UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
Fish Ecology Division
2725 Montlake Boulevard East
Seattle, WA 98112-2097
(206) 860-3270

September 19, 2018

MEMORANDUM FOR: F/NWR5 – Ritchie Graves

FROM: F/NWC3 - Richard W. Zabel

SUBJECT: Preliminary survival estimates for the passage of spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs, 2018

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 2018 spring outmigration. We also provide preliminary estimates of the proportion of Snake River smolts that were transported from Snake River dams in 2018. Our complete detailed analyses and report for the spring migration will follow this memo at a later date. As in past years, changes in the database between the time of our annual summer memo and the publication of our final report may result in differences of up to 3 or 4% in estimated survival values.

Summary of Research

For survival studies funded by BPA in 2018, NOAA Fisheries PIT tagged 20,249 river-run hatchery steelhead, 15,396 wild steelhead, and 11,823 wild yearling Chinook salmon for release into the tailrace of Lower Granite Dam.

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. Note that 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 survival probabilities which are less than or equal to 100%.

We have estimated survival probabilities for migrating PIT-tagged salmonids since 1993. In this memo, we compare 2018 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.

PIT-tagged yearling Chinook salmon have been released from the seven Snake River Basin hatcheries Dworshak, Kooskia, Lookingglass/Imnaha Weir, Rapid River, McCall/Knox Bridge, Pahsimeroi, and Sawtooth every year from 1993 through 2018 (except Pahsimeroi in 1996). Across these “index” hatcheries, the annual mean estimated survival from release to Lower Granite Dam has been relatively stable since 1998 (Figure 1, Table 1). In 2018, the mean was 64.8%; this estimate is close to last year’s mean survival to Lower Granite of 65.0% and the overall mean from 1998 through 2018 of 65.1%. The annual mean has ranged from 49.4% in 1997 to 71.7% in 2016 (Figure 1).

Downstream of Lower Granite Dam, mean estimated survival for Snake River yearling Chinook salmon (hatchery and wild combined) in 2018 was slightly above average in the Lower Granite to Little Goose and the Lower Monumental to McNary reaches, and close to average in the Little Goose to Lower Monumental reach (Table 2, Figure 2). However, estimated survival in the McNary to John Day and John Day to Bonneville reaches was substantially lower than average (Table 2, Figure 3). These estimates resulted in average survival from Lower Granite to McNary, but below average survival in the remaining combined reaches of interest (Table 3).

Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace in 2018 was 73.3% (95% CI: 68.4-78.2%). Mean estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 59.0% (50.2-67.8%). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to Bonneville Dam tailrace was 43.2% (36.2-

50.3%). Estimated survival for the Lower Granite project (head of reservoir to tailrace) was 88.0%, based on fish PIT tagged at and released from the Snake River trap. The combined yearling Chinook salmon survival estimate from the Snake River trap to Bonneville Dam tailrace was 38.1% (31.6-44.6%), substantially below the long-term average of 48.9%.

For wild Snake River yearling Chinook, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was 76.0% (95% CI: 69.9-82.1%), and from McNary Dam tailrace to Bonneville Dam tailrace was 76.2% (48.0-104.4%). Estimated survival from the Snake River trap to Lower Granite Dam tailrace was 87.1%, which resulted in estimated survival from the Snake River trap to Bonneville Dam tailrace of 50.4% (31.0-69.9%). This estimate is above the long-term average of 44.8%.

For Snake River steelhead (hatchery and wild combined), mean estimated survival in 2018 was above average in every individual reach and all resulting combined reaches, though the estimate for the John Day to Bonneville reach was very uncertain (Table 4, Figures 2 and 3). Mean estimated survival for steelhead from Lower Granite Dam tailrace to McNary Dam tailrace was 73.3% (95% CI: 67.2-79.4%). Mean estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 72.7% (50.8-94.7%). The combined Snake River steelhead survival estimate from the Snake River trap to Bonneville Dam tailrace was 52.4% (35.8-69.0%), which was above the long-term average of 45.6% (Table 5).

For wild Snake River steelhead, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was 73.6% (95% CI: 58.9-88.3%), and from McNary Dam tailrace to Bonneville Dam tailrace was 82.2% (55.5-108.9%). Estimated survival from the Snake River trap to Lower Granite Dam tailrace was 84.8%, which resulted in estimated survival from the Snake River trap to Bonneville Dam tailrace of 51.3% (30.5-72.1%).

For PIT-tagged hatchery yearling Chinook salmon originating from the upper Columbia River in 2018, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 74.9% (95% CI: 60.2-93.2%; Table 6), which was below the long-term average of 81.4%.

For PIT-tagged hatchery steelhead originating from the upper Columbia River in 2018, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 116.1% (95% CI: 85.0-158.6%; Table 6). This estimate has high uncertainty; however, unlike Columbia River Chinook, even the low end of the confidence range is above the long-term average of 77.4%.

For fish released from upper Columbia River hatcheries, we cannot estimate survival in reaches upstream from McNary Dam (other than the overall reach from release to McNary Dam tailrace) because of limited PIT-tag detection capabilities at Mid-Columbia River PUD dams.

Estimated survival in 2018 of Snake River sockeye salmon (hatchery and wild combined) from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 64.3% (95% CI: 30.4-50.8%; Table 7). Estimated survival in 2018 of Columbia River sockeye salmon (hatchery and wild combined) from the tailrace of Rock Island Dam to the tailrace of Bonneville Dam was 66.7% (40.7%-61.5%; Table 7). Both estimates were above their respective long-term averages of 40.6% and 51.1%.

Our preliminary estimates of the percentage transported of non-tagged wild and hatchery spring-summer Chinook salmon smolts in 2018 are 44.1% and 45.4%, respectively. For steelhead, the estimates are 47.5% and 46.4% for wild and hatchery smolts, respectively. These estimates represent the percentage of smolts that arrived at Lower Granite Dam that were subsequently transported, either from Lower Granite Dam or downstream at Little Goose or Lower Monumental Dam.

Discussion

For Snake River yearling Chinook salmon in 2018, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 43.2%; this estimate is substantially below the long-term (1999-2018) average of 52.1%. Yearling Chinook survival through the hydropower system has been consistently

below the mean for the past four years, despite a range of different environmental conditions within these years. These low system survival estimates seem to be driven mostly by poor survival in the McNary to Bonneville reach.

For Snake River steelhead in 2018, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 53.3%; above the long-term mean of 47.0% (Table 5). This above-average estimate follows three consecutive years of survival estimates below the mean.

