



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

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MEMORANDUM FOR: F/NWR5 - Bruce Suzumoto
FROM: F/NWC3 - John W. Ferguson *John W. Ferguson*
SUBJECT: Preliminary survival estimates for passage during the spring migration of juvenile salmonids through Snake and Columbia River reservoirs and dams, 2008

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 2008 spring outmigration. We also provide preliminary estimates of the proportion of Snake River migrants that were transported from Snake River dams in 2008. Our complete detailed analyses and report for spring migrants will be available by the end of the year. In past years, changes in the database between the time of our annual summer memo and the publication of our final report have sometimes resulted in differences of up to 3 or 4% in estimated survival.

Summary of Research

For survival studies funded by BPA in 2008, NOAA Fisheries PIT tagged about 18,250 river-run hatchery steelhead, about 15,320 wild steelhead, and about 9,330 wild yearling Chinook salmon for release into the tailrace of Lower Granite Dam. From studies funded by the USACE, we used about 122,000 hatchery yearling Chinook salmon PIT tagged by NOAA Fisheries at Lower Granite Dam for evaluation of "extra" or "latent" mortality related to passage through Snake River dams.

Survival estimates provided in this memorandum are derived from PIT-tag 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 yearling Chinook salmon from Snake River Basin hatcheries, estimated survival to Lower Granite Dam tailrace has been stable since 1998 (Table 1, Figure 1). In that period mean survival for index groups (release groups that most represent production



releases from hatcheries that we have tracked for multiple years, Dworshak, Kooskia, Lookingglass/Imnaha Weir, Rapid River, McCall/Knox Bridge, Pahsimeroi, and Sawtooth) has ranged from 63.5% in 1998 to 69.7% in 2000 (2005 was an exception; mean survival was 54.9% that year, and was more variable among hatcheries than in other recent years). Mean survival to Lower Granite Dam tailrace for the index hatchery release groups was 60.2% in 2008.

Estimated survival for Snake River yearling Chinook salmon (hatchery and wild combined) in 2008 was higher than the 6-year average (2002-2007) in every reach except John Day-to-Bonneville Dam, although not all mean survival estimates were higher than previous individual years (Table 2, Figures 2 and 3). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace in 2008 was 78.1% (95% CI: 75.9, 80.3%). Though this estimate is not significantly¹ different from any year in 2002-2007, it was the second highest estimate in our data series for the Lower Granite-to-McNary reach. Mean estimated survival in 2008 from McNary Dam tailrace to Bonneville Dam tailrace was 53.7% (95% CI: 44.5, 62.9%). This estimate is one of the lowest we have seen for McNary to Bonneville and is statistically significantly lower than all other years in our series except 2001 and 2004. Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to Bonneville Dam tailrace in 2008 was 41.9% (95% CI: 34.6, 49.2%). Estimated survival for the Lower Granite project (head of reservoir to tailrace) was 99.2%, based on fish PIT tagged at and released from the Snake River trap. Combining this estimate with the estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace provides an in-river survival estimate for yearling Chinook salmon traveling through the entire hydropower system (all 8 projects) in 2008 of 41.6% (95% CI: 34.2, 49.0%).

For Snake River steelhead (hatchery and wild combined), mean estimated survival in 2008 was higher than the 6-year average in every reach, although not all mean survival estimates were higher than previous individual years (Table 3, Figures 2 and 3). Mean estimated survival for steelhead from Lower Granite Dam tailrace to McNary Dam tailrace in 2008 was 71.6% (95% CI: 68.7, 74.5%). This estimate was significantly higher than those from 2001, 2002, and 2003, and higher but not significantly so than those from 2006 and 2007. Mean estimated survival in 2008 from McNary Dam tailrace to Bonneville Dam tailrace was 63.9% (95% CI: 60.6, 67.2%). The 2008 McNary-to-Bonneville estimate was significantly higher than those from 2001 and 2004, but not statistically different from other years. Mean estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 45.8% (95%

¹Significance informally assessed by examining whether confidence intervals overlap.

CI: 42.9, 48.7%). Estimated survival for the Lower Granite project (head of reservoir to tailrace) was 99.5%, based on fish PIT tagged at and released from the Snake River trap. Combining this estimate with the estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace provides an in-river survival estimate for steelhead traveling through the entire hydropower system (all 8 projects) in 2008 of 45.5% (95% CI: 42.2, 48.8%).

For PIT-tagged hatchery yearling Chinook salmon originating from the upper Columbia River in 2008, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 59.3% (95% CI: 37.3, 81.2%; see Table 4). This is the lowest point estimate we have seen for this group in the McNary to Bonneville reach (2002-2007, no estimate possible in 2005 or 2006); although great uncertainty in the estimate means that the 2008 survival estimate is not statistically different from any of the previous years. The 2008 McNary-to-Bonneville survival estimate was affected by a low estimate from John Day Dam tailrace to Bonneville Dam tailrace (49.6%). The estimated survival for John Day-to-Bonneville was the lowest seen for that reach in the group of estimates from 2002-2007, and it was significantly lower than all but the 2007 estimate.

Survival probabilities for PIT-tagged steelhead originating from the upper Columbia River in 2008 could be estimated only from point of release to McNary Dam tailrace (Table 5). Low detection probabilities in the Lower Columbia, combined with relatively small numbers of fish released, made survival estimation impossible downstream of McNary Dam. Estimated survival from release to McNary Dam tailrace was 51.9%, which was very similar to previous years. 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.

Our preliminary estimates of the proportion transported of non-tagged wild and hatchery spring-summer Chinook salmon smolts are 54.3% and 45.3%, respectively. For steelhead, the estimates are 50.5% and 46.6% for wild and hatchery smolts, respectively. These estimates represent the proportion of smolts that arrived at Lower Granite Dam that were subsequently transported, either from Lower Granite Dam or from one of the downstream collector dams. Survival estimates presented here are based on PIT-tagged fish that remained in-river. These fish either passed through turbines or spillways, or were intentionally returned to the river after detection in bypass systems. The estimates presented here are applicable only to the non-tagged smolts that remained in-river.

