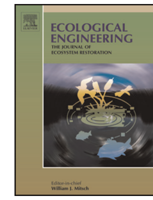
Ecological Engineering 81 (2015) 133–139

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng



Inundation and salinity impacts to above- and belowground productivity in *Spartina patens* and *Spartina alterniflora* in the Mississippi River deltaic plain: Implications for using river diversions as restoration tools

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ARTICLE INFO

Article history:
Received 12 September 2014
Received in revised form 2 March 2015
Accepted 5 April 2015
Available online 11 April 2015

Keywords:
Climate change
Coastal wetlands
Productivity
River deltas
River diversions
Sea-level rise

ABSTRACT

Inundation and salinity directly affect plant productivity and processes that regulate vertical accretion in coastal wetlands, and are expected to increase as sea level continues to rise. In the Mississippi River deltaic plain, river diversions, which are being implemented as ecosystem restoration tools, can also strongly increase inundation in coastal wetlands. We used an in situ mesocosm approach to examine how varying salinity (two levels) and inundation rates (six levels) influenced end-of-season above- and belowground biomass of *Spartina patens* and *Spartina alterniflora* during the growing season (March–October) in 2011. Above- and belowground biomass was highest in both species at higher elevations when inundation was minimal, and decreased exponentially with decreased elevation and increased flood duration. This negative biomass response to flooding was more pronounced in *S. patens* than in *S. alterniflora*, and *S. patens* also showed stronger biomass reductions at higher salinities. This salinity effect was absent for belowground biomass in *S. alterniflora*. These findings suggest that even subtle increases in sea level may lead to substantial reductions in productivity and organic accretion, and also illustrate the importance of considering the inundation tolerance of co-dominant species in receiving areas when utilizing river diversions for delta restoration.

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1. Introduction

Eustatic sea-level rise (ESLR; 3 mm yr^{-1}; IPCC, 2007; Ablain et al., 2009) is a critical problem in coastal regions today. This crisis is exacerbated in subsiding deltas where subsidence contributes to relative sea-level rise (RSLR) rates that far exceed ESLR alone. Vertical accretion, the mechanism by which coastal wetlands maintain their vertical position in the tidal frame despite high RSLR rates, can occur either through mineral sediment deposition or organic matter accumulation (Morris et al., 2002). Though the relative importance of these processes varies with hydrogeomorphic setting, both are strongly regulated by the quantity of wetland vegetation present and the rate at which it is produced. Deposition in vegetated settings is largely governed by reductions in flow turbulence and wave dampening by plant stems (Leonard and Luther, 1995; Christiansen et al., 2000; Neumeier and Ciavola, 2004), whereas organic matter accumulation primarily results from the balance between root growth and decomposition (McCaffrey and Thompson, 1980).

Primary productivity of emergent wetland vegetation can be impaired by excessive inundation and salinity regimes (Mendelssohn and McKee, 1988; McKee and Mendelssohn, 1989), which can lead to decreased trapping efficiency aboveground (Leonard and Croft, 2006) and diminished organic matter accumulation belowground (Nyman et al., 1993), ultimately increasing submergence and further diminishing productivity. Unabated, this cycle can lead to peat collapse, erosion, and eventually convert wetland landscapes to open water (DeLaune et al., 1994).

In the Mississippi River deltaic plain, RSLR rates as high as 10 mm yr^{-1} are not uncommon (Coleman et al., 1998). The fluvial sediment supply that once created and maintained this region has been essentially eliminated for nearly a century due to the construction of containment levees along the river's banks. Additionally, numerous pipeline canals now exist on the deltaic plain and have increased flooding depth and duration of the surrounding marsh due to impoundment associated with dredge spoil placement along canal banks. Canals have also increased marsh salinities by providing conduits for enhanced estuary–ocean

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http://dx.doi.org/10.1016/j.ecoleng.2015.04.035
0925-8574/Published by Elsevier B.V.

exchange (Turner, 1997). Together, these circumstances have contributed to the loss of nearly 5000 km^2 of coastal wetlands since 1932 (Couvillion et al., 2011), with over 50% of that loss directly attributed to submergence and increased flooding (Penland et al., 2001).

As part of a comprehensive restoration plan for a sustainable coast (State of Louisiana, 2012), a series of Mississippi River diversions are being implemented to stimulate delta growth through increased sediment supply to coastal wetlands. The effect of existing diversions on the deltaic landscape over the last two decades has been disputed. Some studies have shown diversions to stimulate mineral sediment accretion (DeLaune et al., 2003; Wheelock, 2003) and above- and belowground productivity in emergent vegetation (Day et al., 2013; DeLaune et al., 2013) as a result of increased sediment and nutrient inputs. However these findings are confounded by the devastation brought about by hurricane Katrina in 2005, in which over 100 km^2 of wetlands were converted to open water in upper Breton Sound (Barras, 2006). This region is the receiving basin of the Caernarvon freshwater diversion, a diversion that has been operational for over 20 years primarily for the purpose of maintaining optimal salinity regimes in Breton Sound for commercial shellfish production and landings (U.S. Army Corps of Engineers, 1984). Other areas much further away from the Caernarvon diversion, but still in the storm's direct path, were much more resilient to storm impacts (Barras, 2006). A variety of mechanisms linking this land loss to river diversions have been put forth, including excessive nutrient loading (Kearney et al., 2011), salinity reduction (Howes et al., 2010), and sulfur accumulation in wetland soils (Swarzenski et al., 2008).

