# APPENDIX E TRIBUTARY ASSESSMENT METHODS AND RESULTS

# Temperature Analysis for Tributaries Discharging into the Columbia River

This appendix provides temperature data and model estimates for tributaries to the Columbia River; describes the seasonal variability in tributary temperatures across the study area; and provides information about potential cold water refuges. The potential for tributary discharges to provide cold water into the Columbia River was evaluated by comparing tributary and Columbia River temperatures at their respective confluences. Available monitoring data were used to assess current temperatures, and model estimates were used to evaluate potential changes to tributary temperatures due to climate change.

*Current Condition Analysis – June/July/August/September*

Mainstem Columbia River temperatures were obtained from the Columbia River Dart website (www.cbr.washington.edu/dart). Specifically, current Columbia River August stream temperatures were estimated from the available data for the 2011 through 2016 period (i.e., yellow dots in **Figure 1**). River temperatures for areas between these monitoring locations were derived by interpolation (i.e., black line in **Figure 1**).

Current mean monthly water temperatures for tributaries draining into the Columbia River were obtained from the USFS "NorWeST" Stream Temperature Modeling website (www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html) . Specifically, there are 202 named tributaries modeled by the NorWeST project that discharge into the Columbia River. Tributary discharge levels during the analysis period (June, July, August, and September) were obtained from the NHDPlus website (www.horizon-systems.com/NHDPlus/NHDPlusV2_17.php). Specifically, Average (1971-2000) monthly flows were derived from the Extended Unit Runoff Method (EROM) model in NHDPlusV2.

Results of this analysis indicate that, based on flow weighted average conditions, tributaries are generally warmer than the Columbia at their confluence with the Columbia River during the spring/early summer period, and subsequently "cool off" relative to the Columbia River later in the summer period (**Table 1**, and **Figures 1** through **4**).

*2040 and 2080 Condition Analysis - August*

Future August Columbia River Mainstem temperatures were derived from the reported observed range of the decadal temperature change rates along the Columbia River (i.e., 0.2°C to 0.4°C) (see Section 5.4.1 of the Columbia River TMDL). Specifically, the average of the reported decadal change rate, 0.3°C, was applied to current mainstem estimates proportion to length of time associated with each future scenario (e.g., 2040 water temperature increase was estimated as 0.78°C, which was calculated as 2.6 decades in the future times 0.3°C increase per decade, and using similar methods, the 2080 mainstem temperature conditions were estimated to increase 1.98°C above current conditions).

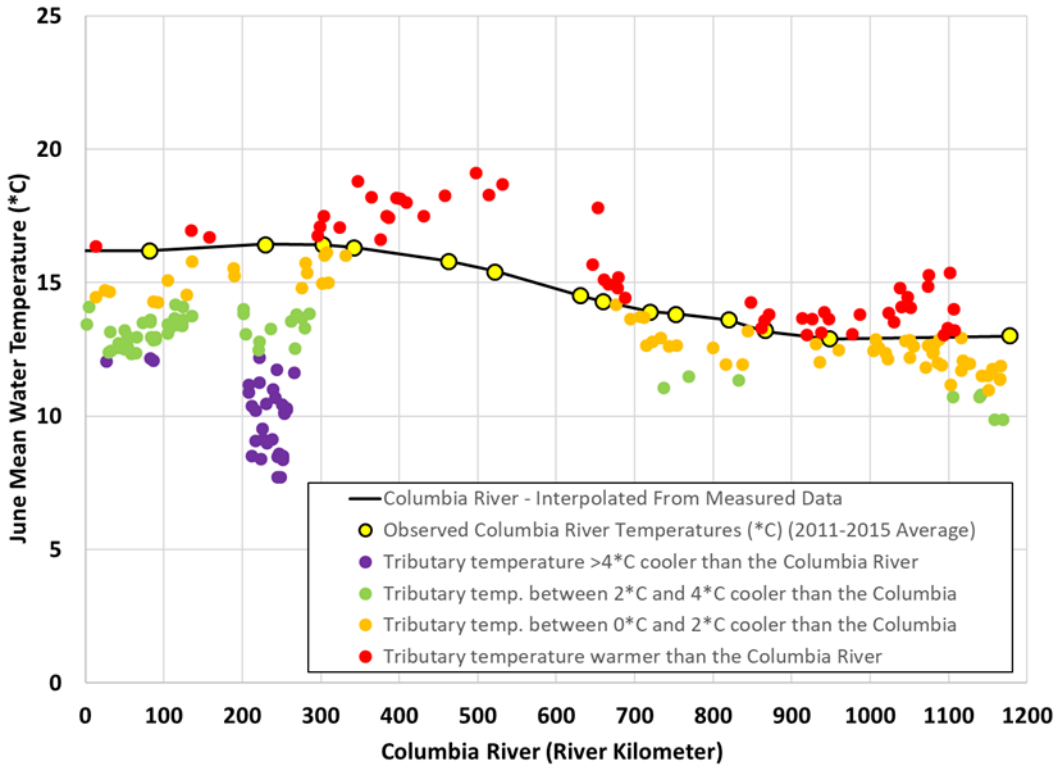
Estimates of future August tributary temperatures were obtained from a Spatial Stream Network (SSN) model developed by the USFS (www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html). Specifically, the SSN model estimated future temperature conditions based on global climate model projections, which were also adjusted for differential stream sensitivity: Future scenarios were based on global

climate model ensemble averages that represent the A1B warming trajectory for 2040's (2030-2059) and 2080's (2070-2099).

Results of this analysis indicate that future tributary temperatures are anticipated to increase between 0.6°C and 0.7°C relative to Columbia River temperature (**Figures 5** through **8**). In addition, many tributaries in the future, despite being relatively cooler than the Columbia River, could become warmer than the applicable water temperature standard and therefor would be less available to function as "Cold Water Refugia" (see Section 6.4.4 of the TMDL).

