



# FISH PASSAGE CENTER

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## MEMORANDUM

TO: Bert Bowler, Snake River Salmon Solutions

*Michele DeHart*

FROM: Michele DeHart, FPC

DATE: November 2, 2017

RE: Snake River Steelhead Survival (to McNary Dam) 2017

In response to your request the Fish Passage Center (FPC) staff estimated adult success of Snake River steelhead in the reach from Bonneville Dam to McNary Dam in 2017 and compared that to other recent years. Our overall conclusion is that the run was late and delayed in the lower river, but survival was at or above average compared to other recent years.

- The estimated Snake River adult steelhead survival from Bonneville to McNary Dam was higher at 0.795 compared to the estimated average of 0.765 for the years 2008 to 2016.
- In 2017, steelhead adults that were transported as juveniles and that migrated in river had similar estimated survival rates (0.791 for transported and 0.796 for in-river migrants).
- Survival estimates for 2017 did not account for straying/hold-over fish. The hold-over rates for the previous years ranged from 0.011 to 0.053, with a mean of 0.018.
- Results suggested an overall delay in adult steelhead arrival at the Bonneville Dam compared to the previous years. Similar patterns of delay were also observed upstream at the McNary Dam.
- There was an increasing potential for returning steelhead to encounter warm water temperature since 2013. In 2017, we observed in our sample 99.8% of returning steelhead adults encountering warm water at the Bonneville Dam forebay, compared to an average of 96.7% in the previous years.

## Background

In this section, we are providing an assessment of 2017 steelhead survival rate (to McNary Dam) in comparison to the survival rates in the past decade. We also compare the adult survival rates between steelhead with different juvenile migration histories (transported vs. in-river) for 2017, hold-over rates (steelhead that enter freshwater during spring and summer, but do not return to their natal origins to spawn until as late as winter during the subsequent calendar year), arrival timing, and water temperature that steelhead adults encountered at the Bonneville Dam when they arrived for the 2017 migration season. In particular, we inspect the portion of steelhead adult that are exposed to temperature equal or greater than 18°C, a criterion based on a previous analysis (FPC, 2016).

## Methods

For this summary, we included Snake River steelhead A-run that were PIT-tagged for the Comparative Survival Study (CSS) and detected at Bonneville Dam as adults during return years 2007 to 2017. For each fish in the data set, we included its detection history at Bonneville, McNary, Ice Harbor, and Lower Granite Dam. At the time of our analysis, we were able to obtain detection up to October 29th, 2017. To be consistent in our survival estimates among years, we only included adult steelhead that arrived Bonneville Dam before October 1st and with detection history up to October 29th for all years in our data set. We employed a Cormack-Jolly-Seber (CJS) model (Lebreton et al., 1992) to estimate the survival rates to McNary Dam for each return year and each juvenile migration history (2017 only), and a bootstrap procedure with 1,000 iterations to estimate the standard errors (SE) and 90% confidence intervals (CI's).

A permutation test (Efron & Hastie 2016) was conducted to test for a difference in the steelhead survival rates between year 2017 and the average from the previous years. Return years were randomly re-assigned to each fish, and difference in the survivals between 2017 and the previous years was calculated. The process was repeated to yield a permutation distribution of 5,000 simulated differences in survival rates.

Because the null hypothesis indicated no difference in the survival rates between steelhead returned in 2017 and in the previous years, the assumption was that the return years were exchangeable between individual steelhead. That is, one can randomly shuffle return years among all fish and simulate a scenario that assumed no difference in the steelhead survivals. By repeating the permutation process, we create an approximate distribution under the null hypothesis. With this model, we may ask whether the observed difference was a likely outcome if no difference was assumed. A *p*-value quantified how extreme the observed result was by calculating the portion of the simulated results that were as far or farther from zero than the observed value.

