Stream Biotic Health and Land Cover in the Soque River Watershed

Duncan Hughes

AUTHOR: Watershed Coordinator, Soque River Watershed Partnership, North Georgia Technical College, P.O. Box 65, Clarkesville, Georgia 30523
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Abstract. The Soque River Watershed Partnership received CWA §319 funding to perform a comprehensive baseline assessment of the biological, chemical, and physical health of the watershed. Certain stream segments in the Soque basin violate State water quality standards for bacteria and sediments. The assessment is designed to identify and prioritize areas for both protection and remediation.

Rapid bioassessment protocols were used to collect macroinvertebrate samples at 19 stream sites in the watershed. Samples were collected during a late fall / winter index period over two years (2005-2006). Benthic data were analyzed to evaluate biotic integrity using a multimetric index designed for the Southern Inner Piedmont (Level IV Ecoregion 45a). Results indicate strong relationships between stream biotic health and land cover in the catchments evaluated. Urbanization and increased development were most strongly correlated with low biotic index scores and poor instream and riparian habitat in the study area.

Data from the assessment will be used by Partnership members to develop a watershed protection plan to aid localities and citizens in making decisions about the use of water resources in the watershed. The goal is to integrate the findings and recommendations from the assessment into decision-making processes that shape the future of the Soque River basin.

BACKGROUND

The Soque River is the northeastern-most tributary of the Chattahoochee River and has a number of beneficial uses both locally and regionally within the State. The river serves as the drinking water source for the City of Clarkesville and tributaries to the river provide water for other localities in Habersham County. Additionally, the river feeds Lake Lanier, the primary drinking water source for the City of Atlanta. The Soque is renowned for the recreational opportunities it provides; primarily fishing. The watershed covers approximately 160 square miles and rests wholly within Habersham County, thus presenting a unique opportunity for watershed protection and management while avoiding jurisdictional conflicts.

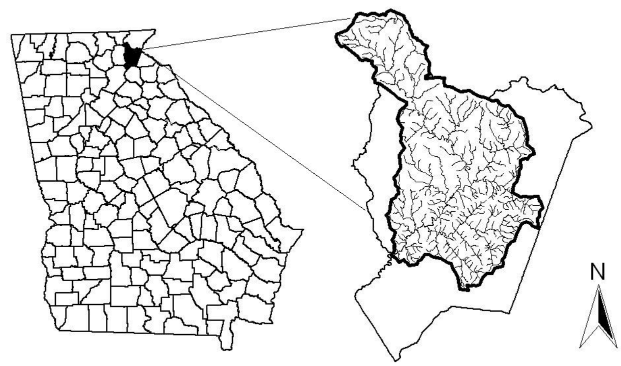

Figure 1. Location of Habersham County and the Soque River Watershed.

As in much of Georgia, rapid population growth in Habersham County is expected to increase the demand for water supplies while adding stressors to aquatic systems. Water quality degradation due to non-point source (NPS) pollution is positively correlated with increasing intensity of land use by humans (Bolstad and Swank 1997, Gage et al. 2004). Potential sources of anthropogenic stress to stream systems include urbanization (increased road and population density and increased impervious surfaces) and agricultural practices. These factors not only contribute to NPS pollution, but also alter the natural flow regimes of lotic systems leading to instream and riparian habitat alteration and loss (Walsh 2004).

The Georgia Department of Community Affairs documented a 30% increase in the population of Habersham County between 1990 and 2000 (GADCA 2006). Growth estimates by the State Office of Planning and Budget forecast an additional 37% increase in population in the County between 2000 and 2015 (GAOPB 2005). These figures together represent a near doubling of the population of the county in a 25 year span.