Estimated survival of Snake River sockeye between Lower Granite Dam and Bonneville Dam tailrace was 64.3%, which is the third highest estimate we have in our time series (1998-2018). The component survival estimates for the Lower Granite Dam to McNary Dam reach and the McNary Dam to Bonneville Dam reach were both above average. This above-average estimate follows three consecutive years with very low survival. The Idaho Department of Fish and Game has adjusted their acclimation methods this year in order to address the causes of the low Snake River Sockeye survival from the past three years; their efforts almost certainly contributed to the higher survival estimate this year. Survival of juvenile Upper Columbia River sockeye in the McNary to Bonneville Dam reach was also above average.

Environmental conditions in 2018 resulted in a year with average water temperatures, but high flow and very high spill for most of the migration season. Mean flow at Little Goose Dam in 2018 during the main migration period (1 April–15 June) was 110.8 kcfs, which was well above the long-term (1993-2018) mean of 92.6 kcfs. Daily flow values were above long-term daily means for most of the migration period; daily flow approached the mean for a brief period in early May and fell below the mean after the beginning of June (Figure 4). Mean water temperature at Little Goose Dam in 2018 during the migration period was 11.5 °C, which was near the long-term mean of 11.2 °C. Daily water temperatures generally tracked the long-term daily mean, alternating between slightly above and slightly below the mean through April and May, then remaining slightly above the long-term mean during June (Figure 4).

Mean spill discharge at the Snake River dams during the 2018 migration was 41.3 kcfs, which was substantially above the long-term (1993-2018) mean of 27.7 kcfs. Daily spill discharges remained above the long-term daily mean throughout April and May, with peaks in early May and again near the end of May (Figure 5).

Spill as a percentage of flow at Snake River dams averaged 37.2% in 2018, which was above the long-term (1993-2018) mean of 27.2. Daily mean spill percentages in 2018 were above the long-term daily means for almost the entire migration period (Figure 5), with higher percent spill during early April than in any previous year.

Estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams in 2018 were substantially higher than in most recent years; 2018 saw one of the highest transportation rates since 2006 (Figure 7). This reversed the recent trend of very low transportation rates seen from 2015-2017.

In 2018, collection of transportation began on 23 April at Lower Granite, Little Goose, and Lower Monumental Dams, which was 8 days earlier than the May 1st start date from most recent years, and the earliest start date for the transportation program since 2006. We estimate that 45% of the annual total passage of wild yearling Chinook and 24% of hatchery yearling Chinook occurred at Lower Granite Dam before transportation began (Figure 6), compared to averages between 2006-2014 of 42% and 31%, respectively. It is worth noting that the percentages passing in 2018 are near average, despite the fact that transportation began earlier in 2018 than in any year in that period except 2006. We estimate that 38% of wild steelhead arrived before transportation began in 2018 (Figure 6), versus the 2006-2014 average of 29%, and 24% of hatchery steelhead versus the average of 33%.

After the beginning of transportation in 2018, higher-than-average proportions of smolts were collected for transportation. This was due to the combination of spill operations and river conditions experienced by the fish as they passed the collector

dams. The combination of early transportation start date and relatively higher collection proportions during transportation resulted in the increased percentages of smolts transported in 2018.

Median estimated travel times for both species between Lower Granite Dam and Bonneville Dam in April in 2018 continued the trend from recent years and were substantially shorter than the long-term mean for most of the migration period (1997-2017; Figure 8). These short travel times coincided with the generally high flows and spills in 2018. When flow levels declined at the beginning of June, travel times converged with the mean of recent years.

Since the institution of court-ordered spill in 2006, and the concurrent installation of surface collectors at four additional federal dams during that period, travel times have decreased on average between Lower Granite and Bonneville dams for steelhead, but the effect is less apparent for Chinook (Figure 8). Differences in travel times for low-flow years versus other years are not so well pronounced for either species (Figure 8). Day in season is a stronger predictor of travel time for Chinook than either flow or spill. Some of the lowest flow years were also low-spill years that occurred before the new spill regime, so the effect of average flow on travel time is difficult to separate from that of spill by simply inspecting the figures without the assistance of a statistical model. Flow and spill also vary within season, so categorizing years by seasonal averages is not optimal, but it does allow for some simple visual comparisons.

cc: F/NWC3 – Faulkner
F/NWC3 – Marsh
F/NWC3 – Smith
F/NWC3 – Widener
F/NWC3 – Zabel

Table 1. 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), 2016 through 2018.

	2016		2017		2018[a]	
Hatchery	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	0.714 (0.007)	0.538 (0.014)	0.693 (0.013)	0.402 (0.015)	0.744 (0.015)	0.546 (0.023)
Kooskia	0.684 (0.012)	0.499 (0.029)	0.565 (0.025)	0.351 (0.040)	0.633 (0.030)	0.438 (0.044)
Lookingglass (Catherine Cr.)	0.371 (0.005)	0.300 (0.016)	0.420 (0.014)	0.303 (0.024)	0.314 (0.008)	0.232 (0.024)
Lookingglass (Grande Ronde)	0.429 (0.016)	0.326 (0.044)	0.398 (0.032)	0.352 (0.096)	0.347 (0.013)	0.238 (0.043)
Lookingglass (Imnaha River)	0.704 (0.007)	0.526 (0.022)	0.585 (0.020)	0.438 (0.041)	0.651 (0.012)	0.429 (0.034)
Lookingglass (Lostine River)	0.586 (0.017)	0.419 (0.039)	0.553 (0.029)	0.409 (0.067)	0.600 (0.014)	0.418 (0.057)
McCall (Johnson Cr.)	---	---	---	---	0.487 (0.029)	0.370 (0.104)
McCall (Knox Bridge)	0.654 (0.006)	0.514 (0.014)	0.700 (0.012)	0.528 (0.021)	0.702 (0.011)	0.519 (0.026)
Pahsimeroi	0.772 (0.008)	0.512 (0.026)	0.746 (0.012)	0.560 (0.041)	0.634 (0.015)	0.342 (0.034)
Rapid River	0.815 (0.005)	0.632 (0.015)	0.652 (0.010)	0.528 (0.020)	0.651 (0.009)	0.491 (0.023)
Sawtooth	0.676 (0.006)	0.474 (0.015)	0.606 (0.010)	0.466 (0.025)	0.519 (0.013)	0.372 (0.029)
Entiat	---	0.631 (0.024)	---	0.639 (0.040)	---	0.572 (0.037)
Winthrop	---	0.577 (0.022)	---	0.578 (0.031)	---	0.587 (0.046)
Leavenworth	---	0.501 (0.016)	---	0.540 (0.022)	---	0.658 (0.038)

a. Estimates are preliminary and subject to change.

