Report for 2004MO35B: Experimental Analysis of Nutrient Uptake in Streams

There are no reported publications resulting from this project.

Report Follows

Missouri Water Resources Research Center Grant Program
Progress Report
May 2005

Title: Experimental Analysis of Nutrient Uptake in Streams
Name: Dr. Dev K. Niyogi
University of Missouri-Rolla
Status: In-progress (project end-date was extended for one year)
Amount funded: $18,985
Amount spent: appr. $13,100
Number of students supported: 3
1 Ph.D. graduate student, Cem Selman
3 undergraduate students, Cindy Buschmann, John Campbell, Jessica Wilson

Project objectives

Excess nutrients, primarily nitrogen and phosporus, in natural ecosystems represent one of the greatest environmental problems of our time (Vitousek et al. 1997). The addition of nutrients, from a variety of anthropogenic sources, can have profound effects on terrestrial, freshwater, estuarine, and marine ecosystems. Aquatic ecosystems, including lakes and estuaries, are of special concern given the effects of eutrophication from excess nutrients on the resources and services that these systems provide to humanity (Carpenter et al. 1998). From declines in lake clarity to the imperilment of estuarine fisheries, many aquatic ecosystems have suffered from excess nutrients.

The delivery of nutrients, often derived from agricultural lands, to lakes and estuaries is mediated by streams (Hall 2003). Streams have often been viewed as simple pipe-like conduits that passively transport pollutants, but that view is changing. As nutrients are transported in streams, they may be taken up by stream algae (and higher plants) and microbes (bacteria and fungi), thereby dampening the flux of nutrients to downstream systems. Several recent studies using large-scale models have suggested that small streams can be particularly effective at retaining nutrients from agricultural landscapes en route to fragile open water systems (Alexander et al. 2000; Seitzinger et al. 2002). The exact mechanisms of nutrient retention, however, are not well understood. Understanding what controls nutrient uptake in streams is critical to predicting and managing the flux of excess nutrients to fragile systems. In this project, I am using a combination of experimental and observational approaches to increase our ability to predict the uptake of nutrients in streams.

The central goal of the research is to examine the biotic controls on nutrient uptake in streams. My research team and I are using experimental streams to measure uptake under varying ecological conditions. In addition, we are measuring uptake in natural streams and comparing actual rates to rates predicted from experimental studies. Our specific goals for the project include:

1) Determine effects of biological demand from algae and microbes on leaf litter on nutrient uptake in experimental channels.

2) Extend the mechanistic understanding of nutrient uptake gained from experimental channels to the prediction and validation of uptake in whole streams.

Results to date

Experimental channels

My students and I have conducted several trials using experimental channels to measure uptake rates of nitrogen and phosphorus. The tests are being used to develop predictive models of the influence of algal biomass and leaf litter on nutrient uptake rates. For example, increasing amounts of algal biomass from Mill Creek, an Ozark stream, are related to higher uptake rates of both soluble reactive phosphorus (SRP) (Fig. 1) and nitrate-nitrogen (NO_3^--N) (Fig. 2).

