Investigating Controls on Stream Temperatures in a Small Watershed

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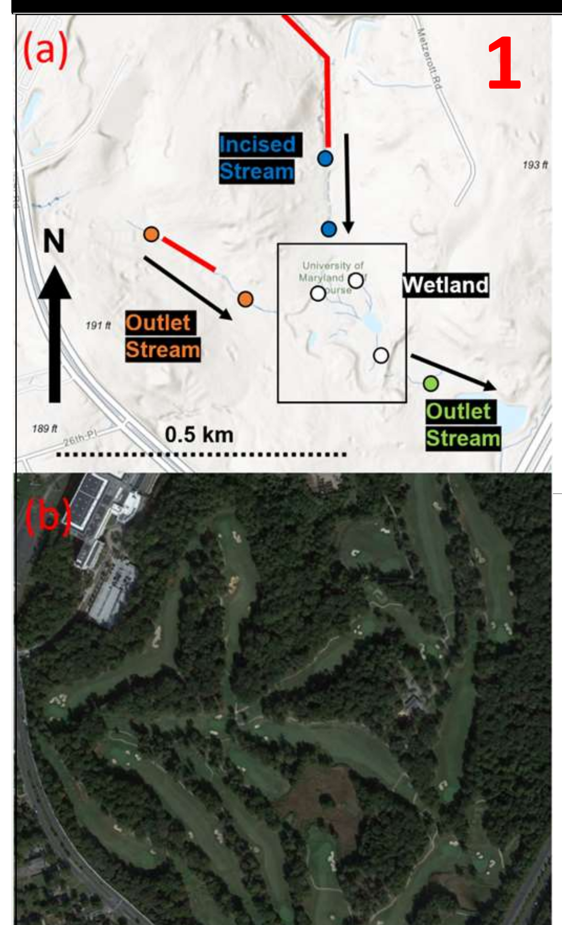
Introduction

Small streams are sensitive environments prone to biodiversity loss due to thermal pollution. Understanding how to best protect streams from anthropogenic thermal pollution requires understanding how geomorphology impacts temperature regimes in small watersheds.

Hypotheses

1) An incised stream will have cooler summer temperatures, warmer winter temperatures, and generally restricted temperature ranges relative to a non-incised stream.
2) A constructed wetland's surface outputs will have cooler summer temperatures, warmer winter temperatures, and generally restricted temperature ranges relative to the wetland's surface inputs.

Study Site



The study site (Fig. 1) was a watershed situated on the University of Maryland Golf Course and comprises two inlet streams, one incised and one non-incised, feeding into a constructed wetland with a single surface outlet.

Figure 1

(a)– Color coded gauge locations and regions of the two segments studied in the longitudinal temperature surveys

(b)- Satellite image of land cover. The non-incised stream is in grass, incised stream in forest

Methods

1) Monthly temperature records for April 2021-March 2022 evaluated with Wilcoxon rank sum analyses for means, medians, and ranges for the non-incised, incised, and outlet streams, with critical $p = 0.05$
2) Baseflow longitudinal temperature surveys of both inlet streams during low flow conditions (October 2021) and high flow conditions (April 2022).
3) Timeseries comparisons for temperatures and water levels for the warmest and coolest months

Results: Monthly Temperature Data

1) Incised stream temperatures were significantly cooler than non-incised stream temperatures for both warm ($p < 0.00005$) and cool months ($p < 0.00005$).
2) The outlet was statistically warmer than the incised and non-incised input streams during warm ($p < 0.00005$) months and statistically cooler in cool months ($p < 0.00005$).
3) Differences in means and medians were insignificant ($0.7000 \geq p \geq 0.1700$).