Table 2. Annual weighted means of survival probability estimates for yearling **Chinook** salmon (hatchery and wild combined), 1995–2018. 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 (1993–2018) are given.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
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	0.925 (0.009)	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 (0.008)	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	0.938 (0.058)	0.827 (0.043)	0.909
2014	0.905 (0.015)	0.940 (0.007)	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)	0.857 (0.036)	0.964 (0.057)	0.802 (0.033)	0.896	0.724 (0.069)	0.937 (0.160)	0.968
2016	0.936 (0.015)	0.956 (0.006)	0.912 (0.100)	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[a]	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
Mean[b]	**0.930 (0.008)**	**0.928 (0.006)**	**0.922 (0.009)**	**0.863 (0.011)**	**0.929 (0.006)**	**0.860 (0.019)**	**0.806 (0.024)**	**0.896 (0.014)**

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 and 1994 are omitted from the table for space.

Table 3. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River yearling **Chinook** salmon (hatchery and wild combined), 1997–2018. Standard errors in parentheses. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR-MCN	MCN-BON	LGR–BON	Trap–BON
1997	NA	0.653 (0.072)	NA	NA	NA
1998	0.924 (0.011)	0.770 (0.009)	NA	NA	NA
1999	0.940 (0.009)	0.792 (0.006)	0.704 (0.058)	0.557 (0.046)	0.524 (0.043)
2000	0.929 (0.014)	0.760 (0.012)	0.640 (0.122)	0.486 (0.093)	0.452 (0.087)
2001	0.954 (0.015)	0.556 (0.009)	0.501 (0.027)	0.279 (0.016)	0.266 (0.016)
2002	0.953 (0.022)	0.757 (0.009)	0.763 (0.079)	0.578 (0.060)	0.551 (0.059)
2003	0.993 (0.023)	0.731 (0.010)	0.728 (0.030)	0.532 (0.023)	0.528 (0.026)
2004	0.893 (0.009)	0.666 (0.011)	0.594 (0.074)	0.395 (0.050)	0.353 (0.045)
2005	0.919 (0.015)	0.732 (0.009)	0.788 (0.093)	0.577 (0.068)	0.530 (0.063)
2006	0.952 (0.011)	0.764 (0.007)	0.842 (0.021)	0.643 (0.017)	0.612 (0.018)
2007	0.943 (0.028)	0.783 (0.006)	0.763 (0.044)	0.597 (0.035)	0.563 (0.037)
2008	0.992 (0.018)	0.782 (0.011)	0.594 (0.066)	0.465 (0.052)	0.460 (0.052)
2009	0.958 (0.010)	0.787 (0.007)	0.705 (0.031)	0.555 (0.025)	0.531 (0.025)
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)	0.792 (0.071)	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)	0.680 (0.035)	0.629 (0.043)	0.428 (0.037)	0.389 (0.055)
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[a]	0.880 (0.022)	0.733 (0.025)	0.590 (0.045)	0.432 (0.036)	0.381 (0.033)
Mean[b]	**0.930 (0.008)**	**0.738 (0.012)**	**0.695 (0.019)**	**0.521 (0.020)**	**0.489 (0.020)**

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.

Table 4. Annual weighted means of survival probability estimates for **steelhead** (hatchery and wild combined), 1995–2018. 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 (1993–2018) are given.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
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)	0.848 (0.039)	0.834 (0.060)	0.939 (0.073)	0.969	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	0.941 (0.020)	0.643 (0.040)	0.802
2018[a]	0.983 (0.025)	0.953 (0.007)	0.950 (0.016)	0.823 (0.036)	0.907	0.847 (0.068)	0.949 (0.137)	0.974
Mean[b]	**0.952 (0.011)**	**0.930 (0.010)**	**0.909 (0.012)**	**0.775 (0.027)**	**0.876 (0.018)**	**0.833 (0.038)**	**0.804 (0.032)**	**0.893 (0.018)**

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 and 1994 are omitted from the table for space.

Table 5. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River **steelhead** (hatchery and wild combined), 1997–2018. Standard errors in parentheses. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR-MCN	MCN-BON	LGR–BON	Trap–BON
1997	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)	0.628 (0.033)	0.663 (0.039)	0.416 (0.033)	0.364 (0.034)
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)	0.605 (0.037)	0.459 (0.030)	NA
2018[a]	0.983 (0.025)	0.733 (0.031)	0.727 (0.112)	0.533 (0.085)	0.524 (0.085)
Mean[b]	**0.952 (0.011)**	**0.660 (0.028)**	**0.677 (0.038)**	**0.470 (0.035)**	**0.456 (0.038)**

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.

Table 6. 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, 1999–2018. 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[a]	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)
Mean[b]	**0.559 (0.012)**	**0.900 (0.022)**	**0.899 (0.042)**	**0.814 (0.031)**	**0.419 (0.014)**	**0.897 (0.029)**	**0.872 (0.057)**	**0.774 (0.050)**

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 7. Estimated survival and standard error (s.e.) for **sockeye** salmon (hatchery and wild combined) from Lower Granite Dam tailrace to Bonneville Dam tailrace for fish originating in the Snake River, and from Rock Island Dam tailrace to Bonneville Dam tailrace for fish originating in the upper Columbia River, 1996–2018. Note that this table represents all available data on sockeye; estimates 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
1996	0.283 (0.184)	NA	NA	NA	NA	NA
1997	NA	NA	NA	0.397 (0.119)	NA	NA
1998	0.689 (0.157)	0.142 (0.099)	0.177 (0.090)	0.624 (0.058)	1.655 (1.617)	1.033 (1.003)
1999	0.655 (0.083)	0.841 (0.584)	0.548 (0.363)	0.559 (0.029)	0.683 (0.177)	0.382 (0.097)
2000	0.679 (0.110)	0.206 (0.110)	0.161 (0.080)	0.487 (0.114)	0.894 (0.867)	0.435 (0.410)
2001	0.205 (0.063)	0.105 (0.050)	0.022 (0.005)	0.657 (0.117)	NA	NA
2002	0.524 (0.062)	0.684 (0.432)	0.342 (0.212)	0.531 (0.044)	0.286 (0.110)	0.152 (0.057)
2003	0.669 (0.054)	0.551 (0.144)	0.405 (0.098)	NA	NA	NA
2004	0.741 (0.254)	NA	NA	0.648 (0.114)	1.246 (1.218)	0.808 (0.777)
2005	0.388 (0.078)	NA	NA	0.720 (0.140)	0.226 (0.209)	0.163 (0.147)
2006	0.630 (0.083)	1.113 (0.652)	0.820 (0.454)	0.793 (0.062)	0.767 (0.243)	0.608 (0.187)
2007	0.679 (0.066)	0.259 (0.084)	0.272 (0.073)	0.625 (0.046)	0.642 (0.296)	0.401 (0.183)
2008	0.763 (0.103)	0.544 (0.262)	0.404 (0.179)	0.644 (0.094)	0.679 (0.363)	0.437 (0.225)
2009	0.749 (0.032)	0.765 (0.101)	0.573 (0.073)	0.853 (0.076)	0.958 (0.405)	0.817 (0.338)
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[a]	0.684 (0.061)	0.940 (0.151)	0.643 (0.088)	0.560 (0.112)	0.839 (0.095)	0.667 (0.144)
Mean[b]	**0.628 (0.034)**	**0.566 (0.070)**	**0.406 (0.052)**	**0.668 (0.031)**	**0.729 (0.074)**	**0.511 (0.053)**

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.