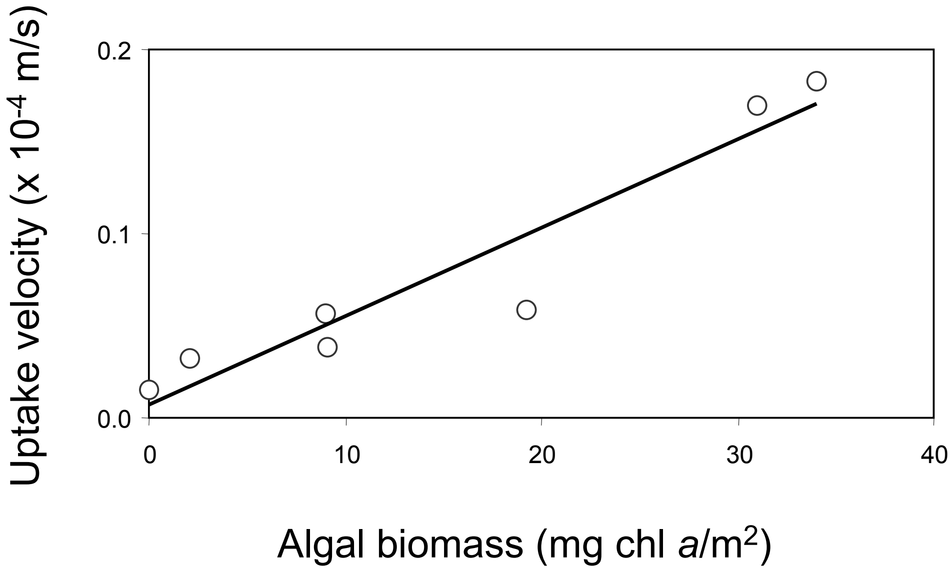

Figure 1. Uptake velocity of soluble reactive phosphorus (SRP) versus algal biomass (measured as chlorophyll *a*) in experimental channels. Experiments were conducted under full sun in late summer; water and algae were collected from Mill Creek in Mark Twain National Forest. $R^2 = 0.91$ for regression line ($P < 0.01$).

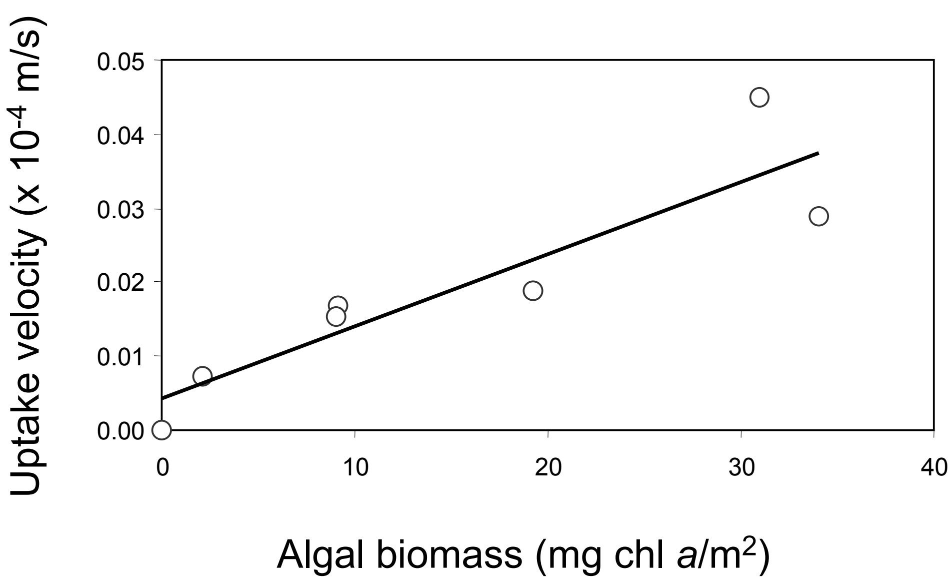

Figure 2. Uptake velocity of nitrate-nitrogen (NO_3^-) versus algal biomass (measured as chlorophyll *a*) in experimental channels. Experiments were conducted as described in Figure 1. $R^2 = 0.81$ for regression line ($P < 0.01$).

Additional experiments were carried out in autumn and winter with varying amounts of decomposing leaf litter in experimental channels. As expected, the amount of leaf litter in experimental channels was closely related to uptake rates of SRP (Fig. 3).