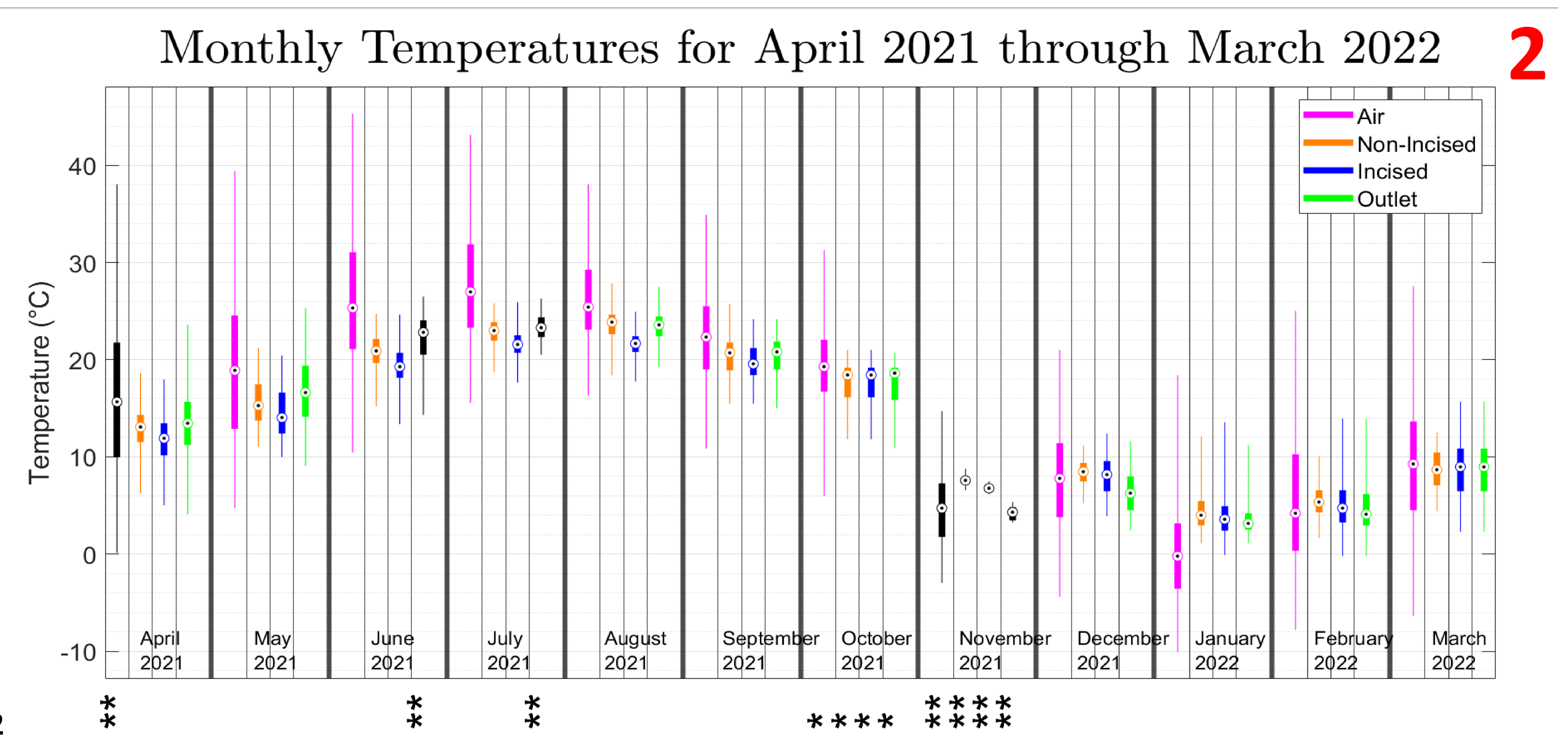


Figure 2
Monthly temperature distributions. Single asterisk denote months with <80% of month recorded. Double asterisk denote months with <50% of month recorded and not used in statistical analyses. ε (Air) = ±0.21 °C and ε (Else) = ±0.44 °C

Results: Longitudinal Profiles

1) In October, the non-incised stream cooled with length, and the incised stream warmed with length (Fig. 3a).
2) In October, non-incised stream temperatures were more heterogenous than incised stream temperatures (Fig. 3c).
3) In April, neither stream had a clear warming or cooling trend (Fig. 3b).
4) In April, incised stream temperatures were more heterogenous than non-incised stream temperatures (Fig. 3d).

