0.111)	0.683 (0.087)
18 May–24 May	1,424	0.998 (0.080)	0.879 (0.174)	0.576 (0.138)	0.505 (0.079)
25 May–31 May	682	0.983 (0.164)	1.087 (0.601)	0.356 (0.203)	0.381 (0.084)
Weighted mean		**0.886 (0.025)**	**0.953 (0.032)**	**0.783 (0.065)**	**0.621 (0.055)**

For daily release groups of steelhead (hatchery and wild combined) returned or released to the tailrace of Lower Granite Dam, estimated survival probabilities were variable and had relatively poor precision. The most notable pattern is a decreasing trend from 14-31 May for survival estimates from Lower Monumental to McNary Dam tailrace (Table 12; Figure 3).

Table 12. Estimated survival probabilities for daily groups of Snake River juvenile steelhead (hatchery and wild combined) detected and returned or PIT tagged and released to the tailrace of Lower Granite Dam in 2013. Daily groups pooled as needed for sufficient sample size on the dates indicated. Weighted means are of independent estimates for 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
28 Mar-7 Apr	157	0.909 (0.043)	0.904 (0.110)	1.286 (1.140)	1.057 (0.930)
8-10 Apr	209	0.861 (0.039)	1.095 (0.165)	0.488 (0.162)	0.460 (0.137)
11-13 Apr	154	0.831 (0.075)	0.863 (0.172)	0.546 (0.184)	0.392 (0.114)
14-16 Apr	111	0.986 (0.130)	0.798 (0.261)	0.344 (0.162)	0.271 (0.100)
17-19 Apr	89	0.905 (0.100)	0.658 (0.151)	0.692 (0.318)	0.412 (0.176)
20-22 Apr	252	0.875 (0.074)	0.954 (0.171)	0.628 (0.205)	0.524 (0.150)
23-25 Apr	216	0.976 (0.077)	0.752 (0.124)	0.985 (0.500)	0.722 (0.354)
26-28 Apr	1,327	0.898 (0.030)	0.849 (0.051)	0.671 (0.079)	0.512 (0.055)
29 Apr-1 May	1,879	0.947 (0.026)	0.912 (0.050)	0.873 (0.104)	0.754 (0.083)
2-4 May	1,153	0.954 (0.030)	0.968 (0.065)	0.982 (0.140)	0.907 (0.118)
5-7 May	1,552	0.964 (0.020)	1.012 (0.055)	0.751 (0.074)	0.733 (0.061)
8-10 May	1,959	0.978 (0.021)	0.918 (0.041)	0.944 (0.099)	0.846 (0.084)
11-13 May	2,149	0.971 (0.018)	0.896 (0.033)	1.148 (0.134)	0.998 (0.113)
14-16 May	2,114	0.971 (0.017)	0.929 (0.035)	0.916 (0.107)	0.827 (0.093)
17-19 May	867	1.029 (0.038)	0.887 (0.062)	0.786 (0.141)	0.718 (0.122)
20-22 May	658	0.825 (0.040)	1.025 (0.102)	0.767 (0.148)	0.649 (0.112)
23-25 May	809	0.827 (0.050)	1.052 (0.113)	0.861 (0.182)	0.749 (0.144)
26-31 May	1,280	0.895 (0.054)	1.005 (0.098)	0.786 (0.135)	0.706 (0.111)
Weighted mean		**0.921 (0.020)**	**0.977 (0.020)**	**0.739 (0.031)**	**0.645 (0.026)**

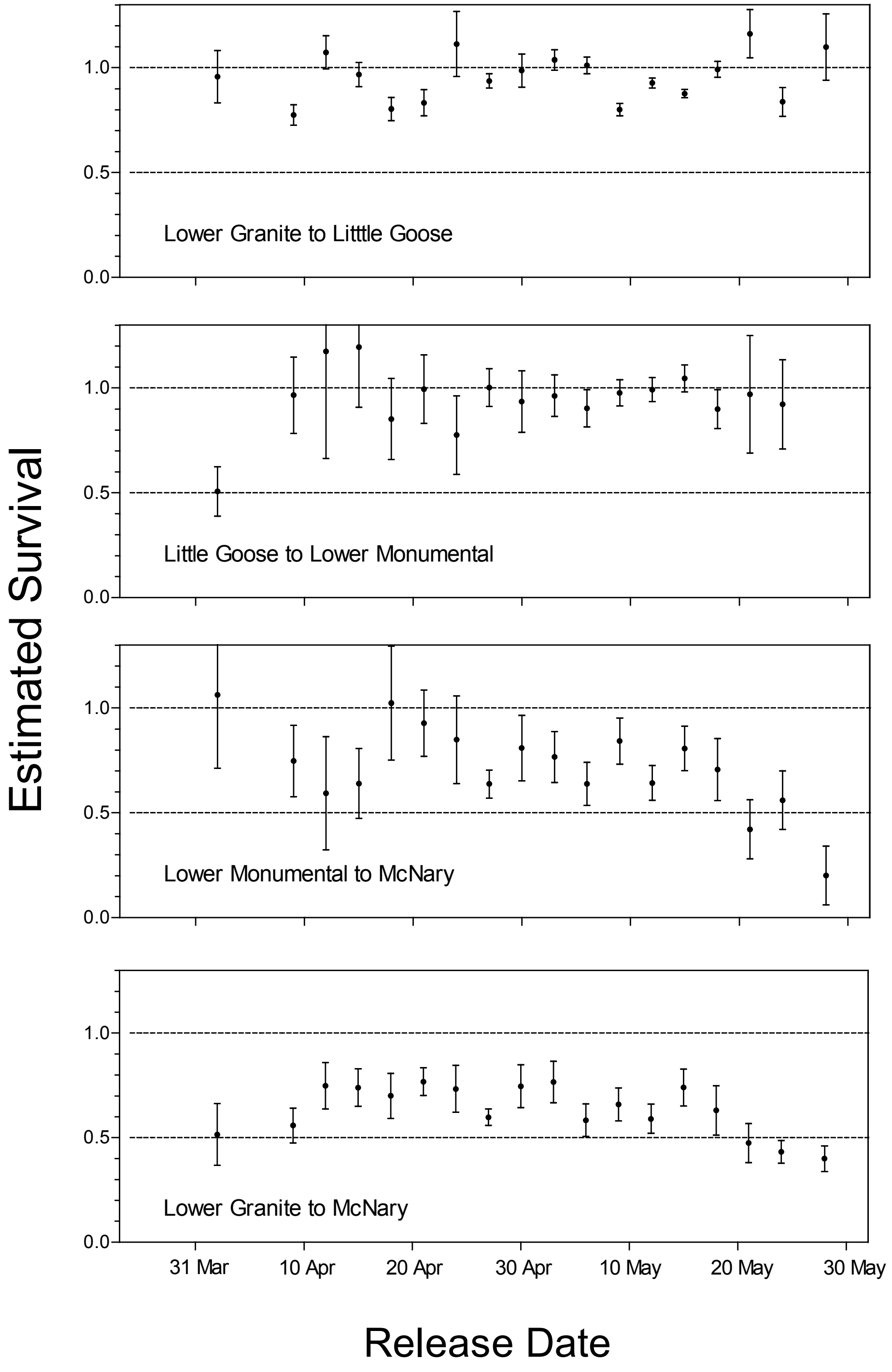


Figure 3. Estimated survival probabilities through various reaches versus release date at Lower Granite Dam for daily release groups of Snake River steelhead (hatchery and wild combined), 2013. Bars extend one standard error above and below point estimates.

Detection Probabilities—For weekly groups of steelhead, estimated detection probabilities were relatively low at all of the Snake and Columbia River dams, but were highest at Little Goose Dam (Tables 13-15). 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, 2013. 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
6 Apr–12 Apr	903	0.443 (0.029)	0.109 (0.020)	0.222 (0.032)
13 Apr–19 Apr	2,275	0.360 (0.018)	0.039 (0.008)	0.170 (0.017)
20 Apr–26 Apr	5,570	0.218 (0.010)	0.068 (0.006)	0.214 (0.013)
27 Apr–3 May	7,732	0.207 (0.009)	0.097 (0.008)	0.103 (0.009)
4 May–10 May	7,334	0.267 (0.009)	0.226 (0.011)	0.091 (0.009)
11 May–17 May	10,693	0.400 (0.008)	0.252 (0.010)	0.082 (0.007)
18 May–24 May	3,728	0.258 (0.016)	0.080 (0.011)	0.180 (0.020)
25 May–31 May	1,787	0.143 (0.021)	0.020 (0.009)	0.183 (0.030)

Table 14. Estimated detection probabilities for bi-weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from the tailrace of McNary Dam, 2013. Standard errors in parentheses.

Estimated detection probability of steelhead from McNary Dam			
Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
20 Apr–3 May	4,860	0.110 (0.011)	0.221 (0.036)
4 May–17 May	5,316	0.109 (0.012)	0.105 (0.022)
18 May–31 May	1,562	0.110 (0.020)	0.122 (0.043)
1 Jun–14 Jun	775	0.045 (0.018)	0.341 (0.121)

Table 15. Estimated detection probabilities for juvenile Snake River hatchery and wild steelhead from the tailrace at Lower Granite Dam, 2013. 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		
6 Apr–12 Apr	603	0.405 (0.035)	0.112 (0.024)	0.208 (0.036)
13 Apr–19 Apr	2,123	0.353 (0.019)	0.040 (0.008)	0.169 (0.018)
20 Apr–26 Apr	5,440	0.214 (0.010)	0.067 (0.006)	0.210 (0.013)
27 Apr–3 May	6,564	0.223 (0.010)	0.099 (0.008)	0.100 (0.010)
4 May–10 May	5,347	0.246 (0.010)	0.227 (0.014)	0.079 (0.010)
11 May–17 May	7,000	0.384 (0.010)	0.225 (0.012)	0.077 (0.009)
18 May–24 May	2,304	0.259 (0.020)	0.068 (0.014)	0.174 (0.026)
		Wild steelhead		
6 Apr–12 Apr	300	0.525 (0.053)	0.101 (0.036)	0.268 (0.069)
13 Apr–19 Apr	152	0.478 (0.078)	0.028 (0.027)	0.190 (0.086)
20 Apr–26 Apr	130	0.356 (0.076)	0.091 (0.050)	0.400 (0.110)
27 Apr–3 May	1,168	0.118 (0.018)	0.086 (0.017)	0.122 (0.026)
4 May–10 May	1,987	0.320 (0.018)	0.223 (0.021)	0.124 (0.020)
11 May–17 May	3,693	0.426 (0.013)	0.302 (0.018)	0.093 (0.013)
18 May–24 May	1,424	0.257 (0.024)	0.097 (0.019)	0.188 (0.032)
25 May–31 May	682	0.206 (0.038)	0.031 (0.017)	0.228 (0.056)

Survival and Detection from Hatcheries and Smolt Traps

Snake River Hatchery Release Groups—For PIT-tagged hatchery yearling Chinook, sockeye salmon, and steelhead, we estimated survival probabilities 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 to Lower Granite Dam tailrace ranged from 0.832 (se 0.025) for Clearwater Hatchery fish released to Clear Creek on the Clearwater River to 0.220 (0.007) for Lookingglass Hatchery fish released to Catherine Creek Pond. For steelhead, estimated survival to Lower Granite Dam tailrace ranged from 1.011 (0.100) for Hagerman Hatchery fish released to the Salmon River to 0.492 (0.019) for Magic Valley Hatchery fish released into the Yankee Fork River. For sockeye salmon released at Redfish Lake Creek Trap in spring, estimated survival to Lower Granite Dam tailrace ranged from 0.557 (0.046) for Oxbow Hatchery fish to 0.548 (0.007) for Sawtooth Hatchery fish.

Snake River Smolt Trap Release Groups—For wild and hatchery juvenile salmonids PIT tagged and released from Snake River Basin smolt traps, estimated probabilities of survival were generally inversely related to distance of the trap from Lower Granite Dam (Appendix Table B7). Estimated probabilities of detection were similar among release groups of the same species and rearing type from different traps (Appendix Table B8). However, for both wild yearling Chinook salmon and steelhead, estimated detection probabilities at Snake River dams were consistently higher than those of hatchery conspecifics released from the same location (i.e., Grande Ronde, Salmon, and Snake River traps). These higher probabilities of detection could be due to fish size (Zabel et al. 2005) but could also be partly due to differences in migration timing.

Upper Columbia River Hatchery Release Groups—We estimated probabilities of survival from release at Upper Columbia River hatcheries to the tailraces of McNary Dam and dams further downstream for yearling Chinook, coho salmon, and steelhead. These estimates varied among hatcheries and release locations (Appendix Table B9), as did estimates of detection probability (Appendix Table B10).

For yearling Chinook originating above the Yakima River, estimated survival from release to McNary Dam tailrace ranged from 0.776 (0.075) for East Bank Hatchery fish released to Dryden Pond on the Wenatchee River to 0.418 (0.037) for Methow Hatchery fish released from Methow Hatchery. For Upper Columbia River steelhead, estimated survival to McNary Dam tailrace ranged from 0.518 (0.081) for Wells

Hatchery fish released to the Methow River to 0.303 (0.075) for East Bank Hatchery fish released to Nason Creek on the Wenatchee River. For Upper Columbia River coho salmon originating above the Yakima River, estimated survival to McNary Dam tailrace ranged from 0.628 (0.082) for Winthrop Hatchery fish released from the hatchery to the Methow River, to 0.360 (0.056)for Willard Hatchery fish released to Rolfing Pond.

Survival Between Lower Monumental and Ice Harbor Dam

A PIT-tag detection system became operational at Ice Harbor Dam in 2005. From 2006 to 2013, detections at Ice Harbor were sufficient to estimate tailrace-to-tailrace survival from Lower Monumental to Ice Harbor and from Ice Harbor to McNary Dam (Table 16). For yearling Chinook salmon in 2013, mean estimated survival was 0.952 (se 0.037) from Lower Monumental to Ice Harbor Dam and 0.938 (0.048) from Ice Harbor to McNary Dam. For steelhead, estimated mean survival through these same respective reaches was 0.996 (0.032) and 0.763 (0.033). Detection probabilities were lower at Ice Harbor than at most other dams.

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), 2013. Estimates are for weekly release groups. Standard errors in parentheses.

		Estimated survival probability		
Date at Lower Granite	Number released	Lower Monumental to Ice Harbor Dam	Ice Harbor to McNary Dam	**Detection probability Ice Harbor Dam**
	Hatchery and wild yearling Chinook salmon			
6 Apr–12 Apr	1,934	0.900 (0.178)	0.983 (0.182)	0.026 (0.006)
13 Apr–19 Apr	2,400	1.188 (0.247)	0.803 (0.158)	0.022 (0.005)
20 Apr–26 Apr	2,736	0.763 (0.105)	1.146 (0.140)	0.041 (0.006)
27 Apr–3 May	6,949	1.099 (0.125)	0.772 (0.077)	0.039 (0.004)
4 May–10 May	10,298	0.979 (0.068)	1.052 (0.087)	0.060 (0.005)
11 May–17 May	10,685	0.914 (0.057)	0.891 (0.061)	0.062 (0.004)
18 May–24 May	1,721	0.896 (0.190)	0.879 (0.152)	0.041 (0.008)
Weighted mean		**0.952 (0.037)**	**0.938 (0.048)**	**0.044 (0.006)**
	Hatchery and wild steelhead			
13 Apr–19 Apr	2,275	1.203 (0.333)	0.671 (0.167)	0.020 (0.005)
20 Apr–26 Apr	5,570	0.849 (0.089)	0.803 (0.073)	0.075 (0.007)
27 Apr–3 May	7,732	1.025 (0.082)	0.852 (0.083)	0.111 (0.008)
4 May–10 May	7,334	0.977 (0.073)	0.777 (0.084)	0.118 (0.009)
11 May–17 May	10,693	1.076 (0.084)	0.704 (0.076)	0.077 (0.006)
18 May–24 May	3,728	0.924 (0.147)	0.606 (0.095)	0.084 (0.011)
25 May–31 May	1,787	0.920 (0.398)	0.534 (0.168)	0.038 (0.012)
Weighted mean		**0.996 (0.032)**	**0.763 (0.033)**	**0.068 (0.014)**

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 and 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 at 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 estimate encompassed any delays associated with dam passage such as 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. We calculated the 20th percentile, median, and 80th percentile travel time and migration rate for each group.

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, all of 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 decreased over the migration season (Tables 17-22). For both species, estimated migration rates were generally highest in the lower river sections. For steelhead, estimated travel times from Lower Granite to Bonneville Dam were generally shorter than those in 2007 and 2010, which were years of similarly low flow (Figure 4). For yearling Chinook, travel times varied through the season in relation to other years and were not consistently different from those in 2007 and 2010.

