Northwest Fisheries Science Center
Fish Ecology Division
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

October 7, 2021

MEMORANDUM FOR: F/NWR5 – Ritchie Graves

FROM: F/NWC3 – Scott Hecht

SUBJECT: Preliminary survival estimates for the passage of spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs, 2021

This memorandum summarizes conditions in the Snake and Columbia Rivers and preliminary estimates of survival of PIT-tagged juvenile salmonids passing through reservoirs and dams during the 2021 spring outmigration. We also provide preliminary estimates of the proportion of Snake River smolts that were collected at Snake River dams and transported in 2021. Our complete detailed analyses and report for the spring migration will follow this memo at a later date. As in past years, possible revisions to the PIT-tag database could result in differences in estimates of survival, likely no more than 3% or 4%. In particular, the addition of PIT-tag recoveries from estuary bird colonies in fall 2021 will result in revised survival estimates.

Summary of Research

The global pandemic caused by COVID-19 limited field work by NOAA Fisheries during the 2021 migration season, but to a lesser extent than in 2020. The tagging program at Lower Granite Dam operated with a reduced capacity in 2021. A total of 1,770 wild yearling Chinook, 4,854 wild steelhead, and 18,120 hatchery steelhead were tagged for release into the tailrace of Lower Granite Dam. The Columbia River estuary trawl, cancelled in 2020, was operated as normal in 2021.

Survival estimates provided in this memorandum are derived from data from fish PIT tagged by or for NOAA Fisheries, as described above, along with fish PIT tagged by others within the Columbia River Basin. For technical reasons, the statistical model for survival estimation can produce estimates that exceed 100%. When

this occurs, we report the actual estimate, but for practical purposes these estimates should be interpreted as representing true survival probabilities that are less than or equal to 100%.

We have estimated survival probabilities for migrating PIT-tagged salmonids since 1993. In this memo, we compare 2021 estimates in various river segments to averages over periods of years. Estimates are not available for every reach in every year. Unless otherwise noted, when we refer to a long-term average for a particular river segment, the average is across all years for which estimates are available.

The reduced capacity for tagging at Lower Granite Dam in 2021 resulted in smaller sample sizes for survival estimation for wild fish. This deficit was partially compensated for by the PIT-tag detection system in the RSW spillway at Lower Granite Dam, operating for the second year in 2021. Without data from the "spillway detector" it is likely that very few survival estimates would have been possible for wild stocks of Chinook or steelhead in 2021.

The mean sample size of wild yearling Chinook smolts available for survival estimation from Lower Granite Dam from 2010-2019, before the addition of extra detections from the spillway detector, was 24,849 smolts, with about half tagged at the dam and half detected in the juvenile bypass system (Table 1). In 2021, even with detections from the spillway detector added to detections in the bypass and smolts tagged at the dam, the total sample size of wild Chinook smolts available at the dam was only 9,190 fish. Smolts detected by the spillway detector comprised nearly two-thirds of that number, which illustrates how far detections and tagging in the bypass system have declined.

The situation was essentially the same for wild steelhead. From 2010-2019, the mean sample size of wild steelhead available for survival estimation from Lower Granite Dam was 20,329 smolts, usually with about three-quarters of the sample tagged at the dam and the remainder detected in the bypass (Table 1). In 2021, the total sample size of wild steelhead smolts was only 12,299, with just over half of that number contributed by the spillway detection system.

Unfortunately, even for groups with seemingly sufficient sample sizes leaving Lower Granite Dam, survival estimation in 2021 was hampered by extremely low detection probabilities at downstream

dams, where detection is possible only in juvenile bypass systems (with the exception of the corner collector at Bonneville Dam). A combination of low flow and very high levels of spill made 2021 one of the worst years on record for overall detection downstream of Lower Granite Dam. Similar to 2020, in 2021 every dam besides Lower Granite had a detection rate well below the 2007-2019 average, and several, including Little Goose Dam, Lower Monumental Dam, and John Day Dam, had detection rates less than half the 2007-2019 average.

These extremely low detection rates resulted in highly imprecise survival estimates for component reaches between Lower Granite Dam and McNary Dam. They also necessitated a change in methodology for survival estimates between McNary Dam and Bonneville Dam. In 2019 and prior years, our method was to create weekly cohorts of fish detected at McNary Dam for survival estimation between McNary and Bonneville. However, too few fish were detected at McNary Dam in 2021 for that method to work. Instead, we used weekly cohorts of fish detected or tagged at Lower Granite Dam for survival estimation in the Columbia River. This is the same change in methodology that was necessary in 2020, also because of low detection rates.

In 2020, because the Columbia River estuary trawl was not operated, we explored alternative sources of data downstream of the hydropower system for survival estimation to Bonneville Dam. We intend to continue using these additional data sources for survival estimation in 2021 and beyond, alongside data from the estuary trawl. The additional data sources available in 2021 include data from an automated pile dike detector known as Pile Dike 7, recoveries of PIT tags from estuary bird colonies, and detections of precocious smolts re-ascending the adult fish ladders at Bonneville Dam.

Detection data from these additional sources is unavailable or incomplete at the present time. Nonetheless, we were able to produce survival estimates to Bonneville Dam for this memo using currently available detection data. However, these estimates have poor precision. We expect these estimates to change more than usual in the detailed report when full detection information is available.

PIT-tagged yearling Chinook salmon have been released from each of the Snake River Basin hatcheries Dworshak, Kooskia, Lookingglass/Imnaha Weir, Rapid River, McCall/Knox Bridge,

Pahsimeroi, and Sawtooth every year from 1993 through 2021 (except Pahsimeroi in 1996). Across these seven "index" hatcheries, the annual mean estimated survival from release to Lower Granite Dam has been relatively stable since 1998 (Figure 1, Table 2). The mean survival in 2021 was 64.1%, which was about equal to the long-term mean (1998-2021) of 64.7%, though slightly below the mean of 67.5% in 2020.

However, while survival estimates for most of these hatchery stocks were typical, the survival of Pahsimeroi Hatchery Chinook was far below normal in 2021, due to an outbreak of bacterial kidney disease (BKD) at the hatchery. Another recent outbreak of BKD at Pahsimeroi hatchery occurred in 2019, which also resulted in unusually low smolt survival very similar to that in 2021. The recurrence of this outbreak is of concern to hatchery managers.

Downstream of Lower Granite Dam, mean estimated survival for Snake River yearling Chinook salmon (hatchery and wild combined) in 2021 was well below average in the Lower Granite to Little Goose reach, and above average in the Little Goose to Lower Monumental and Lower Monumental to McNary reaches, though all three estimates were imprecise and did not differ statistically from the long-term mean (Table 3, Figure 2). Estimated survival was above average in both the McNary to John Day and the John Day to Bonneville reaches, though these estimates were also imprecise (Table 3, Figure 3).

These estimates resulted in average survival from Lower Granite to McNary, and slightly above average survival across the combined reach from Lower Granite to Bonneville (Table 4). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam to McNary Dam in 2021 was 73% (95% CI: 69.1-76.9%). Mean estimated survival from McNary Dam to Bonneville Dam was 81.9% (58.6-105.2%). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam to Bonneville Dam was 59.8% (42.5-77.1%).

Estimated survival for hatchery and wild yearling Chinook salmon in the Lower Granite project (head of reservoir to tailrace) was 85.6%, based on fish PIT tagged at and released from the Snake River trap. This estimate marks the fourth year in a row that the estimate for the Lower Granite project was below the long-term mean of 91.9%. The combined yearling Chinook salmon survival estimate from the Snake River trap to Bonneville Dam

tailrace was 51.2% (95% CI: 31.8-70.6%), which was slightly above the long-term mean of 48.6% (Table 4).

For wild Snake River yearling Chinook, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was 60.7% (95% CI: 47.8-73.6%), and from McNary Dam tailrace to Bonneville Dam tailrace was 57.2% (25.3-89.1%). This resulted in a survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 34.7% (14.0-55.4%). This was substantially below the long-term mean of 47.2%, but not statistically different from it, because the 2021 estimate was very imprecise. We were unable to estimate survival from the Snake River trap to Lower Granite Dam tailrace for wild Chinook salmon in 2021, because only 27 wild smolts were captured and tagged at the trap.

For Snake River steelhead (hatchery and wild combined), mean estimated survival in 2021 was above average in the Lower Granite to Little Goose and the Little Goose to Lower Monumental reaches, but below average in the Lower Monumental to McNary reach, though all three estimates were very imprecise (Table 5, Figure 2). Estimated survival was below average in both the McNary to John Day and the John Day to Bonneville reaches, though the estimate from McNary to John Day was also very imprecise (Table 5, Figure 3).

These estimates resulted in above average survival from Lower Granite to McNary, but below average survival across the combined reach from Lower Granite to Bonneville (Table 6). Mean estimated survival for steelhead from Lower Granite Dam to McNary Dam in 2021 was 79.8% (95% CI: 65.9-93.7%). Mean estimated survival from McNary Dam to Bonneville Dam was 53.5% (47.8-59.2%). Mean estimated survival for steelhead from Lower Granite Dam to Bonneville Dam was 42.7% (34.0-51.4%).

Estimated survival for hatchery and wild steelhead in the Lower Granite project (head of reservoir to tailrace) was 93.0% in 2021, based on fish PIT tagged at and released from the Snake River trap. This estimate was slightly below the long-term mean of 95.0%. The overall steelhead survival estimate from the Snake River trap to Bonneville Dam tailrace was 39.7% (95% CI: 31.2-48.2%), which was below the long-term mean of 45.8%, but not statistically different from it (Table 6).

For wild Snake River steelhead, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was below

average at 62.7% (95% CI: 51.7-73.7%), and from McNary Dam tailrace to Bonneville Dam tailrace was far below average at 43.8% (29.9-57.6%). Estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 27.4% (95% CI: 17.5-37.3%), which was significantly different from the long-term mean of 42.4%. The survival estimate for wild steelhead from the Snake River trap to Lower Granite Dam tailrace was 115.8% (82.5-149.1%) in 2021, which was unusually high but extremely imprecise. These estimates resulted in a survival estimate from the Snake River trap to Bonneville Dam tailrace of 31.8% (17.1-46.4%), which was substantially below the long-term mean of 41.3%, but not statistically different from it.

For PIT-tagged hatchery yearling Chinook salmon originating from the upper Columbia River in 2021, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 61.6% (95% CI: 50.6-75.0%; Table 7), which was well below the long-term mean of 80.2%, but was not statistically different from it.

For PIT-tagged hatchery steelhead originating from the upper Columbia River in 2021, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 43.3% (95% CI: 35.4-52.7%; Table 7). This estimate was far below the long-term mean of 74.5% and the difference was statistically significant.

