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Relating stream function and land cover in the Middle Pee Dee River Basin, SC

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ABSTRACT

Study region: The study region comprised sixteen stream sites and associated contributing watersheds located in the Middle Pee Dee River Basin (MPDRB) of South Carolina, USA.
Study focus: The study was conducted between 2008 and 2010 to quantify how indices of streamflow varied with land cover characteristics analyzed at multiple spatial scales and fluvial geomorphic characteristics of sampled streams in the MPDRB. Study objectives were to relate three indices of streamflow that reflect recent temporal flow variability in a stream, with synoptic stream geomorphological measurements, and land cover type at specific spatial domains.
New hydrological insights for the region: Modifications to the landscape, hydrologic regime, and alteration to channel morphology, are major threats to the functioning of riparian ecosystem functions but can rarely be linked to a single common stressor. Results from the study showed that in the MPDRB, wetland cover in the riparian corridor was an important factor, correlating significantly with stream flashiness, channel enlargement, and bed substrate character. It was also shown that a combination of stream geomorphological characteristics when combined with landscape variables at specific spatial scales were reasonable predictors of all three indices of streamflow. The study also highlights an innovative statistical methodology to relate land cover data to commonly measured metrics of streamflow and fluvial geomorphology.

1. Introduction

In 2010, the South Carolina Legislature sought to regulate withdrawals from surface water sources in the state (A247—South Carolina Surface Water Withdrawal, Permitting, Use, and Reporting Act, 2010). The potential alteration to flow regimes by surface water withdrawals and their impacts on riparian ecosystems is still to some extent an unknown in several watersheds that are affected by the law. In order for regulatory agencies to make sound decisions in granting surface water permits, a greater understanding of the relationship of current streamflow rates, channel morphology, and land cover drivers in South Carolina's watersheds became of critical importance. This study was conducted from 2008 to 2010 to determine the fluvial geomorphic characteristics of the Middle Pee Dee River Basin (MPDRB), and the relationship

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of these riparian systems to land cover. While the physical characteristics of a riparian system are intimately intertwined with the biological and ecological character of the ecosystem, this study focused solely on the abiotic structure of stream and landscape. The goal of this work was to investigate the relationship between landscape characteristics and three indices of stream flow. The overall objective of this work was to determine if by measuring common landscape and stream geomorphological parameters in the MPDRP, could one reasonably estimate characteristics of streamflow regime without having to invest the time and resources needed to measure continuous streamflow at a location. Ultimately, we hoped that this work would provide insight on landscape factors that most influenced flow regime for their inclusion in the development of planned, state-regulated flow regimes that would maintain ecological viability in the MPDRB.

1.1. Watershed scale analyses and stream health

It has been widely documented that anthropogenic changes to the landscape impact riparian systems (Brabec, 2009; Booth et al., 2004; Allan, 2004; Poff et al., 1997; Hammer, 1972) and in many cases can lead to alterations that surpass the system's ability to return to its original state (Blann et al., 2009). Blann et al. (2009) identified modifications to hydrology, geomorphology, nutrient cycling, and sediment dynamics as being major threats to riparian system functions. Land cover changes can result in drastic changes to water quality (Bedoya et al., 2009), hydrologic regime (Booth and Jackson, 1997), and increased sediment inputs that subsequently impair stream habitat (Tufford et al., 2003; Gergel et al., 2002). However, such drastic changes are rarely linked to a single stressor (Bedoya et al., 2009). There are several metrics used to quantify anthropogenic influence on a landscape, these include summed total impervious area (IMP) (Hammer, 1972), Landscape-Disturbance Index (LDI) as defined by Stanfield and Jackson (2011), and the extent of agricultural and commercial land cover within a watershed. Each metric has been found to influence the physical and ecological condition of a stream system (Brabec, 2009; Booth and Jackson, 1997). Impervious area has been shown to have deleterious impacts on stream processes (Brabec et al., 2002) and thresholds for maintaining stream health tend to be watershed-specific ranging from 4 to 15% imperviousness (Schueler, 1994; Klein, 1979; Booth and Jackson, 1997; Hicks and Larson, 1997; Baker et al., 2004; Brabec, 2009). Agricultural land uses within highly modified watersheds are often synonymous with higher nutrient inputs to stream systems (King et al., 2005; Howarth et al., 1996; Vitousek et al., 1997; Tilman et al., 2001) as well as hydromodification associated with stream channelization (Jayakaran and Ward, 2007; Rhoads and Herricks, 1996).

1.2. The analysis of landscape metrics at multiple scales

With evidence of landscape impacts on stream function (Blann et al., 2009; Frimpong et al., 2005; Sutherland et al., 2002; Fitzpatrick et al., 2001; Davies et al., 2000; Stauffer et al., 2000; Roth et al., 1996; Berkman and Rabeni 1987; Oswood and Barber, 1982), there is also evidence that certain landscape drivers have greater influence on instream function at specific spatial scales (e.g. King et al., 2005; Sponseller et al., 2001; Maddock 1999; Rankin, 1995). While some aspects of a stream's character (such as bed material type, presence of woody debris, channel roughness) tend to be influenced by localized/reach-scale factors, others (such as channel shape, bed material transport, stream flashiness) are more influenced by factors at larger landscape/catchment scales (Bedoya et al., 2009; McRae et al., 2004; Wang et al., 2003; Richards et al., 1996; Allan et al., 1997). However, it is important to note distinctions between landscape and reach scale processes are mostly semantic, and pragmatically there is considerable overlap between the two. For example, Allan et al. (1997) showed that land cover could be a strong indicator of reach-specific biological and habitat integrity for 100-m reaches, where biological and habitat integrity were measured by a habitat index (HI) and an index of biotic integrity (IBI), respectively. In that study (Allan et al., 1997), agricultural land cover explained as much as 50% of the variance in IBI and 75% of the variance in HI. The authors also documented that agricultural cover at the catchment scale was far more indicative of biota and habitat at a site than reach-scale land cover information, although correlations were found at both scales.

1.3. Characterizing streamflow

Synoptic physical habitat assessments and fluvial geomorphic measurements provide insight into the current ecological condition of a stream, but do not include information on stream functioning that can only be derived from a record of recent streamflow data. The lack of information on recent flow history is usually a function of the cost-prohibitive nature of installing, and maintaining, continuous streamflow logging equipment. With this study, we hoped to show that through the synoptic measurement of specific characteristics of channel morphology and land cover, certain characteristics of streamflow at a site might be revealed. Secondly, we also hoped to develop insight into what land cover parameters most influenced flow in the streams of the MPDRB. Three indices were chosen to characterize streamflow:

a) A measure of channel enlargement (Pizzuto et al., 2000) requiring knowledge of bankfull flow at that location—Hammer number (H).
b) An estimate of stream flashiness (Baker et al., 2004) requiring a continuous flow record at a site—Richards Baker Flashiness Index (RBI).