PRELIMINARY ANALYSIS OF BIOTIC INDICES AND LAND COVER WITHIN STREAMS OF THE GEORGIA PIEDMONT

Gwendolyn D. Carroll and C. Rhett Jackson

AUTHORS: Warnell School of Forest Resources, University of Georgia, Athens, GA 30602.
REFERENCE: Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. This work evaluates relationships between fish IBI's, land cover metrics, and watershed size. This analysis will provide a baseline from which to analyze how sediment loads and local geomorphology affect IBI scores. The Georgia WRD Stream Survey Team has used indices of biotic integrity (IBI) based on fish communities to assess stream health across the Piedmont of Georgia. They have surveyed fish communities in approximately 175 streams reaches across the Piedmont. The associated watersheds feature a wide mix of land cover characteristics.

INTRODUCTION

Since the establishment of the US Clean Water Act in 1972, biological assessments using fish and macroinvertebrates have been employed to detect stream perturbations (Plafkin 1989, Angermeier and Karr 1994, Naiman et al. 1995, Simon 1999). Because biological community health integrates water quality conditions over time, and because water quality is highly temporally variable, indices of biotic integrity (IBIs) are very attractive water quality indicators. Despite the widespread use of such techniques, many questions remain unanswered concerning relationships between biological factors and physical habitat. Interpretation of biological assessments is clouded by geomorphological differences between streams and between sites within streams (Karr 1981).

In Georgia, relationships between IBI scores, suspended sediment concentrations, and sediment particle size distributions have been controversial issues in developing sediment total maximum daily loads (TMDLs) (Georgia Conservancy Tag, 2002). Georgia Environmental Protection Division (EPD) and the United States Environmental Protection Agency have been using fish and macroinvertebrate IBI scores to identify impacted streams for TMDL purposes. Typically sediment is assumed to be the cause of impairment in rural areas. However, the relationships between sediment loads and IBI scores in the Georgia Piedmont are not known, neither are the confounding factors understood. In many cases long-term flow, water quality, baseflow suspended sediment concentrations (SSC), and turbidity measurements are not available to characterize sediment loads or mean concentrations. Previous studies have shown biological community degradation in response to changes in stream flow, water chemistry, SSC, and turbidity but the interrelationships between these factors and IBI scores is unclear. These problems make it imperative that we gain a better understanding of (1) relationships between aquatic communities, physical habitat, and hydrology, (2) relationships between fish and macroinvertebrate communities, and (3) temporal dynamics of habitats and biological communities. Such information could improve biotic assessment techniques, making them more reliable and useful to environmental resource managers.

BACKGROUND

It is well documented that physical habitat features influence the presence or absence of aquatic organisms. Characteristics such as streamflow velocity, bed roughness, and channel width and depth, and riparian vegetation determine available habitat for organisms. Fluctuations in flow and sediment inputs, particularly those associated with human activities, are potentially harmful to aquatic organisms and increase with increased urbanization (Walsh et al. 2001, Freeman 2001). Several studies have shown that increased urbanization leads to decreased overall abundance and diversity of invertebrates (Paul and Meyer 2001). Researchers have correlated this response with impervious surface cover, housing density, human population density and total effluent discharge (Paul and Meyer 2001). Similarly, Lenat and Crawford (1994) compared macroinvertebrate metrics within three catchments (urban, agricultural, and forested) in North Carolina. Although seasonal variation was evident, invertebrate species at the agricultural site indicated fair water quality, while the severely stressed urban site showed poor water quality. The authors also reported the highest suspended sediment yield for the urban catchment and lowest for the forested catchment.

Differentiating which factor is responsible for changes in biotic community structure is difficult because they often occur simultaneously. In the Etowah River Basin in Georgia, researchers found that geomorphoric and physical habitat measures from the stream-reach scale were more significant predictors of fish and benthic invertebrate indices than basin-wide measures (Leigh et al. 2001). In four Missouri streams, Zweig and Rabeni (2001) attempted to tease out effects of perturbations by correlating sediment deposition to biomonitoring metrics. The authors found that five metrics (taxa richness, density, Ephemeroptera, Plecoptera and Trichoptera [EPT] richness, EPT density, and EPT/Chironomidae richness) were significantly correlated to deposited sediment. Relationships between invertebrate metrics and other variables, (i.e. stream flow and depth) showed no clear patterns among streams (Zweig and Rabeni 2001).

Using regression and ordination analysis this study will address the following questions:

1) What are the relationships between macroinvertebrate community health and fish community health?
2) Are relationships between fish, macroinvertebrates, gradient, streambed sediment, and baseflow turbidity evident?
3) How do fish and macroinvertebrates relate to land cover metrics?

