# Long-Term Citizen-Led Monitoring Detects Biological Responses to an Acute Toxicity Event in Trail Creek, Athens GA, USA

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## INTRODUCTION

The Upper Oconee Watershed Network (UOWN) is a community-based group focused on the watersheds of the North and Middle Oconee Rivers near Athens, GA, USA. UOWN's mission is "to protect water resources and improve stream health through community-based advocacy, monitoring, education, and recreation." This all-volunteer monitoring program has supported quarterly sampling of several tributaries and river sites within the watershed. UOWN monitoring has occurred for close to 20 years in this watershed, where significant urban growth and development has occurred over this period.

## BACKGROUND

Watershed urbanization is a widespread issue for many aquatic ecosystems, including the Upper Oconee Rivers and tributaries. Urban development can have multiple long-term effects on ecosystem integrity, including altered hydrology, sedimentation, and nutrient or toxicant loading (Walsh et al. 2005).

In addition to long-term detrimental effects, urbanization can also increase the prevalence of acute pollution events that affect aquatic life. For example, flooding events can inundate receiving ecosystems with excessive contaminant concentrations (Tilli et al. 2011). Failed infrastructure can also impact contaminant loads to adjacent aquatic systems, as has recently been observed in numerous circumstances (e.g., 2008 coal ash spill on the Emory River; Ruhl et al. 2009).

On July 28, 2010, a chemical storage facility caught fire in Athens, GA, and efforts to control the fire resulted in contamination of nearby Trail Creek with industrial chemicals (Black et al. 2013). Here, our objective was to assess the effects of the chemical spill on the Trail Creek ecosystem using long-term monitoring data collected ∼5-km downstream of the spill site.

Biotic indices based on macroinvertebrate communities are useful metrics for detecting acute and chronic stressors to ecosystems. Macroinvertebrates are particularly useful in this regard because they are relatively long-lived, and exhibit differing tolerance to point and non-point source pollution (Rosenberg and Resh 1993, Roy et al. 2003). We expected that changes in the macroinvertebrate communities in Trail Creek before, during and after the chemical spill would provide a representative metric for overall ecological impacts of this accidental contaminant spill. We compared the macroinvertebrate indices to measures of water quality that could also affect macroinvertebrate communities in Trail Creek (specifically, specific conductance; Kominoski et al. 2007).

We present data from nearly 13 years of quarterly monitoring efforts for three Athens, GA streams to compare Trail Creek to a minimally altered reference stream (Bear Creek) and a stream impacted by chronic pollution (Carr Creek). Our objectives were to 1) provide evidence for baseline biotic integrity of Trail Creek in comparison to reference and chronically impaired sites, 2) assess the effectiveness of two distinct volunteer-generated metrics for monitoring the impact of the chemical spill on Trail Creek, and 3) examine the trajectory of recovery from the acute pollution event during the four years following the chemical spill.

## METHODS

### *Sampling sites*

The Upper Oconee Watershed Network coordinated sampling of three piedmont stream sites in the Upper Oconee watershed, Athens-Clarke County, Georgia, USA. Each site was sampled quarterly from 2001-2014. Two tributaries of the North Oconee River were sampled: Trail Creek (site of the spill; Fig. 1) and Carr Creek, a site with chronically high specific conductance and low biotic indices. A small tributary to Bear Creek in the Middle

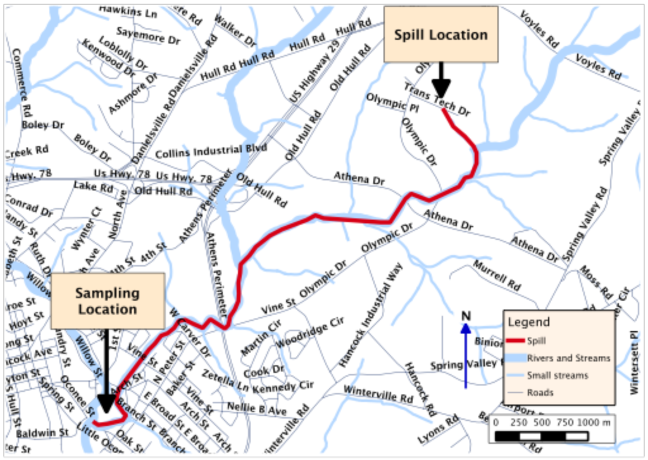


Figure 1: Map of the sampling location and spill site on Trail Creek, Athens, GA.

Oconee River watershed was also sampled and was considered to be our reference site due to the relatively intact riparian area surrounding the stream as well as historical patterns of low specific conductance and high biotic indices.

