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Chattahoochee Trout Temperature Study
Selected Background References

Disclaimer: The information available here represent articles available in the open scientific literature pertaining to the subjects of BMPs, Meteorology/Climate, Forested Streams, Urbanization of Streams, and Trout Fisheries. These articles do not represent "technical guidance" from EPD nor does EPD endorse or recommend their findings.

BMPs

Arrington, K. and A. Roa-Espinosa. 2004. Protecting Cold Water Streams – GIS Tackles Thermal Loading in Urban Watersheds. Land Information Bulletin from the National Consortium for Rural Geospatial Innovations, Great Lakes, University of Wisconson-Madison. Available at www.ruralgis.org. Accessed 9/1/2011. Notes: Use of GIS to plan BMPs to ameliorate stream impacts.

Dorava, J.M., A. Roa-Espinosa, K. Johnson, and D. Severson. 2003. Enhancing Storm Water Infiltration to Reduce Water Temperature Downstream. Proceedings of the National Conference on Urban Stormwater: Enhancing Programs at the Local Level, U.S. EPA, Chicago, Illinois. Notes: Case study of rock infiltration trenches in a 400 acre subdivision in Wisconson to reduce runoff temperature and sediment loading to streams.

Jones, M.P. 2008. Effect of Urban Stormwater BMPs on Runoff Temperature in Trout Sensitive Regions. Dissertation, Department of Biological and Agricultural Engineering. North Carolina State University. Notes: Monitoring of BMPs, light colored pavement, stormwater wetland, pond. Suggestion for BMP modifications, Model of bioretention hydraulics. Models suggest that volume reduction BMPs have a larger impact than temperature reduction.

Jones, M.P. and W.F. Hunt. Stormwater BMPs for Trout Waters - Coldwater Stream Design Guidance for Stormwater Wetlands, Wet Ponds, and Bioretention. Urban Waterways, a publication of the North Carolina Cooperative Extension Service. Notes: Fact Sheet regarding study of BMP impacts on runoff temperature. General discussion of parking lot design, stormwater wetlands, wet ponds, and bioretention areas with small internal storage areas. Suggestions to incorporate shading, infiltration, draw water from lower areas of deep pools for lower discharge temperatures.

Kieser, M.S., F. Fang, and J.A. Spoelstra. 2003. Role of Urban Stormwater Best Management Practices in Temperature TMDLS. Proceedings of the Water Environment Federation. National TMDL Science and Policy 2003 , pp. 1716-1739(24). Notes: Study of traditional wet detention/pond stormwater treatment compared with wetland and infiltration treatment. Study concluded that stormwater BMPs that promote infiltration and provide sufficient vegetative shading should be used to protect coldwater streams.

Thompson, A.M., A. J. Vandermuss, J. M. Norman, and A. Roa-Espinosa. 2008. Modeling the Effect of a Rock Crib on Reducing Stormwater Runoff Temperature. Transactions of the ASABE. 51(3): 947-960. Notes: Model for sizing rock-cribs as a BMP for reducing

urban runoff temperature.

Meteorology/Climate

Boggs, J.L., G. Sun, S.G. McNulty, W. Swartley, E. Treasure, and W. Summer. 2009. Temporal and Spatial Variability in North Carolina Piedmont Stream Temperature. American Water Resource Association 2009 Spring Specialty Conference, May 4-6, Anchorage, Alaska. Notes: Suggests that trees along riparian buffers moderate the affects of air temperature on water temperature by reducing wide fluctuations in temperature. Climate change model also developed showing increase in stream temperature with increase in climate temperature.

Byers, H.R., H, Moses and P.J. Harney. 1949. Measurement of Rain Temperature. Journal of Meteorology Volume 6, February. Notes: Significant difference between rain and ambient temperature usually occur in the first portion of a thunderstorm period, followed by small differences later.

Flebbe, P.A., L.D. Roghair, and J.L. Bruggink. 2006. Spatial Modeling to Project Southern Appalachian Trout Distribution in a Warmer Climate. Transactions of the American Fisheries Society. 135:1371–1382. Notes: Model of expected trout distribution in Southeast U.S. under various Global Warming scenarios. Results: Smaller and more fragmented.

Forested Streams

Boggs, J.L., G. Sun, S.G. McNulty, W. Swartley, E. Treasure, and W. Summer. 2009. Temporal and Spatial Variability in North Carolina Piedmont Stream Temperature. American Water Resource Association 2009 Spring Specialty Conference, May 4-6, Anchorage, Alaska. Notes: Suggests that trees along riparian buffers moderate the affects of air temperature on water temperature by reducing wide fluctuations in temperature. Climate change model also developed showing increase in stream temperature with increase in climate temperature.

Clinton, B.D., J.M. Vose, and D.L. Fowler. 2010. Flat Branch Monitoring Project: Stream Water Temperature and Sediment Responses to Forest Cutting in the Riparian Zone. United States Department of Agriculture, Forest Service, Southern Research Station, Research Paper SRS-51. Notes: Stream water monitoring during timber cutting in Northeast Georgia. Observed only marginal effects of riparian zone cutting on water temperature. Low flows may have contributed to small increase in water temperature.

