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# Water quality of small seasonal wetlands in the Piedmont ecoregion, South Carolina, USA: Effects of land use and hydrological connectivity

Xubiao Yu [a,b], Joanna Hawley-Howard [c], Amber L. Pitt [d], Jun-Jian Wang [b], Robert F. Baldwin [c], Alex T. Chow [b,c,*]

[a] School of Chemistry and Chemical Engineering, South China University of Technology, 510640, China
[b] The Belle W. Baruch Institute of Coastal Ecology and Forest Science, Clemson University, Georgetown, SC 29440, USA
[c] Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC 29634, USA
[d] Department of Biological & Allied Health Sciences, Bloomsburg University of Pennsylvania, Bloomsburg, PA 17815, USA

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ABSTRACT

Small, shallow, seasonal wetlands with short hydroperiod (2–4 months) play an important role in the entrapment of organic matter and nutrients and, due to their wide distribution, in determining the water quality of watersheds. In order to explain the temporal, spatial and compositional variation of water quality of seasonal wetlands, we collected water quality data from forty seasonal wetlands in the lower Blue Ridge and upper Piedmont ecoregions of South Carolina, USA during the wet season of February to April 2011. Results indicated that the surficial hydrological connectivity and surrounding land-use were two key factors controlling variation in dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) in these seasonal wetlands. In the sites without obvious land use changes (average developed area <0.1%), the DOC ($p < 0.001$, t-test) and TDN ($p < 0.05$, t-test) of isolated wetlands were significantly higher than that of connected wetlands. However, this phenomenon can be reversed as a result of land use changes. The connected wetlands in more urbanized areas (average developed area = 12.3%) showed higher concentrations of dissolved organic matter (DOM) (DOC: 11.76 ± 6.09 mg $L^{-1}$, TDN: 0.74 ± 0.22 mg $L^{-1}$, mean ± standard error) compared to those in isolated wetlands (DOC: 7.20 ± 0.62 mg $L^{-1}$, TDN: 0.20 ± 0.08 mg $L^{-1}$). The optical parameters derived from UV and fluorescence also confirmed significant portions of protein-like fractions likely originating from land use changes such as wastewater treatment and livestock pastures. The average of C/N molar ratios of all the wetlands decreased from 77.82 ± 6.72 (mean ± standard error) in February to 15.14 ± 1.58 in April, indicating that the decomposition of organic matter increased with the temperature. Results of this study demonstrate that the water quality of small, seasonal wetlands has a direct and close association with the surrounding environment.



* Corresponding author. The Belle W. Baruch Institute of Coastal Ecology and Forest Science, 130 Heriot Road, Georgetown, SC 29440, USA. Tel.: +1 843 546 1013x232; fax: +1 843 546 6296.
E-mail address: achow@clemson.edu (A.T. Chow).

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## 1. Introduction

Wetlands perform a suite of ecological functions such as water purification, nutrient retention, flood protection, ground water recharge and habitat for wildlife. Based on different scientific and policy objectives, various ecological functions of wetlands have been studied and evaluated, including hydrology (Cook and Hauer, 2007; Min et al., 2010), water quality (Trebitz et al., 2007; Verhoeven et al., 2006; Whigham and Jordan, 2003), vegetation composition (Hebb et al., 2013) and animal population dynamics (Fracz and Chow-Fraser, 2013; Seilheimer and Chow-Fraser, 2006). Among these factors, water quality has generated substantial concern because it is not only essential for all biological growth and reproduction, but also directly interacts with other factors across multiple spatial and temporal scales. For example, land use (Maassen et al., 2012; Morrice et al., 2008), hydrological connections (Cook and Hauer, 2007; Kazezyilmaz-Alhan et al., 2007), soil and vegetation characteristics (Batzer et al., 2000; Montgomery and Eames, 2008) have all been demonstrated to be related to water quality. Thus, water quality serves as an important indicator for characterizing the effects of land use on wetlands, and furthermore, to direct policy and management of the surrounding watershed. Particular water quality parameters are selected as indicators of specific anthropogenic stressors, such as dissolved organic carbon (DOC) with natural organic matter (NOMs), nitrogen (N) and phosphorous (P) for agricultural run-off, electronic conductivity (EC) for anthropogenic discharge and chloride ($Cl^-$) for point-source pollution (Tu, 2011). In most cases, dissolved carbon and nitrogen are significant parameters due to their high content in all dissolved organic matter (DOMs).

