The Effects of Minimum Air Temperature and Maximum Air Temperature on Summer Stream Temperature at Reference Temperature Sites, Umpqua Basin

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Stream temperature is an important factor in aquatic ecosystems in the Pacific Northwest. Stream temperatures affect the aquatic life with higher summer stream temperatures increasing stress in native cold-water salmonids resulting in decreased vigor and possibly death (Brett, 1952; Hokanson, *et al.*, 1977; and Bell, 1986). Stream temperatures are influenced by a combination of factors including day length, canopy cover, discharge, topography, stream bed and morphological characteristics, and solar radiation (Beschta, *et al*., 1987). Radiant energy, specifically, solar radiation, is a very important factor in heating streams (Brown, 1969 and Beschta, *et al.*, 1987), and the sun has been called the principal energy source for warming of streams (Brown and Kryiger, 1970). Isaak *et al.* (2012) also found that air temperature was a much stronger predictor of stream temperature than discharge. Solar radiation reaching streams is reduced by canopy cover, but can vary daily due to changes in day length, changes in cloud cover, and changes in solar output (which is often expressed by air temperature changes). The relationship between air and water temperatures varies from stream to stream based on climatological and morphometric characteristics (Stefan and Preud'homme, 1993). Additionally, air temperature varies diurnally with high air temperatures occurring during the late afternoon and early evening and lows occurring during the late night to early morning, and these diurnal fluctuations have a great impact on the stream's heat budget (Diabat, *et al.*, 2013).

Many studies have documented the relationship between air temperature to water temperature with linear correlations including Johnson (1971), Stefan and Preude'homme (1993), Pilgrim, *et al.* (1998), and Isaak, *et al*. (2012). But few studies have looked at the differences in the effects of daytimes versus nighttime temperature on changes in stream temperatures. A study of streams in Lower Madison River, Montana found that warmer daytime air and increases in solar radiation led to larger maximum increases in stream temperature than warmer nighttime air, but that warmer nighttime air led to more hours of moderate increases in stream temperature than warmer daytime air (Gooseoff, *et al*., 2005). Similarly, a study of Middle Fork John Day River, Oregon tributary stream temperature data modelled with Heat Source found that stream temperature changes were more extreme and of longer duration when driven by air temperatures concentrated in either daytime or nighttime instead of uniformly distributed across the diurnal cycle (Diabat, *et al.*, 2013). Both Diabat, *et al.* (2013) and Gooseff, *et al.* (2005) found that nighttime warming of air was more likely to lead to longer times of moderately warmer stream temperatures than daytime warming of air and Diabat (2014) stated that nighttime warming of air temperatures caused the greatest increase in maximum daily water temperatures.

In the Umpqua Basin, a temperature study began in 1998 with the objective of characterizing stream temperatures by sampling approximately every ten square miles, to establish the range of variability of stream temperature in the Umpqua Basin temporally and spatially (Smith, 2001). Out of that study, five representative sites were chosen for continuous summer air and stream temperature monitoring; sites were chosen based on varying climatic conditions and distance to divide (a surrogate for drainage area) (see Table 1), and sampling has continued annually and a report is produced to document the patterns of stream temperatures in the Umpqua Basin (Smith, 2003, 2004, and 2005; Dammann and Smith, 2006;

Dammann, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, and 2019). Most studies have data at many sites over a few years; however, this study has many years of data over a few sites. This long-term data set, with over 20 years of data, provides a rare opportunity to study the stream temperature patterns at the five reference sites.

In these annual reports the 7-day average maximum (7DAM) stream temperature is documented each year (Figure 1) Summer, 2015 was the hottest summer on record for all three cities surrounding the study sites (Roseburg, Medford, and Eugene, Oregon) (National Weather Service (NWS), 2015a and 2015b); however, they did not result in the hottest stream temperatures. The years 2014 and 2013 had the 2nd and 3rd hottest summers on record, but also did not have the hottest stream temperatures on record. Similarly, though 2014 had more days exceeding 90°F compared to 2015, but 7DAM stream temperatures were higher in 2015 compared to 2014 (Dammann, 2016 and Figure 1). The hottest stream temperatures during the period of record actually primarily occurred in 2006 (Figure 1). In that year there were the highest minimum air temperatures ever recorded in the region (Taylor and Hale, 2006). The hottest stream temperature at one of the sites occurred in 2009 (Figure 1). In 2009, all five reference sites had the highest air temperatures July 28 and 29 which correspond with record breaking air temperatures in the region (The Oregonian July 29 and 30, 2009 and The News-Review July 29 and 30, 2009) and also had high nighttime temperatures as well (NWS, 2020). (Dammann, 2006, 2015, and 2019, and NWS, 2020)

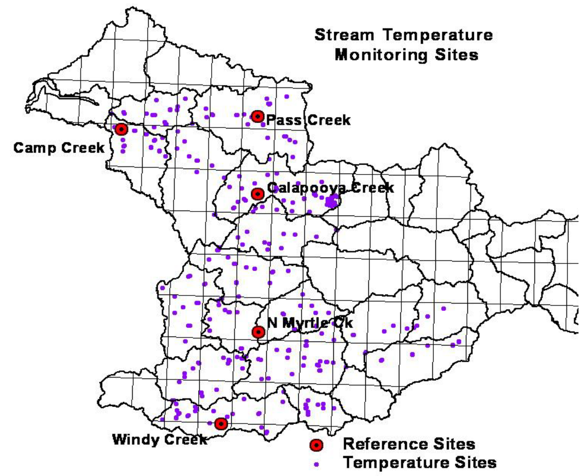


Table 1. Umpqua Basin reference site characteristics. All of the sites are in low-elevation, rain dominated systems.

	Calapooya Ck	Camp Ck	N Myrtle Ck	Pass Ck	Windy Ck
Tributary to	Umpqua R.	Mill Ck.	Myrtle Ck	Elk Ck	Cow Ck
Distance from site to ridgetop divide (miles)	28.47	21.41	18.26	13.30	9.63
Drainage area (acres)	103,500	22,550	37,190	40,090	15,660
Years of survey	21	20	21	21	20

Knowing the key factors that influence the timing and magnitude of high stream temperatures, would allow for better prediction of the timing of increased stress to cold-water fish. This information can help fisheries managers better manage the fishery and fishing regulations. This is especially pertinent as Arismendi, *et al.* (2013) has found that the timing of minimum streamflows has become earlier in the Western United States. This has resulted in a decrease in the time between the two biggest summer stresses to fish, maximum stream temperatures and the minimum stream flows (Arismendi, *et al*., 2013).

The objective of this study is to further investigate the effects of minimum air temperature compared to maximum air temperature on summer stream temperature at the five reference sites as a preliminary study to help better insight into how air temperature influences stream temperatures.

