USING STREAM TEMPERATURE PROFILES TO REFINE MANAGEMENT OPTIONS IN FIVE NEW HAMPSHIRE WATERSHEDS (2010-2016)

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INTRODUCTION

The New Hampshire Fish and Game Department (NHFGD) deployed water temperature loggers in the Beebe River, Jewell Hill Brook, McQuesten Brook, and Winnicut River watersheds during the summer of 2016. Prior to making management decisions or initiating restoration projects, it is important to understand water temperature profiles for those rivers and streams sustaining or having the potential to sustain populations of salmonids. It has clearly been shown that water temperatures influence growth, behavior, survival, and distribution of trout and salmon (Cunjak and Green 1986, Ebersole et al. 2001, Selong et al. 2001, Workman et al. 2002). The objectives of this study were to (1) examine stream temperature ranges during the months of July and August; and (2) determine the duration and extent of stream temperatures considered lethal to sub-lethal for salmonids ($\geq$ 21.1°C). Existing NHFGD stream temperature information that corresponds with fish species presence data was also employed to evaluate the likelihood of young-of-the-year wild Brook Trout (*Salvelinus fontinalis*) being present.

STUDY AREAS

Beebe River Watershed

The Beebe River Watershed drains 81.7 km^2 in the towns of Campton and Sandwich before flowing into the Pemigewasset River. An ongoing land protection effort targeting an area of 25.8 km^2 in conjunction with existing conserved land in the White Mountain National Forest will result in 58% of the entire drainage to be protected from forest conversion and development. NHFGD has partnered with a local Trout Unlimited chapter, The Conservation Fund, Trout Unlimited National, Natural Resource Conservation Service and the towns of Campton and Sandwich to initiate aquatic habitat restoration projects within the parcel of land to be protected. Five culvert replacements on study tributaries, two road relocations, and approximately 5 miles of road restoration are occurring in 2017 within the recently protected property. Fish community and habitat condition assessments have occurred annually in this watershed since 2014. In 2016, 17 thermographs were deployed in the mainstem Beebe River (3 locations) and tributaries (14 locations) within or adjacent to the land parcel recently protected. To examine any influence on water temperature in tributaries (GR1, GR2, GR3 and GR4) from a powerline path, thermographs were deployed above and below the cleared riparian areas in those tributaries. There are two sections of GR5 that flow under the powerline clearing. In this case, thermographs were deployed upstream of the first clearing, immediately downstream of the first clearing, and further downstream before the second powerline encroachment area. One of the thermographs deployed in a tributary (GR3-Upper) was inappropriately programmed to collect water temperature at daily intervals. This thermograph was excluded from analysis.

Jewell Hill Brook

The Jewell Hill Brook Watershed drains an area of 3.4 km^2 in the town of Stratham before flowing into the tidal area of the Squamscott River. A population of wild Brook Trout was documented in this stream in 2015. Two thermographs were deployed in this stream in 2016 (downstream of the Rt. 33 crossing (more upstream location) and upstream of the influence of a large head-of-tide beaver pond (more downstream location)) to develop a better understanding of the habitat suitability for wild Brook Trout. Given that Jewell Hill Brook flows into a marine (saltwater) habitat, there is potential for a salter population of wild Brook Trout to either exist or be created. Future fish community and habitat assessments are planned for this stream.

McQuesten Brook

McQuesten Brook is a small tributary to the Merrimack River that flows through urbanized areas of Manchester and Bedford before entering the Merrimack River. The headwaters of the stream have been covered and leveled to facilitate residential and commercial development making an estimation of the overall watershed size difficult. The stream originates from a culvert structure at a change in elevation on the eastern side of South Main Street in Manchester. Despite intense alterations to the surrounding landscape, a wild Brook Trout population exists here. A partnership between the New Hampshire Rivers Council, the New Hampshire Department of Environmental Services (NHDES), NHFGD, the towns of Bedford and Manchester, and two local angling groups was formed in 2010. A watershed restoration plan that promotes actions that would ensure the sustainability of the wild Brook Trout found here has been completed. Several restoration activities were initiated in 2016. An undersized crossing was replaced by a bridge, another stream crossing was completely removed and day lighted and four impoundments were breached. Future monitoring (including water temperature monitoring) will evaluate results of these activities.

In 2016, thermographs were deployed at the origin of McQuesten Brook in Manchester ("Below South Main St"), upstream and downstream from the Second Street crossing, and downstream from the former Wathen Road crossing in Bedford. The thermograph deployed below the former Wathen Road crossing was lost in a significant sediment deposit, likely associated with upstream stream crossing and dam removal activities. Temperature parameters from 2016 are also compared to profiles recorded between 2010 and 2015.

Thompson Brook

The Winnicut River Watershed is approximately 45.4 km^2 (17.5 mi^2) that enters into the Great Bay Estuary after draining parts of Exeter, Greenland, Hampton, North Hampton, Stratham, and Portsmouth. A head of tide impoundment on the Winnicut River was removed in 2010. Emphasis of temperature monitoring was placed on Thompson Brook, a tributary with a watershed size of 3.3 km^2 (1.3 mi^2) which enters the Winnicut River approximately 1 mile upstream from the former impoundment. Restoration efforts to enhance wild Brook Trout habitat in this stream have recently been initiated. In 2016, a thermograph was deployed in Thompson Brook below the Winnicut Road stream crossing. Water temperature at this location has been monitored annually since 2011.

METHODS

Optic StowAway thermographs (Onset Computer Corp©) were deployed in the locations previously described (Table 1). Thermographs were programmed to record temperature values at 1-hour intervals. When available, temperature data from 2016 is compared with collected temperature data from previous years. In this report focus was placed on water temperature values for the months of July and August because these are the two months where water temperature and subsequent stress on cold water fish species is expected to be the greatest. Additionally, since salmonid stocking generally ends in June in southern New Hampshire, an analysis of July and August water temperatures will be useful to determine the survivability and "hold-over" capability of stocked salmonids. The units were housed in a protective case made of 1.5 in. diameter PVC pipe, capped on both ends and drilled with 1/4 in. diameter holes to allow water to flow through. The cases were attached to cement blocks with steel cable and placed behind large boulders to afford protection from heavy stream flows and from human disturbance. The thermographs recording water temperatures were placed in deep pools to prevent exposure as water levels receded during the summer months.

In an effort to examine the atmospheric influence on stream temperatures in 2016, a meteorological summary from the National Weather Service was used (Appendix I). Although the summary provides records for Concord, NH, the information provided may help to provide an illustration of regional precipitation, air temperature, and other characteristics that may have affected flow patterns and water temperatures in July and August, 2016.

RESULTS AND DISCUSSION

Beebe River Watershed

Three thermographs were deployed within the mainstem Beebe River and 14 thermographs were deployed throughout tributaries in 2016. The mean values of water temperatures from the months of July and August collected in Beebe River Watershed in 2015 and 2016 are displayed in Table 2. Linear graphs displaying daily maximum and average temperature values along with daily fluctuation values in water temperature in the mainstem Beebe River in 2016 are presented in Figures 1-3. Linear graphs displaying daily maximum and average temperature values along with daily fluctuation values in water temperature in the tributaries to the Beebe River in 2016 are presented in Figures 4-6.

Mean water temperature values for both July and August were $\leq$20.1°C in all seventeen monitoring locations. Several observations from 2015 were repeated in 2016. The three monitoring locations within the mainstem and low gradient tributaries associated with significant wetland areas ("ECR2" and "Algonquin Brook") exhibited greater mean monthly water temperatures than the high gradient tributaries ("GR1", GR2", GR3", GR4", GR5" and "ECR1"). The middle Beebe River monitoring location exhibited the lowest mean monthly water temperatures (19.0°C in July and 18.7°C in August) amongst the mainstem monitoring locations. The lower and upper mainstem monitoring locations exhibited greater mean July water temperatures (19.5°C and 19.3°C, respectively) and mean August water temperatures (19.5°C and 19.0°C, respectively). Algonquin Brook which drains several wetlands and the Hall Ponds exhibited the greatest mean water temperature amid the monitoring stations during July and August (19.8°C) for the areas monitored in the watershed. Mean monthly water temperature values recorded in the high gradient tributaries were all less than 17.0°C in July and 18.0°C in August. Similar to 2015, the most downstream monitoring location of GR1 exhibited the greatest mean monthly water temperatures for both July (17.2°C) and August (17.6°C). The most downstream monitoring location within GR5 displayed the coolest mean water temperatures for both July (15.3°C) and August (15.4°C).

The frequency of days in which stream temperatures met or exceeded the lethal to sub-lethal temperature threshold (≥21°C) during the months of July and August in the Beebe River Watershed is summarized in Table 3. The three mainstem Beebe River monitoring locations exceeded >21°C during both July and August. The lower, middle, and upper sections exceeded 21°C on 25 days, 17 days, and 22 days in July, respectively and 23 days, 9 days, and 15 days in August, respectively. The longest continuous duration of water temperature >21°C in the Beebe River mainstem was 15.5 hours at the lower location in August. Algonquin Brook exhibited the longest continuous duration of water temperature >21°C in the Beebe River Watershed in both July (16.5 hours) and August (20.0 hours). In 2015, only the lower monitoring location from GR1 exceeded 21°C for the months of July and August (7 days in August) within the high gradient tributaries. However, in 2016, monitoring locations exceeded 21°C in GR1 (2 days in July and 4 days in August), GR2 (5 days August), and GR5 (1 day in July). These monitoring locations are downstream of clearings associated with a power line corridor.

Five high gradient tributaries (GR1-GR5) drain a south facing slope before entering the Beebe River. An electrical power line parallels the Beebe River on the north side and these tributaries flow through the clearing associated with the power line. In the fall of 2014, the vegetation within the powerline section was removed as part of routine maintenance to protect the power line corridor. The riparian vegetation along these five tributaries was removed for approximately 40 meters. To determine if the removal of riparian vegetation along these tributaries had an influence on water temperature, thermographs were deployed in the forest upstream of the power lines and immediately downstream of the power lines within these five tributaries (GR1 through GR5). Linear graphs displaying daily maximum and average temperature values along with daily fluctuation values in water temperature above and below the cleared power lines in tributaries GR1 through GR5 are presented in Figures 7-18.

While only one monitoring location (GR1, below power lines) associated with the high gradient tributaries exceed 21°C in 2015, four of these monitoring locations exceeded 21°C in 2016. All monitoring locations which exceeded this threshold were associated with areas downstream of power line clearings. In July 2016, water temperatures exceeded 21°C two different days in for an average daily duration of 6 hours below the power line clearing in GR1. During the same month, the monitoring location downstream from the uppermost power line clearing exceeded 21°C during a single day for 3.5 hours. Both monitoring locations downstream of the power line clearings at GR1 and GR2 exceeded 21°C in August. Water temperature exceeded 21°C on four days for an average duration of 5.4 hours and 5 days for an average duration of 2.7 hours below the power line clears of GR1 and GR2, respectively. The monitoring locations below power line clearings at GR3 and GR5 remains <21°C during both July and August.

Mean water temperature was greater at the monitoring locations downstream of the power line sections during both July and August at the GR1, GR2, GR4, and GR5 monitoring locations. The mean water temperature for the area upstream of the power line clearing at GR3 is unavailable. The difference between mean July water temperature above and below the power lines was 1.4°C, 0.6°C, 0.5°C, and 0.6°C at GR1, GR2, GR4 and GR5, respectively. The difference between mean August water temperature above and below the power lines was 2.0°C, 0.8°C, 0.6°C, and 0.6°C at GR1, GR2, GR4 and GR5, respectively. Maximum water temperature was greater at the monitoring locations downstream of the power line sections during both July and August at the GR1, GR2, GR4, and GR5 monitoring locations. The difference between maximum July water temperature above and below the power lines was 4.9°C, 2.8°C, 1.9°C, and 3.5°C at GR1, GR2, GR4 and GR5, respectively. The difference between maximum August water temperature above and below the power lines was 3.4°C, 5.4°C, 1.6°C, and 1.3°C at GR1, GR2, GR4 and GR5, respectively.

A Signed Rank Test (Wilcoxon Signed Rank Test) was preformed to compare water temperature values between thermographs upstream and downstream of the cleared land for the power line for the months of July and August (combined). Recorded water temperatures at GR1, GR2, GR4 and GR5 were all significantly greater ($P \leq 0.05$) at the downstream monitoring locations when compared to recorded water temperatures above the power lines (Table 4). Similarly, in 2015, thermographs were deployed above and below the power line clearing in GR1 and GR4. Recorded water temperatures downstream of the power lines were significantly greater ($P \leq 0.05$) in both locations. Future water temperature monitoring will include deploying thermographs in all tributaries that flow through the cleared land of the powerline. Thermographs will continue to be deployed both upstream and downstream of the cleared area to monitor any potential increase in water temperature and if these observations change as the canopy cover of the riparian area regrows. There is an ongoing effort to address how the power line area is maintained. A strategy is needed to address growing vegetation within the power line corridor while keeping shading canopy along the riparian areas of these tributaries.

While recorded water temperatures in the high gradient tributaries of the Beebe River Watershed (GR1-GR5 and ECR1) offer suitable thermal refuge throughout July and August, recorded water temperatures in the mainstem Beebe River indicate periods of thermal stress on wild Brook Trout. This emphasizes the importance of providing accessibility to coldwater habitats during periods of thermal stress within the mainstem Beebe River. A road closely parallels the mainstem Beebe River on the north side. Five tributaries cross under this main travel corridor before shortly entering the Beebe River. Stream crossing assessments were performed using protocols established by the New Hampshire Geological Survey to determine the ability of a road-stream crossing structure to provide upstream fish passage. These assessments indicate three crossings offer no upstream passage (GR1, GR3 and GR5); one crossing offers upstream fish passage at a reduced rate (GR2); and one crossing offers full upstream movement (GR4). All five tributary crossings are being replaced with bridges in 2017. The streambeds within the project areas will be rebuilt and sloped to match reference conditions of these streams. Future water temperature monitoring will be essential to help document why habitat accessibility to these cold water tributaries is essential for long term sustainability of wild Brook Trout in the Beebe River Watershed.

Jewell Hill Brook

The mean values of water temperatures from the months of July and August collected in Jewell Hill Brook in 2015-2016 are displayed in Table 5. Linear graphs displaying daily maximum and average temperature values along with daily fluctuation values in water temperature are presented in Figures 13-15. Mean July and August water temperature for both monitoring locations appear to be suitable for wild Brook Trout. The downstream monitoring location exhibited cooler mean temperatures for both months (17.2°C and 17.8°C for July and August, respectively). The upstream monitoring location recorded slightly great water temperatures for July and August (18.0°C and 18.6°C, respectively).

The frequency of days in which stream temperatures met or exceeded the lethal to sub-lethal temperature threshold (≥21°C) during the months of July and August is summarized in Table 6. Water temperatures at both monitoring locations exceeded 21°C in July. The upstream location exceeded the threshold on two days for an average duration of 1.5 hours. The downstream location exceeded the threshold one day for 1.5 hours. Only the upstream monitoring location exceeded the threshold in August (for three days with an average duration of 7.2 hours).

McQuesten Brook

The mean values of water temperatures from the months of July and August collected in McQuesten Brook in 2010-2016 are displayed in Table 7. Linear graphs displaying daily maximum and average temperature values along with daily fluctuation values in water temperature in 2016 are presented in Figures 16-18. Information from the long term monitoring location below Wathen Road is unavailable for 2016. This thermograph was lost in a significant sediment deposit, likely associated with upstream stream crossing and dam removal activities. In 2013, mean water temperature was observed to exceed 18°C in the three most downstream locations during the month of July. This represented the first time, in any location, a July mean water temperature value was observed to exceed 18°C since water temperature monitoring began in McQuesten Brook in 2010. While no monitoring location exceeded monthly mean temperature values >18°C in 2014, the “Above Second St” location exhibited mean monthly temperatures of 18.0°C for both July and August in 2015. Both locations adjacent to Second Street exhibited mean July water temperatures meeting or exceeding 18°C for the month of July. The mean July water temperatures recorded in these locations were 18.0°C and 18.4°C for “Above Second St” and “Below Second St”, respectively.

Mean water temperature values for the month of July and August at the “Below South Main St” location continues to be one of the lowest values recorded throughout New Hampshire (NHFGD, unpublished data). The combined monthly mean for July and August for this location was 12.7°C in 2016. The slightly downstream locations continue to exhibit mean monthly water temperatures >4°C warmer than this location. This is likely a result of the influence from current stormwater management practices as well as a small impounded pond draining into McQuesten Brook behind a large string of businesses on Second Street in Manchester. The removal of the small dams creating the impoundment upstream of Second Street occurred in August, 2016. It is expected that the free flowing system would reduce water temperatures throughout the summer. Thermographs will be deployed in future years to monitor how summer water temperatures react to these dam removals.

Upon examination of the linear displays of McQuesten Brook’s water temperature profile (figures 16-18), several noticeable spikes in temperature are readily observed. Similar spikes were also observed in previous years (2010-2015). It is suspected that these large, but short lived temperature variations are related to a high concentration of stormwater entering McQuesten Brook. At this time, no quantitative comparison has been conducted to examine the influence on stormwater or other discharges on stream temperature. The complexity of stormwater drainage systems within the headwaters of McQuesten Brook and the high percentage of impervious surfaces in the watershed needs to be better understood to evaluate specific sources of illicit discharge. Although these brief temperature spikes do exceed values of over 25°C, there still appears to be a robust population of wild Brook Trout, with multiple age classes, which is able to currently withstand this phenomenon.