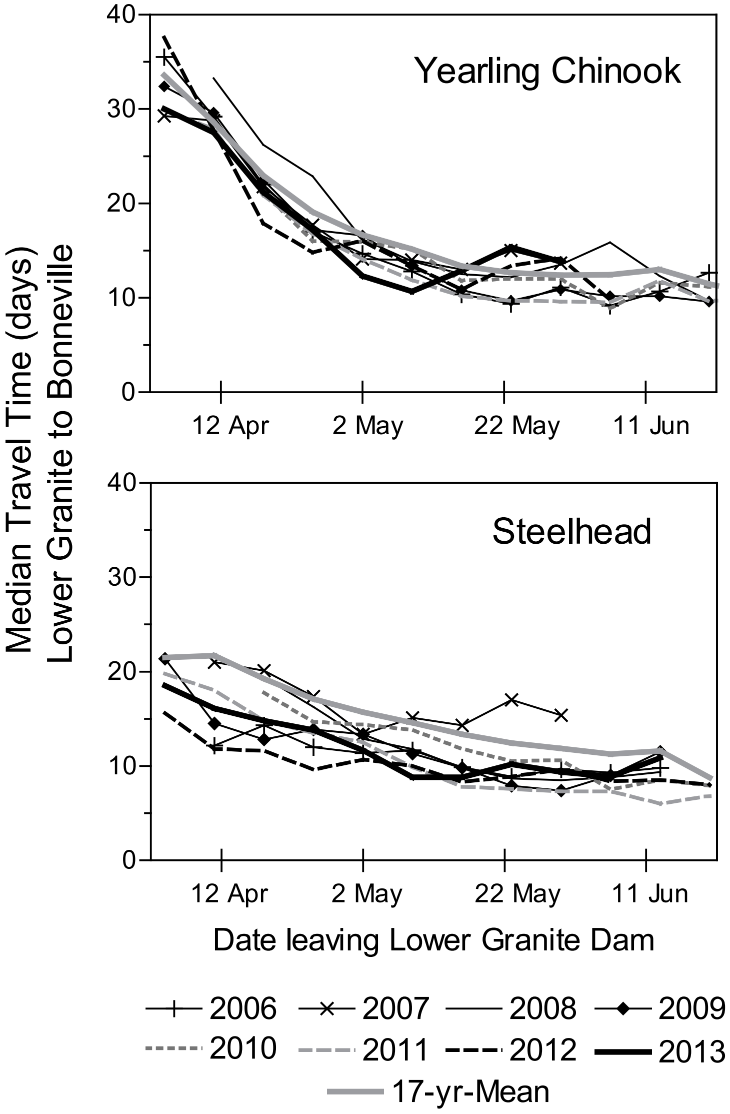
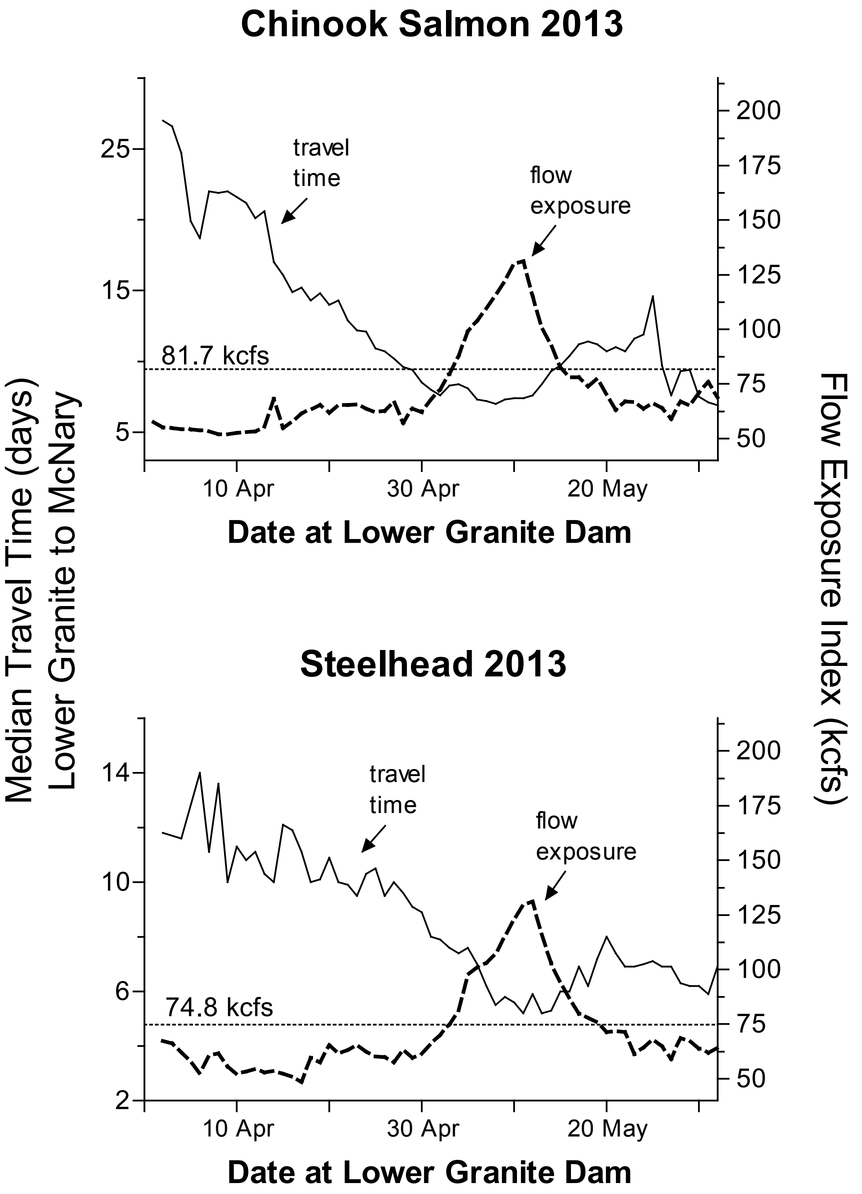


Figure 4. Median travel time (d) from Lower Granite Dam to Bonneville Dam for weekly release groups of Snake River yearling Chinook salmon and steelhead from Lower Granite Dam, 2006-2013.

For both yearling Chinook salmon and steelhead, observed decreases in travel time later in the season generally coincided with increased flow, and presumably with increased levels of smoltification (Figure 5).



Chinook Salmon 2013

Steelhead 2013

Figure 5. Travel time (d) for yearling Chinook salmon and steelhead from Lower Granite to McNary Dam and index of flow exposure at Lower Monumental Dam (kcfs) for daily groups of PIT-tagged fish during 2013. 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 or released to the tailrace at Lower Granite Dam in 2013. 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%
30 Mar–5 Apr	95	4.9	8.2	15.9	7	3.7	7.7	9.5	5	4.0	4.4	5.4
6 Apr–12 Apr	597	5.6	8.2	12.6	33	3.4	5.3	7.8	38	4.7	5.7	7.2
13 Apr–19 Apr	633	4.8	6.3	9.3	26	3.0	3.6	5.8	35	4.0	4.9	6.4
20 Apr–26 Apr	499	3.7	5.0	7.4	33	1.6	1.9	2.4	48	3.2	4.0	5.0
27 Apr–3 May	681	2.9	3.4	4.3	41	1.7	2.0	2.5	46	3.0	3.5	4.1
4 May–10 May	2,677	2.2	2.9	3.6	577	1.2	1.6	2.0	257	2.4	2.8	4.2
11 May–17 May	4,317	2.4	2.9	3.8	725	1.2	1.6	2.1	296	2.8	3.9	5.6
18 May–24 May	254	3.5	4.5	6.8	11	1.8	2.4	2.8	20	3.4	4.4	5.7
25 May–31 May	33	4.0	5.6	10.9	2	2.1	3.3	4.4	2	2.9	3.6	4.2

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	70	17.9	24.3	29.5	19	26.3	30.0	36.3
6 Apr–12 Apr	446	16.5	21.3	26.5	93	22.9	27.5	31.9
13 Apr–19 Apr	590	12.6	15.8	20.1	120	18.7	21.2	25.9
20 Apr–26 Apr	685	10.0	12.0	15.1	146	14.6	17.2	20.6
27 Apr–3 May	1,372	7.5	8.5	9.9	383	11.1	12.3	14.2
4 May–10 May	1,320	6.3	7.4	8.8	590	9.7	10.7	12.0
11 May–17 May	1,723	7.2	9.3	12.2	742	10.2	12.9	16.5
18 May–24 May	487	9.6	11.4	13.8	139	14.0	15.4	18.3
25 May–31 May	60	8.5	11.0	18.3	18	11.2	13.8	19.2

Table 18. Migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected or released to the tailrace at Lower Granite Dam in 2013. 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%
30 Mar–5 Apr	95	3.8	7.3	12.1	7	4.8	6.0	12.4	5	22.1	27.0	29.6
6 Apr–12 Apr	597	4.8	7.3	10.7	33	5.9	8.7	13.4	38	16.5	20.8	25.3
13 Apr–19 Apr	633	6.5	9.5	12.4	26	8.0	12.8	15.6	35	18.6	24.5	29.6
20 Apr–26 Apr	499	8.1	12.0	16.2	33	19.0	24.5	29.3	48	23.6	29.4	37.2
27 Apr–3 May	681	13.9	17.9	20.8	41	18.0	22.5	27.4	46	29.3	33.5	39.8
4 May–10 May	2,677	16.9	20.5	27.1	577	23.0	29.7	37.7	257	28.6	42.7	50.2
11 May–17 May	4,317	15.6	20.7	24.9	725	21.5	29.3	38.0	296	21.4	30.7	43.3
18 May–24 May	254	8.8	13.4	17.4	11	16.4	19.5	25.3	20	20.8	26.8	34.9
25 May–31 May	33	5.5	10.7	15.0	2	10.5	14.1	21.5	2	28.2	33.2	40.5

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	70	7.6	9.3	12.6	19	12.7	15.4	17.5
6 Apr–12 Apr	446	8.5	10.6	13.7	93	14.4	16.8	20.1
13 Apr–19 Apr	590	11.2	14.2	17.8	120	17.8	21.7	24.7
20 Apr–26 Apr	685	14.9	18.8	22.5	146	22.4	26.8	31.6
27 Apr–3 May	1,372	22.6	26.5	29.9	383	32.5	37.6	41.7
4 May–10 May	1,320	25.7	30.5	35.8	590	38.5	43.0	47.8
11 May–17 May	1,723	18.4	24.2	31.0	742	27.9	35.8	45.1
18 May–24 May	487	16.3	19.8	23.3	139	25.2	29.9	33.0
25 May–31 May	60	12.3	20.5	26.3	18	24.0	33.5	41.1

Table 19. Travel time and migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected or released to the tailrace at McNary Dam in 2013.

	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)											
13 Apr–19 Apr	25	4.1	6.1	7.8	4	2.4	2.6	2.9	10	6.8	8.2	9.8
20 Apr–26 Apr	229	4.0	5.3	6.8	31	1.9	2.0	2.3	83	5.8	6.9	8.2
27 Apr–3 May	795	3.8	4.5	5.5	63	1.7	1.8	2.0	391	5.2	5.9	6.9
4 May–10 May	1,965	3.0	3.5	4.2	132	1.3	1.4	1.6	1,687	3.8	4.5	5.1
11 May–17 May	1,128	2.7	3.0	3.6	77	1.3	1.5	1.7	757	3.7	3.9	4.6
18 May–24 May	327	3.0	3.7	4.7	24	1.5	1.6	1.9	227	3.9	4.6	5.5
25 May–31 May	166	3.0	3.9	4.5	22	1.5	1.8	2.0	175	4.6	4.9	5.9
1 Jun–7 Jun	73	2.9	3.2	4.1	11	1.4	1.5	1.8	84	4.0	4.4	5.0
8 Jun–14 Jun	50	2.5	2.9	3.5	6	1.4	1.5	1.6	68	3.7	4.2	4.9
15 Jun–21 Jun	21	2.9	3.2	4.0	2	1.4	1.6	1.7	29	4.0	4.2	4.4
	Migration rate (km/d)											
13 Apr–19 Apr	25	15.8	20.3	29.9	4	38.8	43.3	48.1	10	24.0	28.6	35.0
20 Apr–26 Apr	229	18.0	23.1	30.5	31	49.6	55.4	60.4	83	28.9	34.4	40.5
27 Apr–3 May	795	22.4	27.3	32.0	63	55.1	61.7	66.9	391	34.3	40.1	45.1
4 May–10 May	1,965	29.2	35.3	41.3	132	72.4	80.7	89.0	1,687	46.0	52.4	61.9
11 May–17 May	1,128	34.2	40.7	44.9	77	67.3	76.9	85.6	757	51.3	60.2	63.8
18 May–24 May	327	26.2	33.6	40.7	24	60.4	69.8	76.4	227	43.3	51.8	60.1
25 May–31 May	166	27.2	31.7	40.5	22	55.4	62.1	73.4	175	40.1	47.9	51.8
1 Jun–7 Jun	73	30.2	38.7	42.6	11	62.8	73.4	81.3	84	46.8	53.3	58.9
8 Jun–14 Jun	50	35.5	41.8	49.8	6	69.3	73.4	81.3	68	48.2	56.7	63.6
15 Jun–21 Jun	21	31.1	38.7	41.8	2	65.7	72.4	80.7	29	53.4	56.1	59.6

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 2013.

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%
30 Mar–5 Apr	55	3.2	3.8	5.1	4	2.5	3.0	4.5	2	3.9	4.4	4.9
6 Apr–12 Apr	357	3.0	3.8	4.5	25	2.2	3.6	5.0	15	3.2	4.2	4.9
13 Apr–19 Apr	754	3.0	3.9	4.2	30	2.6	4.0	6.7	14	3.5	3.9	4.6
20 Apr–26 Apr	1,105	3.0	3.4	4.1	63	1.9	2.7	4.6	55	3.5	4.0	4.9
27 Apr–3 May	1,562	2.8	3.1	4.0	147	1.9	2.3	3.5	57	3.0	3.6	4.4
4 May–10 May	1,816	2.0	2.2	3.0	351	1.1	1.4	2.1	101	1.9	2.5	2.9
11 May–17 May	3,900	1.9	2.0	2.6	966	1.1	1.3	2.0	156	2.0	2.5	3.0
18 May–24 May	937	1.9	2.0	2.9	60	1.4	1.8	2.6	23	2.6	3.2	3.9
25 May–31 May	284	1.9	2.0	2.3	4	1.6	1.8	2.2	2	3.4	3.6	3.9
1 Jun–7 Jun	132	1.6	2.0	2.2	5	1.2	1.4	1.7	2	2.2	2.5	2.8
8 Jun–14 Jun	21	1.9	2.0	2.2	0	NA	NA	NA	0	NA	NA	NA

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	11	9.1	11.6	14.8	14	14.4	18.5	22.1
6 Apr–12 Apr	112	8.9	11.0	14.2	110	13.5	16.1	18.6
13 Apr–19 Apr	271	9.2	10.9	13.7	270	13.7	14.8	16.3
20 Apr–26 Apr	796	8.7	9.9	11.3	460	12.4	13.8	15.6
27 Apr–3 May	583	7.7	8.7	10.5	600	10.6	11.7	13.4
4 May–10 May	418	5.3	6.1	7.2	524	7.9	8.8	9.9
11 May–17 May	569	5.0	5.9	7.2	836	7.9	8.8	9.9
18 May–24 May	300	6.0	6.9	7.9	238	9.3	10.2	11.3
25 May–31 May	128	5.8	6.2	7.1	132	8.7	9.4	10.3
1 Jun–7 Jun	92	5.2	6.0	7.2	83	7.9	8.9	10.5
8 Jun–14 Jun	46	5.2	6.4	8.0	62	9.1	10.9	12.7

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 2013.

Migration rate of juvenile steelhead 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%
30 Mar–5 Apr	55	11.8	15.7	19.0	4	10.1	15.4	18.8	2	24.2	27.0	30.4
6 Apr–12 Apr	357	13.3	15.7	19.9	25	9.2	12.9	20.4	15	24.2	28.2	37.3
13 Apr–19 Apr	754	14.2	15.5	20.1	30	6.9	11.6	17.4	14	25.9	30.5	34.0
20 Apr–26 Apr	1,105	14.5	17.9	19.7	63	10.1	16.8	24.6	55	24.1	29.4	34.4
27 Apr–3 May	1,562	15.0	19.3	21.1	147	13.0	19.7	24.0	57	26.8	33.4	39.5
4 May–10 May	1,816	19.7	27.1	30.2	351	21.5	32.9	41.1	101	41.0	48.6	62.0
11 May–17 May	3,900	23.4	29.6	32.3	966	22.4	35.4	43.8	156	39.7	47.8	58.0
18 May–24 May	937	21.0	29.3	31.4	60	17.8	25.4	32.2	23	30.5	37.0	45.4
25 May–31 May	284	26.2	29.6	31.7	4	21.1	24.9	29.5	2	30.8	32.9	35.3
1 Jun–7 Jun	132	27.8	30.5	37.7	5	27.5	33.8	38.0	2	42.8	48.0	54.6
8 Jun–14 Jun	21	27.8	30.8	31.6	0	NA	NA	NA	0	NA	NA	NA

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	11	15.2	19.4	24.8	14	20.9	25.0	32.0
6 Apr–12 Apr	112	15.9	20.4	25.4	110	24.7	28.7	34.2
13 Apr–19 Apr	271	16.4	20.6	24.6	270	28.2	31.2	33.7
20 Apr–26 Apr	796	20.0	22.8	25.8	460	29.6	33.5	37.2
27 Apr–3 May	583	21.4	25.9	29.1	600	34.5	39.5	43.7
4 May–10 May	418	31.3	36.6	42.5	524	46.6	52.5	58.4
11 May–17 May	569	31.2	38.1	45.0	836	46.8	52.1	58.2
18 May–24 May	300	28.4	32.6	37.7	238	40.8	45.0	49.8
25 May–31 May	128	31.9	36.3	38.9	132	44.8	49.0	53.0
1 Jun–7 Jun	92	31.4	37.4	43.2	83	43.7	51.6	58.4
8 Jun–14 Jun	46	28.0	35.0	43.3	62	36.4	42.4	50.4

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 2013.

