Benthic Algae Nutrient Limitation Along an Elevation Gradient in the Poudre Watershed, CO

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BACKGROUND

Many studies have investigated benthic algal nutrient limitation using nutrient-diffusing substrata (NDS). In-stream nutrient concentrations are often associated with nutrient limitation, but a meta-analysis showed that in-stream nutrients do not explain enough variance to be predictive[1]. Identifying factors that modulate nutrient limitation will provide a better understanding of periphyton ecophysiology and inform broad-scale stream management.

We hypothesize that temperature and current velocity are two factors that can explain additional variability in algal responses to NDS treatments. Temperature regulates algal metabolism and demand for nutrients, while current velocity affects nutrient delivery, uptake, and herbivore grazing pressure[2,3].

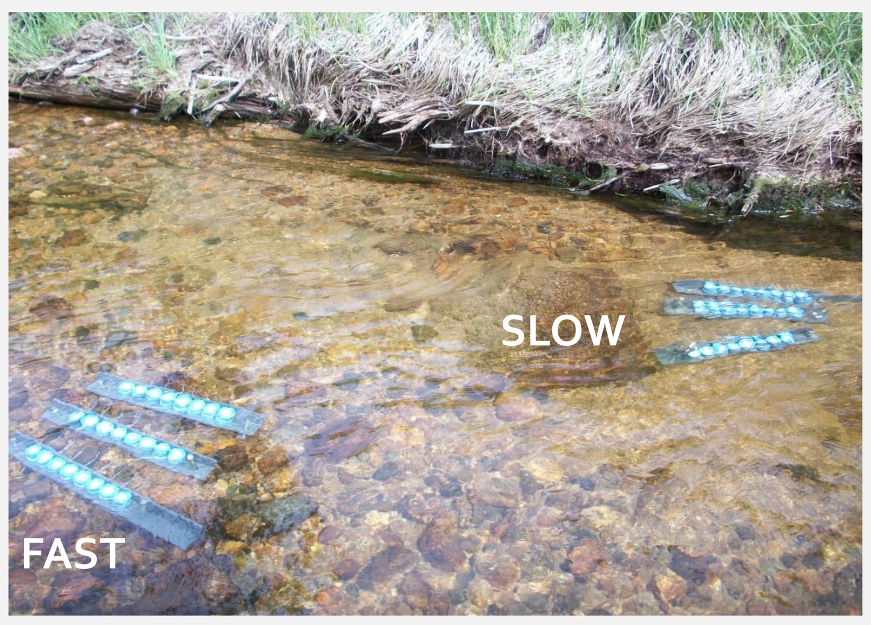

Figure 1: NDS in fast and slow velocities at Pingree (see Objective 2).

OBJECTIVES and METHODS

Objective 1: Use streams along an elevation gradient to determine if **water temperature** is a significant predictor of nutrient limitation.

In August 2015, we deployed NDS at seven streams in the Poudre watershed, Colorado (Table 1). NDS comprised of 30 mL plastic vials filled with 2% agar and six replicates of four treatments: control, nitrogen (0.5M $NaNO_3$), phosphorus (0.2M KH_2PO_4), and nitrogen + phosphorus. Temperature was our main covariate of interest, but we also measured canopy cover, discharge, water velocity, and water chemistry parameters. We used a Turner Designs Aquafluor fluorometer to measure extracted chlorophyll *a* and ammonium.

Objective 2: Use within-stream treatments to determine if **current velocity** changes the magnitude of algal responses to nutrients.

In August 2015, we deployed duplicate NDS treatments in fast (0.33-0.44 cm/sec) and slow (0.05-0.08 cm/sec) velocities of the same reach at two open-canopy streams.

Table 1: Study sites located in the Poudre watershed, along with their elevations. Nutrient limitation was determined via ANOVAs and contrasts of treatment chlorophyll a means.