Ice, G. 2001. How Direct Solar Radiation and Shade Influences Temperature in Forest Streams and relaxation of Changes in Stream Temperature. Cooperative Monitoring, Evaluation and Research (CMER) Workshop: Heat Transfer Processes in Forested Watersheds and Their Effects on Surface Water Temperature, Lacy, Washington. Notes: Stream monitoring and shading experiments presented. Concludes: Solar radiation is the principle energy source that causes stream heating. Shading reduces… stream heating. The influence of vegetation decreases with channel width.

Johnson, S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Can. J. Fish. Aquat. Sci. 61: 913–923. Notes: Discussion of different stream temperature influences including substrate and shading. Shading significantly decreased maximum temperatures in experimental reach.

Johnson, S.L. and S. Wondzell. 2005. Keeping It Cool: Unraveling the Influences on Stream Temperature. Pacific Northwest Research Station USDA Forest Service – Science Findings. S.R. Dodge, Editor. Available online at http://www.fs.fed.us/pnw. Notes:

General article summarizing research findings at USFS Pacific Northwest Research Station on stream temperature. Incoming solar radiation found to be largest contributor to stream temperature (not air temperature as some studies have noted). Bedrock has a greater summer temperature fluctuation than gravel substrate.

Malcolm, I.A., D.M. Hannah, M.J. Donaghy, C. Soulsby, and A.F. Youngson. 2004. The influence of Riparian Woodlands on the spatial and Temporal Variability of Stream Water Temperatures in an Upland Salmon Stream. Hydrology and Earth System Sciences, 8(3) 449-459. Notes: Riparian woodlands in the lower catchment had a substantial impact on thermal regime, reducing diel variability (over a 24 hour period) and temperature extremes.

Roth, T.R., M.C. Westoff, H . Huwald, J .A . Huff, J .F . Rubin, G. Barrenetxea, M. Vetterli, A. Parriaux, J.S. Selker, and M.B. Parlang. 2010. Stream Temperature Response to Three Riparian Vegetation Scenarios by Use of a Distributed Temperature Validated Model. Environ. Sci. Technol. 44: 2072–2078. Notes: Model of stream temperature with open water, reed bed cover, and forested. Mean peak stream temperature ~2 deg C less for forested.

Rutherford, C.J., S. Blackett, C. Blackett, L. Saito, and R.J. Davies-Colley. 1997. Predicting the effects of shade on water temperature in small streams. New Zealand Journal of Marine and Freshwater Research. 31:707-721. Notes: Computer model for stream temperature as a function of canopy angle, topography angle, and canopy shade factor. Model predictions indicate that moderate shade levels (c. 70%) may be sufficient in temperate climates to restore headwater pasture stream temperatures to 20℃. Cold groundwater helps maintain temperature in 1st order streams, but 3rd order streams are most susceptible to increases in stream temperature when shade is reduced.

Swift, L.W. and P.P. Clinton. 1997. Stream Temperature Climate in a Set of Southern Appalachian Streams. First Biennial North American Forest Ecology Workshop Proceedings, June 14-26, N.C. State Univ., Raleigh, NC. Notes: Stream temperature dataset for five western North Carolina forested streams. Summer precipitation did not always influence stream temperature. Water temperature responded more to air temperature and solar radiation fluctuations than precipitation.

Urbanization and Streams

Bartholow, J.M. 1991. A Modeling Assessment of the Thermal Regime for and urban Sport Fishery. Environmental Management, 15:833-845. Notes: Model of 31-km River hydrology and temperature in Ft. Collins, CO. Irrigation diversion dewaters the river, but cold reservoir releases moderate temperature. Supplemental flow or reduced withdrawal/diversion needed to maintain temperature. Shading ineffective due to width. Construction of deep pools for thermal refugia might be helpful.

Caissie, D. 2006. The thermal regime of rivers: a review. Freshwater Biology 51, 1389–1406. Notes: Review of water temperature models.

Cenno, K.A., M. Al-Ebus, B. Hirst, D. Milligan, and T. Kratzer. 2005. Establishing a Temperature Discharge Relationship to Address Temperature Impairment in the Pequannock River, New Jersey for TMDL Development. Proceedings of the Water Environment Federation, National TMDL Science and Policy 2005 , pp. 702-716(15). Notes: Discussion of New Jersey temperature TMDL - Implementing a combination of BMPs and direct remedies of sources of heat.

Herb, W.R.; B. Janke; O. Mohseni; and H.G. Stefan. 2009. Runoff Temperature Model for Paved Surfaces. Journal of Hydrologic Engineering, 14:10:1146-1155. Notes: Small scale model to predict thermal impacts of development.

Herb, W.R.; B. Janke; O. Mohseni; and H.G. Stefan. 2008. Thermal pollution of streams by runoff from paved surfaces. Hydrological Processes. 22, 987–999. Notes: Results of a model of runoff from parking lot. Many storm events had no thermal impact, but some had a large impact depending on dew point temperature, land temperature and volume of rainfall.

