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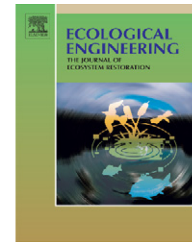

Effects of variable hydroperiods and water level fluctuations on denitrification capacity, nitrate removal, and benthic-microbial community structure in constructed wetlands

Cari K. Ishida [a], *John J. Kelly* [b], *Kimberly A. Gray* [a,*]

[a] *Department of Civil and Environmental Engineering, Northwestern University, Evanston, IL 60208-3109, USA*
[b] *Department of Biology, Loyola University Chicago, 6525 N. Sheridan Road, Chicago, IL 60626, USA*

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ABSTRACT

The hydrologic character of wetlands is one of the attributes by which they are defined. There are, however, conflicting reports about the detrimental versus beneficial responses of wetland systems to water level fluctuations and variable hydroperiods. We conducted water level and hydroperiod fluctuation studies in full-scale experimental wetlands in order to determine the effects of hydraulic operation on wetland performance (in terms of nutrient removal), and benthic-bacterial community function (in terms of denitrification potential, DNP) and structure (via terminal restriction fragment length polymorphisms, T-RFLP). In our comparison, detention time was the controlling factor for nitrate removal at the system level. However, widely fluctuating water levels and variable hydroperiods did not diminish either the nitrate removal *capacity* of the experimental wetlands, or the size or composition of benthic-bacterial communities relative to the more stable water level systems. Rather, significant differences in denitrification potential rates, bacterial cell densities, and benthic community structure were a function of sampling location within the experimental wetlands regardless of hydraulic operation. The results of this study support the need for reconsidering the hydraulic criteria for wetland delineation.

1. Introduction

Wetlands are currently defined as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (USACE, 1987). The main diagnostic environmental characteristics considered are vegetation, soil, and hydrology, and the specific hydrologic requirement is that the area should be either inundated permanently or periodically during the growing season, thereby creating reducing or hydric soil conditions (USACE, 1987). There are many systems, however, that are characterized by hydric soils, support diverse wetland vegetation, and provide critical wetland characteristics, such as habitat for migratory birds or other vertebrates, but do not satisfy the

* *Corresponding author*. Tel.: +1 847 467 4252; fax: +1 847 491 4011.
E-mail address: k-gray@northwestern.edu (K.A. Gray).
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hydrologic requirements in order to be delineated as wetlands. For example, while storm water detention basins support wetland vegetation and attract diverse wildlife, they have variable hydroperiods and water level fluctuations that fail to meet the wetland delineation criteria given above. There is debate that water level fluctuations impair wetland structure and function and that such systems, despite displaying many wetland features, should not be designated as wetlands (Bolscher, 1995; Schouwenaars, 1995; Sheldon et al., 2005). A fundamental issue surrounding wetland delineation, then, is whether the hydrologic character of a wetland is the definitive attribute for its classification.

A major function of wetlands that is affected by variable hydroperiods and water level fluctuations is nitrate (NO_3^-) removal. The conventional thinking about NO_3^- removal in wetland systems is that it is largely controlled by hydroperiod (detention time), and that lower hydraulic loading rates relative to longer hydroperiods provide optimal conditions for nutrient removal (Kadlec and Hey, 1994; Phipps and Crumpton, 1994; Kadlec and Knight, 1996; Shutes et al., 1997; Stober et al., 1997; Carleton et al., 2001). Spieles and Mitsch (2000) showed that flood conditions reduced nitrate removals considerably. However, other biogeochemical factors may also be important in determining the rates of NO_3^- removal in wetlands. There is little detailed knowledge about how the characteristics of the bacterial community influence NO_3^- removal rates or how the interplay of the many parameters defining wetlands affects NO_3^- removal. For instance, we do not understand how wetland hydrology may influence bacterial community structure. Since bacteria are key players in nitrogen cycling in wetland systems it is important to understand the impacts of fluctuating water levels on microbial communities (Bowden, 1987). We pose the question: do water level fluctuations and shortened hydroperiods impair wetland function in terms of NO_3^- reduction by altering the bacterial community structure and function relative to that observed in wetland systems having stable water levels and increased hydroperiods?

The goal of this research was to probe the effects of variable hydroperiod and water level fluctuations on wetland performance (in terms of NO_3^- removal), bacterial function (in terms of denitrification potential), and benthic cell density and bacterial community structure. In our study, two hydraulic regimes were implemented in paired, experimental wetland cells. One hydraulic regime was designed to mimic an inundated wetland pool with dampened water level fluctuations and increased hydroperiod (pooled treatment), and the second regime was designed to simulate widely fluctuating water levels and shortened hydroperiods in a fill and drain basin having no outlet control (swale treatment). We hypothesized that (1) the pooled treatment wetlands with longer hydroperiods and dampened water level fluctuations would outperform the swale (highly variable) treatment wetlands in terms of bulk nitrate removal, and (2) differences in bacterial community structure (as fingerprinted by terminal restriction fragment length polymorphisms, T-RFLP) and function (denitrification potential, as measured by the acetylene inhibition method) would be observed in the experimental wetlands as a function of the hydrologic treatment.

2. Experimental

2.1. Site description

The constructed wetlands in this study are located at the Des Plaines River Wetland Demonstration Project (DPRWDP), a 550-acre experimental station that was established in 1989 along a 2.8 mile stretch of the Des Plaines River (DPR) in Wadsworth, Illinois, 35 miles north of Chicago (http://www.wetlandsresearch.org). The DPRWDP is a long-term project dedicated to the study of wetland restoration and the comparison of constructed wetland function to that of natural systems (Sanville and Mitsch, 1994). The constructed wetlands are fed by the DPR, which flows south, draining 200 square miles in southern Wisconsin and northeastern Illinois. In this geographic region, the watershed is 70% agricultural, 9% urban, 15% forest, 4% open water, and 2% wetland (USGS, 2005a). Experiments were conducted from 2001 to 2004 in the smaller, northern tier wetland cells: C-1, C-2, C-3 and C-4 (Fig. 1a). *Typha × glauca*, a hybrid cattail was the dominant wetland vegetative species having an average aerial coverage in the experimental wetland cells of 40% (mean based on cover class midpoints) over the duration of our study. All other vegetative species combined had an average cover of 28%, such that the total average vegetative coverage was 68% (Boers et al., in press).

The areas and volumes of the experimental cells varied slightly and are listed in Table 1. The widths of the experimental cells varied from 40 to 45 m, and the lengths were each approximately 150 m (USGS, 2005b). Wetland area and volume calculations were based upon stage-storage and topographic data. C1 and C3 were paired as the pooled treatment wetlands because they showed the greatest differences in wetland volume and area. By pairing the most differently sized wetlands, our goal was to test the pooled treatment on the widest range of wetland size possible. The remaining cells, C2 and C4 were the most similar in wetland volume and area and were paired as the swale treatment wetlands.

2.2. Planned storm events

We designed a schedule of random storm events of five different magnitudes for the water level fluctuation study and performed two series of experiments over 2003 and 2004. The results of experiments conducted in 2004 are presented here. DPR water was pumped into the experimental wetlands, each with an influent pipe. The characteristics of the pumping system are described elsewhere (Hey et al., 1994). The storm event calculations were based upon the probability of occurrence in

Table 1 – Wetland cell volumes and areas (Olson et al., 2004)

Parameter	Wetland cell			
	C1	C2	C3	C4
Volume (m^3)	8782	12748	14973	12990
Area (m^2)	1986	2257	2467	2467