

**Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through  
Snake and Columbia River Dams and Reservoirs, 2009**

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## EXECUTIVE SUMMARY

In 2009, the National Marine Fisheries Service completed the 17th year of a study to estimate survival and travel time of juvenile salmonids *Oncorhynchus* spp. passing through dams and reservoirs on the Snake and Columbia Rivers. All estimates were derived from detections of fish tagged with passive integrated transponder (PIT) tags. We PIT tagged and released a total of 18,744 hatchery steelhead *O. mykiss*, 15,235 wild steelhead, and 13,792 wild yearling Chinook salmon *O. tshawytscha* at Lower Granite Dam on the Snake River.

In addition, we utilized fish PIT tagged by other agencies at traps and hatcheries upstream from the hydropower system and at sites within the hydropower system in both the Snake and Columbia Rivers. These included 120,637 yearling Chinook salmon tagged at Lower Granite Dam for evaluation of latent mortality related to passage through Snake River dams. PIT-tagged smolts were detected at interrogation facilities at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville Dams and in the PIT-tag detector trawl operated in the Columbia River estuary. Survival estimates were calculated using a statistical model for tag-recapture data from single release groups (the single-release model).

Primary research objectives in 2009 were to:

- 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, and
- 3) evaluate the survival estimation models under prevailing conditions.

This report provides reach survival and travel time estimates for 2009 for PIT-tagged yearling Chinook salmon (hatchery and wild), hatchery sockeye salmon *O. nerka*, hatchery coho salmon *O. kisutch*, and steelhead (hatchery and wild) in the Snake and Columbia Rivers. Additional details on the methodology and statistical models used are provided in previous reports cited here.

Survival and detection probabilities were estimated precisely for most of the 2009 yearling Chinook salmon and steelhead migrations. Hatchery and wild fish were combined in some analyses. For yearling Chinook salmon, overall percentages for combined release groups used in survival analyses in the Snake River were 78% hatchery-reared and 22% wild. For steelhead, the overall percentages were 77% hatchery-reared and 23% wild. Based on smolt passage data at Lower Granite Dam

collected by the Fish Passage Center, we estimate that 88% of the overall yearling Chinook salmon run is of hatchery origin. We cannot estimate this number for steelhead because separate collection counts for hatchery and wild fish are not available.

Estimated survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam averaged 0.940 for yearling Chinook salmon and 0.972 for steelhead. Reaches of river were measured from tailrace to tailrace, and respective average survival estimates for yearling Chinook salmon and steelhead through the following reaches were:

	Yearling <u>Chinook salmon</u>	<u>Steelhead</u>
Little Goose to Lower Monumental Dam	0.982	0.942
Lower Monumental to McNary Dam <sup>a</sup>	0.855	0.863
McNary to John Day Dam	0.866	0.951
John Day to Bonneville Dam <sup>b</sup>	0.821	0.900

<sup>a</sup> A two-project reach, including Ice Harbor Dam and reservoir.

<sup>b</sup> A two-project reach, including The Dalles Dam and reservoir.

Combining average estimates from the Snake River smolt trap to Lower Granite Dam, from Lower Granite to McNary Dam, and from McNary to Bonneville Dam, estimated average survival through the entire hydropower system from the head of Lower Granite reservoir to the tailrace of Bonneville Dam (eight projects) was 0.531 (se 0.025) for Snake River yearling Chinook salmon and 0.678 (se 0.060) for steelhead during 2009.

For yearling spring Chinook salmon released in the Upper Columbia River basin, estimated survival from point of release to McNary Dam tailrace ranged from 0.632 for East Bank Hatchery fish released to the Chelan River to 0.277 for Wells Hatchery fish released from Wells Hatchery on the Columbia River.

For steelhead released in the Upper Columbia River basin, estimated survival from point of release to McNary Dam tailrace ranged from 0.564 for fish from East Bank Hatchery released to the Chiwawa River to 0.267 for Winthrop Hatchery fish released from Winthrop Hatchery on the Methow River.

During 2009, flows and spill percentages at Snake River dams were near or slightly above the historic average for most of April and May. Water temperatures in 2009 were lower than in most recent years because of below-normal air temperatures in April and cold melt-water from a late-season thaw of greater-than-average snowpack

For Snake River yearling Chinook salmon, estimated survival through the entire hydropower system (Snake River trap to Bonneville Dam tailrace) in 2009 was slightly above the average for the last 10 years. For Snake River steelhead, survival through the hydropower system in 2009 was the highest estimated in the last 12 years (in 2004 and 2005 survival could not be estimated through the entire hydropower system).

In 2009, yearling Chinook salmon and steelhead migration rates through the hydropower system were faster (i.e., travel times shorter) than average, especially for steelhead. These faster rates of travel were likely because of higher water velocities, relatively high spill proportions, and the use of surface collectors at most projects.



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## INTRODUCTION

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

From 1993 through 2008, the National Marine Fisheries Service (NMFS) estimated survival for these stocks using detections of PIT-tagged (Prentice et al. 1990a) juvenile salmonids passing through Snake River dams and reservoirs (Iwamoto et al. 1994; Muir et al. 1995, 1996, 2001a,b, 2003; Smith et al. 1998, 2000a,b, 2003, 2005, 2006; Hockersmith et al. 1999; Zabel et al. 2001, 2002; Faulkner et al. 2007, 2008, 2009). In 2009, NMFS completed the 17th year of the study.

Research objectives in 2009 were to:

- 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, and
- 3) evaluate the performance of survival-estimation models under prevailing operational and environmental conditions.



## METHODS

### Experimental Design

The single-release (SR) model was used to estimate survival for groups of PIT-tagged yearling Chinook salmon, sockeye salmon, coho salmon, and steelhead (Cormack 1964; Jolly 1965; Seber 1965; Skalski 1998; Skalski et al. 1998; Muir et al. 2001a). Iwamoto et al. (1994) presented background information and underlying statistical theory pertaining to the SR model. In 2009, PIT-tagged fish used for survival estimates were released from hatcheries, traps, and Lower Granite Dam in the Snake River Basin, and from hatcheries and dams in the Upper Columbia River.

During the 2009 migration season, automatic PIT-tag detectors (Prentice et al. 1990a,b,c) were operated in juvenile bypass systems at the following seven dams: Lower Granite (rkm 695), Little Goose (rkm 635), Lower Monumental (rkm 589), Ice Harbor (rkm 538), McNary (rkm 470), John Day (rkm 347), and Bonneville (rkm 234; Figure 1).

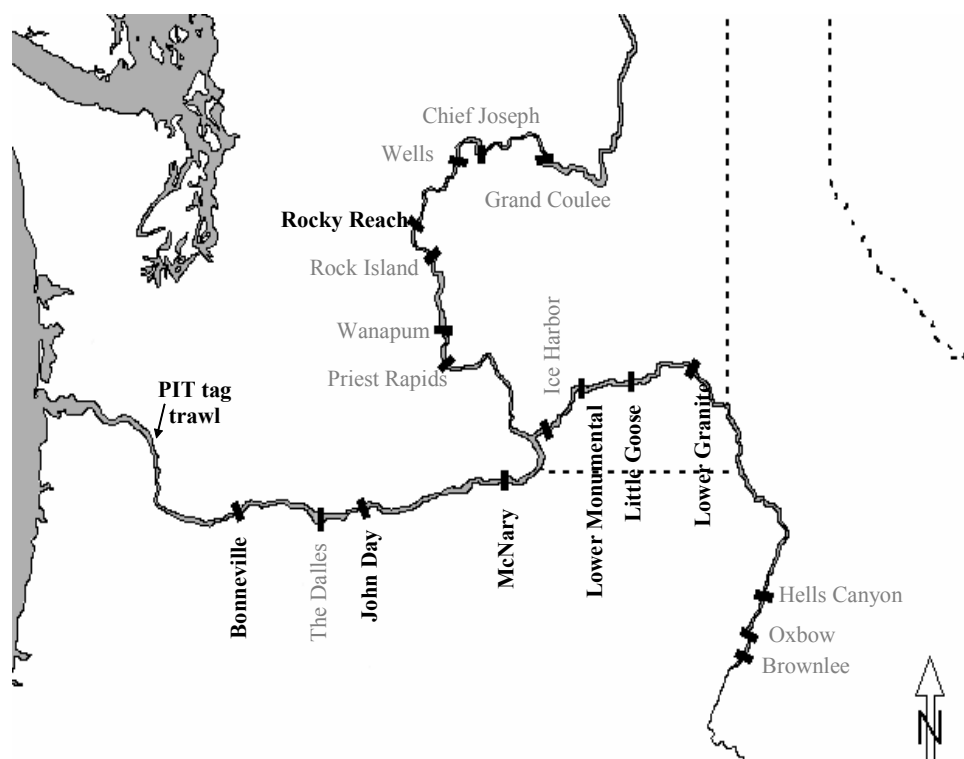


Figure 1. Study area showing sites with PIT-tag detection facilities (names in black), including dams and the PIT-tag trawl in the Columbia River estuary. Dams with names in gray do not have detection facilities.

The PIT-tag detection site farthest downstream was in the Columbia River estuary between rkm 65 and 84, where a pair trawl towed a PIT-tag detector (Ledgerwood et al. 2004). Since spring 2006, the corner collector at Bonneville Dam Second Powerhouse has been operated with a PIT tag detection system. Detections at Bonneville Dam and the pair trawl were sufficient to estimate survival through the reach from John Day tailrace to Bonneville Dam tailrace for both yearling Chinook salmon and steelhead in 2009.

A large proportion of PIT-tagged yearling Chinook salmon used in this analysis were released in the Snake River upstream from Lower Granite Dam for the multi-agency Comparative Survival Study (Schaller et al. 2007). In addition, we utilized about 120,637 yearling Chinook salmon PIT tagged at Lower Granite Dam as part of evaluation of latent mortality related to passage through Snake River dams (Marsh et al. 2006). Of these 120,637 fish, we used 46,232 non-trucked (reference) fish released to Lower Granite tailrace for our Lower Granite release groups. The remaining 74,405 fish were trucked and released to the tailrace of either Lower Granite (45,525) or Ice Harbor Dam (28,880). These latter groups were included only in our McNary release groups (formed by detection date at McNary Dam) if they were subsequently detected and returned to the river at McNary Dam. Most PIT-tagged fish detected at dams downstream from Lower Granite Dam were diverted back to the river, which allowed for the possibility of detection of a particular fish at more than one downstream site (Marsh et al. 1999).

For fish released in the Snake River Basin (upstream from Lower Granite Dam), we used records of downstream PIT-tag detections with the SR model to estimate survival in the following seven reaches:

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

The PIT-tag detection system in the Ice Harbor Dam juvenile bypass facility began operating in 2005. Because of the high level of spill at this dam, too few smolts were detected there to partition survival between Lower Monumental and McNary Dams in 2005. However, in 2006-2009 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
- McNary Dam tailrace to John Day Dam tailrace (123 km)
- John Day Dam tailrace to Bonneville Dam tailrace (112 km)

### **Lower Granite Dam Tailrace Release Groups**

During 2009, hatchery and wild steelhead and wild yearling Chinook salmon were collected at the Lower Granite Dam juvenile facility, PIT tagged, and released to the tailrace for the express purpose of estimating their subsequent survival. Fish were collected in approximate proportion to the numbers arriving at Lower Granite Dam during the migration season. However, in the early and late periods of the season, we tagged relatively more fish in order to provide sufficient numbers for analysis over these periods. No hatchery yearling Chinook salmon were PIT tagged specifically for this study because numbers of hatchery yearling Chinook PIT tagged and released from Snake River Basin hatcheries, traps, and for other studies were sufficient for analysis downstream from Lower Granite Dam. For Lower Granite Dam release groups we also used 46,232 yearling Chinook salmon tagged and released (non-trucked group) in the tailrace of Lower Granite Dam for a study to evaluate latent mortality related to passage through Snake River dams.

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

### **McNary Dam Tailrace Release Groups**

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

## **Hatchery and Trap Release Groups**

In 2009, most hatcheries in the Snake River Basin released PIT-tagged fish as part of research separate from the NMFS survival study. We analyzed data from hatchery releases of PIT-tagged yearling Chinook salmon, sockeye salmon, coho salmon, and steelhead to provide survival estimates and detection probabilities from release to the tailrace of Lower Granite Dam and to points downstream. For fish from the Upper Columbia River basin, we estimated survival to the tailrace of McNary Dam for yearling spring Chinook salmon released from Cle Elum, East Bank, Leavenworth, Wells, and Winthrop Hatcheries. We also estimated survival to McNary Dam for steelhead from Chelan, East Bank, and Winthrop Hatcheries, and for coho salmon from Cascade, Eagle Creek, Entiat, Prosser, Willard, and Winthrop Hatcheries. In the course of characterizing the various hatchery releases, we conducted preliminary analyses (not reported here) to determine whether data from related release groups could be pooled to increase sample sizes.

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

## **Data Analysis**

Tagging and detection data were downloaded on 2 December, 2009, from the Columbia Basin PIT Tag Information System (PTAGIS), a regional database maintained by the Pacific States Marine Fisheries Commission (PTAGIS 2009). Data were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated where appropriate, and all eliminated PIT-tag codes were recorded with the reasons for their elimination. Very few records ( $<0.1\%$ ) were eliminated. For each remaining PIT-tag code, we constructed a record (detection history) indicating all locations at which the tagged fish had been detected and all locations at which it had not been detected. Methods for data retrieval, database quality assurance/control, and construction of detection histories were the same as those used in past years (see Iwamoto et al. 1994 for detail).

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

## **Tests of Assumptions**

As in past years, we evaluated assumptions of the SR model as applied to the data generated from PIT-tagged juvenile salmonids in the Snake and Columbia Rivers (Burnham et al. 1987). These evaluations are detailed in the Appendix.

## **Survival Estimation**

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, estimates should be considered equal to 1.0 in these cases.

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

All survival estimates presented are from point of release (or the tailrace of a dam) to the tailrace of a dam downstream. All survival and detection probability estimates were computed using the statistical computer program SURPH (Survival with Proportional Hazards) for analyzing release-recapture data, developed at the University of Washington (Skalski et al. 1993; Smith et al. 1994).

## **Survival Estimates from Point of Release to Bonneville Dam**

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

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

### **Travel Time and Migration Rate**

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

- 1) Lower Granite Dam to Little Goose Dam (60 km)
- 2) Little Goose Dam to Lower Monumental Dam (46 km)
- 3) Lower Monumental Dam to McNary Dam (119 km)
- 4) Lower Granite Dam to McNary Dam (225 km)
- 5) Lower Granite Dam to Bonneville Dam (461 km)
- 6) McNary Dam to John Day Dam (123 km)
- 7) John Day Dam to Bonneville Dam (113 km)
- 8) McNary Dam to Bonneville Dam (236 km)

Travel time between any two dams was calculated for each fish detected at both dams as the number of days between last detection at the upstream dam (generally at a PIT-tag detector close enough to the outfall site that fish arrived in the tailrace within minutes after detection) and first detection at the downstream dam. Travel time included the time required to move through the reservoir to the forebay of the downstream dam and any delay associated with residence in the forebay, gatewells, or collection channel prior to detection in the juvenile bypass system.

Migration rate through a river section was calculated as the length of the section (km) divided by the travel time (d) (which included any delay at dams as noted above). For each group, the 20th percentile, median and 80th percentile travel times and migration rates were determined.

The true complete set of travel times for a release group includes travel times of both detected and non-detected fish. However, using PIT tags, travel time cannot be determined for a fish that traverses a river section but is not detected at both ends of the



section. Travel time statistics are computed only from travel times for detected fish, which represent a sample of the complete set. Non-detected fish pass dams via turbines and spill; thus, their time to pass a dam is typically minutes to hours shorter than that of detected fish, which pass the dam via the juvenile bypass system.

### **Comparison of Annual Survival Estimates**

We made two comparisons of 2009 results to those obtained in previous years of the NMFS survival study. First, we related migration distance to survival estimates from release at specific hatcheries to Lower Granite Dam. Second, we compared season-wide survival estimates for specific reaches across years.

### **Environmental Conditions and Salmonid Passage Timing**

We obtained data on daily flow, temperature, and spill at Snake River dams in 2009 from the Columbia River DART website on 3 September, 2009. We obtained data on the daily smolt passage index at Lower Granite Dam (yearling Chinook salmon and steelhead; hatchery and wild combined) from the Fish Passage Center website on 25 August 2009. We created plots to compare daily measures of flow, temperature, and spill at Little Goose Dam from 2009 to those from 2002-2008. We created plots and calculated cumulative passage proportions to compare daily estimates of numbers of smolts passing Lower Granite Dam in 2009 to those of 2007-2008.

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 25<sup>th</sup> and 75<sup>th</sup> 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.

## **Estimates of Proportion of Population Transported**

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](http://fpc.org)).
2. Use PIT-tag data to derive daily estimates of detection probability at Lower Granite Dam using method of Sandford and Smith (2002). Virtually every PIT-tagged fish in the collection system is detected, thus the probability of detecting a PIT-tagged fish on a given day is equivalent to the probability of entering the collection system.
3. For each day, divide the collection count by the detection probability to get an estimate of the total number of fish passing Lower Granite Dam that day. This also gives rise to estimates of the number of fish in the Lower Granite Dam collection system and the number of fish that passed via other routes that day.
4. For each daily group of PIT-tagged fish leaving Lower Granite Dam (i.e. detected and returned to the river), estimate the number of “Lower Granite equivalents” that were next detected (i.e. next entered a collection system) at Little Goose Dam and the number that passed Little Goose undetected and next entered a collection system at Lower Monumental Dam. These estimates were based on estimated arrival distributions (i.e., travel time distributions) for each daily group. Travel time distributions varied across groups to take into account that earlier fish generally travel more slowly than later fish.
5. Assume that for the group of untagged fish arriving at Lower Granite Dam on a given day, the proportions of fish first collected at Lower Granite, Little Goose, and Lower Monumental Dam are the same as those for the group of PIT-tagged fish arriving on that day. (The number of PIT-tagged fish that arrived at Lower Granite but were not detected is estimated from daily detection probability estimates from step 2.)
6. For each daily group of fish arriving at Lower Granite Dam, estimate the proportion of those that entered the collection system at each collector dam and were transported from that dam. For Lower Granite Dam groups arriving after the transport starting date at a collector dam, the proportion transported is 100%. For groups arriving before the starting date, the estimated proportion of the daily Lower Granite Dam group transported depends on the travel time distribution (i.e., a certain percentage of each group arrived before transport began).

7. For each daily group of the run-at-large, calculate the product of three quantities:
  - (i) estimated number of fish in the group (step 3)
  - (ii) estimated proportion of fish first entering the collection system at each dam (step 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**

### **Lower Granite Dam Tagging and Release Information**

During 2009, a total of 104,436 yearling Chinook salmon (81,409 hatchery origin, 23,027 wild) were detected and returned or PIT tagged and released to the river in the tailrace of Lower Granite Dam. A total of 86,189 (66,688 hatchery origin and 19,501 wild) steelhead were detected and returned or PIT tagged and released to the river in the tailrace of Lower Granite Dam.

For both species, not all detections were included in the analyses because some fish passed Lower Granite Dam early or late in the season. For fish passing at these times, the daily sample sizes were too small to produce reliable estimates of either survival or travel time. Survival estimates for wild and hatchery fish combined were based predominantly on fish of hatchery origin (78% of yearling Chinook salmon and 77% of steelhead) during 2009. In comparison, we estimate that 88% of the overall yearling Chinook salmon run is of hatchery origin, based on smolt passage data at Lower Granite Dam collected by the Fish Passage Center. We cannot estimate this number for steelhead because separate collection counts for hatchery and wild fish are not available.

### **Survival Estimation**

#### **Tests of Assumptions**

Assumption tests for 2009 indicated more significant differences between observed and expected proportions of fish in different detection-history categories than would be expected by chance alone. In many cases, sample sizes were such that the contingency table-based tests had power to detect violations that had only minimal effect on survival estimates. We present a detailed discussion of the assumption tests, the extent of violations, possible reasons for the occurrence of the violations, and their implications in the Appendix.

#### **Snake River Yearling Chinook Salmon**

Survival probabilities were estimated for weekly groups of yearling Chinook salmon released to the tailrace of Lower Granite Dam for 10 consecutive weeks, from 30 March through 7 June. Tailrace-to-tailrace survival estimates averaged 0.940 (se 0.006) from Lower Granite to Little Goose Dam, 0.982 (se 0.009) from Little Goose to Lower Monumental Dam, and 0.855 (se 0.011) from Lower Monumental to McNary

Dam (Table 1). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, survival averaged 0.787 (se 0.007).

We estimated survival probabilities for weekly groups of yearling Chinook salmon released in the tailrace at McNary Dam for six consecutive weeks from 20 April through 31 May. Tailrace-to-tailrace survival estimates averaged 0.866 (se 0.042) from McNary to John Day Dam and 0.821 (se 0.043) from John Day to Bonneville Dam, and 0.705 (se 0.031) for the combined reach from McNary to Bonneville Dam (Table 2).

The product of average estimates from Lower Granite to McNary and from McNary to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.555 (se 0.025). Estimated survival probability through Lower Granite reservoir and dam for Snake River wild and hatchery Chinook salmon released from the Snake River trap was 0.958 (se 0.010). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River yearling Chinook salmon was 0.531 (se 0.025).

We also calculated separate survival probability estimates for weekly groups of hatchery and wild yearling Chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace (Tables 3 and 4). Weighted mean survival estimates were similar for hatchery and wild yearling Chinook salmon for the combined reach from the tailrace of Lower Granite Dam to the tailrace of McNary Dam in 2009.

Survival probabilities were estimated for daily groups composed of yearling Chinook salmon (hatchery and wild combined) either detected at Lower Granite Dam and returned to the tailrace or collected and tagged at the dam and released to the tailrace. These estimates did not show any consistent increase or decrease in survival through Snake River reaches during the 2009 migration season (Table 5; Figure 2).

Estimates of detection probability varied throughout the season for most weekly groups as flow volumes, spill levels, and degrees of smoltification changed (Tables 6-9). Detection probabilities were generally highest at Little Goose Dam and lowest at John Day and Bonneville Dams.

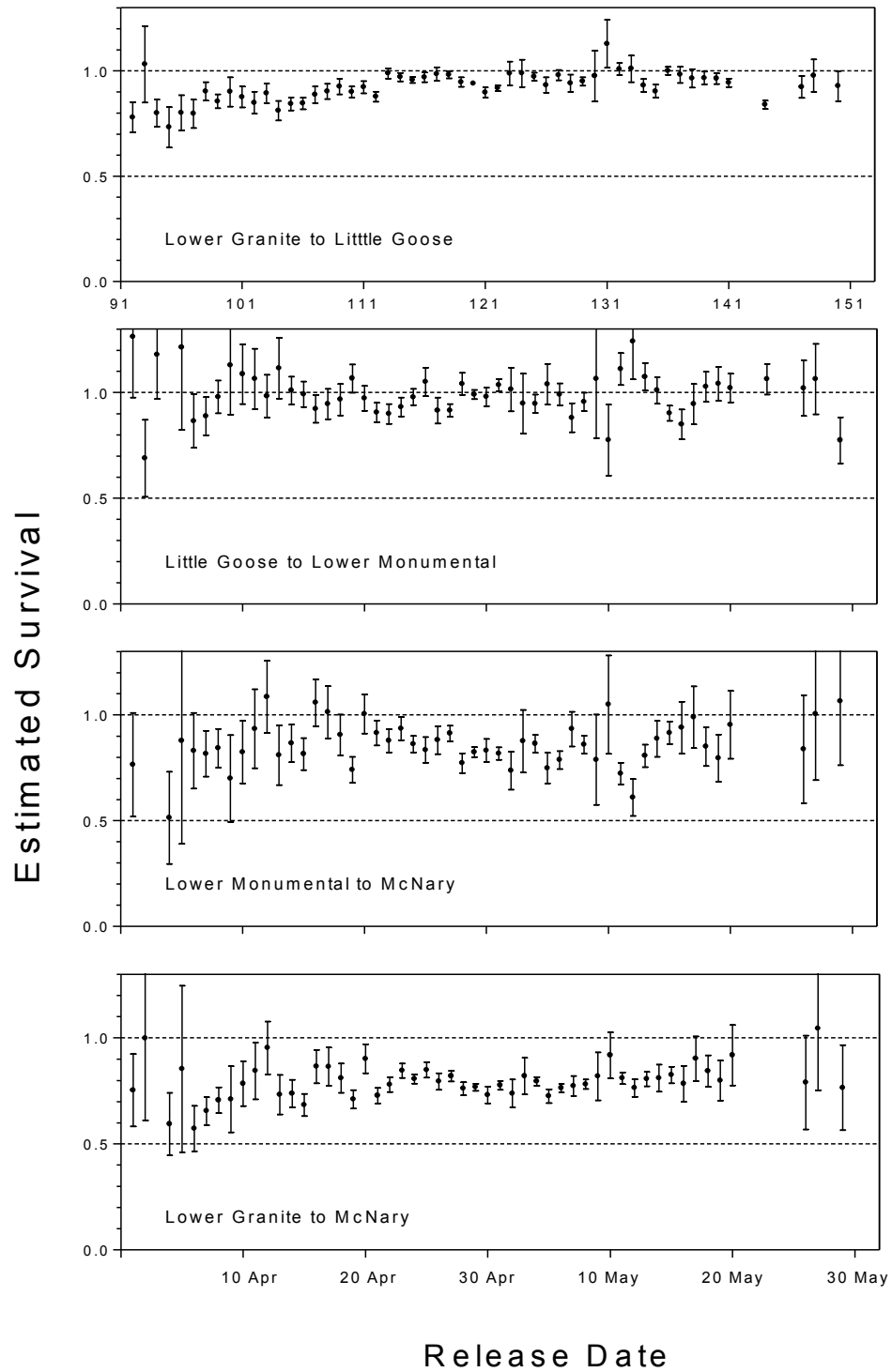


Figure 2. Estimated survival through various reaches vs. release date at Lower Granite Dam for daily release groups of Snake River yearling Chinook salmon, 2009. Bars extend one standard error above and below point estimates.

## **Snake River Steelhead**

We estimated survival probabilities for weekly groups of steelhead from the tailrace of Lower Granite Dam for 10 consecutive weeks from 6 April through 14 June. Average tailrace-to-tailrace survival was estimated at 0.972 (se 0.005) from Lower Granite to Little Goose Dam, 0.942 (se 0.008) from Little Goose to Lower Monumental Dam, and 0.863 (se 0.014) from Lower Monumental to McNary Dam (Table 10). For the combined reach from Lower Granite to McNary Dam tailrace, estimated survival averaged 0.790 (se 0.013).

We estimated survival probabilities for weekly groups of steelhead released in the tailrace of McNary Dam for eight consecutive weeks from 20 April through 14 June. Estimated tailrace-to-tailrace survival averaged 0.951 (se 0.026) from McNary to John Day Dam, 0.900 (se 0.079) from John Day to Bonneville Dam, and 0.856 (se 0.074) for the combined reach from McNary to Bonneville Dam tailrace (Table 11).

The product of average estimates from Lower Granite Dam to McNary Dam and from McNary Dam to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.676 (se 0.059). Estimated survival probability through Lower Granite reservoir and dam for Snake River wild and hatchery steelhead released from the Snake River trap was 1.002 (se 0.011). Thus, estimated survival probability through all eight hydropower projects encountered by Snake River steelhead was 0.678 (se 0.060).

Separate survival probabilities were estimated for weekly groups of hatchery and wild steelhead from Lower Granite Dam tailrace to McNary Dam tailrace (Tables 12 and 13). Survival estimates through most individual reaches and the reaches combined were similar for wild and hatchery steelhead.

