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Influence of the Wax Lake Delta sediment diversion on aboveground plant productivity and carbon storage in deltaic island and mainland coastal marshes

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ABSTRACT

Coastal Louisiana is experiencing a significant loss of coastal wetland area due to increasing sea level rise, subsidence, sediment starvation and marsh collapse. The construction of large scale Mississippi River sediment diversions is currently being planned in an effort to help combat coastal wetlands losses at a rate of >50 km^{-2} y^{-1}. The Wax Lake Delta (WLD) is currently being used as a model for evaluating potential land gain from large scale diversions of Mississippi River water and sediment. In this study, we determine the impact of the WLD diversion on plant production at newly formed islands within the delta and adjacent, mainland freshwater marshes. Plant aboveground productivity, sediment nutrient status and short term accretion were measured at three locations on a transect at each of three fresh water marsh sites along Hog Bayou and at six newly formed emerging island sites in the delta. Spring flooding has resulted in a greater increase in plant production and consequently, greater carbon sequestration potential in adjacent mainland marshes compared to the newly formed island sites, which contain less total carbon (C), nitrogen (N), and phosphorus (P) in the sediment. While sediment diversions are predicted to create land, as seen in island formation in the WLD, the greatest benefit of river sediment diversions from a carbon credit perspective might be to the adjacent freshwater mainland marshes for several reasons. Both greater plant production and sediment C accumulation are two important factors for marsh stability, while perhaps even more critical, is the prevention of the loss of stored sediment C in the marsh profile. This stored C would be lost without the introduction of freshwater, nutrients and sediment through river sediment diversion efforts.

1. Introduction

Coastal wetland loss in Louisiana is an artifact of disconnecting or decoupling the Lower Mississippi River from the surrounding marshes through the installation of flood control levees (Blum and Roberts, 2009). This near continuous run of levees protects communities from spring time floods but also prevents the coastal marshes from receiving annual flood pulses of freshwater and vital sediment needed to keep pace with rising sea level (Day et al., 2007).

Marsh accretion studies in coastal Louisiana show that some marshes can vertically accrete and keep pace with historical subsidence and sea level rise for a period of time (DeLaune et al., 1992). However, a critical level of mineral sediment and organic matter is necessary for accretion rates in the marsh profile to keep pace with increase in water level, especially in a rapidly subsiding coastal environment coupled with increasing sea level rise (DeLaune et al., 2013). Additionally, mineral sediment requirements will increase with increasing salinity and marsh inundation in coastal marshes due to sea level rise. In general, there is limited availability of mineral sediment in Louisiana's coastal region available for maintaining viable marshes due to extensive historical leveeing and the fact that the Mississippi River carries only one half of the historical sediment load, due primarily to the presence of dams further up the watershed (Blum and Roberts, 2009). Sediment input into coastal marshes is required for successful restoration due to high coastal subsidence and increases in global sea level (Reed et al., 1997; Boustany, 2010; DeLaune and White, 2012; McKay

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et al., 2010; Day et al., 2013).

Many researchers and natural resource managers who deal with preserving Louisiana coastal wetlands now realize that meaningful long term and large scale restoration must involve major sediment inputs from the Mississippi River (Day et al., 2009). The feasibility of using river sediment diversions is currently being modeled under the direction of the Louisiana Coastal Protection and Restoration Authority and the U.S. Army Corps of Engineers. Mississippi River diversions can be classified as either freshwater (designed primarily to affect salinity) or sediment (designed to primarily deliver sediment) diversions (Nyman, 2014). Freshwater river diversions have been shown to be an effective ecosystem management tool for slowing the rate of wetland loss by reducing salinity stress on plants and therefore encouraging organic matter accretion (DeLaune et al., 2013).

The benefits of freshwater and sediment input to coastal marsh sites can be fourfold: 1) increase mineral sediment available for vertical accretion; 2) increase in nutrient (N and P available for plant growth) supply; 3) lowering of salinity which reduces plant stress and sediment requirement for vertical maintenance of the marsh surface; 4) increase in iron content of marsh sediment which lowers sulfide content of marsh profile (DeLaune et al., 2013).

There has been a recent controversy surrounding freshwater river diversions, which deliver very little sediment, on coastal marsh stability. While nutrient removal is an important ecosystem service of wetlands, there has been some concern that nutrient loading can have adverse effects on wetland resilience, primarily reduced macrophyte rooting depth (Darby and Turner, 2008a, 2008b; VanZomeren et al., 2012). The Mississippi River water has elevated concentrations of nutrients, in particular NO_3–N as the dominant bioavailable inorganic N form (White et al., 2009; Roy et al., 2013).