METHODS

Forty-five streams within the Piedmont Ecoregion of Georgia are being evaluated for this study. The sites were chosen from among those for which Georgia Water Resources Division (WRD) Stream Survey Team has calculated fish IBI scores. An equal number of streams were selected from each IBI category (excellent, good, fair, poor, and very poor), catchment size, drainage basin and landuse type.

Each site will be surveyed to determine geomorphic characteristics, physicochemical parameters, and macroinvertebrate abundance and diversity. Physical habitat measurements include gradient, pebble counts, turbidity measurements, and total suspended solids (TSS) (Waters and Rivers Commission 2001, Wolman 1954, Geological Survey 1977). The gradient measurement is a water surface

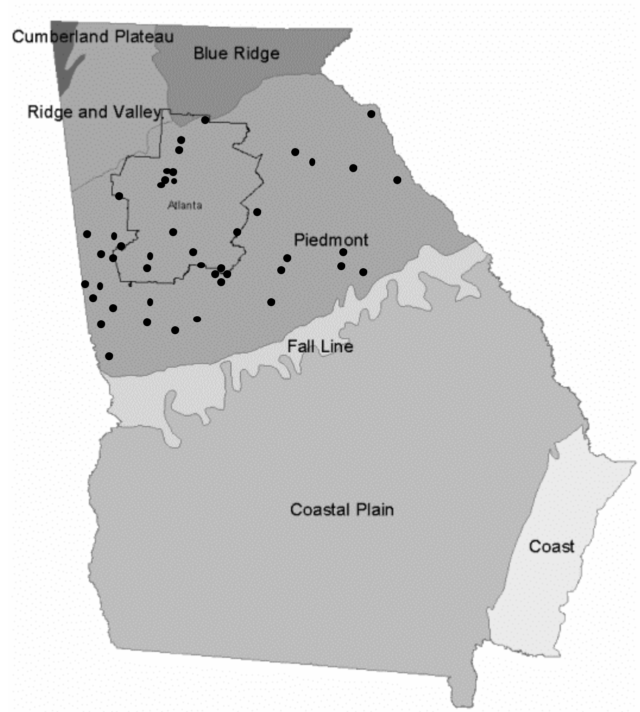

Figure 1. Ecoregion map of Georgia used for classification and accuracy assessment work. Based upon Keyes et al. (From Georgia GAP website)

gradient that will be measured with a surveying level and rod during baseflow conditions. Turbidity, TSS, and electrical conductivity will be collected at each site once every three weeks. Physicochemical parameters (dissolved oxygen, pH, and stream water temperature) will be measured on site using a portable water analyzer (Quanta by Hydrolab Corporation, Austin Texas).

Benthic macroinvertebrates will be sampled for a minimum of two years between September and February of each year using protocol established by Jim Gore for Georgia Department of Natural Resources. Additional samples will be collected for a subset of streams to determine natural seasonal variation. Data from these samples will be used to calculate IBI metrics for each stream.

Land cover for each basin will be measured from Georgia GAP data. Percentages of land cover categories in each basin were measured using Arcview (as determined by Thom Litts of WRD). This data will be used to determine which variable(s) are most likely degrading aquatic communities.

RESULTS AND DISCUSSION

This paper only addresses landcover analysis. This is an ongoing study and the other questions will be addressed at a later date.

Comparison of fish IBI scores and drainage basin area show heteroskedasticity with respect to basin area. There is wide variation in IBI scores for basins less than 100 sq mi, while IBI scores are uniformly high for basins larger than 100 sq mi. Although only a small amount of variation is explained by drainage basin area, it is a significant factor (R-square = 0.1144, p-value 3.04E-08) (Figure 2). This may be explained by the increased number of fish species that are generally found in higher order streams (Karr et al.1986). Due to the difference in scores between large drainage basins and small drainage basins, only sites less than 100 sq. mi. were considered for this study. Drainage basin areas of the 45 study sites range between 2 and 66 sq mi.

The two largest landuse categories of interest were forested and urbanized (Categories were described by Liz Kramer for GAP analysis). For preliminary comparison, the forested category was a combination of deciduous, evergreen, and mixed forest. Deciduous and evergreen forest categories are forests in which 75% of the canopy consists of deciduous or evergreen trees, respectively. High urban and low urban were combined for the urbanized category. High intensity urban areas are comprised of central business districts, multi-family dwellings, commercial facilities, industrial facilities, and high impervious surface areas of institutional facilities. The low urban class includes single family residential areas, urban recreational areas, cemeteries, playing fields, campus-like institutions, parks, and schools.

