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Floodplain influence on carbon speciation and fluxes from the lower Pearl River, Mississippi

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Abstract

To investigate the floodplain influence on carbon speciation and export to the northern Gulf of Mexico, water samples were collected monthly from two sites in the East Pearl River (EPR) basin during 2006–2008. Additionally, four spatial surveys in the river basin between those two sites were also conducted. Compared with the upstream sampling site at Bogalusa, MS, dissolved inorganic carbon (DIC) and particulate organic carbon (POC) concentrations were 36% and 55% lower, respectively, and dissolved organic carbon (DOC) concentration was 49% higher at the downstream Stennis Space Center (SSC) site. In addition, the bulk DOC pool at SSC had a higher colloidal fraction than at Bogalusa (75% vs. 68%). Detailed spatial surveys revealed the differences between the upstream and downstream stations resulted both from input from Hobolochitto Creek, a tributary of the EPR, and from influence of the swamp-rich floodplain. The contributions from Hobolochitto Creek to the carbon pool in the EPR basin were lowest during a high flow event and reached a maximum during the dry season. Meanwhile, the floodplain in the EPR basin acted as a significant sink for DOC, POC and particulate nitrogen during summer and for suspended sediment during a high flow event. However, the floodplain was converted into a source of suspended sediment, DOC, and POC to the EPR during winter, revealing a dynamic nature and seasonality in the floodplain influence. Consistent with its dominant forest coverage, abundant wetlands along the river corridor, and mild anthropogenic disturbance, the Pearl River basin above Bogalusa generally had higher yields of DOC and POC (1903 and 1386 kg-C km^{-2} yr^{-1}, respectively), but a lower yield of DIC (2126 kg-C km^{-2} yr^{-1}) compared to other North American rivers. An estimation based on a mass balance approach suggests the interactions between floodplain and the main river stem could reduce the annual DIC and POC export fluxes from downstream of the EPR by 24% and 40%, respectively, but enhance the annual riverine DOC export by 25%. Similar scenarios likely occur in other wetland-rich coastal rivers and are capable of significantly altering the current estimation of riverine carbon export.

Keywords: Floodplain; Wetlands; Carbon Speciation; River Chemistry; Carbon Flux

1. INTRODUCTION

Rivers are major pathways for the transfer of terrigenous materials into coastal marine environments. The global riverine carbon flux is as high as 250–360 × 10^9 kg-C yr^{-1} for dissolved organic carbon (DOC), 200 × 10^9 kg-C yr^{-1} for particulate organic carbon (POC), and 407 × 10^9 kg-C yr^{-1} for dissolved inorganic carbon (DIC; Hedges and Keil, 1995; Aitkenhead and McDowell, 2000; Cai et al., 2008c). World rivers also discharge 15 × 10^{12} kg sediment annually into the coastal ocean (Milliman, 1991). This terrestrially derived carbon is actively involved in biogeochemical cycles in coastal

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environments (Hedges et al., 1997; Dagg et al., 2004; Hernes and Benner, 2006; Tank et al., 2012; Bianchi et al., 2013). As a result, the carbon cycle, biological productivity, ecological status, and community metabolism in the river-dominated coastal ocean can be extensively altered in response to the riverine carbon inputs (Gattuso et al., 1998; Hernes and Benner, 2003; Wysocki et al., 2006; Bianchi et al., 2008; Bauer et al., 2013). Riverine sediment supply is also an important source for coastal restoration and affects the light availability in coastal regions, thereby having a profound influence on biological productivity (Lohrenz et al., 1999, 2008; Allison et al., 2013). The organic matter and nutrients associated with riverine sediment can also play an important role in regulating the primary productivity and community metabolism (Goni et al., 2006; Turner et al., 2007; Zhang et al., 2010).

