Blue River Temperatures Analysis

Prepared For:

Blue River Watershed Group

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Introduction

The environmental effects of dams and impoundments that modify a wide range of abiotic and biotic factors downstream have been relatively well-documented and reviewed (Ward 1976, 1982, Baxter 1977, Ward and Stanford 1979, 1983, Schmidt and Wilcock 2008, Ellis and Jones 2013, White et al. 2016, Krajenbrink et al. 2019). The above published studies have shown that major downstream impacts of dams including, changes in flow patterns, riverine thermal regimes (depending on if dam releases are from the surface, bottom, or mixed), increased or decreased sedimentation, changes in water chemistry, alterations to the structure and function of benthic macroinvertebrate communities and associated stream fishery resources.

Water temperature essentially 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 monitored 8 locations between Dillon and Green Mountain Reservoirs. These temperature monitoring stations were a combination of temperature 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 location relative to tributaries, access and previous USFS temperature monitoring sites. Sampling sites also included one location upstream from Dillon Reservoir, and one below Green Mountain Reservoir Dam (Figure 1). However, for this report, due to loggers being lost or logger malfunction (after 2021) only five monitoring sites had partial or full data sets for analysis (Table 1).

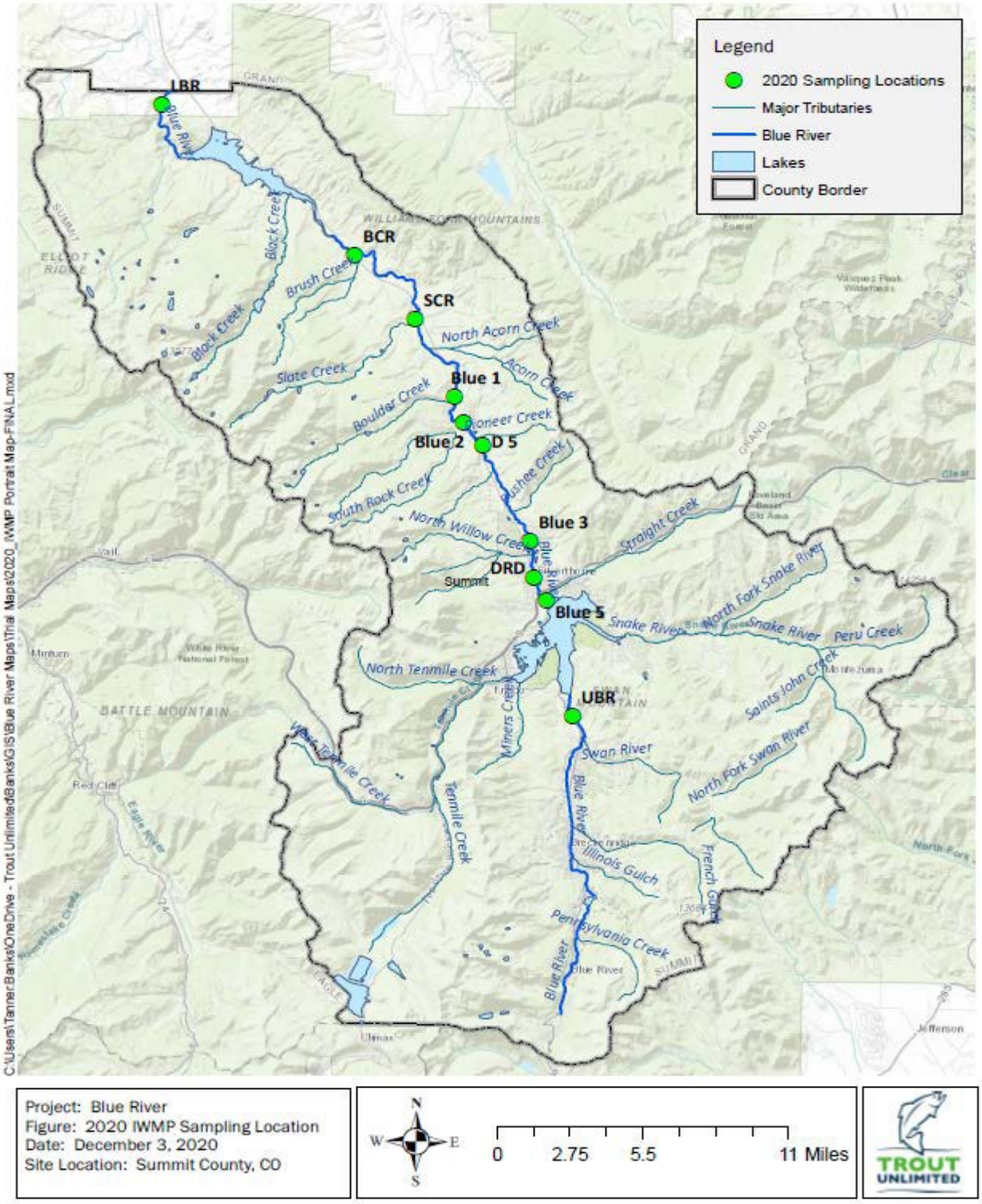

Figure 1. Map of the monitoring sites used for water temperature in 2020 (BRWG 2021).

Table 1. Coordinates and elevation for temperature sampling sites used in the Blue River temperature study. Location in gray scale were not used for this report due to loss, or damage, but are summarized in the Bluer River Integrated Water Management Plan Phase 1 Report (BRWG 2021).