***Table 1.*** Tributary temperatures relative to mainstem Columbia River temperatures at their confluences from June – September. Negative differences indicate tributary temperatures are colder than the mainstem, positive differences indicate temperatures are warmer than the mainstem.

| | Proportion of Total Tributary Flow | Tributary Temperature Difference (°C) |
|---|---|---|
| **June** | | |
| **Flow Weighted Average of all Tributaries (N=202)** | **100.0%** | **1.2** |
| Snake River (N=1) | 52.6% | 2.8 |
| Willamette River (N=1) | 8.6% | 0.4 |
| Deschutes River (N=1) | 4.9% | 0.9 |
| Cowlitz River (N=1) | 4.7% | -0.9 |
| Okanogan River (N=1) | 4.4% | -1.1 |
| Flow Weighted Average of other 197 Tributaries | 24.8% | -1.0 |
| **July** | | |
| **Flow Weighted Average of all Tributaries (N=202)** | **100.0%** | **1.0** |
| Snake River (N=1) | 47.0% | 1.7 |
| Willamette River (N=1) | 9.7% | 1.3 |
| Deschutes River (N=1) | 6.5% | -1.4 |
| Cowlitz River (N=1) | 4.7% | 0.5 |
| Okanogan River (N=1) | 4.7% | 0.7 |
| Flow Weighted Average of other 197 Tributaries | 27.4% | 0.4 |
| **August** | | |
| **Flow Weighted Average of all Tributaries (N=202)** | **100.0%** | **-0.3** |
| Snake River (N=1) | 44.7% | 0.9 |
| Willamette River (N=1) | 14.8% | 0.9 |
| Deschutes River (N=1) | 7.7% | -2.3 |
| Cowlitz River (N=1) | 6.2% | -4.9 |
| Okanogan River (N=1) | 3.2% | 2.0 |
| Flow Weighted Average of other 197 Tributaries | 23.4% | -1.9 |
| **September** | | |
| **Flow Weighted Average of all Tributaries (N=202)** | **100.0%** | **-1.6** |
| Snake River (N=1) | 44.2% | -0.4 |
| Willamette River (N=1) | 18.8% | -0.2 |
| Deschutes River (N=1) | 7.4% | -4.1 |
| Cowlitz River (N=1) | 6.2% | -5.4 |
| Okanogan River (N=1) | 4.0% | -3.6 |
| Flow Weighted Average of other 197 Tributaries | 19.5% | -3.2 |


June Mean Water Temperature (*C)
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Columbia River (River Kilometer)
Columbia River - Interpolated From Measured Data
Observed Columbia River Temperatures (*C) (2011-2015 Average)
Tributary temperature >4*C cooler than the Columbia River
Tributary temp. between 2*C and 4*C cooler than the Columbia
Tributary temp. between 0*C and 2*C cooler than the Columbia
Tributary temperature warmer than the Columbia River

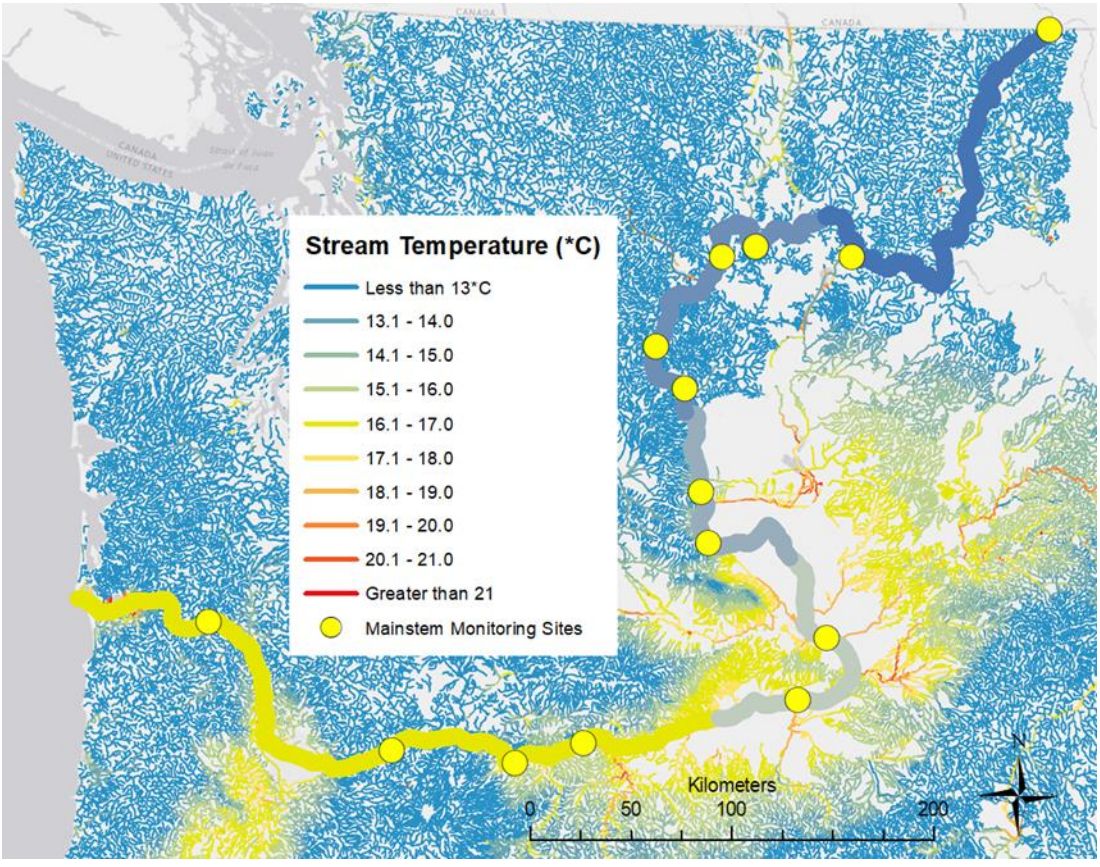
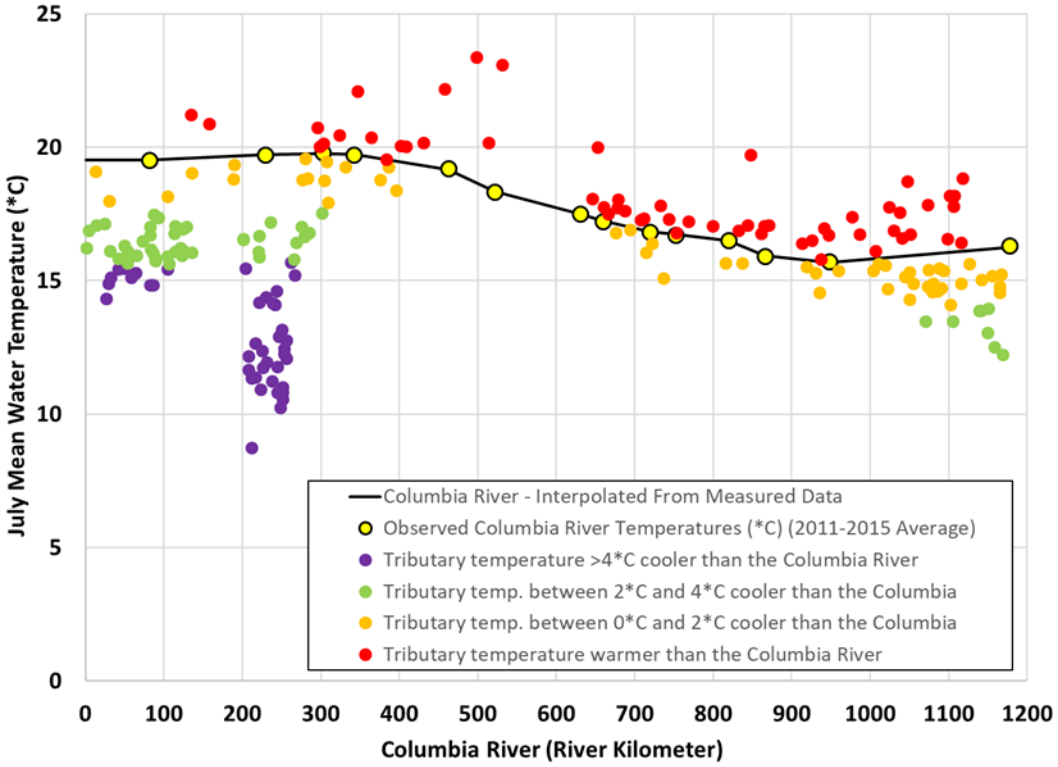