Estimated survival in 2021 of Snake River sockeye salmon (hatchery and wild combined) from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 31.7% (95% CI: 25.2-39.8%; Table 8). Estimated survival in 2021 of Columbia River sockeye salmon (hatchery and wild combined) from the tailrace of Rock Island Dam to the tailrace of Bonneville Dam was 39.1% (20.0-76.5%; Table 8). Both estimates were below their respective long-term means of 40.4% and 49.4%, but not significantly so.

Our preliminary estimates of the percentage transported of non-tagged wild and hatchery spring-summer Chinook salmon smolts in 2021 are 9.8% and 5.9%, respectively. For steelhead, the estimates are 11.1% and 4.3% for wild and hatchery smolts, respectively (Figure 4). These estimates represent the percentage of smolts that arrived at Lower Granite Dam that were subsequently transported, either from Lower Granite Dam or downstream from Little Goose or Lower Monumental Dam. Estimated percentages transported in 2021 are the lowest in our time series by a substantial margin.

Over the last several years we have noted a trend toward shorter smolt travel times relative to levels of flow and spill. However, we did not see strong evidence of this trend in 2021. For the majority of the migration season, travel times for both Chinook and Steelhead were similar to those in other low-flow years since 2006 (Figure 5). The exceptions were after the start of May for Chinook and from late April through early May for steelhead, during which periods travel times were slightly shorter than in other low-flow years. These differences in smolt travel time were modest, in the presence of spill rates were far higher in 2021 than in past low-flow years.

Discussion

Flexible spill operations were conducted for the third consecutive year in 2021 and the second consecutive year using an increased spill cap of 125% dissolved gas saturation. There is much interest in the potential benefits of increased spill to fish survival and travel time through the hydropower system. Unfortunately, the precision of the estimates of these metrics has suffered under the high spill operations due to substantial decreases in detections of fish. This makes it difficult to assess whether the new operations provided benefit or were detrimental for fish, especially when focusing on results from individual river reaches.

For Snake River yearling Chinook salmon in 2021, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was a little higher than the long-term mean (1999-2021), but the difference was not statistically significant. For Snake River steelhead in 2021, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was a little below the long-term mean (1999-2021), but the difference was also not statistically significant.

While the survival estimates for hatchery and wild Chinook and steelhead were a little above average and a little below average respectively, the survival of wild smolts separately was far below average for both species in 2021. Estimates for both were among the lowest in the past 10 years. The precision of these wild-only survival estimates was poor in 2021 due to a combination of smaller that normal sample sizes and very poor

detection. However, despite the lack of certainty, these low survival estimates are concerning, as they are occurring during a management regime of extremely high spill rates intended to boost survival.

Also of concern is that survival from McNary Dam tailrace to Bonneville Dam tailrace was below average for Snake River steelhead (hatchery and wild combined), Snake River sockeye, Upper Columbia River hatchery Chinook, Upper Columbia River hatchery steelhead, and Upper Columbia River sockeye. Although these estimates suffered from uncertainty, the consistency of them all being well below average along with those for wild fish from the Snake River could be pointing to a problem that requires further investigation.

Survival for Chinook from the Snake River Trap to Lower Granite Dam was below average for the fourth consecutive year (Table 4). Additionally, the sample sizes of both wild and hatchery Chinook tagged at the trap have declined substantially from past years. Only 27 wild Chinook were tagged at the trap in 2021, which made it impossible to estimate survival for wild Chinook separately. If this trend of low survival and low capture rates continues it raises a need for further investigation.

Environmental conditions and management actions in 2021 resulted in a year with low flow, warmer than average water temperatures, and extremely high percent spill for the whole migration season. Mean flow at Little Goose Dam in 2021 during the main migration period 1 April–15 June was 56.1 kcfs, which was far below the long-term (1993-2021) mean of 92.0 kcfs and was the third lowest flow year in that time series. Daily flow values were far below long-term daily means except for a few pulses in flow during late April and early May. During those pulses, flow was only somewhat below the long-term daily mean (Figure 6).

Mean water temperature at Little Goose Dam during the 2021 migration period was 11.6 °C, which was slightly above long-term mean (1993-2021) of 11.2 °C. Daily water temperatures were about a degree higher than average from April 23-May 7, May 19-24, and June 4-15, and essentially average otherwise (Figure 6).

Mean spill discharge at the Snake River dams during the 2021 migration was 38.1 kcfs, which was similar to the 2006-2021 mean of 35.6 kcfs. Daily spill discharge was moderately above average

in late April and early May and close to average for the rest of the migration period (Figure 7).

Spill as a percentage of flow at Snake River dams averaged 63.2% in 2021, which was nearly double the long-term (2006-2021) mean of 38.0% and edged out 2020 to become the highest recorded mean spill percent on record. Daily mean spill percentages in 2021 were very consistent and extremely high for the entire migration period (Figure 7).

Daily mean percent dissolved gas saturation was slightly above the long-term mean in 2021, but much lower than in 2020, likely due to the lower spill discharge in 2021 (Figure 8). Daily mean percent dissolved gas saturation remained fairly consistently between 116% and 118% for the majority of the migration season, but hourly values fluctuated between approximately 114% and 125% (data not shown).

An increase in flow from April 30-May 10 may be associated with the large increase in Chinook passage and a smaller increase in steelhead passage around that time (Figures 6 and 9). However, the major spike in steelhead smolt passage around April 20 occurred during a period when both flow and temperature were very consistent and are likely related to some other factor.

The lower flow contributed to longer travel times of fish between Lower Granite Dam and Bonneville Dam. The increased travel times could have contributed to lower estimated survival of several stocks due to increased duration of exposure to mortality factors, including predation, dissolved gas, and increased water temperatures. It is possible that unfavorable tailrace conditions, such as eddies that delay fish and expose them to predation, could have resulted from the combination of low flow and high spill at some dams. Further investigation into the potential causes of increased mortality is needed.

In any given year the percentage of a stock that is transported is largely determined by a combination of three factors: (1) migration timing in relation to (2) the starting date of general smolt transportation, and (3) the percentage of smolts that enter the collection system during the transportation period.

In 2021, collection for transportation began on 24 April at Lower Granite, Little Goose, and Lower Monumental Dams, the same start date as in 2019 and 2020. The start date was at least 7 days

earlier than the start date of 1 May, or later, typical in most previous years. However, the proportion of smolts transported in 2021 was substantially lower than in 2019 or 2020, suggesting that either run timing was earlier in 2021 or that collection rates were lower.

The run in 2021 was only slightly early for steelhead and neither early nor late for Chinook. We estimate that 44.3% of wild and 11.7% of hatchery Chinook salmon, and 20.9% of wild and 54.1% of hatchery steelhead passed prior to the start of transportation. These numbers are slightly higher than in 2019 and 2020 for steelhead, indicating that run timing did reduce steelhead transportation rates some in 2021.

In 2021, extremely low proportions of passing smolts were collected after the start of transportation. We estimate that 14.6% of wild and 6.4% of hatchery Chinook and 11.1% of wild and 7.2% of hatchery steelhead that passed during transport operations were collected and transported. These collection rates are less than half of the already low collection rates from 2020, and less than a quarter of the collection rates from 2018 or 2019. These extremely low collection rates resulted from the combination of extremely high percent spill and low flow during the 2021 migration, and were the primary cause of the very low overall transportation rate.

Unfortunately for quantity and quality of data, a side effect of increased spill since 2006 has been a drop in detection rates of smolts at most Snake and Columbia River dams. The exceptionally high spill in 2020 and 2021 resulted in exceptionally low detection rates.

The addition of a detector in the spillway at Lower Granite Dam offset low detection rates in the juvenile bypass system there: the total numbers of PIT-tagged fish detected at Lower Granite Dam and known to be alive in the tailrace have been similar to past years. However, detection at downstream dams continues to occur only in juvenile bypass systems (with the exception of the corner collector at Bonneville Dam). Despite otherwise sufficient sample sizes of fish leaving Lower Granite Dam, most survival estimates to downstream dams in 2021 were extremely imprecise.

In addition, low detection rates decrease “resolution” of the information, requiring pooling data into larger temporal groups.

For example, we were forced to use two-week groupings of fish for essentially all survival estimates in 2021, when we prefer to use weekly and daily groups to better conform to the assumptions of the CJS model.

The PIT tag is currently the primary tool for research and monitoring of Columbia basin salmon. Numerous agencies in the region have invested enormous amounts of resources into PIT tagging and analysis. The informational return on these investments is diminished when actions are taken that decrease detectability. If management priorities result in spill continuing at the levels of 2020 and 2021, then the region would do well to find ways to compensate for the loss of PIT-tag detection in juvenile bypass systems.

The success of the new spillway detector at Lower Granite Dam is very encouraging. Because the current management goal is to pass as many juveniles via spill as possible, the spillway is the ideal location for expanded PIT-tag detection. Increased detection rates will pay dividends on all of the other investments in PIT-tag research within the region, not merely this project. We believe that the region should place a very high priority on installing similar systems at other dams on the Snake and Columbia rivers, especially McNary Dam and Bonneville Dam. There should also be an emphasis placed on development of alternative technologies that will boost our abilities to detect PIT-tagged fish, such as placing detection barges in the forebay or tailrace of the dams and other detection equipment downstream of Bonneville Dam.

cc: F/NWC3 – Faulkner
F/NWC3 – Marsh
F/NWC3 – Smith
F/NWC3 - Widener
F/NWC3 - Hecht

Table 1. Total number of PIT-tagged hatchery and wild yearling Chinook salmon and juvenile steelhead used for survival probability estimates for weekly and biweekly groups of fish at Lower Granite Dam, 2010-2021. Categories are fish tagged upstream from the dam and detected in spillway or bypass system and fish collected and tagged in the bypass system. Only smolts returned to the river after detection or tagging are included.