Site	Description	Latitude	Longitude	Elevation (m)	Miles from Dillon Dam
UBR	Immediately upstream of DR	39.56651	-106.04884	2773	-
Blue 5	Immediately downstream of DR	39.62601	-106.06658	2684	0.4
DRD	At Dillon Ranger District in Silverthorne	39.63651	-106.07419	2675	1.4
Blue 3	Downstream of Bald Eagle Drive	39.65595	-106.07685	2647	2.9
D5	Upstream of County Road 1870	39.70545	-106.11062	2596	7.3
Blue 2	Downstream of Blue River Campground	39.72713	-106.1321	2575	9.6
Blue 1	Downstream of Boulder Creek	39.74336	-10613196	2558	11.0
SCR	Upstream of County Rd 1450	39.465614	-10693905	2502	14.8
BCR	Upstream of GMR at Blue River State Wildlife Area	39.8217	-106.20584	2443	20.1

Methods

Onset HOBO Water Temperature Pro v2 (Onset Corporation, Bourne, MA, USA) data loggers were deployed at samplings sites in the spring of 2020. The data loggers were set to record water temperature every hour and data loggers were downloaded yearly in late fall except for 2022. 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 temperatures with all comparative annual statistics calculated from daily metrics. Further analysis and graphics were completed in Microsoft Excel (2021). Several temperature metrics were calculated in consideration of aquatic biota.

Results and Discussion

The thermal regime of the Blue River follows the same patterns between years at individual sites as well as longitudinally moving downstream (Figure 2). The spilling of Dillon Reservoir appears to influence the timing of Blue River temperature increases but does not change the maximum temperature or the duration of warmer water downstream of the reservoir. This is evident with years with spill events(2020,2021,2023) not having significantly different temperature progressions moving downstream than a non-spill year like 2022.