The frequency of days in which stream temperatures met or exceeded the lethal to sub-lethal temperature threshold (≥21°C) during the months of July and August is summarized in Table 8. All three locations exceeded 21°C in both months. In July, the number of days in which the fish community was exposed to temperatures >21°C ranged from 4 days for an average duration of 4.5 hours ("Below South Main St") to 24 different days for an average duration of 5.4 hours for each event ("Below Second St"). In August, water temperatures exceeding 21°C was also observed at all three locations. The number of days in which the fish community was exposed to temperatures >21°C in August ranged from 1 day for a duration of 1 hour ("Below South Main St") to 14 different days for an average duration of 4.3 hours for each event ("Above Second St"). The "Below South Main St" location in July, 2016 exhibited the greatest number of days in a month for that specific monitoring location where water temperatures exceeded >21°C since water temperature monitoring began in 2010 (4 days).

The removal of the impoundments associated with a tributary which enters McQuesten Brook shortly upstream of the "Above Second St" monitoring location is expected to reduce water temperature within the tributary and consequently in the downstream reaches of McQuesten Brook. The removal of the final impoundment occurred on August 23, 2016. Given the short period of time between the completion of construction and the end of August, analysis of the water temperature response of the removal of these impoundments will begin using data collected in 2017.

As the restoration plan for the McQuesten Brook watershed progresses and actions are implemented, continued water temperature and fish monitoring is expected to occur. Baseline temperature records will be an invaluable tool to monitor results of different restoration strategies. It is expected that thermographs will be deployed again in 2018.

Thompson Brook

The mean values of water temperatures collected within Thompson Brook in 2011through 2016 are displayed in Table 9. Linear graphs displaying daily maximum and average temperature values along with daily fluctuation values in water temperature from the Thompson Brook are presented in Figures 19-21. Water temperature monitoring within the Winnicut River watershed has concentrated primarily on Thompson Brook where restoration efforts to benefit a wild Brook Trout population had been initiated. Unfortunately, efforts to replace the crossing which served as a barrier to upstream aquatic organism passage have been recently abandoned and future water temperature monitoring is not planned. It is anticipated that the water temperature information collected within the Winnicut River Watershed between 2011 and 2016 will still be beneficial if restoration opportunities arise in the future.

In 2016, the mean July water temperature of Thompson Brook downstream of the Winnicut Road crossing was the lowest recorded since water temperature monitoring began in 2011. Mean July water temperatures for Thompson Brook was 18.9°C in 2016. In previous years mean July water temperatures met or exceeded 20.0°C (2011-2015).

The frequency of days in which stream temperatures met or exceeded the lethal to sub-lethal temperature threshold (≥21°C) during the months of July and August is summarized in Table 10. As observed in previous years, Thompson Brook exceeded 21°C for multiple days during the months of July and August in 2016. However, the number of days in which water temperature exceeded 21°C is the fewest recorded for both July and August since water temperature monitoring began in this stream in 2011. In 2016 this monitoring location exceeded 21°C on 14 days for an average duration of 6.3 hours and on 10 days for an average duration of 6.8 hours during the months of July and August, respectively. Thompson Brook exhibited at least one full day (24 hours) in which water temperature remained >21°C in July during all previous years of monitoring. However, in 2016, the maximum duration of water temperature >21°C was 13.0 hours in July. In August, 2016, water temperature remained >21°C for one single day (24 hours).

The Influence of Average Monthly Water Temperature on Presence of Young-of-the-Year Brook Trout

A comparison of locations throughout New Hampshire with both average monthly water temperature values and fish species presence information indicates young-of-the-year Brook Trout are not *generally* found in waters that exceed a mean July water temperature of 19.5°C (NHFGD unpublished data).

Beebe River Watershed
Regardless of monitoring location (upstream or downstream of the power line clearing), mean July water temperatures values were <19.5°C within the high gradient tributaries (ECR1 and GR1-GR5). This is indicative of streams supporting the presence of young-of-the-year Brook Trout. Concurrent fish community information from 2016 confirms the presence of young-of-the-year Brook Trout at these locations. Records from electrofishing surveys include 52, 13, 32, 43, 37, and 17 young-of-the-year Brook Trout captured in ECR1, GR1, GR2, GR3, GR4, and GR5, respectively. The lower, middle, and upper water temperature monitoring locations within the Beebe River exhibited mean July water temperatures of 19.5°C, 19.0°C, and 19.6°C, respectively. The generalization about the <19.5°C mean July water temperature threshold for young-of-the-year Brook Trout presence is validated by with the fish captured in these three locations. Although adult brook trout (>90 mm) were captured, no young-of-the-year Brook Trout were captured at the lower and middle locations (both locations having a mean July water temperature ≥19.5°C). The mean July water temperature at the middle water temperature monitoring location for the Beebe River was <19.5°C (19.0°C) and 8 young-of-the-year Brook

Trout were captured. Concurrent electrofishing data is unavailable for ECR2 Algonquin Brook. Both of these locations exhibited mean July water temperatures >19.5°C.

Jewell Hill Brook
Both monitoring locations exhibited mean July water temperatures <19.5°C in 2016, suggesting the likelihood of young-of-the-year Brook Trout to be present. An electrofishing survey adjacent to the upstream water temperature monitoring location resulted in the collection of three young-of-the-year Brook Trout <90mm in a 100 meter section in 2015. Forty seven wild Brook Trout >90 mm were also captured. Although no electrofishing on this stream occurred in 2016, given the similarity of mean July temperatures in both 2015 (17.9°C) and 2016 (18.0°C), the presence of young-of-the-year Brook Trout in 2016 would be expected.

McQuesten Brook
Mean July water temperatures recorded in McQuesten Brook suggests that all three water temperature monitoring locations provided suitable temperatures for young-of-the-year Brook Trout in McQuesten Brook in 2016. Electrofishing surveys documented young-of-the-year Brook Trout in two sections of McQuesten Brook. In 2010, 27 and 89 young-of-the-year Brook Trout (<90 mm) were found in 75 m and 100 m reaches, respectively (NHFGD unpublished data).

Thompson Brook
The mean July water temperature exhibited within this monitoring location of Thompson Brook in 2016 was the first occasion in which conditions appear suitable to facilitate the presence of young-of-the-year Brook Trout since water temperature monitoring began in 2011. Unfortunately, there is no concurrent fish community information available for this particular year. In 2010 young-of-the-year Brook Trout were documented in two distinct locations within Thompson Brook. However, hourly water temperature monitoring did not occur. Three fish community surveys in 2011 documented the presence of age 1+ wild Brook Trout (>90 mm), no young-of-the-year Brook Trout were documented in Thompson Brook. Electrofishing surveys in both 2012 and 2013 did not document the presence of any Brook Trout in Thompson Brook.

The Influence of Atmospheric Temperature on Water Temperature

The average air temperature for the summer of 2016 was 21.4°C, 1.5°C greater than the long-term mean air temperature (1868-2016). The summer was the fourth warmest summer on record. Between July 22 and July 28, six out of seven days exceeded 32.2°C (90°F). Air temperatures reached 36.7°C (98°F) and 37.2°C (99°F) on August 11 and August 12, respectively. 2016 was the ninth driest summer on record. Precipitation consisted of 139.7 mm (5.5 in) which was 129.5 mm (5.1 in) below the mean average. (National Weather Service, Appendix I).

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Table 1. The locations, site names, and years where thermographs were deployed between July and August, 2016.

Location	Town	Site Name	Year(s)	Latitude	Longitude
Beebe River Watershed	Campton	Beebe River-Lower	2015-2016	43.82118	-71.60115
		Beebe River-Middle	2015-2016	43.83032	-71.56609
		ECR1	2015-2016	43.83022	-71.56599
		GR1 Lower	2015-2016	43.82800	-71.59897
		GR1 Upper	2015-2016	43.82832	-71.60019
		GR2 Lower	2016	43.83035	-71.58333
		GR2 Upper	2015-2016	43.83116	-71.58288
		GR3 Lower	2016	43.83241	-71.57358
		GR3 Upper	2015-2016	43.83318	-71.57354
		GR4 Lower	2015-2016	43.83526	-71.55510
		GR4 Upper	2015-2016	43.83593	-71.55518
	Sandwich	Algonquin Brook	2015-2016	43.84644	-71.53078
		Beebe River-Upper	2015-2016	43.84533	-71.53283
		ECR2	2015-2016	43.83123	-71.54215
		GR5 Lower	2015-2016	43.84084	-71.53930
		GR5 Middle	2016	43.84027	-71.54049
		GR5 Upper	2016	43.84002	-71.54141
Jewell Hill Brook	Stratham	Upstream	2015-2016	43.03169	-70.90802
		Downstream	2016	43.03028	-70.91231
McQuesten Brook	Manchester	Below South Main St	2010-2016	42.96825	-71.48225
	Manchester	Above Second St	2013-2016	42.96773	-71.48128
	Manchester	Below Second St	2011-2016	42.96680	-71.47982
	Bedford	Below Wathen Rd	2010-2016	42.96482	-71.47801
Thompson Brook	Greenland	Below Winnicut Rd	2011-2016	43.02725	-70.85419

Table 2. The Mean Value of July and August Combined Water Temperature (MJAWT), Mean Value of July Water Temperatures (MJWT), and Mean Value of August Water Temperature (MAWT)* and ranges observed in Beebe River Watershed, 2015-2016.

Site Name	Year	MJAWT (SD) Range	MJWT (SD) Range	MAWT (SD) Range
Beebe River-Lower	2015	18.7 (±2.3) 13.0-25.6	18.2 (±2.4) 13.0-24.4	19.1 (±2.1) 14.7-25.6
Beebe River-Middle		18.3 (±1.8) 13.1-23.6	18.0 (±2.1) 13.1-23.6	18.6 (±1.8) 14.4-23.6
Beebe River-Upper		18.9 (±2.0) 13.4-24.4	18.6 (±2.1) 13.4-23.7	19.2 (±1.8) 15.1-24.4
GR1-Lower		16.4 (±2.0) 11.1-22.9	15.5 (±1.8) 11.1-20.4	17.2 (±1.9) 13.3-22.9
GR1-Upper		15.5 (±1.4) 11.1-18.5	14.9 (±1.4) 11.1-17.9	16.0 (±1.1) 13.2-18.5
GR2		15.5 (±1.4) 11.2-18.4	14.9 (±1.4) 11.2-18.1	16.0 (±1.1) 13.3-18.4
GR3		15.2 (±1.3) 11.1-18.0	14.6 (±1.3) 11.1-17.4	15.9 (±1.0) 13.3-18.0
GR4-Lower		16.0 (±1.7) 10.8-20.8	15.4 (±1.7) 10.8-19.5	16.6 (±1.4) 13.1-20.8
GR4-Upper		15.6 (±1.4) 10.8-18.6	15.1 (±1.5) 10.8-18.3	16.1 (±1.1) 13.3-18.6
GR5		15.2 (±1.4) 10.8-18.0	14.7 (±1.5) 10.8-18.0	15.6 (±1.1) 12.7-17.9
ECR1		15.2 (±1.4) 10.9-18.5	14.7 (±1.4) 10.9-18.0	15.8 (±1.1) 12.9-18.5
ECR2		19.1 (±2.2) 12.1-24.4	18.5 (±2.5) 12.1-24.4	19.7 (±1.8) 15.6-23.8
Algonquin Brook		19.4 (±2.3) 13.2-26.0	19.1 (±2.4) 13.2-25.3	19.8 (±2.1) 15.2-26.0
Beebe River-Lower	2016	19.5 (±2.5) 13.4-26.5	19.5 (±2.6) 13.4-26.5	19.5 (±2.3) 14.0-26.3
Beebe River-Middle		18.8 (±1.9) 13.8-24.2	19.0 (±2.1) 13.8-23.2	18.7 (±1.6) 14.6-24.2
Beebe River-Upper		19.3 (±1.8) 15.2-24.0	19.6 (±2.0) 15.2-24.0	19.0 (±1.5) 15.8-22.4
GR1-Lower		17.2 (±2.0) 11.6-22.6	16.8 (±2.2) 11.6-22.6	17.6 (±1.7) 11.6-22.1
GR1-Upper		15.5 (±1.0) 11.8-18.7	15.4 (±1.1) 11.8-17.7	15.6 (±0.9) 13.4-18.7
GR2-Lower		16.5 (±1.8) 11.2-24.3	16.1 (±1.7) 11.5-20.5	16.9 (±1.8) 11.2-24.3
GR2-Upper		15.8 (±1.2) 11.7-18.9	15.5 (±1.3) 11.7-17.7	16.1 (±1.0) 13.5-18.9
GR3-Lower		15.9 (±1.2) 12.1-18.6	15.6 (±1.3) 12.1-18.2	16.3 (±0.9) 14.0-18.6
GR3-Upper		*	*	*
GR4-Lower		16.5 (±1.5) 11.9-20.5	16.2 (±1.6) 11.9-19.9	16.8 (±1.3) 13.5-20.5
GR4-Upper		16.0 (±1.3) 12.1-18.9	15.7 (±1.4) 12.1-18.0	16.2 (±1.1) 13.7-18.9
GR5-Lower		15.3 (±1.2) 11.3-18.3	15.2 (±1.4) 11.3-17.9	15.4 (±1.0) 13.0-18.3
GR5-Middle		16.3 (±2.0) 11.3-21.6	16.0 (±2.1) 11.3-21.6	16.5 (±1.8) 12.6-20.8
GR5-Upper		15.7 (±1.3) 11.6-19.5	15.4 (±1.5) 11.6-18.1	15.9 (±1.0) 13.4-19.5
ECR1		15.7 (±1.3) 11.6-18.9	15.4 (±1.4) 11.6-17.9	15.9 (±1.3) 11.6-18.9
ECR2		19.4 (±1.7) 14.8-24.6	19.8 (±2.1) 14.8-24.6	19.0 (±1.3) 15.3-22.8
Algonquin Brook		19.8 (±2.2) 15.0-25.7	20.1 (±2.3) 15.0-25.7	19.4 (±2.0) 15.2-24.4

*Thermograph information not available

Table 3. The frequency of days and average daily duration in hours in which water temperature exceeded lethal to sub-lethal values (≥21°C) for salmonids for the months of July and August observed in the Beebe River Watershed, 2015-2016.

Site Name	Year	July Days ≥21°C	Average Duration (Range)	August Days ≥21°C	Average Duration (Range)
Beebe River-Lower	2015	16 days	6.2 hours (2.0-12.0)	15 days	7.2 hours (1.0-15.0)
Beebe River-Middle		10 days	6.6 hours (1.0-11.0)	10 days	7.4 hours (4.0-11.0)
Beebe River-Upper		13 days	7.5 hours (1.0-14.0)	15 days	7.9 hours (2.0-15.0)
GR1-Lower		0 days	n.a.	7 days	4.1 hours (1.0-7.0)
GR1-Upper		0 days	n.a.	0 days	n.a.
GR2		0 days	n.a.	0 days	n.a.
GR3		0 days	n.a.	0 days	n.a.
GR4-Lower		0 days	n.a.	0 days	n.a.
GR4-Upper		0 days	n.a.	0 days	n.a.
GR5		0 days	n.a.	0 days	n.a.
ECR1		0 days	n.a.	0 days	n.a.
ECR2		15 days	3.9 hours (1.0-9.0)	8 days	2.8 hours (1.0-6.0)
Algonquin Brook		19 days	8.5 hours (3.0-18.0)	26 days	7.8 hours (1.0-18.0)
Beebe River-Lower	2016	25 days	8.8 hours (1.0-13.0)	23 days	7.2 hours (0.5-15.5)
Beebe River-Middle		17 days	7.9 hours(1.0-12.0)	9 days	5.8 hours (0.5-14.5)
Beebe River-Upper		22 days	8.8 hours (2.5-14.0)	15 days	5.3 hours (0.5-12.0)
GR1-Lower		2 days	6 hours (5.0-7.0)	4 days	5.4 hours (3.5-7.0)
GR1-Upper		0 days	n.a.	0 days	n.a.
GR2-Lower		0 days	n.a.	5 days	2.7 hours (0.5-7.0)
GR2-Upper		0 days	n.a.	0 days	n.a.
GR3-Lower		0 days	n.a.	0 days	n.a.
GR3-Upper		*	*	*	*
GR4-Lower		0 days	n.a.	0 days	n.a.
GR4-Upper		0 days	n.a.	0 days	n.a.
GR5-Lower		0 days	n.a.	0 days	n.a.
GR5-Middle		1 day	3.5 hours (n.a.)	0 days	n.a.
GR5-Upper		0 days	n.a.	0 days	n.a.
ECR1		0 days	n.a.	0 days	n.a.
ECR2		22 days	10.5 hours (1.5-17.0)	6 days	5.5 hours (2.0-8.5)
Algonquin Brook		25 days	10.2 hours (0.5-16.5)	21 days	8.0 hours (3.0-20.0)

*Thermograph information not available

Table 4. Difference between water temperature after four tributaries (GR1, GR2, GR4 and GR5) flow through a cleared power line in the Beebe River Watershed during the months of July and August, 2015-2016

Year	July and August Water Temperatures Comparison			*P* value
2015	GR1 Upper	<	GR1Lower	<0.001*
	GR4 Upper	<	GR4Lower	<0.001*
2016	GR1 Upper	<	GR1Lower	<0.001*
	GR2 Upper	<	GR2Lower	<0.001*
	GR4 Upper	<	GR4Lower	<0.001*
	GR5 Upper	<	GR5Lower	<0.001*

*Indicates significant difference ($P \leq 0.05$)

Table 5. The Mean Value of July and August Combined Water Temperature (MJAWT), Mean Value of July Water Temperatures (MJWT), and Mean Value of August Water Temperature (MAWT)* and ranges observed in Jewell Hill Brook, 2015-2016.