	Smolt numbers at Lower Granite Dam (n)							
	Detected in spillway system		Detected in juvenile bypass system		Tagged in juvenile bypass system		Total	
Year	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
				Yearling Chinook salmon				
2010	-	-	35,402	12,411	47,902	17,008	83,304	29,419
2011	-	-	70,206	17,495	47	16,029	70,253	33,524
2012	-	-	51,282	12,831	46	16,749	51,328	29,580
2013	-	-	43,617	8,550	13	11,773	43,630	20,323
2014	-	-	69,152	15,502	76	17,917	69,228	33,419
2015	-	-	26,210	3,465	33	8,300	26,243	11,765
2016	-	-	87,431	11,964	85	22,145	87,516	34,109
2017	-	-	45,355	8,158	10	14,241	45,365	22,399
2018	-	-	54,989	9,409	0	11,823	54,989	21,232
2019	-	-	38,961	6,376	14	6,349	38,975	12,725
2020	60,290	5,344	14,106	2,295	0	0	74,396	7,639
2021	94,284	6,821	3,742	599	57	1,770	98,083	9,190
Mean	**77,287**	**6,083**	**45,038**	**9,088**	**4,024**	**12,009**	**61,943**	**22,110**
				Steelhead				
2010	-	-	33,171	5,035	16,173	11,991	49,344	17,026
2011	-	-	60,961	5,350	22,011	18,001	82,972	23,351
2012	-	-	45,350	7,438	20,121	20,122	65,471	27,560
2013	-	-	29,420	5,400	17,380	7,457	46,800	12,857
2014	-	-	42,082	6,823	20,593	14,493	62,675	21,316
2015	-	-	14,626	1,578	25,278	17,065	39,904	18,643
2016	-	-	55,467	5,625	17,972	14,774	73,439	20,399
2017	-	-	42,253	3,619	22,049	18,422	64,302	22,041
2018	-	-	47,465	5,699	20,249	15,396	67,714	21,095
2019	-	-	47,919	4,249	20,888	14,758	68,807	19,007
2020	60,090	3,442	9,899	1,161	0	0	69,989	4,603
2021	83,852	6,978	4,755	467	18,120	4,854	106,727	12,299
Mean	**71,971**	**5,210**	**36,114**	**4,370**	**18,403**	**13,111**	**66,512**	**18,350**

Table 2. Estimated survival and standard error (s.e.) for yearling **Chinook** salmon released at Snake River Basin and Upper Columbia River hatcheries to Lower Granite Dam tailrace (LGR) and McNary Dam tailrace (MCN), 2019 through 2021.

Hatchery	2019		2020		2021[a]	
	Survival to LGR (s.e.)	Survival to MCN (s.e.)	Survival to LGR (s.e.)	Survival to MCN (s.e.)	Survival to LGR (s.e.)	Survival to MCN (s.e.)
Dworshak	0.688 (0.013)	0.466 (0.021)	0.811 (0.011)	0.576 (0.034)	0.786 (0.012)	0.539 (0.040)
Kooskia	0.571 (0.022)	0.352 (0.041)	0.747 (0.029)	0.524 (0.068)	0.801 (0.041)	0.676 (0.152)
Lookingglass (Catherine Cr.)	0.454 (0.018)	0.392 (0.044)	0.530 (0.015)	0.425 (0.047)	0.520 (0.017)	0.311 (0.039)
Lookingglass (Grande Ronde)	0.465 (0.038)	0.253 (0.064)	0.468 (0.053)	0.400 (0.184)	0.500 (0.062)	---
Lookingglass (Imnaha Weir)	0.627 (0.025)	0.459 (0.048)	0.629 (0.017)	0.450 (0.041)	0.760 (0.026)	0.561 (0.073)
Lookingglass (Lostine River)	0.559 (0.022)	0.414 (0.054)	0.567 (0.029)	0.474 (0.092)	0.489 (0.026)	0.298 (0.056)
McCall (Johnson Cr.)	---	---	0.595 (0.056)	0.410 (0.187)	0.552 (0.052)	0.458 (0.190)
McCall (Knox Bridge)	0.616 (0.014)	0.528 (0.029)	0.733 (0.011)	0.519 (0.030)	0.780 (0.012)	0.599 (0.036)
Pahsimeroi	0.280 (0.008)	0.161 (0.020)	0.559 (0.018)	0.360 (0.049)	0.284 (0.012)	0.230 (0.041)
Rapid River	0.491 (0.009)	0.433 (0.024)	0.567 (0.010)	0.398 (0.026)	0.633 (0.011)	0.525 (0.042)
Sawtooth	0.539 (0.021)	0.358 (0.032)	0.681 (0.020)	0.472 (0.049)	0.635 (0.016)	0.481 (0.058)
Entiat	---	0.565 (0.053)	---	0.570 (0.054)	---	0.765 (0.145)
Winthrop	---	0.490 (0.055)	---	0.590 (0.068)	---	0.617 (0.097)
Leavenworth	---	0.515 (0.035)	---	0.618 (0.051)	---	0.505 (0.056)

a. Estimates are preliminary and subject to change.

Table 3. Annual weighted means of survival probability estimates for yearling **Chinook** salmon (hatchery and wild combined), 1998–2021. 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. 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. Simple arithmetic means across all available years (1993–2021) are given.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
1998	0.924 (0.011)	0.991 (0.006)	0.853 (0.009)	0.915 (0.011)	0.957	0.822 (0.033)	NA	NA
1999	0.940 (0.009)	0.949 (0.002)	0.925 (0.004)	0.904 (0.007)	0.951	0.853 (0.027)	0.814 (0.065)	0.902
2000	0.929 (0.014)	0.938 (0.006)	0.887 (0.009)	0.928 (0.016)	0.963	0.898 (0.054)	0.684 (0.128)	0.827
2001	0.954 (0.015)	0.945 (0.004)	0.830 (0.006)	0.708 (0.007)	0.841	0.758 (0.024)	0.645 (0.034)	0.803
2002	0.953 (0.022)	0.949 (0.006)	0.980 (0.008)	0.837 (0.013)	0.915	0.907 (0.014)	0.840 (0.079)	0.917
2003	0.993 (0.023)	0.946 (0.005)	0.916 (0.011)	0.904 (0.017)	0.951	0.893 (0.017)	0.818 (0.036)	0.904
2004	0.893 (0.009)	0.923 (0.004)	0.875 (0.012)	0.818 (0.018)	0.904	0.809 (0.028)	0.735 (0.092)	0.857
2005	0.919 (0.015)	0.919 (0.003)	0.886 (0.006)	0.903 (0.010)	0.950	0.772 (0.029)	1.028 (0.132)	1.014
2006	0.952 (0.011)	0.923 (0.003)	0.934 (0.004)	0.887 (0.008)	0.942	0.881 (0.020)	0.944 (0.030	0.972
2007	0.943 (0.028)	0.938 (0.006)	0.957 (0.010)	0.876 (0.012)	0.936	0.920 (0.016)	0.824 (0.043)	0.908
2008	0.992 (0.018)	0.939 (0.006)	0.950 (0.011)	0.878 (0.016)	0.937	1.073 (0.058)	0.558 (0.082)	0.750
2009	0.958 (0.010)	0.940 (0.006)	0.982 (0.009)	0.855 (0.011)	0.925	0.866 (0.042)	0.821 (0.043)	0.906
2010	0.968 (0.040)	0.962 (0.011)	0.973 (0.019)	0.851 (0.017)	0.922	0.947 (0.021)	0.780 (0.039)	0.883
2011	0.943 (0.009)	0.919 (0.007)	0.966 (0.007)	0.845 (0.012)	0.919	0.893 (0.026)	0.766 (0.080)	0.875
2012	0.928 (0.012)	0.907 (0.009)	0.939 (0.010)	0.937 (0.016)	0.968	0.915 (0.023)	0.866 (0.058)	0.931
2013	0.845 (0.031)	0.922 (0.012)	0.983 (0.014)	0.904 (0.022)	0.951	0.931 (0.054)	0.823 (0.036)	0.907
2014	0.905 (0.015)	0.947 (0.005)	0.919 (0.010)	0.894 (0.017)	0.946	0.912 (0.053)	0.752 (0.104)	0.867
2015	0.909 (0.103)	0.928 (0.031)	0.960 (0.057)	0.785 (0.032)	0.886	0.724 (0.069)	0.937 (0.160)	0.968
2016	0.936 (0.015)	0.956 (0.006)	0.912 (0.010)	0.872 (0.013)	0.934	0.796 (0.039)	0.871 (0.047)	0.933
2017	NA	0.916 (0.009)	0.908 (0.013)	0.912 (0.024)	0.956	0.720 (0.041)	0.871 (0.200)	0.933
2018	0.880 (0.022)	0.942 (0.013)	0.917 (0.019)	0.877 (0.036)	0.936	0.770 (0.074)	0.743 (0.100)	0.862
2019	0.785 (0.027)	0.874 (0.015)	0.953 (0.027)	0.792 (0.032)	0.890	1.015 (0.088)	0.798 (0.111)	0.893
2020	0.848 (0.058)	0.811 (0.039)	1.171 (0.128)	0.847 (0.095)	0.920	0.862 (0.039)[c]	0.865 (0.060)[c]	0.930[c]
2021[a]	0.856 (0.107)	0.792 (0.055)	1.064 (0.133)	0.970 (0.204)	0.985	0.977 (0.093)[c]	0.838 (0.083)[c]	0.915[c]
Mean[b]	**0.918 (0.010)**	**0.918 (0.008)**	**0.937 (0.013)**	**0.864 (0.011)**	**0.929 (0.006)**	**0.871 (0.018)**	**0.810 (0.021)**	**0.898 (0.012)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993-1997 are omitted from the table for space.
c. Estimates for 2020-2021 in the reaches between McNary Dam and Bonneville Dam used a different method than in other years.