Estimated survival probabilities for daily release groups of steelhead (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam did not show any consistent increase or decrease through Snake River reaches during the 2009 migration season (Table 14; Figure 3).

Estimates of detection probability at Snake River dams for weekly steelhead groups varied throughout the season as flow volumes, spill levels, and degrees of smoltification changed (Tables 15-18). Detection probability estimates were generally highest at Little Goose, and lowest at and John Day Dam and Bonneville Dam.



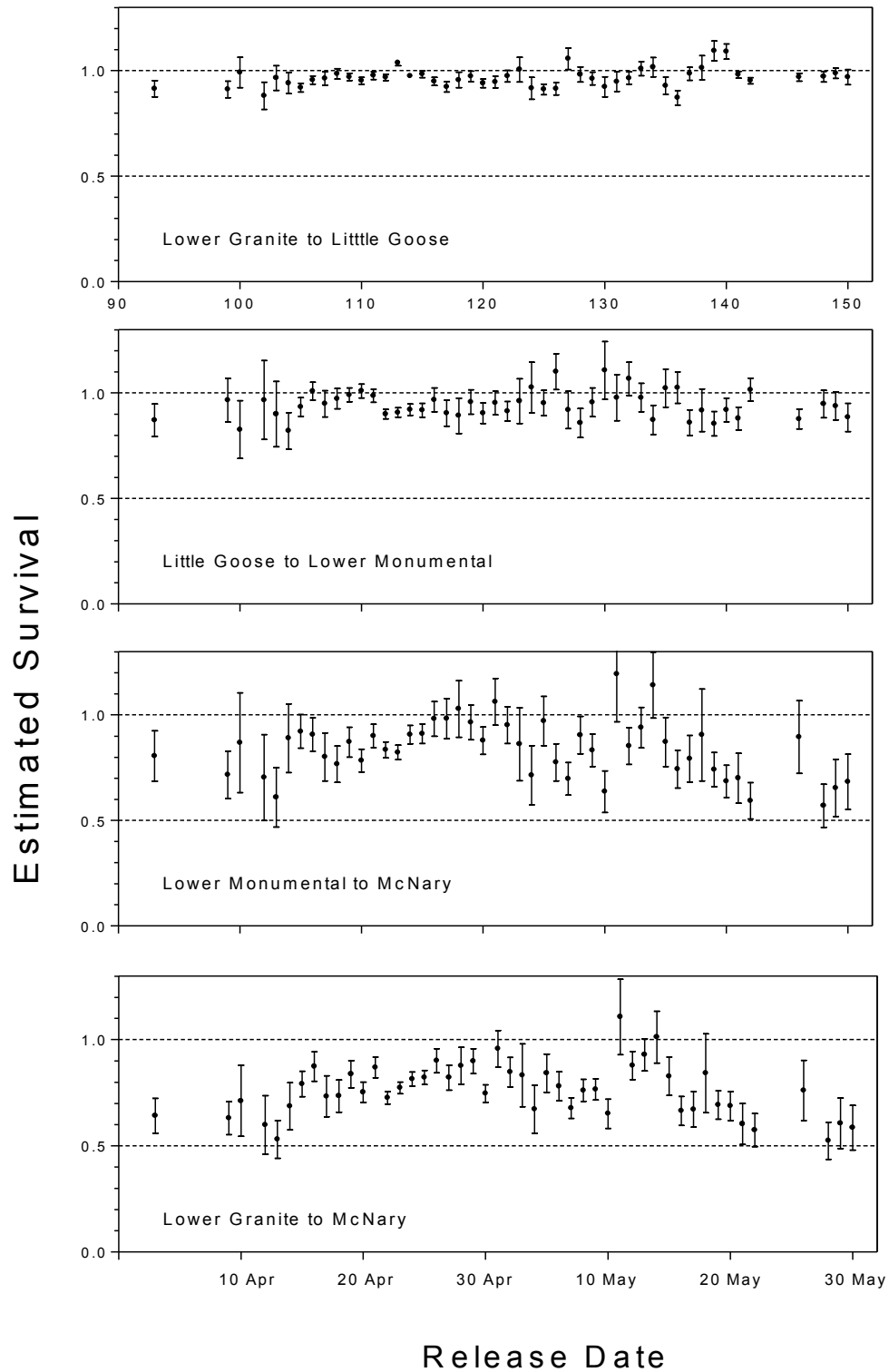


Figure 3. Estimated survival through various reaches versus release date at Lower Granite Dam for daily release groups of Snake River steelhead, 2009. Bars extend one standard error above and below point estimates.

## **Snake River Hatchery Release Groups**

Survival probabilities were estimated for PIT-tagged hatchery yearling Chinook, sockeye salmon, and steelhead from release at Snake River Basin hatcheries to the tailrace of Lower Granite Dam and to downstream dams. These estimates varied among hatcheries and release locations (Tables 19-21), as did estimated detection probabilities among detection sites (Tables 22-24). For yearling Chinook salmon, estimated survival from release to Lower Granite Dam tailrace was highest for fish from Clearwater Hatchery released into Clear Creek (0.799), and lowest for fish from McCall Hatchery released into Johnson Creek (0.309). For steelhead, estimated survival from release to Lower Granite Dam tailrace ranged from 0.939 for fish from Clearwater Hatchery released into the South Fork Clearwater River, to 0.574 for fish from Clearwater Hatchery released into the Crooked River. For sockeye salmon PIT-tagged and released in spring, estimated survival to Lower Granite Dam tailrace ranged from 0.289 from Redfish Lake Creek trap to 0.467 from Sawtooth trap. Estimated survival was lower for sockeye salmon PIT-tagged and released in fall 2008 (0.096-0.370).

## **Snake River Smolt Trap Release Groups**

Survival probability estimates for juvenile salmonids PIT tagged and released from Snake River Basin smolt traps were generally inversely related to distance of the traps from Lower Granite Dam (Table 25). Estimated detection probabilities were similar among release groups of the same species from different traps (Table 26).

## **Upper Columbia River Hatchery Release Groups**

Survival probability estimates for PIT-tagged hatchery yearling Chinook, coho salmon, and steelhead from release at Upper Columbia River hatcheries to the tailrace of McNary Dam and dams downstream varied among hatcheries and release locations (Table 27), as did detection probability estimates (Table 28). For yearling Chinook released in the Upper Columbia River, estimated survival from release to McNary Dam tailrace ranged from 0.632 (se 0.026) for East Bank Hatchery fish released into the Chelan River to 0.277 (se 0.039) for Wells Hatchery fish released from Wells Hatchery.

For Upper Columbia River steelhead, estimated survival from release to McNary Dam tailrace ranged from 0.564 (se 0.081) for fish from East Bank Hatchery released into the Chiwawa River to 0.267 (se 0.034) for Winthrop Hatchery fish released from Winthrop Hatchery. For Upper Columbia River coho salmon, estimated survival from release to McNary Dam tailrace ranged from 0.461 (se 0.060) for fish from Cascade Hatchery released from Leavenworth Hatchery, to 0.065 (se 0.014) for fish from Eagle Creek Hatchery released from Holmes Pond in the Yakima River Basin.

## Travel Time and Migration Rate

Travel time estimates for yearling Chinook salmon and juvenile steelhead released in the tailraces of Lower Granite and McNary Dams varied throughout the season (Tables 29-36). 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 in 2009 were near the average value observed for recent years (2002-2008) earlier in the season, then became shorter than those of recent years later in the season (migration rates faster). Steelhead travel times were among the shortest (migration rates fastest) observed in recent years (Figure 4). The observed increases in migration rates for yearling Chinook salmon and steelhead over the season generally coincided with increases in flow and water temperature, and presumably with increased levels of smoltification (Figure 5).

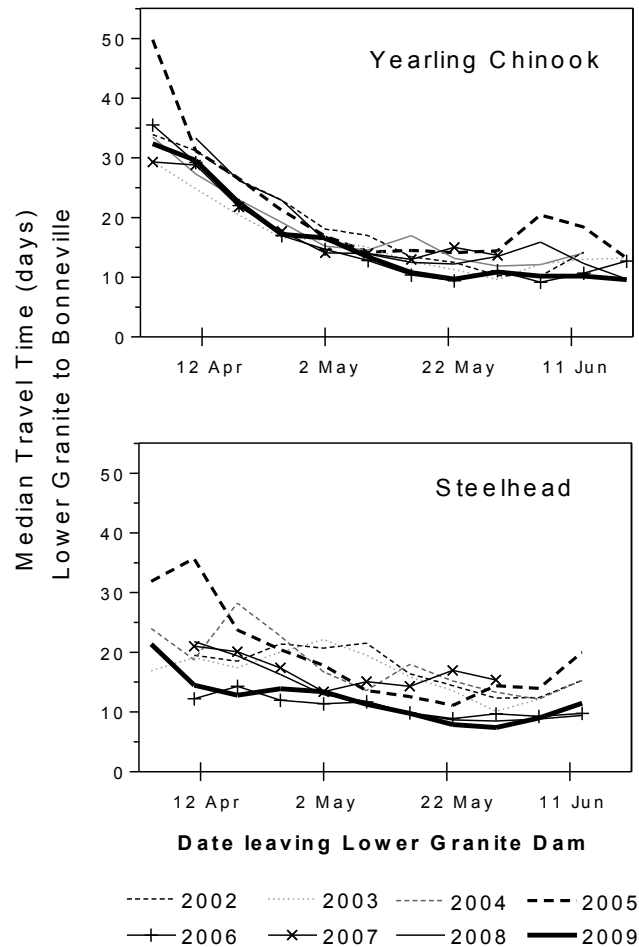


Figure 4. Median travel time (days) from Lower Granite Dam to Bonneville Dam for weekly release groups of Snake River yearling Chinook salmon and steelhead from Lower Granite Dam, 2001-2009.

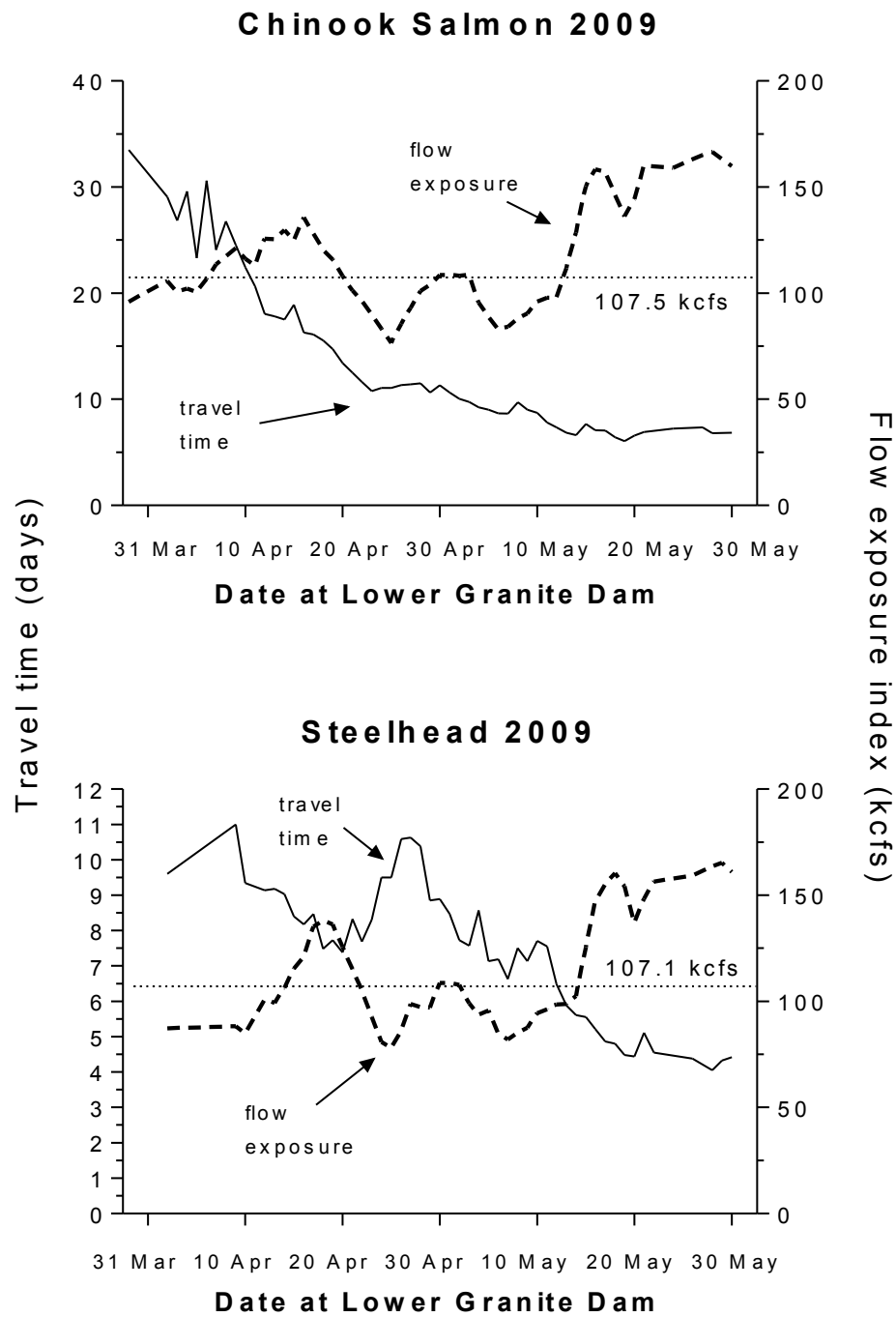


Figure 5. Travel time (days) for yearling Chinook salmon and steelhead from Lower Granite Dam to McNary Dam and index of flow exposure at Lower Monumental Dam (kcfs) for daily groups of PIT-tagged fish during 2009. Dashed horizontal lines represent the annual average flow exposure index, weighted by the number of PIT-tagged fish in each group.

## Tagging Details for Fish PIT Tagged at Lower Granite Dam

We PIT tagged and released 18,744 hatchery steelhead, 15,250 wild steelhead, and 13,864 wild yearling Chinook salmon from 8 April through 13 June at Lower Granite Dam for survival estimates (Table 37-39). Total mortalities of hatchery steelhead, wild steelhead, and yearling Chinook salmon were 17, 8, and 58, respectively. Each of these numbers represented well under 1% of the total fish handled.

## Comparison of Annual Survival Estimates

For yearling Chinook salmon, estimates of survival in 2009 from most Snake River Basin hatcheries to Lower Granite Dam tailrace were similar to those made in recent years. The mean of the hatchery estimates for 2009 was slightly lower than the long-term mean (Table 40). Over the years of the study, we have consistently observed an inverse relationship between migration distance from the release site to Lower Granite Dam and estimated survival through that reach (Figure 6). For 1998-2009 estimates, the negative linear correlation between migration distance and average estimated survival was significant ( $R^2 = 0.877$ ,  $P = 0.002$ ).

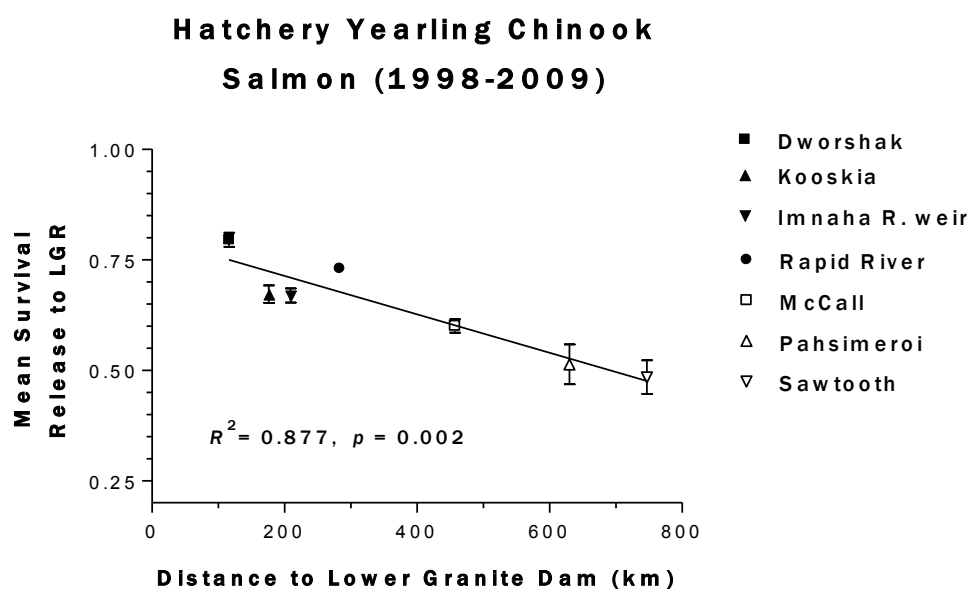


Figure 6. Estimated survival with standard errors from release at Snake River Basin hatcheries to Lower Granite Dam tailrace, 1998-2009 vs. distance (km) to Lower Granite Dam. The squared correlation between survival and migration distance is also shown, along with a  $P$ -value for a test of the null hypothesis of zero correlation.

For yearling Chinook salmon (hatchery and wild combined), mean estimated survival in 2009 was similar to that estimated in 2008 through the Lower Granite Dam to McNary Dam reach, but higher from the McNary Dam to Bonneville Dam reach (Tables 41 and 43; Figures 7 and 8). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace in 2009 was 0.787 (95% CI 0.773-0.800), which is the second highest estimate of our data series for the Lower Granite-to-McNary reach. Mean estimated survival in 2009 from McNary Dam tailrace to Bonneville Dam tailrace was 0.705 (95% CI 0.644-0.766), which was close to the 10-year average.

For steelhead (hatchery and wild combined) in 2009, mean estimated survival from tailrace to tailrace was 0.790 (95% CI 0.765-0.815) for Lower Granite to McNary Dam and 0.856 (95% CI 0.711-1.001) from McNary to Bonneville Dam. These estimates are the highest we have recorded over the past 12 years for these reaches (Tables 42 and 44; Figures 7 and 8).

For several years, we have combined empirical survival estimates for yearling Chinook salmon and steelhead over various reaches to derive estimates of survival throughout the entire hydropower system, from the head of Lower Granite reservoir (Snake River smolt trap) to the tailrace of Bonneville Dam (Tables 43 and 44). Data were sufficient for these estimates starting in 1999 for yearling Chinook and 1997 for steelhead. However in spring 2004, operation of a new corner collector system began at Bonneville Dam Second Powerhouse, and although the system passed fish effectively, it contained no PIT-tag monitors. Thus in 2004 and 2005, detection data through the final reach were no longer sufficient for estimates of steelhead survival. Beginning in 2006, a new PIT tag interrogation system in the corner collector increased detection probability at this site.

For yearling Chinook salmon in 2009, estimated survival through the entire hydropower system was 0.531 (95% CI 0.483-0.580), which was the fourth highest of our data series. For steelhead, estimated hydropower system survival was 0.678 (95% CI 0.560-0.795), which was the highest in any year of our data series (1997-2003, 2006-2009).

For pooled groups of yearling Chinook salmon from Upper Columbia River hatcheries, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace in 2009 was 0.895 (95% CI 0.695-1.15). This was the highest individual survival estimate for that reach among all years with estimates from 1999 to 2009 (Table 45). For pooled groups of steelhead from Upper Columbia hatcheries, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace in 2009 was 0.756 (95% CI 0.577-0.991), just above the average of 0.741 for that reach for 2003-2009 (Table 45).

For pooled groups of sockeye salmon (hatchery and wild combined) originating in the Snake River basin, estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace in 2009 was 0.749 (95% CI 0.689-0.814; Table 46). This estimate was above the average estimated survival of 0.589 for 1996-2009, and was the second highest estimate over that time period. Estimated survival for Snake River sockeye from Lower Granite Dam tailrace to Bonneville Dam tailrace in 2009 was 0.573 (95% CI 0.447-0.735). Large releases of hatchery sockeye in 2009 allowed for a relatively precise estimate of survival from Lower Granite Dam to Bonneville Dam. Comparison of estimates from Lower Granite to Bonneville from previous years is limited by the large sampling errors resulting from typically small release sizes.

For sockeye salmon originating in the Upper Columbia River basin that were captured and tagged at Rock Island Dam and returned to the river, estimated survival from Rock Island Dam tailrace to McNary Dam tailrace in 2009 was 0.853 (95% CI 0.717-1.02; Table 46). This was the highest estimate observed among those from 1997 to 2009. Note that Table 46 provides survival estimates to Bonneville Dam tailrace from the tailraces of Lower Granite, McNary, and Rock Island Dams for all years in which data were sufficient to calculate estimates. However, small release sizes and poor detection probabilities resulted in estimates to Bonneville which were of poor quality for many of the years shown. We presented all available estimates, regardless of quality, in an effort to represent all of the available data on sockeye. Caution should be used if using those estimates for inference.

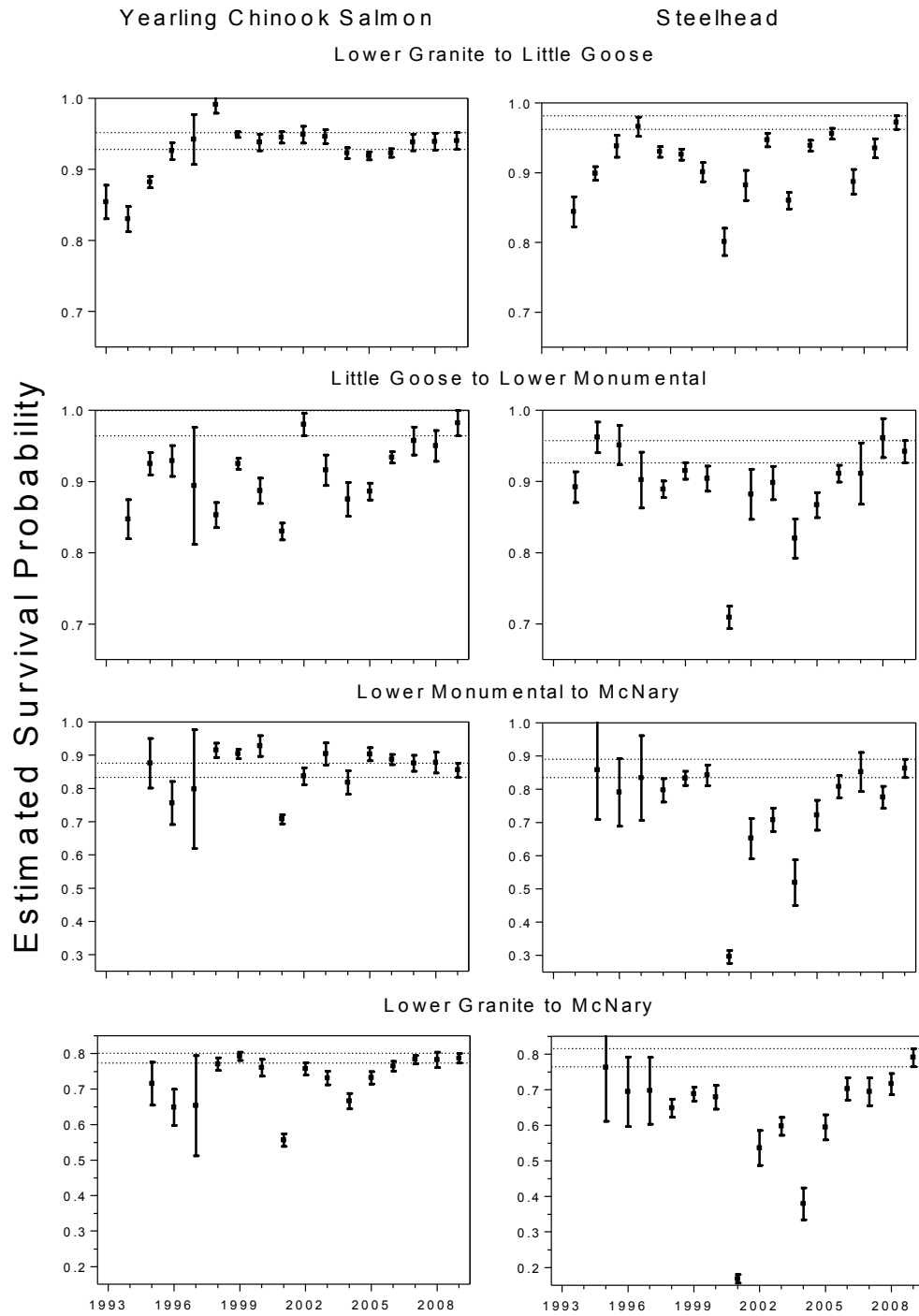


Figure 7. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead through Snake River reaches, 1993-2009. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2009 estimates.



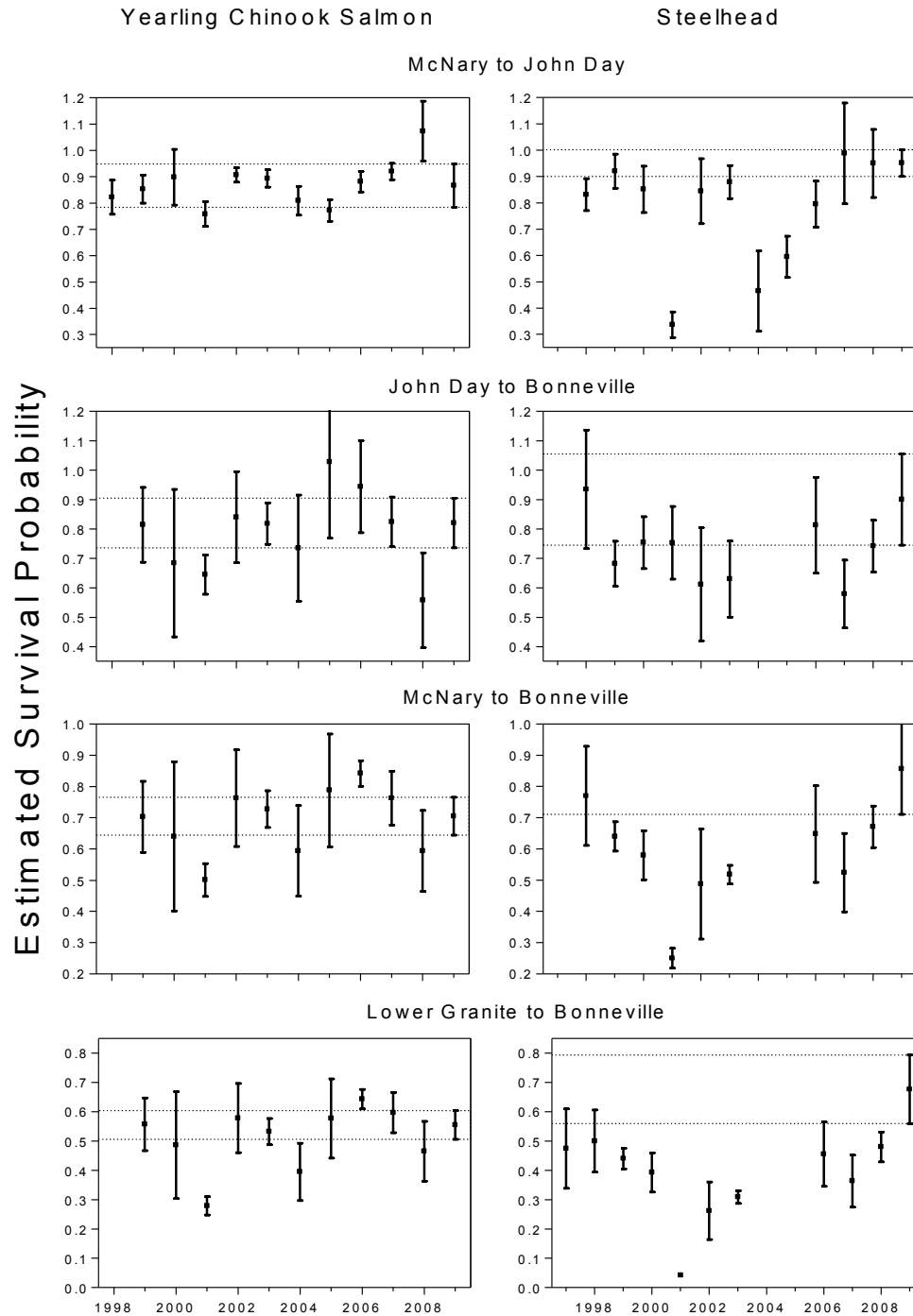


Figure 8. Annual average survival estimates for PIT-tagged Snake River yearling Chinook salmon and steelhead through Columbia River reaches and from Lower Granite Dam to Bonneville Dam, 1993-2009. Estimates are from tailrace to tailrace. Vertical bars represent 95% CIs. Horizontal dashed lines are 95% CI endpoints for 2009 estimates.

