NATIONAL CAPITAL CHAPTER TROUT UNLIMITED

CATOCTIN MOUNTAIN WATER TEMPERATURE STUDY

Summer 2020

PREPARED BY

ANDREW SARCINELLO, CONSERVATION CHAIR, NCC-TU

APRIL 2022

Project Origins

In summer 2020, NCC-TU monitored water temperature at 32 sites across four Catoctin Mountain watersheds. All sites monitored are known to support native brook trout populations ranging from stable populations comprised of hundreds of fish to marginal populations sustained only by a few spawning pairs of adult fish in the entire stream. NCC-TU hoped the data obtained would offer insights into the resilience of these native trout populations to the predicted warming effects of climate change and help Trout Unlimited identify areas that might present opportunities for future projects to reduce water temperatures or otherwise strengthen the resilience of these populations to warming conditions.

Above: *A native brook trout from a Catoctin Mountain stream.*

Why Brook Trout?

The plight of brook trout in Maryland (and in many states across the eastern U.S.) has been well documented: man-made disturbances to the natural environment in the form of development, agriculture, and introduction of non-native fish species (brown and rainbow trout) have reduced the occupied range of brook trout to a tiny fraction of the historical range.

In 2019, the Maryland Department of Natural Resources (DNR) Freshwater Fisheries Program presented the results of a five-year electrofishing study of all known brook trout streams in the state. DNR found that the number of streams inhabited by brook trout has declined by over 20% since thorough recordkeeping began in the early 1980s. The rate of extirpation of Catoctin Mountain populations closely followed the statewide average, with lesser declines in far western MD and a dramatic 49% decline observed in central MD’s piedmont region.

DNR was alarmed by the findings and asked environmental groups across the state to consider undertaking projects that could benefit brook trout in the state. NCC-TU is not blessed with any native brook trout streams within its chapter footprint, but chapter leadership still felt NCC-TU could use its resources and connections to try to help.

Implementation

NCC-TU had never previously engaged its chapter membership in a water temperature study of this nature before. By obtaining an environmental non-profit grant from Patagonia, NCC-TU secured the necessary funding to purchase dozens of HOBO water temperature loggers. The chapter leaders received guidance on the project design from DNR's Freshwater Fisheries Western II Regional Fisheries Manager Michael Kashiwagi and Dr. Than Hitt, a brook trout researcher with the United States Geological Survey (USGS). Amidst the height of the Covid-19 pandemic, the chapter was able to successfully coordinate a socially-distanced volunteer effort to install the monitoring equipment.

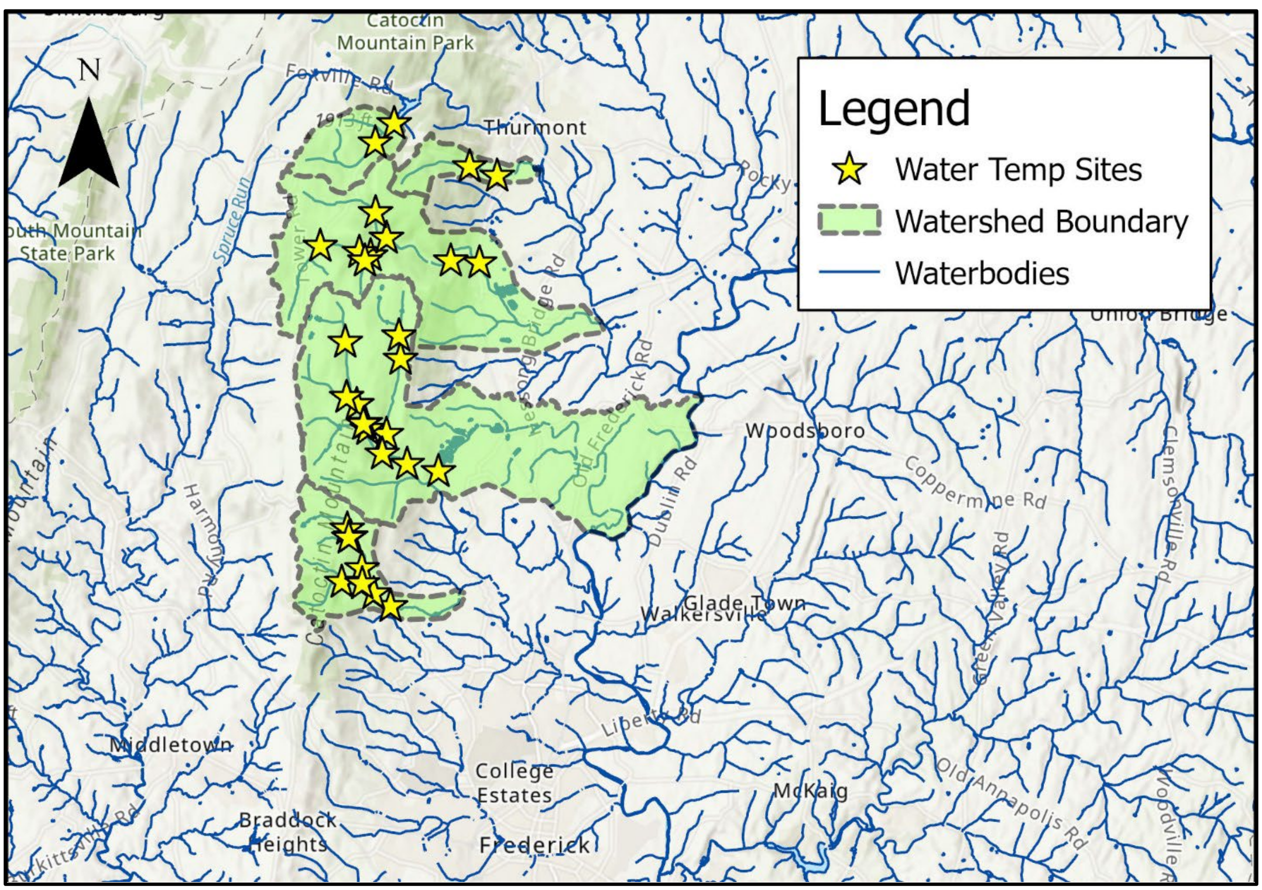
Installation was only half the battle. The water temperature loggers do not have the ability to transmit the temperature readings in real time – they sit in a secure location on the stream bottom, logging the temperature every 20 minutes, and the data cannot be downloaded until the equipment is retrieved in the fall season. Although precautions were taken during installation, the flowing stream environment is unpredictable. Summer 2020 was an anxious one as the project organizers were unsure whether the equipment would still be in place in September. Ultimately, only 3 of 35 probes were lost to floods or human interference, a recovery rate of 91%. The data recovered spanned a total of 21 stream miles.