Site Name	Year	MJAWT (SD) Range	MJWT (SD) Range	MAWT (SD) Range
Upstream Location	2015	18.3 (±1.6) 14.3-22.4	17.9 (±1.5) 14.3-21.5	18.7 (±1.6) 15.0-22.4
Upstream Location	2016	18.3 (±1.4) 14.4-22.9	18.0 (±1.5) 14.4-22.9	18.6 (±1.2) 15.2-22.4
Downstream Location		17.5 (±0.9) 15.3-21.6	17.2 (±1.1) 15.3-21.6	17.8 (±0.5) 16.5-19.4

Table 6. The frequency of days and average daily duration in hours in which water temperature exceeded lethal to sub-lethal values (≥21°C) for salmonids for the months of July and August observed in Jewell Hill Brook, 2015-2016.

Site Name	Year	July Days ≥21°C	Average Duration (Range)	August Days ≥21°C	Average Duration (Range)
Upstream Location	2015	3 days	5.7 hours (4.0-7.0)	7 days	4.7 hours (1.0-11.0)
Upstream Location	2016	2 days	1.5 hours (1.5-1.5)	3 days	7.2 hours (3.0-11.0)
Downstream Location		1 day	1.5 hours (n.a.)	0 days	n.a.

Table 7. The Mean Value of July and August Combined Water Temperature (MJAWT), Mean Value of July Water Temperatures (MJWT), and Mean Value of August Water Temperature (MAWT) and ranges observed in McQuesten Brook in 2010-2016.

Site Name	Year	MJAWT (SD) Range	MJWT (SD) Range	MAWT (SD) Range
Below South Main St	2010	11.7 (±1.1) 10.9-25.1	11.0 (±0.2) 10.9-14.5	12.5 (±1.2) 11.0-25.1
Below Wathen Rd		17.0 (±1.9) 12.2-24.4	17.2 (±2.0) 12.2-21.4	16.8 (±1.8) 13.1-24.4
Below South Main St	2011	13.1 (±1.5) 12.0-24.1	12.6 (±0.9) 12.0-24.1	13.6 (±1.8) 12.4-22.0
Below Second St		17.2 (±2.1) 13.3-23.6	17.2 (±2.2) 13.5-23.6	17.2 (±2.0) 13.3-22.0
Below Wathen Rd		17.2 (±1.7) 13.8-22.2	17.3 (±1.9) 13.8-22.2	17.0 (±1.5) 14.1-21.7
Below South Main St	2012	13.3 (±1.4) 12.2-26.3	12.8 (±0.8) 12.2-22.9	13.8 (±1.7) 12.7-26.3
Above Second St		17.7 (±2.3) 13.1-25.4	17.5 (±2.3) 13.2-24.8	17.9 (±2.3) 13.1-25.4
Below Second St		17.6 (±1.8) 13.4-26.0	17.5 (±2.1) 13.4-26.0	17.7 (±1.6) 15.3-24.0
Below Wathen Rd		17.9 (±1.9) 13.8-25.7	17.7 (±1.9) 13.8-25.7	18.2 (±1.9) 13.8-24.5
Below South Main St	2013	*	*	*
Above Second St		17.5 (±2.0) 12.6-24.2	18.2 (±1.7) 14.8-24.2	16.8 (±2.1) 12.6-22.7
Below Second St		17.5 (±2.1) 12.8-25.8	18.2 (±1.7) 14.9-25.8	16.9 (±2.2) 12.8-22.7
Below Wathen Rd		17.4 (±1.7) 13.1-24.6	18.0 (±1.5) 15.1-24.6	16.9 (±1.8) 13.1-22.4
Below South Main St	2014	13.1(±1.4) 11.6-21.3	13.5(±1.7) 11.6-21.3	12.7 (±0.9) 12.2-19.3
Above Second St		17.0 (±2.2) 12.3-23.7	17.7 (±2.1) 13.6-23.7	16.3 (±2.1) 12.3-21.7
Below Second St		17.1 (±1.7) 13.4-25.7	17.7 (±1.7) 14.4-25.7	16.4 (±1.5) 13.4-20.0
Below Wathen Rd		17.2 (±2.2) 12.5-25.4	17.9 (±2.1) 14.0-25.4	16.5 (±2.0) 12.6-21.5
Below South Main St	2015	13.1 (±1.1) 12.3-22.8	13.3 (±1.1) 12.3-22.3	12.9 (±1.1) 12.3-22.8
Above Second St		18.0 (±2.5) 13.3-23.9	18.0 (±2.4) 13.5-23.7	18.0 (±2.6) 13.3-23.9
Below Second St		17.6 (±2.1) 13.6-23.9	17.7 (±2.1) 13.6-23.9	17.5 (±2.0) 13.7-22.7
Below Wathen Rd		17.8 (±2.0) 13.7-24.3	17.9 (±2.0) 13.7-24.3	17.8 (±2.0) 13.9-22.6
Below South Main St	2016	12.7 (±1.1) 11.9-25.4	12.6 (±1.3) 11.9-25.4	12.7 (±1.0) 12.2-22.1
Above Second St		17.4 (±2.6) 12.6-28.9	18.0 (±2.6) 13.3-25.7	16.9 (±2.5) 12.6-28.9
Below Second St		17.7 (±2.2) 13.8-26.0	18.4 (±2.4) 13.8-25.4	17.2 (±1.9) 14.0-26.0
Below Wathen Rd		*	*	*

*Thermograph information not available

Table 8. The frequency of days and average daily duration in hours in which water temperature exceeded lethal to sub-lethal values (≥21°C) for salmonids for the months of July and August observed in McQuesten Brook in 2010-2016.

Site Name	Year	July Days ≥21°C	Average Duration (Range)	August Days ≥21°C	Average Duration (Range)
Below South Main St	2010	0 days	n.a.	2 days	1.5 hours (1.0-2.0)
Below Wathen Rd		6 days	2 hours (1.0-4.0)	3 days	3 hours (1.0-5.0)
Below South Main St	2011	1 day	1 hour (n.a.)	3 days	2.3 hours (1.0-5.0)
Below Second St		14 days	3.4 hours (1.0-7.0)	9 days	2.7 hours (1.0-6.0)
Below Wathen Rd		5 days	2.8 hours (2.0-5.0)	1 day	3 hours (n.a.)
Below South Main St	2012	2 days	1 hour (1.0-1.0)	6 days	1.7 hours (1.0-2.0)
Above Second St		21 days	3.4 hours (1.0-7.0)	21 days	3.8 hours (1.0-8.0)
Below Second St		13 days	3.5 hours (2.0-6.0)	10days	3.6 hours (1.0-8.0)
Below Wathen Rd		11 days	3.7 hours (1.0-6.0)	13 days	4 hours (2.0-8.0)
Below South Main St	2013	*	*	*	*
Above Second St		14 days	3.2 hours (1.0-5.0)	4 days	3.8 hours (2.0-5.0)
Below Second St		15 days	3.9 hours (1.0-9.0)	8 days	2.8 hours (1.0-6.0)
Below Wathen Rd		5 days	3.4 hours (2.0-6.0)	2 days	3.5 hours (3.0-4.0)
Below South Main St	2014	1 day	2 hours (n.a.)	0 days	n.a.
Above Second St		12 days	3.8 hours (1.0-7.0)	4 days	2.5 hours (2.0-4.0)
Below Second St		6 days	4.0 hours (1.0-7.0)	0 days	n.a.
Below Wathen Rd		13 days	4.2 hours (1.0-8.0)	3 days	2.7 (2.0-3.0)
Below South Main St	2015	2 days	1.5 hours (1.0-2.0)	2 days	1 hour (1.0-1.0)
Above Second St		22 days	4.6 hours (1.0-7.0)	26 days	4.5 hours (1.0-7.0)
Below Second St		15 days	3.8 hours (1.0-6.0)	14 days	3.4 hours (1.0-6.0)
Below Wathen Rd		11 days	4.5 hours (1.0-6.0)	13 days	3.5 hours (1.0-7.0)
Below South Main St	2016	4 days	4.5 hours (0.5-1.5)	1 day	1 hour (n.a.)
Above Second St		22 days	5.2 hours (0.5-9.5)	14 days	4.3 hours (0.5-9.0)
Below Second St		24 days	5.4 hours (0.5-9.0)	10 days	3.7 hours (1.0-7.0)
Below Wathen Rd		*	*	*	*

*Thermograph information not available

Table 9. The Mean Value of July and August Combined Water Temperature (MJAWT), Mean Value of July Water Temperatures (MJWT), and Mean Value of August Water Temperature (MAWT) and ranges observed in Thompson Brook in 2011-2016.

Location	Year	MJAWT (SD) Range	MJWT (SD) Range	MAWT (SD) Range
Below Winnicut Rd	2011	20.0 (±1.8) 16.4-25.3	20.4 (±1.9) 16.9-25.3	19.6 (±1.6) 16.4-24.1
Below Winnicut Rd	2012	20.7 (±2.0) 15.7-26.5	20.2 (±1.8) 15.8-25.3	21.1 (±1.7) 17.7-26.5
Below Winnicut Rd	2013	20.4 (±2.4) 14.8-27.4	21.7 (±2.2) 17.3-27.4	19.2 (±1.7) 14.8-23.8
Below Winnicut Rd	2014	20.4 (±2.0) 15.3-26.4	21.6 (±1.7) 17.9-26.4	19.1 (±1.5) 15.3-22.9
Below Winnicut Rd	2015	20.3 (±2.0) 15.7-25.5	20.8 (±1.9) 16.6-25.5	19.8 (±1.9) 15.7-24.2
Below Winnicut Rd	2016	19.1 (±1.6) 14.0-23.5	18.9 (±1.7) 14.0-22.9	19.3 (±1.4) 16.1-23.5

Table 10. The frequency of days and average daily duration in hours in which water temperature exceeded lethal to sub-lethal values (≥21°C) for salmonids for the months of July and August observed in Thompson Brook in 2011- 2016.

Site Name	Year	July Days ≥21°C	Average Duration (Range)	August Days ≥21°C	Average Duration (Range)
Below Winnicut Rd	2011	21 days	13.3 hours (3.0-24.0)	14 days	13.0 hours (3.0-24.0)
Below Winnicut Rd	2012	18 days	13.7 hours (3.0-24.0)	22 days	17.1 hours (4.0-24.0)
Below Winnicut Rd	2013	29 days	14.6 hours (1.0-24.0)	12 days	8.2 hours (2.0-11.0)
Below Winnicut Rd	2014	30 days	15.7 hours (3.0-24.0)	12 days	6.4 hours (1.0-14.0)
Below Winnicut Rd	2015	23 days	15.0 hours (7.0-24.0)	16 days	13.3 hours (2.0-24.0)
Below Winnicut Rd	2016	14 days	6.3 hours (1.0-13.0)	10 days	6.8 hours (1.0-24.0)

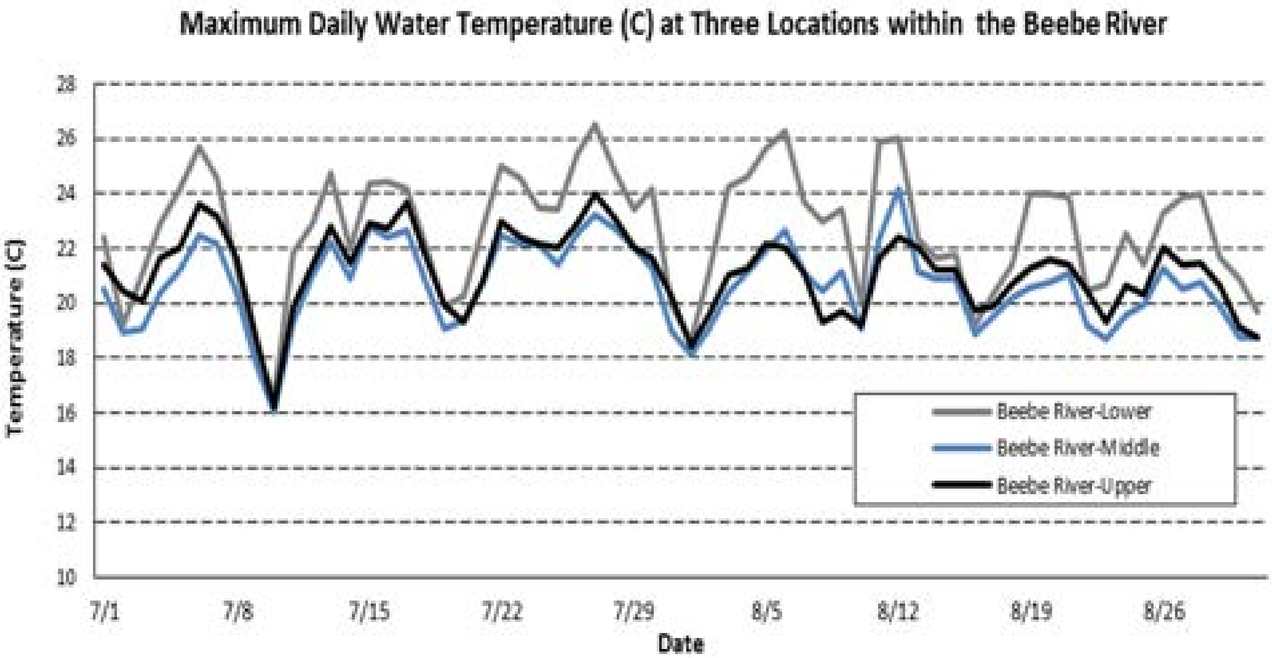

Figure 1. Maximum daily water temperatures (°C) observed at three locations in the Beebe River in 2016.

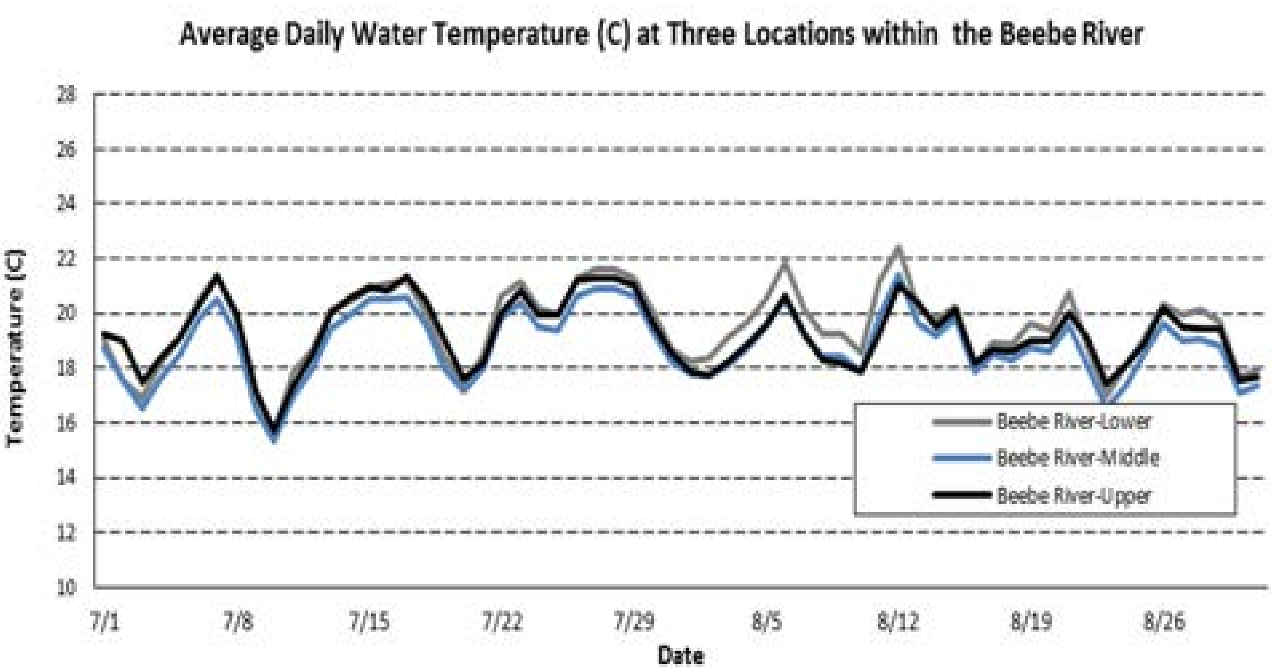

Figure 2. Average daily water temperatures (°C) observed at three locations within the Beebe River in 2016.