## Comparison of Survival Estimates for Upper Columbia and Snake River Fish

In 2009, we compared estimated survival to the tailrace of McNary Dam among yearling spring Chinook salmon released from two hatcheries in the Upper Columbia River and one in the Snake River. These groups migrated similar distances and passed a similar number of dams (Tables 19 and 27). Average estimated survival to McNary Dam for these yearling Chinook is shown below:

<u>Hatchery</u>	<u>River</u>	<u>Release date</u>	<u>Migration distance (rkm)</u>	<u>Projects passed</u>	<u>Estimated survival (se)</u>
Leavenworth	Columbia	28 April	330	4	0.478 (0.020)
Wells	Columbia	15 May	360	5	0.277 (0.039)
Dworshak	Snake	25 March	341	5	0.456 (0.012)

In a similar comparison, survival estimated from Upper Columbia hatcheries to the tailrace of McNary Dam was generally lower for steelhead than for their counterparts from Snake River Basin hatcheries that migrated similar distances and passed a similar number of dams (shown below and in Tables 20 and 27).

<u>Hatchery</u>	<u>River</u>	<u>Release date</u>	<u>Migration distance (rkm)</u>	<u>Projects passed</u>	<u>Estimated survival (se)</u>
East Bank	Wenatchee	6 May	306	4	0.534 (0.030)
Winthrop	Methow	21 April	454	6	0.267 (0.034)
Dworshak	Snake	17 April	341	5	0.638 (0.016)

From McNary Dam tailrace to Bonneville Dam tailrace, estimated survival of spring/summer Chinook salmon from the Snake River (0.705, se 0.031) was lower than estimated survival of those from the Upper Columbia River (0.857, se 0.098; Table 47). For steelhead, estimated survival from McNary to Bonneville was higher for Snake River fish (0.856, se 0.074) than steelhead from the Upper Columbia River (0.703, se 0.077). Estimated survival from McNary Dam tailrace to Bonneville Dam tailrace for Snake River sockeye salmon (0.765, se 0.101) was lower than that for Upper Columbia River sockeye salmon (0.824, se 0.198). Note that the comparisons of survival estimates in this section are not based on formal statistical tests, and if they were, the differences would not be statistically significant in most cases due to the size of the associated sampling errors.

## **Partitioning Survival Between Lower Monumental and Ice Harbor Dams**

A PIT-tag detection system became operational at Ice Harbor Dam in 2005, and sufficient detections occurred in 2006-2009 to partition survival estimates through the individual reaches (Tables 48 and 49). In 2009, estimated mean survival from tailrace to tailrace for yearling Chinook salmon was 0.910 (se 0.012) from Lower Monumental to Ice Harbor Dam and 0.952 (se 0.018) from Ice Harbor to McNary Dam. For steelhead, estimated mean survival through these reaches was 0.938 (se 0.015) and 0.915 (se 0.015), respectively.

## **Environmental Conditions and Salmonid Passage Timing**

Daily flow volume measured at Little Goose Dam in 2009 was near or above the average of recent years throughout April and May (Figure 9). There was a spike in flow in the last week in April, which was followed by a fairly steady increase from early to late May. In 2009, flow in April was higher than in 2008, while flow in May was a bit lower. Water temperatures in the Snake River were on the low side of recent years during April, but became more similar to the average of recent years during May (Figure 9). Water temperatures in 2009 were similar to those in 2008 until the second week of May, when 2008 water temperatures dropped but 2009 temperatures continued to increase. Mean spill as a percentage of flow at the Snake River dams in 2009 was close to the average of recent years and remained fairly constant throughout the season (Figure 10). Spill percentages in 2009 were much like those in 2006 until mid-May, from which point they were more like 2007. Spill percentages in 2009 were lower than those in 2008 for most of the season.

The passage distribution of yearling Chinook salmon smolts at Lower Granite Dam in 2009 differed from that of 2007 and 2008 (Figure 11). The median day of passage for yearling Chinook salmon in 2009 was 7 May, which was later than in 2007 (3 May) and earlier than in 2008 (10 May). Passage of yearling Chinook at Lower Granite Dam in 2009 had four spikes, the first of which occurred in late April and corresponded to a spike in flow at the same time. Based on the smolt passage index at Lower Granite Dam, by 30 April 2009, 32% of the yearling Chinook run had passed. By comparison, 34% had passed by the same date in 2007, and 13% by that date in 2008.

Steelhead smolt passage at Lower Granite Dam in 2009 was much earlier than in 2007 and 2008, including a large spike in passage from around 22-27 April (Figure 11). Median day of passage for steelhead in 2009 was 5 May; earlier than in 2007 (7 May) and 2008 (11 May). As with yearling Chinook salmon, timing of the early spike in steelhead passage corresponded to a spike in flow at the same time, but the spike in

steelhead passage represented a larger proportion of the overall run. By 30 April 2009, approximately 44% of the steelhead run had passed Lower Granite Dam. In contrast, only about 15% of the steelhead run had passed by 30 April in both 2007 and 2008.

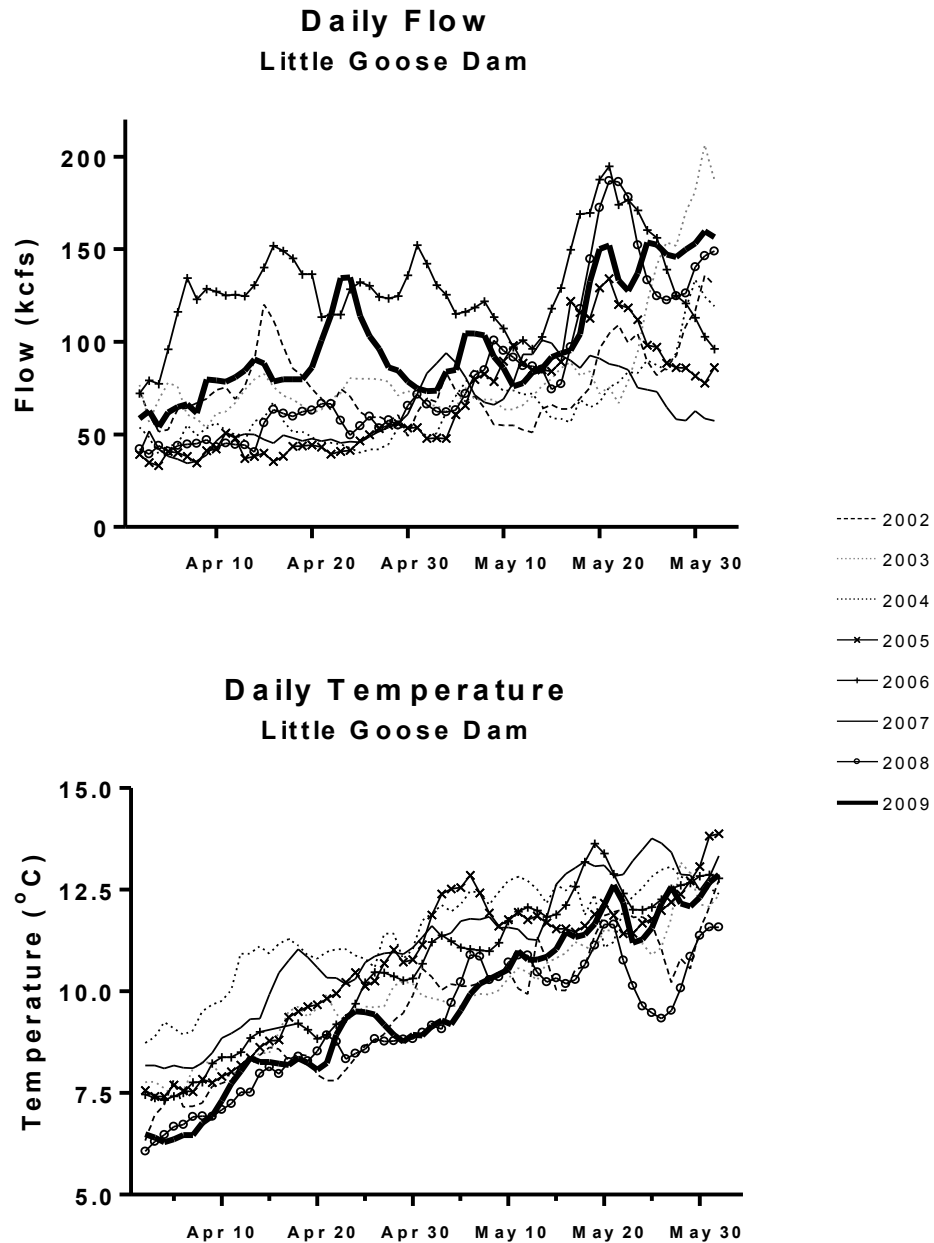


Figure 9. Daily Snake River flow (kcfs) and temperature (°C) measured at Little Goose Dam during April and May, 2002-2009.

# Mean Daily Spill

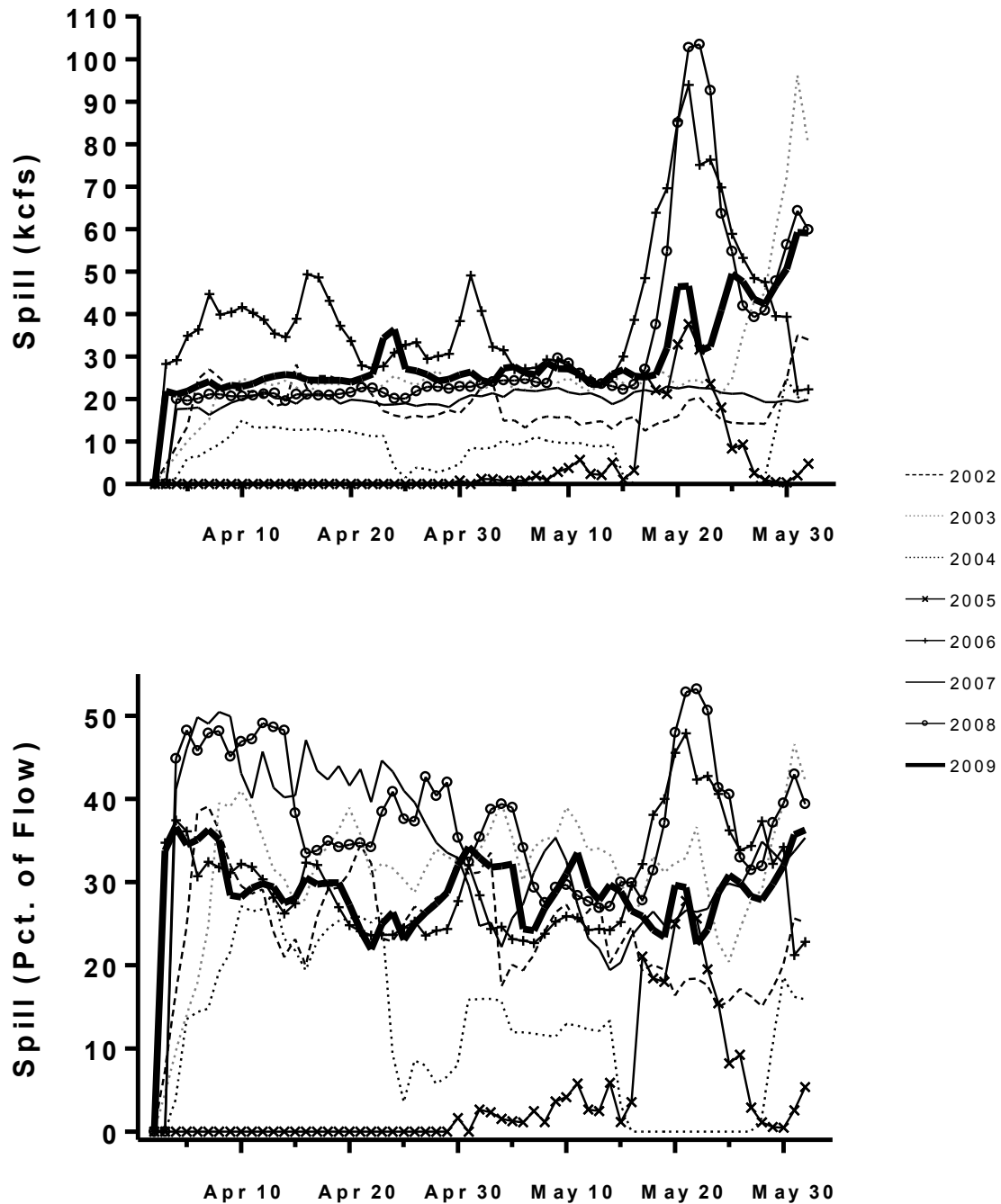
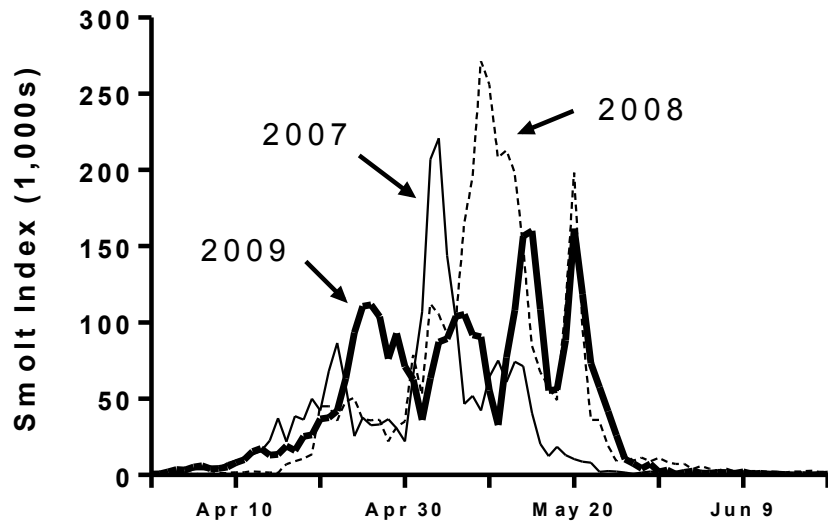


Figure 10. Daily mean spill (top = kcfs; bottom = percentage of total flow) averaged across Lower Granite, Little Goose and Lower Monumental dams during April and May, 2002-2009.

## Smolt Passage at Lower Granite Dam

### Yearling Chinook



### Steelhead

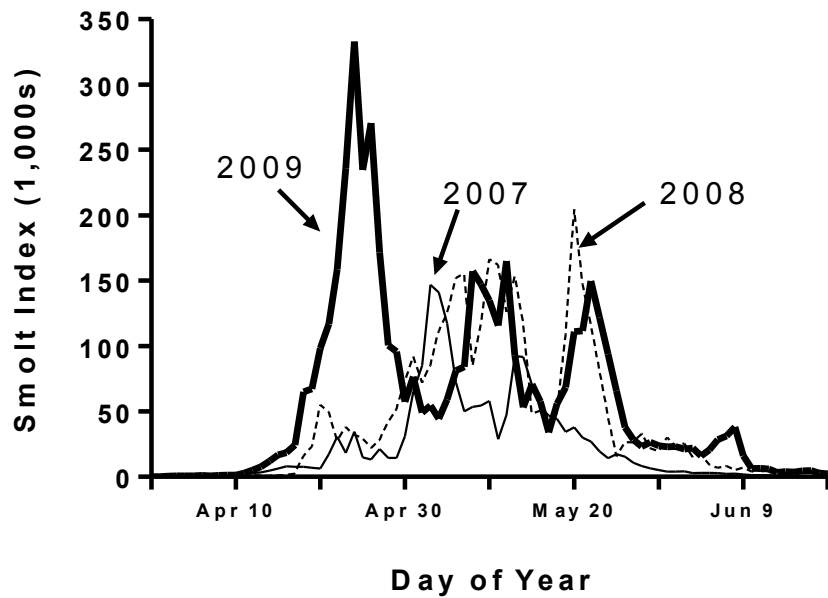


Figure 11. Daily smolt passage index of yearling Chinook salmon and steelhead passing Lower Granite Dam, 2007-2009.

## **Estimates of Proportion of Population Transported**

In 2009, smolt transport began on 1 May at Lower Granite Dam, 6 May at Little Goose Dam, and 8 May at Lower Monumental Dam. Until these dates, smolts collected at Snake River dams were bypassed back to the river. Estimated proportions of non-tagged spring/summer Chinook salmon smolts that were transported during the entire 2009 season were 40% for wild fish and 38% hatchery fish. For non-tagged steelhead, estimated proportions transported were 46 and 43% for wild and hatchery smolts, respectively. These estimates represent the proportion of smolts that arrived at Lower Granite Dam and were subsequently transported from either Lower Granite or one of the downstream collector dams. For both species, the two lowest estimated proportions of fish transported (hatchery and wild fish combined) in the 1995-2009 period occurred in 2007 and 2009 (Figure 12).

Survival estimates presented in this report are based on PIT-tagged fish that remained in-river. These fish either passed through turbines or spillways (including surface passage structures), or were intentionally returned to the river after detection in bypass systems. (PIT-tagged fish that were transported provide survival information up until the point of transport, but not downstream from that point). When considering the implications of in-river survival probability for populations of Snake River salmonids, it is important to remember that in recent years, around half of non-tagged fish were removed from the river for transport. In years before 2007, well over half of the populations at large were transported. Only fish that remained in the river were subject to the reach survival probabilities presented in this report; survival of transported fish is affected by entirely different factors.

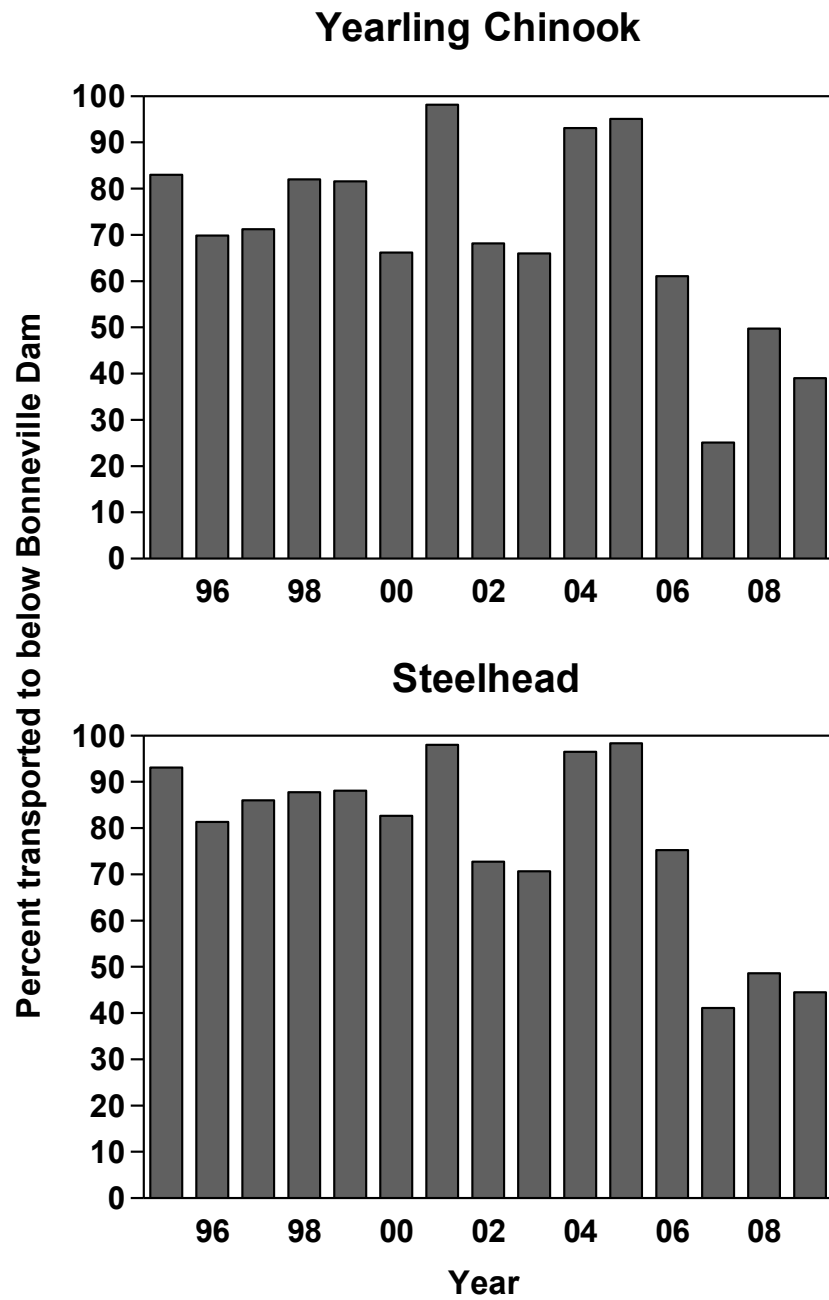


Figure 12. Estimated percent of yearling Chinook salmon and steelhead (hatchery and wild combined) transported to below Bonneville Dam by year (1995-2009).



## DISCUSSION

Snake River flow volume in 2009 was near or above the average of recent years throughout April and May (Figure 9). Water temperatures in the Snake River were on the low side of recent years during April, but became more similar to the average of recent years during May (Figure 9). Mean spill as a percentage of flow at the Snake River Dams in 2009 was close to the average of recent years and remained fairly constant throughout the season (Figure 10).

Operations at most dams in 2009 were similar to those in 2008. One exception was the new operating temporary spillway weir (TSW) at Little Goose Dam in 2009. The removable spillway weir (RSW) at Lower Monumental Dam and the TSW at John Day Dam were in their second year of operation in 2009. Also a new spillway guidance wall at The Dalles Dam was partially completed before the 2009 spring smolt migration.

Estimated travel times through the system in 2009 were among the shortest (migration rates fastest) in recent years for both yearling Chinook and steelhead, particularly later in the migration season when flows were highest (Figures 4 and 5). Within the season, estimated survival from Lower Granite to McNary Dam for daily groups of yearling Chinook remained relatively constant from early April through the end of May, except for an increase over a 1-2 week period in late May (Figure 2). Estimated survival from Lower Granite to McNary Dam for daily groups of steelhead was variable across the season (Figure 3). For yearling Chinook salmon, the survival estimate from Lower Granite tailrace to McNary Dam tailrace in 2009 was among the highest observed over all study years. Estimated survival through the hydropower system from the Snake River trap to Bonneville Dam tailrace was 53% for yearling Chinook salmon; above the 10-year average of 49%. For steelhead, estimated survival through the hydropower system was about 68%, the highest observed in the last 12 years, and well above the average of 38%.

The high estimated survival of steelhead through the hydropower system in 2009 is particularly noteworthy. Mean estimated survival of steelhead in 2009 was relatively high in all reaches in comparison to previous years (Figures 7 and 8). Reaches with unusually high mean estimated survival for steelhead in 2009 were Lower Granite tailrace to Little Goose tailrace and John Day tailrace to Bonneville tailrace. Unusually high annual estimated survival in these reaches, combined with high estimated survival in other reaches, resulted in the hydropower system survival estimate of 68% for steelhead. We can only speculate about reasons for the increased survival at this time. We discuss several possible factors, but the picture is complicated and will require further analysis and collection of supporting evidence before we can provide more conclusive

explanations. We plan to address these issues in more detail in the upcoming report for the 2010 migration season.

One possible contributing factor is the new TSW at Little Goose Dam. Assuming passage survival was higher through the TSW, and steelhead were disproportionately attracted to it as a passage route, the result would be an increase in survival at Little Goose Dam. Estimated survival between Lower Granite Dam and Little Goose Dam in 2009 was the highest we have recorded, which suggests the TSW contributed. Results from a radiotelemetry study conducted there in 2009 may inform this conjecture, but final results are not yet available.

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

Exposure to potentially high water temperatures also decreases with travel time. Exposure to higher water temperatures can result in steelhead reverting to parr and ceasing active migration. Zaugg and Wagner (1973) found that gill  $\text{Na}^+\text{-K}^+$  ATPase (an indicator of migratory readiness) and migratory urge declined at water temperatures of 13°C and above. Reversion to parr was thought prevalent in 2001 during the higher water temperatures and long travel times experienced later in the season (see Zabel et al. 2002). When steelhead travel quickly through the hydropower system, they are less likely to revert to parr, and thus their estimated survival increases (if a PIT-tagged smolt ceases migration it will not be detected at subsequent dams, and for the purposes of the survival-estimation model this cannot be distinguished from mortality).

We will not know the full effect of surface collectors on travel time until we compile results from active tag studies investigating the effects of surface collector operations on survival and forebay residence times of steelhead. These results will be used to conduct analyses investigating the relationships between travel times of PIT tagged fish and number of surface collectors, while accounting for other contributing environmental covariates. This work planned and will be reported for the annual survival report for the 2010 migration year.

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

Between Lower Monumental and McNary Dam, steelhead survival was depressed during 2001-2005, but higher during 2006-2009. Accordingly, the proportion of PIT-tagged steelhead lost to piscivorous birds in McNary pool was lower during 2006-2009 than during 2001-2005 (indexed by the percentage of tags detected in bird colonies; Table 50). The decreased proportion of smolts taken by birds in 2009 was due in part to an increase in the total number of smolts (tagged and untagged) remaining in the river, which in turn resulted from increased spill, increased number of surface passage structures in the Snake River (all 4 dams in 2009), and a delayed initiation of the smolt transport program. A negative and significant correlation was found between estimated survival from Lower Monumental to McNary Dam tailrace and the percentage of PIT tags recovered from both yearling Chinook salmon and steelhead (Figure 13).

Timing of steelhead smolt passage at Lower Granite Dam in 2009 was much earlier than in 2007 and 2008 (see Figure 11). By 30 April 2009, approximately 44% of the steelhead run had passed Lower Granite Dam. In contrast, only about 15% of the run had passed by the same date in both 2007 and 2008. If the yearly total smolt index counts from Figure 10 are taken as estimates of migrating population sizes, then the total number of migrating steelhead was higher in 2009 compared to 2007 and 2008. Daily survival estimates were relatively high during the early peak of the steelhead migration in 2009 (Figure 3).

Because collection for transport did not begin until 1 May at Lower Granite Dam (6 May at Little Goose Dam and 8 May at Lower Monumental Dam), most Snake River steelhead were not transported. This left a much larger number of steelhead migrating in-river in 2009 than in 2007 or 2008. As was demonstrated in our survival report for the 2007 migration (Faulkner et al. 2008), if the total number of fish lost to predation

remained relatively constant between years, years with more fish migrating downstream will lead to higher survival estimates, as the proportion of PIT-tagged fish taken by predators would decrease.

Other predation-related factors that possibly contributed to increased steelhead survival include a reported reduction from 2008 in avian predation at John Day Dam, and the presence of the partially completed spillway guidance wall at The Dalles Dam. The completed spillway guidance wall is expected to reduce tailrace mortality of migrating smolts by directing them away from an area in the tailrace suspected to have relatively high piscine predation rates.