Discussion

Snake River flow volume was near average throughout April 2008 (Figure 4), but increased to above average for most of May, due to the late season thaw of the above average snowpack. The large influx of cold melt water also made water temperatures in April and May in the Snake River the coldest seen in the 8 most recent years (Figure 6). Compared to recent water years, the overall flow volume and seasonal pattern of flow in 2008 were most like 1998 and 2003. However, water temperatures in 2008 were colder than either of those years.

Mean spill as a percentage of flow at the Snake River Dams in 2008 was among the highest in recent years and remained high throughout the season (Figure 5). Spill percentages in 2008 were much like those in 2007 until mid-May, when a sharp increase in flow corresponded with an increase in spill. In contrast, spill percentages dropped off in May of 2007. The combination of high spill, cold water, and average flow early followed by high flow in May distinguished 2008 from other recent water years.

Within the season, estimated survival for daily groups of yearling Chinook salmon from Lower Granite Dam to McNary Dam did not vary much (Figure 7), but there was a slight decline from mid-April until the end of May. A moderate increase in flow in early May corresponded with the peak of the passage index at Lower Granite Dam. This increase in flow presumably flushed out most of the juvenile migrants, and then the remaining migrants were pushed out by the large increase in flow that occurred in the middle of May.

The estimated proportion of smolts transported in 2008 is greater than in 2007, particularly for Chinook salmon. The primary reason is that smolts migrated later in 2008 than in 2007. Transportation began at about the same time at all dams in both years, but in 2008 a smaller proportion of fish passed the dams before transport was initiated. In particular, for wild Chinook salmon in 2007, there was a very large peak of passage at Lower Granite Dam around April 20, a time when no smolts were being collected and transported. No such peak in passage occurred in 2008. Another difference between 2007 and 2008 is the larger discrepancy between the percentages for hatchery and wild fish of the same species, especially for Chinook salmon. For Chinook salmon, it appears that more wild fish were transported than their hatchery counterparts in 2008 because they were more likely to be collected (higher detection probability) on any given day. For steelhead, the cause seems to be more related to a slightly earlier migration of hatchery than of wild fish.

The most notable finding reported in this memo is the low estimated survival from McNary Dam to Bonneville Dam for Snake

River Chinook salmon. This lower-river estimate has two component estimates; a very high estimate from McNary to John Day, and a very low estimate from John Day to Bonneville. We suspect that there are two reasons for the low estimate of survival for the overall reach and for the pattern observed in the two components: (1) survival in the John Day-to-Bonneville reach truly was lower than in past years; (2) violation(s) of assumptions of the single-release recapture model occurred, resulting in overestimation of survival from McNary to John Day and underestimation from John Day to Bonneville.

First, we discuss possible explanations for lower actual survival. High flow in the Lower Columbia resulted in a large accumulation of debris at Bonneville Dam. In particular, debris on the juvenile bypass intake screens reportedly resulted in increased fish descaling and direct mortality, especially for Chinook salmon. This problem was most pronounced during the first three weeks of May. The screens were removed from all of the second powerhouse units from 23 May until 19 June. Over the same period, the proportion of flow entering the powerhouses increased. Removal of the screens and increased turbine flow would have resulted in more fish passing through turbines, a passage route usually associated with relatively higher mortality. The combination of debris-related direct and indirect mortality followed by increased passage mortality could have contributed to low estimated survival in the John Day-to-Bonneville reach for Chinook salmon of both Columbia and Snake River origin. Steelhead are more likely to pass through the spillway or corner collector, and were probably less affected than Chinook salmon.

There is anecdotal evidence that the number of gulls preying on smolts in the tailraces of both John Day Dam and The Dalles Dam were the highest seen in recent years. The new temporary spillway weirs (TSW's) at John Day Dam are suspected to have altered the hydrodynamics in the tailrace and created an upwelling in the center of the spillway downstream of the avian predation barriers. Predation by gulls was concentrated in that zone. It is also possible that the change in hydrodynamics created zones of increased predation by fish in John Day Dam tailrace. Higher predation at The Dalles Dam and in the tailrace of John Day Dam could have further reduced survival from John Day to Bonneville.

However, an increased level of mortality between John Day and Bonneville is not enough by itself to cause the pattern of high estimated survival from McNary to John Day and low estimated survival from John Day to Bonneville for Chinook salmon. The two survival estimates are statistically correlated (negatively), and truly low survival in combination with small sample sizes does make such a pattern more likely to occur by chance. However, the estimates had relatively high precision. In fact, for Chinook

salmon, the mean point estimate for McNary to John Day was actually greater than 1.0 with a standard error so small that the lower limit of a 95% confidence interval on true survival is greater than 1.0. Moreover, the pattern of a high estimate for McNary-to-John Day and a low estimate for John Day-to-Bonneville also occurred for Snake River steelhead and for yearling Chinook from the upper Columbia River.

The observed pattern is consistent with the occurrence of differential mortality downstream of John Day Dam between those fish detected at John Day Dam and those not detected (sometimes referred to as "post-detection mortality"). This would occur if fish leaving the juvenile bypass facility were more likely to pass into zones of increased predation than were non-bypassed fish. It is possible that the hydrodynamics in the tailrace of John Day caused differential post-detection mortality. If detected fish at John Day Dam incurred greater mortality immediately after detection (i.e., in the tailrace before remixing with non-detected fish, or in the bypass system itself), the result would be an underestimate of the detection probability at John Day Dam, and a resultant overestimate of the survival probability from McNary Dam to John Day Dam.

If mortality downstream of Bonneville Dam were equal for fish detected at Bonneville and those not detected then the resultant survival probability from McNary to Bonneville Dam is unbiased; only the two component estimates are biased, the first too high and the second too low. However, if mortality between Bonneville Dam and the area of the PIT trawl were also higher for fish detected at Bonneville Dam than for those not detected, then this would have further biased downward the estimated survival from John Day to Bonneville Dam, and would also have underestimated the true overall survival from McNary to Bonneville Dam. This may have happened, for example, if detected fish were more damaged (descaled) by accumulated debris at Bonneville Dam than were non-detected fish.

Unfortunately, it is not possible to use the detection-history data to statistically detect differential post-detection mortality. We can only speculate this might have occurred in 2008 based on the pattern of observed survival estimates and

anecdotal evidence regarding conditions in the lower dam tailraces. Yet-to-be completed analyses of a dam passage study at John Day dam and of bird predation data may shed light on the situation.