Stream Temperature (*C)
Less than 13*C
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
Greater than 21
Mainstem Monitoring Sites
Kilometers
0
50
100
200
N

***Figure 1.*** Columbia River and Tributary Confluence Monthly Mean Temperatures – June



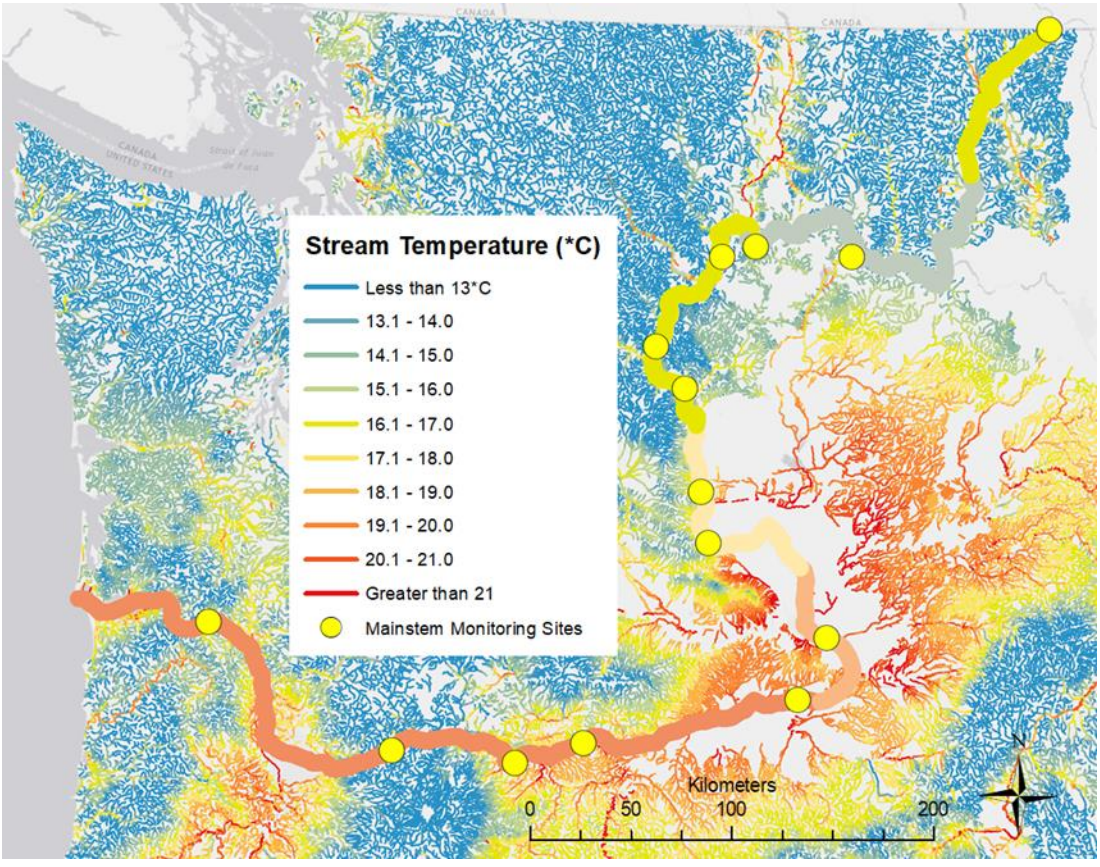
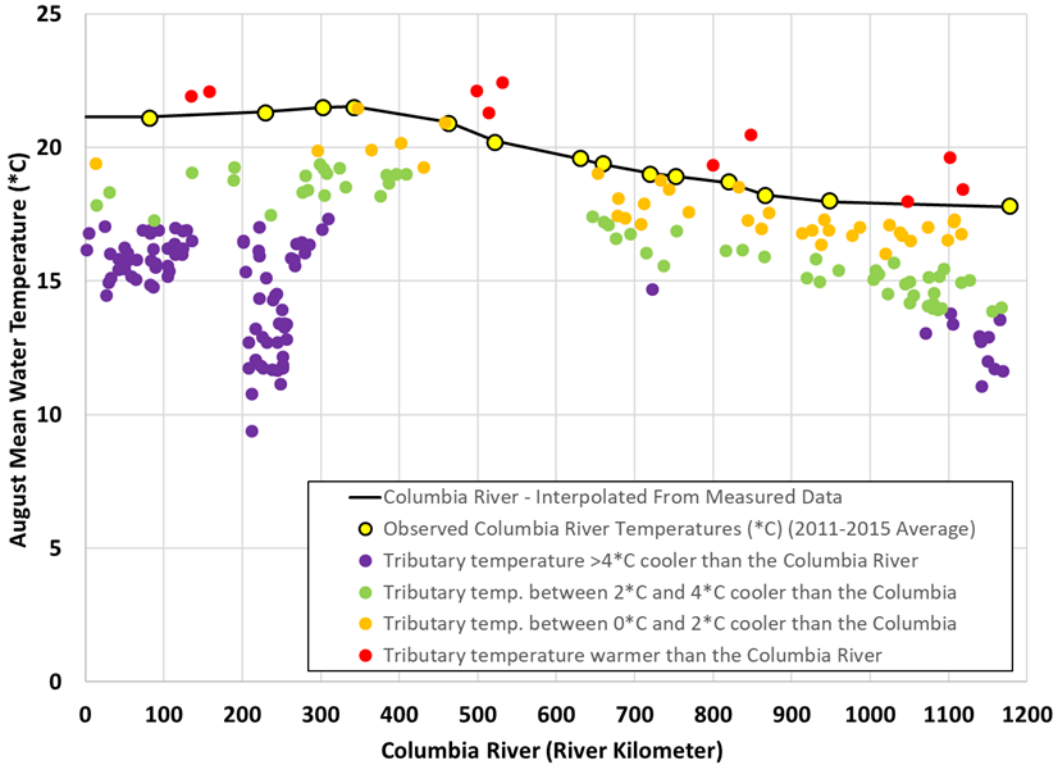



