**Water temperature monitoring: Building a foundation for a spatially continuous map of waterbody temperatures on Refuges and neighboring waters in the southeastern United States.**

**Background**

Water temperature plays a fundamental role in determining the distribution of aquatic organisms, physicochemical water characteristics, and rates of ecological processes such as nutrient cycling. Many waters are flow-regulated and thermally altered by point source discharge, hypolimnetic releases from dams, and climate changes. Understanding the magnitude and characteristics of thermal alteration is crucial to planning conservation actions, especially for rare biota in these systems.

With increased concern regarding climate change and other anthropogenic impacts, there has been increased interest in developing a better understanding of the role of climate variability on trust resources. Consequently, multiple efforts throughout the United States have recently emerged to quantify stream temperature regimes and extrapolate site-level findings to larger geographic areas. New statistical techniques have recently been developed and employed in western states that can predict stream temperatures with 93% accuracy (Isaak et al. 2010). These techniques can readily be applied to southeastern states. However, the foundation for the application of these techniques is continuously collected high quality temperature data.

Fish temperature preference, avoidance, and tolerance have been tested and summarized for many species (e.g. Hasnain et al. 2010). Unfortunately, recent efforts to classify streams based on their thermal characteristics in the southeastern US have resulted in useful, but coarse thermal classifications of stream segments making them less useful for inferences to fish communities. For example, the Southern Instream Flow Network released a map showing four classes of streams based on temperature, with a majority of streams in Region 4 in the "Warm" category (Figure 1). While these maps may serve as broad descriptors of fish community types, authors acknowledge that a substantial amount of thermal diversity exists within these broad classes of stream type but that little data is available to calibrate stream temperature models in the southeast.

The distribution of continuous water temperature monitoring sites in the southeastern United States shows intensive monitoring in the southern Appalachians, coastal, and urban areas. Although our review of continuous stream temperature monitoring locations is not exhaustive, it does highlight that there are broad geographic areas where temperature monitoring is relatively depauperate (Figure 2). Located in many of these "depauperate" areas are National Wildlife Refuges (NWRs) and National Fish Hatcheries (NFHs), making them good locations to begin long-term water temperature monitoring efforts. Co-locating temperature monitoring with NWRs, NFHs, and USGS gages enables scientists and managers to combine datasets from ongoing research and management activities, thereby enabling us to develop 1) better assessments of historic, existing, and future water quality conditions, 2) better predictive models of temperature effects on trust resources, and 3) better foundations for evaluating water quality impacts and compliance in waters flowing through or near Refuges.

**Proposal Description**

We propose to expand upon the existing suite of temperature monitoring locations in the Southeast Region. During this period of reduced budgets, hiring freezes, and increased workloads, it is critical that monitoring continue but that it is conducted in a manner that is affordable, high yield, and not time prohibitive. The monitoring that we propose is relatively inexpensive, and can yield large volumes of data with high accuracy and relatively minimal investment of additional resources (including travel and personnel effort). Recent availability of programmable digital thermal recorders has increased the

collection of stream temperature data. We request funding primarily for acquisition of these devices. Loggers will be deployed on Refuges and intersecting freshwater waterbodies. The Drought Assessment and Response Team (DART) will collaborate with Refuges and Hatcheries during the development of site-specific study designs, and will be responsible for logger programming and data offloading when loggers are annually returned to DART. We expect that Refuge biologists will deploy, retrieve, and mail loggers to (DART) to be offloaded. All data will be immediately shared upon logger offload.

Standardized protocols for temperature logger deployment will be employed whenever possible (Dunham et al. 2005). In future years, the Service will continue to find existing datasets and expand the network of temperature monitoring sites in the region, as a penultimate goal of developing a spatially continuous map of water temperatures.

**Where will data be collected?** We will stratify the deployment of loggers based on four major criteria. These will include Refuges and Fish Hatcheries that:
1) request to participate and/or that have water quality related concerns listed in their CCP.
2) are located in areas of ongoing drought so that we may capture the hydrologic and associated thermal extremes associated with the drought.
3) are located in portions of Southeast Region that have relatively little continuous water temperature monitoring.
4) intersect or are in close proximity to aquatic critical habitat.

**Specific Parameter Measurements.** Temperature at an hourly time step should be sufficient to capture a majority of diel temperature fluctuations (Dunham et al. 2005). Monitoring will continue for a minimum of 5-years, which is the predicted battery life for the TidBit logger. Stream and waterbody temperature data will be compared to meteorological conditions, location, physiography, and water body characteristics to describe patterns in thermal conditions and to develop a classification of waters. Ultimately, we hope to incorporate the water temperature profiles into a classification system for Southeast streams.

**Funding required.** The amount requested is $16,670.99, primarily for the acquisition of Onset data loggers (100 TidBit and 100 Pendant). This would permit 3 data loggers for each of 65 inland refuges. However, the amount is negotiable and the number of sites can be scaled to the award amount.

