Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs, 2012

James R. Faulkner, Steven G. Smith, Douglas M. Marsh, and Richard W. Zabel

Report of research by

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

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EXECUTIVE SUMMARY

In 2012, we completed the 20th 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 22,121 hatchery steelhead *O. mykiss*, 20,122 wild steelhead, and 16,749 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 within the Federal Columbia River Power System. 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 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 2012 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 2012, 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 2012 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 fish detected or released at Lower Granite Dam, the respective overall percentages of hatchery and wild fish were 61 and 39% for yearling Chinook and 67 and 33% 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 82.7% of the overall yearling Chinook salmon run in 2012 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 2012 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	0.907 (0.009)	0.958 (0.006)
Little Goose to Lower Monumental Dam	0.939 (0.010)	0.914 (0.011)
Lower Monumental to McNary Dam[a]	0.937 (0.016)	0.811 (0.022)
Lower Monumental to Ice Harbor	0.952 (0.028)	0.882 (0.025)
Ice Harbor to McNary	0.991 (0.030)	0.924 (0.043)
McNary to John Day Dam	0.915 (0.023)	0.814 (0.048)
John Day to Bonneville Dam[b]	0.866 (0.058)	1.021 (0.148)

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

For the combined groups of wild and hatchery yearling Chinook and steelhead, we also estimated average survival through the entire hydropower system to the tailrace of Bonneville Dam (eight projects). To derive these estimates, we multiplied the 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 2012, estimated survival for the entire hydropower system was 0.588 (95% CI 0.510-0.666) for Snake River yearling Chinook salmon and 0.598 (0.326-0.870) for steelhead.

For Snake River yearling Chinook salmon, estimated survival through the entire hydropower system in 2012 was higher than either the average of estimates over the last 14 years or the average estimate in 2011. Likewise, for Snake River steelhead, estimated survival through the entire hydropower system exceeded both the 14-year average and the average estimated in 2011. However, due to extremely low precision in the 2012 estimates for steelhead, comparisons with previous estimates had little or no meaning.

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 0.681 (0.042) for Entiat Hatchery fish released to the Entiat River to 0.246 (0.038) for Wells Hatchery fish released to the Columbia River below Wells Dam. Similar estimates for Upper Columbia River steelhead ranged from 0.513 (0.034) for Wells Hatchery fish released to the Methow River to 0.236 (0.017) for Chelan Hatchery fish released into the Wenatchee River.

These estimates of survival from 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.

In estimates of survival for both yearling Chinook salmon and steelhead during 1998-2012, we have observed a significant negative correlation between estimated survival from Lower Monumental to McNary Dam and percentage of PIT tags recovered on avian colonies. A smaller proportion of smolts taken by birds was found during 2006-2012, but this decrease was likely due to an increase in the total number of smolts (tagged and untagged) remaining in the river rather than to a decrease in numbers of fish lost to predation. In 2012, this increase in total numbers of smolts remaining in the river was partly due to a decrease in percentages of fish transported from Snake River dams.

Estimated proportions of transported fish (wild and hatchery combined) were the lowest among all estimates from 1993 to 2012, at 24% for yearling Chinook and 27% for steelhead. This was partially explained by early migration of smolts relative to the beginning of the transportation program in 2012. By the time transportation began at Lower Granite Dam on May 2, about 67% of the yearling Chinook and 61% of the steelhead had already passed. Other factors contributing to the higher number of inriver migrants in 2012 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 average (faster migration) for both yearling Chinook and steelhead during late April to early May because of a sharp increase in flow during that period. Travel time was closer to average for most of May and into June.

In recent years, rates of PIT-tag detection have declined due to 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 has been 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 accuracy and precision of survival estimates based on data gathered from PIT-tagged smolts.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 2012, 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). In 2012, NMFS completed the 20th year of the study.

Research objectives in 2012 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 2012 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 2012, detections at Bonneville Dam and in the pair trawl were sufficient to estimate survival from John Day tailrace to Bonneville Dam tailrace. We estimated survival in this reach for groups of 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:

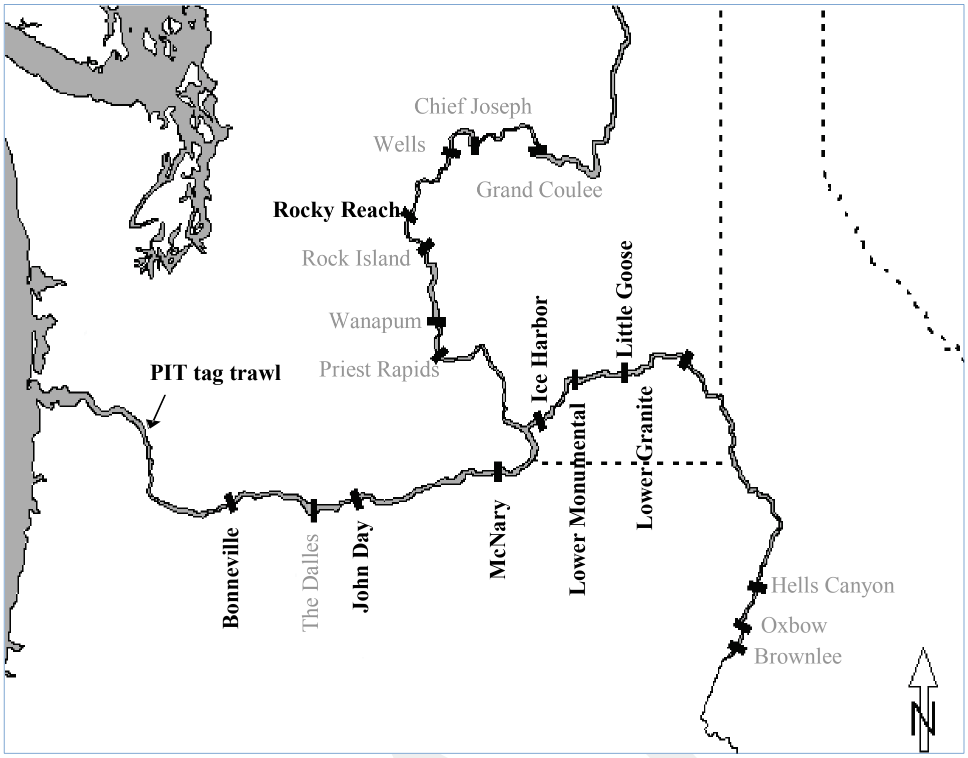

Figure 1. Study area showing sites with PIT-tag detection facilities (names in black), including dams and the PIT-tag trawl in the Columbia River estuary. Dams with names in gray do not have detection facilities.

- 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. However, in 2006-2012 there were sufficient detections at Ice Harbor to partition survival through this reach.

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

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

Study Fish

Releases from Lower Granite Dam—During 2012, 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 in order to provide sufficient numbers for analysis over these periods.

No hatchery yearling Chinook salmon were PIT tagged specifically for this study because sufficient numbers of hatchery yearling Chinook 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 hatchery yearling Chinook.

For both yearling Chinook salmon and steelhead tagged and released upstream from Lower Granite Dam, we created virtual "release groups" of fish according to date of detection at the dam. Each daily 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.

At Lower Granite Dam, we PIT tagged and released 20,121 hatchery steelhead, 20,122 wild steelhead, and 16,749 wild yearling Chinook salmon from 11 April through 16 June 2012 (Table 1). Total mortalities of hatchery steelhead, wild steelhead, and wild yearling Chinook salmon were 23, 9, and 70, respectively. Each of these numbers represented well under 1% of the total fish handled. A total of 68,180 yearling Chinook salmon (41,254 hatchery origin, 26,926 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 77,192 steelhead (51,521 hatchery origin and 25,671 wild) were similarly returned or released to the tailrace of Lower Granite Dam.

Table 1. Number by date of PIT–tagged hatchery steelhead, wild steelhead, and yearling Chinook salmon released at Lower Granite Dam for survival estimates in 2012. 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
11-Apr	701	-	-	440	-	2	510	7	1
12-Apr	698	2	-	406	-	1	721	1	-
18-Apr	875	-	-	415	-	-	893	1	-
19-Apr	876	-	-	551	-	-	782	1	-
25-Apr	1,964	2	1	787	-	4	1,501	12	-
26-Apr	1,531	1	-	1,578	-	5	1,135	2	-
1-May	733	1	-	545	-	-	656	3	1
2-May	734	1	-	830	-	1	235	2	-
3-May	733	-	-	742	-	-	748	-	-
4-May	731	2	-	748	2	-	1,026	5	1
5-May	739	1	-	329	-	-	720	2	-
8-May	665	-	-	733	2	-	426	-	-
9-May	664	1	-	481	2	-	511	1	-
10-May	666	1	-	551	1	1	261	1	-
11-May	663	1	-	669	1	2	455	5	-
12-May	664	-	-	628	-	-	434	1	-
15-May	490	-	-	770	-	2	437	6	1
16-May	492	-	-	672	-	1	618	2	-
17-May	488	-	2	774	-	2	404	-	1
18-May	490	-	-	1,180	-	-	611	3	2
19-May	489	1	-	779	-	1	923	4	-
22-May	350	-	-	766	1	1	631	3	1
23-May	349	1	1	753	-	1	435	-	-
24-May	351	-	1	771	-	1	668	3	-
25-May	547	1	-	745	-	-	434	1	-
26-May	347	1	-	888	-	-	574	4	-
30-May	261	1	-	218	-	-			
31-May	263	-	-	314	-	-			
1-Jun	262	-	-	149	-	-			
2-Jun	261	1	-	137	-	1			
5-Jun	130	-	-	90	-	-			
6-Jun	130	-	-	126	-	-			
7-Jun	129	-	1	137	-	-			
8-Jun	128	2	-	137	-	-			
9-Jun	130	-	-	156	-	-			
12-Jun	80	-	-	31	-	-			
13-Jun	79	-	1	35	-	-			
14-Jun	80	-	-	25	-	-			
15-Jun	79	1	-	28	-	-			
16-Jun	79	1	-	8	-	-			
Totals	20,121	23	7	20,122	9	26	16,749	70	8

We estimated that 82.7% of the overall run of yearling Chinook salmon in 2012 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.

Our analyses excluded some daily groups of both yearling Chinook and steelhead for estimates detection probability. These groups had been detected at the dam either very early or very late in the season and were too small to produce reliable estimates of either survival or travel time. Partly because of these exclusions, the proportions of hatchery fish in the combined groups used to estimate survival were different than those calculated for the run at large during 2012 (61% of yearling Chinook salmon and 67% of steelhead).

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

Releases from Hatcheries and Smolt Traps—In 2012, most hatcheries in the Snake River Basin released PIT-tagged fish as part of research separate from the NMFS survival study. We analyzed data from hatchery releases of PIT-tagged yearling Chinook, sockeye, and coho salmon and steelhead to provide survival estimates and detection probabilities from release to the tailrace of Lower Granite Dam and to points downstream.

For fish from the Upper Columbia River basin, we estimated survival to the tailrace of McNary Dam for yearling spring Chinook salmon released from Chelan, Cle Elum, East Bank, Entiat, Leavenworth, Methow, Wells, and Winthrop Hatcheries. We also estimated survival to McNary Dam for steelhead from Chelan, East Bank, Wells, and Winthrop Hatcheries, and for coho salmon from Cascade, Eagle, Willard, and Winthrop Hatcheries.

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

Data Analysis

Tagging and detection data were downloaded on 19 December 2012 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 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 violations of model assumptions, even for assumptions that had only a 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, they were combined to produce a weighted average (Muir et al. 2001a). For each group, weights were inversely proportional to their respective estimated relative variance (coefficient of variation squared). The variance of an estimated survival probability from the SR model is a function of the estimate itself. Consequently, lower survival estimates tend to have smaller estimated variance. This results in lower survival estimates having disproportionate influence, and the weighted mean being biased toward the lower estimates. Therefore, we used the inverse of estimated *relative* variance rather than *absolute* variance in weighting.

We estimated survival from point of release to the tailrace of Bonneville Dam (the last dam encountered by seaward-migrating juvenile salmonids) for various stocks from both the Snake and Upper Columbia Rivers. These estimates were obtained by first calculating weighted mean survival estimates over shorter reaches for virtual daily or weekly release groups, using the weighting procedure described above. We pooled similar fish from different release sites to form virtual release groups at downstream sites.

Weighted mean survival estimates were then multiplied to estimate survival probabilities through the entire reach. For example, for yearling Chinook salmon released from the Snake River trap, we multiplied the weighted mean survival estimate for daily groups from Lower Granite to McNary Dam by the weighted mean estimate for weekly groups from McNary to Bonneville Dam. This provided an overall mean estimate of survival probability from Lower Granite to Bonneville Dam.

For fish released upstream from the Snake River Trap, this overall estimated mean was then multiplied by estimate of downstream survival from the trap to the tailrace of Lower Granite Dam. The product was an estimate of survival from the headwaters of Lower Granite reservoir to the tailrace of Bonneville Dam; it was essentially an estimate of survival over the entire eight-project hydropower system negotiated by juvenile salmonids from the Snake River Basin.

Results

Snake River Yearling Chinook Salmon

Estimates of Survival—Survival probabilities were estimated for weekly groups of yearling Chinook salmon from Lower Granite Dam to multiple Snake River dams over for 10 consecutive weeks during 23 March-31 May. Mean survival estimates were 0.907 (se 0.009) from Lower Granite to Little Goose Dam, 0.939 (0.010) from Little Goose to Lower Monumental, and 0.937 (0.016) from Lower Monumental to McNary Dam (Table 2). For the combined reach from Lower Granite to McNary Dam, mean estimated survival was 0.790 (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 2012. 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
23 Mar–29 Mar	1,243	0.762 (0.030)	0.804 (0.057)	0.900 (0.106)	0.551 (0.058)
30 Mar–5 Apr	2,776	0.679 (0.019)	0.895 (0.046)	0.865 (0.066)	0.526 (0.034)
6 Apr–12 Apr	3,863	0.804 (0.014)	0.990 (0.032)	0.904 (0.051)	0.720 (0.036)
13 Apr–19 Apr	10,648	0.892 (0.009)	0.932 (0.019)	0.929 (0.034)	0.772 (0.024)
20 Apr–26 Apr	20,456	0.941 (0.007)	0.944 (0.015)	0.959 (0.024)	0.852 (0.018)
27 Apr–3 May	11,784	0.880 (0.010)	0.944 (0.023)	0.947 (0.036)	0.787 (0.023)
4 May–10 May	5,103	0.886 (0.021)	0.920 (0.046)	0.902 (0.058)	0.736 (0.035)
11 May–17 May	5,805	0.882 (0.019)	1.053 (0.050)	0.956 (0.067)	0.887 (0.050)
18 May–24 May	4,838	0.952 (0.014)	0.901 (0.033)	0.991 (0.060)	0.849 (0.043)
25 May–31 May	1,302	1.057 (0.055)	1.048 (0.156)	0.692 (0.121)	0.767 (0.080)
Weighted mean[a]		**0.907 (0.009)**	**0.939 (0.010)**	**0.937 (0.016)**	**0.790 (0.016)**

a Weighted mean estimates for daily groups (22 Mar–31 May; see Table 5)

For weekly groups of yearling Chinook salmon, we estimated survival probabilities from McNary Dam multiple dams on the Columbia River for five consecutive weeks during 27 April-31 May. Survival estimates averaged 0.915 (se 0.023) from McNary to John Day, 0.866 (0.058) from John Day to Bonneville, and 0.802 (0.051) 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 2012. 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
27 Apr–3 May	9,265	0.905 (0.037)	1.111 (0.260)	1.005 (0.232)
4 May–10 May	9,209	0.906 (0.031)	0.826 (0.120)	0.748 (0.106)
11 May–17 May	12,417	1.040 (0.077)	0.794 (0.156)	0.826 (0.151)
18 May–24 May	3,504	0.854 (0.092)	0.749 (0.293)	0.640 (0.241)
25 May–31 May	1,957	0.833 (0.139)	0.869 (0.327)	0.724 (0.244)
Weighted mean		**0.915 (0.023)**	**0.866 (0.058)**	**0.802 (0.051)**

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 estimate was 0.634 (se 0.042) for Snake River hatchery and wild yearling Chinook salmon combined. For these fish, estimated survival was 0.928 (0.012) from the Snake River trap to the tailrace of Lower Granite Dam. Thus, estimated survival probability through all eight hydropower projects encountered by Snake River yearling Chinook salmon was 0.588 (se 0.040).

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). Within this reach, weighted mean survival estimates 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 2012. 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			
23 Mar–29 Mar	879	0.737 (0.038)	0.848 (0.083)	0.865 (0.139)	0.540 (0.076)
30 Mar–5 Apr	2,025	0.652 (0.026)	0.929 (0.072)	0.792 (0.084)	0.480 (0.040)
6 Apr–12 Apr	2,067	0.775 (0.024)	0.956 (0.055)	0.927 (0.081)	0.687 (0.050)
13 Apr–19 Apr	6,975	0.897 (0.013)	0.900 (0.028)	0.935 (0.045)	0.755 (0.030)
20 Apr–26 Apr	14,140	0.939 (0.010)	0.937 (0.019)	0.968 (0.031)	0.852 (0.022)
27 Apr–3 May	8,949	0.859 (0.012)	0.962 (0.031)	0.974 (0.048)	0.805 (0.029)
4 May–10 May	1,979	0.954 (0.058)	0.980 (0.138)	0.766 (0.119)	0.716 (0.063)
11 May–17 May	3,031	0.864 (0.036)	1.028 (0.089)	1.176 (0.148)	1.044 (0.104)
18 May–24 May	1,030	0.946 (0.039)	0.886 (0.089)	0.858 (0.123)	0.719 (0.080)
Weighted mean		**0.891 (0.022)**	**0.935 (0.010)**	**0.951 (0.021)**	**0.793 (0.034)**
		Wild yearling Chinook			
23 Mar–29 Mar	364	0.830 (0.050)	0.756 (0.076)	0.938 (0.158)	0.588 (0.092)
30 Mar–5 Apr	751	0.788 (0.030)	0.872 (0.057)	0.939 (0.104)	0.646 (0.065)
6 Apr–12 Apr	1,796	0.862 (0.017)	0.997 (0.037)	0.874 (0.065)	0.752 (0.051)
13 Apr–19 Apr	3,673	0.920 (0.012)	0.961 (0.026)	0.899 (0.051)	0.795 (0.041)
20 Apr–26 Apr	6,316	0.958 (0.011)	0.952 (0.023)	0.930 (0.039)	0.848 (0.030)
27 Apr–3 May	2,835	0.946 (0.016)	0.904 (0.033)	0.882 (0.053)	0.755 (0.038)
4 May–10 May	3,124	0.904 (0.023)	0.912 (0.048)	0.914 (0.066)	0.753 (0.043)
11 May–17 May	2,774	0.946 (0.023)	1.049 (0.058)	0.822 (0.068)	0.816 (0.054)
18 May–24 May	3,808	0.958 (0.016)	0.906 (0.035)	1.020 (0.069)	0.885 (0.051)
25 May–31 May	1,197	1.091 (0.060)	0.965 (0.143)	0.718 (0.125)	0.756 (0.080)
Weighted mean		**0.932 (0.014)**	**0.945 (0.015)**	**0.912 (0.018)**	**0.798 (0.020)**

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 2012 migration season, except that estimates before 10 April appeared lower in general than those for the remainder of the 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 2012. 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
22–26 Mar	242	0.785 (0.067)	0.733 (0.111)	1.004 (0.277)	0.578 (0.148)
27 Mar	241	0.812 (0.077)	0.707 (0.121)	0.587 (0.133)	0.337 (0.063)
28 Mar	499	0.723 (0.044)	0.911 (0.104)	0.904 (0.181)	0.596 (0.106)
29 Mar	271	0.748 (0.066)	0.781 (0.110)	1.148 (0.277)	0.671 (0.150)
30 Mar	349	0.641 (0.044)	0.920 (0.117)	1.018 (0.218)	0.600 (0.113)
31 Mar	582	0.660 (0.047)	0.873 (0.116)	0.735 (0.128)	0.423 (0.058)
1 Apr	337	0.651 (0.052)	0.854 (0.112)	0.944 (0.177)	0.525 (0.084)
2 Apr	466	0.730 (0.048)	0.878 (0.112)	1.069 (0.230)	0.686 (0.130)
3 Apr	286	0.624 (0.050)	0.912 (0.117)	0.814 (0.159)	0.463 (0.080)
4 Apr	352	0.739 (0.069)	0.927 (0.155)	0.644 (0.135)	0.441 (0.069)
5 Apr	404	0.715 (0.050)	0.914 (0.124)	0.975 (0.223)	0.638 (0.127)
6 Apr	302	0.762 (0.068)	0.860 (0.135)	1.347 (0.419)	0.883 (0.253)
7 Apr	176	0.612 (0.055)	1.060 (0.169)	1.056 (0.328)	0.685 (0.191)
8 Apr	236	0.696 (0.056)	1.044 (0.143)	0.619 (0.114)	0.450 (0.064)
9 Apr	333	0.759 (0.044)	1.024 (0.130)	0.868 (0.184)	0.675 (0.120)
10 Apr	449	0.793 (0.047)	0.907 (0.101)	1.099 (0.210)	0.790 (0.132)
11 Apr	970	0.818 (0.024)	1.106 (0.064)	0.883 (0.092)	0.799 (0.073)
12 Apr	1,397	0.868 (0.023)	0.926 (0.046)	0.871 (0.077)	0.700 (0.055)
13 Apr	784	0.934 (0.040)	0.752 (0.059)	1.103 (0.146)	0.775 (0.092)
14 Apr	1,022	0.881 (0.028)	0.961 (0.074)	0.743 (0.087)	0.629 (0.059)
15 Apr	1,058	0.871 (0.027)	0.940 (0.059)	0.949 (0.100)	0.777 (0.071)
16 Apr	1,367	0.885 (0.025)	0.931 (0.056)	0.928 (0.089)	0.765 (0.062)
17 Apr	1,525	0.923 (0.026)	0.981 (0.063)	0.764 (0.075)	0.692 (0.055)
18 Apr	2,334	0.888 (0.017)	0.960 (0.039)	1.168 (0.107)	0.995 (0.084)

Table 5. Continued.

