COMPARING WATER QUALITY ALONG A GRADIENT OF URBANIZATION

Lee Carrubba

AUTHOR: PhD Candidate, Institute of Ecology, The University of Georgia, Athens, Georgia 30602-2202
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Abstract. Urbanization has a major impact on water quality in the form of point and non-point source pollution from construction and industrial sites, roadways, lawns, and other human-made landscapes. Georgia is currently experiencing urbanization based upon population growth. The Piedmont Province is in transition from a predominantly rural area to an urban/industrial complex. Atlanta, Athens and other urban centers have a major influence on urban development in many areas of the rural piedmont.

A gradient of development in Madison County, Georgia was chosen to demonstrate differences in water quality from a completely developed area to an extremely rural area. The outflow points of six watersheds have been chosen for the water quality comparison. Preliminary results indicate that water quality, in the form of chemical content, declines in relation to the degree of urbanization.

INTRODUCTION

Population growth is accompanied by increased demand for goods and services. In order to meet the needs of a rapidly growing population, land is converted to urban uses. In Georgia, most of the land conversion has been and continues to be in the Ridge and Valley and Piedmont Provinces.

Many studies are being undertaken to determine the impacts of urbanization on rural areas (see, for instance, Meade et al. 1990; and Dierberg 1991). The consequences of suburban sprawl include traffic congestion, as rural areas often lack an extensive transportation network, and the conversion of agricultural land. Agricultural land is often the most attractive land for development since it is cleared and often in a desirable geographic location. Urbanization also has a major impact on water quality in the form of point and non-point source pollution (Tsihrintzis et al. 1996). Water quality is a concern throughout Georgia due to increased urbanization (Groszmann 1996).

The spread of urbanization provides an opportunity for before and after studies of water quality. Studies along gradients of urbanization provide an opportunity to address the problems related to anthropogenic impacts on ecological systems, but also to determine the ecologically important changes in ecosystem structure and function along the gradients which occur due to human activity (McDonnell and Pickett 1991). The gradient considered in this study ranged from completely developed Tanyard Branch watershed in Athens to rural Vineyard Creek watershed in Madison County.

The comparative study discussed in this paper was undertaken to determine whether, as the percentage of developed land within a watershed increases, the water quality, measured as total suspended solids, turbidity and chemical content, decreases.

METHODS

Six watersheds were selected along a gradient from the urban area of Athens northeast away from Atlanta into rural Madison County (Figure 1). The other watersheds encompass Holly Creek, Brush Creek, Biger Creek, and the South Fork of the Broad River, all within Madison County.

The watersheds were selected to provide a comparative index of water quality based upon percent development. The development considered in this study is mainly in the form of residential, subdivision development, though Tanyard Branch flows through both a residential area and The University of Georgia. Vineyard Creek, a second order stream, is the least developed watershed with 12% residential development. Holly Creek, a third order stream, is next with approximately 20% residential development. The South Fork watershed, a fourth order stream, is approximately 60% residential development and encompasses a larger area than the other watersheds. Brush Creek, a third order stream, is approximately 40% residential development. Biger Creek, a third order stream, flows through Hull, Georgia and is approximately 80% residential development.

Samples were collected in clean polyethylene bottles which were rinsed in the creek prior to sample collection. These grab samples were labeled

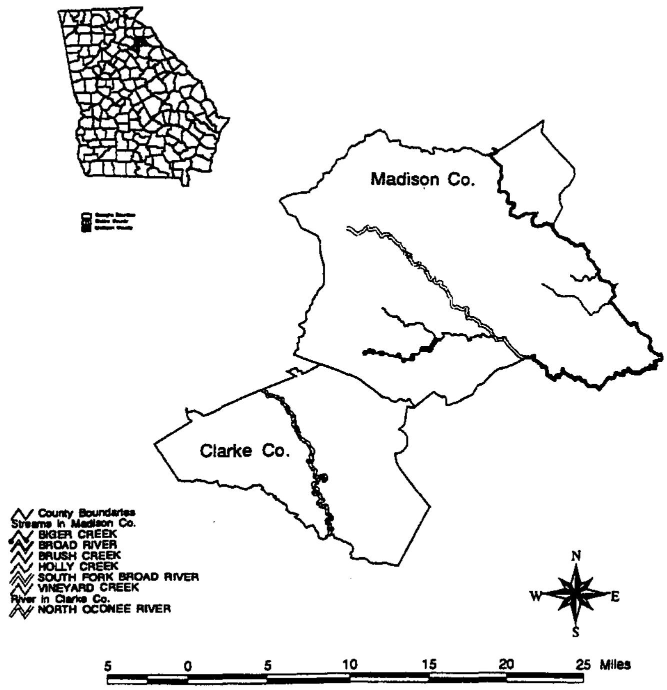

Figure 1. Streams of interest in Clarke and Madison Counties. Note that Tanyard Branch is a tributary of the North Oconee River. An inset is included to show the location of Clarke and Madison Counties in Georgia.