***Figure 2.*** Columbia River and Tributary Confluence Monthly Mean Temperatures – July



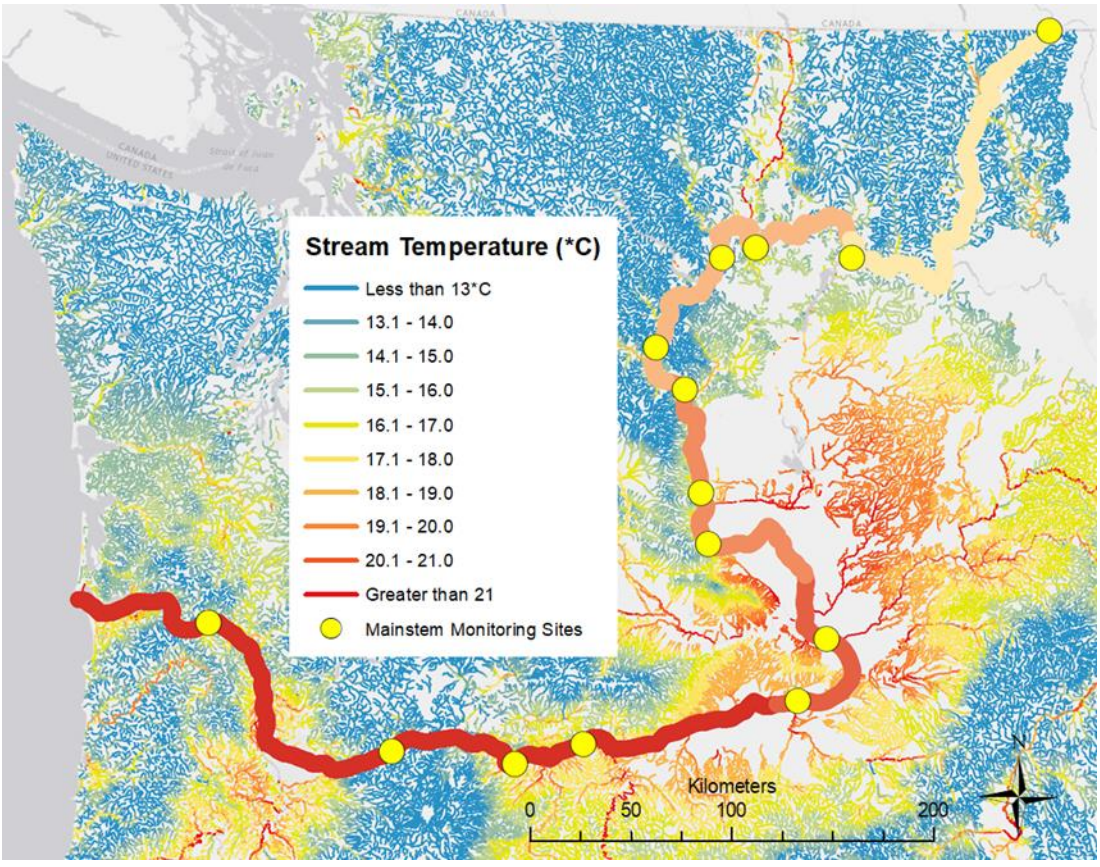
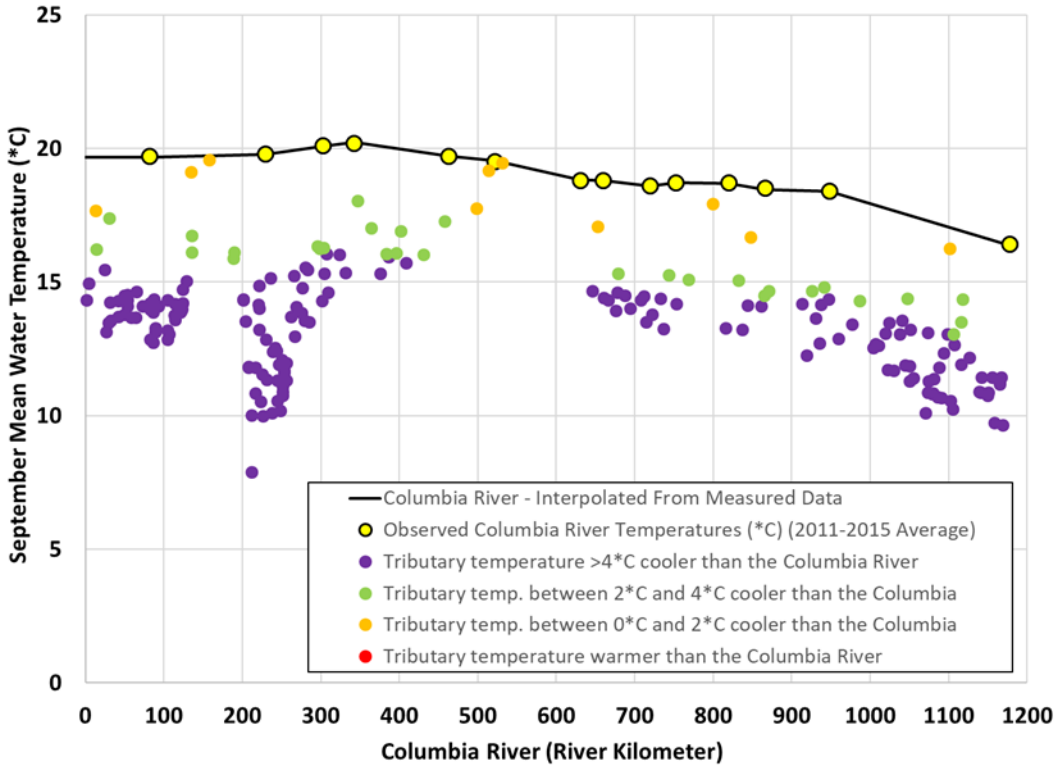