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Table 1. Mean 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), 2006 through 2008.

Hatchery	2006		2007		2008	
	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	0.853 (0.007)	0.560 (0.008)	0.817 (0.007)	0.662 (0.004)	0.737 (0.011)	0.534 (0.016)
Kooskia	0.716 (0.041)	0.513 (0.078)	0.654 (0.015)	0.523 (0.019)	0.624 (0.020)	0.419 (0.047)
Lookingglass (Catherine Cr.)	0.309 (0.007)	0.246 (0.017)	0.340 (0.007)	0.285 (0.009)	0.455 (0.008)	0.378 (0.028)
Lookingglass (Grande Ronde)	0.559 (0.081)	0.209 (0.043)	0.495 (0.022)	0.396 (0.024)	0.416 (0.016)	0.352 (0.050)
Lookingglass (Imnaha River)	0.639 (0.014)	0.428 (0.031)	0.682 (0.010)	0.582 (0.010)	0.694 (0.008)	0.521 (0.022)
Lookingglass (Lostine River)	0.409 (0.085)	0.272 (0.083)	0.594 (0.013)	0.482 (0.016)	0.600 (0.012)	0.480 (0.036)
McCall (Johnson Cr.)	0.326 (0.017)	0.236 (0.023)	0.319 (0.024)	0.260 (0.014)	0.329 (0.030)	0.315 (0.052)
McCall (Knox Bridge)	0.634 (0.006)	0.502 (0.014)	0.554 (0.007)	0.474 (0.006)	0.578 (0.007)	0.408 (0.013)
Rapid River	0.764 (0.004)	0.586 (0.008)	0.748 (0.004)	0.616 (0.005)	0.801 (0.004)	0.594 (0.012)
Entiat	---	0.520 (0.031)	---	0.321 (0.035)	---	---
Winthrop	---	0.423 (0.029)	---	0.492 (0.022)	---	0.574 (0.074)
Leavenworth	---	0.554 (0.014)	---	0.594 (0.011)	---	0.567 (0.022)

Table 2. Mean estimated survival and standard error (s.e.) through various reaches of the Snake and Columbia River hydropower system for yearling Chinook salmon originating in the Snake River, 2002 through 2008. Hatchery and wild fish combined.

Reach	Mean							2008
	2002	2003	2004	2005	2006	2007	2002-07	
Snake Trap-LGR	0.953 (0.022)	0.993 (0.023)	0.893 (0.009)	0.919 (0.015)	0.952 (0.011)	0.943 (0.028)	0.942 (0.014)	0.992 (0.018)
LGR-LGO	0.949 (0.006)	0.946 (0.005)	0.923 (0.004)	0.919 (0.003)	0.923 (0.003)	0.938 (0.006)	0.933 (0.005)	0.939 (0.006)
LGO-LMO	0.980 (0.008)	0.916 (0.011)	0.875 (0.012)	0.886 (0.006)	0.934 (0.004)	0.957 (0.010)	0.925 (0.017)	0.948 (0.011)
LMO-MCN	0.837 (0.013)	0.905 (0.017)	0.818 (0.018)	0.903 (0.010)	0.887 (0.008)	0.876 (0.012)	0.871 (0.015)	0.878 (0.016)
MCN-JD	0.907 (0.014)	0.893 (0.017)	0.809 (0.028)	0.771 (0.021)	0.881 (0.020)	0.920 (0.016)	0.864 (0.024)	1.076 (0.022)
JD-BON	0.840 (0.079)	0.818 (0.036)	0.735 (0.092)	1.028 (0.132)	0.944 (0.030)	0.824 (0.043)	0.865 (0.043)	0.501 (0.052)
LGR-MCN	0.757 (0.009)	0.731 (0.010)	0.666 (0.011)	0.732 (0.009)	0.764 (0.007)	0.783 (0.006)	0.739 (0.017)	0.781 (0.011)
MCN-BON	0.763 (0.079)	0.728 (0.030)	0.594 (0.074)	0.788 (0.092)	0.842 (0.021)	0.763 (0.044)	0.746 (0.034)	0.537 (0.047)
LGR-BON	0.578 (0.060)	0.532 (0.023)	0.395 (0.050)	0.577 (0.069)	0.643 (0.017)	0.597 (0.035)	0.554 (0.035)	0.419 (0.037)
Snake Trap-BON	0.551 (0.059)	0.528 (0.026)	0.353 (0.045)	0.530 (0.063)	0.612 (0.016)	0.563 (0.037)	0.523 (0.036)	0.416 (0.038)

Table 3. Mean estimated survival and standard error (s.e.) through various reaches of the Snake and Columbia River hydropower system steelhead originating in the Snake River, 2002 through 2008. Hatchery and wild fish combined.

Reach	Mean							2008
	2002	2003	2004	2005	2006	2007	2002-07	
Snake Trap-LGR	0.895 (0.015)	0.932 (0.015)	0.948 (0.004)	0.967 (0.004)	0.920 (0.013)	1.016 (0.026)	0.946 (0.017)	0.995 (0.018)
LGR-LGO	0.882 (0.011)	0.947 (0.005)	0.860 (0.006)	0.939 (0.004)	0.956 (0.004)	0.887 (0.009)	0.912 (0.017)	0.935 (0.007)
LGO-LMO	0.882 (0.018)	0.898 (0.012)	0.820 (0.014)	0.867 (0.009)	0.911 (0.006)	0.911 (0.022)	0.882 (0.014)	0.962 (0.014)
LMO-MCN	0.652 (0.031)	0.708 (0.018)	0.519 (0.035)	0.722 (0.023)	0.808 (0.017)	0.852 (0.030)	0.710 (0.048)	0.776 (0.017)
MCN-JD	0.844 (0.063)	0.879 (0.032)	0.465 (0.078)	0.595 (0.040)	0.795 (0.045)	0.988 (0.098)	0.761 (0.079)	0.954 (0.059)
JD-BON	0.612 (0.098)	0.630 (0.066)	-----	-----	0.813 (0.083)	0.579 (0.059)	0.658 (0.053)	0.694 (0.022)
LGR-MCN	0.536 (0.025)	0.597 (0.013)	0.379 (0.023)	0.593 (0.018)	0.702 (0.016)	0.694 (0.020)	0.583 (0.048)	0.716 (0.015)
MCN-BON	0.488 (0.090)	0.518 (0.015)	-----	-----	0.648 (0.079)	0.524 (0.064)	0.544 (0.035)	0.639 (0.017)
LGR-BON	0.262 (0.050)	0.309 (0.011)	-----	-----	0.455 (0.056)	0.364 (0.045)	0.347 (0.041)	0.458 (0.015)
Snake Trap-BON	0.234 (0.045)	0.288 (0.012)	-----	-----	0.418 (0.052)	0.369 (0.047)	0.327 (0.041)	0.455 (0.017)

