Geomorphical and hydraulic controls on thermal regimes in stream pool habitats

Emma Gibson1, Valérie Ouellet2, Nathan Watson3, Melinda D. Daniels2
1Missouri State University, Springfield, MO 2Stroud Water Research Center, Avondale, PA 3Cornell University, Ithaca, NY

Introduction

Stream pools provide important habitat to diverse communities of macroinvertebrates and fish. In the summer, pools serve as vital cold-water refuges for fish and their prey, both of which have distinct thermal tolerance ranges (Torgersen et al. 2012). Some aspects of stream thermal regimes, like the cooling effect of riparian zones, water temperature modeling, spatial and temporal water temperature variation, and the potential effects of climate change on stream temperature and habitat, have been well studied (Caissie 2006, Fullerton et al. 2013, Garner et al. 2014, Isaak et al. 2012). Much research still needs to be done to assess the effect that a stream’s physical characteristics have on its water temperature. This study addresses the need for a better understanding of geotopic or hydraulic influence on thermal regimes in important stream pool habitats. Specifically this study asks: (1) How does pool depth affect water temperature? (2) How do flow velocities affect water temperature? (3) Do sediment characteristics relate to water temperature? (4) Is thermal stratification a distinct characteristic of stream pool thermal regimes?

Study Area

This study includes 10 pools in White Clay Creek, a headwater stream in Chester County, PA. The pools were located in three distinct reaches and were a representative sampling of the many types of pool habitats in the creek. Five of the studied pools are located in an open meadow, three are in an established restoration forest (35 years), and two are in a mature forest (80-90 years).

Methods

Temperature: Stacks of shielded Onset HOBO V2 Pro water temperature loggers were used to measure temperature in the pools at 15 minute intervals over a multi-week summer heat stress period.
Grain Size: Sediment samples were taken in each microhabitat patch in the pool and analyzed for grain size through dry sieving. Where appropriate, Wolman pebble counts were taken in the field.
Organic Matter: Loss on ignition was used to test subsamples of homogenized sediment samples.
Topography: Pool topography was recorded using total station surveying.
Hydraulics: A SonTek handheld acoustic Doppler velocimeter was used to measure flow velocity at equally spaced grid points throughout each pool.

Statistical Analysis: Environmental variables were examined using Non Metric Multidimensional Scaling (NMDS). Spearman rank correlation was used to assess which specific environmental variables were related to a particular NMDS output. A significance cutoff of α = 0.20 was used to assess meaningful relationships between NMDS dimension scores and environmental data values.

Results

A significant difference in thermal regimes was seen between pools located in the three different reaches of the stream. The meadow, restoration forest, and mature forest each had distinct temperature patterns. Many of the environmental parameters studied were correlated to different stream reaches. No significant correlation was found relating sediment size to stream reach. The two pools with the most dissimilar thermal regimes in the restoration forest and mature forest each had distinct temperature patterns. Pool 8’s thermal regime is more closely related to air temperature than that of Pool 10. Thermal stratification is more pronounced in Pool 10. Pool 10 is much deeper than Pool 8. Pool 10 is located in a meander, while Pool 8 is forced in a straight section of channel by several pieces of large woody debris.

Conclusions

• Riparian zones have a significant cooling impact on stream habitats
• Thermal stratification was not a significant factor in the thermal regimes of the studied pools. As stratification was seen in the deepest pool, there may be a depth threshold that must be reached for stratification to occur
• No correlation between sediment grain size and temperature was found; however, sediments with higher organic matter contents were found in the cooler pools of the mature forest
• Deeper pools and pools with large depth variability tend to be cooler
• Flow velocity was positively correlated with the meadow pools which had higher max temperatures and greater temperature variation than the forest pools
• Further study is needed to account for variability in temperature between pools
• Moving forward, pool hydraulics will be analyzed spatially and PAR will be measured at each site

Acknowledgements and References

Isaak D.J. et al. (2012) Climate change effects on stream and river temperatures across the northwest U.S. Climatic Change 113:459-474.

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Looking downstream at Pool 8 (left) and Pool 10

Water temperature at Pool 8 and Pool 10 and air temperature

<table>
<thead>
<tr>
<th>Pool</th>
<th>Top</th>
<th>Bottom</th>
<th>LWD</th>
<th>Top</th>
<th>Bottom</th>
<th>LWD</th>
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<tr>
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<tr>
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</tbody>
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R² values of data from each logger in Pool 8 and Pool 10 compared to air temperature

Maximum daily water temperature per pool Relationships between environmental parameters (NMDS results)