

Quantifying sediment nutrient processing in Falls Lake

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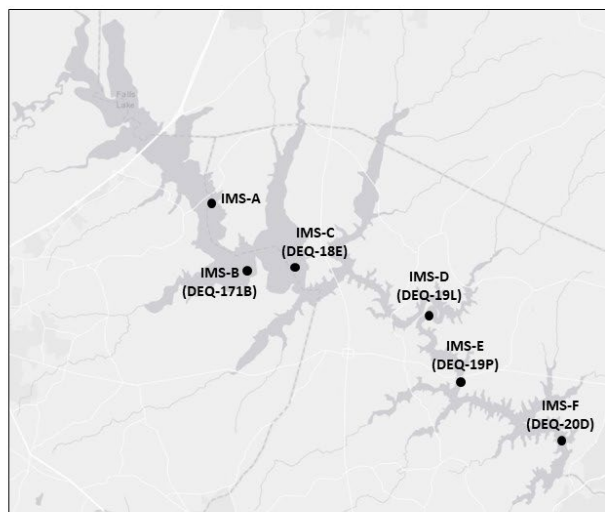
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INTRODUCTION

Managing to maintain acceptable levels of nitrogen and phosphorus pollution from point and non-point sources is best accomplished when the sources, transformations and fates of these nutrient forms are quantified. Quantification of nitrogen (N), phosphorus (P) and carbon (C) in the manner relevant to management relies on the integration of meteorological, hydrological, chemical and biological concepts. Virtually every chemical transformation of C, N and P that is relevant to the transient form of these constituents, whether it is occurring in the water column, the sediments of rivers or lakes, or the flooded soils of tidal marshes and riparian zones, is dependent upon a reaction mediated by a cosmopolitan group of algae and bacteria. Understanding the benthic habitat and controlling factors for the significant members of this group of microorganisms can allow managers to identify significant points in the nutrient migration pathway, leading to targeted intervention and improved models of ecosystem function.

METHODS

Sediment cores and bottom water were collected along a transect of six sites spanning the main stem in Falls Lake from west to east (See map below)



Incubations were run with bottom water that was not aerated in environmental chamber set to 22 deg C to match average *in situ* temperatures of lake water.

RESULTS

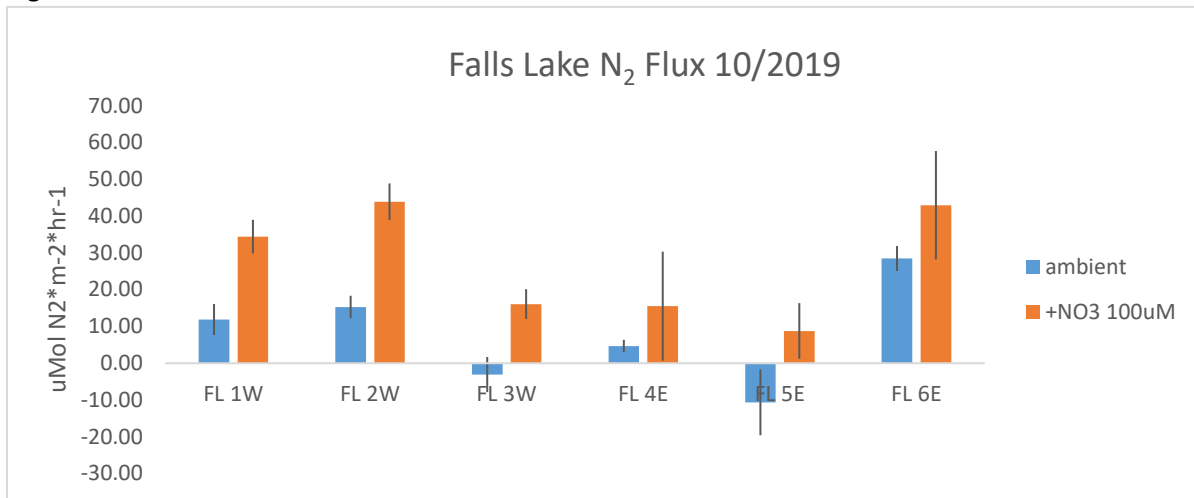
During the sampling trip conducted in mid-October 2019, YSI profile data showed that the lake was not thermally stratified with less than 1 degree difference from surface to bottom water. The table below shows depths ranged from 2 to 7 m, the greatest depth measured at station 5E. Dissolved oxygen (DO) was close to saturation in surface waters of the western sites (7-8 mg/L O₂) that did not vary with

depth. DO measured at the eastern stations ranged between 3-5 mg/L in surface waters and bottom waters were only slightly lower except for station 5E where bottom waters were hypoxic. Dissolved inorganic nitrogen (DIN) concentrations were very low (0-1.3 μM) for NO_x and NH_4 levels ranged from 1-10 μM , trending to the higher end in eastern lake sites.