Above: *Temperature monitoring equipment. HOBO Data Loggers, protective PVC housing, and data offload shuttle.*

Study Design

NCC-TU scoped the study geographically to complement work previously performed by Dr. Hitt's team at USGS a few years prior – that study focused on brook trout streams only on Catoctin Mountain National Park land. NCC-TU focused on obtaining data in 4 other sub-watersheds outside of the National Park, with most sites being located on land owned by the State Park, City of Frederick, and a handful of sites on private land (where permission was obtained to conduct the research). To protect sensitive areas and to keep the results out of internet search engines, the specific names of these streams will not be provided in this public report, though people who are familiar with the area can probably figure out which streams were studied from the map below.

Sites were spread out to be approximately 1 kilometer apart on known brook trout waters, with special attention paid to areas of tributary confluences. At tributaries, temperatures were collected at one location upstream of the tributary, one location in the tributary, and one location downstream of the confluence to help TU identify if any tributaries were substantially warming or cooling the receiving streams. In addition to the 35 water temperature sites, 5 air temperature loggers were deployed at various locations across the stream valleys, with MD DNR contributing several additional air temperature loggers to round out the study. The air temperature sites are intended to help MD DNR and USGS evaluate the amount of groundwater influence at each stream site – this step of the analysis is beyond NCC-TU's capabilities.



Above: *Map showing the locations where water temperature data was successfully obtained during this study. The project volunteers covered a lot of ground and spent many hours installing and later retrieving the equipment.*

Each data logger recorded a temperature reading every 20 minutes, beginning on June 1 and continuing until retrieval sometime after September 1. The raw data from each site was analyzed for statistics important to brook trout survival over the period from June 1 to August 31. Data collection followed MD DNR protocol so it could be incorporated into their statewide water temperature database. Some statistics extracted during post-processing of the data include:

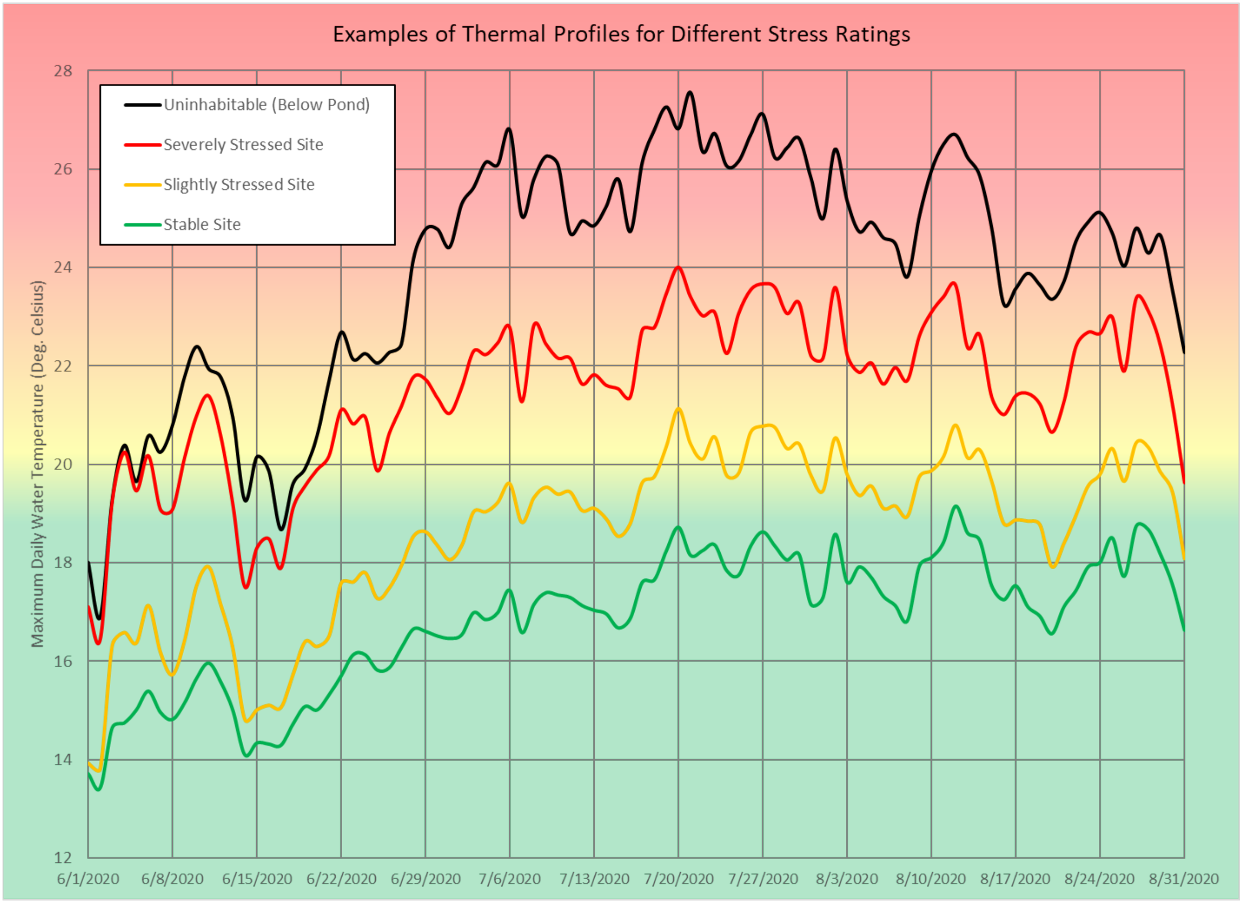
- Maximum Temperature
- Mean Temperature
- Minimum Temperature
- % of readings above 20°C (~68°F)
- % of readings above 24.5°C (~76°F)
- Number of days with Max Temp >20°C
- Number of days with Max Temp >24.5°C
- Date of first Max Temp reading >20°C
- Date of last Max Temp reading >20°C
- The number of days between the first and last dates of Max Temp >20°C
- Within the time span described above, what percentage of days were >20°C

Based on the extracted data, each site's statistics were compared to published temperature stress thresholds for brook trout established by laboratory research. One such study established that brook trout subjected to 14 days of maximum water temperature greater than 24.5°C would perish. Brook trout also exhibit physiological and behavioral changes caused by stress when water temperatures exceed 20°C.

