Sediment chemistry in a hydrologically restored bottomland hardwood forest in Midwestern US

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This paper was presented as a poster at the 2005 American Ecological Engineering Society annual meeting in Columbus, Ohio on May 19-20, 2005.

Abstract

Chemistry was determined of sediments accumulated during flood pulses at a 5-ha bottomland hardwood forest located at the Olentangy River Wetland Research Park (ORWRP) in central Ohio. In the spring of 2000, hydrology was restored at forest by breaching the levee. Flat sediment traps (30 x 30 cm2) were used to collect sediment samples during spring/summer flooding events from 2003 to 2005. We investigated sediment chemistry (major elements) for: Al, B, Ca, Cu, Fe, K, Mg, Mn, Mo, Na, S, P, Zn. Al and Fe dominate the sediment chemistry and results show the elemental abundance in order of Al > Fe > Ca > K > Mg > S > P > Na > Mn > Zn > B > Cu > Mo. Correlations between Al (%) to other elements are positive with 0.95, 0.89, 0.84, 0.69, 0.67, 0.66, 0.59, 0.42 for B, Ca, K, Mn, Fe, Mo, Na, Cu respectively, while negative with 0.03, 0.50, 0.56 for P, Zn and S. Nineteen flooding pulses occurred between 2003 and 2004. Pulsing events may accelerate biogeochemical processes from flooded sediment to surface soils. Restoration of seasonally flooded bottomland forests could stimulate potentially large nutrient and Fe releases, which would eventually lead to enhanced forest productivity and biodiversity.

Introduction

Floodplain wetland ecosystems process large fluxes of energy and materials from upstream systems (Mitsch and Gosselink, 2000); allow unrestricted nutrient flux between the riparian forest and surrounding ecosystems (NRC, 2002); accelerate biogeochemical processes by sedimentation processes during flood pulses; and stimulate potentially large nutrient and Fe releases, which would eventually lead to enhanced forest productivity and biodiversity (Mitsch and Gosselink, 2000; Mitsch and Jorgensen, 2004).

A 5-ha bottomland forest restoration, a cooperative project with Ohio Department of Transportation (ODOT), was done for mitigation of a highway interchange project in downtown Columbus, Ohio. Major restoration began in 2000. Restoration/enhancement of this 5-ha (13-acre) bottomland forest involves two major management approaches: hydrologic restoration and removal of alien honeysuckle (*Lonicera mackii*). For the hydrologic restoration, four 6-m wide breeches were made in an artificial levee that runs most of the northern half length of the bottomland forest. The levee had been constructed to prevent floodwater from reaching the floodplain perhaps as long as 100 years ago. In June 2000 and again in April 2001, the levee was cut in 4 locations to allow floodwater to enter the site. Restored hydrology is expected to result in increased productivity of canopy trees in the forest in the long term and may result in some species shifts in the short term to more flood-tolerant species. The increased flooding is also expected to bring in nutrients and plant propagules, both of which will lead to enhanced forest productivity and biodiversity. Therefore, there is a need to understand how pulsing events accelerate biogeochemical processes from flooded sediment to surface soils.

The objective of this study is to investigated sediment chemistry (major elements) for: Al, B, Ca, Cu, Fe, K, Mg, Mn, Mo, Na, S, P, Zn in a hydrologically restored bottomland hardwood forest during the pulsing periods; to characterize quantify and quality of sediment chemistry (major elements); and to better understand temporal and spatial variability of sedimentation during the flooding period.

Soils results were done by Bouchard and Mitsch (1999) for pre-restoration and by Hossler and Mitsch (2004) for post - restoration.

Methods

The natural hydrology of the 5-ha bottomland forest at the Olentangy River Wetland Research Park in Columbus (Fig. 1) was partially restored, reintroducing floodwaters through the artificial levee built on the river decades before. This was done as an OSU/ODOT cooperative project by cutting 4 notches in the artificial levee in June 2000 with a variety of heavy machinery techniques while avoiding excessive damage to the remainder of the forest. The notches have allowed subsequent seasonal inundation of the floodplain forest by the river (Fig. 2).