		Estimated survival of yearling Chinook salmon from Lower Granite Dam			
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
19 Apr	2,558	0.888 (0.019)	0.931 (0.038)	0.868 (0.061)	0.717 (0.044)
20 Apr	1,814	1.008 (0.040)	0.825 (0.055)	0.923 (0.087)	0.768 (0.062)
21 Apr	1,472	0.971 (0.042)	0.874 (0.064)	0.985 (0.108)	0.837 (0.079)
22 Apr	1,689	0.873 (0.037)	1.016 (0.072)	1.066 (0.114)	0.945 (0.087)
23 Apr	2,237	0.896 (0.027)	1.126 (0.073)	0.763 (0.064)	0.770 (0.046)
24 Apr	3,117	0.971 (0.018)	0.942 (0.038)	0.996 (0.062)	0.911 (0.047)
25 Apr	5,210	0.972 (0.012)	0.943 (0.026)	0.967 (0.045)	0.886 (0.035)
26 Apr	4,917	0.942 (0.013)	0.906 (0.024)	0.969 (0.047)	0.826 (0.035)
27 Apr	3,224	0.870 (0.015)	0.992 (0.039)	0.902 (0.061)	0.779 (0.041)
28 Apr	2,746	0.838 (0.017)	1.000 (0.049)	0.937 (0.076)	0.786 (0.049)
29 Apr	1,445	0.899 (0.036)	0.874 (0.072)	0.994 (0.119)	0.781 (0.071)
30 Apr	972	0.853 (0.049)	0.952 (0.119)	1.130 (0.208)	0.918 (0.132)
1 May	1,187	0.919 (0.031)	0.846 (0.055)	0.869 (0.081)	0.676 (0.052)
2 May	719	0.959 (0.054)	0.992 (0.133)	0.776 (0.135)	0.738 (0.091)
3 May	1,491	0.926 (0.031)	0.904 (0.063)	1.089 (0.116)	0.912 (0.080)
4 May	1,455	0.858 (0.029)	1.003 (0.070)	1.008 (0.111)	0.867 (0.080)
5-7 May	1,454	0.948 (0.046)	0.834 (0.079)	0.818 (0.089)	0.646 (0.048)
8 May	669	0.917 (0.060)	0.881 (0.155)	0.946 (0.200)	0.764 (0.104)
9 May	723	0.994 (0.079)	0.980 (0.186)	0.772 (0.177)	0.752 (0.113)
10 May	802	0.802 (0.064)	0.939 (0.158)	0.931 (0.195)	0.701 (0.104)
11 May	1,024	0.925 (0.067)	0.946 (0.134)	0.929 (0.160)	0.813 (0.099)
12 May	997	0.836 (0.052)	0.893 (0.109)	1.045 (0.189)	0.780 (0.116)
13-15 May	1,690	0.924 (0.045)	0.990 (0.092)	1.250 (0.196)	1.143 (0.155)
16-17 May	2,094	0.908 (0.024)	1.150 (0.078)	0.810 (0.083)	0.847 (0.068)
18 May	1,089	0.926 (0.028)	0.891 (0.058)	0.930 (0.115)	0.768 (0.084)
19 May	1,227	0.983 (0.024)	0.826 (0.047)	0.989 (0.117)	0.802 (0.087)
20 May	252	0.968 (0.064)	0.920 (0.156)	0.948 (0.254)	0.845 (0.185)
21 May	184	0.988 (0.078)	0.870 (0.200)	0.920 (0.281)	0.791 (0.172)
22 May	763	0.922 (0.034)	0.932 (0.104)	0.838 (0.120)	0.719 (0.070)
23-24 May	1,323	0.982 (0.040)	0.851 (0.081)	1.248 (0.175)	1.044 (0.117)
25-31 May	1,302	1.057 (0.055)	1.048 (0.156)	0.692 (0.121)	0.767 (0.080)
Weighted mean		**0.907 (0.009)**	**0.939 (0.010)**	**0.937 (0.016)**	**0.790 (0.016)**

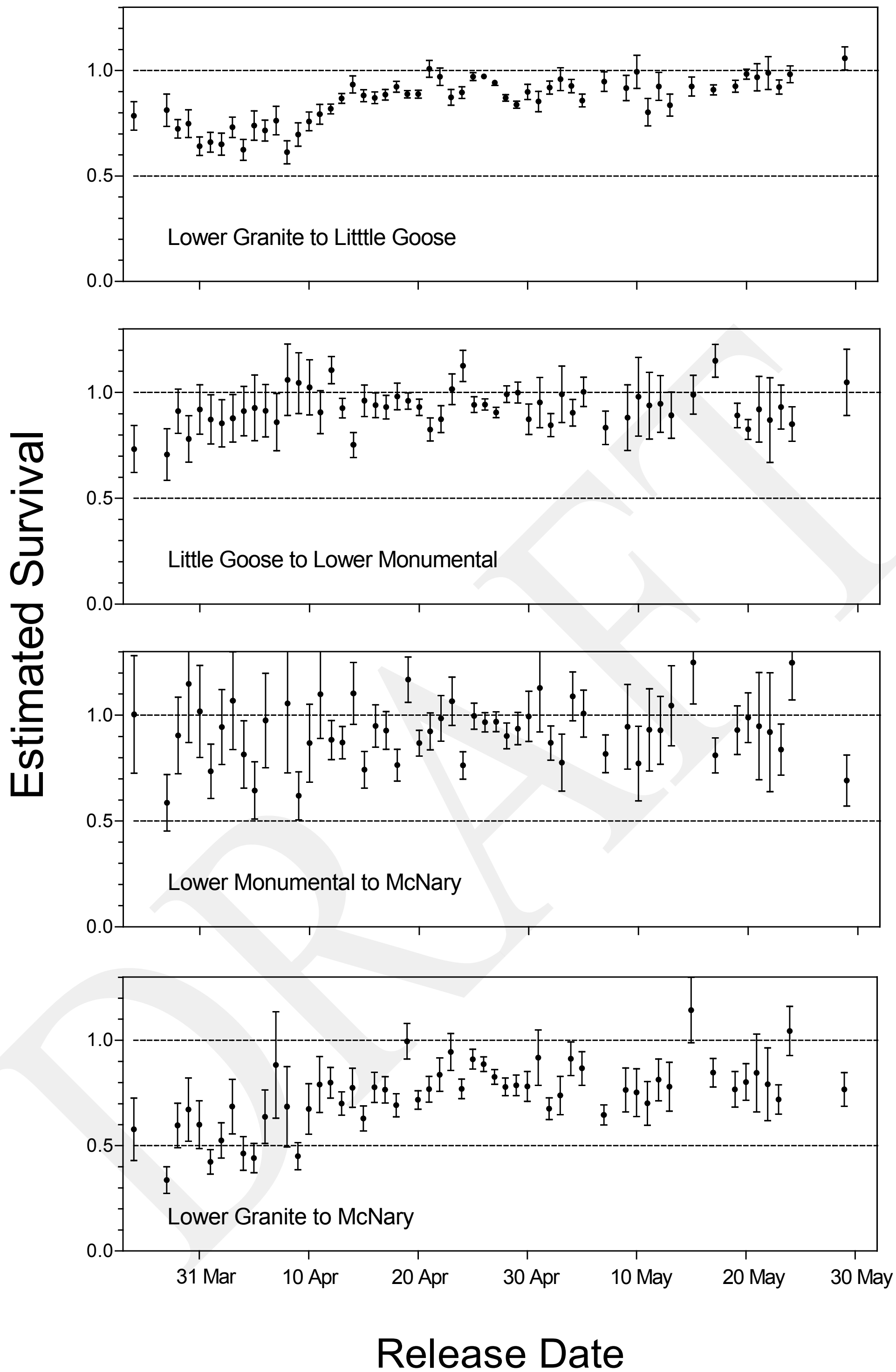

Figure 2. Estimated survival probabilities through various reaches by release date at Lower Granite Dam for daily groups of Snake River yearling Chinook salmon (hatchery and wild combined), 2012. Bars extend one standard error above and below point estimates.

Detection Probabilities—For most weekly groups of yearling Chinook salmon, estimates of detection probability varied throughout the season with changing flow volumes, spill levels, and degrees of smoltification (Tables 6-8). High levels of flow and spill during late April and early May resulted in very low detection rates at McNary, John Day, and Bonneville Dams. Detection probabilities were generally highest at Little Goose and Lower Monumental Dam and 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 released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2012. Daily groups were pooled for weekly estimates. Standard errors in parentheses.

	Estimated detection probability of yearling Chinook salmon from Lower Granite Dam release groups			
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
23 Mar–29 Mar	1,243	0.446 (0.023)	0.345 (0.026)	0.177 (0.024)
30 Mar–5 Apr	2,776	0.428 (0.016)	0.296 (0.017)	0.217 (0.018)
6 Apr–12 Apr	3,863	0.459 (0.011)	0.336 (0.013)	0.187 (0.012)
13 Apr–19 Apr	10,648	0.470 (0.007)	0.296 (0.007)	0.160 (0.006)
20 Apr–26 Apr	20,456	0.404 (0.005)	0.277 (0.005)	0.181 (0.005)
27 Apr–3 May	11,784	0.417 (0.006)	0.315 (0.008)	0.263 (0.009)
4 May–10 May	5,103	0.321 (0.010)	0.158 (0.009)	0.282 (0.015)
11 May–17 May	5,805	0.320 (0.009)	0.169 (0.009)	0.156 (0.010)
18 May–24 May	4,838	0.493 (0.010)	0.242 (0.010)	0.283 (0.016)
25 May–31 May	1,302	0.314 (0.021)	0.083 (0.014)	0.300 (0.034)

Table 7. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace of McNary Dam in 2012. 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
27 Apr–3 May	9,265	0.382 (0.016)	0.067 (0.016)
4 May–10 May	9,209	0.295 (0.011)	0.219 (0.031)
11 May–17 May	12,417	0.109 (0.008)	0.112 (0.021)
18 May–24 May	3,504	0.199 (0.022)	0.122 (0.047)
25 May–31 May	1,957	0.102 (0.018)	0.164 (0.056)

Table 8. Estimated detection probabilities for Snake River hatchery and wild yearling Chinook salmon detected and released to the tailrace of Lower Granite Dam in 2012. Daily groups were pooled to form weekly estimates. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
		Estimated detection probability for Lower Granite Dam release groups		
		Hatchery Yearling Chinook		
23 Mar–29 Mar	879	0.424 (0.028)	0.292 (0.031)	0.152 (0.027)
30 Mar–5 Apr	2,025	0.388 (0.019)	0.237 (0.020)	0.214 (0.022)
6 Apr–12 Apr	2,067	0.391 (0.016)	0.260 (0.017)	0.196 (0.018)
13 Apr–19 Apr	6,975	0.419 (0.009)	0.245 (0.009)	0.170 (0.008)
20 Apr–26 Apr	14,140	0.370 (0.006)	0.265 (0.006)	0.187 (0.006)
27 Apr–3 May	8,949	0.394 (0.008)	0.296 (0.010)	0.258 (0.011)
4 May–10 May	1,979	0.208 (0.016)	0.072 (0.011)	0.263 (0.026)
11 May–17 May	3,031	0.241 (0.013)	0.120 (0.011)	0.123 (0.014)
18 May–24 May	1,030	0.440 (0.024)	0.189 (0.022)	0.286 (0.036)
		Wild Yearling Chinook		
23 Mar–29 Mar	364	0.487 (0.039)	0.447 (0.047)	0.228 (0.046)
30 Mar–5 Apr	751	0.499 (0.026)	0.400 (0.031)	0.223 (0.029)
6 Apr–12 Apr	1,796	0.515 (0.015)	0.408 (0.018)	0.180 (0.016)
13 Apr–19 Apr	3,673	0.546 (0.011)	0.379 (0.013)	0.146 (0.010)
20 Apr–26 Apr	6,316	0.472 (0.008)	0.302 (0.009)	0.171 (0.008)
27 Apr–3 May	2,835	0.482 (0.013)	0.366 (0.015)	0.274 (0.017)
4 May–10 May	3,124	0.376 (0.013)	0.203 (0.012)	0.292 (0.019)
11 May–17 May	2,774	0.385 (0.013)	0.213 (0.013)	0.184 (0.015)
18 May–24 May	3,808	0.504 (0.012)	0.254 (0.012)	0.282 (0.018)
25 May–31 May	1,197	0.307 (0.021)	0.090 (0.015)	0.306 (0.036)

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 11 consecutive weeks during 23 March-7 June. Average estimated survival was 0.958 (se 0.006) from Lower Granite to Little Goose Dam, 0.914 (0.011) from Little Goose to Lower Monumental Dam, and 0.811 (0.022) from Lower Monumental to McNary Dam (Table 9). For the combined reach from Lower Granite to McNary Dam tailrace, estimated survival averaged 0.698 (0.020).

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 2012. 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
23 Mar–29 Mar	256	0.909 (0.036)	0.874 (0.092)	0.895 (0.436)	0.711 (0.340)
30 Mar–5 Apr	560	0.852 (0.037)	0.916 (0.097)	0.529 (0.100)	0.413 (0.068)
6 Apr–12 Apr	3,111	0.930 (0.020)	0.865 (0.036)	0.706 (0.058)	0.568 (0.043)
13 Apr–19 Apr	9,393	0.966 (0.009)	0.933 (0.018)	0.973 (0.048)	0.878 (0.041)
20 Apr–26 Apr	18,146	0.964 (0.009)	0.916 (0.018)	0.874 (0.035)	0.772 (0.028)
27 Apr–3 May	12,832	0.947 (0.008)	0.932 (0.019)	0.836 (0.045)	0.738 (0.036)
4 May–10 May	7,884	0.998 (0.018)	0.820 (0.033)	0.802 (0.057)	0.656 (0.041)
11 May–17 May	9,508	0.955 (0.020)	0.984 (0.051)	0.613 (0.047)	0.576 (0.035)
18 May–24 May	8,462	0.882 (0.015)	1.003 (0.042)	0.632 (0.052)	0.559 (0.040)
25 May–31 May	4,046	1.025 (0.038)	0.775 (0.073)	0.558 (0.072)	0.444 (0.043)
1 Jun–7 Jun	1,791	0.758 (0.046)	1.101 (0.162)	0.717 (0.201)	0.599 (0.146)
Weighted mean[a]		**0.958 (0.006)**	**0.914 (0.011)**	**0.811 (0.022)**	**0.698 (0.020)**

a Weighted mean of estimates for daily groups (22 Mar–31 May; see Table 12)

For weekly groups of steelhead detected and returned to the tailrace of McNary Dam, we estimated probabilities of survival to multiple dams downstream for 5 consecutive weeks during 27 April-31 May. Very low detection rates at John Day and Bonneville Dam precluded estimates downstream from John Day Dam for two weekly groups. Mean estimated survival was 0.814 (se 0.048) from McNary to John Day Dam, 1.021 (se 0.148) from John Day to Bonneville Dam, and 0.856 (se 0.196) for the entire reach from McNary to Bonneville Dam (Table 10).

Table 10. Estimated survival probabilities for weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from McNary Dam in 2012. Daily groups were pooled for 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
27 Apr–3 May	3,704	0.731 (0.054)	NA	NA
4 May–10 May	2,106	0.941 (0.100)	1.141 (0.496)	1.074 (0.452)
11 May–17 May	2,238	0.915 (0.134)	1.246 (0.621)	1.140 (0.543)
18 May–24 May	1,374	0.850 (0.135)	NA	NA
25 May–31 May	793	0.712 (0.142)	0.768 (0.311)	0.546 (0.193)
Weighted mean		**0.814 (0.048)**	**1.021 (0.148)**	**0.856 (0.196)**

We calculated the product of the mean estimate from Lower Granite to McNary Dam and the mean estimate from McNary to Bonneville Dam. This product provided an overall survival estimate of 0.597 (se 0.138) 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 1.001 (0.026). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River steelhead was 0.598 (0.139).

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, 2012. 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		
30 Mar–5 Apr	435	0.816 (0.041)	0.913 (0.105)	0.540 (0.122)	0.403 (0.081)
6 Apr–12 Apr	2,039	0.920 (0.024)	0.882 (0.045)	0.642 (0.066)	0.521 (0.049)
13 Apr–19 Apr	7,565	0.954 (0.010)	0.944 (0.021)	0.962 (0.053)	0.866 (0.044)
20 Apr–26 Apr	13,508	0.960 (0.012)	0.914 (0.022)	0.858 (0.043)	0.753 (0.034)
27 Apr–3 May	10,124	0.948 (0.009)	0.937 (0.022)	0.851 (0.053)	0.756 (0.044)
4 May–10 May	4,923	1.012 (0.023)	0.821 (0.040)	0.832 (0.076)	0.691 (0.056)
11 May–17 May	5,319	0.983 (0.033)	0.978 (0.072)	0.578 (0.064)	0.556 (0.049)
18 May–24 May	3,678	0.913 (0.025)	1.049 (0.076)	0.570 (0.084)	0.546 (0.071)
25 May–31 May	1,817	1.078 (0.066)	0.632 (0.087)	0.506 (0.095)	0.345 (0.049)
Weighted mean		**0.954 (0.009)**	**0.924 (0.016)**	**0.827 (0.045)**	**0.718 (0.046)**
			Wild steelhead		
6 Apr–12 Apr	1,072	0.946 (0.036)	0.828 (0.059)	0.822 (0.114)	0.644 (0.082)
13 Apr–19 Apr	1,828	1.016 (0.020)	0.897 (0.039)	1.018 (0.122)	0.928 (0.106)
20 Apr–26 Apr	4,638	0.990 (0.015)	0.906 (0.031)	0.938 (0.061)	0.841 (0.049)
27 Apr–3 May	2,708	0.942 (0.015)	0.910 (0.035)	0.791 (0.081)	0.678 (0.065)
4 May–10 May	2,961	0.970 (0.028)	0.819 (0.057)	0.758 (0.087)	0.602 (0.058)
11 May–17 May	4,189	0.940 (0.025)	0.961 (0.070)	0.670 (0.071)	0.605 (0.050)
18 May–24 May	4,784	0.864 (0.018)	0.974 (0.050)	0.687 (0.068)	0.578 (0.050)
25 May–31 May	2,229	0.994 (0.045)	0.893 (0.115)	0.597 (0.106)	0.530 (0.069)
1 Jun–7 Jun	661	0.671 (0.063)	1.039 (0.229)	0.523 (0.168)	0.364 (0.092)
Weighted mean		**0.957 (0.018)**	**0.907 (0.015)**	**0.816 (0.046)**	**0.697 (0.047)**

For daily release groups of steelhead (hatchery and wild combined) returned or released to the tailrace of Lower Granite Dam, estimated probabilities of survival to McNary Dam tailrace increased from the beginning of the season until late April and then decreased until the end of May. This pattern influenced the overall seasonal estimates of survival from Lower Granite 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 2012. 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
22-28 Mar	157	0.909 (0.043)	0.904 (0.110)	1.286 (1.140)	1.057 (0.930)
29 Mar-1 Apr	209	0.861 (0.039)	1.095 (0.165)	0.488 (0.162)	0.460 (0.137)
2 Apr	154	0.831 (0.075)	0.863 (0.172)	0.546 (0.184)	0.392 (0.114)
3 Apr	111	0.986 (0.130)	0.798 (0.261)	0.344 (0.162)	0.271 (0.100)
4 Apr	89	0.905 (0.100)	0.658 (0.151)	0.692 (0.318)	0.412 (0.176)
5-7 Apr	252	0.875 (0.074)	0.954 (0.171)	0.628 (0.205)	0.524 (0.150)
8-10 Apr	216	0.976 (0.077)	0.752 (0.124)	0.985 (0.500)	0.722 (0.354)
11 Apr	1,327	0.898 (0.030)	0.849 (0.051)	0.671 (0.079)	0.512 (0.055)
12-13 Apr	1,879	0.947 (0.026)	0.912 (0.050)	0.873 (0.104)	0.754 (0.083)
14 Apr	1,153	0.954 (0.030)	0.968 (0.065)	0.982 (0.140)	0.907 (0.118)
15 Apr	1,552	0.964 (0.020)	1.012 (0.055)	0.751 (0.074)	0.733 (0.061)
16-17 Apr	1,959	0.978 (0.021)	0.918 (0.041)	0.944 (0.099)	0.846 (0.084)
18 Apr	2,149	0.971 (0.018)	0.896 (0.033)	1.148 (0.134)	0.998 (0.113)
19 Apr	2,114	0.971 (0.017)	0.929 (0.035)	0.916 (0.107)	0.827 (0.093)
20 Apr	867	1.029 (0.038)	0.887 (0.062)	0.786 (0.141)	0.718 (0.122)
21 Apr	658	0.825 (0.040)	1.025 (0.102)	0.767 (0.148)	0.649 (0.112)
22 Apr	809	0.827 (0.050)	1.052 (0.113)	0.861 (0.182)	0.749 (0.144)
23 Apr	1,280	0.895 (0.054)	1.005 (0.098)	0.786 (0.135)	0.706 (0.111)
24 Apr	2,569	0.951 (0.036)	0.916 (0.054)	0.934 (0.106)	0.813 (0.085)
25 Apr	5,843	0.997 (0.018)	0.924 (0.035)	0.836 (0.058)	0.771 (0.047)
26 Apr	6,120	0.979 (0.012)	0.875 (0.025)	0.886 (0.057)	0.759 (0.045)
27 Apr	2,100	0.982 (0.021)	0.829 (0.037)	1.011 (0.128)	0.823 (0.099)
28 Apr	2,040	0.997 (0.018)	0.921 (0.048)	0.864 (0.124)	0.793 (0.105)
29 Apr	1,436	0.960 (0.019)	0.831 (0.048)	1.108 (0.178)	0.883 (0.127)
30 Apr	1,491	0.925 (0.020)	1.012 (0.071)	0.772 (0.137)	0.723 (0.110)

Table 12. Continued.

