
To: Blue River Watershed Group

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From: Peggy Bailey, PE
Ken Kehmeier, Ksqrdfish Aquatics LLC

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Subject: Influence of Temperature on the Fishery in the Blue River

Water temperature influences ecosystem function and aquatic diversity, because all life stages of fish and aquatic invertebrates are intricately linked to the thermal regime of a given environment. Water temperature is perhaps the single most important environmental parameter for fish (Magnusen et al 1979). Ambient water temperature drives fish survival (Brinkman et al 2013), behavior (Cook and Bergersen 1988, Rogers 1998), growth (Selong et al. 2001, Bear et al. 2007, Brinkman et al. 2013) and also is known to define the range a fish can occupy (Dunham et al. 2003, de la Hoz Franco and Budy 2005). Recently most temperature research has been associated with rising temperatures and the potential impact to river dwelling fish (Ficke et al. 2007, Wenger et al. 2011, Zeigler et al. 2019, Roberts et al. 2013), with less research on the impacts of cold water on fish habitat and fish populations (Coleman and Fausch 2007a, Coleman and Fausch 2007b, Mullner and Hubert 2005, Simpkins and Hubert 2000, Brown et al 2011). Temperature requirements of different life stages of brown trout have been studied by numerous researchers. (Raleigh et. al 1986, Elliot and Hurley 1999, Elliot and Elliot 2010).

Study Area

In 2020 temperature loggers were monitored at 8 locations between Dillon and Green Mountain Reservoirs. These temperature monitoring stations are a combination of loggers installed by Trout Unlimited (TU) in 2020 and loggers previously installed by the US Forest Service (USFS). Sites were selected based on a combination of factors including locations relative to tributaries, access and previous USFS temperature monitoring sites. Sampling sites also included one location upstream from Dillon Reservoir, and one sampling location downstream from Green Mountain Reservoir. The upstream site was selected as a reference location not impacted by Dillon Reservoir (DR). For the purpose of this report the upstream site and six sites between Dillon and Green Mountain Reservoirs were used for analysis as shown on Figure 1 and in Table 1.

In 2021 temperature loggers were again monitored at the same locations as 2020, however, data collected at the US Forest Service (USFS) sites, has not been made available for analysis.

