

USING LONG-TERM CHEMICAL AND BIOLOGICAL INDICATORS TO ASSESS STREAM HEALTH IN THE UPPER OCONEE RIVER WATERSHED

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Abstract. Macroinvertebrates are commonly used as biological indicators of stream habitat and water quality. Chemical variables, such as dissolved oxygen (DO), specific conductance (SC), and turbidity are used to measure stream water quality. Many aquatic macroinvertebrates are sensitive to changes in water chemistry, and streams with degraded water quality are often characterized by low macroinvertebrate diversity. Chemical (DO, SC, turbidity) and biological (macroinvertebrates) data from multiple tributaries of the North and Middle Oconee Rivers in Clarke County, Georgia, USA were collected seasonally from 2000 – 2006. Macroinvertebrates were identified, and communities were scored using the Georgia Adopt-A-Stream biotic index. Significant differences in biotic index scores were identified across sites and time using a two-way ANOVA. A general linear model relating chemical variables to biological score was more parsimonious than a model without chemical variables. These relationships varied by sample site, but they were consistent across seasons and years. Macroinvertebrate communities became degraded with increasing specific conductance, but associations with the other chemical variables were unclear. Results suggest the importance of using long-term chemical and biological indices in assessing stream health.

INTRODUCTION AND BACKGROUND

The Upper Oconee Watershed Network (UOWN) is a community-based, volunteer watershed monitoring group that collects quarterly biological and chemical samples from multiple tributaries of the North and Middle Oconee Rivers, Athens-Clarke County, Georgia, USA. Since 2000, we have routinely sampled both macroinvertebrates and water chemistry to assess water and habitat quality in seven tributaries.

Land-use change in riparian areas due to urbanization is impacting stream ecosystems (Paul and Meyer 2001, Roy et al. 2003). Accompanying changes include: loss of riparian forests, increased transport of nutrients and sediment, alterations to the thermal and hydrologic regimes of impacted streams, and negative impacts on stream biota.

The presence of wastewater treatment plant effluent and non-point source organic pollutants (Lenat 1988, Lenat and Crawford 1994) along with changes in bed sediment particle size in urbanized streams have been shown to reduce overall aquatic macroinvertebrate diversity and increase the relative abundances of tolerant taxa (Paul and Meyer 2001, Roy et al. 2003). Sedimentation and solute transport have been of specific concern, as these variables often correlate with low dissolved oxygen and negative impacts on macroinvertebrate communities, which are often used to as biotic indicators of stream habitat and water quality.

Macroinvertebrates are widely used as bioindicators of stream water and habitat quality because they are relatively long-lived and immobile, easy to capture, and integrate effects of disturbance (Rosenberg and Resh 1993). Although comprehensive assessments of macroinvertebrate diversity and abundances are often limited by taxonomic knowledge and time (Engel and Voshell 2002), standardized qualitative biomonitoring is effective to assess stream water quality (Lenat 1988).

Here we present a long-term chemical and biological assessment of seven streams in the Upper Oconee River Watershed from 2000-2006. Our objectives were to: 1) measure long-term temporal trends in chemical and biological variables across multiple streams in the watershed; and 2) determine how well chemical variables explain the variation in macroinvertebrate biological scores across sites and across years.

METHODS

Study Region and Sampling Sites

Seven sites in the Upper Oconee River Watershed, Athens-Clarke County, Georgia Piedmont, USA (Figure 1) were sampled from 2000-2006. Carr Creek is located near the GA 10 bypass and is a headwater stream of the North Oconee River (NOR). Trail Creek is located in Dudley Park in Athens and is a tributary of the NOR. Sandy Creek was sampled near its confluence with the NOR at Sandy Creek Nature Center. Brooklyn Creek is a headwater stream of the Middle Oconee River (MOR).

Hunnicut Creek was sampled near its confluence with the MOR at Ben Burton Park. McNutt Creek is located downstream of Ben Burton Park along the MOR. Bear Creek Tributary is a tributary to the MOR.

Sampling Procedures

Dissolved oxygen (DO) (mg l^{-1}), specific conductance (SC) ($\mu\text{S cm}^{-1}$), and turbidity (NTU) were measured quarterly at each site. Samples for DO were measured with a Hydrolab® multi-probe (Hydrolab Corporation, Austin, TX, USA). Specific conductance was measured