Comparison of IBI scores and percent forested land or percent urban land show a general trend of higher IBI scores associated with higher percentages of forest cover (Figure 3) and lower IBI scores correlated with increased urbanization (Figure 4). This pattern is more clearly visible in Figure 5, which compares percent urban land with percent forested land by IBI category. These data suggest the threshold of impairment occurs between 5 – 10% urbanization. Along the north shore of Lake Superior, Richard and Host (1994) correlated streambed sediment composition with macroinvertebrate richness. More importantly, they found a strong relationship between streambed sediment composition and land use, with finer sediments associated with urban development and greater embeddedness linked to increased agriculture. Similarly, Stepnuck, Crunkilton, and Wang (2002) attributed sharp declines in stream quality to impervious surface greater than 8-12 percent of the watershed area of 43 streams in Southeast Wisconsin.

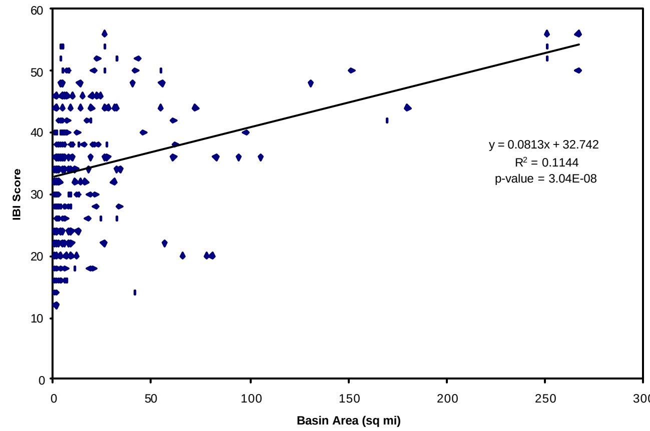

Figure 2. Regression curve indicating relationship between IBI scores and drainage basin area (sq mi) for sites within the Piedmont Ecoregion of Georgia. Dashed line indicates threshold basin size.

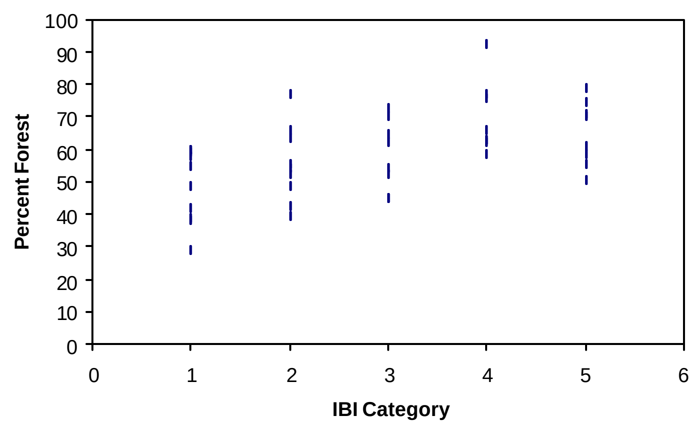

Figure 3. Comparison of IBI Category and Percent Forested Land for 46 study sites within the Piedmont Ecoregion of Georgia.

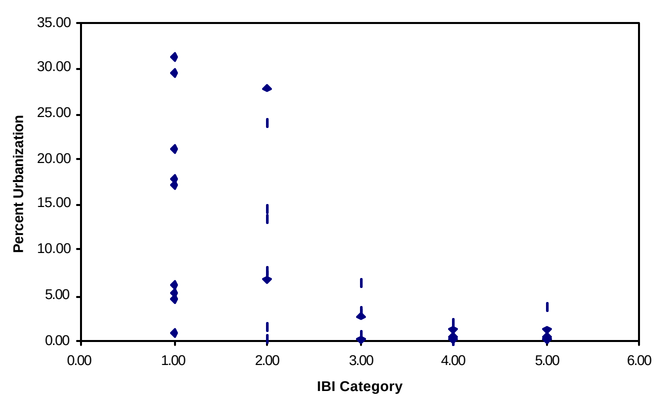

Figure 4. Comparison of IBI scores and Percent Urbanized Land for 46 study sites within the Piedmont Ecoregion of Georgia.

