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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, 2022

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 2022 spring outmigration. We also provide preliminary estimates of the proportion of Snake River smolts that were collected at Snake River dams and transported in 2022. 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, we will revise estimates when data becomes available from PIT-tag recoveries from estuary bird colonies in fall 2022.

Summary of Research

The tagging program at Lower Granite Dam continued to operate with reduced capacity in 2022 due to COVID-19 work protocols. A total of 6,285 wild yearling Chinook, 9,350 wild steelhead, and 21,758 hatchery steelhead were tagged for release into the tailrace of Lower Granite Dam. The Columbia River estuary trawl was conducted in 2022, but with fewer operating hours than in years prior to 2020.

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 2022 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 as well as lower numbers of wild fish using the juvenile bypass system in 2022 resulted in fewer wild fish tagged at the dam compared to years prior to 2020 (Table 1). Additionally, fewer fish passed the dam via the juvenile bypass system and thus fewer fish were detected in that passage route than in years prior to 2020.

However, the RSW spillway detector at Lower Granite Dam, in its third year of operation in 2022, continued to detect far more fish than did the juvenile bypass system detectors. All told, the combined sample size of fish available for survival estimation from Lower Granite Dam was above average in 2022 for hatchery stocks of Chinook and steelhead, about equal to average for wild Chinook, and slightly below average for wild steelhead (Table 1).

The primary limiting factor for survival estimation in 2022 continued to be extremely low detection probabilities at dams downstream of Lower Granite Dam. As in 2020 and 2021, high rates of spill in 2022 resulted in very low probabilities of detection in juvenile bypass systems, where most juvenile PIT-tag detectors are located. Bonneville Dam is the only dam downstream of Lower Granite that has a juvenile PIT-tag detector located outside a juvenile bypass system. There, fish can also be detected as they pass via the surface flow outlet in Powerhouse 2 (known as the corner collector).

Detection rates in 2022 were well below the 2007-2019 average at all dams aside from Lower Granite Dam (Figure 1). Detection rates in 2022 at Little Goose and Lower Monumental were not as low as they were in 2020 or 2021, but were still well below average. Detection rates at McNary reached a new low in 2022, while detection rates at John Day were similar to those from 2020

and 2021. Detection rates at Bonneville Dam were substantially below average in 2022.

These extremely low detection rates resulted in very imprecise survival estimates for most reaches. They also necessitated use of different methodology for survival estimates between McNary Dam and Bonneville Dam than we used through 2019. Previously, our method for estimates in the lower Columbia River was to create weekly cohorts of fish detected at McNary Dam. However, in the last three years, too few fish were detected at McNary Dam for that method. Instead, the same weekly cohorts of fish detected or tagged at Lower Granite Dam used for survival estimation in the Snake River were also used in the lower Columbia.

To estimate survival through reaches that terminate at Bonneville Dam requires data from smolts detected after they pass Bonneville Dam ("post-Bonneville" data). For years through 2019, our preferred source of such data was the Columbia River estuary trawl. However, the trawl was not operated in 2020, and we used alternate data sources, including sites where live fish were detected and recoveries of tags deposited in various sites by predaceous birds. In 2021 the trawl resumed, and we used trawl data in combination with the additional sources.

At this time in 2022, available sources of post-Bonneville data are the estuary trawl, detections from two automated detector systems installed at Pile Dike 6 and Pile Dike 7, and detections of fish that ascend the adult fish ladders at Bonneville Dam not long after passing the dam in the downstream direction. This last category is almost all Chinook salmon; precocious males that are known as "mini-jacks."

In the upcoming months, various avian colonies in the Columbia basin will be surveyed for PIT tags and the records of scanned tags deposited on the colonies will be uploaded to the PTAGIS database. For our 2022 final report we will use data from estuary (post-Bonneville) avian sites for survival estimation. We continue to evaluate the use of data from interior avian sites (upstream of Bonneville Dam), and may use it if the quality of estimates is improved. Data from avian recoveries was not available in time for use for this memo.

The automated PIT-tag detector at Pile Dike 6 is a new detection system, active for the first time in 2022. The previously

existing pile dike detector at Pile Dike 7, active since 2012, does not detect very many spring-migrating juvenile salmonids. Typically only about one hundred juvenile fish have been detected at Pile Dike 7 in a given year.

However, the new detector at Pile Dike 6 was far more successful. A total of 1,675 juvenile spring Chinook and 571 juvenile steelhead were detected at Pile Dike 6 during the 2022 migration season, which comprises approximately 25% and 14% of all detection information currently available for Chinook and steelhead that passed Bonneville Dam, respectively.

PIT-tagged yearling Chinook salmon have been released every year from 1993 through 2022 from each of seven Snake River Basin hatcheries Dworshak, Kooskia, Lookingglass/Imnaha Weir, Rapid River, McCall/Knox Bridge, Pahsimeroi (except 1996), and Sawtooth. Following hatchery practices instituted at these "index" hatcheries for the 1998 migration season, the annual mean estimated survival from release to Lower Granite Dam increased over that observed in 1993-1997, and has remained relatively stable ever since (Figure 2, Table 2). Mean survival in 2022 was 71.0%, which was moderately above both the 2021 mean of 67.0% and the long-term mean (1998-2022) of 65.0%, although the differences were not statistically significant. Estimated survival from release to Lower Granite Dam was the highest on record for fish from both Dworshak and Sawtooth hatcheries.

Downstream of Lower Granite Dam, mean estimated survival for Snake River yearling Chinook salmon (hatchery and wild combined) in 2022 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 very imprecise (Table 3, Figure 3). Estimated survival was below average in the McNary to John Day reach and above average in the John Day to Bonneville reach, though these estimates were also imprecise (Table 3, Figure 4).

Estimated survival was slightly below average for the longer reach from Lower Granite to McNary as well as 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 2022 was 70.5% (95% CI: 53.6-87.4%). Mean estimated survival from McNary Dam to Bonneville Dam was 69.3% (59.3-79.3%). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam to Bonneville Dam was 53.1% (48.2-58.0%).

Estimated survival for hatchery and wild yearling Chinook salmon in the Lower Granite project (head of reservoir to tailrace) was 95.2%, based on fish PIT tagged at and released from the Snake River trap. This estimate is above the long-term mean of 92.0% and follows four consecutive years with below-average estimates. The combined yearling Chinook salmon survival estimate from the Snake River trap to Bonneville Dam tailrace was 50.6% (95% CI: 41.8-59.3%), which was slightly above the long-term mean of 48.5% (Table 4).

For wild Snake River yearling Chinook, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was 65.1% (95% CI: 51.4-78.8%), and from McNary Dam tailrace to Bonneville Dam tailrace was 83.0% (51.1-114.9%). This resulted in a survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 54.0% (36.6-71.4%). This was above the long-term mean of 47.5% but not statistically different from it due to the poor precision of the 2022 estimate.

Only 121 wild spring Chinook smolts were tagged at the Snake River trap in 2022. We estimated that survival from the Snake River trap to Lower Granite Dam tailrace for these fish was 109.8% (95% CI: 57.1-162.5%). These estimates resulted in a survival estimate for wild Chinook from the Snake River trap to Bonneville Dam tailrace of 59.3% (25.0-93.6%), which was above the long-term mean of 44.6% but not statistically different from it. Both the low sample size and the extremely poor precision contribute to the extremely wide confidence intervals on these estimates.

For Snake River steelhead (hatchery and wild combined), mean estimated survival in 2022 was below average in the Lower Granite to Little Goose reach, above average in the Little Goose to Lower Monumental reach, and below average in the Lower Monumental to McNary reach. The precision of all three estimates was poor (Table 5, Figure 3). Estimated survival was far above average in the McNary to John Day reach and far below average in the John Day to Bonneville reach, though both estimates were extremely imprecise (Table 5, Figure 4).

These estimates resulted in below-average estimated survival from Lower Granite to McNary, but above average across the combined reach from Lower Granite to Bonneville (Table 6). Mean estimated survival for steelhead from Lower Granite Dam to McNary Dam in

2022 was 62.4% (95% CI: 51.2-73.6%). Mean estimated survival from McNary Dam to Bonneville Dam was 71.3% (58.8-83.8%). Mean estimated survival for steelhead from Lower Granite Dam to Bonneville Dam was 53.3% (45.3-61.3%).

Estimated survival for hatchery and wild steelhead in the Lower Granite project (head of reservoir to tailrace) was 93.8% in 2022, 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 50.0% (95% CI: 42.1-57.9%), which was above the long-term mean of 46.2%, 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 far below average at 40.8% (95% CI: 30.6-51.0%), and from McNary Dam tailrace to Bonneville Dam tailrace was far above average at 108.6% (65.1-152.1%). Both estimates were statistically different from the long-term mean; however, the precision of both of these estimates is poor. The estimate for the reach from McNary to Bonneville in particular is extremely imprecise.

Estimated survival for wild steelhead from Lower Granite Dam tailrace to Bonneville Dam tailrace was 44.3% (95% CI: 30.4-58.2%), which was similar to the long-term mean of 43.0%. The survival estimate from the Snake River trap to Lower Granite Dam tailrace was 95.2% (77.2-113.2%) in 2022, which was similar to the long-term mean of 95.0%. These estimates resulted in a survival estimate from the Snake River trap to Bonneville Dam tailrace of 42.2% (26.7-57.6%), which was close to the long-term mean of 42.0%, but very imprecise.