The following field and lab methods were used in this study:

* One stream gauging station with an Ott Thalimedes data logger and YSI water quality probe was installed in the river at the northwestern corner of the ORWRP.

* 30-100 rough surface, plastic, flat (0.09 m^2) sediment traps were used to collect sediment deposits during the flooding events from 2003 to 2005.

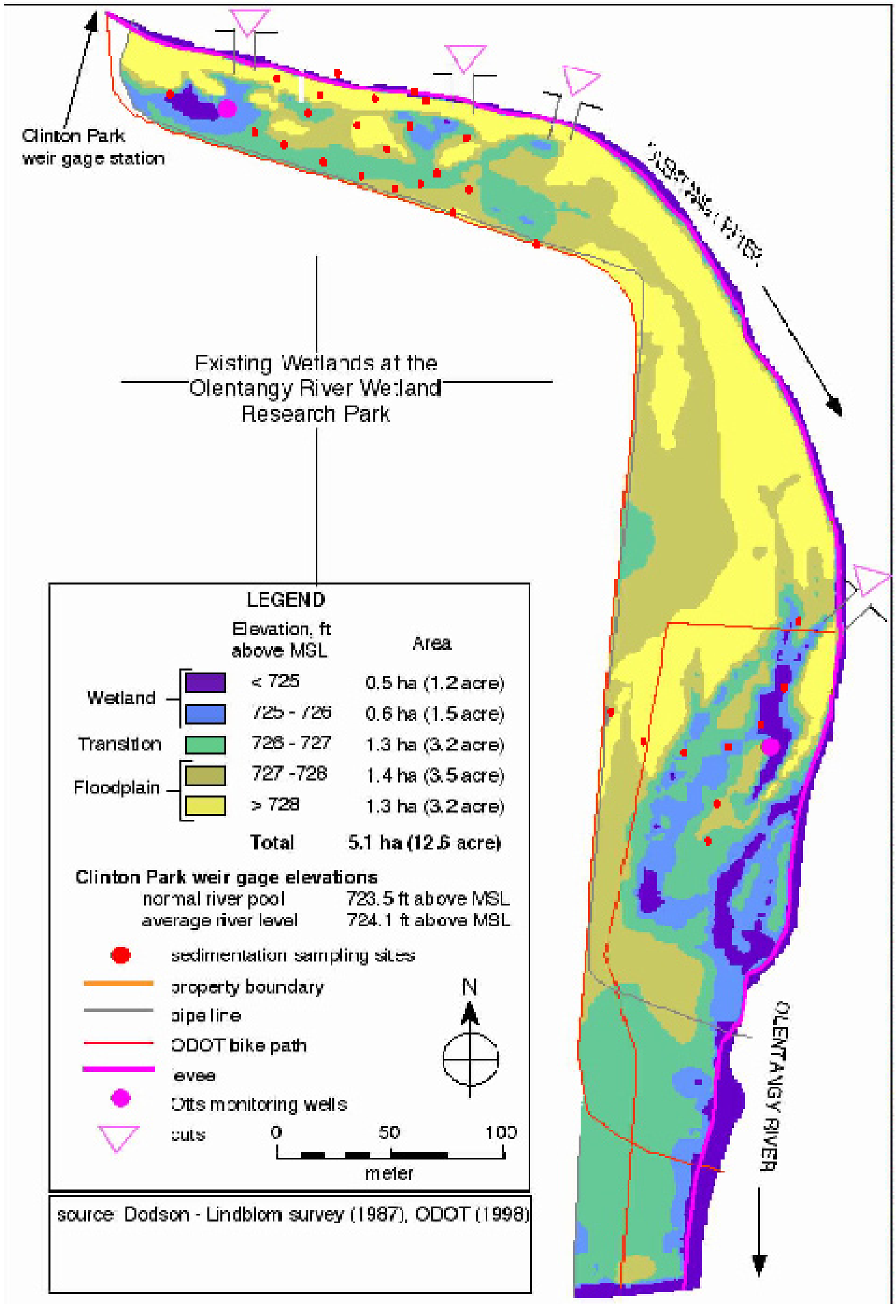

Figure 1. Study site with the bottomland forest area with elevations, Ott water level recorders locations, and sites of sediment sampling traps . The map also indicates locations of 4 "cuts" where artificial levee was breeched to allow bottomland flooding at Olentangy River Wetland Research Park.

