Species Composition and Nitrogen Dynamics in Northern Michigan peatlands

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Abstract

Nutrient dynamics, particularly nitrogen, have become a major focus of peatland research in light of increased anthropogenic N deposition. Recent research conducted in Europe suggests that such nutrient enrichment is responsible for changes in species composition and productivity in these ecosystems. By examining nutrient availability and species composition in Northern Michigan peatlands, this study hoped to provide similar data for the United States. In addition to nitrogen dynamics, this study examined nitrogen and phosphorus enrichment and plant community composition in three types of peatlands (as defined by pH and vegetation): bogs, intermediate fens, and rich fens. It was demonstrated that while species richness was significantly different between peatland types, diversity was not. Nitrogen levels were not found to differ significantly between peatland types. Additionally, there was no statistical significance between nitrogen mineralization rates and pH levels. It was also demonstrated that species diversity was not correlated to nitrogen mineralization rates. These results suggest that species richness does follow Grime's classic 'hump-backed model' but are inconclusive about the relationship between diversity levels and pH. Furthermore, the data suggests that nitrogen is not the limiting nutrient in these peatland ecosystems. Whether other nutrients such as phosphorus play such a role in determining plant community composition in North America is yet to be conclusively determined.

Introduction

Nutrient availability is one mechanism that determines plant community composition. Increased nutrient enrichment via leaching and atmospheric deposition through industrial and agricultural activity is changing species composition and productivity in many ecosystems. Recent observations, particularly in northern Europe where nitrogen deposition levels are as high as 170 kg ha^{-1} yr^{-1}, show species-rich peatlands becoming mono-specific stands of nitrophilous species (Bedford et al., in press). Nutrient enrichment in peatlands is thus believed to lead to changes in species composition, loss of diversity, replacement of native species by exotics, and conversion of unique flora to common species (Bedford et al., in press).

The specific effects of nutrient deposition are currently being investigated in many long-term fertilization experiments. Research demonstrates that eutrophication via fertilization generally leads to an increase in aboveground biomass and a subsequent decrease in species richness of vascular plants (Johnson and Leopold, 1994). Studies (Bedford et al., in press) conducted in Europe agree, concluding that high species diversity is often associated with low nutrient status and that species-rich peatlands exhibit both a low productivity and standing crop. However, these same studies also conclude that the optimum range of productivity for maximum species richness varies among peatland types (Bedford et al., in press).

Previous fertilization studies, the majority of which were conducted in Europe, do not suggest one limiting nutrient in all systems. Rather, N and/or P are believed to limit plant growth and productivity (Beltman et al. 1996, Bridgham, Pastor, Janssens, Chapin, and Malterer 1996, Malmer 1986, and Verhoven, Koerselman, and Beltman 1988). These contrasting results suggest that the question of nutrient limitation among varied peatland communities is far from consistent, and instead must be determined on an individual basis.

Rates of nutrient mineralization as an indicator of nutrient availability is often correlated to the growth and productivity of peatland plants. Studies show that a high productivity is

associated with high uptake of N, P, and K (Verhoven et al. 1988). In the Netherlands, comparisons between the total amount of each nutrient in the biomass and soil give positive correlations for P and K, whereas no significant relation exists for N (Verhoven et al. 1988). Another significant source of minerals is the water table, which arises from either precipitation or ground water. The source of the water table is believed to influence the mineral levels of the peatland. The positive correlations between biomass and soil for P and K suggest that in the Netherlands, peatland soil serves as the primary reservoir for these two nutrients. The lack of positive correlation for N suggests that other sources (such as the water table) are as equally important as the soil in providing these nutrients to the vegetation (Verhoven et al. 1988). In addition, this same study concludes that no relation exists between mineralization rates of N and P and productivity or N and P uptake by peatland vegetation (Verhoven et al. 1988). The results of this study imply that any effect on species composition and/or productivity is achieved directly through eutrophication and not by changing soil mineralization rates. This topic is far from resolved and further study is needed to fully understand the dynamics of nutrient mineralization.

In contrast to Western Europe, few fertilization studies have been conducted using North American peatlands. Thus, the accepted model of peatland vegetation response to nutrient enrichment is based upon studies from the Netherlands (Bedford et al., in press). While this may serve as a useful comparison or initial model, results from these studies are not readily extrapolated to their North American counterparts. The response to increased nutrient supply is influenced by factors such as history, water budgets, hydroperiods, and water chemistry, which differ between North American and European peatlands. The rates and forms of N deposition differ between North America and Europe, as nitrogen deposition rates in Europe range as high as 170 kg ha^{-1} yr^{-1} (Bedford et al., in press). The successional stage of the studied peatlands is also different between North America and Europe. European peatlands are largely influenced by

anthropogenic manipulation such as peat cutting, water control, and mowing, while North American peatlands are more greatly influenced by glacial history and long-term climate patterns (Bedford et al., in press. Differences between European and North American sites in any such variables will likely result in unpredictable responses in North American peatlands to nutrient enrichment.

The majority of studies conducted in North America focus on vascular plants and fail to include bryophytes. While it is believed that mosses may be more responsive to alkalinity-acidity gradients than N or P gradients, failure to include these species preclude drawing strong conclusions about nutrient availability and peatland diversity (Bedford et al.). In contrast, research conducted in Europe has demonstrated an inhibition of bryophyte diversity by nutrient additions. One such study demonstrated a significant loss of *Sphagnum* species from Great Britain peatlands in response to high N deposition (Bridgham et al. 1996). In this case it is evident that N is not limiting *Sphagna*; instead, increases in nitrogen availability result in toxic effects (Chapin 1998).

This study examines the relationship between nutrient availability and plant community composition in three types of peatlands located in Northern Michigan: bogs, intermediate fens, and rich fens. These peatland types are classified according to pH and dominant vegetation. Bogs have a pH of 3.5-3.9 and are dominated by *Sphagnum*. Intermediate fens have a pH of 4.9-5.1 and are dominated by species from both bogs and rich fens. Rich fens have a more alkaline pH of 5.9-6.1, and have vegetation dominated by grasses and sedges (Bridgham et al. 1996). We did not forsee any appreciable difference in species composition due to fertilization during this growing season. As fertilization generally takes three years to have an effect (Chapin 1998), our primary goal was to determine within a natural gradient the relationship, if any, between nutrient availability and species composition. We hypothesized that plant diversity would follow Grime's "hump-backed" curve (Johnson and Leopold 1994) and that greater richness and diversity would be found in the intermediate fens. Nitrogen availability was hypothesized to increase along the

same gradient as richness and diversity. Finally, we hypothesized that nitrogen availability would be correlated to changes in diversity.

Materials and Methods

All fieldwork was conducted at the University of Notre Dame Environmental Research Center (UNDERC) from May 18 – July 22, 1998. Nine sites (three bogs, three intermediate fens, and three rich fens) were selected and classified according to pH and dominant vegetation. The bogs had pH values ranging from 3.9-4.1, as determined by a portable pH meter using a 2:1 soil slurry, and were dominated by *Sphagnum* spp. Intermediate fen sites had pH values ranging from 4.9-5 and possessed *Sphagnum* as well as grasses and sedges. Rich fen sites ranged in pH from 5.8-6.6 and were dominated by grasses and sedges. Soil cores from each peatland were analyzed for both moisture content and bulk density. Bulk density values for two of the peatlands were determined and values for five of the other sites were available from previous experiments.

Within each peatland, four 32x32m treatment quadrats were established. These quadrats were delineated with color-coded PVC pipe to represent treatment type. White pipe was used to designate control quadrats, pink pipe designated N quadrats, yellow pipe designated P quadrats, and orange was used to designate N+P treatment quadrats.

The 1042m^2 treatment quadrats were fertilized twice during the ten-week period, first in May of 1998 and again in July of 1998 during peak growing season. At each application period, we added 3g/m^2 N for the N treatment and 1 g/m^2 P for the P treatment. The 'N+P' plots were treated with both N and P. Both elements were applied in the form of solid commercial fertilizer via a hand-held seed spreader. The total amount added was 6 g/m2 N per year in both N and N+P and 2 g/m2 P per year in both P and N+P.

After the first application of fertilizer, five $1m^2$ permanent plots in each treatment quadrat were created using PVC markers. These permanent plots were used to determine percent covers of each species of vegetation for each site.