For PIT-tagged hatchery yearling Chinook salmon originating from the upper Columbia River in 2022, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 75.2% (95% CI: 60.0-94.3%; Table 7), which was slightly below the long-term mean of 80.0%.

For PIT-tagged hatchery steelhead originating from the upper Columbia River in 2022, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 90.5% (95% CI: 67.7-121.0%; Table 7). This estimate was far above the long-term mean of 76.0%, but the difference was not statistically significant due to the very poor precision of the 2022 estimate.

Estimated survival in 2022 of Snake River sockeye salmon (hatchery and wild combined) from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 37.9% (95% CI: 29.6-48.5%; Table 8). This estimate was slightly below the long-term mean of 40.6%.

In past years, we have reported survival from Rock Island Dam to Bonneville Dam for sockeye from the upper Columbia River. However, tagging operations at Rock Island Dam were discontinued after 2021. In 2022 and future years it is no longer possible to estimate survival for that reach.

The longest continuing time series of PIT-tagged sockeye releases in the upper Columbia is that of fish released from the lower Wenatchee River screw trap. We have previously unpublished survival estimates from this release site starting in 2014. We have selected this series as the one to carry forward for upper Columbia River sockeye, and we publish estimates here for the first time (Table 8).

Estimated survival in 2022 of Columbia River sockeye salmon (hatchery and wild combined) from the lower Wenatchee River screw trap to the tailrace of Bonneville Dam was 46.4% (19.2-112.2%; Table 8). This estimate was above the long-term mean of 25.8%; however, the estimate in 2022 was extremely imprecise and the difference was not statistically significant.

Our preliminary estimates of the percentage transported of non-tagged wild and hatchery spring-summer Chinook salmon smolts in 2022 are 30.6% and 23.9%, respectively. For steelhead, the estimates are 36.7% and 24.0% for wild and hatchery smolts, respectively (Figure 5). 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 2022 were below average, but substantially higher than in 2020 or 2021.

For the majority of the migration season, travel times for both Chinook and Steelhead were unusually long in 2022 (Figure 6). Despite very high rates of spill, travel times for both species were substantially longer than in other recent years through April and most of May. In late May, migrating smolts finally started to move faster, and by early June travel times in 2022

were roughly equal to those in recent high-flow years. This unusual pattern in travel time is almost certainly related to unusual environmental conditions observed in 2022 (discussed below).

Discussion

Flexible spill operations continued at Lower Granite, Little Goose, Lower Monumental, and John Day dams in 2022 with the increased spill cap of 125% dissolved gas saturation. However, spill operations in 2022 at Ice Harbor, McNary, and Bonneville dams were to the 125% gas cap for 24 hours per day. It is worth noting that detection rates this year at McNary Dam were the lowest ever and those at Bonneville Dam were substantially below average.

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 marked decreases in detections of fish. This makes it difficult to assess whether the new operations provided benefits--or were detrimental for fish--especially when focusing on metrics in shorter river reaches.

For Snake River yearling Chinook salmon in 2022, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was near the long-term mean. For Snake River steelhead in 2022, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was a little above the long-term mean, but the difference was not statistically significant.

In 2022 the wild stocks of both Snake River Chinook and steelhead fared similarly to the overall run. Estimated survival of wild Chinook was above average for both the reach between Lower Granite and Bonneville Dam and the reach between the Snake River Trap and Bonneville Dam, though the differences were not statistically significant. Estimated survival of wild Snake River steelhead was near average for both the Lower Granite to Bonneville and the Snake River Trap to Bonneville reaches. However, the precision of our estimates for both stocks was very poor.

Survival for Chinook from the Snake River Trap to Lower Granite Dam was below average from 2018 through 2021. In 2022 that trend was broken and survival was above average for that reach (Table 4). However, the sample sizes of both wild and hatchery Chinook tagged at the trap have declined substantially from past years, and 2022 showed no evidence of a reversal in that trend. Only 121 wild Chinook were tagged at the trap in 2022; this may not be sufficient to represent the overall run.

Environmental conditions in 2022 resulted in a year with very unusual patterns in flow and water temperature during the spring migration season. Overall, 2022 had a cold spring, which resulted in a spring freshet that was very late but not small. Flow conditions in 2022 could not be categorized simply as "low-flow" or "high-flow", as flow was well below average in part of the season but well above average in other parts.

The spring freshet typically starts in April and peaks in mid-May in the Snake River. However, daily flow values in the Snake River in 2022 were well below average for all of April and most of May. The onset of the spring freshet did not noticeably start until the second week of May, and peaked in mid-June (Figure 7). After the spring freshet started in mid-May, there were several large pulses in flow which resulted in daily flow values well above average around 10 May, 18 May, and after the start of June. At the peak of the spring freshet in the second week of June, flow in the Snake River was the highest on record for that period.

Mean water temperature at Little Goose Dam during the 2022 migration period was 10.0°C, which was well below long-term mean (1993-2022) of 11.2°C and was the third coldest spring in that set of years. Daily water temperatures were about average at the beginning of April, but dropped to nearly two degrees below average in the second and third week of April (Figure 7). Daily water temperatures in May and early June alternated between near-average around 7 May, 21 May, and 31 May and well below average between those dates. The peaks in water temperature in May seemed to correlate with peaks in flow.

Mean spill discharge at the Snake River dams during the 2022 migration was 46.6 kcfs, which was well above the 2006-2022 mean of 36.3 kcfs. Daily spill discharge was about equal to the long-term median through April and early May, then steadily increased

throughout May to become the highest on record by the second week of June (Figure 8).

Spill as a percentage of flow at Snake River dams averaged 59.5% in 2022, which was far above the long-term (2006-2022) mean of 39.3%. Daily percentage spill hovered very consistently around 65% in 2020 and 2021. This pattern largely continued in 2022, and daily mean spill percentages were close to 65% through April and early May (Figure 8). However, once flow levels increased in late May 2022, spill percentages dropped to levels substantially below those maintained in 2020 and 2021.

Daily mean percent dissolved gas saturation was about equal to the long-term median in April of 2022. However, levels of dissolved gas increased in May. Daily mean dissolved gas was well above average during the first half of May, the end of May, and the first half of June. Several peaks in daily dissolved gas, to near the cap of 125% saturation, were observed around 31 May, 8 June, and 12 June 2022 (Figure 9). Hourly values during these periods of high gas fluctuated between approximately 109% and 131% (data not shown). Between 28 May and 15 June, hourly dissolved gas percentage exceeded the 125% gas cap 70% of the time at one or more of the three index dams in Figure 9.

Smolt passage at Lower Granite Dam was noticeably late in 2022. Few steelhead passed the dam prior to 23 April, and few Chinook passed prior to 30 April. The first major pulse in flow during the second week of May was correlated with an enormous spike in passage for both species (Figures 7 and 10). Due to the delayed freshet in 2022, likely many smolts waited for flow to increase before actively migrating.

We observed very long travel times of fish between Lower Granite Dam and Bonneville Dam in April and early May of 2022. Though spill rates were very high and likely minimized forebay delay at dams, low flows and cool water during that period were the likely drivers of long smolt travel times.

Despite slow juvenile migration rates for much of the season, our estimates of juvenile survival were generally average to above average for Snake River stocks. Low flow is usually not associated with high survival, but cool temperature is. The cooler than average water temperatures in 2022 could have increased smolt survival by suppressing the activity of predatory fish or by improving conditions in the rearing habitat.

Additionally, the tail end of the migration season in June is generally when we find the lowest survival estimates. Our estimates in 2022 are not precise enough to say with certainty whether survival during this specific period was above or below average. However, the high flow and cool water temperatures during June of 2022 indicate that environmental conditions would likely have promoted higher than normal survival during the end of the migration season.

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.

The overall proportion of smolts transported in 2022 was about equal to the 2006-2022 average, and much higher than in 2019 or 2020 (Figure 5). Collection for transportation in 2022 began on 24 April at Lower Granite, Little Goose, and Lower Monumental Dams, the same start date as in 2019-2021. The start date was at least 7 days earlier than the start date of 1 May, or later, typical in most previous years.

The run in 2022 was very late for both Chinook and steelhead. We estimate that 14.1% of wild and 7.2% of hatchery Chinook salmon, and 2.3% of wild and 12.9% of hatchery steelhead passed prior to the start of transportation. These proportions are much lower than in 2020 or 2021, indicating that run timing contributed to increased transportation rates, as a far greater share of the population was potentially available to be transported.

In 2022, the proportion of passing smolts collected after the start of transportation was below average, but still far higher than in 2020 or 2021. We estimate that 25.4% of wild and 34.9% of hatchery Chinook and 25.9% of wild and 39.6% of hatchery steelhead that passed during transport operations were collected and transported. These collection rates are about ten to fifteen percent less than the 2006-2022 average, but still far higher than those from 2020 or 2021. The combination of a late run and collection rates only moderately below average resulted in the average overall transportation rates we estimated for 2022.

Unfortunately for quantity and quality of data, a side effect of increased spill since 2006 has been a large drop in detection

rates of smolts at most Snake and Columbia River dams (Figure 1). The exceptionally high spill since 2020 has 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 2022 were very imprecise. This is especially true for wild stocks, which are of greatest concern.

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 2022, 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 current levels, 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 continues to be very instructive. 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. Additionally, the success of the new pile-dike system at Pile Dike 6 is also very encouraging. Detection rates below Bonneville Dam have always been low, and any increase in detection there will improve precision for all upstream survival estimates, and particularly for estimates in reaches that extend to Bonneville Dam.

