Sensitivity Analysis of Changing Climate on the Thermal Gradient of Streams

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Climate change has the potential to alter biogeochemical cycles and biological communities in aquatic habitats. Anthropogenic contributions can accelerate these changes to an unnatural rate, which does not allow organisms to adapt or acclimate. Thus, it is important to understand how a stream reacts to climatic changes over a short time period in order to mitigate any harmful effects. This project sought to analyze and project a stream's sensitivity to various scenarios of induced climate change (particularly a warming climate). This is particularly important in semi-arid areas of the Western United States (i.e. states like Montana) where rivers and streams provide important natural resources and are cherished by residents and tourists.

Project Objectives

- Identify stream as study site (Gold Creek, a tributary of the Clark Fork in Powell County~ chosen in conjunction with the Clark Fork Coalition of Missoula, MT)
- Collect relevant field data (i.e. water temperature, meteorological data, hydrological data, etc.) for the site to use in modeling thermal dynamics of the stream via Stream Segment Temperature (SSTEMP) modeling software available through the USGS.
- Calibrate and validate SSTEMP using collected field data for different reaches on the stream over several months.
- Manipulate parameters in the model to determine the streams sensitivity to these changes (e.g. increased air temperature, decreased flow, increase or decrease amount of vegetation, etc.).

The study site for the project was on Gold Creek. Gold Creek is a tributary of the Clark Fork in Powell County. Its headwaters are in the Flint Creek Mountains of Southwestern Montana. Only the lower five miles of the creek were included in the study on private property owned by Don Beck and the Thomas Herford Ranch. In order to take measurements on the creek it was split into three reaches (one served as a reference reach). The reference reach (Reach 1) was designated as suitable trout habitat by the Clark Fork Coalition (CFC). Reaches two and three went through various rangeland/hay fields to the confluence with the Clark Fork. Each reach contained two measurement sites for temperature and discharge, the top (upstream point) and bottom (downstream point). Here, continuous water temperature data-loggers were placed for June, July, August, and early September. Air temperature was taken at the top of the study site (Reach 1 top) and the very bottom (Reach 3 bottom – confluence). Discharge was taken with a metric measurement rod and a Marsh McBirney flow-mate to measure velocity. Inflow was measured at the top of each reach and outflow at the bottom. Flow was measured once a month for July, August, and September. Due to complications with the Clark Fork Coalition, flow data was not collected for the bottom of reach three and the top of reach one. However, using flow data and hydrographs from previous summers, I was able to estimate the flow at these locations well enough to calibrate the model.

Vegetation characteristics and stream geometry were also measure along each of the three reaches. These variables were an "average" measurement and thus required multiple measurements for higher resolution (i.e. average vegetation density, height, etc.). In order to accomplish this, each reach was split into ten systematic transects. At each transect vegetation height, crown, offset, and density were measured along with topographic altitude (i.e. height of topography on either side of the stream) and width/depth ratios. Transects were averaged to obtain a value for both banks of the stream.

The collected field data was then input into SSTEMP to calibrate the model and assess its accuracy at estimating a streams thermal gradient (i.e. change in temperature from top of a reach to bottom). The model was calibrated for specific days when stream discharge was measured. This is because discharge varies diurnally and the model calculates the available sunlight via the day of year. The calibration dates were July 26th, August 26th, and September 8th for Reach 1 and 2. For Reach 3, they were July 26th, August 26th, and September 16th. After input of the required parameters, and tweaking some values, the model was calibrated to within a 5% difference of the observed temperatures from the data-loggers for July 26th. To validate the results, the same parameters were input for the remaining calibration dates to see if they remained within 5% difference. The model was successfully calibrated with my measured data and validated. The next step was to manipulate certain parameters to analyze how the stream temperature was affected. The full results of this step of the project are pending, however, the following outlines results so far:

Results so far

- Increasing air temperature has minimal affect on water temperature most likely due to water's high specific heat, thus air is inefficient at conducting heat through a water column. However, increased annual air temperatures also raise accretion temperature (groundwater) and ground temp (soil) which causes further increase in water temperature. These can add up to a few degrees Fahrenheit increase in the daily mean water temperature (they can cause more fluctuation in daily max and min also). An average increase in daily max temperatures does however produce significant increases in daily max water temperature.
- Increasing or decreasing average shading from vegetation decreases or increases the water temperature drastically, respectively. Less overall shading produces increased daily mean water temperatures and significant increase in the daily max water temperature. This is expected because shading changes the effective water surface absorbing solar radiation (which serves as the most important source of water temperature).
- With warming annual temperatures, any mitigation for rising stream temperatures will most likely want to focus on parameters that involve incoming solar radiation (i.e. albedo, shade from vegetation, etc.).

Project Photos: (left)measuring vegetation density with a densitometer; (center)water temp logger in pipe to keep from washing away; (right)measuring crown of vegetation
Photo on front page of report – old barn located on Reach 2 (Don Beck's property)