*Macroinvertebrates and specific conductance*

Macroinvertebrate communities were sampled using methods adapted from Georgia Adopt-a-Stream guidelines (GA AAS 2004). Briefly, rocky or muddy bottom habitats within small reaches of each study site were sampled for macroinvertebrates using a kick seine or D-frame nets. Samples were elutriated, if needed, and volunteers sorted composite samples. Macroinvertebrates were separated from organic matter and sediment, sorted by taxa, and identified (usually to order) using AAS identification keys. Biological indices were computed using the Save Our Streams index outlined by the Isaak Walton League of America. These biological scores are indicative of water quality ("excellent">22, "good"=17-22, "fair"=11-16, "poor"<11) based on presence/absence of previously established classifications of specific macroinvertebrate taxa into tolerant, somewhat-sensitive and sensitive categories (Georgia AAS 2004).

The specific conductance ($\mu$S/cm) was sampled by collecting water from each site in sterile Whirl-Pak®bags at mid-stream and mid-depth in the study reach. Water samples were transported to a central location, where the specific conductance was measured with a YSI EC300 (YSI Inc., Yellow Springs OH) or HACH Series 10 multimeter (Hach Company, Loveland, CO).

*Statistical analysis*

All analyses of the data were conducted using the statistical software R v. 3.0.1 (R Core Development Team 2013). We identified central tendencies across all years available for the three sites analyzed for this study (mean, median) and used these values to estimate baseline conditions within the stream. We then computed 95% confidence intervals around the mean SOS score and used these values to indicate uncommonly observed SOS scores for the time series presented here. We were specifically interested in detecting the response of the biological index of Trail Creek before, during, and after the chemical spill at this site. We compared the response of Trail Creek to the trends observed in Carr Creek and Bear Creek.

We considered the chronically impacted Carr Creek to demonstrate a baseline for "poor" water quality, and Bear Creek Tributary to be a baseline for "good" water quality. For this reason, we expected that if Trail Creek showed deviations from the general trends observed in Bear Creek or Carr Creek around the time of the spill, then the response observed could be attributed to the effects of the spill, rather than to effects from other regional scale drivers such as drought or high-flow events that could also affect stream biological integrity. To account for potential effects of other contaminants unrelated to the spill, we also used specific conductance to test for possible long-term effects in stream pollution that could be used to explain patterns in biological indices.

## RESULTS

Trail Creek had intermediate biological scores compared to the consistently low scores in Carr Creek and consistently high scores in Bear Creek. Bear and Carr Creeks showed stable SOS scores during the 13-yr study period compared to Trail Creek (Fig. 2).

On average, Trail Creek was found to have a macroinvertebrate community that corresponded to an SOS score of 13.2 (95% CI=6-20.8, n=37, "fair"). In contrast, Bear Creek demonstrated a higher average score for the same period (21.5; 95% CI=15-26, n=44, "good") and Carr Creek had a lower average score compared to Trail Creek (3.5; 95% CI=0-7.4; n=38, "poor").

Following the spill in 2010, macroinvertebrate indices in Trail Creek declined below 95% confidence intervals for the long-term mean score, which was the lowest score observed during the study period (in 2010 SOS=4.5, n=2, "poor"). In the four years following the spill, macroinvertebrate scores tended to increase toward pre-disturbance levels (mean score=12.5, n=11; Fig. 2, "fair").

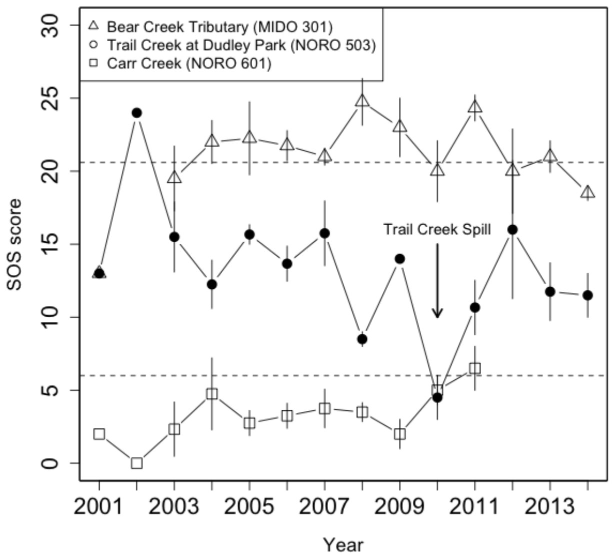


Figure 2: Comparison of three streams (Bear Creek Tributary, Trail Creek, Carr Creek) in the Upper Oconee Watershed using the Save Our Streams biological index (SOS score), from 2001-2014. Mean annual SOS scores for each stream are presented (n=4). Bars represent standard error. Dashed lines denote 95% confidence limits around the overall mean SOS score for Trail Creek for the study period. Arrow indicates the chemical spill.

