REMEDIATION PROCESSES IN A STATE BOTANICAL GARDEN WETLAND IMPACTED BY AGRICULTURAL NUTRIENT LOADING

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Abstract In April 2003, a routine water quality analysis by a local watershed group of a stream site (Orange Trail Creek) in the State Botanical Garden in Athens, GA revealed elevated levels of nitrate. Subsequent testing showed that several streams and springs within the same watershed contained variable nitrate levels as high as 27 ppm. The University of Georgia (UGA) livestock research farms at the top of the watershed were suspected of contaminating the groundwater, and a project was funded by the College of Agricultural and Environmental Sciences at UGA to determine the nitrogen sources. Tests of surface and well water revealed that much of the contamination originated from the waste lagoons at the UGA Swine Facility or from fields that had land applications of swine manure. The college funded a new project to examine processes in a wetland at the base of the Orange Trail watershed for possible remediation and denitrification before the waters enter the Middle Oconee River. A flow structure was installed in July of 2007 to raise water levels and increase wetland coverage. Upstream and downstream samples were routinely analyzed for nutrients and other indicators of contamination, and a gradual decrease in nitrates at the downstream site has been observed over time. The denitrification process will be studied under various flow regimes and residual times. Further enhancement of the wetland for remediation and wildlife habitat will occur over the next several years. Additional on-going work includes a more complete mapping of nutrient sources in the watershed to determine loading into the stream system and to provide baseline data. Baseline date will be used to determine residual time of contaminants in the groundwater after the livestock farms are relocated and the lagoons emptied.

INTRODUCTION

The animal waste generated from agricultural production can contribute to elevated levels of nutrients in ground and surface water. Concentrated animal production requires disposal of large quantities of animal waste, first in waste lagoons and eventually with land applications. Older waste lagoons are often unlined and can leak concentrated waste directly into underlying shallow groundwater. When waste is applied repeatedly to fields, nutrients can exceed the carrying capacity of soils, and contaminate nearby streams through lateral flow and shallow ground water (Karr et al. 2001). Once nutrients reach groundwater and streams, they are hard to mitigate and are of concern for their downstream eutrophication effects.

Wetlands, either constructed or natural, slow stream flow, and have the ability to transform and assimilate excessive nutrients and other contaminants from water (Stone et al. 2003, Hunter and Faulkner 2001). Wetlands are often used to secondarily treat both human and animal waste before discharge into receiving waters.

BACKGROUND

The University of Georgia is the state land grant institution and the UGA livestock farms adjacent to the State Botanical Garden have been a valuable teaching and research resource for many years. In April of 2003, during routine water quality testing of the Orange Trail Creek in the State Botanical Garden, the Upper Oconee Watershed Network, a local nonprofit watershed group, detected high levels (5 mg/L) of NO_3-N (nitrate) in what was otherwise an apparently non-impacted forested stream. Subsequent testing of several springs and streams in the watershed revealed widespread contamination of groundwater below a ridge to the north and east where the various UGA livestock facilities are located (Wenner et al, 2005). Further investigations by Radcliffe and Lichtenstein in the Department of Crop and Soil Sciences at UGA (unpublished data), using groundwater monitoring wells, identified the swine waste lagoons and spray fields and the poultry facility as sources of nitrate contamination. Based on recommendations from these studies, the College of Agricultural and Environmental Sciences funded a project to enhance a wetland at the bottom of the watershed before the stream system enters the Middle Oconee River. The purpose of this study is to evaluate the effectiveness of the wetland in reducing nitrate contamination.

METHODS

All of the identified nitrate-contaminated stream segments converge prior to entering the historic wetland (Fig. 1). Two long-term sampling sites were established and identified as 1) upstream of the wetland and 2) downstream of the wetland. Grab samples were collected in sterile bottles and transported immediately to the UGA Soil, Plant and Water Laboratory (2400 College Station Road, Athens, GA) for processing and analysis of Biological Oxygen Demand (BOD), ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), total Kjeldahl nitrogen, total phosphorus (P), total suspended solids (TSS), dissolved reactive phosphorus, and nitrite-nitrogen (NO_2-N). Flow rates and precipitation were obtained from the USGS station 02217770 on the North Oconee River at College Ave., Athens, and from a data logger installed at the wetland in the spring of 2008.