Table 4. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River yearling **Chinook** salmon (hatchery and wild combined), 1998–2021. 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
1998	0.924 (0.011)	0.770 (0.009)	NA	NA	NA
1999	0.940 (0.009)	0.792 (0.006)	0.704 (0.058)	0.557 (0.046)	0.524 (0.043)
2000	0.929 (0.014)	0.760 (0.012)	0.640 (0.122)	0.486 (0.093)	0.452 (0.087)
2001	0.954 (0.015)	0.556 (0.009)	0.501 (0.027)	0.279 (0.016)	0.266 (0.016)
2002	0.953 (0.022)	0.757 (0.009)	0.763 (0.079)	0.578 (0.060)	0.551 (0.059)
2003	0.993 (0.023)	0.731 (0.010)	0.728 (0.030)	0.532 (0.023)	0.528 (0.026)
2004	0.893 (0.009)	0.666 (0.011)	0.594 (0.074)	0.395 (0.050)	0.353 (0.045)
2005	0.919 (0.015)	0.732 (0.009)	0.788 (0.093)	0.577 (0.068)	0.530 (0.063)
2006	0.952 (0.011)	0.764 (0.007)	0.842 (0.021)	0.643 (0.017)	0.612 (0.018)
2007	0.943 (0.028)	0.783 (0.006)	0.763 (0.044)	0.597 (0.035)	0.563 (0.037)
2008	0.992 (0.018)	0.782 (0.011)	0.594 (0.066)	0.465 (0.052)	0.460 (0.052)
2009	0.958 (0.010)	0.787 (0.007)	0.705 (0.031)	0.555 (0.025)	0.531 (0.025)
2010	0.968 (0.040)	0.772 (0.012)	0.738 (0.039)	0.569 (0.032)	0.551 (0.038)
2011	0.943 (0.009)	0.746 (0.010)	0.687 (0.065)	0.513 (0.049)	0.483 (0.046)
2012	0.928 (0.012)	0.790 (0.016)	0.802 (0.051)	0.634 (0.042)	0.588 (0.040)
2013	0.845 (0.031)	0.781 (0.016)	0.796 (0.064)	0.622 (0.052)	0.525 (0.048)
2014	0.905 (0.015)	0.768 (0.015)	0.715 (0.107)	0.549 (0.083)	0.497 (0.075)
2015	0.909 (0.103)	0.727 (0.033)	0.629 (0.043)	0.457 (0.038)	0.415 (0.058)
2016	0.936 (0.015)	0.752 (0.011)	0.672 (0.060)	0.505 (0.046)	0.473 (0.043)
2017	NA	0.743 (0.019)	0.643 (0.157)	0.478 (0.117)	NA
2018	0.880 (0.022)	0.733 (0.025)	0.590 (0.045)	0.432 (0.036)	0.381 (0.033)
2019	0.785 (0.027)	0.628 (0.027)	0.825 (0.060)	0.518 (0.044)	0.407 (0.037)
2020	0.848 (0.058)	0.766 (0.018)	0.733 (0.045)[c]	0.563 (0.039)	0.477 (0.046)
2021[a]	0.856 (0.107)	0.730 (0.020)	0.819 (0.119)[c]	0.598 (0.088)	0.512 (0.099)
Mean[b]	**0.918 (0.010)**	**0.735 (0.011)**	**0.707 (0.019)**	**0.527 (0.018)**	**0.486 (0.017)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993-1997 are omitted from the table for space.
c. Estimates for 2020-2021 in the reaches between McNary Dam and Bonneville Dam used a different method than in other years.

Table 5. Annual weighted means of survival probability estimates for **steelhead** (hatchery and wild combined), 1998–2021. 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. 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. Simple arithmetic means across all available years (1993–2021) are given.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
1998	0.924 (0.009)	0.930 (0.004)	0.889 (0.006)	0.797 (0.018)	0.893	0.831 (0.031)	0.935 (0.103)	0.967
1999	0.908 (0.011)	0.926 (0.004)	0.915 (0.006)	0.833 (0.011)	0.913	0.920 (0.033)	0.682 (0.039)	0.826
2000	0.964 (0.013)	0.901 (0.006)	0.904 (0.009)	0.842 (0.016)	0.918	0.851 (0.045)	0.754 (0.045)	0.868
2001	0.911 (0.007)	0.801 (0.010)	0.709 (0.008)	0.296 (0.010)	0.544	0.337 (0.025)	0.753 (0.063)	0.868
2002	0.895 (0.015)	0.882 (0.011)	0.882 (0.018)	0.652 (0.031)	0.807	0.844 (0.063)	0.612 (0.098)	0.782
2003	0.932 (0.015)	0.947 (0.005)	0.898 (0.012)	0.708 (0.018)	0.841	0.879 (0.032)	0.630 (0.066)	0.794
2004	0.948 (0.004)	0.860 (0.006)	0.820 (0.014)	0.519 (0.035)	0.720	0.465 (0.078)	NA	NA
2005	0.967 (0.004)	0.940 (0.004)	0.867 (0.009)	0.722 (0.023)	0.850	0.595 (0.040)	NA	NA
2006	0.920 (0.013)	0.956 (0.004)	0.911 (0.006)	0.808 (0.017)	0.899	0.795 (0.045)	0.813 (0.083)	0.902
2007	1.016 (0.026)	0.887 (0.009)	0.911 (0.022)	0.852 (0.030)	0.923	0.988 (0.098)	0.579 (0.059)	0.761
2008	0.995 (0.018)	0.935 (0.007)	0.961 (0.014)	0.776 (0.017)	0.881	0.950 (0.066)	0.742 (0.045)	0.861
2009	1.002 (0.011)	0.972 (0.005)	0.942 (0.008)	0.863 (0.014)	0.929	0.951 (0.026)	0.900 (0.079)	0.949
2010	1.017 (0.030)	0.965 (0.028)	0.984 (0.044)	0.876 (0.032)	0.936	0.931 (0.051)	0.840 (0.038)	0.917
2011	0.986 (0.017)	0.955 (0.004)	0.948 (0.010)	0.772 (0.014)	0.879	0.960 (0.043)	0.858 (0.051)	0.926
2012	1.001 (0.026)	0.959 (0.006)	0.914 (0.011)	0.811 (0.022)	0.901	0.814 (0.048)	1.021 (0.148)	1.010
2013	0.973 (0.032)	0.921 (0.020)	0.977 (0.020)	0.739 (0.031)	0.860	0.799 (0.025)	1.026 (0.154)	1.013
2014	1.018 (0.028)	0.953 (0.009)	0.947 (0.024)	0.836 (0.032)	0.914	1.082 (0.080)	0.982 (0.147)	0.991
2015	0.874 (0.046)	1.017 (0.028)	0.829 (0.059)	0.923 (0.071)	0.961	0.792 (0.066)	0.842 (0.050)	0.918
2016	0.998 (0.016)	0.990 (0.007)	0.918 (0.016)	0.813 (0.025)	0.902	0.927 (0.074)	0.709 (0.071)	0.842
2017	NA	0.962 (0.008)	0.943 (0.015)	0.849 (0.022)	0.921	0.913 (0.020)	1.145 (0.104)	1.070
2018	0.983 (0.025)	0.953 (0.007)	0.950 (0.016)	0.823 (0.036)	0.907	0.851 (0.039)	0.946 (0.150)	0.974
2019	0.965 (0.027)	0.968 (0.006)	0.981 (0.011)	0.774 (0.019)	0.880	1.029 (0.084)	0.734 (0.110)	0.857
2020	0.914 (0.041)	0.991 (0.049)	1.025 (0.109)	0.834 (0.092)	0.913	0.985 (0.090)[c]	0.762 (0.057)[c]	0.873[c]
2021[a]	0.930 (0.029)	1.081 (0.045)	1.079 (0.086)	0.677 (0.040)	0.823	0.765 (0.094)[c]	0.705 (0.031)[c]	0.840[c]
Mean[b]	**0.950 (0.010)**	**0.939 (0.010)**	**0.922 (0.013)**	**0.773 (0.024)**	**0.876 (0.016)**	**0.844 (0.035)**	**0.817 (0.032)**	**0.900 (0.017)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993-1996 are omitted from the table for space.
c. Estimates for 2020-2021 in the reaches between McNary Dam and Bonneville Dam used a different method than in other years.

Table 6. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River **steelhead** (hatchery and wild combined), 1998–2021. 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
1998	0.924 (0.009)	0.649 (0.013)	0.770 (0.081)	0.500 (0.054)	0.462 (0.050)
1999	0.908 (0.011)	0.688 (0.010)	0.640 (0.024)	0.440 (0.018)	0.400 (0.017)
2000	0.964 (0.013)	0.679 (0.016)	0.580 (0.040)	0.393 (0.034)	0.379 (0.033)
2001	0.911 (0.007)	0.168 (0.006)	0.250 (0.016)	0.042 (0.003)	0.038 (0.003)
2002	0.895 (0.015)	0.536 (0.025)	0.488 (0.090)	0.262 (0.050)	0.234 (0.045)
2003	0.932 (0.015)	0.597 (0.013)	0.518 (0.015)	0.309 (0.011)	0.288 (0.012)
2004	0.948 (0.004)	0.379 (0.023)	NA	NA	NA
2005	0.967 (0.004)	0.593 (0.018)	NA	NA	NA
2006	0.920 (0.013)	0.702 (0.016)	0.648 (0.079)	0.455 (0.056)	0.418 (0.052)
2007	1.016 (0.026)	0.694 (0.020)	0.524 (0.064)	0.364 (0.045)	0.369 (0.047)
2008	0.995 (0.018)	0.716 (0.015)	0.671 (0.034)	0.480 (0.027)	0.478 (0.028)
2009	1.002 (0.011)	0.790 (0.013)	0.856 (0.074)	0.676 (0.059)	0.678 (0.060)
2010	1.017 (0.030)	0.770 (0.020)	0.789 (0.027)	0.608 (0.026)	0.618 (0.032)
2011	0.986 (0.017)	0.693 (0.013)	0.866 (0.038)	0.600 (0.029)	0.592 (0.030)
2012	1.001 (0.026)	0.698 (0.020)	0.856 (0.196)	0.597 (0.138)	0.598 (0.139)
2013	0.973 (0.032)	0.645 (0.026)	0.798 (0.112)	0.515 (0.075)	0.501 (0.075)
2014	1.018 (0.028)	0.740 (0.021)	1.023 (0.088)	0.757 (0.069)	0.771 (0.073)
2015	0.874 (0.046)	0.733 (0.027)	0.663 (0.039)	0.486 (0.034)	0.425 (0.037)
2016	0.998 (0.016)	0.730 (0.020)	0.608 (0.040)	0.444 (0.032)	0.443 (0.032)
2017	NA	0.759 (0.019)	1.045 (0.095)	0.793 (0.075)	NA
2018	0.983 (0.025)	0.733 (0.031)	0.802 (0.098)	0.588 (0.076)	0.578 (0.076)
2019	0.965 (0.027)	0.717 (0.017)	0.595 (0.109)	0.427 (0.079)	0.412 (0.077)
2020	0.914 (0.041)	0.807 (0.043)	0.738 (0.052)[c]	0.595 (0.027)	0.544 (0.035)
2021[a]	0.930 (0.029)	0.798 (0.071)	0.535 (0.029)[c]	0.427 (0.044)	0.397 (0.043)
Mean[b]	**0.950 (0.010)**	**0.673 (0.026)**	**0.692 (0.038)**	**0.488 (0.034)**	**0.458 (0.033)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993-1996 are omitted for space.
c. Estimates for 2020-2021 in the reaches between McNary Dam and Bonneville Dam used a different method than in other years.

Table 7. 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, 1999–2021. Abbreviations: Rel–Release site; MCN–McNary Dam; JDA–John Day Dam; BON–Bonneville Dam.

