Flux of Dissolved Organic and Inorganic Constituents in Forested Headwater Streams

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Abstract

Headwaters initiate material export to downstream environments. A nested headwater study examined the flux of dissolved constituents and water from a perennial stream and four ephemeral/intermittent streams in the Upper Gulf Coastal Plain of Mississippi. Water was collected during storm and baseflow conditions. Multiple linear regression was used to model constituent concentration and calculate flux. Event was the major source of water discharged from the ephemeral and intermittent streams however, baseflow was the major source for water discharged by the perennial stream during events. The perennial stream had an area weighted average yields of 10.1, 0.01, 1.03, 0.65 kg/ha/yr of DON (dissolved organic nitrogen), NO$_3$-N, NH$_4$+-N and PO$_4$-3, respectively while large variabilities existed between the ephemeral and intermittent streams. These findings highlight the importance of headwaters in protecting the low order drainage basins as a key to water quality within perennial streams.

Key Words: Headwaters, Flux, Hydrologic event, Hydrogeochemistry, Nutrients, Water quality

1. Introduction

Headwaters are the uppermost areas of drainage basins which initiate stream flow and are important components of the river network with regard to non-point sources of constituents (Nadeau and Rains, 2007). These non-point sources dominant riverine fluxes to coastal regions throughout the world (Howarth et al., 1995). Furthermore, headwater streams transport a wide range of material such as nutrients, dissolved organic carbon, aquatic and terrestrial invertebrates to downstream reaches. These materials play key roles in the structure, function, biodiversity and productivity of riverine ecosystems (Wipfli et al., 2007).

Headwater streams are characterized by distinctive geological features (e.g. geologic composition, stratigraphy and aquicludes), hydrological (e.g. surface and ground water flow paths), biological (e.g. microbiota and vegetation) and chemical processes (Nadeau and Rains, 2007; Triska et al., 2007; Gomi et al., 2002). These headwater streams can be ephemeral, intermittent or perennial depending on the channel bottom’s
elevation above the water table in response to storm events. Storms are of particular importance in discharging water and constituents from headwater streams, and the majority (~90%) of dissolved and particulate material in headwater streams is exported by surface and subsurface flow during storm events (Marshall and Hall Jr. 2004; Wipfli et al., 2007).

The nitrogen flux in many temperate regions has increased 2 to 20 times from pre-industrial levels as a result of fertilizer use and land use changes. Indeed, dissolved nitrogen and phosphorus transported from managed systems (e.g. predominantly agriculture, but also forestry and urban areas) have led to eutrophication and subsequent hypoxia in the coastal environment (Lopez-Veneroni and Cifuentes, 1994).

Keim and Shoenholtz (1999) found that land disturbance adjacent to streams can be a major factor affecting surface water quality in headwaters of Mississippi. Researches conducted in the Upper Gulf Coastal Plain of Mississippi found that harvest activities adhering to BMPs such as streamside management zones (SMZs) in forested headwaters can reduce adverse water quality impacts from non-point source pollution (Keim and Shoenholtz, 1999; Carroll et al., 2004; Choi et al., 2011). However, current forestry best management practices (BMPs) have no harvest regulations on ephemeral streams (Mississippi Forest Commission, 2008). Therefore, it is important to understand the response of the water and constituents within these systems to management disturbances.

This study examined the flux of water and constituents exported from headwater watersheds during important transport events (e.g. storms). The objective of this study was to determine the flux of dissolved constituents in ephemeral and perennial streams to better understand how transport processes differ between perennial and ephemeral streams.

2. Materials and methods

2.1. Site description

The study site was a small-scale headwater watershed located in the Hilly Gulf Coastal Plain province of the Upper Gulf Coastal Plain of Mississippi, USA (33°30′54.35″N, 89°25′49.39″W). The average precipitation for the past 30 years was 1,451 mm with average winter (December, January and February) temperature of 7 °C and summer (June, July and August) temperature of 26 °C. Precipitation was distributed fairly evenly throughout the year with 53% falling between January and May. Short and high intensity storms are common and storm precipitation can exceed 100 mm per day on occasions. Vegetation on the site was characteristic of overstory vegetation in the Southeastern Mixed Forest Province of the Southeastern U.S. (Bailey, 1983). The majority of the site was side slopes underlain by the Sweatman soil series (fine, mixed, semiactive, thermic Typic Hapludults). The ridge tops were of the Providence series (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) while the floodplains were of the Oaklimeter soil series (coarse-silty, mixed, active, thermic Fluvaquentic Dystrudepts).

The ephemeral and intermittent sub-watersheds are nested within the perennial watershed which drains the entire study area (Figure 1). There are a number of intermittent and ephemeral streams within the perennial watershed, 4 of which streams were chosen for examination (Table 1). Within the perennial watershed which drains the entire study area, 4 monitored sub-watersheds have intermittent to ephemeral streams with treatments that are representative of forest management in the Southeastern U.S. The treatments were part of a larger study of the effects of forestry on hydrological function of headwater streams, but were not a focus of this study. However, these treatments represent a range of watershed