Table 4. Mean estimated survival and standard error (s.e.) through reaches of the lower Columbia River hydropower system for yearling Chinook salmon originating in the upper Columbia River, 2004 through 2008. All estimates are for hatchery fish only.

Reach	2004	2005	2006	2007	2008
Release-MCN	0.505 (0.018) ^a	0.546 (0.048) ^b	0.499 (0.039) ^b	0.512 (0.050) ^b	0.503 (0.015) ^c
MCN-JD	0.741 (0.038)	0.801 (0.056)	0.861 (0.060)	0.919 (0.049)	1.200 (0.080) ^c
JD-BON	0.840 (0.111)	NA	NA	0.780 (0.166)	0.496 (0.097) ^c
MCN-BON	0.622 (0.063)	NA	NA	0.709 (0.157)	0.593 (0.112) ^c

- a. mean of estimates for fish released from Entiat, Winthrop, and Leavenworth hatcheries, and fish from Methow hatchery released in Twisp and Chewuch acclimation ponds.
- b. mean of estimates for fish released from Entiat, Winthrop, and Leavenworth hatcheries.
- c. pooled estimates for fish released from East Bank, Leavenworth, Wells, and Winthrop hatcheries.

Table 5. Mean estimated survival and standard error (s.e.) through reaches of the lower Columbia River hydropower system for steelhead originating in the upper Columbia River, 2004 through 2008. All estimates are for hatchery fish only.

Reach	2004	2005	2006	2007	2008
Release-MCN	0.383 (0.018) ^a	0.449 (0.080) ^a	0.497 (0.057) ^b	0.467 (0.058) ^c	0.519 (0.017) ^d
MCN-JD	0.786 (0.059)	0.749 (0.047)	0.826 (0.092)	0.799 (0.038)	NA
JD-BON	0.623 (0.168)	0.755 (0.167)	NA	0.459 (0.019)	NA
MCN-BON	0.496 (0.124)	0.533 (0.119)	NA	0.392 (0.059)	NA

- a. mean of estimates for fish from Chelan, East Bank, Ringold, Wells, and Winthrop hatcheries released at various locations.
- b. mean of estimates for fish from Turtle Rock hatchery released in Chiwawa and Wenatchee rivers and in Nason Creek.
- c. mean of estimates for fish from Chelan and East Bank hatcheries released in the Wenatchee River and fish from Turtle Rock hatchery released in Chiwawa and Wenatchee rivers and in Nason Creek.
- d. pooled estimates for fish from Winthrop hatchery, East Bank hatchery released in the Wenatchee River, and fish from Turtle Rock hatchery released in Chiwawa and Wenatchee rivers and in Nason Creek.

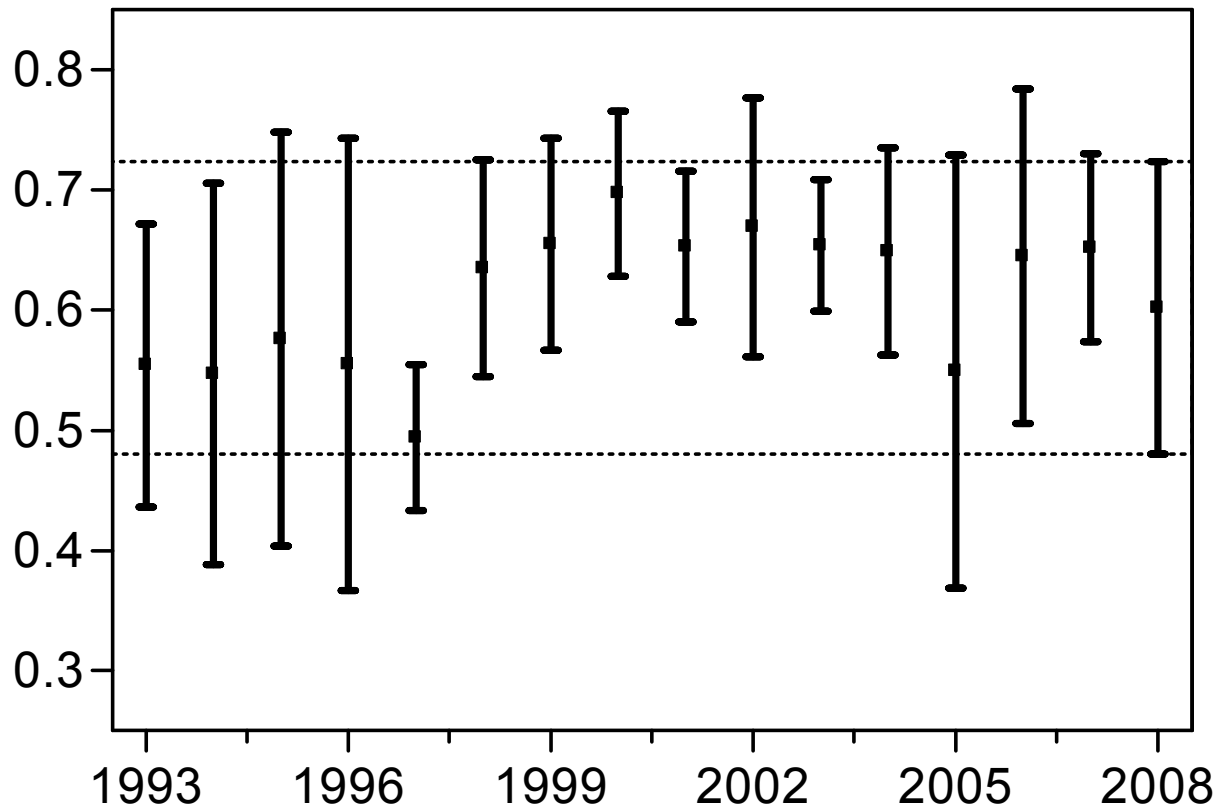


Figure 1. Annual average survival estimates for PIT-tagged yearling Chinook salmon released from Snake River Basin hatcheries, 1993-2008. Hatcheries used for average (index groups) are those with PIT-tag releases through a long series of years. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are the 2008 confidence interval endpoints and are shown for comparison to other years.