Covers of permanent plots

Graminoid and forb species percent cover in each 0.1 ha permanent plot was determined using a point-intercept method. Pins were lowered through a wooden frame with ten holes placed ten cm apart. As the pins were lowered, we recorded the number of times each species was hit. One pin constituted a point, and 40 points were taken in each permanent plot.

Sphagnum cover was analyzed by the nickel method, in which all Sphagnum under a randomly placed nickel was harvested. This procedure was repeated five times in each permanent plot. The harvested moss was dried in the laboratory, separated by species and identified and counted. Percent composition from each quadrat was then determined.

Shrub and tree cover was analyzed in two randomly selected 10x10 m areas per quadrat. Within these 100 m^2 areas, stem number (at ground level) was counted. In addition, tree cover was estimated visually.

Nitrogen mineralization.

N-mineralization rates were determined using buried bag incubations (Binkley and Hart 1989). A 10.16 cm diameter PVC pipe was used to remove ten peat cores at a depth of ten cm from each peatland site. The cores were taken from outside the 32x32m quadrats and from the control site when space was limited). The cores were immediately placed in plastic bags. The bagged cores were inserted into their original holes in the peat and covered with a vegetation plug. The buried bags were incubated for approximately three weeks, after which they were removed and the peat material analyzed for extractable N (Binkley and Hart 1989). Three soil samples were taken from each of the nine peatlands to determine the initial extractable N levels. The mineralization rate was computed by subtracting the initial N level from the incubated N level.

This is a net rate because no consideration was given to denitrification, microbial uptake, or geochemical adsorption.

Inorganic nitrogen was extracted from the 0-10cm and 10-20 cm initial cores, 54 core sections in all, and the 45 incubated cores. For each core, 5g of field moist soil was measured into an Erlenmeyer flask and 50 ml of 2.0M KCl solution was added. Each flask, including three reagent blanks, were hand swirled at approximately fifteen minute intervals for one hour. Each sample was filtered through acid washed GF/C filters. Some samples produced a slightly yellow filtrate and were then re-filtered.

Approximately 20 ml of N_i were poured into appropriately labeled 25 ml plastic scintillation vials and frozen in preparation for colorometric analysis.

Analysis of total N via digestions

Soil samples from each of the nine peatlands were digested for total N determination. Approximately 30 mg of soil for each depth (0-10cm and 10-20cm) for each of the three cores taken from each peatland site was weighed into small aluminum cups and dried at 65°C for 48 hours. The dried soil samples were ground individually in the UDY Cyclone Sample Mill. Approximately100 mg of each ground soil sample was measured into 50 ml digest tubes. The 54 ground samples along with 3 blanks and 3 standards (#1575 Pine Needles from NIST) were run in the Lachat BD-46 Block Digester using a sulfuric acid/hydrogen peroxide method. In a fume hood, 4.0 ml of concentrated H_2SO_4 was added to each digest tube and vortexed. Then 2.0ml of 30% H_2O_2 was added to each digest tube and vortexed. The digest tubes were inserted into the Lachat digester and run on a cycle of 170°C for 10 minutes, 45 minutes raising the temperature to 320°C, and then 320°C for 15 minutes. The tubes cooled for 15 minutes and then another 2 ml of 30% H_2O_2 was added to each digest tube and vortexed. The tubes were then reinserted into the Lachat digester and the same cycle was repeated. The addition of 2 ml 30% H_2O_2 followed by the Lachat digester cycle had to repeated at least once more for all tubes since a yellow to brown color

persisted in each, indicating a continued presence of undigested organic matter. After the digestion of all organic matter, the tubes were cooled for 30 minutes. Approximately 50 ml of DI water was added to each tube and vortexed immediately. After cooling again, the tubes were filled with DI water to 70 ml total. The tubes were stoppered and inverted 5 times, then approximately 20 ml of each digested sample poured into 25 ml plastic scintillation vials and frozen for later colorometric analysis.

This digestion procedure was carried out for approximately 100mg of ground plant material, separated by species, that was collected from three 25x25 cm above ground clippings per site. Sphagnum was harvested from three 5x5 cm random areas from each site but not separated by species.

Data Analysis

Since fertilization generally takes three years to show a noticeable effect, it was assumed that no difference would be observed between control and treatment vegetation. Mean percent covers were calculated for each site, as well as the Shannon-Weiner diversity index (H). Statistical significance was tested for using the SYSTAT program. Shannon-Weiner diversity indexes, species richness values, total N, and rates of nitrogen mineralization were analyzed using ANOVA. Regression analysis was used to analyze species richness.

Results

As fertilization effects are generally not apparent until the third year of treatment, it was assumed that any differences in percent covers (Appendix 1) between treatment quadrats were due to the site itself and not the fertilization treatments. All graphical and statistical analyses thus examined differences between sites.

Mean species richness varied greatly between sites, ranging from 13.75 to 25.5 species per site. Regression analysis of richness versus pH gave a best fit of a second order polynomial

with an R^2 of 0.7461 (Figure 1). Differences in species richness between mean pH levels (4.1, 4.95, 6.13) were slightly significant (p=0.06). Tukey HSD multiple comparisons demonstrated that while a slightly significant difference existed between richness values for bogs and intermediate fens (pH 4.1 and 4.95; p=0.007), as well as bogs and rich fens (pH 4.1 and 6.13; p=0.015), the difference between intermediate and rich fens (pH 4.95 and 6.13) was not significant (p=0.766).

Mean Shannon-Weiner diversity indexes ranged in value from 2.85 to 3.5 between sites. Analysis of the differences in Shannon-Weiner diversity indexes between mean pH levels using an ANOVA was not significant (p=0.8; Figure 2). Additionally, regression analysis of Shannon-Weiner diversity indexes versus available nitrogen failed to demonstrate any strong correlation (R^2 = 0.3267; Figure 3).

Rates of nitrogen mineralization did not exhibit a consistent trend between sites. Mineralization values were negative for two bogs (South Gate and Donut), one intermediate fen (Degobah), and one rich fen (Ward), representing a net immobilization of nitrogen (Table 1). The other sites exhibited positive values, indicating that a net mineralization of nitrogen had occurred during the seventeen-day incubation period. These mineralization rates were not statistically significant (p=0.323; Figure 4). Additionally, the amount of N in aboveground vegetation was not correlated to the daily rate of N mineralization (R2=0.1921; Figure 5).

Table 1. Total N and Mineralized N (± standard deviation) by peatland. Peatlands are grouped according to peatland type (bog, intermediate fen, rich fen) and groups are arranged according to increasing pH.

Site	**pH**	**Total N (mg/g)**	**Mineralized N (mg/cm^3 per day)**
Donut	3.9	22.594±7.674	-3.92e-06±8.33e-05
South Gate	4.1	25.001±6.718	-7.25e-05±5.95e-05
County B	4.3	23.284±5.628	7.29e-06±5.02e-04

Degobah	4.9	22.666±5.872	-2.5e-07±9.88e-05
IF1	4.95	34.002±6.807	1.69e-05±3.62e-04
NIH	5.00	46.735±6.038	9.11e-06±3.62e-04
Bolger	5.8	26.863±2.746	2.36e-05±3.35e-04
Ward	6	30.475±5.809	-8.00e-07±1.15e-03
RF2	6.6	41.445±6.038	9.11e-06±1.22e-04

As with nitrogen mineralization rates, total N did not show a clear trend between sites (Table 1). In each peatland type, high and low total N values were observed. Differences between total N values at the three mean pH levels (4.1, 4.95, and 6.13) were not statistically significant ($p=0.372$). Regression analysis of the Shannon-Weiner diversity index versus total nitrogen was not strongly correlated ($R^2=0.0924$; Figure 6).

Despite correlation between available N and pH ($R^2=0.556$; Figure 7), the increase in available N with increasing pH is quite small. Differences in available N by pH level were not significant ($p=0.201$).

Discussion

Although European peatlands have undergone extensive studies involving nutrient dynamics and their role in determining vegetation patterns, a relatively small pool of data exists for their North American counterparts. To this end, this study focused on analyzing the effects nitrogen has on both the species richness and diversity for varying pH values.