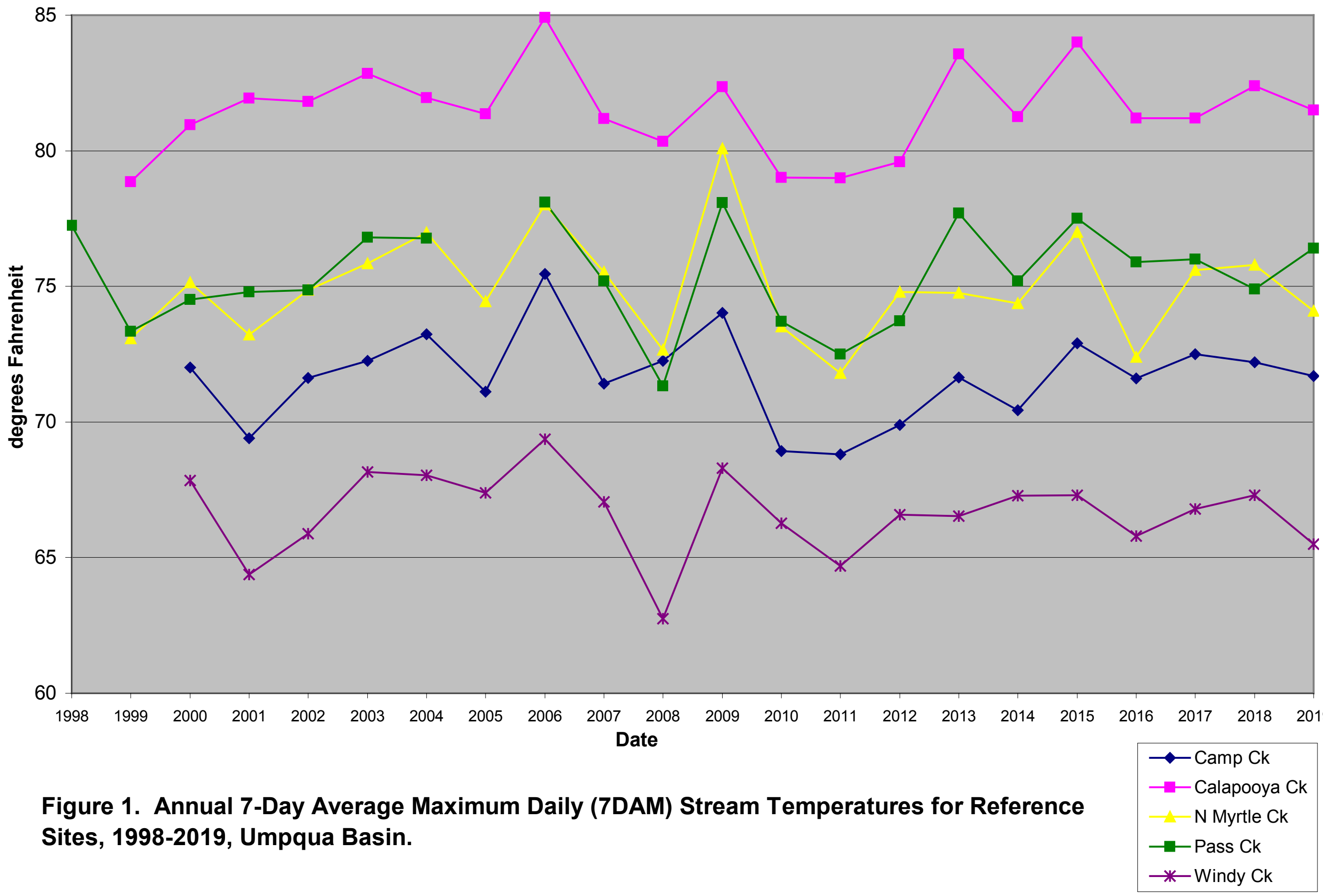


Figure 1. Annual 7-Day Average Maximum Daily (7DAM) Stream Temperatures for Reference Sites, 1998-2019, Umpqua Basin.

Closer Look at Summer High Daytime and Nighttime Stream Temperatures in Umpqua Basin:

Typically, late night to early morning, stream temperature is at its lowest of the day. However, sometimes the atmospheric conditions reduce the likelihood of cooling resulting in the minimum daily temperatures still being in the high 60's to low 70's in the region. There were six days where the lowest daily air temperature exceeded 70°F in Roseburg since 1998; this occurred June 27, 2015, July 22-24, 2006, and July 28-29, 2009 (Table 2). If looking at a 3-day average, the highest minimum daily air temperatures occurred in 2006, 2009, and 2015 respectively (Table 3). At four of the sites, the highest two years of 7DAM stream temperatures occurred in 2009 and 2006, during the times of the highest minimum daily stream temperatures (Figure 1). At Calapooya Creek, a larger stream, the highest stream temperatures occurred in 2006 and 2015 respectively. The highest 3-day average maximum daily stream temperatures were in 2017, 2015, and 2009; 2006 ranked 6th (Table 3). If averaging over a longer period of time, such as the 7-day average, 2006, 2009, and 2015 still had the highest minimum temperatures recorded and 2017 and 2009 had the highest maximum air temperatures (Table 4).

Table 2. Maximum daily minimum air temperatures (highest nighttime temperatures) for Roseburg, Oregon during the period of study 1998-2019 (NWS, 2020).

Maximum 1-Day Minimum Temperature for Roseburg Regional Airport		
Rank	**Value degrees F**	**Ending Date**
1	74	6/27/2015
2	73	7/22/2006
3	72	7/23/2006
4	71	7/29/2009
-	71	7/28/2009
6	70	7/24/2006
7	69	7/26/2013
-	69	7/26/1998
9	68	8/9/2017
-	68	7/23/2017
-	68	6/5/2016
-	68	8/1/2015
-	68	6/28/2015
-	68	7/16/2014
-	68	7/2/2013
-	68	7/10/2008
-	68	7/27/2006
18	67	7/31/2015
-	67	7/2/2015
-	67	6/9/2015
-	67	7/3/2013
-	67	8/25/2011
-	67	7/11/2010
-	67	8/2/2009
-	67	7/30/2009
Period of record: 1998-01-01 to 2019-12-31		

Table 3. Maximum 3-day minimum air temperatures (rolling 3-day average of highest nighttime temperatures) and maximum 3-day maximum air temperatures (rolling 3-day average of highest daytime temperatures) for Roseburg, Oregon during the period of study 1998-2019 (NWS, 2020).

Maximum 3-Day Mean Minimum Temperature		
for Roseburg Regional Airport		
Rank	**Value**	**Ending Date**
1	71.7	7/24/2006
2	70	7/23/2006
3	69.7	7/30/2009
4	69.3	6/28/2015
5	68.7	7/29/2009
6	68.3	6/29/2015
-	68.3	7/25/2006
8	66.7	8/10/2017
-	66.7	8/2/2015
-	66.7	8/1/2015
-	66.7	7/31/2009
12	66.3	8/9/2017
-	66.3	7/4/2015
-	66.3	7/3/2013
15	66	7/5/2015
-	66	6/27/2015
-	66	7/26/2013
-	66	7/28/2009
19	65.7	8/11/2017
-	65.7	7/25/2017
-	65.7	7/3/2015
-	65.7	7/27/2013
-	65.7	7/28/1998
24	65.3	6/7/2016
-	65.3	8/3/2015
Last value also occurred in one or more previous years.		
Period of record: 1998-01-01 to 2019-12-31		

Maximum 3-Day Mean Max Temperature		
for ROSEBURG REGIONAL Airport		
Rank	**Value**	**Ending Date**
1	106	8/3/2017
-	106	7/31/2015
-	106	7/29/2009
4	105.7	8/4/2017
5	104.7	8/1/2015
6	104.3	7/24/2006
-	104.3	7/30/2003
8	103.7	7/28/2009
-	103.7	7/23/2006
10	103.3	7/30/2009
11	103	7/29/2003
-	103	8/15/2002
-	103	8/14/2002
-	103	7/28/1998
15	102.7	8/20/2016
16	102.3	8/2/2017
17	102	7/31/2003
-	102	7/27/1998
19	101.7	7/3/2015
20	101	8/5/2017
21	100.7	7/26/2018
22	100.3	7/30/2015
-	100.3	7/2/2015
-	100.3	8/16/2008
-	100.3	7/25/2006
Last value also occurred in one or more previous years.		
Period of record: 1998-01-01 to 2019-12-31		

Table 4. Maximum 7-day minimum air temperatures (rolling 7-day average of highest nighttime temperatures) and maximum 7-day maximum air temperatures (rolling 7-day average of highest daytime temperatures) for Roseburg, Oregon during the period of study 1998-2019 (NWS, 2020).

Maximum 7-Day Mean Min Temperature

for ROSEBURG REGIONAL AP, OR

Click column heading to sort ascending, click again to sort descending.

Rank	Value	Ending Date	Missing Days
1	67.4	7/27/2006	0
2	66.6	7/28/2006	0
3	66.4	8/2/2009	0
4	66.1	7/3/2015	0
-	66.1	7/2/2015	0
6	66	8/3/2009	0
7	65.9	8/1/2009	0
8	65.6	7/26/2006	0
9	65.4	7/31/2009	0
10	65	7/4/2015	0
11	64.9	7/6/2015	0
-	64.9	7/1/2015	0
13	64.7	7/5/2015	0
14	64.6	7/7/2015	0
-	64.6	7/30/2009	0
16	64.3	7/25/2006	0
17	64.2	7/29/2009	1
18	64.1	8/12/2017	0
-	64.1	8/10/2017	0
-	64.1	8/4/2009	0
21	64	8/9/2017	0
-	64	7/8/2015	0
-	64	7/3/2013	0
24	63.9	8/13/2017	0
-	63.9	8/11/2017	0

Last value also occurred in one or more previous years.

Period of record: 1998-01-01 to 2019-12-31

Maximum 7-Day Mean Max Temperature

for ROSEBURG REGIONAL AP, OR

Click column heading to sort ascending, click again to sort descending.

Rank	Value	Ending Date	Missing Days
1	100.4	8/5/2017	0
-	100.4	8/1/2009	0
-	100.4	7/31/2009	0
4	100.1	8/6/2017	0
5	100	8/7/2017	0
-	100	8/4/2017	0
-	100	7/30/2009	0
8	99.6	8/2/2009	0
9	99.4	8/8/2017	0
-	99.4	7/27/2006	0
-	99.4	7/26/2006	0
12	98.6	7/25/2006	0
-	98.6	8/1/2003	0
14	98.3	7/29/2018	0
-	98.3	7/29/2009	0
16	98.1	8/3/2017	0
-	98.1	8/16/2002	0
-	98.1	8/15/2002	0
19	98	7/6/2015	0
-	98	7/5/2015	0
-	98	8/3/2009	0
-	98	7/31/2003	0
-	98	8/17/2002	0
24	97.9	7/30/2018	0
-	97.9	7/3/2015	0

Period of record: 1998-01-01 to 2019-12-31

Trends in Air Temperature and Stream Temperature Relationship during Years of Extreme Temperatures

Although the air temperature data were collected in the riparian areas for this long-term project, the NWS data from Roseburg, Oregon, central to all of the project sites, was used for this study. As stated, 2006 had the highest stream temperatures for four of the five reference sites during the 21 year period of record and 2015 was the hottest summer on record (NWS, 2015a and 2015b) with no summers hotter since then. Figures 2 and 3 compare the maximum and minimum daily air temperatures in Roseburg with the maximum daily summer stream temperatures for the five sites for 2006 and 2015 respectively. In 2006, the maximum stream temperatures at all five sites occurred at the time of the seasonal maximum daytime and nighttime air temperatures during the July 22-24 time period. 2015 showed the same pattern (high day and nighttime air temperatures) at the end of July, but there was also a period of high nighttime air temperatures in late June. For both 2006 and 2015, the period of the highest air temperatures, also has an increase in minimum (nighttime) temperatures at the same time. These heat waves are also reflective in the stream temperature. This is the case during other heat waves as well, but not as evident much later in the summer when the day length is decreasing rapidly. This is also consistent with what was found in Dammann (2019). From the data in Figures 2 and 3, it appears that air temperature has an influence on stream temperature but is difficult to discern if maximum or minimum air temperature has a greater influence.