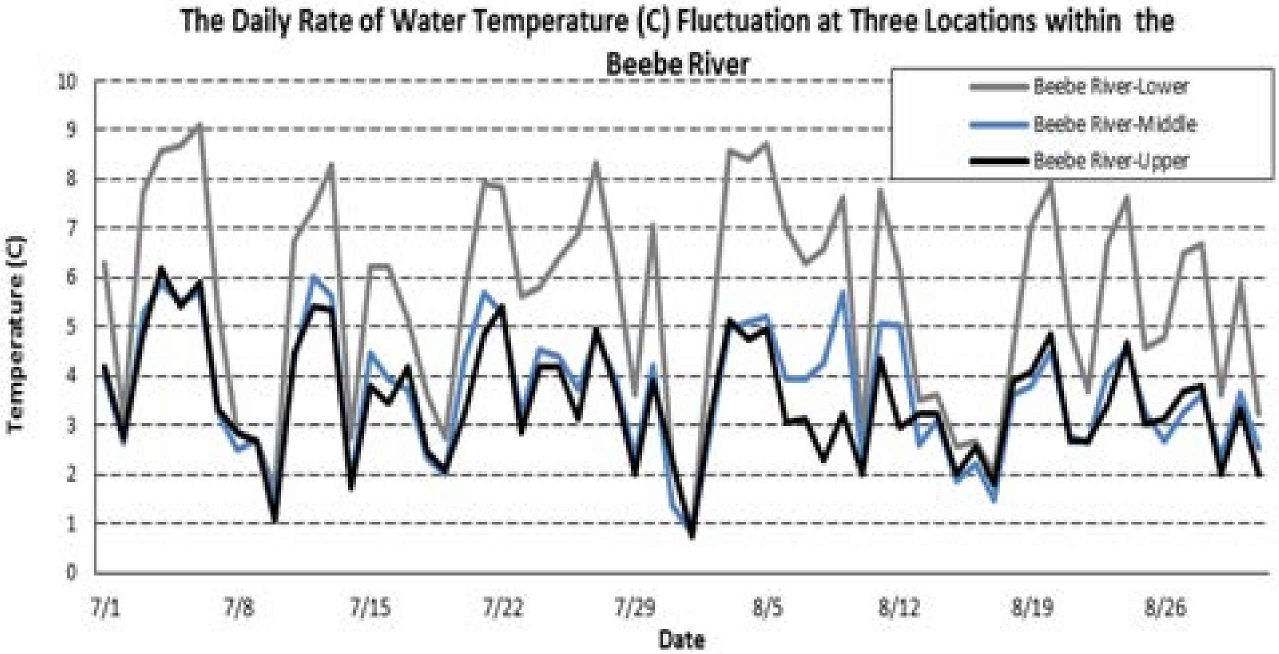

Figure 3. The fluctuation of water temperatures observed at three locations within the Beebe River in 2016.

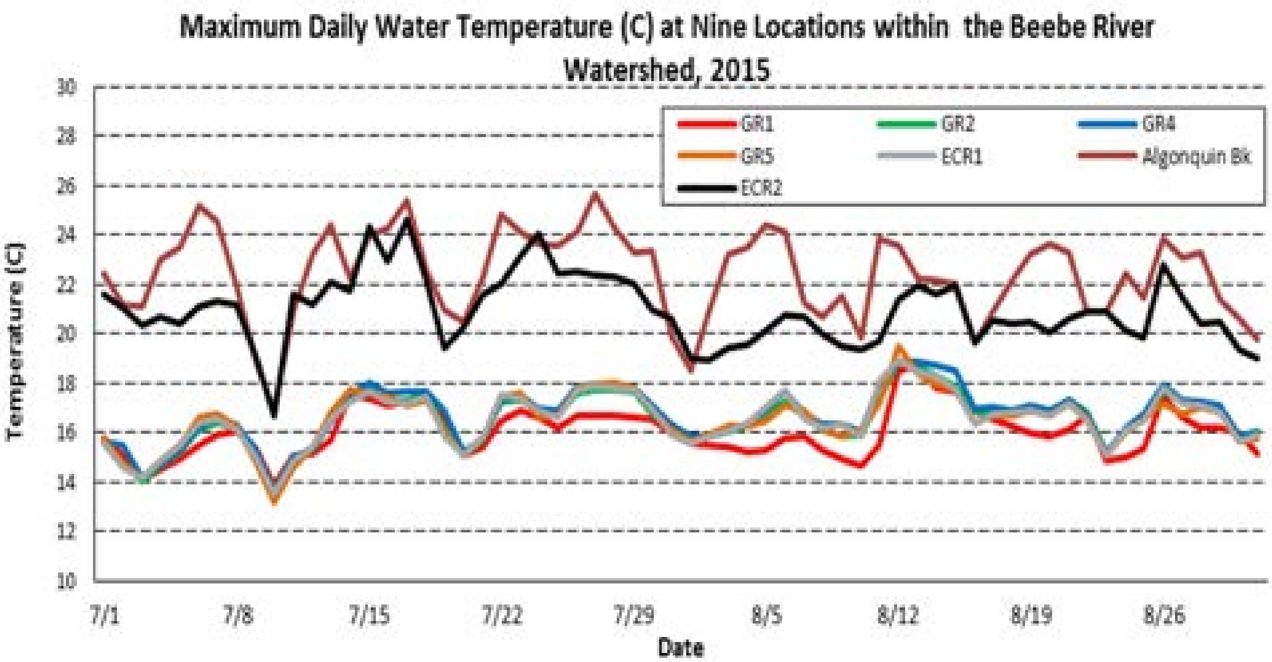

Figure 4. Maximum daily water temperatures (°C) observed at seven locations within the Beebe River Watershed in 2016.

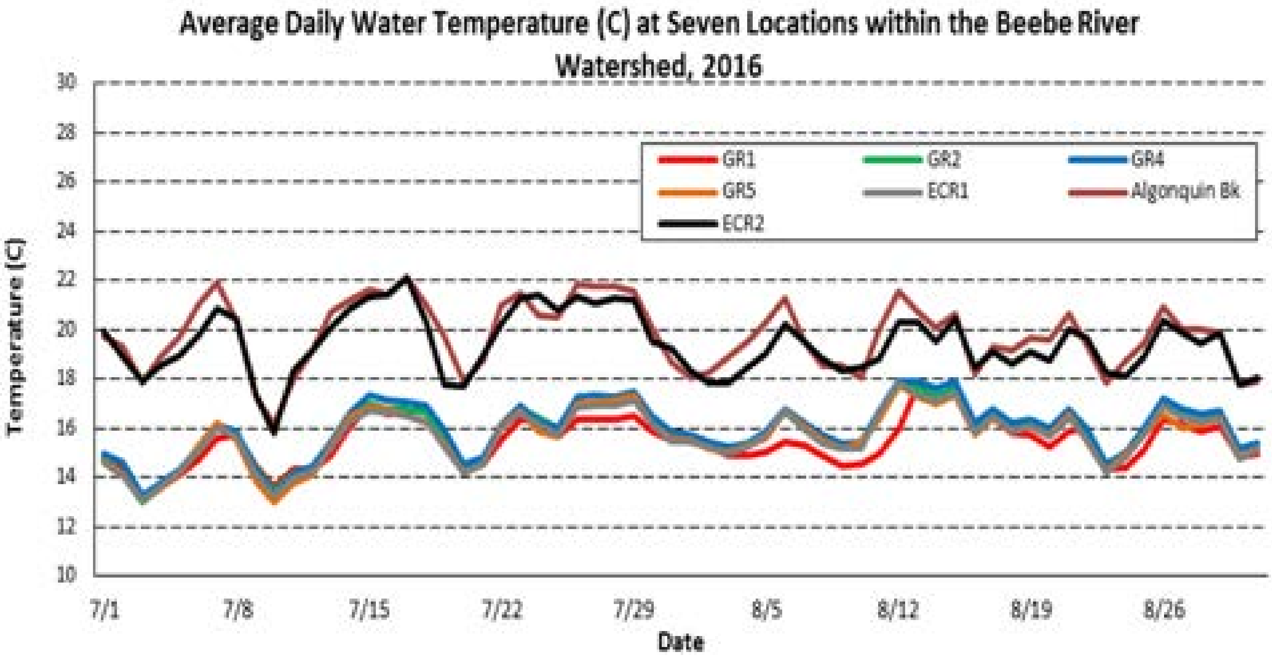

Figure 5. Average daily water temperatures (°C) observed at seven locations within the Beebe River Watershed in 2016.

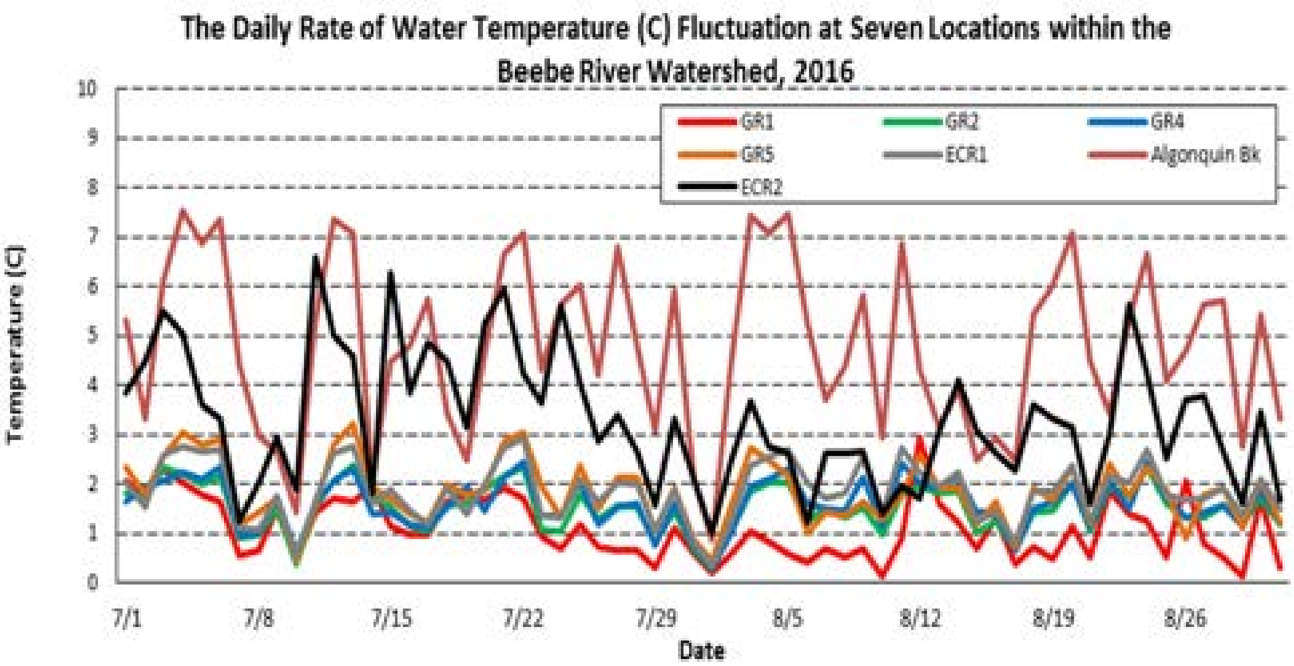

Figure 6. The fluctuation of water temperatures observed at seven locations within the Beebe River Watershed in 2016.

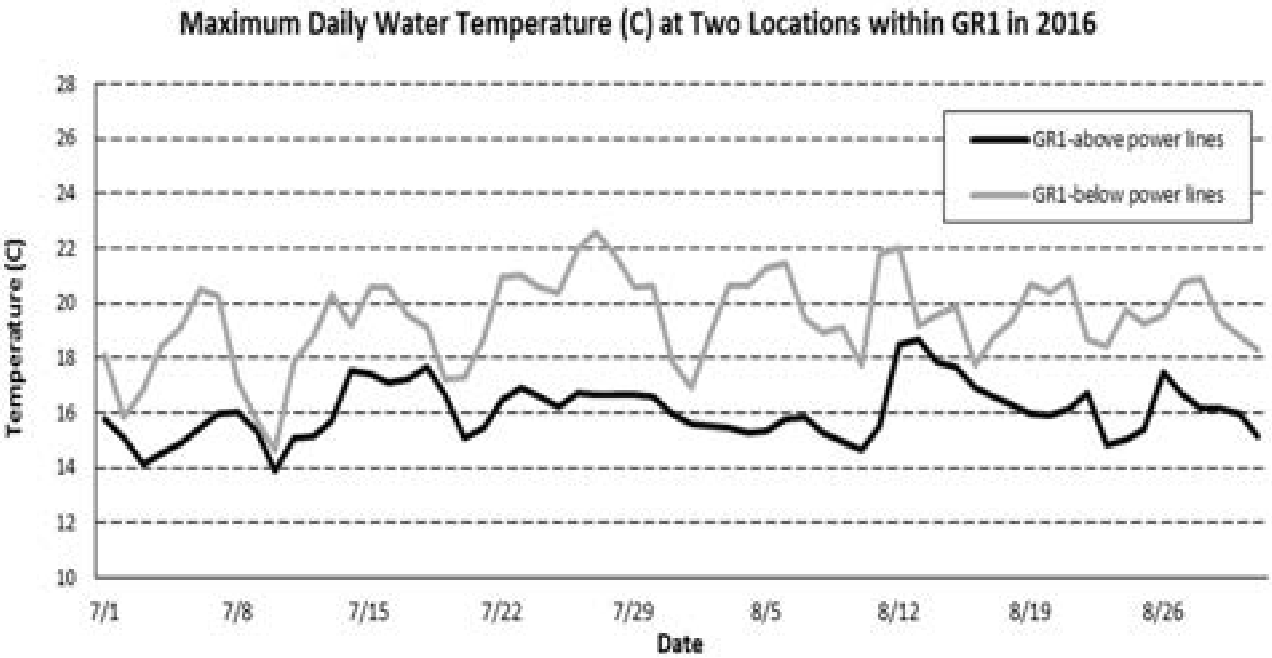

Figure 7. Maximum daily water temperatures (°C) observed at two locations within GR1 (a tributary to the Beebe River) in 2016.

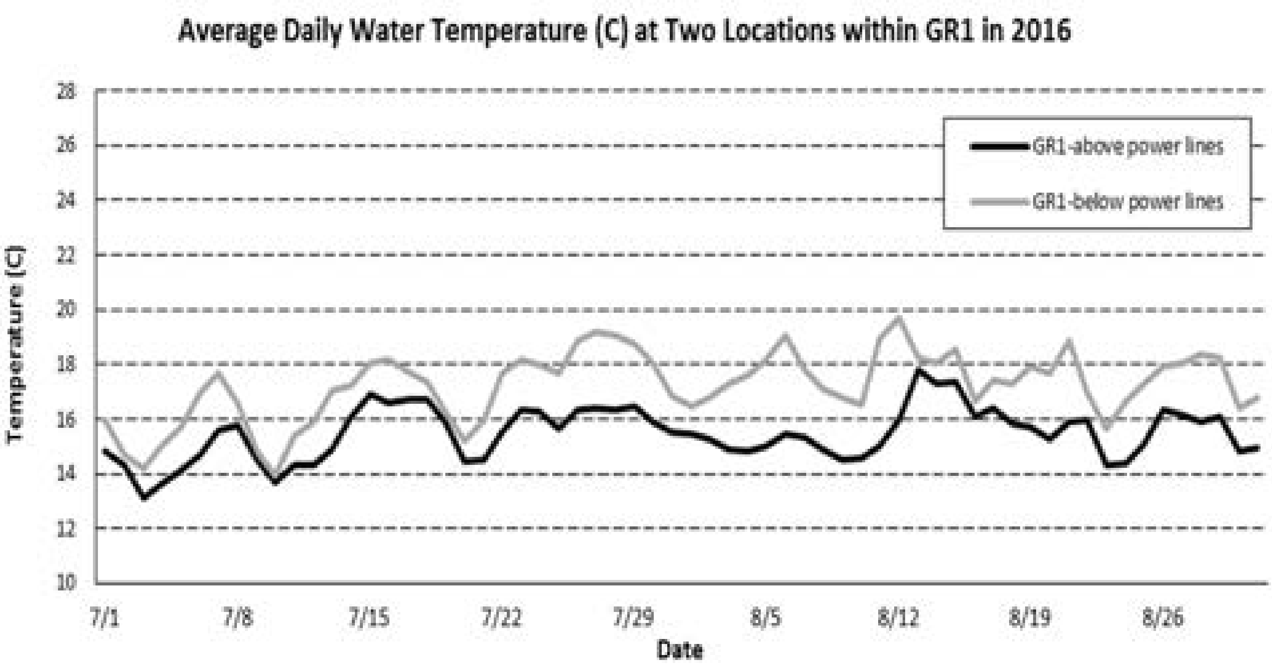

Figure 8. Average daily water temperatures (°C) observed at two locations within GR1 (a tributary to the Beebe River) in 2016.

