Resiliency of Patches of Brook Trout Habitat to Climate Change

Bradly Trumbo

January 22, 2010

MS Research Proposal

Department of Biology

Background

The Brook Trout (*Salvelinus fontinalis*) is the only native salmonid to the eastern United States (MacCrimmon et al. 1969, Fleebe et al. 2006, Hudy et al. 2008). Historically, brook trout thrived throughout the east coast and occurred in lower elevation areas such as the floor of the Shenandoah Valley, Virginia (Mohn and Bugas 1980, Hudy et al. 2008). Brook trout require cold water streams and have a maximum sustained thermal tolerance of approximately 19-25 degrees Celsius (Clark 2001, Wehrly et al. 2007). Stream temperature is the basic factor limiting distribution of trout species (Fleebe 1994); therefore, maximum stream temperatures must remain cold enough to maintain brook trout populations. Thermal maxima may only be tolerated by brook trout for short time periods. Sustained critical maximum thermal limits for brook trout will alter metabolism leading to extirpation (Wehrly et al. 2007). Urban expansion and land use practices may slowly be causing brook trout populations to recede to higher elevations to more suitable thermal habitat throughout the east coast (Meisner 1990, Fleebe et al. 2006, Hudy et al. 2008). Lower densities and lower percentage of habitat occupation decrease the resiliency of a population to increased environmental disturbance (Opdam and Wascher 2004). As brook trout habitat becomes fragmented, the mosaic of extirpated habitat increases leading to genetic isolation of populations (Opdam and Wascher 2004).

Climate change is currently being studied as a cause of habitat degradation for brook trout and other salmonid species. Increased thermal regimes associated with climate change are predicted to extirpate many of the existing brook trout throughout their native range, and potentially eliminate brook trout in the state of Virginia (Meisner 1990, Clark et al. 2001, Fleebe et al. 2006). The effects of climate change may be exacerbated when coupled with land use changes leading to greater fragmentation of remaining habitat (NAST 2000).

Previous large-scale assessments of the effects of climate change on cold-water fishes used models that assumed a steady relationship between air and water temperature (Clark et al. 2001, Fleebe et al. 2006). While these models were appropriate for large-scale assessments, they may not be accurate at the smaller scales where brook trout management occurs. Regional models may prevent the incorporation of site-specific aspects of streams, therefore limiting interpretations of trout responses to climate change (Clark et al. 2001). Landscape patterns are often disregarded in studies of spatial responses to climate change (Opdam and Wascher 2004), however, these patterns may be important drivers of variation among patches. Many small patches of brook trout habitat may persist in Virginia even under the most pessimistic thermal projections due to localized conditions (i.e. springs, aspect). The influence of such metrics as groundwater input at localized scales may play a more important role in stream thermal stability than expected (Meisner 1990, Wehrly et al. 2007).

To quantify the potential effects of climate change on brook trout habitat, it is necessary to understand the relationship between air and water temperatures in patches of brook trout habitat. Paired air and water temperature relationships can be quantified and modeled to rank existing patches of brook trout habitat for their resiliency to climate change. A pilot study showed that the relationship between air and water temperature is 1) highly variable at the catchment scale (average size = 237 ha); 2) potentially influenced by local conditions (i.e. elevation, aspect, riparian cover, latitude, and ground water sources); and 3) is often best fitted to a sigmoid curve (Wehrly et al. 2007, Fink 2008).

Significance

My research will rank patches of brook trout habitat within the state of Virginia for resiliency to climate change under varying climate change scenarios. These resiliency rankings will be useful in determining future brook trout habitat and which patches of brook trout habitat are most important for conservation/restoration (Wehrly et al. 2007).

Research Questions

1. Do air and water temperature relationships vary significantly among patches?
2. What local physical habitat and land use metrics influence air and water temperature relationships?

Study Area

My research will include all brook trout habitat within the state of Virginia (Figure 1). Brook trout habitat for this study has been delineated into contiguous patches (N=272, average patch size 2,856 hectares), each thought to be genetically isolated from one another (Mohn and Bugas 1980, Fleebe et al. 2006, Hudy et al. 2008).