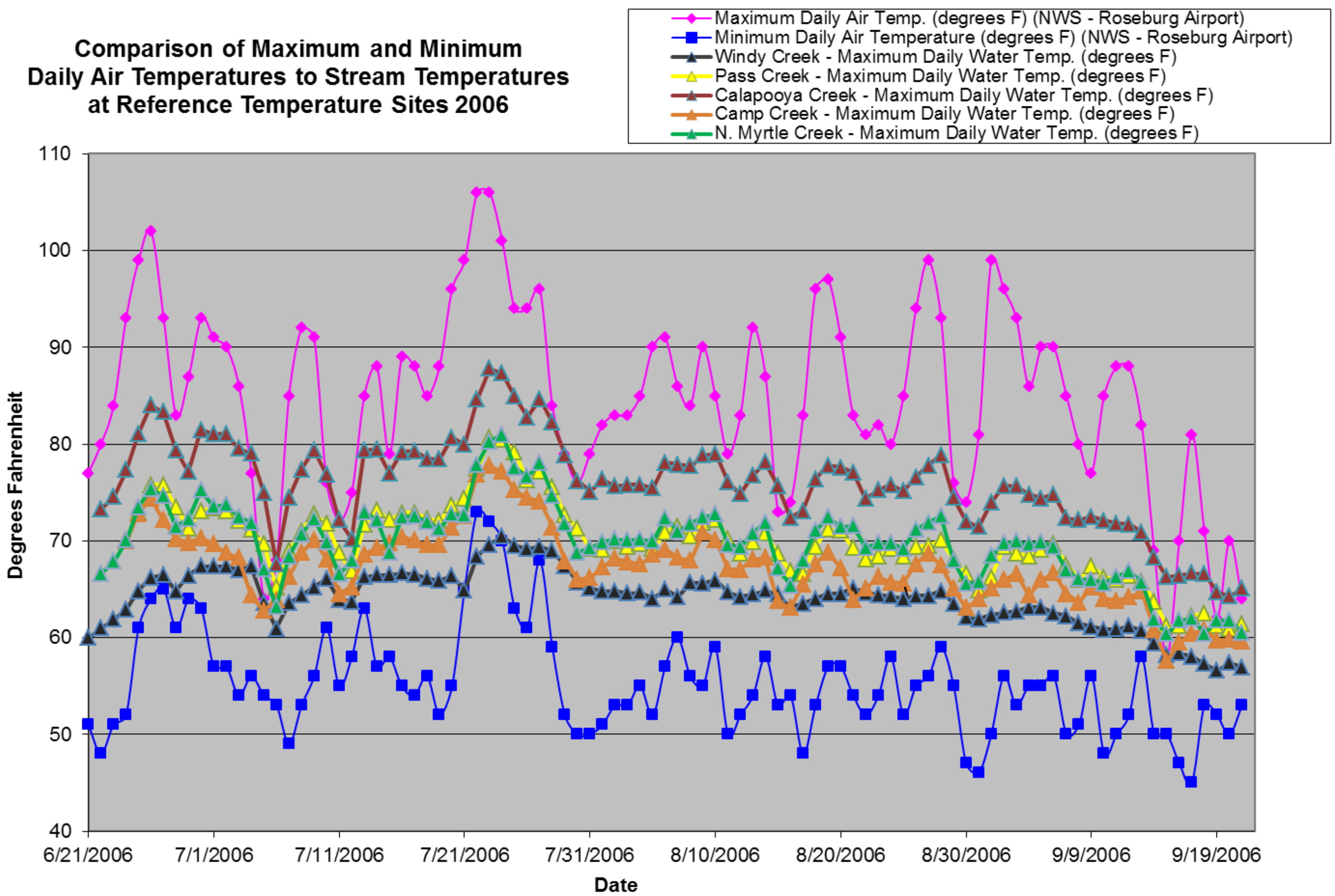


Figure 2. Comparison of maximum and minimum daily air temperatures in Roseburg (NWS, 2020) to maximum daily stream temperatures at reference temperature sites for Summer, 2006, the year of the highest nighttime air temperatures on record.

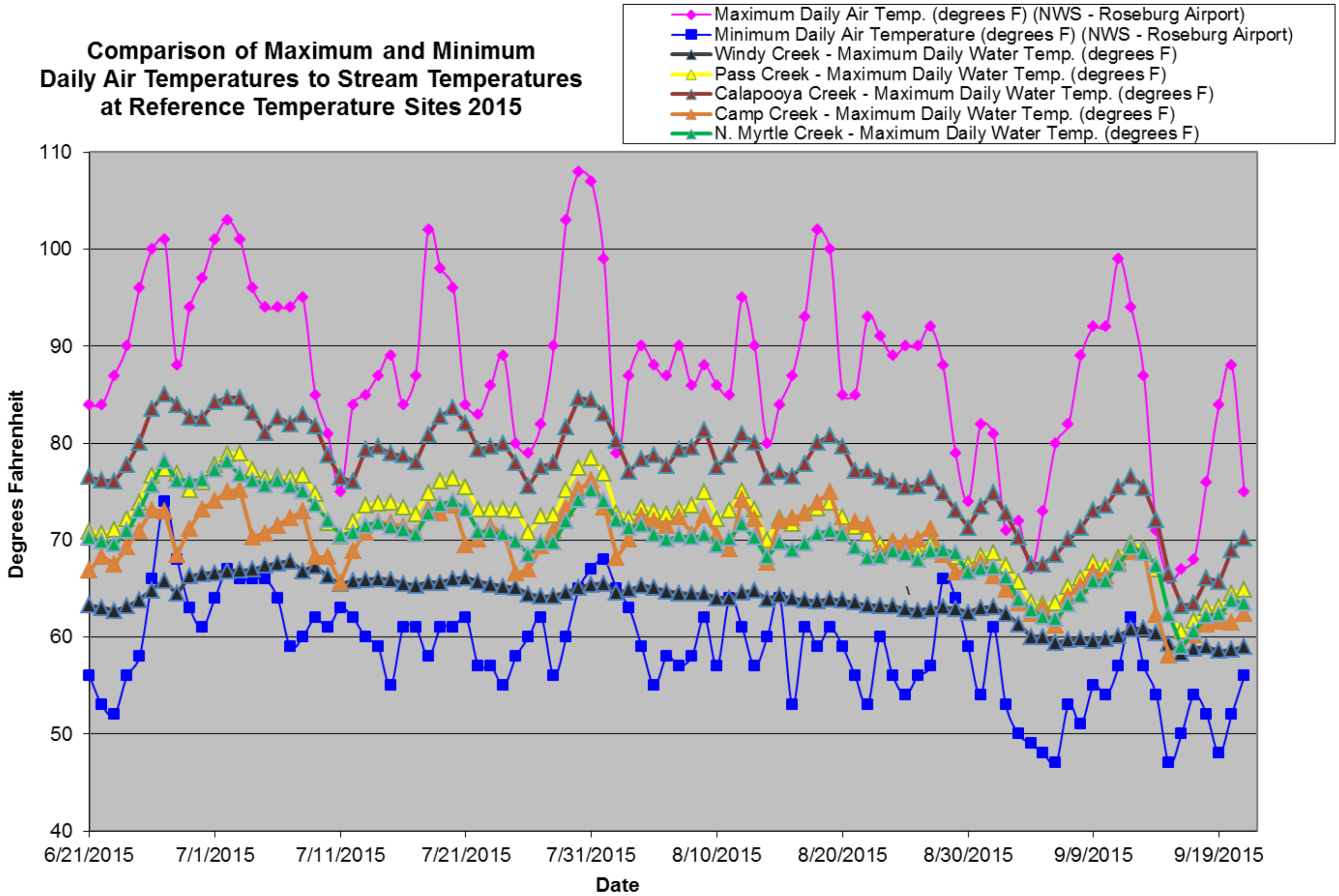
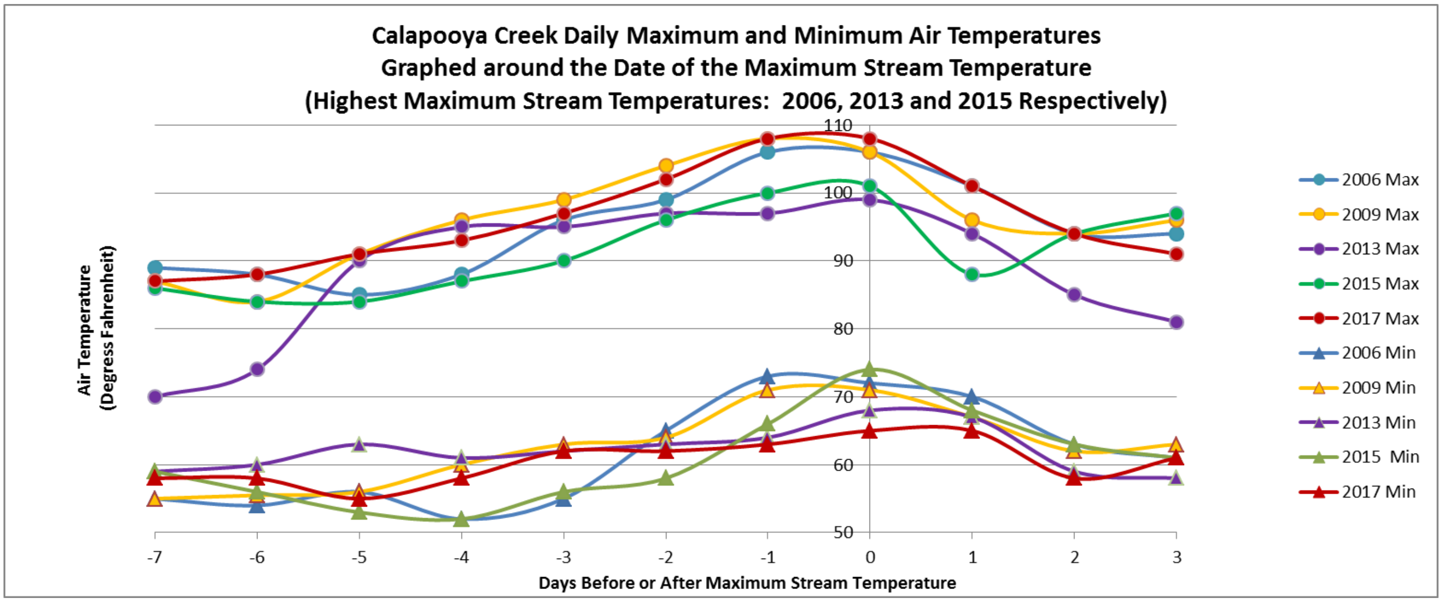