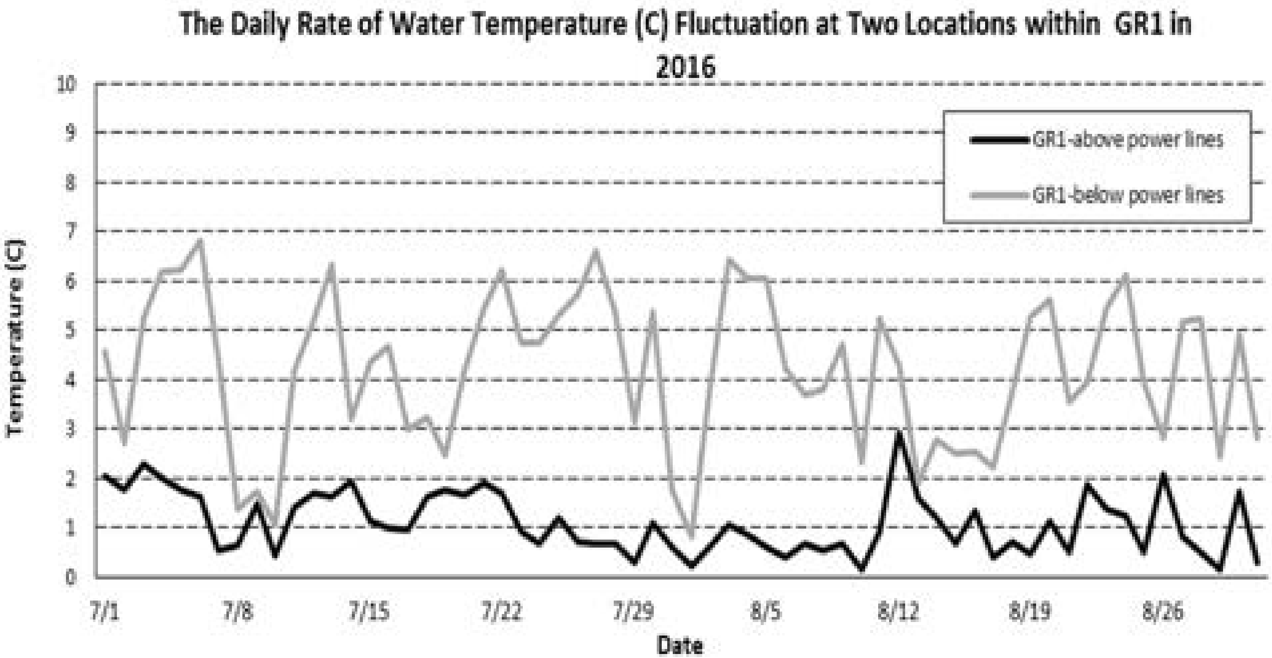

Figure 9. The fluctuation of water temperatures observed at two locations within GR1 (a tributary to the Beebe River) in 2016.

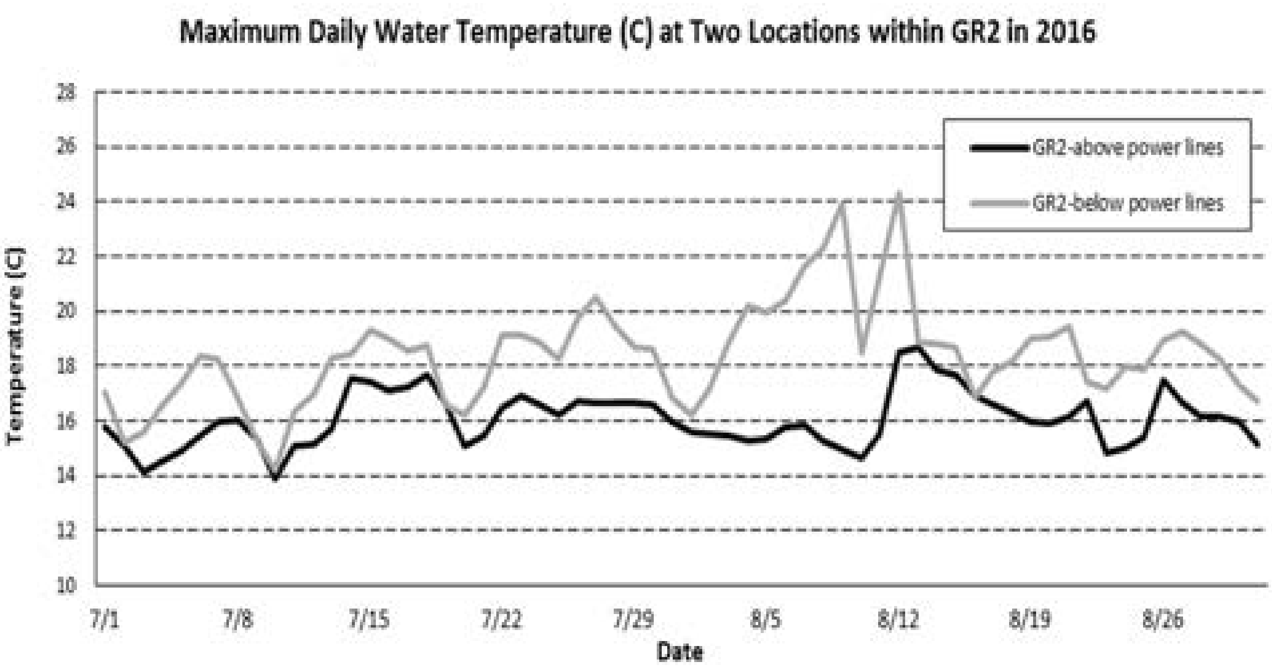

Figure 10. Maximum daily water temperatures (°C) observed at two locations within GR2 (a tributary to the Beebe River) in 2016.

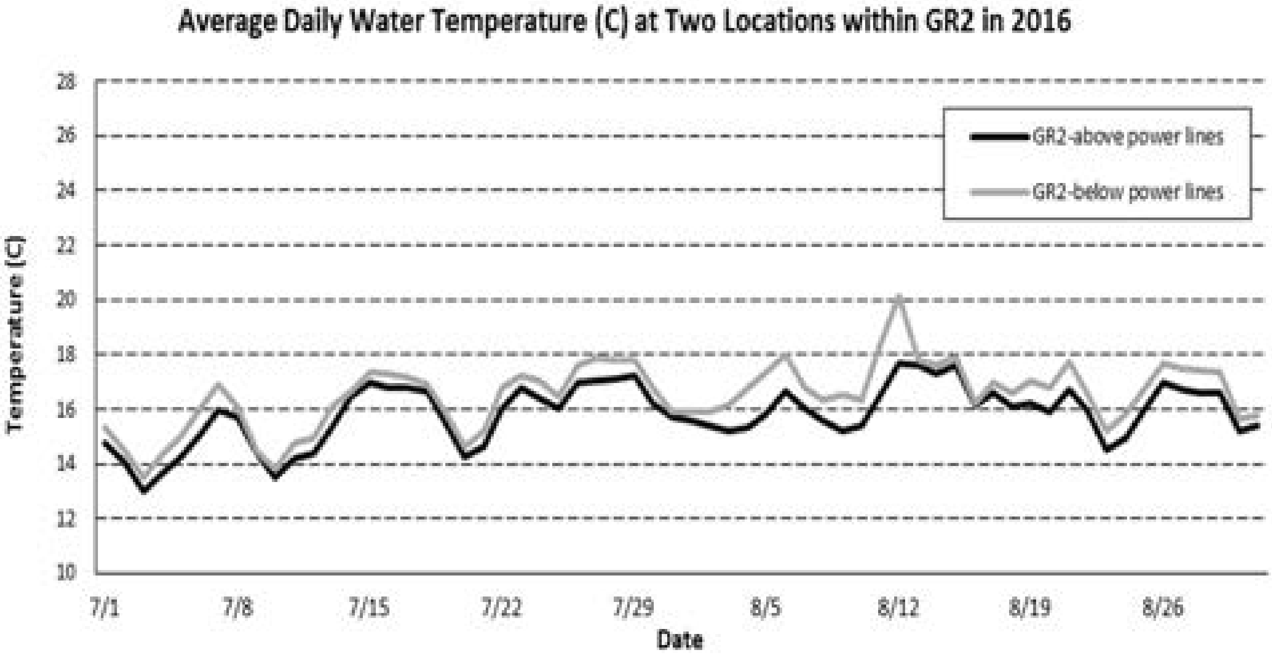

Figure 11. Average daily water temperatures (°C) observed at two locations within GR2 (a tributary to the Beebe River) in 2016.

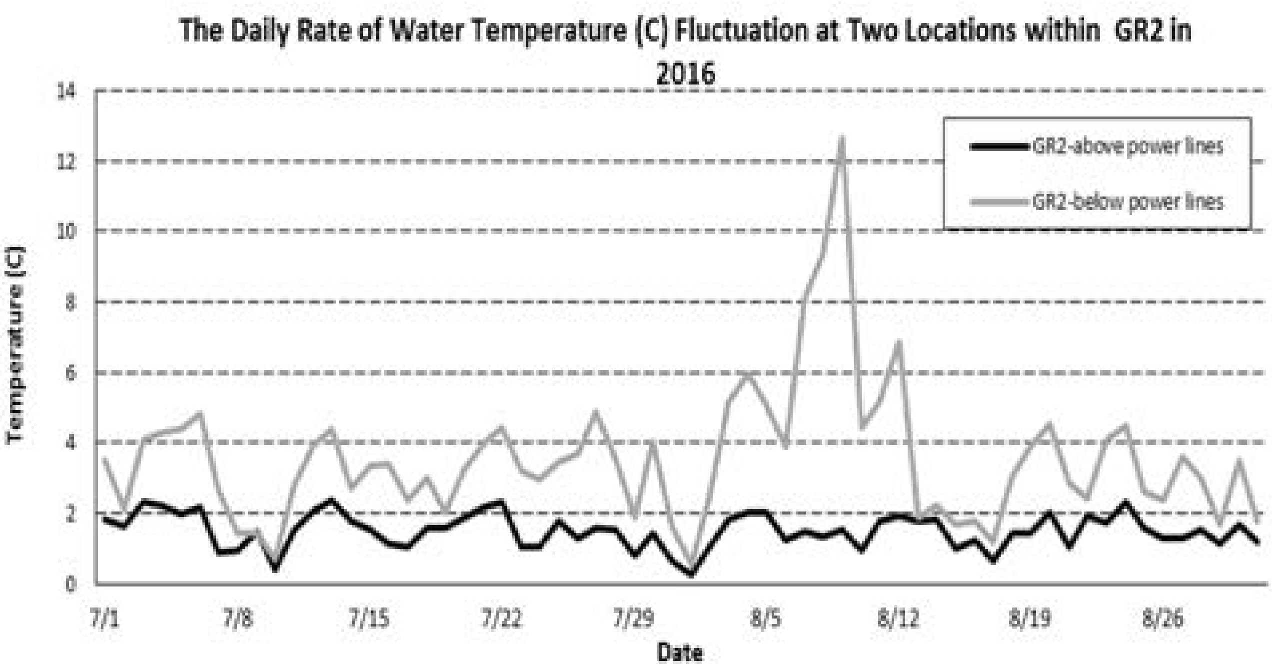

Figure 12. The fluctuation of water temperatures observed at two locations within GR2 (a tributary to the Beebe River) in 2016.

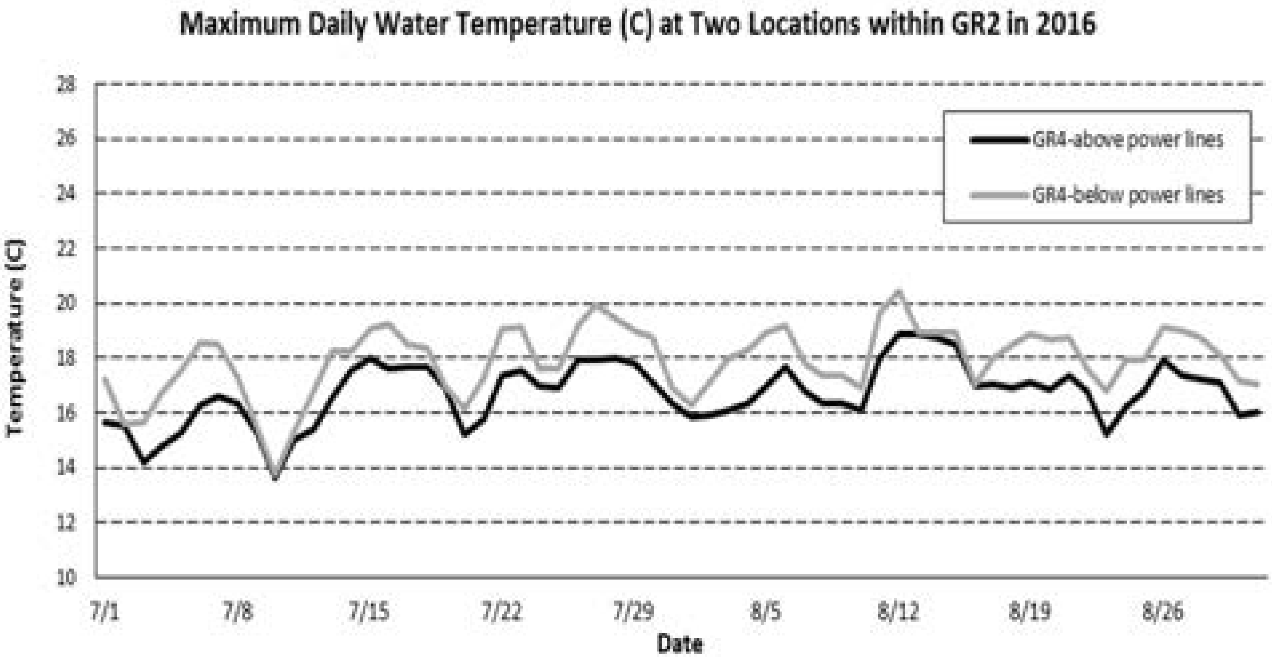

Figure 13. Maximum daily water temperatures (°C) observed at two locations within GR4 (a tributary to the Beebe River) in 2016.

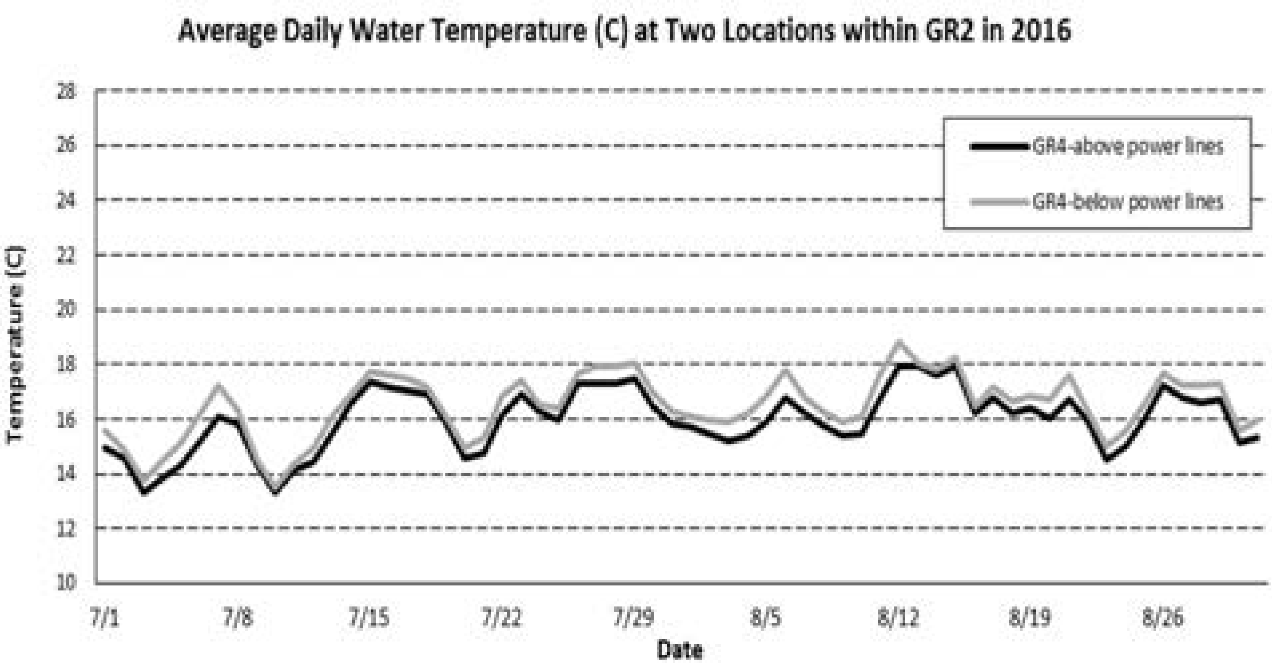

Figure 14. Average daily water temperatures (°C) observed at two locations within GR4 (a tributary to the Beebe River) in 2016.