Site Name	Elevation (m)	Limitation
Elkhorn (EK)	1992	N+P (p = 0.01)
Seven Mile (SM)	2212	None
Little Beaver (LB)	2443	None
Beaver (BV)	2590	None
Pingree (PG)	2740	None
Killpecker (KP)	2798	N+P (p = 0.04)
E. Fork Sheep (EFS)	3166	N (p < 0.01)

RESULTS

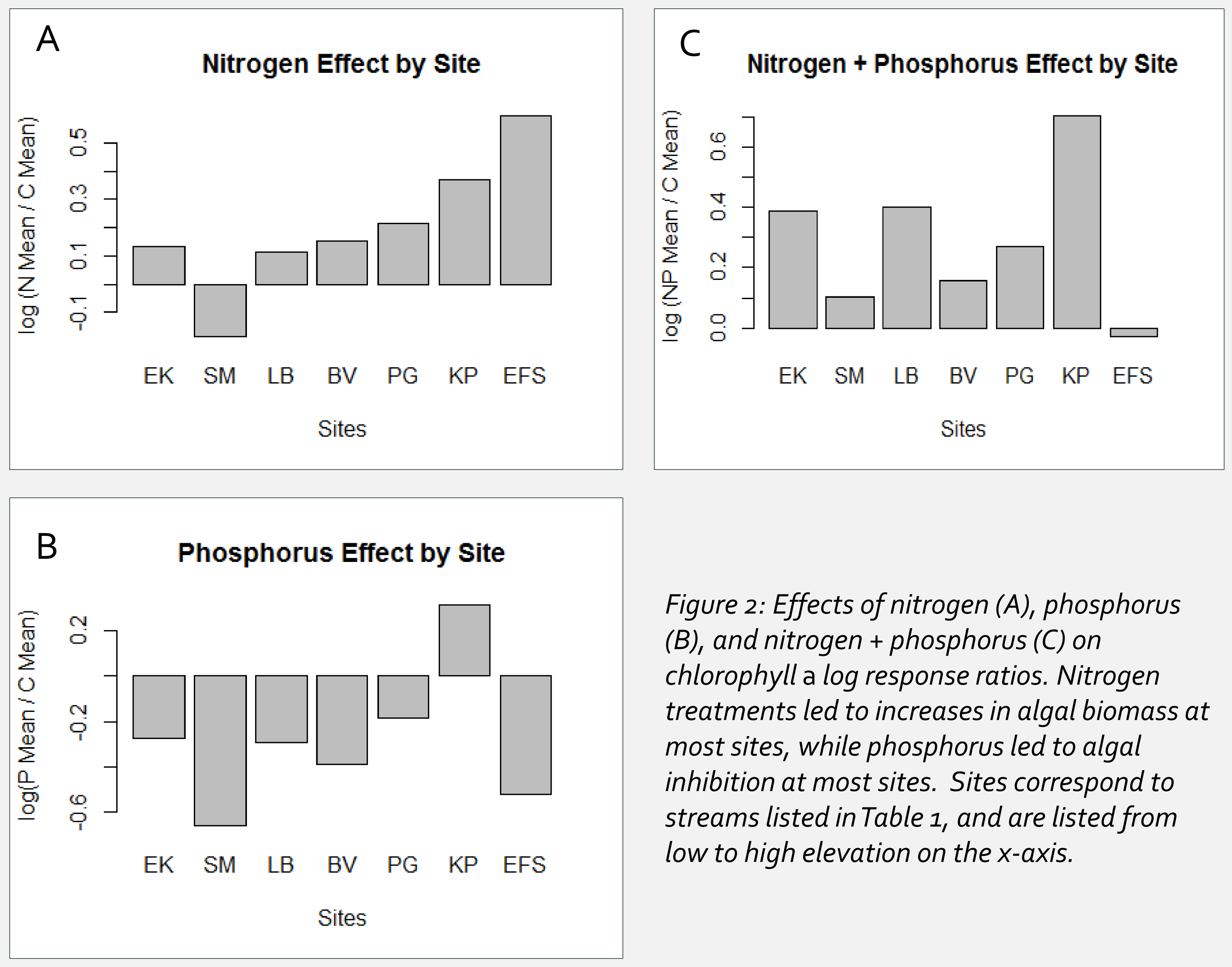

Figure 2: Effects of nitrogen (A), phosphorus (B), and nitrogen + phosphorus (C) on chlorophyll a log response ratios. Nitrogen treatments led to increases in algal biomass at most sites, while phosphorus led to algal inhibition at most sites. Sites correspond to streams listed in Table 1, and are listed from low to high elevation on the x-axis.