Migration conditions and associated hydropower system survival estimates from 1993 through 2009 show suggestive correlations among flow, spill, temperature, and estimated survival (data not shown). Analyses based on early data (1973-1979) suggested that increases in spill directly increased survival (Sims and Ossiander 1981). From our own research, estimated survival through the Snake River was lower in 1993 and 1994, when spill occurred only in excess of powerhouse capacity, than it was in subsequent years, after the 1995 BiOp (NMFS 1995) prescribed spill at all dams. Estimated survival was lowest during the 2001 migration, when spill was eliminated or severely reduced at all dams.

However, demonstrating positive correlation between spill and survival within a single migration season has been more problematic (Smith et al. 2002; Zabel et al. 2002; Williams et al. 2005). In modeling efforts for the Comprehensive Passage Model (COMPASS), we demonstrated strong correlations between reach survival and distance traveled, travel time, flow, spill, and temperature (Zabel et al. 2008). We plan to expand on these models for reach survival in relation to environmental covariates.

Results from the 2009 studies provide estimates of survival only during the downstream portion of the migration. We will analyze these data in conjunction with adult returns over the next 3 years to determine whether variations in spill, flow, temperature, and passage-route produce patterns in smolt-to-adult survival consistent with those observed during the downstream migration phase.

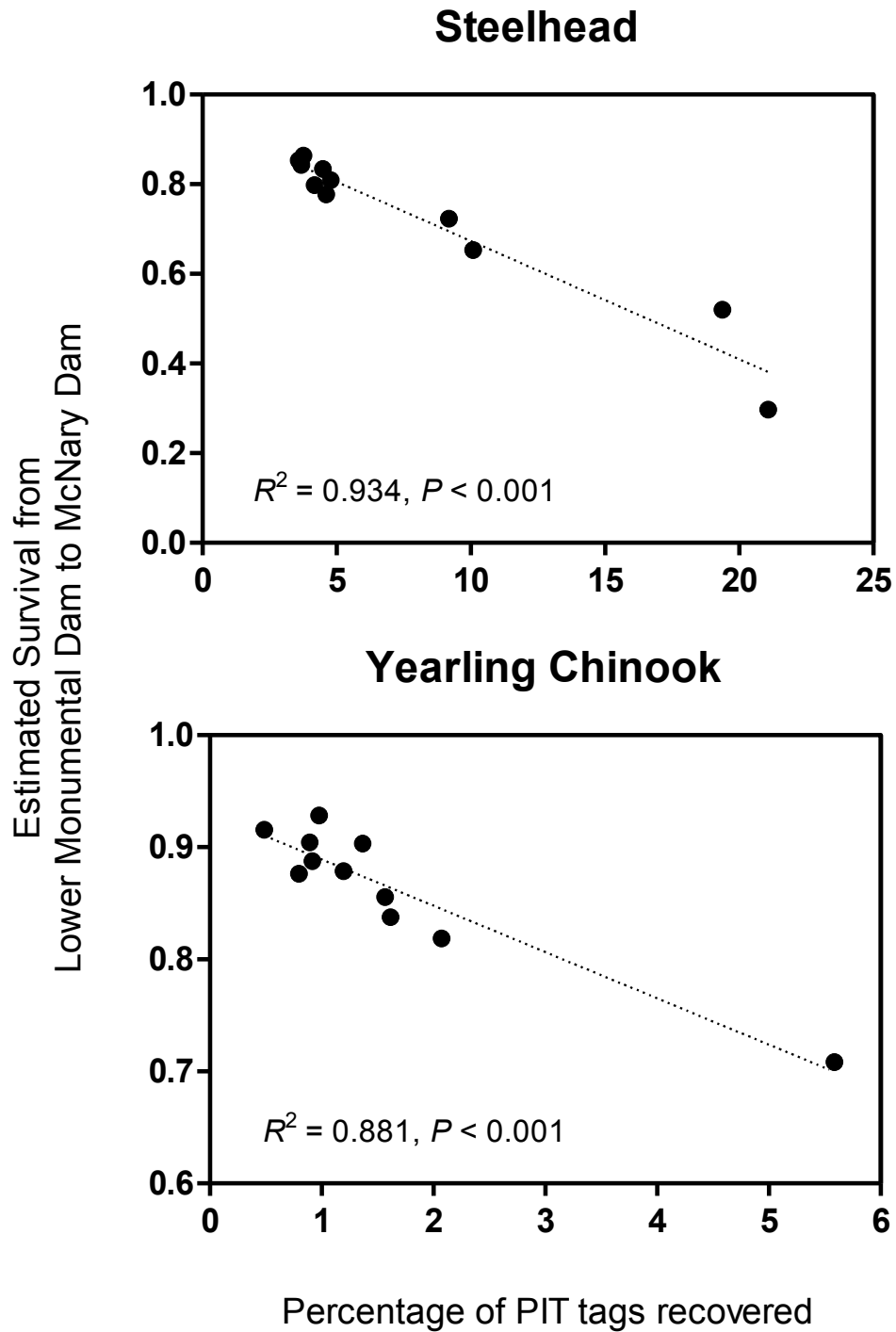


Figure 13. Estimated survival between Lower Monumental and McNary Dams versus percentage of Lower Monumental Dam-detected PIT tags recovered on bird colonies, 1998-2009 (excluding 2003, which had incomplete recovery effort).



## RECOMMENDATIONS

- 1) Coordination of future survival studies with other projects should continue in order to maximize the data-collection effort and minimize study effects on salmonid resources.
- 2) Estimates of survival from hatcheries to Lower Granite Dam suggest that substantial mortality occurs upstream from the Snake and Clearwater River confluence. Efforts to identify where this mortality occurs should continue.
- 3) Increasing the number of detection facilities in the Columbia River Basin will improve survival investigations. We recommend installation of detectors and diversion systems at The Dalles Dam and upper Columbia River dams. Although there is now a PIT-tag detection system in the juvenile bypass facility at Ice Harbor Dam, because of the high rate of spill, too few fish are detected for survival estimation in some years. Development of flat-plate and full-flow detector technology in bypass systems and other suitable locations at dams (including spillways), as well as portable streambed flat-plate detectors for use in tributaries, would greatly enhance knowledge of juvenile salmonid survival.

## TABLES



Table 1. Estimated survival probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
30 Mar–05 Apr	446	0.798 (0.040)	1.107 (0.119)	0.959 (0.152)	0.848 (0.105)
06 Apr–12 Apr	1,969	0.863 (0.019)	0.990 (0.048)	0.834 (0.056)	0.713 (0.037)
13 Apr–19 Apr	4,125	0.872 (0.014)	0.982 (0.028)	0.922 (0.040)	0.789 (0.029)
20 Apr–26 Apr	14,248	0.951 (0.008)	0.965 (0.019)	0.882 (0.021)	0.810 (0.013)
27 Apr–03 May	28,380	0.945 (0.007)	0.987 (0.014)	0.834 (0.014)	0.778 (0.010)
04 May–10 May	25,753	0.962 (0.011)	0.961 (0.024)	0.838 (0.022)	0.776 (0.011)
11 May–17 May	20,457	0.973 (0.012)	1.032 (0.027)	0.810 (0.025)	0.814 (0.017)
18 May–24 May	7,430	0.928 (0.012)	1.064 (0.037)	0.886 (0.058)	0.875 (0.049)
25 May–31 May	1,046	0.919 (0.033)	0.965 (0.073)	1.021 (0.176)	0.905 (0.144)
01 Jun–07 Jun	235	0.893 (0.062)	0.948 (0.160)	1.172 (0.406)	0.992 (0.308)
<b>Weighted mean*</b>		<b>0.940 (0.006)</b>	<b>0.982 (0.009)</b>	<b>0.855 (0.011)</b>	<b>0.787 (0.007)</b>

\* Weighted means of the independent estimates for daily groups (25 March –31 May), with weights inversely proportional to respective estimated relative variances (see Table 5).

Table 2. Estimated survival probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses. .

Date at McNary	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
20 Apr–26 Apr	1,646	1.105 (0.108)	0.613 (0.139)	0.677 (0.138)
27 Apr–03 May	5,072	0.869 (0.052)	1.107 (0.180)	0.962 (0.146)
04 May–10 May	25,980	0.976 (0.050)	0.766 (0.067)	0.748 (0.052)
11 May–17 May	43,488	0.857 (0.033)	0.788 (0.052)	0.675 (0.036)
18 May–24 May	31,900	0.756 (0.034)	0.869 (0.076)	0.657 (0.049)
25 May–31 May	4,189	0.731 (0.101)	0.964 (0.285)	0.705 (0.185)
<b>Weighted mean*</b>		<b>0.866 (0.042)</b>	<b>0.821 (0.043)</b>	<b>0.705 (0.031)</b>

\* Weighted means of the independent estimates for weekly pooled groups (20 April–31 May), with weights inversely proportional to respective estimated relative variances.

Table 3. Estimated survival probabilities for Snake River hatchery yearling Chinook salmon detected and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

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
30 Mar–05 Apr	265	0.801 (0.066)	1.307 (0.251)	0.677 (0.160)	0.708 (0.108)
06 Apr–12 Apr	936	0.885 (0.038)	1.035 (0.104)	0.774 (0.100)	0.709 (0.065)
13 Apr–19 Apr	2,617	0.883 (0.021)	0.965 (0.042)	0.928 (0.054)	0.791 (0.037)
20 Apr–26 Apr	10,729	0.950 (0.010)	0.990 (0.025)	0.861 (0.026)	0.810 (0.016)
27 Apr–03 May	22,519	0.944 (0.008)	0.998 (0.017)	0.833 (0.017)	0.785 (0.012)
04 May–10 May	20,423	0.962 (0.013)	0.951 (0.028)	0.869 (0.027)	0.794 (0.013)
11 May–17 May	18,248	0.977 (0.014)	1.020 (0.029)	0.824 (0.027)	0.821 (0.018)
18 May–24 May	5,092	0.944 (0.018)	1.007 (0.049)	0.890 (0.073)	0.846 (0.058)
25 May–31 May	263	0.876 (0.071)	1.727 (0.532)	0.690 (0.407)	1.044 (0.527)
01 Jun–07 Jun	118	0.888 (0.082)	1.100 (0.261)	0.698 (0.282)	0.682 (0.231)
<b>Weighted mean*</b>		<b>0.948 (0.008)</b>	<b>0.995 (0.013)</b>	<b>0.848 (0.010)</b>	<b>0.798 (0.006)</b>

\* Weighted means of the independent estimates for weekly pooled groups (30 March–07 June), with weights inversely proportional to respective estimated relative variances.

Table 4. Estimated survival probabilities for Snake River wild yearling Chinook salmon detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

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
30 Mar–05 Apr	181	0.821 (0.049)	0.969 (0.116)	1.363 (0.319)	1.084 (0.229)
06 Apr–12 Apr	1,033	0.872 (0.022)	0.985 (0.052)	0.847 (0.066)	0.728 (0.046)
13 Apr–19 Apr	1,508	0.880 (0.018)	0.988 (0.038)	0.896 (0.058)	0.779 (0.044)
20 Apr–26 Apr	3,519	0.964 (0.013)	0.914 (0.029)	0.922 (0.037)	0.813 (0.024)
27 Apr–03 May	5,861	0.967 (0.012)	0.949 (0.022)	0.824 (0.026)	0.756 (0.020)
04 May–10 May	5,330	0.973 (0.019)	0.969 (0.043)	0.757 (0.036)	0.714 (0.020)
11 May–17 May	2,209	0.989 (0.027)	1.050 (0.060)	0.732 (0.056)	0.760 (0.043)
18 May–24 May	2,338	0.956 (0.015)	1.101 (0.053)	0.877 (0.095)	0.924 (0.090)
25 May–31 May	783	0.931 (0.037)	0.916 (0.070)	1.067 (0.190)	0.910 (0.152)
01 Jun–07 Jun	117	0.897 (0.093)	0.760 (0.176)	2.568 (1.696)	1.751 (1.106)
<b>Weighted mean*</b>		<b>0.949 (0.012)</b>	<b>0.968 (0.017)</b>	<b>0.847 (0.031)</b>	<b>0.765 (0.018)</b>

\* Weighted means of the independent estimates for weekly pooled groups (30 March–07 June), with weights inversely proportional to respective estimated relative variances.

Table 5. Estimated survival probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled as necessary to calculate estimates. Estimates based on the single-release model. Standard errors in parentheses. Abbreviations: LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; MCN–McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
25 Mar–01 Apr	81	0.757 (0.094)	0.958 (0.261)	0.757 (0.236)	0.549 (0.111)
02 Apr	80	0.779 (0.071)	1.264 (0.287)	0.765 (0.245)	0.753 (0.171)
03 Apr	85	1.031 (0.181)	0.689 (0.183)	1.406 (0.591)	0.998 (0.388)
04 Apr	103	0.799 (0.064)	1.179 (0.209)	2.152 (0.977)	2.028 (0.852)
05 Apr	101	0.733 (0.096)	1.577 (0.563)	0.513 (0.218)	0.593 (0.148)
06 Apr	126	0.801 (0.083)	1.214 (0.390)	0.877 (0.486)	0.853 (0.393)
07 Apr	105	0.796 (0.068)	0.865 (0.127)	0.830 (0.178)	0.572 (0.108)
08 Apr	366	0.902 (0.044)	0.888 (0.090)	0.816 (0.109)	0.654 (0.067)
09 Apr	519	0.856 (0.033)	0.979 (0.077)	0.843 (0.092)	0.706 (0.061)
10 Apr	164	0.900 (0.070)	1.129 (0.234)	0.699 (0.205)	0.710 (0.156)
11 Apr	341	0.876 (0.050)	1.087 (0.141)	0.824 (0.148)	0.784 (0.106)
12 Apr	348	0.849 (0.052)	1.064 (0.143)	0.935 (0.187)	0.844 (0.134)
13 Apr	340	0.893 (0.047)	0.983 (0.101)	1.085 (0.171)	0.953 (0.125)
14 Apr	397	0.811 (0.047)	1.115 (0.144)	0.810 (0.141)	0.732 (0.093)
15 Apr	830	0.843 (0.030)	1.009 (0.066)	0.866 (0.090)	0.737 (0.065)
16 Apr	705	0.846 (0.028)	0.992 (0.061)	0.815 (0.076)	0.683 (0.053)
17 Apr	533	0.886 (0.039)	0.922 (0.065)	1.058 (0.110)	0.865 (0.078)
18 Apr	640	0.903 (0.036)	0.945 (0.071)	1.013 (0.124)	0.864 (0.091)
19 Apr	680	0.926 (0.038)	0.967 (0.074)	0.906 (0.096)	0.810 (0.069)
20 Apr	775	0.899 (0.026)	1.066 (0.067)	0.741 (0.062)	0.710 (0.043)
21 Apr	805	0.922 (0.029)	0.972 (0.058)	1.005 (0.092)	0.901 (0.069)
22 Apr	1,249	0.878 (0.024)	0.906 (0.046)	0.915 (0.059)	0.727 (0.037)
23 Apr	1,641	0.988 (0.025)	0.899 (0.046)	0.878 (0.055)	0.779 (0.035)
24 Apr	2,455	0.970 (0.020)	0.931 (0.045)	0.935 (0.055)	0.845 (0.034)
25 Apr	5,021	0.957 (0.014)	0.978 (0.039)	0.861 (0.039)	0.806 (0.022)
26 Apr	2,302	0.969 (0.023)	1.051 (0.067)	0.834 (0.061)	0.849 (0.036)
27 Apr	1,896	0.985 (0.032)	0.915 (0.062)	0.881 (0.066)	0.794 (0.038)
28 Apr	5,862	0.981 (0.017)	0.915 (0.031)	0.912 (0.038)	0.819 (0.025)
29 Apr	2,691	0.947 (0.022)	1.041 (0.053)	0.772 (0.047)	0.761 (0.031)

Table 5. Continued.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
30 Apr	9,681	0.940 (0.012)	0.990 (0.022)	0.824 (0.024)	0.767 (0.017)
01 May	1,373	0.897 (0.024)	0.980 (0.045)	0.832 (0.055)	0.731 (0.040)
02 May	6,204	0.918 (0.014)	1.035 (0.029)	0.818 (0.030)	0.776 (0.021)
03 May	673	0.988 (0.057)	1.014 (0.104)	0.736 (0.090)	0.737 (0.066)
04 May	705	0.988 (0.065)	0.947 (0.142)	0.876 (0.148)	0.820 (0.087)
05 May	8,193	0.972 (0.019)	0.947 (0.044)	0.864 (0.043)	0.795 (0.021)
06 May	2,225	0.933 (0.036)	1.039 (0.097)	0.748 (0.072)	0.726 (0.033)
07 May	6,921	0.979 (0.024)	0.991 (0.052)	0.787 (0.042)	0.763 (0.020)
08 May	1,687	0.941 (0.041)	0.880 (0.069)	0.933 (0.082)	0.773 (0.047)
09 May	5,768	0.950 (0.020)	0.956 (0.043)	0.860 (0.042)	0.781 (0.022)
10 May	254	0.976 (0.120)	1.065 (0.281)	0.788 (0.213)	0.818 (0.113)
11 May	375	1.128 (0.114)	0.776 (0.168)	1.049 (0.233)	0.918 (0.109)
12 May	5,232	1.008 (0.029)	1.111 (0.075)	0.722 (0.051)	0.809 (0.028)
13 May	1,660	1.010 (0.063)	1.242 (0.179)	0.609 (0.087)	0.764 (0.042)
14 May	5,754	0.931 (0.031)	1.074 (0.065)	0.807 (0.053)	0.806 (0.034)
15 May	1,706	0.903 (0.031)	1.010 (0.063)	0.887 (0.085)	0.810 (0.064)
16 May	4,670	1.000 (0.019)	0.902 (0.036)	0.915 (0.053)	0.825 (0.039)
17 May	1,060	0.982 (0.038)	0.849 (0.070)	0.940 (0.122)	0.783 (0.085)
18 May	1,142	0.964 (0.044)	0.945 (0.096)	0.989 (0.147)	0.901 (0.106)
19 May	2,307	0.966 (0.030)	1.027 (0.071)	0.850 (0.092)	0.844 (0.075)
20 May	1,835	0.963 (0.026)	1.041 (0.080)	0.796 (0.111)	0.798 (0.095)
21 May	1,374	0.944 (0.020)	1.021 (0.068)	0.953 (0.160)	0.918 (0.143)
22–26 May	937	0.839 (0.020)	1.063 (0.072)	1.472 (0.408)	1.312 (0.353)
27 May	309	0.924 (0.052)	1.020 (0.132)	0.838 (0.256)	0.790 (0.222)
28 May	200	0.977 (0.078)	1.064 (0.167)	1.005 (0.313)	1.044 (0.291)
29–31 May	372	0.928 (0.072)	0.774 (0.109)	1.065 (0.303)	0.765 (0.201)
<b>Weighted mean*</b>		<b>0.940 (0.006)</b>	<b>0.982 (0.009)</b>	<b>0.855 (0.011)</b>	<b>0.787 (0.007)</b>

\* Weighted means of the independent estimates for daily groups (25 March –31 May), with weights inversely proportional to respective estimated relative variances.

Table 6. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
30 Mar–05 Apr	446	0.435 (0.032)	0.222 (0.031)	0.326 (0.047)
06 Apr–12 Apr	1,969	0.478 (0.016)	0.257 (0.016)	0.405 (0.024)
13 Apr–19 Apr	4,125	0.419 (0.010)	0.300 (0.011)	0.404 (0.017)
20 Apr–26 Apr	14,248	0.412 (0.005)	0.161 (0.004)	0.521 (0.009)
27 Apr–03 May	28,380	0.328 (0.004)	0.215 (0.004)	0.528 (0.008)
04 May–10 May	25,753	0.231 (0.004)	0.081 (0.002)	0.512 (0.008)
11 May–17 May	20,457	0.242 (0.004)	0.130 (0.004)	0.388 (0.009)
18 May–24 May	7,430	0.489 (0.008)	0.257 (0.010)	0.192 (0.012)
25 May–31 May	1,046	0.437 (0.022)	0.325 (0.027)	0.116 (0.021)
01 Jun–07 Jun	235	0.514 (0.048)	0.272 (0.053)	0.167 (0.058)

Table 7. Estimated detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
20 Apr–26 Apr	1,646	0.236 (0.025)	0.184 (0.039)
27 Apr–03 May	5,072	0.199 (0.013)	0.146 (0.023)
04 May–10 May	25,980	0.074 (0.004)	0.165 (0.012)
11 May–17 May	43,488	0.069 (0.003)	0.214 (0.012)
18 May–24 May	31,900	0.083 (0.004)	0.187 (0.014)
25 May–31 May	4,189	0.081 (0.012)	0.150 (0.040)

Table 8. Estimated detection probabilities for Snake River hatchery yearling Chinook salmon detected and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
30 Mar–05 Apr	265	0.339 (0.042)	0.170 (0.038)	0.354 (0.063)
06 Apr–12 Apr	936	0.400 (0.024)	0.177 (0.021)	0.346 (0.036)
13 Apr–19 Apr	2,617	0.359 (0.013)	0.250 (0.013)	0.381 (0.020)
20 Apr–26 Apr	10,729	0.381 (0.006)	0.144 (0.005)	0.511 (0.011)
27 Apr–03 May	22,519	0.302 (0.004)	0.191 (0.004)	0.519 (0.008)
04 May–10 May	20,423	0.207 (0.004)	0.070 (0.003)	0.502 (0.009)
11 May–17 May	18,248	0.228 (0.004)	0.119 (0.004)	0.386 (0.009)
18 May–24 May	5,092	0.420 (0.011)	0.221 (0.012)	0.201 (0.015)
25 May–31 May	263	0.456 (0.048)	0.134 (0.044)	0.067 (0.037)
01 Jun–07 Jun	118	0.506 (0.066)	0.286 (0.076)	0.217 (0.086)



Table 9. Estimated detection probabilities for Snake River wild yearling Chinook Salmon detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
30 Mar–05 Apr	181	0.559 (0.049)	0.282 (0.049)	0.287 (0.069)
06 Apr–12 Apr	1,033	0.535 (0.020)	0.316 (0.022)	0.449 (0.032)
13 Apr–19 Apr	1,508	0.510 (0.016)	0.384 (0.019)	0.448 (0.029)
20 Apr–26 Apr	3,519	0.502 (0.011)	0.212 (0.010)	0.548 (0.018)
27 Apr–03 May	5,861	0.420 (0.008)	0.305 (0.009)	0.560 (0.016)
04 May–10 May	5,330	0.318 (0.009)	0.122 (0.007)	0.546 (0.017)
11 May–17 May	2,209	0.343 (0.014)	0.220 (0.014)	0.398 (0.025)
18 May–24 May	2,338	0.605 (0.014)	0.328 (0.018)	0.176 (0.019)
25 May–31 May	783	0.432 (0.025)	0.373 (0.031)	0.128 (0.025)
01 Jun–07 Jun	117	0.524 (0.071)	0.263 (0.073)	0.105 (0.070)

Table 10. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

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
06 Apr–12 Apr	858	0.917 (0.024)	0.916 (0.057)	0.786 (0.078)	0.660 (0.055)
13 Apr–19 Apr	6,267	0.957 (0.010)	0.959 (0.019)	0.862 (0.035)	0.791 (0.029)
20 Apr–26 Apr	31,566	0.993 (0.006)	0.926 (0.011)	0.869 (0.017)	0.799 (0.014)
27 Apr–03 May	12,833	0.956 (0.010)	0.935 (0.023)	0.949 (0.035)	0.848 (0.025)
04 May–10 May	10,791	0.946 (0.014)	0.984 (0.032)	0.800 (0.034)	0.745 (0.024)
11 May–17 May	8,485	0.965 (0.014)	0.990 (0.030)	0.913 (0.043)	0.872 (0.034)
18 May–24 May	7,052	1.011 (0.012)	0.945 (0.027)	0.684 (0.042)	0.654 (0.037)
25 May–31 May	4,501	0.974 (0.012)	0.915 (0.030)	0.736 (0.072)	0.656 (0.061)
01 Jun–07 Jun	2,235	0.989 (0.014)	0.952 (0.040)	0.657 (0.070)	0.619 (0.061)
08 Jun–14 Jun	1,554	0.934 (0.039)	0.923 (0.094)	0.559 (0.087)	0.482 (0.060)
<b>Weighted mean*</b>		<b>0.972 (0.005)</b>	<b>0.942 (0.008)</b>	<b>0.863 (0.014)</b>	<b>0.790 (0.013)</b>

\* Weighted means of the independent estimates for daily groups (28 March–31 May), with weights inversely proportional to respective estimated relative variances (see Table 14).

Table 11. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at McNary Dam	Number released	McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
20 Apr–26 Apr	1,867	1.044 (0.095)	0.799 (0.257)	0.834 (0.257)
27 Apr–03 May	6,077	0.903 (0.053)	0.947 (0.143)	0.855 (0.119)
04 May–10 May	6,371	0.971 (0.058)	0.742 (0.098)	0.721 (0.085)
11 May–17 May	5,187	1.014 (0.077)	0.956 (0.163)	0.969 (0.148)
18 May–24 May	5,387	0.942 (0.082)	1.568 (0.467)	1.478 (0.421)
25 May–31 May	1,282	0.874 (0.192)	0.931 (0.475)	0.814 (0.375)
01 Jun–07 Jun	465	0.707 (0.111)	0.546 (0.275)	0.386 (0.185)
08 Jun–14 Jun	349	0.865 (0.210)	0.790 (0.511)	0.684 (0.410)
<b>Weighted mean*</b>		<b>0.951 (0.026)</b>	<b>0.900 (0.079)</b>	<b>0.856 (0.074)</b>

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

Table 12. Estimated survival probabilities for juvenile Snake River hatchery steelhead detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

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
06 Apr–12 Apr	670	0.913 (0.028)	0.876 (0.062)	0.834 (0.098)	0.668 (0.068)
13 Apr–19 Apr	5,572	0.964 (0.010)	0.957 (0.020)	0.864 (0.038)	0.797 (0.032)
20 Apr–26 Apr	28,675	0.994 (0.006)	0.922 (0.011)	0.858 (0.018)	0.786 (0.014)
27 Apr–03 May	10,288	0.952 (0.012)	0.933 (0.026)	0.937 (0.039)	0.833 (0.028)
04 May–10 May	8,598	0.943 (0.016)	0.979 (0.035)	0.799 (0.039)	0.738 (0.028)
11 May–17 May	5,286	0.971 (0.019)	0.976 (0.037)	0.908 (0.056)	0.861 (0.045)
18 May–24 May	4,063	1.022 (0.017)	0.952 (0.037)	0.709 (0.060)	0.689 (0.053)
25 May–31 May	1,595	0.958 (0.021)	0.947 (0.052)	0.742 (0.117)	0.673 (0.100)
01 Jun–07 Jun	1,125	0.990 (0.022)	0.964 (0.059)	0.710 (0.112)	0.677 (0.100)
08 Jun–14 Jun	701	0.992 (0.063)	0.916 (0.144)	0.464 (0.096)	0.422 (0.060)
<b>Weighted mean*</b>		<b>0.979 (0.008)</b>	<b>0.938 (0.007)</b>	<b>0.857 (0.019)</b>	<b>0.784 (0.017)</b>

\* Weighted means of the independent estimates for weekly pooled groups (06 April –14 June), with weights inversely proportional to respective estimated relative variances.