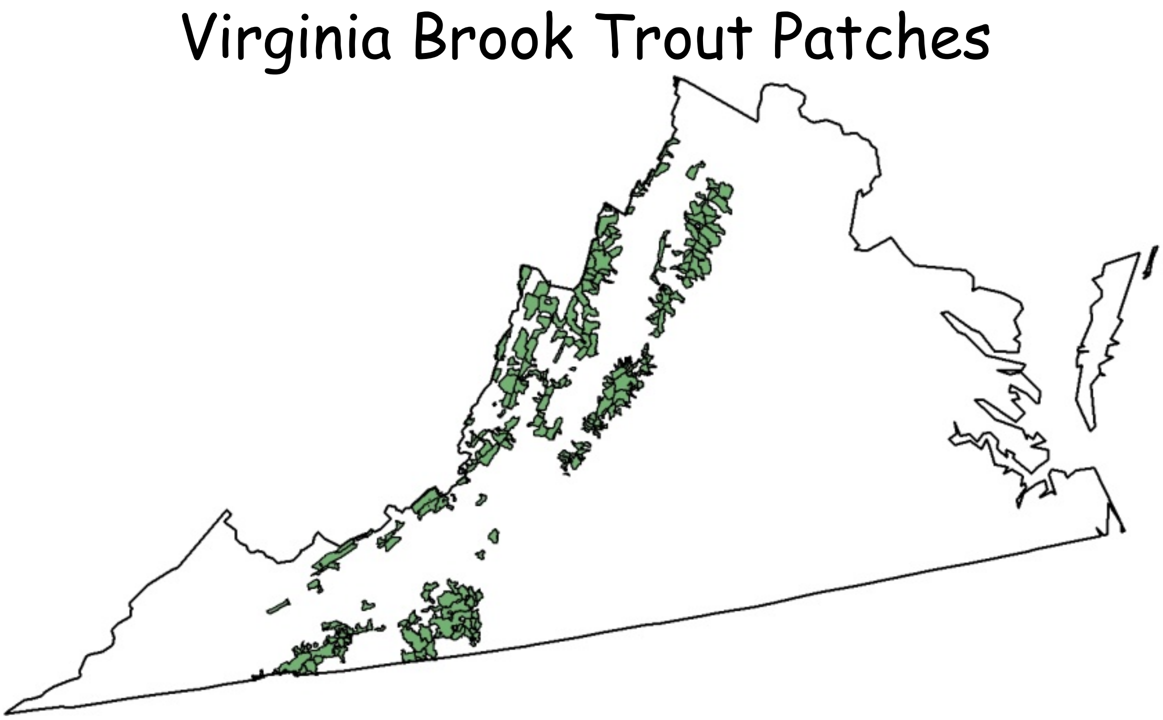

Figure 1. Distribution of patches of brook trout habitat (N=272) within the state of Virginia (Hudy et al. 2008). Average patch size = 2,856 hectares.

Methods

Patch Delineation

My research uses brook trout habitat patches (N=272) delineated from the National Hydrography Dataset seventh level Hydrologic Unit Code (HUC) catchment polygons (average patch size = 2,856 ha). Each HUC specifies an area of land that drains into a specific stream segment. The catchment level is the finest scale of Hydrologic Unit (USGS 2008). Catchments were coupled with brook trout presence/absence data using Virginia Trout Stream Sensitivity Survey data (Mohn and Bugas 1980, EBTJV 2006, Hudy et al. 2008) to determine which catchments contain reproducing populations of brook trout. Contiguous catchments containing brook trout were then dissolved into one patch.

Choosing Sample Patches

I used Geographic Information Systems (GIS) to summarize important physical habitat metrics to the patch scale (Table 1).

Table 1: Metrics for use in analyzing patches of brook trout habitat

Metric	Units	Source
Patch Area	Hectares	
Riparian Area	Hectares	
Patch Total Annual Solar Gain	kWh	ESRI 2009
Riparian Total Annual Solar Gain	kWh	ESRI 2009
Patch Mean Annual Solar Gain	kWh/30m pixel	ESRI 2009
Riparian Mean Annual Solar Gain	kWh/30m pixel	ESRI 2009
Pour-point Elevation	meters	USGS 2008
Centroid Elevation	meters	USGS 2008
Pour-point 30-year Mean Max Temp	Celsius	PRISM 2009
Centroid 30-year Mean Max Temp	Celsius	PRISM 2009
Number of Spring per Patch	Count	Unpublished, VA Tech
Patch Mean Canopy Cover	Percentage	NLCD 2001 (USGS 2008)
Riparian Mean Canopy Cover	Percentage	NLCD 2001 (USGS 2008)
Patch Landuse Area by Category (N=15)	Hectares	NLCD 2001 (USGS 2008)
Riparian Landuse Area by Category (N=15)	Hectares	NLCD 2001 (USGS 2008)
Geology Type (N=58)		Webb 2009
Geology category (N=5)		Webb 2009