	Yearling Chinook Salmon				Steelhead			
Year	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)	NA	NA	NA	NA
2000	0.539 (0.025)	0.781 (0.094)	NA	NA	NA	NA	NA	NA
2001	0.428 (0.009)	0.881 (0.062)	NA	NA	NA	NA	NA	NA
2002	0.555 (0.003)	0.870 (0.011)	0.940 (0.048)	0.817 (0.041)	NA	NA	NA	NA
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)
2010	0.660 (0.014)	0.924 (0.040)	0.796 (0.046)	0.735 (0.037)	0.512 (0.017)	0.996 (0.054)	0.628 (0.038)	0.626 (0.033)
2011	0.534 (0.010)	1.042 (0.047)	0.612 (0.077)	0.637 (0.077)	0.435 (0.012)	1.201 (0.064)	0.542 (0.101)	0.651 (0.119)
2012	0.576 (0.012)	0.836 (0.035)	1.140 (0.142)	0.953 (0.115)	0.281 (0.011)	0.862 (0.047)	1.240 (0.186)	1.069 (0.159)
2013	0.555 (0.013)	0.965 (0.050)	1.095 (0.129)	1.056 (0.117)	0.384 (0.020)	0.957 (0.071)	0.974 (0.104)	0.932 (0.099)
2014	0.571 (0.013)	0.974 (0.047)	0.958 (0.122)	0.933 (0.114)	0.468 (0.043)	0.883 (0.124)	0.807 (0.153)	0.712 (0.130)
2015	0.512 (0.015)	0.843 (0.043)	1.032 (0.081)	0.870 (0.062)	0.351 (0.019)	0.807 (0.084)	0.707 (0.073)	0.570 (0.043)
2016	0.610 (0.009)	0.857 (0.027)	0.942 (0.068)	0.807 (0.055)	0.416 (0.011)	0.771 (0.037)	0.633 (0.046)	0.487 (0.032)
2017	0.582 (0.013)	0.853 (0.030)	1.107 (0.142)	0.944 (0.120)	0.437 (0.025)	0.880 (0.062)	1.095 (0.210)	0.964 (0.188)
2018	0.608 (0.016)	0.914 (0.044)	0.820 (0.096)	0.749 (0.084)	0.416 (0.021)	0.942 (0.062)	1.232 (0.194)	1.161 (0.186)
2019	0.506 (0.018)	0.853 (0.042)	0.920 (0.066)	0.785 (0.056)	0.342 (0.016)	0.812 (0.048)	0.746 (0.054)	0.606 (0.047)
2020	0.629 (0.025)	0.867 (0.045)	0.922 (0.094)	0.800 (0.083)	0.420 (0.035)	0.879 (0.082)	0.859 (0.084)	0.756 (0.092)
2021[a]	0.521 (0.027)	0.767 (0.061)	0.803 (0.084)	0.616 (0.062)	0.334 (0.027)	0.872 (0.109)	0.495 (0.057)	0.432 (0.044)
Mean[b]	**0.558 (0.011)**	**0.890 (0.020)**	**0.896 (0.036)**	**0.802 (0.028)**	**0.410 (0.013)**	**0.890 (0.025)**	**0.843 (0.052)**	**0.745 (0.046)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment.

Table 8. 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, 1998–2021; years prior to 1998 omitted for space. Note that estimates in this table are provided regardless of the precision, which in some years was very poor. Abbreviations: LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam; RIS–Rock Island Dam.

	Snake River Sockeye			Upper Columbia River Sockeye		
Year	LGR-MCN	MCN-BON	LGR-BON	RIS-MCN	MCN-BON	RIS-BON
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)
2010	0.723 (0.039)	0.752 (0.098)	0.544 (0.077)	0.778 (0.063)	0.627 (0.152)	0.488 (0.111)
2011	0.659 (0.033)	NA	NA	0.742 (0.088)	0.691 (0.676)	0.513 (0.498)
2012	0.762 (0.032)	0.619 (0.084)	0.472 (0.062)	0.945 (0.085)	0.840 (0.405)	0.794 (0.376)
2013	0.691 (0.043)	0.776 (0.106)	0.536 (0.066)	0.741 (0.068)	0.658 (0.217)	0.487 (0.155)
2014	0.873 (0.054)	0.817 (0.115)	0.713 (0.096)	0.428 (0.056)	0.565 (0.269)	0.242 (0.111)
2015	0.702 (0.054)	0.531 (0.151)	0.373 (0.037)	0.763 (0.182)	0.446 (0.200)	0.340 (0.130)
2016	0.523 (0.047)	0.227 (0.059)	0.119 (0.030)	0.807 (0.082)	0.545 (0.126)	0.448 (0.144)
2017	0.544 (0.081)	0.324 (0.107)	0.176 (0.055)	0.719 (0.113)	0.611 (0.181)	0.500 (0.332)
2018	0.684 (0.061)	0.940 (0.151)	0.643 (0.088)	0.927 (0.118)	0.560 (0.112)	0.344 (0.124)
2019	0.836 (0.053)	0.520 (0.044)	0.434 (0.031)	0.941 (0.125)	0.701 (0.120)	0.737 (0.191)
2020	0.803 (0.111)	0.546 (0.149)	0.439 (0.104)	0.910 (0.218)	0.288 (0.154)	0.352 (0.325)
2021[a]	0.799 (0.092)	0.397 (0.065)	0.317 (0.037)	0.883 (0.224)	0.425 (0.141)	0.391 (0.138)
Mean[b]	**0.650 (0.032)**	**0.555 (0.060)**	**0.404 (0.045)**	**0.713 (0.032)**	**0.682 (0.068)**	**0.494 (0.048)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1995-1996 are omitted for space.

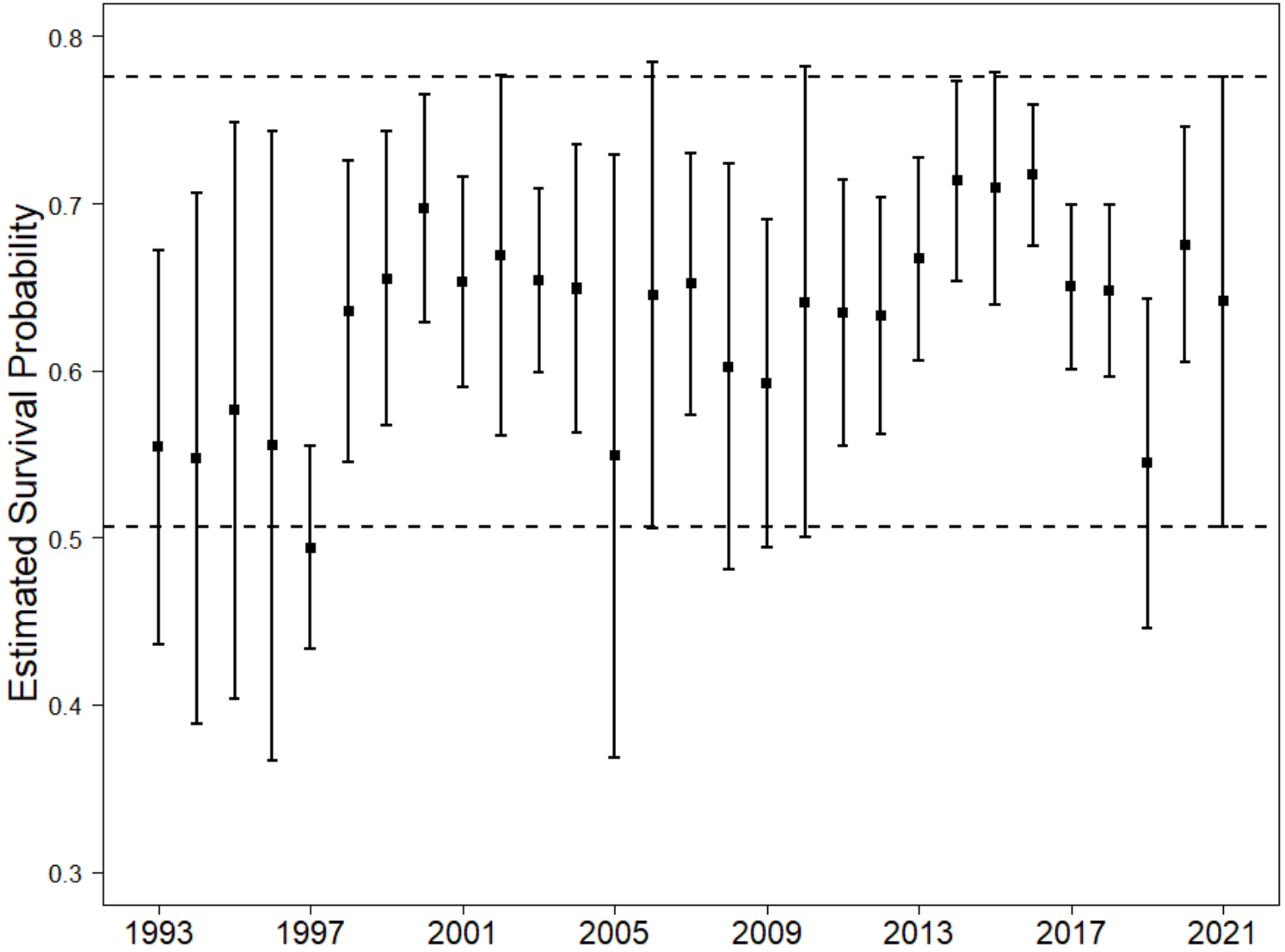

Figure 1. Annual mean survival estimates from release to Lower Granite Dam for PIT-tagged yearling **Chinook** salmon released from Snake River Basin hatcheries, 1993-2021. Hatcheries used for the mean (index groups) are those with consistent PIT-tag releases through the series of years shown. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are the 2021 confidence interval endpoints and are shown for comparison to other years.