Estimated survival of steelhead daily groups from Lower Granite Dam					
Date at Lower Granite Dam	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
1 May	2,109	0.917 (0.018)	0.983 (0.045)	0.691 (0.076)	0.623 (0.062)
2 May	1,911	0.904 (0.018)	0.987 (0.049)	0.885 (0.126)	0.789 (0.106)
3 May	1,745	0.972 (0.030)	0.910 (0.062)	0.721 (0.123)	0.638 (0.102)
4 May	1,713	1.004 (0.035)	0.729 (0.054)	0.806 (0.108)	0.589 (0.070)
5 May	1,245	0.996 (0.040)	0.829 (0.081)	1.025 (0.226)	0.846 (0.171)
6-7 May	378	1.001 (0.090)	0.766 (0.119)	0.687 (0.191)	0.527 (0.131)
8 May	1,629	0.994 (0.038)	0.826 (0.068)	0.747 (0.096)	0.613 (0.065)
9 May	1,346	0.987 (0.044)	0.863 (0.091)	0.789 (0.144)	0.672 (0.104)
10 May	1,573	1.017 (0.050)	0.951 (0.110)	0.844 (0.190)	0.816 (0.162)
11 May	1,759	1.068 (0.054)	0.832 (0.091)	0.590 (0.093)	0.524 (0.066)
12 May	1,807	1.032 (0.047)	0.882 (0.095)	0.808 (0.142)	0.736 (0.107)
13-14 May	884	0.825 (0.070)	1.337 (0.298)	0.509 (0.158)	0.562 (0.129)
15 May	1,740	0.945 (0.052)	1.028 (0.156)	0.601 (0.132)	0.584 (0.097)
16 May	1,603	0.885 (0.049)	1.181 (0.144)	0.532 (0.099)	0.556 (0.084)
17 May	1,715	0.890 (0.037)	0.960 (0.107)	0.524 (0.082)	0.448 (0.052)
18 May	2,108	0.865 (0.034)	0.987 (0.084)	0.670 (0.113)	0.572 (0.086)
19 May	1,586	0.908 (0.028)	0.987 (0.077)	0.639 (0.120)	0.573 (0.099)
20-21 May	710	0.995 (0.045)	1.133 (0.191)	0.615 (0.243)	0.693 (0.249)
22 May	1,416	0.917 (0.028)	0.844 (0.072)	0.616 (0.122)	0.477 (0.087)
23 May	1,322	0.915 (0.042)	1.071 (0.131)	0.624 (0.124)	0.611 (0.099)
24 May	1,320	0.894 (0.092)	0.929 (0.155)	0.510 (0.102)	0.423 (0.064)
25-26 May	2,728	1.086 (0.051)	0.790 (0.093)	0.531 (0.079)	0.455 (0.047)
27-31 May	1,318	0.907 (0.051)	0.706 (0.108)	0.733 (0.218)	0.470 (0.122)
Weighted mean		**0.958 (0.006)**	**0.914 (0.011)**	**0.811 (0.022)**	**0.698 (0.020)**

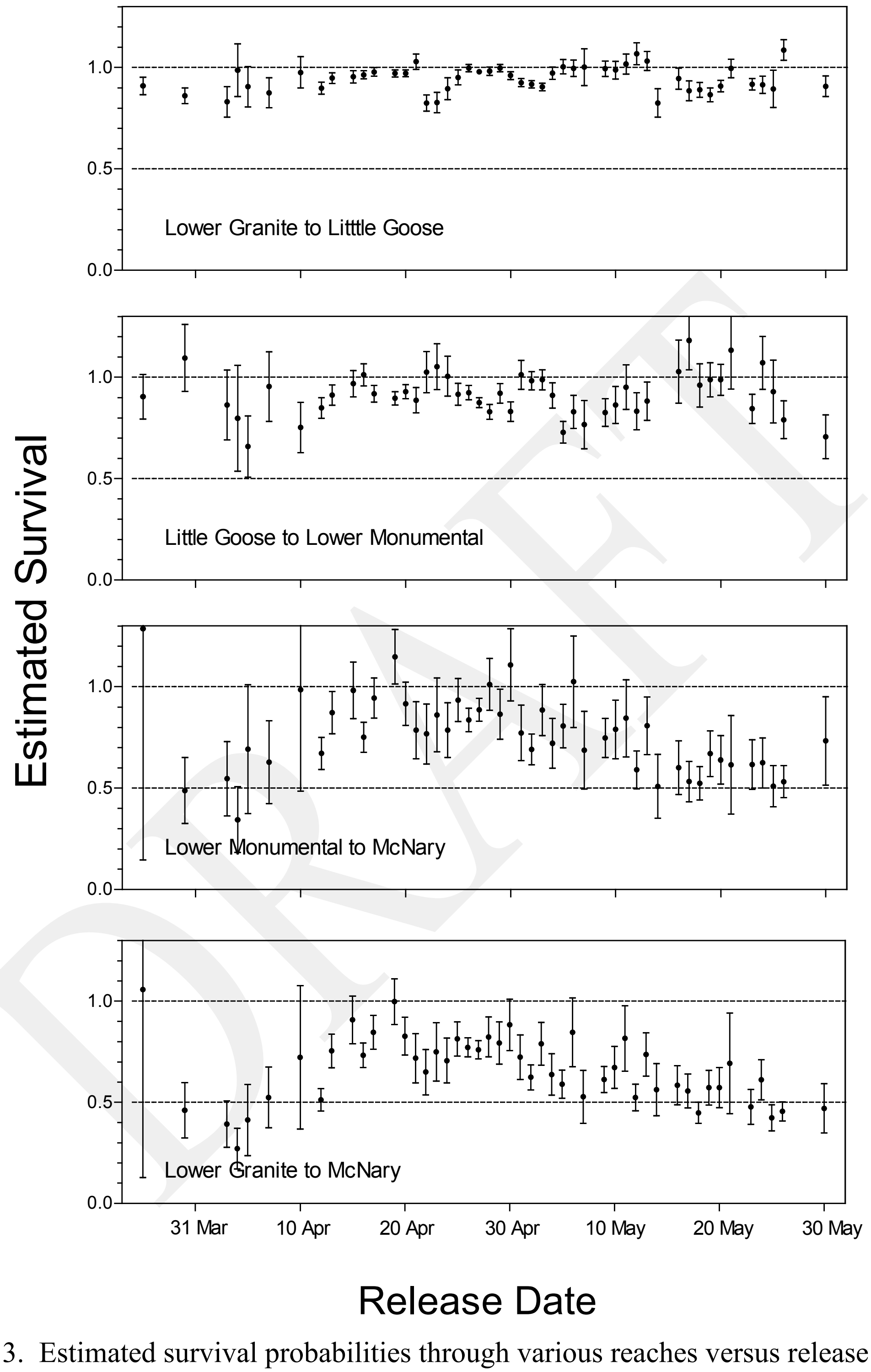

Figure 3. Estimated survival probabilities through various reaches versus release date at Lower Granite Dam for daily release groups of Snake River steelhead (hatchery and wild combined), 2012. Bars extend one standard error above and below point estimates.

Detection Probabilities—For weekly groups of steelhead, estimated detection probability at Snake River dams varied throughout the season with changing flow volume, spill level, and degrees of smoltification (Tables 13-15). High flow and spill levels during late April and early May caused decreases in detection at most dams. Detection probability estimates were generally highest at Little Goose and Lower Monumental Dams and lowest at McNary, John Day, and Bonneville Dams through the season. Detection rates were very low at McNary, John Day, and Bonneville for most of the season, which greatly impaired our ability to estimate survival in that part of the river. 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, 2012. Weekly estimates from pooled daily groups. Standard errors in parentheses.

Estimated detection probability of steelhead from Lower Granite Dam				
Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
23 Mar–29 Mar	256	0.700 (0.038)	0.588 (0.066)	0.064 (0.036)
30 Mar–5 Apr	560	0.553 (0.032)	0.406 (0.046)	0.227 (0.046)
6 Apr–12 Apr	3,111	0.421 (0.013)	0.416 (0.017)	0.156 (0.014)
13 Apr–19 Apr	9,393	0.495 (0.007)	0.365 (0.008)	0.086 (0.005)
20 Apr–26 Apr	18,146	0.385 (0.005)	0.294 (0.006)	0.094 (0.004)
27 Apr–3 May	12,832	0.520 (0.006)	0.437 (0.009)	0.117 (0.007)
4 May–10 May	7,884	0.396 (0.009)	0.255 (0.010)	0.143 (0.010)
11 May–17 May	9,508	0.324 (0.008)	0.160 (0.008)	0.118 (0.008)
18 May–24 May	8,462	0.410 (0.009)	0.264 (0.011)	0.129 (0.010)
25 May–31 May	4,046	0.351 (0.015)	0.153 (0.014)	0.188 (0.020)
1 Jun–7 Jun	1,791	0.304 (0.022)	0.166 (0.024)	0.075 (0.020)

Table 14. Estimated detection probabilities for weekly groups of juvenile Snake River steelhead (hatchery and wild combined) from the tailrace of McNary Dam, 2012. Standard errors in parentheses.

Estimated detection probability of steelhead from McNary Dam			
Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
27 Apr–3 May	3,704	0.414 (0.032)	NA
4 May–10 May	2,106	0.239 (0.027)	0.087 (0.037)
11 May–17 May	2,238	0.155 (0.024)	0.069 (0.033)
18 May–24 May	1,374	0.182 (0.031)	NA
27 Apr–3 May	793	0.158 (0.035)	0.202 (0.074)

Table 15. Estimated detection probabilities for juvenile Snake River hatchery and wild steelhead from the tailrace at Lower Granite Dam, 2012. Daily groups pooled weekly. 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
	Hatchery steelhead			
30 Mar–5 Apr	435	0.544 (0.036)	0.448 (0.054)	0.214 (0.052)
6 Apr–12 Apr	2,039	0.422 (0.016)	0.431 (0.022)	0.149 (0.018)
13 Apr–19 Apr	7,565	0.492 (0.008)	0.364 (0.009)	0.090 (0.006)
20 Apr–26 Apr	13,508	0.357 (0.006)	0.301 (0.007)	0.087 (0.005)
27 Apr–3 May	10,124	0.512 (0.007)	0.430 (0.011)	0.110 (0.008)
4 May–10 May	4,923	0.378 (0.011)	0.273 (0.014)	0.140 (0.013)
11 May–17 May	5,319	0.261 (0.011)	0.166 (0.012)	0.106 (0.011)
18 May–24 May	3,678	0.385 (0.014)	0.246 (0.018)	0.107 (0.016)
25 May–31 May	1,817	0.324 (0.023)	0.186 (0.025)	0.205 (0.033)
	Wild steelhead			
6 Apr–12 Apr	1,072	0.419 (0.022)	0.390 (0.028)	0.168 (0.026)
13 Apr–19 Apr	1,828	0.509 (0.015)	0.367 (0.018)	0.071 (0.010)
20 Apr–26 Apr	4,638	0.459 (0.010)	0.276 (0.011)	0.113 (0.008)
27 Apr–3 May	2,708	0.550 (0.013)	0.464 (0.019)	0.143 (0.016)
4 May–10 May	2,961	0.430 (0.015)	0.224 (0.017)	0.148 (0.016)
11 May–17 May	4,189	0.400 (0.013)	0.154 (0.012)	0.132 (0.013)
18 May–24 May	4,784	0.427 (0.012)	0.276 (0.015)	0.144 (0.014)
25 May–31 May	2,229	0.371 (0.020)	0.132 (0.018)	0.177 (0.025)
1 Jun–7 Jun	661	0.332 (0.037)	0.183 (0.041)	0.149 (0.044)

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 0.763 (se 0.024) for Looking Glass Hatchery fish released to the Grand Ronde River to 0.298 (0.011) for Sawtooth Hatchery fish released to the Yankee Fork River. For steelhead, estimated survival to Lower Granite Dam tailrace ranged from 0.892 (0.012) for Magic Valley Hatchery fish released to the Little Salmon River, to 0.605 (0.018) for Hagerman Hatchery fish released into the Yankee Fork River. For sockeye salmon PIT-tagged and released at Redfish Lake Creek Trap in spring, estimated survival to Lower Granite Dam tailrace ranged from 0.702 (0.058) for Oxbow Hatchery fish to 0.592 (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 wild yearling Chinook salmon, 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 partly due to differences in migration timing. In contrast, detection probability estimates were not consistently different between hatchery and wild steelhead released from the same location.

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, estimated survival from release to McNary Dam tailrace ranged from 0.681 (0.042) for Entiat Hatchery fish released to the Entiat River to 0.246 (0.038) for Wells Hatchery fish released to the Columbia River below Wells Dam. For Upper Columbia River steelhead, estimated survival to McNary Dam tailrace ranged from 0.513 (0.034) for Wells Hatchery fish released to the Methow River to 0.236 (0.017) for Chelan Hatchery fish released to the Wenatchee River. For Upper Columbia River coho salmon, estimated survival to McNary Dam tailrace ranged from 0.504 (0.043) for Willard Hatchery fish released to the Twisp River, to 0.241 (0.033) for Eagle Hatchery fish released to the Yakima River from Easton Pond.

Partitioning Survival Between Lower Monumental and Ice Harbor Dam

A PIT-tag detection system became operational at Ice Harbor Dam in 2005, and sufficient detections occurred in 2006-2012 to estimate tailrace-to-tailrace survival through partitioned reaches from Lower Monumental to Ice Harbor and from Ice Harbor to McNary Dam (Table 16). In 2012, estimated mean survival for yearling Chinook salmon was 0.952 (se 0.028) from Lower Monumental to Ice Harbor Dam and 0.991 (0.030) from Ice Harbor to McNary Dam. For steelhead, estimated mean survival through these reaches was 0.882 (0.025) and 0.924 (0.043), respectively. 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), 2012. Daily groups were pooled for weekly estimates and weighted means. 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		
23 Mar–29 Mar	1,243	1.088 (0.136)	0.814 (0.126)	0.117 (0.018)
30 Mar–5 Apr	2,776	0.924 (0.071)	0.924 (0.083)	0.139 (0.013)
6 Apr–12 Apr	3,863	0.859 (0.042)	1.080 (0.068)	0.158 (0.010)
13 Apr–19 Apr	10,648	0.919 (0.036)	1.003 (0.047)	0.091 (0.005)
20 Apr–26 Apr	20,456	0.932 (0.027)	1.019 (0.034)	0.083 (0.003)
27 Apr–3 May	11,784	1.016 (0.041)	0.928 (0.042)	0.116 (0.005)
4 May–10 May	5,103	1.002 (0.062)	0.911 (0.062)	0.129 (0.008)
11 May–17 May	5,805	0.826 (0.044)	1.200 (0.082)	0.160 (0.008)
18 May–24 May	4,838	1.129 (0.060)	0.882 (0.061)	0.144 (0.008)
25 May–31 May	1,302	1.256 (0.236)	0.612 (0.112)	0.071 (0.012)
Weighted mean		**0.952 (0.028)**	**0.991 (0.030)**	**0.104 (0.009)**
		Hatchery and wild steelhead		
23 Mar–29 Mar	256	0.982 (0.225)	0.874 (0.458)	0.218 (0.056)
30 Mar–5 Apr	560	0.969 (0.202)	0.566 (0.143)	0.139 (0.032)
6 Apr–12 Apr	3,111	0.876 (0.088)	0.784 (0.095)	0.081 (0.010)
13 Apr–19 Apr	9,393	0.984 (0.045)	0.991 (0.063)	0.083 (0.005)
20 Apr–26 Apr	18,146	0.859 (0.025)	1.030 (0.045)	0.134 (0.004)
27 Apr–3 May	12,832	0.836 (0.034)	1.010 (0.062)	0.136 (0.006)
4 May–10 May	7,884	1.047 (0.063)	0.790 (0.064)	0.128 (0.008)
11 May–17 May	9,508	0.835 (0.049)	0.790 (0.060)	0.147 (0.008)
18 May–24 May	8,462	0.793 (0.041)	0.755 (0.063)	0.216 (0.010)
25 May–31 May	4,046	0.990 (0.177)	0.540 (0.101)	0.047 (0.008)
Weighted mean		**0.882 (0.025)**	**0.924 (0.043)**	**0.117 (0.013)**

TRAVEL TIME AND MIGRATION RATES

Methods

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

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

Travel time between any two dams was calculated only for fish detected at both dams. Travel time was defined as the number of days between last detection at the upstream dam and first detection at the downstream dam. Generally, the last detection 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. For each group, the 20th percentile, median, and 80th percentile travel times and migration rates were determined.

The true complete set of travel times for individual fish within a release group includes travel times of both detected and non-detected fish. However, travel time based on PIT-tag detections cannot be determined for a fish that traverses a reach of river without being detected at both ends of the reach. Therefore, travel time statistics are computed only from the travel times of detected fish, and thus they represent a subsample of the complete release group. Non-detected fish pass dams via turbines and spill; thus, their time to pass a dam is typically minutes to hours shorter than that of detected fish, 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 varied throughout the migration season (Tables 17-22). For both species, estimated migration rates were generally highest in the lower river sections. Estimated travel times from Lower Granite to Bonneville Dam for yearling Chinook salmon and steelhead were among the shortest observed in recent years (2005-2011) during parts of the 2012 season (Figure 4).

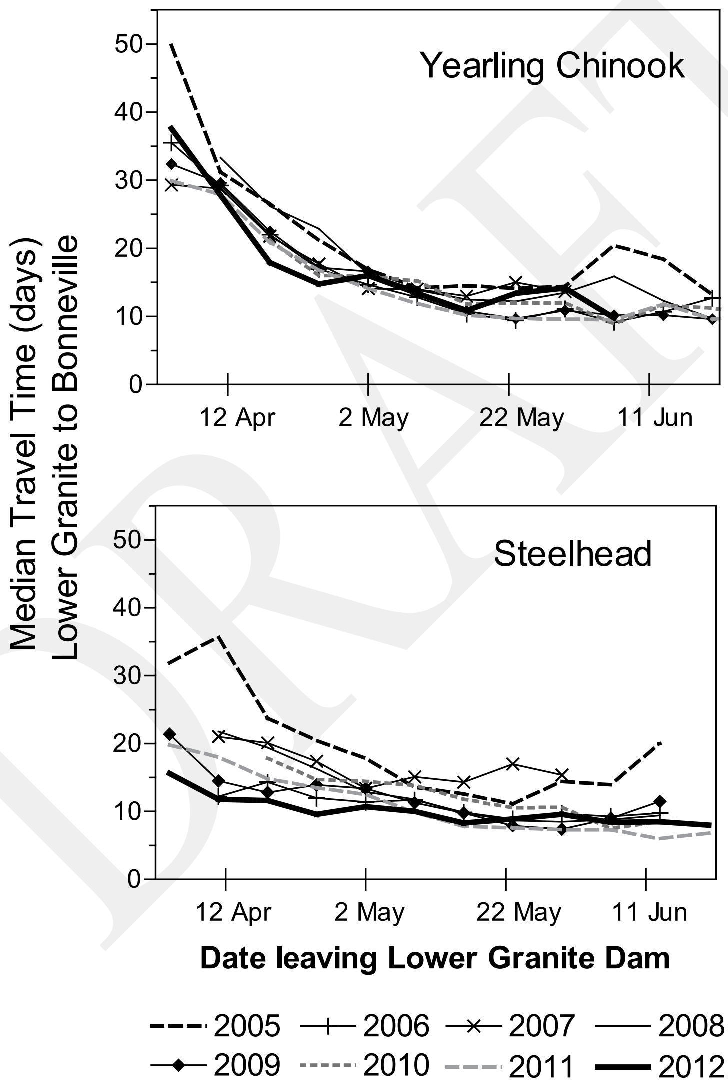

Figure 4. Median travel time (days) from Lower Granite Dam to Bonneville Dam for weekly release groups of Snake River yearling Chinook salmon and steelhead from Lower Granite Dam, 2005-2012.

The observed decreases in travel times for yearling Chinook salmon and steelhead later in the season generally coincided with increases in flow, and presumably with increased levels of smoltification (Figure 5).

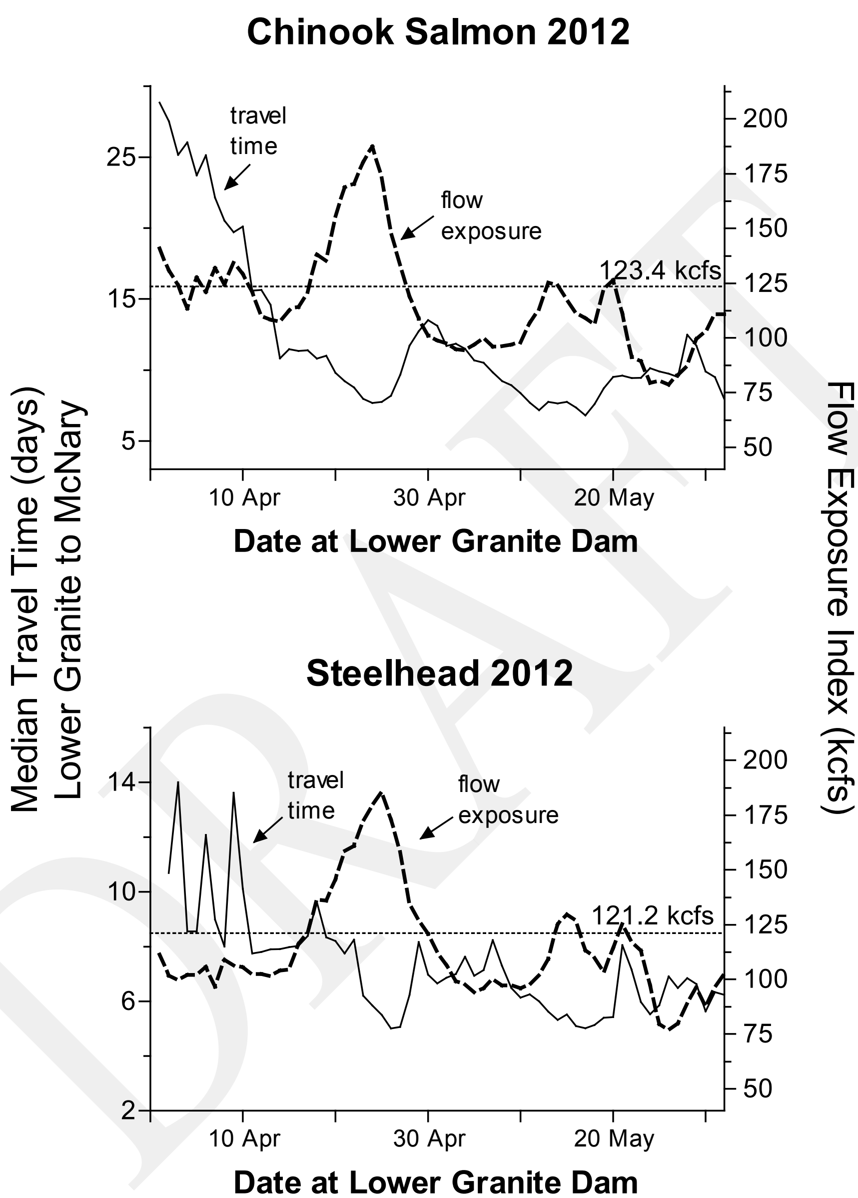

Figure 5. Travel time (days) for yearling Chinook salmon and steelhead from Lower Granite Dam to McNary Dam and index of flow exposure at Lower Monumental Dam (kcfs) for daily groups of PIT-tagged fish during 2012. Dashed horizontal lines represent the annual average flow exposure index, weighted by the number of PIT-tagged fish in each group.