Janke, B.D., W.R. Herb, O. Mohseni, and H.G. Stefan. 2008. Simulation of heat export by rainfall–runoff from a paved surface. Journal of Hydrology. 365:3-4: 195-212. Notes: Model of runoff temperature. Most sensitive to antecedent air temperature, rainfall temperature and duration.

Jones, M.P. 2008. Effect of Urban Stormwater BMPs on Runoff Temperature in Trout Sensitive Regions. Dissertation, Department of Biological and Agricultural Engineering. North Carolina State University. Notes: Monitoring of BMPs, light colored pavement, stormwater wetland, pond. Suggestion for BMP modifications, Model of bioretention hydraulics. Models suggest that volume reduction BMPs have a larger impact than temperature reduction.

Krause, C.W., B. Lockard, T.J. Newcomb, D. Kibler, V. Lohani, and D.J. Orth. 2004. Predicting Influences of Urban Development on Thermal Habitat in a Warm Water Stream. JAWRA Journal of the American Water Resources Association. 40:6:1645-1658. Notes: Model of thermal impacts on streams from urbanization. Influenced strongly by canopy cover and stream width.

LeBlanc, R.T., R.D. Brown and J.E. FitzGibbon. 1997. Modeling the Effects of Land Use Change on the Water Temperature in Unregulated Urban Streams. Journal of Environmental Management 49: 445–469. Notes: Landscape scale model of stream temperature changes due to urbanization. Shade/transmissivity of riparian vegetation, groundwater discharge, and stream width had the greatest influence on stream temperature. These variables are also highly influenced by urbanization. Model predicts stream temperature change as a result of amount, type, and location of urbanization.

Moglen, G.E., K.C. Nelson, M.A. Palmer, J.E. Pizzulo, C.E. Rogers, and M.I. Hejazi. 2004. Hyro-Ecologic Responses to Land Use in Small Urbanizing Watersheds Within the Chesapeake Bay Watershed. Reprinted in Ecosystems and Land Use Changes, Editor, R.S. DeFries. American Geophysical Union. Notes: Model of combined effects of development including both pollutant movement and temperature. Compared to spawning conditions. Highly stressful conditions for all fish species under the fully developed scenario.

Nelson, K.C., and M.A. Palmer, 2007. Stream Temperature Surges Under Urbanization and Climate Change: Data, Models, and Responses. Journal of the American Water Resources Association (JAWRA) 43(2):440-452. Notes: Climate change and urbanization model and empirical study. Temperature surges from rainstorms examined. Headwaters streams shown to be impacted by urbanization and climate change. Expected shift from coldwater to warmwater species shown based on urbanization and climate change impacts and the “good growth” range of coldwater species.

Pucci, A.A. and M. Bowker. Thermal Impact Assessment for Discharging Stormwater Runoff: Case Study. Accessed 9/14/2011. http://www3.villanova.edu/vusp/Outreach/pasym07/papers/C_I_4.pdf Notes: Case study of ~100 acre site development in Pennsylvania. Use of earth as a “heat sink”. BMPs.

Roa-Espinosa, A., T.B. Wilson, J.M. Norman, and K. Johnson. 2003. Predicting the impact of urban development on stream temperature using a thermal urban runoff model (TURM). National Conference on Urban Stormwater: Enhancing Programs at the Local Level, February 17-20. United States Environmental Protection Agency.

http://water.epa.gov/polwaste/nps/stormwater/upload/2003_03_26_NPS_natlstormwater03_31Roa.pdf. Notes: Model to predict increase in runoff temperature from contact with impervious surface.

Fisheries

Runge, J.P., J.T. Peterson, and C.R. Martin. 2008. Survival and dispersal of hatchery-raised rainbow trout (Onchorynchus mykiss) in a river basin undergoing urbanization. Final Report to the Georgia Dept. of Natural Resources and North American Journal of Fisheries Management 28:745–757. Notes: Evaluation of effects of urbanization on water temperature for Chattahoochee trout. Trout survival inversely related to amount of time temperature exceeded 20º C. Empirical temperature-discharge models indicated that water temperatures in the river, downstream of Morgan Falls Dam have increased with increasing urbanization from 1976 - 2006. Estimate change from 20% loss of stocked trout pre-1976 to 70% loss of stocked trout post-urbanization.

Biagi, J. and T. Hess. 1991. Summer Water Temperature Survey Chattahoochee River Below Morgan Falls Dam 1987-1989. Notes: Documents high trout mortality during a drought with long periods (10 days) of no generation.

Biagi, J. and R.P. Brown. 1997. Upper Temperature Tolerance of Juvenile and Adult Brown and Rainbow Trout Tested Under Flowing Conditions. Final Report Georgia Dept. of Natural Resources, Wildlife Resource Division. Notes: Temperature tolerances evaluated under experimental conditions simulating flowing conditions in the Chattahoochee.