N_2O fluxes in created riparian wetlands receiving hydrologic pulses in central Ohio

Maria E. Hernandez and William J. Mitsch

Olentangy River Wetland Research Park, Environmental Science Graduate Program, The Ohio State University

Abstract

N_2O emissions were studied in plots with different hydrologic conditions in the two experimental wetlands at Olentangy River Wetland Research Park (ORWRP) during summer and fall 2003. Wetlands received flood pulses during the summer and steady flow during fall. Plots were distributed in transects along the wetlands at different elevations (transitional- upland, edge, and marsh). The average N_2O fluxes were 30.79 ± 9.42 μg m-2 h^{-1} for Wetland 1 and 32.32 ± 16.52 μg m^{-2} h^{-1} for Wetland 2. During the summer, nitrous oxide fluxes were smaller while flood pulses occurred. No significant differences were observed in the fluxes from plots near the inflow versus plots near the outflow; nor were significant differences found in plots at different elevations. In the summer, nitrous oxide fluxes were smaller when the sediments were flooded than when the soils were exposed to air.

Introduction

Creation and restoration of wetlands in the Midwestern United States has been proposed as a means to mitigate hypoxia in the Gulf of Mexico (Mitsch, et al., 2001). Denitrification is the dominant mechanism of nitrogen elimination in wetlands and is a major source of nitrous oxide (Freeman et al., 1997). Formation and release of N_2O into the atmosphere is a concern because of its contribution to the green house effect and to ozone depletion (Johansson, et al., 2003). If a major proportion of the gases produced by denitrification is N_2O, wetlands could increase atmospheric N_2O. Therefore the attempt to solve the NO_3-N pollution problem may actually contribute to global warming. On the other hand, if N_2 is the predominant gas formed during denitrification in created wetlands, these ecosystems represent environmental ways of removing nitrates from water.

Riparian wetlands are exposed to seasonal flood pulses that cause changes in the soil physical and chemical environment, influencing the microbial processes involved in the nitrogen cycle. When a flood pulse occurs, wetland area increases causing changes in oxidizing and reducing conditions along the edges and terrestrial-wetland transitional zones. How flood pulses affect nitrogen gas fluxes in wetlands is not well understood. The aim of this study is to investigate the spatial and seasonal nitrous oxide fluxes in two created experimental wetlands receiving hydrologic pulses in the Midwestern United States.

Methods

Site description

The study was carried out in two kidney-shaped 1-hectare experimental wetlands, which were constructed in 1993 at the Olentangy River Wetland Research Park in Columbus Ohio, USA. Water from the Olentangy River enters into these wetlands at the north end and flows southwards until finally the water returns to the river. Seasonal hydrologic pulses were simulated by pumping river water at a high rate (500-1000 gpm) during the first week of each month, and in the remaining three weeks of the month the wetlands received a low flow (100-200 gpm). The pulse schedule operated from January thru June, and then from July to December the wetlands received a steady flow; an extraordinary simulated flood pulse was performed in August 2003. Natural flooding also occurred on August 30, 2003.

Gas fluxes measurements

N_2O fluxes were measured using a closed chamber technique (Smith et al., 1983). Nine plots in each wetland were sampled. The plots were distributed in transects along the two experimental wetlands (near the inflow, middle and outflow). Plots were placed at different elevations in the transitional upland zone, in the edges with alternate wet and dry conditions, and in the marsh that was regularly flooded (Figure 1). In each plot a Plexiglas chamber (24.5 cm x 24.5 cm x 70 cm) was placed 10 cm into the soil (Figure 2). During gas collection the chambers were closed using a water seal. Gas fluxes were measured from June 2003 to June 2004. Samples were taken weekly three times a month when pulsing events occurred and once a month when no pulses were performed. All samples were taken between 11:00 am to 3:00 pm for uniformity within the diurnal period. Chambers were sealed for 2 hours. Gas samples and internal chamber temperatures were collected or measured before the chambers were closed and every 30 min after they had been closed.