	Hatchery and wild juvenile steelhead from McNary Dam											
Date at 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)											
13 Apr–19 Apr	40	3.2	4.1	8.6	8	1.6	1.6	1.7	54	4.8	5.8	6.8
20 Apr–26 Apr	121	3.8	4.5	6.5	32	1.5	1.7	1.8	288	4.8	5.5	6.6
27 Apr–3 May	315	3.0	4.0	5.6	47	1.5	1.6	1.9	438	4.3	4.8	5.4
4 May–10 May	290	2.9	3.5	4.4	38	1.2	1.3	1.4	344	3.5	4.0	4.8
11 May–17 May	188	2.1	2.9	3.6	23	1.2	1.3	1.3	214	3.4	3.8	4.3
18 May–24 May	89	2.5	3.0	3.6	12	1.2	1.3	1.4	117	3.5	3.8	4.4
25 May–31 May	31	2.9	3.0	3.6	6	1.4	1.5	1.8	90	3.7	4.2	4.7
1 Jun–7 Jun	11	2.4	3.0	3.6	2	1.3	1.4	1.4	61	3.5	3.9	4.3
8 Jun–14 Jun	15	2.1	2.3	3.4	2	1.4	1.4	1.4	71	3.1	3.7	4.2
15 Jun–21 Jun	3	2.2	2.2	2.7	1	1.3	1.3	1.3	32	3.4	3.9	4.3
	Migration rate (km/d)											
13 Apr–19 Apr	40	14.4	30.2	38.6	8	65.7	69.3	71.1	54	34.5	40.9	49.6
20 Apr–26 Apr	121	19.0	27.4	31.9	32	61.7	64.9	73.9	288	36.0	42.8	48.7
27 Apr–3 May	315	22.0	31.1	40.6	47	60.4	71.5	76.9	438	44.0	48.9	55.1
4 May–10 May	290	27.8	35.7	42.6	38	79.6	89.0	95.8	344	49.0	59.4	66.9
11 May–17 May	188	34.5	42.0	57.5	23	85.0	86.3	92.6	214	54.6	62.9	69.4
18 May–24 May	89	34.2	40.7	50.2	12	78.5	85.0	92.6	117	53.8	62.3	67.4
25 May–31 May	31	34.2	41.1	42.7	6	63.5	76.4	79.0	90	50.0	56.3	63.1
1 Jun–7 Jun	11	34.3	41.4	52.1	2	81.3	82.5	84.3	61	54.8	60.7	66.7
8 Jun–14 Jun	15	36.5	53.5	59.1	2	78.5	79.0	80.1	71	56.6	63.6	75.9
15 Jun–21 Jun	3	46.1	55.4	56.7	1	85.6	85.6	85.6	32	54.9	61.0	69.2

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, following 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 daily estimates 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 at Little Goose Dam (i.e. next entered a collection system) 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 2013, collection for transportation began on 27 April at Lower Granite Dam, 3 May at Little Goose Dam, and 7 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 transported during the entire 2013 season were 36.1% for wild and 31.0% for hatchery smolts. For non-tagged steelhead, estimated percentages transported were 40.0% for wild and 35.5% for hatchery smolts. These estimates represent the proportion of smolts that arrived at Lower Granite Dam and were subsequently transported, either from Lower Granite or from one of the downstream collector dams. The estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams in 2013 were not as low as those for 2012, but were still among the lowest estimates for 1993-2013 (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 could potentially provide survival information up until the point of transport, but not downstream from that point).

When considering the implications of in-river survival probability for populations of Snake River salmonids, it is important to remember that in recent years, 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.

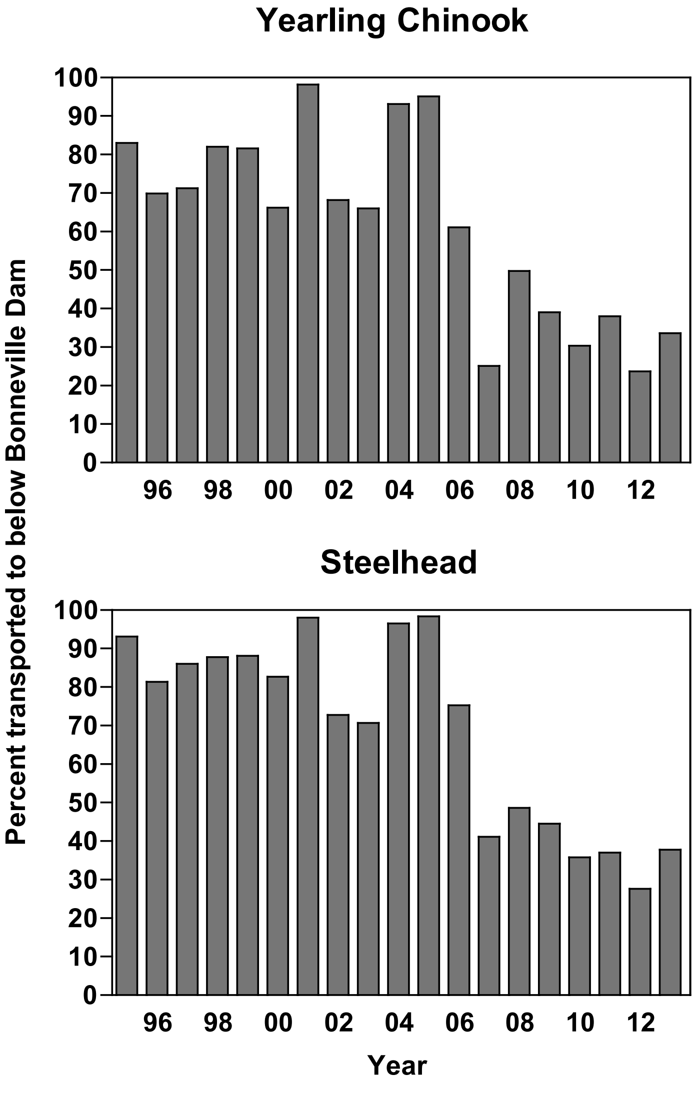


Figure 6. Estimated percent of yearling Chinook salmon and steelhead (hatchery and wild combined) transported to below Bonneville Dam by year (1995-2013).

Table 23. Annual estimated percentages of migrating Snake River yearling Chinook salmon and steelhead that were transported (1993-2013). 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
2012	24.7	22.7	23.7	26.7	28.4	27.6
2013	31.0	36.1	33.6	35.0	40.0	37.8
Mean	**64.1**	**67.4**	**65.8**	**71.6**	**72.9**	**72.3**

For yearling Chinook salmon and steelhead, the estimated percentages transported from Snake River dams in 2013 were larger than the record low percentages estimated in 2012. This increase was due to a combination of an earlier transportation start date and a later arrival of smolts at Lower Granite Dam. In 2013, collection for transportation started 5 days earlier than in 2012 at Lower Granite Dam, and 1 day earlier at Little Goose and Lower Monumental Dams. When smolt transportation started at Lower Granite Dam in 2013, approximately 26% of Chinook and 26% of steelhead smolts had already passed the dam. Smolt passage increased rapidly with increasing flow in early May (Appendix Figures C1 and C3), and 90% passage at Lower Granite Dam occurred by approximately 14 May for Chinook and 17 May for steelhead.

Throughout the migration season, relatively high percentages of flow were spilled in combination with continuous operation of surface bypass collectors at each collector dam on the Snake River. This resulted in low proportions of fish entering juvenile bypass systems. Low flow conditions in 2013 may have increased spillway passage because lower water velocities allow fish more time to react to conditions and may increase the attractiveness of surface bypass collectors (NMFS unpublished report).

During general transportation operations in 2013, we estimated that approximately 46% of Chinook and 51% of steelhead smolts that arrived at Lower Granite Dam were transported, either from Lower Granite or from another collector dam. These percentages were actually smaller than those estimated for 2012 (59% Chinook and 62% steelhead), despite the fact that the estimated percentages transported for these populations over the entire 2013 migration (including period before transportation started) were larger than those in 2012. This is due to fewer fish entering bypass systems in 2013. Though a larger proportion of smolts were transported overall in 2013 than in 2012, the transport percentages for 2013 are still among the lowest estimated over the period for which we have estimates (1993-2013).

COMPARISONS BETWEEN STOCKS AND AMONG YEARS

Comparison of Annual Survival Estimates Among Years

We made two comparisons of annual survival estimates from 2013 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 overall seasonal survival estimates within 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 2013 were similar to those made in recent years. In 2013, mean survival of fish from these hatcheries was higher than the long-term mean (Table 24). Over the years of the study, we have consistently observed an inverse relationship between the distance from release to Lower Granite Dam and estimated survival. For yearling Chinook from Snake River hatcheries, there has been a significant negative linear correlation between migration distance and average estimated survival (Figure 7; $R^2 = 0.871$, $P = 0.002$).

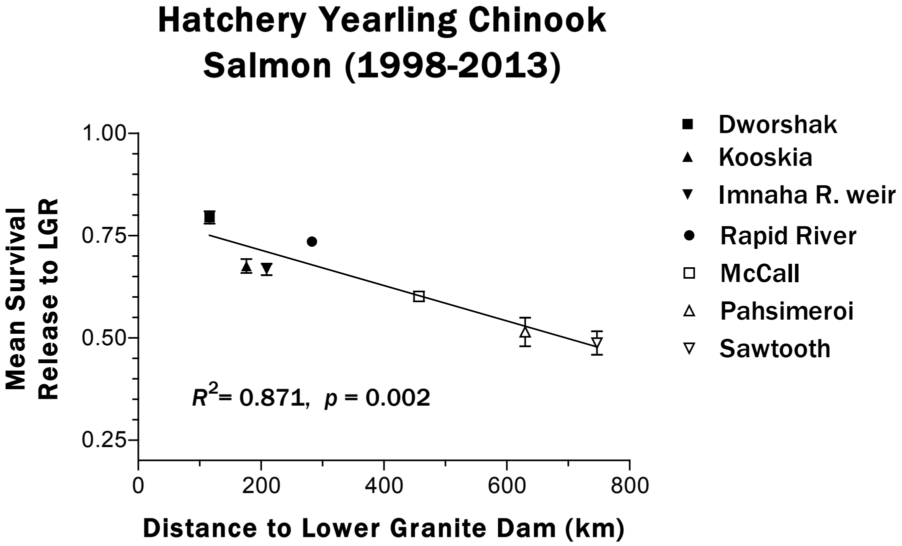


Figure 7. Estimated survival from release at Snake River Basin hatcheries to Lower Granite Dam tailrace, 1998-2013 vs. distance (km) to Lower Granite Dam. The squared correlation between survival and migration distance is also shown, along with a *p*-value for a test of the null hypothesis of zero correlation. 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, 1993–2013. 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)
2012	0.743 (0.008)	0.652 (0.013)	0.689 (0.009)	0.718 (0.014)	0.571 (0.006)	0.581 (0.006)	0.473 (0.008)	0.632 (0.036)
2013	0.794 (0.015)	0.609 (0.026)	0.703 (0.019)	0.735 (0.011)	0.656 (0.011)	0.606 (0.016)	0.564 (0.011)	0.667 (0.031)
Mean	**0.777 (0.017)**	**0.677 (0.018)**	**0.658 (0.012)**	**0.698 (0.021)**	**0.579 (0.014)**	**0.491 (0.031)**	**0.434 (0.034)**	**0.617 (0.011)**

* Released at Imnaha River Weir.

For wild and hatchery yearling Chinook salmon combined, mean estimated survival was 0.781 (95% CI 0.749-0.812) from Lower Granite to McNary Dam tailrace and 0.796 (0.671-0.921) from McNary to Bonneville Dam tailrace (Tables 25 and 27; Figures 8 and 9). These estimates were lower than those in 2012 for both reaches. For these fish, estimated survival was 0.525 (0.432-0.619) through the entire hydrosystem (Snake River Trap to Bonneville tailrace; Table 27). This estimate was greater than the 17-year (1997-2013) mean of 0.501, but lower than the 2012 estimate of 0.588. The difference between estimates in 2012 and 2013 was not statistically significant ($P = 0.31$). For wild yearling Chinook salmon alone, mean estimated survival through the entire hydrosystem was 0.422 (0.300-0.544); lower than that for hatchery and wild Chinook combined (Table 28).

For wild and hatchery steelhead combined, mean estimated survival was 0.645 (95% CI 0.594-0.696) from Lower Granite to McNary Dam and 0.798 (0.578-1.00) from McNary to Bonneville Dam. These estimates were higher than the 17-year means but were lower than those from 2012 (Table 29; Figures 8 and 9). Estimated survival through the entire hydrosystem for this group of fish was 0.501 (0.354-0.648; Table 29). Again, this estimate was higher than the long-term mean, but lower than the corresponding estimate for 2012. The difference between the 2012 and 2013 estimates for the hydrosystem was not statistically significant ($P = 0.54$). For wild steelhead alone, mean estimated survival through the entire hydrosystem was 0.384 (0.205-0.563) in 2013, and was lower than that for hatchery and wild steelhead combined (Table 30).

Table 25. Annual weighted means of survival probability estimates for yearling Chinook salmon (hatchery and wild combined), 1995–2013. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root of the two–project estimate to facilitate comparison with other single-project estimates. Simple arithmetic means across all available years (1993-2013) are given.

Annual survival estimates for hatchery and wild 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
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
2012	0.928 (0.012)	0.907 (0.009)	0.939 (0.010)	0.937 (0.016)	0.968	0.915 (0.023)	0.866 (0.058)	0.931
2013	0.845 (0.031)	0.922 (0.012)	0.983 (0.014)	0.904 (0.022)	0.951	0.931 (0.054)	0.823 (0.036)	0.907
Mean	**0.934 (0.009)**	**0.926 (0.008)**	**0.922 (0.011)**	**0.862 (0.014)**	**0.928**	**0.884 (0.019)**	**0.796 (0.029)**	**0.890**

Table 26. Annual weighted means of survival probability estimates for steelhead (hatchery and wild combined), 1995–2013. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root of the two–project estimate to facilitate comparison with other single-project estimates. Simple arithmetic means across all available years (1993–2013) are given.

Annual survival estimates for hatchery and wild 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
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
2012	1.001 (0.026)	0.959 (0.006)	0.914 (0.011)	0.811 (0.022)	0.901	0.814 (0.048)	1.021 (0.148)	1.010
2013	0.973 (0.032)	0.921 (0.020)	0.977 (0.020)	0.739 (0.031)	0.860	0.799 (0.025)	1.026 (0.154)	1.013
Mean	**0.956 (0.009)**	**0.919 (0.010)**	**0.907 (0.014)**	**0.755 (0.032)**	**0.864**	**0.807 (0.046)**	**0.796 (0.038)**	**0.889**

Table 27. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River yearling Chinook salmon (hatchery and wild combined), 1997–2013. Standard errors in parentheses. Simple arithmetic means are given.

	Annual survival estimates for hatchery and wild yearling Chinook				
Year	Trap to Lower Granite Dam	Lower Granite to McNary Dam	McNary to Bonneville Dam	Lower Granite to Bonneville Dam	Trap to Bonneville Dam
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)
2012	0.928 (0.012)	0.790 (0.016)	0.802 (0.051)	0.634 (0.042)	0.588 (0.040)
2013	0.845 (0.031)	0.781 (0.016)	0.796 (0.064)	0.622 (0.052)	0.525 (0.048)
Mean	**0.940 (0.009)**	**0.742 (0.015)**	**0.710 (0.024)**	**0.533 (0.025)**	**0.501 (0.023)**

Table 28. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River yearling Chinook salmon (wild only) 1999–2013. Standard errors in parentheses. Simple arithmetic means are given.