***Figure 3.*** Columbia River and Tributary Confluence Monthly Mean Temperatures – August



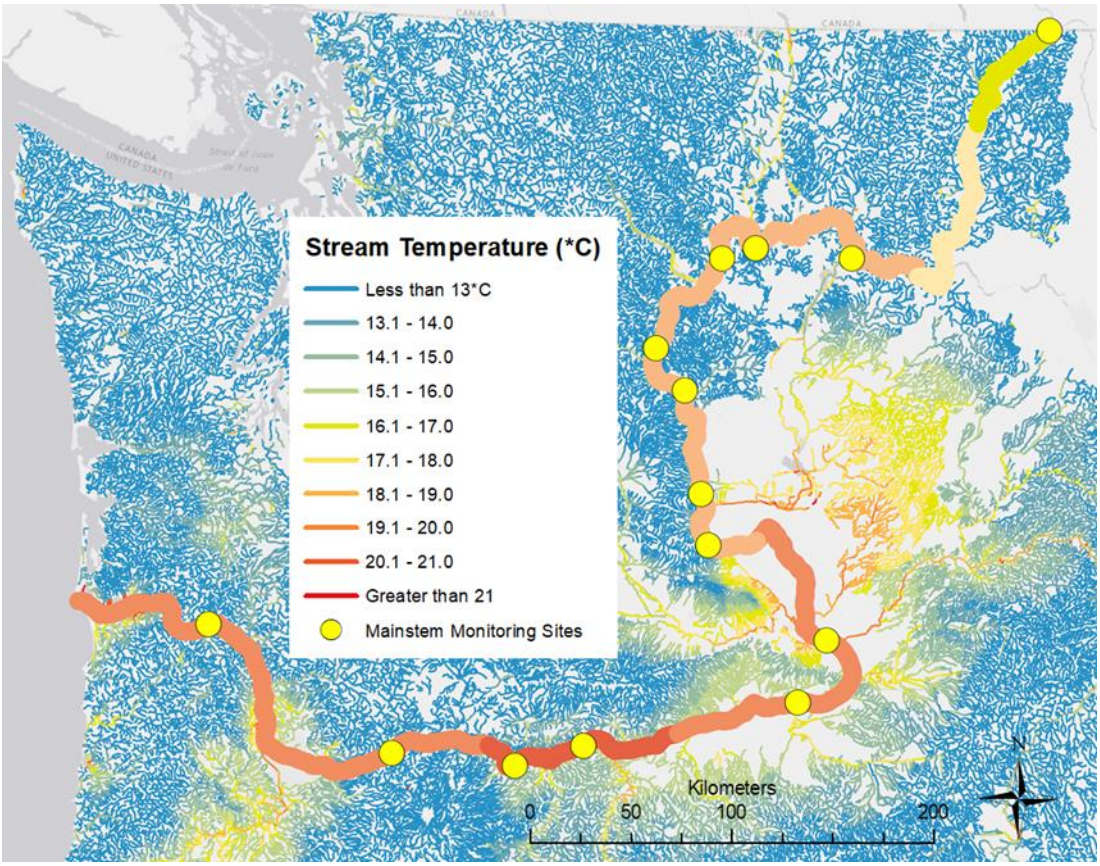
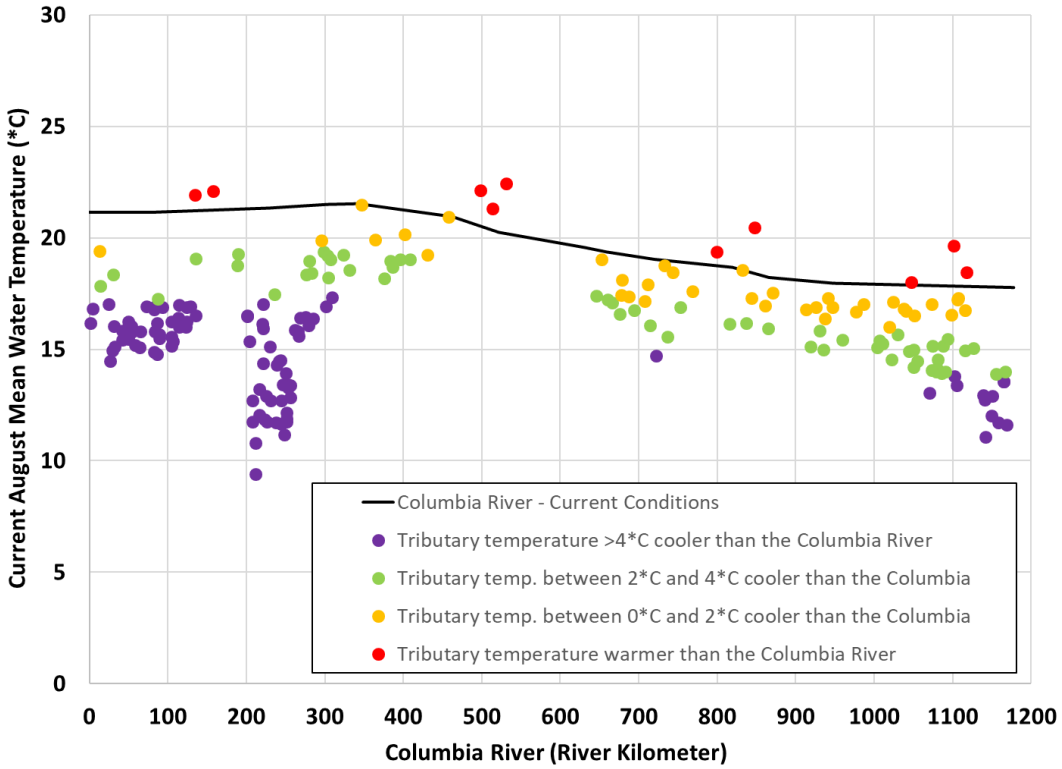