While the issue of marsh resilience is focused on freshwater diversions, wetlands that receive both water and sediment do not appear to be affected by lower soil bulk density. For example, Roberts et al. (2015) and Day et al. (2012) have shown that marsh in close proximity to the Wax Lake Outlet Sub Delta (WLD) as well as surrounding marshes benefit from the sediment introduction leading to increased bulk density compared to the highly organic, sediment starved marshes of Barataria basin (DeLaune et al., 1990). Perez et al. (2003) also reported that adjacent Atchafalaya River discharges are efficient mechanism of nutrient delivery to adjacent wetlands and are important in maintaining marsh stability. Concomitant with marsh development, the total soil nutrient status increases, providing an important feedback for sustaining marsh growth and research by VanZomeren et al. (2012) has shown that plants and soil will immobilize up to 36% of nitrate available in the diverted river water. Pezeshki et al. (1987a; 1987b) have demonstrated that the lowering of salinity stress on coastal marshes leads to increased plant growth. Finally, DeLaune et al. (2003) have demonstrated that the increased Fe content of the mineral sediment binds with sulfide lowering the sulfide content proven to be detrimental to plant growth.

The Atchafalaya River, the largest distributary of the Mississippi River, has formed prograding deltaic features along the Gulf of Mexico coastline. The Atchafalaya River Delta complex is composed of two such prograding deltaic features; the Atchafalaya River Sub Delta (ARD) and Wax Lake Outlet Sub Delta (WLD). This area is one of the few areas where active land building is occurring along the Louisiana Gulf Coast (Rosen and Xu, 2013), in stark juxtaposition to large tracts of coastal land loss which characterizes much of the deltaic coastline (DeLaune and White, 2012). Large scale restoration of the Louisiana coast must include sediment from the Mississippi river mimicking how the existing delta was formed. Diversion of Mississippi River water and sediment is the preferred method of introducing sediment into areas that need to be maintained or rebuilt (Blum and Roberts, 2009). In the case of the Atchafalaya Delta and Wax Lake Delta, the flood cycle is the underlying process that provides and mobilizes sediment for delta building and surrounding marsh accretion. Rosen and Xu (2013) reported that over a 21 year period (1989–2010), a gain of 59 km^2 in area of coastal wetland was realized, with the Atchafalaya River delta accounting for 58% of the gain and 42% gain within the Wax Lake outlet delta. As a result, the Wax Lake and Atchafalaya Deltas have been referenced as physical models for projected results from large scale Mississippi River sediment diversions.

Much of the emphasis on diversion thus far has been on how fast land will be built and develops over time. This is an important component of river diversion-centric restoration, but perhaps an equally important component, is the potential for positively influencing adjacent and surrounding coastal wetland areas through sediment subsidy. Consequently, data is needed on sediment accretion and nutrient sediment content correlated to coastal marsh plant productivity in coastal marshes; both located directly within the active delta and at marshes more distally located from the delta in order to estimate the impact of sediment diversion operations on surrounding marshland resilience.

The effect of the spring flood cycle on plant production from both within the Wax Lake Delta (WLD) proper and at adjacent coastal marshes is relatively unknown. In the case of the Wax Lake Delta (WLD), it is clear that the flood cycle is the underlying process that provides sediment for delta-building and increasing stability of surrounding marsh by enhancing marsh stability (Roberts et al., 2015). In this study, we compare vegetation productivity related to sediment properties at sites on a recently formed island within the delta as well as at adjacent well-established, freshwater coastal marsh sites under the hydrodynamic influence of the Wax Lake Delta.

2. Materials and methods

2.1. Study area

The study area of Wax Lake delta and surrounding marshlands are microtidal coastal regions. However, previous studies have noted that wind speed and direction largely control water levels in the estuarine environments of Louisiana (Roberts et al., 2015). In fact, it has been documented for these marsh sites that winter cold fronts are correlated with inorganic marsh soil accretion events, evidence of sediment distribution from the delta to surrounding marsh (Roberts et al., 2015). The vegetation community at the Hog Bayou marsh study sites consisted of a robust mixture of freshwater species dominated by *Phragmites australis*, *Panicum hemitomon*, *Typha latifolia*, and *Carex hyalinolepis*. The vegetation community on the Wax Lake Delta Island had less vegetation species, consisting primarily of *Colocasia esculenta*, *Schoenoplectus* sp., and *Triadenum virginicum*. These co-dominants and other vegetation species noted at the sites are typical of the freshwater vegetation type in coastal Louisiana (Sasser et al., 2014).

2.2. Sediment characteristics

Surface sediment (0–15 cm) was collected by push core at identical marsh and island sites where aboveground biomass was collected. Bulk density was determined on a weight basis for each core section based on dry weight per unit volume of individual section and the C and N content of the sediment was determined on dried, ground sub-samples using a total carbon and nitrogen analyzer (Heraeus CHN-O-Rapid Elemental Analyzer: DIC, Inc., Joliet, IL). Approximately 50 mg of each sample was weighed into a