Small, seasonal wetlands are found throughout the Piedmont ecoregion of the southeastern United States. These wetlands usually occur in areas with depressional topography and are characterized by their small area and shallow depth (Hayashi and van der Kamp, 2000). These wetlands typically have a shorter hydroperiod than larger wetlands with greater surface water area, and usually hold water for only three to five months per year (Hayashi and van der Kamp, 2000). Because of their relatively small size and ephemeral nature, these wetlands are not typically protected as fully as coastal and riparian wetlands, which satisfy the criteria for protection under the Clean Water Act (McCauley et al., 2013; Stokstad, 2006). In recent decades, wetlands have suffered significant habitat loss and degradation across the US due to the rapid urbanization processes (McCauley et al., 2013). Despite small surface areas and short hydroperiods, these wetlands harbor a great deal of biological diversity, especially for some amphibians (e.g., wood frogs, spotted salamanders, spade foot toads) for which there are selective pressures to breed in more ephemeral sites (Stokstad, 2006). Moreover, the stagnant nature of seasonal wetlands provide more time for microbes to convert excess nutrients and prevent downstream algal blooms (Whitmire and Hamilton, 2005). Based on the unique benefits for both biodiversity and downstream water quality, many researchers are calling for the amendment of wetland regulations to include protection of small, seasonal wetlands (Stokstad, 2006).

Research on water quality of small, seasonal wetlands has been limited as a result of the small water surface area and short hydroperiod that characterize these habitats. With regard to hydrological characteristics, these seasonal wetlands are generally considered to have little or no connection with surface water or ground water, and they are primarily dependent on precipitation and runoff (Whigham and Jordan, 2003). Because of this dependency on precipitation, these wetlands may represent a simpler water pathway than that of large wetlands (i.e., water quality of small wetlands may be more closely linked to the characteristics of the surrounding watershed such as land-use and vegetation cover). Moreover, these wetlands hold significantly lower volumes of water than other wetlands and the water quality parameters may therefore respond to variation in the surrounding environment in a more rapid and sensitive manner.

In order to better understand the water quality of these seasonal wetlands, we collected water samples from forty seasonal wetlands located in the lower Blue Ridge and upper Piedmont ecoregions of northwestern South Carolina from February through April of 2011. In addition to general water parameters, DOM was quantified and characterized using UV spectra and fluorescence to determine the compositional variations among land-use and hydrological factors. We hypothesized that small, seasonal wetlands have a strong relationship with the surrounding watershed, and can serve as a sensitive indicator to evaluate the water quality at the landscape scale and also reflect the influences of human activities on water quality rapidly.

## 2. Materials and methods

### 2.1. *Study sites*

Wetland study sites were distributed throughout northwestern South Carolina (34°48′N, 82°56′W), across Oconee, Pickens, Anderson and Greenville Counties (Fig. 1). This region is located at the base of the Appalachian Mountains and near the headwaters of the Savannah River (boundary river of South Carolina and Georgia). The water quality in this upper portion of the watershed may influence the middle and lower reaches where there are large urban populations. There is a paucity of data regarding seasonal wetlands in this region, and until recently few had been mapped (Pitt et al., 2012). Increasing development pressure since 1990 associated with the region's location between two major urban centers (Atlanta, GA and Charlotte, NC) (Campbell et al., 2008), prolonged drought cycles, and increasing constraints on aquatic resources necessitate timely assessment of small, seasonal wetlands in this region. The southern Appalachians span the northern portion of the study area and the general topography transitions from steep mountainous terrain in the lower Blue Ridge ecoregion to hilly foothills in the upper Piedmont ecoregion. Wetland elevation decreased approximately 700 m from north to south. The climate in this portion of the southeastern US is temperate forest and the annual precipitation level is approximately 1700 mm.