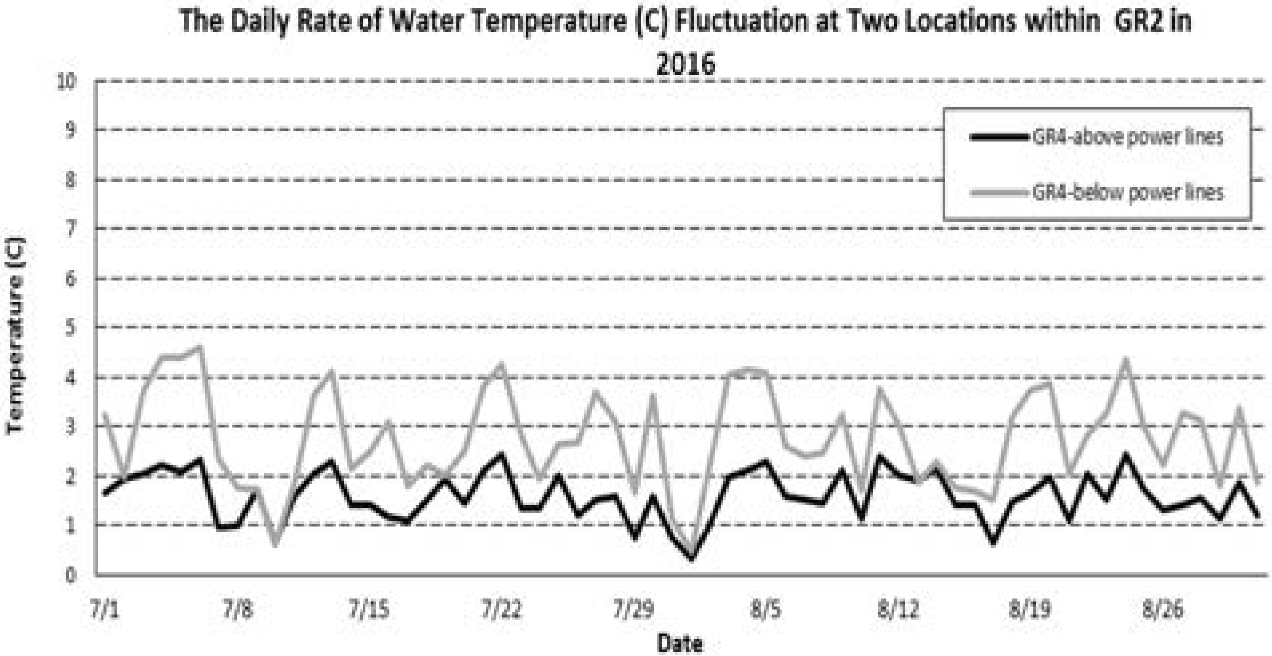

Figure 15. The fluctuation of water temperatures observed at two locations within GR4 (a tributary to the Beebe River) in 2016.

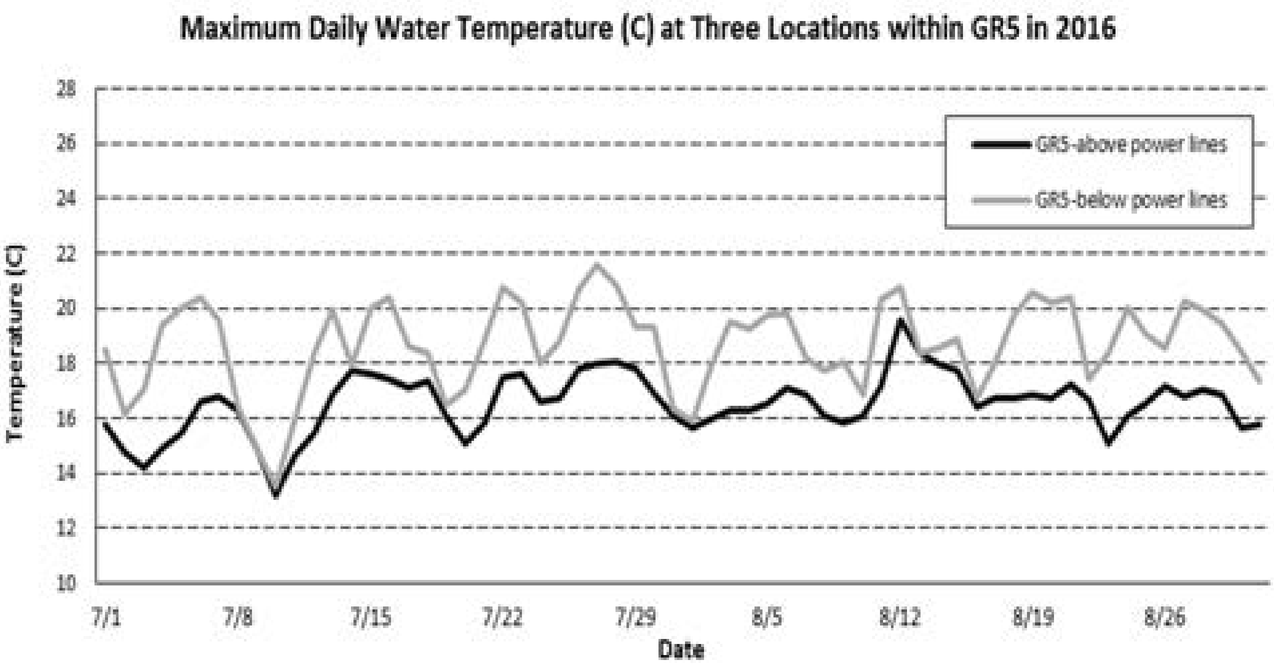

Figure 16. Maximum daily water temperatures (°C) observed at two locations within GR5 (a tributary to the Beebe River) in 2016.

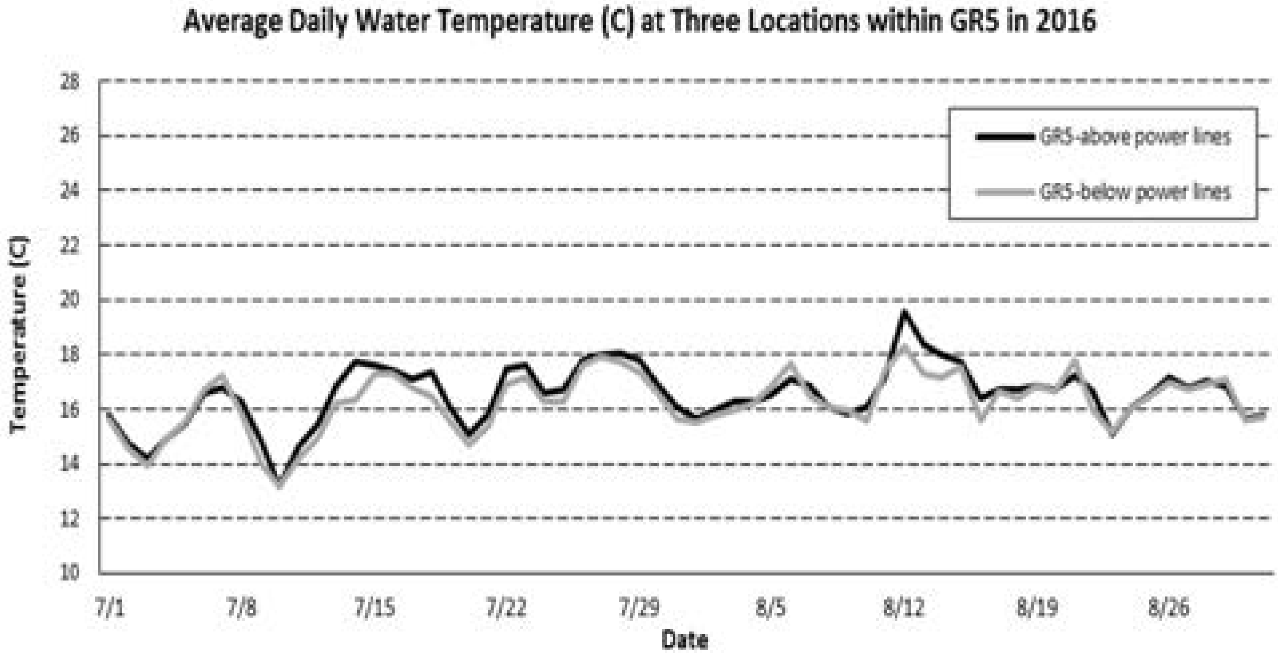

Figure 17. Average daily water temperatures (°C) observed at two locations within GR5 (a tributary to the Beebe River) in 2016.

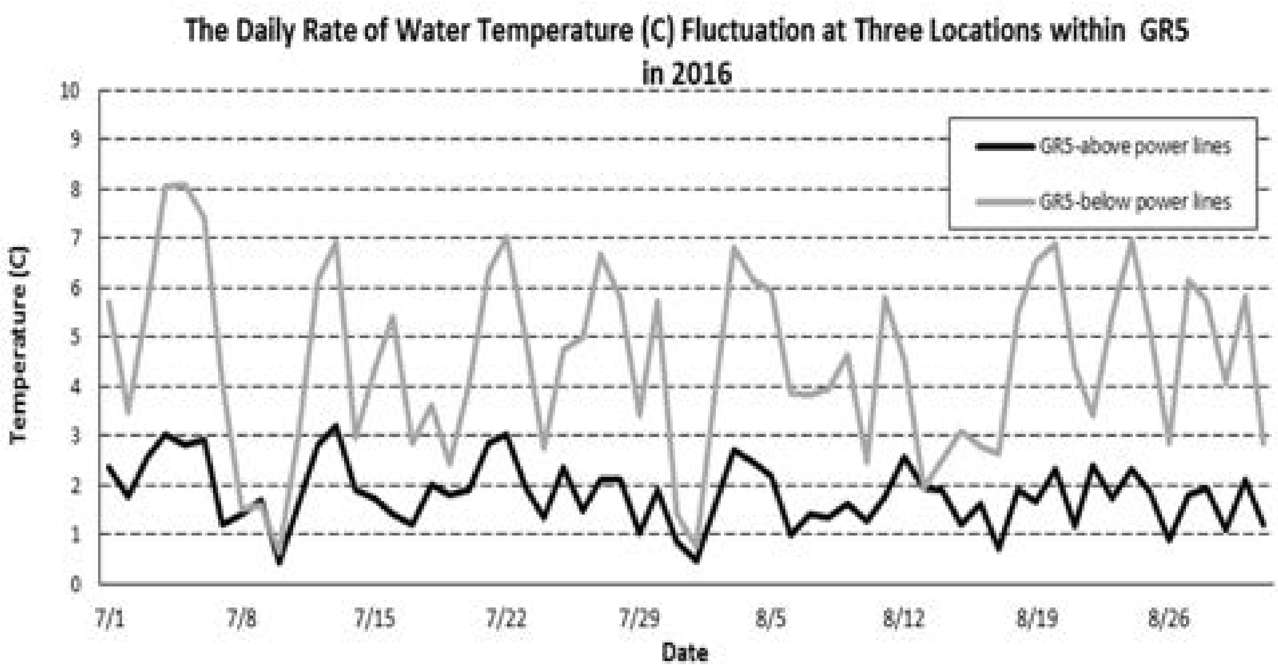

Figure 18. The fluctuation of water temperatures observed at two locations within GR5 (a tributary to the Beebe River) in 2016.

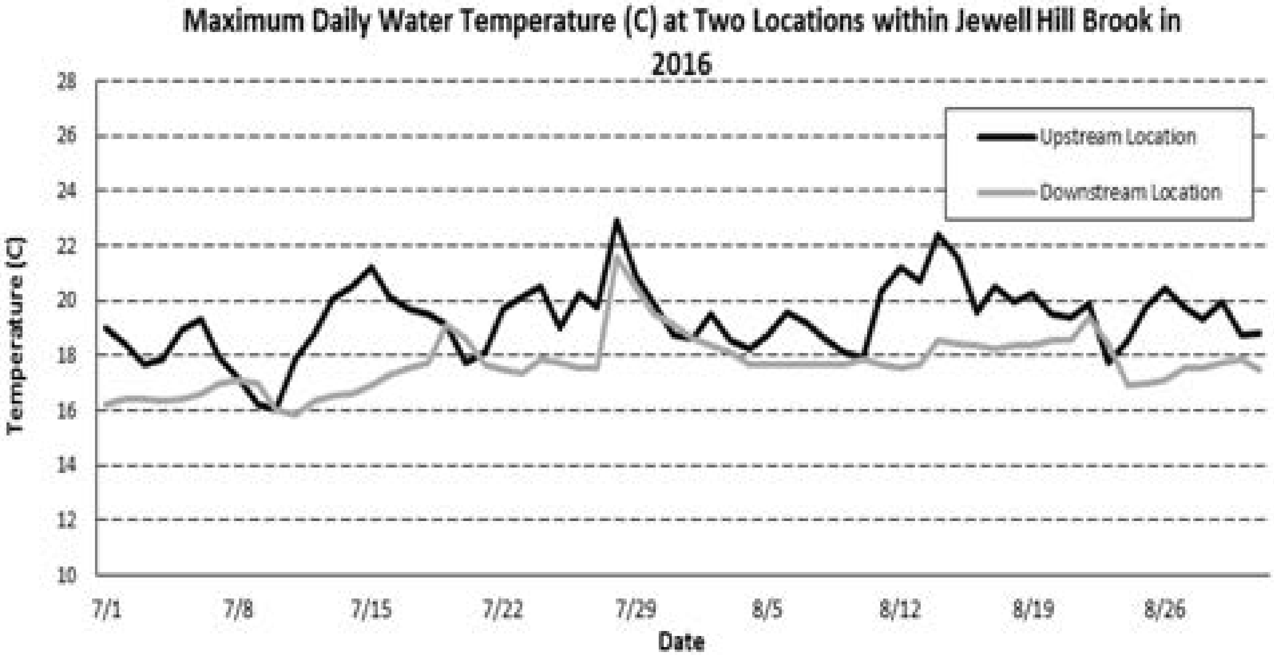

Figure 19. Maximum daily water temperatures (°C) observed at two locations in Jewell Hill Brook in 2016.

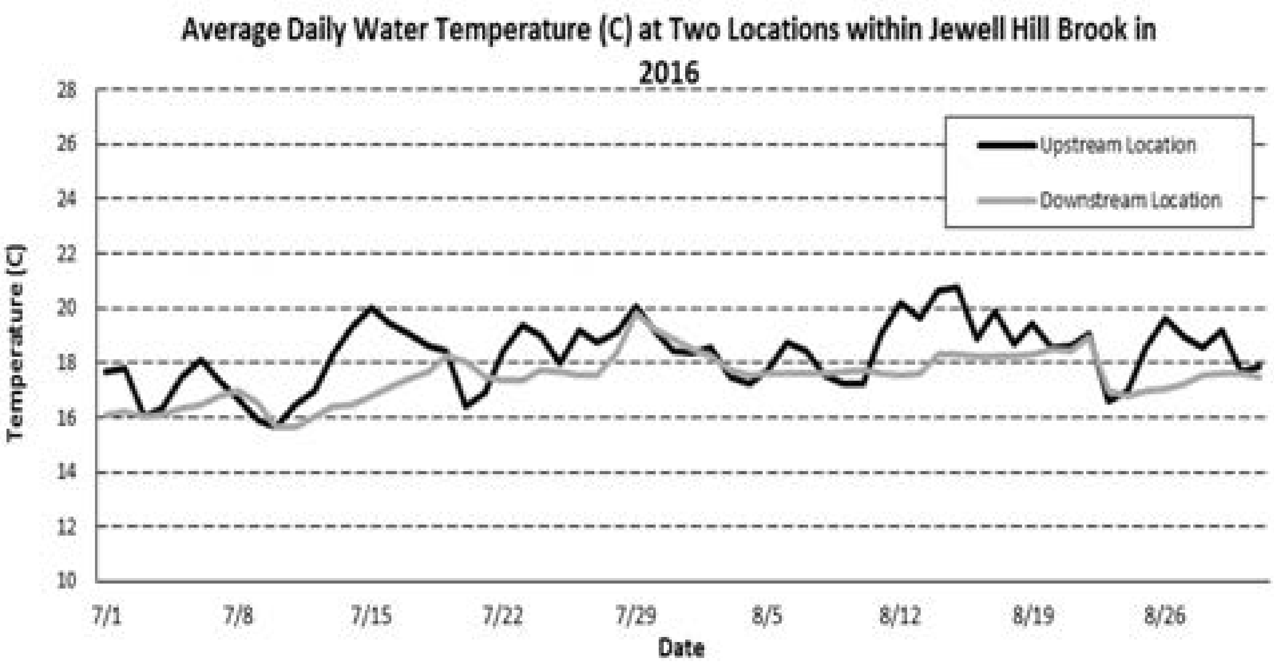

Figure 20. Average daily water temperatures (°C) observed at two locations in Jewell Hill Brook in 2016.

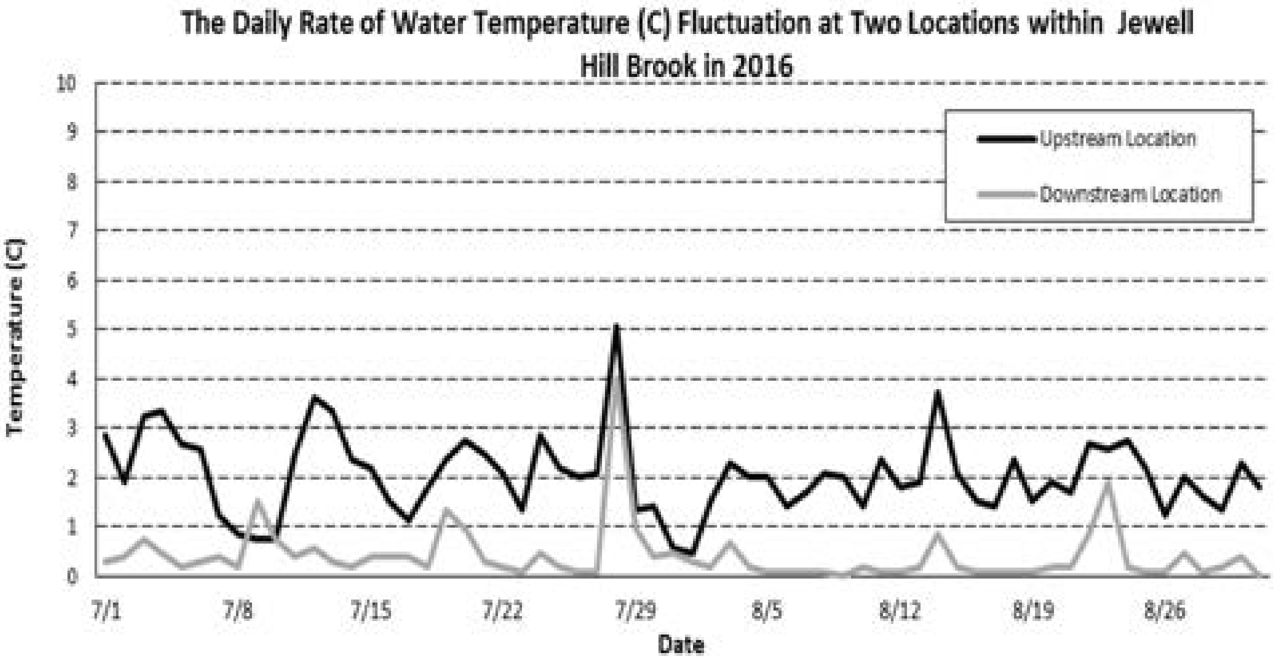

Figure 21. The fluctuation of water temperatures (°C) observed in two locations in Jewell Hill Brook in 2016.