	Annual survival estimates for wild yearling Chinook				
Year	Trap to Lower Granite Dam	Lower Granite to McNary Dam	McNary to Bonneville Dam	Lower Granite to Bonneville Dam	Trap to Bonneville Dam
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)
2012	0.942 (0.013)	0.798 (0.020)	0.831 (0.065)	0.663 (0.054)	0.625 (0.052)
2013	0.791 (0.045)	0.778 (0.018)	0.685 (0.092)	0.553 (0.073)	0.422 (0.062)
Mean	**0.921 (0.014)**	**0.737 (0.018)**	**0.667 (0.037)**	**0.497 (0.032)**	**0.457 (0.031)**

Table 29. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River steelhead (hatchery and wild combined), 1997–2013. Standard errors in parentheses; simple arithmetic means are given.

	Annual survival estimates for hatchery and wild steelhead				
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
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)
2012	1.001 (0.026)	0.698 (0.020)	0.856 (0.196)	0.597 (0.138)	0.598 (0.139)
2013	0.973 (0.032)	0.645 (0.026)	0.798 (0.112)	0.515 (0.075)	0.501 (0.075)
Mean	**0.963 (0.010)**	**0.631 (0.037)**	**0.660 (0.044)**	**0.448 (0.041)**	**0.436 (0.043)**

Table 30. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River steelhead (wild only), 1999–2013. Standard errors in parentheses; simple arithmetic means are given.

	Annual survival estimates for wild steelhead				
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
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)
2012	1.107 (0.070)	0.697 (0.047)	NA	NA	NA
2013	0.921 (0.057)	0.621 (0.055)	0.671 (0.142)	0.417 (0.096)	0.384 (0.091)
Mean	**0.967 (0.015)**	**0.634 (0.043)**	**0.604 (0.046)**	**0.416 (0.044)**	**0.400 (0.044)**

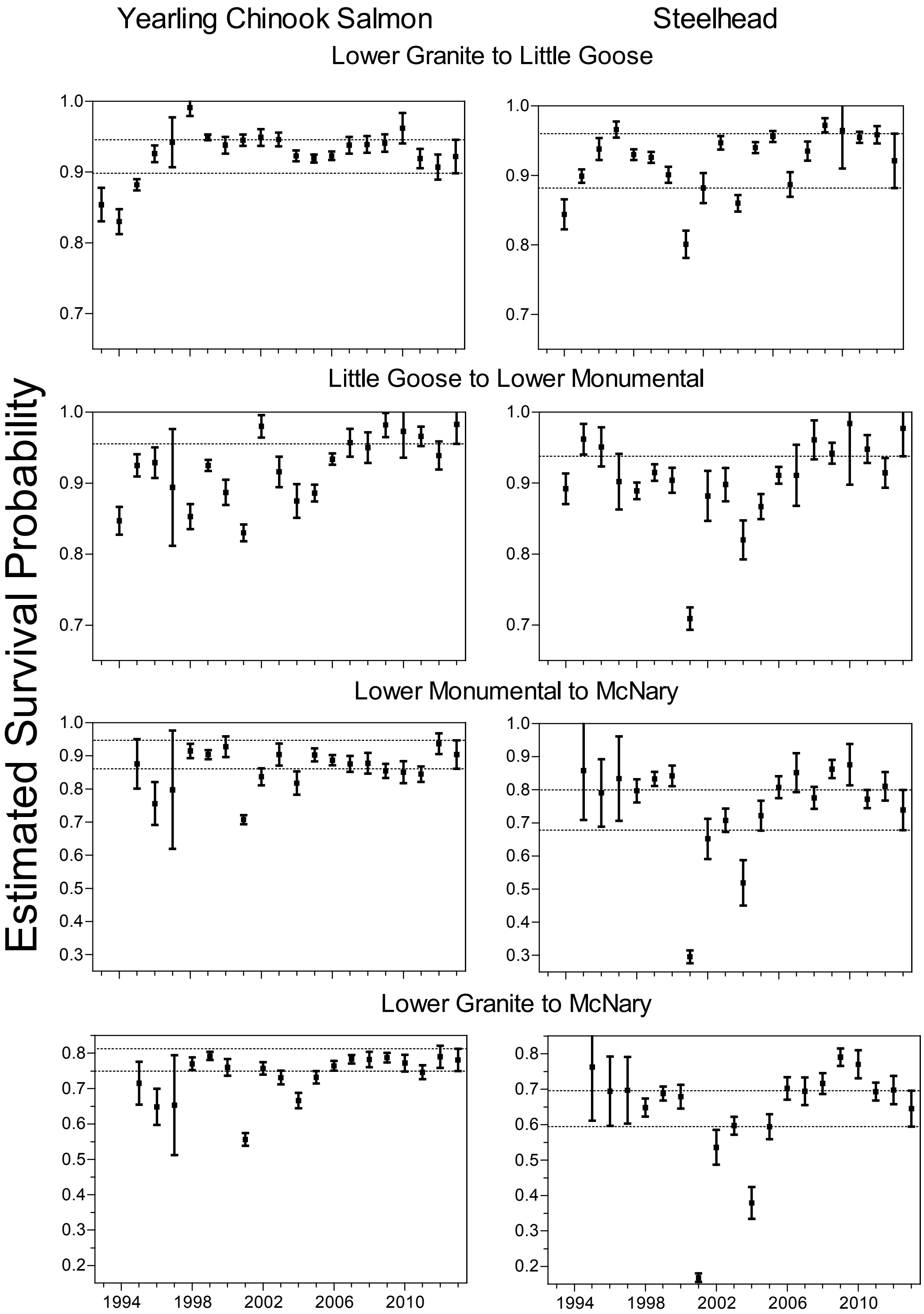


Figure 8. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead (hatchery and wild combined) through Snake River reaches, 1993-2013. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2013 estimates.

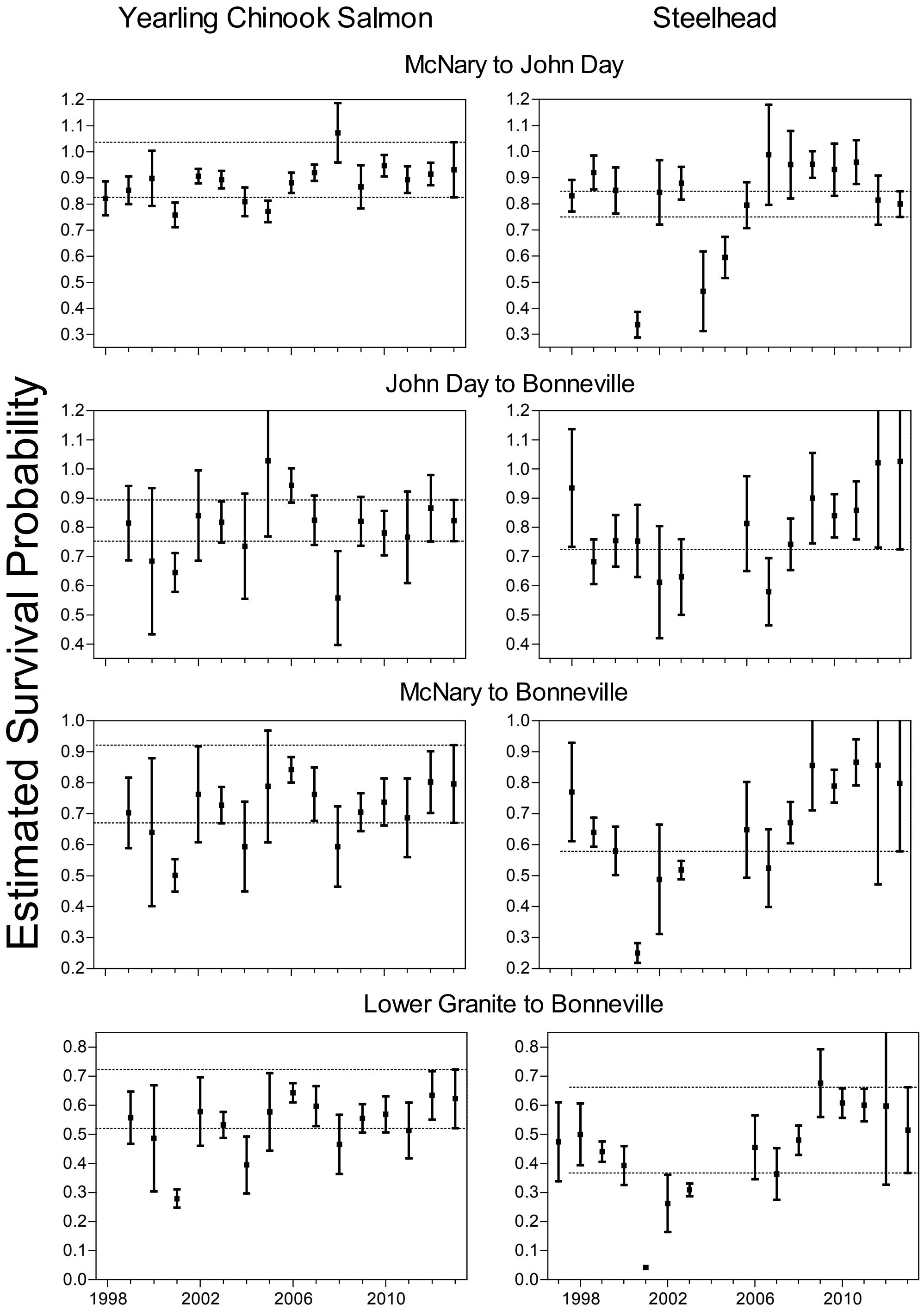


Figure 9. Annual average survival estimates for PIT-tagged Snake River yearling Chinook salmon and steelhead (hatchery and wild combined) through Columbia River reaches and from Lower Granite Dam to Bonneville Dam, 1993-2013. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2013 estimates.

Sockeye Salmon—For pooled groups of wild and hatchery sockeye salmon originating in the Snake River basin, estimated survival from Lower Granite to McNary Dam tailrace in 2013 was 0.691 (95% CI 0.612-0.781; Table 31). The estimate for this reach was lower in 2013 than in 2012, but higher than the average for 1996-2013. Estimated survival from Lower Granite to Bonneville Dam was 0.536 (0.421-0.682) for Snake River sockeye salmon in 2013. For pooled groups of wild and hatchery sockeye originating in the Upper Columbia basin, estimated survival was 0.741 (0.619-0.890) from Rock Island to McNary Dam tailrace and 0.487 (0.265-0.895) from Rock Island to Bonneville Dam tailrace.

Table 31. 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, 1996–2013. Standard errors in parentheses.

	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
2012	0.762 (0.032)	0.619 (0.084)	0.472 (0.062)
2013	0.691 (0.043)	0.776 (0.106)	0.536 (0.066)
Mean	**0.617 (0.041)**	**0.566 (0.085)**	**0.406 (0.059)**

	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)
2012	0.945 (0.085)	0.840 (0.405)	0.794 (0.376)
2013	0.741 (0.068)	0.658 (0.217)	0.487 (0.155)
Mean	**0.671 (0.035)**	**0.775 (0.096)**	**0.537 (0.067)**

Upper Columbia River Stocks

Sockeye Salmon—For Upper Columbia River sockeye salmon captured, tagged, and released to the tailrace of Rock Island Dam in 2013, estimated survival to McNary tailrace was 0.741 (95% CI 0.619-0.887; Table 31). Estimated survival of these fish from Rock Island to Bonneville Dam was 0.487 (0.265-0.895). Note that this estimate to Bonneville was imprecise due to low detection rates of these fish at McNary and Bonneville Dam.

Yearling Chinook Salmon and Steelhead—For pooled groups of yearling Chinook from Upper Columbia River hatcheries, estimated survival from McNary tailrace to Bonneville tailrace was 1.056 (0.850-1.311). This estimate was greater than the 1999-2013 average of 0.794 for that reach (Table 32), but was very imprecise due to poor detection at Bonneville Dam.

For pooled groups of hatchery steelhead from Upper Columbia hatcheries, estimated survival from McNary tailrace to Bonneville tailrace in 2013 was 0.932 (0.757-1.147). This estimate was again imprecise due to poor and variable detection rates at Lower Columbia River dams (Table 32).

Table 32. Estimated survival and standard error (se) through reaches of the lower Columbia River hydropower system for hatchery yearling Chinook salmon (1999–2013) and steelhead (2003–2013) 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)
2012	0.576 (0.012)	0.836 (0.035)	1.140 (0.142)	0.953 (0.115)
2013	0.555 (0.013)	0.965 (0.050)	1.095 (0.129)	1.056 (0.117)
Mean	**0.554 (0.014)**	**0.904 (0.028)**	**0.869 (0.054)**	**0.794 (0.040)**
	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)
2012	0.281 (0.011)	0.862 (0.047)	1.240 (0.186)	1.069 (0.159)
2013	0.384 (0.020)	0.957 (0.071)	0.974 (0.104)	0.932 (0.099)
Mean	**0.419 (0.020)**	**0.917 (0.041)**	**0.860 (0.068)**	**0.772 (0.048)**

Comparison of Annual Survival Estimates Among Snake and Columbia River Stocks

Estimated survival from McNary to Bonneville Dam tailrace was lower for Snake (0.792, se 0.071) than for Upper Columbia River spring/summer Chinook migrating in 2013 (1.025, se 0.103; Table 33). However, because of low precision in the estimates, the difference was not statistically significant ($P = 0.21$). For steelhead migrating in this same reach during 2013, estimated survival was lower for Snake (0.798, se 0.112) than for Upper Columbia River fish (0.910, se 0.075), although again the difference was not statistically significant ($P = 0.59$) because of low precision. For sockeye salmon, estimated survival from McNary to John Day tailrace was similar between Snake (0.776, se 0.106) and Upper Columbia River fish (0.771, se 0.236), but both estimates were very imprecise.

Table 33. 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 2013. For each reach, the survival estimate represents either a weighted average of weekly estimates (indicated by *), or a single seasonal estimate for pooled release cohorts. Numbers released for pooled estimates (no asterisk) are from points upstream of McNary Dam. Abbreviations: Sp/Su, spring/summer.

			Survival estimates (standard errors)		
Stock	Release location	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
Snake R Chinook (Sp/Su)*	McNary Dam tailrace	45,802*	0.931 (0.054)	0.823 (0.036)	0.796 (0.064)
Upper Columbia Chinook (Sp/Su)	Upper Columbia sites[a]	134,287	0.955 (0.042)	1.073 (0.114)	1.025 (0.103)
Upper Columbia Chinook (Sp/Su)	Yakima River sites[b]	83,435	0.797 (0.037)	0.954 (0.156)	0.760 (0.121)
Upper Columbia Coho	Upper Columbia sites	51,729	0.805 (0.053)	1.026 (0.114)	0.826 (0.087)
Upper Columbia Coho	Yakima River sites	20,958	0.889 (0.098)	1.518 (0.392)	1.349 (0.335)
Snake River Sockeye	Snake River sites[c]	54,939	0.845 (0.090)	0.918 (0.139)	0.776 (0.106)
Upper Columbia Sockeye	Upper Columbia sites	6,235	1.174 (0.243)	0.657 (0.229)	0.771 (0.236)
Snake River Steelhead*	McNary Dam Tailrace	12,513*	0.799 (0.025)	1.026 (0.154)	0.798 (0.112)
Upper Columbia Steelhead	Upper Columbia sites	88,892	0.953 (0.053)	0.955 (0.081)	0.910 (0.075)

[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

For Snake River yearling Chinook salmon in 2013, estimated survival from Lower Granite to Bonneville Dam tailrace was 61.9%, which was the third highest we have observed in the 1999-2013 time series (higher only in 2006 and 2012). However, an unusually low survival probability (84.5%) was estimated from the Snake River Trap to Lower Granite Dam tailrace. This resulted in a survival estimate of 52.5% through the entire hydropower system. This was lower than, but not significantly different from the 2012 estimate of 58.8% ($P = 0.31$; Table 4). For yearling Chinook salmon in 2013, estimated survival was 3.9% higher than the long-term average (78.1 vs. 74.2%) between Lower Granite and McNary Dam and 8.7% higher than the long-term average (79.6 vs. 70.9%) between McNary and Bonneville Dam. Chinook survival through the hydropower system has remained relatively stable since 1999 with the exception of lower estimates in 2001 and 2004.

For steelhead in 2013, estimated survival through the hydropower system was 50.1%, which was higher than the long-term average of 43.2% but also the lowest estimate since 2008 (Table 29). Despite being 9.8% lower than in 2012 (59.8%), the 2013 and 2012 estimates were not significantly different due to high uncertainty in the latter ($P = 0.54$; Table 29). Estimated survival through the entire hydropower system was low for steelhead in 2013 relative to recent years due to lower-than-average mean survival estimates from McNary to John Day (79.9 vs. 80.7% average) and from Lower Monumental to McNary Dam tailrace (73.9 vs. 75.5% average). Estimates for weekly release groups of steelhead indicated that survival from Lower Granite to McNary Dam tailrace decreased through the last few weeks of the season. This pattern has been observed in previous years and could be caused by increased predation and higher temperatures during that period.