SITE	Depth (m)	Temp (deg C)	DO surface (mg/L)	DO bottom (mg/L)	[NO_x] (μM)	[NH_4] (μM)
1W	1.9	21	7.89	7.82	BD	1.3
2W	2.1	21	8.17	8.14	1.29	0.96
3W	3.6	22	7.47	7.32	0.18	3.69
4E	4.9	23	4.50	3.95	0.07	10.14
5E	7.0	23	3.60	1.11	0.29	9.43
6E	3.0	23	4.99	3.78	BD	4.58

Net N_2 fluxes showed low rates (5-20 $\mu\text{M N}_2 \cdot \text{m}^{-2} \cdot \text{hr}^{-1}$) of denitrification throughout most of the lake (stations, 1W,2W,4E,6E) (Fig 1). Fluxes were not different from 0 at site 3W and fluxes were slightly negative for site 5E. The addition of excess nitrate to the feed water resulted in net denitrification for all sites and showed an increase over rates measured at ambient nutrient levels. On the whole, 10-20% of the added nitrate was taken up by the cores and mean denitrification efficiency for all sites (N removed via denitrification compared to flux of N_2 and DIN from the cores) was 26% at ambient nitrate levels.

Figure 1



Oxygen fluxes (expressed as sediment oxygen demand, or SOD) ranged from 300-600 $\mu\text{M O}_2 \cdot \text{m}^{-2} \cdot \text{hr}^{-1}$ for all lake sites and exhibited no distinct pattern with site characteristics (Fig 2). At ambient NO_3^- , N_2 flux showed no significant relationship with SOD but after the NO_3^- addition, N_2 flux showed a significant ($p < 0.05$) positive relationship with SOD ($R^2 = 0.32$) (Fig. 3). O_2 concentrations in water collected from core incubations did not drop below 6 mg/L for any site throughout the experiment.

Sediment organic matter (SOM) varied from 0.8 to 8 % carbon and did not relate to either N₂ or O₂ gas fluxes.

Figure 2

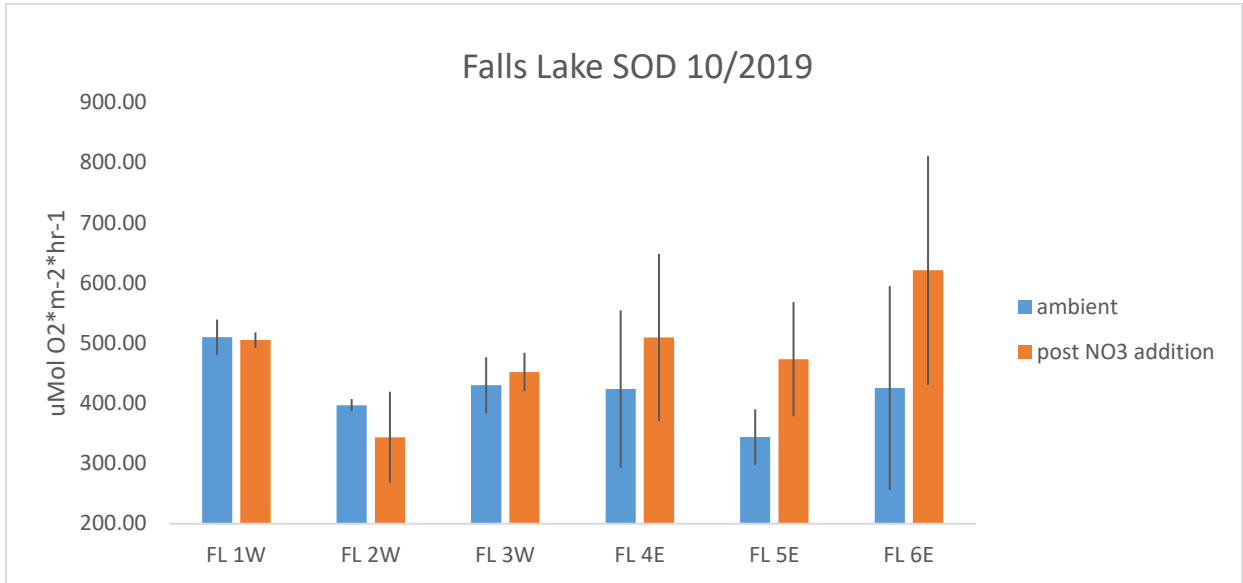
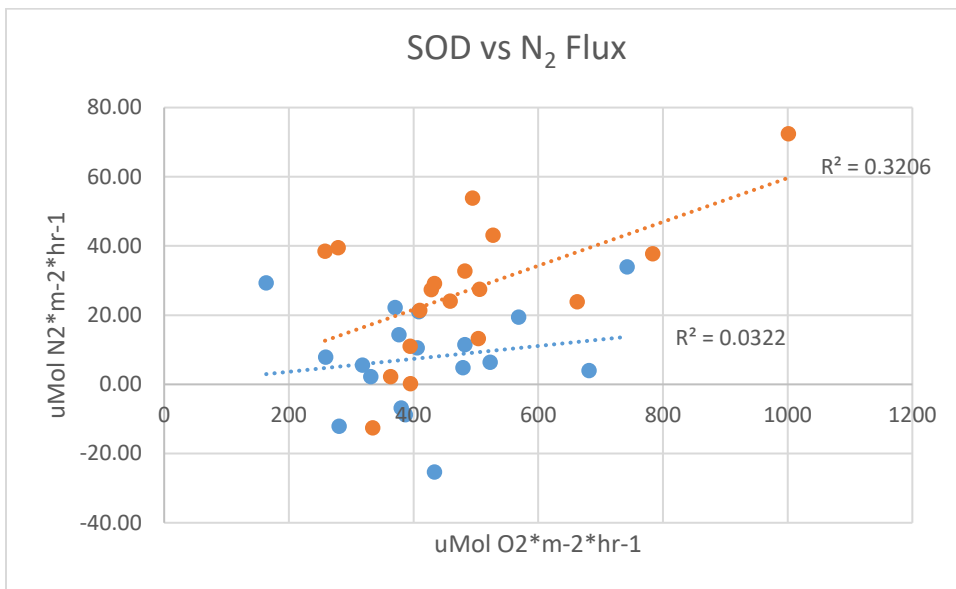