By analyzing the number of days recorded where the max water temp exceeded the two critical thresholds of 20°C and 24.5°C, NCC-TU was able to estimate the amount of stress theoretically experienced by brook trout at each site. Each site was assigned a rating of Stable, Slightly Stressed, Severely Stressed, or Uninhabitable depending on the temperature statistics observed. Typical sites showing what each stress level looked like in the raw data are shown in the chart below. GIS software was used to map the results and calculate the miles of stream in each stress category for each watershed.

The stress rating only considers water temperature and does not consider other factors such as physical habitat quality, water chemistry, food availability, predation, or angling pressure. Because the study was only conducted during a single season, the ability to produce any strong conclusions is somewhat limited. Due to the time and resource limitations of this study, the stress ratings are educated guesses used to help classify current and future conditions experienced by the brook trout in these locations.

According to climate records, the summer (June through August) of 2020 was the second-hottest summer on record in Frederick County. The temperatures observed during this study may have been unusually warm compared to the past several decades but may end up being commonplace under a warmer climate.

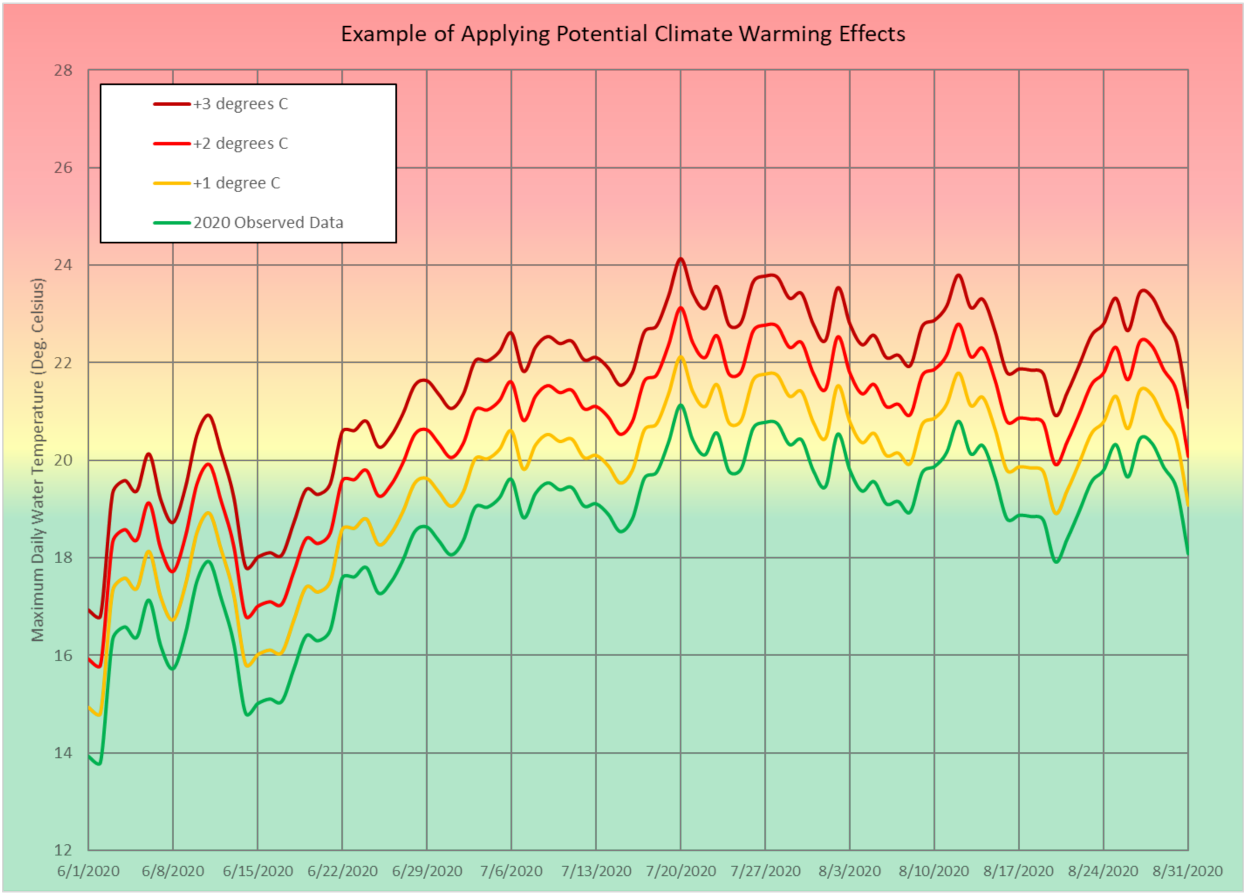


To model the potential impacts of climate warming on the stress rating of each stream segment, NCC-TU considered three potential "What-if" scenarios: What if climate warming causes water temperature increases of 1 degree Celsius, 2 degrees, and 3 degrees? At what threshold of increased water temperature would the effects become very concerning for the survival of Catoctin Mountain brook trout? To answer these questions, the 2020 daily maximum water temperature readings were increased by the amounts mentioned above and the number of days above 20°C and 24.5°C at each site were recalculated.

There were many assumptions made for this analysis that should preclude anyone from taking the findings as absolute predictions. To name a few assumptions:

- Temperature increases of exactly 1°C/2°C/3°C occur every single day.
- The temperatures recorded in 2020 (and the dates of which days were hottest and coolest, which days it rained) perfectly represent a future summer.
- Findings of thermal stress and mortality thresholds on brook trout in a tank in a laboratory apply to wild brook trout found in Catoctin Mountain streams.

NCC-TU hopes the findings of this analysis are informative, thought-provoking, and ultimately inform TU's decision-making to engage in projects to efficiently protect a vulnerable and iconic native fish. However, this report is not to be construed as a peer-reviewed scientific study.