Table 17. Travel time statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at Lower Granite Dam in 2012. 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	807	6.2	14.8	24.9	173	1.8	2.7	5.0	77	3.7	4.8	7.1
6 Apr–12 Apr	1,425	4.1	6.2	11.8	459	1.8	2.4	3.5	150	3.8	5.1	7.3
13 Apr–19 Apr	4,467	3.2	4.1	5.9	1,159	1.5	2.0	2.6	340	2.9	3.7	5.5
20 Apr–26 Apr	7,771	2.4	3.1	4.4	1,807	1.1	1.5	2.1	737	2.6	3.5	5.1
27 Apr–3 May	4,321	3.2	4.7	6.8	934	1.5	2.0	2.6	356	3.3	4.4	5.8
4 May–10 May	1,453	3.0	3.9	5.3	229	1.6	2.0	2.4	155	3.1	3.9	5.2
11 May–17 May	1,640	2.0	2.8	3.4	315	1.4	1.8	2.3	107	2.5	3.3	4.5
18 May–24 May	2,268	2.8	3.1	4.0	482	1.3	1.7	2.1	257	3.2	4.0	5.1
25 May–31 May	432	3.0	3.9	4.7	36	1.9	2.4	3.0	23	3.2	3.6	4.2
1 Jun–7 Jun	34	1.9	2.4	2.9	2	1.4	1.5	1.6	1	3.8	3.8	3.8

Date at Lower Granite Dam	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	281	19.8	26.5	33.9	86	31.9	37.6	44.9
6 Apr–12 Apr	488	11.5	16.4	22.7	128	18.5	27.8	33.7
13 Apr–19 Apr	1,251	8.8	10.7	15.5	319	13.5	17.9	25.4
20 Apr–26 Apr	2,902	6.6	8.5	12.5	1,189	12.0	14.8	18.6
27 Apr–3 May	1,837	9.5	12.2	15.5	871	13.7	16.0	19.0
4 May–10 May	1,049	8.1	9.7	11.9	272	11.3	13.4	15.8
11 May–17 May	789	6.4	7.4	9.3	417	9.7	10.9	13.1
18 May–24 May	1,138	8.1	9.6	11.3	367	11.5	13.4	15.5
25 May–31 May	295	8.6	9.6	11.2	72	12.8	14.2	15.9
1 Jun–7 Jun	14	6.2	7.4	8.1	12	9.2	9.8	10.5

Table 18. Migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at Lower Granite Dam in 2012. 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	807	2.4	4.1	9.6	173	9.3	16.9	25.6	77	16.7	24.8	32.3
6 Apr–12 Apr	1,425	5.1	9.7	14.5	459	13.1	18.9	25.0	150	16.2	23.5	31.0
13 Apr–19 Apr	4,467	10.2	14.7	18.5	1,159	17.8	23.2	30.9	340	21.7	31.9	41.2
20 Apr–26 Apr	7,771	13.6	19.4	25.2	1,807	21.4	31.1	41.8	737	23.4	33.9	45.1
27 Apr–3 May	4,321	8.8	12.7	18.8	934	17.8	23.5	29.9	356	20.5	27.2	36.4
4 May–10 May	1,453	11.4	15.5	20.1	229	19.5	23.5	28.9	155	23.0	30.6	38.3
11 May–17 May	1,640	17.7	21.1	30.5	315	19.8	26.1	32.4	107	26.4	36.1	47.0
18 May–24 May	2,268	15.2	19.4	21.1	482	21.5	27.4	34.8	257	23.5	30.1	37.4
25 May–31 May	432	12.7	15.4	19.8	36	15.5	19.6	24.6	23	28.5	32.9	37.1
1 Jun–7 Jun	34	20.8	25.0	31.2	2	28.6	30.5	32.4	1	31.5	31.5	31.5

	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	281	6.6	8.5	11.4	86	10.3	12.3	14.5
6 Apr–12 Apr	488	9.9	13.7	19.6	128	13.7	16.6	24.9
13 Apr–19 Apr	1,251	14.6	21.0	25.7	319	18.2	25.8	34.2
20 Apr–26 Apr	2,902	18.0	26.5	33.9	1,189	24.8	31.2	38.5
27 Apr–3 May	1,837	14.5	18.4	23.6	871	24.3	28.9	33.7
4 May–10 May	1,049	18.9	23.2	27.6	272	29.2	34.5	40.6
11 May–17 May	789	24.2	30.4	35.3	417	35.2	42.3	47.5
18 May–24 May	1,138	20.0	23.4	28.0	367	29.7	34.3	40.0
25 May–31 May	295	20.1	23.4	26.2	72	29.0	32.5	35.9
1 Jun–7 Jun	14	28.0	30.3	36.4	12	43.7	46.9	50.0

Table 19. Travel time and migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2012.

Date at McNary Dam	Hatchery and wild yearling Chinook salmon from McNary Dam											
	McNary to John Day Dam				John Day to Bonneville Dam				McNary to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
	Travel time (d)											
13 Apr–19 Apr	93	4.0	5.0	7.7	10	1.7	1.9	2.1	14	6.2	6.8	8.0
20 Apr–26 Apr	747	3.0	3.5	4.5	22	1.4	1.7	2.0	48	4.3	5.1	6.4
27 Apr–3 May	3,200	3.0	3.6	4.5	253	1.6	1.9	2.4	623	4.9	5.9	7.2
4 May–10 May	2,463	3.2	3.9	5.0	445	1.7	1.9	2.3	1,503	4.8	5.6	6.6
11 May–17 May	1,407	2.9	3.5	4.2	125	1.4	1.7	2.0	1,150	3.9	4.5	5.2
18 May–24 May	595	2.9	3.2	4.1	54	1.4	1.5	1.9	273	3.7	4.2	5.3
25 May–31 May	166	3.0	3.6	4.6	23	1.7	1.8	2.0	232	4.3	4.8	5.6
1 Jun–7 Jun	103	3.0	3.6	4.2	4	1.3	1.4	1.5	84	4.3	4.8	5.4
8 Jun–14 Jun	19	3.1	3.8	4.6	2	1.7	1.9	2.1	7	4.9	5.5	6.2
	Migration rate (km/d)											
13 Apr–19 Apr	93	16.1	24.8	30.8	10	54.9	59.2	66.5	14	29.6	34.5	38.3
20 Apr–26 Apr	747	27.3	34.9	41.4	22	56.8	67.7	81.3	48	36.8	46.1	54.8
27 Apr–3 May	3,200	27.3	34.4	41.4	253	48.1	58.9	72.4	623	32.8	40.3	48.6
4 May–10 May	2,463	24.7	31.2	38.9	445	49.3	58.2	67.7	1,503	35.8	42.3	49.0
11 May–17 May	1,407	29.1	35.5	42.1	125	57.7	67.3	80.7	1,150	45.3	52.0	60.7
18 May–24 May	595	30.3	38.4	42.9	54	60.1	73.9	83.7	273	44.4	56.9	63.8
25 May–31 May	166	26.8	33.9	41.7	23	57.4	61.7	66.5	232	42.3	49.1	54.9
1 Jun–7 Jun	103	28.9	34.2	41.4	4	75.3	81.3	86.9	84	43.9	49.1	55.0
8 Jun–14 Jun	19	27.0	32.8	39.2	2	52.8	58.9	66.5	7	37.9	42.7	48.0

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 2012.

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	264	2.5	3.0	3.9	91	1.4	2.3	7.8	19	3.3	4.0	6.4
6 Apr–12 Apr	1,217	2.0	2.9	3.6	404	1.4	2.2	4.0	107	2.7	3.1	4.7
13 Apr–19 Apr	4,494	2.1	2.9	3.8	1,354	1.6	2.3	4.8	251	2.2	2.9	4.0
20 Apr–26 Apr	6,733	1.7	1.9	2.7	1,715	0.9	1.3	2.7	368	1.9	2.3	3.6
27 Apr–3 May	6,316	1.8	2.1	2.9	2,223	1.2	1.6	3.0	322	2.2	2.9	3.9
4 May–10 May	3,120	1.9	2.1	2.9	605	1.3	1.9	3.0	192	2.5	2.8	3.6
11 May–17 May	2,940	1.9	2.0	2.4	445	1.1	1.3	2.0	99	2.0	2.4	2.8
18 May–24 May	3,057	1.8	1.9	2.6	827	1.0	1.3	2.0	178	2.0	2.5	3.0
25 May–31 May	1,457	1.9	2.1	2.9	145	1.1	1.5	2.0	49	2.4	2.7	3.2
1 Jun–7 Jun	413	1.9	1.9	2.2	73	1.0	1.3	1.8	19	1.9	2.2	2.5
8 Jun–14 Jun	255	1.8	1.9	2.2	36	1.2	1.6	2.1	1	2.6	2.6	2.6
15 Jun–21 Jun	42	1.9	1.9	2.2	5	1.5	2.2	2.5	1	2.5	2.5	2.5

Date at Lower Granite Dam	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	49	8.5	11.1	20.8	9	13.3	15.6	18.4
6 Apr–12 Apr	266	6.4	8.0	12.3	115	10.3	11.8	13.5
13 Apr–19 Apr	674	6.9	8.1	11.9	251	10.3	11.6	16.6
20 Apr–26 Apr	1,271	4.4	5.3	7.9	638	8.2	9.6	14.8
27 Apr–3 May	892	5.6	7.0	10.6	696	9.2	10.7	13.8
4 May–10 May	721	5.9	6.6	8.1	447	8.9	10.0	11.5
11 May–17 May	634	4.9	5.5	6.4	511	7.5	8.3	9.5
18 May–24 May	593	5.0	5.7	6.8	525	8.3	8.9	10.3
25 May–31 May	331	5.9	6.5	7.6	194	8.8	9.6	10.8
1 Jun–7 Jun	79	4.9	5.2	6.2	70	7.6	8.4	9.6
8 Jun–14 Jun	22	5.2	5.6	6.4	59	7.8	8.5	9.1
15 Jun–21 Jun	4	5.7	6.1	6.5	12	7.4	8.0	9.1

Table 21. Migration rate statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2012.

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	264	15.4	19.9	23.6	91	5.9	19.7	32.9	19	18.5	29.8	36.5
6 Apr–12 Apr	1,217	16.6	20.9	30.3	404	11.4	20.6	33.3	107	25.2	38.3	44.2
13 Apr–19 Apr	4,494	15.7	20.7	28.6	1,354	9.5	19.7	28.9	251	29.8	41.5	54.8
20 Apr–26 Apr	6,733	21.9	30.9	35.7	1,715	16.8	35.9	51.1	368	33.1	51.3	62.3
27 Apr–3 May	6,316	21.0	28.3	33.7	2,223	15.1	28.2	39.3	322	30.5	41.6	53.6
4 May–10 May	3,120	20.6	28.6	31.6	605	15.1	24.5	35.4	192	33.4	41.9	48.6
11 May–17 May	2,940	25.0	30.2	32.3	445	23.2	34.6	43.4	99	42.2	50.2	59.8
18 May–24 May	3,057	23.4	31.2	33.7	827	23.1	36.2	44.2	178	39.1	48.0	58.9
25 May–31 May	1,457	21.0	28.6	31.1	145	22.4	30.5	40.0	49	37.7	44.1	50.4
1 Jun–7 Jun	413	27.4	30.9	32.3	73	25.4	36.5	46.5	19	47.8	53.8	61.3
8 Jun–14 Jun	255	27.5	31.1	32.4	36	22.2	29.3	37.1	1	44.9	44.9	44.9
15 Jun–21 Jun	42	27.3	31.4	32.1	5	18.5	21.2	30.3	1	47.8	47.8	47.8

Date at Lower Granite Dam	Lower Granite to McNary Dam				Lower Granite to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%
30 Mar–5 Apr	49	10.8	20.3	26.3	9	25.1	29.6	34.7
6 Apr–12 Apr	266	18.2	28.3	35.2	115	34.2	39.1	44.8
13 Apr–19 Apr	674	18.9	27.7	32.8	251	27.8	39.6	44.6
20 Apr–26 Apr	1,271	28.4	42.6	50.7	638	31.1	48.1	56.2
27 Apr–3 May	892	21.2	32.1	40.2	696	33.4	43.3	49.9
4 May–10 May	721	27.7	33.9	38.1	447	40.1	46.0	52.0
11 May–17 May	634	35.3	41.1	45.9	511	48.5	55.7	61.8
18 May–24 May	593	32.9	39.2	45.0	525	44.8	51.9	55.6
25 May–31 May	331	29.5	34.4	38.1	194	42.7	48.0	52.4
1 Jun–7 Jun	79	36.5	42.9	45.7	70	48.1	54.9	60.8
8 Jun–14 Jun	22	35.0	40.0	43.2	59	50.8	54.4	59.3
15 Jun–21 Jun	4	34.6	36.6	39.8	12	50.7	57.7	62.4

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 2012.

Date at McNary Dam	Hatchery and wild juvenile steelhead from McNary Dam											
	McNary to John Day Dam				John Day to Bonneville Dam				McNary to Bonneville Dam			
	N	20%	Median	80%	N	20%	Median	80%	N	20%	Median	80%
	Travel time (d)											
13 Apr–19 Apr	86	3.1	3.9	5.6	4	1.3	1.4	1.4	21	4.3	4.4	5.3
20 Apr–26 Apr	592	3.0	3.9	6.7	11	1.1	1.1	1.3	40	3.7	4.3	5.2
27 Apr–3 May	1,122	3.0	3.6	6.2	64	1.2	1.3	1.8	149	3.9	4.8	7.3
4 May–10 May	473	3.0	4.1	7.8	43	1.2	1.4	1.8	197	3.8	4.5	5.7
11 May–17 May	317	2.6	3.4	4.9	30	1.1	1.3	1.5	175	3.5	3.9	4.8
18 May–24 May	213	2.3	3.0	4.1	24	1.2	1.2	1.9	120	3.3	3.6	4.4
25 May–31 May	89	2.9	3.1	4.0	15	1.3	1.4	1.6	87	3.7	4.3	4.7
1 Jun–7 Jun	44	2.5	3.0	4.5	3	1.2	1.2	1.4	41	3.7	4.3	4.7
8 Jun–14 Jun	11	2.0	2.4	3.0	2	1.4	1.7	2.0	17	3.3	3.5	3.9
	Migration rate (km/d)											
13 Apr–19 Apr	86	22.1	31.9	39.9	4	77.9	80.1	84.3	21	44.5	53.9	54.9
20 Apr–26 Apr	592	18.5	31.9	41.7	11	88.3	98.3	100.0	40	45.6	55.0	63.8
27 Apr–3 May	1,122	20.0	33.7	41.7	64	63.5	85.6	95.0	149	32.2	49.6	61.1
4 May–10 May	473	15.7	29.7	40.6	43	63.8	80.1	91.9	197	41.5	52.2	61.3
11 May–17 May	317	24.9	36.3	46.9	30	75.3	87.6	101.8	175	49.6	60.7	67.2
18 May–24 May	213	30.2	41.0	52.6	24	60.4	90.4	95.0	120	54.1	65.4	71.1
25 May–31 May	89	30.7	39.8	42.7	15	69.8	77.9	86.3	87	49.8	54.4	64.0
1 Jun–7 Jun	44	27.3	41.0	49.4	3	83.1	97.4	97.4	41	50.1	55.1	63.6
8 Jun–14 Jun	11	41.6	50.8	60.6	2	55.4	65.7	80.7	17	60.8	67.8	71.5

ESTIMATES OF THE PROPORTION TRANSPORTED FROM SPRING MIGRANT POPULATIONS

Methods

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

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

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

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

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

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

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

transport starting date at a collector dam, the proportion transported is 100%. For groups arriving before the starting date, the estimated proportion of the daily Lower Granite Dam group transported depends on the travel time distribution (i.e., a certain percentage of each group arrived before transport began), and travel time distribution changes throughout the season (e.g., fish that arrive earlier at Lower Granite Dam tend to take longer to get to the downstream dams).

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

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

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

Results

In 2012, collection for transportation began on 2 May at Lower Granite Dam, 4 May at Little Goose Dam, and 6 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 that were transported during the entire 2012 season were 22.7% for wild and 24.7% for hatchery smolts. For non-tagged steelhead, estimated percentages transported were 28.4% for wild and 26.7% for hatchery smolts. These estimates represent the proportion of smolts that arrived at Lower Granite Dam and were subsequently transported from either Lower Granite or one of the downstream collector dams. The 2012 estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams in 2012 were the lowest seen in twenty years of our estimates 1993-2012 (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.

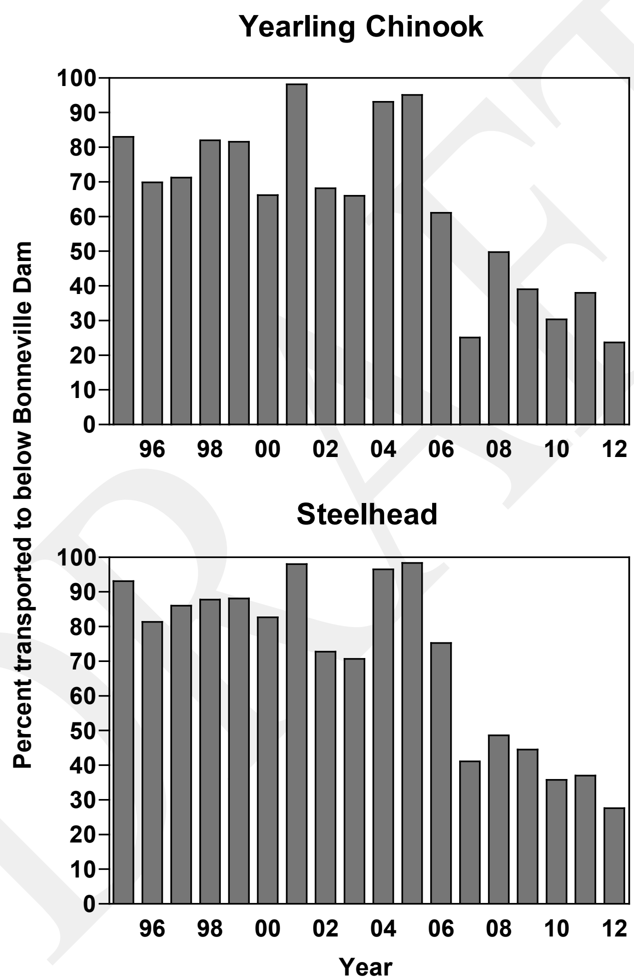

Figure 6. Estimated percent of yearling Chinook salmon and steelhead (hatchery and wild combined) transported to below Bonneville Dam by year (1995-2012).

Table 23. Annual estimated percentages of migrating Snake River yearling Chinook salmon and steelhead that were transported (1993-2012). 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
Mean	**64.1**	**67.4**	**65.8**	**71.6**	**72.9**	**72.3**

When transportation began at Lower Granite on 2 May, approximately 67% of the yearling Chinook salmon and 61% of the steelhead had already passed the dam (see Appendix Figure C3 for smolt indices). Over the 5 previous years, the median (50%) passage date at Lower Granite fell within 3-10 May for yearling Chinook salmon and 5-11 May for steelhead. In contrast, the median passage date in 2012 at Lower Granite fell on approximately 28 April for yearling Chinook salmon and 29 April for steelhead.

Similar to 2011, passage conditions at Snake River collector dams were characterized by high spill percentages combined with use of surface bypass structures, which resulted in lower rates of fish collection. Low collection rates in turn led to reduced rates of detection, as fewer fish entered juvenile bypass systems throughout the 2012 migration season. In addition, these relatively low collection rates, along with the late start in collection relative to run timing, resulted in historically low proportions of fish being transported in 2012.

COMPARISONS BETWEEN STOCKS AND AMONG YEARS

Comparison of Annual Survival Estimates Among Years

We made two comparisons of annual survival estimates from 2012 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 2012 were similar to those made in recent years. Mean survival of fish from these hatcheries in 2012 was a little higher than the long-term mean (Table 24). Over the years of the study, we have consistently observed an inverse relationship between the distance from release to Lower Granite Dam and estimated survival. For yearling Chinook from Snake River hatcheries from 1998 to 2012, there has been a significant negative linear correlation between migration distance and average estimated survival (Figure 7; R^2 = 0.879, P = 0.002).

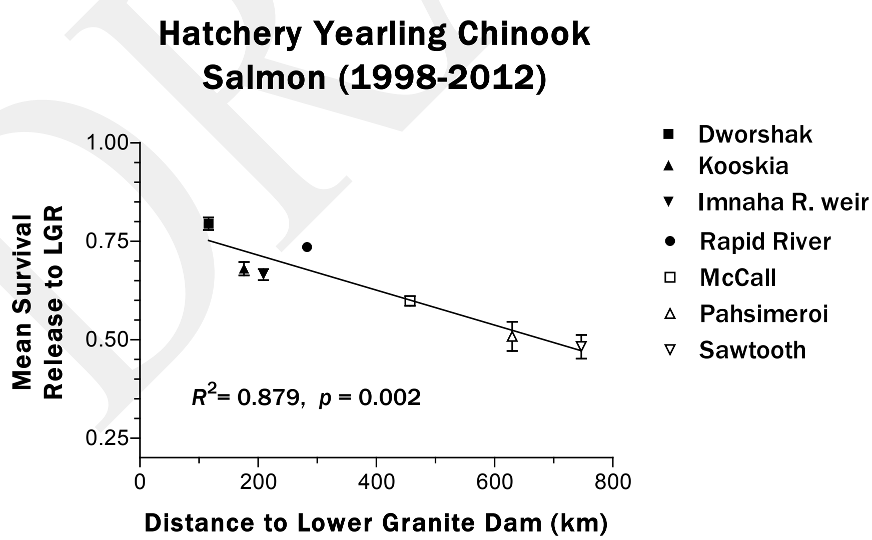

Figure 7. Estimated survival from release at Snake River Basin hatcheries to Lower Granite Dam tailrace, 1998-2012 vs. distance (km) to Lower Granite Dam. The squared correlation between survival and migration distance is also shown, along with a p-value for a test of the null hypothesis of zero correlation. 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, 1993–2012. 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)
Mean	**0.776 (0.017)**	**0.681 (0.019)**	**0.656 (0.012)**	**0.696 (0.022)**	**0.575 (0.014)**	**0.485 (0.032)**	**0.428 (0.035)**	**0.614 (0.012)**

* Released at Imnaha River Weir.

