DEVELOPMENT OF A SCIENTIFIC UNDERSTANDING OF THE EFFECTS OF CHANGING LAND USE ON STREAM ECOSYSTEMS

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Abstract. Changing land use promises to be a hallmark of this decade and in the years ahead in Georgia. Local and state governments are continually faced with decisions concerning the conversion of forested or agricultural lands into residential and commercial use. Few studies have quantified the effects of such change on stream ecosystems and the quality of freshwater resources. We have the opportunity to conduct a study in the Etowah River basin in which we will establish relationships between land use and indicators of the effects of change on the physical and biotic structure of streams. The database we develop will help determine the predictive relationships between thresholds in land use with indicators of stream geomorphology, in-stream habitat and biotic integrity (using fish and invertebrate indicators). Such relationships can be used to understand the scientific basis of why certain types or degrees of land conversion lead to degradation of water quality. In addition, these data can also be used to illustrate the effects of land use change on stream ecosystems and thus, can be used to facilitate informed decision-making on the tradeoffs presented by land use changes.

INTRODUCTION

We are presenting an overview of a study that was recently initiated to illustrate 1) the complexity of effects of changing land use on natural systems, 2) how multi-investigator efforts can address such complex effects, and 3) how development and integration of different types of indicators can help quantify and define effects of changing land use on streams.

The main objective of this upcoming research project, funded by the U.S. Environmental Protection Agency, is to define the predictive capabilities of scale-variable attributes of land cover and geomorphology as risk assessment indicators of biotic integrity of stream ecosystems. Our study area is the Upper Etowah River basin north of Atlanta, where we will examine watershed-scale (15-100 km^2) and reach-scale (100-1000m) variables that incorporate temporal dimensions of antecedent and current land use. Focusing on watersheds that range from 0 to less than 50% urban land cover (including residential), we will model and define incipient levels of ecological decline, rather than focusing on heavily urbanized landscapes.

The overarching hypothesis shaping our approach is that ecological stressors and responses vary as a function of land use, and that land use is a predictor of ecological response. Because landscapes are not amenable to experimental manipulation, landscape gradients (e.g., a range in urban land cover) can provide a "natural experiment" to investigate linkages among stressors and responses. Common types of land conversion, such as that which occurs from forested to urban or agricultural use, typically lead to changes in the fluxes of water and sediment in streams (Trimble, 1974). These stressors affect channel geomorphology (Hirsch et al. 1990, Leopold 1994), which serves as the physical template of stream ecosystems. Such changes in land use can also result in changes in biotic integrity (Kerans and Karr 1994). We will focus on how these stressors (altered hydrology and sediment transport) affect channel morphology, and consequently, how these stressors affect stream biota (fish and invertebrates). Thus, we will link indicators of land use, using Geographic Information Systems (GIS), with geomorphic indicators and indicators of biotic integrity of streams.

STUDY SITE AND METHODS

The proposed study area is the upper Etowah River watershed on the Piedmont of north Georgia, northeast of

Atlanta. The Piedmont region includes the majority of major metropolitan areas in the southeastern U.S., including Atlanta, where rapid human population growth threatens streams that support globally significant levels of freshwater biodiversity. The Etowah River above Lake Allatoona drains parts of Cobb, Cherokee, Forsyth, Dawson, Lumpkin, and Pickens Counties. Beginning in the 1970's, the population growth rate of these six counties has been high and well above the statewide average in Georgia.

Objective 1: To quantify relationships between landscape indices and stream responses, we will select 30 sub-basins that will be stratified into three groups of ten, including approximate drainages of 15, 50, and 100 km^2. Each group of ten will include a 0-50% range of urban land cover. At each watershed, we plan to measure, compare, and correlate 1) patterns in land use, 2) geomorphic characteristics, and 3) biological response varibles. We will measure these parameters at the same 100 m reaches within each sub-basin.

Landscape metrics: Both current and historical landscape indices will be determined using satellite imagery and aerial photography. Current and historical landscape indicators will include % forest cover, % urban cover, road density, % riparian forest cover, road density, and population density.

Geomorphic measurements: Geomorphic measurements, including attributes of channel form and sediment composition will be made at the outlets of the 30 sub-basins. Measurements will include bankfull channel cross section, longitudinal profile, plan form characterization, bed and bank sediment grain size, and bank vegetation.

Biotic response: Fish assemblages will be characterized at each site. Fish species diversity, abundances by species and population size-class structure, as well as indices of species distributions (e.g., % gravel and % crevice spawners, index of biotic integrity) will be determined. We will sample benthic invertebrate assemblages quantitatively in the spring months, which will be weighted by substrate type. Several biotic indices will be determined including the EPT index and the benthic index of biotic integrity (B-IBI).

Data analysis and hypothesis testing: We will use correlation and ordination procedures to identify statistically significant predictors of changing land use. The best predictive relationships between landscape indicators and biotic integrity can then be made using regression analysis. Differences in predictive relationships due to basin size will be determined using analysis of covariance.

Objective 2: We will focus on a subset of ten sites for our second objective, for which we will develop mechanistic understandings of relationships obtained as part of objective 1. In objective 2, we will work on 1 km stream segments, in part to determine the representativeness of the 100 m reaches used in objective 1. Further, we will examine sites where predictive relationships could be derived as part of objective 1 and those that were 'outliers' in those relationships, to determine factors that contribute to lack of fit. We will also link geomorphic characteristics of streams to biotic assemblages via studies of changes in in-stream habitat in response to changes in land use.

Geomorphic characterization: The main goals of the geomorphic work will be to determine the representativeness of the 100 m reaches using cross-sectional data, and to determine effects of tributaries. Characteristics of channel morphology will be available for correlation with biotic characteristics measured within the reach.

In-stream habitat quantification: In-stream habitat patterns will be assessed using measures of channel slope, average width to depth ratio, number and lengths of riffles, and others. Habitat features (e.g., pool and riffle boundaries, woody-debris dams) will be determined. Cross sectional data will be used to simulate depth and velocities in relation to stream flow. We will also characterize sites using the Stream Visual Assessment Protocol (SVAP), recently developed for the Natural Resources Conservation Service. Analysis of results using SVAP, compared with other measures of habitat quantification, will test whether this simple procedure can be used to achieve the same predictive capabilities as more time-intensive methods.

Biotic sampling: More intensive fish and invertebrate sampling will be conducted in the 1 km reaches, including measurements of other variables (e.g., benthic organic matter, patches of emergent vegetation) that may explain variation in distribution.

Data analysis and hypothesis testing: Correlation and multiple regression analyses will be used to identify relationships between biotic metrics and habitat features measured at microhabitat to segment scales.

EXPECTED RESULTS AND BENEFITS

A major benefit of our research will be the development of a wide array of landscape/geomorphic indicators to correlate with biotic and physical habitat conditions of streams. By applying watershed-scale, reach-scale, and temporal-scale analyses we will develop indicators that are useful in monitoring ecosystem integrity based upon the most important variables. Our analysis will determine which indicators are most useful and robust. This will ultimately result in improved information for risk assessment and management of stream ecosystems in the Piedmont. Another important outcome of our analysis will be a better understanding of basin-scale versus reach-scale parameters as indicators of ecosystem health, which can ultimately be used by resource managers and planners. In addition, our data set will provide a sound geomorphic-biotic model for stream restoration projects.

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