The Soque River Watershed Partnership was formed to take advantage of the opportunity for local protection of water resources and in response to water quality concerns and the anticipated impacts of rapid growth in the watershed. The Partnership is comprised of numerous local and state agencies and organizations and is guided by a Steering Committee of stakeholders and a Technical Advisory Committee of scientific and resource professionals. Members of the Partnership include the City of Clarkesville and all other localities in Habersham County, the Soque River Watershed Association, North Georgia Technical College and the Georgia Cooperative Extension Service, among others. The purpose of the Partnership is to provide stakeholders with data and information necessary to make informed decisions about the future use and protection of water resources in the watershed. Partnership formation was driven by a concern for the sustainability of local water supplies and the identification of impaired waters in the watershed.

Recent surveys by the Georgia Environmental Protection Division (GAEPD) and the United States Environmental Protection Agency (USEPA) identified stream segments in the watershed that do not meet State water quality standards. These stream segments have subsequently been placed on the State's 303(d) list of impaired waters. Specifically, a 29 mile segment of the Soque River is not supporting its designated use because of a violation of the fecal coliform bacteria standard from unspecified NPS pollution. Additionally, a four mile segment of Hazel Creek, a tributary to the Soque, is not fully supporting its designated use due to NPS sediment impacts on instream habitat and biota (GAEPD 2006).

In recognition of these water quality impairments from NPS pollution, the Partnership applied for and received CWA §319 funding from the USEPA which was administered through GAEPD. The funding was to complete a comprehensive watershed assessment to document current biological, chemical, and physical conditions in the watershed and to draft a science-based watershed protection plan for use by stakeholders. In addition to water quality monitoring for sediment and bacteria, a major component of the assessment was the characterization of the biological health of streams in the watershed using benthic macroinvertebrates.

Biological assessment

Biological assessment (bioassessment) provides a more holistic approach to monitoring water quality than traditional chemical monitoring (Bolstad and Swank 1997). Bioassessments typically consider direct chemical measurements but place more emphasis on the physical condition of stream and riparian habitat and the structure and function of the benthic community. The main purpose of biological assessment is to determine to what extent waters support aquatic life (Barbour 1997). Evaluating the health and condition of stream biota (resident monitors) reveals more about both aquatic habitat and water quality over time than periodic or "snapshot" chemical monitoring. Water chemistry fluctuates diurnally, seasonally, and with changes in discharge (Johnson et al. 1997). Recent federal recommendations for monitoring plans have emphasized the need to accelerate the development of biological sampling and assessment as a component of surface water management programs.

The focus on biological assessment led to the formulation of guidelines for conducting such assessments. The USEPA published the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* (RBP) (Barbour et al. 1999) to establish methodologies for biological assessment. The RBP provides for the integration of protocols for habitat assessment, physical characterization, cross-sectional profiles, substrate determination, chemical monitoring, and biological sampling. Data collected from RBP sampling may be used to make management decisions about the use and protection of water resources (*e.g.* identifying impaired streams, establishing TMDLs, evaluating Best Management Practices (BMPs), determining causes and sources of impairment, allocating flows, monitoring water quality trends over time, setting priorities for restoration activities, and preserving areas of optimal water quality) (Barbour et al. 1999). Although the RPB is applicable to fish, macroinvertebrates, and periphyton, all data presented here are based on benthic macroinvertebrates. Advantages of using benthic macroinvertebrates include their ubiquity in aquatic habitats, sedentary nature, and multi-year life cycles, which allows integration of both chemical and physical perturbations over time. Changes in stream conditions such as nutrient enrichment, toxic contamination and morphologic and habit changes caused by erosion and sedimentation, are reflected by changes in macroinvertebrate community structure and function (Gibson et al. 1996).

METHODS

Field sampling

RBP protocols were used to sample 19 catchments in the Soque River Watershed over a two year period (2005-2006). All samples were collected during a late fall / early winter index period to minimize the influence of seasonal variation on the results. Sample effort was allocated to characterize biological health of catchments of differing land cover and to maximize the amount of the watershed evaluated.

At each sample location, a representative 100-m stream reach was delineated and flagged at zero, 50 and 100 meters. Global positioning system coordinates were taken at the zero meter mark and recorded on applicable field sheets. Data and samples collected at each site included; *in situ* water chemistry parameters with a YSI

6920 multi-probe sonde (dissolved oxygen, temperature, pH, and conductivity), RBP physical characterization and habitat assessments, stream cross sectional profiles, substrate determinations (Wolman 1954) and benthic macroinvertebrates.