Nitrous oxide was analyzed using a gas chromatograph (Shimadzu GC-14-A) fitted with a 2 ml sampling loop, Porapak-Q 1.8 m column and an electron capture detector

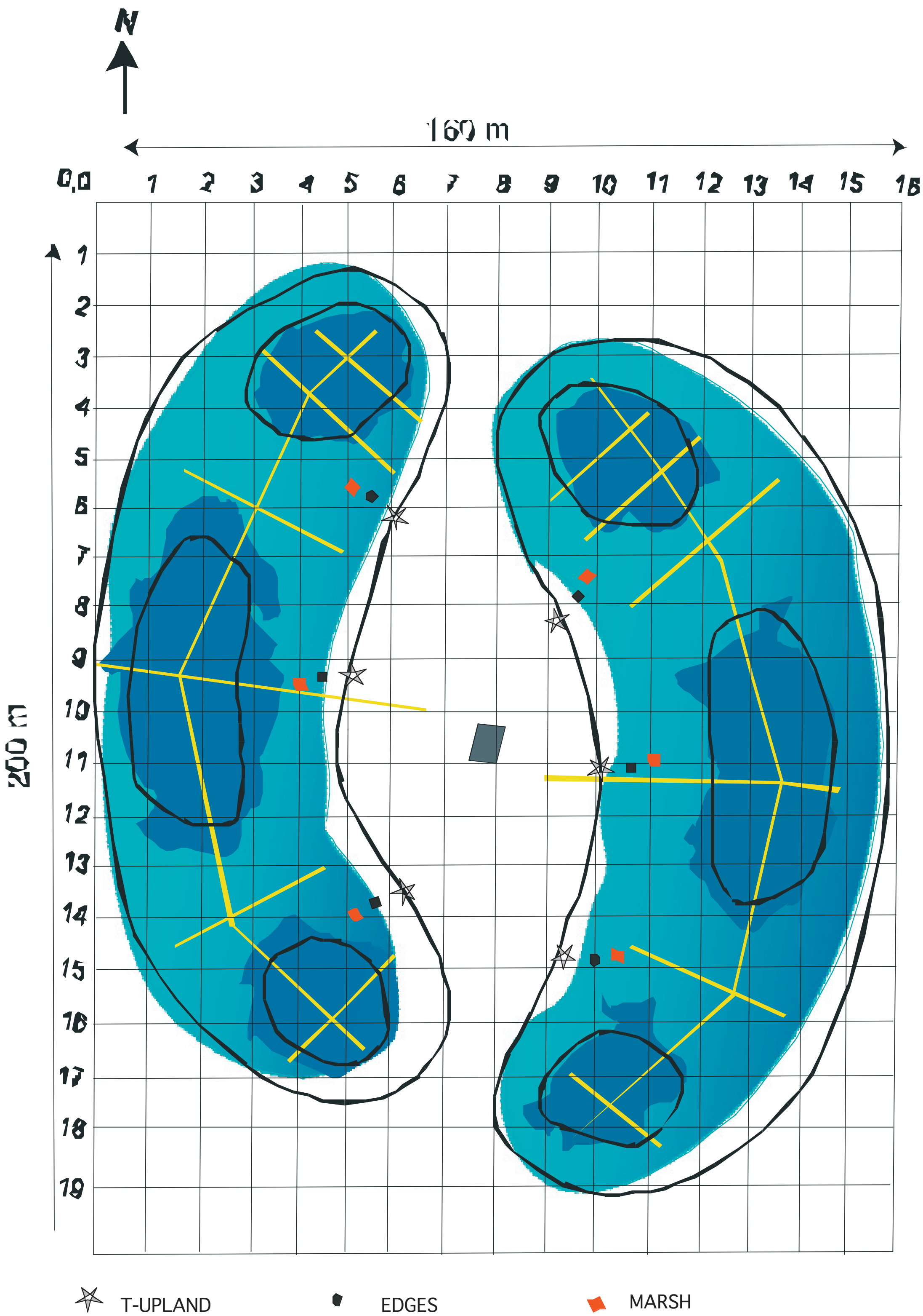

Figure 1. Plan view and soil sampling grid (10 x 10 m) of the ORW experimental wetlands. Areas in black indicate the Open Water Zones. Areas in gray indicate Emergent Vegetation Zones. Areas outside these areas are Transitional/ Upland Zones. Stars, squares and diamonds indicate sampling plots locations.

^{63}Ni. The instrument used ultra pure nitrogen carrier gas (10 ml min-1) and operated at temperatures of 70, 80 and 300ºC for column, injector and detector, respectively. Nitrous oxide fluxes were estimated according to the following equation:

$f = V \times C_{rate}/A$

Where

f= Nitrous oxide flux as $\mu g\ m^{-2}\ h^{-1}$

V= Internal volume of the chamber (m^3)

A= The base chamber soil-surface area (m^2)

C_{rate} = Change in Nitrous oxide concentration (Cm) over the enclosure period, expressed as $\mu g\ m^{-3}\ h^{-1}$

Nitrous oxide concentrations were calculated according to the following equation:

$C_m = (C_v \times M \times P)/ (R \times T)$

Where:

C_m= the mass/volume concentration (mg l^{-1})

C_v= The volume/volume concentration (trace gas concentration expressed as a part per billion)

M= The molecular weight of N_2O

P = Barometric pressure (atm)

T = Air temperature within the enclosure at the time of sampling (K).