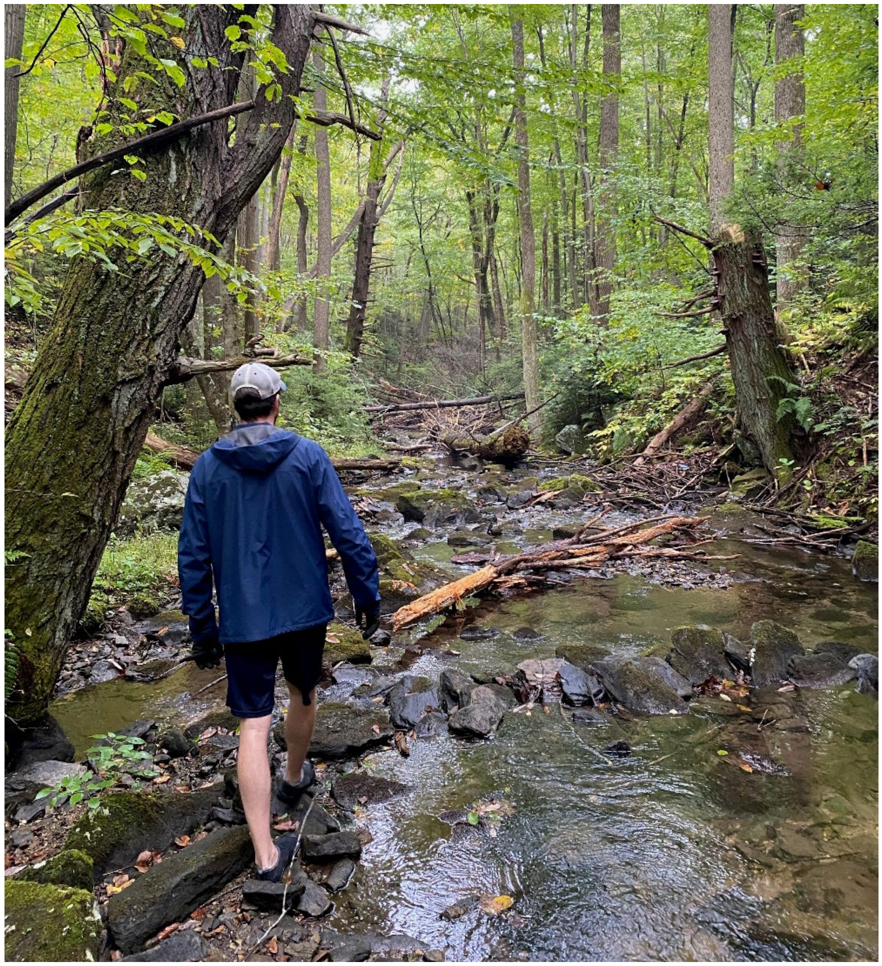
Findings

The water temperature data collected revealed some incredibly useful information. From the 2020 data, NCC-TU captured:

- Severe negative thermal impacts below ponds and lakes
- Areas of groundwater recharge and thermal refuge
- Impacts of road runoff
- Correlation of coldest water temperatures with the strongest brook trout populations

Using the 2020 data to project the aforementioned climate warming scenarios, NCC-TU learned:

- Every degree of warming increases the severity of impacts on brook trout range in Catoctin Mountain streams: 1°C increase may not produce noticeable impacts, but 3 degrees would be severe.
- Even a 3-degree increase would not eliminate brook trout from Catoctin Mountain.
- As water temperature increases, brook trout populations will become less dense and potentially more isolated (even more so than they already are).



Above: NCC-TU Conservation Chair Andrew Sarcinello hikes along a brook trout stream to retrieve water temperature data. Photo courtesy of Ben Simonds.

Thermal Impacts of Ponds and Lakes

The summer 2020 data identified 3 locations where water warms substantially below an impoundment, regardless of how forested the surrounding watershed is. All 3 ponds/lakes release water from the top of the dams, where the stagnant water is warmed by the sun. The warmest reading of the entire project occurred approximately 200 yards downstream of a pond in the headwaters of one brook trout stream, with water temperatures exceeding 80°F observed. One-third of a mile downstream on the same waterway, the temperature never exceeded 71°F, pointing to substantial groundwater influence to overcome the effects of the pond. It is likely that if this pond were removed, brook trout could expand their range upstream.

In another instance, a water supply reservoir warms the downstream flow into the mid-70s. Current temperatures are borderline for brook trout survival, although a modest population exists in that location. Because the water is borderline at present, any amount of climate-induced warming will make the downstream water uninhabitable for brook trout. Before considering whether it would be wise to remove this dam, be aware that not only is it a significant water supply source, but the dam also prevents non-native brown trout from entering the headwaters of the watershed, where brook trout are abundant.

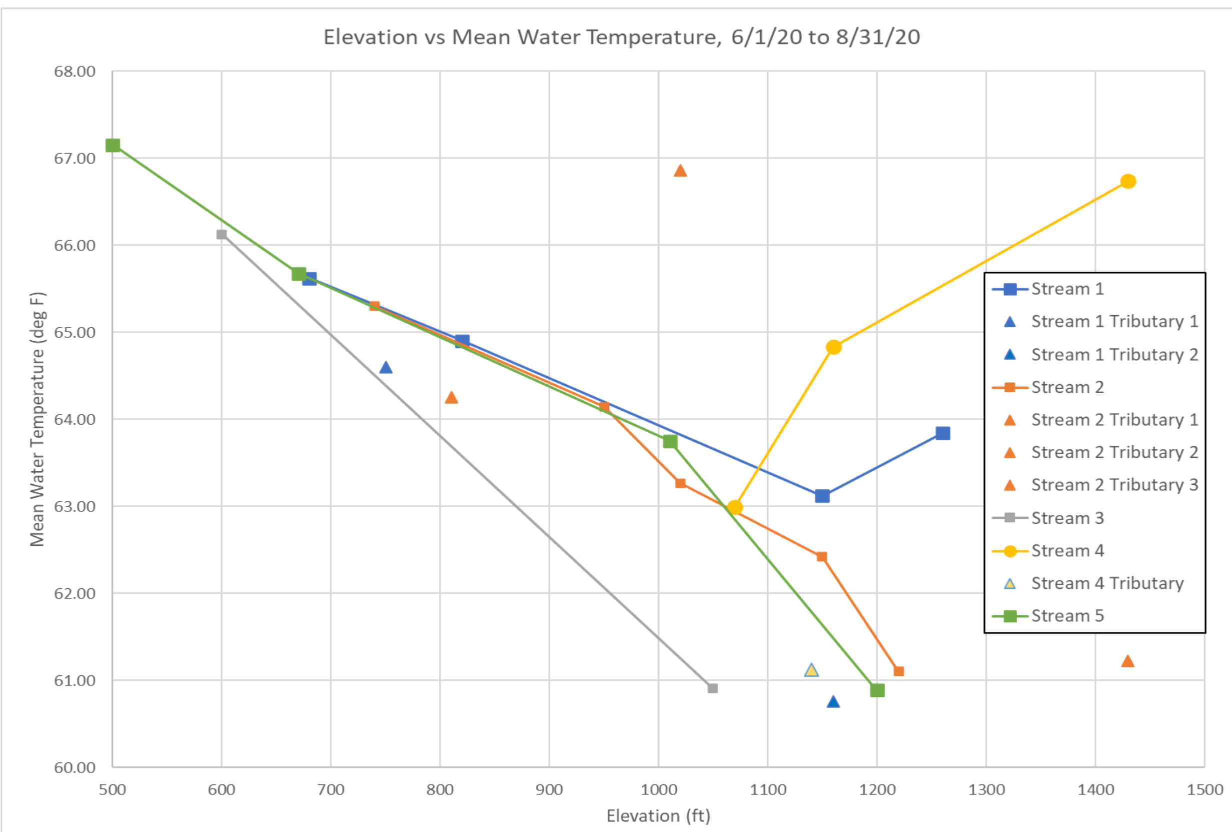
In the third and final instance, the pond in question is small, and the water exiting it is a few degrees warmer than upstream, but not to the point where it is greatly impacting brook trout downstream. The fact that such a small, well-shaded pond causes any increase is notable.