In general, river flows during the 2013 spring migration were low, with moderately high temperatures at times and with above-average spill percentages. These conditions are similar to those that occurred in 2007 and 2010. Estimated survival through the hydropower system was lower in 2013 than in either 2007 or 2010 for yearling Chinook salmon (Table 27). For steelhead in 2013, estimated survival probabilities were intermediate to those of 2007 and 2010 (2007 and 2010 estimates were very different from each other) (Table 29). Migration rates were faster for steelhead in 2013 than in either 2007 and 2010.

With the addition of a temporary spillway weir (TSW) at Little Goose Dam in 2009, all eight mainstem dams encountered by migrating smolts from the Snake River Basin have some form of surface-bypass structure. These include removable spillway weirs (RSWs) at Lower Granite, Lower Monumental, and Ice Harbor Dam; TSWs at Little Goose, McNary, and John Day Dam, the ice-trash sluiceway at The Dalles 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 (i.e., not higher than) those through juvenile bypass systems or unaltered spillways. However, surface bypass structures provide an advantage by reducing smolt delay in the forebay. For migrating smolts, less time spent in the reservoir and forebay of a dam means decreased travel time and reduced exposure to predators.

Decreased forebay delay and overall shortened travel times also potentially decrease exposure to the elevated water temperatures that may occur late in spring or in early summer. In steelhead smolts, warmer water can trigger reversion to the parr stage, accompanied by cessation of migration. Zaugg and Wagner (1973) found that gill Na^+K^+-ATPase (an indicator of migratory readiness) and migratory urge declined in steelhead at water temperatures of 13°C and above.

A PIT-tagged smolt that ceases migration will not be detected at further downstream dams. Therefore, reversion to parr cannot be distinguished from mortality using PIT-tag data, and survival estimates will be biased downward if significant numbers of fish revert to parr. This may have been a factor in the low survival estimates we observed for steelhead in 2001, when longer travel times were observed late in the season and water temperatures exceeded 13°C (see Zabel et al. 2002). Thus, estimated survival should be higher for populations of steelhead when travel times are reduced.

Predation is another factor that 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 their populations and consumption rates are intensively monitored (Ryan et al. 2001, 2003; Roby et al. 2008, Evans et al. 2012). 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.*

Studies have shown that steelhead smolts are particularly susceptible to predation by birds (Hostetter et al. 2012). For example, Collis et al. (2001) found that over 15% of the PIT-tags from steelhead detected at Bonneville Dam in 1998 were later found on estuarine bird colonies, but on the same colonies they found only 2% of the PIT-tags from detected yearling Chinook salmon. As indexed by the percentages of tags detected at Lower Monumental Dam and subsequently detected on bird colonies (Table 34), the estimated proportion of PIT-tagged steelhead lost to piscivorous birds Lake Wallula was lower during 2006-2012 than during 2001-2005.

Table 34. Percentages of PIT–tagged smolts detected at Lower Monumental Dam and subsequently detected on avian predator colonies in McNary reservoir, 1998-2012. Estimates are not adjusted for detection efficiency on individual colonies and therefore are minimum estimates of predation rates.

	Proportion of wild and hatchery smolts detected at Lower Monumental Dam and subsequently detected on Lake Wallula 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
2012	0.52	2.32

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

Steelhead survival between Lower Monumental and McNary Dams was, correspondingly, lower during 2001-2005 and higher during 2006-2012 For both yearling Chinook salmon and steelhead detected at Lower Monumental Dam, we have observed a significant negative correlation between estimated survival to McNary Dam and percentage of PIT tags recovered on avian colonies (Figure 10). The smaller proportion of smolts taken by birds during 2006-2012 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 since 2009), and delayed initiation of the smolt transportation program.

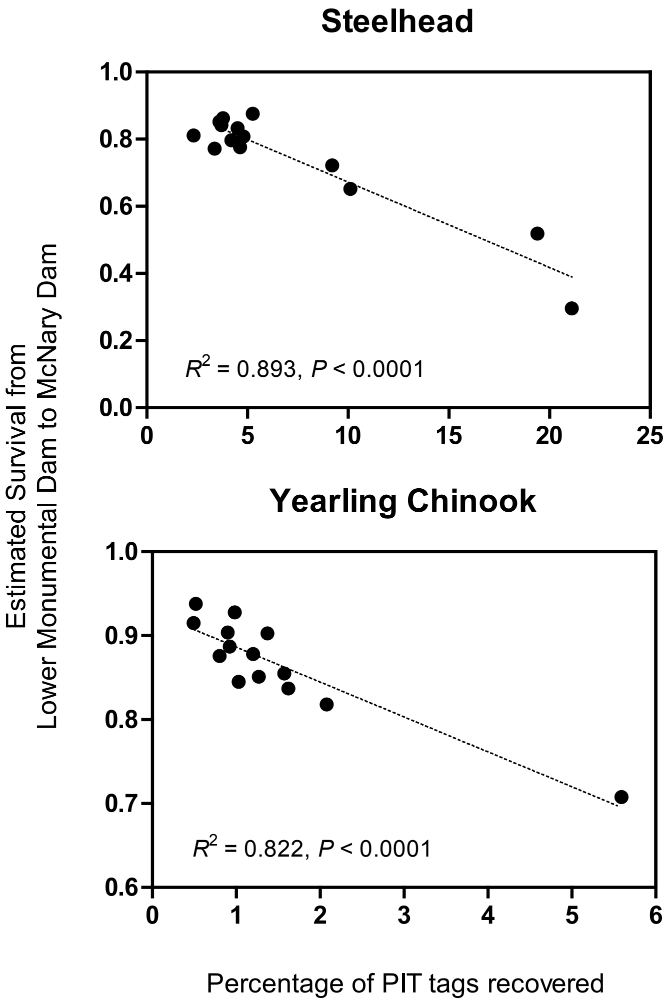


Figure 10. Estimated survival between Lower Monumental and McNary Dams vs. percentage of Lower Monumental Dam-detected PIT tags recovered on bird colonies, 1998-2012 (excluding 2003, which had incomplete recovery effort).

Piscivorous fish also contribute significantly to mortality of migrating Chinook salmon and steelhead smolts (Rieman et al. 1991). Species of reservoir-dwelling fishes that may prey heavily on migrating smolts include northern pikeminnow *Ptychocheilus oregonensis*, walleye *Sander vitreus*, and smallmouth bass *Micropterus dolomieu*. Reiman et al. (1991) found that fish predators (primarily pikeminnow) could consume nearly 14% of all smolts migrating through John Day reservoir, and more recently, salmonid smolts accounted for 15% of identifiable prey items recovered from pikeminnow stomachs in 2012 (Porter 2012).

Since 1990, the Bonneville Power Administration has funded a sport reward fishery for northern pikeminnow in the lower Columbia River under the Northern Pikeminnow Management Plan. Abundance estimates of large (>250 mm FL) pikeminnow in The Dalles and John Day reservoirs have declined steadily since the inception of the sport reward program; abundance estimates for large fish over the last 5 years are only one-tenth those in 1990 (Porter 2012).

The effective sample size for survival estimation with PIT tags is a result of both the number of PIT-tagged fish migrating and the detection rate as the fish migrate. Low detection rates of PIT-tagged fish have become common in recent years, as management has relied increasingly on use of spill and surface-bypass structures. Spill is now the primary management strategy to increase the survival of juvenile fish passing dams within the Federal Columbia River Power System. This management strategy reduces detection rates by reducing the proportion of fish that pass dams via juvenile bypass systems, the only passage routes (other than the Bonneville Dam corner collector) for which PIT-tag monitoring technology is currently available.

While smolt survival might indeed be increased by emphasizing spillway passage, the quality of information gathered with PIT-tags is reduced. Three consequences are:

1) Less certainty in survival estimates (larger standard errors; wider confidence intervals).
2) Greater negative correlation between survival estimates in consecutive reaches (increased chance that estimates will be high in one reach and low in the next, or vice versa).
3) Insufficient data to estimate survival at all in some cases.

All three consequences are most serious in the final reaches of the migration corridor for which we estimate smolt survival, McNary to John Day Dam, and John Day Dam to Bonneville Dam.

Smaller effective sample sizes also heighten uncertainty in estimates of travel time and smolt-to-adult return ratios. Such uncertainty reduces the quality of predictive models, which are based on these estimates. Ultimately, this uncertainty may weaken the efficacy of management decisions informed by estimates and model predictions, hinder the development of appropriate restoration plans, and impair the ability to monitor and assess restoration plans after they are implemented.

At a given rate of PIT-tag detection, precision in survival estimates can be increased only by increasing the number of tagged fish released to the system. Unfortunately, this option would be costly and would further strain an already stressed biological resource. Therefore, assuming the emphasis on surface-bypass and spillway passage will continue, the best option for retaining or increasing precision in survival estimates would be to equip additional passage routes with PIT-tag monitoring technology. Adding this capability will not only increase the proportions of fish detected at each dam, it will also act to stabilize detection rates across the season.

Currently, fluctuations in spill and flow produce variable detection rates through each migration season. These variations can have negative consequences on the accuracy of estimates from mark-recapture models, as well as introduce bias to estimates of travel time. Detection capability in multiple routes at a dam will reduce this variation and will advance our understanding of passage via different routes throughout the migration season, producing valuable insight into fish passage behavior.

Finally, the ability to detect PIT-tagged fish in additional passage routes may increase the accuracy of survival estimates. Detection of fish passing multiple routes will reduce the possibility of bias in survival estimates that results if survival is not equal between detected and undetected fish.

For all of these reasons, we believe there is an urgent need to develop and install PIT-tag monitoring systems in passage routes other than juvenile bypass systems. In terms of their importance to survival estimates, the highest priority for new systems are the spillway at Bonneville Dam, and surface passage structures Lower Granite and McNary Dams.

Because of consistently poor detection rates at Bonneville Dam, the reach from John Day to Bonneville has been the weakest link in our ability to estimate survival through the entire hydropower system. At present, we rely on detections in the pair trawl system operated below Bonneville Dam; however, rates of detection in the trawl are low and not likely to increase substantially. Adding detection capability at Bonneville Dam is therefore the greatest priority.

Lower Granite and McNary Dams are important as the “starting points” for our estimates of juvenile smolt survival. Increasing the number of detections at these two dams in particular will increase precision of estimates and modeling of in-season trends and patterns. These two sites are also critical for investigations of the relationship between juvenile migration timing and downstream survival or smolt-to-adult return rates. For either assessment, the “time-stamp” provided by detection of a PIT-tag is required.

The PIT tag is a valuable research tool that yields a great deal of important information that cannot be obtained by any other tagging method. For example, the PIT-tag allows continuous monitoring of large fish groups through both their juvenile and adult migrations. It allows comparison of smolt-to-adult return ratios between different treatment groups. Therefore, it is critical that we take the necessary steps to maximize the quantity and quality of information already offered by the PIT tag at our current levels of tagging.

CONCLUSIONS AND RECOMMENDATIONS

Results from the 2013 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 sources of mortality in these areas are to be identified.

3) Increasing the number of PIT-tag detection facilities in the Columbia River Basin will improve survival estimation. 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 and surface structures would improve detection rates and greatly enhance certainty in estimates 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. (1987; 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 2013 (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. (1987) 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 2013 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 8 weekly groups of yearling Chinook salmon. For these, the overall sum of the χ^2 test statistics was significant 4 times (50%). For 8 steelhead groups, the overall test was significant 2 times (25%). Counting all individual component tests (i.e., 2.C2, 3.SR3, etc.), 7 tests of 39 (18%) were significant for yearling Chinook salmon and 4 of 39 (10%) were significant for steelhead (Appendix Tables A1-A3).

We diagnosed the patterns in the contingency tables that led to significant tests and results were similar to those we reported in past years. Six of the 11 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 steelhead but not for (Appendix Tables A4-A6). For yearling Chinook salmon, there were no significant tests out of the 10 individual component tests, and for steelhead 1 (20%) of the 5 component tests were significant. The one significant component tests for steelhead was for Test 2.C2.

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 2013, as in previous years. Zabel et al. (2002) and Zabel et al. (2005) provided evidence of inherent differences related to length of fish at tagging, and similar observations were made in 2013 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 non-detected 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 non-detected fish in the tailrace of the detection dam of interest and downstream. The fate of fish not detected at the site of interest is only known for those fish detected again downstream, and not for those never detected again. Therefore, none of the assumptions tests described here can detect differential post-detection mortality between two adjacent detection sites.

Results in previous years (e.g., Zabel et al. 2002) led us to conclude that 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, 2013.

	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	8	3	8	1	8	0	7	0	8	3	8	3	8	1	8	4
Steelhead	8	1	8	1	7	1	7	1	8	0	8	1	8	0	8	2
Total	16	4	16	2	16	1	16	1	16	3	16	4	16	1	16	6

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 2013.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
30 Mar–5 Apr	19.83	**0.003**	4.44	0.218	1.51	0.470	2.93	0.087
6 Apr–12 Apr	10.97	0.089	6.38	0.094	5.17	0.075	1.21	0.271
13 Apr–19 Apr	9.44	0.150	4.86	0.182	4.61	0.100	0.25	0.616
20 Apr–26 Apr	3.17	0.788	1.68	0.642	1.66	0.437	0.02	0.886
27 Apr–3 May	24.51	**<0.001**	23.82	**<0.001**	11.81	**0.003**	12.01	**0.001**
4 May–10 May	16.04	**0.014**	8.84	**0.032**	8.82	**0.012**	0.02	0.897
11 May–17 May	18.82	**0.004**	11.92	**0.008**	9.63	**0.008**	2.28	0.131
18 May–24 May	0.49	0.993	0.39	0.942	0.20	0.905	0.19	0.660
Total (df)	103.27 (47)		62.32 (24)		43.41 (16)		18.20 (8)	

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
30 Mar–5 Apr	15.39	**0.002**	0.05	0.827	1.31	0.252	14.04	**<0.001**
6 Apr–12 Apr	4.59	0.204	1.28	0.257	3.30	0.069	0.00	0.968
13 Apr–19 Apr	4.58	0.206	1.74	0.188	0.18	0.672	2.66	0.103
20 Apr–26 Apr	1.49	0.685	0.81	0.368	0.29	0.590	0.39	0.534
27 Apr–3 May	0.69	0.876	0.07	0.786	0.48	0.487	0.13	0.719
4 May–10 May	7.21	0.066	0.12	0.726	0.98	0.322	6.10	**0.013**
11 May–17 May	6.91	0.075	0.02	0.876	0.58	0.448	6.31	**0.012**
18 May–24 May	0.09	0.955	0.03	0.872	.	.	0.07	0.795
Total (df)	40.94 (23)		4.13 (8)		7.13 (7)		29.69 (8)	

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 2013.

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
6 Apr–12 Apr	4.73	0.579	2.36	0.502	0.62	0.733	1.74	0.188
13 Apr–19 Apr	5.23	0.514	3.82	0.282	1.51	0.471	2.31	0.128
20 Apr–26 Apr	11.37	0.078	4.45	0.216	4.31	0.116	0.14	0.709
27 Apr–3 May	3.39	0.759	1.83	0.609	1.15	0.562	0.68	0.411
4 May–10 May	15.03	**0.020**	7.65	0.054	5.55	0.062	2.10	0.147
11 May–17 May	30.51	**<0.001**	26.52	**<0.001**	20.14	**<0.001**	6.38	**0.012**
18 May–24 May	7.01	0.320	0.88	0.830	0.80	0.669	0.08	0.781
25 May–31 May	3.48	0.481	3.44	0.329	3.28	0.194	0.16	0.689
Total (df)	80.74 (46)		50.94 (24)		37.37 (16)		13.58 (8)	

	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
6 Apr–12 Apr	2.37	0.499	0.61	0.436	0.99	0.320	0.78	0.378
13 Apr–19 Apr	1.41	0.702	0.95	0.331	0.47	0.495	0.00	0.947
20 Apr–26 Apr	6.92	0.075	3.99	**0.046**	2.20	0.138	0.73	0.392
27 Apr–3 May	1.56	0.669	0.22	0.637	1.22	0.269	0.11	0.737
4 May–10 May	7.38	0.061	3.40	0.065	2.90	0.088	1.08	0.300
11 May–17 May	3.99	0.262	2.13	0.145	1.35	0.245	0.51	0.473
18 May–24 May	6.13	0.105	0.93	0.335	4.49	**0.034**	0.71	0.400
25 May–31 May	0.04	0.841	.	.	.	.	0.04	0.841
Total (df)	29.80 (22)		12.22 (7)		13.62 (7)		3.96 (8)	

Appendix Table A4. Number of tests of goodness of fit to the single release model conducted for weekly release groups of yearling Chinook salmon and steelhead (hatchery and wild combined) from McNary Dam, and number of significant ($\alpha = 0.05$) test results, 2013.