To help determine a sub-sample protocol, I used six metrics for cluster analysis that have a strong influence on stream temperatures (Table 2). Ward's method of cluster analysis determined that 9 clusters had the greatest power of separation of the patches. Cluster analysis provided a stratified representation of patches allowing a proportional number of patches from each cluster to be randomly sampled. From the 9 clusters, a total of 50 patches were selected for sampling.

Table 2: Six brook trout patch metrics used for cluster analysis

Metric	Units
Riparian Total Annual Solar Gain	kWh
Pour-point Elevation	meters
Pour-point 30-year Mean Max Temp	Celsius
Number of Spring per Patch	Count
Riparian Mean Canopy Cover	Percentage
Total Forest Area per Patch	Hectares

Sampling Materials and Standard Operating Procedures

I chose the HOBO Watertemp Pro v2 thermograph for water and air temperature monitoring due to the balance of cost ($85 each when bid out), stability (0.1 ˚C annual drift), and accuracy (0.2˚C over a 0-50˚C range) (Onset computer Corporation 2008).

Paired air and water thermographs were placed at the centroid (geometric center of the patch as defined by GIS) and pour-point (downstream population boundary of patch) of each sampled patch. Thermographs will be left in place for 17 months collecting temperature readings every 30 minutes. The sample period will include two critical summer periods of July 1st through September 15th. The critical summer period typically produces greater stress on wild trout due to low water levels and maximum annual stream temperatures.

Centroid and pour-point locations from GIS loaded into GPS units are used to locate the sample sites within each patch. Variables such as private land access and dry stream conditions may alter locations of actual centroid and pour-point sites.

I. Site Location

1) Before departing headquarters, it is necessary to have a route plan as to which site are to be set. The use of a handheld GPS unit, as well as a map will allow for more expedient travel

2) Handheld GPS units should be pre-programmed with "theoretical" centroid and pour-point locations for each patch. Theoretical centroid points will not likely be directly overtop of stream segments on the GPS unit. It is necessary to determine the closest stream segment to the centroid point as the site for deploying HOBOs in each patch.
    - The goal should be to navigate to the closest possible location to the "theoretical" centroid and pour-point in the GPS unit
    - IF the point falls WITHIN, or requires passing THROUGH PRIVATE property, try to contact the landowner.
    - If a remote site and landowner cannot be contacted, one of the following options should be based upon best professional judgment:
        - a site may be set as close as possible to the theoretical site where access is granted or public land is available
        - in cases of danger or serious inconvenience a new patch may be randomly selected for sampling

3) Once a site is located, HOBOs placed in the water should be placed near maximum residual pool depth. Residual depth is defined as "the difference in depth or bed elevation between a pool and the downstream riffle crest" (Lisle 1987).
    - Pools with at least knee depth should be selected when possible to ensure the HOBO will be submersed throughout late summer

II. Setting In-stream HOBOs

1) Copper wire (coated 14ga.) has been used with great success in Virginia. It is necessary to use some type of extremely tough material for attaching HOBOs to the stream bank, etc., since debris will likely catch on, and greatly stress the material

2) Protective rubber boots with caps should be used to set HOBOs in water to prevent surfaces and serial numbers from being worn off. Friction between substrate particles and the clear surface where data is transferred could be damaged causing potential data lost

3) Once maximum residual pool depth has been located, determine what stream bank structure will be used to anchor the HOBO. Be certain the tree, root, boulder, log etc. is PERMANENT

4) Secure wire tightly around structure wrapping wire back upon itself a minimum of five wraps

5) Estimate the length of wire necessary to reach the location where the HOBO is to be placed

6) Cut wire to length leaving extra length for movement around substrate. Attach HOBO, and place HOBO in stream

- Place HOBO FIRMLY under a rock large enough to be stationary with high flow
    - DO NOT bury HOBO into substrate
- Lay wire along substrate burying it under rocks, etc. It is necessary to have wire hidden as well as possible from human detection, but more importantly from debris such as leaves that may catch and dislodge the HOBO