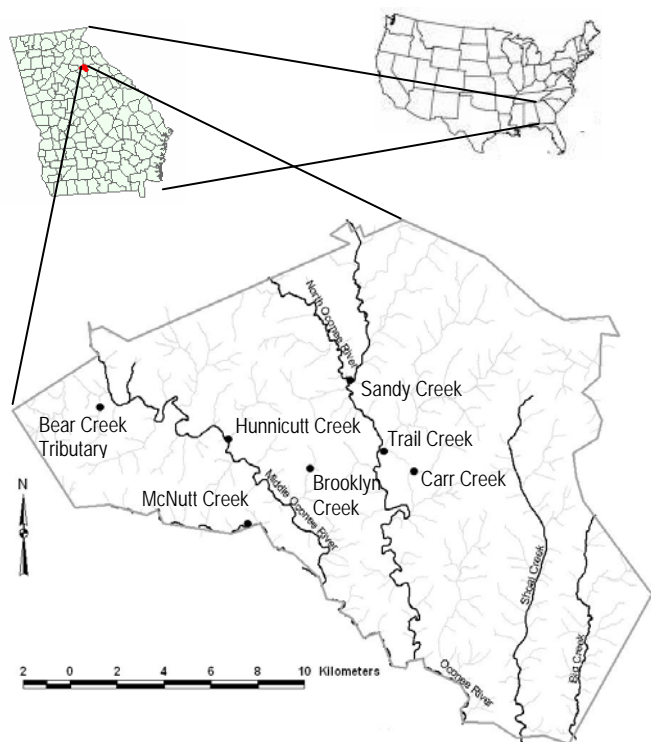


Figure 1. Map of seven sampling sites within the Upper Oconee River Watershed, Athens-Clarke County, Georgia, USA.

using an Oakton pH/conductivity meter (OAKTON Instruments, Vernon Hills, IL, USA), and turbidity was measured using a LaMotte® 2020 turbidimeter (LaMotte Company, Chestertown, MD, USA).

On a quarterly basis and in conjunction with water chemistry sampling, macroinvertebrates were collected, identified, and scored following the Georgia Adopt-A-Stream protocol for rocky and muddy bottom streams (GA AAS 2004). Either riffles or pools were sampled depending on the dominant habitat type at each site. Samples were elutriated when necessary. Macroinvertebrates were sorted by taxa, counted, identified (usually to order) using identification keys, and scored according to the Save Our

Streams (SOS) Program of the Izaak Walton League of America. The SOS score was based on presence/absence of sensitive, somewhat-sensitive, and tolerant taxa. Scores were used to indicate water quality (excellent > 22, good = 17-21, fair = 11-16, poor < 11); (Georgia AAS 2004).

Statistical Analyses

First, differences in mean annual macroinvertebrate score across sites and years were compared using a two-way ANOVA in PROC GLM at an alpha of 0.05. Data were log-transformed to meet assumptions of homoscedasticity. Second, a linear model with biological score as the response and the three water chemistry variables (DO, SC, turbidity) was constructed, and PROC GENMOD was used to obtain residuals. Some of the 95% confidence intervals (CIs) for residuals grouped by sample site did not overlap, while groupings by time did. This indicates that the relationship between water chemistry and macroinvertebrates was spatially, not temporally, dependent. This model was compared to the null model (i.e., model with no predictor variables) using Akaike's Information Criterion corrected for small sample size (AIC_c ; Burnham and Anderson 2002). We obtained AIC_c and parameter estimates using PROC MIXED. All analyses were conducted in SAS v 9.1 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

There were significant differences in macroinvertebrate scores among sites ($F_{6,108} = 27.0$, $P < 0.0001$) and among years ($F_{6,108} = 3.27$, $P = 0.0054$) (Figure 2). In general, scores ranged from 0 to 30 for the most impaired and least impaired sites, respectively. Carr (NOR) and Brooklyn (MOR) Creeks were the most impaired sites, whereas Bear (MOR) and McNutt (MOR) Creeks were the least impaired sites. Mean macroinvertebrate score for most sites was higher in 2005 than each of the other years.

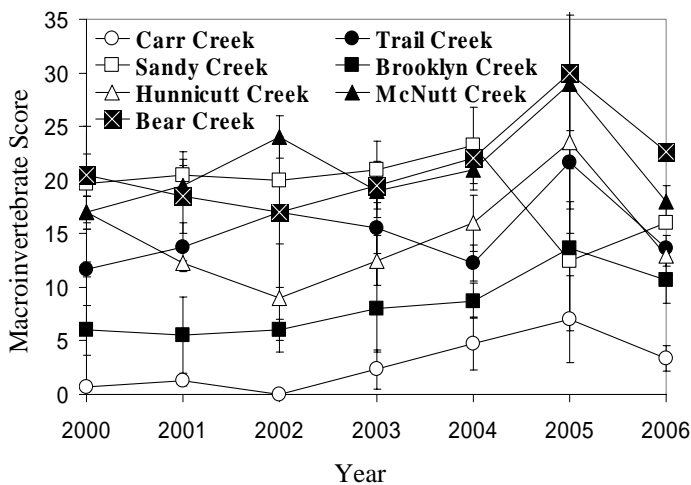


Figure 2. Mean macroinvertebrate biotic index scores (\pm 1SE) for seven sampling sites in the Upper Oconee River Watershed, Georgia, USA from 2000-2006. Scores indicate water quality (excellent > 22, good = 17-21, fair = 11-16, poor <11).

A model with the three water chemistry variables was much more parsimonious than a null model ($AIC_c > 40$; Burnham and Anderson 2002). Furthermore, specific conductance was negatively associated with macroinvertebrate score ($s_c = -0.21 \pm 0.043$ 95% CI) (Figure 3a). However, associations between macroinvertebrate score and DO (Figure 3b) and turbidity were unclear (Figure 3c).