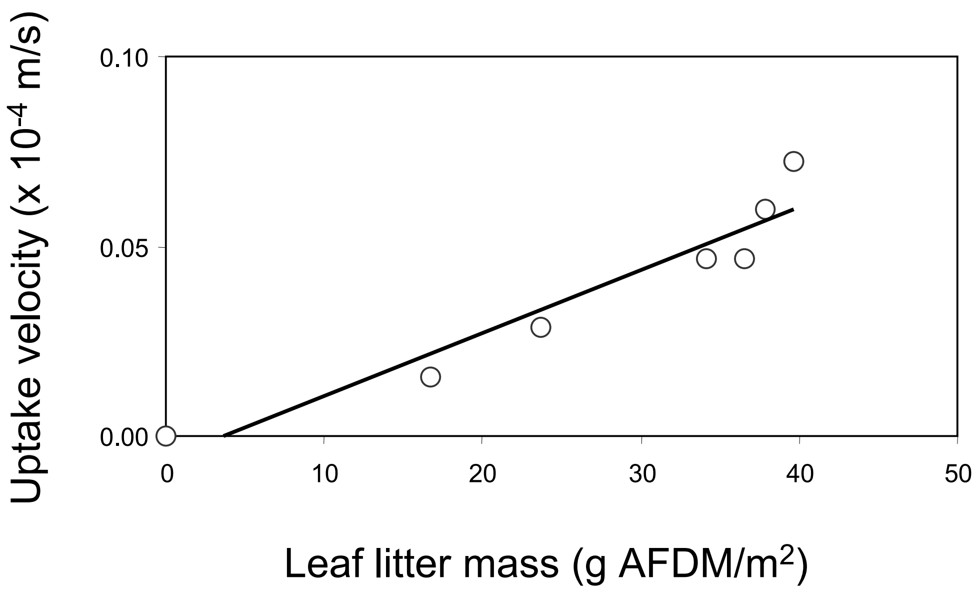

Figure 3. Uptake velocity of soluble reactive phosphorus (SRP) versus leaf litter mass (measured as ash-free dry mass, AFDM) in experimental channels. Experiments were conducted in the lab; water and leaf litter were collected from Mill Creek in Mark Twain National Forest. $R^2 = 0.91$ for regression line ($P < 0.01$).

Natural streams

As part of our research, my students and I have conducted monthly sampling of several nearby streams. Downstream changes in nutrient concentrations, although influenced by several factors, can reflect uptake of nutrients by stream biota. For example, nutrient concentrations decline along Mill Creek from its source at a spring to its confluence with the Little Piney River (Fig. 4). This section of Mill Creek is a losing stream without any tributaries, so the decline in nitrate is probably related to uptake by

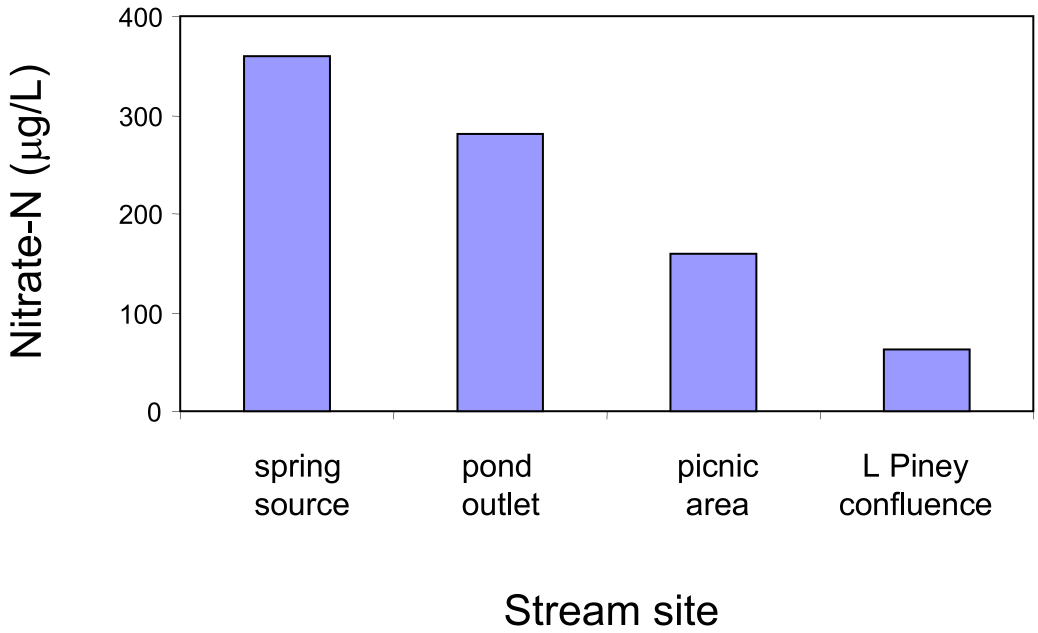

Figure 4. Concentrations of nitrate-N at several sites along Mill Creek in Mark Twain National Forest on April 5, 2005. Water emanates from a spring (first site) and then enters a pond (second site). The third site is at a USFS picnic area about 5 km downstream from the source, and the confluence with the Little Piney River is an additional 5 km from the picnic area.

algae and microbes in the stream. Measurements using the experimental channels at this site (Fig. 1) support this idea. It is remarkable that most of the nitrate present in the source water at the spring is attenuated by the biota in the stream.