The data for species richness indicate that maximum species richness occurred at an intermediate pH value (Figure 1). These results are consistent with Grime's 'hump-backed model of herbaceous floristic diversity' (Johnson and Leopold 1994). pH, like nutrient availability, is a measure of environmental stress, thus playing a crucial role in determining species richness and composition. A low pH level indicates a high stress environment in which species are primarily

concerned with survival as opposed to competition. Conversely, at high pH (and low stress) levels, competition is a prominent form of species interaction. Both high and low stress levels thus limit species richness. Intermediate pH levels, which signify an intermediate stress level, allow for an overlap of species as neither survival or competition is the dominating factor. Intermediate fens thus possess higher levels of species richness than do bogs and rich fens. Matrix analysis of individual pH levels showed significance between bogs and fens (both rich and intermediate), but no difference between intermediate and rich fens. The extremely low pH and nutrient poor conditions of a bog severely restrict the number of species which are able to populate the area, resulting in low richness values. The high nutrient content and circumneutral pH levels of rich fens lead to statistical insignificance between intermediate and rich fens in terms of species richness.

While species richness exhibited a clear trend in relation to pH, Shannon-Weiner diversity index values did not. It was hypothesized that the maximal levels of diversity would occur at intermediate pH values for the same reasons as species richness. However, no statistical significance was demonstrated between pH levels and diversity values. It is thus clear that a correlation between the two variables does not exist. In addition, it was hypothesized that the highest species diversity would occur at an intermediate level of available nitrogen. However, there was only a slight correlation between available N and species diversity (R^2= 0.3267). The data supports no correlation between N availability and species diversity and suggests other mechanisms are involved.

The increase in daily mineralization rates of nitrogen with increasing pH levels (Figure 4) seemed to support the prediction that rich fens would posses the highest mineralization rates. However, the weak correlation coefficient (R^2 = 0.2635) does not provide conclusive proof of this trend. Additionally, no correlation exists between daily N mineralization rates and N concentration in aboveground vegetation (R^2 = 0.1921; Figure 5). This suggests that N is not the

limiting nutrient for plant growth, and that other unknown factors are more significant in determining N uptake by peatland species.

The lack of statistical significance between total N and pH ($p = 0.372$) also indicates that nitrogen levels are not primarily determined by pH. While not significant, pH should not be completely eliminated as a possible determinant of total nutrient levels. Although this may act in conjunction with other factors such as hydrology and alkalinity, further research is required to fully understand this relationship. Total N levels were also not correlated with Shannon-Weiner diversity index values ($R^2 = 0.0924$; Figure 6), again indicating that nitrogen is not the limiting nutrient for these ecosystems. However, it is possible that nutrient levels are not responsible for diversity levels among peatland types. The lack of statistical significance between Shannon-Weiner diversity values and pH complicates the analysis. Further testing to clarify this relationship and to investigate phosphorus dynamics are needed to resolve this issue.

Additionally, while a correlation exists ($R^2 = 0.556$) between available nitrogen and pH levels, available nitrogen increase with pH is miniscule (Figure 7). This might be a function on the very low available nitrogen levels (on the order of 10^{-4}) which are characteristic of a peatland and its low decomposition rate. Further testing is thus required to determine the true relationship of these variables.

These data reveal that a great deal of future research is needed to determine the mechanisms controlling species diversity and how these interact with nitrogen availability in peatlands. The lack of statistical significance in all but one test suggest that either flaws in experimental procedure existed or that clear relationships between the variables do not exist. One further possibility is that experimentation should be continued throughout the year rather than a ten-week duration. However, this study is intended to be a long term investigation of nutrient dynamics and plant community composition. It is thus possible that more definitive results will be obtained in future years.

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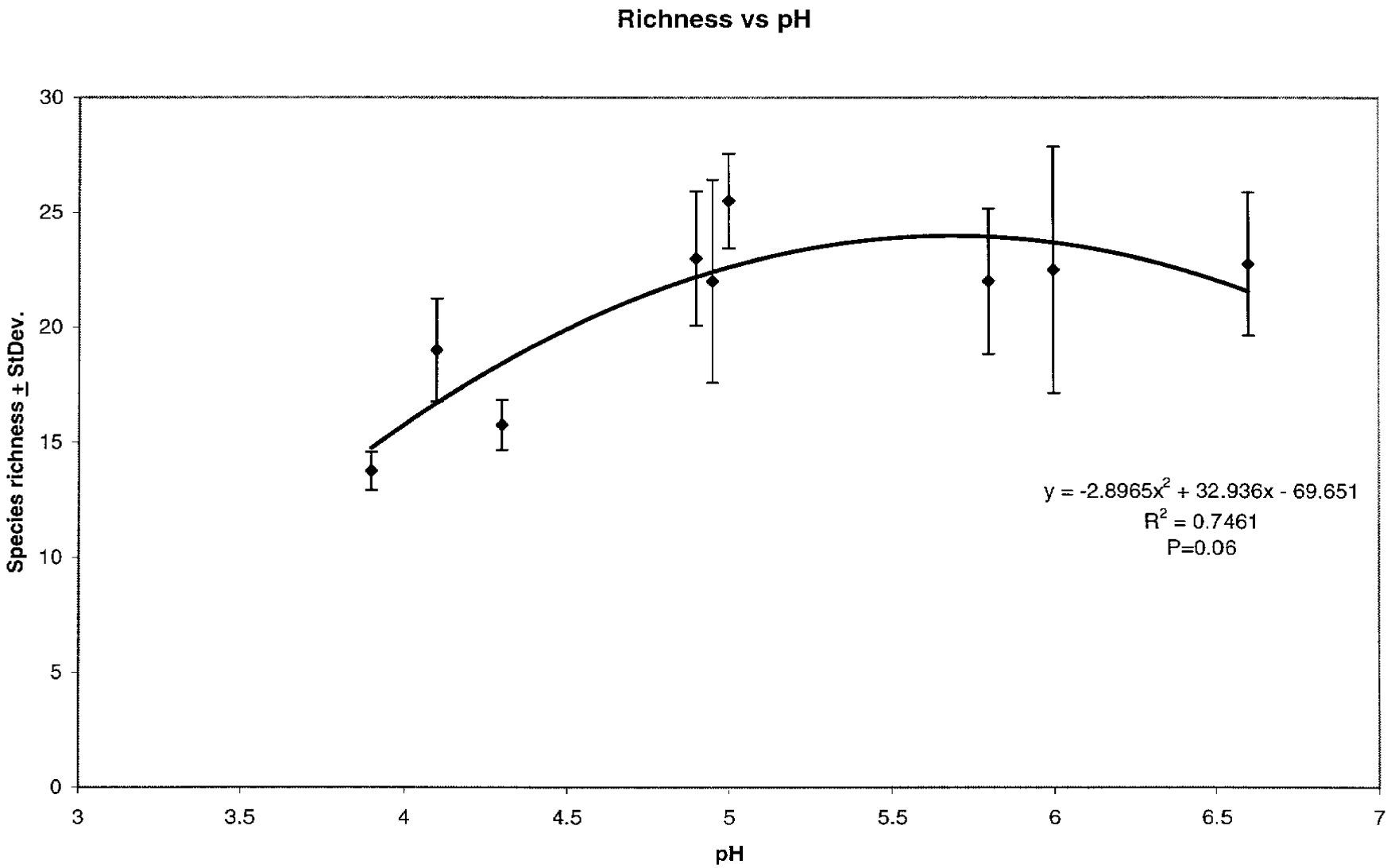

Figure 1. Richness (mean number of species per quadrat in each peatland) versus pH. Error bars represent one standard deviation. P=0.06.