Groundwater and Thermal Refuge

Thanks to some long hikes from volunteers, some data loggers were installed in spring-fed headwater streams that have little to no man-made disturbances within the upstream watershed: in other words, the sites essentially recorded the temperature of pure groundwater. Despite the small size of the spring-fed sources, brook trout were observed in these trickles wherever there was enough depth and some rocks or sticks to hide under.

6 of the 32 water temperature sites recorded 0 days above the 20°C threshold widely considered to be stressful for brook trout. The coldest of these 6 sites recorded a maximum temperature of 65.5°F. This site required a 3-mile hike to reach and the volunteers who made the trek reported that "brook trout were everywhere" in this small stream. Interestingly, the coldest site was at the lowest elevation of the 6 coldest sites, meaning the groundwater input is particularly strong.

There are several instances where the water temperature did not follow what one might expect based on elevation of the site. Several streams were warmer at their highest elevations than the middle sections of those streams before again warming in the lowest elevations. The findings appear to suggest that most Catoctin Mountain brook trout streams receive a strong input of groundwater somewhere around 1,100 to 1,200 feet elevation.



Impacts of Road Runoff

At a few roadside sites, the maximum temperature observed during the study period occurred following a heavy downpour on a hot afternoon. The temperature of the runoff by itself was not at a level that would pose a threat to brook trout survival, but it does indicate that any pollutants on road surfaces (including sediment and gravel) are entering some Catoctin Mountain brook trout streams. Over time, roadway pollutants can accumulate and degrade the quality of brook trout habitat.

Correlation to Brook Trout Numbers

Trout Unlimited is not in possession of brook trout population survey results, but many of the volunteers who helped install the water temperature loggers for this project are intimately familiar with the trout populations of the streams studied. Unsurprisingly, areas known to support high-density brook trout populations also recorded the coldest water temperatures. The high-density brook trout streams can be characterized by pools containing multiple brook trout of various age classes. Most of these stream sections rated as “Stable” or “Slightly Stressed” based on the 2020 water temperature data. By contrast, the low-density streams, which may only contain a dozen adult brook trout per mile, typically rated as “Severely Stressed.”

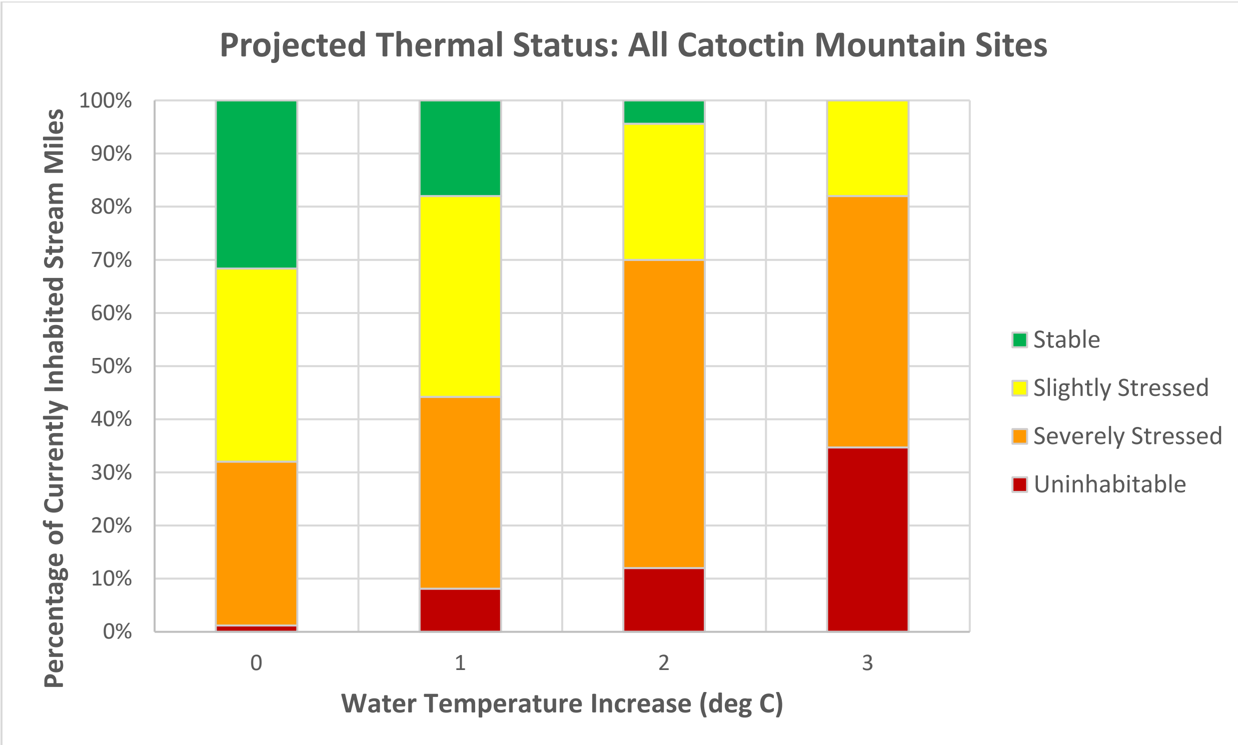
Impacts Due to Climate Warming

Using the 2020 summer water temperature readings as a baseline, NCC-TU added 1, 2, and 3 degrees C to each day’s maximum water temperature and reclassified the stress rating of each site. While the results of these simple projections were initially concerning, there are reasons for optimism about the future of Catoctin Mountain native brook trout.

With a water temperature increase of 1°C, only two sites are projected to become uninhabitable for brook trout, representing 8% of the total currently inhabited stream miles. Both of those sites are located below a water supply reservoir and there is potential refuge available in a cold tributary nearby (which was not studied due to private property). Approximately 35% of currently stable temperature stream mileage will warm to become slightly stressful to brook trout, showing an increase in impacts to even the coldest stream reaches. This magnitude of temperature increase would not result in a noticeable change in numbers or distribution of brook trout populations except in isolated instances.