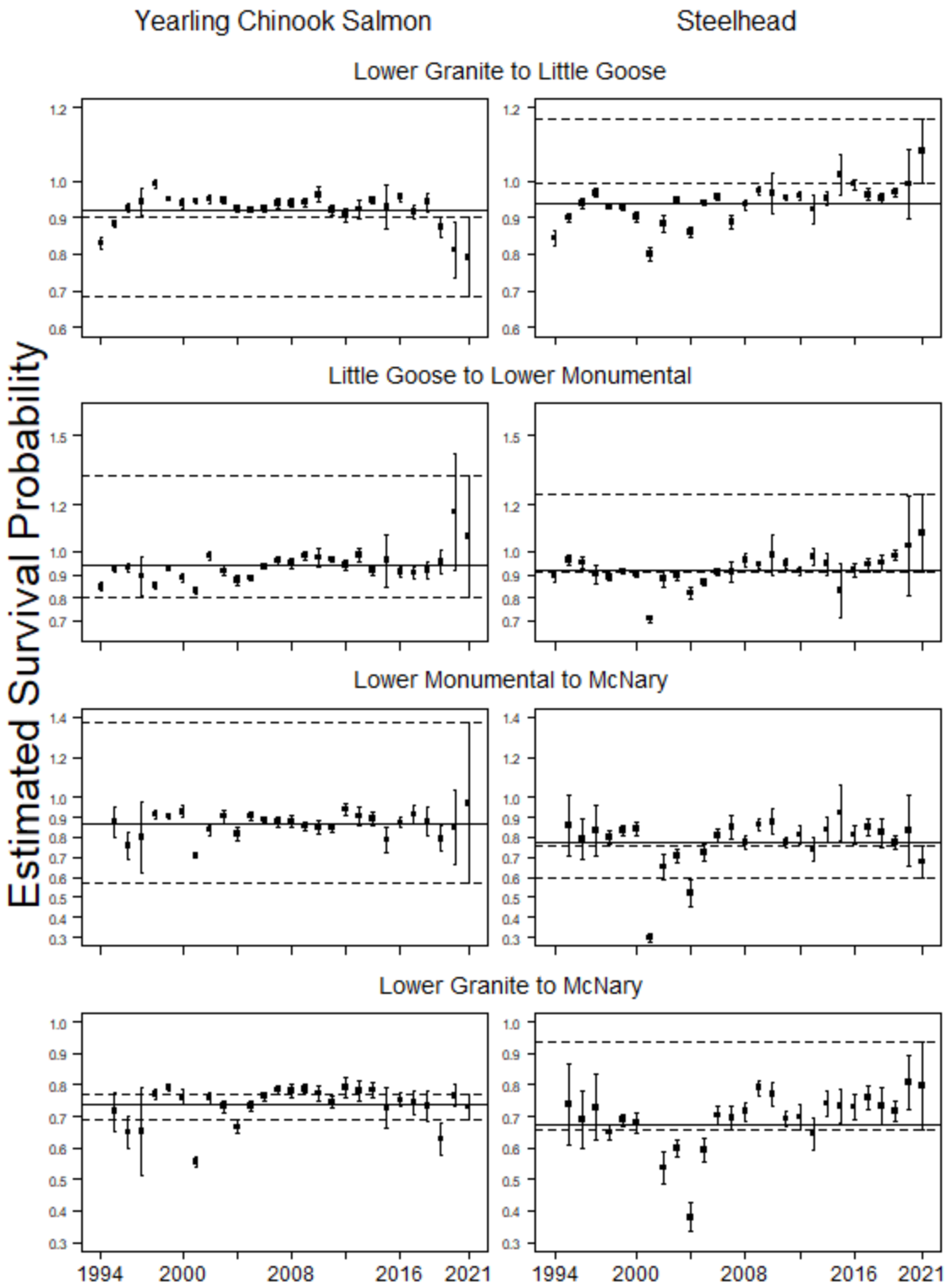

Figure 2. Annual mean survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2021 estimates, and horizontal solid lines represent long-term means.

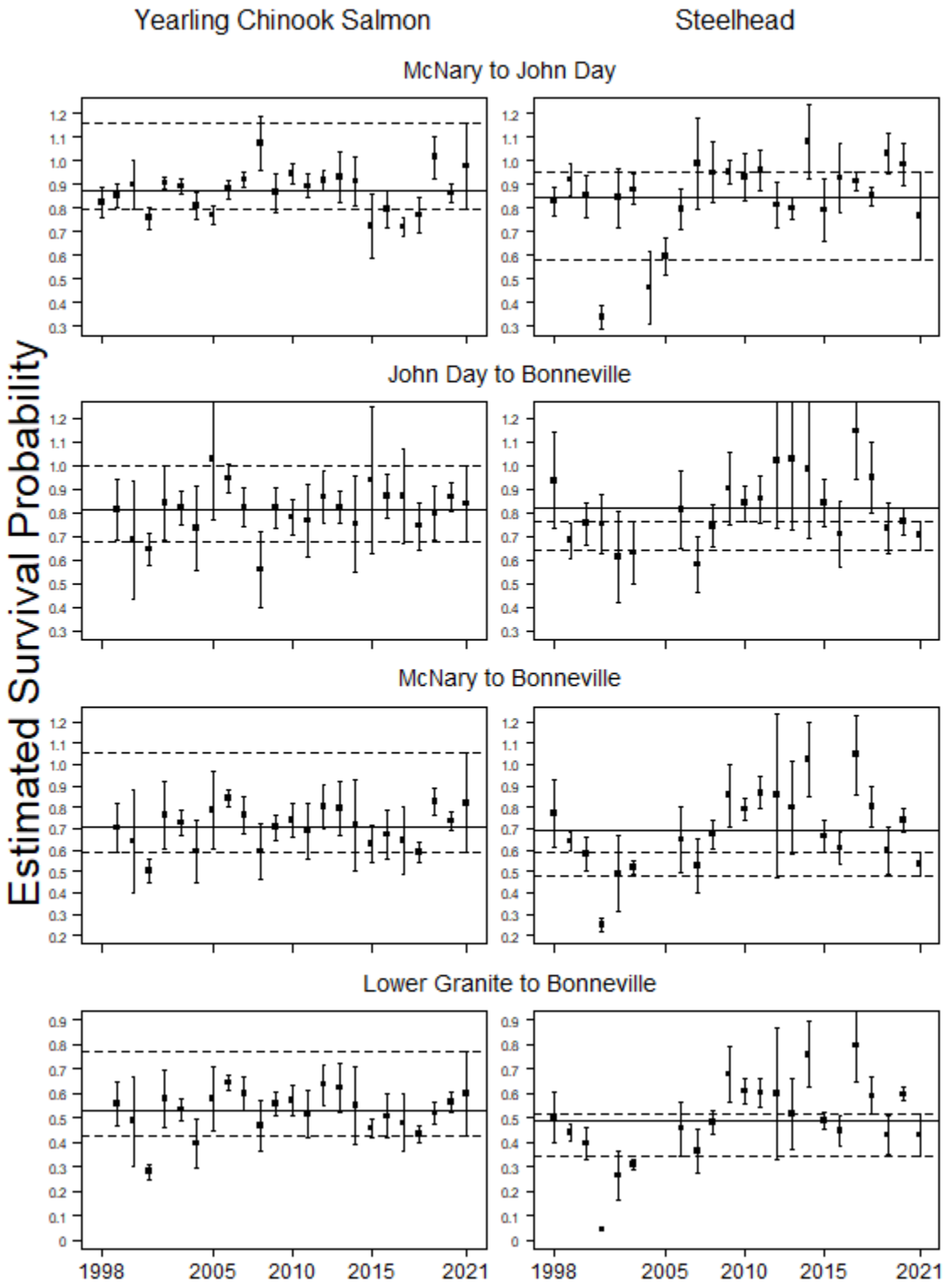

Figure 3. Annual mean survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2021 estimates, and horizontal solid lines represent long-term means.

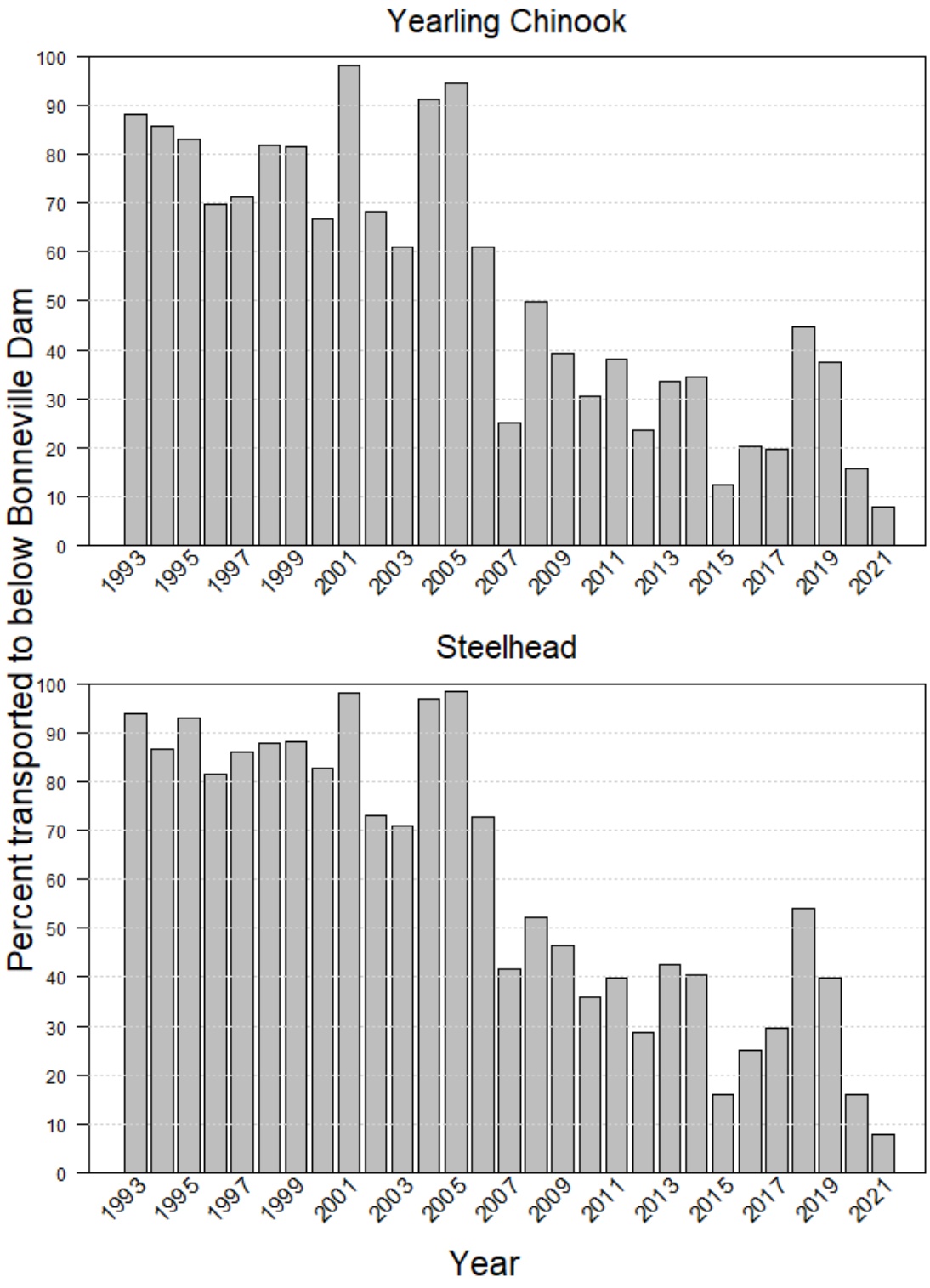

Figure 4. Annual estimates of the percentage of yearling Chinook salmon and steelhead smolts (mean of estimates for hatchery and wild smolts) that arrived at Lower Granite Dam that were subsequently transported, either from Lower Granite Dam or downstream from Little Goose or Lower Monumental Dam, to below Bonneville Dam (1993-2021).