7) Use handheld GPS to collect a “Waypoint” while standing where the HOBO was placed. These coordinates are required for future mapping and locating the HOBO

- Rename the waypoint to the population number, centroid or pour-point, air or water
    - Example: 172CW = Population 172 Centroid, Water

8) Place a tree tag in plain view of the HOBO attachment point from the most likely direction of approach

- Tree tag placement has proven to be highly beneficial when finding set HOBOs since it offers a visual cue to the submerged HOBO

III. Setting Air Temperature HOBOs

1) Carry copper wire for attachment, PVC shield (Figure 2) to reduce direct UV contact with HOBO (Dunham et al. 2005), tree tags and GPS unit for air set

2) If possible, locate a tree within 50m of stream set, upslope (Dunham et al. 2005), away from stream

- Not all sites will offer “upslope” areas, or a 50m wide buffer zone. Use best professional judgment to find a suitable area

3) Use GPS unit to locate NORTH aspect/compass direction

4) Run wire through PVC shield cap, attach HOBO to wire, and then attach wire to tree at approximately head height

  - Head height may vary depending upon who is setting the HOBO. Keep in mind that someone else may be checking the HOBO at a later date; therefore, anyone greater than 6 feet in height should set HOBOs at shoulder height

5) Use handheld GPS to collect a "Waypoint" while standing where the HOBO was placed. These coordinates are required for future mapping and locating the HOBO

6) Place a tree tag in plain view of the HOBO attachment point from the most likely direction of approach

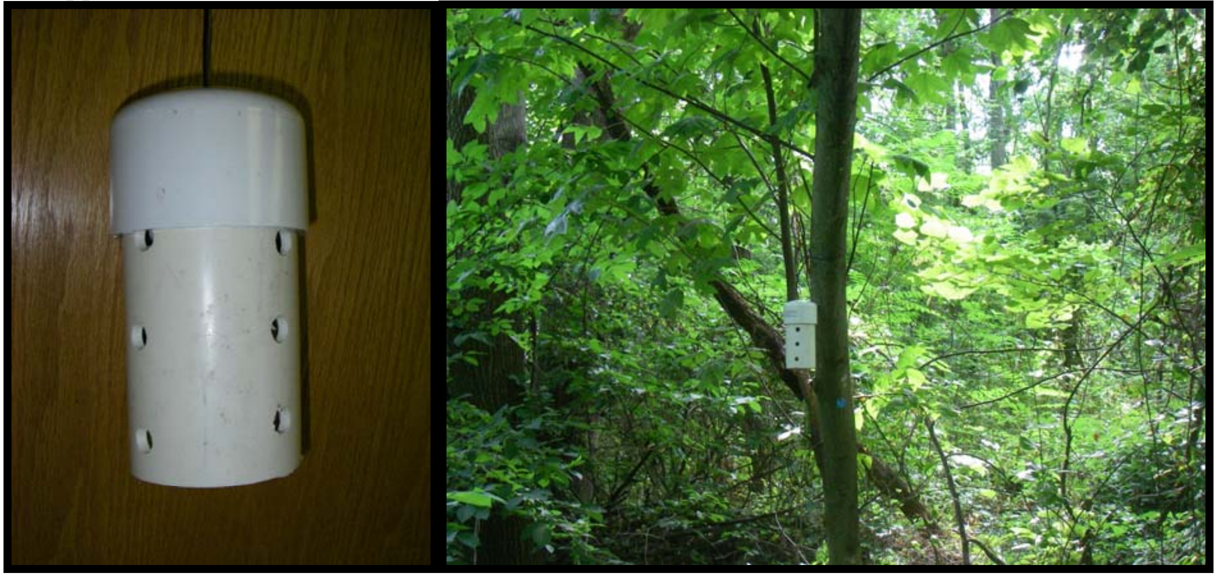

Figure 2. PVC shield for air temperature HOBO. Dimensions: 3in PVC, 6in long, ½in drilled holes for air flow (12)

IV. Site/HOBO Documentation

1) A "Site Description" datasheet should be completely filled out upon setting HOBOs at a site.