with the time, date and site and placed in a cooler. Two samples were collected from each site. The samples were stored at 4°C until they could be analyzed. The pH and alkalinity measures were taken at each site, but the other chemical tests were conducted once the samples had been transported to the lab. The pH, alkalinity, nitrate, nitrite, chlorine, and detergent levels were all measured using chemical test kits manufactured by Ward or LaMotte. A turbidity meter was used to determine the turbidity of each sample. Total suspended solids within each sample were measured using vacuum filtration. The filters were air-dried for 24 hours and then reweighed.

The sampling techniques used in this study yielded coarse-resolution data which can be used as a screening method to identify the watersheds with the poorest water quality (Hunsaker and Levine 1995). This is a preliminary study to answer the question of whether there is a difference in water quality related to the degree of development.

RESULTS AND DISCUSSION

No traces of free or total chlorine were found in any of the streams. The total alkalinity of all the streams was in the form of bicarbonate alkalinity as $CaCO_3$. Detergents were detected only in Tanyard Branch, but always at a level equal to or less than 0.25ppm, which is considered "safe." Nitrate was present in low concentrations (1.1 ppm NO_3 or less) in all but Tanyard Branch which consistently contained concentrations above 10 mg N/L, the level at which water is no longer considered potable (Figure 2). Nitrite was found only in Tanyard Branch and only intermittently. The concentration of nitrite within Tanyard Branch was always less than 0.1ppm NO2-N. This low level indicates that the most likely source is either natural oxidation and reduction reactions or wastewater. Due to the high levels of nitrate in Tanyard Branch, finding trace amounts of nitrite is not surprising.

The turbidity levels were always highest in the streams which are not part of a municipal water supply (Figure 3). Because Tanyard Branch is part of a municipal system, the water in the creek is filtered and treated which accounts for both the low turbidity and the high nitrate content of the water. Turbidity levels in all the creeks were consistently lower than 100 NTU (nephelometric turbidity units). Water containing levels from 10-250 NTU is considered a good source of drinking water requiring filtration and disinfection. Water containing levels from 0-10 NTU is considered an excellent source of drinking water requiring only disinfection (Wilber 1983). The levels of total suspended solids (TSS) also were low (Figure 4). The levels were similar in all the streams and well below the "safe" level of 500 mg/L.

Testing for the presence or absence of fecal coliform has begun. The presence of fecal coliform bacteria is often related to urban development, especially poor storm water management. Initial results indicate that Tanyard Branch is the only stream which contains the bacteria.

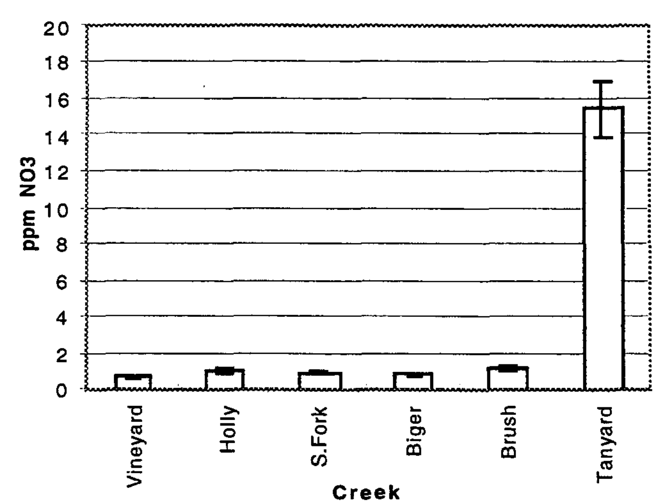

Figure 2. Average nitrate levels found in each stream. Note the significant difference between Tanyard Branch and the streams in Madison County.