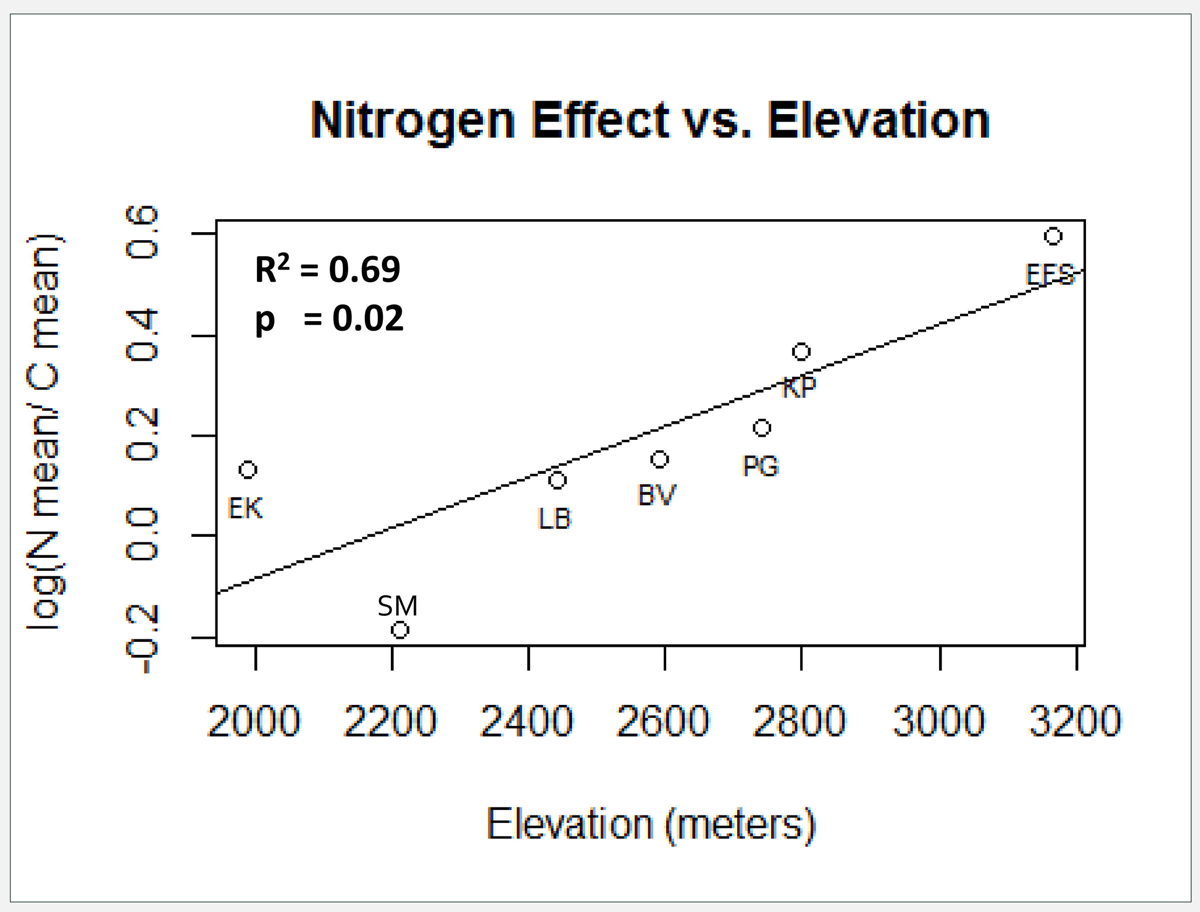

Figure 3: Site elevation was a significant predictor of nitrogen treatment effect size. Sites correspond to streams listed in Table 1.