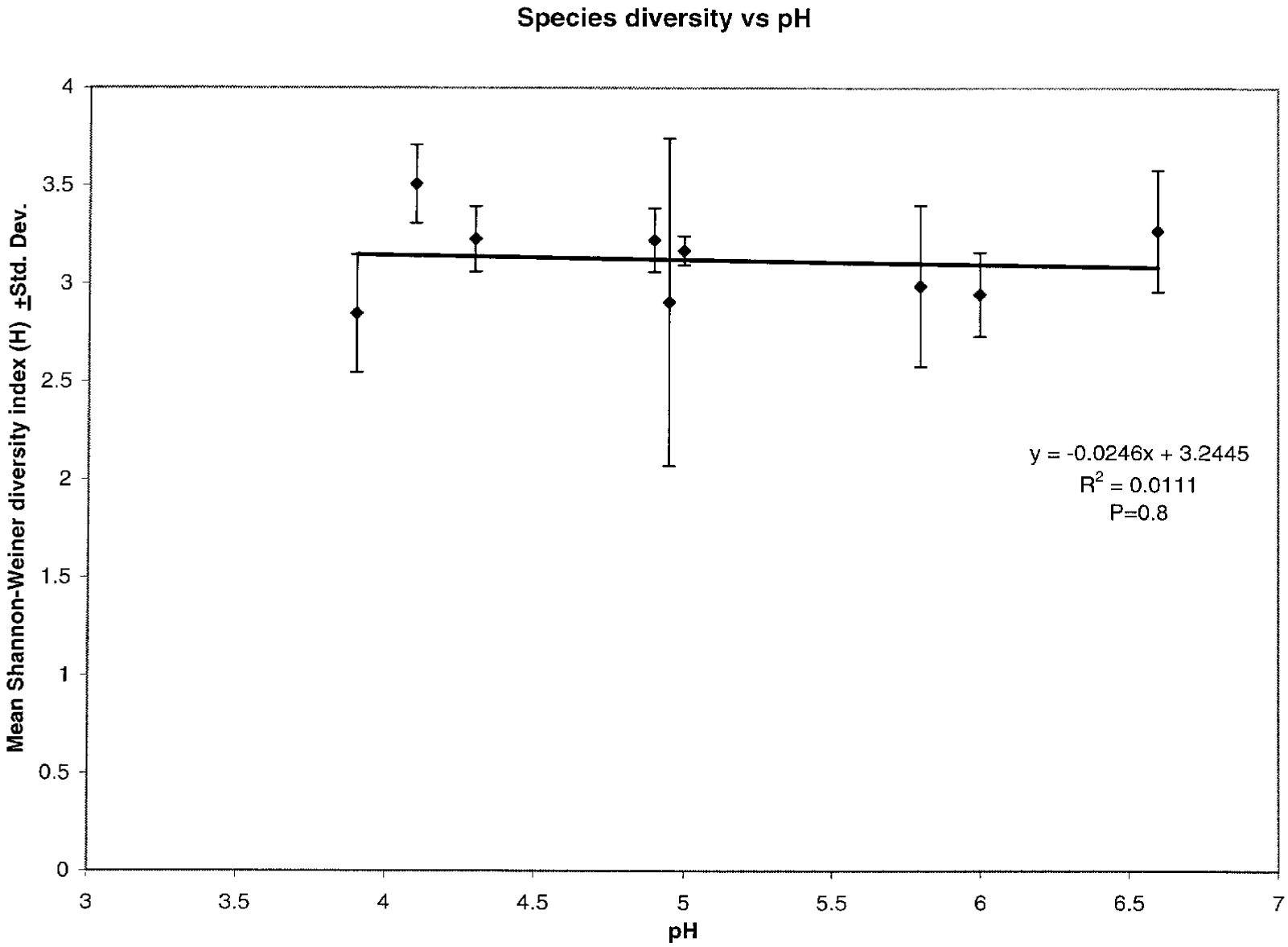

Figure 2. Shannon-Weiner diversity index (H) vs pH. Error bars represent one standard deviation. P=0.8.

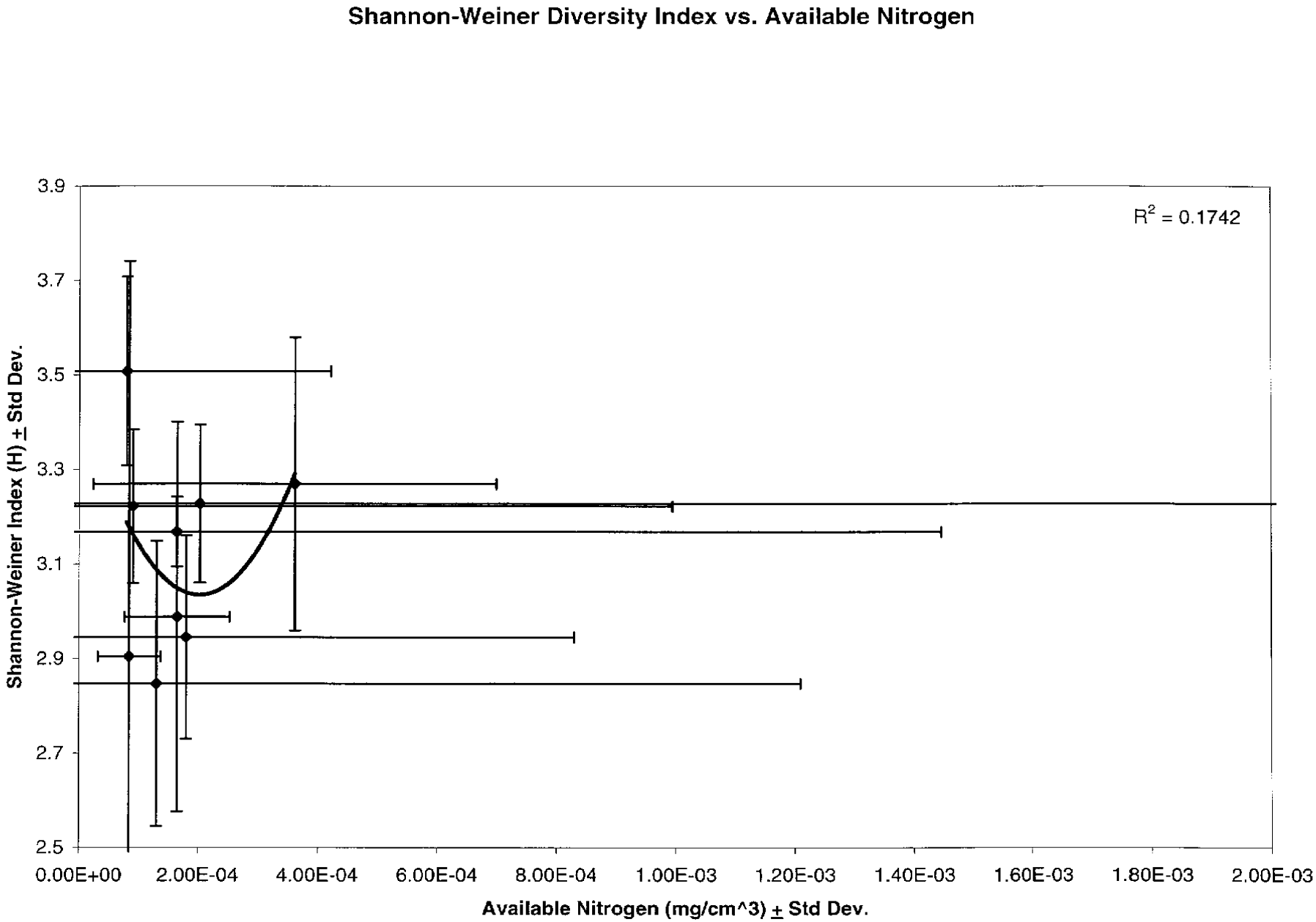

Figure 3. Shannon-Weiner Index (H) of diversity vs. Available Nitrogen (mg/cm^3). Error bars represent 1 standard deviation.