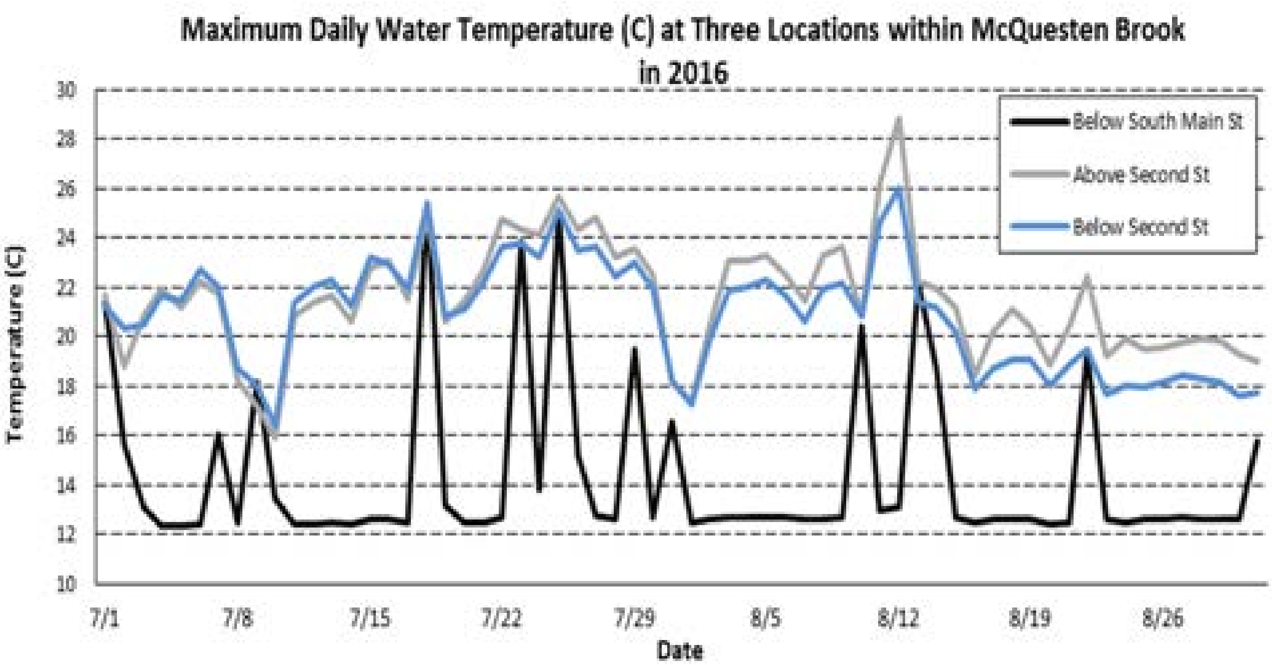

Figure 22. Maximum daily water temperatures (°C) observed at three locations in McQuesten Brook in 2016.

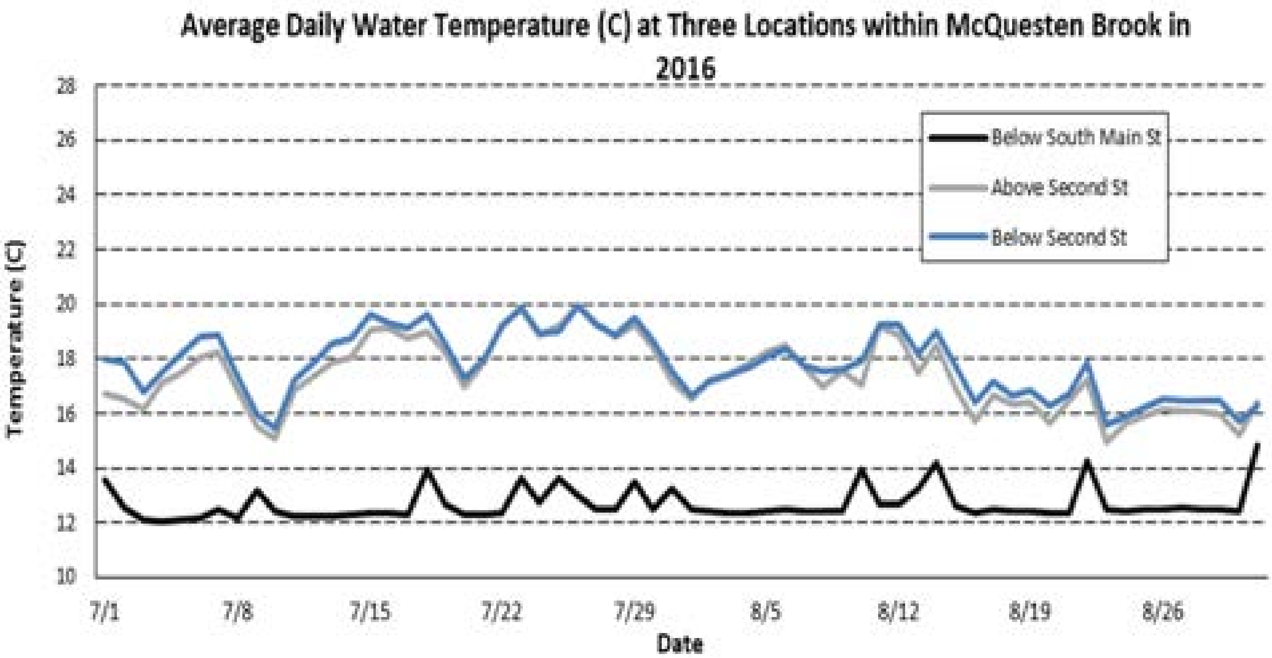

Figure 23. Average daily water temperatures (°C) observed at three locations in McQuesten Brook in 2016.

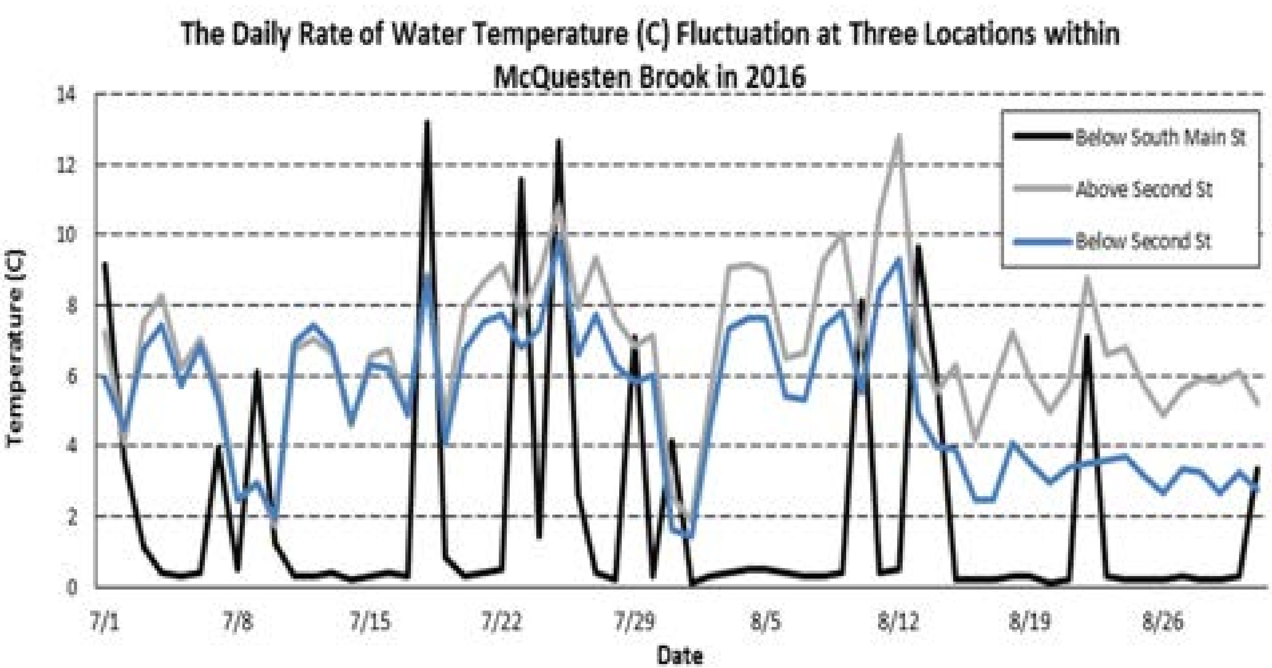

Figure 24. The fluctuation of water temperatures (°C) observed in three locations in McQuesten Brook in 2016.

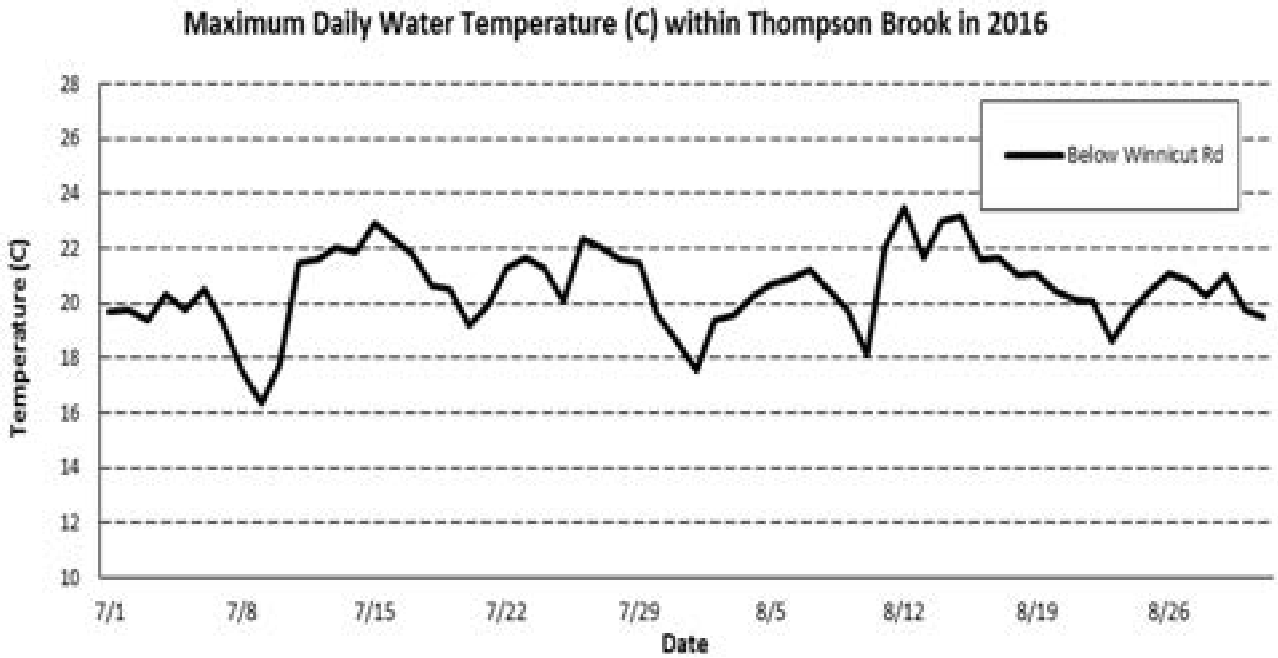

Figure 25. Maximum daily water temperatures (°C) observed within Thompson Brook in 2016.

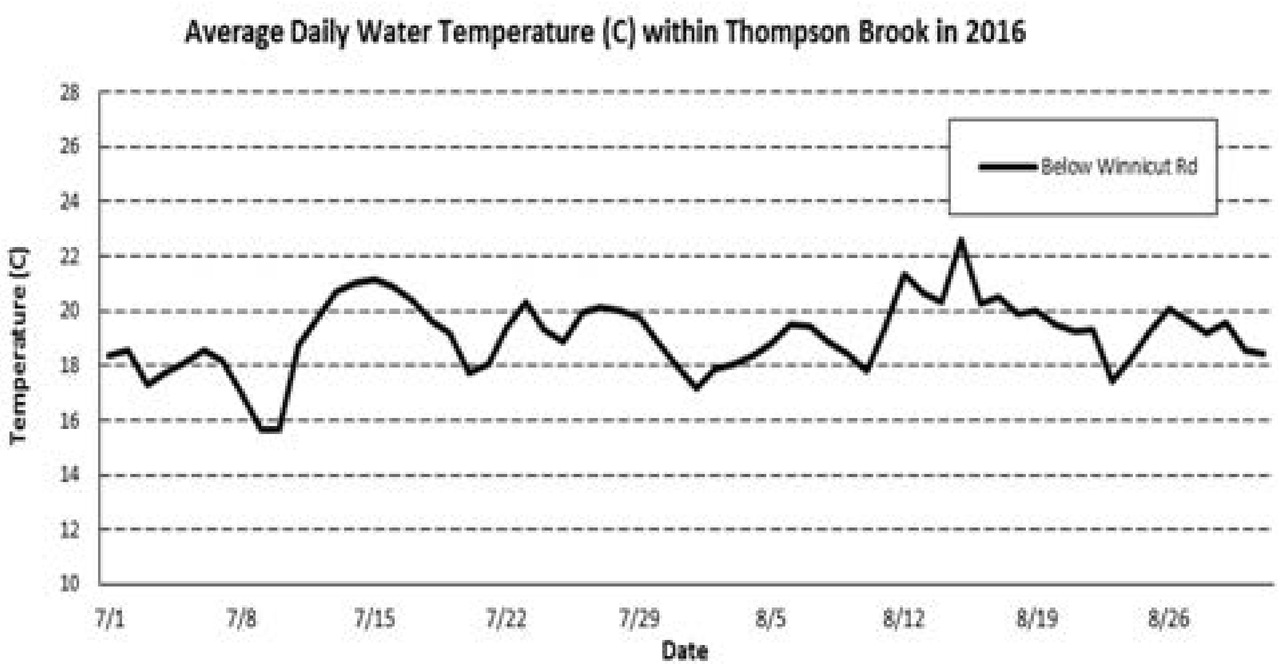

Figure 26. Average daily water temperatures (°C) observed within Thompson Brook in 2016.

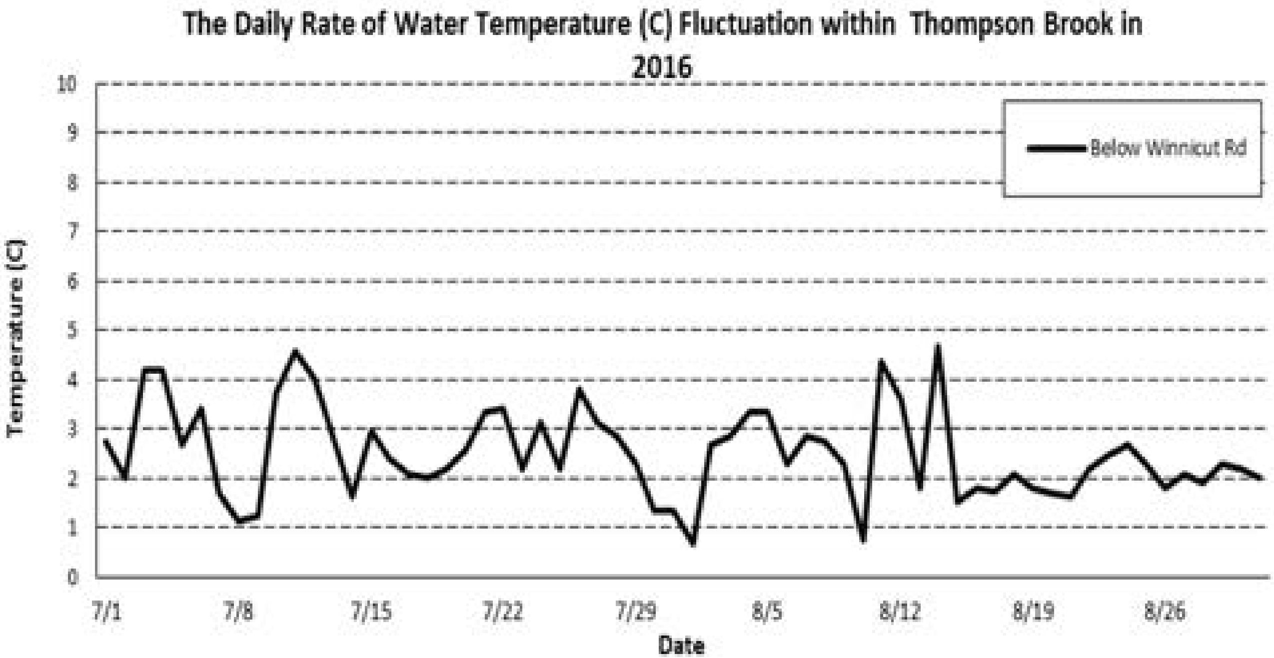

Figure 27. The fluctuation of water temperatures observed within Thompson Brook in 2016.