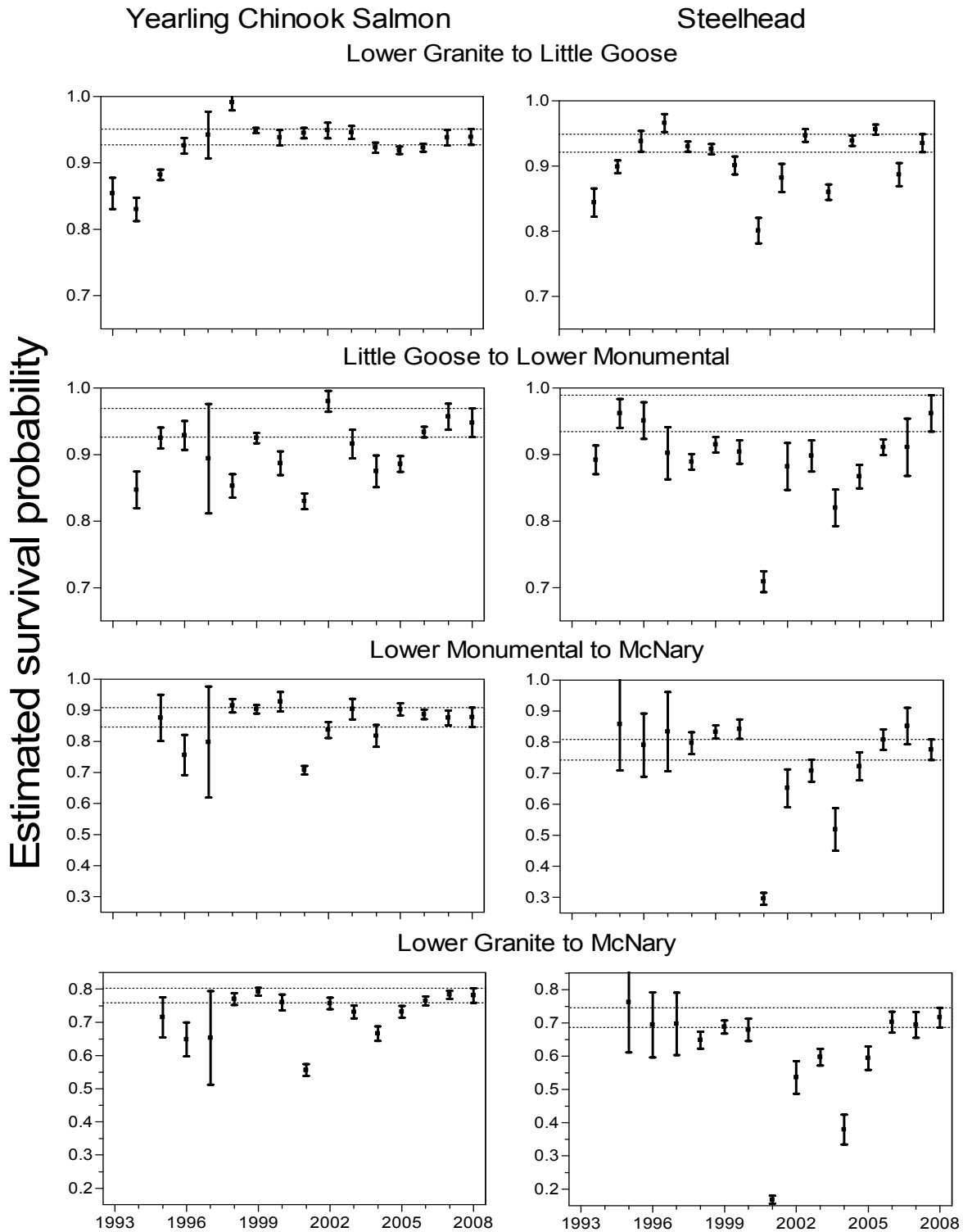


Figure 2. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2008 estimates.