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 increasing detection capabilities 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 at the dams and at new detection sites downstream of Bonneville Dam.

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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, 2010-2022. 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	94,298	6,850	3,768	600	57	1,770	98,123	9,220
2022	81,694	8,993	22,920	3,967	57	6,285	104,671	19,245
Mean	**78,761**	**7,062**	**43,338**	**8,694**	**3,718**	**11,568**	**65,232**	**21,892**
				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	83,846	7,173	4,756	476	18,120	4,854	106,722	12,503
2022	68,917	3,059	16,294	1,390	21,758	9,350	106,969	13,799
Mean	**70,951**	**4,558**	**34,589**	**4,142**	**18,661**	**12,822**	**69,624**	**18,015**

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), 2020 through 2022.

Hatchery	2020		2021		2022[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	0.811 (0.011)	0.576 (0.034)	0.784 (0.012)	0.536 (0.039)	0.915 (0.015)	0.512 (0.080)
Kooskia	0.747 (0.029)	0.524 (0.068)	0.808 (0.041)	0.701 (0.158)	0.756 (0.035)	---
Lookingglass (Catherine Cr.)	0.530 (0.015)	0.425 (0.047)	0.515 (0.016)	0.315 (0.038)	0.531 (0.016)	0.284 (0.053)
Lookingglass (Grande Ronde)	0.468 (0.053)	0.400 (0.184)	0.483 (0.058)	---	0.486 (0.046)	---
Lookingglass (Imnaha Weir)	0.629 (0.017)	0.450 (0.041)	0.757 (0.026)	0.549 (0.069)	0.646 (0.025)	0.420 (0.177)
Lookingglass (Lostine River)	0.567 (0.029)	0.474 (0.092)	0.485 (0.025)	0.312 (0.059)	---	---
McCall (Johnson Cr.)	0.595 (0.056)	0.410 (0.187)	0.552 (0.052)	0.458 (0.190)	0.626 (0.065)	---
McCall (Knox Bridge)	0.733 (0.011)	0.519 (0.030)	0.783 (0.012)	0.586 (0.034)	0.731 (0.012)	0.451 (0.060)
Pahsimeroi	0.559 (0.018)	0.360 (0.049)	0.287 (0.012)	0.233 (0.041)	0.475 (0.012)	0.406 (0.120)
Rapid River	0.567 (0.010)	0.398 (0.026)	0.631 (0.011)	0.524 (0.041)	0.738 (0.010)	0.539 (0.095)
Sawtooth	0.681 (0.020)	0.472 (0.049)	0.637 (0.016)	0.486 (0.058)	0.708 (0.018)	0.340 (0.080)
Entiat	---	0.570 (0.054)	---	0.790 (0.150)	---	0.486 (0.084)
Winthrop	---	0.590 (0.068)	---	0.568 (0.084)	---	0.899 (0.436)
Leavenworth	---	0.618 (0.051)	---	0.505 (0.055)	---	0.542 (0.132)

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), 1993–2022. 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 are given.

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)	NA	NA	NA	NA	NA	NA
1994	0.935 (0.023)	0.830 (0.009)	0.847 (0.010)	NA	NA	NA	NA	NA
1995	0.905 (0.010)	0.882 (0.004)	0.925 (0.008)	0.876 (0.038)	0.936	NA	NA	NA
1996	0.977 (0.025)	0.926 (0.006)	0.929 (0.011)	0.756 (0.033)	0.870	NA	NA	NA
1997	NA	0.942 (0.018)	0.894 (0.042)	0.798 (0.091)	0.893	NA	NA	NA
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

Table 3. Continued.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
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)[b]	0.865 (0.060)[b]	0.930[b]
2021	0.867 (0.108)	0.806 (0.067)	1.136 (0.127)	0.854 (0.146)	0.924	0.960 (0.077)[b]	0.796 (0.096)[b]	0.892[b]
2022[a]	0.952 (0.071)	0.745 (0.047)	1.046 (0.043)	0.880 (0.064)	0.938	0.850 (0.088)[b]	0.902 (0.118)[b]	0.950[b]
Mean	**0.920 (0.009)**	**0.912 (0.010)**	**0.943 (0.014)**	**0.860 (0.010)**	**0.927 (0.006)**	**0.870 (0.017)**	**0.812 (0.020)**	**0.898 (0.012)**

a. Estimates are preliminary and subject to change.
b. Estimates for 2020-2022 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), 1993–2022. 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
1993	0.828 (0.013)	NA	NA	NA	NA
1994	0.935 (0.023)	NA	NA	NA	NA
1995	0.905 (0.010)	0.715 (0.031)	NA	NA	NA
1996	0.977 (0.025)	0.648 (0.026)	NA	NA	NA
1997	NA	0.653 (0.072)	NA	NA	NA
1998	0.924 (0.011)	0.770 (0.009)	NA	NA	NA
1999	0.940 (0.009)	0.792 (0.006)	0.704 (0.058)	0.557 (0.046)	0.524 (0.043)
2000	0.929 (0.014)	0.760 (0.012)	0.640 (0.122)	0.486 (0.093)	0.452 (0.087)
2001	0.954 (0.015)	0.556 (0.009)	0.501 (0.027)	0.279 (0.016)	0.266 (0.016)
2002	0.953 (0.022)	0.757 (0.009)	0.763 (0.079)	0.578 (0.060)	0.551 (0.059)
2003	0.993 (0.023)	0.731 (0.010)	0.728 (0.030)	0.532 (0.023)	0.528 (0.026)
2004	0.893 (0.009)	0.666 (0.011)	0.594 (0.074)	0.395 (0.050)	0.353 (0.045)
2005	0.919 (0.015)	0.732 (0.009)	0.788 (0.093)	0.577 (0.068)	0.530 (0.063)
2006	0.952 (0.011)	0.764 (0.007)	0.842 (0.021)	0.643 (0.017)	0.612 (0.018)
2007	0.943 (0.028)	0.783 (0.006)	0.763 (0.044)	0.597 (0.035)	0.563 (0.037)
2008	0.992 (0.018)	0.782 (0.011)	0.594 (0.066)	0.465 (0.052)	0.460 (0.052)
2009	0.958 (0.010)	0.787 (0.007)	0.705 (0.031)	0.555 (0.025)	0.531 (0.025)
2010	0.968 (0.040)	0.772 (0.012)	0.738 (0.039)	0.569 (0.032)	0.551 (0.038)
2011	0.943 (0.009)	0.746 (0.010)	0.687 (0.065)	0.513 (0.049)	0.483 (0.046)
2012	0.928 (0.012)	0.790 (0.016)	0.802 (0.051)	0.634 (0.042)	0.588 (0.040)
2013	0.845 (0.031)	0.781 (0.016)	0.796 (0.064)	0.622 (0.052)	0.525 (0.048)
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)

Table 4. Continued.

Year	Trap–LGR	LGR-MCN	MCN-BON	LGR–BON	Trap–BON
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)[b]	0.563 (0.039)	0.477 (0.046)
2021	0.867 (0.108)	0.730 (0.026)	0.746 (0.112)[b]	0.543 (0.085)	0.471 (0.094)
2022[a]	0.952 (0.071)	0.705 (0.086)	0.693 (0.051)[b]	0.531 (0.025)	0.506 (0.045)
Mean	**0.920 (0.009)**	**0.734 (0.011)**	**0.704 (0.017)**	**0.525 (0.017)**	**0.485 (0.017)**

a. Estimates are preliminary and subject to change.
b. Estimates for 2020-2022 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), 1993–2022. 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 are given.

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)	NA	NA	NA	NA	NA	NA	NA
1994	0.794 (0.009)	0.844 (0.011)	0.892 (0.011)	NA	NA	NA	NA	NA
1995	0.945 (0.008)	0.899 (0.005)	0.962 (0.011)	0.858 (0.076)	0.926	NA	NA	NA
1996	0.951 (0.015)	0.938 (0.008)	0.951 (0.014)	0.791 (0.052)	0.889	NA	NA	NA
1997	0.964 (0.015)	0.966 (0.006)	0.902 (0.020)	0.834 (0.065)	0.913	NA	NA	NA
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

Table 5. Continued.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
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)[b]	0.762 (0.057)[b]	0.873[b]
2021	0.936 (0.029)	1.070 (0.045)	1.089 (0.083)	0.681 (0.043)	0.825	0.757 (0.071)[b]	0.795 (0.029)[b]	0.892[b]
2022[a]	0.938 (0.024)	0.881 (0.025)	0.994 (0.045)	0.692 (0.035)	0.832	1.372 (0.240)[b]	0.676 (0.105)[b]	0.822[b]
Mean	**0.950 (0.009)**	**0.937 (0.010)**	**0.925 (0.013)**	**0.771 (0.023)**	**0.874 (0.015)**	**0.865 (0.040)**	**0.815 (0.030)**	**0.899 (0.017)**

a. Estimates are preliminary and subject to change.
b. Estimates for 2020-2022 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), 1993–2022. 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
1993	0.905 (0.006)	NA	NA	NA	NA
1994	0.794 (0.009)	NA	NA	NA	NA
1995	0.945 (0.008)	0.739 (0.066)	NA	NA	NA
1996	0.951 (0.015)	0.688 (0.046)	NA	NA	NA
1997	0.964 (0.015)	0.728 (0.053)	0.651 (0.082)	0.474 (0.069)	0.457 (0.067)
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)

Table 6. Continued.