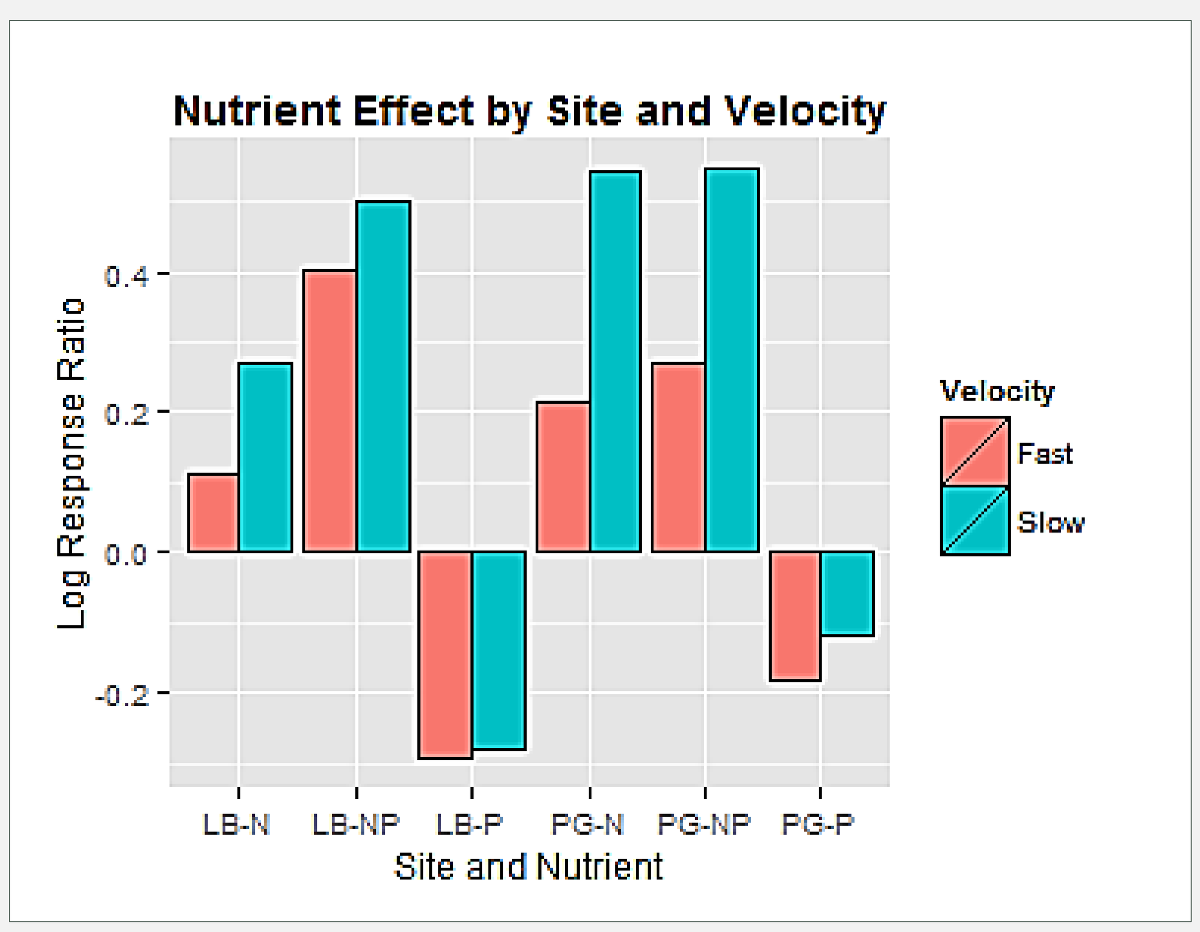

Figure 4: NDS were deployed in fast and slow velocities of the same reach at Pingree (PG) and Little Beaver (LB). These sites along with each nutrient treatment are shown on the x-axis, and log-response ratios associated with each nutrient are shown on the y-axis. Slow velocities resulted in higher algal responses to nutrient treatments, although these effects were most apparent for nitrogen and nitrogen + phosphorus additions.

DISCUSSION

- Nitrogen effects significantly increased with elevation (Fig. 3), but were not related to in-stream nitrate or ammonium.
- Temperature fell with elevation and was positively related to nitrogen effects (p = 0.1 and R^2 = 0.45).
- Phosphorus-inhibition was evident at most sites and has been observed in other studies.
- Algae responded more strongly to nutrients in slow velocities, as compared to fast velocities.
- Velocity affects many variables that control algal accrual: scouring potential, grazing, nutrient delivery, nutrient uptake, sedimentation, and algal taxa.

Figure 5: NDS experiments were completed in mountain streams of the Poudre watershed, Colorado. Shown here are Killpecker (left) and Little Beaver (right), which are high and mid-elevation streams respectively.

FUTURE DIRECTIONS

Temperature: Deploy NDS at the same study sites in June (summer) and September (fall) of 2016. Quantify nutrient effects on chlorophyll *a* and ash-free dry mass. Use multiple regression to determine individual and interactive effects of environmental variables across seasons.

Velocity: Complete a macroinvertebrate electrical exclusion experiment to determine how velocity, grazers, and nutrients interact to structure algal biomass, C:N:P, and taxa.

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