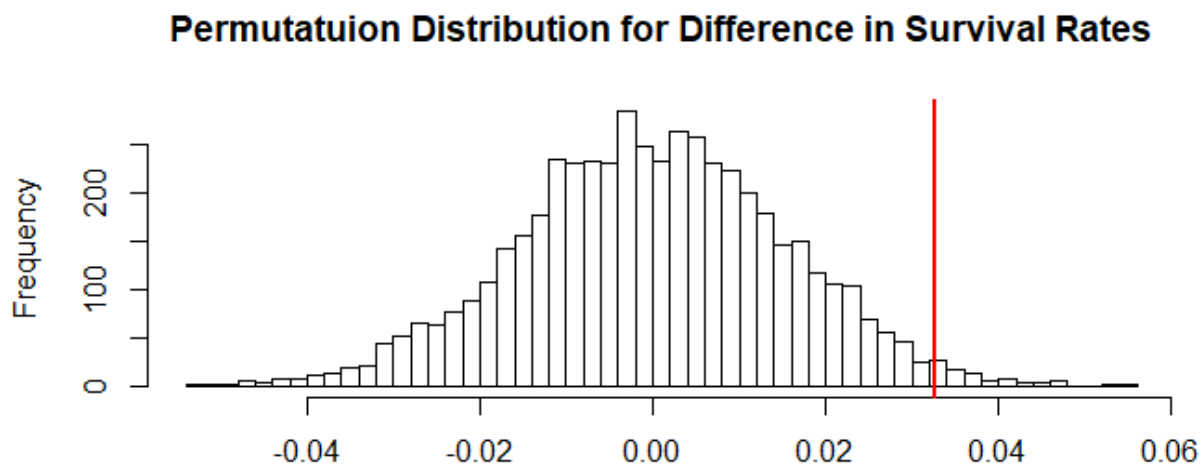
For each year, we summarized the arrival timing and water temperature encountered by the returning adult steelhead and calculated the area under the temperature curve that was greater than 18°C. The area under the temperature curve served as an index for potential exposure to warm water, with larger the area indicating a higher risk. Because 2017 had an earlier cutoff date for temperature collection (at Bonneville Dam forebay), we only calculated the areas up to September 22nd for all years included.

## Results

There were total of 16,925 fish in the data set; however, our analysis excluded year 2007 (Table 1) because there were only three fish from that year. The estimated survival rate to McNary for 2017 CSS steelhead A-run was 0.795 (SE= 0.014, 90% CI= 0.772 to 0.818), the estimated mean survival rate to McNary for 2008 to 2016 was 0.765 (SE= 0.003, 90% CI= 0.76 to 0.771), and the estimated difference was 0.03 (SE= 0.014, 90% CI= 0.007 to 0.054). Because there were only 70 out of 5,000 in the simulated distribution that were equal or greater than the observed value, a 0.03 difference in the survivals was unlikely under the null hypothesis ( $p= 0.014$ ; Figure 1). We also calculated the survival rates without the September/October cutoffs, and the summary was included in the Appendix.

**Table 1: CJS estimates of the survival rate to McNary Dam for the CSS PIT-tagged A-run steelhead by return year.**

	Survival (90% CI)	SE
<b>2008</b>	0.811 (0.75, 0.864)	0.034
<b>2009</b>	0.78 (0.768, 0.791)	0.007
<b>2010</b>	0.777 (0.763, 0.79)	0.008
<b>2011</b>	0.794 (0.781, 0.807)	0.008
<b>2012</b>	0.772 (0.755, 0.791)	0.011
<b>2013</b>	0.736 (0.718, 0.753)	0.011
<b>2014</b>	0.748 (0.731, 0.764)	0.009
<b>2015</b>	0.757 (0.74, 0.775)	0.011
<b>2016</b>	0.687 (0.659, 0.713)	0.016
<b>2017</b>	0.795 (0.772, 0.818)	0.014



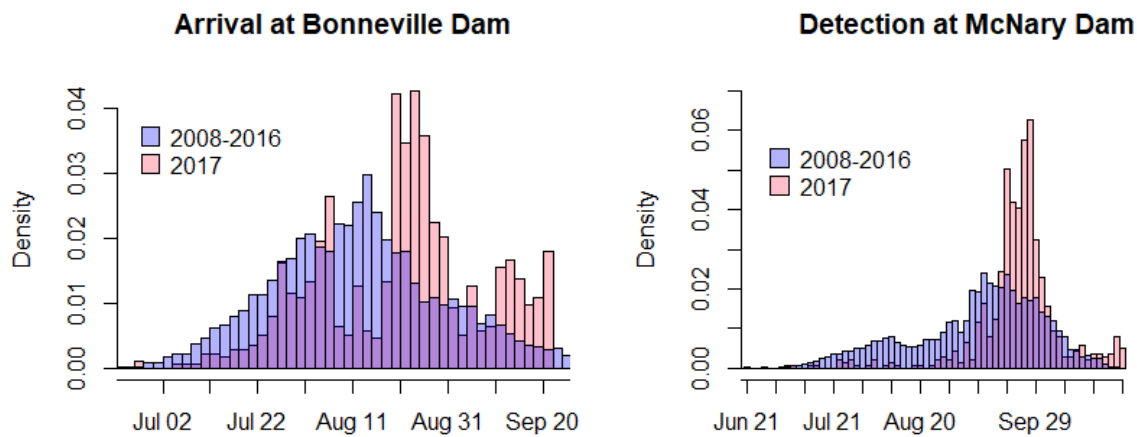
**Figure 1: Histogram of permutation distribution under the null hypothesis consists 5,000**