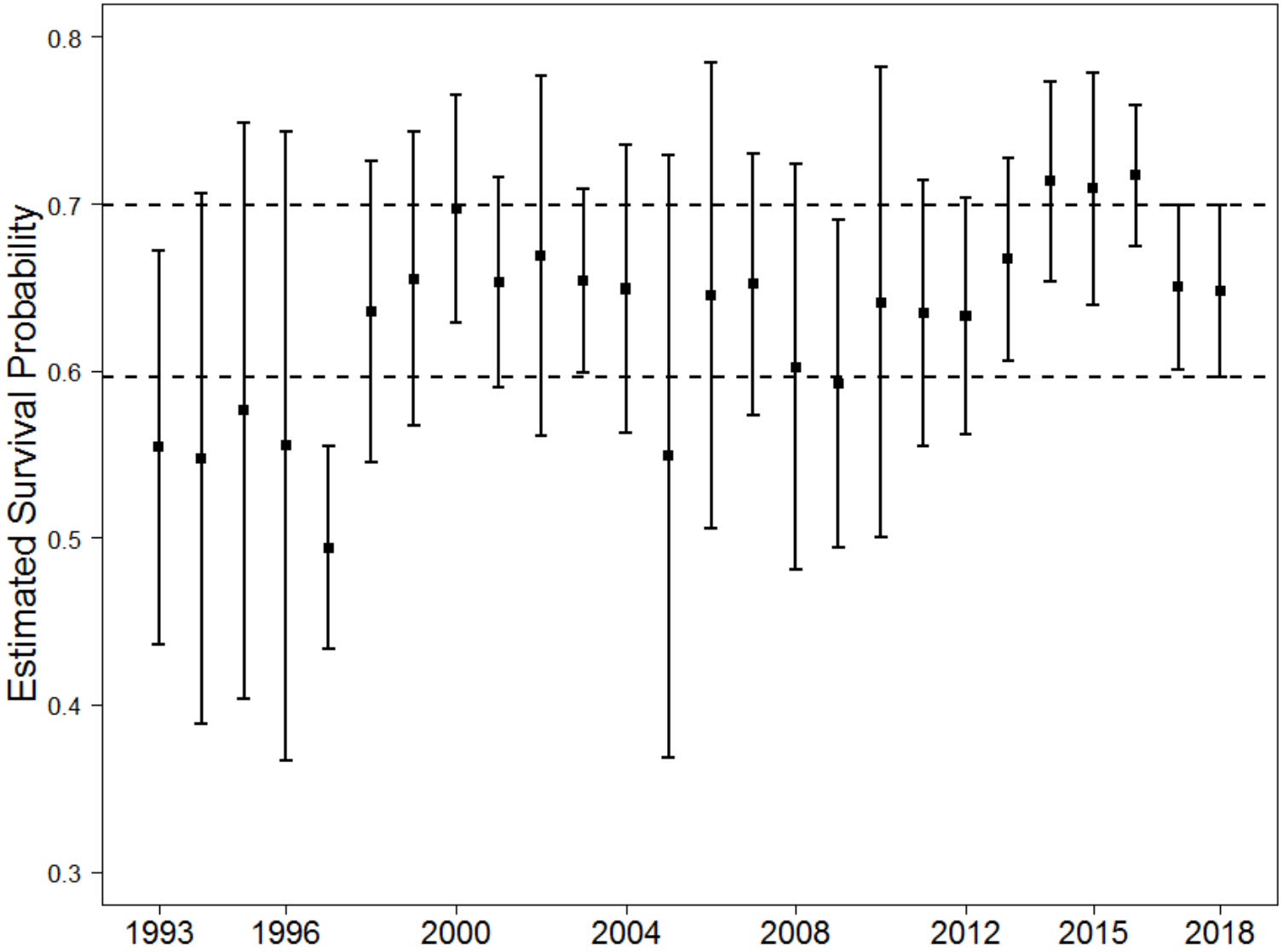

Figure 1. Annual average survival estimates from release to Lower Granite Dam for PIT-tagged yearling **Chinook** salmon released from Snake River Basin hatcheries, 1993-2018. Hatcheries used for average (index groups) are those with consistent PIT-tag releases through the series of years shown. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are the 2018 confidence interval endpoints and are shown for comparison to other years.