Figure 3



CONCLUSIONS

These results present an assay of denitrification through the Falls Lake transect during October, 2019 in the absence of thermal stratification. During this period, denitrification appeared to be limited by N availability as demonstrated by low DIN concentrations (1-10 μM) in bottom water and increased denitrification rates following the NO_3^- addition. Mean ambient total nitrogen (TN) for all transect sites measured in bottom water was 0.38mg/L (27 μM). By comparison, annual mean of TN in surface waters sampled monthly in 2018 (DEQ) was 0.70mg/L (about 50 μM). Although not thermally stratified during the sample trip in October 2019, concentrations of TN were lower in bottom water, and this difference is predicted to be greater under stratified conditions. SOD did not appear to be a primary regulating factor for denitrification at this time but when nitrate limitation was alleviated, N_2 flux increased with SOD indicating availability of labile carbon was a secondary regulator. The minimal oxygen draw-down in overlying water of cores during the incubation could have restricted the anoxic zone where denitrification is favored over aerobic processing of carbon to deeper sediments where NO_3^- was less available. At site 5E, the deepest lake site where hypoxic conditions were measured *in situ*, fluxes of N_2 were negative and became positive with the nitrate addition. Negative net N_2 fluxes have been observed in sediments of nearby Jordan Lake particularly under summer stratified lake conditions and at sites with low levels of bottom water NO_3^- (how to reference? Also include comparison with Matta?). SOM varied among lake transect sites but bulk measures of SOM did not correlate with N_2 fluxes.

Although not extremely high rates, extrapolation of the mean of measured denitrification rates (at ambient nitrate concentration) over the lake area (estimated at 50.2 km^2) yields an estimated of 131 kg of nitrogen removed per day. Compared to a modeled load of 825 kg/day reported in the Falls Lake Watershed Analysis Risk Management Framework (WARMF) (N.C. Department of Environment and Natural Resources Division of Water Quality Planning Section Modeling/TMDL Unit, October 2009) an estimated 16% of loaded total nitrogen reaching the lake could be removed via denitrification. Using NO_3^- amended denitrification rates, this potential removal increases to 26.9 kg/day or 55% of modeled load. Ongoing monitoring of water quality in Falls Lake by the NC Division of Environmental Quality Department of Water Resources from 2010-present, shows that throughout much of Falls Lake, low levels of DIN are maintained in the photic zone by high primary production in the water column for much of the year. The results reported here demonstrate considerable potential for lake sediments to remove nitrate if seasonal competition for DIN is alleviated (although denitrification rates decrease at lower temperatures as well) and during pulsed loading in rain events if mixing occurs. Additional measures of denitrification through spring and summer seasons including periods when the lake is stratified will provide a more complete assessment of this pathway for nitrogen removal from Falls Lake.