R= The Universal gas constant (0.0820575 l. atm .K. mole)

The change in nitrous oxide concentrations per unit time were estimated from the slope of the line obtained by plotting the nitrous oxide concentration in the headspace of the chamber versus time. Results were only included if r^2 was higher than 0.8.

Results

Hydrologic conditions

Marsh plots were flooded in 80-90% of the instances where gas fluxes were measured and were exposed to air only two times (Figure 2). Plots located on the edges had more alternating flooded and exposed conditions, approximately 60% of the time they were inundated and 40% of the time they were exposed to air. In contrast, soil in the transitional upland plots was exposed to air during the entire sampling period.

N_2O fluxes

The average of nitrous oxide fluxes during 2003 were very similar in both wetlands, 30.79 ± 9.42 $\mu gm^{-2}\ h^{-1}$ for Wetland 1 and 32.32 ± 16.52 $\mu gm^{-2}\ h^{-1}$ for Wetland 2. In Wetland 1, significantly higher (P= 0.010) nitrous oxide fluxes were observed during summer compared with fluxes observed during the fall. In Wetland 2, fluxes were also observed to be higher in summer than in fall, but the differences were not significant (P=0.180). Comparing nitrous oxide fluxes during the summer when a pulse event occurred versus when no pulse occurred (Figure 3) it was observed that there were higher gas fluxes when no pulse event occurred. However, due to high data variability such differences were not significant (P>0.05). When nitrous oxide fluxes were compared for inundated plots and plots without standing water higher nitrous oxide fluxes were observed when plots were not inundated than when they were inundated. This pattern was observed in the summer but not in the fall

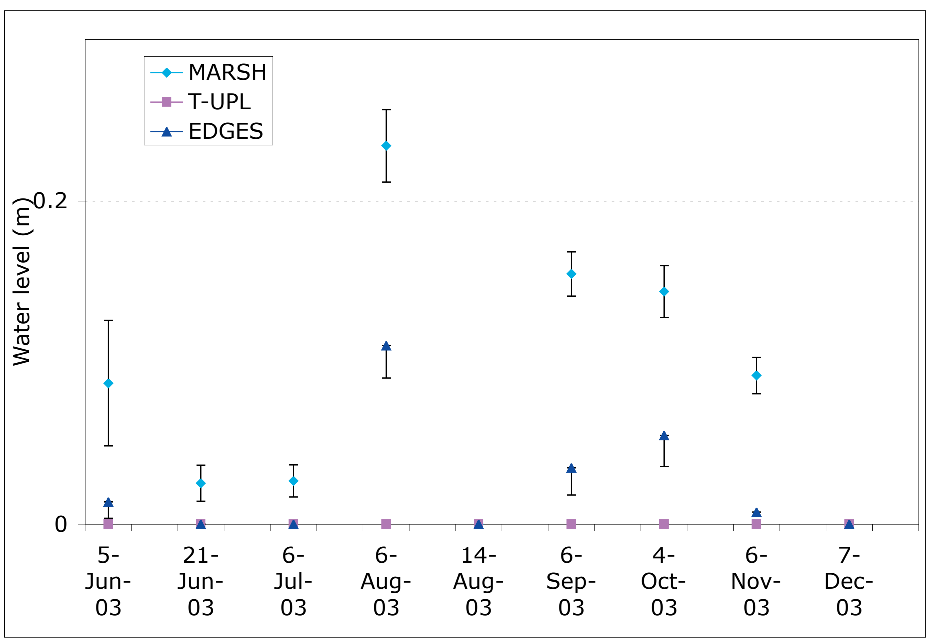

Figure 2. Average water level in the plots with different hydrologic conditions in the experimental wetlands at ORWRP during the N_2O emission measurements. Bars indicate standard error.

(Figure 4). Regarding spatial variation (Figure 5), in both wetlands no significant differences were observed between nitrous oxide fluxes in the inflow basin and outflow basin (P>0.05). Also, in both wetlands no significant differences were observed in N_2O fluxes in the plots distributed at different elevations (Figure 6).

