



FISH PASSAGE CENTER

847 NE 19th Avenue, #250, Portland, OR 97232

Phone: (503) 833-3900 Fax: (503) 232-1259

www.fpc.org

e-mail us at fpcestaff@fpc.org

MEMORANDUM

TO: Lance Hebdon, Idaho Fish and Game

Michele DeHart

FROM: Michele DeHart, FPC

DATE: December 27, 2017

SUBJECT: 2017 Snake River B-run Steelhead Survival (Bonneville to McNary Dam)

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

- The estimated survival from Bonneville to McNary Dam was 0.83 in 2017, and the estimated weighted mean survival for year 2008 to 2016 was 0.804 for Snake River B-run adult steelhead.
- In 2017, the estimated survival for one year ocean age was 0.885, and for two years plus ocean age was 0.768.
- For B-run steelhead adults returning in 2017, the estimated Bonneville-to-McNary survival was 0.778 for those that were transported as juveniles, and was 0.838 for those that migrated in-river.
- For all B-run steelhead in our data set, the estimated Bonneville-to-McNary survival (2008 to 2017) was 0.748 for those that were transported and 0.827 for those that were not transported.
- Survival estimates for 2017 were not adjusted for adults that strayed or are overwintering below McNary Dam, and thus may increase after their fish complete their migration

in winter to spring 2018. The hold-over rates for the previous years ranged from 0.021 to 0.143, with a mean of 0.043.

- Results showed a slightly delayed but overall similar arrival timing at Bonneville Dam in 2017 compared to the previous years.
- The overall pattern of water temperature in 2017 did not seem to be unusual in October to December, but we observed a lower portion of adult B-run steelhead (79.3%) encountering water temperature greater than 18°C at Bonneville Dam in 2017, compared to the previous years (91.3%).

Background

This summary is the second part of an assessment of 2017 adult steelhead survival (Bonneville to McNary Dam) in comparison to the survivals in the past decade (FPC, 2017). Specifically, this is in response to a request to investigate adult survival of Snake River B-run steelhead. We follow the previous analytic procedures and compare the 2017 adult survivals between B-run steelhead with different juvenile migration histories (transported vs. in-river), hold-over rates, arrival timing, and water temperature that steelhead adults might encounter at Bonneville Dam to those over the previous nine years (2008 to 2016). In particular, we inspect the portion of steelhead adult that were 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 B-run that were PIT-tagged as juveniles for the Comparative Survival Study (CSS) and detected at Bonneville Dam as adults during return years 2008 to 2017. For each fish in the data set, we included its adult detection history at Bonneville, McNary, Ice Harbor, and Lower Granite Dam. At the time of our analysis, we were able to obtain detection through December 13th, 2017. To be consistent in our survival estimates among years, we only included adult steelhead that arrived Bonneville Dam before November 15th and followed upstream detection through December 13th for all years in our data set. We employed a Cormack-Jolly-Seber (CJS) model (Lebreton et al., 1992) to estimate the survivals to McNary Dam for each return year, ocean age (one year and two years plus), and juvenile migration history (transported or in-river). We used a nonparametric bootstrap procedure with 1,000 iterations to estimate the standard errors (SE) and 90% confidence intervals (CI).

A permutation test (Efron & Hastie 2016) was conducted to test for a difference in the steelhead survivals between 2017 and the weighted mean¹ 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

¹All data from 2008 to 2016 were used for a single survival estimate. This survival estimate was essentially the weighted mean because years with more fish would carry more weight in the estimate.

distribution of 5,000 simulated differences in survivals. 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. More details and background regarding the permutation test can be found in Appendix A.

Similar to previous analyses of A-run steelhead adults, upstream migration success of B-run steelhead that were transported as juveniles was compared to those that migrated in-river. Also using a permutation test, we tested for a difference in survivals between B-run steelhead adults that were transported as juveniles and those that migrated in-river. Due to a small sample size, in addition to comparison for 2017, we expanded to include all years in the data set for the comparison of adult upstream migration success between transported and non-transported juvenile migration histories.

We plotted and summarized the arrival distribution of the B-run steelhead at Bonneville and McNary Dams. 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 $18^{\circ}C$. The area under the temperature curve served as an index for potential exposure to warm water, with a larger area indicating a higher risk. Because temperature monitoring at the Bonneville Dam forebay typically stops in early to mid-September every year, we substituted the temperature information using data collected at The Dalles Dam tailrace monitor.

