**EXTENDED ABSTRACT**

# THE INFLUENCE OF LAND USE ON AQUATIC MACROINVERTEBRATES IN STREAMS AND RIVERS OF SOUTH CAROLINA

James B. Glover[1], Jeannie P. Eidson[1], David A. Eargle[1], Richard T. Renfrow[1], William S. Castleberry[1], and Marisa E. Domino[2]

AUTHORS: [1]The South Carolina of Health and Environmental Control, Bureau of Water. [2] The University of North Carolina Chapel Hill, School of Public Health.
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The South Carolina Department of Health and Environmental Control (SCDHEC) began conducting bioassessments in 1974. At that time point source pollution was a major problem for water resources. However, over the decades more attention has been placed on discovering the effects of non-point source pollution on the waters of the Nation (see review by Allan 2004). It has become clear that human activities such as deforestation, road construction, and agricultural practices can cause profound changes to the flora and fauna of surface waters.

As Geographic Information System (GIS) technology has advanced researchers have attempted to identify and quantify the relative contributions of certain landscape variables to surface water quality. One of the first studies to examine the effects of land use on aquatic biota in South Carolina (SC) was Glover and Eidson (1999), who found that urban land use had a detrimental effect on freshwater aquatic macroinvertebrates. Since then more accurate land use cover types have been developed along with the accumulation of additional bioassessment data. The objective of the present study was to determine if land use, human population density, and road density has had an effect on water quality of streams in SC as measured by the South Carolina Bioclassification System.

The Aquatic Biology Section (ABS) of the SCDHEC, as part of its statewide bioassessment program, collects freshwater aquatic macroinvertebrates from streams and rivers across South Carolina. From 1995 to 2007, nearly half a million macroinvertebrate individuals representing 1092 taxa were collected, identified, and archived by ABS staff. Of the 827 stations sampled across SC, 190 were chosen for data analysis in this study. These stations were restricted to the Piedmont of SC and were contained in the Savannah, Broad, Pee Dee, Catawba, and Saluda Basins. Because of severe drought conditions in 2002 and 2007 data from these years were excluded.

After aquatic macroinvertebrates were collected and identified a bioclassification score for each station was calculated. These scores range from 1-5 in increments of 0.1, with 1 being the lowest bioclassification score and 5 being the highest. A narrative bioclassification category was assigned to each station based on the bioclassification score as follows: Poor=1, Fair=2, Good/Fair=3, Good=4. Excellent=5. For data analysis, stations in the Poor and Fair categories were combined. If the bioclassification was Poor, Fair, or Good/Fair the stream was classified as Impaired for Aquatic Life. If the bioclassification was Good or Excellent the stream was considered Unimpaired. For details of collection methods and data analysis see SCDHEC (1998).

Watershed landscape data were quantified using hydrologic units, land cover, road segments and demographic data through GIS (ESRI 2008). The USGS 12-digit state hydrologic units, which were delineated to the 1:24,000 scale base map, were used as a reference to delineate each biological sampling site's watershed. Land use classifications were obtained from the National Land Cover Data (NLCD). The NLCD was developed from 30-meter Landsat Thematic Mapper (TM) data acquired by the Multi-resolution Land Characterization

(MRLC) Consortium. The NLCD data has a consistent land cover data layer for the entire U.S., with 21 possible land cover classes represented. Classes were aggregated to represent developed, undeveloped, and agricultural uses. Road segments were derived from the Census Bureau 2000 TIGER/Line files. Road density was calculated by summing road lengths within a watershed, then dividing by the area. Population statistics were derived from the Census Bureau 2000 Census Tracts. The census tract areas were intersected with the delineated watersheds. The area percentage was calculated by dividing the original census area by the intersected tract area. The percentage was used to adjust the population. Population density was calculated by summing adjusted population within a watershed, then dividing by the area.

Data analyses were performed using SAS Institute's SAS/STAT (SAS Institute 2002) and StataCorp's STATA (StataCorp LP 2007). The relationships between the bioclassification score and landscape variables were tested using Spearman correlations and independent single linear regressions. Spline regressions were performed for bioclassification scores to percent developed land use with knots at 10%, 20%, and 30% developed land use. Single independent ANOVA's were performed to test relationships of bioclassifications and condition categories with landscape variables.

Mean watershed area was 101.9 $km^2$ with a range of 2.06 $km^2$ to 968.8 Km2. The mean bioclassification score was 3.4 and ranged from 1.5 to 4.7. Mean and ranges for the independent variables were: percent developed land use (15.9%, 3.0% to 89.0%), percent undeveloped land use (54.8%, 10.0% to 86.0%), percent agricultural land use (29.2%, 2.0% to 65.0%), human population density (270.4/$mi^2$, 15/$mi^2$ to 2295/$mi^2$), and road density (3.94 km/$km^2$, 1.1 km/$km^2$ to 17.0 km/$km^2$).

Spearman correlations between bioclassification score were relatively strong for most landscape variables: percent developed land use (R= -0.46, p<0.0001) percent undeveloped land use (R= 0.40, p<0.0001), population density (R= -0.41, p<0.0001), and road density (R= -0.44, p<0001). There was little correlation between bioclassification score and percent agricultural land use (R=0.15, p=0.04). Each individual watershed variable (in independent single regressions) predicted 4% (for percent agriculture) to 40% (for percent developed) of variance in the bioclassification score. Spline regressions improved the percent developed model ($R^2$=0.46) and fit more closely with ecological theory. The shape of the spline regression curve indicated a non-linear response with the effect at the lower end of the stressor gradient.

Results from ANOVA indicated that percent developed, percent undeveloped, population density, and road density varied significantly across bioclassification categories (p<0.001). Duncan's pairwise comparisons were used to test for *post hoc* differences in landscape values between bioclassification categories (SAS Institute, 2002). The Poor/Fair category could be distinguished from Good/Fair, Good, and Excellent categories for all landscape variables except percent agriculture, which was not a good predictor of bioclassification categories (p=0.03). Results were similar for stream condition with all landscape variables except percent agriculture varying significantly across stream condition (Impaired, Unimpaired). There was a wide range of watershed development for streams that were classified as impaired (3%-89%). However, the maximum amount of development that was associated with unimpaired streams was 21%.

Allan (2004) noted that several studies have shown adverse impacts to stream organisms at 15%-25% urban land use. Our results indicate that any level over 21% watershed development placed the stream into the SC impaired condition category. The biological response to the stressor gradient was similar to that shown in other studies (Allan 2004). No significant relationship between the variables was evident between 0 and 10% developed land use (p=0.523). However between 10% and 20% development the relationship was significant (p=0.008) and was most significant between 20% and 30% development (p=0.001). While a body of literature has begun to immerge confirming the importance of watershed land use to aquatic life, many hypotheses exist as to why urban streams are degraded. As watersheds move from undeveloped or agricultural to urban the streams have increased pollution runoff, increased temperature, eroded banks, increased sediment input, and flashy flows. All these factors make urban streams inhospitable to aquatic life. The challenge facing future generations and us is to determine how water resources can be protected in the face of drastic landscape alterations.

**Literature Cited**

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