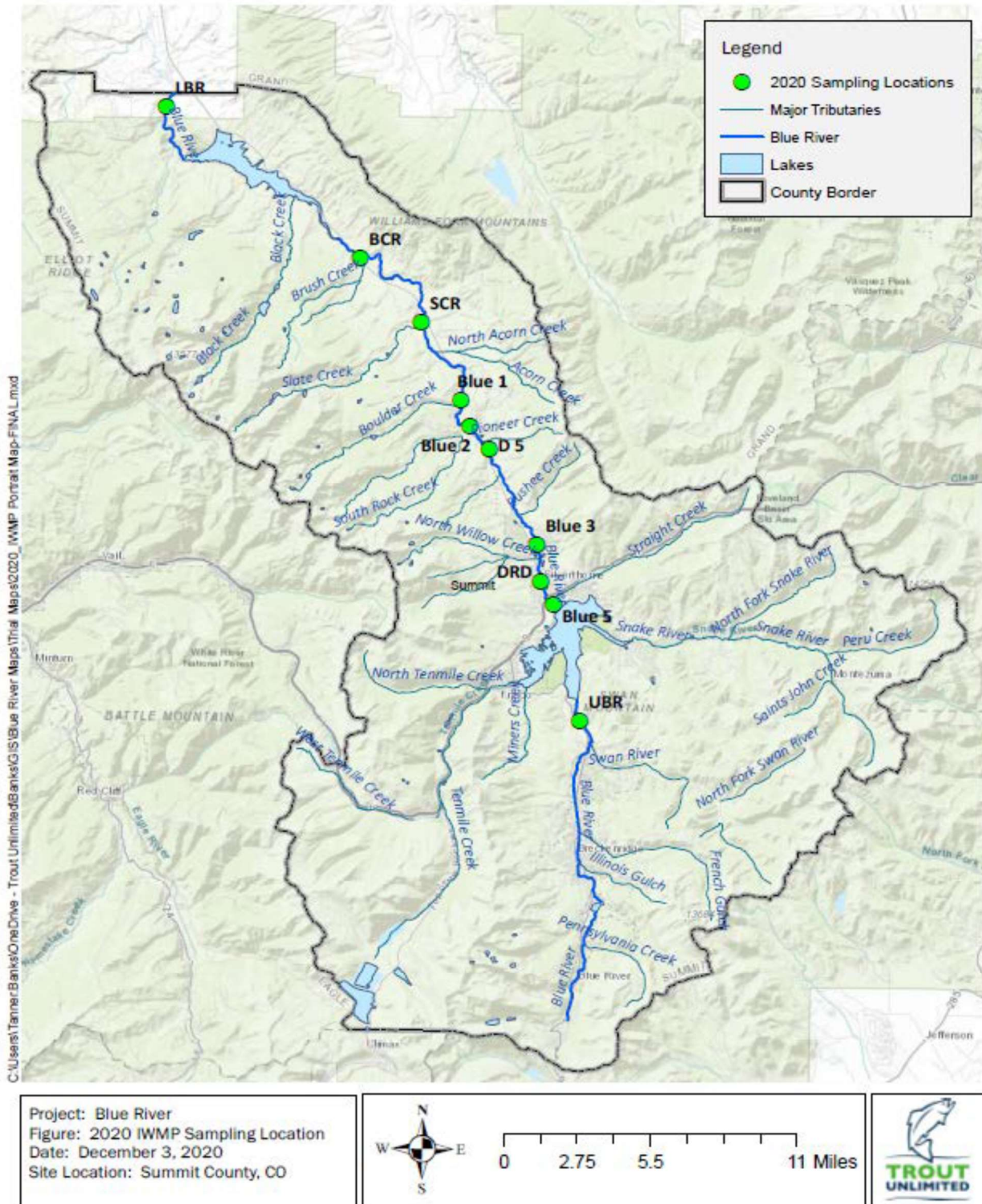


Figure 1. Map of the study sites used for temperature, macroinvertebrates, and periphyton in 2020.

Table 1. Coordinates and elevation for temperature sampling sites 2020 and 2021

| Site | Data Source | Description | Latitude | Longitude | Miles from Dillon Dam | Sampling year | |
|---------------|-------------|---|----------|------------|-----------------------|---------------|------|
| | | | | | | 2020 | 2021 |
| UBR | USFS | Immediately upstream of DR | 39.56651 | -106.04884 | - | √ | |
| Blue 5 | USFS & TU | Immediately downstream of DR | 39.62601 | -106.06658 | 0.4 | √ | √ |
| DRD | TU | At Dillon Ranger District in Silverthorne | 39.63651 | -106.07419 | 1.4 | √ | √ |
| Blue 3 | USFS | Downstream of Bald Eagle Drive | 39.65595 | -106.07685 | 2.9 | √ | |
| D5 | USFS & TU | Upstream of County Road 1870 | 39.70545 | -106.11062 | 7.3 | √ | √ |
| Blue 2 | TU | Downstream of Blue River Campground | 39.72713 | -106.1321 | 9.6 | √ | √ |
| Blue 1 | USFS | Downstream of Boulder Creek | 39.74336 | -106.13196 | 11.0 | √ | |
| SCR | TU | Slate Creek Ranch | 39.78226 | -106.1608 | 14.8 | | √ |
| BCR | TU | Upstream of GMR at Blue River State Wildlife Area | 39.8217 | -106.20584 | 20.1 | √ | |

Methods

Onset HOBO Water Temperature Pro v2 (Onset Corporation, Bourne, MA, USA) data loggers were deployed at all TU samplings sites in the spring of 2020. The data loggers were set to record water temperature every hour and data loggers were downloaded in late fall, and the information exported to files that could be analyzed by WaTSS 3.0 a water summary software developed by Colorado Parks and Wildlife. (Rogers K. B. 2015).