Figure 3. Comparison of maximum and minimum daily air temperatures in Roseburg (NWS, 2020) to maximum daily stream temperatures at reference temperature sites for Summer, 2015, the year of the highest daytime air temperatures on record.

In order to take a closer look at the patterns of the air temperatures during the times of the maximum stream temperatures during these extreme years, the daily maximum and minimum air temperatures were graphed for the 10 days around the date of the maximum stream temperature for 2006, 2009, 2013, 2015, and 2017 (Figure 4). This means for instance on Calapooya Creek in 2006, the maximum stream temp occurred on July 23, 2006 so that would be the zero date and the 7 days before and 3 days after were graphed. The 7DAM stream temperature for Calapooya Creek in 2006 occurred on July 25, so that would be the zero date (Figure 4). The graphs show when the high maximum and minimum air temperatures and 7DAM air temperatures occur related to maximum and 7DAM stream temperatures. To better see how many days before the maximum stream temperature the highest maximum and minimum air temperatures occurred, Figure 5 was created using data from the entire period of record. Figure 5 shows that for Calapooya, Camp, North Myrtle and Pass Creeks, the maximum stream temperature typically occurred on the same day as the maximum air temperature and the maximum nighttime air temperature, but could occur up to 3 days before. For Windy Creek it did occur up to three days before, with one exception, but the occurrences were more spread out over those three days rather than being closer to the date of the maximum stream temperature.



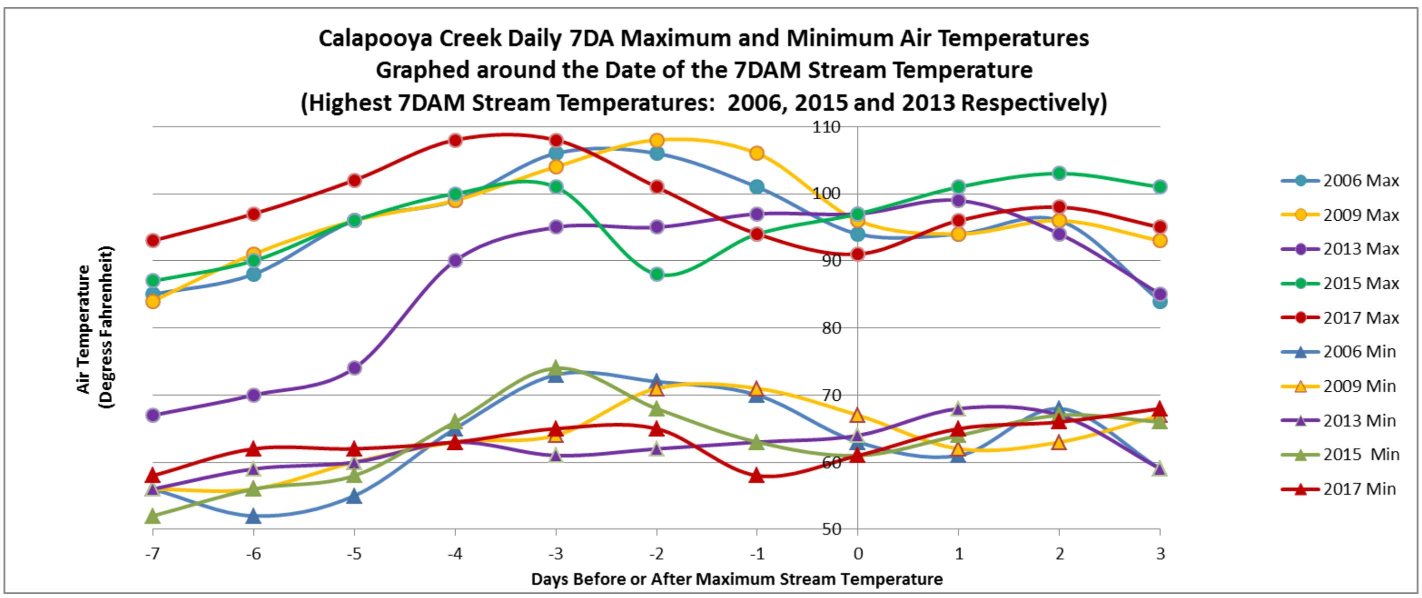
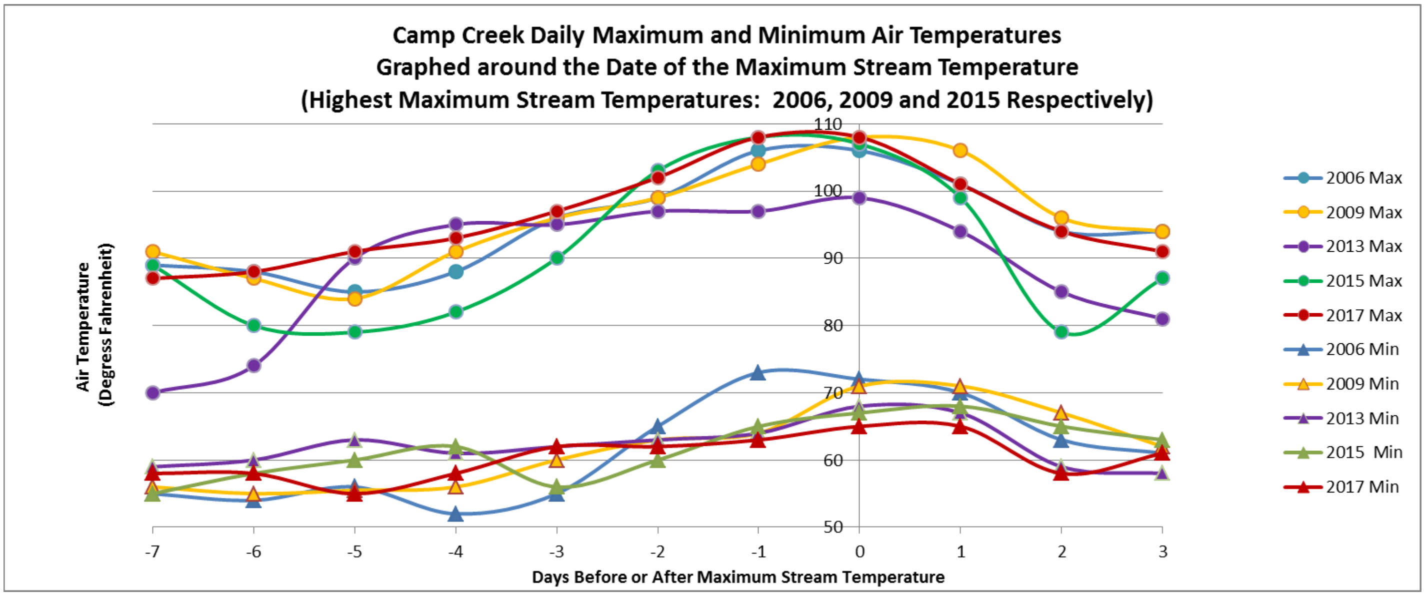
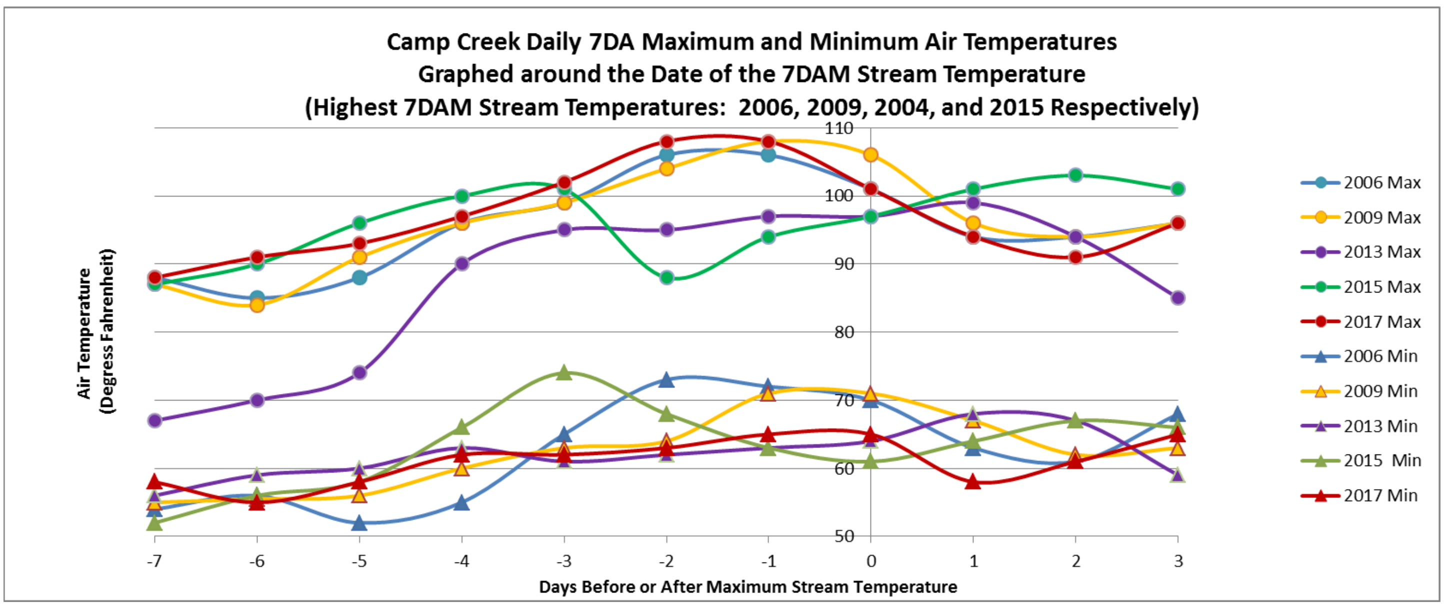