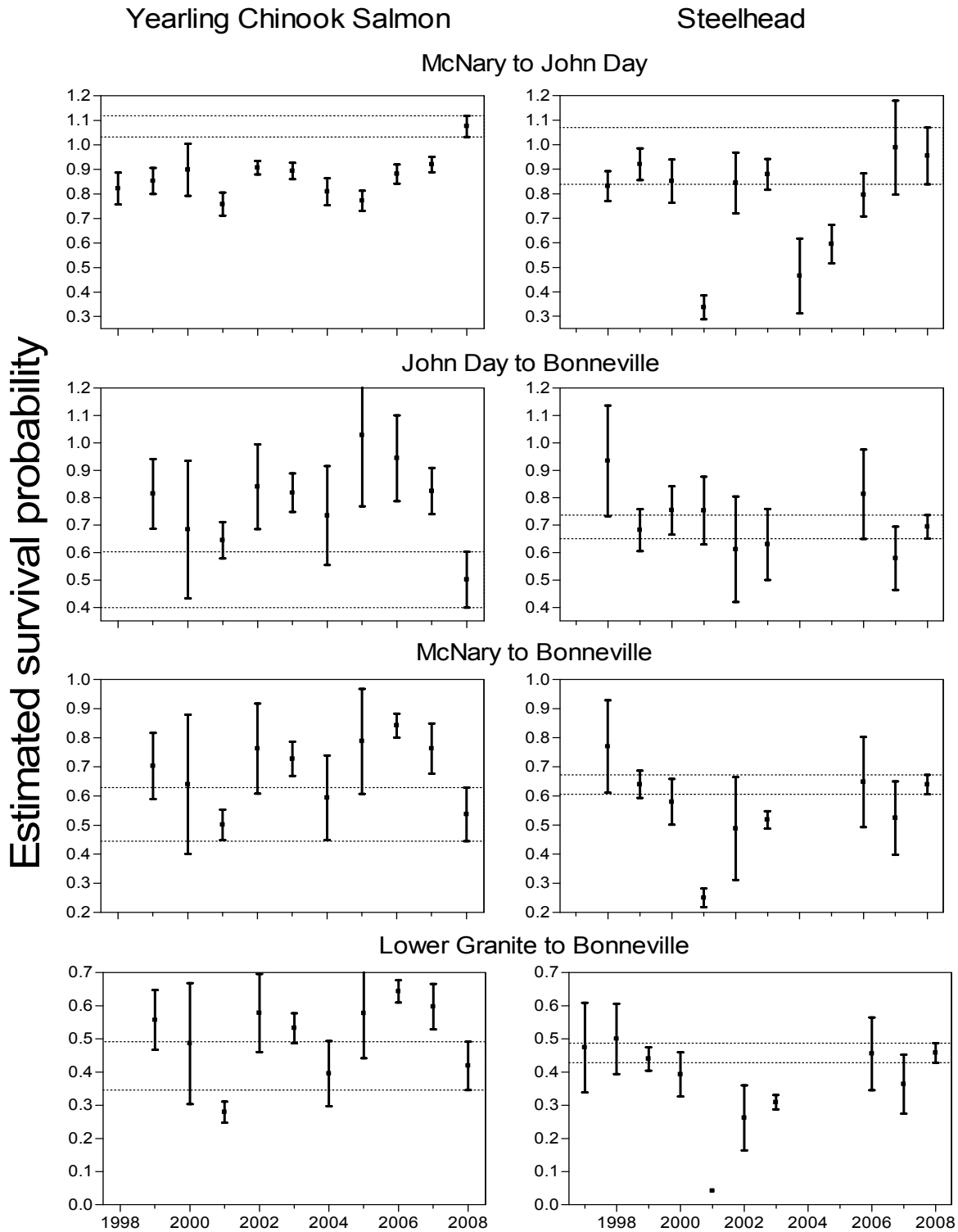


Figure 3. Annual average survival estimates for PIT-tagged yearling Chinook salmon and steelhead, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2008 estimates.

Little Goose Dam

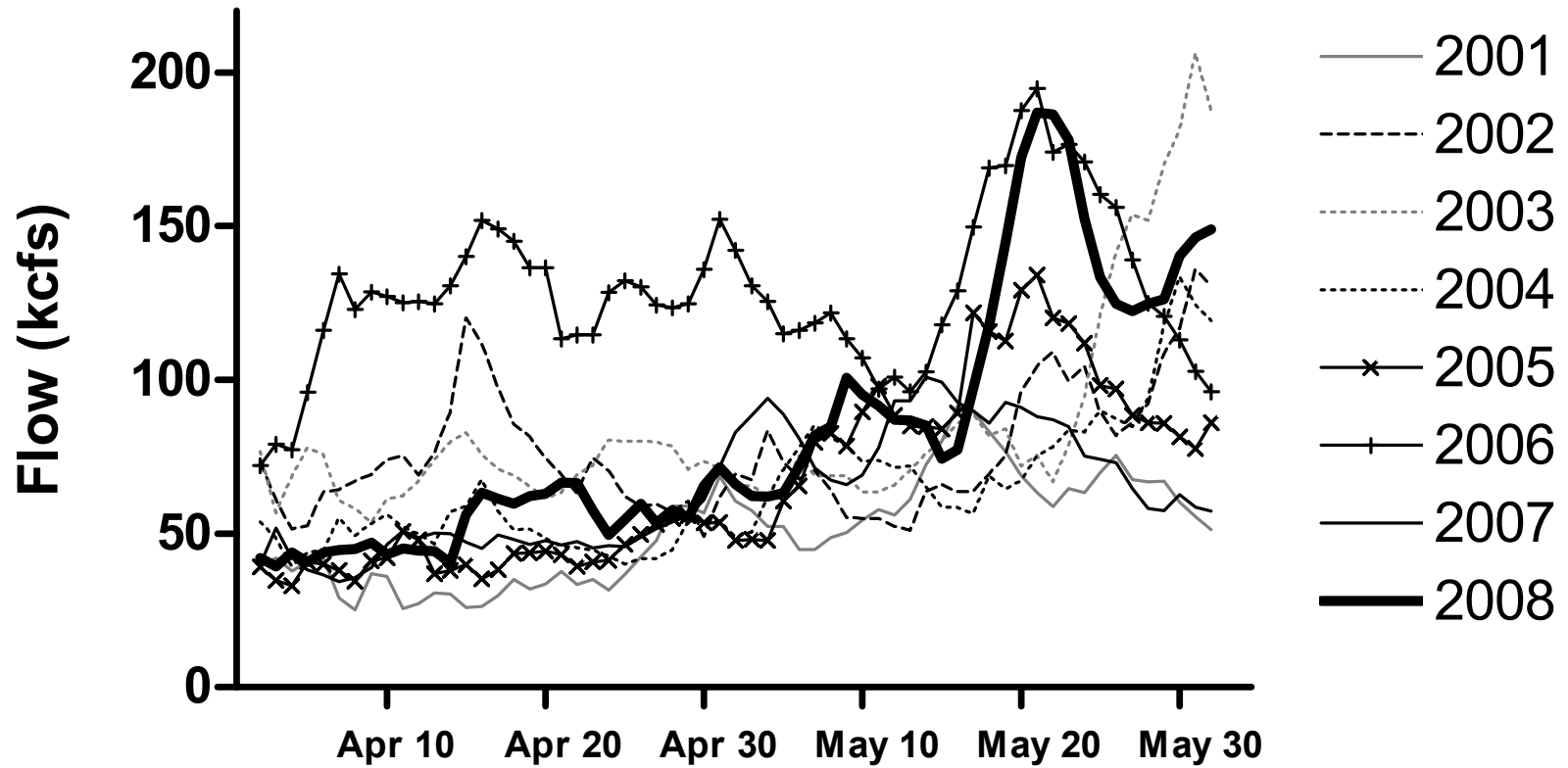


Figure 4. Snake River flow (kcfs) measured at Little Goose Dam during April and May, 2001-2008.