***Figure 4.*** Columbia River and Tributary Confluence Monthly Mean Temperatures – September



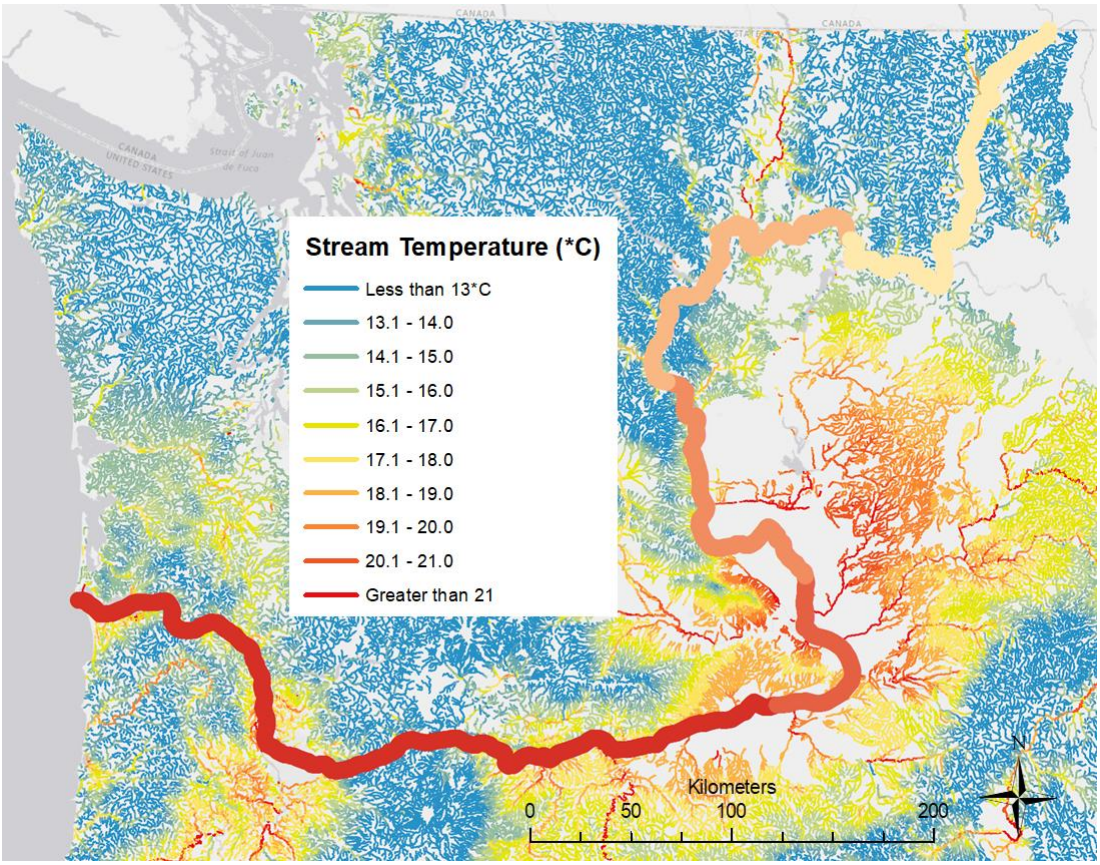
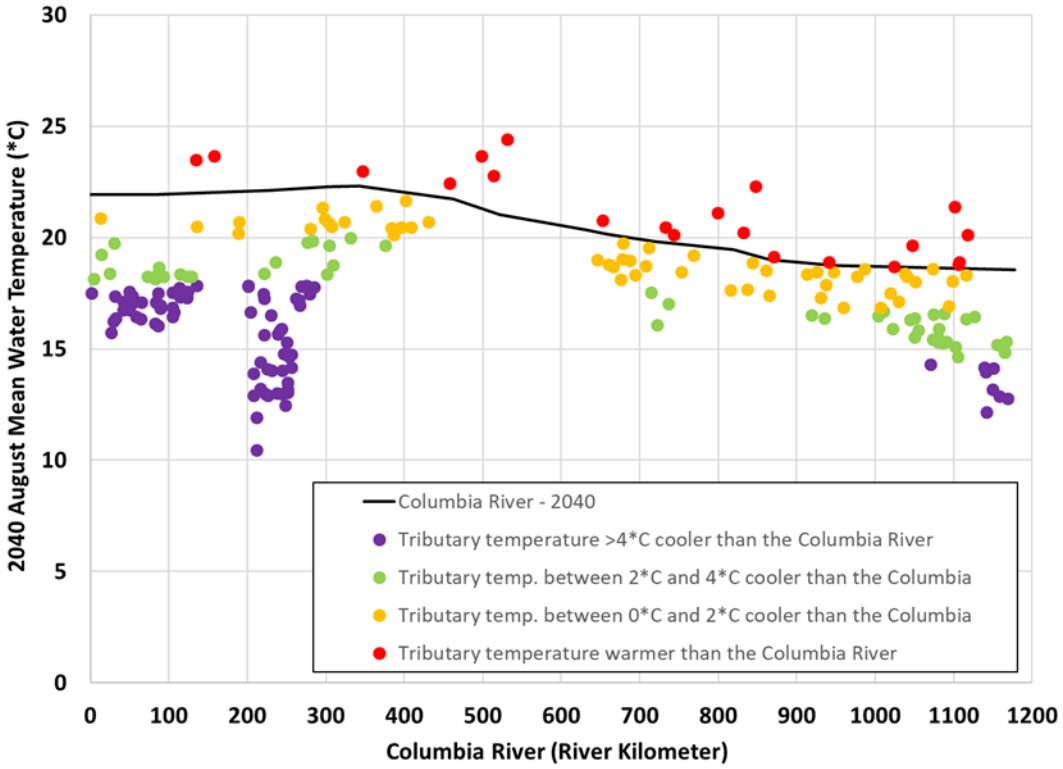