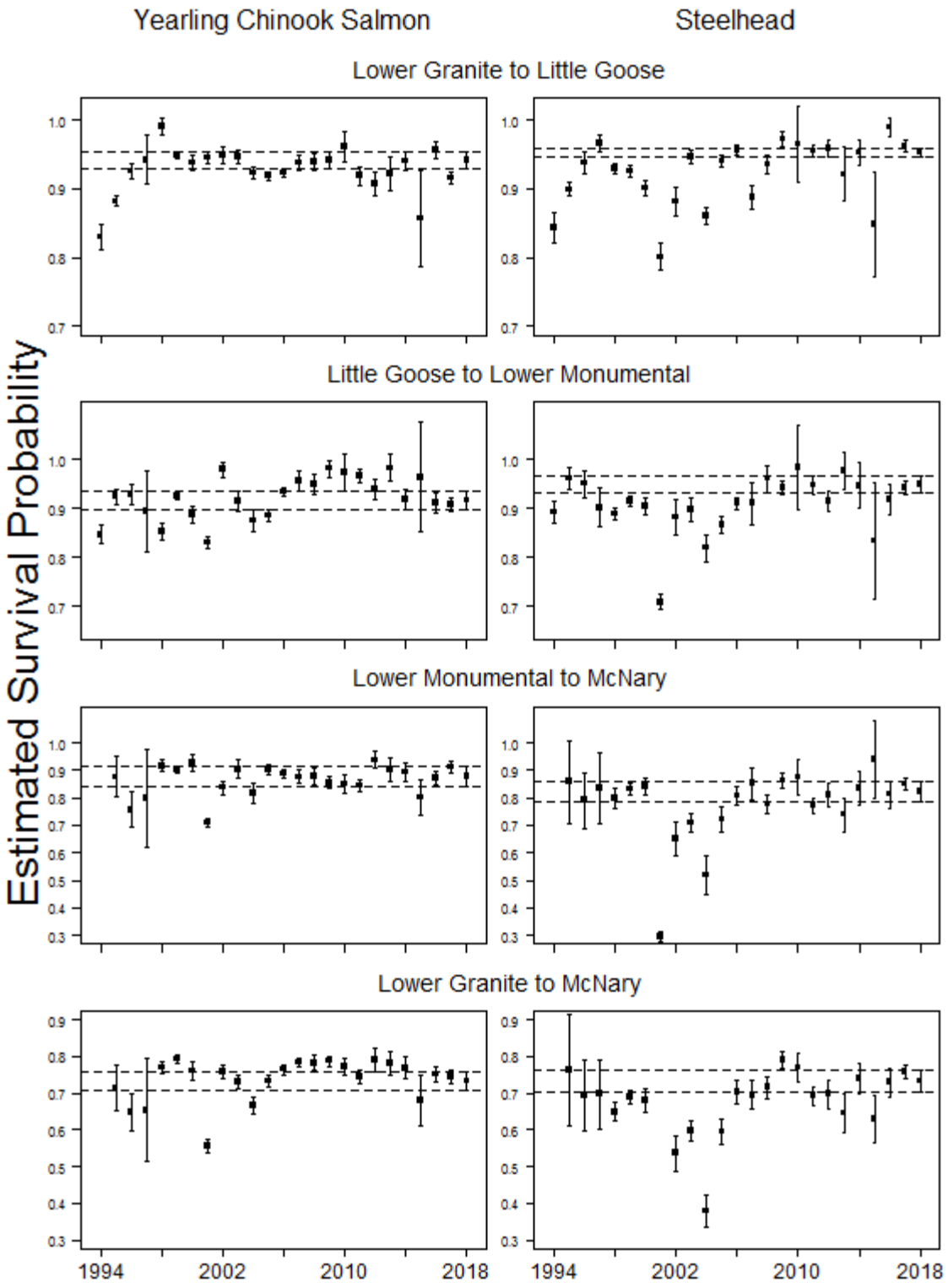

Figure 2. Annual average survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2018 estimates.

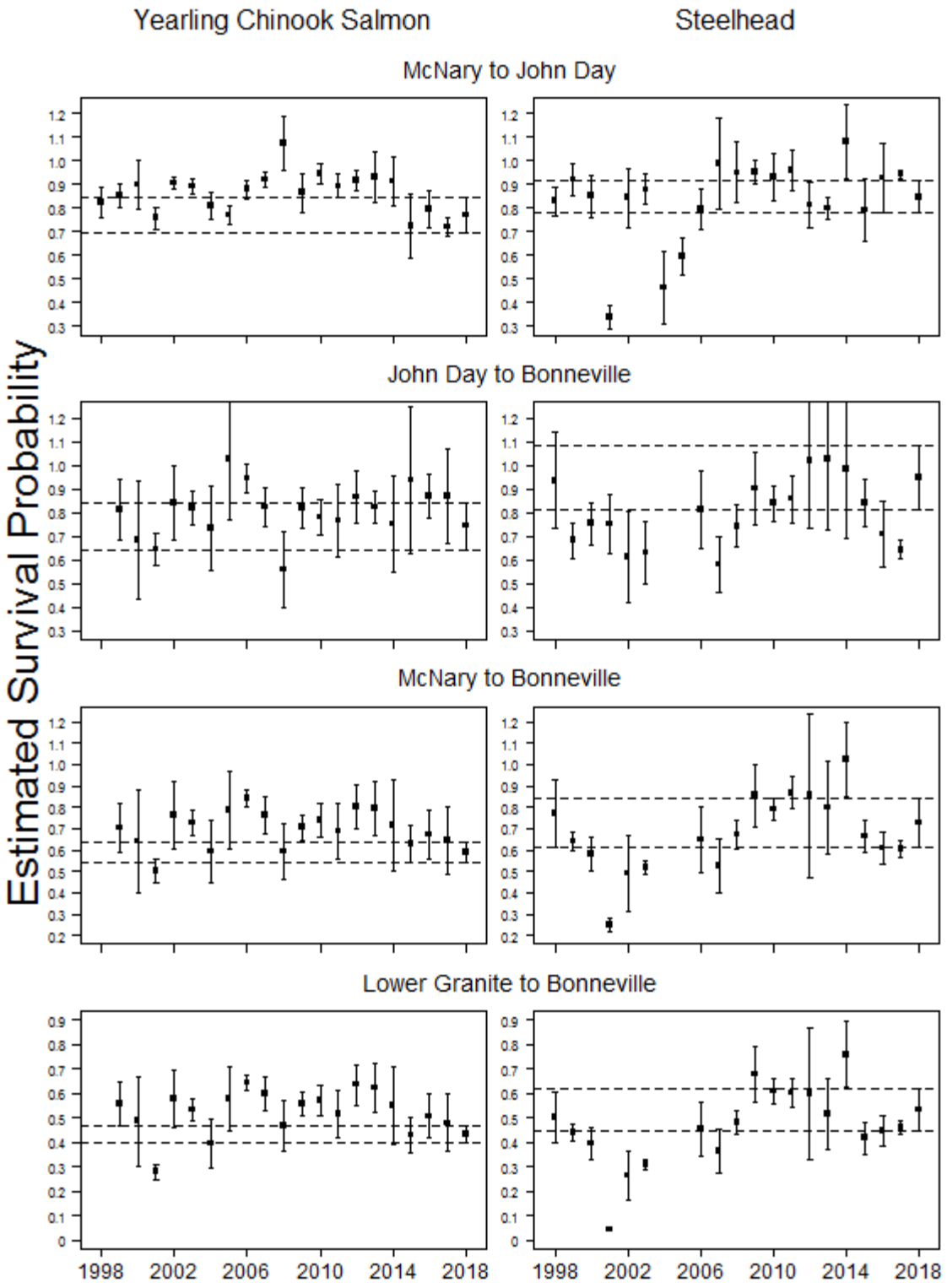

Figure 3. Annual average survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2018 estimates.