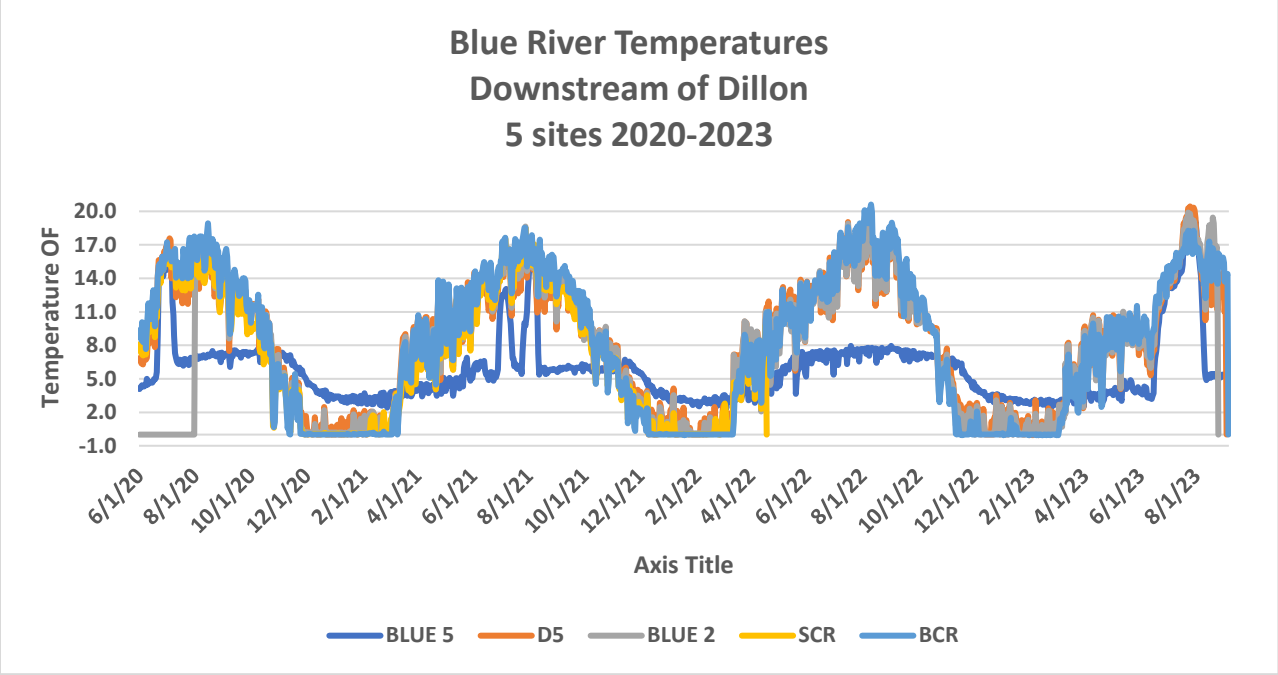

Figure 2. Blue River temperatures collected at the 5 sites downstream of Dillon Reservoir. Data is from June 1, 2020 to August 9,2023

The surface release associated with a spill event increases overall maximum water temperature as well as daily average water temperature just downstream of the dam, however that impact diminishes the farther you move from the release point. In 2020, at the temperature monitoring site (Blue 5), 0.4 miles downstream, between June 17-19, 2020, increased 13.5^0 C (0.56 ^{0}C/Hour) and again on July 4-10 with a decrease of 19.9^0 C (-0.28^0 C/hour), coinciding with the increasing and decreasing discharge associated with the surface releases from Dillon Reservoir. This sudden change in temperature and the associated discharge has been shown to limit survival of brown trout and aquatic invertebrates (BRWG 2021). Denver Water working with the Blue River Watershed Group agreed to attempt ramping rates in 2023 for the Dillon Reservoir spill events. The Blue 5 monitoring station between June 7 to July 4 temperature increased 12.1^0 C (0.02^0 C/Hour) and again on July 7 to July 18 decreased 9.9 ^{0}C (0.03 ^{0}C/Hour) (Figure 3). This approach of limiting temperature increases and decreases associated with the spill of Dillion Reservoir should provide aquatic organisms with less stress due to temperature shock and only have to deal with flow changes.