Mean at LGR, LGO, LMN

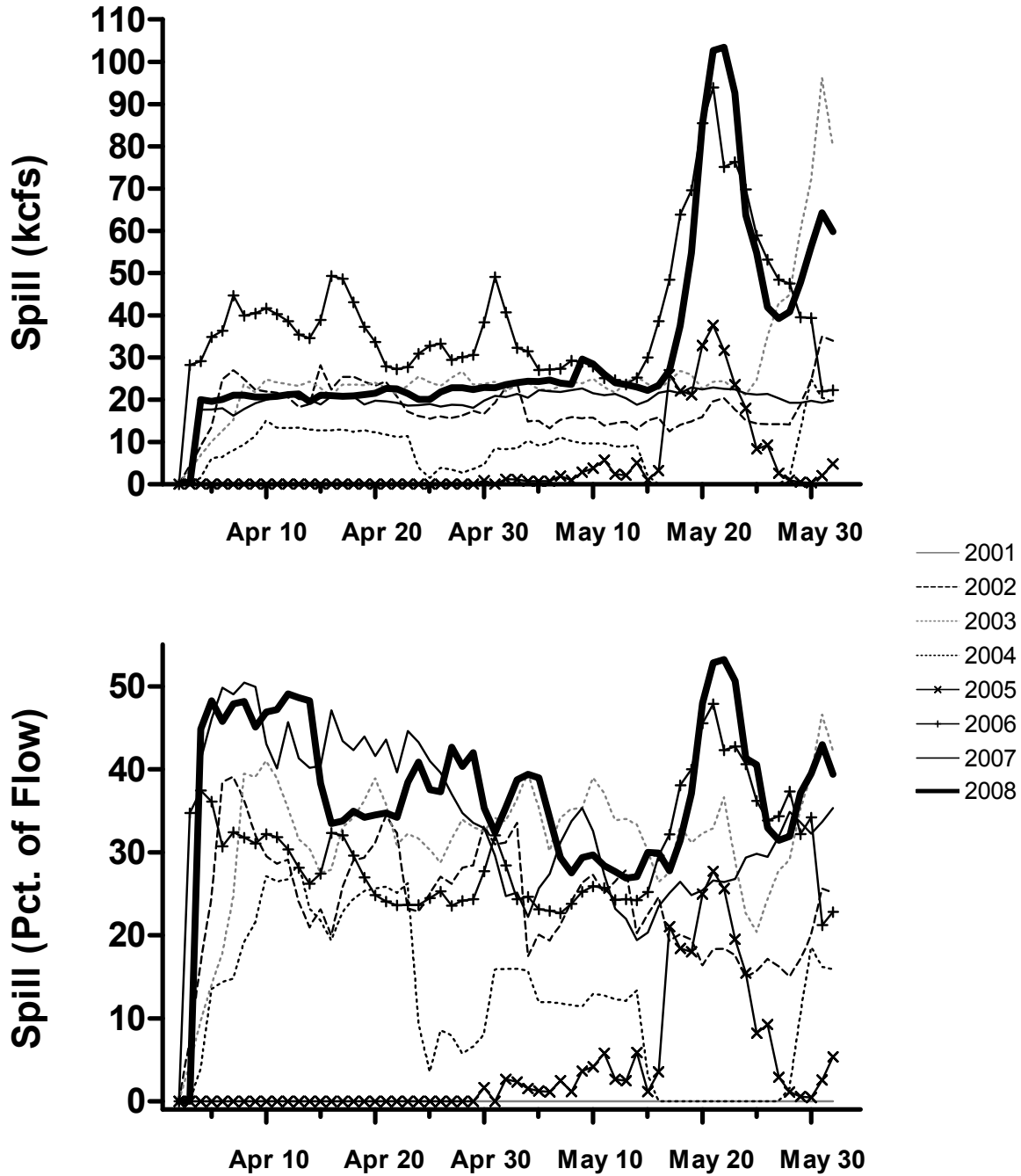


Figure 5. Mean spill (top=kcfs; bottom=percentage of total flow) at Snake River dams during April and May, 2001-2008.

