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Water quality of a coastal Louisiana swamp and how dredging is undermining restoration efforts

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ABSTRACT

The Bayou Boeuf Basin (BBB), a sub-basin of the Barataria Basin estuary in coastal Louisiana, consists of forested and floating wetlands receiving drainage from surrounding agricultural fields and urban watersheds. We characterized surface water quality in the BBB, and determined through hydrologic modeling if a series of levee breaks along major drainage channels would significantly improve water quality by allowing flow into surrounding wetlands. Surface water monitoring found surrounding sugarcane farm fields to be major sources of nutrient and sediment loading. Hydrological modeling indicated that levee breaks would increase N reduction from the current 21.4% to only 29.2%, which is much lower than the anticipated 90–100% removal rate. This was due to several factors, one them being dredging of main drainage channels to such a degree that water levels do not rise much above the surrounding wetland elevation even during severe storms, so only a very small fraction of the stormwater carried in the channel is exposed to wetlands. These unexpected results provide insight into an undoubtedly pervasive problem in human dominated wetland systems; that of decreased flooding during storm events due to channel deepening by dredging activities. Additional water quality management practices should be implemented at the farm field level, prior to water entering major drainage canals.

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1. Introduction

The Bayou Boeuf Basin (BBB) includes a network of bayous and streams that drain surrounding agricultural fields, as well as the northeast portion of the city of Thibodaux, Louisiana (Fig. 1). Stormwater runoff from agricultural and developed areas contains high levels of nutrients, sediments, and other pollutants, and is rapidly routed through the BBB with minimal retention or filtration. Prior to the construction of flood control levees, the BBB was an overflow swamp of Bayou Lafourche and the Mississippi River (Roberts, 1997), with spring flooding providing sediments, nutrients, and freshwater (Day et al., 2012). Today, flood control levees prevent this overflow, and water levels in the basin are controlled by rainfall and stormwater runoff from the surrounding uplands. Populated upland areas are confined to the perimeter of the basin, accounting for 22.7% of the total basin area, of which 10.0% (711 ha) is urbanized and 90.0% (6386 ha) is in various forms of agriculture, mostly sugarcane farming (43.7%, 3100 ha; Braud et al., 2006). Stormwater runoff from sugarcane farm fields is a major source of sediment and nutrient pollution in the upper Barataria Basin (Southwick et al., 2002; LDEQ, 2007; Yu et al., 2008), and a majority of sediment and nutrient pollution in the BBB is from stormwater drainage of farm fields surrounding the perimeter of the basin (LDEQ, 2004).

One proposed way to improve water quality as well as wetland viability is to restore the hydrological connectivity of the basin so that upland runoff is directed through surrounding wetlands rather than past them. Numerous studies have shown that wetlands efficiently remove nutrients and sediments from overlying water (Nichols, 1983; Knight et al., 1987; Martin, 1988; Kantrowit and Woodham, 1995; Kadlec and Knight, 1996; Raisin et al., 1997; Day et al., 2004; Hunter et al., 2009). By allowing stormwater runoff to flow through wetlands rather than past them, water quality would be improved and forest productivity and reproductive success increased (Hopkinson and Day, 1980a,b). Water quality in the

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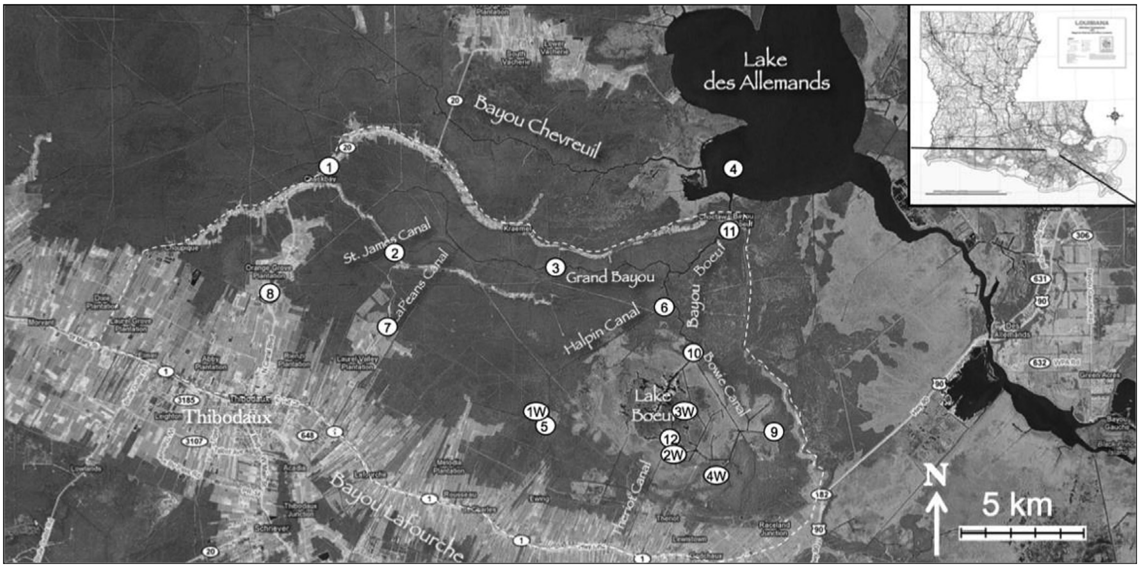

