NITROGEN SOURCES AND SINKS IN LAKE SEMINOLE: IMPLICATIONS FOR THE APALACHICOLA-CHATTAHOOCHEE-FLINT (ACF) NUTRIENT BUDGET

Stephen Opsahl[1] and Patrick Inglett[2]

AUTHORS: [1]J. W. Jones Ecological Research Center, Route 2, Box 2324 Newton Georgia 39870 ; [2]University of Florida, Department of Soil and Water Science, Gainesville, FL

REFERENCE: *Proceedings of the 2009 Georgia Water Resources Conference*, held April 27–29, 2009, at the University of Georgia.

Abstract Lake Seminole is formed at the confluence of two major watersheds (the Chattahoochee and Flint Rivers) and serves as the source water for the Apalachicola River/Bay system. Watershed hydrology, ecology and biogeochemistry have been fundamentally altered through the formation of this shallow 37,600 acre reservoir. Nutrient loading is characteristically different between the Chattahoochee and Flint rivers. The Chattahoochee has relatively high phosphorus which may be due to effluent from larger urban centers and/or reservoir effects. Nitrate concentrations in the Flint River are high during drought because the proportion of groundwater to river discharge is high and ground water from the Floridan aquifer is enriched in nitrate. The invasive macrophyte, *Hydrilla verticillata*, is now predominant throughout most of Lake Seminole. We are studying how biological processes within Lake Seminole alter the nutrient regime. Denitrification represents one potentially important process for the permanent removal of nitrate pollution. Denitrification appears to be especially active in hydrilla beds and these areas may disproportionately contribute to total nitrogen removal from the system.

INTRODUCTION

Human activities are substantially altering the global nitrogen cycle and excess nitrogen is becoming an increasingly apparent problem in freshwater ecosystems (Vitousek et al. 1997). Questions about the nitrogen cycle of lakes and reservoirs are further complicated by the relatively recent proliferation of invasive submerged aquatic vegetation as evidenced by the widespread proliferation of *Hydrilla verticillata* in the southeastern USA (http://nas.er.usgs.gov/ taxgroup/plants/maps/). Denitrification is a critical process that permanently removes nitrogen, yet relatively little is known about rates of denitrification in lakes and reservoirs (Seitzinger et al. 2006). In light of the continued widespread creation of reservoirs to meet human water needs, studies are needed to better understand both the sources and fates of excess nitrogen in watersheds.

The Apalachicola-Chattahoochee-Flint (ACF) basin is particularly vulnerable to excess nitrogen inputs through a combination of rapid urbanization in the Chattahoochee River watershed and agricultural fertilization in the Flint River watershed and the Spring Creek sub-watershed (Frick et al. 1996). Excess nutrient input from these major waterways poses problems for municipal water supplies (both surface water and ground water) and may have dire consequences to Apalachicola Bay if elevated nutrient discharges continue to increase. Lake Seminole may play a critical role in reducing nutrient discharge to the Apalachicola River through active biogeochemical processes. Here, we present preliminary data comparing differences in nutrient inputs from the three major surface water sources to Lake Seminole and provide estimates of denitrification from both open areas and beds of submerged macrophyte vegetation within the lake.

METHODS

Study Area: Lake Seminole is a 37,000 acre reservoir that was created by the completion of the Jim Woodruff Lock and Dam in 1956 (Figure 1). As part of a larger study, a sampling network was established to collect samples from inflowing tributaries (CHAT84, SPRING84, and BBAIN), midreach stations that are influenced by backwater conditions (CHATEND, SPRING253, and FFACE), surface water and bottom water above the dam (LSDAM), and outflowing water into the Apalachicola River (APDAM).

Sampling Sites: Two sampling events are presented in this paper. First, October 9-10, 2007, triplicate surface water and sediment samples were collected from the mid-reach stations of each tributary (CHATEND, SPRING253, and FFACE; Figure 1). Water samples were collected from just below the water's surface. Sediment samples were collected using a piston coring device. Second, on September 25, 2008, depth profiles for water chemistry and sediment samples were collected from four stations along a transect across a large macrophyte bed consisting primarily of *Hydrilla verticillata*. Water samples were collected using a peristaltic pump that was lowered to specific depths and pumped for 2 minutes to purge the tubing prior to collection.