Year	Trap–LGR	LGR-MCN	MCN-BON	LGR–BON	Trap–BON
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)[b]	0.595 (0.027)	0.544 (0.035)
2021	0.936 (0.029)	0.788 (0.073)	0.602 (0.029)[b]	0.487 (0.026)	0.456 (0.028)
2022[a]	0.938 (0.024)	0.624 (0.057)	0.713 (0.064)[b]	0.533 (0.041)	0.500 (0.041)
Mean	**0.950 (0.009)**	**0.671 (0.025)**	**0.696 (0.036)**	**0.493 (0.032)**	**0.462 (0.032)**

a. Estimates are preliminary and subject to change.
b. Estimates for 2020-2022 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, 1999–2022. 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)

Table 7. Continued.

	Yearling Chinook Salmon				Steelhead			
Year	Rel–MCN	MCN-JDA	JDA-BON	MCN–BON	Rel–MCN	MCN-JDA	JDA-BON	MCN–BON
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	0.529 (0.028)	0.807 (0.066)	0.773 (0.071)	0.624 (0.053)	0.324 (0.025)	0.854 (0.100)	0.661 (0.066)	0.564 (0.050)
2022[a]	0.487 (0.038)	0.776 (0.078)	0.970 (0.105)	0.752 (0.087)	0.210 (0.023)	1.623 (0.257)	0.558 (0.086)	0.905 (0.135)
Mean[b]	**0.556 (0.011)**	**0.887 (0.019)**	**0.898 (0.034)**	**0.800 (0.027)**	**0.400 (0.016)**	**0.927 (0.045)**	**0.837 (0.049)**	**0.760 (0.042)**

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 the Lower Wenatchee River Trap to Bonneville Dam tailrace for fish originating in the upper Columbia River, 1996–2022. 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; WENA4T– Lower Wenatchee River Trap.

	Snake River Sockeye			Upper Columbia River Sockeye		
Year	LGR-MCN	MCN-BON	LGR-BON	WENA4T-MCN	MCN-BON	WENA4T-BON
1996	0.283 (0.184)	NA	NA	NA	NA	NA
1997	NA	NA	NA	NA	NA	NA
1998	0.689 (0.157)	0.142 (0.099)	0.177 (0.090)	NA	1.655 (1.617)	NA
1999	0.655 (0.083)	0.841 (0.584)	0.548 (0.363)	NA	0.683 (0.177)	NA
2000	0.679 (0.110)	0.206 (0.110)	0.161 (0.080)	NA	0.894 (0.867)	NA
2001	0.205 (0.063)	0.105 (0.050)	0.022 (0.005)	NA	NA	NA
2002	0.524 (0.062)	0.684 (0.432)	0.342 (0.212)	NA	0.286 (0.110)	NA
2003	0.669 (0.054)	0.551 (0.144)	0.405 (0.098)	NA	NA	NA
2004	0.741 (0.254)	NA	NA	NA	1.246 (1.218)	NA
2005	0.388 (0.078)	NA	NA	NA	0.226 (0.209)	NA
2006	0.630 (0.083)	1.113 (0.652)	0.820 (0.454)	NA	0.767 (0.243)	NA
2007	0.679 (0.066)	0.259 (0.084)	0.272 (0.073)	NA	0.642 (0.296)	NA
2008	0.763 (0.103)	0.544 (0.262)	0.404 (0.179)	NA	0.679 (0.363)	NA
2009	0.749 (0.032)	0.765 (0.101)	0.573 (0.073)	NA	0.958 (0.405)	NA
2010	0.723 (0.039)	0.752 (0.098)	0.544 (0.077)	NA	0.627 (0.152)	NA
2011	0.659 (0.033)	NA	NA	NA	0.691 (0.676)	NA
2012	0.762 (0.032)	0.619 (0.084)	0.472 (0.062)	NA	0.840 (0.405)	NA
2013	0.691 (0.043)	0.776 (0.106)	0.536 (0.066)	NA	0.658 (0.217)	NA
2014	0.873 (0.054)	0.817 (0.115)	0.713 (0.096)	0.332 (0.079)	0.565 (0.269)	0.053 (0.044)
2015	0.702 (0.054)	0.531 (0.151)	0.373 (0.037)	0.430 (0.062)	0.446 (0.200)	0.195 (0.064)
2016	0.523 (0.047)	0.227 (0.059)	0.119 (0.030)	0.270 (0.055)	0.545 (0.126)	NA

Table 8. Continued.

	Snake River Sockeye			Upper Columbia River Sockeye		
Year	LGR-MCN	MCN-BON	LGR-BON	WENA4T-MCN	MCN-BON	WENA4T-BON
2017	0.544 (0.081)	0.324 (0.107)	0.176 (0.055)	0.551 (0.141)	0.611 (0.181)	NA
2018	0.684 (0.061)	0.940 (0.151)	0.643 (0.088)	0.655 (0.064)	0.560 (0.112)	0.364 (0.154)
2019	0.836 (0.053)	0.520 (0.044)	0.434 (0.031)	0.640 (0.135)	0.701 (0.120)	0.264 (0.126)
2020	0.803 (0.111)	0.546 (0.149)	0.439 (0.104)	0.436 (0.095)	0.288 (0.154)	0.106 (0.062)
2021	0.817 (0.094)	0.452 (0.067)	0.369 (0.034)	0.642 (0.238)	0.425 (0.141)	0.361 (0.332)
2022[a]	1.073 (0.199)	0.353 (0.079)	0.379 (0.048)	0.529 (0.107)	0.860 (0.336)	0.464 (0.220)
Mean[b]	**0.667 (0.035)**	**0.549 (0.058)**	**0.406 (0.042)**	**0.498 (0.047)**	**0.694 (0.064)**	**0.258 (0.056)**

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.

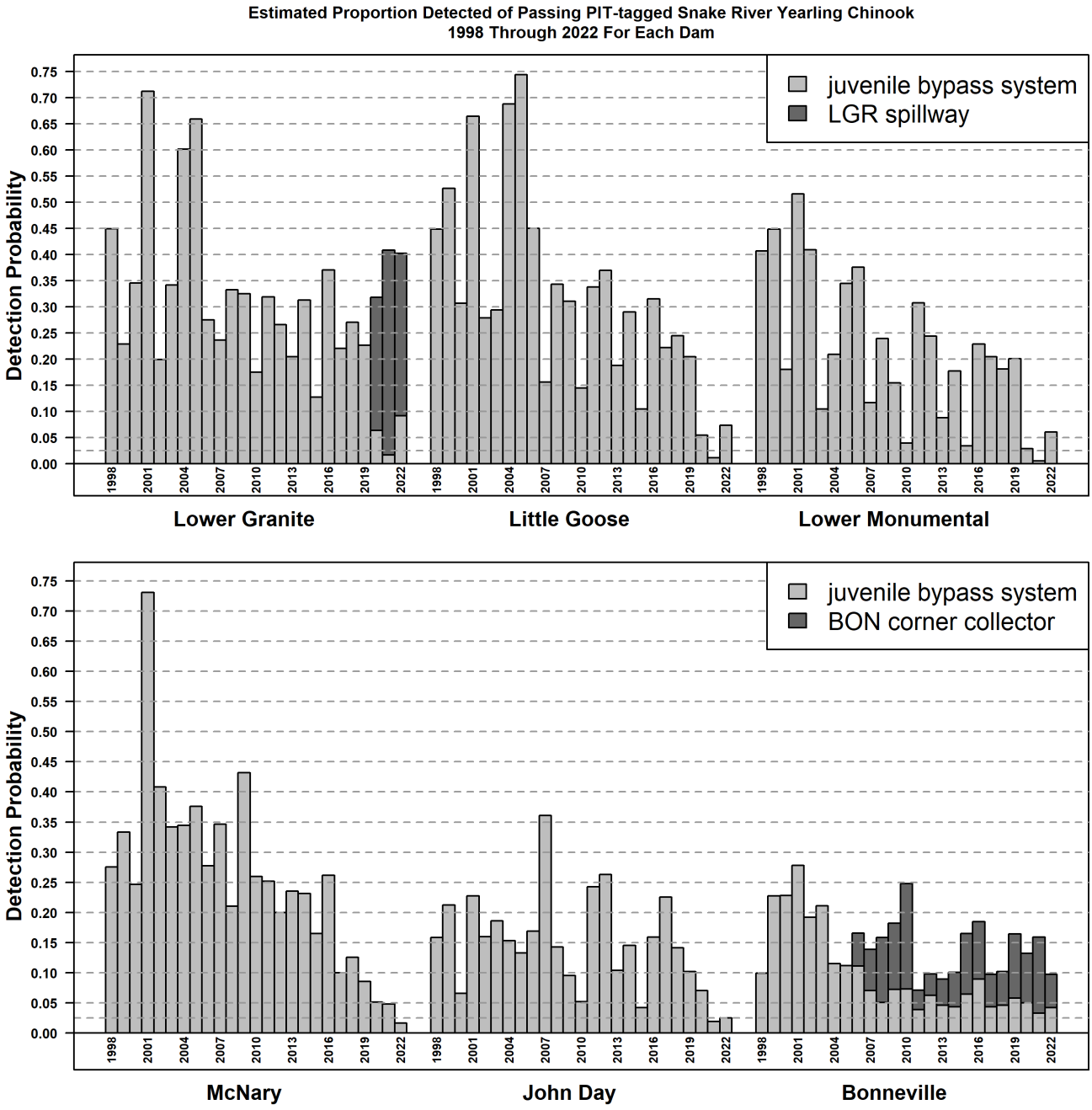

Figure 1. Annual mean detection probability for Snake River yearling Chinook salmon at six major dams on the Snake and Columbia Rivers, 2000-2022. Ice Harbor Dam was excluded because of persistent very low juvenile detection probabilities.