**simulated differences. The test compares the adult steelhead survivals between year 2017 and the average of previous years (2008 to 2016). The red line indicates the observed difference from our sample.**

The estimated survival rate for 2017 steelhead that were transported as juveniles was 0.791 (SE= 0.029, 90% CI= 0.743 to 0.838), and the estimated survival rate for the fish that migrated in-river as juveniles was 0.796 (SE= 0.016, 90% CI= 0.772 to 0.822).

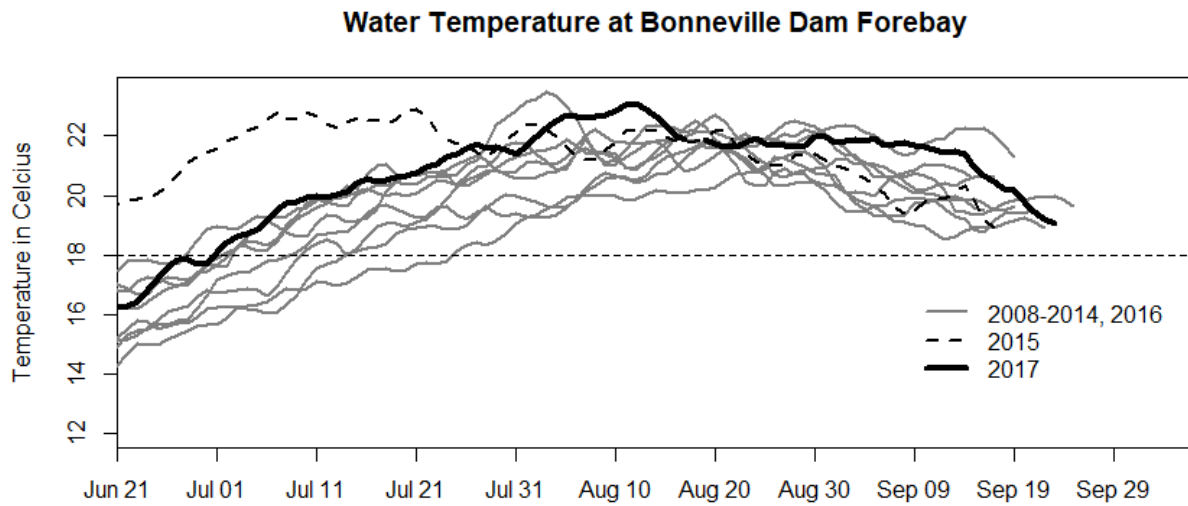
The hold-over rates for 2008 to 2016 in our data set ranged from 0.011 to 0.053, with a mean of 0.018. Since we did not know the hold-over rate for the current year, the steelhead survival rate for 2017 could be underestimated.

Results showed an overall delay in adult steelhead arrival at the Bonneville Dam compared to the previous years. Figure 2 showed that the days we observed the highest steelhead counts at Bonneville were around mid August for years 2008 to 2016. In 2017, the majority of adult steelhead arrived in late August and early September. Similar patterns of delay were also observed at the McNary Dam (Figure 2).

