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The respiration of flocculent detrital organic matter (floc) is driven by phosphorus limitation and substrate quality in a subtropical wetland

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ABSTRACT

The aerobic respiration of flocculent detrital organic material (floc) from Everglades National Park was found to be dependent on phosphorus limitation and carbon quality and is likely influenced by substrate age, hydrology, and local biomass productivity. Floc was collected at four sites along the Shark River and Taylor Sloughs of Everglades National Park and incubated for up to one week at room temperature in the dark. Floc respiration was determined by measuring the total amount of CO_2 evolved and CO_2 generation rates. To investigate the effect of hydrological conditions, samples were collected in a typical dry (April) and wet (October) season and from short- and long-hydroperiod sites. Floc from the short-hydroperiod freshwater site generated more CO_2 compared to the long-hydroperiod site due to the labile nature of the periphyton-derived organic matter at the former and the presence of more degraded and aged material at the latter. The tidally-influenced Shark River Slough mangrove site generated more CO_2 compared to the Taylor Slough mangrove site, likely as a result of phosphorus inputs from the adjacent Gulf of Mexico at the former and reduced phosphorus inputs and prolonged inundation at the latter. Generally, more CO_2 was generated during the dry season. Floc respiration rates were faster in the wet season, suggesting that fresh vegetation inputs to the floc can influence this process. Phosphorus and glucose additions enhanced CO_2 generation suggesting that phosphorus limitation and carbon quality are important factors regulating floc decomposition.

1. Introduction

The cycling of organic carbon (OC) in wetlands has been widely studied due to the complexity of carbon dynamics in these environments and its critical role in the global carbon cycle (Bridgham et al., 2006; DeBusk and Reddy, 2005; Kayranli et al., 2010; Neue et al., 1997). The accumulation of OC in wetlands occurs when carbon fixation through net primary production exceeds decomposition through carbon mineralization or respiration (DeBusk and Reddy, 2003), which in turn, is governed by several environmental factors, such as nutrient availability, temperature, moisture and electron acceptor availability (Reddy and D'Angelo, 1994). The decomposition of OC in wetland soils occurs at a much slower rate compared to upland ecosystems, because of occasional anaerobic or sub-oxic conditions that develop as a result of flooding (Amador and Jones, 1997; DeBusk and Reddy, 2005). Furthermore, the decomposition rate of OC in wetland soils has been found to be directly influenced by the chemical and physical composition of the organic substrate with potential carbon mineralization rates decreasing with substrate age (DeBusk and Reddy, 1998).

Wetlands are considered important carbon dioxide (CO_2) sinks and sources of atmospheric methane (CH_4) and although they cover only 6–8% of the earth's land and freshwater surface, they are responsible for about one-third of the global soil OC pool, containing about 450×10^{15} g of OC (Mitsch and Gosselink, 2007). The amount of OC stored in wetland soils, as well as the amount of carbon emitted, is likely to change in response to climate change and anthropogenic disturbance.

The Florida Everglades is the largest wetland in the United States, covering approximately 7900 km^2 from south of Lake Okeechobee to the Gulf of Mexico and Florida Bay. Surface water entering Everglades National Park (ENP), the southern-most extent of the Greater Everglades Ecosystem (GEE), is controlled by a series of levees and canals and comes from the Water Conservation Areas (Fig. 1), a 3400 km^2 area of shallow water reservoirs that connects ENP to the Everglades Agricultural Area. In contrast to wetlands in river floodplains in tropical and sub-tropical lowlands that receive significant inputs of nutrient rich sediments and do not accumulate significant amounts of OM (Junk, 2012 and references therein) the Everglades is a naturally oligotrophic wetland with no significant external inputs of sediments.