Results

There were total of 5,393 B-run CSS tagged steelhead adults from year 2008 to 2017 in our data set. Of these 5,393 steelhead, 212 were from 2017 (Table 1). The estimated survival to McNary for 2017 CSS B-run steelhead was 0.83 (SE= 0.025, 90% CI= 0.788 to 0.873), the estimated weighted mean survival to McNary for years 2008 to 2016 was 0.804 (SE= 0.005, 90% CI= 0.795 to 0.813), and the estimated difference was 0.026 (SE= 0.025, 90% CI= -0.015 to 0.068). We only had seven fish from 2008, so for that year the estimate had a large SE and was deemed unreliable (Table 2).

Table 1: **Summary of B-run steelhead counts by ocean age and by migration year.**

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Age 1	6	178	58	129	45	94	70	135	0	113
Age 2	1	62	849	831	619	302	534	338	706	87
Age 3	0	1	105	44	18	10	12	16	12	12
Age 4	0	0	0	3	2	1	0	0	0	0
Total	7	241	1012	1007	684	407	616	489	718	212

Table 2: CJS estimates of the survival to McNary Dam for the CSS PIT-tagged B-run steelhead by return year.

	Survival (90% CI)	SE
2008	0.714 (0.429, 1)	0.173
2009	0.84 (0.801, 0.877)	0.023
2010	0.785 (0.762, 0.806)	0.013
2011	0.779 (0.759, 0.8)	0.012
2012	0.774 (0.748, 0.799)	0.016
2013	0.775 (0.743, 0.807)	0.02
2014	0.835 (0.811, 0.861)	0.015
2015	0.867 (0.843, 0.89)	0.015
2016	0.829 (0.804, 0.852)	0.014
2017	0.83 (0.788, 0.873)	0.025

There were 866 out of 5,000 in the simulated distribution that were equal or greater than the observed value in our permutation test, which suggested that survivals in 2017 were similar to previous years ($p= 0.173$; Figure 1). We also calculated the survivals without the November/December cutoffs, and the summary was included in Appendix B (Table 5).

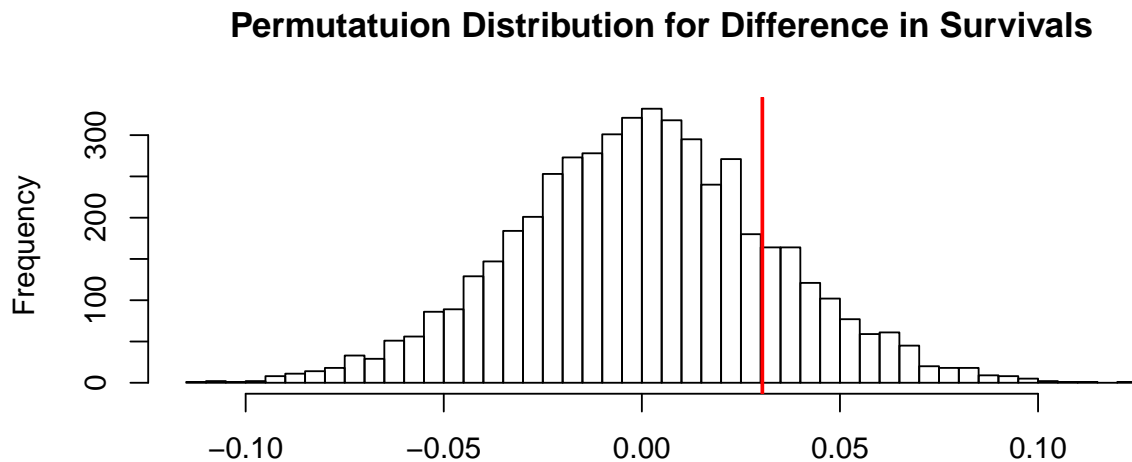


Figure 1: Histogram of permutation distribution under the null hypothesis consists 5,000 simulated differences. The test compares the adult B-run steelhead survivals between year 2017 and the weighted mean of previous years (2008 to 2016). The red line indicates the observed difference from our sample.

We estimated the 2017 survivals for steelhead with one year and two years plus ocean age. And for comparison, we also estimated the survivals by ocean age for years 2008 to 2016 (Table 3).