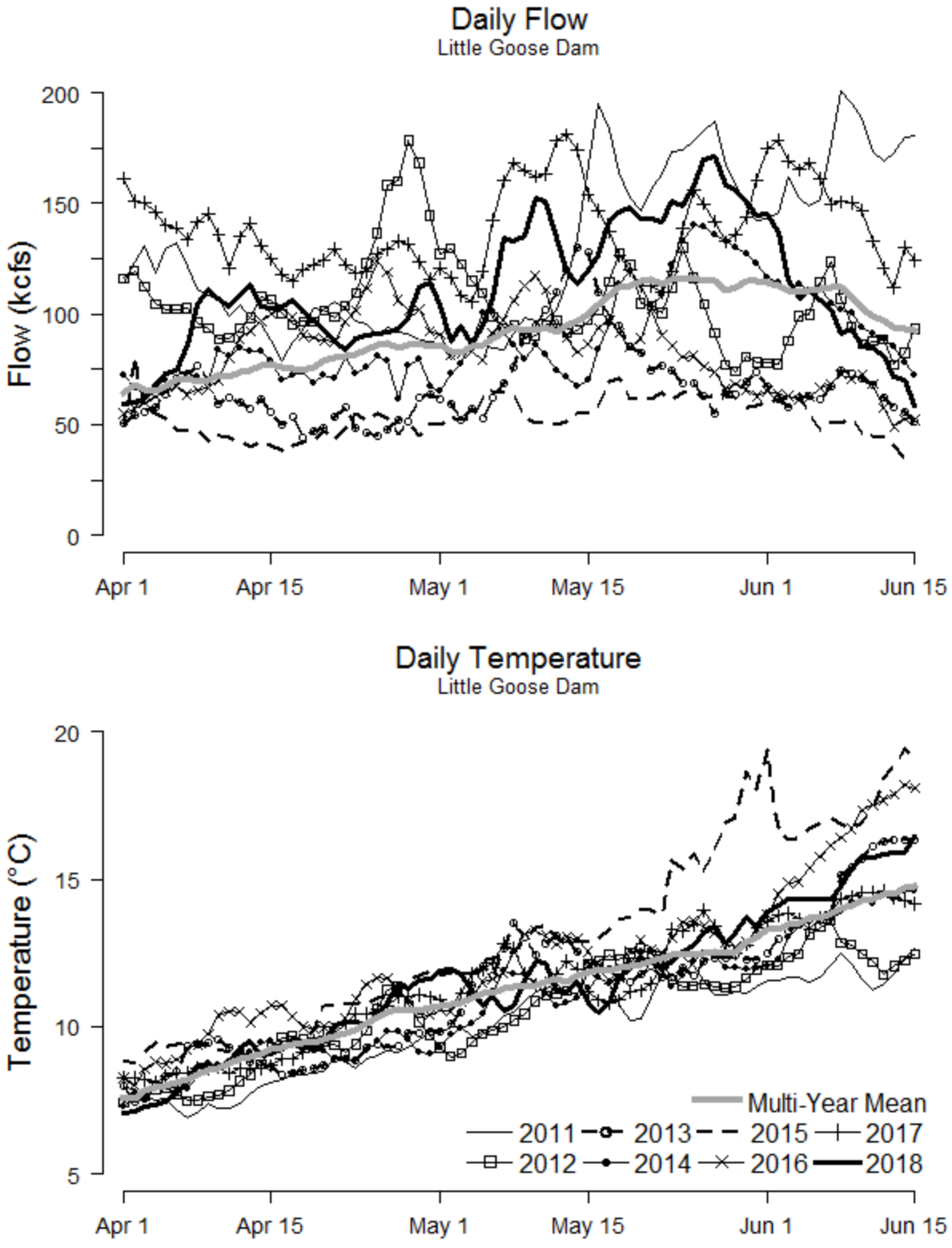

Figure 4. Snake River flow (kcfs; top panel) and water temperature (^{o}C; bottom panel) measured at Little Goose Dam during April and May, 2011-2018, including daily long-term means (1993-2018).

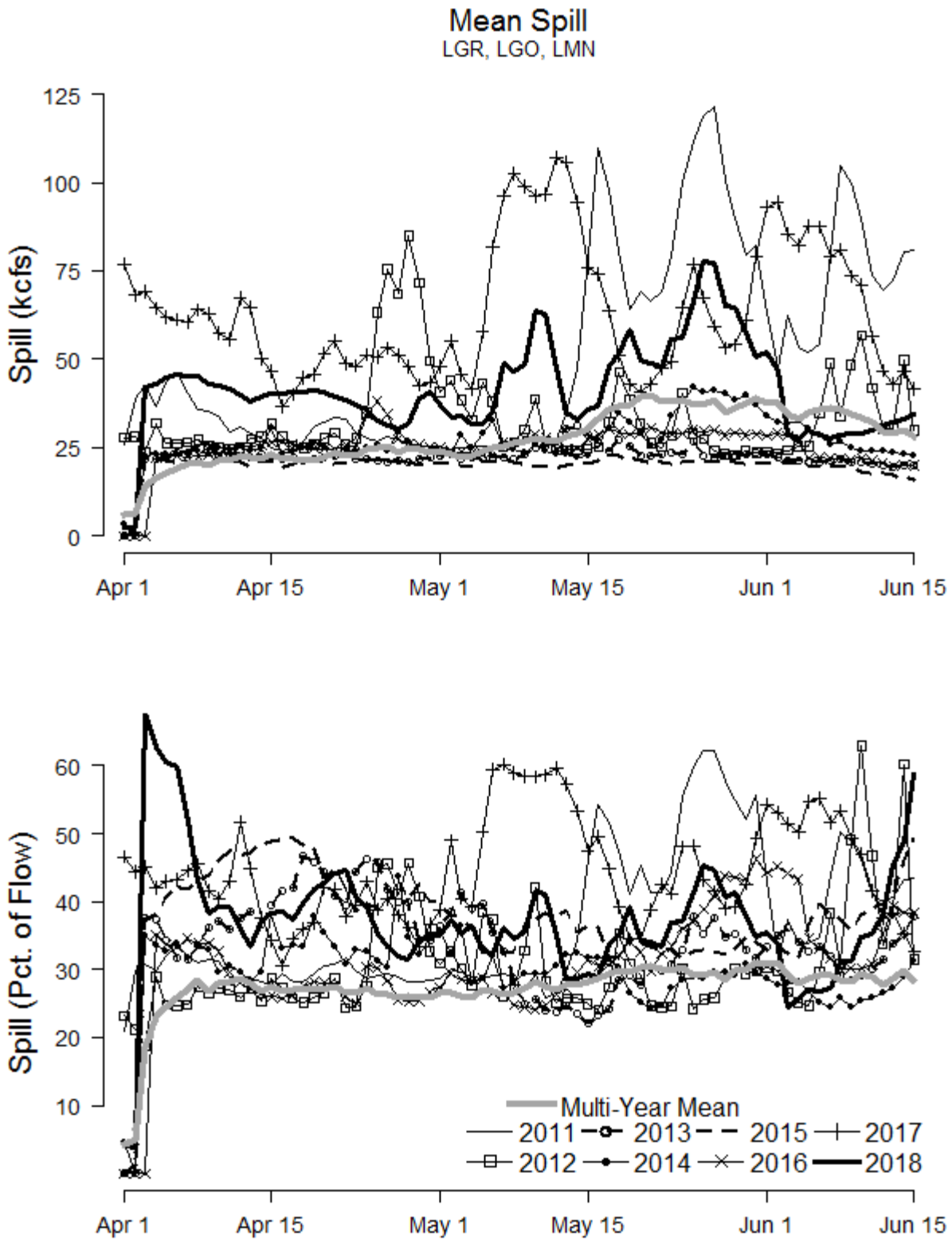

Figure 5. Mean spill (top panel shows kcfs; bottom panel shows percentage of total flow) at Snake River dams during April and May, 2011-2018, including daily long-term means (1993-2018).