	Test 2.C2		Test 3.SR3		Test 2 + 3	
Species	No.	sig.	No.	sig.	No.	sig.
Chinook	6	0	4	0	6	0
Steelhead	3	1	2	0	3	1
Total	9	1	6	0	9	1

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 2013.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
20 Apr–26 Apr	0.48	0.788	0.38	0.539	0.10	0.753
27 Apr–3 May	1.06	0.588	0.05	0.820	1.01	0.315
4 May–10 May	1.24	0.539	0.54	0.464	0.70	0.403
11 May–17 May	0.55	0.761	0.00	0.984	0.55	0.460
18 May–24 May	2.91	0.088	2.91	0.088	.	.
25 May–31 May	1.99	0.158	1.99	0.158	.	.
Total (df)	8.22 (10)		5.87 (6)		2.36 (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 2013.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
20 Apr–3 May	0.05	0.974	0.02	0.876	0.03	0.868
4 May–17 May	0.81	0.668	0.07	0.793	0.74	0.390
18 May–31 May	4.54	**0.033**	4.54	**0.033**	.	.
1 Jun–14 Jun	.	.	.	.	.	.
Total (df)	5.40 (5)		4.64 (3)		0.77 (2)	

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 2013. 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	17,081	0.832 (0.025)	0.943 (0.044)	0.963 (0.067)	0.870 (0.060)	0.657 (0.022)
Crooked River	25,451	0.550 (0.013)	1.070 (0.041)	0.997 (0.063)	0.857 (0.056)	0.503 (0.017)
Powell Pond	17,058	0.544 (0.018)	1.001 (0.053)	1.189 (0.112)	0.756 (0.073)	0.489 (0.022)
Red River Pond	16,848	0.582 (0.019)	1.068 (0.060)	1.023 (0.092)	0.824 (0.075)	0.524 (0.024)
Selway River	17,063	0.584 (0.016)	0.958 (0.041)	1.056 (0.082)	0.784 (0.061)	0.463 (0.016)
			Dworshak Hatchery			
NF Clearwater River	51,798	0.794 (0.015)	0.970 (0.028)	1.010 (0.043)	0.850 (0.036)	0.661 (0.014)
			Kooskia Hatchery			
Kooskia	13,282	0.609 (0.026)	0.985 (0.060)	0.959 (0.080)	0.845 (0.072)	0.487 (0.022)
			Lookingglass Hatchery			
Catherine Creek Pond	20,816	0.220 (0.007)	0.899 (0.047)	1.061 (0.096)	1.003 (0.119)	0.210 (0.018)
Grande Ronde Pond	1,668	0.382 (0.024)	0.957 (0.091)	1.198 (0.214)	0.999 (0.274)	0.438 (0.097)
Imnaha Weir	20,896	0.703 (0.019)	0.985 (0.046)	1.024 (0.075)	0.891 (0.068)	0.633 (0.026)
Lostine Pond	5,977	0.604 (0.014)	0.982 (0.036)	0.956 (0.061)	1.032 (0.105)	0.585 (0.050)
			McCall Hatchery			
Johnson Creek	2,092	0.554 (0.026)	0.942 (0.075)	1.143 (0.180)	0.786 (0.155)	0.469 (0.064)
Knox Bridge	53,900	0.656 (0.011)	1.059 (0.032)	1.062 (0.052)	0.820 (0.043)	0.605 (0.018)
			Pahsimeroi Hatchery			
Pahsimeroi Pond	22,390	0.606 (0.016)	1.002 (0.041)	0.972 (0.066)	0.966 (0.069)	0.570 (0.021)
			Rapid River Hatchery			
Rapid River Hatchery	51,897	0.735 (0.011)	1.039 (0.030)	1.084 (0.052)	0.788 (0.042)	0.653 (0.021)
			Sawtooth Hatchery			
Sawtooth Hatchery	22,278	0.564 (0.011)	0.993 (0.035)	1.082 (0.070)	0.950 (0.079)	0.575 (0.033)

Appendix Table B2. Estimated survival probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2013. 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 R.	5,988	0.670 (0.028)	0.920 (0.052)	0.985 (0.136)	0.766 (0.120)	0.465 (0.039)
Meadow Creek	17,154	0.648 (0.020)	0.835 (0.033)	1.107 (0.095)	0.788 (0.083)	0.472 (0.031)
Newsome Creek	3,390	0.563 (0.043)	0.838 (0.087)	1.110 (0.198)	0.742 (0.179)	0.389 (0.066)
Dworshak Hatchery						
Clearwater R.	18,199	0.816 (0.019)	0.907 (0.035)	1.239 (0.091)	0.627 (0.049)	0.574 (0.023)
Lolo Creek	3,264	0.602 (0.045)	0.795 (0.088)	0.797 (0.147)	0.930 (0.261)	0.354 (0.079)
S.F. Clearwater R.	8,888	0.637 (0.017)	0.967 (0.037)	0.920 (0.076)	0.816 (0.083)	0.462 (0.030)
Hagerman Hatchery						
Salmon River	2,192	1.011 (0.100)	0.798 (0.104)	0.773 (0.116)	0.879 (0.144)	0.548 (0.058)
East Fork Salmon R.	9,737	0.625 (0.019)	1.051 (0.058)	0.887 (0.086)	0.705 (0.098)	0.411 (0.043)
Sawtooth Hatchery	15,321	0.731 (0.029)	1.066 (0.063)	0.959 (0.082)	0.696 (0.071)	0.520 (0.035)
Yankee Fork	3,989	0.834 (0.045)	0.847 (0.066)	0.962 (0.102)	1.292 (0.303)	0.878 (0.186)
Irrigon Hatchery						
Big Canyon Facility	8,468	0.788 (0.028)	0.941 (0.051)	1.222 (0.114)	0.854 (0.119)	0.774 (0.084)
Little Sheep Facility	21,882	0.742 (0.014)	0.937 (0.028)	1.052 (0.059)	0.660 (0.056)	0.483 (0.032)
Wallowa Hatchery	13,407	0.777 (0.024)	0.956 (0.043)	0.960 (0.072)	0.808 (0.080)	0.576 (0.041)
Lyons Ferry Hatchery						
Cottonwood Pond	5,991	0.818 (0.044)	1.045 (0.083)	0.942 (0.108)	0.870 (0.131)	0.700 (0.078)

Appendix Table B2. Continued.

	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
			Magic Valley Hatchery			
Little Salmon R.	7,180	0.912 (0.035)	0.937 (0.054)	0.981 (0.087)	0.900 (0.121)	0.754 (0.080)
Pahsimeroi R. Trap	11,651	0.774 (0.026)	1.011 (0.050)	0.896 (0.069)	0.688 (0.084)	0.483 (0.048)
Salmon R. (rkm 347)	1,498	0.893 (0.111)	0.992 (0.177)	0.737 (0.166)	0.800 (0.202)	0.522 (0.088)
Salmon R. (rkm 385)	1,500	0.832 (0.074)	0.980 (0.130)	1.056 (0.240)	0.692 (0.194)	0.596 (0.110)
Salmon R. (rkm 476)	1,495	0.876 (0.104)	0.864 (0.140)	1.611 (0.478)	0.414 (0.144)	0.504 (0.101)
Sqaw Creek, Salmon R.	2,890	0.720 (0.051)	0.954 (0.100)	1.068 (0.206)	1.379 (0.636)	1.012 (0.426)
Yankee Fork	11,259	0.492 (0.019)	0.984 (0.064)	0.936 (0.108)	0.800 (0.156)	0.362 (0.059)
			Niagara Springs Hatchery			
Hells Canyon Dam	9,075	0.595 (0.020)	1.125 (0.072)	1.223 (0.159)	0.660 (0.098)	0.540 (0.046)
Little Salmon R.	7,084	0.772 (0.027)	0.949 (0.052)	0.992 (0.096)	0.849 (0.125)	0.617 (0.071)
Pahsimeroi R. Trap	12,051	0.645 (0.018)	1.043 (0.046)	0.985 (0.087)	0.603 (0.069)	0.400 (0.031)

Appendix Table B3. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2013. 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	9 May 13	2,000	0.557 (0.046)	0.908 (0.168)	1.134 (0.389)	0.576 (0.265)	0.593 (0.213)	0.330 (0.116)
Sawtooth Hatchery								
Redfish L. Cr. Trap	9 May 13	50,064	0.548 (0.007)	0.913 (0.031)	0.981 (0.079)	0.774 (0.077)	0.693 (0.045)	0.379 (0.024)

Appendix Table B4. Estimated detection probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2013. 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	17,081	0.128 (0.005)	0.127 (0.005)	0.045 (0.003)	0.300 (0.011)
Crooked River	25,451	0.185 (0.005)	0.170 (0.006)	0.066 (0.004)	0.274 (0.010)
Powell Pond	17,058	0.167 (0.006)	0.144 (0.007)	0.047 (0.004)	0.263 (0.013)
Red River Pond	16,848	0.185 (0.007)	0.148 (0.008)	0.071 (0.006)	0.240 (0.012)
Selway River	17,063	0.158 (0.006)	0.159 (0.006)	0.043 (0.004)	0.331 (0.012)
			Dworshak Hatchery		
NF Clearwater R.	51,798	0.143 (0.003)	0.150 (0.004)	0.065 (0.003)	0.265 (0.006)
			Kooskia Hatchery		
Kooskia	13,282	0.133 (0.007)	0.164 (0.008)	0.064 (0.006)	0.324 (0.015)
			Lookingglass Hatchery		
Catherine Cr. Pond	20,816	0.312 (0.011)	0.292 (0.014)	0.155 (0.014)	0.189 (0.017)
Grande Ronde Pond	1,668	0.285 (0.024)	0.265 (0.027)	0.131 (0.025)	0.136 (0.033)
Imnaha Weir	20,896	0.188 (0.006)	0.172 (0.007)	0.088 (0.006)	0.205 (0.009)
Lostine Pond	5,977	0.340 (0.010)	0.292 (0.012)	0.176 (0.012)	0.170 (0.016)
			McCall Hatchery		
Johnson Creek	2,092	0.318 (0.019)	0.243 (0.021)	0.097 (0.016)	0.179 (0.027)
Knox Bridge	53,900	0.192 (0.004)	0.164 (0.004)	0.089 (0.004)	0.186 (0.006)
			Pahsimeroi Hatchery		
Pahsimeroi Pond	22,390	0.146 (0.005)	0.163 (0.006)	0.044 (0.003)	0.236 (0.009)
			Rapid River Hatchery		
Rapid River H.	51,897	0.227 (0.004)	0.175 (0.004)	0.110 (0.005)	0.162 (0.006)
			Sawtooth Hatchery		
Sawtooth H.	22,278	0.278 (0.007)	0.265 (0.008)	0.133 (0.008)	0.161 (0.010)

Appendix Table B5. Estimated detection probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2013. 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					
Meadow Creek	17,154	0.139 (0.005)	0.337 (0.010)	0.070 (0.006)	0.116 (0.008)
Newsome Creek	3,390	0.169 (0.015)	0.300 (0.023)	0.122 (0.022)	0.098 (0.019)
S.F. Clearwater R.	5,988	0.142 (0.008)	0.345 (0.015)	0.049 (0.008)	0.147 (0.014)
Dworshak Hatchery					
Clearwater R.	18,199	0.185 (0.005)	0.176 (0.006)	0.054 (0.004)	0.188 (0.008)
Lolo Creek	3,264	0.202 (0.017)	0.359 (0.029)	0.183 (0.032)	0.111 (0.027)
S.F. Clearwater R.	8,888	0.199 (0.007)	0.382 (0.012)	0.095 (0.009)	0.155 (0.012)
Hagerman Hatchery					
East Fork Salmon R.	9,737	0.268 (0.010)	0.302 (0.014)	0.198 (0.017)	0.100 (0.012)
Salmon River	2,192	0.117 (0.013)	0.248 (0.022)	0.129 (0.018)	0.181 (0.022)
Sawtooth Hatchery	15,321	0.136 (0.006)	0.208 (0.009)	0.108 (0.008)	0.099 (0.008)
Yankee Fork	3,989	0.198 (0.013)	0.343 (0.018)	0.283 (0.027)	0.059 (0.014)
Irrigon Hatchery					
Big Canyon Facility	8,468	0.189 (0.008)	0.268 (0.012)	0.143 (0.013)	0.071 (0.008)
Little Sheep Facility	21,882	0.245 (0.006)	0.343 (0.008)	0.192 (0.010)	0.105 (0.008)
Wallowa Hatchery	13,407	0.173 (0.006)	0.262 (0.009)	0.125 (0.009)	0.098 (0.008)
Lyons Ferry Hatchery					
Cottonwood Pond	5,991	0.130 (0.008)	0.193 (0.012)	0.111 (0.012)	0.086 (0.011)
Magic Valley Hatchery					
Little Salmon R.	7,180	0.190 (0.009)	0.302 (0.013)	0.175 (0.014)	0.091 (0.011)
Pahsimeroi R. Trap	11,651	0.167 (0.007)	0.330 (0.012)	0.210 (0.015)	0.082 (0.009)
Salmon R. (rkm 347)	1,498	0.113 (0.016)	0.211 (0.028)	0.125 (0.025)	0.139 (0.027)
Salmon R. (rkm 385)	1,500	0.170 (0.018)	0.263 (0.027)	0.112 (0.025)	0.120 (0.025)
Salmon R. (rkm 476)	1,495	0.135 (0.018)	0.266 (0.030)	0.092 (0.026)	0.118 (0.027)
Sqaw Creek, Salmon R.	2,890	0.182 (0.015)	0.349 (0.026)	0.181 (0.033)	0.031 (0.014)
Yankee Fork	11,259	0.229 (0.010)	0.301 (0.016)	0.203 (0.021)	0.078 (0.014)
Niagara Springs Hatchery					
Hells Canyon Dam	9,075	0.220 (0.009)	0.208 (0.012)	0.076 (0.010)	0.105 (0.010)
Little Salmon R.	7,084	0.228 (0.010)	0.320 (0.014)	0.181 (0.017)	0.094 (0.012)
Pahsimeroi Trap	12,051	0.217 (0.007)	0.316 (0.012)	0.145 (0.012)	0.122 (0.011)

Appendix Table B6. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2013. 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	9 May 2013	2,000	0.259 (0.024)	0.121 (0.023)	0.053 (0.017)	0.039 (0.016)
			Sawtooth Hatchery			
Redfish L Cr Trap	9 May 2013	50,064	0.401 (0.006)	0.246 (0.008)	0.096 (0.007)	0.093 (0.006)

Appendix Table B7. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2013. 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				
Catherine Creek	15 Feb-28 May	827	0.218 (0.039)	NA	NA	NA	NA
Clearwater River	07 Mar-07 May	323	0.676 (0.067)	NA	NA	NA	NA
Crooked Fk. Cr.	26 Mar-21 May	132	0.345 (0.072)	0.800 (0.179)	NA	NA	NA
Crooked River	22 Mar-29 May	280	0.450 (0.074)	NA	NA	NA	NA
Elgin (G. Ronde)	27 Feb-31 May	769	0.676 (0.028)	1.005 (0.066)	1.073 (0.152)	0.753 (0.168)	0.549 (0.100)
Grande Ronde	06 Mar-21 May	3,943	0.865 (0.024)	0.968 (0.048)	1.061 (0.108)	0.731 (0.083)	0.650 (0.040)
Imnaha	11 Jan-30 May	4,334	0.741 (0.019)	1.017 (0.044)	1.083 (0.089)	0.761 (0.078)	0.621 (0.043)
Johnson Creek	01 Mar-31 May	798	0.400 (0.031)	1.033 (0.114)	1.392 (0.381)	0.727 (0.249)	0.418 (0.094)
Knox Bridge	13 Mar-05 May	285	0.446 (0.057)	NA	NA	NA	NA
Lemhi River	06 Mar-31 May	892	0.513 (0.033)	1.122 (0.140)	0.914 (0.252)	0.816 (0.255)	0.429 (0.074)
Lostine River	03 Jan-30 May	1,200	0.539 (0.033)	1.124 (0.136)	1.117 (0.318)	0.954 (0.312)	0.646 (0.122)
Marsh Creek	21 Mar-31 May	564	0.345 (0.046)	0.934 (0.229)	1.274 (0.760)	0.652 (0.404)	0.268 (0.070)
Lower Marsh Cr.	21 Mar-31 May	555	0.293 (0.039)	NA	NA	NA	NA
Minam River	05 Mar-31 May	760	0.656 (0.049)	1.143 (0.181)	1.230 (0.382)	0.698 (0.256)	0.644 (0.152)
Pahsimeroi	02 Mar-31 May	1,242	0.384 (0.030)	NA	NA	NA	NA
Salmon	12 Mar-05 May	8,194	0.811 (0.021)	0.993 (0.039)	0.943 (0.057)	0.903 (0.061)	0.686 (0.029)
Sawtooth	21 Mar-31 May	1,475	0.453 (0.024)	1.147 (0.136)	1.132 (0.359)	0.742 (0.251)	0.437 (0.068)
Snake	25 Mar-15 May	285	0.791 (0.045)	1.356 (0.200)	1.213 (0.519)	0.592 (0.276)	0.770 (0.171)
U. Grande Ronde	16 Mar-31 May	736	0.319 (0.027)	1.189 (0.163)	1.007 (0.261)	0.751 (0.232)	0.286 (0.061)
			Wild Sockeye Salmon				
Pettit Lake Cr	27 Apr-16 May	494	0.212 (0.025)	1.037 (0.210)	1.116 (0.494)	0.673 (0.378)	0.165 (0.066)
Redfish Lake Cr	11 Apr-07 Jun	1,353	0.255 (0.022)	1.162 (0.212)	1.007 (0.368)	0.767 (0.388)	0.229 (0.090)