Little Goose Dam

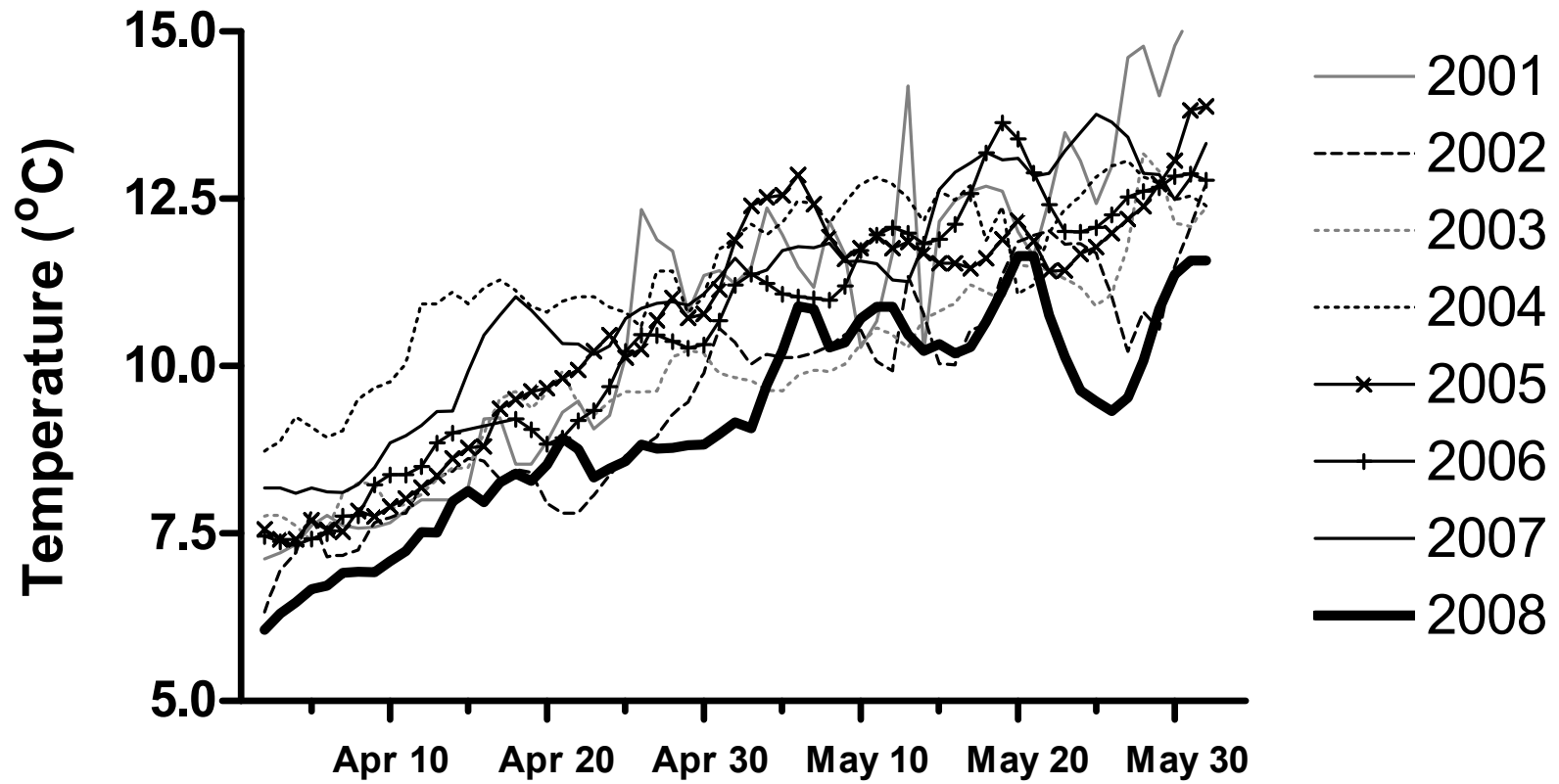


Figure 6. Snake River water temperature ($^{\circ}\text{C}$) measured at Little Goose Dam during April and May, 2001-2008.

Survival, Flow, Passage Index Yearling Chinook 2008

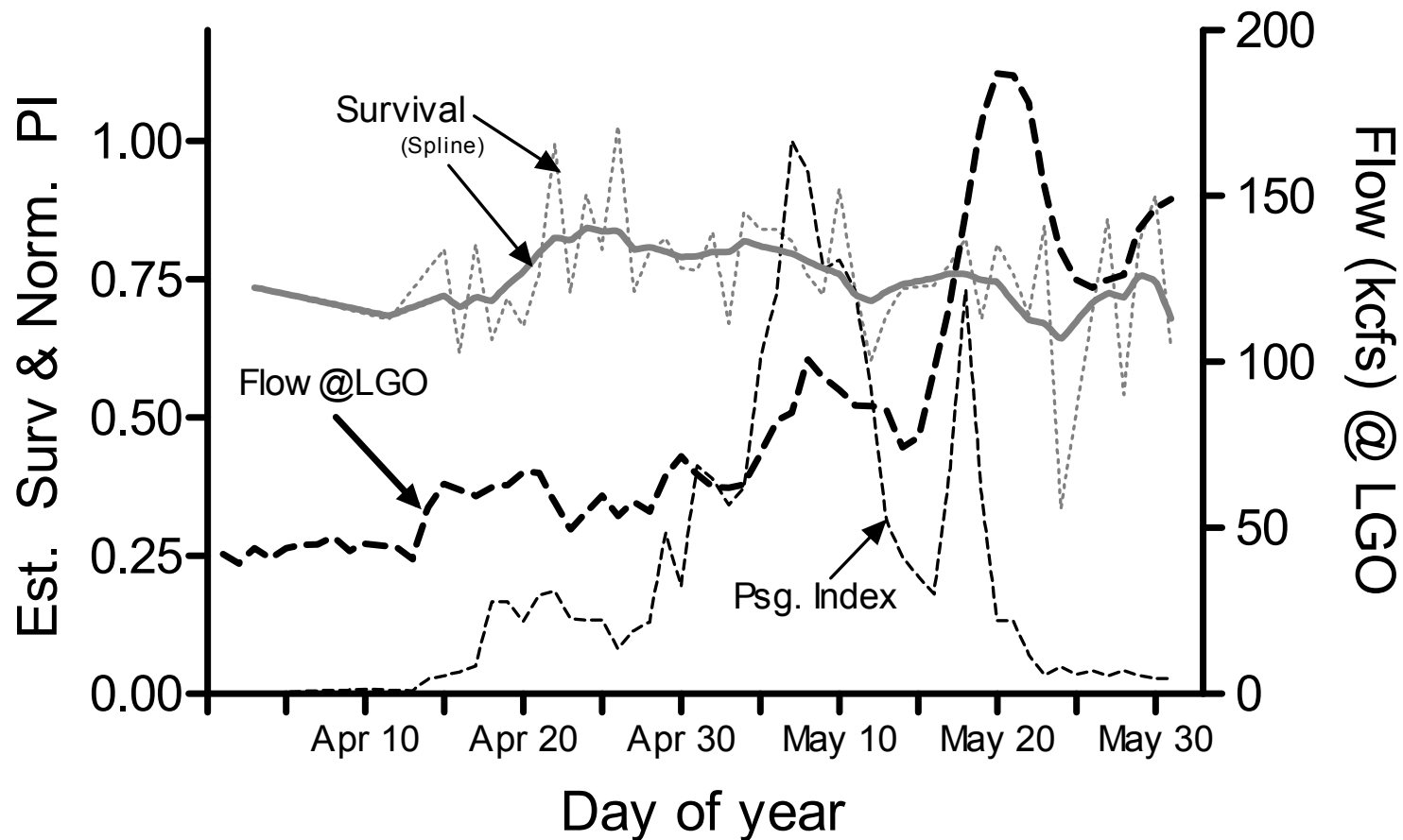


Figure 7. Estimated survival probability for yearling Chinook salmon from Lower Granite Dam to McNary Dam, flow volume at Little Goose Dam, and passage index at Lower Granite Dam (normalized: peak day = 1.0) by day of year, 2008. A curve showing a spline smooth of estimated survival is included.