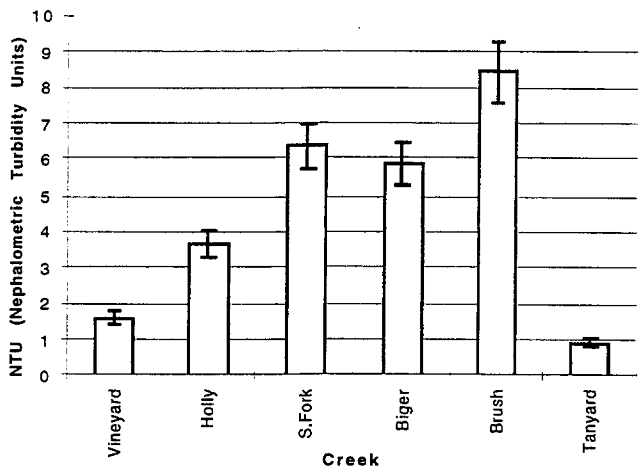

Figure 3. Average turbidity of each stream. Vineyard and Holly Creek are located in the most rural areas. Tanyard Branch contains wastewater, which is commonly low in turbidity. Overall, the averages indicate very low turbidities. On a sampling event basis, the highest turbidities have been in Biger Creek with peaks around 14 NTU, which is still extremely low.

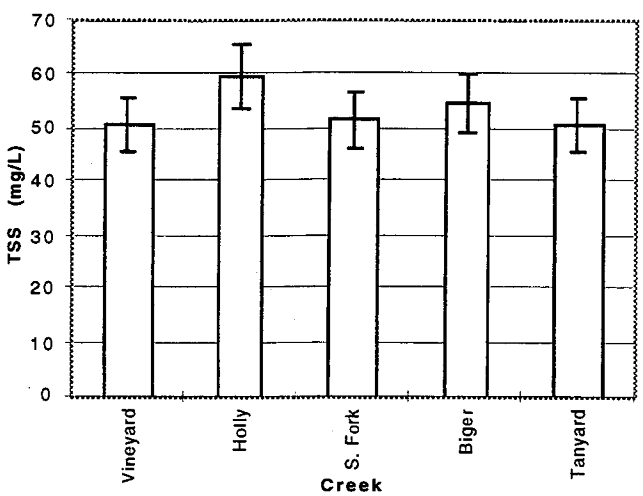

Figure 4. Average total suspended solids (TSS) for each creek. The levels have been consistent between streams each time TSS measures have been taken. Brush Creek was not included in the graph as the TSS measurement for the creek has been taken only once, unlike the other creeks.

This study is in its early stages. The results to date indicate that the streams in Madison County are relatively consistent in terms of water quality. And, the rural streams differ from the urbanized stream in nitrate and turbidity.

CONCLUSIONS

The most widespread threats to lotic ecosystems are hydrologic changes to streams and rivers resulting from changes in land use, habitat alteration and non-point source pollution (Hunsaker and Levine 1995). In spite of progress that has been made controlling point sources, there have been no net reductions in nutrient levels of many rivers due to increased urbanization (Burton and King 1983).

This study is in its early stages. The results to date indicate that the streams in Madison County are relatively consistent in terms of low chemical content. However, the South Fork, Biger and Brush Creek watersheds had higher turbidity levels than the other streams. In the case of the South Fork watershed, this difference may be due to the larger size of the watershed. Brush and Biger Creek both had high turbidity levels due to the fact that both watersheds are undergoing rapid development in the form of large subdivisions. These subdivisions are, for the most part, being built on land adjacent to the creek. Erosion control measures in these areas are either lacking or inadequate. The input of soil into Biger and Brush Creeks in these subdivision developments is not reflected in the TSS measurements due in large part to the high sand content of the soils.

The water quality sampling that has been done to date on the six watersheds has taken place during periods of vegetation growth and biotic activity. This may mask high nutrient inputs due to human activity. Thus, this water quality study will be spread over other months to determine seasonal fluxes in water quality. The maintenance of a relatively constant water chemistry is dependent upon the stability of the ecosystem (Likens et al 1977). Once human disturbance increases, the stability of the streams will decrease. This will be reflected in the watersheds within Madison County as the subdivision development continues. The level of nitrate has been found to be a good tracer of urban effects (Botshon 1996). In this study, the most urban watershed, Tanyard Branch, was found to have high levels of nitrates and the least developed watershed, Vineyard Creek, had the lowest, sometimes containing no detectable level of nitrate. Community wells already exist in many of the developing areas in Madison County. One of these is Hull, Georgia where Biger Creek is located. If population growth continues, this could be converted to a municipal water supply and the chemical content of Biger Creek would increase.

In the future, these data will be coupled with a Geographic Information System (GIS) database which is being developed in conjunction with a land use change model. The results of the water quality comparison, coupled with the predictive model, will lead to the development of management strategies to avoid declines in water quality as development continues in Madison County.

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