Table 13. Estimated survival probabilities for juvenile Snake River wild steelhead detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite	Number released	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Lower Granite to McNary Dam
06 Apr–12 Apr	188	0.932 (0.045)	1.062 (0.142)	0.665 (0.128)	0.658 (0.095)
13 Apr–19 Apr	695	0.904 (0.028)	0.963 (0.059)	0.860 (0.092)	0.748 (0.070)
20 Apr–26 Apr	2,891	0.988 (0.017)	0.956 (0.039)	0.901 (0.058)	0.851 (0.045)
27 Apr–03 May	2,450	0.973 (0.026)	0.935 (0.052)	0.891 (0.070)	0.811 (0.050)
04 May–10 May	2,193	0.959 (0.027)	0.984 (0.068)	0.771 (0.068)	0.728 (0.044)
11 May–17 May	3,199	0.956 (0.020)	0.996 (0.049)	0.863 (0.062)	0.822 (0.046)
18 May–24 May	2,989	0.999 (0.018)	0.935 (0.039)	0.649 (0.059)	0.606 (0.050)
25 May–31 May	2,906	0.982 (0.015)	0.896 (0.037)	0.728 (0.091)	0.640 (0.076)
01 Jun–07 Jun	1,110	0.989 (0.017)	0.937 (0.054)	0.609 (0.088)	0.564 (0.075)
08 Jun–14 Jun	853	0.888 (0.049)	0.918 (0.121)	0.759 (0.200)	0.619 (0.145)
<b>Weighted mean*</b>		<b>0.975 (0.008)</b>	<b>0.946 (0.011)</b>	<b>0.815 (0.032)</b>	<b>0.763 (0.029)</b>

\* Weighted means of the independent estimates for weekly pooled groups (06 April–14 June), with weights inversely proportional to respective estimated relative variances.

Table 14. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled as necessary to calculate estimates. Estimates based on the single-release model. Standard errors in parentheses. Abbreviations: LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; MCN–McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
28 Mar–08 Apr	357	0.915 (0.039)	0.871 (0.078)	0.805 (0.119)	0.642 (0.083)
09 Apr	263	0.911 (0.039)	0.965 (0.103)	0.716 (0.112)	0.630 (0.078)
10–11 Apr	137	0.992 (0.072)	0.826 (0.137)	0.868 (0.237)	0.711 (0.167)
12 Apr	139	0.881 (0.064)	0.966 (0.187)	0.703 (0.204)	0.599 (0.138)
13 Apr	276	0.966 (0.058)	0.900 (0.155)	0.609 (0.141)	0.530 (0.089)
14 Apr	370	0.941 (0.050)	0.820 (0.087)	0.890 (0.162)	0.687 (0.111)
15 Apr	1,563	0.920 (0.021)	0.933 (0.044)	0.922 (0.080)	0.791 (0.060)
16 Apr	1,474	0.956 (0.019)	1.008 (0.043)	0.907 (0.079)	0.874 (0.069)
17 Apr	500	0.964 (0.032)	0.949 (0.062)	0.801 (0.114)	0.733 (0.096)
18 Apr	817	0.985 (0.025)	0.972 (0.048)	0.767 (0.086)	0.735 (0.076)
19 Apr	1,267	0.970 (0.017)	0.991 (0.033)	0.871 (0.071)	0.838 (0.064)
20 Apr	1,968	0.952 (0.017)	1.009 (0.032)	0.784 (0.054)	0.753 (0.048)
21 Apr	2,998	0.977 (0.019)	0.987 (0.031)	0.901 (0.055)	0.869 (0.049)
22 Apr	5,150	0.968 (0.015)	0.899 (0.023)	0.835 (0.037)	0.726 (0.030)
23 Apr	6,841	1.037 (0.012)	0.907 (0.022)	0.822 (0.034)	0.773 (0.027)
24 Apr	5,978	0.975 (0.012)	0.922 (0.027)	0.907 (0.044)	0.814 (0.033)
25 Apr	5,512	0.984 (0.016)	0.918 (0.032)	0.910 (0.046)	0.822 (0.033)
26 Apr	3,119	0.949 (0.020)	0.967 (0.057)	0.981 (0.082)	0.901 (0.056)
27 Apr	2,061	0.924 (0.024)	0.904 (0.062)	0.983 (0.095)	0.821 (0.059)
28 Apr	1,261	0.956 (0.036)	0.892 (0.084)	1.028 (0.134)	0.877 (0.087)
29 Apr	2,831	0.973 (0.025)	0.957 (0.058)	0.965 (0.082)	0.899 (0.059)
30 Apr	2,638	0.941 (0.021)	0.904 (0.048)	0.878 (0.065)	0.746 (0.042)
01 May	1,837	0.946 (0.028)	0.953 (0.056)	1.062 (0.111)	0.957 (0.087)
02 May	1,816	0.975 (0.028)	0.913 (0.046)	0.952 (0.087)	0.847 (0.070)
03 May	389	1.006 (0.058)	0.961 (0.106)	0.862 (0.173)	0.832 (0.148)
04 May	389	0.917 (0.053)	1.026 (0.120)	0.714 (0.141)	0.672 (0.113)
05 May	1,342	0.911 (0.025)	0.952 (0.060)	0.971 (0.117)	0.842 (0.090)
06 May	1,661	0.915 (0.029)	1.101 (0.085)	0.775 (0.088)	0.780 (0.069)

Table 14. Continued.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
07 May	1,869	1.057 (0.050)	0.920 (0.088)	0.697 (0.077)	0.678 (0.049)
08 May	2,382	0.982 (0.035)	0.857 (0.068)	0.904 (0.089)	0.761 (0.052)
09 May	2,328	0.962 (0.030)	0.956 (0.068)	0.832 (0.077)	0.766 (0.051)
10 May	820	0.924 (0.048)	1.107 (0.137)	0.637 (0.098)	0.651 (0.068)
11 May	607	0.949 (0.047)	0.978 (0.109)	1.194 (0.225)	1.107 (0.178)
12 May	1,775	0.965 (0.029)	1.067 (0.080)	0.853 (0.088)	0.878 (0.066)
13 May	1,812	1.010 (0.033)	0.978 (0.067)	0.940 (0.095)	0.929 (0.076)
14 May	1,161	1.017 (0.046)	0.872 (0.070)	1.142 (0.157)	1.012 (0.122)
15 May	1,273	0.929 (0.041)	1.022 (0.090)	0.872 (0.117)	0.828 (0.090)
16 May	920	0.871 (0.035)	1.026 (0.075)	0.743 (0.089)	0.664 (0.068)
17 May	937	0.986 (0.031)	0.859 (0.060)	0.792 (0.110)	0.671 (0.084)
18 May	575	1.014 (0.057)	0.918 (0.102)	0.905 (0.217)	0.842 (0.186)
19 May	1,543	1.094 (0.047)	0.854 (0.058)	0.741 (0.081)	0.692 (0.067)
20 May	1,883	1.091 (0.036)	0.919 (0.057)	0.685 (0.077)	0.687 (0.068)
21 May	1,496	0.981 (0.016)	0.879 (0.054)	0.700 (0.119)	0.603 (0.096)
22 May	1,555	0.953 (0.015)	1.015 (0.055)	0.593 (0.087)	0.573 (0.078)
23 May	1,475	0.970 (0.019)	0.876 (0.047)	0.896 (0.172)	0.761 (0.142)
24 May	1,243	0.972 (0.025)	0.947 (0.065)	0.569 (0.102)	0.524 (0.088)
25–27 May	963	0.988 (0.024)	0.938 (0.067)	0.654 (0.136)	0.606 (0.119)
28 May	820	0.970 (0.036)	0.884 (0.067)	0.683 (0.131)	0.586 (0.106)
29 May	1,869	1.057 (0.050)	0.920 (0.088)	0.697 (0.077)	0.678 (0.049)
30–31 May	2,382	0.982 (0.035)	0.857 (0.068)	0.904 (0.089)	0.761 (0.052)
<b>Weighted mean*</b>		<b>0.972 (0.005)</b>	<b>0.942 (0.008)</b>	<b>0.863 (0.014)</b>	<b>0.790 (0.013)</b>

\* Weighted means of the independent estimates for daily groups (28 March–31 May), with weights inversely proportional to respective estimated relative variances.

Table 15. Estimated detection probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Little Goose Dam	Lower Monumental Dam	McNary Dam
06 Apr–12 Apr	858	0.599 (0.023)	0.354 (0.027)	0.312 (0.032)
13 Apr–19 Apr	6267	0.493 (0.008)	0.433 (0.010)	0.215 (0.010)
20 Apr–26 Apr	31,566	0.423 (0.004)	0.326 (0.004)	0.227 (0.005)
27 Apr–03 May	12,833	0.408 (0.006)	0.222 (0.006)	0.229 (0.008)
04 May–10 May	10,791	0.361 (0.007)	0.183 (0.006)	0.254 (0.009)
11 May–17 May	8,485	0.366 (0.007)	0.236 (0.008)	0.253 (0.011)
18 May–24 May	7,052	0.467 (0.008)	0.404 (0.012)	0.197 (0.012)
25 May–31 May	4,501	0.556 (0.010)	0.468 (0.016)	0.112 (0.012)
01 Jun–07 Jun	2,235	0.639 (0.014)	0.459 (0.021)	0.147 (0.017)
08 Jun–14 Jun	1,554	0.400 (0.021)	0.246 (0.026)	0.229 (0.032)



Table 16. Estimated detection probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at McNary Dam	Number released	John Day Dam	Bonneville Dam
20 Apr–26 Apr	1,867	0.209 (0.021)	0.222 (0.069)
27 Apr–03 May	6,077	0.169 (0.011)	0.190 (0.027)
04 May–10 May	6,371	0.156 (0.010)	0.235 (0.028)
11 May–17 May	5,187	0.118 (0.010)	0.179 (0.028)
18 May–24 May	5,387	0.118 (0.011)	0.091 (0.026)
25 May–31 May	1,282	0.104 (0.024)	0.123 (0.058)
01 Jun–07 Jun	465	0.386 (0.065)	0.273 (0.134)
08 Jun–14 Jun	349	0.172 (0.047)	0.253 (0.154)

Table 17. Estimated detection probabilities for juvenile Snake River hatchery steelhead detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Lower		
		Little Goose Dam	Monumental Dam	McNary Dam
06 Apr–12 Apr	670	0.592 (0.026)	0.368 (0.031)	0.290 (0.036)
13 Apr–19 Apr	5,572	0.492 (0.008)	0.438 (0.011)	0.206 (0.010)
20 Apr–26 Apr	28,675	0.416 (0.004)	0.333 (0.005)	0.220 (0.005)
27 Apr–03 May	10,288	0.417 (0.007)	0.226 (0.007)	0.211 (0.008)
04 May–10 May	8,598	0.352 (0.008)	0.191 (0.008)	0.230 (0.010)
11 May–17 May	5,286	0.336 (0.009)	0.258 (0.010)	0.209 (0.012)
18 May–24 May	4,063	0.454 (0.011)	0.390 (0.016)	0.179 (0.016)
25 May–31 May	1,595	0.532 (0.017)	0.442 (0.026)	0.102 (0.018)
01 Jun–07 Jun	1,125	0.588 (0.020)	0.438 (0.029)	0.126 (0.022)
08 Jun–14 Jun	701	0.384 (0.031)	0.219 (0.036)	0.280 (0.046)

Table 18. Estimated detection probabilities for juvenile Snake River wild steelhead detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Lower		
		Little Goose Dam	Monumental Dam	McNary Dam
06 Apr–12 Apr	188	0.622 (0.046)	0.312 (0.053)	0.383 (0.068)
13 Apr–19 Apr	695	0.508 (0.025)	0.393 (0.029)	0.295 (0.034)
20 Apr–26 Apr	2,891	0.488 (0.012)	0.261 (0.013)	0.307 (0.018)
27 Apr–03 May	2,450	0.371 (0.014)	0.206 (0.013)	0.325 (0.022)
04 May–10 May	2,193	0.396 (0.015)	0.157 (0.013)	0.364 (0.024)
11 May–17 May	3,199	0.414 (0.012)	0.203 (0.012)	0.348 (0.022)
18 May–24 May	2,989	0.484 (0.012)	0.422 (0.018)	0.224 (0.021)
25 May–31 May	2,906	0.569 (0.013)	0.484 (0.021)	0.119 (0.016)
01 Jun–07 Jun	1,110	0.689 (0.018)	0.482 (0.031)	0.172 (0.027)
08 Jun–14 Jun	853	0.414 (0.029)	0.273 (0.037)	0.168 (0.042)

Table 19. Estimated survival probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2009. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Release to McNary Dam
<b>Clearwater Hatchery</b>						
Clear Creek	11,549	0.799 (0.013)	0.939 (0.022)	1.109 (0.040)	0.913 (0.038)	0.759 (0.021)
Crooked River	15,080	0.369 (0.010)	0.885 (0.036)	1.043 (0.066)	0.885 (0.063)	0.301 (0.014)
Powell Pond (3/23)	5,989	0.628 (0.020)	0.983 (0.052)	0.914 (0.066)	0.962 (0.070)	0.542 (0.024)
Powell Pond (4/1)	5,992	0.626 (0.018)	0.939 (0.044)	1.113 (0.084)	0.885 (0.072)	0.579 (0.028)
Red River Pond	15,086	0.360 (0.009)	1.011 (0.045)	1.013 (0.077)	0.782 (0.067)	0.289 (0.015)
Selway River	14,943	0.718 (0.010)	0.975 (0.020)	1.030 (0.034)	0.909 (0.034)	0.656 (0.016)
<b>Dworshak Hatchery</b>						
NF Clearwater River	50,829	0.696 (0.007)	0.959 (0.016)	0.989 (0.025)	0.825 (0.023)	0.544 (0.010)
<b>Kooskia Hatchery</b>						
Kooskia Hatchery	9,888	0.633 (0.012)	0.876 (0.024)	1.060 (0.051)	0.776 (0.045)	0.456 (0.017)
<b>Lookingglass Hatchery</b>						
Catherine Creek Pond	20,840	0.371 (0.006)	0.975 (0.029)	1.030 (0.054)	0.801 (0.049)	0.298 (0.012)
Grande Ronde Pond	1,481	0.444 (0.022)	0.919 (0.063)	1.107 (0.156)	0.653 (0.116)	0.295 (0.036)
Imnaha River	4,166	0.536 (0.016)	0.997 (0.052)	0.838 (0.062)	1.077 (0.092)	0.483 (0.032)
Imnaha Weir	16,697	0.699 (0.009)	0.949 (0.024)	1.060 (0.049)	0.789 (0.041)	0.555 (0.017)
Lookingglass Hatchery	1,483	0.730 (0.024)	0.968 (0.053)	0.964 (0.090)	0.840 (0.092)	0.572 (0.043)
Lostine Pond (3/18)	3,949	0.485 (0.015)	0.913 (0.040)	1.231 (0.104)	0.716 (0.072)	0.391 (0.026)

Table 19. 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
<b>Lookingglass Hatchery (cont.)</b>						
Lostine Pond (4/11)	3,977	0.686 (0.014)	0.955 (0.031)	1.084 (0.067)	0.775 (0.071)	0.550 (0.040)
<b>McCall Hatchery</b>						
Johnson Creek	2,094	0.309 (0.019)	0.868 (0.060)	1.040 (0.120)	1.172 (0.284)	0.326 (0.072)
Knox Bridge	51,488	0.513 (0.005)	0.974 (0.017)	1.094 (0.034)	0.757 (0.025)	0.414 (0.008)
<b>Pahsimeroi Hatchery</b>						
Pahsimeroi Pond	18,738	0.510 (0.006)	0.950 (0.016)	1.028 (0.028)	0.870 (0.028)	0.433 (0.010)
<b>Rapid River Hatchery</b>						
Rapid River H.	51,778	0.728 (0.005)	0.984 (0.013)	1.041 (0.023)	0.847 (0.021)	0.631 (0.010)
<b>Sawtooth Hatchery</b>						
Sawtooth H.	18,671	0.367 (0.007)	0.976 (0.032)	1.074 (0.063)	0.801 (0.049)	0.308 (0.010)

Table 20. Estimated survival probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2009. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Release to Lower Granite Dam	Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Monumental to McNary Dam	Release to McNary Dam
<b>Clearwater Hatchery</b>						
S.F. Clearwater (rkm 31)	7,089	0.939 (0.008)	0.996 (0.016)	0.940 (0.025)	0.857 (0.037)	0.754 (0.028)
S.F. Clearwater (rkm 62)	7,151	0.890 (0.008)	1.021 (0.020)	0.856 (0.027)	0.864 (0.044)	0.672 (0.030)
Crooked River	1,987	0.574 (0.024)	1.012 (0.082)	1.044 (0.177)	0.682 (0.177)	0.414 (0.082)
Lolo Creek	1,398	0.713 (0.027)	1.187 (0.090)	0.861 (0.114)	0.802 (0.147)	0.584 (0.083)
Red River Pond	3,570	0.719 (0.013)	1.028 (0.032)	0.900 (0.054)	0.792 (0.074)	0.528 (0.040)
<b>Dworshak Hatchery</b>						
S.F. Clearwater	9,203	0.814 (0.007)	0.991 (0.015)	0.900 (0.023)	0.855 (0.039)	0.620 (0.025)
Dworshak NFH	19,109	0.838 (0.004)	0.975 (0.008)	0.952 (0.014)	0.820 (0.022)	0.638 (0.016)
<b>Hagerman Hatchery</b>						
Little Salmon (3/30-4/3)	3,566	0.902 (0.010)	1.010 (0.022)	0.917 (0.037)	0.845 (0.058)	0.707 (0.042)
Little Salmon (4/6-4/10)	6,380	0.875 (0.008)	1.005 (0.018)	0.914 (0.033)	0.816 (0.050)	0.655 (0.034)
East Fork Salmon R.	4,288	0.792 (0.013)	0.956 (0.030)	0.999 (0.070)	0.798 (0.086)	0.604 (0.052)
Sawtooth Trap (4/17-4/23)	2,748	0.854 (0.026)	0.920 (0.057)	1.091 (0.117)	0.756 (0.106)	0.649 (0.063)
Sawtooth Trap (4/28-5/4)	4,904	0.834 (0.015)	0.954 (0.032)	1.021 (0.068)	0.790 (0.074)	0.641 (0.045)
Yankee Fork	3,034	0.719 (0.017)	0.997 (0.041)	0.967 (0.076)	0.732 (0.127)	0.507 (0.079)

Table 20. 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
<b>Irrigon Hatchery</b>						
Big Canyon Fac. (4/16)	4,891	0.828 (0.014)	0.978 (0.030)	0.950 (0.050)	0.928 (0.082)	0.714 (0.053)
Big Canyon Fac. (4/28)	4,815	0.820 (0.024)	0.913 (0.046)	1.093 (0.092)	0.741 (0.090)	0.606 (0.056)
Big Sheep Creek	4,860	0.786 (0.012)	1.028 (0.031)	0.891 (0.050)	0.831 (0.082)	0.598 (0.051)
Little Sheep Facility	15,990	0.800 (0.007)	0.983 (0.018)	0.937 (0.029)	0.874 (0.046)	0.644 (0.029)
Wallowa H. (4/12)	8,261	0.816 (0.010)	0.992 (0.023)	0.900 (0.034)	0.930 (0.060)	0.677 (0.038)
Wallowa H. (4/25)	3,558	0.827 (0.023)	0.986 (0.052)	0.934 (0.085)	0.788 (0.098)	0.600 (0.056)
<b>Lyons Ferry Hatchery</b>						
Cottonwood Pond	5,999	0.724 (0.012)	1.016 (0.030)	0.980 (0.049)	0.822 (0.068)	0.593 (0.041)
<b>Magic Valley Hatchery</b>						
E. F. Salmon (rkm 01)	4,148	0.812 (0.012)	0.997 (0.030)	0.914 (0.055)	0.831 (0.075)	0.615 (0.044)
E. F. Salmon (rkm 29)	1,296	0.716 (0.032)	0.959 (0.074)	1.188 (0.220)	0.707 (0.232)	0.577 (0.154)
Little Salmon R.	4,174	0.808 (0.010)	1.017 (0.023)	0.892 (0.037)	0.941 (0.074)	0.689 (0.048)
Pahsimeroi R. Trap	595	0.704 (0.025)	1.134 (0.073)	0.861 (0.091)	1.282 (0.260)	0.881 (0.164)
Salmon R. (rkm 347)	1,788	0.864 (0.015)	0.947 (0.030)	0.996 (0.062)	0.908 (0.099)	0.740 (0.070)
Salmon R. (rkm 385)	2,378	0.782 (0.013)	0.983 (0.028)	0.967 (0.051)	0.972 (0.093)	0.722 (0.060)
Salmon R. (rkm 476)	2,382	0.828 (0.015)	0.971 (0.032)	0.938 (0.056)	0.783 (0.072)	0.590 (0.045)
Salmon R. (rkm 506)	2,388	0.846 (0.014)	0.964 (0.029)	0.940 (0.058)	0.898 (0.086)	0.689 (0.053)
Salmon R. (rkm 547)	1,192	0.844 (0.020)	1.029 (0.048)	0.818 (0.067)	1.144 (0.153)	0.812 (0.093)
Slate Creek	1,627	0.783 (0.027)	1.094 (0.091)	0.931 (0.147)	0.711 (0.136)	0.567 (0.073)
Squaw Creek	12,293	0.733 (0.009)	0.967 (0.023)	0.960 (0.041)	0.760 (0.048)	0.517 (0.026)

Table 20. 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
<b>Magic Valley Hatchery (cont.)</b>						
Valley Creek	1,196	0.764 (0.030)	1.020 (0.078)	1.150 (0.184)	0.682 (0.154)	0.611 (0.098)
Yankee Fork	1,940	0.779 (0.027)	0.877 (0.050)	0.904 (0.074)	0.572 (0.088)	0.353 (0.047)
<b>Niagara Springs Hatchery</b>						
Hells Canyon Dam (3/24)	3,433	0.890 (0.015)	0.962 (0.031)	0.954 (0.056)	0.826 (0.082)	0.676 (0.056)
Hells Canyon Dam (3/31)	3,967	0.886 (0.014)	1.023 (0.032)	0.836 (0.045)	1.032 (0.102)	0.783 (0.068)
Little Salmon R.	6,756	0.916 (0.009)	0.982 (0.019)	0.935 (0.034)	0.930 (0.057)	0.783 (0.041)
Pahsimeroi Trap (4/14-4/20)	5,158	0.902 (0.015)	0.972 (0.033)	0.938 (0.058)	0.874 (0.078)	0.719 (0.050)
Pahsimeroi Trap (4/23-4/29)	5,150	0.881 (0.018)	0.945 (0.040)	0.981 (0.071)	0.859 (0.093)	0.701 (0.060)

Table 21. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2009. 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.

Release site	Release date	Number released	Release to LGR	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN	Release to MCN
<b>Oxbow Hatchery</b>								
Redfish L. Cr. Trap	07 May 09	10,890	0.289 (0.020)	1.044 (0.135)	0.912 (0.174)	0.649 (0.147)	0.618 (0.108)	0.179 (0.028)
<b>Sawtooth Hatchery</b>								
Alturus Lake	06 Oct 08	977	0.183 (0.019)	0.951 (0.100)	0.996 (0.166)	0.742 (0.213)	0.703 (0.181)	0.129 (0.033)
Pettit Lake	06 Oct 08	1,005	0.370 (0.028)	0.896 (0.076)	0.918 (0.134)	1.006 (0.376)	0.827 (0.294)	0.306 (0.108)
Redfish Lake	07 Oct 08	1,006	0.096 (0.016)	0.800 (0.150)	0.630 (0.131)	2.984 (2.745)	1.506 (1.392)	0.144 (0.132)
Sawtooth Trap	07 May 09	52,551	0.467 (0.006)	0.937 (0.020)	0.905 (0.029)	0.875 (0.046)	0.742 (0.034)	0.347 (0.015)



Table 22. Estimated detection probabilities for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries in 2009. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
<b>Clearwater Hatchery</b>					
Clear Creek	11,549	0.230 (0.006)	0.257 (0.006)	0.115 (0.005)	0.416 (0.012)
Crooked River	15,080	0.267 (0.009)	0.276 (0.010)	0.134 (0.009)	0.392 (0.019)
Powell Pond (3/23)	5,989	0.239 (0.010)	0.211 (0.011)	0.107 (0.009)	0.443 (0.021)
Powell Pond (4/1)	5,992	0.256 (0.010)	0.237 (0.011)	0.106 (0.009)	0.410 (0.021)
Red River Pond	15,086	0.293 (0.009)	0.272 (0.012)	0.150 (0.011)	0.338 (0.019)
Selway River	14,943	0.230 (0.006)	0.257 (0.006)	0.115 (0.005)	0.416 (0.012)
<b>Dworshak Hatchery</b>					
NF Clearwater River	50,829	0.251 (0.003)	0.268 (0.004)	0.129 (0.004)	0.410 (0.008)
<b>Kooskia Hatchery</b>					
Kooskia Hatchery	9,888	0.314 (0.008)	0.363 (0.010)	0.149 (0.008)	0.478 (0.019)
<b>Lookingglass Hatchery</b>					
Catherine Creek Pond	20,840	0.355 (0.008)	0.335 (0.010)	0.176 (0.010)	0.393 (0.017)
Grande Ronde Pond	1,481	0.380 (0.024)	0.375 (0.029)	0.153 (0.024)	0.354 (0.047)
Imnaha River	4,166	0.331 (0.013)	0.262 (0.015)	0.171 (0.014)	0.398 (0.028)
Imnaha Weir	16,697	0.384 (0.006)	0.304 (0.008)	0.142 (0.007)	0.415 (0.014)

Table 22. Continued.

