Wild Brook Trout Thermal Tolerance — Study Summary

"Local conditions drive interpopulation variation in field-based critical thermal maximum of brook trout" published in *Conservation Physiology* (doi.org/10.1093/conphys/coae086)

Erin Stewart, Jacob Bowman, Chris Wilson, and Graham Raby

erinstewart@trentu.ca

Context

Brook trout are a coldwater fish whose ecology is heavily influenced by temperature, making it an important species for studying the effects of climate change. Their ability to cope with warming environments may vary in important ways among individual animals and among different lakes and streams. Variation in tolerance to warming can be shaped by factors like genetic ancestry and diversity, their ability to acclimate, and local environmental conditions. Laboratory studies have provided valuable information on tolerance to warming in brook trout, but there had been less understanding of how this trait varies in the wild under natural conditions.

A brook trout recovering after release in Byersville Creek, Peterborough.

Our study aimed to fill this gap by measuring the upper thermal tolerance of wild brook trout populations across 20 streams in Ontario, Canada. By pairing these measurements with stream temperature data, we examined how acclimation temperature and other site-specific watershed characteristics influence thermal performance. We calculated thermal safety margins (TSMs)—the difference between upper thermal tolerance and the highest stream temperatures experienced by populations—to identify which populations could be most at risk from future warming.

Electrofishing for brook trout in Costello Creek, Algonquin Provincial Park.

What We Did

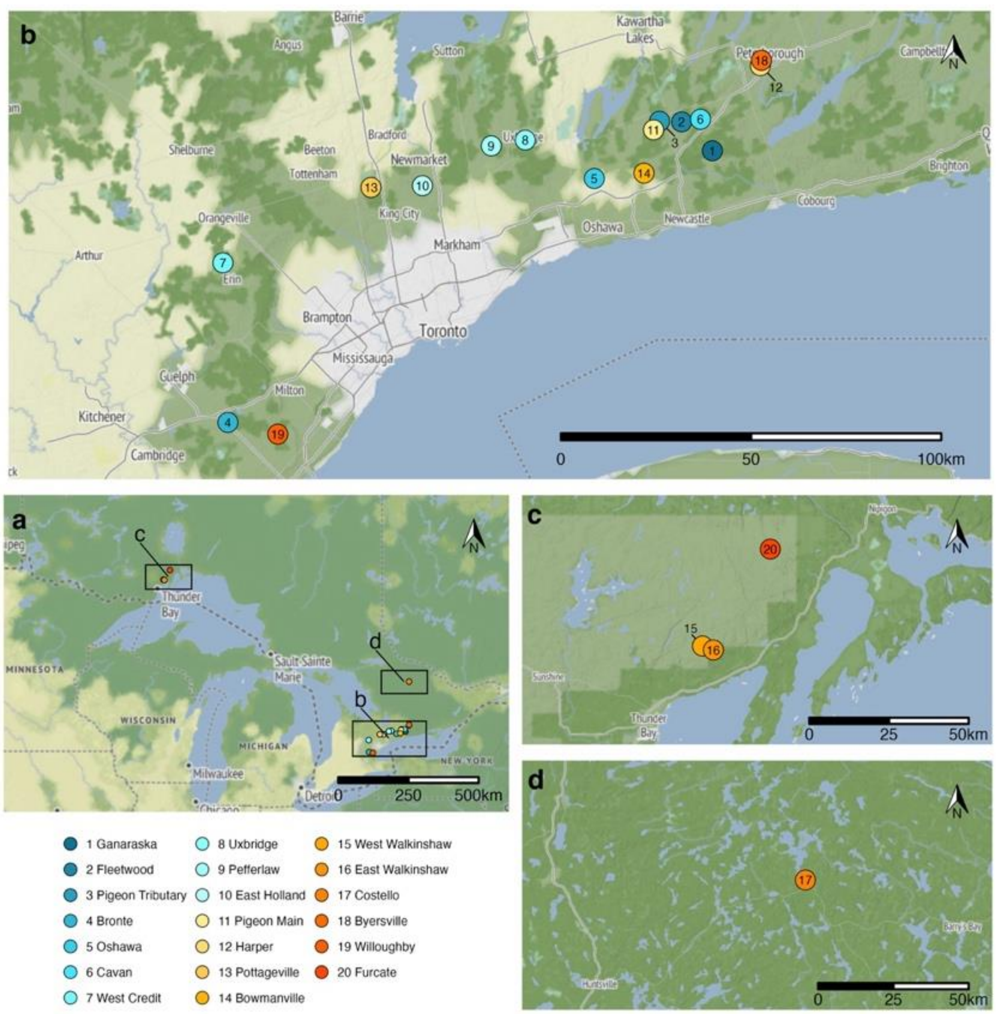
We conducted field experiments to measure critical thermal maximum (CT_{max}) on brook trout at 20 streams: 16 in southern Ontario from the Niagara Escarpment across the Oak Ridges Moraine, one in Algonquin Provincial Park, and three northeast of Thunder Bay. CT_{max} is a rapid, non-lethal method for estimating the lethal upper temperature for a fish. As well as measuring CT_{max} for brook trout from each stream, we analyzed short- and long-term stream temperature data to explore how acclimation periods and seasonal thermal regimes shape thermal tolerance.