Discussion

The average of N_2O fluxes found in this study (30.79 ± 9.42 mgm-2 h-1 for Wetland 1 and 32.32 ± 16.52 $\mu gm^{-2}h^{-1}$ for Wetland 2) is within the range (9.82 – 171$\mu gm^{-2}h^{-1}$) reported for other freshwater riparian wetlands (Smith, et al, 1983, Johanson et al, 2003, Machefert, et al, 2004). In 1998 the role of soil organic matter on denitrification potential was investigated (Filippi and Mitsch 1998) in relation to soil organic matter. Organic matter content ranged from 5.3 to 7.3 %, and the variation of average nitrous oxide concentration in soil pore water ranged from 0.237 to 0.202 ppm. Little comparison can be made between that study and the present study because the present study reports nitrous oxide fluxes, taking into account soil area and time, while previous researchers at the ORWRP (Fillipi et al., 1998) reported nitrous oxide concentrations as a function of organic content.

In this study a strong seasonal effect on nitrous oxide emission was found. This pattern has also been observed in other temperate riparian wetlands where fluxes were generally higher in spring and summer than in fall and winter (Machefert, et al, 2003). We found that nitrous oxide flux was smaller when plots were inundated than when plots were exposed to air. This phenomenon has also been found in rice paddies where the release of N_2O from the soil to the atmosphere was hampered by the presence of standing water (Yan, et al, 2000). In the Amazon floodplain, nitrous oxide emission was never detected in flooded sediments but it was detected in exposed sediments (Kern et al, 1996). Smith et al (1983) described an inverse relationship between N_2O fluxes and water depth.

Conclusions

Both wetlands showed similar mean N_2O fluxes. A strong seasonal effect on nitrous oxide fluxes was observed, with higher fluxes occurring during the summer. Hydrology also significantly affected nitrous oxide fluxes, especially during the summer. Nitrous oxide emissions were found to be lower in flooded plots than in plots that were exposed to air.

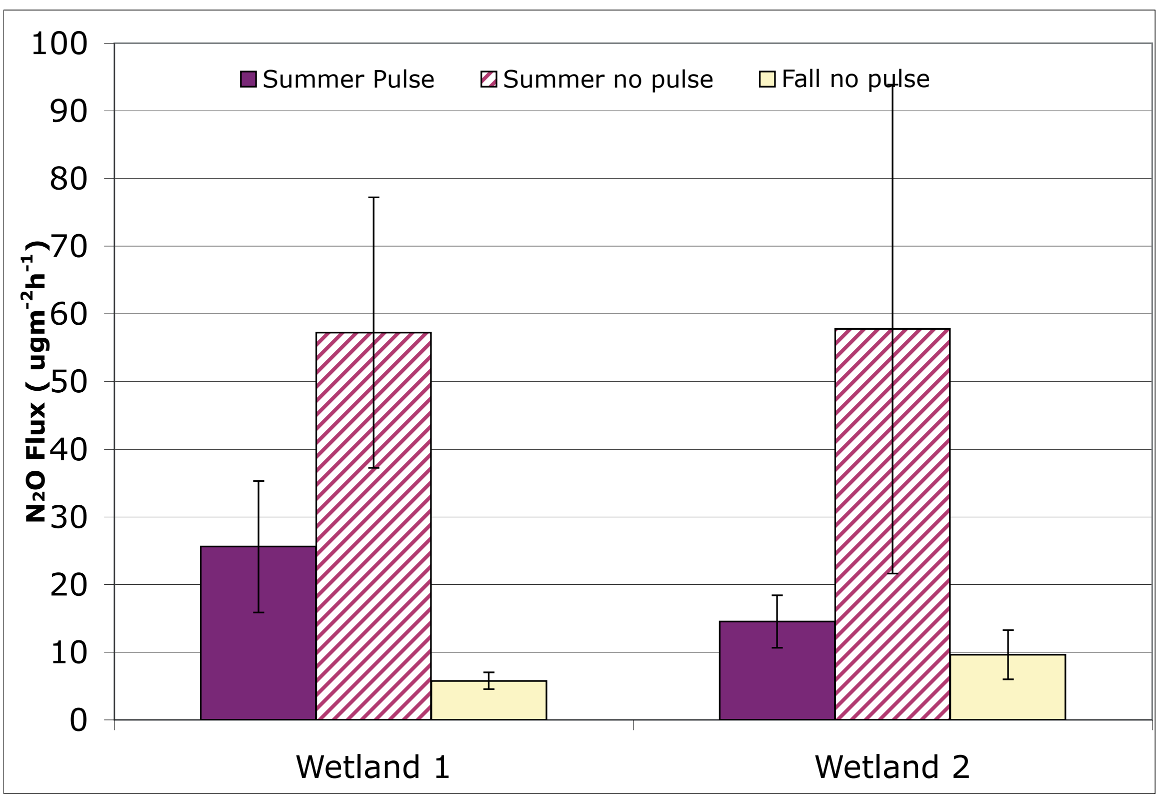

Figure 3. Seasonal N_2O emissions in the experimental Wetlands. Bars indicate standard error.