Table 3: **CJS estimates of the survival to McNary Dam for the CSS PIT-tagged B-run steelhead by ocean age, separated by year 2017 and years 2008 to 2016.**

	Survival (90% CI)	SE
Age 1 (2017)	0.885 (0.841, 0.93)	0.03
Age 2+ (2017)	0.768 (0.697, 0.838)	0.042
Age 1 (2008 to 2016)	0.843 (0.822, 0.864)	0.013
Age 2+ (2008 to 2016)	0.798 (0.788, 0.808)	0.006

In our data set of 212 B-run steelhead adults returning in 2017, 185 were not transported as juveniles and 27 were transported as juveniles. The estimated Bonneville-to-McNary survival for 2017 was 0.778 (SE= 0.08, 90% CI= 0.63 to 0.889) for those that were transported as juveniles, and was 0.838 (SE= 0.028, 90% CI= 0.789 to 0.881) for those that migrated in-river. Although the point estimates of survival for the transported versus the non-transported B-run steelhead suggested a higher upstream migration success for the non-transported fish, our results remained inconclusive due to overlapping confidence intervals and a large p value from our permutation test ($p= 0.295$). The lack of power to detect a difference might be caused by a small sample size.

Transport versus non-transport upstream survival was evaluated using the larger sample size of all available data by analyzing 2008 through 2017 together. The estimated Bonneville-to-McNary survival for 2008 to 2017 was 0.748 (SE= 0.011, 90% CI= 0.729 to 0.765) for those that were transported as juveniles, and was 0.827 (SE= 0.006, 90% CI= 0.817 to 0.838) for those that migrated in-river. Combining all available years, permutation test strongly suggested a higher upstream migration success for the non-transported fish, compared to the transported fish ($p < 0.001$; Figure 2).

The overwintering rates for 2008 to 2016 in our data set ranged from 0.021 to 0.143, with a mean of 0.043. Since we did not yet know the overwintering portion for 2017, the steelhead survival for 2017 could be an underestimate.

Results suggested a slightly delayed but overall similar arrival timing at Bonneville Dam for adult B-run steelhead in 2017 compared to the previous years. At both Bonneville and McNary Dams, peak adult counts in 2017 occurred only a few days later than the previous years (Figure 3).

Difference in Survivals between Migration Histories

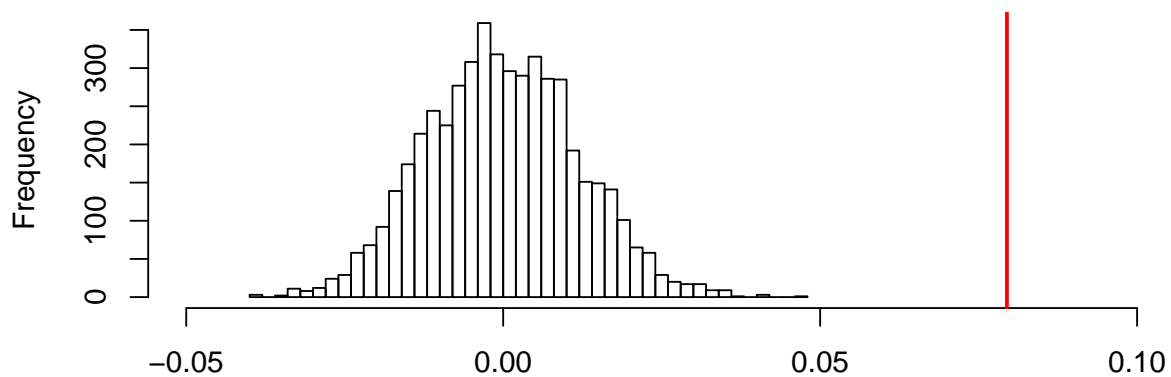


Figure 2: Histogram of permutation distribution under the null hypothesis consists 5,000 simulated differences. The test compares the survivals for adult B-run steelhead returning in 2008 to 2017 that were transported as juveniles and those that migrated in-river. The red line indicates the observed difference from our sample.