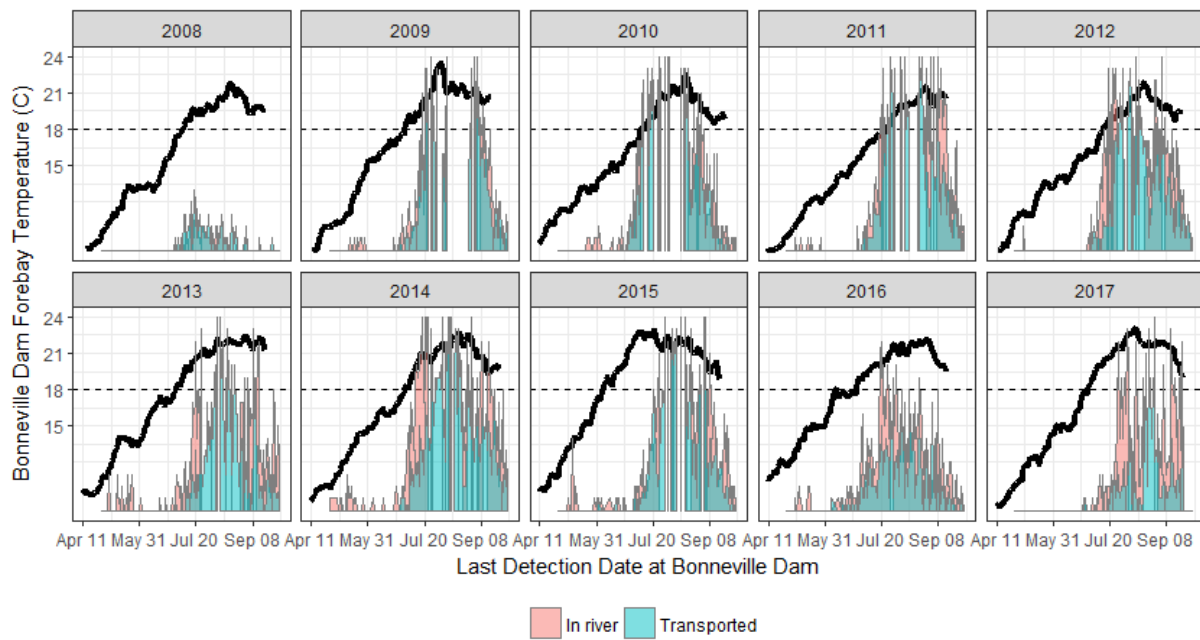


**Figure 2: The left histogram shows the distribution of adult steelhead arrival at the Bonneville Dam, and the right shows the distribution of adult steelhead arrival at the McNary Dam.**

In 2017, water temperature during July through September at the Bonneville Dam forebay seemed to be higher than the previous years, but we did not see patterns of early onset of warm water in 2017 (Figure 3). Still, with an overall delayed arrival, we observed 99.8% of adult steelhead encountered water temperature greater than 18°C at the Bonneville Dam in 2017, compared to 96.7% in the previous years. We also observed an increase in potential exposure to warm water since 2013 (Figure 4; Table 2).



**Figure 3:** Plot shows the water temperature at the Bonneville Dam forebay during months of July through September for years 2008 to 2017. 2015 (shown in dash line) has an early onset of warm water temperature.



**Figure 4:** Black lines indicate the forebay temperature corresponding to the adult steelhead arrival dates at Bonneville Dam. Below the temperature lines are the distributions of arrival dates for in river and transported fish.

**Table 2:** Table shows the area under the temperature curve (AUTC) that is greater than 18°C and the portions of steelhead adults that encountered water temperature greater than

**18°C, for return years 2008 to 2017. The AUTC served as an index for potential exposure to warm water, with larger the area indicating a higher potential.**

	AUTC	Encounter
<b>2008</b>	138.2	0.9618
<b>2009</b>	213.6	0.9959
<b>2010</b>	151.5	0.9291
<b>2011</b>	112.3	0.9237
<b>2012</b>	128.8	0.9712
<b>2013</b>	249.6	0.9864
<b>2014</b>	230.3	0.9837
<b>2015</b>	312.9	0.991
<b>2016</b>	214.5	0.959
<b>2017</b>	265.4	0.9977

## **Reference**

Efron, B. and T. Hastie. 2016. *Computer Age Statistical Inference: Algorithms, Evidence, and Data Science*. Cambridge University Press.

Fish Passage Center. 2016. The effect of water temperature on steelhead upstream passage [Memorandum]. Portland, Oregon: Fish Passage Center.  
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## Appendix

**Table 3: CJS estimates of the survival rate to McNary Dam for the CSS PIT-tagged A-run steelhead by return year (without the September/October cutoffs).**

	Survival (90% CI)	SE
<b>2008</b>	0.825 (0.776, 0.874)	0.031
<b>2009</b>	0.791 (0.779, 0.803)	0.007
<b>2010</b>	0.789 (0.775, 0.802)	0.008
<b>2011</b>	0.802 (0.79, 0.814)	0.007
<b>2012</b>	0.794 (0.775, 0.81)	0.01
<b>2013</b>	0.748 (0.73, 0.765)	0.01
<b>2014</b>	0.77 (0.754, 0.784)	0.009
<b>2015</b>	0.773 (0.757, 0.789)	0.009
<b>2016</b>	0.699 (0.673, 0.725)	0.016
<b>2017</b>	0.796 (0.774, 0.819)	0.014