Nutrient chemistry. Water samples were collected in acid-washed 1-liter polycarbonate bottles from each location and the samples were immediately placed on ice. In the laboratory, the samples were filtered using 47 mm glass fiber filters with a 0.7 mm nominal pore size and a filter tower. From the filtered samples, subsamples were collected and analyzed for nitrate, ammonium, and phosphate using a Latchet QuikChem 8000.

Denitrification: Potential denitrification rates were estimated by acetylene (C_2H_2) block assay (Teidje et al.,1989). Approximately 3-4 g wet weight of sediment samples were transferred into 60 ml serum bottles and 5 ml of sterile double distilled (DDI) water was added before they were capped and sealed with aluminum crimps. Bottles were purged with nitrogen (N_2) gas to achieve anaerobic conditions. Acetylene was generated by adding water to calcium carbide in a sealed bottle. Within each sampling bottle, 10% (v/v) of headspace gas sample were removed and replaced by acetylene gas. Bottles were shaken longitudinally for 1 hour to allow distribution of the acetylene gas throughout the samples. This was followed by addition of assay medium containing glucose, nitrate and an antibiotic chloroamphenicol. Final concentrations of glucose-C, nitrate-N, and antibiotic were 288 mg C l^{-1}, 56 mg N l^{-1}, and 2mg l^{-1}. Samples were incubated in dark at 25ºC before gas samples were collected from the headspace at 30, 60 and 90 minutes. Prior to gas sampling, samples were shaken well to equilibrate N_2O between water and bottle headspace.

Gas samples were analyzed using a Shimadzu GC-8A gas chromatograph (Shimadzu, CA, USA) equipped with a poropak Q column and detected via electron capture. Total concentration of N_2O at each sampling period was calculated using Bunsen adsorption coefficient to determine the amount of gas dissolved in the liquid portion at a given headspace concentration (Knowles, 1979). N_2O production rate was then expressed as μg N_2O-N produced per sample dry wt per day (μg N g^{-1}dw h^{-1}). Because these results were determined by providing optimum substrates to the sample, these numbers are best viewed as potential denitrification rates.

RESULTS AND DISCUSSION

The Chattahoochee River had the lowest nitrate concentrations, the Flint River was intermediate and Spring Creek nitrate levels were highest among the three tributary inputs to Lake Seminole (Table 1). The source of elevated nitrate to the Flint River and Spring Creek is likely from agricultural fertilization which contributes excess nitrogen to ground water that is then discharged into regional streams. The observed gradient in nitrate concentrations is consistent with relative proportions of ground water that contribute to the tributaries. Spring Creek is predominantly ground water fed and typically has a higher proportion of ground water in comparison to the Flint River. Nitrate in Lake Seminole near the dam had lower nitrate than any of the inputs indicating a substantial amount of nitrate is lost during passage through the lake.

The Chattahoochee River had higher phosphate and ammonium concentrations compared to the Flint River and Spring Creek. The source of elevated phosphate and ammonium are likely derived from surface water inputs because regional groundwater typically has low phosphate and ammonium (Hicks, et al. 1987). This was supported by the low phosphate and ammonium concentrations observed in Spring Creek which is fed predominantly by ground water. Sources of elevated phosphate and ammonium to the Chattahoochee River include numerous upstream wastewater treatment plants. Large reservoirs are also characteristic of the Chattahoochee watershed but their impacts on nutrient concentrations in the Chattahoochee River are not well understood. Phosphate concentrations in Lake Seminole near the dam were low relative to the two major inputs (the Chattahoochee and Flint rivers) indicating some phosphate removal during transport through the lake.