What We Found

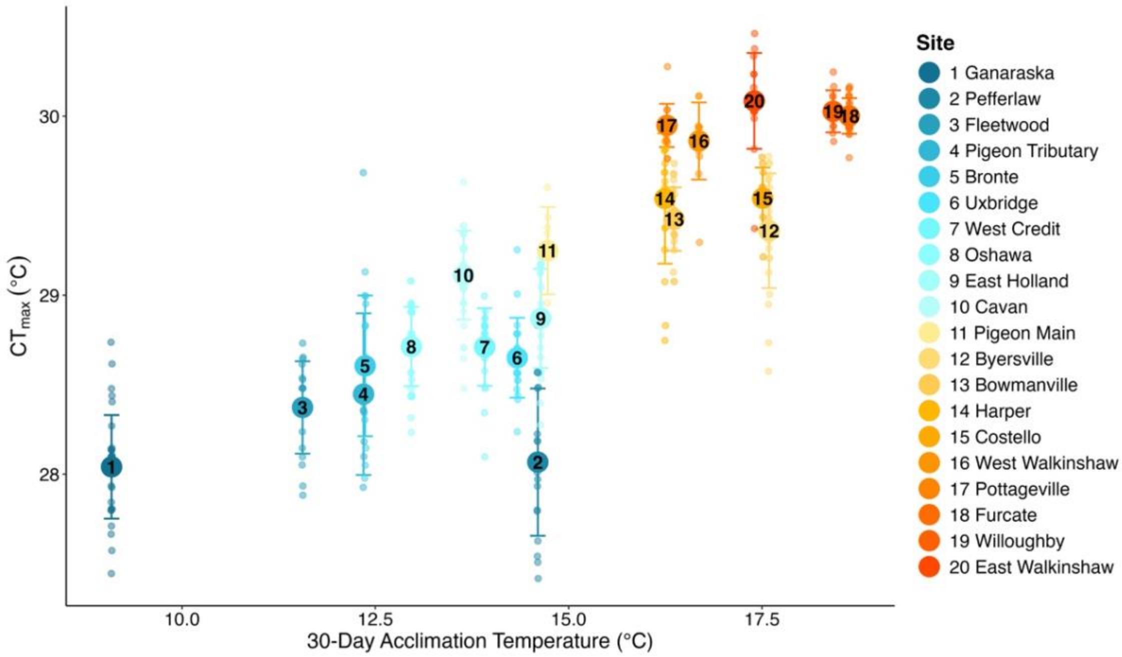
CT_{max} varied among sites, ranging from 27.41°C to 30.46°C. Short-term acclimation to local ambient temperatures (between 4 to 40 days) was a strong predictor of differences in CT_{max} among sites, aligning closely with findings from laboratory studies. Seasonal temperature profiles varied profoundly across the sites. Average stream temperatures in the 30 days prior to our experiments ranged from 9.09°C to 18.63°C: that variation was responsible for 66% of the variation in CT_{max} among populations. Acclimation temperature did not explain all the variation in CT_{max}, suggesting that other factors like the presence of groundwater upwellings may influence thermal tolerance.

Cavan Creek brook trout during the CT_{max} trial.

Thermal safety margins ranged from 0.51°C to 15.51°C, reflecting substantial differences in the thermal vulnerability of populations to further, future warming. Streams in watersheds with more urban or agricultural development and those fed by lake surface water had the lowest thermal safety margins. Streams with low levels of development and groundwater inflow from the Niagara Escarpment or Oak Ridges Moraine had the highest thermal safety margins, representing vital climate change refugia for the species.



Twenty sites in Ontario, Canada where field CT_{max} was conducted on wild brook trout (a). Sites were concentrated in three regions: south (b), north (c) and Algonquin (d). Most sites were in the southern region of the province (b; 16 sites). Three sites were in the northern region (c), and one in the Algonquin region (d). Sites are numbered and coloured based on 30-day mean stream temperatures prior to sampling (1 being the lowest, 20 being the highest). Basemap colouration is a broad index of land cover, where white depicts a high degree of urban and residential development, light yellow is predominantly agricultural and light to dark green depicts increasing tree cover over less developed areas (e.g., with small-scale agriculture, forestry, protected areas).



Brook trout CT_{max} and 30-day acclimation temperature (i.e., stream temperature) at 20 stream sites across Ontario. CT_{max} increased by 0.23°C for every 1°C increase in 30-day acclimation temperature. Large circles and error bars indicate site mean ± S.D. and small circles indicate individual fish (n = 384). Overlaid numbers correspond to legend, where sites are ordered and coloured by increasing mean CT_{max}. Individual points jittered for presentation.