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
<b>Lookingglass Hatchery (cont.)</b>					
Lookingglass Hatchery	1,483	0.389 (0.018)	0.283 (0.019)	0.152 (0.017)	0.421 (0.035)
Lostine Pond (3/18)	3,949	0.312 (0.014)	0.282 (0.014)	0.117 (0.011)	0.414 (0.029)
Lostine Pond (4/11)	3,977	0.376 (0.012)	0.370 (0.014)	0.197 (0.013)	0.264 (0.021)
<b>McCall Hatchery</b>					
Johnson Creek	2,094	0.252 (0.021)	0.468 (0.030)	0.236 (0.031)	0.180 (0.042)
Knox Bridge	51,488	0.286 (0.004)	0.263 (0.005)	0.111 (0.004)	0.463 (0.009)
<b>Pahsimeroi Hatchery</b>					
Pahsimeroi Pond	18,738	0.338 (0.006)	0.290 (0.006)	0.162 (0.006)	0.458 (0.011)
<b>Rapid River Hatchery</b>					
Rapid River H.	51,778	0.360 (0.003)	0.272 (0.004)	0.136 (0.003)	0.440 (0.007)
<b>Sawtooth Hatchery</b>					
Sawtooth H.	18,671	0.300 (0.008)	0.260 (0.009)	0.095 (0.006)	0.502 (0.017)

Table 23. Estimated detection probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2009. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
<b>Clearwater Hatchery</b>					
S.F. Clearwater (rkm 31)	7,089	0.508 (0.007)	0.379 (0.008)	0.342 (0.010)	0.235 (0.011)
S.F. Clearwater (rkm 62)	7,151	0.491 (0.008)	0.386 (0.009)	0.343 (0.011)	0.226 (0.012)
Crooked River	1,987	0.396 (0.021)	0.383 (0.029)	0.245 (0.040)	0.203 (0.044)
Lolo Creek	1,398	0.372 (0.020)	0.357 (0.028)	0.269 (0.034)	0.256 (0.041)
Red River Pond	3,570	0.456 (0.012)	0.427 (0.015)	0.301 (0.019)	0.242 (0.022)
<b>Dworshak Hatchery</b>					
S.F. Clearwater	9,203	0.527 (0.007)	0.407 (0.008)	0.371 (0.010)	0.217 (0.010)
Dworshak NFH	19,109	0.520 (0.004)	0.432 (0.005)	0.429 (0.007)	0.246 (0.007)
<b>Hagerman Hatchery</b>					
Little Salmon (3/30-4/3)	3,566	0.561 (0.010)	0.432 (0.012)	0.324 (0.014)	0.205 (0.015)
Little Salmon (4/6-4/10)	6,380	0.536 (0.008)	0.458 (0.010)	0.314 (0.012)	0.197 (0.012)
East Fork Salmon R.	4,288	0.454 (0.011)	0.427 (0.014)	0.218 (0.016)	0.154 (0.015)
Sawtooth Trap (4/17-4/23)	2,748	0.399 (0.015)	0.311 (0.019)	0.232 (0.024)	0.229 (0.025)
Sawtooth Trap (4/28-5/4)	4,904	0.416 (0.010)	0.382 (0.013)	0.215 (0.015)	0.204 (0.017)
Yankee Fork	3,034	0.422 (0.014)	0.493 (0.019)	0.417 (0.032)	0.131 (0.024)

Table 23. Continued

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
<b>Irrigon Hatchery</b>					
Big Canyon Fac. (4/16)	4,891	0.410 (0.010)	0.359 (0.012)	0.282 (0.015)	0.164 (0.014)
Big Canyon Fac. (4/28)	4,815	0.311 (0.012)	0.341 (0.015)	0.235 (0.019)	0.162 (0.017)
Big Sheep Creek	4,860	0.482 (0.010)	0.368 (0.013)	0.295 (0.016)	0.153 (0.015)
Little Sheep Facility	15,990	0.422 (0.006)	0.373 (0.007)	0.305 (0.009)	0.161 (0.008)
Wallowa H. (4/12)	8,261	0.423 (0.008)	0.350 (0.009)	0.284 (0.011)	0.147 (0.010)
Wallowa H. (4/25)	3,558	0.351 (0.013)	0.309 (0.016)	0.205 (0.018)	0.168 (0.018)
<b>Lyons Ferry Hatchery</b>					
Cottonwood Pond	5,999	0.380 (0.009)	0.365 (0.012)	0.301 (0.015)	0.179 (0.014)
<b>Magic Valley Hatchery</b>					
E. F. Salmon (rkm 01)	4,148	0.469 (0.011)	0.425 (0.014)	0.271 (0.017)	0.226 (0.019)
E. F. Salmon (rkm 29)	1,296	0.357 (0.022)	0.460 (0.032)	0.255 (0.047)	0.141 (0.041)
Little Salmon R.	4,174	0.533 (0.010)	0.466 (0.013)	0.380 (0.017)	0.213 (0.018)
Pahsimeroi R. Trap	595	0.518 (0.027)	0.342 (0.031)	0.318 (0.036)	0.155 (0.033)
Salmon R. (rkm 347)	1,788	0.543 (0.015)	0.448 (0.018)	0.291 (0.020)	0.195 (0.022)
Salmon R. (rkm 385)	2,378	0.541 (0.013)	0.443 (0.016)	0.315 (0.019)	0.191 (0.019)
Salmon R. (rkm 476)	2,382	0.500 (0.014)	0.425 (0.017)	0.302 (0.020)	0.226 (0.021)
Salmon R. (rkm 506)	2,388	0.511 (0.013)	0.460 (0.017)	0.245 (0.017)	0.219 (0.020)
Salmon R. (rkm 547)	1,192	0.520 (0.019)	0.390 (0.023)	0.285 (0.026)	0.206 (0.028)
Slate Creek	1,627	0.432 (0.020)	0.338 (0.028)	0.202 (0.030)	0.241 (0.036)
Squaw Creek	12,293	0.411 (0.007)	0.409 (0.010)	0.303 (0.013)	0.231 (0.013)

Table 23. Continued

Release site	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
<b>Magic Valley Hatchery (cont.)</b>					
Valley Creek	1,196	0.416 (0.022)	0.396 (0.029)	0.232 (0.038)	0.207 (0.038)
Yankee Fork	1,940	0.383 (0.018)	0.495 (0.023)	0.500 (0.038)	0.198 (0.034)
<b>Niagara Springs Hatchery</b>					
Hells Canyon Dam (3/24)	3,433	0.440 (0.011)	0.441 (0.015)	0.321 (0.019)	0.181 (0.018)
Hells Canyon Dam (3/31)	3,967	0.420 (0.010)	0.420 (0.014)	0.325 (0.018)	0.151 (0.016)
Little Salmon R.	6,756	0.487 (0.008)	0.424 (0.010)	0.294 (0.011)	0.180 (0.011)
Pahsimeroi Trap (4/14-4/20)	5,158	0.413 (0.010)	0.346 (0.012)	0.228 (0.014)	0.171 (0.014)
Pahsimeroi Trap (4/23-4/29)	5,150	0.399 (0.011)	0.354 (0.014)	0.268 (0.018)	0.179 (0.018)

Table 24. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Snake River Basin hatcheries released for migration year 2009. Estimates based on the single-release model. Standard errors in parentheses.

Release site	Release date	Number released	Lower Granite	Little Goose	Lower Monumental	McNary
<b>Oxbow Hatchery</b>						
Redfish L. Cr. Trap	07 May 09	10,890	0.197 (0.015)	0.163 (0.018)	0.146 (0.023)	0.094 (0.017)
<b>Sawtooth Hatchery</b>						
Alturus Lake	06 Oct 08	977	0.241 (0.037)	0.506 (0.051)	0.317 (0.060)	0.209 (0.062)
Pettit Lake	06 Oct 08	1,005	0.245 (0.027)	0.540 (0.040)	0.332 (0.052)	0.109 (0.042)
Redfish Lake	07 Oct 08	1,006	0.281 (0.060)	0.506 (0.083)	0.522 (0.104)	0.077 (0.074)
Sawtooth Trap	07 May 09	52,551	0.260 (0.004)	0.341 (0.006)	0.293 (0.008)	0.168 (0.008)

Table 25. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2009. 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
<b>Wild Chinook Salmon</b>							
American River	01 Apr-31 May	159	0.446 (0.106)	1.018 (0.404)	0.619 (0.334)	0.875 (0.568)	0.246 (0.128)
Catherine Creek	23 Feb-11 May	490	0.491 (0.061)	0.713 (0.117)	1.179 (0.278)	1.113 (0.437)	0.459 (0.149)
Clearwater	13 Mar-02 Apr	194	1.001 (0.098)	0.621 (0.081)	1.318 (0.262)	0.580 (0.151)	0.475 (0.077)
E. Fork Salmon	18 Mar-15 May	223	0.536 (0.065)	0.910 (0.147)	0.779 (0.169)	0.953 (0.244)	0.362 (0.077)
Grande Ronde	09 Mar-28 May	3,463	0.904 (0.013)	0.966 (0.024)	1.016 (0.047)	0.826 (0.052)	0.732 (0.034)
Imnaha	26 Feb-21 May	5,909	0.858 (0.010)	0.920 (0.015)	0.979 (0.028)	0.890 (0.036)	0.688 (0.023)
Johnson Creek	03 Mar-15 May	638	0.529 (0.029)	0.902 (0.054)	1.149 (0.131)	1.282 (0.388)	0.703 (0.200)
Knox Bridge	26 Feb-17 Apr	1,462	0.621 (0.022)	0.964 (0.053)	0.930 (0.094)	0.922 (0.138)	0.514 (0.062)
Lostine River	03 Mar-08 May	596	0.679 (0.038)	0.850 (0.068)	0.882 (0.099)	1.149 (0.222)	0.585 (0.100)
Marsh Creek	23 Mar-30 May	239	0.461 (0.040)	1.164 (0.142)	0.964 (0.269)	1.304 (0.842)	0.674 (0.399)
Minam	03 Mar-17 May	415	0.612 (0.041)	0.894 (0.079)	1.193 (0.213)	0.740 (0.206)	0.483 (0.108)
Pahsimeroi	03 Mar-31 May	374	0.491 (0.054)	0.879 (0.152)	0.679 (0.131)	1.618 (0.454)	0.474 (0.125)
Salmon	17 Mar-17 May	3,689	0.881 (0.010)	0.950 (0.018)	1.023 (0.038)	0.845 (0.041)	0.724 (0.025)
Sawtooth	22 Mar-18 May	1,208	0.626 (0.031)	0.880 (0.061)	1.085 (0.136)	0.979 (0.210)	0.586 (0.103)
Snake	24 Mar-20 May	3,818	0.940 (0.012)	0.960 (0.023)	0.885 (0.035)	0.885 (0.042)	0.706 (0.025)
<b>Wild Sockeye Salmon</b>							
Alturas Lake Cr	08 May-23 May	115	0.509 (0.104)	0.757 (0.160)	0.831 (0.149)	0.883 (0.466)	0.283 (0.148)
Pettit Lake Cr	07 May-18 May	96	0.372 (0.076)	1.007 (0.243)	0.833 (0.369)	NA	NA
Redfish Lake Cr	17 Apr-16 Jun	487	0.267 (0.053)	0.702 (0.160)	1.221 (0.508)	0.906 (0.893)	0.207 (0.187)

Table 25. Continued.

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
<b>Wild Steelhead</b>							
Catherine Creek	03 Mar-12 May	317	0.413 (0.040)	0.941 (0.134)	0.656 (0.150)	1.564 (0.662)	0.399 (0.158)
Crooked Fork Cr	28 Mar-06 May	110	0.688 (0.061)	1.023 (0.138)	1.036 (0.320)	1.655 (1.101)	1.206 (0.723)
Grande Ronde	20 Mar-05 May	1,209	0.927 (0.019)	0.994 (0.040)	0.967 (0.072)	0.778 (0.084)	0.694 (0.060)
Imnaha	26 Feb-31 May	4,973	0.876 (0.013)	0.979 (0.027)	0.982 (0.048)	0.696 (0.054)	0.586 (0.037)
Lemhi River Weir	21 Mar-31 May	638	0.136 (0.020)	0.943 (0.203)	1.400 (0.760)	NA	NA
Lostine River	19 Feb-17 May	570	0.307 (0.027)	0.965 (0.097)	1.169 (0.245)	0.463 (0.158)	0.160 (0.044)
Minam River	24 Feb-18 May	269	0.520 (0.046)	0.961 (0.114)	0.932 (0.243)	0.601 (0.216)	0.280 (0.075)
Pahsimeroi	03 Mar- 31 May	428	0.220 (0.060)	0.641 (0.214)	1.418 (0.697)	0.308 (0.282)	0.061 (0.046)
Rapid River	11 Mar-20 May	206	0.717 (0.062)	1.083 (0.174)	1.255 (0.733)	0.557 (0.564)	0.542 (0.445)
Salmon	02 Apr-17 May	182	0.867 (0.046)	0.984 (0.098)	0.891 (0.180)	1.173 (0.479)	0.892 (0.329)
Sawtooth	22 Mar-18 May	261	0.268 (0.037)	0.820 (0.117)	1.829 (1.035)	0.353 (0.228)	0.142 (0.042)
Snake	24 Mar-20 May	1,219	0.981 (0.019)	0.952 (0.036)	0.891 (0.062)	0.921 (0.100)	0.766 (0.070)
Spoolcart*	05 Mar-04 May	532	0.538 (0.034)	0.962 (0.085)	0.981 (0.174)	0.535 (0.138)	0.272 (0.055)
<b>Hatchery Chinook Salmon</b>							
Grande Ronde	10 Mar-20 Apr	1,401	0.780 (0.031)	0.894 (0.052)	1.129 (0.116)	0.873 (0.113)	0.687 (0.062)
Salmon	17 Mar-17 May	4,367	0.800 (0.017)	0.942 (0.031)	1.077 (0.064)	0.779 (0.053)	0.633 (0.027)
Snake	24 Mar-20 May	4,058	0.982 (0.018)	0.959 (0.029)	0.982 (0.046)	0.847 (0.050)	0.783 (0.034)
<b>Hatchery Sockeye Salmon</b>							
Alturas Lake Cr	13 May-23 May	162	0.782 (0.104)	0.807 (0.132)	0.938 (0.191)	1.632 (1.510)	0.965 (0.879)
Redfish Lake Cr	14 Apr-21 Jun	591	0.391 (0.028)	1.017 (0.080)	1.053 (0.168)	0.517 (0.119)	0.216 (0.040)
<b>Hatchery Steelhead</b>							
Grande Ronde	22 Mar-29 Apr	3,602	0.932 (0.012)	1.006 (0.025)	0.978 (0.042)	0.850 (0.065)	0.778 (0.052)
Salmon	02 Apr-17 May	1,567	0.871 (0.019)	0.990 (0.040)	0.976 (0.072)	0.872 (0.102)	0.735 (0.072)
Snake	28 Mar-20 May	3,290	1.011 (0.013)	0.963 (0.024)	0.919 (0.038)	0.815 (0.055)	0.730 (0.042)

\* Grande Ronde River



Table 26. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2009. 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
<b>Wild Chinook Salmon</b>						
American River	01 Apr-31 May	159	0.282 (0.082)	0.397 (0.131)	0.385 (0.163)	0.400 (0.219)
Catherine Creek	23 Feb-11 May	490	0.299 (0.045)	0.453 (0.055)	0.213 (0.058)	0.266 (0.093)
Clearwater	13 Mar-02 Apr	194	0.330 (0.047)	0.548 (0.055)	0.248 (0.061)	0.517 (0.093)
E. Fork Salmon	18 Mar-15 May	223	0.318 (0.054)	0.514 (0.073)	0.343 (0.084)	0.474 (0.114)
Grande Ronde	09 Mar-28 May	3,463	0.429 (0.010)	0.462 (0.013)	0.249 (0.014)	0.483 (0.025)
Imnaha	26 Feb-21 May	5,909	0.438 (0.008)	0.478 (0.010)	0.279 (0.010)	0.475 (0.017)
Johnson Creek	03 Mar-15 May	638	0.361 (0.030)	0.564 (0.036)	0.315 (0.043)	0.182 (0.055)
Knox Bridge	26 Feb-17 Apr	1,462	0.404 (0.020)	0.505 (0.028)	0.310 (0.034)	0.342 (0.047)
Lostine River	03 Mar-08 May	596	0.403 (0.031)	0.484 (0.038)	0.320 (0.043)	0.327 (0.062)
Marsh Creek	23 Mar-30 May	239	0.354 (0.049)	0.495 (0.074)	0.370 (0.104)	0.133 (0.088)
Minam	03 Mar-17 May	415	0.390 (0.037)	0.502 (0.046)	0.248 (0.051)	0.328 (0.081)
Pahsimeroi	03 Mar-31 May	374	0.381 (0.052)	0.386 (0.062)	0.258 (0.060)	0.320 (0.093)
Salmon	17 Mar-17 May	3,689	0.467 (0.010)	0.476 (0.012)	0.239 (0.012)	0.534 (0.021)
Sawtooth	22 Mar-18 May	1,208	0.348 (0.023)	0.561 (0.030)	0.287 (0.040)	0.221 (0.044)
Snake	24 Mar-20 May	3,818	0.444 (0.010)	0.440 (0.012)	0.255 (0.012)	0.560 (0.022)
<b>Wild Sockeye Salmon</b>						
Alturas Lake Cr	08 May-23 May	115	0.205 (0.065)	0.655 (0.088)	0.625 (0.121)	0.400 (0.219)
Pettit Lake Cr	07 May-18 May	96	0.308 (0.090)	0.500 (0.125)	0.300 (0.145)	NA
Redfish Lake Cr	17 Apr-16 Jun	487	0.185 (0.048)	0.493 (0.080)	0.218 (0.096)	0.111 (0.105)

Table 26. Continued.

Trap	Release dates	Number released	Lower Granite Dam	Little Goose Dam	Lower Monumental Dam	McNary Dam
<b>Wild Steelhead</b>						
Catherine Creek	03 Mar-12 May	317	0.451 (0.054)	0.477 (0.073)	0.305 (0.078)	0.219 (0.096)
Crooked Fork Cr	28 Mar-06 May	110	0.515 (0.066)	0.500 (0.085)	0.228 (0.086)	0.143 (0.094)
Grande Ronde	20 Mar-05 May	1,209	0.491 (0.018)	0.400 (0.020)	0.250 (0.021)	0.361 (0.035)
Imnaha	26 Feb-31 May	4,973	0.408 (0.009)	0.421 (0.012)	0.329 (0.016)	0.276 (0.020)
Lemhi River Weir	21 Mar-31 May	638	0.403 (0.068)	0.444 (0.096)	0.302 (0.161)	NA
Lostine River	19 Feb-17 May	570	0.371 (0.043)	0.498 (0.054)	0.355 (0.080)	0.292 (0.093)
Minam River	24 Feb-18 May	269	0.400 (0.049)	0.545 (0.067)	0.273 (0.079)	0.333 (0.103)
Pahsimeroi	03 Mar- 31 May	428	0.255 (0.079)	0.649 (0.088)	0.395 (0.204)	0.250 (0.216)
Rapid River	11 Mar-20 May	206	0.433 (0.052)	0.574 (0.084)	0.181 (0.109)	0.265 (0.224)
Salmon	02 Apr-17 May	182	0.558 (0.047)	0.470 (0.058)	0.269 (0.062)	0.192 (0.077)
Sawtooth	22 Mar-18 May	261	0.429 (0.071)	0.690 (0.084)	0.130 (0.084)	0.500 (0.158)
Snake	24 Mar-20 May	1,219	0.487 (0.017)	0.460 (0.021)	0.266 (0.021)	0.285 (0.030)
Spoolcart*	05 Mar-04 May	532	0.419 (0.035)	0.453 (0.044)	0.292 (0.055)	0.277 (0.065)
<b>Hatchery Chinook Salmon</b>						
Grande Ronde	10 Mar-20 Apr	1,401	0.296 (0.018)	0.286 (0.019)	0.130 (0.016)	0.384 (0.038)
Salmon	17 Mar-17 May	4,367	0.313 (0.010)	0.276 (0.011)	0.120 (0.008)	0.423 (0.020)
Snake	24 Mar-20 May	4,058	0.309 (0.009)	0.288 (0.010)	0.173 (0.009)	0.405 (0.019)
<b>Hatchery Sockeye Salmon</b>						
Alturas Lake Cr	13 May-23 May	162	0.237 (0.048)	0.454 (0.065)	0.467 (0.098)	0.053 (0.051)
Redfish Lake Cr	14 Apr-21 Jun	591	0.346 (0.036)	0.477 (0.044)	0.310 (0.054)	0.367 (0.074)
<b>Hatchery Steelhead</b>						
Grande Ronde	22 Mar-29 Apr	3,602	0.494 (0.010)	0.358 (0.011)	0.292 (0.014)	0.173 (0.014)
Salmon	02 Apr-17 May	1,567	0.475 (0.016)	0.369 (0.018)	0.246 (0.020)	0.210 (0.024)
Snake	28 Mar-20 May	3,290	0.438 (0.010)	0.405 (0.012)	0.312 (0.014)	0.215 (0.015)

\* Grande Ronde River

Table 27. Estimated survival probabilities for PIT-tagged yearling Chinook salmon and steelhead from upper-Columbia River hatcheries released in 2009. Estimates based on the single-release model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Hatchery	Release site	Number released	Release to MCN	MCN to JDA	JDA to BON	MCN to BON	Rel to BON
<b>Yearling Chinook Salmon</b>							
Cle Elum	Clark Flat Pond	15,999	0.437 (0.012)	0.811 (0.056)	1.347 (0.314)	1.092 (0.247)	0.477 (0.107)
Cle Elum	Easton Pond	12,010	0.384 (0.013)	0.854 (0.070)	0.869 (0.198)	0.742 (0.161)	0.285 (0.061)
Cle Elum	Jack Creek Pond	12,001	0.348 (0.013)	0.834 (0.075)	1.774 (0.650)	1.480 (0.531)	0.514 (0.184)
East Bank	Chelan River	19,936	0.632 (0.026)	0.922 (0.090)	2.327 (0.830)	2.145 (0.745)	1.355 (0.468)
East Bank	Chiwawa Pond	10,025	0.435 (0.020)	0.916 (0.101)	0.858 (0.205)	0.786 (0.174)	0.342 (0.074)
Leavenworth	Leavenworth NFH	14,905	0.478 (0.020)	0.814 (0.062)	0.835 (0.168)	0.680 (0.132)	0.325 (0.062)
Wells	Wells Hatchery	5,978	0.277 (0.039)	0.983 (0.316)	0.542 (0.289)	0.533 (0.250)	0.148 (0.066)
Winthrop	Winthrop NFH	1,998	0.372 (0.043)	0.795 (0.224)	0.484 (0.202)	0.385 (0.133)	0.143 (0.047)
<b>Steelhead</b>							
Chelan	Chiwawa River	1,457	0.522 (0.087)	1.015 (0.296)	0.733 (0.505)	0.744 (0.496)	0.388 (0.251)
Chelan	Nason Creek	7,951	0.500 (0.038)	0.700 (0.077)	1.096 (0.313)	0.767 (0.218)	0.384 (0.105)
East Bank	Chiwawa River	2,008	0.564 (0.081)	0.769 (0.176)	0.591 (0.280)	0.454 (0.210)	0.256 (0.113)
East Bank	Wenatchee R. (3/27)	5,933	0.515 (0.048)	0.798 (0.122)	0.970 (0.339)	0.774 (0.264)	0.398 (0.131)
East Bank	Wenatchee R. (5/6)	11,227	0.534 (0.030)	0.869 (0.084)	0.831 (0.186)	0.722 (0.156)	0.386 (0.081)
Winthrop	Winthrop NFH	4,997	0.267 (0.034)	0.969 (0.230)	1.229 (0.717)	1.191 (0.669)	0.318 (0.174)

Table 27. Continued.

Hatchery	Release Site	Number released	Release to MCN	MCN to JDA	JDA to BON	MCN to BON	Rel to BON
<b>Coho Salmon</b>							
Cascade	Butcher Creek Pond	2,861	0.432 (0.052)	0.853 (0.138)	0.912 (0.581)	0.778 (0.497)	0.336 (0.211)
Cascade	Leavenworth NFH	2,995	0.461 (0.060)	1.135 (0.236)	1.234 (0.694)	1.401 (0.775)	0.646 (0.348)
Cascade	Rolfing Pond	3,000	0.446 (0.055)	0.728 (0.121)	0.612 (0.186)	0.446 (0.137)	0.199 (0.056)
Eagle Creek	Easton Pond	2,524	0.236 (0.047)	0.551 (0.147)	NA	NA	NA
Eagle Creek	Holmes Pond	1,427	0.065 (0.014)	1.504 (0.787)	0.270 (0.174)	0.407 (0.185)	0.027 (0.011)
Eagle Creek	Lost Creek Pond	2,331	0.396 (0.060)	0.652 (0.140)	NA	NA	NA
Eagle Creek	Stiles Pond	3,755	0.448 (0.038)	0.768 (0.113)	0.935 (0.383)	0.718 (0.288)	0.322 (0.126)
Entiat	Leavenworth NFH	8,929	0.440 (0.036)	0.804 (0.106)	0.672 (0.161)	0.540 (0.125)	0.238 (0.052)
Prosser	Holmes Pond	2,512	0.079 (0.014)	1.012 (0.416)	NA	NA	NA
Prosser	Lost Creek Pond	2,508	0.358 (0.045)	0.899 (0.202)	0.876 (0.483)	0.787 (0.420)	0.282 (0.147)
Prosser	Stiles Pond	2,515	0.445 (0.042)	0.790 (0.150)	1.060 (0.576)	0.838 (0.441)	0.373 (0.193)
Willard	Butcher Creek Pond	3,001	0.441 (0.084)	0.649 (0.153)	NA	NA	NA
Willard	Rolfing Pond	2,873	0.368 (0.060)	0.867 (0.191)	0.450 (0.214)	0.390 (0.187)	0.143 (0.065)
Winthrop	Winthrop NFH (4/20)	5,997	0.345 (0.036)	0.931 (0.182)	0.724 (0.282)	0.674 (0.247)	0.232 (0.082)
Winthrop	Winthrop NFH (5/1)	5,483	0.366 (0.032)	1.026 (0.201)	0.664 (0.226)	0.681 (0.206)	0.250 (0.073)

Table 28. Estimated detection probabilities for PIT-tagged yearling Chinook salmon and steelhead from upper-Columbia River hatcheries released in 2009. Estimates based on the single-release model. Standard errors in parentheses.

Hatchery	Release Site	Number released	McNary Dam	John Day Dam	Bonneville Dam
<b>Yearling Chinook Salmon</b>					
Cle Elum	Clark Flat Pond	15,999	0.380 (0.011)	0.160 (0.011)	0.127 (0.029)
Cle Elum	Easton Pond	12,010	0.363 (0.014)	0.168 (0.014)	0.193 (0.042)
Cle Elum	Jack Creek Pond	12,001	0.346 (0.014)	0.160 (0.014)	0.094 (0.034)
East Bank	Chelan River	19,936	0.197 (0.009)	0.086 (0.008)	0.037 (0.013)
East Bank	Chiwawa Pond	10,025	0.271 (0.014)	0.110 (0.012)	0.177 (0.039)
Leavenworth	Leavenworth NFH	14,905	0.206 (0.010)	0.175 (0.012)	0.181 (0.035)
Wells	Wells Hatchery	5,978	0.245 (0.047)	0.130 (0.050)	0.339 (0.194)
Winthrop	Winthrop NFH	1,998	0.147 (0.022)	0.058 (0.018)	0.177 (0.080)
<b>Steelhead</b>					
Chelan	Chiwawa River	1,457	0.132 (0.025)	0.142 (0.036)	0.144 (0.094)
Chelan	Nason Creek	7,951	0.125 (0.011)	0.202 (0.018)	0.148 (0.041)
East Bank	Chiwawa River	2,008	0.132 (0.021)	0.189 (0.036)	0.200 (0.089)
East Bank	Wenatchee R. (3/27)	5,933	0.127 (0.013)	0.152 (0.020)	0.113 (0.038)
East Bank	Wenatchee R. (5/6)	11,227	0.148 (0.009)	0.164 (0.014)	0.139 (0.030)
Winthrop	Winthrop NFH	4,997	0.142 (0.020)	0.122 (0.026)	0.079 (0.044)

Table 28. Continued.

Hatchery	Release Site	Number released	McNary Dam	John Day Dam	Bonneville Dam
<b>Coho Salmon</b>					
Cascade	Butcher Creek Pond	2,861	0.104 (0.015)	0.254 (0.031)	0.202 (0.127)
Cascade	Leavenworth NFH	2,995	0.096 (0.015)	0.113 (0.020)	0.120 (0.065)
Cascade	Rolfing Pond	3,000	0.114 (0.016)	0.223 (0.029)	0.337 (0.097)
Eagle Creek	Easton Pond	2,524	0.127 (0.029)	0.211 (0.043)	NA
Eagle Creek	Holmes Pond	1,427	0.290 (0.073)	0.115 (0.063)	0.667 (0.272)
Eagle Creek	Lost Creek Pond	2,331	0.128 (0.022)	0.218 (0.037)	NA
Eagle Creek	Stiles Pond	3,755	0.192 (0.019)	0.163 (0.022)	0.219 (0.086)
Entiat	Leavenworth NFH	8,929	0.119 (0.011)	0.128 (0.014)	0.230 (0.050)
Prosser	Holmes Pond	2,512	0.283 (0.058)	0.125 (0.052)	NA
Prosser	Lost Creek Pond	2,508	0.171 (0.025)	0.151 (0.031)	0.169 (0.089)
Prosser	Stiles Pond	2,515	0.241 (0.026)	0.142 (0.026)	0.178 (0.093)
Willard	Butcher Creek Pond	3,001	0.065 (0.014)	0.220 (0.034)	NA
Willard	Rolfing Pond	2,873	0.084 (0.016)	0.189 (0.031)	0.378 (0.172)
Winthrop	Winthrop NFH (4/20)	5,997	0.137 (0.016)	0.078 (0.014)	0.242 (0.086)
Winthrop	Winthrop NFH (5/1)	5,483	0.190 (0.018)	0.078 (0.015)	0.213 (0.063)

Table 29. Travel time statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at Lower Granite Dam in 2009. Abbreviations: LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; MCN–McNary Dam; BON–Bonneville Dam; N–Number of fish on which statistics are based; Med.–Median.