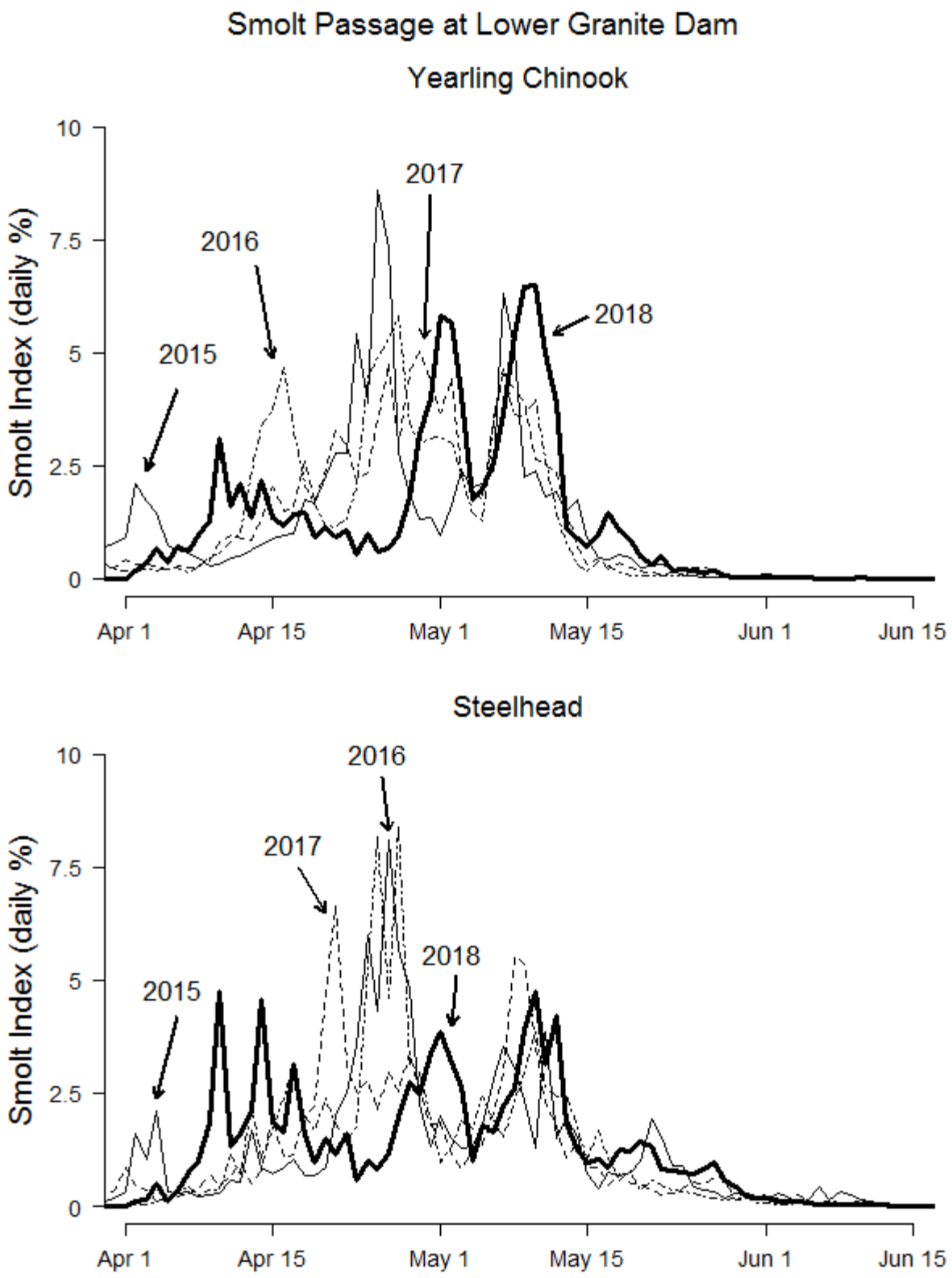

Figure 6. Smolt index as daily percentage of total passage at Lower Granite Dam 2015-2018 for hatchery and wild combined yearling **Chinook** and **steelhead**.