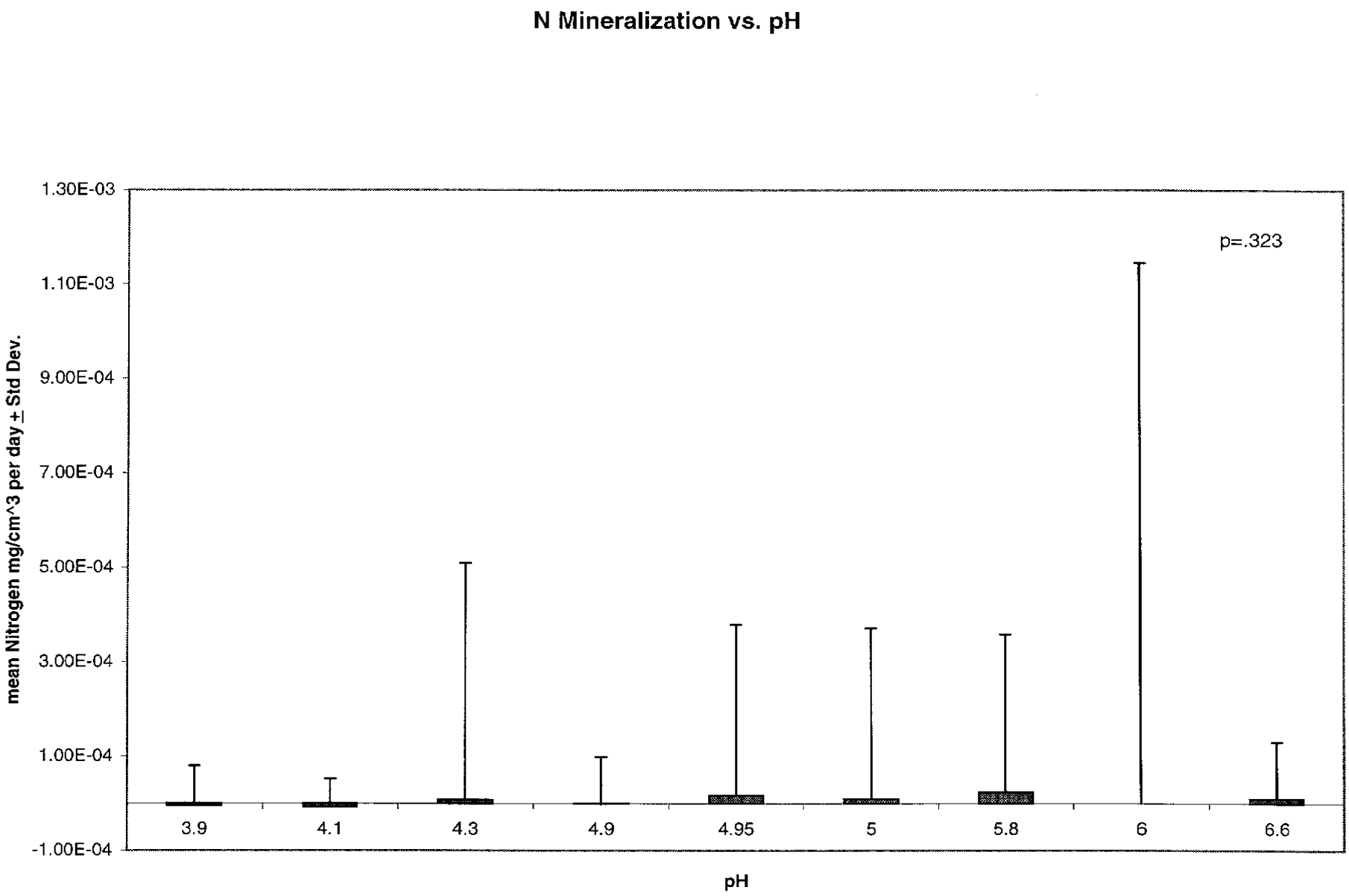

Figure 4. Analysis of mean N mineralization rate (mg/cm^3 per day) for 9 peatlands, at different pH levels. Mineralization is determined by subtracting the amount of available nutrient before incubation from the amount of available nutrient after incubation. P=0.323. Error bars represent 1 standard deviation.

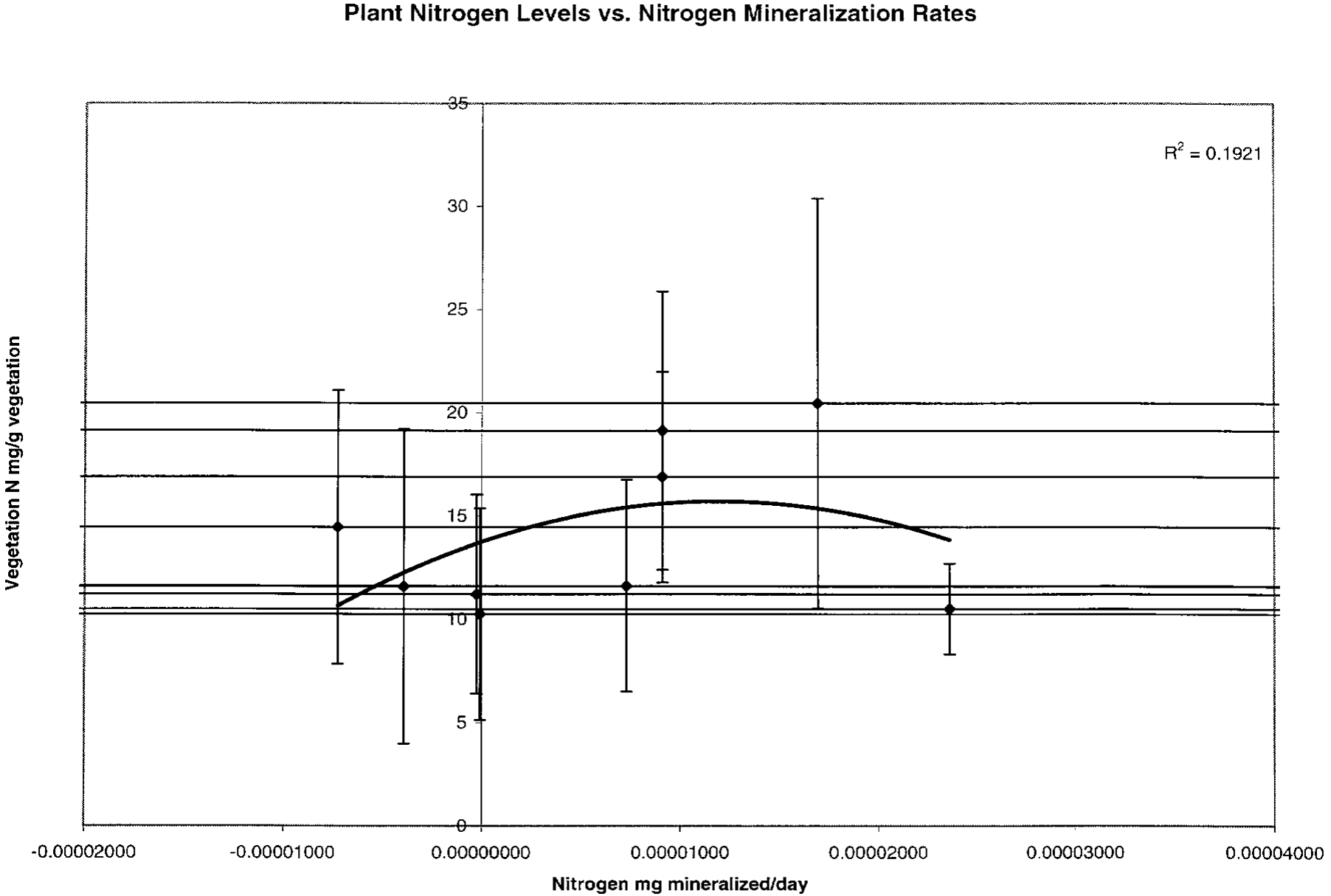

Figure 5. Regression analysis of nitrogen in vegetation at each peatland vs. nitrogen mineralization rates.