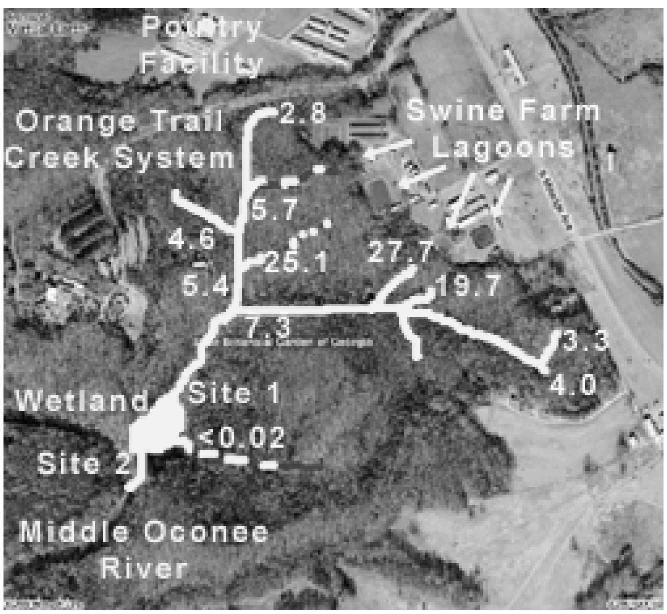

Figure 1. Map of Orange Trail Creek stream system, wetland, sample sites, surface water nitrate concentrations (mg/L) and agricultural facilities.

Samples were collected for one year prior to the enhancement of the wetland in June 2007 when a flow restriction device that restricts flow out of the wetland was established in a natural berm near the river. This was the site of a former beaver dam that had subsequently disappeared, resulting in increased stream channelization through the wetland. The enhanced wetland again raised the water level to reestablish the wetland pool upstream of the flow restriction device.

RESULTS

The average nitrate concentration above and below the wetland before the enhancement was 5.8 mg/L and 4.0 mg/L, respectively, for an average nitrate reduction of 1.8 mg/L. Nitrate averages above and below the wetland after enhancement were 5.0 and 2.8, respectively, for an average reduction of 2.2 mg/L. However, during the summer of 2008, one year after enhancement of the wetland, nitrate remediation across the wetland increased significantly (Fig. 2) with an average reduction of 3.4 mg/L (4.9 mg/L to 1.5 mg/L).

Table 1. Mean TKN, NO_3-N, and NH_4-N concentrations (mg/L) and % removal before and after enhancement of the wetland in June, 2007.

	Inflow		Outflow		% reduction	
	pre	post	pre	post	pre	post
TKN	1.1	0.4	0.7	0.9	36	-56
NO_3-N	5.8	5.0	4.0	2.8	31	44
NH_4-N	0.32	0.14	0.17	0.15	47	-7
DRP	0.04	0.03	0.03	0.02	25	33
TP	0.07	0.04	0.03	0.06	57	-33

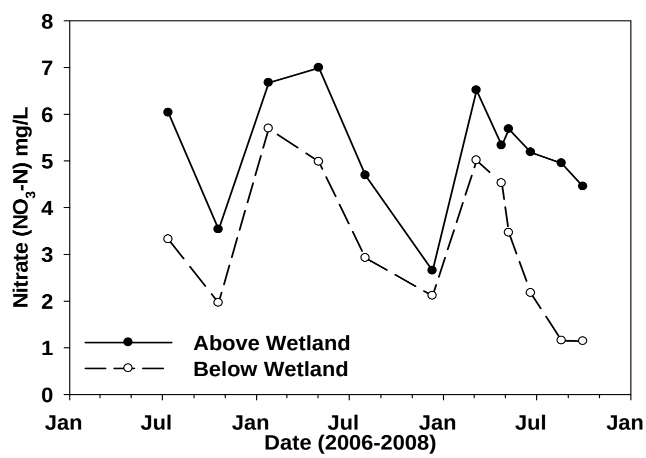

Figure 2. Nitrate (NO_3-N) concentrations over time in Orange Trail Creek above and below the wetland. Wetland enhanced in June 2007.

