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Impacts of Mississippi River diversions on salinity gradients in a deltaic Louisiana estuary: Ecological and management implications

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A R T I C L E I N F O

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A B S T R A C T

Large-scale river diversions on the lower Mississippi River are considered to be an important component of wetland restoration efforts in coastal Louisiana. Diversions are used primarily for salinity control but increasingly proposed also as a major way to deliver sediments and nutrients to coastal wetlands impacted by the construction of flood control levees. We used a coupled hydrology–hydrodynamics model of the Barataria estuary, a site of the Davis Pond Diversion – the world's largest river diversion project, to examine salinity variations under different diversion discharge scenarios. Discharge scenarios were selected based on actual freshwater discharges in different years and management alternatives that included a scenario with several new diversions. The model results indicate that river diversions strongly affect salinities only in the middle section of the Barataria estuary. The upper parts of the estuary are fresh most of the time and so the excess fresh water from river diversions has only a minor impact on salinity in this region. Also, the Davis Pond diversion has little impact on salinities in the coastal section of the estuary because of strong marine influence in this area adjacent to the Gulf of Mexico. Interestingly, the predicted salinity differences between different model scenarios can be as high as 10 in some months and places. These differences can be biologically significant depending on the salinity tolerance of different species and could cause a shift in community composition within the affected region.

1. Introduction

Estuaries in Louisiana that historically received Mississippi River water are now devoid of riverine freshwater inputs primarily because of closure of active distributaries and the artificial flood control levees that have been constructed along the Mississippi River during the last 100 years (Day et al., 1997; Turner, 1997). Diverting water from the Mississippi River back into the estuaries and coastal wetlands was proposed over three decades ago (Chatry et al., 1983). The primary motivation at the time was to prevent increased salinities in the oyster producing regions adjacent to the Mississippi River Delta. The use of river diversions was later expanded to include marsh nourishment via riverine sediment and nutrient additions (Gagliano et al., 1971; Day and Templet, 1989), as well as control nutrient loading from the Mississippi River to the Gulf of Mexico (Mitsch et al., 2001). Some scientists and managers agree that controlled diversions of the river water back into coastal wetlands are important mechanisms that could reverse coastal land loss (e.g., Boesch et al., 1994). They are also thought to be effective in reducing high salinities caused by salt water intrusions and reduced tidal inundation (Boesch et al., 1994), to stimulate marsh growth by providing sediments and nutrients, and supply iron that can precipitate toxic sulfides (DeLaune et al., 2003). There are concerns, however, that diversions may increase nutrient inputs and thus create eutrophication problems in estuaries and wetlands adjacent to the diversion sites (Dortch et al., 1999). For example, high nutrient concentrations in the Mississippi and Atchafalaya Rivers have led to eutrophication in stratified coastal waters of the northern Gulf of Mexico, where a seasonally severe hypoxic zone has persisted for several decades (Justic et al., 2002; Rabalais et al., 2002, 2007). The concerns of increased nutrient inputs are not limited to the water column. High nutrient concentrations could also adversely affect marsh plants by causing faster soil decomposition (Bragazza et al., 2006; Swarzenski et al., 2008), lower soil strength (Swarzenski et al., 2008; Turner et al., 2009) and lower accumulation of below-ground biomass (Darby and Turner, 2008a,b).

There are two major controlled river diversions in Louisiana, Caernarvon and Davis Pond (Fig. 1). The Caernarvon diversion

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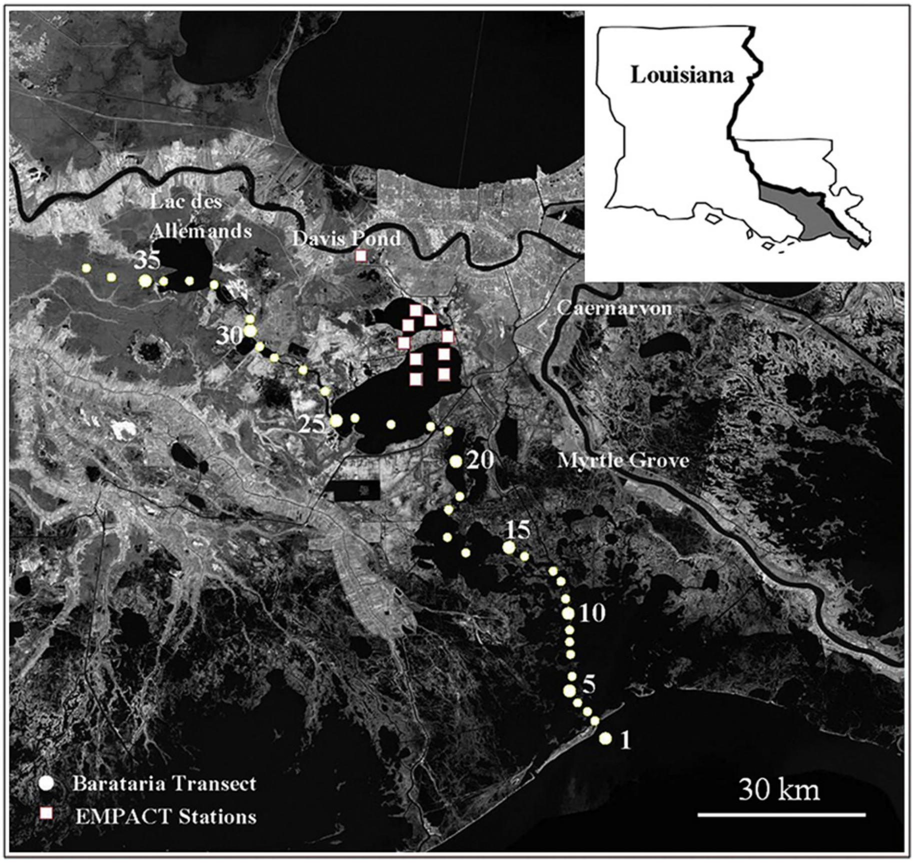