Figure 2. Bottomland flooding a) in April soon after the initial inflow cutting and b) in April, 2004, indicating understory vegetation cover developed after two years of hydrologically restoration at the bottomland forest, Olentangy River Wetland Research Park.

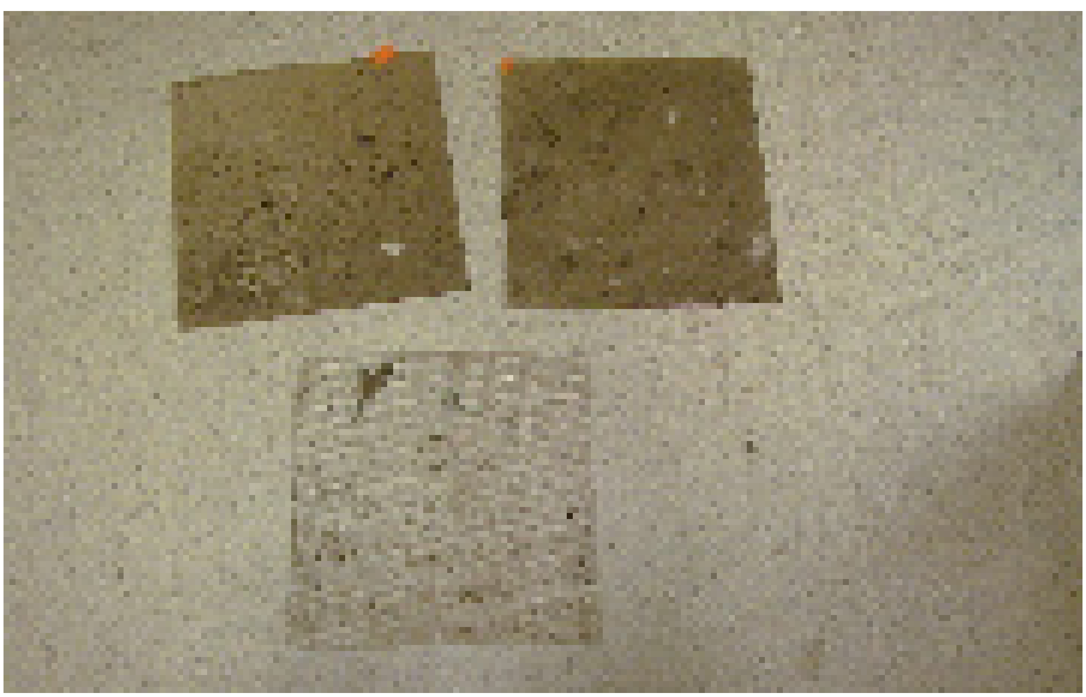

Figure 3. Flat sampling traps used in this study (size = 0.09 m^2)