For yearling Chinook salmon in 2012, mean estimated survival was 0.790 (95% CI 0.759-0.821) from Lower Granite Dam tailrace to McNary Dam tailrace and 0.802 (0.702-0.902) from McNary Dam tailrace to Bonneville Dam tailrace (Tables 25 and 27; Figures 8 and 9). These estimates were higher than those in 2011 for both reaches; however, meaningful comparisons were not possible due to low precision in these estimates.

For yearling Chinook salmon (hatchery and wild combined) migrating in 2012, estimated survival through the entire hydrosystem (Snake River Trap to Bonneville tailrace) was 0.588 (0.510-0.666; Table 27). This estimate was greater than both the annual mean of 0.483 estimated for 2011 and the 14-year mean of 0.499 estimated for 1999-2012. The imprecision of 2011 and 2012 estimates made their difference not statistically significant ($P = 0.08$). For wild yearling Chinook salmon alone, the mean estimate for 2012 through the entire hydrosystem was higher than that for hatchery and wild Chinook combined, at 0.625 (Table 27). However, this estimate was also imprecise, as evidenced by its wide confidence interval (0.523-0.727).

For steelhead (hatchery and wild combined) migrating in 2012, mean estimated survival was 0.697 (95% CI 0.658-0.737) through the reach from Lower Granite to McNary Dam and 0.856 (0.472-1.240) through the reach from McNary to Bonneville Dam. These estimates were close to those from 2011 (Table 28; Figures 8 and 9).

For steelhead (hatchery and wild combined) migrating in 2012, estimated survival through the entire hydrosystem (Snake River Trap to Bonneville tailrace) was 0.598 (0.326-0.870; Table 28). Again, this estimate was higher than the annual mean estimate for 2011, but because of its poor precision, no meaningful comparison with estimates from past years was possible. Poor detection rates at dams on the Lower Columbia River produced insufficient data to estimate survival through the entire hydrosystem for wild steelhead. In the Snake River, mean estimated survival for wild steelhead from Lower Granite to McNary was 0.697 (0.605-0.789; Table 28).

Table 25. Annual weighted means of survival probability estimates for yearling Chinook salmon (hatchery and wild combined), 1993–2012. 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 years are given.

Annual survival estimates for wild and hatchery yearling Chinook salmon

Year	Trap to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam*	L Monumental to Ice Harbor and Ice Harbor to McNary	McNary to John Day Dam	John Day to Bonneville Dam *	John Day to The Dalles and The Dalles to Bonneville Dam
1993	0.828 (0.013)	0.854 (0.012)						
1994	0.935 (0.023)	0.830 (0.009)	0.847 (0.010)					
1995	0.905 (0.010)	0.882 (0.004)	0.925 (0.008)	0.876 (0.038)	0.936			
1996	0.977 (0.025)	0.926 (0.006)	0.929 (0.011)	0.756 (0.033)	0.870			
1997	NA	0.942 (0.018)	0.894 (0.042)	0.798 (0.091)	0.893			
1998	0.925 (0.009)	0.991 (0.006)	0.853 (0.009)	0.915 (0.011)	0.957	0.822 (0.033)		
1999	0.940 (0.009)	0.949 (0.002)	0.925 (0.004)	0.904 (0.007)	0.951	0.853 (0.027)	0.814 (0.065)	0.902
2000	0.929 (0.014)	0.938 (0.006)	0.887 (0.009)	0.928 (0.016)	0.963	0.898 (0.054)	0.684 (0.128)	0.827
2001	0.954 (0.015)	0.945 (0.004)	0.830 (0.006)	0.708 (0.007)	0.841	0.758 (0.024)	0.645 (0.034)	0.803
2002	0.953 (0.022)	0.949 (0.006)	0.980 (0.008)	0.837 (0.013)	0.915	0.907 (0.014)	0.840 (0.079)	0.917
2003	0.993 (0.023)	0.946 (0.005)	0.916 (0.011)	0.904 (0.017)	0.951	0.893 (0.017)	0.818 (0.036)	0.904
2004	0.893 (0.009)	0.923 (0.004)	0.875 (0.012)	0.818 (0.018)	0.904	0.809 (0.028)	0.735 (0.092)	0.857
2005	0.919 (0.015)	0.919 (0.003)	0.886 (0.006)	0.903 (0.010)	0.950	0.772 (0.029)	1.028 (0.132)	1.014
2006	0.952 (0.011)	0.923 (0.003)	0.934 (0.004)	0.887 (0.008)	0.942	0.881 (0.020)	0.944 (0.030)	0.972
2007	0.943 (0.028)	0.938 (0.006)	0.957 (0.010)	0.876 (0.012)	0.936	0.920 (0.016)	0.824 (0.043)	0.908
2008	0.992 (0.018)	0.939 (0.006)	0.950 (0.011)	0.878 (0.016)	0.937	1.073 (0.058)	0.558 (0.082)	0.750
2009	0.958 (0.010)	0.940 (0.006)	0.982 (0.009)	0.855 (0.011)	0.925	0.866 (0.042)	0.821 (0.043)	0.906
2010	0.968 (0.040)	0.962 (0.011)	0.973 (0.019)	0.851 (0.017)	0.922	0.947 (0.021)	0.780 (0.039)	0.883
2011	0.943 (0.009)	0.919 (0.007)	0.966 (0.007)	0.845 (0.012)	0.919	0.893 (0.026)	0.766 (0.080)	0.875
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
Mean	**0.939 (0.009)**	**0.926 (0.008)**	**0.918 (0.011)**	**0.860 (0.014)**	**0.927**	**0.880 (0.020)**	**0.795 (0.032)**	**0.889**

Table 26. Annual weighted means of survival probability estimates for steelhead (hatchery and wild combined), 1993–2012. 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 years are given.

Annual survival estimates for wild and hatchery steelhead									
Year	Trap to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam*	L Monumental to Ice Harbor and Ice Harbor to McNary	McNary to John Day Dam	John Day to Bonneville Dam*	John Day to The Dalles and The Dalles to Bonneville Dam
1993	0.905 (0.006)							
1994	NA	0.844 (0.011)	0.892 (0.011)					
1995	0.945 (0.008)	0.899 (0.005)	0.962 (0.011)	0.858 (0.076)	0.926			
1996	0.951 (0.015)	0.938 (0.008)	0.951 (0.014)	0.791 (0.052)	0.889			
1997	0.964 (0.015)	0.966 (0.006)	0.902 (0.020)	0.834 (0.065)	0.913			
1998	0.924 (0.009)	0.930 (0.004)	0.889 (0.006)	0.797 (0.018)	0.893	0.831 (0.031)	0.935 (0.103)	0.967
1999	0.908 (0.011)	0.926 (0.004)	0.915 (0.006)	0.833 (0.011)	0.913	0.920 (0.033)	0.682 (0.039)	0.826
2000	0.964 (0.013)	0.901 (0.006)	0.904 (0.009)	0.842 (0.016)	0.918	0.851 (0.045)	0.754 (0.045)	0.868
2001	0.911 (0.007)	0.801 (0.010)	0.709 (0.008)	0.296 (0.010)	0.544	0.337 (0.025)	0.753 (0.063)	0.868
2002	0.895 (0.015)	0.882 (0.011)	0.882 (0.018)	0.652 (0.031)	0.807	0.844 (0.063)	0.612 (0.098)	0.782
2003	0.932 (0.015)	0.947 (0.005)	0.898 (0.012)	0.708 (0.018)	0.841	0.879 (0.032)	0.630 (0.066)	0.794
2004	0.948 (0.004)	0.860 (0.006)	0.820 (0.014)	0.519 (0.035)	0.720	0.465 (0.078)	NA	NA
2005	0.967 (0.004)	0.940 (0.004)	0.867 (0.009)	0.722 (0.023)	0.850	0.595 (0.040)	NA	NA
2006	0.920 (0.013)	0.956 (0.004)	0.911 (0.006)	0.808 (0.017)	0.899	0.795 (0.045)	0.813 (0.083)	0.902
2007	1.016 (0.026)	0.887 (0.009)	0.911 (0.022)	0.852 (0.030)	0.923	0.988 (0.098)	0.579 (0.059)	0.761
2008	0.995 (0.018)	0.935 (0.007)	0.961 (0.014)	0.776 (0.017)	0.881	0.950 (0.066)	0.742 (0.045)	0.861
2009	1.002 (0.011)	0.972 (0.005)	0.942 (0.008)	0.863 (0.014)	0.929	0.951 (0.026)	0.900 (0.079)	0.949
2010	1.017 (0.030)	0.965 (0.028)	0.984 (0.044)	0.876 (0.032)	0.936	0.931 (0.051)	0.840 (0.038)	0.907
2011	0.986 (0.017)	0.955 (0.004)	0.948 (0.010)	0.772 (0.014)	0.879	0.960 (0.043)	0.858 (0.051)	0.926
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
Mean	**0.955 (0.009)**	**0.919 (0.011)**	**0.903 (0.014)**	**0.756 (0.034)**	**0.865**	**0.807 (0.050)**	**0.778 (0.037)**	**0.879**

Table 27. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River hatchery and wild yearling Chinook salmon 1999–2012. Standard errors in parentheses. Simple arithmetic means are given.

Year	Trap to Lower Granite Dam	Lower Granite to McNary Dam	McNary to Bonneville Dam	Lower Granite to Bonneville Dam	Trap to Bonneville Dam
			Hatchery and wild yearling Chinook		
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)
Mean	**0.948 (0.007)**	**0.744 (0.016)**	**0.704 (0.025)**	**0.527 (0.026)**	**0.499 (0.025)**
			Wild yearling Chinook		
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)
Mean	**0.930 (0.011)**	**0.734 (0.019)**	**0.666 (0.039)**	**0.493 (0.034)**	**0.459 (0.033)**

Table 28. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River steelhead, 1999–2012. Standard errors in parentheses; simple arithmetic means are given.

Year	Snake River Trap to Lower Granite Dam	Lower Granite to McNary Dam	McNary to Bonneville Dam	Lower Granite to Bonneville Dam	Trap to Bonneville Dam
			Hatchery and wild steelhead		
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)
Mean	**0.962 (0.011)**	**0.622 (0.042)**	**0.641 (0.049)**	**0.435 (0.048)**	**0.424 (0.049)**
			Wild steelhead		
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
Mean	**0.970 (0.014)**	**0.635 (0.044)**	**0.598 (0.050)**	**0.416 (0.048)**	**0.402 (0.048)**

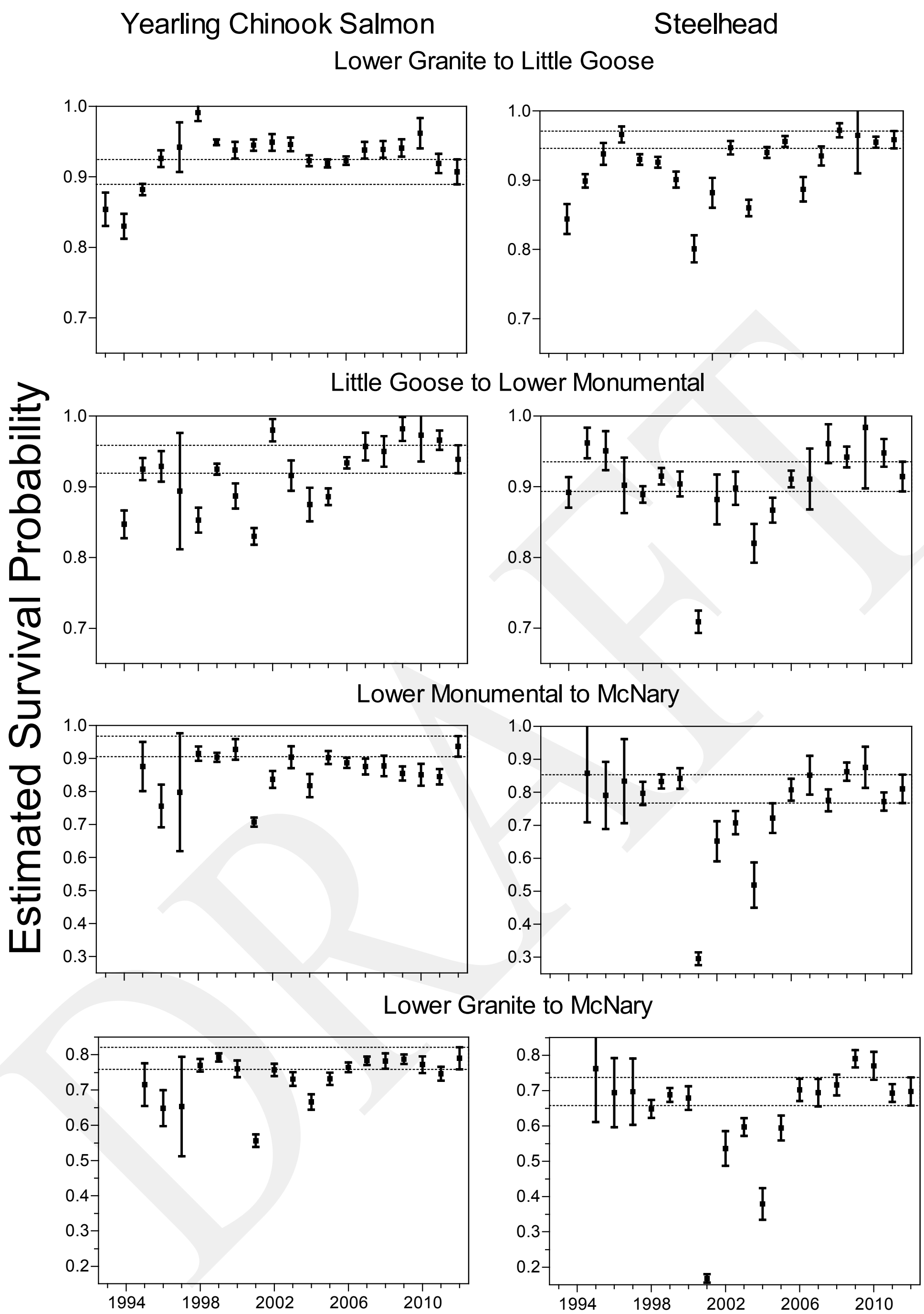

Figure 8. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead (hatchery and wild combined) through Snake River reaches, 1993-2012. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2012 estimates.

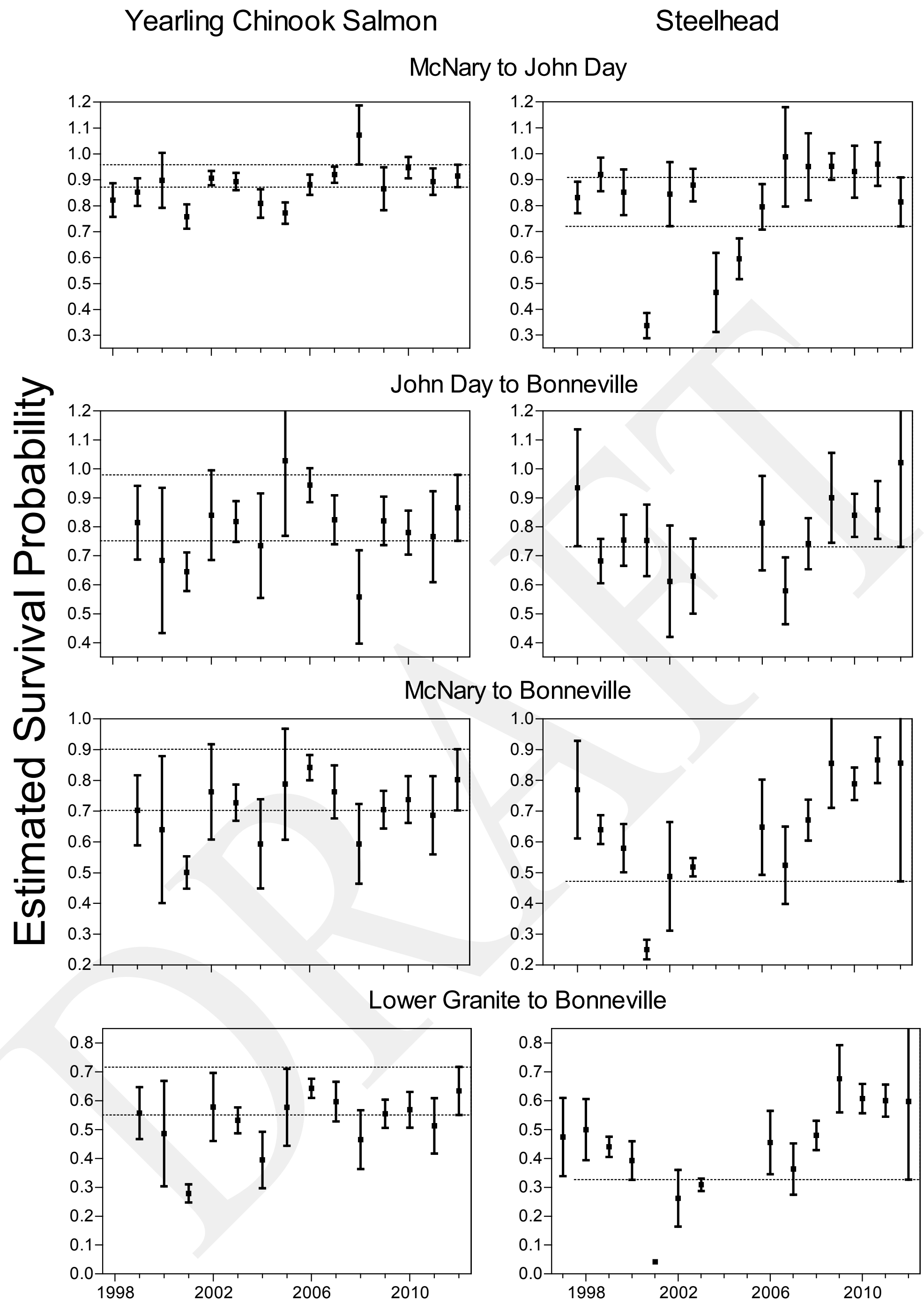

Figure 9. Annual average survival estimates for PIT-tagged Snake River yearling Chinook salmon and steelhead (hatchery and wild combined) through Columbia River reaches and from Lower Granite Dam to Bonneville Dam, 1993-2012. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2012 estimates.

Sockeye Salmon—For pooled groups of wild and hatchery sockeye salmon originating in the Snake River basin, estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace in 2012 was 0.762 (95% CI 0.702-0.827; Table 29). This estimate was higher than the average estimate for this same reach in 2011 and higher than the average for 1996-2012. Estimated survival from Lower Granite Dam to Bonneville Dam for Snake River sockeye salmon in 2012 was 0.472 (0.365-0.610).

Table 29. Estimated survival for sockeye salmon (hatchery and wild combined) from Lower Granite Dam tailrace to Bonneville Dam tailrace for fish originating in the Snake River and from Rock Island Dam tailrace to Bonneville Dam tailrace for fish originating in the upper Columbia River, 1996–2012. Standard errors in parentheses. All available data for sockeye are shown; estimates are provided regardless of precision. Estimates to Bonneville tailrace were of poor quality in many cases due to small sample sizes and low detection probabilities.

	Annual survival estimates Snake River sockeye		
Year	Lower Granite to McNary	McNary to Bonneville Dam	Lower Granite to Bonneville Dam
1996	0.283 (0.184)	NA	NA
1997	NA	NA	NA
1998	0.689 (0.157)	0.142 (0.099)	0.177 (0.090)
1999	0.655 (0.083)	0.841 (0.584)	0.548 (0.363)
2000	0.679 (0.110)	0.206 (0.110)	0.161 (0.080)
2001	0.205 (0.063)	0.105 (0.050)	0.022 (0.005)
2002	0.524 (0.062)	0.684 (0.432)	0.342 (0.212)
2003	0.669 (0.054)	0.551 (0.144)	0.405 (0.098)
2004	0.741 (0.254)	NA	NA
2005	0.388 (0.078)	NA	NA
2006	0.630 (0.083)	1.113 (0.652)	0.820 (0.454)
2007	0.679 (0.066)	0.259 (0.084)	0.272 (0.073)
2008	0.763 (0.103)	0.544 (0.262)	0.404 (0.179)
2009	0.749 (0.032)	0.765 (0.101)	0.573 (0.073)
2010	0.723 (0.039)	0.752 (0.098)	0.544 (0.077)
2011	0.659 (0.033)	NA	NA
2012	0.762 (0.032)	0.619 (0.084)	0.472 (0.062)
Mean	**0.612 (0.043)**	**0.548 (0.090)**	**0.395 (0.063)**

	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)
Mean	**0.667 (0.037)**	**0.784 (0.103)**	**0.541 (0.073)**

Upper Columbia River Stocks

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 0.953 (95% CI 0.753-1.206). This estimate was greater than the 1999-2012 average of 0.770 for that reach (Table 30), 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 2012 was 1.069 (0.800-1.429). This estimate exceeded 1.0 but was again unreliable due to poor and variable detection rates at Lower Columbia River dams (Table 30).

Sockeye Salmon—For Upper Columbia River sockeye salmon captured, tagged, and released to the tailrace of Rock Island Dam, estimated survival to McNary tailrace was 0.945 (0.793-1.127; Table 29). We estimated survival of these fish from McNary to Bonneville and from Rock Island to Bonneville Dam. However, estimates were extremely imprecise due to low detection rates of these fish at McNary and Bonneville Dam in 2012.

Table 30. Estimated survival and standard error (se) through reaches of the lower Columbia River hydropower system for hatchery yearling Chinook salmon (1999–2012) and steelhead (2003–2012) 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)
Mean	**0.553 (0.015)**	**0.899 (0.030)**	**0.848 (0.055)**	**0.770 (0.036)**
		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)
Mean	**0.423 (0.020)**	**0.913 (0.045)**	**0.847 (0.074)**	**0.754 (0.050)**

Comparison of Annual Survival Estimates Among Snake and Columbia River Stocks

Estimated survival from McNary to Bonneville Dam tailrace was lower for Snake (0.802, se 0.051) than for Upper Columbia River spring/summer Chinook migrating in 2012 (0.845, se 0.092; Table 31), although the difference was not statistically significant ($P = 0.68$). For steelhead migrating in this same reach during 2012, estimated survival was lower for Snake (0.856, se 0.196) than for Upper Columbia River fish (1.014, se 0.106); however, estimates for fish from both basins were very imprecise, and the difference was not statistically significant ($P = 0.48$). For sockeye salmon, estimated survival from McNary tailrace to John Day tailrace was lower for Snake River fish (0.609, se 0.106) than for Upper Columbia River fish (0.840, se 0.405), but again, the estimates were very uncertain and no meaningful comparisons were possible ($P = 0.58$).