GAEPD and RBP benthic macroinvertebrate protocols required 20 jabs (D-frame net; 500µm mesh) from the variety of habitats present (sample units) in each 100-m stream reach sampled (GAEPD 1999). Composite macroinvertebrate samples, including detritus, were labeled and preserved in the field with ethanol. Samples were then transported to the laboratory for processing.

Laboratory processing

The first step in processing a sample was to prepare the sample for sub-sampling. A fixed count random sub-sample is the preferred technique of the RBPs (Barbour et al. 1999). Sub-sampling for this project is in accordance with RBP recommendations and follows the protocol set out by Caton (1991).

Samples were rinsed in tap water to temporarily remove alcohol residue. The entire sample was then spread evenly on a gridded tray (30 x 36 cm or thirty 6 x 6 cm grid squares) and covered in water to preclude desiccation of the organisms and detritus. Random number sheets were generated to indicate the 6 x 6 cm grid squares that were selected from the sample and sorted.

Each grid square picked was removed and placed in a white picking tray under bright light and sorted with forceps to separate all aquatic organisms from detritus and inorganic material. The target number of organisms for this method was 200, with 160 to 240 considered within the acceptable range. All benthic macroinvertebrates were preserved in vials of 95% ethanol, labeled, and held for taxonomic identification.

Macroinvertebrate identification was to lowest practicable taxonomic level, usually genus. An exception is the classification of the Dipteran, Chironomidae. The primary taxonomic resources were Merritt and Cummins (1996) and Brigham et al. (1982). Final identifications were recorded on macroinvertebrate bench sheets and used to calculate biological metrics for use in a multi-metric index of stream health.

Metric and biotic index calculations

The benthic macroinvertebrate index (BMI) used in this assessment is proposed by GAEPD for the Southern Inner Piedmont and is comprised of five metrics; # EPT Taxa, % Chironomidae, NCBI (North Carolina Biotic Index), % Scraper, and % Clinger.

Raw metric scores from each stream sample were complied and standardized on a 0-100 point scale using data from minimally impaired streams in the Southern Inner Piedmont in Georgia (Gore et al. 2005). The final BMI score was then calculated by adding the standardized scores for each metric and dividing by the number of metrics used in the index, resulting in a numeric score on a scale of 0-100. Narrative classifications of “very good” through “poor” were also assigned for each catchment sampled based on percentile values of minimally impaired and impaired stream sites previously sampled in the Southern Inner Piedmont (Gore et al. 2005). This narrative classification scheme was based on percentile values of “very good” = > 95th, “good” = 75th-95th, “fair” = 25th-75th, “poor” 5th-25th, and “very poor” = < 5th.

Data analysis

Geographic information systems (GIS) analysis of land cover data for comparison with field measurements and observations was accomplished using Arcview 9.1 (ESRI 2005). Data necessary for use in Arcview included GPS coordinates collected in the field at each stream site, a stream layer and digital elevation model (DEM) for Habersham County obtained from the Georgia GIS Clearinghouse, and a digital raster of Georgia land cover, specifically Habersham County (NARSAL 2001). GPS coordinates, the stream layer, and the DEM were used with the Arc Hydro extension (ESRI 2002) to delineate catchments sampled. The catchments were overlain on the land cover data and used to calculate percentages of differing land cover types (primarily forest cover, urbanization, and agriculture) to compare with BMI scores and data collected in the field.

Comparisons between land cover percentages, BMI scores, habitat assessment scores, Wolman pebble count data, and *in situ* physiochemical values from each catchment sampled were made using Pearson-product moment correlations (Statsoft 2004). Pearson’s r-values indicate the strength of the relationship between two variables and range from 1 to -1 (with 1 indicating a perfect positive relationship and -1 indicating a perfect negative relationship).