2) Site Description datasheet requirements:

  - Date
  - Time
  - Unique patch number
  - Pour-point or Centroid
  - Datum and UTM zone
  - Serial Number for both In-Stream and Near-Stream HOBOs
  - GPS coordinate for both In-Stream and Near-Stream HOBOs
  - Driving direction and drive time from headquarters (may be filled in at the office)
  - Hiking directions, time, and distance from vehicle
  - Physical description of location of both In-Stream and Near-Stream HOBOs with photo numbers noted
    - Should include tree tag placement and what the HOBO was attached to

V. Site Photography

This may appear to be common sense, but guidelines may actually result in better quality, more useful photos.

1) Understand how to use your camera thoroughly

2) Take photos of In-Stream and Near-Stream (Figure 2) HOBO locations from the most likely direction of approach

3) Be certain the person taking photos is far enough from the site that recognizable landmarks such as unique trees or boulders, etc. may be included in the photo.

4) Be certain the person taking photos is close enough to the site that landmarks and tree tags are recognizable

5) Photos organized by date and camera (given there are multiple crews working) are easily matched to the "Site Description" datasheet by photo number for future reference

Data Analysis

Linear and logistic regression will be used to look at relationships among air temperature, water temperature and patch metrics. Rolling maximums (Werhly et al. 2007, Fink 2008) will be determined for each water temperature dataset in order to plot relationships.

References

Clark, M. E., K. A. Rose, D. A. Levine and W. W. Hargrove. 2001. Predicting climate change effects on appalachian trout: combining GIS and individual-based modeling. Ecological Applications 11(1):161-178.

Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: a user's guide. USDA Forest Service General Technical Report RMRS-GTR-150WWW

EBTJV (Eastern Brook Trout Joint Venture). 2006. About the Eastern Brook Trout Venture. Available: www.easternbrooktrout.org. (December 2006).

ESRI. 2009. Solar radiation, extension of spatial analyst tools. Redlands, California

Fink, D. B. 2008. Artificial shading and stream temperature modeling for watershed restoration and brook trout (*Salvelinus fontinalis*) management. Master's thesis. James Madison University, Harrisonburg, Virginia.

Fleebe, P. A. 1994. A regional view of the margin: salmonid abundance and distribution in the soutern Appalachian mountains of north carolina and virginia. Transactions of the American Fisheries Society 123:657-667

Flebbe, P. A., L. D. Roghair and J. L. Bruggink. 2006. Spatial Modeling to Project Southern Appalachian Trout Distribution in a Warmer Climate. 2006. Transactions of the American Fisheries Society 135:1371-1382.

Hudy, M., T. M. Thieling, N. Gillespie and E. P. Smith. 2008. Distribution, status, and land use characteristics of subwatersheds within the native range of brook trout in the eastern united states. North American Journal of Fisheries Management 28:1069-1085

Lisle, Thomas E. 1987. Using "residual depths" to monitor pool depths independently of discharge. US Forest Service Research Note PSW-394

MacCrimmon, H. R. and J. S. Campbell. 1969. World Distribution of Brook Trout, *Salvelinus fontinalis.* Journal of Fisheries Research Board of Canada 26(7):1699- 1725.

Meisner, J. D. 1990. Effect of climatic warming on the southern margins of the native range of brook trout (*Salvelinus fontinalis*). Canadian Journal of Fisheries and Aquatic Sciences 47:1065-1070.

Mohn, L. and P. E. Bugas, Jr. 1980. Virginia trout stream and environmental inventory. Federal Aid in Fish Restoration, Project F-32, final report. Virginia Department of Game and Inland Fisheries. Richmond, Virginia.

NAST (National Assessment Synthesis Team). 2000. Climate change impacts on the United States: the potential consequences of climate variability and change – overview report. Cambridge University Press, New York.

Onset Computer Corporation. 2009. HOBO U22 Water Temp Pro v2 users manual. Document # 10366-C. http://www.onsetcomp.com/files/manual_pdfs/10366-C-MAN-U22-001.pdf

Opdamn, P. and D. Wascher. 2004. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. Biological Conservation 117:285-297

PRISM. 2007. Title. Oregon State University, Corvallis. Available: http://www.prism.oregonstate.edu/. (November 2009).

USGS (Unites States Geological Survey) 2008. The national map seamless server. http://seamless.usgs.gov/website/seamless/viewer.htm. Accessed 24 September, 2008

Webb, R. 2009, University of Virginia, personal communication

Wehrly, K. E., L. Wang and M. Mitro. 2007. Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation. Transactions of the American Fisheries Society 136:365-374.