Potential denitrification rates in sediments at the tributary sites and the lake near the dam ranged from 1.2 to 3.7 μg N/g/d (Figure 2). These rates are within the range of values that are typical for lakes and reservoirs (Seitzinger et al. 2006). Measured rates in the Chattahoochee arm were significantly lower than those at the other three sites. The reason for this difference is unknown at present.

The distribution of nitrate within the hydrilla bed showed trends in both horizontal and vertical directions (Figure 3). Site 1 (adjacent to the shoreline) and Site 2 both had very low nitrate concentrations indicating that water chemistry was fundamentally different within the hydrilla beds in comparison to open water. Site 3 had lower concentrations and nitrate was lower in both the top and bottom water in comparison to the middle of the water column. The concentrations at site 4 (open water adjacent to the Flint River arm of Lake Seminole) were uniform from the top to bottom of the water column.

Potential denitrification rates ranged from 2.0 to 16.0 μg N/g/d among the four sites within the hydrilla bed (Figure 4). Average values in the hydrilla bed (6.4 μg N/g/d) were about 3-fold higher than average values for the open water sites (2.1 μg N/g/d). Significantly higher rates were measured at site 2 and these rates were 4 to 8-fold higher than at the other three sites. The reason for this large difference is unknown at present.

CONCLUSIONS

Preliminary data indicate active denitrification is occurring in the sediments of Lake Seminole. These initial measurements indicate patterns in spatial variability among different open water sites within the lake. Hydrilla beds showed higher average rates of denitrification than open water and may therefore be more active sites of permanent N removal within the system. Presently, more detailed sampling is being conducted to determine how nutrient inputs, nutrient outputs, and denitrification rates vary spatially and seasonally.

Figure 1 Location of Lake Seminole within the ACF Basin (inset) and sampling network that includes inflowing tributary sites.
(CHAT84, SPRING84, and BBAIN), mid-reach stations (CHATEND, SPRING253, and FFACE), Lake Seminole above the dam (LSDAM), and outflowing water below the dam (APDAM). The location of the hydrilla bed transect is show as a solid line in which 4 sites were selected to create a transect that spanned from the shoreline through dense hydrilla to open water.

Table 1. Comparison of nutrient chemistry of inflowing Lake Seminole tributaries and above the Jim Woodruff Lock and Dam (October 9-10, 2007)

	Chattahoochee (n=3) conc. (std. dev.)	Flint (n=3) conc. (std. dev.)	Spring Creek (n=3) conc. (std. dev.)	Seminole Dam (n=3) conc. (std. dev.)
NO_3^- (ppb)	304 (3)	1093 (1)	2017 (4)	199 (2)
PO_4^-(ppb)	22.8 (0.4)	13.8 (1.3)	BD	4.2 (0.5)
NH_4^+(ppb)	70.5 (0.5)	7.2 (0.9)	15.0 (0.8)	54.1 (0.7)

Nitrate (NO_3^-), phosphate (PO_4^-), ammonium (NH_4^+); ppb, parts per billion; BD, below detection limit (2 ppb)

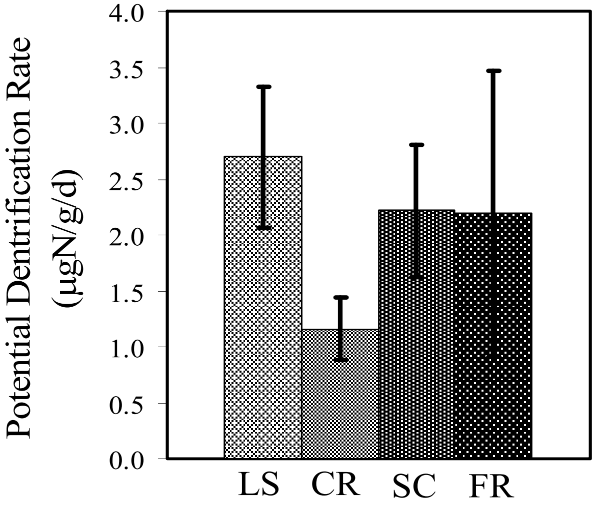

Figure 2. Potential denitrification rates measured in lake sediments from four stations.
(LS DAM (LS), CHATEND (CR), SPRING253 (SC), and FFACE (FR). See Figure 1 for specific sampling locations)