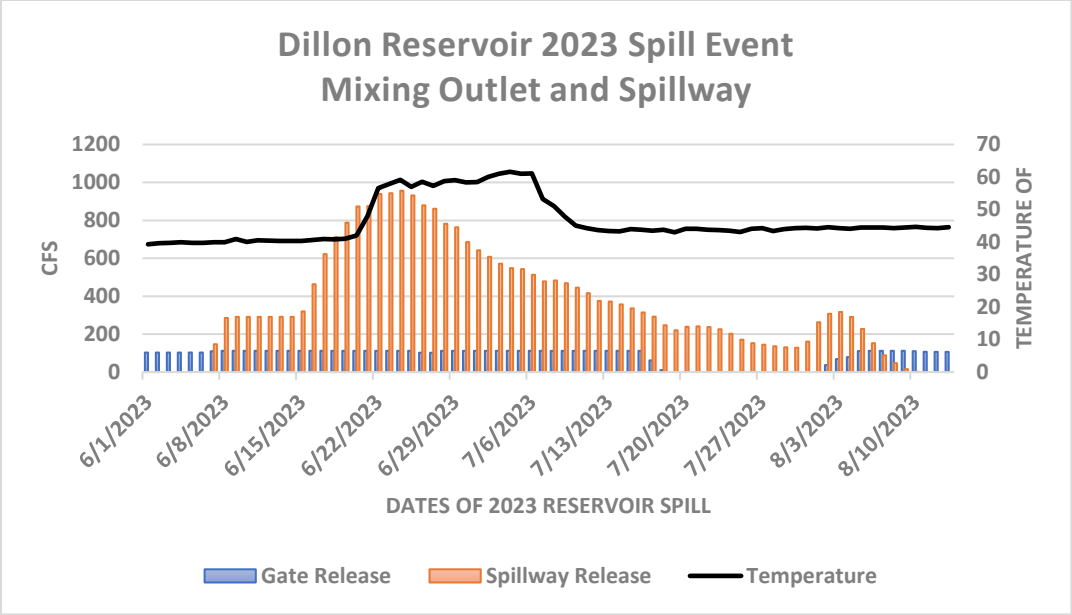

Figure 3. Dillon Reservoir 2023 spill event with flow information showing the mixing of spillway and gate releases and associated water temperature at 0.4 mile below the dam. Completed to avoid simultaneous increases of both stream flow and temperature.

Table 2. shows the yearly minimum, maximum, average temperatures, and the average temperature for the May through October growing seasons for the Blue River in 2021 and 2022. The May through October average temperature is more realistic of temperatures on in the Blue River, with minor increases the farther away from Dillon Reservoir. The yearly average water temperatures and minimum yearly temperature are being influenced by reservoir releases or the very low reading through most of the winter. Downstream loggers may be impacted by freezing conditions or ice. If this is not the case, these very low temperatures are negatively impacting aquatic organisms. Dillon Reservoir spilled in 2021 but not in 2022, which has a dramatic influence on the maximum temperature at Blue 5, which is closes to the dam. By the time the river reaches D5 and below the temperature influence of spilling Dillon Reservoir does not appear to significantly impact stream temperatures. At these lower sites maximum yearly temperatures appear to be less affected by reservoir spill temperatures and more influenced by local conditions and tributary flows. In all cases maximum yearly temperatures occur from mid-July and mid-August. The May through October temperatures show some minor fluctuations from upstream to downstream.

Table 2. Recorded daily minimum, maximum and average temperatures in 2021 and 2022 for the Blue River between Dillon Reservoir and Green Mountain Reservoir. Also presented are the number of days that a temperature logger is recording temperatures below 0.3^0 C.

Site	Blue 5		D5		Blue 2		SRC		BCR	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Year Min.	2.4	2.4	0	0	0.1	0.1	0		0	-0.1
Year Max.	19.1	8.0	17.4	19.0	18.6	19.0	18.5		18.5	20.6
Yearly Ave.	4.5	4.1	5.4	5.5	5.5	5.5	5.7	-	6.1	5.9
Days <0.3 ^{0} C	0	0	38	54	100	63	66		86	131
May-Oct Ave	6.8	7	12.9	12.1	12.1	12.4	12.5	-	13	12.9

Water temperatures in the Blue River are influenced on yearly basis by changes in yearly snowfall and variable seasonal weather and the hypolimnetic release from Dillon Reservoir. One year of information on Willow Creek, a tributary to the Blue River, which has its confluence between Blue 5 and D5 does not provide much information on the influence of the tributaries to the Blue River temperatures (Table 3). Of the temperature metrics presented in Table 3, M30AT is the most relevant metric for growth and recruitment in fish (Roberts et al. 2013) and describes the average temperature of the warmest month. Coleman and Fausch (2007a, 2007b) suggest that for cutthroat trout an M30AT<8 °C will result in no recruitment, and that M30AT>9 °C is required for robust recruitment to occur.