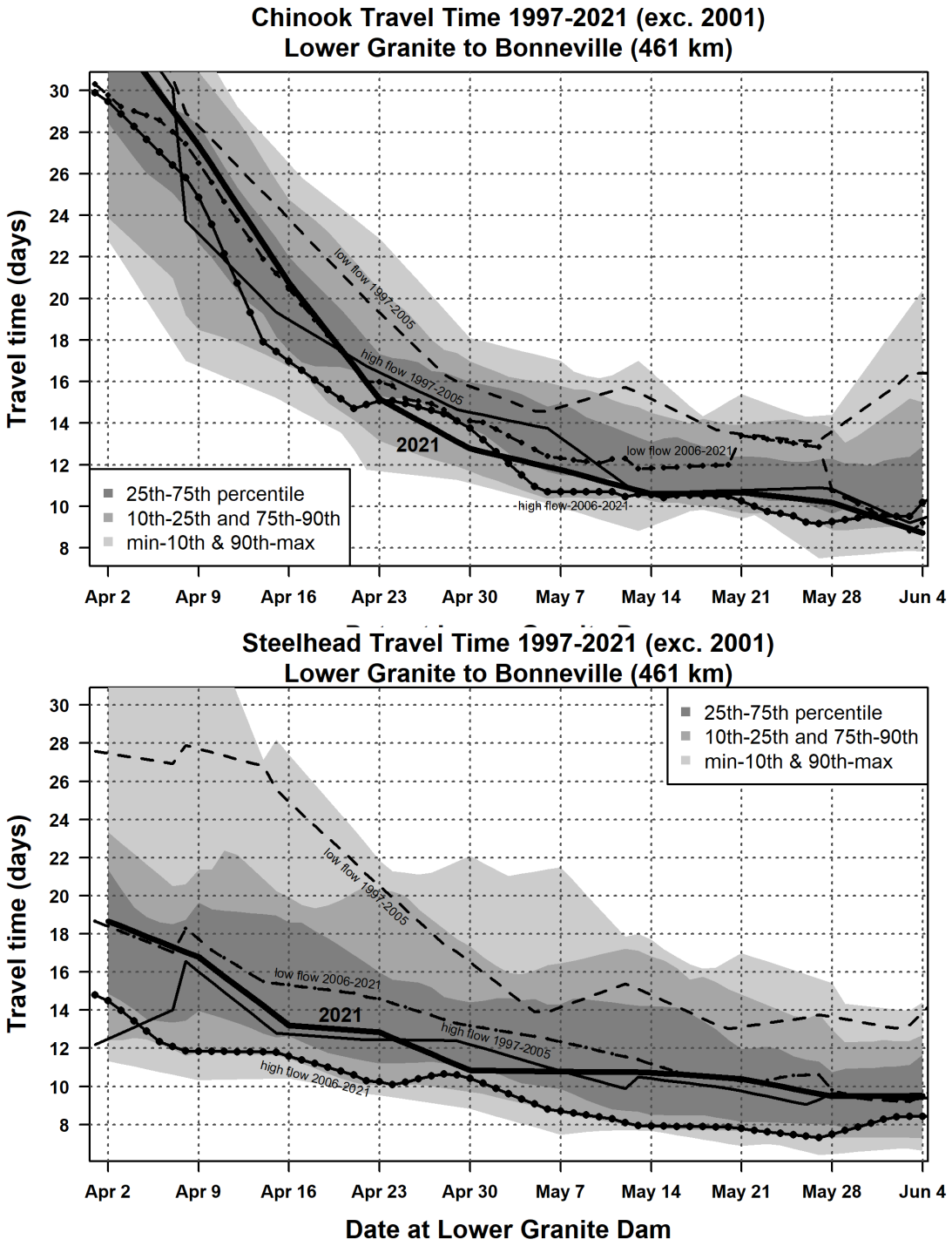

Figure 5. Median travel time (d) from Lower Granite to Bonneville Dam (461 km) vs. date passing Lower Granite Dam for yearling Chinook salmon and juvenile steelhead. Shaded regions show daily quantiles during 1997-2021 (excluding 2001). Lines show daily medians from selected subsets of years: low-flow years during the former (2004-2005) and present spill regimes (2007, 2010, 2013, 2015, and 2021); high-flow years during the former (1997 and 2006) and present spill regimes (2011, 2012, 2017, 2018, and 2019).

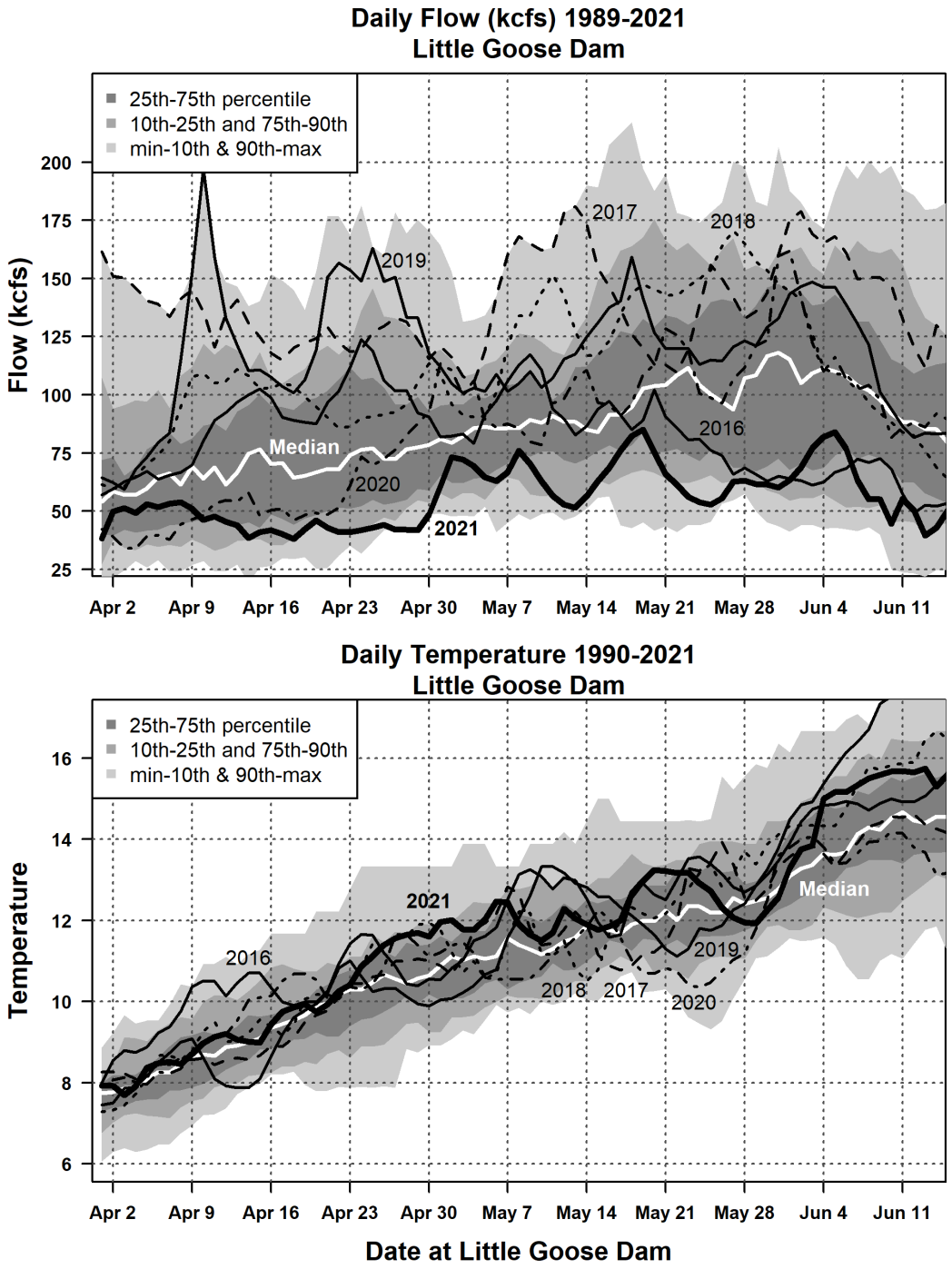

Figure 6. Upper panel shows daily mean flow at Little Goose Dam from April to mid-June. Lines show daily mean flows for 2021 and selected recent years and long-term median. Shaded areas illustrate daily quantiles from 1989-2021. Lower panel uses the same format to show daily mean temperature at Little Goose Dam. Quantiles for daily temperature are calculated from 1996-2021.