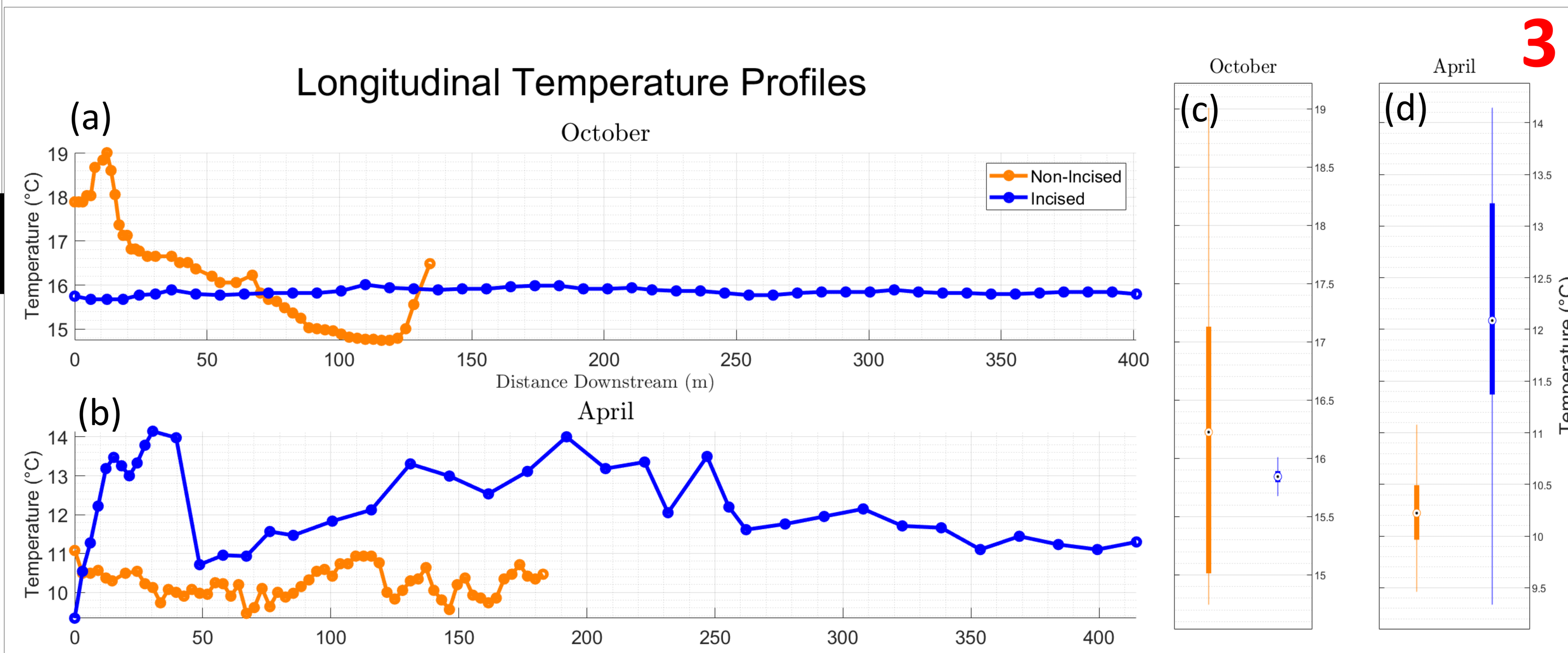
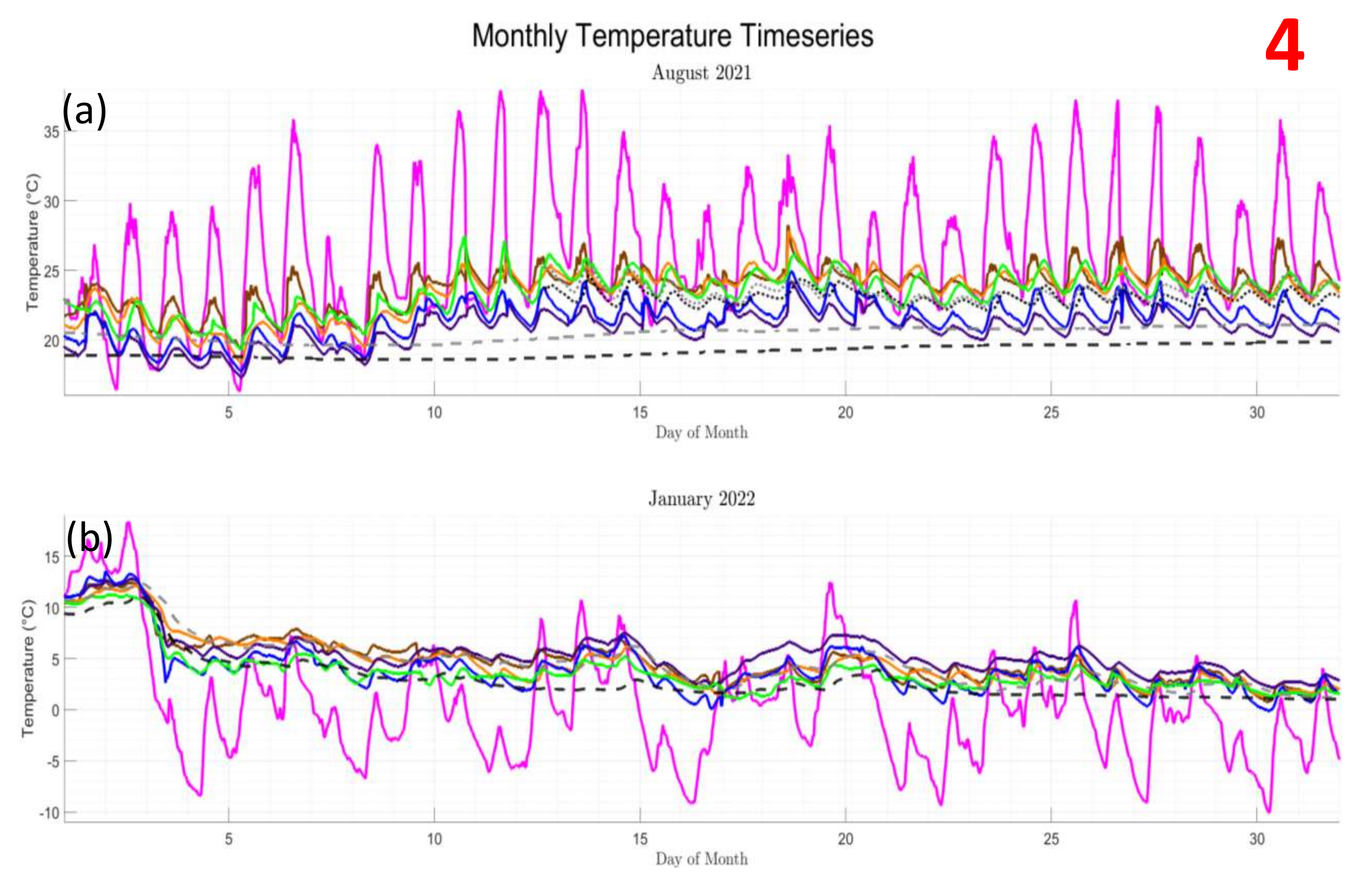