***Figure 5.*** Current Mean Temperature in the Columbia River and Tributaries – August



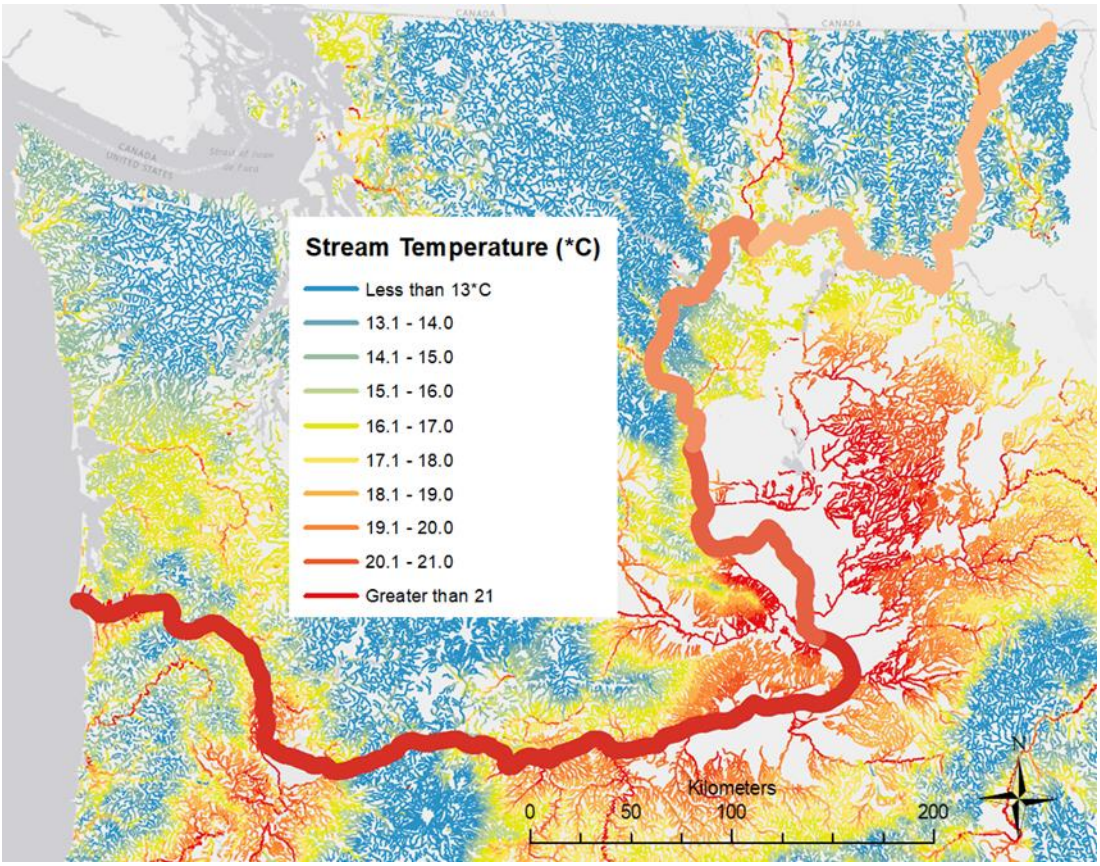
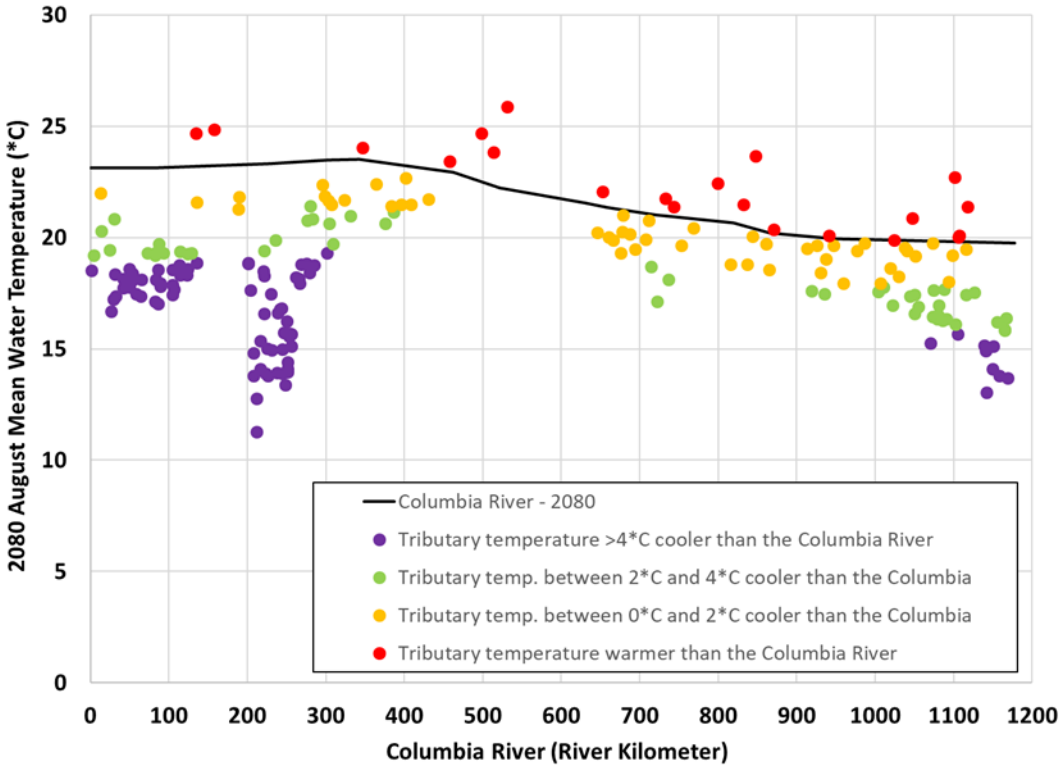