Fig. 1. Location of Bayou Boeuf Basin, a sub-basin within the larger Barataria Basin, Louisiana. Location of water quality sampling sites are indicated by numbers. 'W's refer to wetland sites, otherwise samples were collected in the channel. The dashed line indicates watershed boundary.

main channels of the basin is greatly influenced by non-point source agricultural runoff, and to a lesser extent by residential and commercial point sources (LDEQ, 2004, 2007). Water quality in the interior wetlands, however, is often quite different because of hydrological modifications, mainly low levee spoil banks formed from drainage canal and pipeline construction, which have isolated surrounding wetlands from the main drainage channels. Spoil banks have been found to decrease the net flux of materials to and from nearby wetlands, making these areas prone to excessive inundation (Swenson and Turner, 1987; Bryant and Chabreck, 1998). Not only do spoil banks decrease the quantity of sediments and nutrients available to maintain wetland elevation (Boumans and Day, 1994; Reed et al., 1997), but they also can increase flooding and lower soil Eh levels such that anoxic conditions and high sulfide concentrations cause dieback of vegetation (Mendelssohn et al., 1981; Cahoon and Turner, 1989; Mendelssohn and Morris, 2000).

The primary mechanisms by which wetlands remove nutrients from the water column are physical settling and filtration, chemical precipitation and adsorption reactions, and biological processes such as storage in vegetation, and denitrification and volatization (Reddy and DeLaune, 2008). The ability of wetlands to remove nutrients from inflowing water is primarily dependent on the nutrient species, residence time, and the area of receiving wetlands (Kadlec and Knight, 1996; Dettmann, 2001; Day et al., 2004). Nutrient input into a wetland is normally expressed as a loading rate, which integrates nutrient concentration, inflow volume, and the area of the receiving wetland, and is generally expressed as the amount of nutrient introduced per unit area of wetland per unit time; normally as g N or P per m^2/yr. Richardson and Nichols (1985) found a clear relationship between loading rate and removal efficiency for N and P in a review of wetlands receiving regular inputs of municipal effluent, which have similar nutrient removal efficiencies as wetlands receiving stormwater runoff (Carleton et al., 2001). Comparable nutrient loading-uptake rates have also been reported for Louisiana coastal wetlands receiving water from the Mississippi River (Lane et al., 1999, 2004), from the Atchafalaya River (Smith et al., 1985; Lane et al., 2002), and for wetlands in the upper Mississippi River basin (Mitsch et al., 2001, 2005), as well as from other areas (Fisher and Acreman, 2004). Nutrient uptake is also influenced by temperature and the hydrology of the specific wetland site. For example, when flow becomes overly channelized in a wetland it decreases the physical interface and time of interaction between the water and the surrounding landscape, resulting in lowered nutrient removal efficiency.

Intuitively, the most cost-effective way to restore the connection between wetlands and surrounding waterways would be a series of levee breaks along major drainage channels to allow water to flow into surrounding wetlands during storm events. We used FVCOM (Chen et al., 2003, 2006, 2007, 2008; Huang et al., 2008b) to simulate the hydrodynamics of strategic removal of spoil banks in the BBB (Huang et al., 2014).

2. Methods

2.1. Study area

Currently, the BBB is hydrologically bounded to the north and west by a natural levee between Grand Bayou and Bayou Chevreuil, to the south by the natural levee of Bayou Lafourche, and to the east by Louisiana Highway 307 (Fig. 1). Inflow from outside the basin occurs at the western end of Grand Bayou (a distributary of Bayou Citamon), and to some extent through Bayou Boeuf via Lac des Allemands during storms or wind induced high water in the greater Barataria Basin. Theriot Canal connects to Bayou Lafourche, but hydrological exchange is limited by a gated structure that is normally closed except to allow boats to pass (LDEQ, 2004).

The construction of roads, flood-control levees, access canals, and accompanying spoil banks have altered the natural hydrology of the BBB. Louisiana Highway 20 was completed in 1930, blocking flow from upper Barataria Basin except for a few culverts and bridges over major bayous, such as Grand Bayou (Conner et al., 1981, Fig. 1). Bayou Chevreuil was dredged in the 1950's, leaving spoil deposits along the sides, impeding exchange of water and materials between the forests and bayou (LDEQ, 2004).

Virgin stands of baldcypress forests were logged in the BBB between 1900 and 1920 (Mancil, 1972, 1980). After logging, water tupelo (*Nyssa aquatica*) and maple (*Acer rubrum* var. *drummondii*) increased in importance (Conner and Day, 1976). More recently, interruption of riverine inputs and permanent flooded conditions