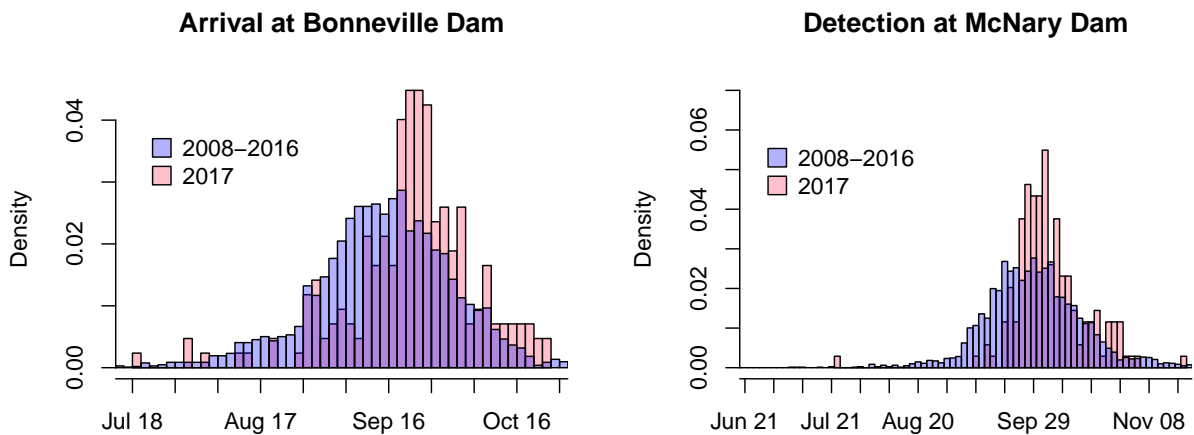


Figure 3: The left histogram shows the distribution of adult steelhead arrival at the Bonneville Dam, and the right shows the distribution of adult steelhead arrival at the McNary Dam.

Because temperature information from the Bonneville forebay was unavailable after mid-to late September, we used temperature data from The Dalles tailrace as a surrogate (please see Appendix C for details on the relationship between the two locations). The overall pattern

of water temperature in 2017 did not seem to be unusual in the October to December time period, compared to the previous years. The water temperature in 2017 cooled down below 18°C in October as it did in the previous years (Figure 4). We observed 79.3% of adult B-run steelhead encountered water temperature greater than 18°C at the Bonneville Dam in 2017, compared to 91.3% in the previous years (Table 4; Figure 5).

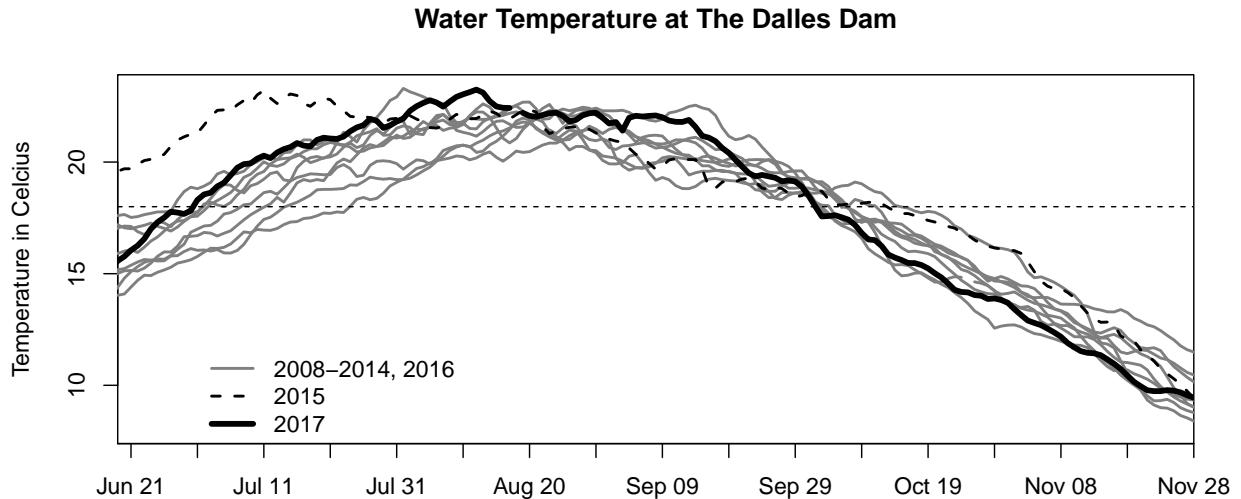


Figure 4: Plot shows the water temperature at The Dalles Dam during months of June through November for years 2008 to 2017. 2015 water temperature (shown in dash line) is known to be warmer than average.