Figure 3
Longitudinal stream temperature profiles for (a) 20/10/2021 (non-incised), (a) 22/10/2021 (incised), and (b) 04/04/2022 (both). Difference in non-incised profiled length due to low water levels in October. Boxplots for (c) October and (d) April temperatures from longitudinal profiles. ε = ±0.21 °C

Results: Timeseries Analysis of Gauged Sites

1) Diurnal stream temperature variation was less evident in January (Fig. 4b) than in August (Fig. 4a).
2) The incised stream warmed with length downstream in August (Fig. 5b) and cooled with length downstream in January (Fig. 5d). The non-incised stream cooled with length downstream in August (Fig. 5b) but did not show consistent temperature change with longitudinal direction in January (Fig. 5d).
3) Groundwater temperatures varied more during January than August (Fig. 6). Groundwater temperatures did not fluctuate significantly during storm events (Fig. 6).



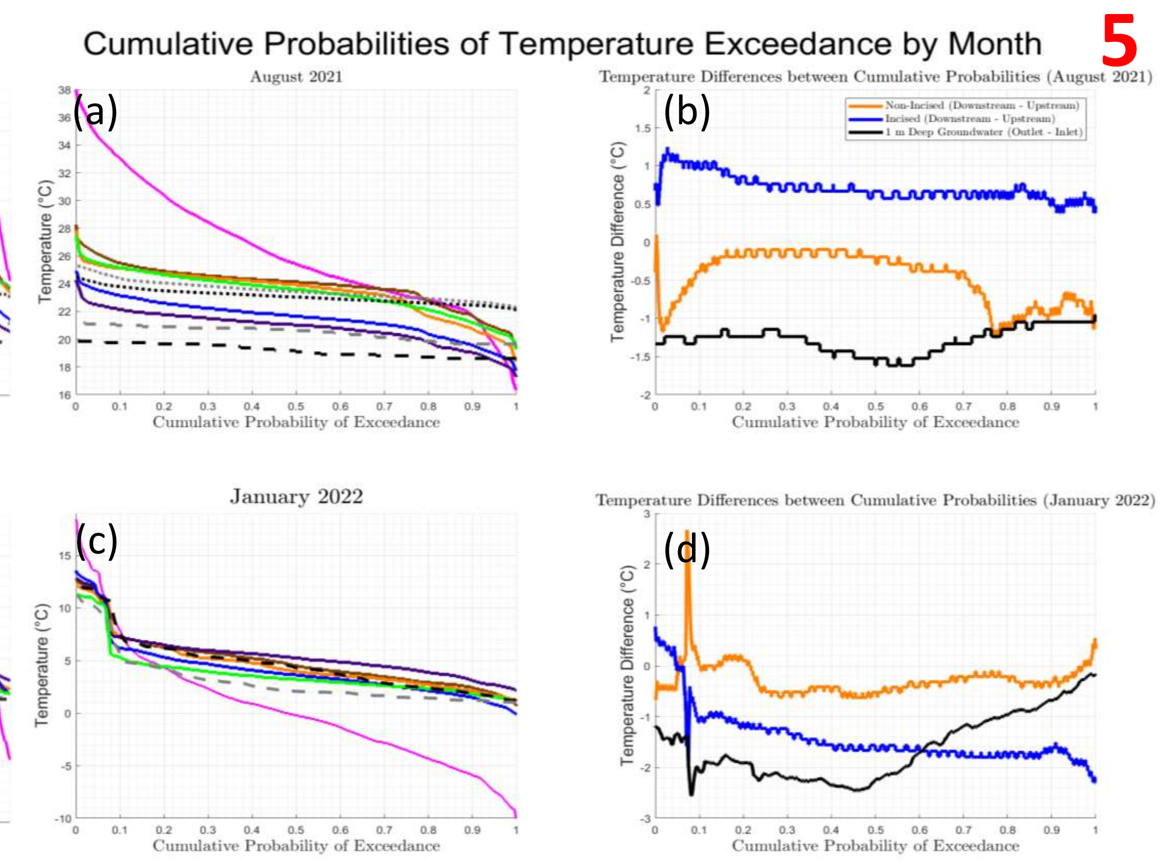


Figure 4 (above)
Monthly water temperature timeseries for (a) the warmest and (b) the coolest months of the study period. ε (Air, 10 cm Groundwater) = ±0.21 °C and ε (Else) = ±0.44 °C

Figure 6 (below)