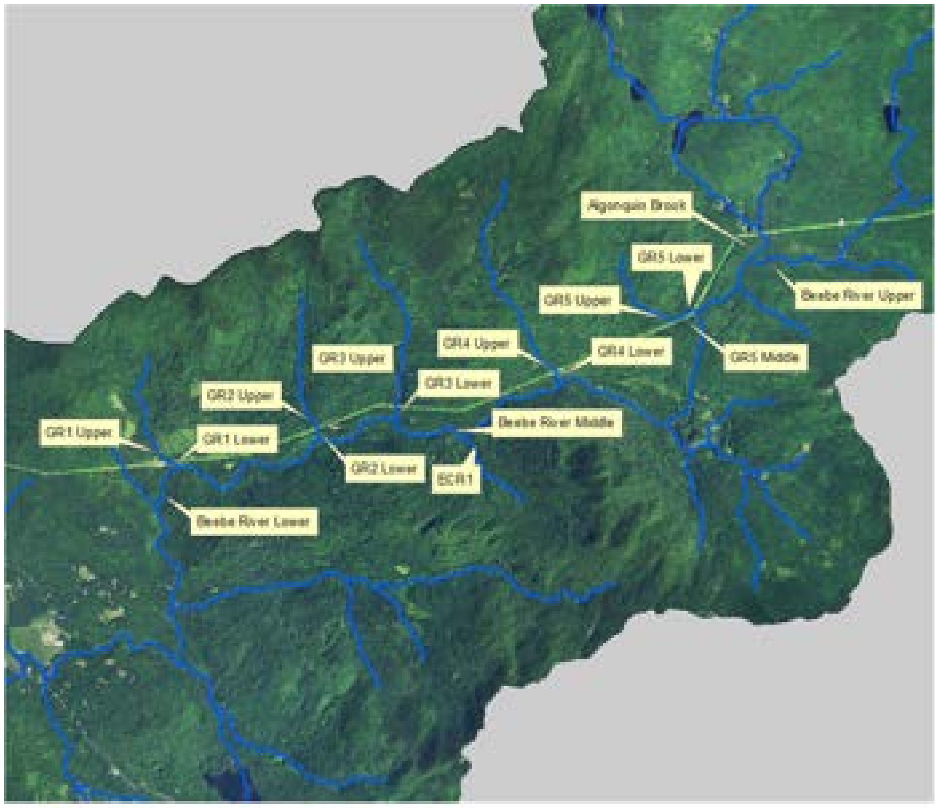

Figure 28. Locations within the Beebe River Watershed where thermograph loggers were deployed in 2016.

Figure 29. Locations within Jewell Hill Brook where thermograph loggers were deployed in 2016.

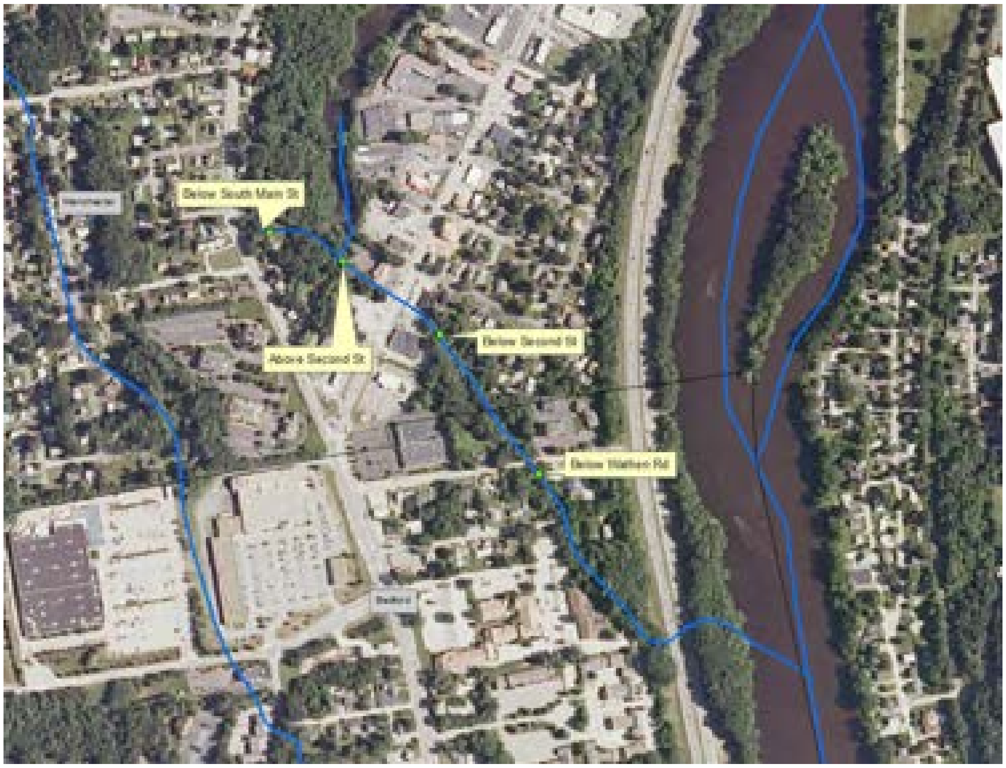

Figure 30. Locations within McQuesten Brook where thermograph loggers were deployed in 2016.

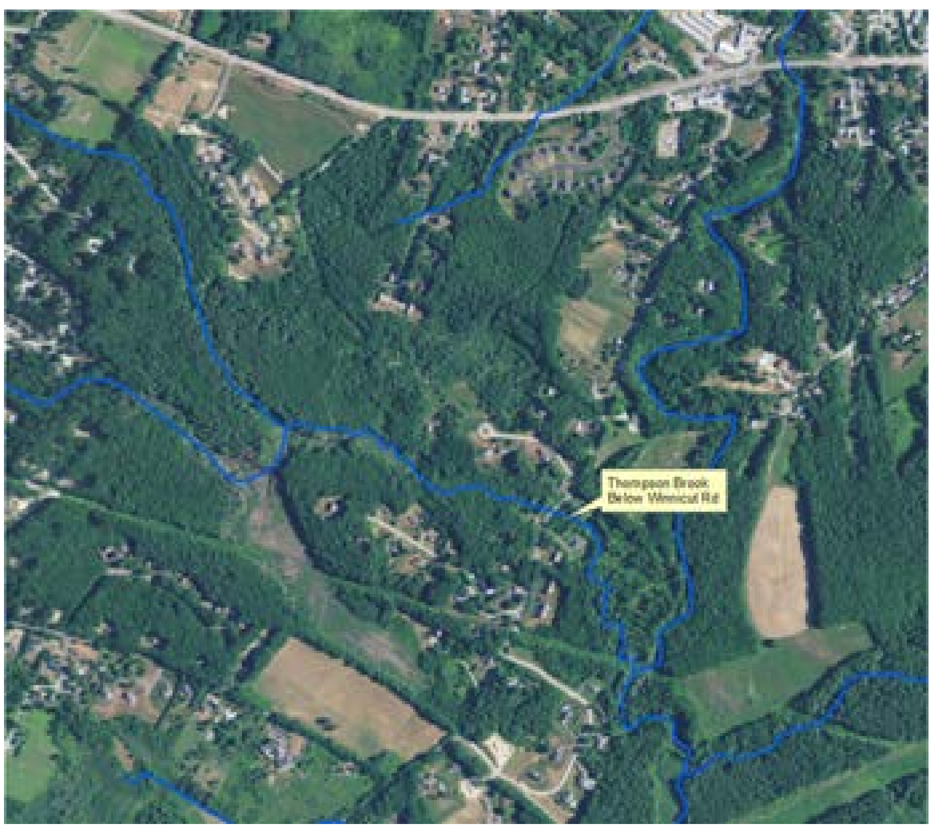

Figure 31. Location within Thompson Brook where thermograph loggers were deployed in 2016.

Appendix I. National Weather Service. 9-2-16Seasonal Climate Report, Concord, NH. (http://w2.weather.gov/climate/getclimate.php?wfo=gyx)

THE CONCORD NH CLIMATE SUMMARY FOR THE SUMMER SEASON, FROM 6/1/2016 TO 8/31/2016...

CLIMATE NORMAL PERIOD 1981 TO 2010
CLIMATE RECORD PERIOD 1868 TO 2016

WEATHER	OBSERVED VALUE	DATE(S)	NORMAL VALUE	DEPART FROM NORMAL	LAST YEAR`S VALUE	DATE(S)
TEMPERATURE (F)						
RECORD						
HIGH	102	07/03/1966				
		07/04/1911				
LOW	29	08/31/1965				
HIGHEST	99	08/12	95	4	96	07/29
LOWEST	46	08/23	37	9	38	06/07
		06/11				
AVG. MAXIMUM	84.1		80.2	3.9	81.0	
AVG. MINIMUM	56.9		55.5	1.4	56.0	
MEAN	70.5		67.8	2.7	68.5	
DAYS MAX >= 90	22		9.9	12.1	10	
PRECIPITATION (INCHES)						
RECORD						
MAXIMUM	20.49	1897				
MINIMUM	2.74	1999				
TOTALS	5.48		10.61	-5.13	12.89	
DAILY AVG.	0.06		0.12	-0.06	0.15	
DAYS >= .01	26		33.4	-7.4	35	
DAYS >= .10	16		20.2	-4.2	16	
DAYS >= .50	3		7.0	-4.0	8	
DAYS >= 1.00	0		2.6	-2.6	5	
GREATEST						
24 HR. TOTAL	0.95	06/05				
DEGREE_DAYS						
HEATING TOTAL	53		133	-80	103	
SINCE 7/1	12		48	-36	8	
COOLING TOTAL	584		395	189	436	
SINCE 1/1	624		413	211	502	

SKY COVER
AVERAGE SKY COVER 0.30

WEATHER CONDITIONS NUMBER OF DAYS WITH

THUNDERSTORM	10	HEAVY RAIN	11
RAIN	16	LIGHT RAIN	35
FREEZING RAIN	0	LT FREEZING RAIN	0
HEAVY SNOW	0	SNOW	0
LIGHT SNOW	0	FOG	36
FOG W/VIS <= 1/4 MILE	7	HAZE	6

THE SUMMER BEGAN WITH A PERIOD OF COOL, WET WEATHER. ON JUNE 5, 0.95INCHES OF RAIN FELL AT CONCORD. THIS ENDED UP BEING THE HEAVIEST RAIN ALL SUMMER AS DROUGHT CONDITIONS DEVELOPED AND INTENSIFIED AS THE SUMMER WENT ON. FROM MID JUNE THROUGH MID JULY, THE WEATHER PATTERN CONSISTED OF GRADUALLY WARMING TEMPERATURES WHICH WERE TYPICALLY FOLLOWED BY A COLD FRONT BRINGING COOLER AND DRIER AIR BACK INTO THE AREA EVERY FEW DAYS. THIS BEGAN TO CHANGE IN MID JULY WHEN EASTERLY WINDS BROUGHT COOL, WET WEATHER TO THE AREA. THE HIGH TEMPERATURE ON JULY 9 WAS ONLY 63 DEGREES, THE COOLEST JULY DAY SINCE 2009. THIS COOL WEATHER WAS ONLY TEMPORARY AS A SHIFT TOWARD WARMER WEATHER BEGAN SOON AFTERWARDS, LASTING THROUGH MUCH OF AUGUST. FROM JULY 22 THRU JULY 28 THE TEMPERATURE TOPPED 90 DEGREES ON 6 OUT OF 7 DAYS. THE HOT WEATHER RETURNED IN AUGUST WHEN THE TEMPERATURE REACHED 98 DEGREES ON AUGUST 11 AND 99 ON AUGUST 12. ALTHOUGH WARM WEATHER CONTINUED THROUGH THE REST OF AUGUST, THE BRUTALLY HOT WEATHER DID NOT RETURN. OVERALL IT WAS THE 4TH WARMEST AND 9TH DRIEST SUMMER ON RECORD AT CONCORD.

THE AVERAGE TEMPERATURE FOR THE SUMMER WAS 70.5 DEGREES WHICH WAS 2.7 DEGREES ABOVE NORMAL AND THE 4TH WARMEST ON RECORD. THE WARMEST SUMMER WAS IN 1872 WHEN THE AVERAGE TEMPERATURE WAS 72.3 DEGREES. THE COOLEST WAS 1903 AT ONLY 62.6 DEGREES. THE FOLLOWING TABLE LISTS THE WARMEST SUMMERS AT CONCORD.

WARMEST AVERAGE TEMPERATURE IN SUMMER (SINCE 1868)

Rank	Temp	Year
1	72.3	1872
2	72.1	1876
3	71.7	1870
4	**70.5**	**2016**
5	70.4	1877
6	70.1	1949
7	70.0	2005
	70.0	1938
9	69.9	1955
	69.9	1937

THE TEMPERATURE HIT 99 DEGREES ON AUGUST 12, TYING AS THE 4TH HOTTEST TEMPERATURE OBSERVED IN THE MONTH OF AUGUST. THE HIGH OF 98 ON AUGUST 11 ALSO MADE THE TOP TEN. THE FOLLOWING TABLE LISTS THE HOTTEST TEMPERATURES RECORDED IN AUGUST AT CONCORD.

HOTTEST TEMPERATURES IN AUGUST (SINCE 1868)

Rank	Temp	Date
1	101	AUG 2, 1975
2	100	AUG 5, 1955
	100	AUG 26, 1948
4	99	**AUG 12, 2016**
	99	AUG 14, 2002
	99	AUG 13, 1944
	99	AUG 12, 1944
	99	AUG 1, 1917
9	98	**AUG 11, 2016**
	98	MULTIPLE DATES

THERE WERE 71 DAYS THIS SUMMER WHICH TOPPED 80 DEGREES, THE MOST IN 50 YEARS. IN ADDITION, 22 DAYS TOPPED 90 DEGREES, TYING FOR THE 6TH MOST ON RECORD. THE FOLLOWING TABLES LIST THE MOST DAYS WITH HIGH TEMPERATURES OF 80 DEGREES OR HIGHER AND 90 DEGREES OR HIGHER.

SUMMER DAYS REACHING OR EXCEEDING 80 AND 90 DEGREES (SINCE 1868)

	80+ DEGREES			90+ DEGREES		
RANK	DAYS	YEAR		DAYS	YEAR	
1	74	1870		29	1955	
2	72	1966		26	1870	
3	**71**	**2016**	<===	25	1988	
4	67	1952		25	1966	
5	66	1995		24	1949	
6	66	1950		**22**	**2016**	<===
7	66	1949		22	1978	
8	65	2005		21	2010	
9	64	2012		21	2002	
10	63	1993		21	1952	
	63	1882		21	1876	

A TOTAL OF 5.48 INCHES OF RAIN FELL THIS SUMMER WHICH WAS 5.13 INCHES BELOW NORMAL AND THE 9TH DRIEST ON RECORD. THE HEAVIEST RAIN WAS ON JUNE 5 WHEN 0.95 INCHES FELL. THE DRIEST SUMMER ON RECORD WAS IN 1999 WHEN ONLY 2.74 INCHES FELL. THE WETTEST WAS 1897 WITH 20.49 INCHES. THE FOLLOWING TABLE LISTS THE DRIEST SUMMERS ON RECORD AT CONCORD.

DRIEST SUMMERS (SINCE 1868)

RANK	PRECIP	YEAR
1	2.74	1999
2	3.65	1913
3	4.35	1994
4	4.69	1869
5	4.71	1919
6	4.83	1870
7	5.43	1974
	5.43	1894
9	**5.48**	**2016** <===
10	5.61	1932

THE FOLLOWING DAILY RECORDS WERE SET OR TIED IN SUMMER 2016...

DATE	RECORD		PREVIOUS
AUG 12	99	- WARMEST HIGH TEMPERATURE	99 IN 1944 /TIED/

NOTE
CHANGES TO THE GROUND COVER NEAR THE TEMPERATURE SENSOR AT THE CONCORD AIRPORT ON JULY 13 LIKELY CAUSED THE AFTERNOON TEMPERATURE TO READ A DEGREE OR TWO TOO HIGH ON MANY DAYS THROUGH THE END OF AUGUST. IT IS IMPOSSIBLE TO KNOW EXACTLY HOW MUCH THIS AFFECTED CONCORD`S TEMPERATURE READINGS, BUT IT IS LIKELY THAT THIS CHANGE CAUSED A SLIGHT WARM BIAS IN TEMPERATURES. THIS PROBLEM WAS IDENTIFIED AND HAS BEEN ADDRESSED BY MAINTENANCE STAFF.