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	21 Feb-31 May	3,213	0.794 (0.097)	0.778 (0.178)	NA	NA	NA
Crooked Fk. Cr.	31 Mar-27 May	243	0.554 (0.100)	NA	NA	NA	NA
Crooked River	22 Mar-31 May	212	0.443 (0.052)	NA	NA	NA	NA
Elgin (G. Ronde)	01 Mar-31 May	1,319	0.446 (0.036)	0.816 (0.093)	1.139 (0.240)	0.906 (0.329)	0.375 (0.115)
Grande Ronde	14 Mar-21 May	663	0.941 (0.063)	0.896 (0.107)	NA	NA	NA
Imnaha	15 Mar-30 May	6,796	0.872 (0.021)	0.928 (0.039)	0.979 (0.079)	0.709 (0.090)	0.561 (0.057)
Minam River	04 Mar-31 May	381	0.556 (0.062)	1.031 (0.182)	NA	NA	NA
Pahsimeroi	02 Mar-31 May	498	0.252 (0.048)	NA	NA	NA	NA
Salmon	17 Mar-08 May	425	1.054 (0.150)	0.880 (0.182)	1.173 (0.445)	0.493 (0.224)	0.537 (0.153)
Sawtooth	21 Mar-31 May	323	0.176 (0.046)	0.699 (0.248)	NA	NA	NA
Snake	26 Mar-15 May	1,009	0.921 (0.057)	0.995 (0.112)	0.729 (0.117)	0.848 (0.195)	0.567 (0.106)
U. Grande Ronde	16 Mar-31 May	737	0.256 (0.036)	0.944 (0.190)	NA	NA	NA
			Hatchery Chinook Salmon				
Grande Ronde	06 Apr-07 May	1,401	0.735 (0.038)	0.889 (0.071)	1.072 (0.155)	0.776 (0.146)	0.544 (0.073)
Salmon	13 Mar-04 Apr	3,992	0.819 (0.038)	0.953 (0.072)	1.048 (0.122)	0.719 (0.094)	0.588 (0.049)
Snake	25 Mar-15 May	1,192	0.842 (0.036)	0.968 (0.074)	0.979 (0.129)	0.946 (0.188)	0.756 (0.123)
			Hatchery Steelhead				
Grande Ronde	18 Mar-21 May	2,398	0.883 (0.033)	1.056 (0.064)	1.019 (0.113)	0.596 (0.100)	0.566 (0.076)
Salmon	02 Apr-08 May	2,245	1.113 (0.069)	0.809 (0.066)	1.150 (0.146)	0.646 (0.128)	0.668 (0.107)
Snake	25 Mar-15 May	2,864	0.991 (0.038)	0.910 (0.052)	1.102 (0.114)	0.605 (0.091)	0.602 (0.070)

Appendix Table B8. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2013. 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			
Catherine Creek	15 Feb-28 May	827	0.183 (0.042)	0.188 (0.048)	0.072 (0.033)	0.400 (0.089)
Clearwater River	07 Mar-07 May	323	0.371 (0.047)	0.359 (0.056)	0.131 (0.046)	0.320 (0.093)
Crooked Fk. Cr.	26 Mar-21 May	132	0.286 (0.083)	0.200 (0.073)	0.106 (0.082)	0.400 (0.155)
Crooked River	22 Mar-29 May	280	0.310 (0.062)	0.143 (0.068)	0.182 (0.067)	0.286 (0.121)
Elgin (G. Ronde)	27 Feb-31 May	769	0.431 (0.026)	0.403 (0.031)	0.213 (0.033)	0.235 (0.047)
Grande Ronde	06 Mar-21 May	3,943	0.308 (0.011)	0.296 (0.014)	0.105 (0.011)	0.338 (0.023)
Imnaha	11 Jan-30 May	4,334	0.314 (0.011)	0.301 (0.013)	0.144 (0.012)	0.288 (0.022)
Johnson Creek	01 Mar-31 May	798	0.301 (0.032)	0.312 (0.038)	0.086 (0.026)	0.219 (0.054)
Knox Bridge	13 Mar-05 May	285	0.361 (0.058)	0.323 (0.100)	0.129 (0.091)	0.357 (0.128)
Lemhi River	06 Mar-31 May	892	0.367 (0.030)	0.321 (0.041)	0.135 (0.038)	0.300 (0.057)
Lostine River	03 Jan-30 May	1,200	0.326 (0.026)	0.249 (0.031)	0.075 (0.022)	0.207 (0.042)
Marsh Creek	21 Mar-31 May	564	0.350 (0.054)	0.274 (0.064)	0.058 (0.037)	0.381 (0.106)
Lower Marsh Cr.	21 Mar-31 May	555	0.271 (0.047)	0.276 (0.067)	0.097 (0.053)	0.250 (0.088)
Minam River	05 Mar-31 May	760	0.309 (0.030)	0.202 (0.033)	0.096 (0.029)	0.240 (0.060)
Pahsimeroi	02 Mar-31 May	1,242	0.296 (0.029)	0.215 (0.033)	0.036 (0.024)	0.252 (0.054)
Salmon	12 Mar-05 May	8,194	0.204 (0.007)	0.263 (0.009)	0.126 (0.008)	0.308 (0.014)
Sawtooth	21 Mar-31 May	1,475	0.399 (0.026)	0.298 (0.036)	0.076 (0.025)	0.291 (0.049)
Snake	25 Mar-15 May	285	0.390 (0.038)	0.315 (0.053)	0.091 (0.040)	0.310 (0.077)
U. Grande Ronde	16 Mar-31 May	736	0.324 (0.037)	0.255 (0.041)	0.122 (0.034)	0.325 (0.074)
			Wild Sockeye Salmon			
Pettit Lake Cr	27 Apr-16 May	494	0.516 (0.064)	0.286 (0.069)	0.125 (0.058)	0.210 (0.094)
Redfish Lake Cr	11 Apr-07 Jun	1,353	0.359 (0.037)	0.200 (0.039)	0.092 (0.033)	0.107 (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	21 Feb-31 May	3,213	0.253 (0.032)	0.285 (0.048)	NA	0.100 (0.027)
Crooked Fk. Cr.	31 Mar-27 May	243	0.208 (0.050)	0.389 (0.088)	0.167 (0.098)	0.250 (0.108)
Crooked River	22 Mar-31 May	212	0.415 (0.063)	0.376 (0.091)	0.149 (0.131)	0.125 (0.117)
Elgin (G. Ronde)	01 Mar-31 May	1,319	0.259 (0.026)	0.313 (0.034)	0.154 (0.034)	0.092 (0.031)
Grande Ronde	14 Mar-21 May	663	0.336 (0.029)	0.362 (0.039)	0.211 (0.053)	0.038 (0.027)
Imnaha	15 Mar-30 May	6,796	0.287 (0.009)	0.348 (0.013)	0.200 (0.016)	0.125 (0.014)
Minam River	04 Mar-31 May	381	0.278 (0.042)	0.360 (0.059)	0.149 (0.064)	0.031 (0.031)
Pahsimeroi	02 Mar-31 May	498	0.343 (0.073)	0.214 (0.116)	0.125 (0.111)	NA
Salmon	17 Mar-08 May	425	0.150 (0.027)	0.285 (0.047)	0.105 (0.039)	0.182 (0.058)
Sawtooth	21 Mar-31 May	323	0.352 (0.103)	0.588 (0.130)	NA	0.429 (0.187)
Snake	26 Mar-15 May	1,009	0.282 (0.023)	0.281 (0.029)	0.239 (0.035)	0.163 (0.035)
U. Grande Ronde	16 Mar-31 May	737	0.239 (0.043)	0.277 (0.055)	0.190 (0.063)	0.094 (0.052)
			Hatchery Chinook Salmon			
Grande Ronde	06 Apr-07 May	1,401	0.274 (0.019)	0.291 (0.023)	0.130 (0.020)	0.233 (0.034)
Salmon	13 Mar-04 Apr	3,992	0.174 (0.010)	0.152 (0.011)	0.083 (0.010)	0.206 (0.019)
Snake	25 Mar-15 May	1,192	0.334 (0.020)	0.270 (0.022)	0.162 (0.022)	0.180 (0.032)
			Hatchery Steelhead			
Grande Ronde	18 Mar-21 May	2,398	0.232 (0.012)	0.281 (0.017)	0.156 (0.017)	0.109 (0.017)
Salmon	02 Apr-08 May	2,245	0.126 (0.010)	0.281 (0.018)	0.130 (0.017)	0.090 (0.016)
Snake	25 Mar-15 May	2,864	0.194 (0.011)	0.308 (0.016)	0.131 (0.014)	0.107 (0.014)

Appendix Table B9. Estimated survival probabilities for PIT-tagged yearling Chinook, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2013. 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			
Chelan						
Chelan River	4,075	0.553 (0.056)	0.834 (0.192)	NA	NA	NA
Cle Elum						
Clark Flat Pond	15,999	0.398 (0.016)	0.792 (0.064)	0.828 (0.200)	0.656 (0.153)	0.261 (0.060)
Easton Pond	11,999	0.288 (0.015)	0.864 (0.101)	1.231 (0.543)	1.064 (0.459)	0.307 (0.131)
Jack Creek Pond	11,999	0.295 (0.016)	0.794 (0.103)	0.820 (0.359)	0.651 (0.277)	0.192 (0.081)
East Bank						
Chiwawa Pond	9,986	0.462 (0.030)	0.994 (0.135)	NA	NA	NA
Dryden Accl. Pond	5,018	0.776 (0.075)	1.140 (0.246)	0.675 (0.246)	0.769 (0.250)	0.597 (0.185)
Similkameen River	5,036	0.688 (0.067)	0.850 (0.180)	0.794 (0.315)	0.675 (0.244)	0.464 (0.162)
Entiat						
Entiat Hatchery	9,970	0.627 (0.049)	0.969 (0.170)	NA	NA	NA
Leavenworth						
Leavenworth NFH	14,951	0.616 (0.026)	0.964 (0.089)	0.983 (0.253)	0.947 (0.234)	0.584 (0.142)
Methow						
Chewuch Accl. Pond	4,999	0.627 (0.097)	0.616 (0.177)	0.676 (0.359)	0.416 (0.207)	0.261 (0.123)
Methow Hatchery	11,984	0.418 (0.037)	1.020 (0.195)	0.797 (0.240)	0.813 (0.214)	0.340 (0.084)
Twisp Accl. Pond	4,975	0.581 (0.094)	NA	NA	NA	NA
Winthrop						
Winthrop NFH	16,869	0.571 (0.034)	0.871 (0.104)	1.298 (0.328)	1.130 (0.269)	0.645 (0.149)
Yakima						
Natches River	15,065	0.277 (0.016)	1.022 (0.162)	NA	NA	NA
Roza Tailrace	15,084	0.225 (0.017)	0.944 (0.193)	NA	NA	NA

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						
Chiwawa River	2,882	0.397 (0.056)	0.988 (0.210)	1.404 (0.576)	1.388 (0.557)	0.551 (0.208)
Wenatchee R. (Apr 3)	1,656	0.391 (0.093)	0.736 (0.215)	NA	NA	NA
Wenatchee R. (Apr 25)	10,348	0.425 (0.047)	0.785 (0.117)	0.961 (0.227)	0.754 (0.182)	0.320 (0.069)
East Bank						
Nason Creek (Apr 27)	7,685	0.377 (0.044)	1.019 (0.171)	1.155 (0.406)	1.176 (0.411)	0.443 (0.146)
Nason Creek (May 7)	1,975	0.303 (0.075)	0.648 (0.243)	0.317 (0.122)	0.205 (0.074)	0.062 (0.017)
Wells						
Methow River	4,050	0.518 (0.081)	0.896 (0.195)	1.327 (0.482)	1.188 (0.434)	0.616 (0.204)
Omak Creek	9,370	0.337 (0.034)	1.074 (0.171)	0.892 (0.243)	0.958 (0.250)	0.323 (0.078)
Twisp Accl. Pond	4,900	0.356 (0.049)	0.877 (0.168)	0.869 (0.251)	0.762 (0.220)	0.271 (0.070)
Winthrop						
Winthrop NFH	29,020	0.400 (0.035)	1.089 (0.139)	0.888 (0.139)	0.968 (0.149)	0.387 (0.049)
			Coho Salmon			
Cascade						
Leavenworth NFH	7,335	0.583 (0.049)	0.748 (0.096)	1.292 (0.325)	0.967 (0.238)	0.564 (0.131)
Rolfing Pond	2,962	0.538 (0.086)	0.595 (0.140)	1.278 (0.607)	0.760 (0.357)	0.409 (0.181)
Eagle						
Natches River	2,505	0.512 (0.094)	0.718 (0.205)	NA	NA	NA
Yakima R. (rkm 256)	2,506	0.194 (0.045)	0.814 (0.340)	NA	NA	NA
Yakima R. (rkm 325)	3,464	0.219 (0.031)	1.070 (0.275)	0.798 (0.348)	0.854 (0.344)	0.187 (0.071)
Willard						
Beaver Pond	5,995	0.376 (0.055)	0.687 (0.174)	0.727 (0.286)	0.500 (0.182)	0.188 (0.063)
Coulter Pond	5,991	0.349 (0.035)	1.291 (0.269)	0.713 (0.255)	0.921 (0.296)	0.322 (0.099)
Gold Creek	5,994	0.450 (0.062)	0.838 (0.217)	0.695 (0.284)	0.582 (0.216)	0.262 (0.090)
Leavenworth NFH	2,487	0.445 (0.067)	0.733 (0.172)	1.123 (0.444)	0.823 (0.315)	0.366 (0.129)
Rolfing Pond	2,990	0.360 (0.056)	0.869 (0.272)	0.668 (0.329)	0.580 (0.254)	0.209 (0.086)
Twisp Accl. Pond	5,996	0.465 (0.051)	0.807 (0.162)	1.018 (0.363)	0.822 (0.273)	0.382 (0.120)
Winthrop Back Channel	5,984	0.521 (0.072)	0.795 (0.186)	1.327 (0.517)	1.055 (0.386)	0.550 (0.187)

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
			Coho Salmon			
Winthrop						
Winthrop NFH	5,995	0.628 (0.082)	0.804 (0.156)	1.016 (0.268)	0.817 (0.209)	0.513 (0.113)
Yakima						
Cowchie Creek	2,495	0.193 (0.035)	NA	NA	NA	NA
Lost Creek Pond	2,531	0.280 (0.050)	0.814 (0.250)	NA	NA	NA
Prosser Dam	2,469	0.376 (0.052)	0.697 (0.163)	1.142 (0.634)	0.796 (0.430)	0.299 (0.156)
Rattlesnake Creek	1,263	0.207 (0.066)	0.554 (0.288)	NA	NA	NA
Roza Dam	1,221	0.363 (0.088)	0.838 (0.424)	NA	NA	NA
Stiles Pond	2,504	0.463 (0.069)	NA	NA	NA	NA

Appendix Table B10. Estimated detection probabilities for PIT-tagged yearling Chinook salmon, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2013. 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		
Chelan	Chelan River	4,075	0.185 (0.020)	0.111 (0.024)	0.026 (0.026)
Cle Elum	Clark Flat Pond	15,999	0.233 (0.010)	0.224 (0.017)	0.120 (0.028)
Cle Elum	Easton Pond	11,999	0.254 (0.015)	0.210 (0.023)	0.063 (0.027)
Cle Elum	Jack Creek Pond	11,999	0.255 (0.016)	0.206 (0.025)	0.087 (0.037)
East Bank	Chiwawa Pond	9,986	0.169 (0.012)	0.103 (0.013)	0.028 (0.016)
East Bank	Dryden Accl. Pond	5,018	0.126 (0.013)	0.057 (0.012)	0.113 (0.036)
East Bank	Similkameen River	5,036	0.147 (0.015)	0.068 (0.014)	0.130 (0.046)
Entiat	Entiat Hatchery	9,970	0.135 (0.011)	0.057 (0.010)	0.063 (0.025)
Leavenworth	Leavenworth NFH	14,951	0.192 (0.009)	0.128 (0.011)	0.087 (0.022)
Methow	Chewuch Accl. Pond	4,999	0.105 (0.017)	0.103 (0.026)	0.062 (0.030)
Methow	Methow Hatchery	11,984	0.120 (0.012)	0.051 (0.009)	0.114 (0.029)
Methow	Twisp Accl. Pond	4,975	0.109 (0.018)	0.058 (0.023)	0.018 (0.018)
Winthrop	Winthrop NFH	16,869	0.131 (0.008)	0.074 (0.008)	0.076 (0.018)
Yakima	Natches River	15,065	0.255 (0.016)	0.118 (0.018)	0.026 (0.026)
Yakima	Roza Tailrace	15,084	0.218 (0.018)	0.106 (0.021)	NA
			Steelhead		
Chelan	Chiwawa River	2,882	0.098 (0.016)	0.120 (0.022)	0.115 (0.044)
Chelan	Wenatchee R. (Apr 3)	1,656	0.065 (0.018)	0.174 (0.034)	0.092 (0.062)
Chelan	Wenatchee R. (Apr 25)	10,348	0.064 (0.008)	0.132 (0.014)	0.136 (0.030)
East Bank	Nason Creek (Apr 27)	7,685	0.070 (0.009)	0.117 (0.015)	0.111 (0.037)
East Bank	Nason Creek (May 7)	1,975	0.109 (0.030)	0.137 (0.042)	0.500 (0.134)
Wells	Methow River	4,050	0.063 (0.011)	0.102 (0.017)	0.098 (0.033)
Wells	Omak Creek	9,370	0.085 (0.010)	0.090 (0.012)	0.157 (0.038)
Wells	Twisp Accl. Pond	4,900	0.082 (0.013)	0.132 (0.020)	0.176 (0.046)
Winthrop	Winthrop NFH	29,020	0.043 (0.004)	0.056 (0.006)	0.117 (0.015)
			Coho Salmon		
Cascade	Leavenworth NFH	7,335	0.098 (0.009)	0.091 (0.010)	0.177 (0.042)
Cascade	Rolfing Pond	2,962	0.091 (0.016)	0.088 (0.018)	0.202 (0.090)

Appendix Table B10. Continued.