Date at Lower Granite	LGR to LGO (d)				LGO to LMO (d)				LMO to MCN (d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	155	8.7	13.8	25.8	35	1.9	2.9	4.5	22	4.2	5.4	7.8
06 Apr–12 Apr	813	5.2	8.7	18.4	203	2.0	2.8	4.2	141	4.2	5.6	8.8
13 Apr–19 Apr	1,507	4.0	5.8	10.4	471	1.6	2.1	2.7	396	3.8	5.6	9.0
20 Apr–26 Apr	5,586	2.7	3.8	5.5	739	1.5	2.0	2.6	893	3.9	4.9	6.4
27 Apr–03 May	8,796	3.5	4.5	6.0	1,740	1.5	1.8	2.3	2,362	3.6	4.5	5.8
04 May–10 May	5,720	2.4	3.0	4.2	524	1.5	1.9	2.6	785	3.3	4.1	5.3
11 May–17 May	4,819	2.4	2.8	3.5	841	1.0	1.3	1.8	731	2.4	3.0	3.7
18 May–24 May	3,373	1.5	2.4	2.9	885	1.1	1.4	1.8	272	2.4	3.0	4.0
25 May–31 May	420	1.5	2.3	2.5	121	0.9	1.2	1.6	31	2.6	3.5	6.0
01 Jun–07 Jun	108	1.5	2.3	2.5	27	0.8	1.1	1.3	9	2.1	2.6	3.1
08 Jun–14 Jun	60	1.5	2.4	2.5	8	1.1	1.6	1.9	5	2.5	3.6	4.8
15 Jun–21 Jun	16	1.4	1.6	2.5	2	1.0	1.1	1.1	0	NA	NA	NA

Date at Lower Granite	LGR to MCN (d)				LGR to BON (d)			
	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	117	19.3	28.6	36.7	30	26.6	32.4	41.4
06 Apr–12 Apr	554	14.8	23.5	31.4	140	21.9	29.6	37.3
13 Apr–19 Apr	1,289	10.2	16.2	22.7	362	15.4	22.5	29.3
20 Apr–26 Apr	5,866	9.2	11.2	14.1	1,455	14.8	17.2	21.0
27 Apr–03 May	11,177	9.1	11.0	13.6	2,709	14.4	16.6	19.4
04 May–10 May	10,035	7.6	8.9	10.7	2,419	12.0	13.4	15.4
11 May–17 May	6,351	6.3	7.0	8.2	1,872	9.8	10.8	12.1
18 May–24 May	1,159	5.5	6.4	7.9	631	8.8	9.7	11.2
25 May–31 May	106	5.9	7.0	9.1	87	8.9	10.9	12.8
01 Jun–07 Jun	37	5.1	6.0	7.7	21	9.6	10.2	11.8
08 Jun–14 Jun	56	5.8	6.8	8.1	28	9.2	10.2	11.8
15 Jun–21 Jun	20	4.7	5.7	6.9	6	9.0	9.6	11.3

Table 30. Migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at Lower Granite Dam in 2009. Abbreviations: LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; MCN–McNary Dam; BON–Bonneville Dam; N–Number of fish observed; Med–Median.

Date at Lower Granite	LGR to LGO (km/d)				LGO to LMO (km/d)				LMO to MCN (km/d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	155	2.3	4.3	6.9	35	10.3	15.6	24.2	22	15.3	21.9	28.0
06 Apr–12 Apr	813	3.3	6.9	11.6	203	10.8	16.4	23.4	141	13.6	21.1	28.2
13 Apr–19 Apr	1,507	5.8	10.4	15.2	471	16.8	22.1	27.9	396	13.2	21.4	31.1
20 Apr–26 Apr	5,586	11.0	15.8	21.9	739	17.6	23.2	29.9	893	18.7	24.1	30.5
27 Apr–03 May	8,796	10.1	13.5	17.4	1,740	20.2	25.0	31.5	2,362	20.6	26.4	32.8
04 May–10 May	5,720	14.1	20.1	25.2	524	17.8	24.6	30.9	785	22.5	28.7	36.0
11 May–17 May	4,819	17.0	21.6	24.8	841	25.3	34.3	45.5	731	32.3	39.1	49.2
18 May–24 May	3,373	21.0	25.4	39.7	885	25.3	32.9	42.2	272	29.7	39.7	48.8
25 May–31 May	420	24.2	26.1	41.1	121	29.5	38.0	48.9	31	19.8	33.9	46.1
01 Jun–07 Jun	108	23.6	25.8	40.8	27	36.2	43.8	56.8	9	37.9	44.9	56.9
08 Jun–14 Jun	60	23.6	25.1	41.1	8	23.7	29.3	41.8	5	25.1	32.9	48.4
15 Jun–21 Jun	16	23.7	38.5	41.7	2	40.7	43.4	46.0	0	NA	NA	NA

Date at Lower Granite	LGR to MCN (km/d)				LGR to BON (km/d)			
	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	117	6.1	7.9	11.6	30	11.1	14.2	17.4
06 Apr–12 Apr	554	7.2	9.6	15.2	140	12.4	15.6	21.0
13 Apr–19 Apr	1,289	9.9	13.9	22.0	362	15.7	20.5	29.9
20 Apr–26 Apr	5,866	15.9	20.1	24.4	1,455	21.9	26.8	31.2
27 Apr–03 May	11,177	16.5	20.5	24.7	2,709	23.8	27.7	32.0
04 May–10 May	10,035	21.0	25.1	29.6	2,419	30.0	34.5	38.4
11 May–17 May	6,351	27.5	31.9	35.8	1,872	38.0	42.8	47.0
18 May–24 May	1,159	28.3	35.2	40.6	631	41.3	47.4	52.3
25 May–31 May	106	24.8	32.1	38.2	87	36.0	42.3	51.9
01 Jun–07 Jun	37	29.4	37.4	44.4	21	38.9	45.2	47.8
08 Jun–14 Jun	56	27.7	32.9	38.6	28	39.0	45.2	50.2
15 Jun–21 Jun	20	32.6	39.8	48.4	6	40.8	48.3	51.3



Table 31. Travel time statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2009. Abbreviations: N=number of fish on which statistics are based; Med.-median.

Date at Lower Granite Dam	McNary to John Day Dam (d)				John Day to Bonneville Dam (d)				McNary to Bonneville Dam (d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	26	3.6	4.4	6.5	7	1.5	2.1	2.2	24	5.5	5.9	7.2
20 Apr–26 Apr	429	3.2	4.3	6.0	48	1.9	2.2	2.5	204	4.5	5.7	7.7
27 Apr–03 May	876	4.1	4.9	6.4	152	1.9	2.1	2.5	709	5.7	6.6	8.3
04 May–10 May	1,873	3.6	4.4	5.5	250	1.8	2.0	2.3	3,202	4.8	5.7	6.8
11 May–17 May	2,566	3.1	3.7	4.8	439	1.5	1.7	1.9	6,274	4.3	4.9	5.7
18 May–24 May	2,004	2.4	2.7	3.4	334	1.4	1.6	1.8	3,906	3.6	4.0	4.4
25 May–31 May	249	2.4	2.7	3.4	33	1.4	1.5	1.9	440	3.2	3.4	4.1
01 Jun–07 Jun	71	2.4	2.7	3.7	8	1.5	1.6	2.0	37	3.3	4.1	4.8
08 Jun–14 Jun	16	2.5	2.9	3.7	1	1.5	1.5	1.5	16	3.7	4.4	5.4
15 Jun–21 Jun	14	1.7	2.4	2.7	3	2.2	3.1	3.3	22	3.2	3.9	4.6

Table 32. Migration rate statistics for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to the tailrace at McNary Dam in 2009. Abbreviations: N=number of fish on which statistics are based; Med.=median.

Date at LGR	McNary to John Day Dam (d)				John Day to Bonneville Dam (d)				McNary to Bonneville Dam (d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	26	18.8	28.2	34.2	7	50.4	53.1	75.3	24	32.8	40.1	42.6
20 Apr–26 Apr	429	20.3	28.4	38.9	48	45.6	52.3	60.8	204	30.5	41.6	52.2
27 Apr–03 May	876	19.3	25.2	29.9	152	45.7	52.6	60.8	709	28.5	35.8	41.2
04 May–10 May	1,873	22.5	28.1	34.6	250	49.1	56.8	62.8	3,202	34.9	41.3	48.7
11 May–17 May	2,566	25.4	33.3	39.9	439	58.2	66.1	73.9	6,274	41.3	48.0	54.5
18 May–24 May	2,004	36.3	45.4	50.6	334	62.4	71.5	81.3	3,906	53.4	58.6	66.1
25 May–31 May	249	36.0	45.4	51.7	33	60.4	74.8	82.5	440	57.7	69.4	74.2
01 Jun–07 Jun	71	33.4	44.9	51.2	8	55.1	71.5	75.3	37	49.5	57.0	71.5
08 Jun–14 Jun	16	33.2	42.0	49.6	1	76.9	76.9	76.9	16	43.6	53.3	63.3
15 Jun–21 Jun	14	45.2	51.2	71.9	3	34.1	36.0	50.7	22	50.9	60.4	72.8

Table 33. 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 2009. Abbreviations: LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; MCN–McNary Dam; BON–Bonneville Dam; N–Number of fish on which statistics are based; Med.–Median.

Date at LGR	LGR to LGO (d)				LGO to LMO (d)				LMO to MCN (d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	18	3.4	4.8	11.4	7	1.7	2.4	3.7	4	2.6	3.0	4.0
06 Apr–12 Apr	471	2.3	2.8	4.2	136	1.7	2.4	5.1	60	3.0	3.6	5.1
13 Apr–19 Apr	2,959	2.4	2.7	3.6	1,197	1.5	2.2	3.8	475	2.4	3.1	4.8
20 Apr–26 Apr	13,260	1.6	2.4	3.3	3,666	1.4	2.4	5.2	1,924	3.0	4.0	5.8
27 Apr–03 May	5,011	2.4	3.0	4.3	962	1.7	2.6	4.7	522	3.0	3.9	5.1
04 May–10 May	3,687	1.5	1.9	2.8	631	1.4	2.1	3.5	364	2.9	3.4	4.4
11 May–17 May	2,993	1.4	1.7	2.4	702	1.1	1.5	2.4	395	2.1	2.7	3.2
18 May–24 May	3,331	1.2	1.4	2.0	1,217	1.0	1.2	1.7	324	1.9	2.3	2.8
25 May–31 May	2,436	1.0	1.3	1.4	995	0.8	1.0	1.6	138	1.8	2.1	2.4
01 Jun–07 Jun	1,412	1.1	1.4	1.8	598	0.9	1.1	1.5	93	1.8	2.2	2.8
08 Jun–14 Jun	581	1.4	1.6	2.4	125	1.1	1.4	2.1	42	2.3	2.7	3.0

Date at LGR	LGR to MCN (d)				LGR to BON (d)			
	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	7	10.8	12.6	14.2	6	15.3	21.4	29.0
06 Apr–12 Apr	170	7.5	9.5	14.6	101	12.3	14.5	20.2
13 Apr–19 Apr	1,055	7.0	8.4	11.6	954	11.1	12.8	16.4
20 Apr–26 Apr	5,603	6.5	8.9	13.0	4,585	11.3	13.9	17.1
27 Apr–03 May	2,389	7.5	9.1	11.9	1,690	12.0	13.4	16.1
04 May–10 May	1,977	6.1	7.3	9.4	1,258	10.3	11.3	13.2
11 May–17 May	1,828	5.4	6.0	7.0	896	8.6	9.8	11.3
18 May–24 May	850	3.9	4.6	5.5	541	7.2	7.9	8.9
25 May–31 May	316	3.8	4.3	5.2	261	6.9	7.4	9.0
01 Jun–07 Jun	196	4.1	4.7	5.9	158	7.4	9.0	12.5
08 Jun–14 Jun	163	4.7	5.5	6.7	94	9.3	11.5	14.7

Table 34. 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 2009. Abbreviations: LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; MCN–McNary Dam; BON–Bonneville Dam; N–Number of fish on which statistics are based; Med.–Median.

Date at LGR	LGR to LGO (km/d)				LGO to LMO (km/d)				LMO to MCN (km/d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	18	5.3	12.6	17.5	7	12.4	19.5	26.9	4	29.9	40.1	46.1
06 Apr–12 Apr	471	14.1	21.3	26.1	136	9.0	18.9	27.5	60	23.4	32.9	39.5
13 Apr–19 Apr	2,959	16.5	22.0	25.4	1,197	12.1	20.8	30.3	475	24.7	37.9	48.8
20 Apr–26 Apr	13,260	18.0	25.4	38.2	3,666	8.8	19.5	31.7	1,924	20.3	29.4	39.0
27 Apr–03 May	5,011	13.9	20.0	24.9	962	9.7	17.7	26.9	522	23.3	30.7	39.0
04 May–10 May	3,687	21.8	31.4	40.5	631	13.0	21.8	32.6	364	27.0	34.9	41.5
11 May–17 May	2,993	24.8	35.9	41.7	702	19.0	30.7	43.0	395	36.7	44.1	55.6
18 May–24 May	3,331	30.5	42.6	48.0	1,217	26.9	39.3	47.4	324	42.5	52.2	61.7
25 May–31 May	2,436	41.7	46.2	58.3	995	29.1	44.7	54.1	138	49.4	57.8	65.7
01 Jun–07 Jun	1,412	33.9	44.1	54.1	598	31.3	41.8	52.3	93	42.2	54.8	64.3
08 Jun–14 Jun	581	25.3	38.7	44.1	125	21.5	34.1	41.8	42	39.0	44.6	52.0

Date at LGR	LGR to MCN (km/d)				LGR to BON (km/d)			
	N	20%	Med.	80%	N	20%	Med.	80%
30 Mar–05 Apr	7	15.9	17.8	20.9	6	15.9	21.6	30.1
06 Apr–12 Apr	170	15.4	23.7	30.1	101	22.8	31.8	37.5
13 Apr–19 Apr	1,055	19.3	26.9	32.4	954	28.2	35.9	41.7
20 Apr–26 Apr	5,603	17.3	25.2	34.4	4,585	27.0	33.0	40.7
27 Apr–03 May	2,389	18.8	24.8	30.0	1,690	28.7	34.5	38.4
04 May–10 May	1,977	23.9	30.7	36.9	1,258	35.0	40.7	44.9
11 May–17 May	1,828	32.0	37.8	42.0	896	40.8	47.0	53.6
18 May–24 May	850	40.9	49.1	57.1	541	51.8	58.4	64.0
25 May–31 May	316	43.3	52.0	59.2	261	51.3	62.0	67.0
01 Jun–07 Jun	196	37.9	47.7	54.6	158	36.9	51.1	62.1
08 Jun–14 Jun	163	33.6	40.8	47.8	94	31.4	40.0	49.8

Table 35. 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 McNary Dam in 2009. Abbreviations: N–Number of fish on which statistics are based; Med.–Median.

Date at LGR	McNary to John Day Dam (d)				John Day to Bonneville Dam (d)				McNary to Bonneville Dam (d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	37	2.6	3.4	4.4	6	1.5	1.7	1.9	29	4.4	5.0	5.4
20 Apr–26 Apr	407	2.5	3.4	5.6	71	1.4	1.6	1.8	344	3.9	4.3	5.2
27 Apr–03 May	929	3.5	4.7	8.0	160	1.6	1.8	2.0	983	4.5	5.3	6.2
04 May–10 May	966	3.0	4.0	6.0	153	1.5	1.6	1.8	1,076	4.3	4.5	5.4
11 May–17 May	618	2.7	3.4	4.9	102	1.3	1.5	1.7	898	3.8	4.3	4.9
18 May–24 May	601	2.4	2.9	3.8	88	1.2	1.4	1.7	726	3.2	3.8	4.4
25 May–31 May	116	1.7	2.5	3.5	14	1.1	1.3	1.5	128	2.8	3.2	3.4
01 Jun–07 Jun	127	2.2	2.8	3.8	17	1.2	1.3	1.6	48	3.0	3.5	4.3
08 Jun–14 Jun	52	2.4	3.1	5.6	9	1.4	1.8	1.9	60	4.1	6.1	10.3
15 Jun–21 Jun	37	2.8	3.2	4.6	7	1.4	1.6	1.8	42	4.1	5.1	7.1

Table 36. 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 2009. Abbreviations: N–Number of fish on which statistics are based; Med.–Median.

Date at LGR	McNary to John Day Dam (d)				John Day to Bonneville Dam (d)				McNary to Bonneville Dam (d)			
	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
13 Apr–19 Apr	37	28.0	36.0	47.5	6	60.8	64.9	73.4	29	43.9	47.2	53.8
20 Apr–26 Apr	407	21.9	36.0	49.0	71	62.1	70.6	80.1	344	45.6	54.9	60.7
27 Apr–03 May	929	15.5	26.3	35.3	160	55.9	62.8	70.6	983	38.2	44.4	52.0
04 May–10 May	966	20.5	30.6	40.7	153	62.1	68.9	75.8	1,076	43.9	52.8	55.4
11 May–17 May	618	25.1	35.9	45.7	102	66.9	74.8	85.0	898	48.2	54.9	62.6
18 May–24 May	601	32.7	42.1	51.2	88	67.7	81.3	91.1	726	54.1	62.9	73.1
25 May–31 May	116	34.6	48.2	71.9	14	76.9	85.6	98.3	128	69.0	74.4	82.8
01 Jun–07 Jun	127	32.0	43.6	56.7	17	72.0	89.0	93.4	48	55.3	68.2	80.0
08 Jun–14 Jun	52	22.0	39.2	51.2	9	59.8	62.8	80.1	60	23.0	38.6	57.7
15 Jun–21 Jun	37	26.7	38.0	44.4	7	63.8	70.2	79.0	42	33.1	46.4	57.4

Table 37. Number of PIT-tagged hatchery steelhead released at Lower Granite Dam by day for survival estimates in 2009. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost tags	Release date	Number released	Mortalities	Lost tags
8-Apr	226	-	-	19-May	351	1	-
9-Apr	157	-	-	20-May	347	-	-
15-Apr	935	1	1	21-May	348	1	-
16-Apr	821	-	-	22-May	350	-	-
22-Apr	1,035	-	-	27-May	263	-	-
23-Apr	2,616	3	1	28-May	262	1	-
25-Apr	21	-	-	29-May	261	1	-
29-Apr	908	-	-	30-May	262	-	-
30-Apr	946	1	-	2-Jun	197	2	-
1-May	849	2	-	3-Jun	113	-	-
2-May	978	3	-	4-Jun	113	-	-
5-May	662	-	-	5-Jun	112	-	1
6-May	664	-	-	8-Jun	112	-	-
7-May	662	-	1	9-Jun	80	-	-
8-May	665	-	-	10-Jun	80	-	-
9-May	664	-	2	11-Jun	80	-	-
12-May	491	-	-	12-Jun	80	-	-
13-May	486	-	-	13-Jun	80	-	-
14-May	489	1	-				
15-May	489	-	-				
16-May	440	-	1				
17-May	49	-	-	Total	18,744	17	7

Table 38. Number of PIT-tagged wild steelhead released at Lower Granite Dam by day for survival estimates in 2009. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost tags	Release date	Number released	Mortalities	Lost tags
8-Apr	74	-	-	19-May	430	-	1
9-Apr	94	-	-	20-May	685	-	-
15-Apr	268	-	1	21-May	489	1	1
16-Apr	154	-	-	22-May	745	-	-
22-Apr	34	-	-	27-May	848	-	1
23-Apr	116	1	-	28-May	899	1	-
25-Apr	1,079	1	-	29-May	637	-	-
29-Apr	797	-	-	30-May	391	-	-
30-Apr	481	-	-	2-Jun	408	-	-
1-May	364	-	-	3-Jun	199	-	-
2-May	373	-	-	4-Jun	200	1	-
5-May	176	-	-	5-Jun	220	-	1
6-May	206	-	-	8-Jun	123	-	-
7-May	326	-	-	9-Jun	173	-	-
8-May	305	-	1	10-Jun	170	-	-
9-May	674	-	-	11-Jun	151	-	-
12-May	700	1	1	12-Jun	129	-	-
13-May	790	-	-	13-Jun	96	-	-
14-May	304	1	-				
15-May	304	-	-				
16-May	100	-	-				
17-May	523	1	-	Total	15,235	8	7



Table 39. Number of PIT-tagged wild yearling Chinook salmon released at Lower Granite Dam by day for survival estimates in 2009. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost Tags	Release date	Number released	Mortalities	Lost tags
8-Apr	279	-	-	19-May	266	-	1
9-Apr	347	1	-	20-May	334	1	-
15-Apr	363	1	-	21-May	484	5	2
16-Apr	329	2	-	22-May	411	-	-
22-Apr	280	1	-	27-May	223	1	-
23-Apr	110	-	-	28-May	125	1	-
25-Apr	468	3	-	29-May	196	1	-
29-Apr	935	7	7	30-May	50	-	-
30-Apr	1,067	4	1	2-Jun			
1-May	754	4	1	3-Jun			
2-May	710	2	-	4-Jun			
5-May	1,242	6	1	5-Jun			
6-May	1,184	2	-	8-Jun			
7-May	939	1	-	9-Jun			
8-May	747	4	1	10-Jun			
9-May	404	1	-	11-Jun			
12-May	202	6	-	12-Jun			
13-May	195	-	-	13-Jun			
14-May	140	2	-				
15-May	472	1	-				
16-May	146	-	-				
17-May	390	1	-	Total	13,792	58	14

Table 40. Estimated survival for yearling Chinook salmon from selected Snake River Basin hatcheries to the tailrace of Lower Granite Dam, 1993–2009. Distance (km) from each hatchery to Lower Granite Dam in parentheses in header. Standard errors in parentheses following each survival estimate.

Year	Dworshak (116)	Kooskia (176)	Lookingglass* (209)	Rapid River (283)	McCall (457)	Pahsimeroi (630)	Sawtooth (747)	Mean
1993	0.647 (0.028)	0.689 (0.047)	0.660 (0.025)	0.670 (0.017)	0.498 (0.017)	0.456 (0.032)	0.255 (0.023)	0.554 (0.060)
1994	0.778 (0.020)	0.752 (0.053)	0.685 (0.021)	0.526 (0.024)	0.554 (0.022)	0.324 (0.028)	0.209 (0.014)	0.547 (0.081)
1995	0.838 (0.034)	0.786 (0.024)	0.617 (0.015)	0.726 (0.017)	0.522 (0.011)	0.316 (0.033)	0.230 (0.015)	0.576 (0.088)
1996	0.776 (0.017)	0.744 (0.010)	0.567 (0.014)	0.588 (0.007)	0.531 (0.007)	—	0.121 (0.017)	0.555 (0.096)
1997	0.576 (0.017)	0.449 (0.034)	0.616 (0.017)	0.382 (0.008)	0.424 (0.008)	0.500 (0.008)	0.508 (0.037)	0.494 (0.031)
1998	0.836 (0.006)	0.652 (0.024)	0.682 (0.006)	0.660 (0.004)	0.585 (0.004)	0.428 (0.021)	0.601 (0.033)	0.635 (0.046)
1999	0.834 (0.011)	0.653 (0.031)	0.668 (0.009)	0.746 (0.006)	0.649 (0.008)	0.584 (0.035)	0.452 (0.019)	0.655 (0.045)
2000	0.841 (0.009)	0.734 (0.027)	0.688 (0.011)	0.748 (0.007)	0.689 (0.010)	0.631 (0.062)	0.546 (0.030)	0.697 (0.035)
2001	0.747 (0.002)	0.577 (0.019)	0.747 (0.003)	0.689 (0.002)	0.666 (0.002)	0.621 (0.016)	0.524 (0.023)	0.653 (0.032)
2002	0.819 (0.011)	0.787 (0.036)	0.667 (0.012)	0.755 (0.003)	0.592 (0.006)	0.678 (0.053)	0.387 (0.025)	0.669 (0.055)
2003	0.720 (0.008)	0.560 (0.043)	0.715 (0.012)	0.691 (0.007)	0.573 (0.006)	0.721 (0.230)	0.595 (0.149)	0.654 (0.028)
2004	0.821 (0.003)	0.769 (0.017)	0.613 (0.004)	0.694 (0.003)	0.561 (0.002)	0.528 (0.017)	0.547 (0.018)	0.648 (0.044)
2005	0.823 (0.003)	0.702 (0.021)	0.534 (0.004)	0.735 (0.002)	0.603 (0.003)	0.218 (0.020)	0.220 (0.020)	0.549 (0.092)
2006	0.853 (0.007)	0.716 (0.041)	0.639 (0.014)	0.764 (0.004)	0.634 (0.006)	0.262 (0.024)	0.651 (0.046)	0.645 (0.071)
2007	0.817 (0.007)	0.654 (0.015)	0.682 (0.010)	0.748 (0.004)	0.554 (0.007)	0.530 (0.038)	0.581 (0.015)	0.652 (0.040)
2008	0.737 (0.011)	0.631 (0.015)	0.694 (0.008)	0.801 (0.004)	0.578 (0.007)	0.447 (0.011)	0.336 (0.012)	0.603 (0.062)
2009	0.696 (0.007)	0.633 (0.012)	0.699 (0.009)	0.728 (0.005)	0.513 (0.005)	0.510 (0.006)	0.367 (0.007)	0.592 (0.050)
<b>Mean</b>	<b>0.774 (0.019)</b>	<b>0.676 (0.022)</b>	<b>0.657 (0.013)</b>	<b>0.685 (0.025)</b>	<b>0.572 (0.016)</b>	<b>0.485 (0.037)</b>	<b>0.419 (0.040)</b>	<b>0.610 (0.014)</b>

\* Released at Imnaha River Weir.