DISCUSSION

Biotic index scores indicating higher water quality were associated with lower dissolved ion concentration (SC). This indicates that SC levels are associated with poor water quality and impaired stream health (i.e., low macroinvertebrate score), which is consistent with results from previous studies in the Georgia Piedmont (UOWN 2001, Roy et al. 2003). Streams in the Piedmont province of Georgia, which acquire most of their dissolved ions from groundwater, have naturally low concentrations of dissolved ions. Therefore, elevated levels of SC likely indicate pollution (Wenner et al. 2003). In the Upper Oconee River Watershed, two sites have a history of high SC due to contaminated groundwater from a former fertilizer plant (Carr Creek) and other non-point source pollution (Brooklyn Creek) (UOWN 2001, Wenner et al. 2003). Results from this study suggest that high SC impacts stream biotic integrity.

Decreases in natural land cover (i.e., forests and wetlands) negatively affect the structure and function of stream ecosystems. Watershed urbanization, in particular, reduces natural land cover, which results in sedimentation

and elevated transport of solutes (Roy et al. 2003). Lower percent natural land cover or higher percent urbanization has been shown to increase SC levels (Omoto et al. 2000, Roy et al. 2003) and decrease density of stream macroinvertebrates associated with good water quality (Roy et al. 2003). Natural land cover in the Upper Oconee River Watershed is variable and ranges from approximately 20-100% for the sites we sampled (Connors et al. 2001). Carr and Brooklyn Creeks are among the most developed sites we sampled, having the lowest percent natural land cover (Connors et al. 2001), and both had the lowest macroinvertebrate scores and highest SC of all sites, which corresponds to previous findings (Connors et al. 2001, Wenner et al. 2003).

CONCLUSIONS AND RECOMMENDATIONS

Long-term chemical and biological monitoring of streams is needed to assess watershed disturbance and water quality. Our monitoring data suggest that biotic integrity of specific streams in the Upper Oconee River Watershed is impaired due to urbanization. High specific conductance was associated with the most urbanized sites and best explained low biotic index scores. Development of watershed monitoring groups across the globe and educating the public and local governments about how they can contribute to monitoring water quality are crucial components to maintaining stream health.

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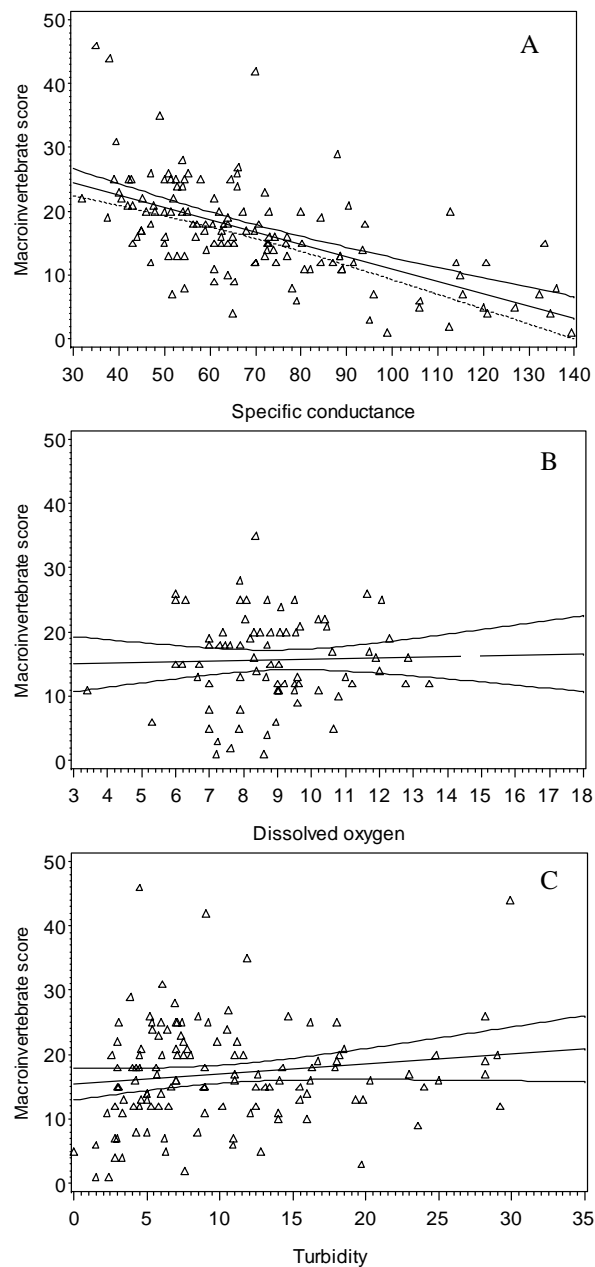


Figure 3. Macroinvertebrate score as a function of specific conductance (A), dissolved oxygen (B), and turbidity (C). Lines through points are mean slopes and 95% confidence limits from a model that included the three water chemistry variables. Variables were used in combination in the linear model, but are shown here separately for ease of comparison with macroinvertebrate scores. Carr Creek specific conductance data were removed from the linear model to maintain normality of residuals.