Hatchery	Release site	Number released	McNary Dam	John Day Dam	Bonneville Dam
		Coho Salmon			
Eagle	Natches River	2,505	0.085 (0.017)	0.074 (0.018)	0.118 (0.078)
Eagle	Yakima R. (rkm 256)	2,506	0.119 (0.031)	0.068 (0.027)	NA
Eagle	Yakima R. (rkm 325)	3,464	0.138 (0.023)	0.082 (0.020)	0.263 (0.101)
Willard	Beaver Pond	5,995	0.083 (0.013)	0.047 (0.011)	0.318 (0.107)
Willard	Coulter Pond	5,991	0.112 (0.013)	0.049 (0.010)	0.236 (0.073)
Willard	Gold Creek	5,994	0.078 (0.012)	0.037 (0.009)	0.274 (0.095)
Willard	Leavenworth NFH	2,487	0.106 (0.018)	0.090 (0.019)	0.232 (0.083)
Willard	Rolfing Pond	2,990	0.121 (0.021)	0.050 (0.016)	0.311 (0.129)
Willard	Twisp Accl. Pond	5,996	0.104 (0.013)	0.055 (0.010)	0.196 (0.062)
Willard	Winthrop Back Channel	5,984	0.057 (0.009)	0.032 (0.007)	0.181 (0.062)
Winthrop	Winthrop NFH	5,995	0.055 (0.008)	0.053 (0.009)	0.201 (0.045)
Yakima	Cowchie Creek	2,495	0.204 (0.041)	0.032 (0.022)	0.113 (0.106)
Yakima	Lost Creek Pond	2,531	0.119 (0.024)	0.076 (0.022)	0.112 (0.074)
Yakima	Prosser Dam	2,469	0.168 (0.026)	0.146 (0.031)	0.159 (0.084)
Yakima	Rattlesnake Creek	1,263	0.149 (0.052)	0.131 (0.061)	NA
Yakima	Roza Dam	1,221	0.156 (0.041)	0.076 (0.036)	NA
Yakima	Stiles Pond	2,504	0.117 (0.020)	0.050 (0.015)	0.069 (0.047)

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 2013 from the Columbia River DART website[1] on 21 August, 2013. We created plots to compare daily measures of flow, temperature, and spill at Little Goose Dam from 2013 to those from 2006-2012. We created plots and calculated passage proportions to compare daily estimates of proportion of smolts passing Lower Granite Dam in 2013 to those of 2010-2012.

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 of the main text).

Results

In general, river conditions during the 2013 spring migration could be categorized as low flow with moderately high temperatures at times and with above average spill percentages. These conditions are similar to those that occurred in 2007 and 2010.

Mean flow volume at Little Goose Dam in 2013 during the main migration period (1 April – 15 June) was 67.8 kcfs, which was below the long-term (1993-2013) mean of 92.0 kcfs, and fifth lowest among mean flows over the past 21 years. Daily flow volumes were below average for much of the season, but were above average from 9-16 May as a pulse of flow moved through (Appendix Figure C1). Mean water temperature at Little Goose Dam in 2013 during the migration period was 11.3 °C, which is slightly above the long-term mean of 11.1 °C. Daily water temperatures fluctuated around the long term daily averages, with excursions above average occurring during 4-12 April, 2-16 May, and 3-15 June (Appendix Figure C1).

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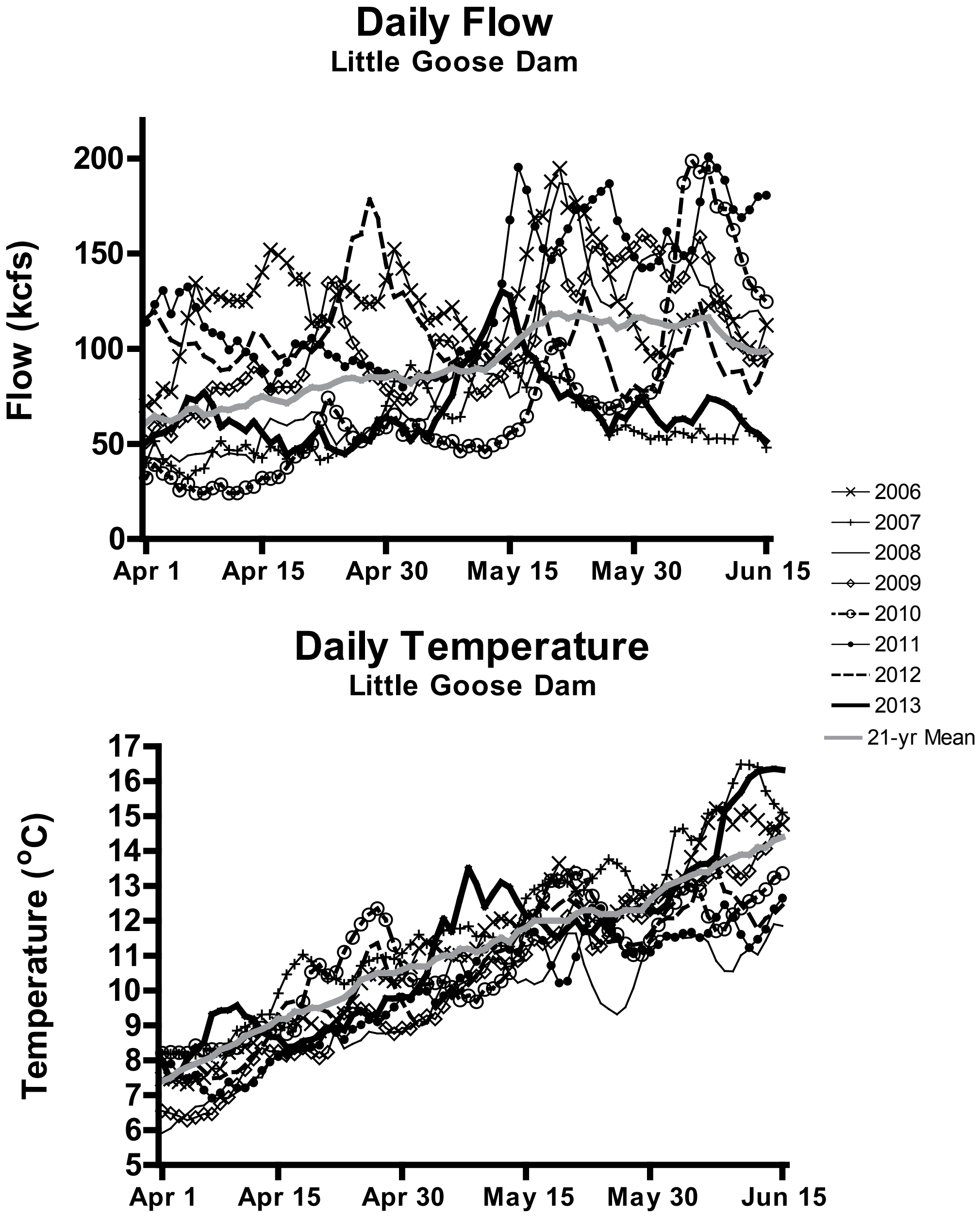
[1] www.cbr.washington.edu/dart

Mean spill volume at the Snake River dams during the 2013 migration was 22.3 kcfs, which was a little below the long-term mean of 25.9 kcfs. Daily spill volumes remained near the long-term daily averages until going below average during 15 May through 15 June (Appendix Figure C2).

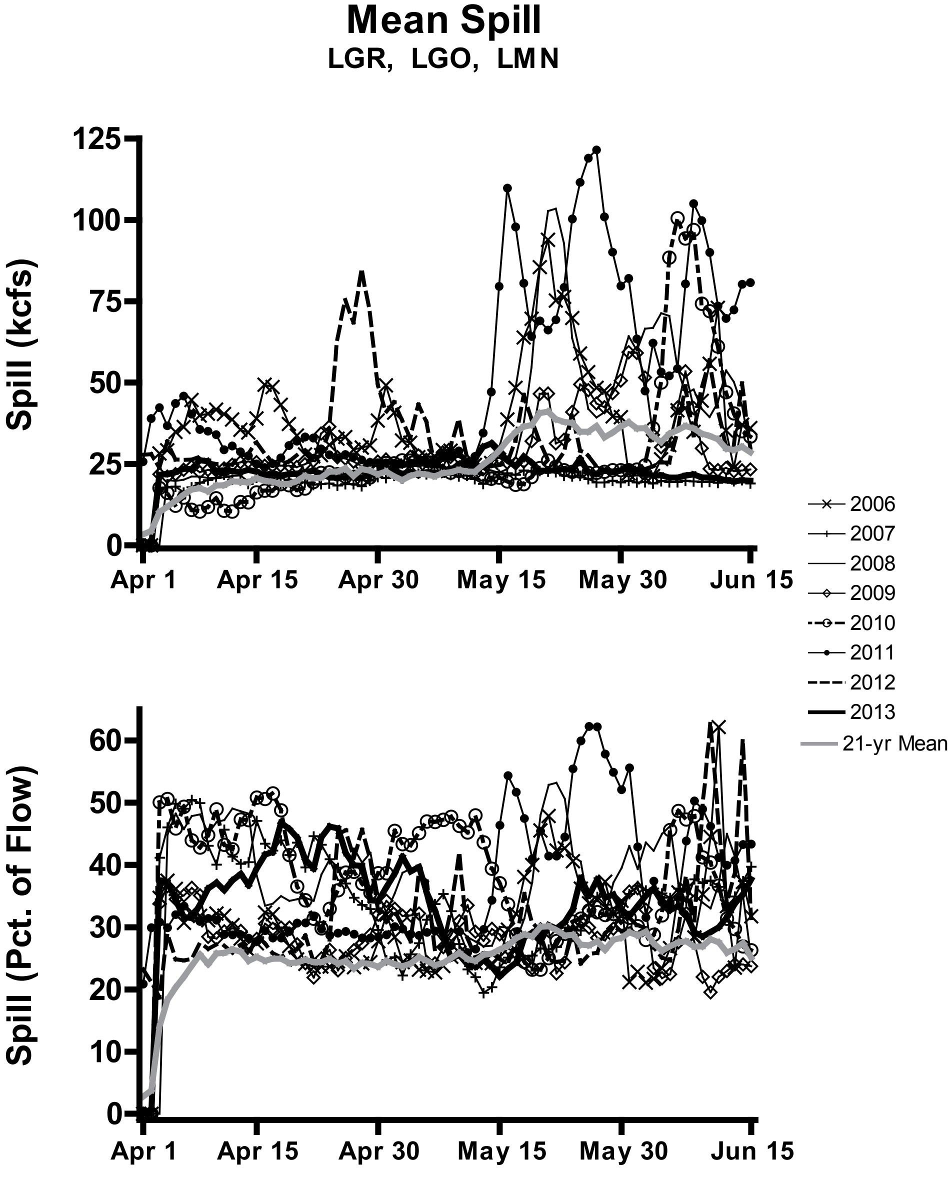


Daily Flow
Little Goose Dam

Daily Temperature
Little Goose Dam

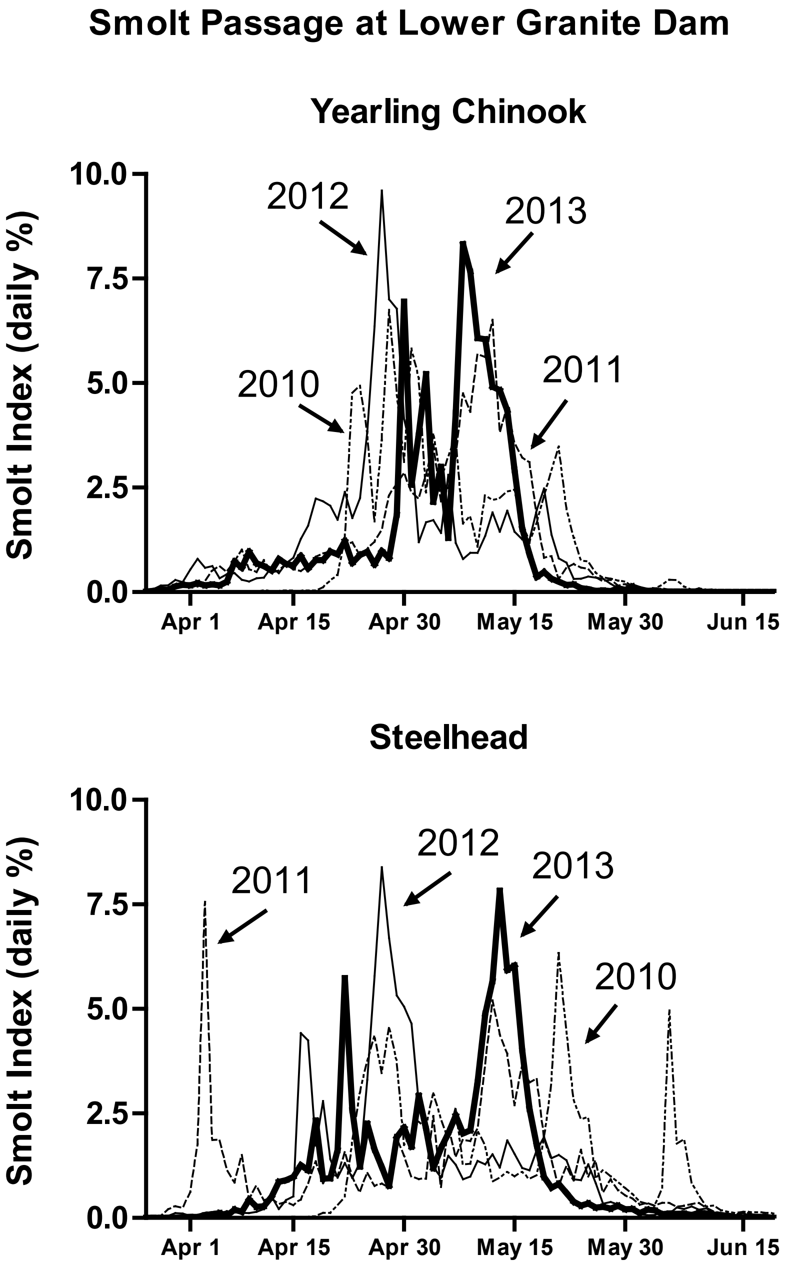
Appendix Figure C1. Daily Snake River flow (kcfs) and temperature (°C) measured at Little Goose Dam from April through mid-June, 2006-2013, including daily long-term means (1993-2013).

Mean spill as a percentage of flow at the Snake River dams during the 2013 migration was 33.5%, which was above the long-term mean of 25.1%. Daily average spill percentages in 2013 were above the long-term daily averages for the entire migration except for the period 9-18 May, which corresponded to the period of increased flow.



Appendix Figure C2. Daily mean spill (top = kcfs; bottom = percentage of total flow) averaged across Lower Granite, Little Goose and Lower Monumental dams from April through mid-June, 2006-2013, including daily long-term means (1993-2013).

The peak in flow in mid-May corresponded with peaks in smolt passage for both yearling Chinook salmon and steelhead at Lower Granite Dam in 2013 (Appendix Figure C3). For yearling Chinook salmon, this resulted in a 50% passage at Lower Granite Dam occurring on approximately 7 May and 80% passage on 12 May. For steelhead smolts, 50% passage occurred approximately on 9 May and 80% passage on 14 May.



Appendix Figure C3. Daily smolt passage index of yearling Chinook salmon and steelhead passing Lower Granite Dam, 2010-2013.