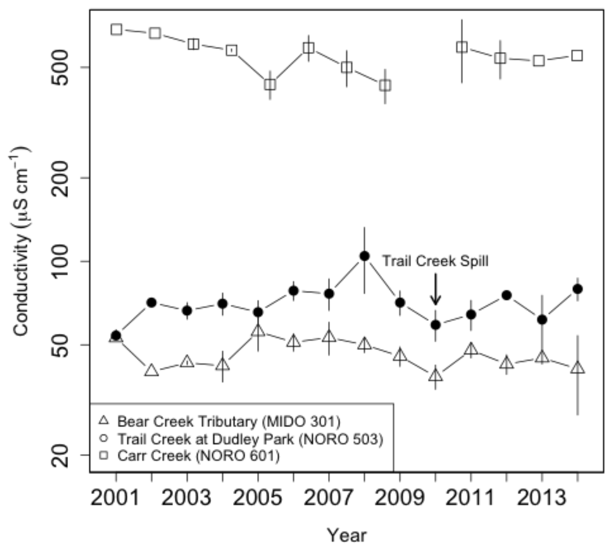


Figure 3: Comparison of three streams (Bear Creek Tributary, Trail Creek, Carr Creek) in the Upper Oconee Watershed using specific conductance ($\mu$S/cm, note log scale) from 2001-2014. Arrow indicates the chemical spill.

As with central tendencies for SOS scores, Bear Creek consitently had lower mean specific conductance (46.5 $\mu$S/cm; n=44), and Carr Creek had higher mean specific conductance (537.5 $\mu$S/cm; n=38), compared to Trail Creek (71.3 $\mu$S/cm; n=37). Carr Creek exhibited specific conductances that consistently exceeded 400 $\mu$S/cm throughout the study period. Specific conductance during the spill year in Trail Creek (2010; 59 $\mu$S/cm; n=3) was within 95% confidence limits for the period from 2001-2014, and was 17% lower than the mean value for the same time period.

## DISCUSSION

Establishing long-term datasets to determine baseline ecosystem status is a crucial step toward detecting detrimental effects of watershed scale disturbances and land-use change in recipient ecosystems. We found that long-term monitoring data allowed us to detect the effects of an acute pollution event in Trail Creek. Specfically, during the year when peak impact from the chemical spill could be expected, Trail Creek had comparable macroinvertebrate scores to the chronically-impacted Carr Creek, even though specific conductance remained comparable to the less impacted Bear Creek Tributary. Further, we found little evidence for parallel marked declines in SOS scores during 2010 in the other two streams that were analyzed for this study. These lines of evidence suggest that the catastrophic event in Trail Creek led to decreased biotic integrity of the system for most of the year following the spill.

While we provide evidence for detrimental effects of the chemical spill in Trail Creek, our long-term monitoring has also shown signs that the biotic community in Trail Creek has some resiliency to acute disturbance, evidenced by the relatively quick recovery from the spill. In the four years following 2010, SOS scores indicated water quality that reflected "fair" conditions, an improvement over the "poor" water quality observed in 2010. However, we note that our sampling site was ~5-km downstream of the spill source; more sampling closer to areas where toxins may have been retained could help fully characterize a potential recovery – or lack of recovery – from the spill (e.g., Black et al. 2013). Importantly, a large wetland complex occurs between the spill site and our long-term sampling location. This wetland has been implicated in not only the storage of contaminants, but also their potential uptake and breakdown (Black et al. 2013).

In addition to the acute effects of the spill, Trail Creek provides an interesting example of the chronic effects of land development decisions. This stream has typically observed "fair" biological index scores over this 13 year period of record. Trail Creek provides an important site for potential conservation and stormwater management actions in order to avoid declines to a consistently polluted condition analogous to Carr Creek.

## CONCLUSIONS

The long-term data presented in this study underscore the importance of citizen-led science to establish baseline status for imperiled ecosystems, and the ability to detect detrimental effects when they occur. We demonstrated that an urban watershed characterized by intermediately elevated specific conductance and "fair" water quality based on SOS scores was acutely impacted by a chemical spill.

We recommend continued support of monitoring efforts in the Athens-Clarke County area, and in particular, additional sampling efforts to confirm the possible recovery of Trail Creek following the impacts of the spill. Further, we suggest stronger statutory strategies could be used to prevent future catastrophic events and minimize their impact when they do occur, including (but not limited to): use of firefighting foams (Shearer 2013), wider riparian buffers to absorb contaminated runoff, and prohibition of chemical storage facilities within critical riparian zones of streams.

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