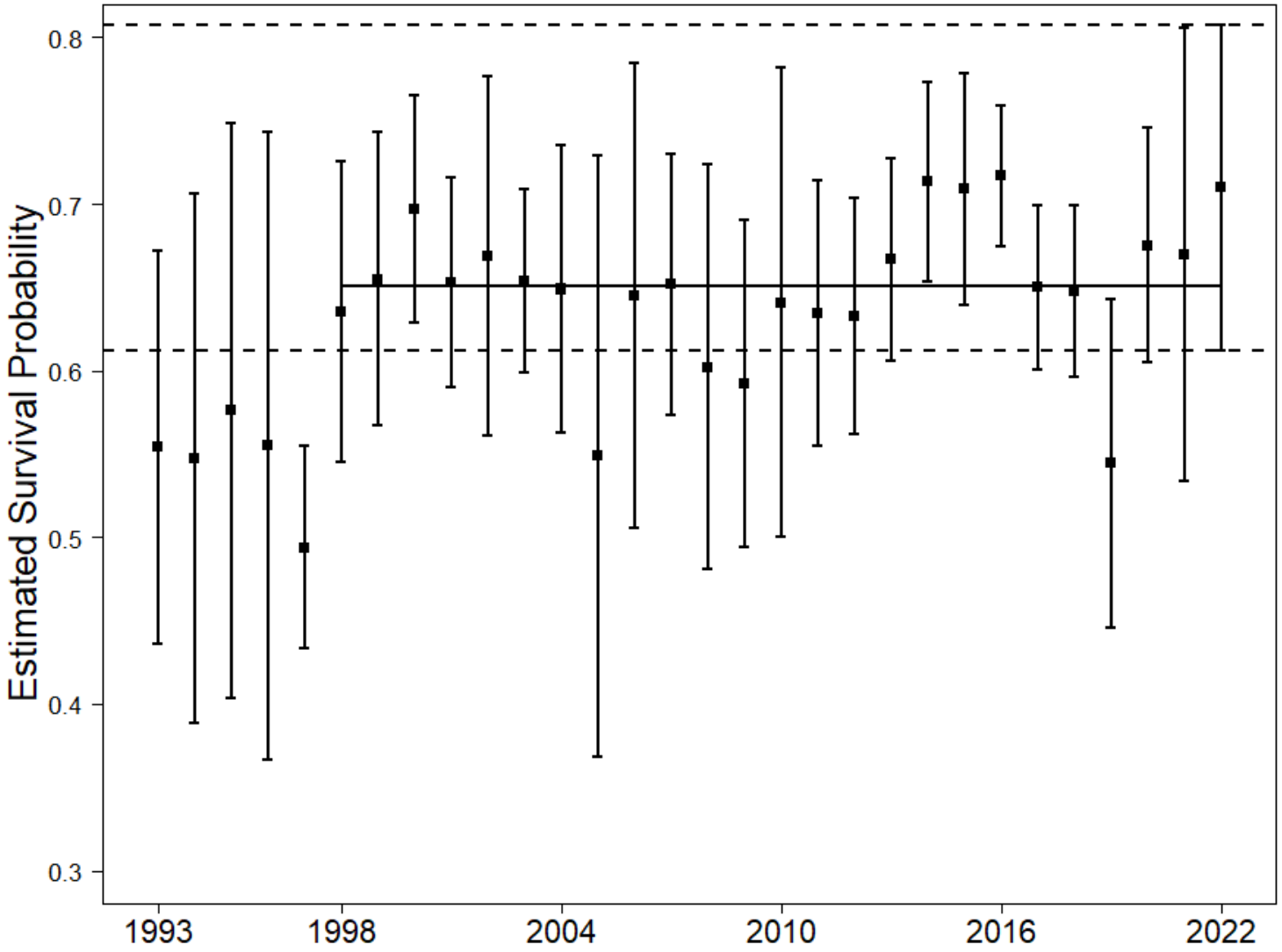

Figure 2. Annual mean survival estimates from release to Lower Granite Dam for PIT-tagged yearling **Chinook** salmon released from Snake River Basin hatcheries, 1993-2022. Hatcheries used for the mean (index groups) are those with consistent PIT-tag releases through the series of years shown. Vertical bars represent 95% confidence intervals. The 1998-2022 mean is shown as a horizontal solid line. Horizontal dashed lines are the 2022 confidence interval endpoints and are shown for comparison to other years.

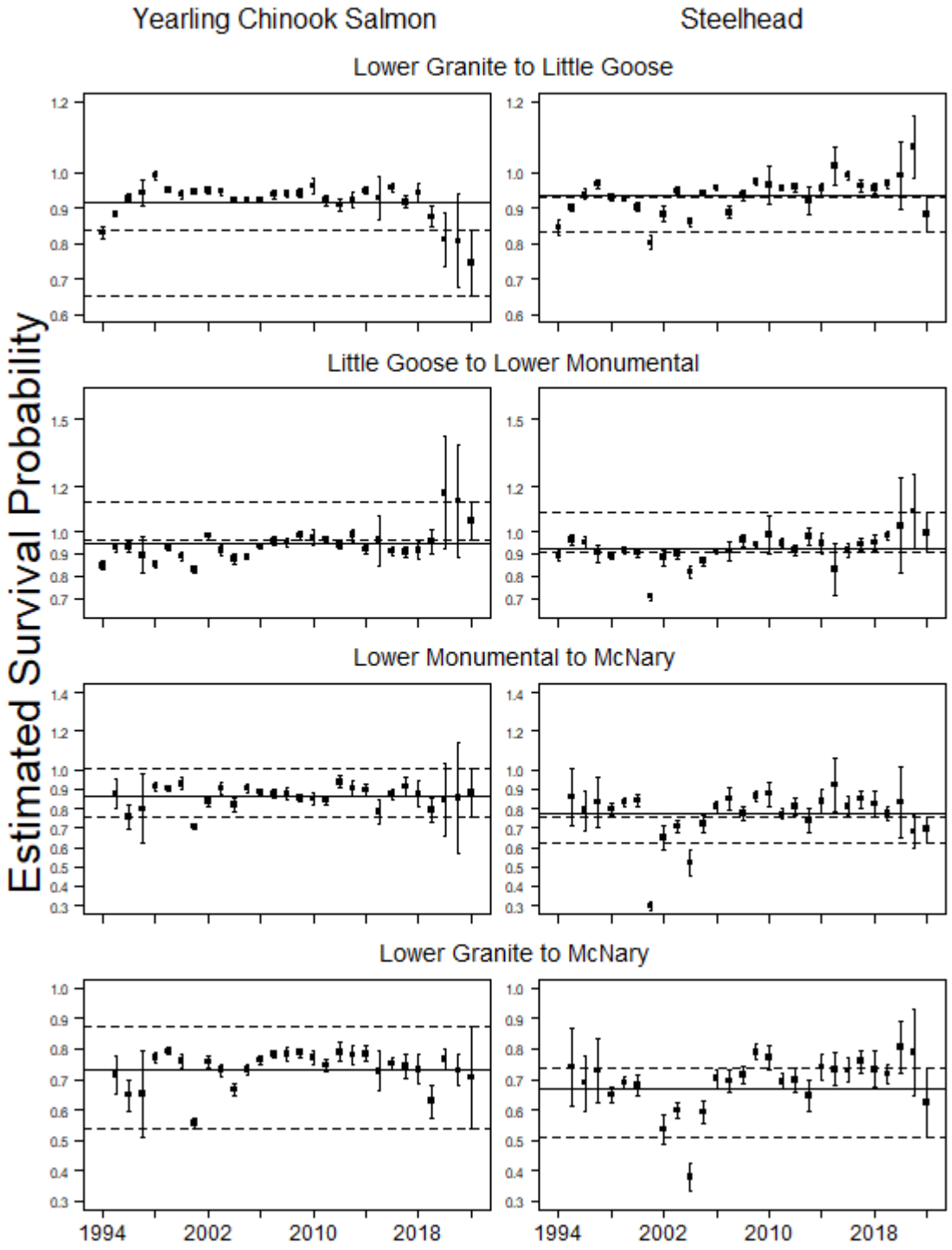

Figure 3. Annual mean survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2022 estimates, and horizontal solid lines represent long-term means.