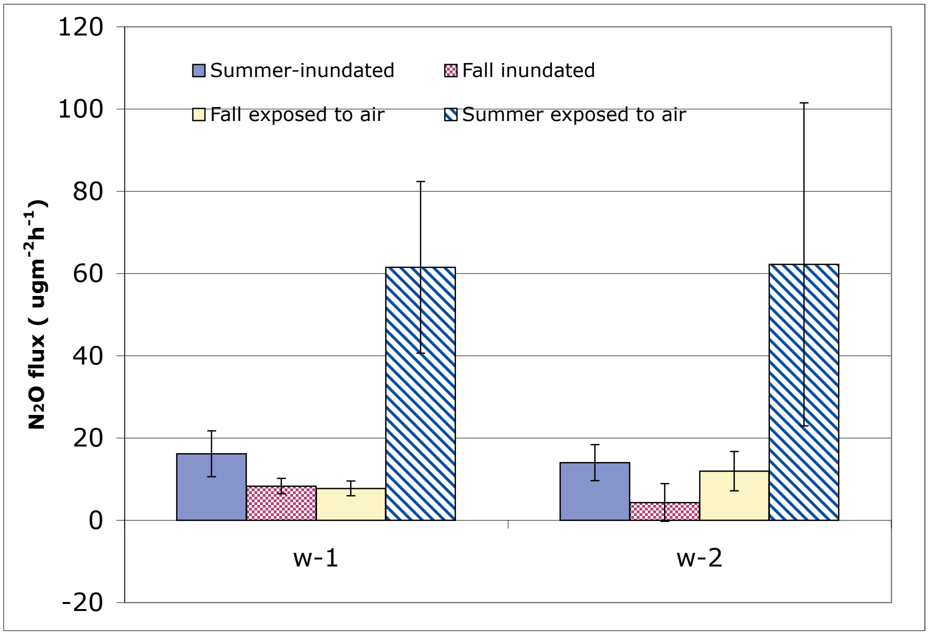

Figure 4. Effect of hydrologic conditions on N_2O emissions in the experimental wetlands. Bars indicate standard error.