Hypolimnetic release reservoirs, like Dillon Reservoir, alter the natural temperature regimes downstream resulting in warmer-than-natural winter (November to March)water temperatures, and colder than normal temperatures in the summer and fall (April to October) (Figure 2). The Dillon Dams' influence on temperature extended downstream approximately 3 miles (Blue 3) where the effect of the hypolimnetic release was lost. Temperature monitoring in 2020 also indicates these temperatures remain cold and below the temperatures of the river upstream (UBR) of Dillon Reservoir for at least the first 10 to 11 miles downstream (D5 or Blue1)(Figure 4) (BRWG2021).

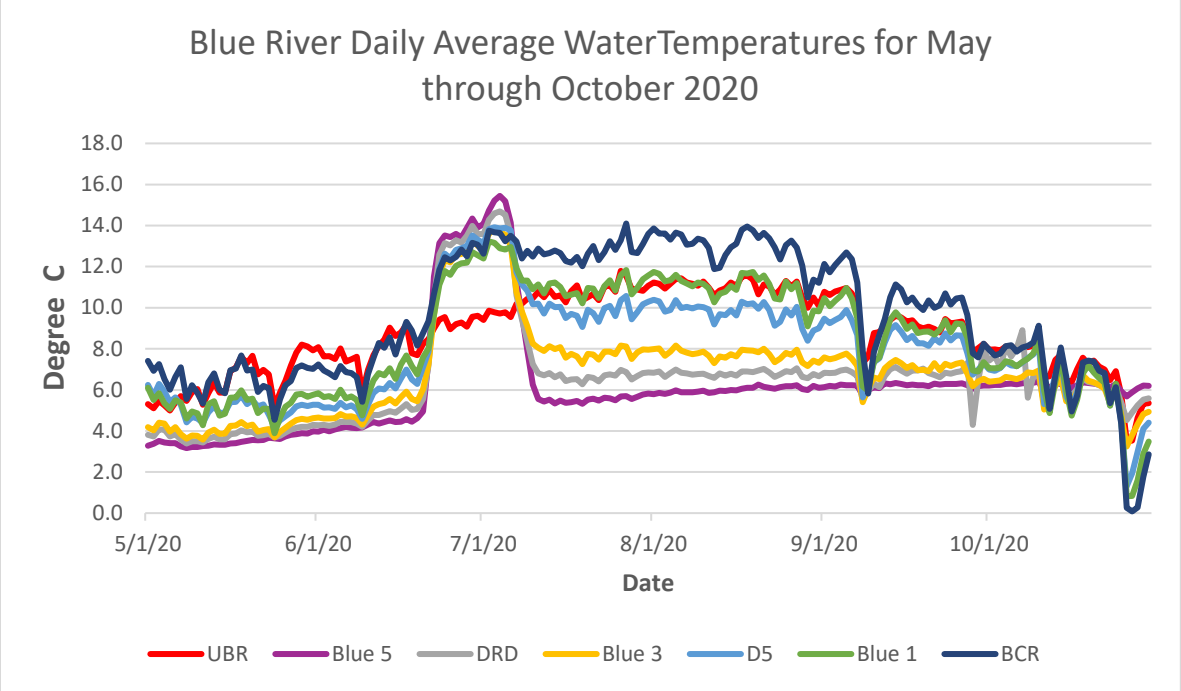

Figure 4. A comparison of temperatures above and below Dilon Reservoir between May and October 2020, noting the influence of the hypolimnetic release on the downstream Blue River.