Figure 4. Comparison of minimum and maximum air temperatures and seven day averages (7DA) around the date of the maximum and 7DA maximum stream temperature for years of extremes minimum or maximum air temperatures (NWS, 2020). Zero is the day of the maximum or 7-day average maximum stream temperatures. (Page 1 of 5)





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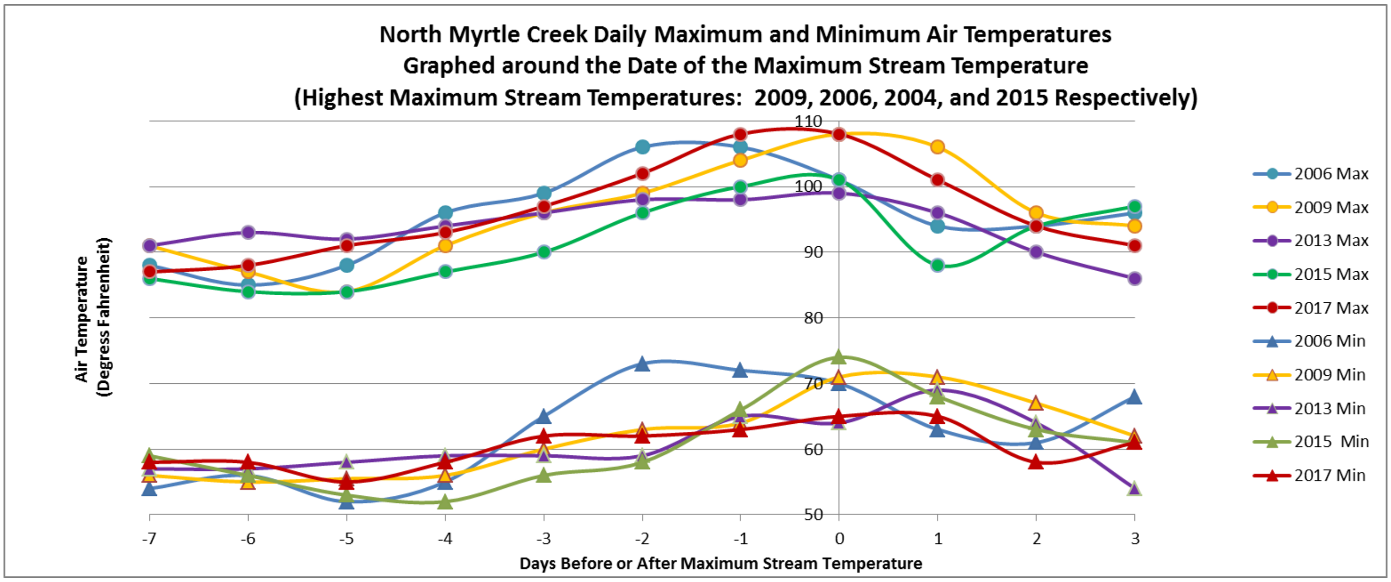

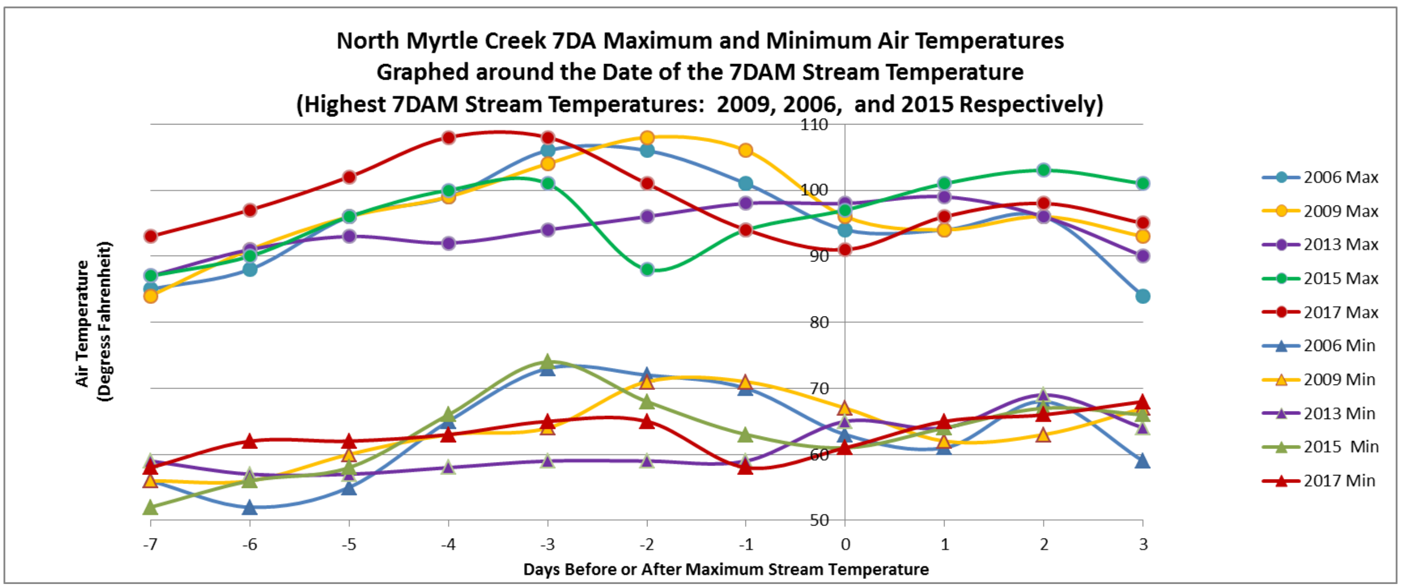

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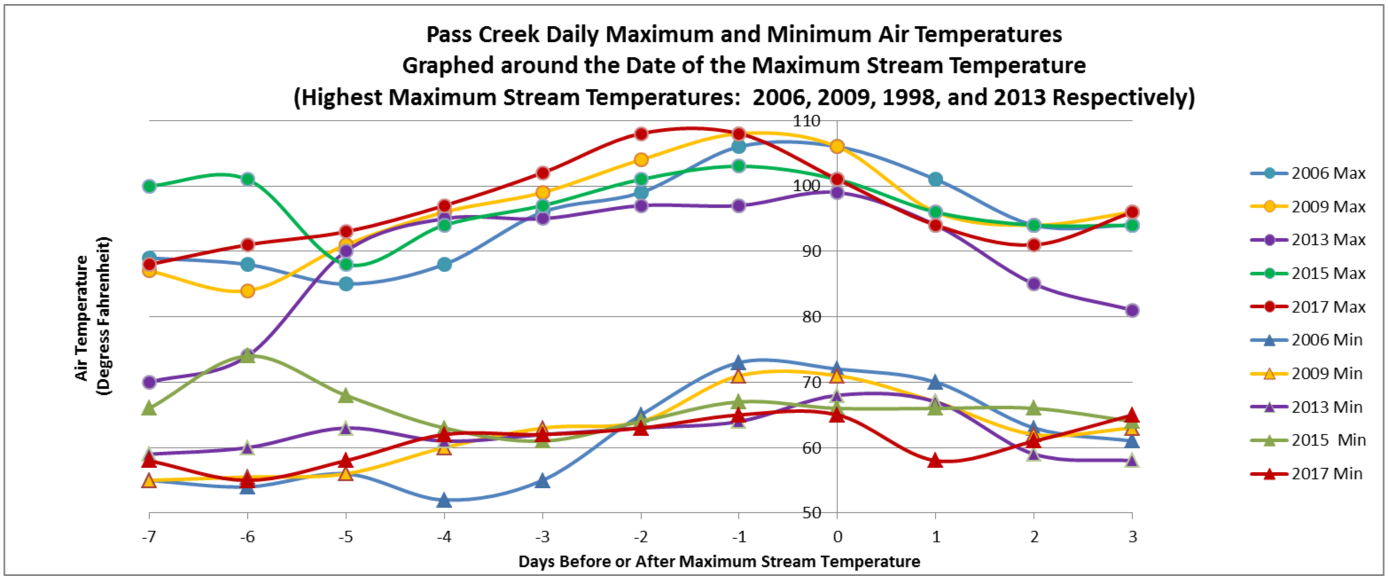