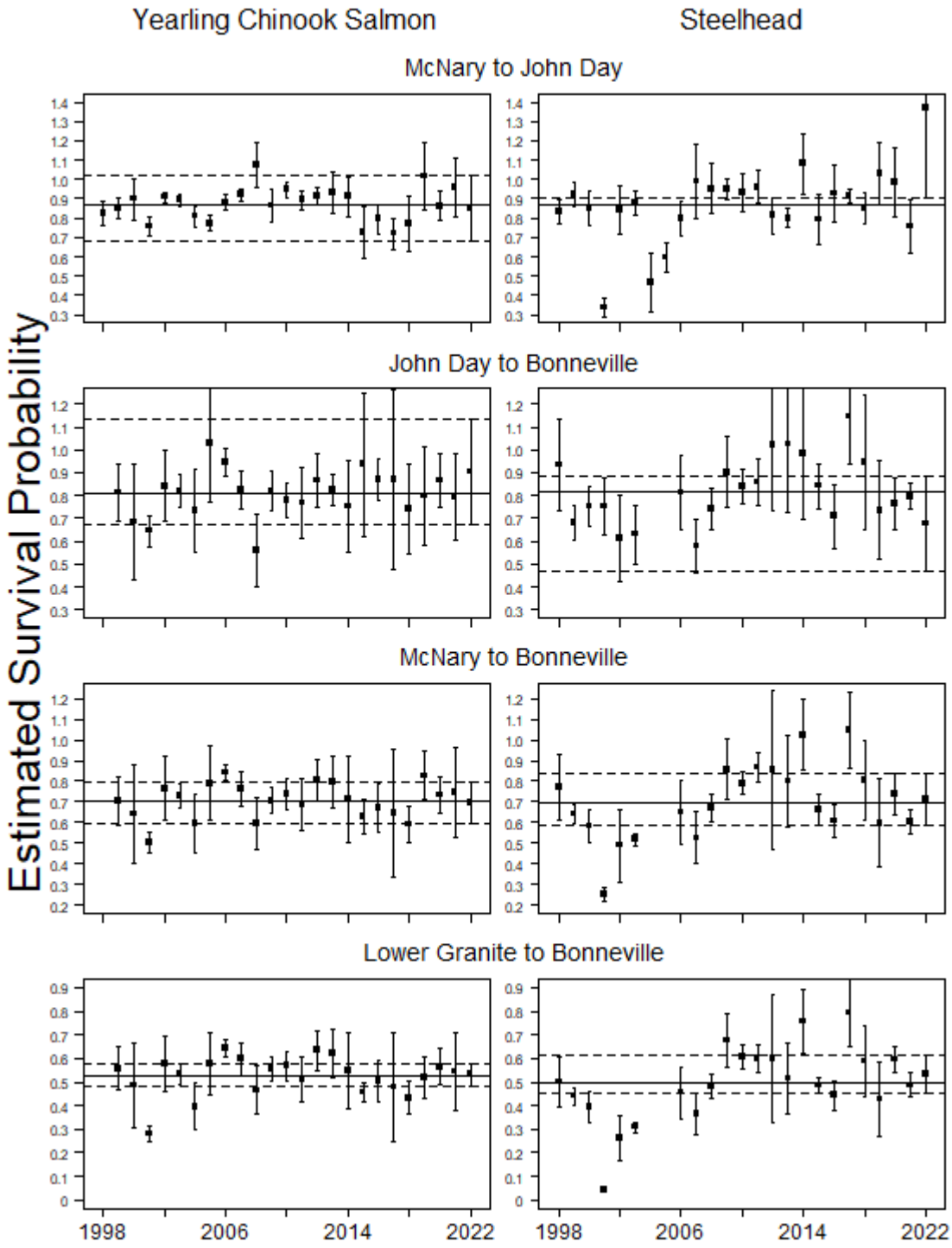

Figure 4. Annual mean survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2022 estimates, and horizontal solid lines represent long-term means.

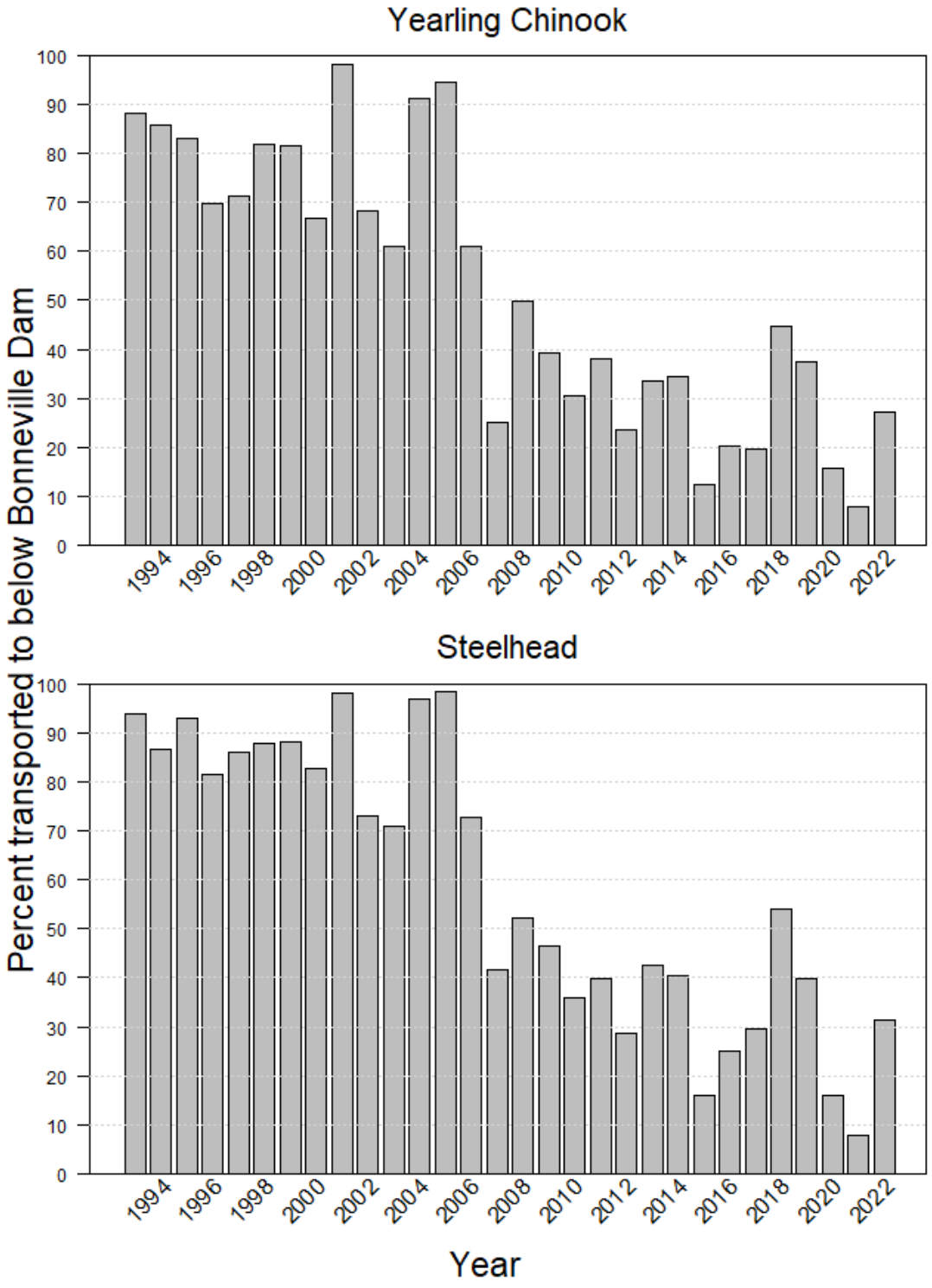

Figure 5. Annual estimates of the percentage of yearling Chinook salmon and steelhead smolts (mean of estimates for hatchery and wild smolts) that arrived at Lower Granite Dam that were subsequently transported, either from Lower Granite Dam or downstream from Little Goose or Lower Monumental Dam, to below Bonneville Dam (1993-2022).