	Temperature Metric							
Site	**MWAT**		**MWMT**		**M30AT**		**Degree Days**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Blue 5	15.1	6.1	15.5 ^{0} C	7.7	9.9	5.9	2575	2342
D5	13.7	12.5	16.0	17.3	11.4	12.1	2444	2320
Blue 2	13.7	13.5	16.8	17.6	12.2	12.9	2439	2250
SCR	13.8		16.7		12.9		2321	
BCR	14.5	15.8	17.4	19.6	13.7	14.9	2455	2214
Willow Ck.		11.9		14.5		11.4		1431

Table 3. Temperature metric for the Blue River for 2021 and 2022. . (MWAT= maximum weekly average temperature, MWMT = maximum weekly mean temperature, M30AT = maximum 30-day average temperature). All temperature metric values include a reservoir spill event in 2021 and a non-spill year in 2022.

Temperatures downstream of Dillon Dam are impacting spawning, recruitment and growth of fish in the river. M30AT results for Blue 5 shows very limited recruitment could be expected in spill years and year class failures could happen in non-spill years. This lack of recruitment should be less of a concern downstream of D5 or approximately 7 miles downstream of the dam (Table 3)

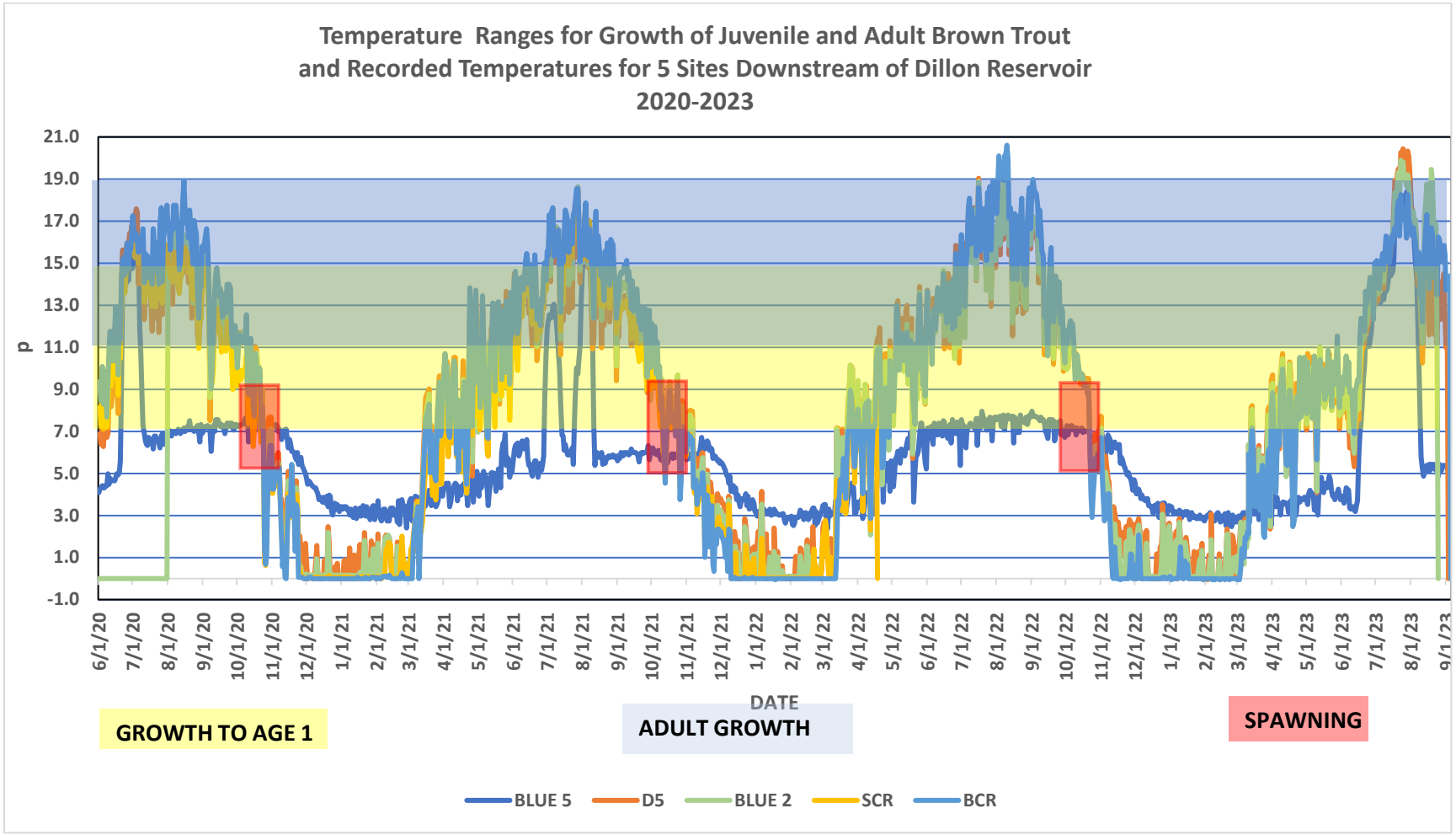

Figure 5. Blue River average daily temperature with growth and spawning temperature requirements and known range of dates those temperatures are needed for adult growth, growth to age 1 and spawning. Temperature ranges from Raleigh et. al 1986.

Temperature data shows the Blue River has little to no warm temperature standard exceedances but can often be very cold, dropping below narrative standards established by the USFWS for support of brown trout (Raleigh et al, 1986). Downstream of the Dillon Dam for what is suspected to be approximately 3+ miles, the Blue River is below narrative standards recommended by USFWS for brown trout. At site Blue 5, river temperatures fail to warm up into the known temperature range for brown trout growth of age 1 except for a few weeks in mid-summer and during spill events. And only during spill events does the river temperatures provide potential growth for adult fish, not considering the flow changes associated with spill events (Figure 5, Table 4). Downstream approximately 7 miles (Site D5) to Green Mountain Reservoir, spring to early fall water temperatures are in the range that provide potential conditions for growth of all life stages of brown trout, including spawning which occurs in October-November when water temperatures are decreasing past 9° C. Potentially concerning are the low temperatures reaching <3° C except Blue 5 during the winter. If these are valid and not loggers