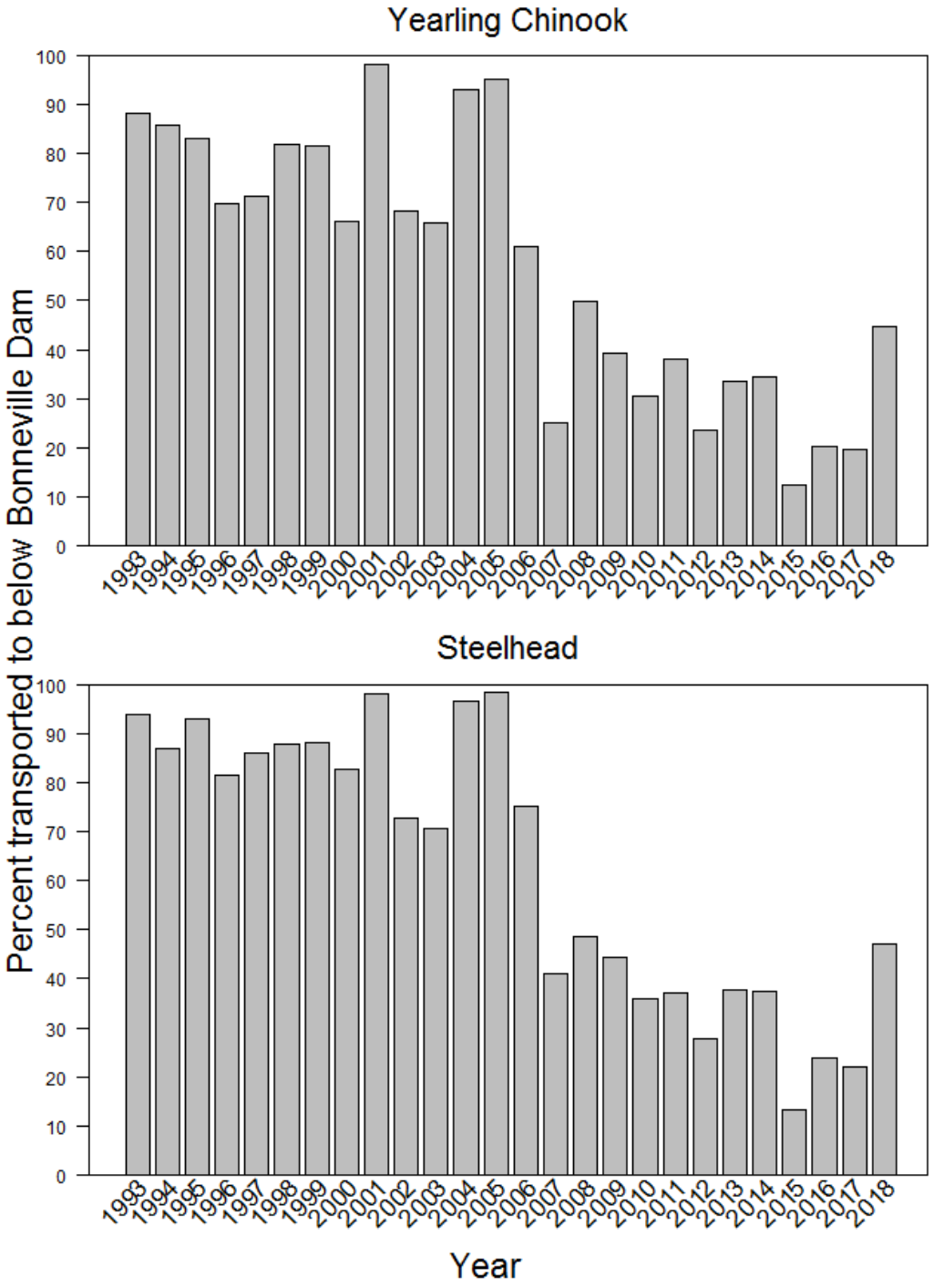

Figure 7. Estimated percent of yearling **Chinook** salmon and **steelhead** (hatchery and wild combined) transported to below Bonneville Dam by year (1993-2018).

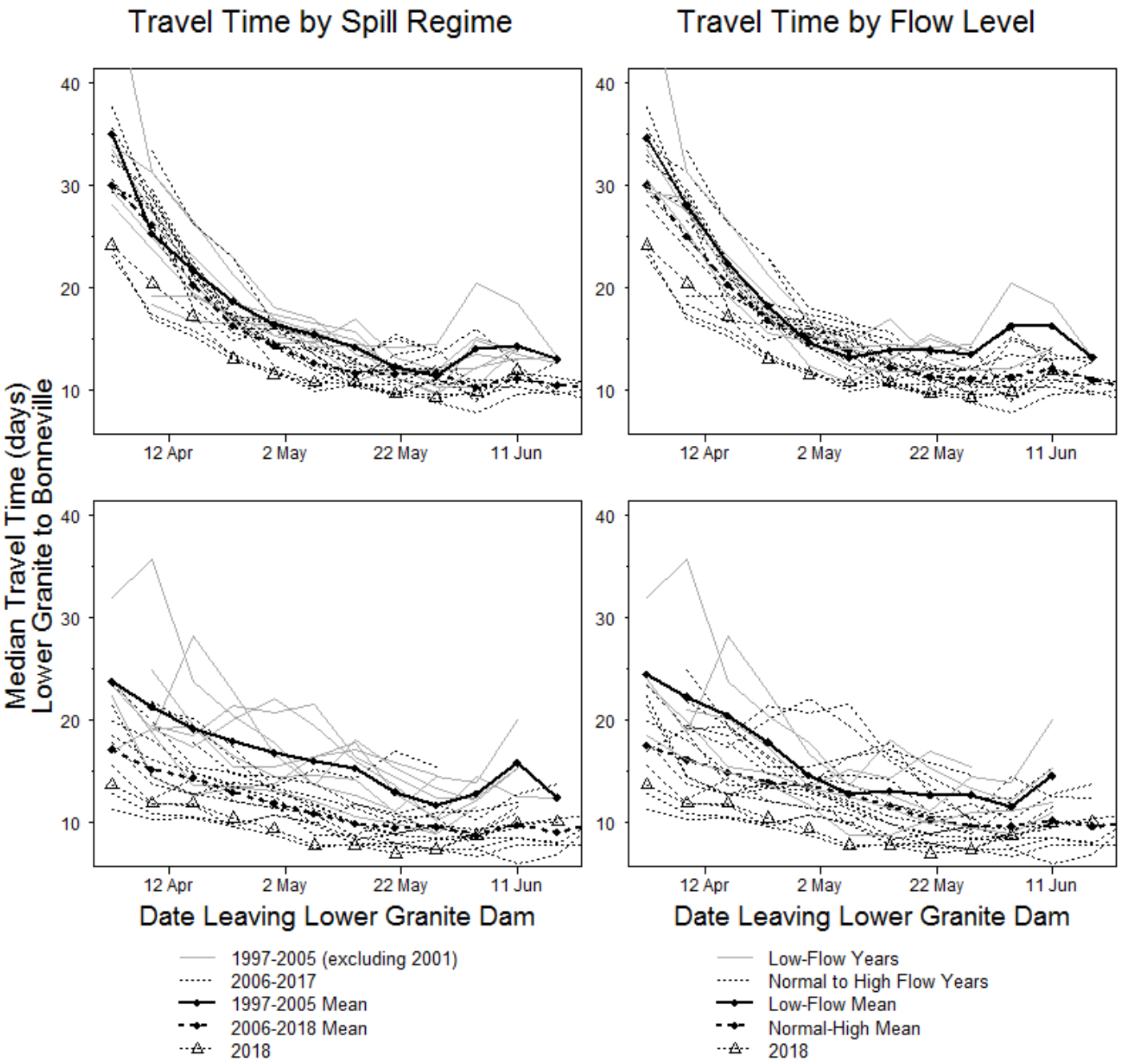

Figure 8. Median travel time from Lower Granite Dam to Bonneville Dam for yearling **Chinook** salmon and **steelhead** by spill regime (left) and mean flow category (right) in the period 1998-2018 (excluding 2001), with long-term mean for the same period. Here spill regime is defined by court-ordered spill starting in 2006 and the concurrent installation of additional surface collectors, and low-flow years are those with mean of 70 kcfs or less for the period of 1 April through 15 June. The 2001 migration year is excluded from the individual years and means due to its unusual combination of low flow and no spill and the influence that has on the group means.