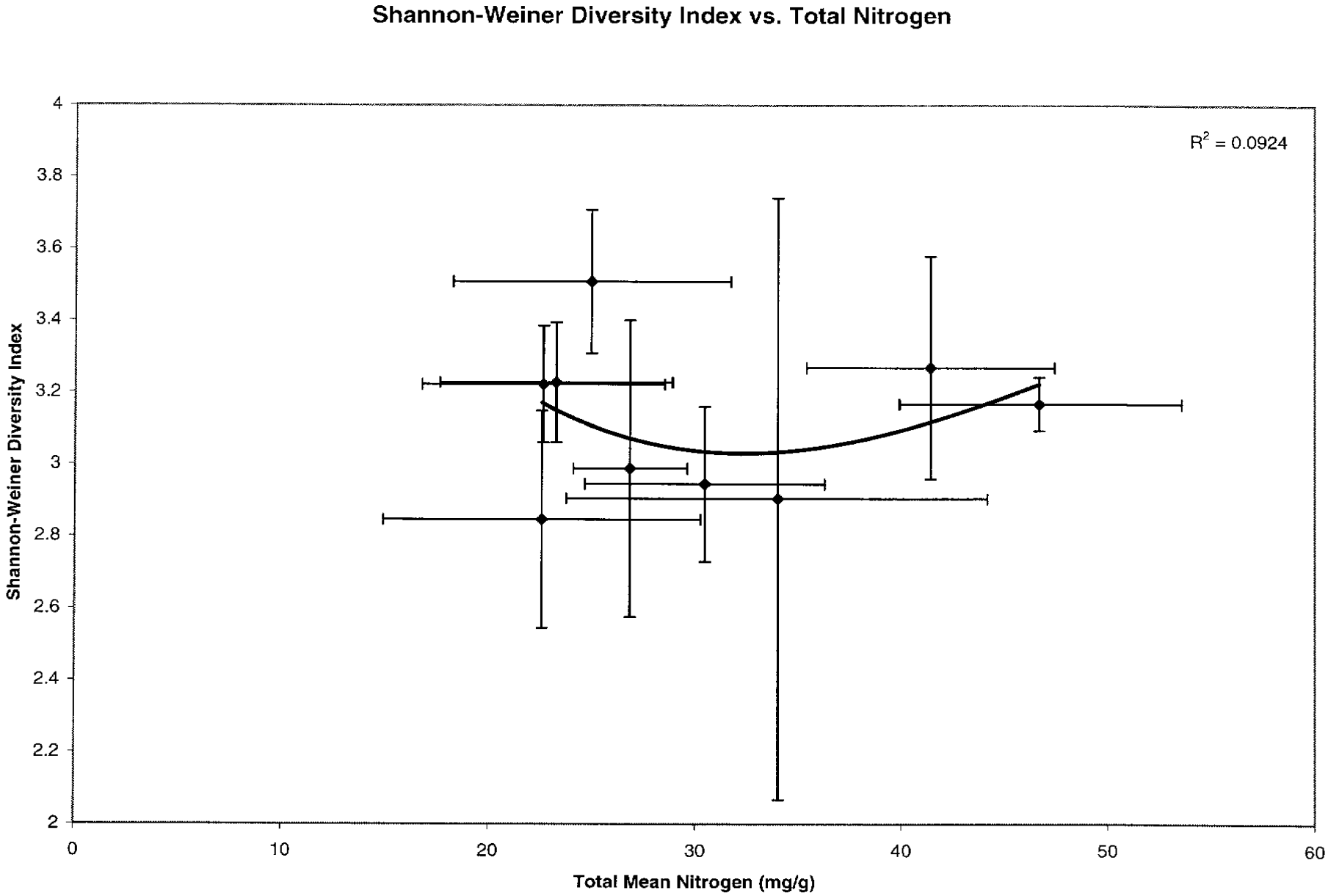

Figure 6. Regression analysis of the Shannon-Weiner Diversity Index vs. total mean nitrogen (mg/g) for the 9 peatlands studied. Error bars represent 1 standard deviation.

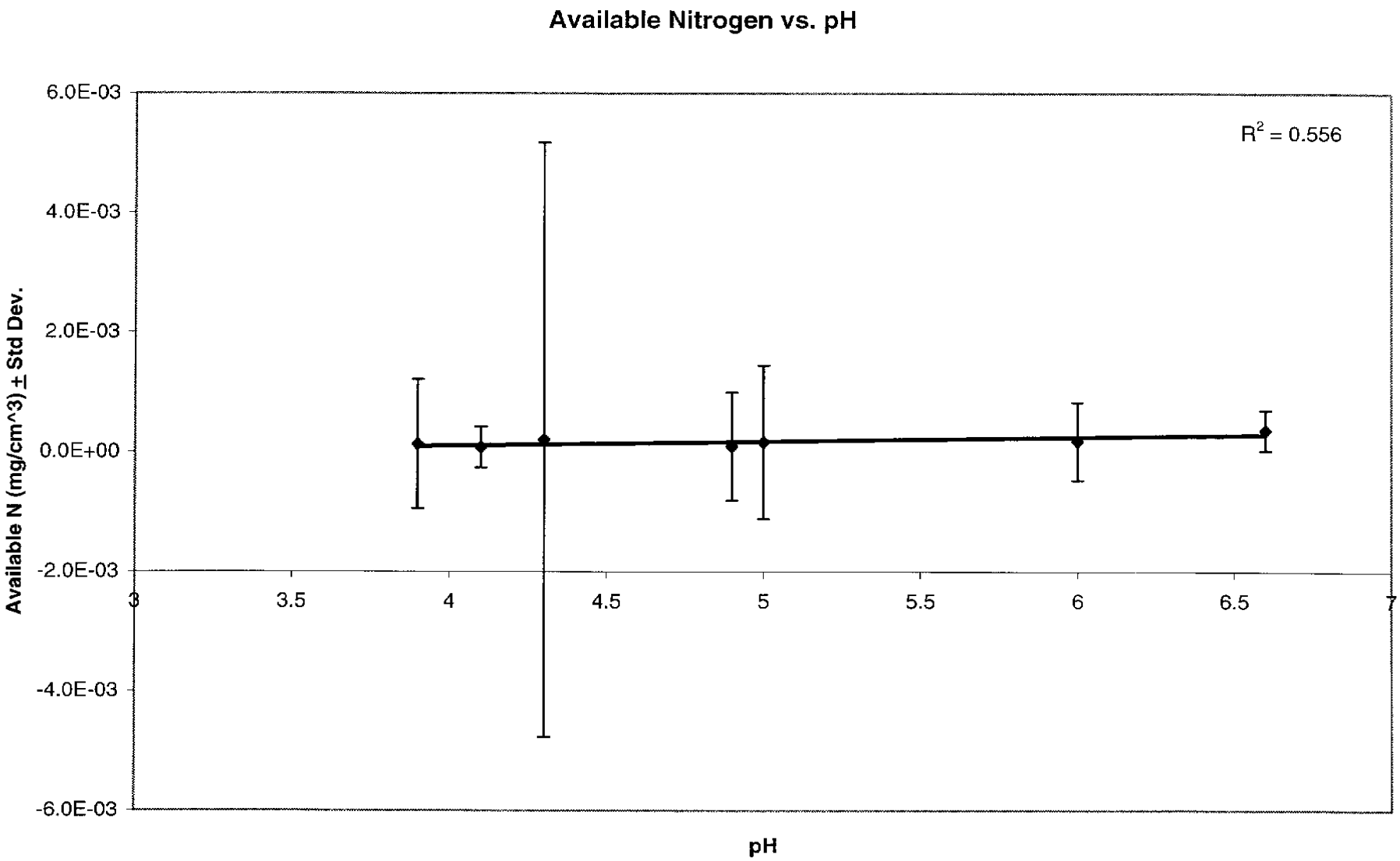

Figure 7. Available Nitrogen (mg/cm^3) vs. pH. Error bars represent 1 standard deviation.

Appendix 1. Mean covers of species by wetland.

Bolger

		Mean cover	Std. Dev.
Graminoids and Forbs			
	Carex rostrata	7.96%	9.21%
	Glyceria striata	0.12%	0.24%
	Sarracenia purpurea	0.06%	0.12%
	Scirpus cyperinus	0.06%	0.23%
	Carex lasiocarpa	2.25%	4.49%
	Chamadaphne calyculata	2.41%	4.82%
	Vaccinuim oxycoccos	0.41%	0.81%
	Carex oligosperma	0.00%	0.00%
	Carex interior	0.00%	0.00%
	Carex sterilis	2.53%	0.58%
	Calamagrostis canadensis	3.85%	2.19%
	Calla palustris	3.81%	7.49%
	Iris versicolor	0.35%	0.32%
	Carex leptalea	0.12%	0.24%
	Carex disperma	0.47%	0.66%
	Carex paupercula	0.00%	0.00%
	Carex trisperma	0.06%	0.12%
	Asclepias incarnata	0.06%	0.12%
	Lycopus americanus	0.71%	0.72%
	Solidago gigantea	0.00%	0.00%
	Osmunda cinnamomea	0.00%	0.00%
	Pontederia cordata	0.00%	0.00%
	Aster puniceus	0.39%	0.48%
	Horsetail	0.38%	0.46%
	Carex stricta	5.36%	2.81%
	swamp aster	0.85%	1.54%
	Broad Leaved Arrowhead	0.00%	0.00%
	Typha x glauca	0.00%	0.00%
	Potentilla palustris	0.37%	0.48%
	Sparganium eurycarpum	0.06%	0.12%
	Dulichium arundinaceum	0.11%	0.23%
	Kalmia polifolia	0.06%	0.11%
	Ledum groenlandicum	0.06%	0.11%
	Andromeda glaucophylla	0.11%	0.23%
	Hypericum perforatum	0.25%	0.50%
	Lysimachia terrestris	1.05%	0.72%
	Graminae sp. 1	2.87%	4.16%
	Cyperceae sp. 1	2.54%	2.01%
	Campanula aparinoides	0.34%	0.31%
	Galium trifidium	0.70%	1.03%
	Sparganium chlorocarpum	59.23%	11.29%
	Hypericum ascyron	0.00%	0.00%
Trees			
	Picea mariana	2.75%	2.63%
	Larix laricina	1.38%	2.43%
Sphagnum			
	S. magellicum	46.75%	20.95%
	S. angustifolium	16.25%	11.81%
	S. recurvum	0.00%	0.00%
	S. squarrosum	1.50%	2.38%
	S. fallax	20.00%	9.13%