Table 31. Average survival estimates (with standard errors in parentheses) from McNary Dam tailrace to Bonneville Dam tailrace for various spring–migrating salmonid stocks (hatchery and wild combined) in 2012. 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	36,352*	0.915 (0.023)	0.866 (0.058)	0.802 (0.051)
Upper Columbia Chinook (Sp/Su)	Upper Columbia sites[a]	110,764	0.845 (0.030)	1.001 (0.112)	0.845 (0.092)
Upper Columbia Chinook (Sp/Su)	Yakima River sites[b]	85,754	0.866 (0.033)	0.644 (0.093)	0.558 (0.079)
Upper Columbia Coho	Upper Columbia sites	48,232	0.854 (0.048)	0.871 (0.124)	0.744 (0.102)
Upper Columbia Coho	Yakima River sites	26,526	0.993 (0.103)	0.763 (0.242)	0.758 (0.232)
Snake River Sockeye	Snake River sites[c]	47,519	0.741 (0.071)	0.822 (0.151)	0.609 (0.106)
Upper Columbia Sockeye	Upper Columbia sites	3,231	0.837 (0.155)	1.004 (0.503)	0.840 (0.405)
Snake River Steelhead*	McNary Dam Tailrace	10,215*	0.814 (0.048)	1.021 (0.148)	0.856 (0.196)
Upper Columbia Steelhead	Upper Columbia sites	111,094	0.875 (0.034)	1.159 (0.122)	1.014 (0.106)

[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 2012, estimated survival through the hydropower system (Snake River trap to Bonneville tailrace) was 58.8%. This estimate was the second highest observed from 1999 to 2012 (higher only in 2006) and exceeded the 2011 estimate of 48.8% ($P = 0.08$). Compared to the long-term average, estimated survival for yearling Chinook salmon in 2012 was 4.6% higher between Lower Granite and McNary Dam, and 9.8% higher between McNary and Bonneville Dam. Likewise, estimated survival through the hydropower system was 59.8% for steelhead migrating in 2012. This was the third highest in our times series (behind 2008 and 2009) and was greater than the long-term average of 42.4% and nearly identical to the 2011 estimate of 59.2% ($P = 0.96$).

With the addition in 2009 of a temporary spillway weir (TSW) at Little Goose Dam, all eight mainstem dams encountered by smolts migrating 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 in helping to reduce 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, with accompanied 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 bird populations and consumption rates are intensively monitored (Ryan et al. 2001, 2003; Roby et al. 2008). In Lake Wallula (McNary Dam reservoir), Crescent Island harbors the second largest Caspian tern *Hydroprogne caspia* colony in North America (about 500 breeding pairs annually on average in the last 10 years), as well as large populations of gulls *Larus* spp. Other avian piscivores in this area include the American white pelican *Pelecanus erythrorhynchos,* cormorant *Phalacrocorax auritus*, egret *Ardea alba*, and herons *A. herodias* and *Nycticorax nycticorax.*

Studies have shown that steelhead smolts are particularly susceptible to predation by birds. 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 32), the proportion of PIT-tagged steelhead lost to piscivorous birds Lake Wallula was lower during 2006-2012 than during 2001-2005.

Table 32. 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 during 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 in 2012), and delayed initiation of the smolt transportation program.

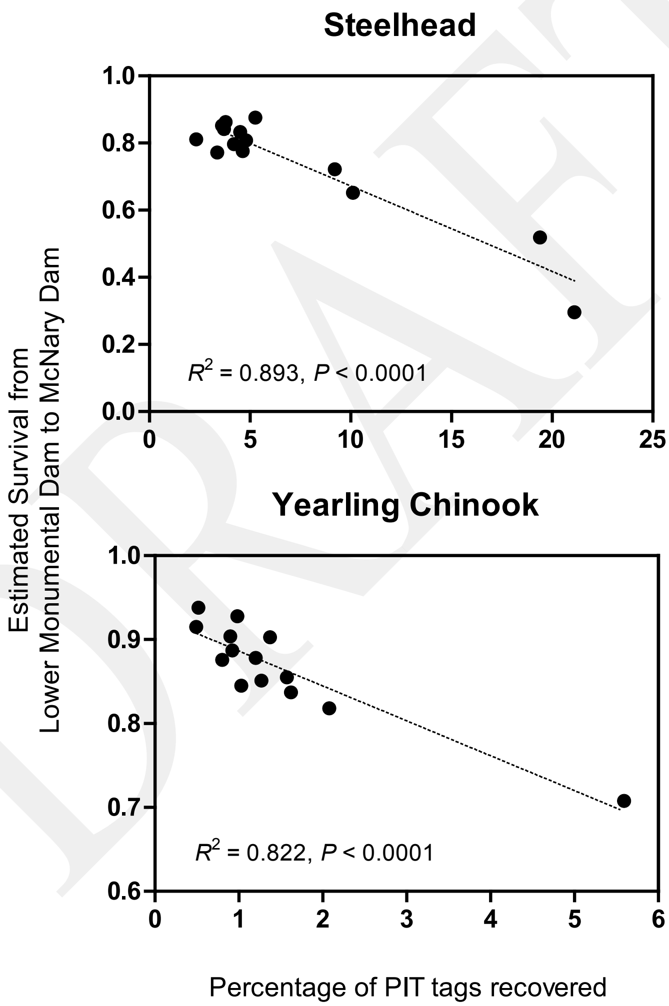

Figure 10. Estimated survival between Lower Monumental and McNary Dams vs. percentage of Lower Monumental Dam-detected PIT tags recovered on bird colonies, 1998-2012 (excluding 2003, which had incomplete recovery effort).

The estimated percentage of steelhead (hatchery and wild combined) transported in 2012 was 27%. Similar to 2007-2011, this low rate of transport left a large number of steelhead migrants in the river during 2012. As we have previously demonstrated (cf. Faulkner et al. 2008), larger numbers of fish migrating in the river will lead to higher survival, even if the total number of fish lost to predation remains relatively constant between years, because the proportion of fish taken by predators will decrease.

Percentages of yearling Chinook salmon and steelhead transported from Snake River dams in 2012 were the lowest we have estimated in the past 20 years, from 1993 to 2012. Transportation in 2012 did not start later in the season than in previous years (2 May at Lower Granite Dam, 4 May at Little Goose Dam, and 6 May at Lower Monumental Dam). However, large spikes in smolt passage for both yearling Chinook and steelhead were associated with a large spike in flow during late April. As a result, about 67% of the yearling Chinook and 61% of the steelhead smolt populations had already passed Lower Granite Dam when the 2012 transportation programs began (Appendix Figures C1 and C3).

Throughout the migration season, high spill percentages, combined with surface bypass collection at each collector dam on the Snake River, resulted in low proportions of fish entering juvenile bypass systems. Thus, during transportation operations in 2012, approximately 60% of smolts that arrived at Lower Granite Dam were transported from a collector dam. Thus, the historically low proportions of fish transported in 2012 resulted from a late start in collection relative to run timing combined with relatively low collection rates.

In response to relatively high descaling rates for juvenile sockeye passing Bonneville Dam during 8-14 May, managers decided to decrease flow through Powerhouse 2 and increase flow through Powerhouse 1. On 16 May, the Powerhouse 2 turbines were reduced to half of peak efficiency, which resulted in lower flows entering the powerhouse. From 21-23 May the operations at Powerhouse 2 went back to normal, but then returned to operating at less than peak efficiency from late 23 May until 13 June.

The effect of these changes in operation on overall survival through Bonneville dam is not known, but it is known that the probability of detecting PIT-tagged fish in the juvenile bypass system at Powerhouse 2 was drastically reduced during the period of reduced flow through this powerhouse. These low rates of detection resulted in very low precision for survival probabilities estimated during that period. For some weekly groups, detection data was insufficient to estimate the probability of survival to Bonneville Dam.

Low detection rates of PIT-tagged fish have become common in recent years, as management relies increasingly on use of spill and surface-bypass structures to enhance the survival of juvenile fish passing dams within the Federal Columbia River Power System. Low detection rates will persist as long as the juvenile bypass systems remain as the only dam-passage route equipped with PIT-tag monitoring technology (aside from the Bonneville Dam corner collector). Juvenile passage survival may indeed benefit from the use of surface-bypass structures and increased spill (that does not exceed the allowable limits for dissolved gas). However, our ability to monitor the passage survival rates of juvenile fish is seriously impaired when the number of PIT-tagged fish that pass via monitored routes is reduced. Low detection rates greatly reduce the quality of survival estimates, and in some cases defeat our ability to estimate survival at all.

A low rate of detection has several negative effects on the value of data collected from PIT-tagged fish. Lower rates of detection result in smaller effective sample sizes, which introduce higher sampling variance to estimates (i.e., less precision; more uncertainty). For several years, our estimates of survival through the Lower Columbia River (McNary Dam to Bonneville Dam) have been impaired by high sampling variance, and reduced rates of detection only exacerbate this problem. 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.

If levels of detection remain fixed, then 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 these new passage routes with PIT-tag monitoring antennas. 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 variation in rates of detection and will advance our understanding of passage via different routes throughout the migration season. This understanding would produce valuable insight into fish passage behavior.

Finally, the ability to detect PIT-tagged fish in surface bypass structures may increase the accuracy of survival estimates. At present, estimates of survival are based on fish detected in the bypass system, virtually all of which pass via the juvenile fish facility. With increased proportions of juvenile fish passing via surface structures, the proportion of fish entering the juvenile bypass decreases, along with the ability of detected fish to represent the passage experience of their non-detected cohorts. Detection of fish passing two different routes will reduce the possibility of bias in survival estimates that could result if there is differential mortality 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 surface passage structures at Bonneville, 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 Dam 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 2012 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 estimates. We recommend installation of PIT-tag detection systems at The Dalles Dam and at upper Columbia River dams.

4) High rates of spill and the use of surface-bypass structures (RSWs, TSWs) in recent years have resulted in low PIT-tag detection rates and consequently reduced precision of survival estimates. Development of PIT-tag detection capability in the spillways 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. (1997; pp 71-77) to assess the goodness-of-fit of the SR model to observed detection history data. In these tests, we compiled a series of contingency tables from detection history data for each group of tagged fish, and used χ^2 tests to identify systematic deviations from what was expected if the assumptions were met. We applied the tests to weekly groups of yearling Chinook salmon and steelhead (hatchery and wild combined) leaving Lower Granite and McNary Dam in 2012 (Snake River-origin fish only, i.e., the fish used for survival estimates reported in Tables 2-3 and 9-10).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Results

For weekly Lower Granite Dam release groups in 2012 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 10 weekly groups of yearling Chinook salmon. For these, the overall sum of the χ^2 test statistics was significant 3 times (30%). For 11 steelhead groups, the overall test was significant 5 times (45%). Counting all individual component tests (i.e., 2.C2, 3.SR3, etc.), 6 tests of 50 (12%) were significant for yearling Chinook salmon and 11 of 55 (20%) 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. Eleven of the 17 significant individual component tests for Lower Granite groups of yearling Chinook salmon and steelhead were for component tests of Test 2. This provides evidence that fish previously detected were either more or less likely to be detected again at downstream dams than fish not previously detected. The direction of the relationship was not consistent, going either way with nearly equal frequency for both yearling Chinook salmon and steelhead.

For weekly groups from McNary Dam, significant contingency table test results were more common than expected for yearling Chinook but not for steelhead (Appendix Tables A4-A6). For yearling Chinook salmon, there were two (22%) significant test out of the 9 individual component tests, and for steelhead 0 of the 7 component tests were significant. One of the significant component tests for yearling Chinook was for Test 2.C2 and the other for Test 3.SR3.

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 2012, as in previous years. Zabel et al. (2002) provided evidence of inherent differences related to length of fish at tagging, and similar observations were made in 2012 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, 2012.

	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	10	2	10	1	10	2	10	0	10	1	10	3	10	2	10	3
Steelhead	11	5	11	3	11	1	11	2	11	0	11	5	11	1	11	5
Total	21	7	21	4	21	3	21	2	21	1	21	8	21	3	21	8

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 2012.

	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
23 Mar–29 Mar	3.40	0.757	2.17	0.538	0.88	0.643	1.29	0.257
30 Mar–5 Apr	1.36	0.968	0.10	0.991	0.10	0.950	0.00	0.965
6 Apr–12 Apr	10.70	0.098	10.66	**0.014**	9.49	**0.009**	1.17	0.280
13 Apr–19 Apr	6.35	0.385	6.32	0.097	4.22	0.121	2.09	0.148
20 Apr–26 Apr	5.66	0.462	0.97	0.809	0.09	0.957	0.88	0.348
27 Apr–3 May	30.69	**<0.001**	8.34	**0.040**	5.24	0.073	3.10	0.078
4 May–10 May	16.05	**0.013**	5.67	0.129	5.06	0.079	0.61	0.436
11 May–17 May	19.80	**0.003**	16.88	**0.001**	10.86	**0.004**	6.03	**0.014**
18 May–24 May	7.92	0.244	2.72	0.437	1.77	0.412	0.95	0.330
25 May–31 May	3.50	0.745	0.04	0.998	0.04	0.982	0.00	0.978
Total (df)	105.42 (60)		53.86 (30)		37.75 (20)		16.12 (10)	

	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
23 Mar–29 Mar	1.23	0.745	0.32	0.573	0.59	0.441	0.32	0.570
30 Mar–5 Apr	1.26	0.739	0.05	0.825	0.00	0.958	1.21	0.272
6 Apr–12 Apr	0.04	0.998	0.01	0.910	0.01	0.914	0.02	0.892
13 Apr–19 Apr	0.04	0.998	0.02	0.891	0.01	0.938	0.01	0.916
20 Apr–26 Apr	4.69	0.196	4.28	**0.039**	0.34	0.562	0.08	0.781
27 Apr–3 May	22.35	**<0.001**	3.11	0.078	0.18	0.674	19.06	**<0.001**
4 May–10 May	10.38	**0.016**	4.26	**0.039**	3.81	0.051	2.30	0.129
11 May–17 May	2.92	0.405	0.03	0.865	0.15	0.703	2.74	0.098
18 May–24 May	5.20	0.158	3.22	0.073	1.97	0.161	0.00	0.967
25 May–31 May	3.46	0.326	2.32	0.128	0.66	0.416	0.48	0.489
Total (df)	51.56 (30)		17.62 (10)		7.72 (10)		26.22 (10)	

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 2012.

Release	Overall		Test 2		Test 2.C2		Test 2.C3	
period	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
23 Mar–29 Mar	5.10	0.404	3.04	0.385	0.35	0.840	2.69	0.101
30 Mar–5 Apr	5.68	0.460	1.35	0.717	1.30	0.522	0.05	0.817
6 Apr–12 Apr	6.10	0.412	0.80	0.849	0.54	0.765	0.27	0.606
13 Apr–19 Apr	15.49	**0.017**	10.37	**0.016**	9.80	**0.007**	0.57	0.450
20 Apr–26 Apr	28.83	**<0.001**	21.60	**<0.001**	20.79	**<0.001**	0.81	0.369
27 Apr–3 May	5.92	0.432	1.68	0.641	0.69	0.710	1.00	0.318
4 May–10 May	19.95	**0.003**	16.06	**0.001**	11.92	**0.003**	4.14	**0.042**
11 May–17 May	6.13	0.409	2.11	0.551	1.76	0.414	0.34	0.557
18 May–24 May	36.83	**<0.001**	27.57	**<0.001**	15.03	**0.001**	12.55	**<0.001**
25 May–31 May	20.43	**0.002**	16.22	**0.001**	16.06	**<0.001**	0.16	0.685
1 Jun–7 Jun	10.55	0.103	7.18	0.066	1.32	0.517	5.86	**0.015**
Total (df)	161.00 (65)		107.98 (33)		79.54 (22)		28.44 (11)	

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
23 Mar–29 Mar	2.06	0.358	1.75	0.186	0.31	0.581	NA	NA
30 Mar–5 Apr	4.32	0.229	1.19	0.276	0.30	0.584	2.84	0.092
6 Apr–12 Apr	5.30	0.151	0.04	0.847	1.74	0.188	3.53	0.060
13 Apr–19 Apr	5.12	0.163	0.50	0.482	2.36	0.125	2.27	0.132
20 Apr–26 Apr	7.23	0.065	1.81	0.179	5.35	**0.021**	0.07	0.788
27 Apr–3 May	4.24	0.237	0.20	0.652	3.93	**0.047**	0.10	0.747
4 May–10 May	3.89	0.274	3.52	0.061	0.18	0.674	0.20	0.658
11 May–17 May	4.03	0.259	2.95	0.086	1.06	0.304	0.02	0.880
18 May–24 May	9.26	**0.026**	5.75	**0.016**	3.23	0.072	0.28	0.599
25 May–31 May	4.21	0.240	2.97	0.085	0.95	0.329	0.29	0.591
1 Jun–7 Jun	3.37	0.338	0.37	0.543	0.54	0.461	2.46	0.117
Total (df)	53.02 (32)		21.04 (11)		19.94 (11)		12.05 (10)	

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, 2012.

	Test 2.C2		Test 3.SR3		Test 2 + 3	
Species	No.	sig.	No.	sig.	No.	sig.
Chinook	5	1	4	1	5	1
Steelhead	5	0	2	0	5	0
Total	10	1	6	1	10	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 2012.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
27 Apr–3 May	1.25	0.263	1.25	0.263	NA	NA
4 May–10 May	10.34	**0.006**	6.47	**0.011**	3.87	**0.049**
11 May–17 May	0.84	0.658	0.76	0.385	0.08	0.776
18 May–24 May	0.61	0.737	0.34	0.561	0.27	0.601
25 May–31 May	0.16	0.925	0.14	0.705	0.01	0.910
Total (df)	13.20 (10)		8.96 (5)		4.24 (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 2012.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	*P* value	χ^2	*P* value	χ^2	*P* value
27 Apr–3 May	0.52	0.471	0.52	0.471	NA	NA
4 May–10 May	1.63	0.442	1.62	0.203	0.01	0.906
11 May–17 May	2.23	0.136	2.23	0.136	NA	NA
18 May–24 May	1.49	0.223	1.49	0.223	NA	NA
25 May–31 May	1.15	0.562	1.15	0.283	0.00	0.959
Total (df)	11.04 (7)		7.00 (5)		0.02 (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 2012. 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	17,079	0.756 (0.010)	0.863 (0.016)	0.945 (0.026)	0.952 (0.038)	0.587 (0.019)
Crooked River	25,479	0.572 (0.007)	0.882 (0.013)	0.966 (0.023)	0.971 (0.034)	0.473 (0.013)
Powell Pond	17,117	0.675 (0.010)	0.901 (0.018)	1.004 (0.032)	0.972 (0.044)	0.593 (0.021)
Red River Pond	17,040	0.651 (0.012)	0.858 (0.022)	0.964 (0.037)	1.077 (0.055)	0.580 (0.022)
Selway River	16,974	0.703 (0.009)	0.883 (0.016)	0.970 (0.028)	0.986 (0.043)	0.594 (0.021)
			Dworshak Hatchery			
NF Clearwater River	51,868	0.743 (0.008)	0.860 (0.012)	0.933 (0.017)	1.077 (0.029)	0.642 (0.013)
			Kooskia Hatchery			
Kooskia	15,021	0.652 (0.013)	0.752 (0.020)	0.899 (0.035)	0.930 (0.053)	0.409 (0.018)
			Lookingglass Hatchery			
Catherine Creek Pond	20,641	0.345 (0.007)	0.846 (0.025)	0.979 (0.045)	1.000 (0.067)	0.286 (0.015)
Grande Ronde Pond	2,909	0.453 (0.018)	0.929 (0.048)	0.790 (0.056)	1.053 (0.113)	0.350 (0.033)
Imnaha Weir	20,817	0.689 (0.009)	0.871 (0.015)	0.942 (0.024)	1.003 (0.038)	0.568 (0.017)
Lookingglass Hatchery	1,992	0.763 (0.024)	0.930 (0.040)	0.932 (0.055)	0.983 (0.095)	0.650 (0.055)
Lostine Pond	5,969	0.665 (0.017)	0.865 (0.030)	0.880 (0.041)	1.079 (0.080)	0.546 (0.035)
			McCall Hatchery			
Johnson Creek	4,375	0.357 (0.016)	0.884 (0.052)	1.008 (0.104)	1.165 (0.188)	0.370 (0.049)
Knox Bridge	53,895	0.571 (0.006)	0.892 (0.012)	0.973 (0.019)	1.132 (0.031)	0.561 (0.012)
			Pahsimeroi Hatchery			
Pahsimeroi Pond	22,373	0.581 (0.006)	0.952 (0.013)	0.892 (0.020)	0.888 (0.029)	0.438 (0.012)
			Rapid River Hatchery			
Rapid River Hatchery	10,681	0.718 (0.014)	0.925 (0.029)	0.985 (0.051)	0.969 (0.066)	0.634 (0.030)
			Sawtooth Hatchery			
Sawtooth Hatchery	19,041	0.473 (0.008)	0.900 (0.020)	0.950 (0.036)	0.985 (0.054)	0.398 (0.016)
Yankee Fork	3,381	0.298 (0.011)	1.048 (0.050)	0.892 (0.078)	0.927 (0.117)	0.258 (0.025)

Appendix Table B2. Estimated survival probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2012. 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			
Meadow Creek	7,229	0.803 (0.012)	0.973 (0.023)	0.988 (0.040)	0.861 (0.072)	0.664 (0.050)
Newsome Creek	2,269	0.658 (0.025)	1.010 (0.061)	0.986 (0.120)	0.764 (0.174)	0.500 (0.097)
			Dworshak Hatchery			
Clearwater R.	17,528	0.749 (0.006)	0.977 (0.011)	0.956 (0.019)	0.828 (0.032)	0.579 (0.020)
Lolo Creek	905	0.557 (0.040)	0.836 (0.084)	0.853 (0.145)	0.841 (0.258)	0.334 (0.086)
S.F. Clearwater R.	11,649	0.650 (0.008)	0.989 (0.017)	0.967 (0.030)	0.813 (0.050)	0.506 (0.028)
			Hagerman Hatchery			
East Fork Salmon R.	7,052	0.806 (0.022)	1.005 (0.053)	0.822 (0.073)	0.772 (0.114)	0.514 (0.062)
Sawtooth Hatchery (4/11)	6,658	0.792 (0.015)	0.974 (0.029)	0.982 (0.046)	0.750 (0.072)	0.568 (0.049)
Sawtooth Hatchery (4/18)	6,784	0.800 (0.013)	0.978 (0.025)	0.954 (0.043)	0.846 (0.087)	0.631 (0.058)
Yankee Fork	8,069	0.605 (0.023)	0.877 (0.054)	0.892 (0.107)	0.715 (0.151)	0.339 (0.059)
			Irrigon Hatchery			
Big Canyon Facility	8,735	0.803 (0.012)	0.953 (0.022)	0.930 (0.037)	1.009 (0.092)	0.719 (0.060)
Little Sheep Facility	21,943	0.699 (0.008)	0.964 (0.016)	0.926 (0.028)	0.924 (0.064)	0.577 (0.036)
Wallowa Hatchery	13,643	0.802 (0.010)	1.007 (0.020)	0.864 (0.028)	0.975 (0.071)	0.681 (0.046)
			Lyons Ferry Hatchery			
Cottonwood Pond	5,978	0.762 (0.013)	0.943 (0.024)	0.951 (0.040)	0.953 (0.100)	0.651 (0.063)

Appendix Table B2. Continued.