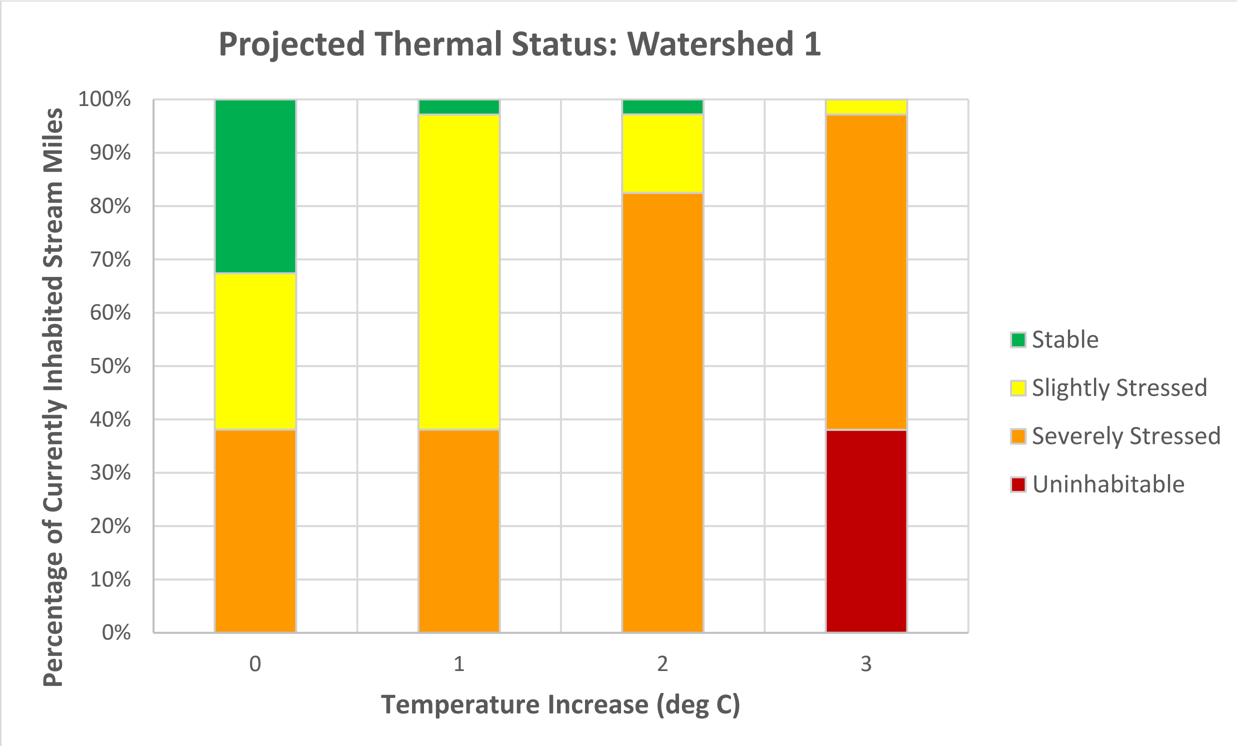
With an increase of 2°C, only one additional site becomes uninhabitable for brook trout during the summer months, but nearly 60% of all presently inhabited stream miles will warm into the severely stressed category. If present thermal profiles of low-density brook trout populations are any indication, this prediction would correlate to large-scale noticeable declines in brook trout abundance, although not necessarily any decrease in the range they are able to inhabit.

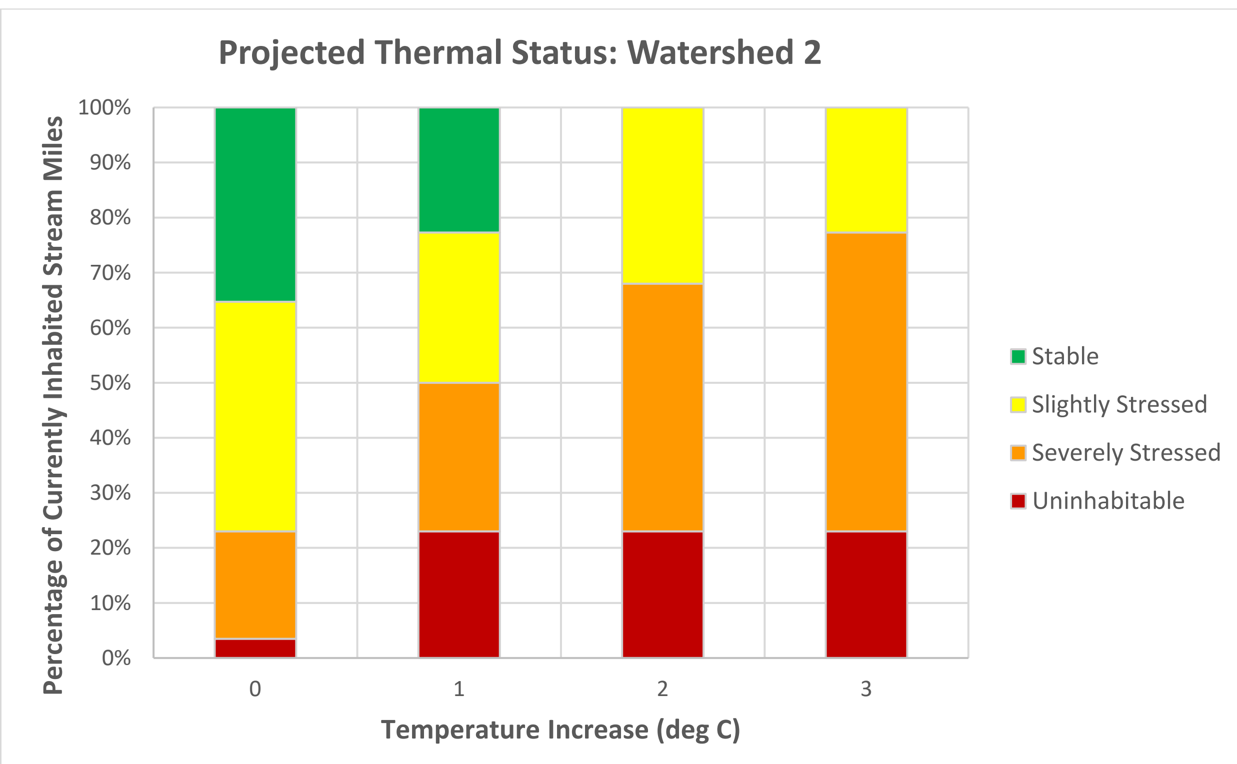
With an increase of 3°C, all presently “stable” stream miles would be considered at least slightly stressed (and approximately half would become severely stressed). Additionally, the number of stream miles that remain within the tolerable thermal profiles for summer brook trout survival will decrease by 34% compared to present conditions. 82% of all presently inhabited miles would become severely stressed or uninhabitable during the summer. The 3-degree increase is also the threshold where one entire stream would become uninhabitable due to warm water. That stream currently has the lowest-density brook trout population of the streams studied.