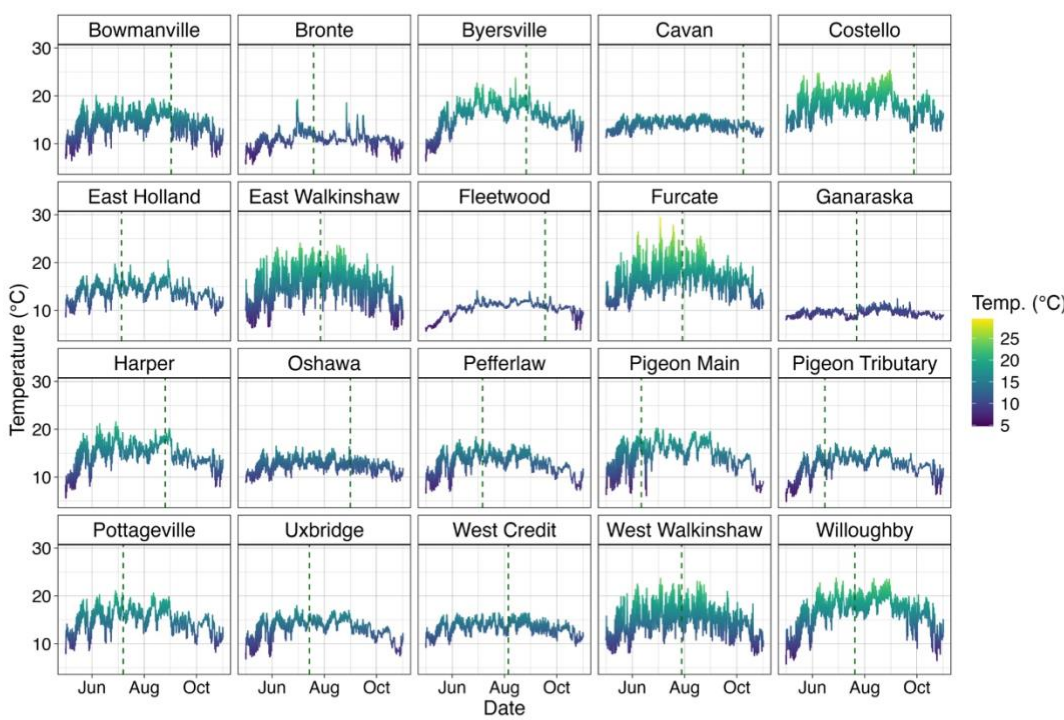
Why It Matters

Our study showed that wild brook trout populations vary meaningfully in their thermal tolerance and vulnerability to future warming. While acclimation to local temperatures plays a key role in thermal tolerance, brook trout will not in all cases be able to cope with future warming through acclimation, which has limits. Local environmental factors beyond air and water temperature contribute to variation in the vulnerability of a stream. Watershed characteristics such as groundwater inflow, riparian shading, and connectivity can all affect the susceptibility of streams to heat waves. Ultimately, higher temperatures put brook trout at risk of extirpation.

Data such as these can help in decisions around which populations should be prioritized for long-term conservation efforts in light of climate change.

Brook trout from Willoughby Creek, Burlington.

Hourly stream temperature (°C) at 20 brook trout CT_{max} sites across Ontario from 1 May 2021 to 31 October 2021. Vertical dashed lines depict the date that the CT_{max} trial was conducted at each site. Where hourly stream temperature records were incomplete, water temperature was back-calculated using air temperature.



Acknowledgements

Thank you to Paul Finigan for his help with the initial conceptualization of the study. Thank you to Rob Wilson (Lake Simcoe Region Conservation Authority), Phil Bird (Credit Valley Conservation), Andrea Dunn (Halton Region Conservation Authority), Lindsay Champagne and Cody Woodcock (Ganaraska Region Conservation Authority), Dan Moore (Central Lake Ontario Conservation Authority), Brett Tregunno (Kawartha Conservation), Jim Bowlby (Trout Unlimited Canada), Brian Round (Fleming College), Cindy Chu (Fisheries and Oceans Canada), Rob Mackereth, Adam Challice, and Victoria Kopf (all OMNR), and all of their students and technicians for their assistance with site selection, fish collection, and obtaining stream temperature data. Thank you to Edwin Hegge for collecting 2023 temperature data at our northern sites. Thank you to Christopher Wilson (OMNR Fish Culture Section) for providing provincial brook trout stocking records. The RBR temperature loggers we used for stream temperature monitoring were provided by the Real Time Aquatic Ecosystem Observation Network (RAEON; University of Windsor; https://raeon.org/). Thank you to Elise Millar, Megan Murphy, Erin Ritchie, Ben Hlina, Morgan Flintoff, Vince Frasca, Sarah Haworth, Katie Cunningham, Anna Dlugosz, Gwen Bourgeois, Hannah Darling, and Luke Hanna for their assistance in the field. Finally, thank you to the many landowners who granted us access to streams on their properties.

Brook trout from the headwaters of the East Holland River, Aurora

Running a field CT_{max} trial at Pottageville Creek.

Erin Stewart (lead author) with a Harper Creek brook trout in Peterborough.

Jacob Bowman (second author) measuring a brook trout after its CT_{max} trial.

A Thunder Bay area brook trout from East Walkinshaw Creek.

A brook trout from Costello Creek, Algonquin Provincial Park.