Fig. 1. The map of the Barataria estuary depicting major water bodies, the Davis Pond, Lac des Allemands and Myrtle Grove diversions and locations of sampling stations. White dots denote the Barataria estuary transect stations and white squares are the EMPACT project stations.

(maximum design discharge = 227 $m^3 s^{-1}$) is located on the east bank of the Mississippi River and diverts fresh water into the Breton Sound estuary. The Davis Pond diversion (maximum design discharge = 300 $m^3 s^{-1}$) is located on the west bank of the Mississippi River and diverts water into the Barataria estuary (Fig. 1). Mississippi River diversions are considered to be an important part of future restoration plans for coastal Louisiana (Reed and Wilson, 2004). The "Coast 2050" report, for example, outlines strategies to use river diversions to maintain suitable salinity gradients in estuaries (LCWCRTF, 1998; LCA, 2004). To this end, a number of new river diversions were proposed, including three additional diversions into the Barataria estuary (Fig. 1) – two into Lac des Allemands (28 $m^3 s^{-1}$ each) and another at Myrtle Grove (142 $m^3 s^{-1}$). Recently, the state of Louisiana has released a Louisiana's Comprehensive Master Plan for a Sustainable Coast (2012) that proposes dramatic expansion of river diversions into the Barataria Basin, including a Mid-Barataria and a Lower Barataria diversion, each conveying a maximum of 1415 $m^3 s^{-1}$.

In this paper, we examine the impacts of the magnitude and timing of freshwater diversion inflows on salinity in the Barataria Estuary for a variety of observed and hypothetical discharge scenarios. We use a 2-dimensional (2-D) high-resolution coupled hydrology–hydrodynamic model that was previously developed by our research team (Inoue et al., 2008; Das et al., 2011).

2. Study area

The Barataria estuary (Fig. 1) is a 120 km long estuary located in the north-central Gulf of Mexico, just to the west of the Mississippi River. The northern half of the estuary contains several large lakes. The southern half of the estuary contains tidally influenced marshes interconnected by ponds, lakes, and channels that finally empty into a large bay system behind the barrier islands. The average depth of the estuary is about 2 m. The estuary is connected to the Gulf of Mexico through four tidal passes (Barataria, Caminada, Abel and Quatre Bayou). The tropic diurnal tide range is approximately 0.35 m at the coastal endpoint, but decreases by an order of magnitude as tide progresses up the estuary. Salinities range from near zero in the upper reaches of the estuary to about 25 in the southernmost section of the estuary. Fresh water enters the Barataria estuary mainly from four sources: rainfall, stream runoff, man-made diversions and siphons, and from the Gulf Intracoastal Waterway. Due to its proximity to the Mississippi River Birdfoot Delta, the coastal section of the estuary is influenced by discharges from the Mississippi River.

With its maximum design discharge capacity of 300 $m^3 s^{-1}$, the Davis Pond diversion is the largest man-made freshwater diversion in the world (LaCoast, 2002). The diversion structure is located on the bank of the Mississippi River 192 km above head of passes and is designed to convey water through the river's west containment levee into an outflow channel, and then into Lake Cataouatche (Fig. 2). The primary purpose of the Davis Pond diversion, when it became operational in 2002, was salinity control in the Barataria estuary (Allison and Meselhe, 2010). Salinity intrusions from the Gulf of Mexico have historically pushed the brackish, intermediate and freshwater zones farther up the estuary. Reduced freshwater inflow conditions have the potential to move the 5 isohaline over 20 km into the estuary (Swenson, 2003) and so to be effective, the