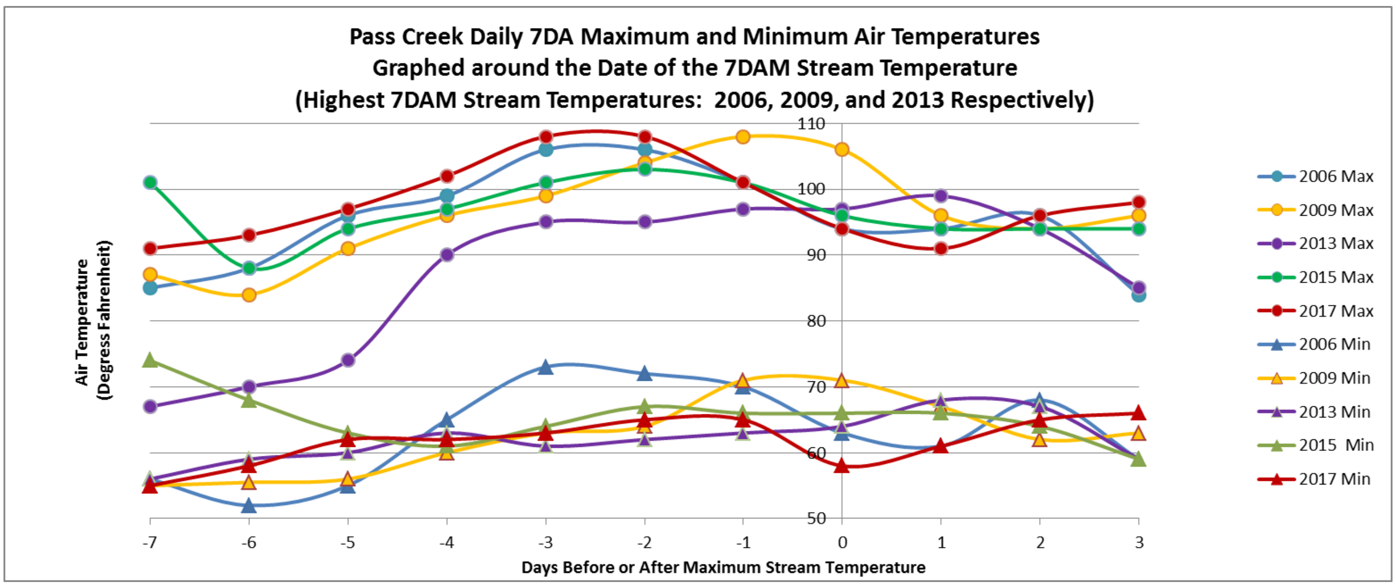

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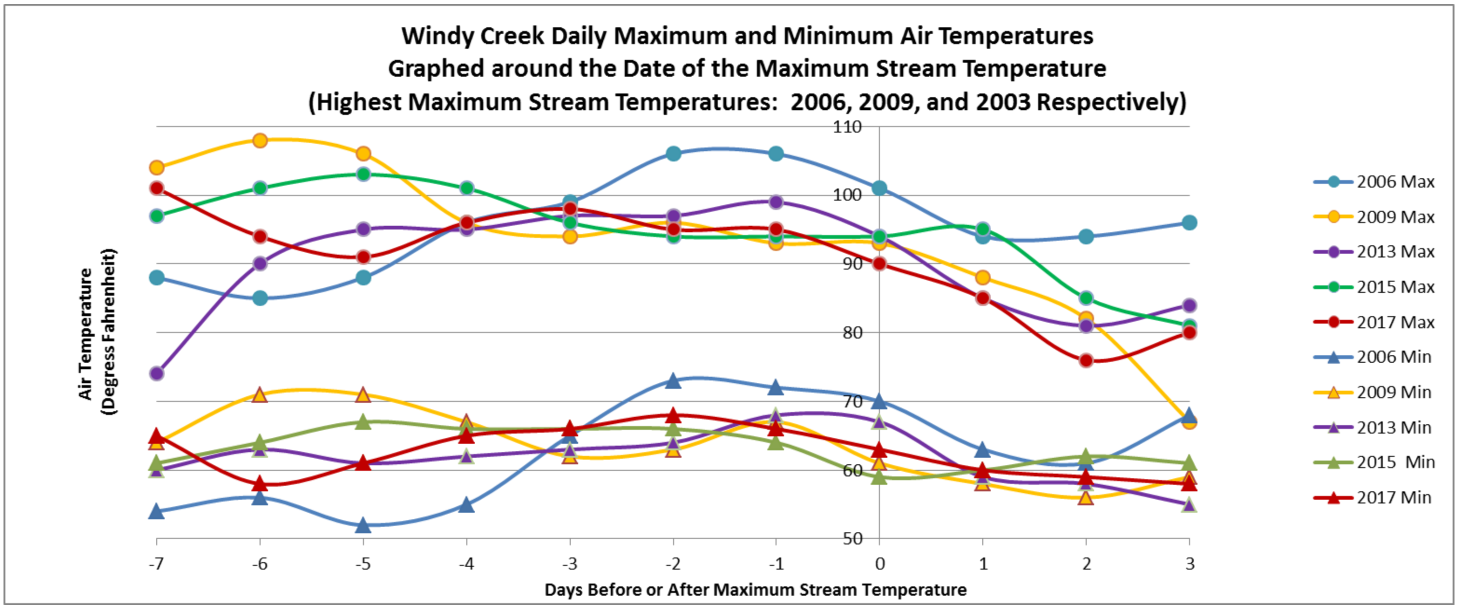