**Who would monitor and manage data?** DART would be responsible for programming data loggers. Refuge biologists that participate will be responsible for deployment, retrieval, and mailing loggers back to DART. Data would be made immediately available. Ideally, the I&M program would house the data in a regional repository. However, data also can be organized and stored by DART. Prior funding was used by DART to acquire Hoboware Pro for download and summary of thermistor data. Free analysis packages are available including ThermoStat V3 and Indicators of Hydrologic Alteration, both of which can be used to quickly summarize large data volumes. Quantitative inferences regarding optimal habitat for specific species are also available in ThermoStat V3.

**Partners.** This is a collaborative effort between Ecological Services, Refuges, and National Fish Hatcheries, each sharing responsibilities, expertise, and workloads. Ecological Services staff and DART would assist with programming, study design and delivery, and data management. Refuge and hatchery staff will take the lead in soliciting temperature monitoring opportunities from managers and biologists. Refuges and hatcheries will help to establish long-term trend monitoring stations where waters are representative of conditions in a wider geographic/physiographic area. Additional refuge areas will be

monitored where water quality issues or species questions have been identified. In order to build a spatially continuous map in the future, the partnership will necessarily expand to include USGS, USFS, and others.

**How the proposed monitoring relates to broader monitoring efforts (e.g., by USGS, EPA, States, university researchers, LCC, etc.)**. The proposed monitoring effort will implement actions envisioned by the USFWS Climate Change Strategic Plan, by helping generate empirical data needed to track climate change effects on the distribution and abundance of fish, wildlife, plants and their habitats; model predicted population and habitat change; and help us determine if we are achieving our goals. This effort is part of a larger program to understand the ecology of Southeast Rivers, and responds to the top research need identified by the Southern Instream Flow Network (Develop a regional river classification system).


Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: a user's guide. Gen. Tech. Rep. RMRSGTR- 150WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15p.

Hasnain S.S., Minns C.K., Shuter B.J., Birk-Urovitz E., Birk-Urovitz A. 2010. Compilation of Ecological Temperature Metrics for Canadian Freshwater Fishes. Climate Change Research Report CCRR-17, Ontario Ministry of Natural Resources; 55.

Isaak, D.J., C.H. Luce, B.E. Rieman, D.E. Nagel, E.E. Peterson, D.L. Horan, S. Parkes, and G.L. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350-1371. Archived online at Treesearch http://www.treesearch.fs.fed.us/pubs/35471


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**Budget:**

| | Quantity; Adjust values in green as needed | Cost/ea | Total Cost |
|---|---|---|---|
| Approximate # of inland Refuges with freshwater | 65 | | |
| # Pendant Temperature loggers | 100 | $ 50.00 | $ 5,000.00 |
| # TidBit Temperature loggers | 100 | $ 113.05 | $11,305.00 |
| Total cost | | | **$16,305.00** |
| Total # loggers/refuge | | | **3.07692308** |
| | Quantity | | |
| Fox FX - 764 underwater epoxy (2 QT) | 1 | $ 76.00 | $ 76.00 |
| Stainless stell cable (500ft) | 1 | $ 39.19 | $ 39.19 |
| Zinc Plated Copper Sleeves 1/16" | 4 | $ 7.25 | $ 29.00 |
| Polypropylene Olive Drab Sandbag (15) | 4 | $ 17.95 | $ 71.80 |
| PVC canister housings for tidbit loggers | 50 | $ 3.00 | $ 150.00 |
| | | | |
| **Total request** | | | **$16,670.99** |