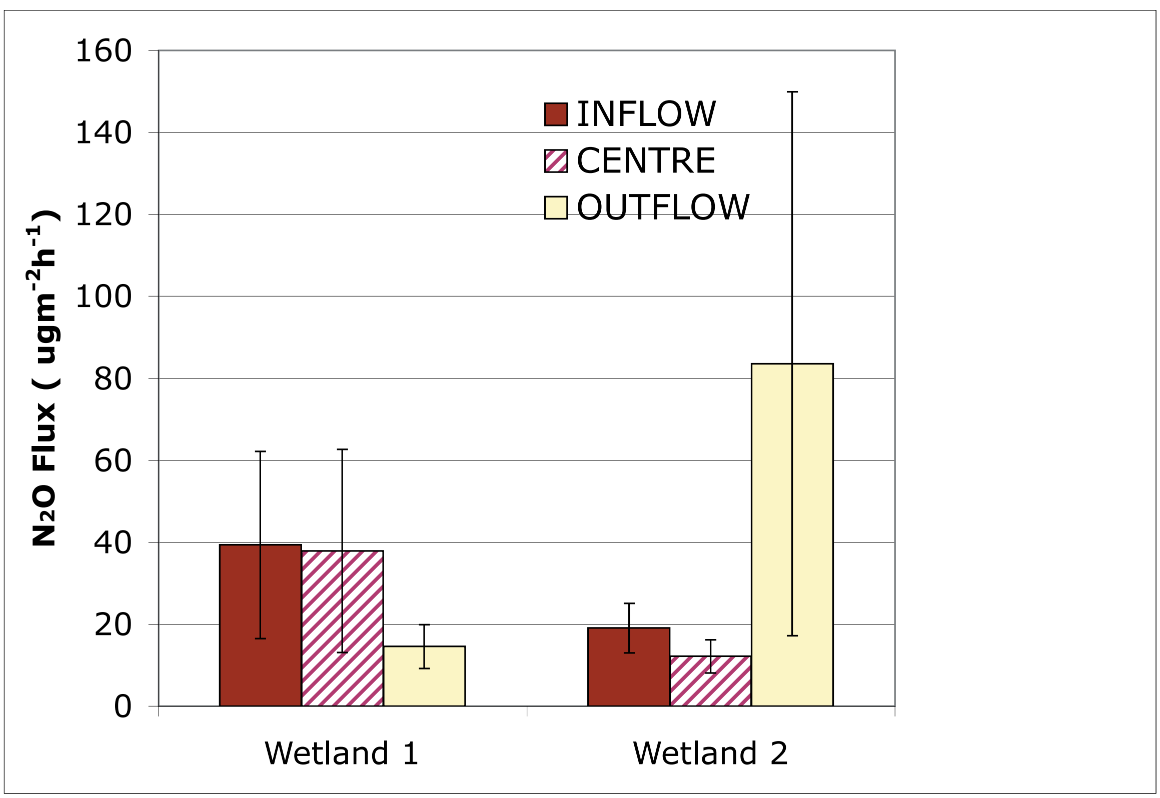

Figure 5. Spatial N_2O emissions in the experimental wetlands. Bars indicate standard error.

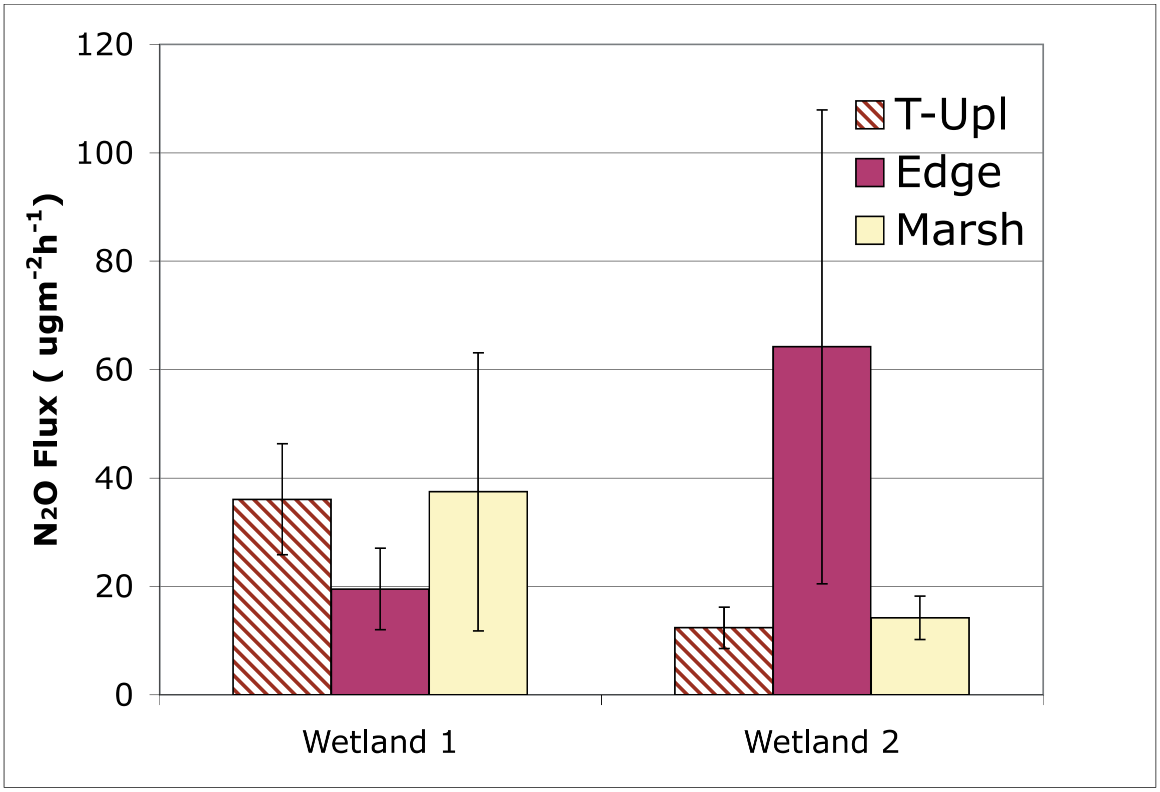

Figure 6. N_2O emissions in plots at different elevation the experimental wetlands at ORWRP. Bars indicate standard error.

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