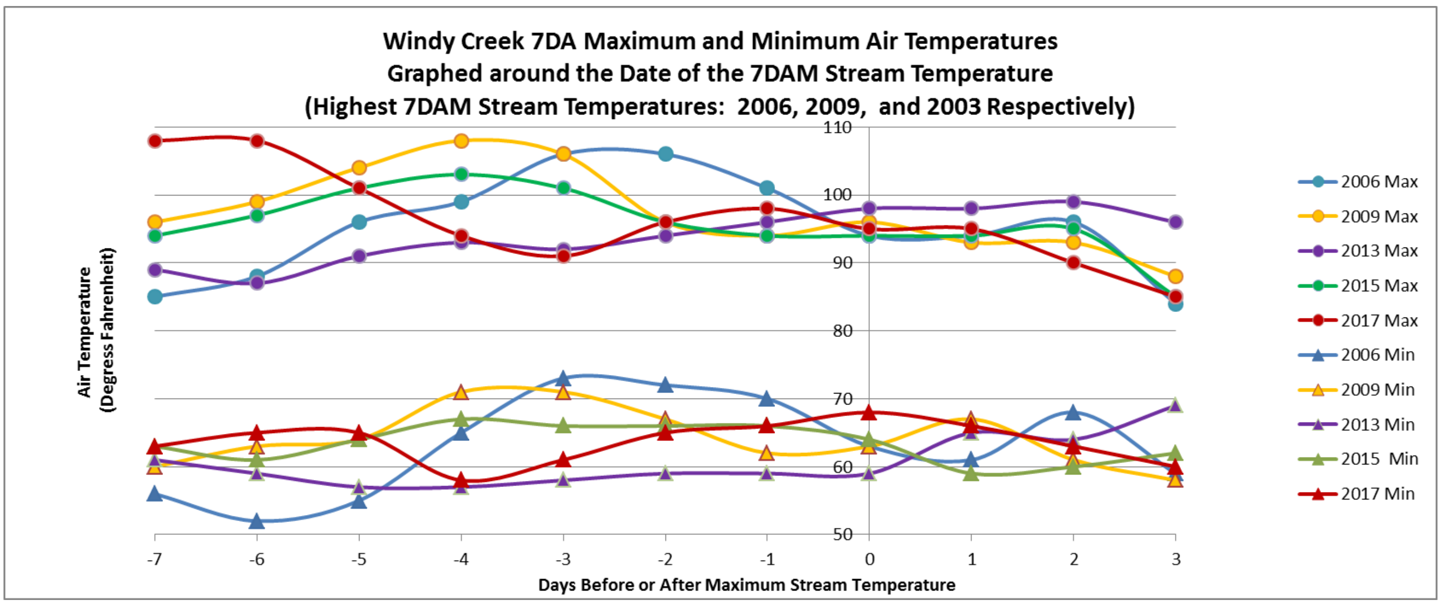

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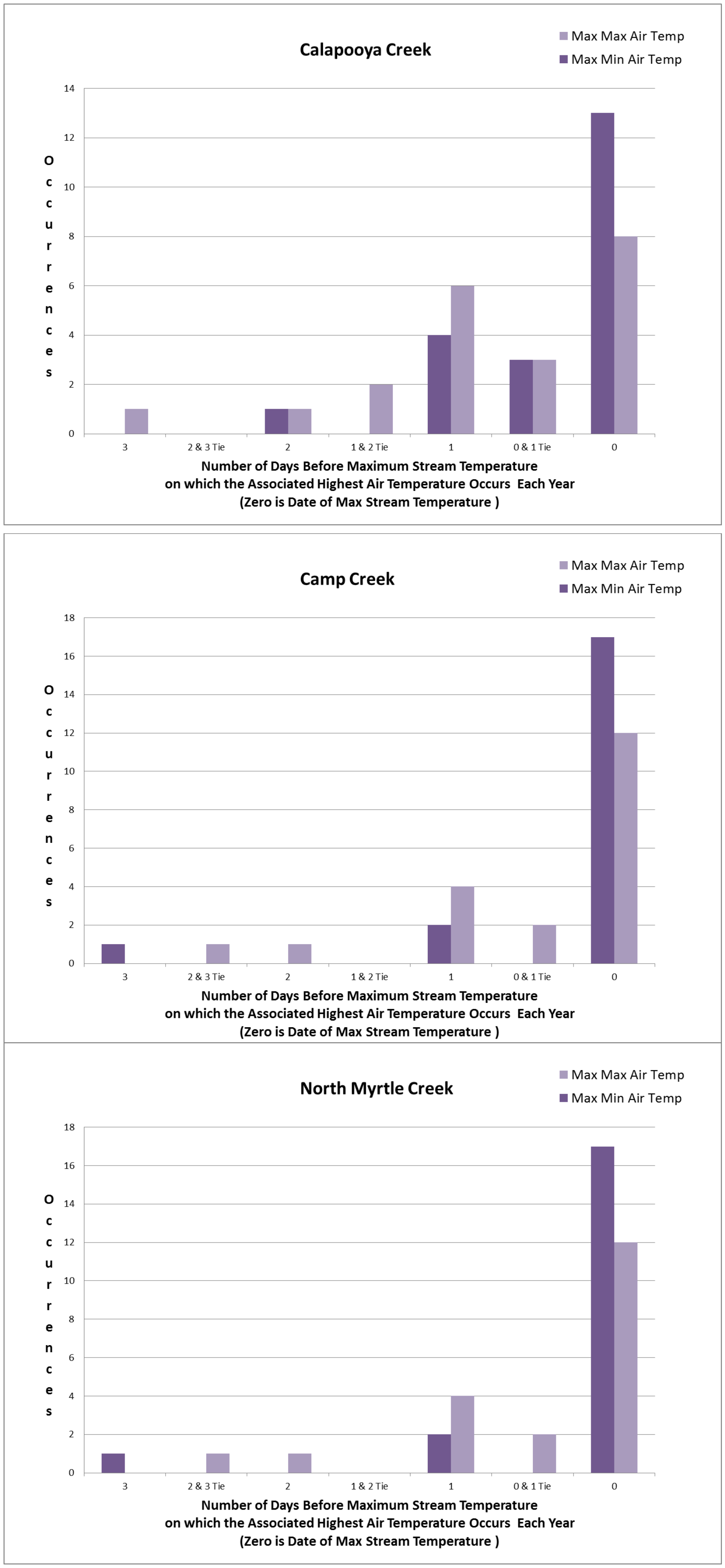
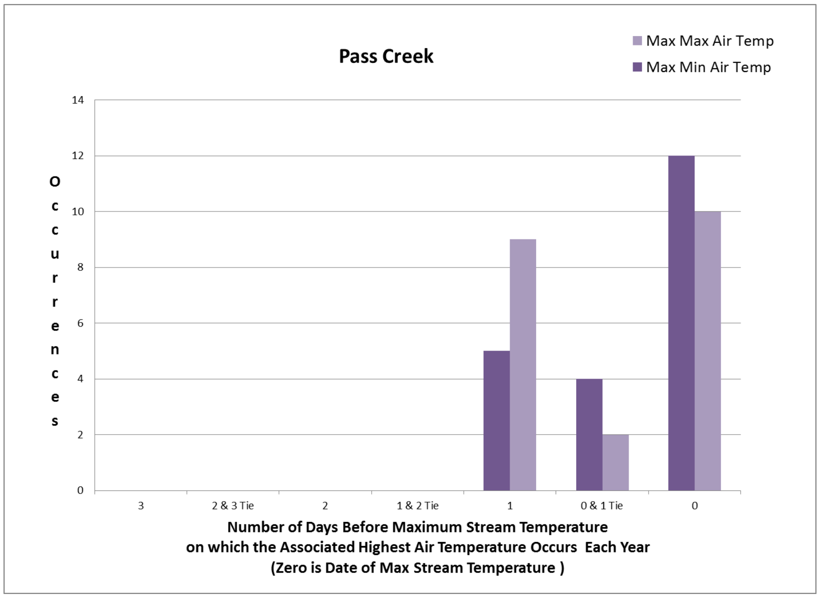


Figure 5. Days between minimum and maximum air temperatures and associated air temperatures occurring on or prior to that date for reference temperature sites from 1998-2019. (NWS, 2020). (Page 1 of 2)



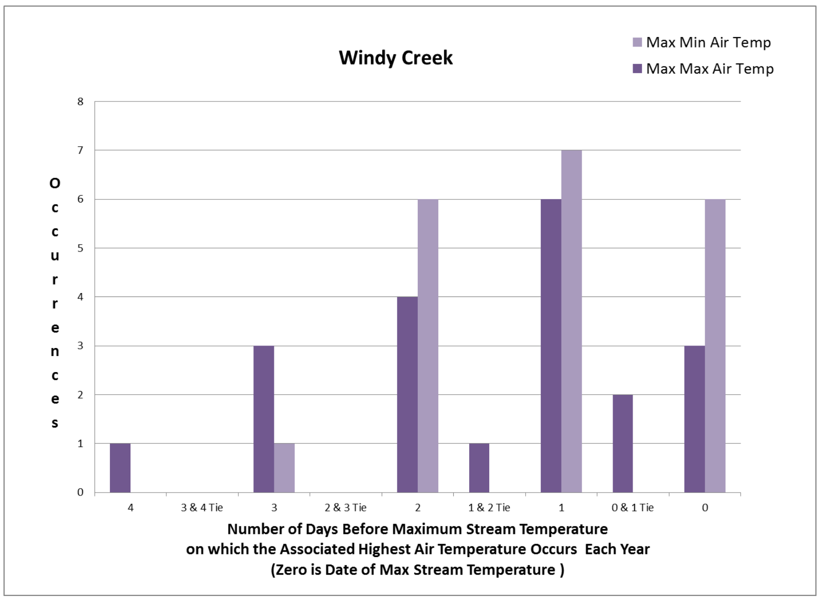


Figure 5. Continued. (Page 2 of 2)

Statistical Analysis Methods:

To further examine if minimum or maximum daily air temperature had a stronger effect on stream temperature at the five reference sites, the following variables in Table 5 were compared.

Three-day average temperatures were chosen as the length of time to observe temperatures because this study found that typically the minimum air temperature was the highest the day of the highest maximum stream temperature, one day before, or two days before (see Figures 4 and 5).

Air temperature data were from Roseburg, Oregon (NWS, 2020). All data were compiled in Excel. Data were analyzed in Excel using the Analysis ToolPak Add-in and in JMP Statistical Software from SAS.

Table 5. Variables used in statistical analysis.

Variables	Independent (x) or dependent (y)	Definition of Variable
Max Stream Temp	y(1)	Maximum stream temperature of the year
7DAM Stream Temp	y(2)	7DAM stream temperature of the year
Max Min Air Temp	x(1)	Maximum minimum daily (high nighttime) air temperature during the period of the maximum stream temperature (up to 3 days before)
Max Max Air Temp	x(1)	Maximum maximum daily (high daytime) air temperature during the period of the maximum stream temperature (up to 3 days before)
7DA Min Air Temp	x(2)	7DA minimum air temperature during the period of the 7DAM stream temperature (centered on the date)
7DA Max Air Temp	x(2)	7DA maximum air temperature during the period of the 7DAM stream temperature (centered on the date)

Normal quantile plots were created for each of these six variables at each of the five sites with JMP Statistical Software from SAS (Appendix 1) in order to determine the type of statistical analyses that would be appropriate for the data. In addition, the Shapiro-Wilk test was performed for all of these parameters to check for normalcy (Zar, 1974). The data for all of the sites was normally distributed ($p>.05$) with the exception of Max Min Air temp at North Myrtle Creek, 7DA Min Air Temp and 7DA Max Air Temp for Camp Creek (Table 6).