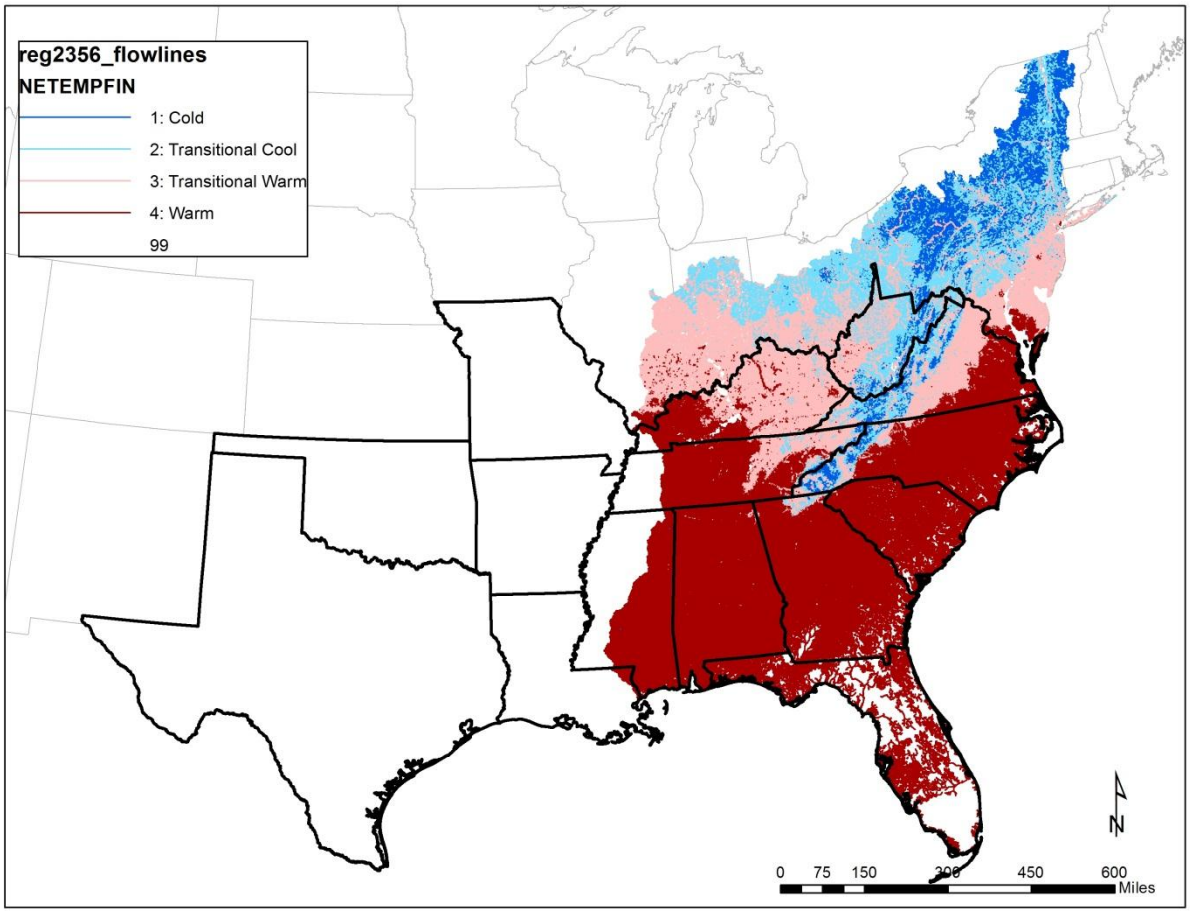


Figure 1. Draft map produced by Southern Instream Flow Network showing a regional stream temperature classification system.

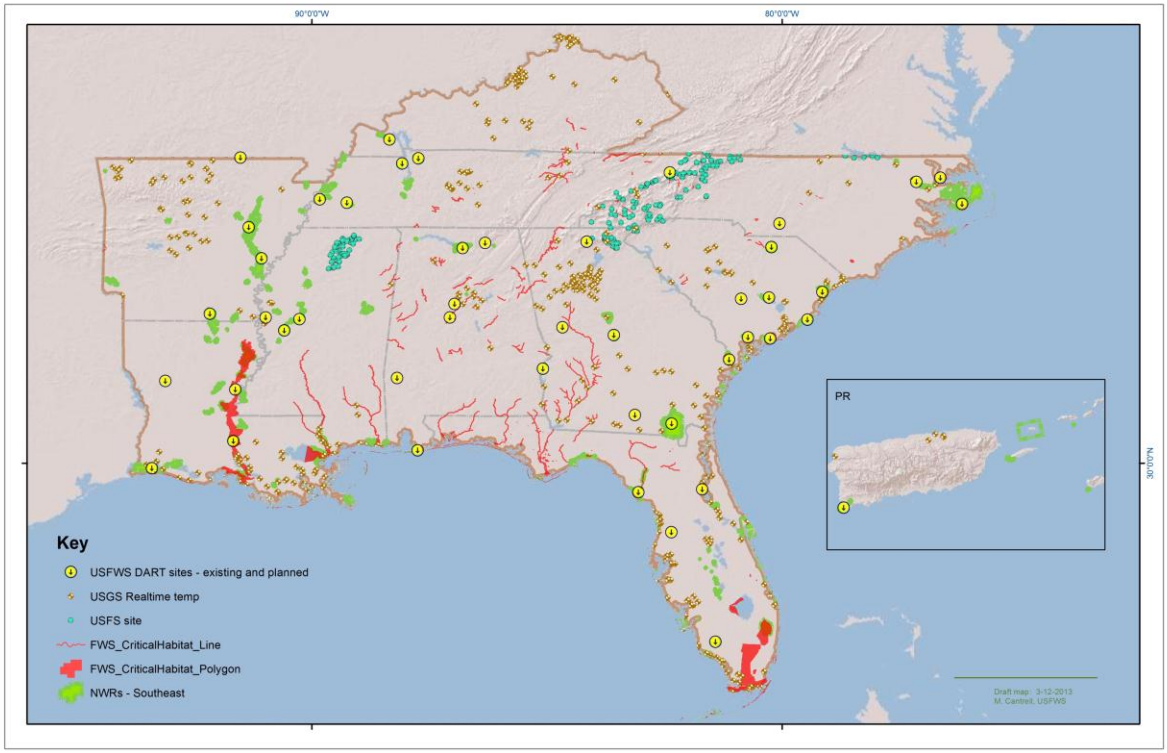


Figure 2. Ongoing continuous temperature monitoring locations, critical habitat, and Service properties (hatcheries and refuges) in the Southeast Region.