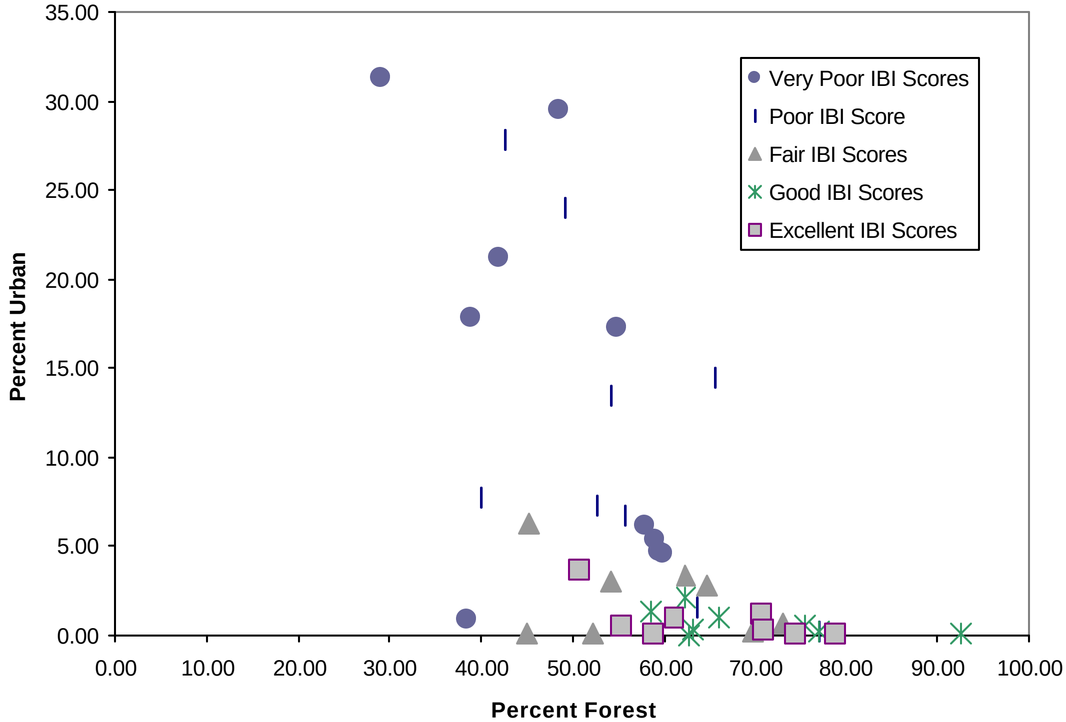

Figure 5. Comparison of percent forested land and percent urban land by IBI category for 46 study sites within the Piedmont Ecoregion of Georgia.

CONCLUSIONS

While this data suggests that land use is not the only influence in determining IBI scores it is a dominant driver for streams within the Georgia Piedmont. In this data set, the types of landuse that cause degradation may not constitute a major portion of the watershed, thus IBI scores may not reflect perturbations in larger rivers. The next step to further this research would be for WRD to sample streams with a large drainage basin area (e.g. > 100sq. mi.), in which the watershed is predominantly urbanized, such as Peachtree Creek and South River.

ACKNOWLEDGEMENTS

We are grateful to Patti Lanford and Thom Litts of the WRD Stream Survey Team for the use of their fish IBI data and compilation of landuse data.

LITERATURE CITED

Angermeir, P.L., and J.R. Karr. 1994. Biological integrity versus biological diversity as policy directives. Bioscience. 44(10):690-697.

Freeman, M., Z Bowen, K. Bovee, and E. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered regimes. Ecological Applications 11(1):179-190.

Geological Survey. 1977. National handbook of recommended method for water-data acquisition. U.S. Department of Interior, Reston, Virginia.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries (Bethesda) 17:11-19.

Leigh, D.S., B.J. Freeman, M.C. Freeman, E.A. Kramer, C.M. Pringle, A.D. Rosemond, M.J. Paul, D.M. Walters, A.Roy, C.P. Lo. Overview of land cover and geomorphic indicators of biotic integrity in the Etowah River Basin, Georgia. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, the University of Georgia.

Lenat and Crawford. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia. 294:185-199.

Naiman, R.J., J.J. Magnuson, D.M. McKnight, J.A.

Stanford, and J.R. Karr. 1995. Freshwater ecosystems and their management: a national initiative. Science 270:584-585.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. U.S. EPA, Office of Water, EPA/444/4-89-001. Washington D.C.

Paul, M.J., and J.L. Meyer. 2001. Streams in an Urban Landscape. Ann. Rev. Ecol. Syst. 32:333-365.

Simon, T.P. ed. 1999. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press. Boca Raton, Florida. Pp. 3-23.

Technical Advisory Group for Georgia Conservancy. 2002. A protocol for establishing sediment TMDLs TAG White Paper.

Walsh, C.J., A.K. Sharpe, P.F. Breen, and J.A. Sonneman. 2001. Effects of urbanization on streams of the Melbourne region, Victoria, Austrailia. I. Benthic macroinvertebrates. Freshwater Biology 46:535-551.

Waters and Rivers Commission. 2001. Stream Channel Analysis. The government of Western Australia. Report No. RR 9.

Wolman, M. 1954. A method of sampling coarse river-bed material. Transactions American Geophysical Union 35: 951 – 956.

Zweig, L.D., and C.F. Rabeni. 2001. Biomonitoring for deposited sediment using benthic invertebrates: a test on 4 Missouri streams. Journal of the North American Benthological Society. 201(4): 643 -657.