Influence of alternative states on nitrogen removal in experimental wetlands

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INTRODUCTION

Denitrification is the main process that remove nitrate from the water in wetlands. Plants can supply denitrifying bacteria with organic carbon and suitable attachment surfaces (Weisner et al. 1994). They also promote the development of anaerobic conditions through litter accumulation and decomposition, which would favour denitrification. The presence of plants has been shown to enhance nitrate removal in field studies (Bachand and Horne 2000). Toet et al. (2005) found a higher nitrogen removal in wetland compartments with emergent plants than with submersed plants. Results from microcosm studies have shown that the potential for denitrification is specific for different plant species (Bastviken et al. 2005).

Wetlands may typically exist in alternative states, dominated by different kinds of vegetation. The purpose of this study was to investigate the effect of alternative state on nitrogen removal under controlled conditions in experimental wetlands.

METHODS

The study was performed in pilot scale wetlands in southern Sweden. The system was constructed in 2002 and consisted of 18 wetland basins with similar shape, an area of 16 m^2 at the bottom and 40 m^2 at the ground surface and a side slope of about 1:1. During this study, the water surface area was set to about 22 m^2 with a mean depth of 0.4 m in all wetlands. The experimental setup during this study was two different flows and three different vegetation types, which resulted in 3 replicate basins for each treatment.

The wetland basins were planted with the two different vegetation types (emergent and submersed) during May 2003, or left unplanted. In the basins with emergent vegetation, *Phragmites australis* (Trin.), *Glyceria maxima* (Hartm.) and *Phalaris arundinacea* (L.) were established. The basins with submersed vegetation were dominated by *Elodea canadensis* (Rich.), *Myriophyllum alterniflorum* (DC.) and *Ceratophyllum demersum* (L.). From 2004 to 2006, the remaining basins were gradually colonized by algae and higher plants, which were dominated by *Alopecurus geniculatus* (L.), *Agrostis gigantea* (Roth.) and *Typha latifolia* (L.).

Water samples were collected about once every other week. The inflow water was groundwater and the water flows were adjusted using gate valves fitted on the inlet pipe at each wetland basin. Flows were set to result in hydraulic loads of 0.13 m d^{-1} and 0.39 m d^{-1}, equal to theoretical residence times of 3 and 1 days, respectively. The nitrogen concentration in the incoming water was dominated by nitrate as the water contained about 11 mg L^{-1} total nitrogen and 11 mg L^{-1} nitrate-N, with a mean ammonium-N concentration of only 10 µg L^{-1}. Total nitrogen and nitrate-N were analysed spectrophotometrically with Flow injection analysis. The water temperature varied between 0 ^oC in winter to 22 ^oC in summer.

Statistics

All data were analysed by repeated measures ANOVA, followed by Tukey's post hoc test. The differences were accepted as significant at the p = 0.05 level. The fixed factors used were vegetation type and hydraulic load. A block factor was also included as the experimental wetlands were divided and randomised within three blocks. There was no significant difference between the blocks, and thus this factor was not used in further statistical analyses.

RESULTS AND DISCUSSION

The statistical analysis showed no significant difference in nitrate removal (kg ha-1 y-1) between high and low hydraulic loads ($p = 0.17$; Fig. 1). There was a significantly higher nitrate removal in the wetlands with emergent plants than in the other vegetation types ($p < 0.01$; Fig. 1), but there was no difference between the wetlands containing submersed plants and the wetlands with free vegetation development.

The wetland systems achieved higher nitrate removal as the wetlands matured and the density of vegetation increased. This study emphasises the importance of dense emergent vegetation for nitrate removal at high nitrate concentrations.

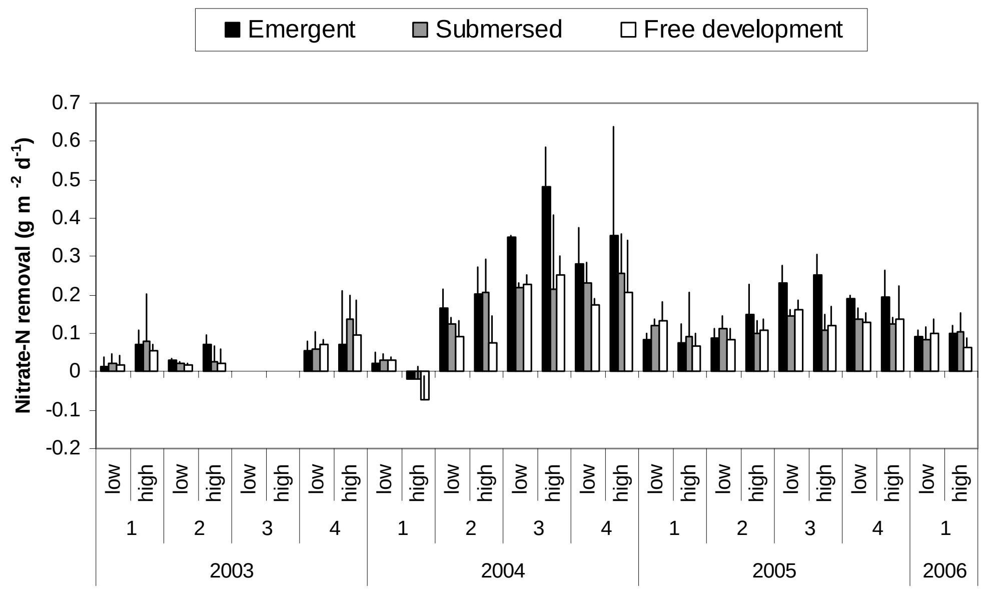

Fig. 1. Nitrate-N removal (g m-2 d-1) in wetlands containing emergent, submersed and freely developing vegetation with different hydraulic loads (low: 0.13 m d-1 and high: 0.39 m d-1), and during different seasons (Period 1: December to February; period 2: March to May; period 3: June to August; period 4: September to November). Error bars show standard errors.

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