It has been demonstrated that human activities, such as damming, land use, and water control structures, can significantly alter riverine export fluxes of carbon and sediment (Raymond et al., 2008; Meade and Moody, 2010; Gao et al., 2012; Zhang et al., 2014). Climatic variability and associated extreme events also have huge impacts on terrigenous material export (Raymond and Cole, 2003; Striegl et al., 2005; Allison et al., 2012; Bianchi et al., 2013; Cai et al., 2013). However, most riverine flux estimates, including the Mississippi, Amazon, and Yangtze Rivers, are based on measurements tens to hundreds kilometers upstream of the river mouth due to sampling constraints and limitations in determining water discharge in tidal reaches and floodplains in lower river basins as well as due to difficulties in obtaining representative river end-member samples (e.g., Emmerton et al., 2008; Allison et al., 2012; Gao et al., 2012; Cai et al., 2013; Seidel et al., 2015; Ward et al., 2015). These constraints can result in a large uncertainty in riverine flux estimation and hinder the understanding of the role of rivers and their floodplains as the connection between terrestrial and marine systems (Meade, 1996).

Lower river wetlands, consisting of river swamps, salt marshes, lakes, and other water bodies, are widespread in river deltas and lowermost river floodplains with extended coastal plains. It is well acknowledged that wetland-rich river deltas and floodplains are productive and their dynamic biogeochemical processes have a large capacity to significantly alter the concentrations, chemical composition and riverine loads of carbon, nutrients and suspended sediment in the main river channel. For example, Cai et al. (2000) suggested that metabolic processes in salt marshes could result in a tenfold increase of riverine DIC export. For the Atchafalaya River, the swamps also enhance the riverine DOC export by up to 25% although its sediment load to the coastal ocean was reduced by 30% (Allison et al., 2012; Shen et al., 2012). The floodplain and river delta in the Danube and Mackenzie Rivers have been shown to reduce the riverine POC load by 7% and 15%, respectively (Tockner et al., 1999; Emmerton et al., 2008). In the Amazon River, which represents 16% of the global freshwater discharge, the flooded forests supported a large amount of riverine carbon export as DOC and dissolved CO_2 through their primary production (Richey et al., 2002; Abril et al., 2014). Recent observations in the lower reach of the Amazon River further revealed about a 50% decrease of POC concentration and 8% increase of DOC concentration during riverine transport as well as a decreasing reactivity of the organic matter (Seidel et al., 2015; Ward et al., 2015). In river basins with significant influences from floodplains and wetlands, fluvial flux estimates from the continents could significantly deviate from the actual riverine carbon and sediment fluxes. Nevertheless, the interaction between floodplains and rivers could be an important process in altering riverine material export in addition to anthropogenic and extreme climatic events, such as hurricanes and major flooding and drought events (Cai et al., 2008c, 2013; Raymond et al., 2008; Meade and Moody, 2010; Bianchi et al., 2013).

There have been extensive efforts to direct investigations on the floodplain-river interactions in wetland-rich river systems, such as the Atchafalaya and Amazon Rivers. Observations have shown a great variation in the influence of floodplains on the riverine material export (Tockner et al., 1999; Cai et al., 2000; Richey et al., 2002; Emmerton et al., 2008; Allison et al., 2012; Shen et al., 2012; Abril et al., 2014; Ward et al., 2015). Due to their dynamic nature, the same floodplain can show contradictory roles based on different field observations (e.g., Xu, 2006; Shen et al., 2012; BryantMason et al., 2013; Scott et al., 2014). Although the floodplain's capacity to change the riverine material export fluxes is likely linked to the differences of geomorphologic, ecologic and hydrologic conditions among various floodplains, the controlling mechanisms and subsequent variations in the quantity and quality of riverine chemical species remain largely unknown.

To better understand the effects of lower river floodplains in altering carbon speciation and export, a comprehensive study was executed in the East Pearl River (EPR) floodplain in southern Mississippi, which has widespread swamps and wetlands. Monthly water samples from upstream and downstream stations in the EPR floodplain were collected during 2006–2008. In addition, four spatial surveys on the floodplain and tributaries were carried out in different seasons throughout the 2007–2008 water year. Concentrations of three carbon species (DIC, DOC and POC) and suspended sediment and their stable carbon and nitrogen isotopic composition were quantified to examine the roles of floodplain and tributaries and their influence on the EPR water chemistry as well as their relationship to watershed geographic and ecological characteristics and possible controlling factors.

2. MATERIALS AND METHODS

2.1. Site description

The Pearl River originates in the east-central portion of the state of Mississippi and discharges into the Gulf of Mexico via the Mississippi Sound (Fig. 1). It is a small, forested, blackwater river with a drainage basin of 22,690 km^2 and a length of approximately 790 km. The Pearl River Basin covers southeastern Louisiana and