In addition to delivering large quantities of sediment and nutrients, river diversions can also result in elevated water levels and prolonged inundation of marshes (Snedden et al., 2007a,b). Thus, whereas diversions may provide much needed mineral sediments for sustaining deltas, these subsidies may come at the expense of vegetation productivity and actually increase submergence brought about by sea-level rise if diversions induce flooding regimes that exceed physiological tolerances of co-dominant plant species in their receiving basins. A clearer understanding of how wetland plants respond to increased hydroperiod is vital not only for forecasting impacts of sea level rise to coastal wetlands, but also for successfully using river diversions to restore deltas.

We examined how variations in inundation duration influence end-of-season above- and belowground biomass in *S. patens* and *S. alterniflora*, two common marsh vegetation species of the Mississippi River deltaic plain. We conducted a mesocosm experiment in the field to simulate flooding regimes at six different marsh elevations and to allow for natural variations in salinity and sea level, driven by a combination of lunar tides and meteorological events. Our objective was to generate above- and belowground biomass response curves for the two species as a function of inundation duration. We also explored how salinity variation may modify the inundation responses of the two species.

2. Materials and methods

Two sites in the Breton Sound estuary were selected for the study (Fig. 1). One situated in middle Breton Sound (MBS; 29.69°N, 89.76°W), is dominated by *S. patens*; whereas the other, in lower Breton Sound (LBS; 29.66°N, 89.60°W), is dominated by *S. alterniflora*. Mean salinity at LBS exceeded that at MBS during the study, though mean water levels at the two sites were similar (Table 1). Water levels at both sites are strongly meteorologically-driven, and the lunar tide only accounts for around 20% and 50% of total water level variance at MBS and LBS, respectively. The Caernarvon freshwater diversion is situated at the head of basin (Fig. 1). While it is capable of discharging Mississippi River water to

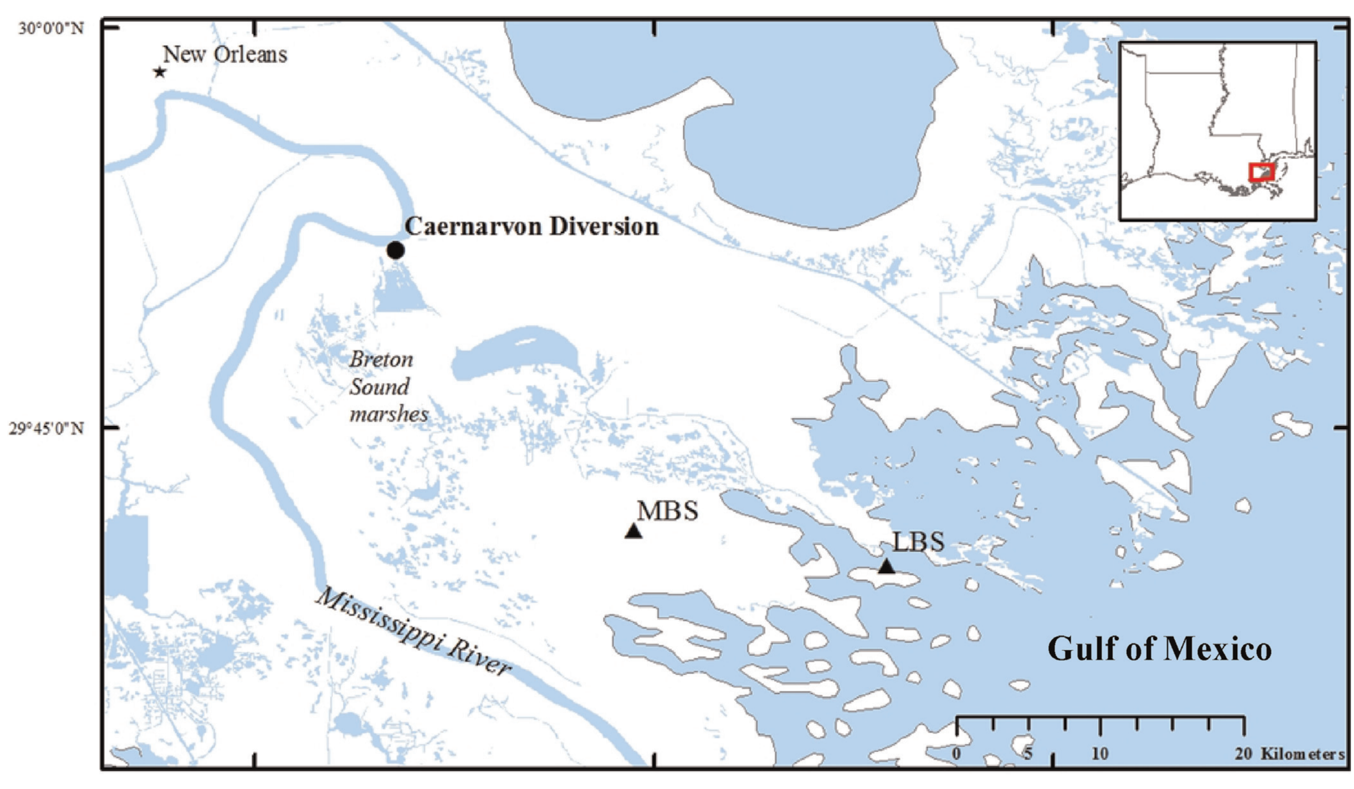

Fig. 1. The location of the Breton Sound estuary, including the middle Breton Sound (MBS) and lower (LBS) Breton Sound sites where marsh organs were deployed, and the Caernarvon freshwater diversion.