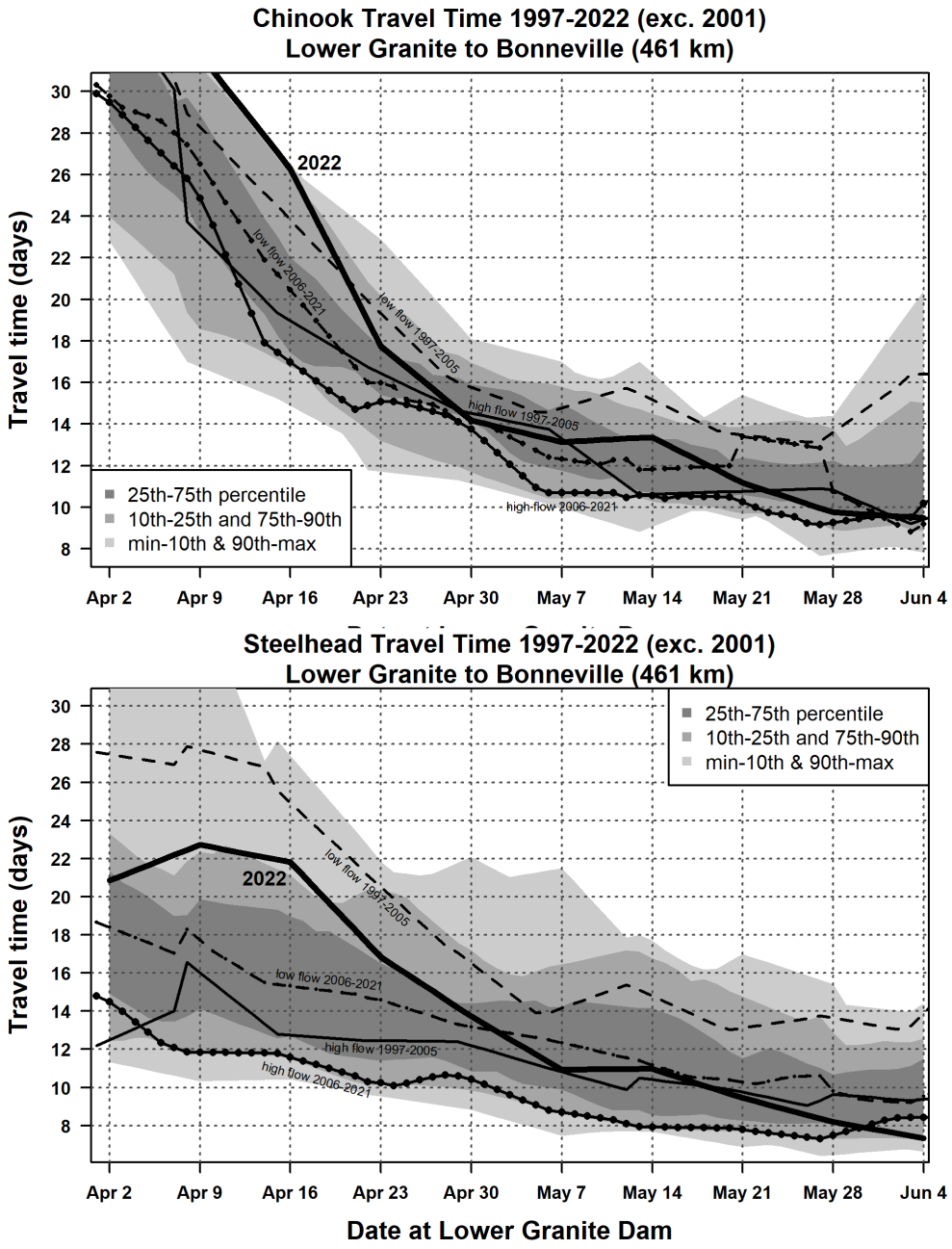

Figure 6. Median travel time (d) from Lower Granite to Bonneville Dam (461 km) vs. date passing Lower Granite Dam for yearling Chinook salmon and juvenile steelhead. Shaded regions show daily quantiles during 1997-2022 (excluding 2001). Lines show daily medians from selected subsets of years: low-flow 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).

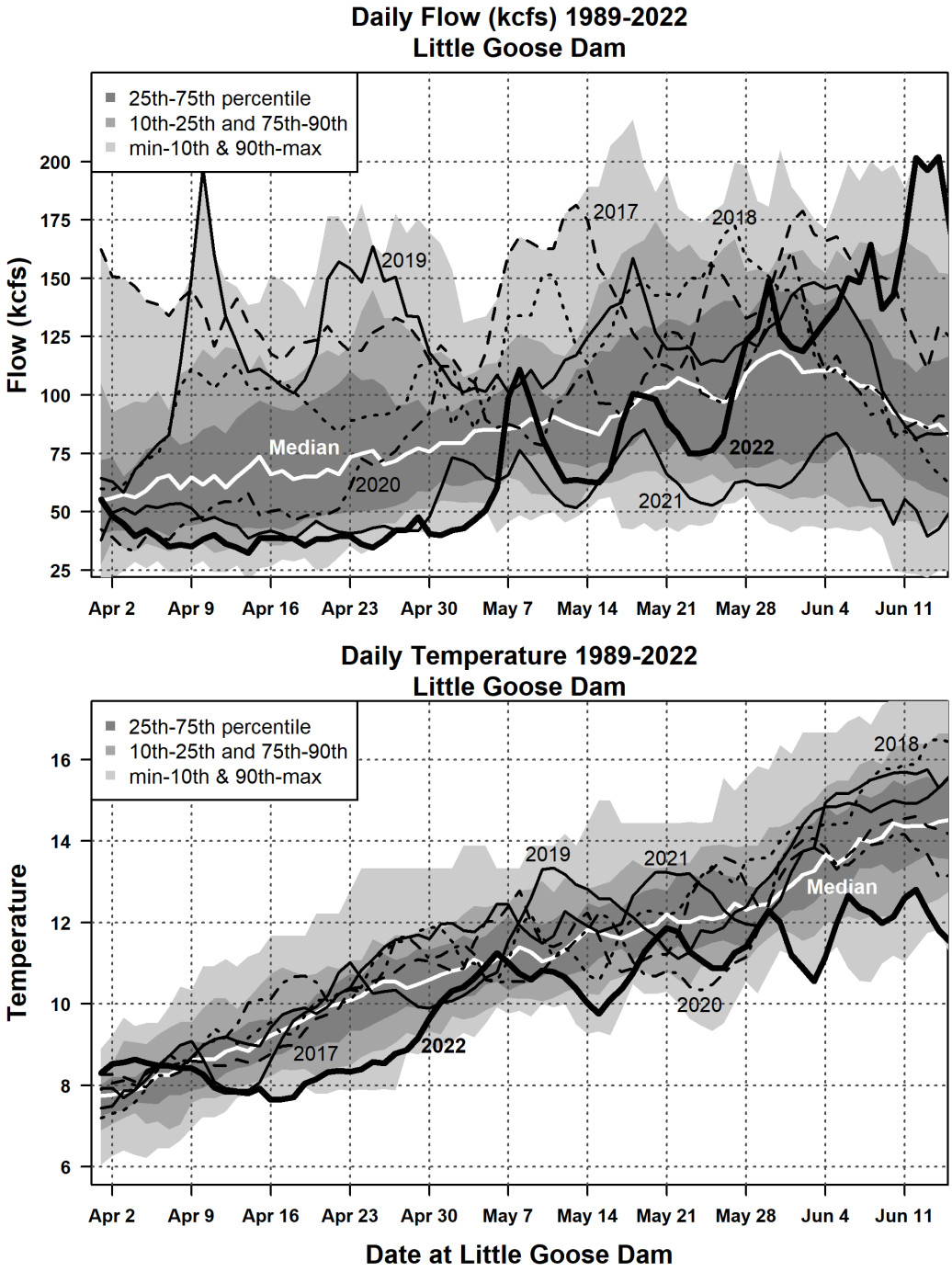

Figure 7. Upper panel shows daily mean flow at Little Goose Dam from April to mid-June. Lines show daily mean flows for 2022 and selected recent years and long-term median. Shaded areas illustrate daily quantiles from 1989-2022. Lower panel uses the same format to show daily mean temperature at Little Goose Dam. Quantiles for daily temperature are calculated from 1996-2022.

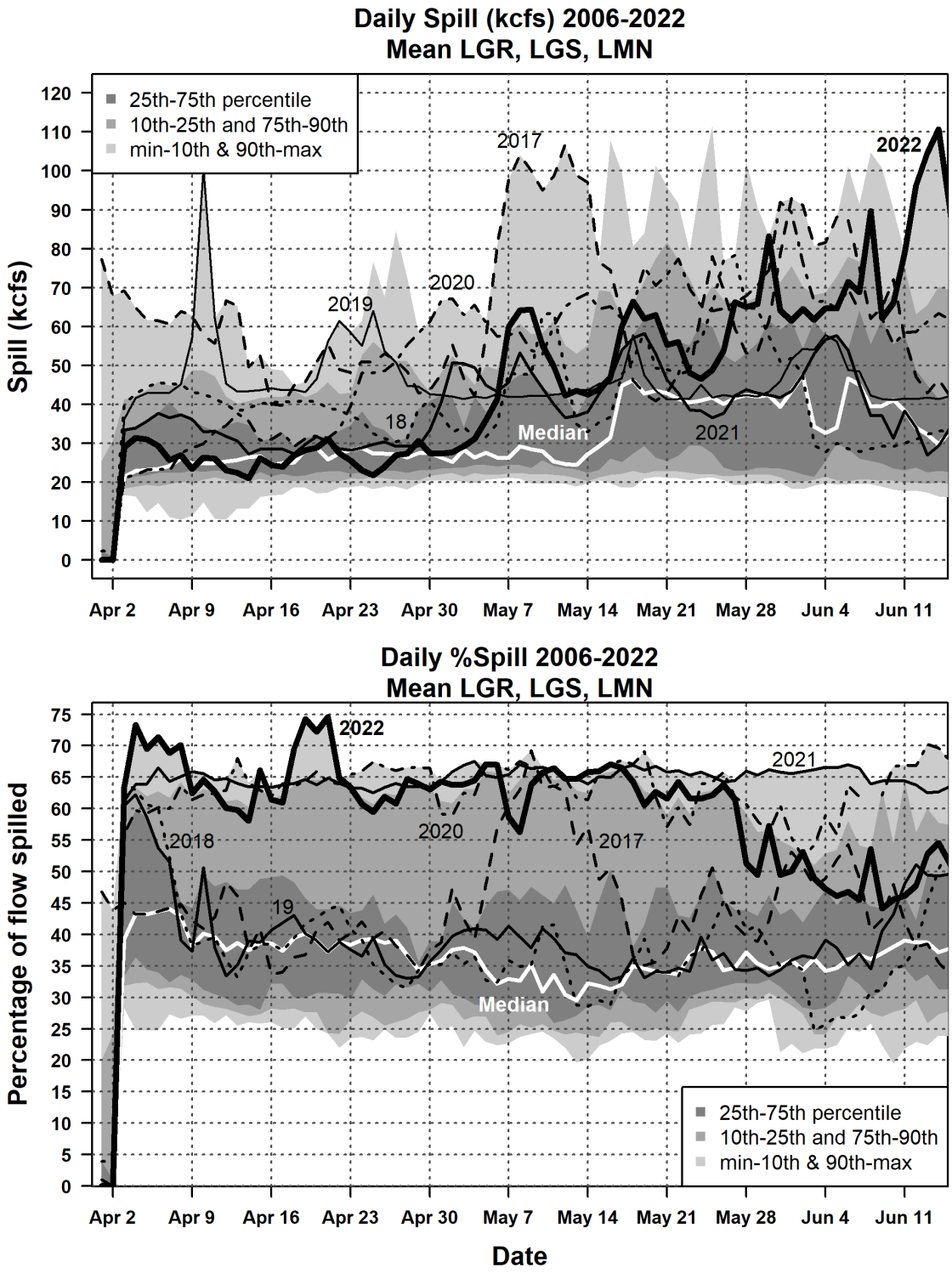

Figure 8. Upper panel shows daily mean Snake River spill (kcfs) from April to mid-June, averaged across Lower Granite, Little Goose and Lower Monumental Dams. Lower panel shows daily spill as a percentage of total flow. Lines show daily values for 2022 and selected recent years and long-term median. Shaded areas indicate daily quantiles for 2006-2022.