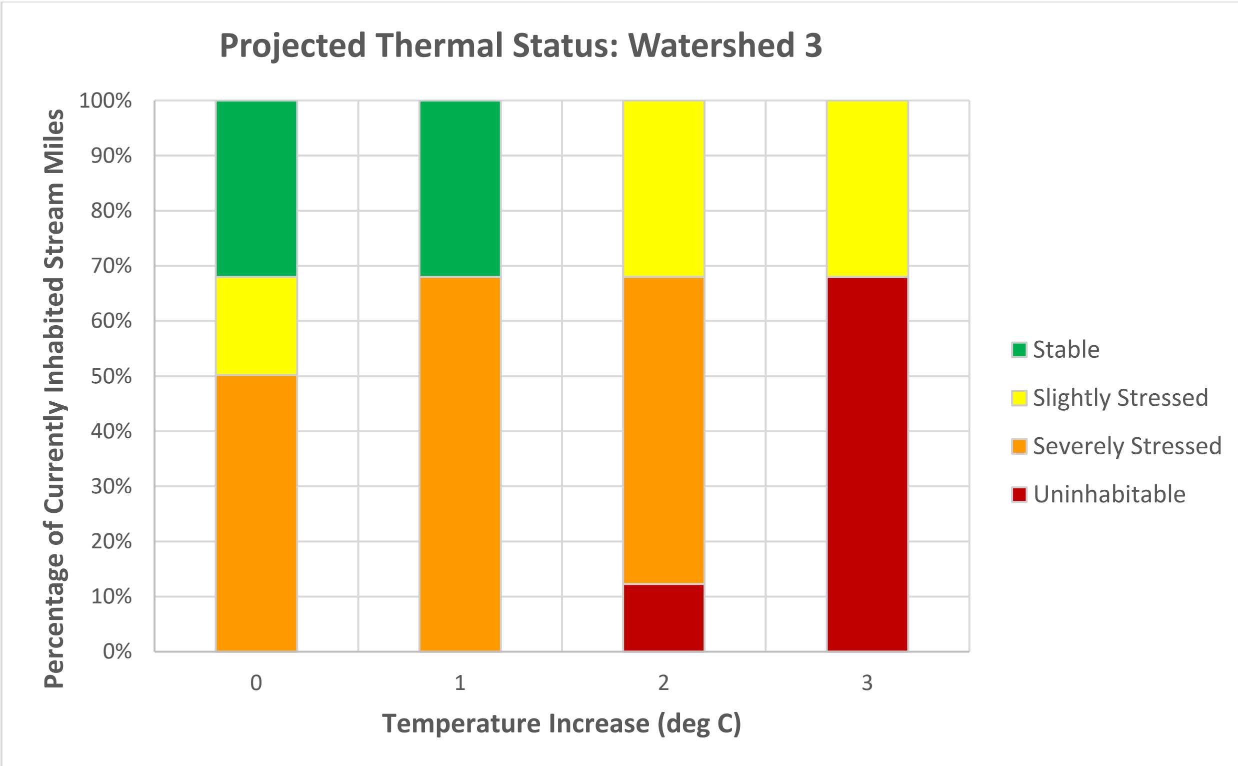


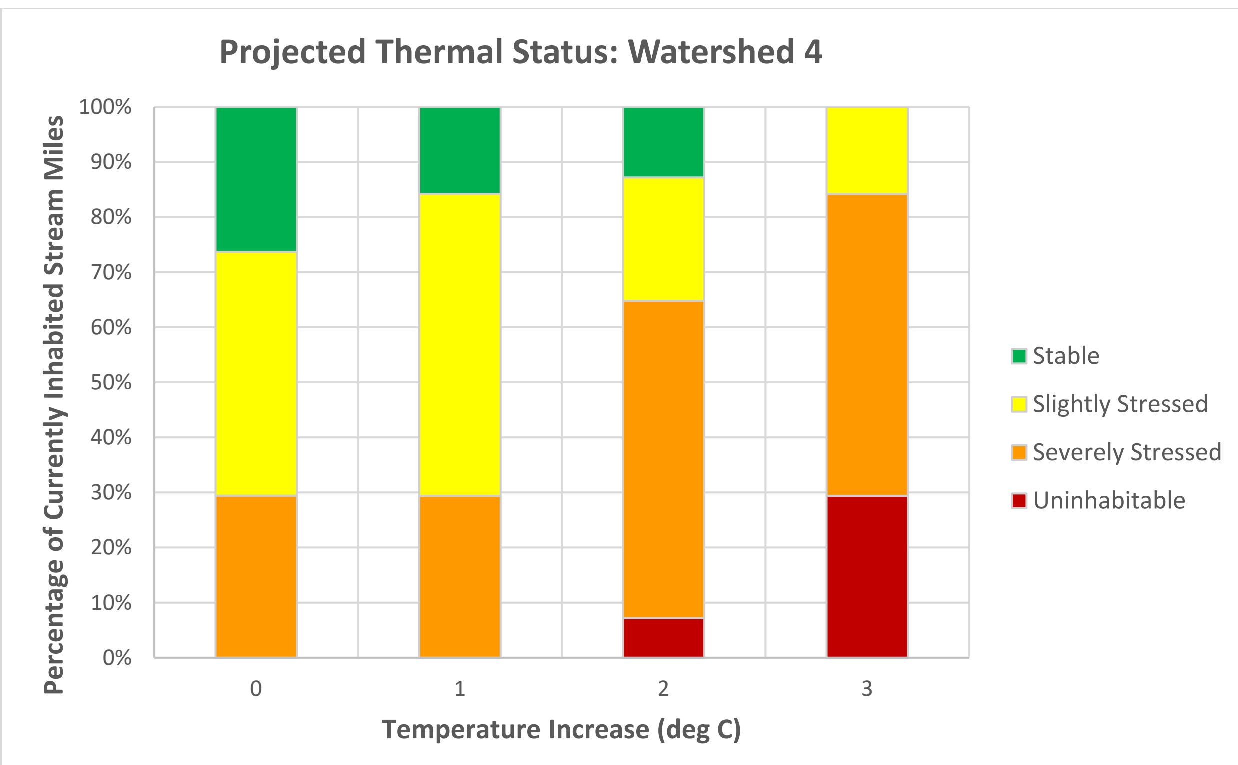
Viewing a map illustrating the projected stress ratings and comparing to present stress ratings, it could be argued that the increase in water temperatures will result in the brook trout populations becoming more fragmented than they already are. If lower elevation stream reaches warm beyond tolerable limits, and this warming extends upstream past tributary mouths, those tributary populations then become effectively cut off from the fish in the main stream, at least for several months of the year. On the other hand, this effect may not be too dramatic, because brook trout can still move freely through the warmer reaches of the watershed during cooler seasons (which is when spawning and hatching of trout fry occurs).