Table 4: 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
2008	135.69	1.00
2009	205.95	0.95
2010	166.29	0.96
2011	134.47	0.94
2012	136.90	0.87
2013	260.99	0.84
2014	228.90	0.98
2015	204.83	0.94
2016	236.69	0.81
2017	253.92	0.79

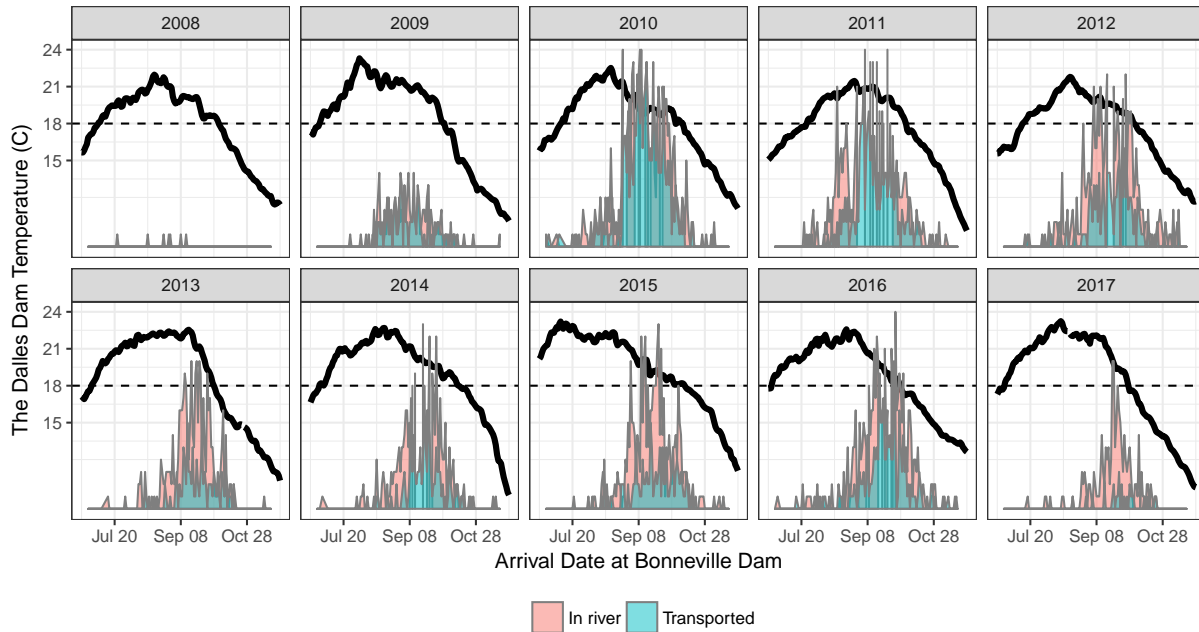


Figure 5: **Black lines indicate The Dalles temperature corresponding to the adult steelhead arrival dates at the Bonneville Dam. Below the temperature lines are the distributions of arrival dates for in river and transported fish.**

References

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Appendix

A. Permutation Test

In our permutation tests, we let the null hypothesis to indicate no difference in the survivals between the two groups in comparison; we either compare the survivals between steelhead returning in 2017 and in the previous years, or the survivals between groups that have been transported as juveniles or migrated in-river. The main assumption is that the "label", either the return year or juvenile migration history, were exchangeable between individual steelhead. That is, one can randomly shuffle return years (or migration history) 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.

B. Survival Estimates without Cutoff Dates

Table 5: CJS estimates of the survivals to McNary Dam for the CSS PIT-tagged B-run steelhead by return year (without the November/December cutoffs).

	Survival (90% CI)	SE
2008	0.714 (0.429, 1)	0.173
2009	0.84 (0.801, 0.877)	0.023
2010	0.785 (0.762, 0.806)	0.013
2011	0.779 (0.759, 0.8)	0.012
2012	0.774 (0.748, 0.799)	0.016
2013	0.775 (0.743, 0.807)	0.02
2014	0.835 (0.811, 0.861)	0.015
2015	0.867 (0.843, 0.89)	0.015
2016	0.829 (0.804, 0.852)	0.014
2017	0.83 (0.788, 0.873)	0.025

C. Comparing Water Temperature at the Bonneville and The Dalles Dams

We compared the water temperature at the Bonneville Dam forebay and The Dalles Dams tailrace in order to make sure that it was reasonable to substitute one with the other in our analysis. There were total 1,887 comparable dates between the Bonneville and The Dalles Dams. The difference in temperatures between the dams ranged from $-0.546^{\circ}C$ to $0.958^{\circ}C$, with the first quartile = $-0.076^{\circ}C$, median = $0.0463^{\circ}C$, and the third quartile = $0.19^{\circ}C$ (Figure 6).