	S. fimbratum	14.25%	15.46%
	S. teres	1.25%	2.50%

County Road B

Graminoids and Forbs		**Mean cover**	**Std. Dev.**
	Chamadaphne calyculata	21.33%	6.11%
	Ledum groenlandicum	1.78%	1.50%
	Andromeda glaucophylla	4.91%	2.02%
	Vaccinuim oxycoccos	4.46%	2.48%
	Kalmia polifolia	4.96%	3.85%
	Sarracenia purpurea	0.26%	0.52%
	Carex lasiocarpa	46.15%	6.97%
	Carex oligosperma	0.91%	1.23%
	Liparis loeselli	4.64%	4.49%
	Eriophorum spissum	0.56%	0.44%
	Sedge A	10.03%	3.51%
Trees			
	Picea mariana	35.00%	3.54%
	Larix laricina	2.00%	0.61%
Sphagnum			
	S. magellicum	28.75%	18.87%
	S. angustifolium	41.25%	10.31%
	S. fuscum	12.50%	11.90%
	S. capillifolium var. tenellum	10.00%	7.07%
	S. capillifolium var. capillifolium	7.50%	6.45%

Degobah

Graminoids and Forbs		**Mean cover**	**Std. Dev.**
	Carex rostrata	32.08%	26.55%
	Carex lasiocara	4.28%	3.49%
	Chamadaphne calyculata	38.06%	10.78%
	Ledum groenlandicum	1.40%	1.50%
	Liparis loeselli	1.50%	2.52%
	Vaccinuim oxycoccos	0.81%	0.94%
	Kalmia polifolia	0.66%	1.08%
	Carex oligosperma	0.00%	0.00%
	Carex interior	0.72%	1.27%
	Carex sterilis	1.29%	1.71%
	Calamagrostis canadensis	0.40%	0.46%
	Calla palustris	1.56%	2.23%
	Iris versicolor	0.94%	0.92%
	Drosera rotundifolia	0.26%	0.35%
	Myrica gale	2.22%	4.44%
	Eriopharum angustifolium	1.02%	1.39%
	Carex leptalea	0.14%	0.28%
	Carex disperma	0.49%	0.48%
	Carex paupercula	0.78%	1.06%
	Thelypteris palustris	0.35%	0.53%
	Carex trisperma	0.09%	0.19%
	Gaultheria hispidula	0.28%	0.56%
	Asclepias incarnata	0.36%	0.72%
	Lycopus americanus	0.07%	0.14%
	Solidago gigantea	0.14%	0.29%
	Hypericum perforatum	0.80%	0.93%
	Lysimachia terrestris	1.25%	2.50%
	Graminae sp 1	2.83%	2.59%

	Cyperceae sp 1	5.23%	3.15%
Trees			
	Picea mariana	8.63%	3.04%
	Larix laricina	6.75%	3.95%
	Alnus rugosa	9.25%	2.99%
	Unknown	2.63%	4.92%
Sphagnum			
	S. magellicum	42.50%	31.75%
	S. angustifolium	21.25%	19.31%
	S. flexuosum	2.50%	5.00%
	S. teres	2.50%	2.89%
	S. squarrosm	1.25%	2.50%
	S. cuspidatum	3.75%	7.50%
	S. subsecundum	35.00%	40.41%
	S. capillifolium var. tenellum	0.00%	0.00%
	S. fuscum	2.50%	2.89%

Donut

		Mean cover	**Std. Dev.**
Graminoids and Forbs			
	Chamadaphne calyculata	37.37%	5.14%
	Carex lasiocara	33.00%	9.57%
	Ledum groenlandicum	2.57%	2.18%
	Vaccinuim oxycoccos	2.79%	2.15%
	Kalmia polifolia	2.52%	2.06%
	Carex oligosperma	7.78%	7.74%
	Eriophorum spissum	1.55%	1.83%
	Liparis loeselii	0.05%	0.10%
	Carex rostrata	6.98%	13.95%
	Drosera rotundifolia	0.07%	0.14%
	Carex disperma	0.14%	0.28%
	Carex trisperma	0.07%	0.14%
	Lysimachia terrestris	3.11%	3.42%
	Graminae C	1.66%	2.01%
	Graminae D	0.41%	0.68%
Trees			
	Picea mariana	4.38%	5.45%
	Larix laricina	1.50%	0.71%
Sphagnum			
	S. magellicum	35.00%	10.80%
	S. flexuosum	5.00%	10.00%
	S. angustifolium	53.75%	14.93%
	S. recurvum	6.25%	12.50%

IF1

		Mean cover	**Std. Dev.**
Graminioids and Forbs			
	Carex rostrata	0.28%	0.34%
	Carex lasiocara	0.46%	0.92%
	Chamadaphne calyculata	8.46%	11.14%
	Ledum groenlandicum	2.21%	4.41%
	Liparis loeselli	0.71%	0.79%
	Vaccinuim oxycoccos	3.36%	4.20%
	Kalmia polifolia	0.00%	0.00%
	Carex oligosperma	0.00%	0.00%
	Carex interior	0.00%	0.00%
	Carex sterilis	0.09%	0.17%
	Calamagrostis canadensis	1.56%	1.17%

	Calla palustris	9.24%	7.97%
	Iris versicolor	1.29%	1.56%
	Drosera rotundifolia	0.00%	0.00%
	Eriopharum spissum	1.77%	2.18%
	Carex leptalea	0.33%	0.24%
	Carex disperma	0.28%	0.56%
	Carex paupercula	5.38%	6.49%
	Eriopharum angustifolium	0.17%	0.33%
	Carex trisperma	0.33%	0.49%
	Gaultheria hispidula	0.00%	0.00%
	Asclepias incarnata	1.06%	1.83%
	Lycopus americanus	0.00%	0.00%
	Solidago gigantea	0.00%	0.00%
	Typha x glauca	0.34%	0.68%
	Dulichium arundinaceum	1.97%	3.10%
	Glyceria canadensis	0.37%	0.49%
	Scirpus cyperinus	0.79%	1.00%
	Viola nephrophylla	0.09%	0.17%
	Pontederia cordata	0.17%	0.34%
	Hypericum perforatum	2.28%	4.00%
	Lysimachia terrestris	0.96%	0.65%
	Graminae sp 1	2.85%	2.76%
	Cyperceae sp 1	33.49%	6.94%
	Campanula aparinoides	0.09%	0.17%
	Galium trifidium	0.09%	0.17%
	Sparganium chlorocarpum	15.15%	8.94%
	Unknown 11	4.40%	8.80%
Trees			
	Picea mariana	2.75%	2.63%
	Larix laricina	11.25%	7.50%
Sphagnum			
	S. magellicum	0.25%	0.50%
	S. angustifolium	25.00%	23.45%
	S. fallax	56.25%	19.31%
	S. capillifolium var. capillifolium	17.50%	18.48%

	NIH		
Graminoids and Forbs		**Mean cover**	**Std. Dev.**
	Chamadaphne calyculata	1.01%	1.62%
	Carex lasiocara	0.93%	0.61%
	Kalmia polifolia	0.00%	0.00%
	Liparis loeselii	5.02%	5.28%
	Carex rostrata	0.00%	0.00%
	Carex disperma	1.72%	2.76%
	Carex trisperma	0.98%	0.96%
	Carex oligosperma	0.80%	1.01%
	Carex sterilis	9.47%	8.88%
	Carex leptalea	2.32%	1.45%
	Calla palustris	1.05%	1.51%
	Lycopus americanus	1.29%	1.90%
	Solidago ohioensis	2.96%	1.76%
	Osmunda cinnamomea	0.29%	0.57%
	Glyceria striata	4.72%	6.12%
	Ledum groenlandicum	12.35%	12.23%
	Asclepias incarnata	0.07%	0.14%
	Calamagrostis canadensis	1.27%	1.11%