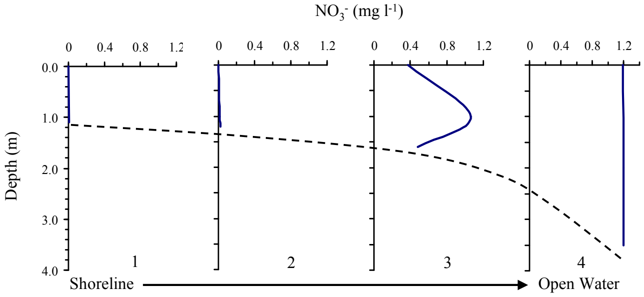

Figure 3. Nitrate (NO_3^-) concentrations at four sites along a transect through a dense hydrilla bed
(See Figure 1 for specific location within the lake). The dashed line indicates bottom depth.

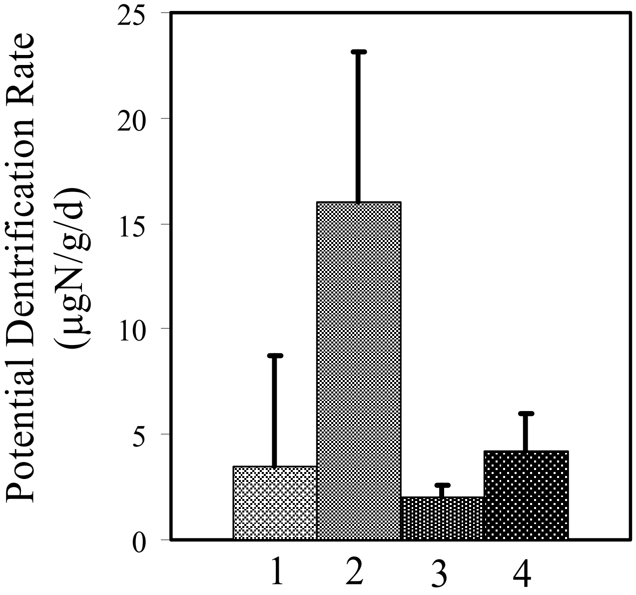

Figure 4. Potential denitrification rates measured in lake sediments from four sites located within the hydrilla bed transect.
(see Figure 1 for specific transect location within the lake).

REFERENCES

Hicks, D. W., H. E. Gill, and S. A. Longsworth. 1987. Hydrogeology, chemical quality, and availability of groundwater in the Upper Floridan aquifer, Albany area, Georgia. USGS Water-Resources Investigations Report 87-4145, Atlanta.

Frick, E. A., G.R. Buell & E. A. Hopkins. 1996. Nutrient sources and analysis of nutrient water-quality data, Apalachicola-Chattahoochee-Flint river basin, Georgia, Alabama, and Florida, 1972-90. U.S. Geological Survey Water Resources Investigations Report 96-4104, p. 120.

Knowles, R. 1979. Denitrification, acetylene reduction, and methane metabolism in lake sediment exposed to acetylene. Appl Environ. Microbiol 38:486–493.

Seitzinger, S., J. A. Harrison, J. K. Bohlke, A. F. Bouman, R. Lowrance, B. Peterson, C. Tobias, and G. Van Drecht. 2006. Denitrification across landscapes and waterscapes: A synthesis. Ecol. Appl. 15: 2064-2090.

Tiedje, J. M., S. Simkins, and P. M. Groffman. 1989. Perspective on measurement of denitrification in the field including recommended protocols for acetylene based methods. Plant and Soil. 114:261-284.

Vitousek, P.M., H.A. Mooney, J. Lubchenco & J.M. Melillo. 1997. Human Domination of Earth's Ecosystems. Science 277: 494-499.