Difference between Bonneville and The Dalles water temperature (C)

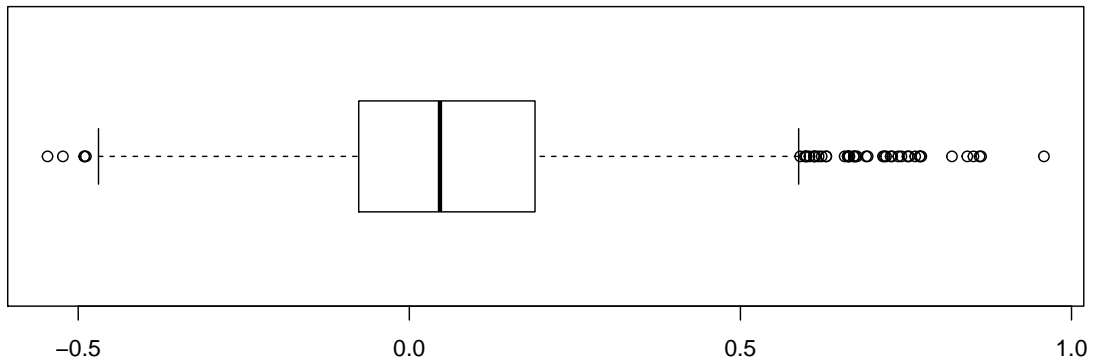


Figure 6: Boxplot shows the distribution for the difference between water temperatures at the Bonneville and The Dalles Dams including years 2008 to 2017.

The Pearson's correlation = 0.999 between the water temperatures at the two dams. We overlapped on a plot the water temperatures at Bonneville and at The Dalles Dam using dates with available temperature information, and they seem to correspond quite nicely to each other (Figure 7).

Temperature at Bonneville forebay and The Dalles tailrace

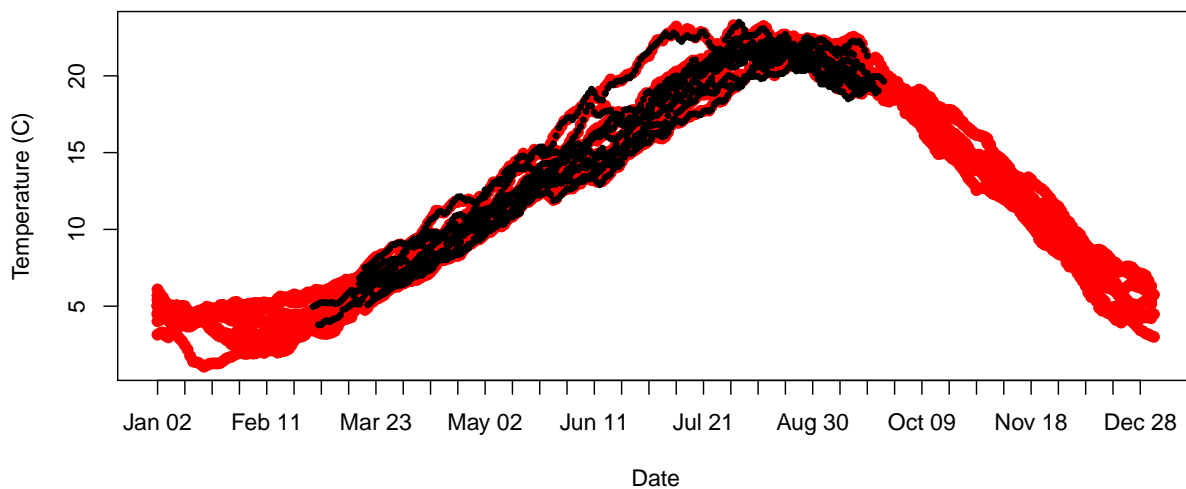


Figure 7: Plot shows the water temperature at the Bonneville forebay (black) and The Dalles tailrace (red) for years 2008 to 2017.