RESULTS

Numeric and narrative macroinvertebrate index scores and land cover percentages for catchments evaluated (n = 19) in this assessment are presented in Table 1. The average catchment area in this study was 19.7 mi^2, with 14 less than 10.0 mi^2. The only catchments that were larger than 10.0 mi^2 were three sites on the main stem of the Soque River and two sites on Hazel Creek.

Of the six sites that scored “very good” or “good” on the index, five are in the northern, more forested portion of the Soque River watershed. The mean % urban of the top six sites was 1.8%. Seven of the ten lowest scoring

Table 1. Index scores and land cover data for selected catchments

Stream Name	Site Number	Index Score	Ecological Condition	Area (mi^2)	% Urban	% Agriculture	% Forest
Soque River	SRFW-1	78	very good	58.7	0.5	9.4	83.0
Oaky Creek	OC-1	74	good	2.2	0.6	3.6	94.2
Left Fork Soque	LFSR-1	69	good	5.1	0.0	0.4	99.1
Hazel Creek	HC-2	68	good	28.2	6.4	26.5	44.9
Shoal Creek	SC-1	68	good	9.7	0.8	5.9	82.9
Soque River	SRST-1	68	good	156.0	2.4	18.3	64.4
Sutton Mill Creek	SMC-1	63	fair	4.0	0.8	33.4	47.7
Soque River	SRSW-1	62	fair	39.4	0.2	5.9	89.5
Raper Creek	RC-1	60	fair	5.1	0.3	4.9	89.7
Deep Creek	DC-1	59	fair	4.5	4.7	4.5	71.1
Deep Creek	DC-2	58	fair	3.4	2.6	23.9	57.7
Beaverdam Creek	BDC-1	58	fair	8.7	0.2	18.4	67.2
Law Creek	LC-1	57	fair	1.3	1.0	31.0	49.4
Glade Creek	GC-1	52	fair	5.1	2.1	43.1	40.4
Bruner Creek	BRC-1	52	fair	2.7	0.4	26.5	50.9
Breazeale Creek	BC-1	50	poor	1.1	0.2	28.2	50.3
Lick Log Creek	LLC-1	42	poor	3.2	7.3	26.3	48.0
Camp Creek	CC-1	41	poor	4.7	19.8	13.3	38.2
Hazel Creek	HC-1	32	poor	31.9	6.4	24.5	46.7

sites were in the Hazel Creek (mean % urban among 4 sites = 8.6%) and Deep Creek watersheds (mean % urban among 3 sites = 6.0%).

Pearson correlations for selected variables are shown in Table 2. Correlations indicate moderate to strong relationships between BMI scores and some land cover and instream and riparian habitat variables.

Habitat scores among all catchments ranged from 100-191 (on a 200 point scale), but were only moderately positively correlated with BMI scores ($r = 0.55$). *In situ* chemical parameters were weakly correlated with BMI scores or land cover. Values for pH ranged from 6.1-7.3, dissolved oxygen from 10.1 -12.2 mg/l, and conductivity from 0.011-0.089 mS/ cm^2.

Instream substrate is related to BMI and habitat scores and land cover. Cobble substrate was positively correlated with BMI score ($r = 0.56$) and habitat assessment score ($r = 0.72$). Finer substrates (silt and clay) were positively correlated with increasing urban land cover ($r = 0.75$) and negatively correlated with habitat score ($r = -0.55$) and BMI score ($r = -0.44$).

Two additional metrics, not used in the BMI, are of import; # of total taxa and # of intolerant taxa. Total taxa numbers among all catchments ranged from 17-33 and were only weakly correlated with BMI scores ($r = .48$, $p < .05$). BMI scores were more strongly correlated with the more specific metric # of intolerant taxa.