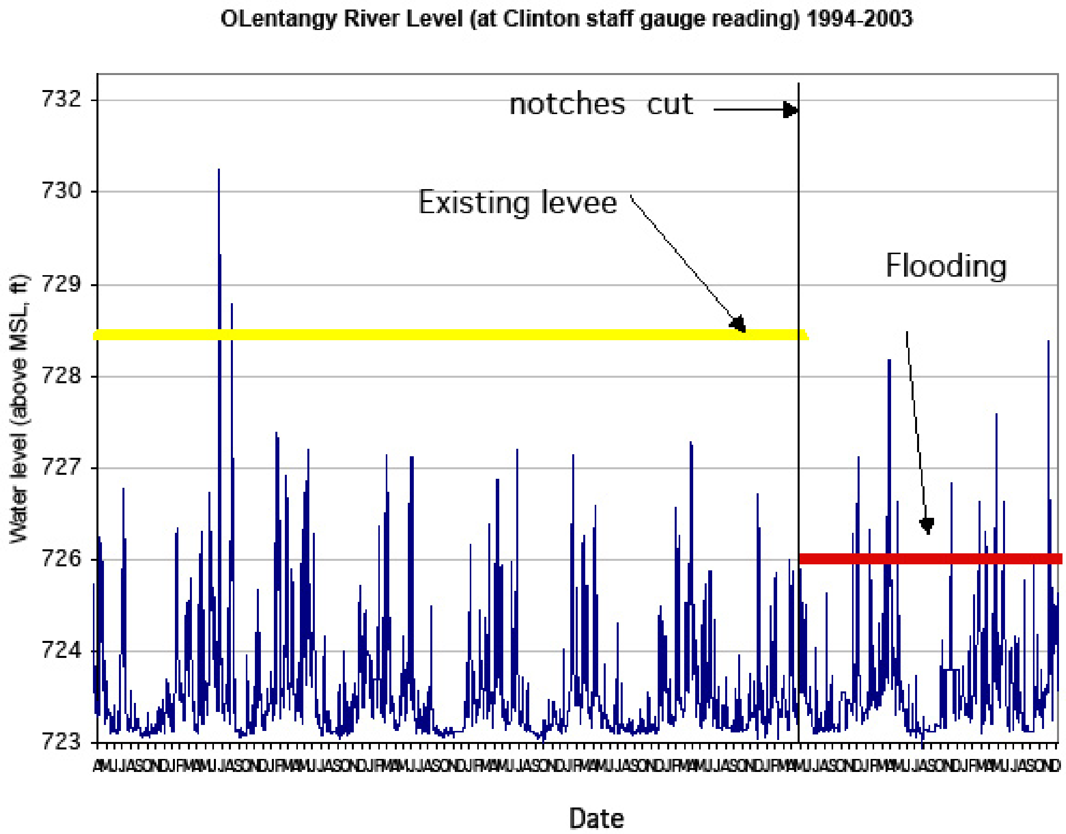

Figure 4. Olentangy River water level (above MSL, ft), 1994-2003, showing existing levee, time of breech cutting, and current flooding at the bottomland forest

* Collected samples were weighed after air drying at 20 oC in the Heffner Wetland Research and Education Building adjacent to the site;

* Major elements (Al, B, Ca, Cu, Fe, K, Mg, Mn, Mo, Na, S, P, Zn) were analyzed at STARLAB (Wooster Campus, The Ohio State University).

* Soil cores were taken at 10 m intervals along the six transects using a hand auger. The core sections (0-5 cm and 5 - 10 cm) were compared to a Munsell Soil Color Chart.

Results and Discussion

Hydrological pulsing

Fig. 3 presents the river water level (above MSL, ft), 1994-2003, showing existing levee, time of breech cutting, and current flooding at the bottomland forest (left) and hydroperiod for 2004 (right). Nine major independent flooding events occurred in the 2004 water year (Oct 1, 2003 - Sept 30, 2004) with sufficient stage to flood the bottomland forest through the levee breeches (Fig. 3).

River flooding water quality

Fig. 4 shows river stage and water quality in the Olentangy River during flooding events in May and June 2004. Flooding generally decreased dissolved materials (see conductivity) and dampened diurnal patterns of temperature, dissolved oxygen, and pH, indicating the effects of floods on changing in-stream productivity. There are often significant increases in turbidity (suspended sediments) immediately before and during bottomland flooding, maximizing sediment transport into the bottomland forest. This increased sediment input yields increased nutrient input which will likely contribute in the long term to enhanced forest productivity.