My research team has also directly measured uptake rates in natural streams. Currently, we have collected data from several small streams, including one located in a new preserve purchased by the Audubon Society. Uptake rates of SRP and NO_3^- vary across the seasons (Fig. 5), with the highest rates thus far seen in late summer. Several factors can influence these rates, including hydrology, temperature, and stream biota. Stream temperature was highest during the measurement during late summer, and high algal biomass was also present then. During the winter measurement (March 2005), rates were still somewhat high (compared to other studies), probably because of the large

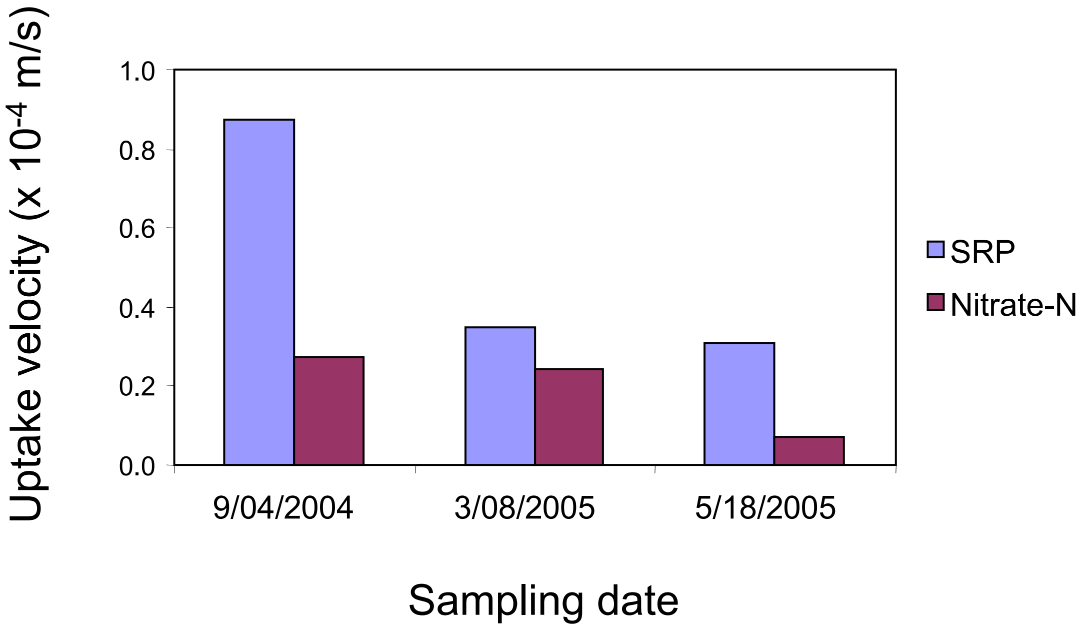

Figure 5. Uptake velocities of soluble reactive phosphorus (SRP) and nitrate-N in a small stream flowing through the Audubon Society nature preserve in Rolla. The site is a small (2^{nd}-order) stream with a baseflow discharge of about 5 L/s during the measurements.

amounts of leaf litter present in the stream. Future experiments will help elucidate the main controls on uptake rates in this and other streams during different times of the year.

Plans for the coming year

My graduate student and I are currently running additional trials with the experimental channels to predict the effects of algal biomass on uptake rates. These measurements will add to the data shown in Figure 1, and allow testing of other factors that affect algal uptake, such as temperature and light. Some of these new experiments will be conducted in the new greenhouse at UMR (on the roof of the new Civil Engineering building). Similar experiments will be conducted during autumn and winter with the focus on the role of leaf litter on nutrient uptake.

We are also planning to expand our sampling of natural streams to include additional sites in the Ozarks. These measurements will be conducted over the summer, and again in the autumn/winter when leaf litter inputs are highest. Additional assays will be conducted to measure activity of primary producers (mainly algae) and leaf litter microbes in the streams, as these biota are thought to primarily responsible for nutrient uptake. The final part of the project will be the development and refinement of predictive models to compare the experimental results with measurements along natural streams.

Student involvment

Up to this point, 4 students have been directly involved with the research project. Cem Selman is a graduate student at UMR pursuing a Ph.D. in the Department of Environmental Engineering. Three undergraduates (Cindy Buschmann, John Campbell, Jessica Wilson) from the Department of Biological Sciences have also helped out with both field and lab analyses. Additional undergraduate students will help out during the coming year. All students have gained experience in field stream sampling, including measuring stream discharge, collecting water and biological samples, and conducting nutrient uptake measurements. In the lab, students have gained experience in running nutrient tests using spectrophotometric and chromatographic assays, measuring algal biomass (as chlorophyll *a*) and leaf litter amounts, following lab safety and waste guidelines, and analyzing data using spreadsheet and statistical software. At least two of the undergraduate students are now considering careers in conservation or water quality given their training and experience with this project.

References

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