There are other silver linings to be found, even with the 3-degree increase scenario. Except for one particular stream that is already in a highly stressed condition with few remaining brook trout, all of the studied watersheds are projected to retain at least one tributary or coldwater refuge that will remain in the slightly stressed category even with a 3-degree temperature increase. Assuming there are no barriers to fish movement, in theory, brook trout that normally reside in reaches that are projected to become severely stressed or uninhabitable can move upstream and find relatively comfortable water temperatures. Competition for limited space and food would result in decreased numbers of trout, but the existence of the refuge areas would allow brook trout to continue seasonally inhabiting much of their present range.


Projected Thermal Status: Watershed 1
Percentage of Currently Inhabited Stream Miles
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
Temperature Increase (deg C)
Stable
Slightly Stressed
Severely Stressed
Uninhabitable


Projected Thermal Status: Watershed 2
Percentage of Currently Inhabited Stream Miles
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
Temperature Increase (deg C)
Stable
Slightly Stressed
Severely Stressed
Uninhabitable


Projected Thermal Status: Watershed 3
Percentage of Currently Inhabited Stream Miles
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
Temperature Increase (deg C)
Stable
Slightly Stressed
Severely Stressed
Uninhabitable


Projected Thermal Status: Watershed 4
Percentage of Currently Inhabited Stream Miles
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
Temperature Increase (deg C)
Stable
Slightly Stressed
Severely Stressed
Uninhabitable

Percentage of Uninhabitable Stream Miles Within Current Brook Trout Range

Temperature Increase	Watershed 1	Watershed 2	Watershed 3	Watershed 4
0 (2020 temps)	0.0%	1.2%	0.0%	0.0%
+1 degree Celsius	0.0%	21.0%	0.0%	0.0%
+2 degrees Celsius	0.0%	21.0%	12.3%	7.2%
+3 degrees Celsius	38.1%	21.0%	68.0%	29.4%

How can TU help?

The 2020 summer water temperature study illustrates several ways that Trout Unlimited can work to protect brook trout in Catoctin Mountain against the projected impacts of climate warming:

1. **Ensure fish can freely migrate to areas of coldwater refuge.** NCC-TU has already identified a site on one studied stream where a diverted tributary mouth into an unnatural channel (an old road bed/current mountain biking trail) makes it difficult for brook trout to move from the warmer main stem into the colder tributary. Addressing the issue at this particular site will require coordination with the City of Frederick and local trail user groups.
2. **Monitor the brook trout watersheds for proposed land-use changes** that may degrade the habitat conditions in the critical thermal refuge stream sections. Fish accessing the coldest water is one thing, but there must also be deep water and cover to hide from predators within those cold trickles. Land clearing for houses or other construction contributes to siltation of in-stream habitat and increases flood flows which can push important woody debris out of the stream channel and onto the banks.
3. **Push for removal of defunct pond dams and oppose construction of new ponds in brook trout watersheds.**
4. **Encourage the cessation of stocking over native brook trout populations**, where it is still occurring. Given the predictions of increased stress on brook trout in the future, stocked trout represent nothing besides competition for dwindling habitat and are potential vectors for disease transmission to stressed native trout.
5. **Support projects that reduce stormwater runoff from existing paved and gravel roadways.**
6. **Initiate projects to establish riparian buffers to shade and cool brook trout streams.** Fortunately, most of the Catoctin Mountain brook trout streams are already fully forested, so there are not many riparian buffer opportunities here, unless more land clearing occurs in the future.
7. **Monitor current populations of mixed brook and brown trout streams for population shifts in favor of brown trout.** Additionally, monitor brook trout-only streams for introduction/natural establishment of non-native brown trout. Brown trout are more tolerant of warm water and siltation than brook trout. They replace brook trout over time by outcompeting brook trout during stressful conditions.
8. **As anglers, avoid fishing these brook trout streams whenever water temperatures consistently exceed 65 degrees F.** Trout that are caught and released during warm water temperatures are susceptible to dying afterward, as their bodies are subjected to more stress than they would otherwise be if left alone. Based on the 2020 data, this period occurs in most streams between the middle of June and middle of July and lasts until the middle to end of August.

Future Water Temperature Monitoring Projects

The equipment used in the 2020 study has a life span of 5 to 6 years and will be able to make additional contributions to other coldwater conservation initiatives in the near future:

1. 10 of the 32 water temperature loggers used in the 2020 study are still in place in Catoctin Mountain streams. The plan for these 10 loggers is to obtain water temperature data for a continuous 3-year period to assist Maryland Department of the Environment in developing a new water temperature TMDL program (essentially regulating water temperature as a pollutant to improve the health of the Chesapeake Bay watershed).
2. Some of the 2020 equipment was reused for an ongoing Upper Patuxent Watershed temperature monitoring project. NCC partnered with Potomac-Patuxent TU and purchased even more water temperature loggers for the new study. A total of 36 data loggers were deployed in spring of 2021. The results of the study are currently being analyzed.
3. NCC may reuse some of the equipment a third time to collect data on potential brook trout reintroduction locations to verify that water temperature conditions are within brook trout tolerances. The reintroduction candidate streams have not yet been identified.

Acknowledgments

NCC-TU could not have implemented this important water temperature study without help from many organizations and individuals. We would like to thank:

- **Patagonia** for providing the grant funding used to purchase the temperature monitoring equipment.
- **Maryland DNR Freshwater Fisheries** and **Dr. Nathaniel Hitt with USGS** for their early guidance and influence on the study design and for helping arrange access to a few restricted areas.
- **All of the volunteers** (NCC-TU members and non-members alike) who supported the project with volunteer hours spent constructing protective housing, providing tools for the installation, and for spending hours hiking through the rugged Catoctin Mountain terrain to successfully reach the installation locations.
- **The NCC-TU Board** for agreeing to undertake and support this unique project.

This project was a true team effort, and we greatly appreciate the contributions of everybody involved. Thank you!