being influenced by ice, winter temperatures could be limiting trout populations. Degree days (Table 3) remain relatively unchanged downstream of Dillon Reservoir Dam. In a natural river you would see increases in degree days as river temperatures warmed moving downstream. Table 4 provides the number of days at each site that temperatures are within the range recommended for brown trout. It also provides the number of days where water temperatures were recorded to be less than 0.3° C.

	Site									
	Blue 5		**D5**		**Blue 2**		**SCR**		**BCR**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Adult Growth Days 11-19°C	0	0	130	136	136	133	122	-	148	132
Growth To Age 1 Days 7-15°C	*28*	*110*	*185*	*151*	*167*	*144*	*154*	-	*149*	*128*
Cold Days <0.3°C	0	0	38	54	100	63	66	-	86	131

Table 4. Number of days per sited by years where Blue River average daily temperatures met the recommended standard for brown trout growth for adults (11-19°C)and juveniles up to age 1 (7-15°C). Also, the number of days per site by year where average daily temperatures did not exceed 0.3°C.

Recommendations for continued temperature monitoring

Water temperatures in the Blue River downstream are one of the variables limiting trout fisheries downstream of Dillon Dam. Temperature monitoring will continue to be important in the coming years to monitor projects which will be occurring associated with the implementation of Integrated Water Management Plan and other restorations projects within the Blue River Basin.

- Continue to work with Denver Water to formalize ramping rates that mix flows from the outlet gates and the spillway to mitigate temperature fluctuations that could benefit downstream fisheries and potentially aquatic invertebrates. Evaluate with temperature monitoring and invertebrate sampling.
- Visit and reposition if needed all temperature loggers to ensure icing and desiccation does not impact data collection.
- Determine if cold winter temperatures are limiting fisheries.
- Replace logger between Blue 5 and D5 to provide a more continuous temperature profile for the Blue River below Dillon Reservoir. This is a priority so potential changes to habitat or flows can be evaluated.
- Replace the logger upstream of Dillon Reservoir to provide a temperature profile for the Upper Blue River not impacted by a reservoir.
- In addition to Willow Creek, add loggers to select other significant tributaries that could influence Blue River temperature regimes.

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