Release site	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Release to McNary Dam
	Juvenile steelhead					
			Magic Valley Hatchery			
E. F. Salmon R.	5,079	0.705 (0.014)	0.957 (0.031)	0.977 (0.067)	0.876 (0.143)	0.578 (0.084)
Little Salmon R.	7,383	0.892 (0.012)	0.969 (0.022)	0.986 (0.041)	0.736 (0.059)	0.627 (0.043)
Pahsimeroi R. Trap	7,174	0.758 (0.018)	1.039 (0.052)	0.902 (0.086)	0.642 (0.093)	0.456 (0.051)
Salmon R. (rkm 347)	3,793	0.807 (0.017)	0.976 (0.031)	0.921 (0.045)	0.966 (0.110)	0.701 (0.074)
Salmon R. (rkm 476)	4,395	0.837 (0.018)	0.999 (0.035)	0.891 (0.046)	1.041 (0.132)	0.775 (0.092)
Salmon R. (rkm 567)	5,084	0.743 (0.022)	0.944 (0.053)	0.849 (0.084)	0.918 (0.192)	0.547 (0.101)
			Niagara Springs Hatchery			
Hells Canyon Dam	8,249	0.630 (0.009)	0.984 (0.019)	0.963 (0.032)	0.972 (0.093)	0.580 (0.052)
Little Salmon R.	6,906	0.837 (0.013)	1.021 (0.027)	0.864 (0.037)	0.975 (0.103)	0.720 (0.071)
Pahsimeroi Trap	12,768	0.721 (0.010)	0.921 (0.020)	0.908 (0.032)	0.877 (0.074)	0.529 (0.041)

Appendix Table B3. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2012. 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	10 May 12	9,971	0.702 (0.058)	0.769 (0.095)	1.183 (0.239)	0.862 (0.220)	0.784 (0.154)	0.550 (0.096)
Sawtooth Hatchery								
Redfish L. Cr. Trap	10 May 12	51,710	0.592 (0.007)	0.791 (0.014)	0.951 (0.027)	0.870 (0.043)	0.654 (0.028)	0.387 (0.016)

Appendix Table B4. Estimated detection probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2012. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Yearling Chinook salmon				
	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
			Clearwater Hatchery		
Clear Creek	17,079	0.245 (0.005)	0.375 (0.007)	0.222 (0.007)	0.194 (0.007)
Crooked River	25,479	0.273 (0.005)	0.403 (0.006)	0.239 (0.006)	0.201 (0.007)
Powell Pond	17,117	0.225 (0.005)	0.359 (0.007)	0.208 (0.007)	0.192 (0.008)
Red River Pond	17,040	0.224 (0.006)	0.327 (0.008)	0.201 (0.008)	0.229 (0.010)
Selway River	16,974	0.270 (0.005)	0.373 (0.007)	0.217 (0.007)	0.166 (0.007)
			Dworshak Hatchery		
NF Clearwater R.	51,868	0.167 (0.003)	0.322 (0.004)	0.226 (0.004)	0.189 (0.005)
			Kooskia Hatchery		
Kooskia	15,021	0.239 (0.006)	0.395 (0.009)	0.256 (0.010)	0.201 (0.011)
			Lookingglass Hatchery		
Catherine Cr. Pond	20,641	0.281 (0.008)	0.372 (0.010)	0.251 (0.012)	0.226 (0.013)
Grande Ronde Pond	2,909	0.301 (0.016)	0.357 (0.020)	0.271 (0.021)	0.235 (0.025)
Imnaha Weir	20,817	0.253 (0.005)	0.370 (0.006)	0.280 (0.008)	0.233 (0.008)
Lookingglass H.	1,992	0.269 (0.014)	0.386 (0.017)	0.285 (0.019)	0.210 (0.021)
Lostine Pond	5,969	0.255 (0.009)	0.339 (0.012)	0.235 (0.012)	0.198 (0.014)
			McCall Hatchery		
Johnson Creek	4,375	0.243 (0.015)	0.344 (0.019)	0.137 (0.016)	0.173 (0.024)
Knox Bridge	53,895	0.221 (0.003)	0.332 (0.004)	0.227 (0.005)	0.217 (0.005)
			Pahsimeroi Hatchery		
Pahsimeroi Pond	22,373	0.392 (0.005)	0.390 (0.006)	0.261 (0.006)	0.198 (0.007)
			Rapid River Hatchery		
Rapid River H.	10,681	0.290 (0.007)	0.308 (0.009)	0.200 (0.010)	0.198 (0.011)
			Sawtooth Hatchery		
Sawtooth H.	19,041	0.282 (0.006)	0.417 (0.009)	0.260 (0.010)	0.246 (0.012)
Yankee Fork	3,381	0.356 (0.018)	0.427 (0.023)	0.303 (0.029)	0.259 (0.030)

Appendix Table B5. Estimated detection probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2012. 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	7,229	0.310 (0.008)	0.400 (0.010)	0.291 (0.012)	0.090 (0.008)
Newsome Creek	2,269	0.304 (0.016)	0.396 (0.022)	0.248 (0.030)	0.088 (0.020)
Dworshak Hatchery					
Clearwater R.	17,528	0.349 (0.005)	0.470 (0.006)	0.315 (0.007)	0.127 (0.006)
Lolo Creek	905	0.311 (0.029)	0.502 (0.041)	0.312 (0.055)	0.145 (0.045)
S.F. Clearwater R.	11,649	0.343 (0.006)	0.426 (0.008)	0.308 (0.010)	0.111 (0.008)
Hagerman Hatchery					
East Fork Salmon R.	7,052	0.312 (0.010)	0.309 (0.014)	0.279 (0.022)	0.115 (0.015)
Sawtooth Hatch. (4/11)	6,658	0.275 (0.008)	0.319 (0.010)	0.279 (0.013)	0.075 (0.008)
Sawtooth Hatch. (4/18)	6,784	0.332 (0.008)	0.419 (0.011)	0.351 (0.016)	0.102 (0.011)
Yankee Fork	8,069	0.271 (0.012)	0.386 (0.018)	0.229 (0.026)	0.091 (0.017)
Irrigon Hatchery					
Big Canyon Facility	8,735	0.324 (0.007)	0.401 (0.009)	0.345 (0.014)	0.098 (0.009)
Little Sheep Facility	21,943	0.326 (0.005)	0.393 (0.007)	0.325 (0.010)	0.080 (0.006)
Wallowa Hatchery	13,643	0.309 (0.006)	0.363 (0.007)	0.300 (0.010)	0.078 (0.006)
Lyons Ferry Hatchery					
Cottonwood Pond	5,978	0.305 (0.008)	0.416 (0.011)	0.377 (0.016)	0.098 (0.011)
Magic Valley Hatchery					
E. F. Salmon R.	5,079	0.379 (0.011)	0.454 (0.014)	0.361 (0.025)	0.097 (0.016)
Little Salmon R.	7,383	0.340 (0.007)	0.397 (0.010)	0.310 (0.013)	0.109 (0.009)
Pahsimeroi R. Trap	7,174	0.365 (0.010)	0.320 (0.015)	0.242 (0.021)	0.119 (0.015)
Salmon R. (rkm 347)	3,793	0.317 (0.010)	0.385 (0.013)	0.346 (0.017)	0.085 (0.011)
Salmon R. (rkm 476)	4,395	0.284 (0.010)	0.326 (0.012)	0.319 (0.016)	0.065 (0.009)
Salmon R. (rkm 567)	5,084	0.359 (0.013)	0.360 (0.018)	0.320 (0.029)	0.083 (0.017)
Niagara Springs Hatchery					
Hells Canyon Dam	8,249	0.385 (0.008)	0.442 (0.010)	0.393 (0.014)	0.073 (0.008)
Little Salmon R.	6,906	0.341 (0.008)	0.355 (0.010)	0.340 (0.014)	0.072 (0.008)
Pahsimeroi Trap	12,768	0.307 (0.006)	0.377 (0.008)	0.326 (0.011)	0.070 (0.006)

Appendix Table B6. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2012. 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	10 May 2012	9,971	0.129 (0.011)	0.154 (0.014)	0.066 (0.012)	0.032 (0.006)
Sawtooth Hatchery						
Redfish L Cr Trap	10 May 2012	51,710	0.309 (0.004)	0.418 (0.006)	0.309 (0.008)	0.207 (0.009)

Appendix Table B7. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2012. Estimates based on the single-release model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Trap	Release dates	Number released	Release to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Release to MCN
				Wild Chinook Salmon			
American River	22 Mar-31 May	928	0.381 (0.056)	1.083 (0.260)	2.918 (2.804)	0.283 (0.290)	0.341 (0.130)
Catherine Creek	24 Feb-30 May	1,026	0.297 (0.028)	0.767 (0.086)	1.199 (0.221)	1.234 (0.399)	0.337 (0.091)
Crooked Fk. Cr.	21 Mar-29 May	243	0.351 (0.050)	0.945 (0.204)	0.988 (0.427)	0.910 (0.530)	0.299 (0.131)
Crooked River	29 Mar-30 May	176	0.884 (0.114)	0.588 (0.100)	0.972 (0.226)	1.141 (0.699)	0.576 (0.330)
Clearwater River	07 Mar-24 Mar	349	0.538 (0.066)	0.882 (0.184)	0.783 (0.285)	1.407 (0.827)	0.523 (0.253)
Elgin (G. Ronde)	06 Mar-31 May	367	0.680 (0.045)	0.939 (0.086)	1.024 (0.164)	1.004 (0.300)	0.657 (0.174)
Grande Ronde	07 Mar-19 Apr	3,344	0.894 (0.015)	0.875 (0.021)	0.949 (0.035)	0.951 (0.065)	0.706 (0.043)
Imnaha	01 Jan-31 May	2,621	0.764 (0.016)	0.909 (0.027)	1.077 (0.056)	1.039 (0.109)	0.778 (0.072)
Johnson Creek	31 Mar-31 May	880	0.453 (0.027)	0.961 (0.071)	0.912 (0.108)	0.881 (0.159)	0.349 (0.054)
Knox Bridge	04 Mar-31 May	1,260	0.380 (0.022)	0.955 (0.075)	0.867 (0.104)	1.041 (0.205)	0.327 (0.055)
Lemhi River	07 Mar-28 May	322	0.678 (0.054)	1.000 (0.114)	0.851 (0.156)	2.131 (0.985)	1.231 (0.533)
Lookingglass Cr.	06 Jan-29 May	216	0.351 (0.039)	0.982 (0.102)	0.831 (0.116)	1.125 (0.276)	0.323 (0.080)
Lostine River	29 Jan-16 May	1,842	0.549 (0.019)	0.946 (0.044)	0.946 (0.074)	1.153 (0.171)	0.567 (0.075)
Marsh Creek	22 Mar-31 May	378	0.386 (0.044)	0.906 (0.172)	1.722 (1.027)	0.672 (0.505)	0.405 (0.189)
Minam	14 Mar-15 May	1,018	0.516 (0.026)	0.943 (0.065)	0.861 (0.093)	1.306 (0.262)	0.548 (0.099)
Pahsimeroi	28 Feb-31 May	673	0.420 (0.027)	0.961 (0.076)	1.161 (0.182)	0.696 (0.164)	0.326 (0.060)
Red River	11 Apr-31 May	929	0.404 (0.063)	1.362 (0.443)	0.624 (0.315)	0.768 (0.391)	0.264 (0.082)
Salmon	11 Mar-02 Apr	7,300	0.846 (0.009)	0.911 (0.013)	1.003 (0.023)	0.965 (0.043)	0.745 (0.030)
Sawtooth	26 Mar-23 Apr	865	0.519 (0.028)	0.934 (0.075)	0.917 (0.125)	0.956 (0.207)	0.425 (0.074)
Snake	17 Mar-23 May	3,944	0.942 (0.013)	0.929 (0.020)	0.986 (0.037)	0.936 (0.061)	0.808 (0.045)
U. Grande Ronde	10 Mar-31 May	615	0.411 (0.033)	0.880 (0.084)	0.863 (0.121)	1.311 (0.364)	0.409 (0.105)
				Wild Sockeye Salmon			
Pettit Lake Cr	05 May-18 May	225	0.222 (0.063)	0.750 (0.291)	0.531 (0.184)	NA	NA
Redfish Lake Cr	11 Apr-08 Jun	1,585	0.504 (0.023)	0.879 (0.052)	0.825 (0.068)	1.118 (0.208)	0.409 (0.072)

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	04 Jan-22 May	4,083	0.797 (0.015)	1.022 (0.037)	0.781 (0.048)	1.020 (0.115)	0.649 (0.065)
Catherine Creek	24 Feb-31 May	765	0.168 (0.025)	0.771 (0.125)	1.059 (0.239)	0.618 (0.279)	0.085 (0.034)
Crooked River	31 Mar-31 May	395	0.673 (0.056)	0.921 (0.125)	1.019 (0.288)	0.662 (0.322)	0.418 (0.165)
Elgin (G. Ronde)	07 Mar-31 May	345	0.436 (0.062)	0.777 (0.144)	1.485 (0.573)	0.687 (0.488)	0.346 (0.211)
Grande Ronde	15 Mar-23 May	385	0.921 (0.060)	0.881 (0.096)	1.207 (0.302)	0.447 (0.142)	0.438 (0.091)
Imnaha	19 Feb-31 May	5,148	0.900 (0.017)	0.935 (0.030)	0.915 (0.054)	0.979 (0.119)	0.753 (0.082)
Johnson Creek	05 Mar-31 May	539	0.084 (0.022)	0.693 (0.201)	1.053 (0.380)	0.400 (0.155)	0.025 (0.007)
Lookingglass Cr.	06 Jan-30 May	217	0.432 (0.069)	0.830 (0.152)	1.022 (0.316)	0.887 (0.574)	0.325 (0.190)
Lostine River	30 Jan-16 May	429	0.284 (0.037)	0.789 (0.120)	1.185 (0.324)	0.747 (0.344)	0.198 (0.077)
Minam River	15 Mar-15 May	568	0.485 (0.033)	1.151 (0.109)	0.721 (0.103)	1.039 (0.289)	0.418 (0.109)
Pahsimeroi	28 Feb-31 May	205	0.413 (0.080)	0.785 (0.227)	1.105 (0.897)	0.143 (0.132)	0.051 (0.019)
Salmon	16 Mar-11 May	336	0.876 (0.046)	1.052 (0.104)	1.007 (0.216)	0.737 (0.281)	0.684 (0.223)
Snake	18 Mar-23 May	430	1.107 (0.070)	0.845 (0.089)	1.238 (0.298)	0.626 (0.241)	0.725 (0.221)
U. Grande Ronde	10 Mar-31 May	737	0.466 (0.037)	0.825 (0.081)	0.986 (0.158)	0.633 (0.150)	0.240 (0.046)
				Hatchery Chinook Salmon			
Grande Ronde	14 Mar-17 May	1,400	0.810 (0.032)	0.922 (0.054)	0.958 (0.088)	0.871 (0.118)	0.623 (0.068)
Salmon	14 Mar-23 Apr	3,756	0.806 (0.020)	0.921 (0.034)	0.888 (0.044)	1.051 (0.076)	0.692 (0.042)
Snake	18 Mar-19 May	3,599	0.925 (0.021)	0.893 (0.031)	0.900 (0.047)	0.928 (0.070)	0.690 (0.042)
				Hatchery Sockeye Salmon			
Redfish Lake Cr	16 May-07 Jun	429	0.408 (0.038)	0.927 (0.112)	1.236 (0.318)	0.706 (0.288)	0.330 (0.109)
				Hatchery Steelhead			
Grande Ronde	09 Apr-23 May	1,361	0.937 (0.031)	0.889 (0.047)	1.064 (0.100)	0.671 (0.118)	0.595 (0.091)
Salmon	03 Apr-11 May	2,180	0.938 (0.026)	0.974 (0.048)	0.830 (0.062)	0.786 (0.119)	0.597 (0.083)
Snake	24 Mar-23 May	1,465	0.975 (0.028)	0.966 (0.049)	0.949 (0.084)	0.882 (0.160)	0.788 (0.129)

Appendix Table B8. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2012. Estimates based on the single-release model. Standard errors in parentheses.

Trap	Release dates	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
			Wild Chinook Salmon			
American River	22 Mar-31 May	928	0.232 (0.040)	0.299 (0.057)	0.025 (0.024)	0.109 (0.046)
Catherine Creek	24 Feb-30 May	1,026	0.292 (0.035)	0.469 (0.044)	0.211 (0.046)	0.161 (0.049)
Crooked Fk. Cr.	21 Mar-29 May	243	0.410 (0.070)	0.476 (0.097)	0.194 (0.094)	0.273 (0.134)
Crooked River	29 Mar-30 May	176	0.315 (0.054)	0.535 (0.070)	0.362 (0.094)	0.091 (0.061)
Clearwater River	07 Mar-24 Mar	349	0.362 (0.054)	0.409 (0.074)	0.222 (0.083)	0.158 (0.084)
Elgin (G. Ronde)	06 Mar-31 May	367	0.364 (0.037)	0.414 (0.044)	0.251 (0.046)	0.132 (0.041)
Grande Ronde	07 Mar-19 Apr	3,344	0.388 (0.011)	0.460 (0.013)	0.344 (0.015)	0.164 (0.013)
Imnaha	01 Jan-31 May	2,621	0.374 (0.013)	0.480 (0.016)	0.324 (0.020)	0.149 (0.017)
Johnson Creek	31 Mar-31 May	880	0.319 (0.028)	0.425 (0.035)	0.276 (0.037)	0.267 (0.047)
Knox Bridge	04 Mar-31 May	1,260	0.372 (0.028)	0.469 (0.036)	0.367 (0.047)	0.291 (0.056)
Lemhi River	07 Mar-28 May	322	0.316 (0.038)	0.453 (0.052)	0.302 (0.061)	0.100 (0.047)
Lookingglass Cr.	06 Jan-29 May	216	0.408 (0.062)	0.517 (0.072)	0.508 (0.084)	0.269 (0.087)
Lostine River	29 Jan-16 May	1,842	0.359 (0.018)	0.457 (0.023)	0.277 (0.025)	0.156 (0.024)
Marsh Creek	22 Mar-31 May	378	0.418 (0.057)	0.443 (0.078)	0.097 (0.061)	0.136 (0.073)
Minam	14 Mar-15 May	1,018	0.384 (0.026)	0.449 (0.033)	0.312 (0.038)	0.198 (0.041)
Pahsimeroi	28 Feb-31 May	673	0.364 (0.033)	0.434 (0.040)	0.248 (0.044)	0.167 (0.041)
Red River	11 Apr-31 May	929	0.202 (0.037)	0.199 (0.058)	0.107 (0.046)	0.152 (0.053)
Salmon	11 Mar-02 Apr	7,300	0.395 (0.007)	0.495 (0.008)	0.353 (0.010)	0.171 (0.009)
Sawtooth	26 Mar-23 Apr	865	0.401 (0.029)	0.429 (0.037)	0.329 (0.048)	0.250 (0.051)
Snake	17 Mar-23 May	3,944	0.386 (0.010)	0.485 (0.012)	0.312 (0.014)	0.191 (0.013)
U. Grande Ronde	10 Mar-31 May	615	0.332 (0.036)	0.465 (0.046)	0.289 (0.048)	0.192 (0.055)
			Wild Sockeye Salmon			
Pettit Lake Cr	05 May-18 May	225	0.261 (0.092)	0.294 (0.110)	0.604 (0.138)	NA
Redfish Lake Cr	11 Apr-08 Jun	1,585	0.342 (0.021)	0.429 (0.026)	0.386 (0.033)	0.193 (0.037)

Appendix Table B8. Continued.