Sediments chemistry

Concentrations of Na, K, Al, Fe, Mg and Mn in sediments deposited in May 2003 flooding were higher than in May 2004 flooding (Table 1), but concentrations of Ca, Zn, P, and S were lower in 2003 flooding than in 2004 flooding. Al and Fe dominate the sediment chemistry and results show the elemental abundance in order of Al > Fe > Ca > K > Mg > S > P > Na > Mn > Zn >Mo> B > Cu. Correlations between Al (%) to other elements are positive with 0.95, 0.89, 0.84, 0.69, 0.67, 0.66, 0.59, 0.42 for B, Ca, K, Mn, Fe, Mo, Na, Cu respectively, while negative with 0.03, 0.50, 0.56 for P, Zn and S (Table 2).

Sediments quantity

The flood events provided sediment deposits, nutrients, and undoubtedly introduced seeds and small organisms into

Table 1. Flooding events, durations (hrs), flooded area and average water depths in 2003

Flooding event	Date	Duration (hrs)	Flooded area (ha)	Flooding water depths (ft)
1	March, 14	38	1.1	0.58
2	April, 07	46	0.6<wet area<1.2	0.02, 0.41
3	May, 14	111.5	1.1	0.4
			(2 hrs) 5.1	1.11
4	May, 21	15	1.1	0.58
5	June, 13	55.5	0.5	0.13
6	July, 13	24.5	0.5	0.13
7	August, 30	53.5(5 hrs)	5.1	0.3, 2.97
8	Sept., 27	67	2.4	0.56
9	Nov., 30	113.5	2.4	0.52

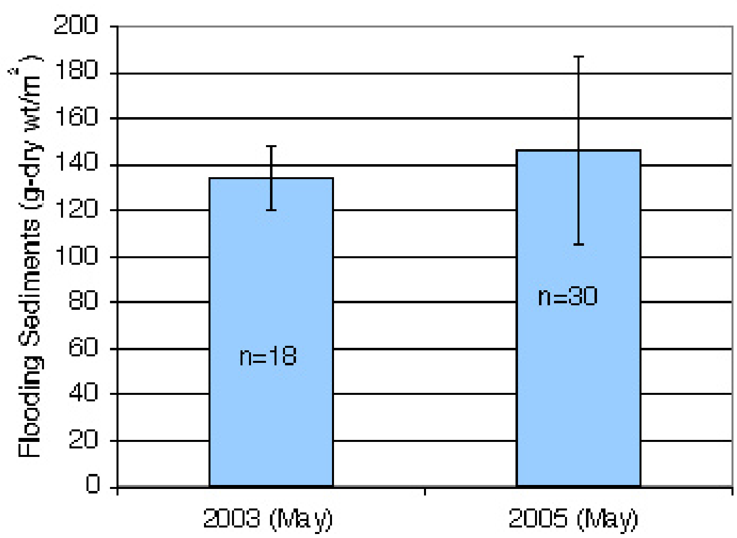

Figure 5. Dry weight (g/m2; ave ± std error) of sediments from the sampling traps during two flooding events (May, 2003 and May 2005) at the bottomland hardwood forest, Olentangy River Wetland Research Park, Columbus, Ohio

the bottomland forest. The flooding river is characterized by pulses in turbidity, but sediment deposits were determined by temporal variability during flooding events. Net sediment deposits averaged 134^{-+}12 g-dry wt/ m^2 in May, 2003 and 147±41 g-dry wt/ m^2 in May 2005 (Fig. 5). Flooding duration may impact quality and quantify of sedimentation. This rate is consistent in temporal variability of sedimentation processes during the flooding events in a number of other freshwater wetlands/riparian forests (eg. Mitsch et al., 1979; Fennessy et al., 1994; Steiger et al., 2003).

Soils

Significant differences in soil chromas (0 to 5 cm, and 5 -10 cm) were found (Table 3) from pre- to post-restoration. Twenty-eight % of cores were hydric in 1998 (pre-restoration) for 0-5 cm and 5- 10 cm depth; by comparison, 37% of cores were hydric in 2003 (post-restoration) for 0-5 cm and 5- 10 cm depths (Hossler and Mitsch, 2004).

However, pulsing events may accelerate biogeochemical processes from flooded sediment to surface soils. Restoration of seasonally flooded bottomland forests could stimulate potentially large nutrient and Fe releases, which would eventually lead to enhanced forest productivity and biodiversity.

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