Table 2. Correlations for selected variables ($p < .05$)

Variable 1	Variable 2	Pearson's r
BMI	% Cobble	0.56
BMI	% Forest	0.67
BMI	% Urban	-0.54
BMI	Intolerant taxa	0.73
Habitat Score	% Silt / Clay	-0.55
Habitat Score	% Cobble	0.72
Habitat Score	% Forest	0.71
% Silt / Clay	% Urban	0.75

DISCUSSION

Increasing human land use, especially increases in urban land cover, has documented effects on both water quality and benthic macroinvertebrate communities (Gage et al. 2004). In this study, *in situ* water quality parameters were not strongly correlated with BMI scores, habitat parameters, or land cover. These data did not reveal obvious water quality problems. However, this very limited set of water quality data, taken only at baseflow during RBP sampling, should not be used as a basis for evaluating overall stream health of the catchments included in this study.

Urban land cover increased (and % forest decreased) in the Hazel Creek and Deep Creek catchments relative to the remainder of the watershed. This increase in urban land cover was negatively correlated with BMI scores and habitat assessment scores in those catchments. The lowest scoring catchments on the BMI had the top three highest percentages of urbanization. Catchments scoring "very good" or "good" on the BMI had an average % forest of 78% (the remaining "fair" and "poor" catchments had an average % forest of 57%). Instream substrate values were also strongly correlated with specific land cover types.

The six sites that scored "very good" or "good" on the BMI had an average of 47% cobble and boulder substrates while the remaining 13 "fair" and "poor" sites had an average of 18% cobble and boulder. The two lowest scoring BMI sites, CC-1 and HC-1 had no cobble or boulder substrate and contained the most silt and clay (mean = 13%). The "very good" and "good" sites contained a diversity of substrate material and the "poor" sites were dominated by finer sediments. The percentage of silt and clay substrates was strongly correlated with increasing urban land cover ($r = 0.75$, $p < .05$).

One exception to the land cover and BMI relationship occurred at site HC-2. Catchment-wide land cover and physiochemical parameters were nearly identical between that site and HC-1 (both sites were on Hazel Creek; HC-2 drained slightly less area). The striking difference in variables measured at the two sites lies in % cobble and boulder and the habitat assessment score. HC-2, which scored "good" on the BMI, had 64% cobble and boulder as instream substrate and scored 152 on the habitat assessment score (a measure of the quality of both instream and riparian habitat). HC-1, which scored "poor" on the BMI, had 0% cobble and boulder instream and scored 117 on the visual based habitat assessment. Although the land cover and BMI relationship did not hold up in this case, the quality of instream habitat is a likely driver for the disparity between the BMI scores at the two sites. This finding documents that both catchment-wide land cover and local conditions (instream and riparian habitat) affect the composition, structure and function of the benthic community.

Two additional metrics not used in the BMI warrant discussion; # of total taxa and # intolerant taxa. The "universal metric", total taxa, was only weakly positively correlated with BMI scores. There are certainly instances where this metric would be useful. However, the performance of this metric in this study may indicate that land cover variables do not always affect total numbers of taxa, but rather alter the structure and function of the benthic community (as judged by other metric categories and more specific richness measures, *e.g.* EPT taxa).

The # intolerant taxa metric was calculated based on assigned tolerance values for specific macroinvertebrate identifications. Tolerance values were obtained from the RBP and Lenat (1993) and were based on a scale of 0-10 (with 0 being intolerant to pollution). The fact that fewer intolerant taxa occurred in the Hazel and Deep Creek watersheds (where urbanization has increased the most), supports the idea that, to a point, the macroinvertebrate community shifts to more pollution tolerant species (not necessarily fewer total taxa) as urban land cover increases and instream and riparian habitat are altered. The percentage of intolerant individuals in the catchments evaluated was strongly correlated with BMI scores ($r = 0.73$, $p < .05$).

CONCLUSIONS

Localities and citizens in Habersham County have an opportunity for long-term trend monitoring and protection of water resources in the Soque River watershed. The baseline data provided by this assessment will be used to prioritize protection and restoration activities and monitor changes in habitat and biota over time. It is evident that an increasingly urban environment as well as alterations of instream and riparian habitat will strain biological communities and affect water quality in some way. Careful planning and cooperative efforts among all stakeholders are necessary to achieve anti-degradation goals and protect water supplies and aquatic habitat quality for future generations.

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