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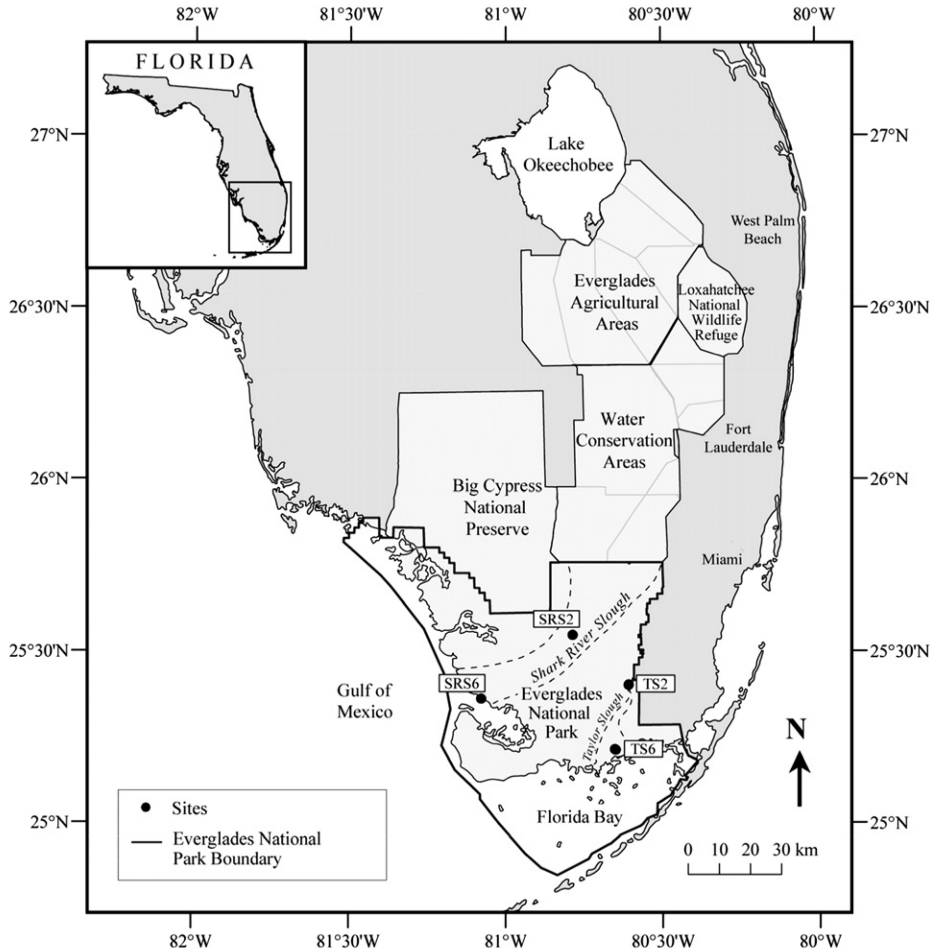

Fig. 1. A map of south Florida showing the compartmentalization of the Everglades into the Everglades Agricultural Areas, Loxahatchee National Wildlife Refuge, the Water Conservation Areas, Big Cypress National Preserve and Everglades National Park (ENP). Within ENP, the sampling locations along the Shark River Slough (SRS) and Taylor Slough (TS) are indicated.

While nutrient-rich wetlands can experience high levels of planktonic primary productivity (Junk, 2012), the oligotrophic nature of the Everglades limits the production of free-floating plankton and instead features abundant periphyton mats and macrophytes (Childers et al., 2006) whose remains are preserved as floc (Neto et al., 2006) and OM rich soils (Childers et al., 2003).

The GEE has experienced large changes in ecosystem structure and function as a result of increased anthropogenic nutrient loading and hydrologic changes (Noe et al., 2001; Noe and Childers, 2007). Nutrient loading (especially phosphorus, P) in the GEE has been a major concern and has been implicated in causing changes in vegetation, peat accretion rates, and soil microbial activity (Childers et al., 2003; Wright and Reddy, 2001). The enhanced heterotrophic microbial activity that can result from P loading has the potential to increase OC turnover, leading to an increased supply of bio-available nutrients to emergent macrophytes and periphyton as well as higher nutrient concentrations in the water column (Wright and Reddy, 2001). Increased nutrient concentrations in the northern part of the ENP may influence carbon mineralization rates of peat soils (Amador and Jones, 1995; DeBusk and Reddy, 1998; Wright and Reddy, 2001) and decomposing plant litter (Corstanje et al., 2006; DeBusk and Reddy, 2005), decomposition of organic matter (OM) (Newman et al., 2001), soil organic nitrogen mineralization (White and Reddy, 2000), and may be the cause for the high dissolved OM export from the canals in the Everglades Agricultural Areas (Yamashita et al., 2010).

While numerous OC mineralization studies have focused on peat soils of the Water Conservation Areas (Amador and Jones, 1993, 1995; DeBusk and Reddy, 2003; Newman et al., 2001; Wright and Reddy, 2001; Wright et al., 2009), there is a paucity of published work on floc. Floc in the GEE is an unconsolidated layer of particulate matter, known to be composed mainly of an assemblage of decaying periphyton, higher plant detritus and carbonates (Noe et al., 2003). Previous studies have shown that the OM composition of floc is controlled by local vegetation inputs, including a significant contribution from periphyton (Neto et al., 2006; Pisani et al., 2013), filamentous green algae (Gao et al., 2007), and submerged aquatic vegetation such as *Utricularia* species (Troxler and Richards, 2009). Recent models of floc transport (Larsen et al., 2009a,b) have implied its importance in the formation and maintenance of the ridge and slough landscape in the GEE. It is believed that floc has limited mobility (Larsen et al., 2009a) although some authors have suggested that floc and periphyton are mobile enough to reach the estuarine areas of the GEE (Jaffé et al., 2001; Pisani et al., 2013).

On a mass per unit area basis, floc is known to contain less P than Everglades' soils (Noe and Childers, 2007). The P stored in the floc can either be incorporated into the soil by diffusive flux and particle settling, or enter the water column through diffusion and particle suspension (Noe et al., 2003) and through light-induced dissolution processes (Pisani et al., 2011). Furthermore, flocculent materials may constitute an important component of the detrital food chain in this wetland ecosystem (Belicka et al., 2012; Williams and Trexler, 2006). Although floc is ubiquitous in the GEE not much is known about its biogeochemical dynamics in this environment. It is therefore important to understand floc bio-reactivity in terms of CO_2 respiration and potential effects of