	Carex interior	0.59%	0.75%
	Viola nephrophylla	1.00%	0.88%
	Drosera rotundifolia	0.22%	0.27%
	Rubus pubescens	1.64%	2.62%
	Thelypteris palustris	0.09%	0.18%
	Pontederia cordata	0.18%	0.37%
	Iris versicolor	14.77%	19.38%
	Hypericum peforatum	4.63%	2.81%
	Lysimachia terrestris	0.00%	0.00%
	Graminae sp 1	14.65%	17.69%
	Cyperceae sp 1	10.37%	13.35%
	Campanula aparinoides	0.00%	0.00%
	Unknown 5	0.14%	0.29%
	Galium trifidum	0.00%	0.00%
	Sparganium chlorocarpum	0.76%	1.08%
	Hypericum asycron	3.43%	2.95%
	Fragonia americanus	1.22%	1.80%
	Unknown 10	0.07%	0.13%
Trees			
	Salix serissima	20.00%	14.72%
	Alnus rugosa	69.38%	10.87%
Sphagnum			
	S. magellicum	0.25%	0.50%
	S. fuscum	80.75%	8.10%
	S. squarrosum	0.25%	0.50%
	S. angustifolium	0.25%	0.50%
	S. fallax	10.00%	7.07%
	S. recurvum	2.50%	5.00%
		3.75%	4.79%

RF2

Graminoids and Forbs		**Mean cover**	**Std. Dev.**
	Carex rostrata	14.43%	21.11%
	Carex lasiocarpa	0.00%	0.00%
	Chamadaphne calyculata	5.41%	6.44%
	Ledum groenlandicum	0.00%	0.00%
	Liparis loeselli	0.00%	0.00%
	Vaccinuim oxycoccos	0.00%	0.00%
	Kalmia polifolia	0.00%	0.00%
	Carex oligosperma	0.00%	0.00%
	Carex interior	0.00%	0.00%
	Carex sterilis	6.88%	10.73%
	Calamagrostis canadensis	11.67%	3.90%
	Calla palustris	0.18%	0.36%
	Iris versicolor	2.07%	1.51%
	Drosera rotundifolia	0.00%	0.00%
	Carex leptalea	3.56%	7.11%
	Thelypteris palustris	2.05%	2.14%
	Asclepias incarnata	1.71%	0.70%
	Lycopus americanus	0.36%	0.73%
	Solidago gigantea	2.01%	1.56%
	Osmunda cinnamomea	0.43%	0.72%
	Glyceria striata	0.27%	0.41%
	Pontederia cordata	0.11%	0.22%
	Aster puniceus	1.79%	0.39%
	Horsetail	1.85%	1.56%

	Carex stricta	0.39%	0.78%
	Onoclea sensibilis	0.04%	0.07%
	swamp aster	0.74%	0.49%
	Broad Leaved Arrowhead	0.29%	0.58%
	Typha x glauca	0.07%	0.15%
	Dulichium arundinaceum	0.17%	0.33%
	Graminae sp 1	0.89%	1.35%
	Cyperceae sp 1	0.84%	0.86%
	Campanula aparinoides	3.44%	1.05%
	Galium trifidum	0.40%	0.80%
	Sparganium chlorocarpum	37.08%	27.14%
	Hypericum ascyron	0.87%	0.59%
Trees			
	Salix candida	29.75%	16.94%
	Alnus rugosa	15.00%	10.80%
	Unknown tree 2	10.00%	14.14%
	Unknown Salix	3.75%	4.79%
Sphagnum			
	S. subsecundum	1.25%	2.50%
	S. warnstorfi rosson	0.25%	0.50%
	S. contortum	48.75%	40.90%
	S. russomi	6.25%	12.50%
	S. squarrosm	6.25%	12.50%
	S. wulfianum	5.00%	10.00%
	S. quinquefarium	2.50%	5.00%

South Gate

Graminoids and Forbs		**Mean cover**	**Std. Dev.**
	Chamadaphne calyculata	22.27%	9.47%
	Ledum groenlandicum	15.18%	9.05%
	Andromeda glaucophylla	1.44%	1.73%
	Vaccinuim oxycoccos	4.99%	1.72%
	Kalmia polifolia	3.76%	1.57%
	Sarracenia purpurea	0.09%	0.17%
	Carex lasiocarpa	20.00%	18.73%
	Carex oligosperma	2.57%	2.19%
	Liparis loeselli	6.52%	3.80%
	Carex paupercula	0.58%	0.96%
	Eriophorum spissum	0.51%	0.59%
	Asclepias incarnata	0.85%	1.01%
	Carex trisperma	2.16%	2.97%
	Gaultheria hispidula	0.70%	1.40%
	Carex pauciflora	0.61%	1.22%
	Drosera rotundifolia	0.35%	0.70%
	Sedge A	1.48%	2.96%
	Sedge B	4.61%	9.22%
	Hypericum perforatum	0.26%	0.33%
	Grass C	8.17%	10.44%
	Grass D	2.91%	2.77%
Trees			
	Picea mariana	28.38%	11.64%
	Larix laricina	6.19%	6.20%
	Pinus strobus	0.25%	0.50%
Sphagnum			
	S. magellicum	38.75%	10.31%
	S. angustifolium	25.00%	17.32%

	S. fuscum	0.00%	0.00%
	S. capillifolium var. tenellum	0.00%	0.00%
	S. capillifolium var. capillifolium	0.00%	0.00%
	S. recurvum	21.25%	11.09%
	S. flexuosum	15.00%	10.80%

Ward

Graminoids and Forbs		**Mean cover**	**Std. Dev.**
	Carex rostrata	0.00%	0.00%
	Glyceria striata	0.22%	0.23%
	Clamarostis canadensis	13.73%	6.75%
	Chamadaphne calyculata	15.62%	21.01%
	Carex lasiocarpa	24.78%	9.35%
	Hummock sedge	2.80%	1.61%
	Carex sterilis	1.44%	1.28%
	Iris versicolor	0.18%	0.36%
	Thelypteris palustris	0.97%	1.20%
	Osmunda cinnamomea	0.33%	0.44%
	Onoclea sensibilis	0.05%	0.09%
	Asclepias incarnata	0.22%	0.17%
	Potentilla palustris	1.68%	1.10%
	Solidago ohioensis	0.34%	0.32%
	Lycopus americanus	0.20%	0.31%
	Carex disperma	0.04%	0.09%
	Gaultheria hispidula	0.20%	0.39%
	Vaccinuim oxycoccos	0.24%	0.47%
	Rubus pubescens	0.31%	0.43%
	Valeriana edulis var. ciliata	0.08%	0.16%
	Drosera rotundifolia	0.04%	0.08%
	Horsetail	0.04%	0.08%
	Acer puniceus	0.04%	0.08%
	Salix serissima	0.12%	0.15%
	Hypericum perforatum	0.58%	0.28%
	Lysimachia terrestris	0.00%	0.00%
	Graminae sp 1	1.12%	1.43%
	Cyperceae sp 1	0.25%	0.31%
	Campanula aparinoides	0.34%	0.39%
	Galium trifidum	0.00%	0.00%
	Sparganium chlorocarpum	34.05%	8.18%
	Hypericum ascyron	0.00%	0.00%
	Maianthemum canadense	0.00%	0.00%
Trees			
	Alnus rugosa	0.25%	0.50%
	Pinus strobus	6.75%	9.03%
	Unknown Salix	26.25%	17.02%
	Picea mariana	0.50%	0.58%
	Larix laricinia	1.50%	2.38%
	Acer rubrum	2.75%	2.63%
	Salix candida	1.50%	2.38%
	Colonius stolonifera	1.25%	2.50%
Sphagnum			
	S. magellicum	27.50%	42.72%
	S. squarrosum	0.13%	0.25%
	S. fallax	0.25%	0.50%
	S. contortum	2.50%	5.00%