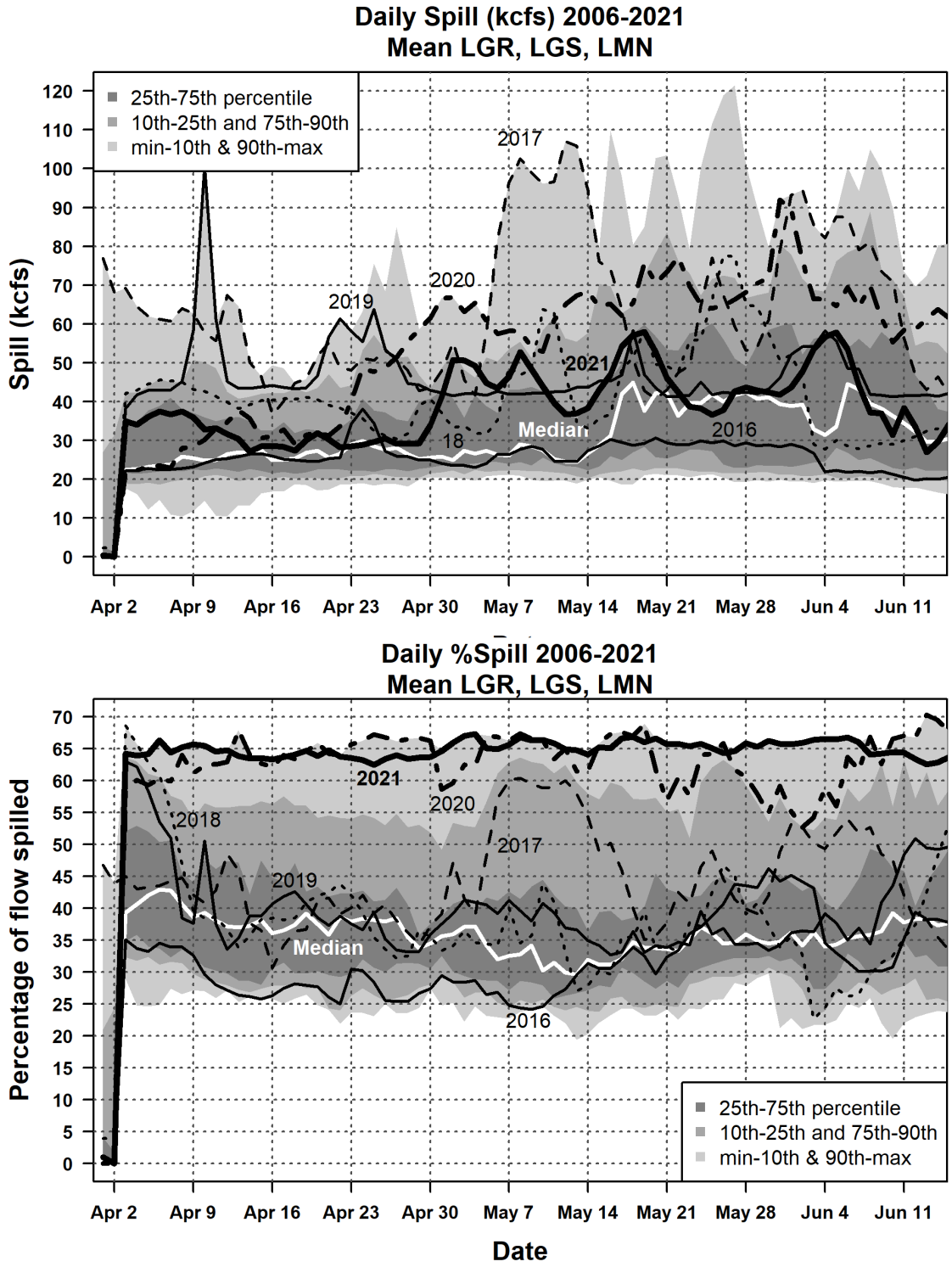

Figure 7. Upper panel shows daily mean Snake River spill (kcfs) from April to mid-June, averaged across Lower Granite, Little Goose and Lower Monumental Dams. Lower panel shows daily spill as a percentage of total flow. Lines show daily values for 2021 and selected recent years and long-term median. Shaded areas indicate daily quantiles for 2006-2021.

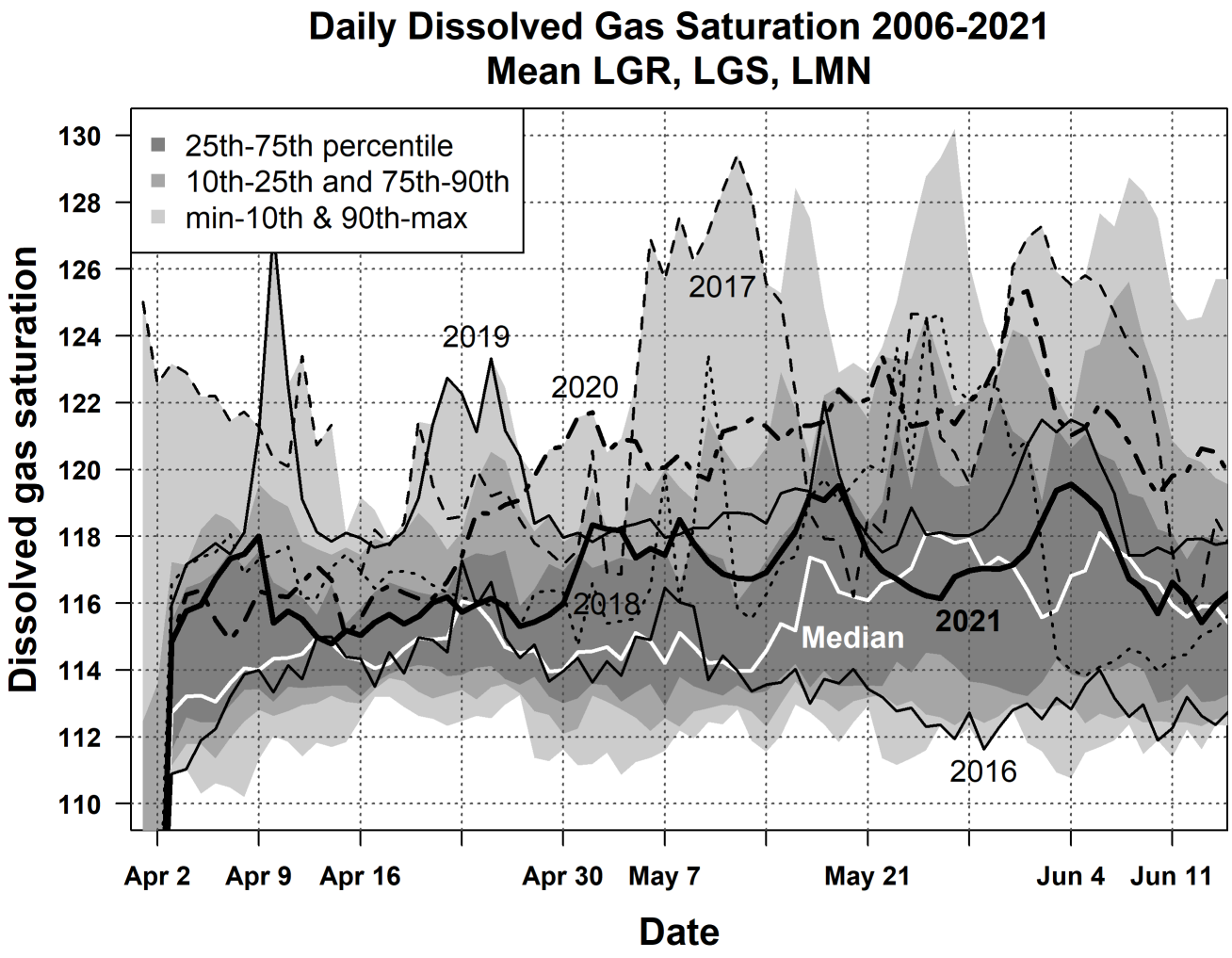

Figure 8. Daily mean percentage of dissolved gas averaged across Lower Granite, Little Goose and Lower Monumental Dam from April to mid-June 2021. Lines show daily percentage for 2021 and selected recent years and long-term median. Shaded areas indicate daily quantiles for 2006-2021.

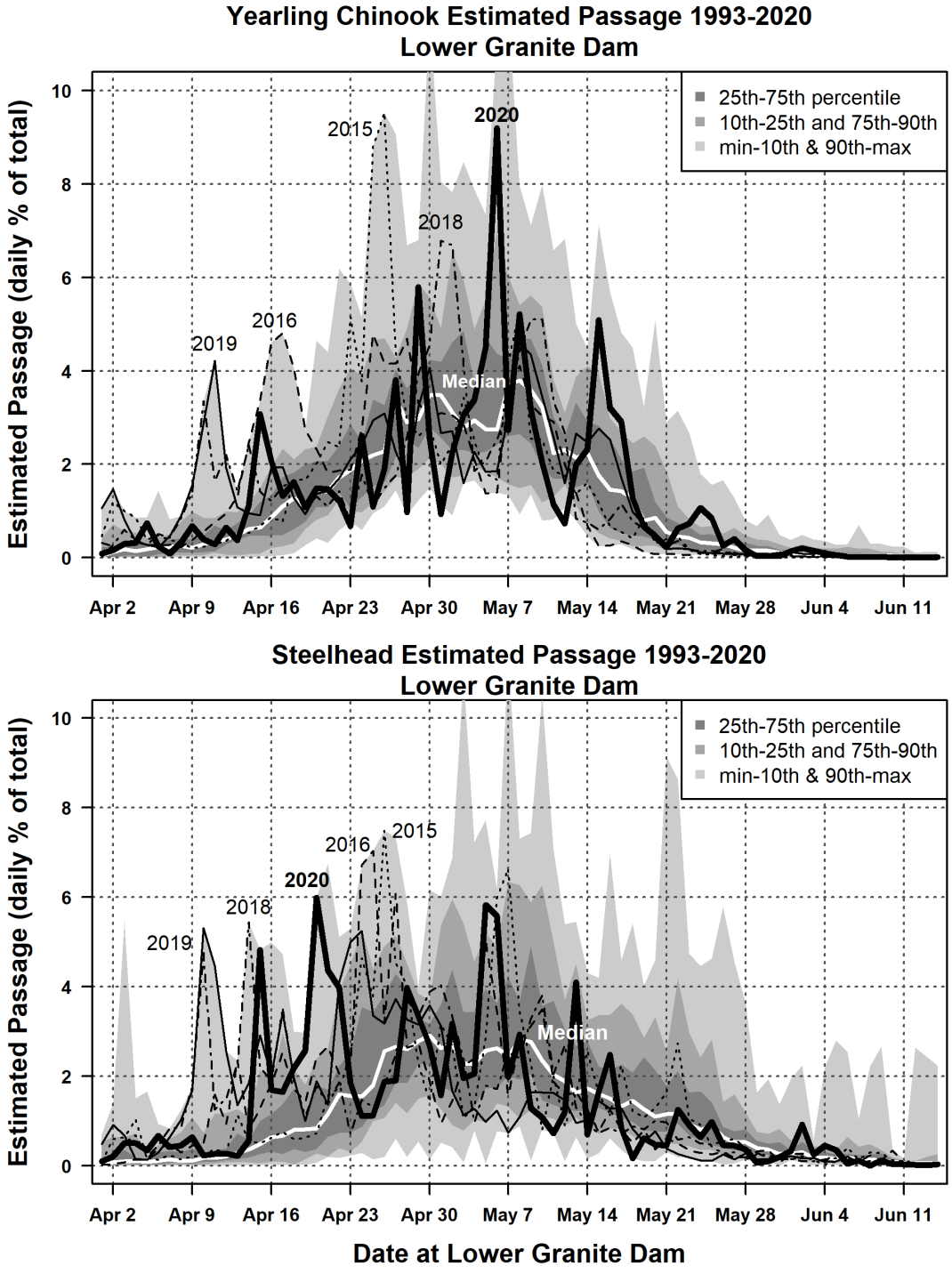

Figure 9. Estimated daily smolt passage at Lower Granite Dam for yearling Chinook salmon and steelhead. Daily passage is expressed as percentage of the yearly total. Lines indicate daily values for 2021, the long-term median, and selected recent years. Shaded areas indicate smolt-passage quantiles from 1993 to 2021.