Table 41. Annual weighted means of survival probability estimates for yearling Chinook salmon (hatchery and wild combined), 1993–2009. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root (i.e., geometric mean) of the two–project estimate to facilitate comparison with other single–project estimates. Simple arithmetic means across all years, and across all years excluding 2001 are given. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; IHR–Ice Harbor Dam; MCN–McNary Dam; JDA–John Day Dam; TDA–The Dalles Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
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
<b>Mean</b>	<b>0.937 (0.010)</b>	<b>0.926 (0.011)</b>	<b>0.911 (0.011)</b>	<b>0.856 (0.016)</b>	<b>0.925</b>	<b>0.871 (0.024)</b>	<b>0.792 (0.040)</b>	<b>0.887</b>

Table 42. Annual weighted means of survival probability estimates for steelhead (hatchery and wild combined), 1993–2009. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root (i.e., geometric mean) of the two–project estimate to facilitate comparison with other single–project estimates. Simple arithmetic means across all years, and across all years excluding 2001 are given. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; IHR–Ice Harbor Dam; MCN–McNary Dam; JDA–John Day Dam; TDA–The Dalles Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
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
<b>Mean</b>	<b>0.947 (0.009)</b>	<b>0.912 (0.012)</b>	<b>0.895 (0.015)</b>	<b>0.743 (0.040)</b>	<b>0.856</b>	<b>0.784 (0.060)</b>	<b>0.740 (0.038)</b>	<b>0.858</b>

Table 43. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River yearling Chinook salmon (hatchery and wild combined), 1997–2009. Standard errors in parentheses. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR–MCN	MCN–BON	LGR–BON	Trap–BON
1997	NA	0.653 (0.072)	NA	NA	NA
1998	0.924 (0.011)	0.770 (0.009)	NA	NA	NA
1999	0.940 (0.009)	0.792 (0.006)	0.704 (0.058)	0.557 (0.046)	0.524 (0.043)
2000	0.929 (0.014)	0.760 (0.012)	0.640 (0.122)	0.486 (0.093)	0.452 (0.087)
2001	0.954 (0.015)	0.556 (0.009)	0.501 (0.027)	0.279 (0.016)	0.266 (0.016)
2002	0.953 (0.022)	0.757 (0.009)	0.763 (0.079)	0.578 (0.060)	0.551 (0.059)
2003	0.993 (0.023)	0.731 (0.010)	0.728 (0.030)	0.532 (0.023)	0.528 (0.026)
2004	0.893 (0.009)	0.666 (0.011)	0.594 (0.074)	0.395 (0.050)	0.353 (0.045)
2005	0.919 (0.015)	0.732 (0.009)	0.788 (0.093)	0.577 (0.068)	0.530 (0.063)
2006	0.952 (0.011)	0.764 (0.007)	0.842 (0.021)	0.643 (0.017)	0.612 (0.018)
2007	0.943 (0.028)	0.783 (0.006)	0.763 (0.044)	0.597 (0.035)	0.563 (0.037)
2008	0.992 (0.018)	0.782 (0.011)	0.594 (0.066)	0.465 (0.052)	0.460 (0.052)
2009	0.958 (0.010)	0.787 (0.007)	0.705 (0.031)	0.555 (0.025)	0.531 (0.025)
<b>Mean</b>	<b>0.946 (0.008)</b>	<b>0.733 (0.019)</b>	<b>0.693 (0.030)</b>	<b>0.515 (0.031)</b>	<b>0.488 (0.030)</b>

Table 44. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River steelhead (hatchery and wild combined), 1997–2009. Standard errors in parentheses. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR–MCN	MCN–BON	LGR–BON	Trap–BON
1997	1.020 (0.023)	0.728 (0.053)	0.651 (0.082)	0.474 (0.069)	0.484 (0.072)
1998	0.924 (0.009)	0.649 (0.013)	0.770 (0.081)	0.500 (0.054)	0.462 (0.050)
1999	0.908 (0.011)	0.688 (0.010)	0.640 (0.024)	0.440 (0.018)	0.400 (0.017)
2000	0.964 (0.013)	0.679 (0.016)	0.580 (0.040)	0.393 (0.034)	0.379 (0.033)
2001	0.911 (0.007)	0.168 (0.006)	0.250 (0.016)	0.042 (0.003)	0.038 (0.003)
2002	0.895 (0.015)	0.536 (0.025)	0.488 (0.090)	0.262 (0.050)	0.234 (0.045)
2003	0.932 (0.015)	0.597 (0.013)	0.518 (0.015)	0.309 (0.011)	0.288 (0.012)
2004	0.948 (0.004)	0.379 (0.023)	NA	NA	NA
2005	0.967 (0.004)	0.593 (0.018)	NA	NA	NA
2006	0.920 (0.013)	0.702 (0.016)	0.648 (0.079)	0.455 (0.056)	0.418 (0.052)
2007	1.016 (0.026)	0.694 (0.020)	0.524 (0.064)	0.364 (0.045)	0.369 (0.047)
2008	0.995 (0.018)	0.716 (0.015)	0.671 (0.034)	0.480 (0.027)	0.478 (0.028)
2009	1.002 (0.011)	0.790 (0.013)	0.856 (0.074)	0.676 (0.059)	0.678 (0.060)
<b>Mean</b>	<b>0.954 (0.012)</b>	<b>0.609 (0.047)</b>	<b>0.600 (0.048)</b>	<b>0.400 (0.049)</b>	<b>0.384 (0.049)</b>

Table 45. Estimated survival and standard error (s.e.) through reaches of the lower Columbia River hydropower system for hatchery yearling Chinook salmon and steelhead originating in the upper Columbia River, 1997–2009.  
Abbreviations: Rel–Release site; MCN–McNary Dam; JDA–John Day Dam; BON–Bonneville Dam.

Year	Yearling Chinook Salmon				Steelhead			
	Rel–MCN	MCN–JDA	JDA–BON	MCN–BON	Rel–MCN	MCN–JDA	JDA–BON	MCN–BON
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)	0.471 (0.004)	0.997 (0.012)	0.874 (0.036)	0.871 (0.036)
2004	0.507 (0.005)	0.812 (0.019)	0.761 (0.049)	0.618 (0.038)	0.384 (0.005)	0.794 (0.021)	1.037 (0.112)	0.823 (0.088)
2005	0.545 (0.012)	0.751 (0.042)	NA	NA	0.399 (0.004)	0.815 (0.017)	0.827 (0.071)	0.674 (0.057)
2006	0.520 (0.011)	0.954 (0.051)	0.914 (0.211)	0.871 (0.198)	0.397 (0.008)	0.797 (0.026)	0.920 (0.169)	0.733 (0.134)
2007	0.584 (0.009)	0.895 (0.028)	0.816 (0.091)	0.730 (0.080)	0.426 (0.016)	0.944 (0.064)	0.622 (0.068)	0.587 (0.059)
2008	0.582 (0.019)	1.200 (0.085)	0.522 (0.114)	0.626 (0.133)	0.438 (0.015)	NA	NA	NA
2009	0.523 (0.013)	0.847 (0.044)	1.056 (0.143)	0.895 (0.116)	0.484 (0.018)	0.809 (0.048)	0.935 (0.133)	0.756 (0.105)
<b>Mean</b>	<b>0.543 (0.015)</b>	<b>0.890 (0.036)</b>	<b>0.848 (0.058)</b>	<b>0.769 (0.040)</b>	<b>0.428 (0.015)</b>	<b>0.859 (0.036)</b>	<b>0.869 (0.057)</b>	<b>0.741 (0.042)</b>

Table 46. Estimated survival and standard error (s.e.) 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, 1996–2009. Note that this table represents all available data on sockeye, and so estimates are provided regardless of the size of their associated standard errors. The estimates to Bonneville tailrace are of questionable quality in several cases due to small release sizes and low detection probabilities. Caution should be used if using those estimates for inference. Abbreviations: LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam; RIS–Rock Island Dam.

Year	Snake River Sockeye			Upper Columbia River Sockeye		
	LGR-MCN	MCN-BON	LGR-BON	RIS-MCN	MCN-BON	RIS-BON
1996	0.283 (0.184)	NA	NA	NA	NA	NA
1997	NA	NA	NA	0.397 (0.119)	NA	NA
1998	0.689 (0.157)	0.142 (0.099)	0.177 (0.090)	0.624 (0.058)	1.655 (1.617)	1.033 (1.003)
1999	0.655 (0.083)	0.841 (0.584)	0.548 (0.363)	0.559 (0.029)	0.683 (0.177)	0.382 (0.097)
2000	0.679 (0.110)	0.206 (0.110)	0.161 (0.080)	0.487 (0.114)	0.894 (0.867)	0.435 (0.410)
2001	0.205 (0.063)	0.105 (0.050)	0.022 (0.005)	0.657 (0.117)	NA	NA
2002	0.524 (0.062)	0.684 (0.432)	0.342 (0.212)	0.531 (0.044)	0.286 (0.110)	0.152 (0.057)
2003	0.669 (0.054)	0.551 (0.144)	0.405 (0.098)	NA	NA	NA
2004	0.741 (0.254)	NA	NA	0.648 (0.114)	1.246 (1.218)	0.808 (0.777)
2005	0.388 (0.078)	NA	NA	0.720 (0.140)	0.226 (0.209)	0.163 (0.147)
2006	0.630 (0.083)	1.113 (0.652)	0.820 (0.454)	0.793 (0.062)	0.767 (0.243)	0.608 (0.187)
2007	0.679 (0.066)	0.259 (0.084)	0.272 (0.073)	0.625 (0.046)	0.642 (0.296)	0.401 (0.183)
2008	0.763 (0.103)	0.544 (0.262)	0.404 (0.179)	0.644 (0.094)	0.679 (0.363)	0.437 (0.225)
2009	0.749 (0.032)	0.765 (0.101)	0.573 (0.073)	0.853 (0.076)	0.958 (0.405)	0.817 (0.338)
<b>Mean</b>	<b>0.589 (0.051)</b>	<b>0.521 (0.107)</b>	<b>0.372 (0.074)</b>	<b>0.628 (0.036)</b>	<b>0.804 (0.134)</b>	<b>0.524 (0.091)</b>



Table 47. 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 2009. 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. Number released for single pooled estimates (no asterisk) is from points above McNary. Dam release sites are in tailraces. Abbreviations: Sp–spring Chinook salmon; Sp–Su–spring/summer.

Stock	Release location	Number released	Survival estimates (standard errors)		
			McNary to John Day Dam	John Day to Bonneville Dam	McNary to Bonneville Dam
Snake R. Chinook (Sp–Su)*	McNary Dam Tailrace	112,275*	0.866 (0.042)	0.821 (0.043)	0.705 (0.031)
U. Columbia Chinook (Sp–Su)	Upper Columbia sites <sup>a</sup>	68,404	0.847 (0.038)	1.012 (0.121)	0.857 (0.098)
U. Columbia Chinook (Sp–Su)	Yakima River sites <sup>b</sup>	78,532	0.820 (0.034)	1.077 (0.137)	0.883 (0.108)
Upper Columbia Coho	Upper Columbia sites	35,139	0.838 (0.052)	0.749 (0.102)	0.627 (0.084)
Upper Columbia Coho	Yakima River sites	29,506	0.760 (0.063)	1.249 (0.326)	0.950 (0.244)
Snake River Sockeye	Snake River sites <sup>c</sup>	67,941	1.075 (0.104)	0.711 (0.109)	0.765 (0.101)
Upper Columbia Sockeye	Upper Columbia sites	5,742	0.855 (0.087)	0.964 (0.244)	0.824 (0.198)
Snake River Steelhead*	McNary Dam Tailrace	26,985*	0.951 (0.026)	0.900 (0.079)	0.856 (0.074)
Upper Columbia Steelhead	Upper Columbia sites	46,578	0.792 (0.040)	0.888 (0.100)	0.703 (0.077)

a. Upper Columbia sites include any release sites on the Columbia River or its tributaries that are above 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 above Lower Granite Dam on the Snake River or its tributaries.

Table 48. Estimated survival and detection probabilities for Snake River yearling Chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite	Number released	Survival probability		Detection probability Ice Harbor Dam
		Lower Monumental to Ice Harbor Dam	Ice Harbor to McNary Dam	
30 Mar–05 Apr	446	0.712 (0.086)	1.409 (0.198)	0.200 (0.029)
06 Apr–12 Apr	1,969	0.874 (0.058)	0.972 (0.072)	0.155 (0.013)
13 Apr–19 Apr	4,125	0.984 (0.042)	0.964 (0.050)	0.152 (0.008)
20 Apr–26 Apr	14,248	0.920 (0.023)	0.970 (0.024)	0.122 (0.004)
27 Apr–03 May	28,380	0.910 (0.019)	0.923 (0.020)	0.092 (0.002)
04 May–10 May	25,753	0.910 (0.028)	0.931 (0.025)	0.063 (0.002)
11 May–17 May	20,457	0.890 (0.038)	0.942 (0.040)	0.044 (0.002)
18 May–24 May	7,430	0.859 (0.045)	1.083 (0.078)	0.130 (0.007)
25 May–31 May	1,046	0.830 (0.098)	1.210 (0.228)	0.155 (0.020)
01 Jun–07 Jun	235	1.142 (0.338)	1.073 (0.440)	0.111 (0.037)
<b>Weighted mean*</b>		<b>0.910 (0.012)</b>	<b>0.952 (0.018)</b>	<b>0.075 (0.010)</b>

\* Weighted means of the independent estimates for weekly pooled groups (30 Mar –07 June), with weights inversely proportional to respective estimated relative variances.

Table 49. Estimated survival and detection probabilities for Snake River Steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace at Lower Granite Dam in 2009. Daily groups pooled weekly. Estimates based on the single-release model. Standard errors in parentheses.

Date at Lower Granite Dam	Number released	Survival probability		Detection probability Ice Harbor Dam
		Lower Monumental to Ice Harbor Dam	Ice Harbor Dam to McNary Dam	
06 Apr–12 Apr	858	0.875 (0.106)	0.894 (0.121)	0.113 (0.018)
13 Apr–19 Apr	6267	0.930 (0.036)	0.934 (0.047)	0.150 (0.007)
20 Apr–26 Apr	31,566	0.948 (0.020)	0.922 (0.023)	0.116 (0.003)
27 Apr–03 May	12,833	0.978 (0.031)	0.973 (0.038)	0.153 (0.005)
04 May–10 May	10,791	0.906 (0.034)	0.875 (0.038)	0.164 (0.006)
11 May–17 May	8,485	1.028 (0.055)	0.937 (0.058)	0.079 (0.005)
18 May–24 May	7,052	0.876 (0.040)	0.819 (0.057)	0.190 (0.010)
25 May–31 May	4,501	0.923 (0.046)	0.782 (0.081)	0.279 (0.014)
01 Jun–07 Jun	2,235	0.863 (0.065)	0.782 (0.094)	0.207 (0.017)
08 Jun–14 Jun	1,554	0.607 (0.108)	0.973 (0.192)	0.078 (0.016)
<b>Weighted mean*</b>		<b>0.938 (0.015)</b>	<b>0.915 (0.015)</b>	<b>0.129 (0.012)</b>

\* Weighted means of the independent estimates for weekly pooled groups (06 April –14 June), with weights inversely proportional to respective estimated relative variances.

Table 50. Percentage of PIT–tagged smolts (wild and hatchery combined) detected at Lower Monumental Dam later detected on McNary pool bird colonies, 1998-2009.

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 <sup>a</sup>	1.06	3.71
2004 <sup>b</sup>	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

<sup>a</sup> Only Crescent Island Caspian tern colony sampled.

<sup>b</sup> Only Crescent Island and Foundation Island colonies sampled.

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## APPENDIX

### Tests 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 survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, and detection at 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, then, is the record of the outcomes of the series of events. (The detection history is an imperfect record of outcomes; if the history ends with one or more “zeroes,” we cannot distinguish mortality from 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  $\chi^2$  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 dams (Snake River-origin fish only) in 2009 (i.e., the fish used for survival estimates reported in Tables 1, 2, 10, and 11).

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. Using detection information, inherent differences and behavioral responses are virtually indistinguishable. 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 “Test 2.C2,” which is based on the contingency table:

Test 2.C2 df = 2	First site detected below LGO		
	LMN	MCN	JDA or below
Not detected at LGO	$n_{11}$	$n_{12}$	$n_{13}$
Detected at LGO	$n_{21}$	$n_{22}$	$n_{23}$

In this table, all fish that were detected somewhere below Little Goose Dam are cross-classified according to their history at Little Goose Dam and according to their first detection site below Little Goose Dam (e.g.,  $n_{11}$  is the number of fish not detected at Little Goose Dam that were first detected downstream at Lower Monumental Dam). If all assumptions were met, the counts for fish detected at LGO should be in constant proportion to those for fish not detected (i.e.,  $n_{11}/n_{21}$ ,  $n_{12}/n_{22}$ , and  $n_{13}/n_{23}$  should be equal). Because this table counts only fish detected below LGO (i.e., all fish survived LGO passage), differential *direct* mortality for fish detected and not detected at LGO will not cause violations of Test 2.C2 by itself. However, differential *indirect* mortality related to LGO passage could cause violations if differences are not expressed until fish are below LMO. Behavioral response to guidance at LGO could cause violations of Test 2.C2: if fish detected at LGO become more likely to be detected downstream, then they will tend to have more first downstream detections at LMO. If detected fish at LGO 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 df = 1	First site detected below LMN	
	MCN	JDA or below
Not detected at LMN	$n_{11}$	$n_{12}$
Detected at LMN	$n_{21}$	$n_{22}$

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

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 df = 1	Detected again at MCN or below?	
	YES	NO
Detected at LMN, not detected at LGO	$n_{11}$	$n_{12}$
Detected at LMN, detected at LGO	$n_{21}$	$n_{22}$

In this table, all fish detected at LMN are cross-classified according to their status at LGO and whether or not they were detected again downstream from LMN. As with the Test 2 series, differential mortality in different passage routes at LGO will not be detected by this test if all the mortality is expressed before the fish arrive at LMN. Differences in mortality expressed below MCN could cause violations, however, as could behavioral responses (possibly somewhat harder to detect because of the conditioning on detection at LMN) or inherent differences in detectability or survival between fish detected at LGO 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 df = 1	Site first detected below LMN	
	MCN	JDA
Detected at LMN, not detected at LGO	$n_{11}$	$n_{12}$
Detected at LMN, detected at LGO	$n_{21}$	$n_{22}$

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 LMN, it is not sensitive to differences in survival between LMN and MCN.

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

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



This table classifies all fish detected at MCN according to whether they had been detected at least once at LGO and LMN and whether they were detected again below MCN. A significant test indicates that some below-MCN parameter(s) differ between fish detected above MCN and those not detected. The cause of such an assumption violation could be differences in indirect survival associated with detection at LGO and/or LMN (mortality expressed between MCN 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  $\chi^2$  distribution in these cases. (For Test 2.C2, when the expected values in the “LMN” and “MCN” columns were all greater than 1.0, but one or two of the expected values in the “JDA or below” column were less than 1.0, we collapsed the “MCN” and “JDA 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  $\chi^2$  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 df = 1	First site detected below JDA	
	BON	Trawl
Not detected at JDA	$n_{11}$	$n_{12}$
Detected at JDA	$n_{21}$	$n_{22}$

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

Test 3.SR3 df = 1	Detected at Trawl	
	Yes	No
Detected at BON, not detected at JDA	$n_{11}$	$n_{12}$
Detected at BON, detected at JDA	$n_{21}$	$n_{22}$

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 2009 there were more significant ( $\alpha = 0.05$ ) tests than expected by chance alone for both yearling Chinook salmon and steelhead (Appendix Table 1). There were 10 weekly groups of yearling Chinook salmon. For these, the overall sum of the  $\chi^2$  test statistics was significant 5 times. For 10 steelhead groups, the overall test was significant 3 times. Counting all individual component tests (i.e., 2.C2, 3.SR3, etc.), 12 tests of 50 (24%) were significant for yearling Chinook salmon and 7 of 50 (14%) were significant for steelhead (Appendix Tables 1-3).

We diagnosed the patterns in the contingency tables that led to significant tests and results were similar to those we reported in past years: in 12 of the 19 significant cases (individual component tests) for Lower Granite Dam groups of yearling Chinook salmon and steelhead, and in all of the most highly significant cases, there was evidence that fish previously detected were more likely to be detected again at downstream dams.

Significant contingency table test results were more common than expected for weekly groups from McNary Dam (Appendix Tables 4-6). For yearling Chinook salmon, there were 3 (27%) significant tests out of the 11 individual component tests, and for steelhead 1 (14%) of the 14 component tests were significant. All 4 of the significant component tests for yearling Chinook salmon and steelhead were for test 2.C2, which provides evidence that fish detected at John Day Dam were more likely to be detected again downstream than those not detected at John Day Dam.

## Discussion

We believe that inherent differences in detectability (guidability) of fish within a release group are the most likely cause of the patterns we observed in the contingency table tests in 2009, 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 2009 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 LGR), suggests that the heterogeneity is inherent, and not a behavioral response.

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

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

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

Appendix Table 1. 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, 2009.

	<u>Test 2.C2</u>		<u>Test 2.C3</u>		<u>Test 3.SR3</u>		<u>Test 3.Sm3</u>		<u>Test 3.SR4</u>		<u>Test 2 sum</u>		<u>Test 3 sum</u>		<b><u>Test 2 + 3</u></b>	
Species	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	<b>No.</b>	<b>sig.</b>
Chinook	10	6	10	2	10	2	10	1	10	1	10	6	10	2	<b>10</b>	<b>5</b>
Steelhead	10	3	10	1	10	0	10	1	10	2	10	3	10	2	<b>10</b>	<b>3</b>
Total	20	9	20	3	20	2	20	2	20	3	20	9	20	0	<b>20</b>	<b>8</b>

Appendix Table 2. 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 2009.

Release	<u>Overall</u>		<u>Test 2</u>		<u>Test 2.C2</u>		<u>Test 2.C3</u>	
	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value
30 Mar–05 Apr	4.44	0.617	1.86	0.602	0.37	0.833	1.49	0.222
06 Apr–12 Apr	11.42	0.076	0.79	0.851	0.79	0.674	0.01	0.941
13 Apr–19 Apr	18.94	0.004	18.30	<0.001	16.43	<0.001	1.87	0.172
20 Apr–26 Apr	37.57	<0.001	32.88	<0.001	24.66	<0.001	8.22	0.004
27 Apr–03 May	11.79	0.067	10.97	0.012	9.69	0.008	1.28	0.258
04 May–10 May	53.59	<0.001	44.01	<0.001	43.92	<0.001	0.09	0.766
11 May–17 May	165.96	<0.001	164.43	<0.001	148.97	<0.001	15.46	<0.001
18 May–24 May	24.66	<0.001	22.50	<0.001	21.65	<0.001	0.85	0.357
25 May–31 May	2.56	0.862	1.76	0.624	1.22	0.542	0.54	0.464
01 Jun–07 Jun	2.20	0.900	0.85	0.838	0.68	0.712	0.17	0.683
Total (df)	333.11 (60)	<0.001	298.34 (30)	<0.001	268.38 (20)	<0.001	29.97 (10)	0.001

Appendix Table 2. Continued.

Release	<u>Test 3</u>		<u>Test 3.SR3</u>		<u>Test 3.Sm3</u>		<u>Test 3.SR4</u>	
	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value
30 Mar–05 Apr	2.58	0.461	0.59	0.441	1.47	0.225	0.51	0.473
06 Apr–12 Apr	10.63	0.014	4.17	0.041	4.55	0.033	1.91	0.168
13 Apr–19 Apr	0.65	0.886	0.05	0.828	0.05	0.823	0.55	0.459
20 Apr–26 Apr	4.69	0.196	0.56	0.453	0.14	0.711	3.99	0.046
27 Apr–03 May	0.82	0.844	0.19	0.665	0.14	0.709	0.50	0.481
04 May–10 May	9.57	0.023	7.62	0.006	1.89	0.169	0.06	0.809
11 May–17 May	1.53	0.676	0.04	0.846	0.88	0.348	0.61	0.435
18 May–24 May	2.16	0.540	1.58	0.208	0.01	0.922	0.56	0.453
25 May–31 May	0.80	0.850	0.04	0.839	0.14	0.710	0.62	0.433
01 Jun–07 Jun	1.36	0.716	0.01	0.944	1.35	0.245	0.00	0.982
Total (df)	34.77 (30)	0.251	14.85 (10)	0.137	10.62 (10)	0.388	9.30 (10)	0.504

Appendix Table 3. 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 2009.

Release	<u>Overall</u>		<u>Test 2</u>		<u>Test 2.C2</u>		<u>Test 2.C3</u>	
	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value
06 Apr–12 Apr	2.98	0.811	2.31	0.510	2.31	0.315	0.00	0.976
13 Apr–19 Apr	8.54	0.201	4.09	0.252	1.29	0.525	2.80	0.094
20 Apr–26 Apr	128.30	<0.001	107.52	<0.001	77.84	<0.001	29.67	<0.001
27 Apr–03 May	6.08	0.415	4.00	0.262	1.34	0.512	2.66	0.103
04 May–10 May	20.25	0.002	17.86	<0.001	15.48	<0.001	2.39	0.122
11 May–17 May	8.94	0.177	7.21	0.066	4.31	0.116	2.89	0.089
18 May–24 May	26.13	<0.001	20.19	<0.001	19.77	<0.001	0.43	0.514
25 May–31 May	12.55	0.051	2.47	0.481	1.73	0.421	0.74	0.389
01 Jun–07 Jun	3.06	0.802	0.86	0.835	0.04	0.980	0.82	0.366
08 Jun–14 Jun	7.34	0.291	2.03	0.566	0.09	0.954	1.94	0.164
Total (df)	224.16 (60)	<0.001	168.54 (30)	<0.001	124.20 (20)	<0.001	44.34 (10)	<0.001

Appendix Table 3. Continued.

Release	<u>Test 3</u>		<u>Test 3.SR3</u>		<u>Test 3.Sm3</u>		<u>Test 3.SR4</u>	
	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value
06 Apr–12 Apr	0.67	0.881	0.00	0.993	0.01	0.935	0.66	0.417
13 Apr–19 Apr	4.45	0.217	0.42	0.517	2.70	0.100	1.33	0.250
20 Apr–26 Apr	20.78	<0.001	0.11	0.744	14.64	<0.001	6.04	0.014
27 Apr–03 May	2.08	0.556	0.88	0.349	0.76	0.383	0.44	0.506
04 May–10 May	2.39	0.496	0.32	0.573	1.37	0.243	0.71	0.401
11 May–17 May	1.73	0.629	0.01	0.908	0.06	0.811	1.66	0.197
18 May–24 May	5.94	0.115	2.09	0.148	0.66	0.418	3.19	0.074
25 May–31 May	10.08	0.018	0.27	0.607	2.58	0.109	7.24	0.007
01 Jun–07 Jun	2.20	0.532	1.55	0.213	0.64	0.426	0.01	0.904
08 Jun–14 Jun	5.31	0.150	0.36	0.546	3.68	0.055	1.27	0.260
Total (df)	55.62 (30)	0.003	6.00 (10)	0.815	27.07 (10)	0.003	22.55 (10)	0.013



Appendix Table 4. 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, 2009.

Species	Test 2.C2		Test 3.SR3		Test 2 + 3	
	No.	sig.	No.	sig.	No.	sig.
Chinook	6	3	5	0	6	1
Steelhead	8	1	6	0	8	1
Total	14	4	11	0	14	2

Appendix Table 5. 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 2009.

Release	<u>Overall</u>		<u>Test 2.C2</u>		<u>Test 3.SR3</u>	
	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value
20 Apr–26 Apr	0.62	0.733	0.06	0.813	0.57	0.452
27 Apr–03 May	5.62	0.060	5.59	0.018	0.03	0.875
04 May–10 May	7.66	0.022	6.51	0.011	1.15	0.285
11 May–17 May	2.97	0.227	2.03	0.154	0.94	0.332
18 May–24 May	4.85	0.088	4.74	0.029	0.11	0.739
25 May–31 May	0.47	0.492	0.47	0.492	NA	NA
Total (df)	22.19 (11)	0.023	19.40 (6)	0.004	2.79 (5)	0.733

Appendix Table 6. 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 2009.

Release	<u>Overall</u>		<u>Test 2.C2</u>		<u>Test 3.SR3</u>	
	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value	$\chi^2$	<i>P</i> value
20 Apr–26 Apr	0.22	0.897	0.12	0.725	0.10	0.758
27 Apr–03 May	1.32	0.518	0.89	0.345	0.43	0.515
04 May–10 May	8.69	0.013	8.35	0.004	0.33	0.565
11 May–17 May	0.45	0.797	0.22	0.637	0.23	0.630
18 May–24 May	1.12	0.572	1.02	0.314	0.10	0.749
25 May–31 May	0.42	0.516	0.42	0.516	NA	NA
01 Jun–07 Jun	0.63	0.730	0.62	0.430	0.01	0.938
08 Jun–14 Jun	1.32	0.251	1.32	0.251	NA	NA
Total (df)	14.16 (14)	0.438	12.97 (8)	0.113	1.19 (6)	0.977