Monthly groundwater temperature and depth timeseries for the warmest and coolest months of the study period. ε = = ±0.44 °C, ±0.008 m

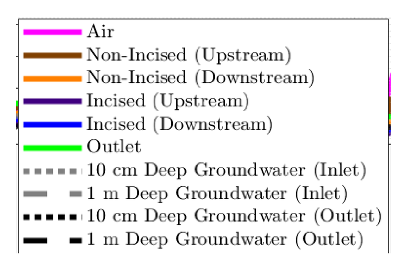
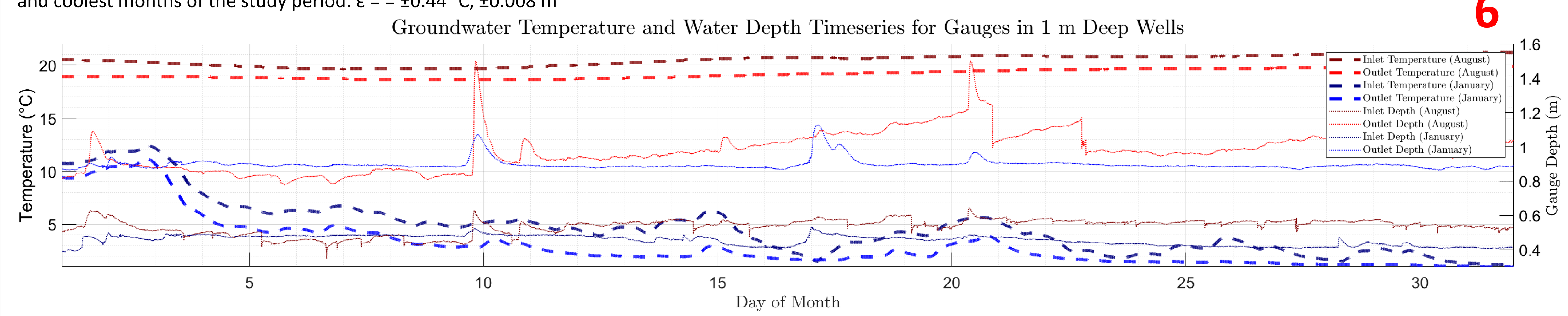


Figure 5 (above)
(a) Warmest and (c) coolest month cumulative probabilities of temperature exceedance from Fig. 3 and select (b,d) differences in temperature at same temperature probabilities.
ε (Air, 10 cm Deep Groundwater) = ±0.21 °C, ε (Differences) = ±0.62 °C, and ε (Else) = ±0.44 °C



Conclusions

1) The original hypotheses were not supported.
   - The incised stream was generally cooler than the non-incised stream throughout the year.
   - The wetland outlet stream was warmer in the summer and cooler in the winter than the non-incised and incised inlet streams.
   - Monthly ranges were comparable for the non-incised, incised, and outlet streams.
2) There was evidence for multiple distinct seasonal groundwater mixing regimes that likely influenced stream temperatures.
3) Incision may have utility in reducing mean temperatures in certain small urban streams, and constructed wetlands may exacerbate stream warming in certain small urban watersheds.