Trap	Release dates	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
			Wild Steelhead			
Asotin Creek	04 Jan-22 May	4,083	0.386 (0.011)	0.418 (0.016)	0.320 (0.019)	0.127 (0.015)
Catherine Creek	24 Feb-31 May	765	0.272 (0.051)	0.516 (0.068)	0.368 (0.092)	0.120 (0.065)
Crooked River	31 Mar-31 May	395	0.376 (0.041)	0.485 (0.057)	0.278 (0.081)	0.143 (0.066)
Elgin (G. Ronde)	07 Mar-31 May	345	0.279 (0.051)	0.381 (0.066)	0.166 (0.068)	0.087 (0.059)
Grande Ronde	15 Mar-23 May	385	0.361 (0.034)	0.431 (0.046)	0.164 (0.044)	0.181 (0.049)
Imnaha	19 Feb-31 May	5,148	0.353 (0.009)	0.409 (0.013)	0.249 (0.015)	0.084 (0.010)
Johnson Creek	05 Mar-31 May	539	0.307 (0.094)	0.421 (0.113)	0.308 (0.128)	0.154 (0.100)
Lookingglass Cr.	06 Jan-30 May	217	0.245 (0.056)	0.532 (0.081)	0.270 (0.093)	0.118 (0.078)
Lostine River	30 Jan-16 May	429	0.329 (0.055)	0.458 (0.068)	0.222 (0.069)	0.143 (0.066)
Minam River	15 Mar-15 May	568	0.298 (0.032)	0.394 (0.042)	0.368 (0.052)	0.134 (0.042)
Pahsimeroi	28 Feb-31 May	205	0.331 (0.077)	0.484 (0.116)	0.222 (0.182)	0.286 (0.171)
Salmon	16 Mar-11 May	336	0.408 (0.035)	0.416 (0.046)	0.208 (0.048)	0.100 (0.039)
Snake	18 Mar-23 May	430	0.321 (0.030)	0.421 (0.041)	0.170 (0.043)	0.099 (0.035)
U. Grande Ronde	10 Mar-31 May	737	0.297 (0.032)	0.451 (0.042)	0.256 (0.046)	0.187 (0.045)
			Hatchery Chinook Salmon			
Grande Ronde	14 Mar-17 May	1,400	0.288 (0.017)	0.342 (0.021)	0.210 (0.021)	0.203 (0.026)
Salmon	14 Mar-23 Apr	3,756	0.264 (0.010)	0.310 (0.012)	0.230 (0.013)	0.217 (0.015)
Snake	18 Mar-19 May	3,599	0.293 (0.010)	0.352 (0.013)	0.215 (0.012)	0.210 (0.015)
			Hatchery Sockeye Salmon			
Redfish Lake Cr	16 May-07 Jun	429	0.365 (0.045)	0.406 (0.054)	0.200 (0.056)	0.222 (0.080)
			Hatchery Steelhead			
Grande Ronde	09 Apr-23 May	1,361	0.328 (0.017)	0.382 (0.021)	0.241 (0.024)	0.097 (0.018)
Salmon	03 Apr-11 May	2,180	0.338 (0.014)	0.306 (0.016)	0.297 (0.022)	0.093 (0.015)
Snake	24 Mar-23 May	1,465	0.357 (0.016)	0.347 (0.019)	0.243 (0.022)	0.082 (0.016)

Appendix Table B9. Survival probabilities for PIT-tagged yearling Chinook, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2012. 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	4,185	0.671 (0.053)	0.850 (0.140)	0.986 (0.491)	0.838 (0.405)	0.562 (0.268)
Cle Elum						
Clark Flat Pond	15,998	0.412 (0.013)	0.824 (0.052)	0.769 (0.171)	0.634 (0.138)	0.262 (0.056)
Easton Pond	12,002	0.384 (0.016)	0.867 (0.078)	0.476 (0.132)	0.413 (0.110)	0.158 (0.042)
Jack Creek Pond	12,000	0.386 (0.017)	0.713 (0.063)	1.186 (0.510)	0.846 (0.360)	0.327 (0.138)
East Bank						
Chiwawa Pond	5,015	0.557 (0.040)	0.802 (0.104)	NA	NA	NA
Entiat						
Entiat Hatchery	9,949	0.681 (0.042)	0.998 (0.135)	0.684 (0.189)	0.682 (0.175)	0.464 (0.116)
Leavenworth						
Leavenworth NFH	14,901	0.589 (0.020)	0.802 (0.055)	1.001 (0.256)	0.803 (0.202)	0.473 (0.118)
Methow						
Methow Hatchery	18,499	0.568 (0.029)	0.750 (0.074)	1.148 (0.287)	0.862 (0.208)	0.489 (0.115)
Wells						
Wells Hatchery	5,967	0.246 (0.038)	0.778 (0.200)	0.870 (0.840)	0.678 (0.648)	0.166 (0.157)
Winthrop						
Winthrop NFH	4,922	0.535 (0.036)	0.960 (0.129)	1.262 (0.505)	1.212 (0.470)	0.648 (0.248)
Winthrop Back Channel	5,974	0.548 (0.042)	0.740 (0.102)	1.077 (0.424)	0.797 (0.306)	0.437 (0.165)

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	3,603	0.403 (0.056)	1.018 (0.214)	NA	NA	NA
Nason Creek	4,065	0.325 (0.041)	0.877 (0.166)	0.583 (0.221)	0.511 (0.191)	0.166 (0.059)
Wenatchee River (Apr)	2,099	0.366 (0.065)	0.971 (0.251)	1.113 (0.771)	1.080 (0.744)	0.396 (0.264)
Wenatchee River (May)	17,852	0.236 (0.017)	0.940 (0.098)	1.308 (0.370)	1.229 (0.345)	0.290 (0.079)
East Bank						
Rolfing Pond	9,782	0.057 (0.013)	0.898 (0.303)	NA	NA	NA
Wells						
Methow River	8,746	0.513 (0.034)	0.916 (0.094)	0.717 (0.168)	0.657 (0.152)	0.337 (0.075)
Omak Creek	17,488	0.481 (0.030)	0.758 (0.064)	NA	NA	NA
Salmon Creek	1,630	0.418 (0.079)	1.041 (0.336)	0.848 (0.601)	0.883 (0.603)	0.369 (0.243)
Twisp Pond	4,598	0.294 (0.045)	1.148 (0.265)	0.734 (0.326)	0.843 (0.367)	0.248 (0.102)
Winthrop						
Winthrop NFH	29,809	0.355 (0.019)	0.794 (0.061)	1.204 (0.252)	0.956 (0.199)	0.340 (0.069)
			Coho Salmon			
Cascade						
Beaver Pond	2,762	0.300 (0.044)	0.947 (0.256)	0.302 (0.111)	0.286 (0.091)	0.086 (0.025)
Leavenworth NFH	3,418	0.397 (0.034)	0.812 (0.131)	NA	NA	NA
Rolfing Pond	2,952	0.353 (0.036)	0.973 (0.197)	0.456 (0.183)	0.444 (0.166)	0.157 (0.057)
Eagle						
Easton Pond	7,624	0.241 (0.033)	0.647 (0.151)	0.584 (0.313)	0.378 (0.196)	0.091 (0.046)
Natches River	5,069	0.444 (0.036)	1.089 (0.181)	0.838 (0.358)	0.913 (0.374)	0.405 (0.163)
Willard						
Beaver Pond	2,997	0.280 (0.059)	0.829 (0.330)	NA	NA	NA
Coulter Pond	5,946	0.480 (0.043)	0.672 (0.098)	0.697 (0.207)	0.468 (0.135)	0.225 (0.062)
Rolfing Pond	2,970	0.370 (0.082)	0.622 (0.229)	0.977 (0.958)	0.608 (0.584)	0.225 (0.211)
Twisp Pond	5,990	0.504 (0.043)	0.743 (0.101)	0.802 (0.225)	0.596 (0.163)	0.301 (0.078)
Winthrop						
Winthrop NFH	5,950	0.366 (0.026)	0.979 (0.143)	0.744 (0.249)	0.728 (0.231)	0.266 (0.082)

Appendix Table B10. Estimated detection probabilities for PIT-tagged yearling Chinook salmon, steelhead, and coho salmon from upper-Columbia River hatcheries released in 2012. 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	4,185	0.184 (0.016)	0.168 (0.026)	0.069 (0.033)
Cle Elum	Clark Flat Pond	15,998	0.273 (0.010)	0.292 (0.017)	0.142 (0.031)
Cle Elum	Easton Pond	12,002	0.267 (0.012)	0.241 (0.021)	0.207 (0.055)
Cle Elum	Jack Creek Pond	12,000	0.252 (0.013)	0.272 (0.022)	0.089 (0.038)
East Bank	Chiwawa Pond	5,015	0.187 (0.015)	0.161 (0.019)	0.036 (0.020)
Entiat	Entiat Hatchery	9,949	0.151 (0.010)	0.096 (0.012)	0.105 (0.026)
Leavenworth	Leavenworth NFH	14,901	0.224 (0.009)	0.214 (0.014)	0.115 (0.029)
Methow	Methow Hatchery	18,499	0.152 (0.008)	0.110 (0.010)	0.095 (0.023)
Wells	Wells Hatchery	5,967	0.106 (0.018)	0.167 (0.036)	0.101 (0.096)
Winthrop	Winthrop NFH	4,922	0.196 (0.015)	0.137 (0.017)	0.107 (0.041)
Winthrop	Winthrop Back Channel	5,974	0.172 (0.014)	0.145 (0.018)	0.131 (0.050)
			Steelhead		
Chelan	Chiwawa River	3,603	0.088 (0.014)	0.163 (0.028)	0.023 (0.023)
Chelan	Nason Creek	4,065	0.111 (0.016)	0.198 (0.030)	0.231 (0.083)
Chelan	Wenatchee River (Apr)	2,099	0.094 (0.019)	0.205 (0.042)	0.087 (0.059)
Chelan	Wenatchee River (May)	17,852	0.103 (0.009)	0.202 (0.017)	0.086 (0.024)
East Bank	Rolfing Pond	9,782	0.102 (0.026)	0.158 (0.044)	NA
Wells	Methow River	8,746	0.109 (0.009)	0.226 (0.019)	0.129 (0.029)
Wells	Omak Creek	17,488	0.080 (0.006)	0.246 (0.015)	0.038 (0.013)
Wells	Salmon Creek	1,630	0.113 (0.024)	0.138 (0.039)	0.107 (0.071)
Wells	Twisp Pond	4,598	0.078 (0.014)	0.135 (0.025)	0.139 (0.058)
Winthrop	Winthrop NFH	29,809	0.098 (0.006)	0.207 (0.013)	0.078 (0.016)
			Coho Salmon		
Cascade	Beaver Pond	2,762	0.152 (0.025)	0.120 (0.030)	0.502 (0.144)
Cascade	Leavenworth NFH	3,418	0.224 (0.022)	0.207 (0.031)	NA
Cascade	Rolfing Pond	2,952	0.213 (0.024)	0.141 (0.027)	0.333 (0.122)
Eagle	Easton Pond	7,624	0.130 (0.020)	0.128 (0.026)	0.232 (0.117)
Eagle	Natches River	5,069	0.166 (0.015)	0.093 (0.015)	0.180 (0.073)
Willard	Beaver Pond	2,997	0.125 (0.028)	0.089 (0.032)	NA

Appendix Table B10. Continued.

Hatchery	Release site	Number released	McNary Dam	John Day Dam	Bonneville Dam
			Coho Salmon		
Willard	Coulter Pond	5,946	0.149 (0.015)	0.158 (0.020)	0.225 (0.062)
Willard	Rolfing Pond	2,970	0.108 (0.026)	0.110 (0.034)	0.112 (0.106)
Willard	Twisp Pond	5,990	0.130 (0.013)	0.135 (0.016)	0.242 (0.063)
Winthrop	Winthrop NFH	5,950	0.203 (0.017)	0.123 (0.017)	0.217 (0.068)

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 2012 from the Columbia River DART website[1] on 3 October, 2012. We created plots to compare daily measures of flow, temperature, and spill at Little Goose Dam from 2012 to those from 2005-2011. We created plots and calculated cumulative passage proportions to compare daily estimates of numbers of smolts passing Lower Granite Dam in 2012 to those of 2009-2011.

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

Snake River flow volume in 2012 was in the mid to upper range of that in 2005-2011 for most of the migration period, but was higher at the end of April than in any of those years (Appendix Figure C1). Snake River flow increased sharply starting around 22 April, rising from near 98 kcfs to near 180 kcfs on 27 April, and then decreased again to around 100 kcfs and fluctuated there to with another increase in mid to late May. This pattern of flow was unique among recent years.

Snake River temperature in 2012 was variable in its rate of increase through the season. The temperature profile was not extreme in either direction in comparison to other years for 2005-2011 (Appendix Figure C1).

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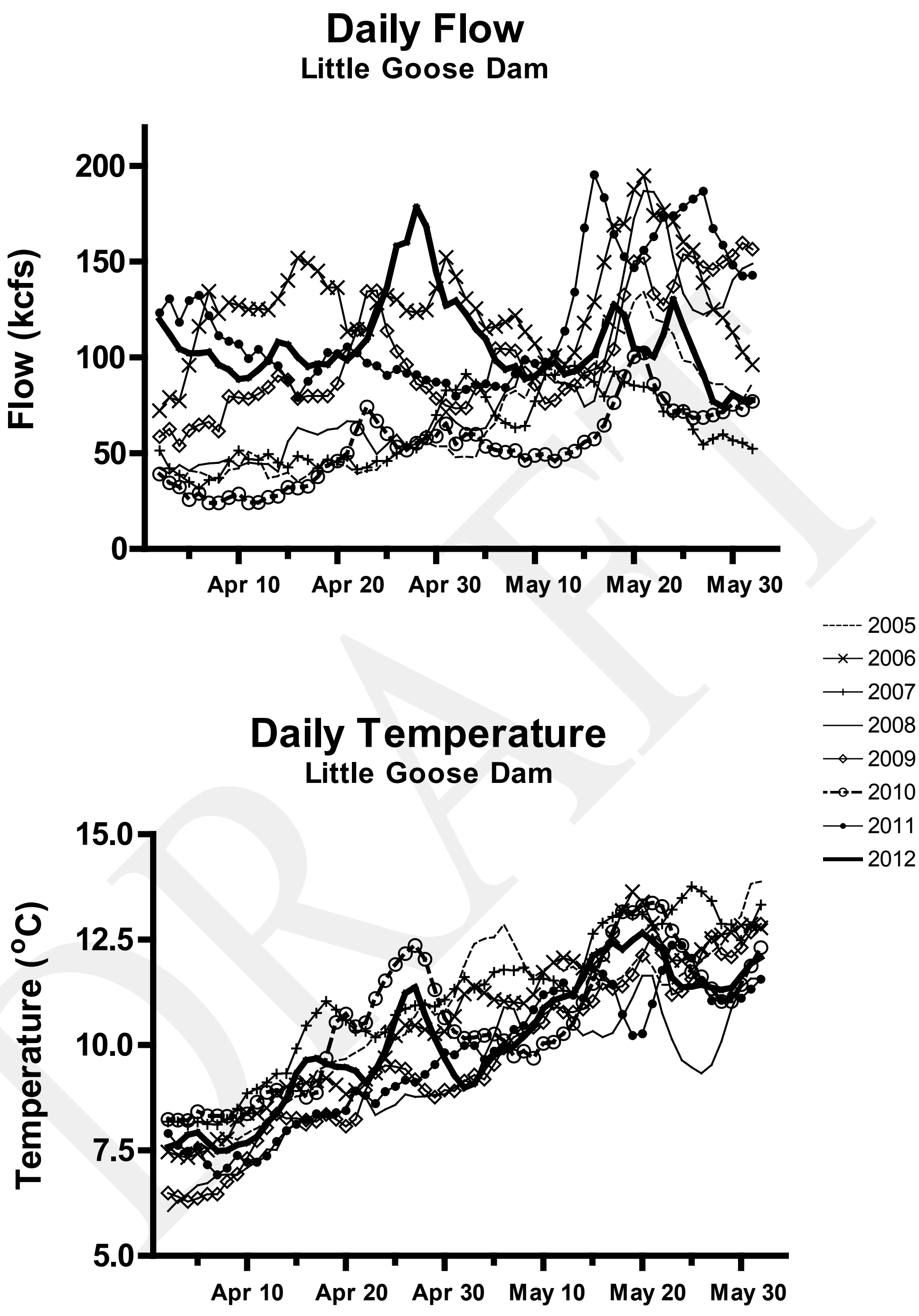
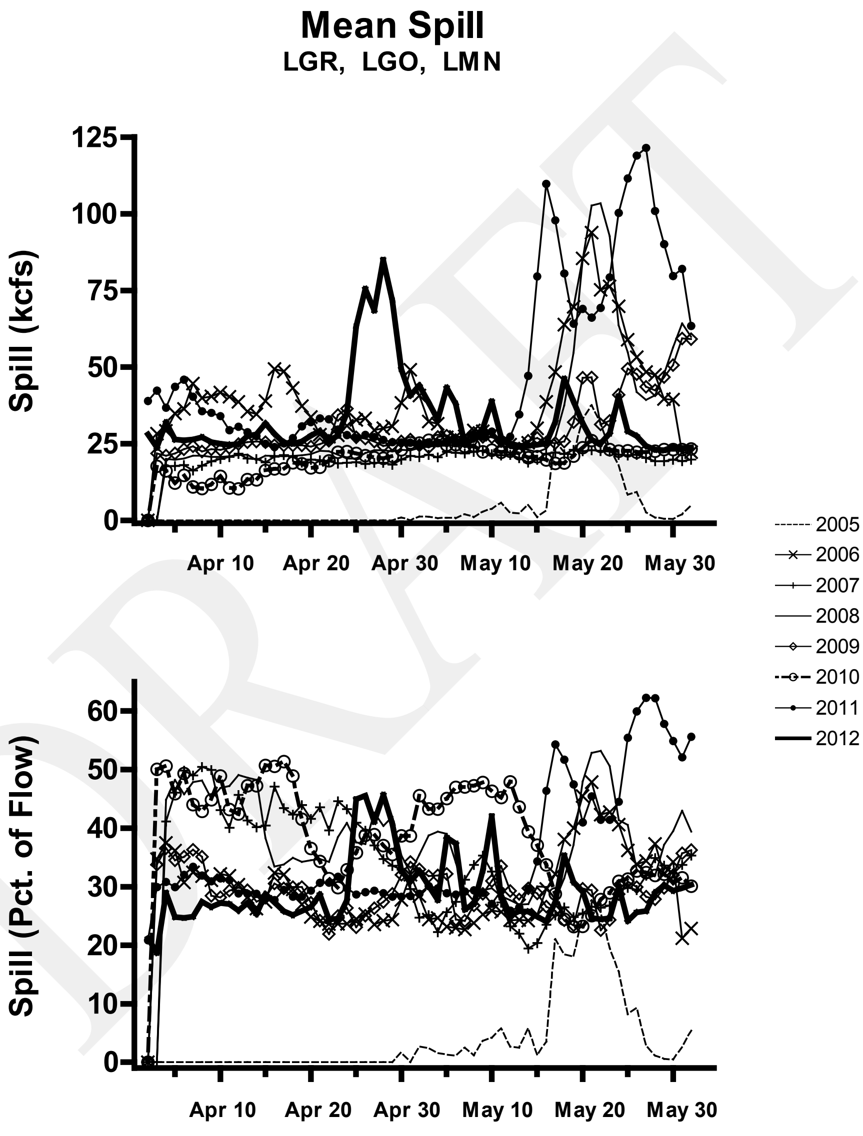
[1] www.cbr.washington.edu/dart



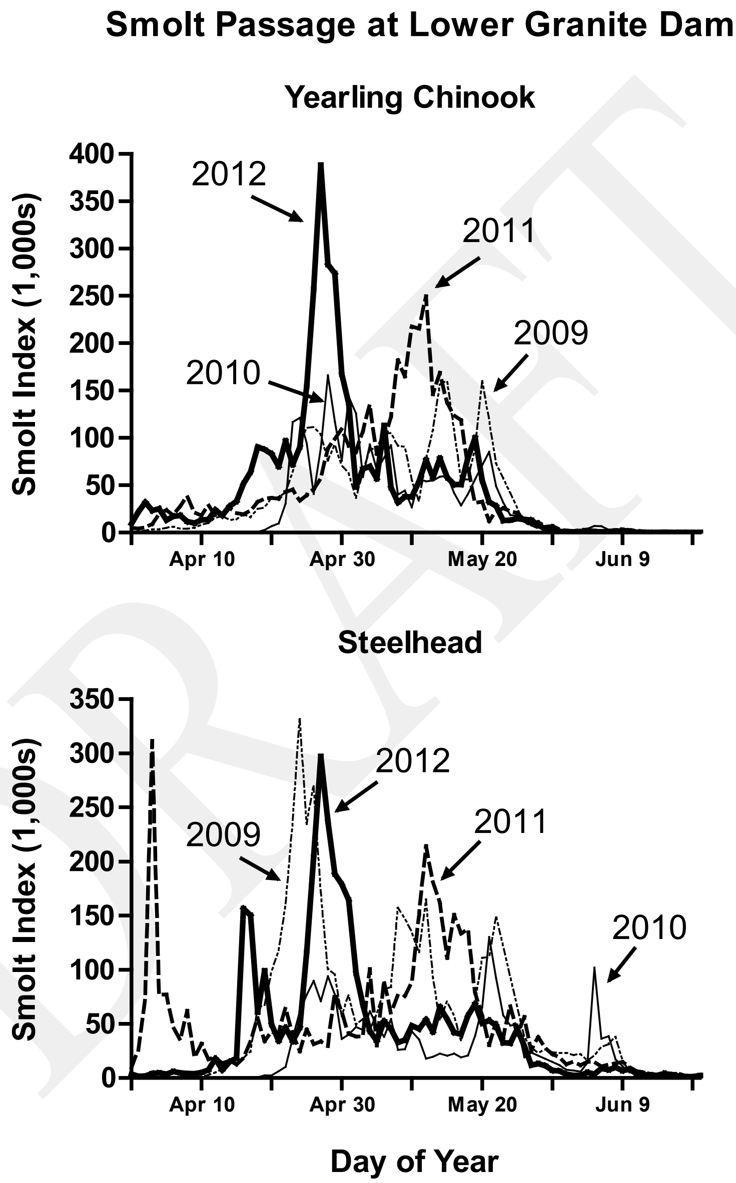
Appendix Figure C1. Daily Snake River flow (kcfs) and temperature (°C) measured at Little Goose Dam during April and May, 2005-2012.

Mean spill volume at the Snake River dams in 2012 was similar to several of the other years from 2005-2011, with the exception of the spike corresponding to the high flow event in late April and early May (Appendix Figure C2). Average Snake River spill percentages in 2012 hovered around 28% until the flow increase in late April, and then fluctuated between 25% and 45% through the remainder of the season (Appendix Figure C2).



Appendix Figure C2. Daily mean spill (top = kcfs; bottom = percentage of total flow) averaged across Lower Granite, Little Goose and Lower Monumental dams during April and May, 2005-2012.

The peak in flow in late April corresponded with peaks in smolt passage for both yearling Chinook salmon and steelhead at Lower Granite Dam in 2012 (Appendix Figure C3). For yearling Chinook salmon, this resulted in a 50% passage at Lower Granite Dam occurring on approximately 28 April and 80% passage on 11 May. For steelhead smolts, 50% passage occurred approximately on 29 April and 80% passage on 14 May.



Appendix Figure C3. Daily smolt passage index of yearling Chinook salmon and steelhead passing Lower Granite Dam, 2009-2012.