Hourly temperatures were analyzed into several temperature statistics. Daily temperature metrics were calculated from hourly daily temperatures. Monthly, growing season (May 1 to Oct 31) and comparative annual statistics (when available) were all calculated from daily metrics. Further analysis and graphics were completed in Microsoft Excel (2021). Several temperature metrics were calculated in consideration of aquatic biota. The maximum weekly temperature (MWMT) was calculated as a prediction of fish population persistence. Survival of brown trout is expected when MWMT is $<27.2^{\circ}\text{C}$. Optimal growth range for adult brown trout was found to occur when the MWMT is between 11°C and 19°C , with spawning occurring in the fall as day length shortens and temperatures decrease to $<9^{\circ}\text{C}$ (Range $2\text{-}13^{\circ}\text{C}$) and growth to 1-year from 7° to 15°C (Raleigh et.al 1986). The 30-day average temperature (M30AT) was also calculated as a measurement of potential fish production.

Degree day metrics are utilized to analyze the influence of temperature on various life stages of fish and can provide insight into potential impacts of temperature on invertebrates and periphyton. Degree day increases for each station was calculated for each site for the growing season of May 1 to October 31, providing insight into both emergence and growth and in 2021 for the full calendar year for insight on winter temperatures. Degree day metrics utilize a Daily Temperature Unit, which is equal to 1°F above freezing (0°C) for a 24 period. For example, if the average daily water temperature is 10°C , it would equal to 10 DTU ($10^0\text{-}0^0$) (Piper 1983).

Results for the 2020 and 2021 Temperature Sampling Season

The M30AT and MWAT for growing seasons in both years showed similar results with overall increases at the downstream sites, increasing with distance below Dillon Reservoir. Detailed analysis on the 2020 data showed the influence of reservoir spills with an immediate jump and drop in temperatures associated with surface spills from the reservoir. M30AT ranged from 10.2°C to 13.2°C , and MWMT ranged from 14.8°C to 17.3°C in 2020 and 14.4°C to 17.4°C and 9.2°C to 13.7°C in 2021 (Table 2). Warm water temperatures never approach critical levels (27.2°C) with respect to survival for brown trout. The Upper Blue River (UBR) values are not influenced by the spill event from Dillon Reservoir and also never approached critical levels (27.2°C) with respect to survival for brown trout in 2020.

Degree days calculated for May 1 through October increased moving downstream from Dillon Dam for both 2020 and 2021 consistent with the trends seen in the MWAT and M30AT. The 2020 and 2021 data degree days were also assessed for the full year beginning October 1, 2020 to September 30, 2021 and show a reverse trend with degree days dropping in the downstream direction. This shows the effects of cold reservoir releases in the summer that are slower to warm moving downstream. In the winter months, however, the releases are warmer than would occur naturally, and cool moving downstream and at some locations could be creating both frazil and anchor ices conditions before the stream is covered by sheet ice. The declining results in

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3801 Automation Way, Suite 100, Fort Collins, CO 80525

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degree day moving downstream could influence timing of brown trout spawning, egg development, hatching and overall growth and survival of brown trout in the Blue River below Dillon.

Table 2. Summary of the fish-temperature metrics for the Blue River. (M30AT = maximum 30-day average temperature, MWMT = maximum weekly mean maximum temperature). Accumulated Degree Day values include the influence of the Dillon Reservoir spill seen in 2020. All values summarize May 1 to October 31, 2020. *not influenced by reservoir spill

| Site | Temperature Metric, °C | | | | | | |
|--------|------------------------|------|-------|------|-------------------------|------|--------------------------|
| | MWMT | | M30AT | | Degree Days (May - Oct) | | Degree Days (Oct 1-Sept) |
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020/ 2021 |
| UBR | 14.8 | | 11.1 | | 1606 | | |
| Blue 5 | 15.7 | 15.5 | 10.2 | 9.2 | 1098 | 1028 | 2609 |
| DRD | 15.7 | 14.4 | 10.4 | 9.4 | 1176 | 1098 | 2536 |
| Blue 3 | 15.5 | | 10.5 | | 1260 | | |
| D5 | 16.8 | 16 | 11.5 | 11.4 | 1436 | 1492 | 2303 |
| Blue 1 | 16.2 | | 11.6 | | 1546 | | |
| B2 | | 16.8 | | 12.2 | | 1584 | 2291 |
| SCR | | 16.7 | | 12.9 | 1607 | 1678 | 2207 |
| BCR | 17.3 | 17.4 | 13.2 | 13.7 | 1759 | 1863 | 2363 |

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