***Figure 6.*** Estimated 2040 Mean Temperature in the Columbia River and Tributaries – August



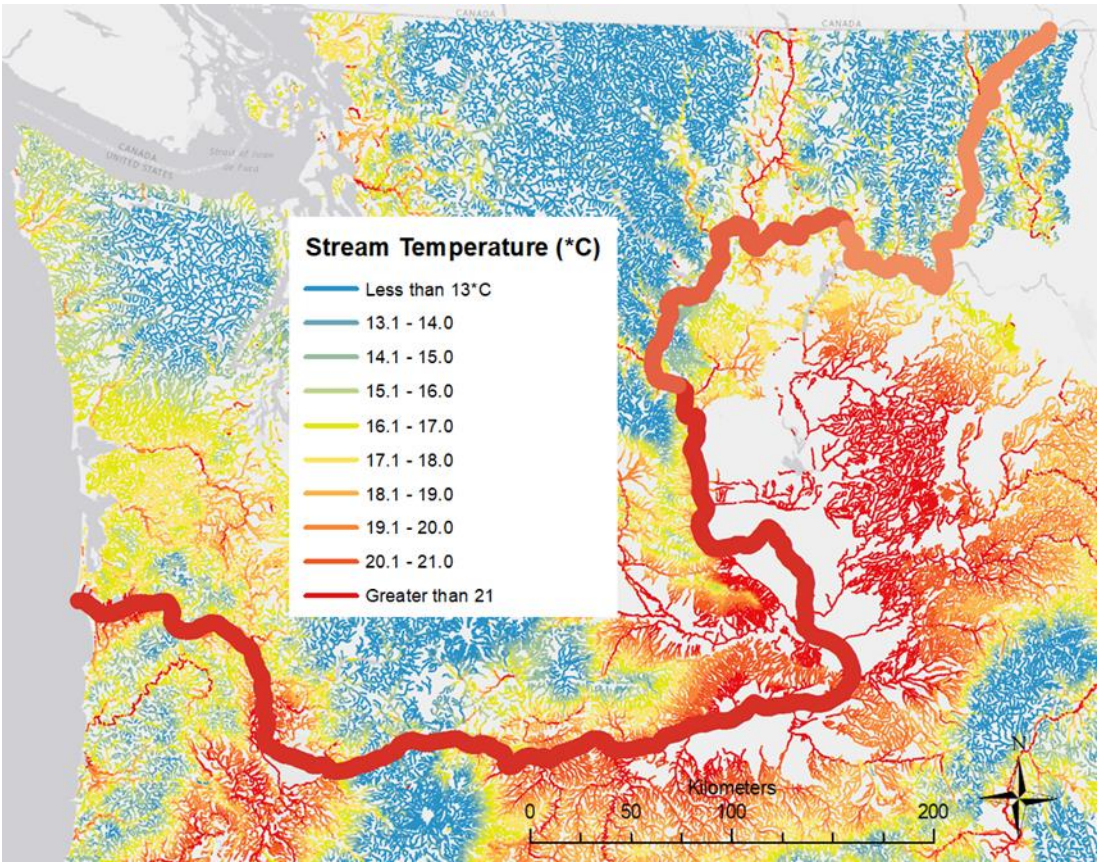



***Figure 7.*** Estimated 2080 Mean Temperature in the Columbia River and Tributaries – August

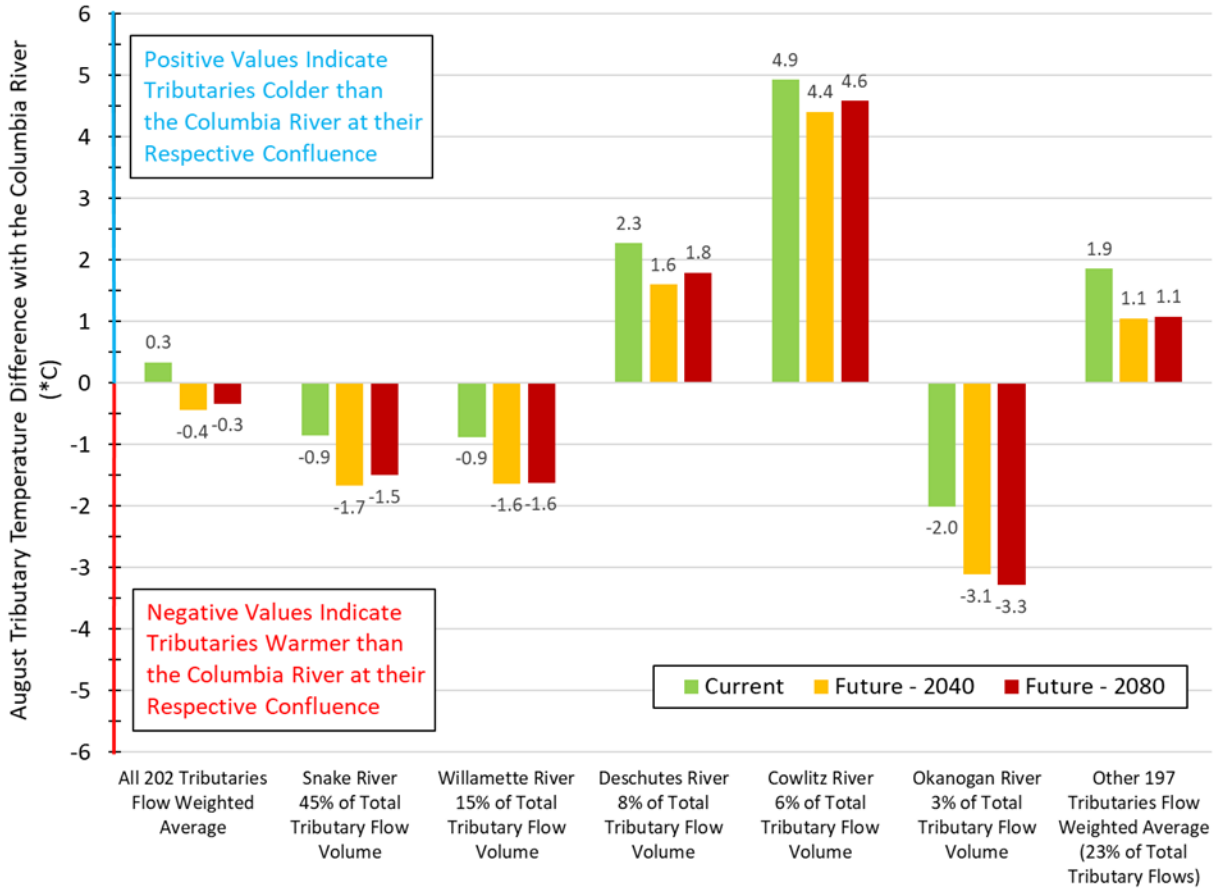



***Figure 8.*** Tributary Temperatures Relative to Mainstem Columbia River Temperatures at their Respective Confluences at current, 2040 and 2080 conditions.