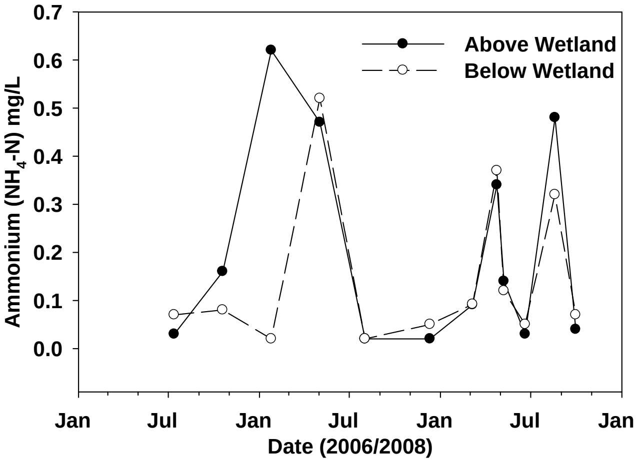

Figure 3. Ammonium (NH4-N) concentrations over time in the Orange Trail Creek above and below the wetland.

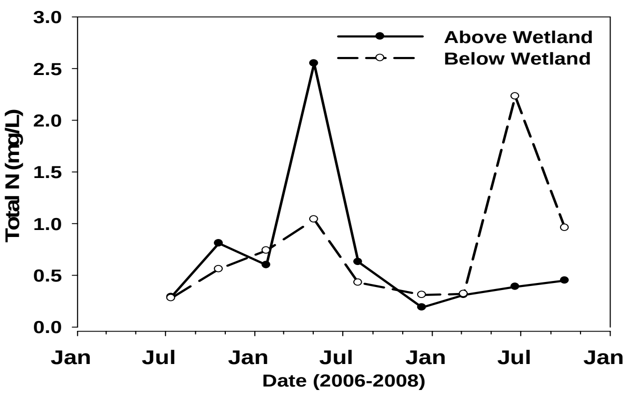

Figure 4. Total Kjeldahl nitrogen (TKN) concentrations over time in the Orange Trail Creek above and below the wetland.

Ammonium, total nitrogen, and total phosphorus concentrations increased downstream after enhancement of the wetland, while dissolved reactive phosphorus remained at low and fairly constant concentrations (Table 1). However, one outlying point in the ammonium results skewed the results, and the wetland appears to have little effect on ammonium concentrations (Fig. 3).

Total nitrogen levels fluctuated over time, but outflow concentrations increased, compared with inflow, starting in the summer of 2008, one year after enhancement (Fig. 4).

Stream branches and seeps in the upper watershed of Orange Trail Creek were sampled and analyzed for nitrate, ammonium, and dissolved reactive phosphorus in an effort to pinpoint sources of stream nitrogen. Very high levels of nitrate were found in seeps coming into the stream below each of the three operational swine lagoons (Fig. 1). Ammonium also tended to be high in these seeps (up to 2.5 mg/L) but not in the stream. Each lagoon appeared to be constructed on top of a natural drainage to the stream based on examination of contour maps. The bedrock in this area is shallow based on the Radcliffe and Lichtenstein study. Above the swine lagoon seeps, stream nitrate levels were high (2.8 to 4.6 mg/L) near the headwaters of the branches of the stream on the north and east, indicating nitrate sources other than swine lagoons were impacting the Orange Trail Creek system. In-stream nitrate levels below the swine lagoon seeps varied from 4.6 to 7.6 mg/L. Nitrate concentration in a non-impacted seep on the east side of the wetland was below detection (<0.02 mg/L).

CONCLUSIONS

Wetland effectiveness to remediate nitrate appeared to increase over time, especially during the warm months of summer 2008, presumably due to the increased wetland stabilization with growth of wetland vegetation and microbial populations (Hunt et. al. 1995). Wetland function should continue to increase over time.

Stream ammonium levels were generally low (<1 mg/L) and were only elevated when associated with groundwater seepage below swine lagoons. Ammonium can quickly convert to nitrate under the high oxygen conditions in streams. The lack of ammonium remediation in the wetland may be due to an increase in low oxygen conditions due to detrital mineralization (Stone et. al, 2003, Fig. 3). Total nitrogen is composed of both inorganic (nitrates, nitrites, and ammonium) and organic nitrogen. Decomposition of organic materials could contribute to the increased levels of TKN seen below the wetland.

Nitrogen moves slowly through groundwater, over a period of several years. Nitrate levels found throughout the Orange Trail watershed may be due to both historic and current sources, and the watershed will serve as an excellent model for the fate of groundwater nitrate once the livestock facilities are moved to modern facilities over the next few years.

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