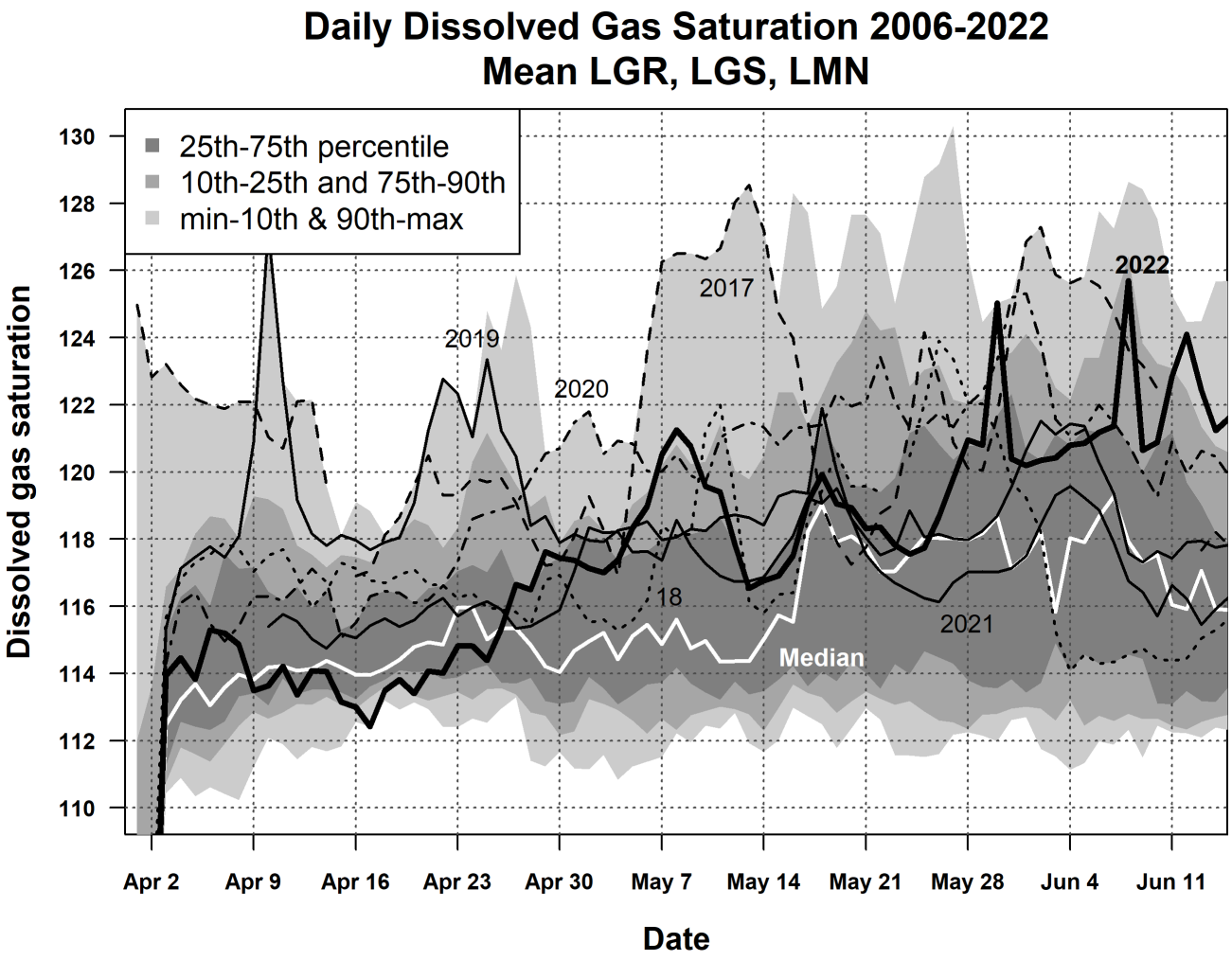

Figure 9. Daily mean percentage of dissolved gas averaged across Lower Granite, Little Goose and Lower Monumental Dam from April to mid-June 2022. Lines show daily percentage for 2022 and selected recent years and long-term median. Shaded areas indicate daily quantiles for 2006-2022.

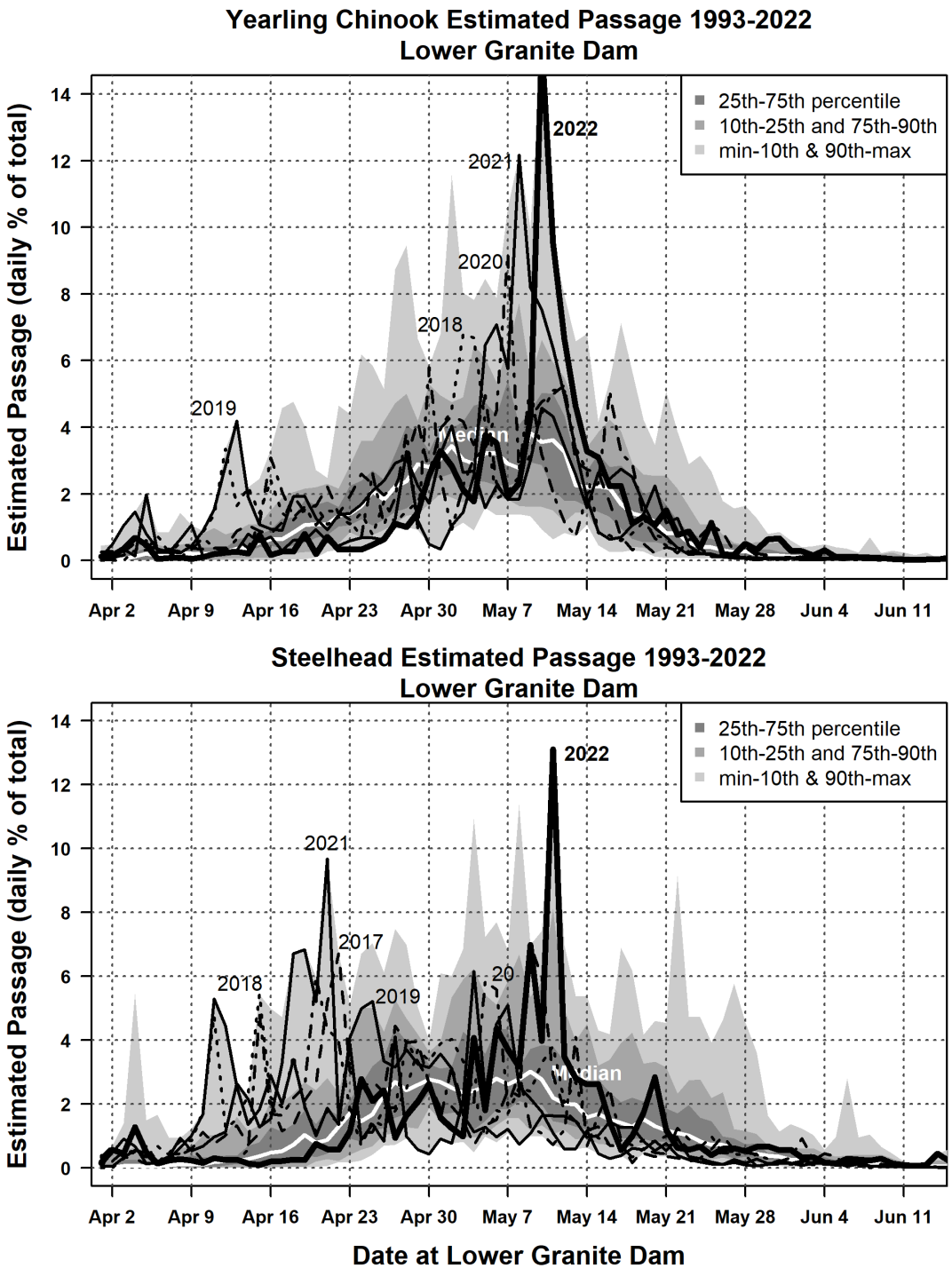

Figure 10. Estimated daily smolt passage at Lower Granite Dam for yearling Chinook salmon and steelhead. Daily passage is expressed as percentage of the yearly total. Lines indicate daily values for 2022, the long-term median, and selected recent years. Shaded areas indicate smolt-passage quantiles from 1993 to 2022.