Table 6. Shapiro-Wilk test results for normalcy for the variables to be analyzed (p>.05). Analysis conducted in JMP Statistical Software from SAS.

Shapiro Wilk Test Results		
Max Min Air temp:		
Stream	**W**	**Prob<W**
Calapooya	0.914079	0.0661
Camp	0.921407	0.1055
North Myrtle	0.901443	0.0373*
Pass	0.948558	0.3198
Windy	0.944087	0.312
Max Max Air temp:		
Stream	**W**	**Prob<W**
Calapooya	0.950999	0.3557
Camp	0.927947	0.141
North Myrtle	0.946613	0.2935
Pass	0.943072	0.2505
Windy	0.95887	0.5503
Max Stream temp:		
Stream	**W**	**Prob<W**
Calapooya	0.949292	0.3303
Camp	0.948543	0.3455
North Myrtle	0.949097	0.3275
Pass	0.964495	0.6108
Windy	0.962099	0.6144
7DA Min Air temp:		
Stream	**W**	**Prob<W**
Calapooya	0.914766	0.0682
Camp	0.853871	0.0062*
North Myrtle	0.92282	0.0988
Pass	0.980372	0.9305
Windy	0.958843	0.5498
7DA Max Air temp:		
Stream	**W**	**Prob<W**
Calapooya	0.981153	0.9408
Camp	0.899377	0.0401*
North Myrtle	0.953433	0.3948
Pass	0.957706	0.4712
Windy	0.967342	0.7223
7DAM Stream temp:		
Stream	**W**	**Prob<W**
Calapooya	0.96065	0.5293
Camp	0.960096	0.5458
North Myrtle	0.961218	0.541
Pass	0.963882	0.5975
Windy	0.963481	0.6426

For each stream, the following relationships were examined for each site: (1) maximum minimum daily air temperature to the maximum daily stream temperature, (2) maximum maximum daily air temperature to the maximum daily stream temperature, (3) 7DA minimum air temperature to the 7DA maximum stream temperature, (4) 7DA maximum daily air temperature to the 7DA maximum stream temperature. To check to see if the data for these relationships was normally distributed, normal probability plots and residual plots were graphed for each relationship at each site using the MS Excel Analysis ToolPak (Appendix 2) showing normal distribution.

There is potential for autocorrelation of the maximum and minimum air temperatures between years due to multi-year events that can affect the climactic condition in the Pacific Northwest such as Pacific Decadal Oscillations or "the Blob", a large patch of warm water in the North Pacific (L'Heureaux, 2019 and National Oceanic and Atmospheric Association (NOAA) – Fisheries, 2019). If the data were not independent, but autocorrelated, it would skew the results of the analysis; therefore, the Durbin-Watson test for autocorrelation was performed on all four relationships for all five sites (Table 7) (Draper and Smith, 1998 and Montgomery, *et al.*, 2012). The results of the Durbin-Watson test showed that there was no autocorrelation with 95% confidence.

Pearson correlations were run on 1998-2019 data comparing the following four relationships between the variables (Table 8). Then, the Pearson correlation coefficients for the maximum minimum (high nighttime) and maximum maximum (high daytime) temperatures were compared to determine if either had a stronger effect. For the three data sets with non-normal distribution Max Min Air temp at North Myrtle Creek, 7DA Min Air Temp and 7DA Max Air Temp for Camp Creek, (see Table 6) Spearman rank correlations (Zar, 1974) were also ran and since they had consistent results, the Pearson correlations were able to be reported. All values with a Significance F<.05 are reportable. Additionally, for all streams the linear regressions of the air temperatures were graphed with the stream temperatures and reported with the r^2 values in Appendix 3.

Max Min Air temp to Max Stream Temp:		
Stream	**Durbin-Watson**	**Prob<DW**
Calapooya	1.1412055	0.0175
Camp	1.3673099	0.0775
North Myrtle	1.9292353	0.4439
Pass	2.2280325	0.7075
Windy	2.1749377	0.6606
Max Max Air temp to Max Stream Temp:		
Stream	**Durbin-Watson**	**Prob<DW**
Calapooya	1.9328325	0.4126
Camp	1.8449049	0.3623
North Myrtle	2.1914873	0.6446
Pass	2.1067055	0.5935
Windy	2.6544141	0.9475
7DA Min Air temp to 7DAM Stream Temp:		
Stream	**Durbin-Watson**	**Prob<DW**
Calapooya	1.1797995	0.0255
Camp	1.1175855	0.0192
North Myrtle	1.9804191	0.4878
Pass	1.9362025	0.4297
Windy	2.0038415	0.5144
7DA Max Air temp to 7DAM Stream Temp:		
Stream	**Durbin-Watson**	**Prob<DW**
Calapooya	1.5392139	0.1405
Camp	1.5787019	0.187
North Myrtle	2.6794877	0.9455
Pass	1.7895684	0.3098
Windy	2.3019526	0.755

Table 7. Durbin-Watson test results for autocorrelation of the relationships to be analyzed (p>.05). Analysis conducted in JMP Statistical Software from SAS.

Results, Conclusions, and Future Studies:

The results in Table 8 indicate that for Calapooya Creek for both the maximum minimum stream temperature and 7DA minimum stream temperature had a stronger correlation with maximum stream temperature than the maximum and 7DA maximum stream temperatures. For Windy Creek, that was the same for the 7DA's only. Windy Creek had the least significant results and interestingly also had the highest variability in how many days before date of maximum stream temperature the maximum daytime and nighttime air temperature occurred. For North Myrtle Creek, the maximum and 7DA maximum air temperatures had a stronger correlation with stream temperature than the minimum and 7DA minimum stream temperatures. For Pass and Camp Creek, it was variable, with one parameter having a stronger effect for the 7DA's and one for non-averaged statistic. There was no relationship evident between drainage area or other site characteristics and a stronger correlation between the effects of minimum or maximum air temperature on stream temperature. There were mixed, site-specific results on whether there was stronger correlation between minimum (nighttime) or maximum (daytime) air temperature on maximum stream temperature.

Table 8. Pearson correlation coefficients for air temperature related to stream temperatures at reference sites. Analysis was conducted in Excel using the Analysis ToolPak.

MAXIMUM VALUES Effects on Max Stream Temperatures						**7DAM VALUES Effects on 7DAM Stream Temperatures**				
	Pearson Correlation Coefficient (r values)	**Significance F**	**Pearson Correlation Coefficient (r values)**	**Significance F**			**Pearson Correlation Coefficient (r values)**	**Significance F**	**Pearson Correlation Coefficient (r values)**	**Significance F**
Stream	**Max Min Air Temperature**	**Max Min Air Temperature**	**Max Max Air Temperature**	**Max Max Air Temperature**		**Stream**	**7DA Min Air Temperature**	**7DAM Min Air Temperature**	**7DA Max Air Temperature**	**7DA Max Air Temperature**
Calapooya	**0.55179**	0.00951	0.41889	0.05876		Calapooya	**0.65911**	0.00116	0.50849	0.01858
Camp	0.48558	0.02997	**0.75027**	0.00014		Camp	**0.61037**	0.00426	0.56139	0.01001
N. Myrtle	0.49130	0.02371	**0.70352**	0.00037		N. Myrtle	0.64113	0.00174	**0.71309**	0.00029
Pass	**0.71316**	0.00028	0.55514	0.00899		Pass	0.70469	0.00036	**0.80811**	0.00001
Windy	0.37469	0.11397	0.40132	0.08856		Windy	**0.58802**	0.00810	0.52396	0.02130
	Black - significant values (f<0.05)		Red - not significant values							
	Bold - the stronger relationship - minimum vs. maximum									

There are several other possible ways of analyzing this data in the future. Analyzing a longer period than just the week around max/7DAM stream temperatures would give a greater understanding of the differences in temperatures throughout the summer. Also, summarizing degree days or degree hours above a certain temperature instead of temperature would be a more detailed approach. Use the Mohseni method (Mohseni, *et al*., 1998) or Van Vliet method (Van Vliet, *et al.*, 2011) to look at maximum and minimum daily air temperatures and compare which on has the strongest influence would also be possible analysis tools. The Mohseni method is a nonlinear regression analysis of weekly air and stream temperatures. The Van Vliet method is also a nonlinear regression model, but incorporates air temperature and discharge on water temperatures. Surrogate discharge measurements would need to be used. In addition a principal components analysis such as the one in Isaak *et al.* (2018), could help to chase out which parameter has the strongest influence.

Understanding what influences stream temperatures is an important factor for aquatic resource specialists to be able to effectively manage streams and cold-water fisheries. The connection between nighttime temperatures and stream temperature is just beginning to be explored. While there was no general conclusion of a strong effect in the analysis performed in this study that does not necessarily indicate that there wouldn't be if the data were analyzed another way. There are many ways to compare the data that couldn't all be explored in this preliminary study.

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How to Obtain Data and Previous Reports:

This report; the annual reference temperature report updates (Smith, 2004-2005, Dammann and Smith, 2006, and Dammann 2007-2019); the data; and Umpqua Basin stream characterization study (Smith, 2003) are available through PUR or from Denise Dammann Consulting: ddammann@jeffnet.org.

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